

Virtuoso Simulator Components and Device Models Reference

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Virtuoso Simulator Components and Device Models Reference

Preface

This manual assumes that you are familiar with the development, design, and simulation of integrated circuits and that you have some familiarity with SPICE simulation.

This manual describes equations and parameters for models supported by the Virtuoso[®] Spectre circuit simulator, Virtuoso[®] UltraSim[™] simulator, and the Virtuoso[®] BSIMProPlus model extractor.

Spectre is an advanced circuit simulator that simulates analog and digital circuits at the differential equation level. The simulator uses improved algorithms that offer increased simulation speed and greatly improved convergence characteristics over SPICE. Besides the basic capabilities, the Spectre circuit simulator provides significant additional capabilities over SPICE. Verilog[®]-A uses functional description text files (modules) to model the behavior of electrical circuits and other systems. Virtuoso[®] SpectreRF Simulation Option adds several new analyses that support the efficient calculation of the operating point, transfer function, noise, and distortion of common RF and communication circuits, such as mixers, oscillators, sample holds, and switched-capacitor filters.

The UltraSim simulator is a fast and multi-purpose single engine, hierarchical simulator, designed for the verification of analog, mixed signal, and digital circuits. Covering a wide range of applications, the Virtuoso UltraSim simulator can be used for functional verification of billion-transistor memory circuits, as well as for high-precision simulation of complex analog circuits. Because of its true hierarchical simulation approach, the Virtuoso UltraSim simulator is faster and uses less memory than traditional circuit simulators, while maintaining near SPICE accuracy. The Virtuoso UltraSim simulator has powerful deep-submicron analysis capabilities, including timing, power, noise, and reliability. The Virtuoso UltraSim simulator recognizes a variety of netlist formats, including HSPICE (registered trademark of Synopsys, Inc.), Virtuoso Spectre[®], and supports Virtuoso RelXpert format for reliability simulation.

The BSIMProPlus model extractor is a new generation SPICE model generator that is used to extract and optimize model parameters.

This preface discusses the following topics:

- [Related Documents](#) on page 40
- [Typographic and Syntax Conventions](#) on page 41

Related Documents

The following can give you more information about the Spectre circuit simulator and related products:

- The Spectre circuit simulator is often run within the Virtuoso® analog design environment, under the Cadence® design framework II. To see how the Spectre circuit simulator is run under the analog circuit design environment, read the *Cadence Analog Design Environment User Guide*.
- To learn more about specific parameters of components and analyses, consult the Spectre online help (`spectre -h`) or the *Virtuoso Spectre Circuit Simulator Reference* manual.
- For more information about using the Spectre circuit simulator with Verilog-A, see the *Verilog-A Language Reference* manual.
- If you want to see how SpectreRF is run under the analog circuit design environment, read *SpectreRF Simulation Option User Guide*.
- For more information about RF theory, see *SpectreRF Simulation Option Theory*.
- For more information about how you work with the design framework II interface, see *Design Framework II Help*.
- For more information about specific applications of Spectre analyses, see *The Designer's Guide to SPICE & Spectre*¹.

The following can give you more information about the UltraSim simulator and related products:

- *Virtuoso UltraSim Simulator User Guide*
- *Virtuoso Unified Reliability Interface Reference*
- *Virtuoso UltraSim Waveform Interface*
- *Virtuoso UltraSim Simulator: What's New*
- *RelXpert Reliability Simulator User Guide*

The following can give you more information about the BSIMProPlus model extractor and related products:

- *Virtuoso BSIMPro User's Manual*

1. Kundert, Kenneth S. *The Designer's Guide to SPICE & Spectre*. Boston: Kluwer Academic Publishers, 1995.

- *Virtuoso BSIMProPlus Basic Operations Guide*
- *Virtuoso BSIMProPlus Model Extractor: What's New*
- *BSIM3v3.2.2 MOSFET Model: User's Manual* (Department of Electrical Engineering and Computer Sciences, University of California, Berkeley)
- *BSIM4 User's Manual*
- *BSIMPD User's Manual*
- Taur, Y., Zicherman, D. S., et al (1992). *A new shift and ratio method for MOSFET channel-length extraction*, IEEE Electron Device Let.: Vol. 12, page 267

Typographic and Syntax Conventions

This list describes the syntax conventions used for the Spectre circuit simulator.

<i>literal</i>	Nonitalic words indicate keywords that you must enter literally. These keywords represent command (function, routine) or option names, file names and paths, and any other sort of type-in commands.
<i>argument</i>	Words in italics indicate user-defined arguments for which you must substitute a name or a value. (The characters before the underscore (<u> </u>) in the word indicate the data types that this argument can take. Names are case sensitive.
	Vertical bars (OR-bars) separate possible choices for a single argument. They take precedence over any other character.
[]	Brackets denote optional arguments. When used with OR-bars, they enclose a list of choices. You can choose one argument from the list.
{ }	Braces are used with OR-bars and enclose a list of choices. You must choose one argument from the list.
...	Three dots (...) indicate that you can repeat the previous argument. If you use them with brackets, you can specify zero or more arguments. If they are used without brackets, you must specify at least one argument, but you can specify more.

Virtuoso Simulator Components and Device Models Reference

Preface



Important

The language requires many characters not included in the preceding list. You must enter required characters exactly as shown.

Circuit Components

This chapter contains component statements for the following:

- [Current Sources](#) on page 44
- [Voltage Sources](#) on page 80
- [Behavioral Source \(bsource\)](#) on page 105
- [Independent Resistive Source \(port\)](#) on page 112
- [Linear N Port \(nport\)](#) on page 125
- [Current Probe \(iprobe\)](#) on page 137
- [Circuit Reduced Order Model \(cktrom\)](#) on page 138
- [Analog-to-Logic Converter \(a2d\)](#) on page 140
- [device checker \(assert\)](#) on page 140
- [Logic-to-Analog Converter \(d2a\)](#) on page 142
- [Ideal Switch \(switch\)](#) on page 143
- [Ratiometric Fourier Analyzer \(fourier\)](#) on page 145
- [IBIS I/O buffer \(ibis_buffer\)](#) on page 149

Current Sources

Linear Current Controlled Current Source (cccs)

A current-controlled source senses the current with a probe device. A valid probe is a component instance in the circuit that naturally computes current. For example, probes can be voltage sources (independent or controlled), inductors, transmission lines, microstrip lines, N-ports, and transformers. If the probe device computes more than one current (such as transmission lines, microstrip lines, and N-ports), the index of the probe port through which the controlling current flows needs to be specified. Positive current exits the source node and enters the sink node of the controlled source.

This device can also model ideal digital gates.

This device is supported within altergroups.

Sample Instance Statement

```
vcs (pos gnd) cccs gain=2.5 probe=v1 m=1 //Note that v1 is an instance of a voltage source
```

Instance Definition

```
Name sink src cccs parameter=value ...
```

Instance Parameters

- | | | |
|---|----------------------------|---|
| 1 | <code>m=1</code> | Multiplicity factor. |
| 2 | <code>probe</code> | Device through which the controlling current flows. |
| 3 | <code>mprobe</code> | The mprobe functions the same as probe except that it will divide the input current by the mfactor. |
| 4 | <code>port=0</code> | Index of the probe port through which the controlling current flows. |
| 5 | <code>probes=[...]</code> | Devices through which the controlling currents flow. For multi-input digital gates only. |
| 6 | <code>mprobes=[...]</code> | The mprobes function the same as probes except that they will divide the input currents by the mfactor. |

Virtuoso Simulator Components and Device Models Reference

Circuit Components

- 7 `ports=[...]` Indices of the probe ports through which the controlling currents flow. For multi-input digital gates only.
- 8 `type=cccs` Type of the source.
Possible values are `cccs`, `and`, `nand`, `or`, or `nor`.
- 9 `delta=0` Smoothing parameter. This may lead to circuit convergence. Its value should be in the range between 0 and 0.5, both ends included. The smaller the delta is, the sharper the corner is.

Linear source parameters

- 10 `gain=0 A/A` Current gain.
- 11 `td=0.0 s` Time delay.
- 12 `min (A)` Minimum output current.
- 13 `max (A)` Maximum output current.
- 14 `abs=off` Output current is absolute value if `abs` is set to `on`.
Possible values are `off` or `on`.

PWL source parameters

- 15 `file` Name of file containing current/current pairs that define the PWL transfer function.
- 16 `pwl=[...]` Vector of current/current pairs that defines the PWL transfer function. The format of the vector is `[in1 out1 in2 out2 ...]`.
- 17 `scale=1` Scale factor for the PWL output current.
- 18 `stretch=1` Scale factor for the PWL controlling current.

Temperature effects parameters

- 19 `tc1=0 1/C` Linear temperature coefficient.
- 20 `tc2=0 C-2` Quadratic temperature coefficient.

Virtuoso Simulator Components and Device Models Reference

Circuit Components

The Smoothing Factor

The parameter delta is the smoothing factor. When it is nonzero, a curve is introduced to smooth the corner. The value of delta defines the position of the starting and ending points of the curve that is used to smooth the corner. The minimum value 0 means no smoothing curve is introduced. The maximum value 0.5 means the distance between the starting point of the curve and the corner point is half of the shortest distance. The shortest distance is the length of the shortest segment of the piecewise linear function. Or, when there is no shortest segment in the controlling function, i.e. only `abs=on` is specified, spectre uses 1 as the shortest distance.

Operating-Point Parameters

- 1 `i` (A) Input current.
- 2 `v` (V) Output voltage.
- 3 `pwr` (W) Power dissipation.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

<code>abs</code> I-14	<code>max</code> I-13	<code>probe</code> I-2	<code>tc1</code> I-19
<code>delta</code> I-9	<code>min</code> I-12	<code>probes</code> I-5	<code>tc2</code> I-20
<code>file</code> I-15	<code>mprobe</code> I-3	<code>pwl</code> I-16	<code>td</code> I-11
<code>gain</code> I-10	<code>mprobes</code> I-6	<code>pwr</code> OP-3	<code>type</code> I-8
<code>i</code> OP-1	<code>port</code> I-4	<code>scale</code> I-17	<code>v</code> OP-2
<code>m</code> I-1	<code>ports</code> I-7	<code>stretch</code> I-18	

Linear Current Controlled Voltage Source (ccvs)

A current-controlled source senses the current with a probe device. A valid probe is a component instance in the circuit that naturally computes current. For example, probes can be voltage sources (independent or controlled), inductors, transmission lines, microstrip lines, N-ports, and transformers. If the probe device computes more than one current (such as transmission lines, microstrip lines, and N-ports), the index of the probe port through which the controlling current flows needs to be specified. Current through the controlled voltage source is calculated and is defined to be positive if it flows from the positive terminal, through the source, to the negative terminal.

This device can also model ideal digital gates.

This device is supported within altergroups.

Sample Instance Statement

```
vvs (pos gnd) ccvs rm=1 probe=v1 m=1 //Note that v1 is an instance of a voltage source
```

Instance Definition

```
Name p n ccvs parameter=value ...
```

Instance Parameters

1	<code>m=1</code>	Multiplicity factor.
2	<code>probe</code>	Device through which the controlling current flows.
3	<code>mprobe</code>	The mprobe functions the same as probe except that it will divide the input current by the mfactor.
4	<code>port=0</code>	Index of the probe port through which the controlling current flows.
5	<code>probes=[...]</code>	Devices through which the controlling currents flow. For multi-input digital gates only.
6	<code>mprobes=[...]</code>	The mprobes function the same as probes except that they will divide the input currents by the mfactor.

Virtuoso Simulator Components and Device Models Reference

Circuit Components

- 7 `ports=[...]` Indices of the probe ports through which the controlling currents flow. For multi-input digital gates only.
- 8 `type=ccvs` Type of the source.
Possible values are `ccvs`, `and`, `nand`, `or`, or `nor`.
- 9 `delta=0` Smoothing parameter. This may lead to circuit convergence. Its value should be in the range between 0 and 0.5, both ends included. The smaller the delta is, the sharper the corner is.

Linear source parameters

- 10 `rm=0 Ω` Trans resistance.
- 11 `td=0.0 s` Time delay.
- 12 `min (V)` Minimum output voltage.
- 13 `max (V)` Maximum output voltage.
- 14 `abs=off` Output voltage is absolute value if `abs` is set to `on`.
Possible values are `off` or `on`.

PWL source parameters

- 15 `file` Name of file containing current/voltage pairs that define the PWL transfer function.
- 16 `pwl=[...]` Vector of current/voltage pairs that defines the PWL transfer function. The format of the vector is `[in1 out1 in2 out2 ...]`.
- 17 `scale=1` Scale factor for the PWL output voltage.
- 18 `stretch=1` Scale factor for the PWL controlling current.

Temperature effects parameters

- 19 `tc1=0 1/C` Linear temperature coefficient.
- 20 `tc2=0 C-2` Quadratic temperature coefficient.

Virtuoso Simulator Components and Device Models Reference

Circuit Components

The Smoothing Factor

The parameter delta is the smoothing factor. When it is nonzero, a curve is introduced to smooth the corner. The value of delta defines the position of the starting and ending points of the curve that is used to smooth the corner. The minimum value 0 means no smoothing curve is introduced. The maximum value 0.5 means the distance between the starting point of the curve and the corner point is half of the shortest distance. The shortest distance is the length of the shortest segment of the piecewise linear function. Or, when there is no shortest segment in the controlling function, i.e. only `abs=on` is specified, spectre uses 1 as the shortest distance.

Operating-Point Parameters

- 1 `i` (A) Output current.
- 2 `v` (V) Output voltage.
- 3 `pwr` (W) Power dissipation.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

<code>abs</code> I-14	<code>min</code> I-12	<code>probes</code> I-5	<code>tc1</code> I-19
<code>delta</code> I-9	<code>mprobe</code> I-3	<code>pwl</code> I-16	<code>tc2</code> I-20
<code>file</code> I-15	<code>mprobes</code> I-6	<code>pwr</code> OP-3	<code>td</code> I-11
<code>i</code> OP-1	<code>port</code> I-4	<code>rm</code> I-10	<code>type</code> I-8
<code>m</code> I-1	<code>ports</code> I-7	<code>scale</code> I-17	<code>v</code> OP-2
<code>max</code> I-13	<code>probe</code> I-2	<code>stretch</code> I-18	

Independent Current Source (isource)

The value of the DC current as a function of the temperature is given by:

$$I(T) = I(tnom) * [1 + tc1 * (T - tnom) + tc2 * (T - tnom)^2].$$

Sample Instance Statement

```
i1 (in 0) isource dc=0 type=pulse delay=10n val0=0 val1=500u period=500n rise=1n fall=1n width=250n
```

Instance Definition

```
Name sink src [ctlp] [ctln] isource parameter=value ...
```

Positive current exits the source node and enters the sink node. The third node (`ctl`) is used as a switch only for prbs.

Instance Parameters

1 `dc=0 A` DC value.

General waveform parameters

2 `type=dc` Waveform type.
Possible values are `dc`, `pulse`, `pwl`, `sine`, `exp`, `bit`, `prbs`, `pwlz`, and `sigbus`.

3 `fundname` Name of the fundamental frequency. Must be specified if the source is active during a `pdisto` analysis or it is the active clock during an `envlp` analysis.

4 `delay=0 s` Waveform delay time.

5 `edgetype=linear` Type of the rising and falling edges, effective for pulse, pulse-like piecewise linear, bit and prbs sources.
Possible values are `linear` and `halfsine`.

Pulse waveform parameters

6 `val0=0 A` Zero value used in pulse and exponential waveforms.

7 `val1=1 A` One value used in pulse and exponential waveforms.

Virtuoso Simulator Components and Device Models Reference

Circuit Components

8	<code>period=∞ s</code>	Period of waveform. When <code>type=prbs</code> , period defines the bit duration.
9	<code>rise (s)</code>	Rise time for pulse waveform (time for transition from <code>val0</code> to <code>val1</code>). If parameter <code>rise</code> is not given, then the rise time will be the same as fall time; if fall time is not given either, then the rise time will be 1/100 of the waveform period; if the waveform is not periodic, then the rise time will be 1/100 of the simulation interval; if <code>type=prbs</code> , the rise time is 1/10 of the bit duration.
10	<code>fall (s)</code>	Fall time for pulse waveform (time for transition from <code>val1</code> to <code>val0</code>). If parameter <code>fall</code> is not given, then the fall time will be the same as rise time; if rise time is not given either, then the fall time will be 1/100 of the waveform period; if the waveform is not periodic, then the fall time will be 1/100 of the simulation interval; if <code>type=prbs</code> , the fall time is 1/10 of the bit duration.
11	<code>width=∞ s</code>	Pulse width (duration of <code>val1</code>).

PWL waveform parameters

12	<code>file</code>	Name of file containing waveform.
13	<code>wave=[...]</code>	Vector of time/value pairs that defines waveform.
14	<code>offset=0 A</code>	DC offset for the PWL waveform.
15	<code>scale=1</code>	Scale factor for the PWL waveform.
16	<code>stretch=1</code>	Scale factor for time given for the PWL waveform.
17	<code>rms</code>	Desired rms (root of mean square) value of the PWL waveform.
18	<code>pwlfilter=none</code>	Add filter to pwl source, where the pwl data should be equal space sampled. Possible values are 'nrc'(normal raised cosine filter) and 'none'. Possible values are <code>none</code> and <code>nrc</code> .
19	<code>rolloff</code>	Desired rolloff factor for the raised cosine filter, default value is 0.2. Only valid when 'pwlfilter' is set to <code>nrc</code> .
20	<code>pwlbandwidth</code>	Bandwidth of the pwl input signal. Be used when 'pwlfilter' is set to <code>nrc</code> .

Virtuoso Simulator Components and Device Models Reference

Circuit Components

- 21 `allbrkpts` All the points in the PWL waveform are breakpoints if set to yes. Default is yes if the number of points is less than 20. Possible values are `no` and `yes`.
- 22 `pwlperiod` (s) Period of the periodic PWL waveform.
- 23 `pwlperiodstart` (s) Period start time of the periodic PWL waveform.
- 24 `twidth=pwlperiod/1000` s Transition width used when making PWL waveforms periodic.
- 25 `highz=1e12` The impedance of high z state.
- 26 `min_z_transition_width=10e-12` s Minimum width of transition from z-state to non z-state. The width of transition is set as $1e-3 \times (\text{z-state duration})$.

Sinusoidal waveform parameters

- 27 `sinedc=dc` A DC level for sinusoidal waveforms.
- 28 `ampl=1` A Peak amplitude of sinusoidal waveform.
- 29 `freq=0` Hz Frequency of sinusoidal waveform.
- 30 `sinphase=0` ° Phase of sinusoid when `t=delay`.
- 31 `ampl2=1` A Peak amplitude of second sinusoidal waveform.
- 32 `freq2=0` Hz Frequency of second sinusoidal waveform.
- 33 `sinphase2=0` ° Phase of second sinusoid when `t=delay`.
- 34 `fundname2` Name of the fundamental frequency associated with `freq2`. Must be specified if `freq2` is used in a `pdisto` analysis.
- 35 `iqmodfiles=[...]` Two file names which containing pwl I/Q source waveform.
- 36 `fmodindex=0` FM index of modulation for sinusoidal waveform.
- 37 `fmodfreq=0` Hz FM modulation frequency for sinusoidal waveform.

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38	<code>fmodfiles=[...]</code>	One or two file names: containing FM waveform for one file case, and FM I/Q signals for two files with I file first.
39	<code>ammodindex=0</code>	AM index of modulation for sinusoidal waveform.
40	<code>ammodoffset=1</code>	AM offset of modulation for sinusoidal waveform.
41	<code>ammodfreq=0 Hz</code>	AM modulation frequency for sinusoidal waveform.
42	<code>ammodphase=0 °</code>	AM phase of modulation for sinusoidal waveform.
43	<code>damp=0 1/s</code>	Damping factor for sinusoidal waveform.
44	<code>freqvec=[...] Hz</code>	Vector of support frequency of sinusoid channel source.
45	<code>amplvec=[...] A</code>	Vector of Peak amplitude of sinusoid channel source.
46	<code>phasevec=[...] °</code>	Vector of Phase of sinusoid channel source.
47	<code>maxharms=[...]</code>	Array of number of harmonics of each frequency.

Exponential waveform parameters

48	<code>td1=0 s</code>	Rise start time for exponential wave.
49	<code>tau1 (s)</code>	Rise time constant for exponential wave.
50	<code>td2 (s)</code>	Fall start time for exponential wave.
51	<code>tau2 (s)</code>	Fall time constant for exponential wave.
52	<code>expperiod (s)</code>	Period of the periodic EXP waveform.

Pattern parameters

53	<code>data</code>	The bit string. A string that contains a series of the four states, 1 0 m z. For prbs, it can contain only 0 and 1, and m, z is not supported.
54	<code>rptstart=1</code>	The starting bit when repeating. The data repeats from the specified bit to the end of the bit string. The parameter should be an integer from 1 to the length of the bit string.

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Circuit Components

55 `rpttimes=0` The repeat times. The output will maintain the state of the last bit after the last repeat. If its value is negative, the string repeats forever.

Prbs parameters

56 `ref (A)` Sets the crossing reference for the control node. This parameter applies only when the Prbs source operates as a 3 or 4 terminal device. When the voltage across terminals 3 and 4 drops below `ref`, the output of the source is set to 0. If terminal 4 is not specified, it is assumed to be connected to ground.

57 `jitter (s)` The parameter `jitter` is obsolete. It has no effect on the output.

58 `rjseed=1` The seed for random number generator, used in generating random jitter for PRBS sources. The default value is 1.

59 `rjrms (s)` When set for PRBS source or Bit source, the source has a normally distributed random jitter, whose mean is zero and whose standard deviation is `rjrms`.

60 `pjamp=[...] s` When set for PRBS source or Bit source, the source has multiple periodic jitters, whose amplitudes are defined by `pjamp` and frequencies are defined by `pjfreq`.

61 `pjfreq=[...] Hz` When set for PRBS source or Bit source, the source has multiple periodic jitters, whose amplitudes are defined by `pjamp` and whose frequency are defined by `pjfreq`.

62 `pjtype="sine"` For PRBS source or Bit source, `pjtype` defines the types of periodic jitters. Possible valudes are 'sine', 'sawtooth', or 'square'.

63 `seed` This parameter is obsolete but retained for backward compatability. Set `registerlength=[2 ... 32]` to choose a Maximum Length Sequence or define a custom PRBS by use of the parameters, `lfsrtaps` and `lfsrseed`.

64 `taps=[...]` The use of `taps` is discouraged. For PRBS, `taps` is an integer array which sets the locations of the LFSR taps. Please use `lfsrtaps` instead. Please see the section, 'PRBS Type Waveform' below for details of the PRBS operation.

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- 65 `lfsrtaps=[...]` For PRBS source, `lfsrtaps` is an integer array which sets the location of LFSR taps. Locations are 1-based and ordered from MSB to LSB of the LFSR. The largest element of the taps array is equal to the width of the LFSR. Please see the section, 'PRBS Type Waveform' for details of PRBS source operation.
- 66 `lfsrseed=[...]` For PRBS source, `lfsrseed` is an integer array which sets the initial state of the LFSR. Array elements sets the locations of non-zero bits. Locations are 1-based and ordered from MSB to LSB of the LFSR. For example, assume `lfsrtaps=[6]` and `lfsrseed=[1 3 5]`. The width of the register is then 6 bits and the initial state is '101010'.
- 67 `registerlength` When set for PRBS, the `registerlength` defines the width of the LFSR and the LFSR works in Maximum Length Sequence mode. Please see the section 'PRBS Type Waveform' below for details of MLS setting.
- 68 `triggerthreshold` (A) For PRBS, when `triggerthreshold` is set and the source is instantiated with optional control terminals (terminals 3 and optionally 4; if terminal 4 is unspecified it is assumed to be connected to ground), `triggerthreshold` defines the crossing threshold for the trigger event. The event causes the emission of the next PRBS pulse.
- 69 `triggerdelthresh` (A) For PRBS in external triggering mode, `triggerdelthresh` is used with `triggerthreshold` to define the crossing threshold. For rising edge triggering, the actual threshold is (`triggerthreshold + triggerdelthresh`); for falling edge triggering, the threshold is (`triggerthreshold - triggerdelthresh`). The default value is zero.
- 70 `triggerdirection="both"` For PRBS in external triggering mode, `trigger direction` defines the direction of the control signal at the crossing event. Possible valudes are 'rise', 'fall', or 'both'.
- 71 `transitionreference` Defines the voltage swing for the duration of rise and fall time, as a percentage of `val1 - val0`. For example, `transitionreference =100` means that the output voltage transitions from `val0` to `val1` in rise seconds. `90` means that it transitions from $0.1*(val1-val0)$

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Circuit Components

to $0.9 \cdot (\text{val1} - \text{val0})$ in rise seconds, 80 means from $0.2 \cdot (\text{val1} - \text{val0})$ to $0.8 \cdot (\text{val1} - \text{val0})$, etc. Possible values are 100, 90, 80, 70 and 60.

Noise Parameters

- 72 `noisefile` Name of file containing excess spot noise data in the form of frequency-noise pairs. The noise can be specified as the spectral density in V^2/Hz , or as single-sideband phase noise in dBc. The parameter `noisetype` determines how Spectre interprets the noise data..
- 73 `noisevec=[...]` A^2/Hz Excess spot noise as a function of frequency in the form of frequency-noise pairs. The parameter `noisetype` determines how Spectre interprets the noise data..
- 74 `noisetype=noisevoltage` When set to `noisevoltage`, the noise data represents the noise spectral density in V^2/Hz . When set to `ssbphasenoise`, the noise data represents single-sideband phase noise in dBc. When set to `noisevoltage`, the frequencies are absolute. For `ssbphasenoise`, the frequencies are offset from carrier.. Possible values are `noisevoltage` and `ssbphasenoise`.
- 75 `noiseinterp=linear` Determine how the specified noise data is interpolated. This parameter only applies to `noisetype=noisevoltage`. When set to `linear`, interpolation is linear over both axes. When set to `loglog`, Spectre uses log interpolation over both axes.. Possible values are `linear` and `loglog`.
- 76 `isnoisy=yes` Should `isource` generate noise. Possible values are `no` and `yes`.

Small signal parameters

- 77 `mag=0` A Small signal current.
- 78 `phase=0` Small signal phase.
- 79 `xfmag=1` A/A Transfer function analysis magnitude.

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80 `pacmag=0 A` Periodic AC analysis magnitude.

81 `pacphase=0` Periodic AC analysis phase.

Multiplication factor parameters

82 `m=1` Multiplicity factor.

Temperature effects parameters

83 `tc1=0 1/C` First order temperature coefficient.

84 `tc2=0 C-2` Second order temperature coefficient.

85 `tnom=27 C` Parameter measurement temperature. Default set by options.

86 `trise=0.0 C` Temperature rise from ambient.

If you do not specify the DC value, it is assumed to be the `time=0` value of the waveform.

Sinusoidal waveform in the time interval $0 < t < \text{delay}$ has constant value equal to that at $t = \text{delay}$.

In DC analyses, the only active parameters are `dc`, `m`, and the temperature coefficient parameters. In AC analyses, the only active parameters are `m`, `mag` and `phase`. In transient analyses, all parameters are active except the small signal parameters and the noise parameters. The `type` parameter selects which type of waveform is generated. You may specify parameters for more than one waveform type, and use the `alter` statement to change the waveform type between analyses. There is one exception for type `bit`. You cannot change `bit` type to other types or other types to `bit`.

PWL Type Waveform

A vector of time-value pairs describes the piecewise linear waveform. As an alternative, you can read the waveform from a file. In this case, you give time-value pairs one pair per line with a space or tab between the time and the value.

If you set `allbrkpts` to `yes`, you force the simulator to place time points at each point specified in a PWL waveform during a transient analysis. This can be very expensive for waveforms with many points. If you set `allbrkpts` to `no`, Spectre inspects the waveform, looking for abrupt changes, and forces time points only at those changes.

The PWL waveform is periodic if you specify `pwlperiod` and/or `pwlperiodstart`. If both `pwlperiod` and `pwlperiodstart` are specified, `pwlperiod` should be longer than $(\text{wavelength} - \text{pwlperiodstart})$, where `wavelength` means the last time point. If only `pwlperiod` is specified and `pwlperiodstart` is undefined, then the period will start at first time point or $(\text{wavelength} - \text{pwlperiod})$, whichever is greater. If only `pwlperiodstart` is specified and `pwlperiod` is undefined, then the period will end at the last time point in the waveform vector. If the value of the waveform specified is not exactly the same at both the period beginning and the period end, then you must provide a nonzero value `twidth`. Before repeating, the waveform changes linearly in an interval of `twidth` from its value at $(\text{period} - \text{twidth})$ to its value at the beginning of the waveform. Thus, `twidth` must always be less than `period`.

Bit Type Waveform

Bit type waveform is the analog waveform of a series of digital logic state. It uses the pattern parameters to provide the digital state sequence, and some pulse waveform parameters to define the waveform characteristics.

To define the waveform characteristics, use parameters: `val1`, `val0`, `rise`, `fall`, and `period`. Note that parameter `period` here defines the length of a bit and it must be given. The general parameter `delay` can also be used for bit type to define the delay time from the beginning of the transient interval to the beginning of the first bit. The state during the delay time is the same as the first state specified in `data`.

Pattern parameters are used to specify the digital bit string. The pattern parameters of sources are the same as those of a pattern, except that you can specify `rpttimes` to a negative number for sources but not for patterns. Type `spectre -h pattern` for details on how to use pattern parameters.

PRBS Type Waveform

When `type=prbs`, the source emits a pseudo-random bit sequence. The sequence is defined by the LSB of a Fibonacci Linear Feedback Shift Register (LFSR) at trigger events.

The LFSR is initially loaded by a 'seed'. The value fed back to the input (MSB) is given by $\text{feedback} = \text{tap}_1 \wedge \text{tap}_2 \wedge \dots \wedge \text{tap}_N$, where \wedge represents an exclusive-or operation, and `tapi` represents the *i*-th bit of the register, counting from 1 and starting from the MSB. At a trigger event, the LFSR is shifted to the right and the MSB is given by the 'feedback'.

LFSR Modes

The sequence can be defined by custom values of seeds and taps. Alternatively, you can specify a maximum length sequence by setting the length of the LFSR. To specify custom seeds and taps, use the `lfsrseed` and `lfsrtaps` arrays. To specify a maximum length sequence, use the parameter, `registerlength=[2 ... 32]`. Spectre sets the seeds and taps automatically. You can optionally set `lfsrseed` to override the automatically chosen seed.

Triggering Mode

By default, the sequence is triggered by an internal clock and pulses are emitted every 'period' seconds, excluding the optional jitter. Alternatively, you can apply an external clock to the optional 3rd and 4th terminals. In external trigger mode, the pulses are emitted when the clock crossed the specified threshold in the specified direction. The threshold is defined by the `triggerthreshold` parameter; the direction is specified by `triggerdirection`. In external trigger mode, jitter and bit period parameters are ignored.

Jitter

Let $\{s_i\}$ be a sequence of ones and zeros whose transitions occur at intervals given by $n \cdot T + j(t)$, where T is the bit duration. Then, borrowing Verilog-A terminology, the jittered output is given by $s(t+j(t)) = \text{transition}(s_i? \text{Vhigh} : \text{Vlow}, \text{rise}, \text{fall})$. $j(t) = rj(t) + pj(t)$, where rj (random jitter) is a normally distributed random variable whose mean is 0 and standard deviation is given by the parameter `rjrms`; and pj is the periodic jitter whose amplitude is `pjamp` and whose frequency is `pjfreq`. The parameter, `pjtype`, defines the type of jitter waveform. For sine, the periodic jitter is given by $pj(t) = pjamp \cdot \cos(2 \cdot \pi \cdot pjfreq \cdot t)$. Other types are square and sawtooth.

Noise of the source

You can give the excess noise of the source as a file or specify it with a vector of frequency-noise pairs. For a file, give the frequency-noise pairs one pair per line with a space or tab between the frequency and noise values.

Output Parameters

1 `tempeff (C)` Effective temperature for a single device.

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Circuit Components

Operating-Point Parameters

1	<code>i</code> (A)	Current through the source.
2	<code>v</code> (V)	Voltage across the source.
3	<code>pwr</code> (W)	Power dissipation.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

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<code>ammodfreq</code> I-41	<code>highz</code> I-25	<code>pjtype</code> I-62	<code>tau2</code> I-51
<code>ammodindex</code> I-39	<code>i</code> OP-1	<code>pwlbandwidth</code> I-20	<code>tc1</code> I-83
<code>ammodoffset</code> I-40	<code>iqmodfiles</code> I-35	<code>pwlfilter</code> I-18	<code>tc2</code> I-84
<code>ammodphase</code> I-42	<code>isnoisy</code> I-76	<code>pwlperiod</code> I-22	<code>td1</code> I-48
<code>ampl</code> I-28	<code>jitter</code> I-57	<code>pwlperiodstart</code> I-23	<code>td2</code> I-50
<code>ampl2</code> I-31	<code>lfsrseed</code> I-66	<code>pwr</code> OP-3	<code>tempeff</code> O-1
<code>amplvec</code> I-45	<code>lfsrtaps</code> I-65	<code>ref</code> I-56	<code>tnom</code> I-85
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<code>dc</code> I-1	<code>maxharms</code> I-47	<code>rjrms</code> I-59	<code>triggerdirection</code> I-70

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fundname I-3	pjump I-60	taps I-64	

Polynomial Current Controlled Current Source (pcccs)

A vector of coefficients specifies the polynomial function that defines the relationship between the output current and the controlling currents. You must specify at least one coefficient.

This device is supported within altergroups.

For a polynomial in M variables a1, a2, ... am, the polynomial function F(a0,a1,...,am) is given by

$$\begin{aligned}
 F = & c_0 + c_1 * a_1 + c_2 * a_2 + \dots \\
 & + c_{(m+1)} * a_1^2 + c_{(m+2)} * a_1 * a_2 + \dots \\
 & + c_{(2m+1)} * a_2^2 + c_{(2m+2)} * a_2 * a_3 + \dots
 \end{aligned}$$

where the *c*s are coefficients of the polynomial terms.

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Circuit Components

Sample Instance Statement

```
vpc (net1 0) pcccs probes=[vb vc ve vlp vpn] coeffs=[0 8.8e6 -8.8e6 9e6 8e6 -9e6]
```

Instance Definition

```
Name sink src pcccs parameter=value ...
```

Instance Parameters

- | | | |
|----|----------------------------|---|
| 1 | <code>m=1</code> | Multiplicity factor. |
| 2 | <code>gain=1</code> | Gain Parameter. |
| 3 | <code>probes=[...]</code> | Devices through which the controlling currents flow. |
| 4 | <code>mprobes=[...]</code> | The mprobes function the same as probes except that they will divide the input currents by the mfactor. |
| 5 | <code>ports=[...]</code> | Indices of the probe ports through which the controlling currents flow. |
| 6 | <code>coeffs=[...]</code> | Polynomial coefficients. At least one must be given. |
| 7 | <code>file</code> | File that contains nonzero polynomial coefficients. |
| 8 | <code>min (A)</code> | Minimum output current. |
| 9 | <code>max (A)</code> | Maximum output current. |
| 10 | <code>abs=off</code> | Absolute output current.
Possible values are <code>off</code> or <code>on</code> . |
| 11 | <code>delta=0</code> | Smoothing parameter. This may lead to circuit convergence. The smaller the delta is, the sharper the corner is. |

Temperature effects parameters

- | | | |
|----|-----------------------------------|------------------------------------|
| 12 | <code>tc1=0 1/C</code> | Linear temperature coefficient. |
| 13 | <code>tc2=0 C⁻²</code> | Quadratic temperature coefficient. |

Operating-Point Parameters

1	<i>i</i> (A)	Output current.
2	<i>v</i> (V)	Output voltage.
3	<i>pwr</i> (W)	Power dissipation.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

<i>abs</i> I-10	<i>gain</i> I-2	<i>min</i> I-8	<i>pwr</i> OP-3
<i>coeffs</i> I-6	<i>i</i> OP-1	<i>mprobes</i> I-4	<i>tc1</i> I-12
<i>delta</i> I-11	<i>m</i> I-1	<i>ports</i> I-5	<i>tc2</i> I-13
<i>file</i> I-7	<i>max</i> I-9	<i>probes</i> I-3	<i>v</i> OP-2

Polynomial Voltage Controlled Current Source (pvccs)

A vector of coefficients specifies the polynomial function that defines the relationship between the output current and the controlling voltages. You must specify at least one coefficient. Current exits the source node and enters the sink node.

This device is supported within altergroups.

For a polynomial in *M* variables *a*₁, *a*₂, ... *a*_{*m*}, the polynomial function *F*(*a*₀,*a*₁,...,*a*_{*m*}) is given by

$$F = c_0 + c_1 * a_1 + c_2 * a_2 + \dots \\ + c_{(m+1)} * a_1^2 + c_{(m+2)} * a_1 * a_2 + \dots$$

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$$+ c(2m+1) * a2^2 + c(2m+2) * a2 * a3 + \dots$$

where the c s are coefficients of the polynomial terms.

Sample Instance Statement

```
v2 (net1 0 net2 0) pvccs coeffs=[0 -2e-3 - 10e-3] gain=2 m=1
```

Instance Definition

```
Name sink src ps1 ns1 ... pvccs parameter=value ...
```

Instance Parameters

- | | | |
|---|---------------------------|---|
| 1 | <code>m=1</code> | Multiplicity factor. |
| 2 | <code>type=pvccs</code> | Type of the source.
Possible values are <code>pvccs</code> , <code>vcr</code> or <code>vccap</code> . |
| 3 | <code>gain=1</code> | Gain Parameter. |
| 4 | <code>coeffs=[...]</code> | Polynomial coefficients. At least one must be given. |
| 5 | <code>file</code> | File that contains nonzero polynomial coefficients. |
| 6 | <code>min (A)</code> | Minimum output current. |
| 7 | <code>max (A)</code> | Maximum output current. |
| 8 | <code>abs=off</code> | Absolute output current.
Possible values are <code>off</code> or <code>on</code> . |
| 9 | <code>delta=0</code> | Smoothing parameter. This may lead to circuit convergence. The smaller the delta is, the sharper the corner is. |

Temperature effects parameters

- | | | |
|----|-----------------------------------|------------------------------------|
| 10 | <code>tc1=0 1/C</code> | Linear temperature coefficient. |
| 11 | <code>tc2=0 C⁻²</code> | Quadratic temperature coefficient. |

Operating-Point Parameters

1	<code>i</code> (A)	Output current.
2	<code>v</code> (V)	Output voltage.
3	<code>pwr</code> (W)	Power dissipation.

Parameter Index

In the following index, `I` refers to instance parameters, `M` refers to the model parameters section, `O` refers to the output parameters section, and `OP` refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of `M-35` means the 35th model parameter.
`ss-Domain Linear Current Controlled Current Source (scccs)`

<code>abs</code>	I-8	<code>gain</code>	I-3	<code>min</code>	I-6	<code>type</code>	I-2
<code>coeffs</code>	I-4	<code>i</code>	OP-1	<code>pwr</code>	OP-3	<code>v</code>	OP-2
<code>delta</code>	I-9	<code>m</code>	I-1	<code>tc1</code>	I-10		
<code>file</code>	I-5	<code>max</code>	I-7	<code>tc2</code>	I-11		

s-Domain Linear Current Controlled Current Source (scccs)

The device output is defined through a transfer function given as a ratio of two polynomials in the complex variable s . Polynomials can be specified in terms of either coefficients or roots. The roots of the numerator are the zeros of the transfer function and the roots of the denominator are the poles.

To specify the polynomial in terms of the coefficients, you enter them as a vector in ascending order of the power of the variable s , starting from the constant term. For example, to specify a denominator of $3s^2 + 4s + 1$, use `denom=[1 4 3]`.

To specify a polynomial in terms of its roots, you give the roots as a vector of complex frequencies (frequencies should be in radians/second). You must give both the real and imaginary parts of the root, even when the root is real. For the transfer function to be stable, all poles must have negative real values. When specifying a complex root, you should also

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specify its complex conjugate. However, if you omit the conjugate root, Spectre will supply the missing root and print a warning that a missing root was supplied. The order of the roots is not important. For example, to specify poles of $s = -1$, $s = 4j$, $s = -4j$, $s = -2 + 2j$, and $s = -2 - 2j$; use `poles=[-1 0 0 4 0 -4 -2 2 -2 -2]`.

Either the numerator or the denominator specification can be omitted. An omitted denominator or numerator is taken to be 1.

Notes on gain and gainfactor

The parameter `gain` is interpreted either as the DC gain or, if the function has zeros or poles at the origin, as a constant factor. Note that `gain` has a default value of 1, so if you do not want to specify the DC gain, you should always use parameter `gainfactor` to disable parameter `gain`. When `gainfactor` is specified, `gain` is not valid any more. For example, if the instant statement is:

```
s1 (1 0 control 0) svcvs numer=[1 2] denom=[3 4]
```

the transfer function will be $2*(2s+1)/(4s+3)$. Factor 2 is applied to make the DC gain of the transfer function to be 1. If you just want the transfer function to be $(2s+1)/(4s+3)$, specify `gainfactor=1` to disable the default value of `gain`. In this example, the statement will be:

```
s1 (1 0 control 0) svcvs numer=[1 2] denom=[3 4] gainfactor=1
```

where the transfer function is $1*(2s+1)/(4s+3)$. 1 is the gainfactor.

This device is not supported within altergroup.

Sample Instance Statement

```
l1 (2 1) inductor l=15
```

```
sc1 (1 0) scccs probe=l1 zeros=[0 6 0 -6 2 -8 2 8] poles=[-1 0 0 64 0 -64 -2 8 -2 -8]
```

Instance Definition

```
Name sink src scccs parameter=value ...
```

Instance Parameters

1 `probe` Device through which the controlling current flows.

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2	<code>mprobe</code>	The <code>mprobe</code> functions the same as <code>probe</code> except that it will divide the input current by the <code>mfactor</code> .
3	<code>port=0</code>	Index of the probe port through which the controlling current flows.
4	<code>gain=1</code>	DC gain or constant transfer function factor. See notes on <code>gain</code> and <code>gainfactor</code> for details.
5	<code>gainfactor</code>	Constant factor applied to transfer function. It disables the parameter gain.
6	<code>numer=[...]</code>	Vector of numerator coefficients.
7	<code>denom=[...]</code>	Vector of denominator coefficients.
8	<code>zeros=[...]</code>	Vector of complex zeros.
9	<code>poles=[...]</code>	Vector of complex poles.
10	<code>m=1</code>	Multiplicity factor.
11	<code>tc1=0 1/C</code>	Linear temperature coefficient.
12	<code>tc2=0 C⁻²</code>	Quadratic temperature coefficient.

Operating-Point Parameters

1	<code>i (A)</code>	Input current.
2	<code>v (V)</code>	Output voltage.
3	<code>pwr (W)</code>	Power dissipation.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

Virtuoso Simulator Components and Device Models Reference

Circuit Components

denom	I-7	m	I-10	port	I-3	tc2	I-12
gain	I-4	mprobe	I-2	probe	I-1	v	OP-2
gainfactor	I-5	numer	I-6	pwr	OP-3	zeros	I-8
i	OP-1	poles	I-9	tc1	I-11		

s-Domain Linear Voltage Controlled Current Source (svccs)

The device output is defined through a transfer function given as a ratio of two polynomials in the complex variable s . Polynomials can be specified in terms of either coefficients or roots. The roots of the numerator are the zeros of the transfer function and the roots of the denominator are the poles.

To specify the polynomial in terms of the coefficients, you enter them as a vector in ascending order of the power of the variable s , starting from the constant term. For example, to specify a denominator of $3s^2 + 4s + 1$, use `denom=[1 4 3]`.

To specify a polynomial in terms of its roots, you give the roots as a vector of complex frequencies (frequencies should be in radians/second). You must give both the real and imaginary parts of the root, even when the root is real. For the transfer function to be stable, all poles must have negative real values. When specifying a complex root, you should also specify its complex conjugate. However, if you omit the conjugate root, Spectre will supply the missing root and print a warning that a missing root was supplied. The order of the roots is not important. For example, to specify poles of $s = -1$, $s = 4j$, $s = -4j$, $s = -2 + 2j$, and $s = -2 - 2j$; use `poles=[-1 0 0 4 0 -4 -2 2 -2 -2]`.

Either the numerator or the denominator specification can be omitted. An omitted denominator or numerator is taken to be 1.

Notes on gain and gainfactor

The parameter `gain` is interpreted either as the DC gain or, if the function has zeros or poles at the origin, as a constant factor. Note that `gain` has a default value of 1, so if you do not want to specify the DC gain, you should always use parameter `gainfactor` to disable parameter `gain`. When `gainfactor` is specified, `gain` is not valid any more. For example, if the instant statement is:

```
s1 (1 0 control 0) svccs numer=[1 2] denom=[3 4]
```

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Circuit Components

the transfer function will be $2*(2s+1)/(4s+3)$. Factor 2 is applied to make the DC gain of the transfer function to be 1. If you just want the transfer function to be $(2s+1)/(4s+3)$, specify `gainfactor=1` to disable the default value of `gain`. In this example, the statement will be:

```
s1 (1 0 control 0) svccs numer=[1 2] denom=[3 4] gainfactor=1
```

where the transfer function is $1*(2s+1)/(4s+3)$. 1 is the `gainfactor`.

This device is not supported within `altergroup`.

Sample Instance Statement

```
s2 (1 0 control 0) svccs gain=0.4 numer=[2 3] denom=[4 5 1]
```

Instance Definition

```
Name sink src ps ns svccs parameter=value ...
```

Instance Parameters

1	<code>gain=1</code>	DC gain or constant transfer function factor. See notes on <code>gain</code> and <code>gainfactor</code> for details.
2	<code>gainfactor</code>	Constant factor applied to transfer function. It disables the parameter <code>gain</code> .
3	<code>numer=[...]</code>	Vector of numerator coefficients.
4	<code>denom=[...]</code>	Vector of denominator coefficients.
5	<code>zeros=[...]</code>	Vector of complex zeros.
6	<code>poles=[...]</code>	Vector of complex poles.
7	<code>m=1</code>	Multiplicity factor.
8	<code>tc1=0 1/C</code>	Linear temperature coefficient.
9	<code>tc2=0 C⁻²</code>	Quadratic temperature coefficient.

Operating-Point Parameters

1	<code>i (A)</code>	Output current.
---	--------------------	-----------------

Virtuoso Simulator Components and Device Models Reference

Circuit Components

- 2 `v` (V) Output voltage.
- 3 `pwr` (W) Power dissipation.

Parameter Index

In the following index, `I` refers to instance parameters, `M` refers to the model parameters section, `O` refers to the output parameters section, and `OP` refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of `M-35` means the 35th model parameter.

<code>denom</code>	<code>I-4</code>	<code>i</code>	<code>OP-1</code>	<code>poles</code>	<code>I-6</code>	<code>tc2</code>	<code>I-9</code>
<code>gain</code>	<code>I-1</code>	<code>m</code>	<code>I-7</code>	<code>pwr</code>	<code>OP-3</code>	<code>v</code>	<code>OP-2</code>
<code>gainfactor</code>	<code>I-2</code>	<code>numer</code>	<code>I-3</code>	<code>tc1</code>	<code>I-8</code>	<code>zeros</code>	<code>I-5</code>

Linear Voltage Controlled Current Source (`vccs`)

Positive current exits the source node and enters the sink node.

This device can also model ideal digital gates, voltage controlled resistors and voltage controlled capacitors.

Type of `vccs`:

You can use `vccs` to model three types of devices.

When `type=vccs`, the device is a regular voltage controlled current source. This is also the default type. When `type=vcr`, the device is a voltage controlled resistor. When `type=vccap`, the device is a voltage controlled capacitor.

Input type of `vccs`:

You can use `vccs` to model ideal digital gates. Ideal digital gates have more than one inputs. The parameter `inputtype` is used to specify which input is going to control the `vccs` (or `vcr`, or `vccap`, specified by parameter `type`).

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Circuit Components

When `inputtype=single`, the device has only one input. This is also the default `inputtype`. When `inputtype=and/nand`, the smallest input controls the device. When `inputtype=or/nor`, the largest input controls the device. When `inputtype=npwl`, node `ns` should be connected to either `src` or `sink`. if $v(\text{src},\text{sink}) > 0$, then the controlling voltage would be $v(\text{ps},\text{sink})$. Otherwise, the controlling voltage is $v(\text{ps},\text{src})$. When `inputtype=ppwl`, node `ns` should be connected to either `src` or `sink`. if $v(\text{src},\text{sink}) > 0$, then the controlling voltage would be $v(\text{ps},\text{src})$. Otherwise, the controlling voltage is $v(\text{ps},\text{sink})$. If `inputtype` is `npwl` or `ppwl` but node `ns` is not connected to `src` or `sink`, then spectre change `inputtype` to `pwl`.

When you are using regular `vccs`, you can specify `and/nand/or/nor` in either type parameter of `inputtype` parameter. Please also note that spectre does not check if the gate behaves like an and or an nand, it just take the smallest input as the controlling voltage. And so is the case for `or/nor`.

This device is supported within `altergroups`.

Sample Instance Statement

```
v1 (1 0 2 3) gm=-1 m=2
```

Instance Definition

```
Name sink src ps ns ... vccs parameter=value ...
```

Instance Parameters

- | | | |
|---|-------------------------------|---|
| 1 | <code>m=1</code> | Multiplicity factor. |
| 2 | <code>type=vccs</code> | Type of the source.
Possible values are <code>vccs</code> , <code>vcr</code> , <code>vccap</code> , <code>and</code> , <code>nand</code> , <code>or</code> , <code>nor</code> , or <code>vcrspice</code> . |
| 3 | <code>inputtype=single</code> | Type of the input of the source.
Possible values are <code>single</code> , <code>and</code> , <code>nand</code> , <code>or</code> , <code>nor</code> , <code>npwl</code> , or <code>ppwl</code> . |
| 4 | <code>delta=0</code> | Smoothing parameter. This may lead to circuit convergence. Its value should be in the range between 0 and 0.5, both ends included. The smaller the delta is, the sharper the corner is. |

Linear source parameters

- | | | |
|---|---------------------|-------------------|
| 5 | <code>gm=0 S</code> | Transconductance. |
|---|---------------------|-------------------|

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Circuit Components

6	<code>td=0.0 s</code>	Time delay.
7	<code>min (A)</code>	Minimum output current.
8	<code>max (A)</code>	Maximum output current.
9	<code>abs=off</code>	Output current is absolute value if <code>abs</code> is set to on. Possible values are <code>off</code> or <code>on</code> .

PWL source parameters

10	<code>file</code>	Name of file containing voltage/current pairs that define the PWL transfer function.
11	<code>pwl=[...]</code>	Vector of voltage/current pairs that defines the PWL transfer function. The format of the vector is [in1 out1 in2 out2 ...].
12	<code>scale=1</code>	Scale factor for the PWL output current.
13	<code>stretch=1</code>	Scale factor for the PWL controlling voltage.
14	<code>logslope=1e3</code>	Used for PWL VCR only. If the slope between PWL points is larger than <code>logslope</code> , then log scale interpolation is used between the points.

Temperature effects parameters

15	<code>tc1=0 1/C</code>	Linear temperature coefficient.
16	<code>tc2=0 C⁻²</code>	Quadratic temperature coefficient.

The Smoothing Factor:

The parameter `delta` is the smoothing factor. When it is nonzero, a curve is introduced to smooth the corner. The value of `delta` defines the position of the starting and ending points of the curve that is used to smooth the corner. The minimum value 0 means no smoothing curve is introduced. The maximum value 0.5 means the distance between the starting point of the curve and the corner point is half of the shortest distance. The shortest distance is the length of the shortest segment of the piecewise linear function. Or, when there is no shortest segment in the controlling function, i.e. only `abs=on` is specified, `spectre` uses 1 as the shortest distance.

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Circuit Components

Operating-Point Parameters

1	i (A)	Output current.
2	v (V)	Output voltage.
3	pwr (W)	Power dissipation.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

abs	I-9	$inputtype$	I-3	pwl	I-11	$tc2$	I-16
$delta$	I-4	$logslope$	I-14	pwr	OP-3	td	I-6
$file$	I-10	m	I-1	$scale$	I-12	$type$	I-2
gm	I-5	max	I-8	$stretch$	I-13	v	OP-2
i	OP-1	min	I-7	$tc1$	I-15		

z-Domain Linear Current Controlled Current Source (zcccs)

The output is defined with a transfer function given as the ratio of two polynomials in the complex variable z . Each polynomial can be specified using either its coefficients or its roots. The roots of the numerator are the zeros of the transfer function and the roots of the denominator are the poles.

You may specify polynomials either in the complex variable z or $1/z$ by setting optional parameter `polyarg` to `z` or `inversez` respectively. By default, it is set to `inversez`. If you choose to provide the coefficients of a polynomial, enter them as a vector in ascending order of the power of the variable z or $1/z$, starting from the constant term. For example, to specify a denominator of $3z^{-2} + 4z^{-1} + 1$, use `denom=[1 4 3]`. Or to specify a denominator of $4z^2 + 3z - 2$, use `polyarg=z denom=[2 3 4]`.

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Circuit Components

To specify transfer function in terms of its zeros and poles in z-plane, give them as vectors of complex numbers. You must always give the real and imaginary portions of the root, even when the root is real. You may give either both roots of a complex-conjugate pair or only one. In the latter case the conjugate complex root will be generated automatically. The order of the roots is not important. For example, to specify poles of $z = 1$, $z = 4j$, $z = -4j$, $z = 2 + 2j$, and $z = 2 - 2j$, use `poles=[1 0 0 4 0 -4 2 2 2 -2]` or, omitting conjugate poles, `poles=[1 0 0 4 2 2]`.

Either the numerator or the denominator specification can be omitted. An omitted denominator or numerator is taken to be 1.

Transition time (`tt`) is an optional parameter that at each sampling point forces linear transition of the output to a new value within the specified time range. By default, it is set to one percent of the sampling period.

The sampling delay (`td`) is another optional parameter, with the default value of 0, that lets you set asynchronous sampling rates.

To use the s to z transformation, set the optional `sxz` parameter to one of the transformation methods - forward differences, backward differences, or bilinear. When the `sxz` parameter is specified, the transfer function specification is assumed to be given in the complex variable s and it will be transformed to the complex variable z using the indicated method.

Notes on gain and gainfactor

The parameter `gain` is interpreted either as the DC gain or, if the function has zeros or poles at the origin, as a constant factor. Note that `gain` has a default value of 1, so if you do not want to specify the DC gain, you should always use parameter `gainfactor` to disable parameter `gain`. When `gainfactor` is specified, `gain` is not valid any more. For example, if the instant statement is:

```
s1 (1 0 control 0) svcvs numer=[1 2] denom=[3 4]
```

the transfer function will be $2*(2s+1)/(4s+3)$. Factor 2 is applied to make the DC gain of the transfer function to be 1. If you just want the transfer function to be $(2s+1)/(4s+3)$, specify `gainfactor=1` to disable the default value of `gain`. In this example, the statement will be:

```
s1 (1 0 control 0) svcvs numer=[1 2] denom=[3 4] gainfactor=1
```

where the transfer function is $1*(2s+1)/(4s+3)$. 1 is the gainfactor.

This device is not supported within altergroup.

Sample Instance Statement

```
va (1 0) vsource type=sine freq=10K
z2 (2 0) zcccs probe=va gain=1 ts=4.9e-5 tt=1e-5 polyarg=inversez
numer=[1 -1] denom=[1 0]
```

Instance Definition

```
Name sink src zcccs parameter=value ...
```

Instance Parameters

- | | | |
|----|------------------|---|
| 1 | probe | Device through which the controlling current flows. |
| 2 | mprobe | The mprobe functions the same as probe except that it will divide the input current by the mfactor. |
| 3 | port=0 | Index of the probe port through which the controlling current flows. |
| 4 | ts=1 s | Sampling period. |
| 5 | td=0 s | Sampling delay. |
| 6 | tt=0.01 ts s | Transition time. |
| 7 | gain=1 | DC gain or constant transfer function factor. See notes on gain and gainfactor for details. |
| 8 | gainfactor | Factor applied to transfer function. It overwrites the parameter gain. |
| 9 | polyarg=inversez | Polynomial argument.
Possible values are z or inversez. |
| 10 | sxz=none | s to z transformation.
Possible values are none, backward, forward, or bilinear. |
| 11 | numer=[...] | Vector of numerator coefficients. |
| 12 | denom=[...] | Vector of denominator coefficients. |
| 13 | zeros=[...] | Vector of complex zeros. |

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Circuit Components

- 14 `poles=[...]` Vector of complex poles.
- 15 `m=1` Multiplicity factor.
- 16 `tc1=0 1/C` Linear temperature coefficient.
- 17 `tc2=0 C-2` Quadratic temperature coefficient.

Operating-Point Parameters

- 1 `i` (A) Input current.
- 2 `v` (V) Output voltage.
- 3 `pwr` (W) Power dissipation.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

<code>denom</code> I-12	<code>mprobe</code> I-2	<code>probe</code> I-1	<code>td</code> I-5
<code>gain</code> I-7	<code>numer</code> I-11	<code>pwr</code> OP-3	<code>ts</code> I-4
<code>gainfactor</code> I-8	<code>poles</code> I-14	<code>sxz</code> I-10	<code>tt</code> I-6
<code>i</code> OP-1	<code>polyarg</code> I-9	<code>tc1</code> I-16	<code>v</code> OP-2
<code>m</code> I-15	<code>port</code> I-3	<code>tc2</code> I-17	<code>zeros</code> I-13

z-Domain Linear Voltage Controlled Current Source (zvccs)

The output is defined with a transfer function given as the ratio of two polynomials in the complex variable z . Each polynomial can be specified using either its coefficients or its roots.

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Circuit Components

The roots of the numerator are the zeros of the transfer function and the roots of the denominator are the poles.

You may specify polynomials either in the complex variable z or $1/z$ by setting optional parameter `polyarg` to `z` or `inversez` respectively. By default, it is set to `inversez`. If you choose to provide the coefficients of a polynomial, enter them as a vector in ascending order of the power of the variable z or $1/z$, starting from the constant term. For example, to specify a denominator of $3z^{-2} + 4z^{-1} + 1$, use `denom=[1 4 3]`. Or to specify a denominator of $4z^2 + 3z - 2$, use `polyarg=z denom=[2 3 4]`.

To specify transfer function in terms of its zeros and poles in z -plane, give them as vectors of complex numbers. You must always give the real and imaginary portions of the root, even when the root is real. You may give either both roots of a complex-conjugate pair or only one. In the latter case the conjugate complex root will be generated automatically. The order of the roots is not important. For example, to specify poles of $z = 1$, $z = 4j$, $z = -4j$, $z = 2 + 2j$, and $z = 2 - 2j$, use `poles=[1 0 0 4 0 -4 2 2 2 -2]` or, omitting conjugate poles, `poles=[1 0 0 4 2 2]`.

Either the numerator or the denominator specification can be omitted. An omitted denominator or numerator is taken to be 1.

Transition time (τ_t) is an optional parameter that at each sampling point forces linear transition of the output to a new value within the specified time range. By default, it is set to one percent of the sampling period.

The sampling delay (τ_d) is another optional parameter, with the default value of 0, that lets you set asynchronous sampling rates.

To use the s to z transformation, set the optional `sxz` parameter to one of the transformation methods - forward differences, backward differences, or bilinear. When the `sxz` parameter is specified, the transfer function specification is assumed to be given in the complex variable s and it will be transformed to the complex variable z using the indicated method.

Notes on gain and gainfactor

The parameter `gain` is interpreted either as the DC gain or, if the function has zeros or poles at the origin, as a constant factor. Note that `gain` has a default value of 1, so if you do not want to specify the DC gain, you should always use parameter `gainfactor` to disable parameter `gain`. When `gainfactor` is specified, `gain` is not valid any more. For example, if the instant statement is:

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Circuit Components

s1 (1 0 control 0) svcvs numer=[1 2] denom=[3 4]

the transfer function will be $2*(2s+1)/(4s+3)$. Factor 2 is applied to make the DC gain of the transfer function to be 1. If you just want the transfer function to be $(2s+1)/(4s+3)$, specify `gainfactor=1` to disable the default value of `gain`. In this example, the statement will be:

s1 (1 0 control 0) svcvs numer=[1 2] denom=[3 4] gainfactor=1

where the transfer function is $1*(2s+1)/(4s+3)$. 1 is the `gainfactor`.

This device is not supported within altergroup.

Sample Instance Statement:

va (1 0) vsource type=sine freq=10K

z1 (2 0 1 0) zvccs gain=2 ts=4.5e-5 tt=1e-5 zeros=[-1 0] poles=[0 0]

Instance Definition

Name sink src ps ns zvccs parameter=value ...

Instance Parameters

1	<code>ts=1 s</code>	Sampling period.
2	<code>td=0 s</code>	Sampling delay.
3	<code>tt=0.01 ts s</code>	Transition time.
4	<code>gain=1</code>	DC gain or constant transfer function factor. See notes on <code>gain</code> and <code>gainfactor</code> for details.
5	<code>gainfactor</code>	Factor applied to transfer function. It overwrites the parameter <code>gain</code> .
6	<code>polyarg=inversez</code>	Polynomial argument. Possible values are <code>z</code> or <code>inversez</code> .

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Circuit Components

7	<code>sxz=none</code>	s to z transformation. Possible values are <code>none</code> , <code>backward</code> , <code>forward</code> , or <code>bilinear</code> .
8	<code>numer=[...]</code>	Vector of numerator coefficients.
9	<code>denom=[...]</code>	Vector of denominator coefficients.
10	<code>zeros=[...]</code>	Vector of complex zeros.
11	<code>poles=[...]</code>	Vector of complex poles.
12	<code>m=1</code>	Multiplicity factor.
13	<code>tc1=0 1/C</code>	Linear temperature coefficient.
14	<code>tc2=0 C⁻²</code>	Quadratic temperature coefficient.

Operating-Point Parameters

1	<code>i (A)</code>	Output current.
2	<code>v (V)</code>	Output voltage.
3	<code>pwr (W)</code>	Power dissipation.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

<code>denom</code>	I-9	<code>numer</code>	I-8	<code>tc1</code>	I-13	<code>v</code>	OP-2
<code>gain</code>	I-4	<code>poles</code>	I-11	<code>tc2</code>	I-14	<code>zeros</code>	I-10
<code>gainfactor</code>	I-5	<code>polyarg</code>	I-6	<code>td</code>	I-2		

i	OP-1	pwr	OP-3	ts	I-1
m	I-12	sxz	I-7	tt	I-3

Voltage Sources

Polynomial Current Controlled Voltage Source (pccvs)

The polynomial function defining the relationship between the output voltage and the controlling currents is specified by a vector of coefficients. At least one coefficient must always be specified. Current through the voltage source is calculated and is defined to be positive if it flows from the positive terminal, through the source, to the negative terminal.

This device is supported within altergroups.

For a polynomial in M variables a_1, a_2, \dots, a_m , the polynomial function $F(a_0, a_1, \dots, a_m)$ is given by

$$F = c_0 + c_1 * a_1 + c_2 * a_2 + \dots \\ + c_{(m+1)} * a_1^2 + c_{(m+2)} * a_1 * a_2 + \dots \\ + c_{(2m+1)} * a_2^2 + c_{(2m+2)} * a_2 * a_3 + \dots$$

where the c_s are coefficients of the polynomial terms.

Sample Instance Statement

```
ixy (net1 0) pccvs coeffs=[0 1 0 1] probes=[vin1 vin2] gain=2
```

Instance Definition

```
Name p n pccvs parameter=value ...
```

Instance Parameters

1 m=1 Multiplicity factor.

2 gain=1 Gain Parameter.

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Circuit Components

3	<code>probes=[...]</code>	Devices through which the controlling currents flow.
4	<code>mprobes=[...]</code>	The mprobes function the same as probes except that they will divide the input currents by the mfactor.
5	<code>ports=[...]</code>	Indices of the probe ports through which the controlling currents flow.
6	<code>coeffs=[...]</code>	Polynomial coefficients. At least one must be given.
7	<code>file</code>	File that contains nonzero polynomial coefficients.
8	<code>min (V)</code>	Minimum output voltage.
9	<code>max (V)</code>	Maximum output voltage.
10	<code>abs=off</code>	Absolute output voltage. Possible values are <code>off</code> or <code>on</code> .
11	<code>delta=0</code>	Smoothing parameter. This may lead to circuit convergence. The smaller the delta is, the sharper the corner is.

Temperature effects parameters

12	<code>tc1=0 1/C</code>	Linear temperature coefficient.
13	<code>tc2=0 C⁻²</code>	Quadratic temperature coefficient.

Operating-Point Parameters

1	<code>i (A)</code>	Output current.
2	<code>v (V)</code>	Output voltage.
3	<code>pwr (W)</code>	Power dissipation.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the

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Circuit Components

description for that parameter. For example, a reference of M-35 means the 35th model parameter.

abs	I-10	gain	I-2	min	I-8	pwr	OP-3
coeffs	I-6	i	OP-1	mprobes	I-4	tc1	I-12
delta	I-11	m	I-1	ports	I-5	tc2	I-13
file	I-7	max	I-9	probes	I-3	v	OP-2

Polynomial Voltage Controlled Voltage Source (pvcvs)

A vector of coefficients specifies the polynomial function that defines the relationship between the output voltage and the controlling voltages. You must specify at least one coefficient. Current through the voltage source is calculated and is defined to be positive if it flows from the positive terminal, through the source, to the negative terminal.

This device is supported within altergroups.

For a polynomial in M variables a_1, a_2, \dots, a_m , the polynomial function $F(a_0, a_1, \dots, a_m)$ is given by

$$F = c_0 + c_1 * a_1 + c_2 * a_2 + \dots \\ + c_{(m+1)} * a_1^2 + c_{(m+2)} * a_1 * a_2 + \dots \\ + c_{(2m+1)} * a_2^2 + c_{(2m+2)} * a_2 * a_3 + \dots$$

where the c_s are coefficients of the polynomial terms.

Sample Instance Statement

```
v1 (p 0 c1 0) pvcvs coeffs=[0 0 0 0.1 1 1] gain=1
```

Instance Definition

```
Name p n ps1 ns1 ... pvcvs parameter=value ...
```

Virtuoso Simulator Components and Device Models Reference

Circuit Components

Instance Parameters

1	<code>m=1</code>	Multiplicity factor.
2	<code>gain=1</code>	Gain Parameter.
3	<code>coeffs=[...]</code>	Polynomial coefficients. At least one must be given.
4	<code>file</code>	File that contains nonzero polynomial coefficients.
5	<code>min (V)</code>	Minimum output voltage.
6	<code>max (V)</code>	Maximum output voltage.
7	<code>abs=off</code>	Absolute output voltage. Possible values are <code>off</code> or <code>on</code> .
8	<code>delta=0</code>	Smoothing parameter. This may lead to circuit convergence. The smaller the delta is, the sharper the corner is.

Temperature effects parameters

9	<code>tc1=0 1/C</code>	Linear temperature coefficient.
10	<code>tc2=0 C⁻²</code>	Quadratic temperature coefficient.

Operating-Point Parameters

1	<code>i (A)</code>	Output current.
2	<code>v (V)</code>	Output voltage.
3	<code>pwr (W)</code>	Power dissipation.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

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abs	I-7	gain	I-2	min	I-5	v	OP-2
coeffs	I-3	i	OP-1	pwr	OP-3		
delta	I-8	m	I-1	tc1	I-9		
file	I-4	max	I-6	tc2	I-10		

s-Domain Voltage Controlled Voltage Source (svcv)

The device output is defined through a transfer function given as a ratio of two polynomials in the complex variable s . Polynomials can be specified in terms of either coefficients or roots. The roots of the numerator are the zeros of the transfer function and the roots of the denominator are the poles.

To specify the polynomial in terms of the coefficients, you enter them as a vector in ascending order of the power of the variable s , starting from the constant term. For example, to specify a denominator of $3s^2 + 4s + 1$, use `denom=[1 4 3]`.

To specify a polynomial in terms of its roots, you give the roots as a vector of complex frequencies (frequencies should be in radians/second). You must give both the real and imaginary parts of the root, even when the root is real. For the transfer function to be stable, all poles must have negative real values. When specifying a complex root, you should also specify its complex conjugate. However, if you omit the conjugate root, Spectre will supply the missing root and print a warning that a missing root was supplied. The order of the roots is not important. For example, to specify poles of $s = -1$, $s = 4j$, $s = -4j$, $s = -2 + 2j$, and $s = -2 - 2j$; use `poles=[-1 0 0 4 0 -4 -2 2 -2 -2]`.

Either the numerator or the denominator specification can be omitted. An omitted denominator or numerator is taken to be 1.

Notes on gain and gainfactor

The parameter `gain` is interpreted either as the DC gain or, if the function has zeros or poles at the origin, as a constant factor. Note that `gain` has a default value of 1, so if you do not want to specify the DC gain, you should always use parameter `gainfactor` to disable parameter `gain`. When `gainfactor` is specified, `gain` is not valid any more. For example, if the instant statement is:

```
s1 (1 0 control 0) svcv numer=[1 2] denom=[3 4]
```

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the transfer function will be $3*(2s+1)/(4s+3)$. Factor 3 is applied to make the DC gain of the transfer function to be 1. If you just want the transfer function to be $(2s+1)/(4s+3)$, specify `gainfactor=1` to disable the default value of `gain`. In this example, the statement will be:

```
s1 (1 0 control 0) svcvs numer=[1 2] denom=[3 4] gainfactor=1
```

where the transfer function is $1*(2s+1)/(4s+3)$. 1 is the `gainfactor`.

This device is not supported within `altergroup`.

Sample Instance Statement

```
e1 (1 0 control 0) svcvs gain=5 poles=[-1 0 1 0] zero=[0 0 1 0]
```

Instance Definition

```
Name p n ps ns svcvs parameter=value ...
```

Instance Parameters

1	<code>gain=1</code>	DC gain or constant transfer function factor. See notes on <code>gain</code> and <code>gainfactor</code> for details.
2	<code>gainfactor</code>	Factor applied to transfer function. It disables the parameter <code>gain</code> .
3	<code>numer=[...]</code>	Vector of numerator coefficients.
4	<code>denom=[...]</code>	Vector of denominator coefficients.
5	<code>zeros=[...]</code>	Vector of complex zeros.
6	<code>poles=[...]</code>	Vector of complex poles.
7	<code>m=1</code>	Multiplicity factor.
8	<code>tc1=0 1/C</code>	Linear temperature coefficient.
9	<code>tc2=0 C⁻²</code>	Quadratic temperature coefficient.

Operating-Point Parameters

1	<code>i (A)</code>	Output current.
---	--------------------	-----------------

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Circuit Components

- 2 `v` (V) Output voltage.
- 3 `pwr` (W) Power dissipation.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

<code>denom</code>	I-4	<code>i</code>	OP-1	<code>poles</code>	I-6	<code>tc2</code>	I-9
<code>gain</code>	I-1	<code>m</code>	I-7	<code>pwr</code>	OP-3	<code>v</code>	OP-2
<code>gainfactor</code>	I-2	<code>numer</code>	I-3	<code>tc1</code>	I-8	<code>zeros</code>	I-5

Linear Voltage Controlled Voltage Source (vcvs)

Current through the voltage source is calculated and is defined to be positive if it flows from the positive terminal, through the source, to the negative terminal.

This device can also model ideal digital gates.

This device is supported within altergroups.

Sample Instance Statement

```
e1 (out1 0 pos neg) vcvs gain=10
```

Instance Definition

```
Name p n ps ns ... vcvs parameter=value ...
```

Instance Parameters

- 1 `m=1` Multiplicity factor.

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- 2 `type=vcvs` Type of the source.
Possible values are `vcvs`, `and`, `nand`, `or`, or `nor`.
- 3 `delta=0` Smoothing parameter. This may lead to circuit convergence. Its value should be in the range between 0 and 0.5, both ends included. The smaller the delta is, the sharper the corner is.

Linear source parameters

- 4 `gain=0 V/V` Voltage gain.
- 5 `td=0.0 s` Time delay.
- 6 `min (V)` Minimum output voltage.
- 7 `max (V)` Maximum output voltage.
- 8 `abs=off` Output voltage is absolute value if `abs` is set to on.
Possible values are `off` or `on`.

PWL source parameters

- 9 `file` Name of file containing voltage/voltage pairs that define the PWL transfer function.
- 10 `pwl=[...]` Vector of voltage/voltage pairs that defines the PWL transfer function. The format of the vector is `[in1 out1 in2 out2 ...]`.
- 11 `scale=1` Scale factor for the PWL output voltage.
- 12 `stretch=1` Scale factor for the PWL controlling voltage.

Temperature effects parameters

- 13 `tc1=0 1/C` Linear temperature coefficient.
- 14 `tc2=0 C-2` Quadratic temperature coefficient.

The Smoothing Factor

The parameter delta is the smoothing factor. When it is nonzero, a curve is introduced to smooth the corner. The value of delta defines the position of the starting and ending points of

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the curve that is used to smooth the corner. The minimum value 0 means no smoothing curve is introduced. The maximum value 0.5 means the distance between the starting point of the curve and the corner point is half of the shortest distance. The shortest distance is the length of the shortest segment of the piecewise linear function. Or, when there is no shortest segment in the controlling function, i.e. only `abs=on` is specified, `spectre` uses 1 as the shortest distance.

Operating-Point Parameters

1	<code>i</code> (A)	Output current.
2	<code>v</code> (V)	Output voltage.
3	<code>pwr</code> (W)	Power dissipation.

Parameter Index

In the following index, `I` refers to instance parameters, `M` refers to the model parameters section, `O` refers to the output parameters section, and `OP` refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of `M-35` means the 35th model parameter.

<code>abs</code> I-8	<code>m</code> I-1	<code>scale</code> I-11	<code>type</code> I-2
<code>delta</code> I-3	<code>max</code> I-7	<code>stretch</code> I-12	<code>v</code> OP-2
<code>file</code> I-9	<code>min</code> I-6	<code>tc1</code> I-13	
<code>gain</code> I-4	<code>pwl</code> I-10	<code>tc2</code> I-14	
<code>i</code> OP-1	<code>pwr</code> OP-3	<code>td</code> I-5	

Independent Voltage Source (`vsource`)

Current through the source is computed and is defined to be positive if it flows from the positive node, through the source, to the negative node.

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This device is supported within altergroups.

The value of the DC voltage as a function of the temperature is given by:

$$V(T) = V(tnom) * [1 + tc1 * (T - tnom) + tc2 * (T - tnom)^2].$$

Sample Instance Statement

```
vpulse1 (1 0) vsource type=pulse val0=0 vall=5 period=100n rise=10n fall=10n
width=40n
vpwl1 (1 0) vsource type=pwl wave=[1n 0 1.1n 2 1.5n 0.5 2n 3 5n 5] pwlperiod=5n
vpwlz1 (1 0) vsource type=pwlz wave=[1n 0 1.1n z 1.5n 0.5 2n z 5n 5] pwlperiod=5n
```

Instance Definition

Name p n vsource parameter=value ...

Instance Parameters

1 dc=0 V DC value.

General waveform parameters

- 2 type=dc Waveform type.
Possible values are dc, pulse, pwl, sine, exp, bit, prbs, pwlz, and sigbus.
- 3 fundname Name of the fundamental frequency. Must be specified if the source is active during a pdisto analysis or it is the active clock during an envlp analysis.
- 4 delay=0 s Waveform delay time.
- 5 edgetype=linear Type of the rising and falling edges. This is for pulse waveform and pulse-like piecewise linear waveform.
Possible values are linear and halvesine.

Pulse waveform parameters

- 6 val0=0 V Zero value used in pulse and exponential waveforms.
- 7 val1=1 V One value used in pulse and exponential waveforms.

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8	<code>period=∞ s</code>	Period of waveform.
9	<code>rise (s)</code>	Rise time for pulse waveform (time for transition from <code>val0</code> to <code>val1</code>). If parameter <code>rise</code> is not given, then the rise time will be the same as fall time; if fall time is not given either, then the rise time will be 1/100 of the waveform period; if the waveform is not periodic, then the rise time will be 1/100 of the simulation interval.
10	<code>fall (s)</code>	Fall time for pulse waveform (time for transition from <code>val1</code> to <code>val0</code>). If parameter <code>fall</code> is not given, then the fall time will be the same as rise time; if rise time is not given either, then the fall time will be 1/100 of the waveform period; if the waveform is not periodic, then the fall time will be 1/100 of the simulation interval.
11	<code>width=∞ s</code>	Pulse width (duration of <code>val1</code>).

PWL waveform parameters

12	<code>file</code>	Name of file containing waveform.
13	<code>wave=[...]</code>	Vector of time/value pairs that defines waveform.
14	<code>offset=0 V</code>	DC offset for the PWL waveform.
15	<code>scale=1</code>	Scale factor for the PWL waveform.
16	<code>stretch=1</code>	Scale factor for time given for the PWL waveform.
17	<code>rms</code>	Desired rms (root of mean square) value of the PWL waveform.
18	<code>pwlfilter=none</code>	Add filter to pwl source, where the pwl data should be equal space sampled. Possible values are 'nrc'(normal raised cosine filter) and 'none'. Possible values are <code>none</code> and <code>nrc</code> .
19	<code>rolloff</code>	Desired rolloff factor for the raised cosine filter, default value is 0.2. Only valid when 'pwlfilter' is set to <code>nrc</code> .
20	<code>pwlbandwidth</code>	Bandwidth of the pwl input signal. Be used when 'pwlfilter' is set to <code>nrc</code> .

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- 21 `allbrkpts` All the points in the PWL waveform are breakpoints if set to yes. Default is yes if the number of points is less than 20. Possible values are `no` and `yes`.
- 22 `pwlperiod` (s) Period of the periodic PWL waveform.
- 23 `pwlperiodstart` (s) Period start time of the periodic PWL waveform.
- 24 `twidth=pwlperiod/1000` s Transition width used when making PWL waveforms periodic.
- 25 `highz=1e12` The impedance of high z state.
- 26 `min_z_transition_width=10e-12` s Minimum width of transition from z-state to non z-state. The width of transition is set as $1e-3 \times (\text{z-state duration})$.

Sinusoidal waveform parameters

- 27 `sinedc=dc` V DC level for sinusoidal waveforms.
- 28 `ampl=1` V amplitude of sinusoidal waveform.
- 29 `freq=0` Hz Frequency of sinusoidal waveform.
- 30 `sinphase=0` ° Phase of sinusoid when `t=delay`.
- 31 `ampl2=1` V amplitude of second sinusoidal waveform.
- 32 `freq2=0` Hz Frequency of second sinusoidal waveform.
- 33 `sinphase2=0` ° Phase of second sinusoid when `t=delay`.
- 34 `fundname2` Name of the fundamental frequency associated with `freq2`. Must be specified if `freq2` is used in a `pdisto` analysis.
- 35 `iqmodfiles=[...]` Two file names which containing pwl I/Q source waveform.
- 36 `fmodindex=0` FM index of modulation for sinusoidal waveform.
- 37 `fmodfreq=0` Hz FM modulation frequency for sinusoidal waveform.

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38	<code>fmodfiles=[...]</code>	One or two file names: containing FM waveform for one file case, and FM I/Q signals for two files with I file first.
39	<code>ammodindex=0</code>	AM index of modulation for sinusoidal waveform.
40	<code>ammodoffset=1</code>	AM offset of modulation for sinusoidal waveform.
41	<code>ammodfreq=0 Hz</code>	AM modulation frequency for sinusoidal waveform.
42	<code>ammodphase=0 °</code>	AM phase of modulation for sinusoidal waveform.
43	<code>damp=0 1/s</code>	Damping factor for sinusoidal waveform.
44	<code>freqvec=[...] Hz</code>	Vector of support frequency of sinusoidal channel source.
45	<code>amplvec=[...] V</code>	Vector of amplitude of sinusoidal channel source.
46	<code>phasevec=[...] °</code>	Vector of phase of sinusoidal channel source.
47	<code>maxharms=[...]</code>	Array of number of harmonics of each frequency.

Exponential waveform parameters

48	<code>td1=0 s</code>	Rise start time for exponential wave.
49	<code>tau1 (s)</code>	Rise time constant for exponential wave.
50	<code>td2 (s)</code>	Fall start time for exponential wave.
51	<code>tau2 (s)</code>	Fall time constant for exponential wave.
52	<code>expperiod (s)</code>	Period of the periodic EXP waveform.

Pattern parameters

53	<code>data</code>	The bit string. A string that contains a series of the four states, 1 0 m z. For prbs, it can contain only 0 and 1, and m, z is not supported.
54	<code>rptstart=1</code>	The starting bit when repeating. The data repeats from the specified bit to the end of the bit string. The parameter should be an integer from 1 to the length of the bit string.

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55 `rpttimes=0` The repeat times. The output will maintain the state of the last bit after the last repeat. If its value is negative, the string repeats forever.

Prbs parameters

56 `ref (V)` Sets the crossing reference for the control node. This parameter applies only when the Prbs source operates as a 3 or 4 terminal device. When the voltage across terminals 3 and 4 drops below `ref`, the output of the source is set to 0. If terminal 4 is not specified, it is assumed to be connected to ground.

57 `jitter (s)` The parameter `jitter` is obsolete. It has no effect on the output.

58 `rjseed=1` The seed for random number generator, used in generating random jitter for PRBS sources. The default value is 1.

59 `rjrms (s)` When set for PRBS source or Bit source, the source has a normally distributed random jitter, whose mean is zero and whose standard deviation is `rjrms`.

60 `pjamp=[...] s` When set for PRBS source or Bit source, the source has multiple periodic jitters, whose amplitudes are defined by `pjamp` and frequencies are defined by `pjfreq`.

61 `pjfreq=[...] Hz` When set for PRBS source or Bit source, the source has multiple periodic jitters, whose amplitudes are defined by `pjamp` and whose frequency are defined by `pjfreq`.

62 `pjtype="sine"` For PRBS source or Bit source, `pjtype` defines the types of periodic jitters. Possible valudes are 'sine', 'sawtooth', or 'square'.

63 `seed` This parameter is obsolete but retained for backward compatability. Set `registerlength=[2 ... 32]` to choose a Maximum Length Sequence or define a custom PRBS by use of the parameters, `lfsrtaps` and `lfsrseed`.

64 `taps=[...]` The use of `taps` is discouraged. For PRBS, `taps` is an integer array which sets the locations of the LFSR taps. Please use `lfsrtaps` instead. Please see the section, 'PRBS Type Waveform' below for details of the PRBS operation.

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- 65 `lfsrtaps=[...]` For PRBS source, `lfsrtaps` is an integer array which sets the location of LFSR taps. Locations are 1-based and ordered from MSB to LSB of the LFSR. The largest element of the taps array is equal to the width of the LFSR. Please see the section, 'PRBS Type Waveform' for details of PRBS source operation.
- 66 `lfsrseed=[...]` For PRBS source, `lfsrseed` is an integer array which sets the initial state of the LFSR. Array elements sets the locations of non-zero bits. Locations are 1-based and ordered from MSB to LSB of the LFSR. For example, assume `lfsrtaps=[6]` and `lfsrseed=[1 3 5]`. The width of the register is then 6 bits and the initial state is '101010'.
- 67 `registerlength` When set for PRBS, the `registerlength` defines the width of the LFSR and the LFSR works in Maximum Length Sequence mode. Please see the section 'PRBS Type Waveform' below for details of MLS setting.
- 68 `triggerthreshold` (V) For PRBS, when `triggerthreshold` is set and the source is instantiated with optional control terminals (terminals 3 and optionally 4; if terminal 4 is unspecified it is assumed to be connected to ground), `triggerthreshold` defines the crossing threshold for the trigger event. The event causes the emission of the next PRBS pulse.
- 69 `triggerdelthresh` (V) For PRBS in external triggering mode, `triggerdelthresh` is used with `triggerthreshold` to define the crossing threshold. For rising edge triggering, the actual threshold is (`triggerthreshold + triggerdelthresh`); for falling edge triggering, the threshold is (`triggerthreshold - triggerdelthresh`). The default value is zero.
- 70 `triggerdirection="both"` For PRBS in external triggering mode, `trigger direction` defines the direction of the control signal at the crossing event. Possible valudes are 'rise', 'fall', or 'both'.
- 71 `transitionreference` Defines the voltage swing for the duration of rise and fall time, as a percentage of `val1 - val0`. For example, `transitionreference =100` means that the output voltage transitions from `val0` to `val1` in rise seconds. `90` means that it transitions from $0.1*(val1-val0)$

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to $0.9 \cdot (\text{val1} - \text{val0})$ in rise seconds, 80 means from $0.2 \cdot (\text{val1} - \text{val0})$ to $0.8 \cdot (\text{val1} - \text{val0})$, etc. Possible values are 100, 90, 80, 70 and 60.

Noise Parameters

- 72 `noisefile` Name of file containing excess spot noise data in the form of frequency-noise pairs. The noise can be specified as the spectral density in V^2/Hz , or as single-sideband phase noise in dBc. The parameter `noisetype` determines how Spectre interprets the noise data..
- 73 `noisevec=[...] V2/Hz` Excess spot noise as a function of frequency in the form of frequency-noise pairs. The parameter `noisetype` determines how Spectre interprets the noise data..
- 74 `noisetype=noisevoltage` When set to `noisevoltage`, the noise data represents the noise spectral density in V^2/Hz . When set to `ssbphasenoise`, the noise data represents single-sideband phase noise in dBc. When set to `noisevoltage`, the frequencies are absolute. For `ssbphasenoise`, the frequencies are offset from carrier.. Possible values are `noisevoltage` and `ssbphasenoise`.
- 75 `noiseinterp=linear` Determine how the specified noise data is interpolated. This parameter only applies to `noisetype=noisevoltage`. When set to `linear`, interpolation is linear over both axes. When set to `loglog`, Spectre uses log interpolation over both axes.. Possible values are `linear` and `loglog`.
- 76 `isnoisy=yes` Should `vsource` generate noise. Possible values are `no` and `yes`.

Small signal parameters

- 77 `mag=0 V` Small signal voltage.
- 78 `phase=0` Small signal phase.
- 79 `xfmag=1 V/V` Transfer function analysis magnitude.

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80 `pacmag=0 V` Periodic AC analysis magnitude.

81 `pacphase=0` Periodic AC analysis phase.

Multiplication factor parameters

82 `m=1` Multiplicity factor.

Temperature effects parameters

83 `tc1=0 1/C` First order temperature coefficient.

84 `tc2=0 C-2` Second order temperature coefficient.

85 `tnom=27 C` Parameter measurement temperature. Default set by options.

86 `trise=0.0 C` Temperature rise from ambient.

If you do not specify the DC value, it is assumed to be the `time=0` value of the waveform.

Sinusoidal waveform in the time interval $0 < t < \text{delay}$ has constant value equal to that at $t = \text{delay}$.

In DC analyses, the only active parameters are `dc`, `m`, and the temperature coefficient parameters. In AC analyses, the only active parameters are `m`, `mag` and `phase`. In transient analyses, all parameters are active except the small signal parameters and the noise parameters. The `type` parameter selects which type of waveform is generated. You may specify parameters for more than one waveform type, and use the `alter` statement to change the waveform type between analyses. There is one exception for type `bit`. You cannot change `bit` type to other types or other types to `bit`.

PWL Type Waveform

A vector of time-value pairs describes the piecewise linear waveform. As an alternative, you can read the waveform from a file. In this case, you give time-value pairs one pair per line with a space or tab between the time and the value.

If you set `allbrkpts` to `yes`, you force the simulator to place time points at each point specified in a PWL waveform during a transient analysis. This can be very expensive for waveforms with many points. If you set `allbrkpts` to `no`, Spectre inspects the waveform, looking for abrupt changes, and forces time points only at those changes.

The PWL waveform is periodic if you specify `pwlperiod` and/or `pwlperiodstart`. If both `pwlperiod` and `pwlperiodstart` are specified, `pwlperiod` should be longer than $(\text{wavelength} - \text{pwlperiodstart})$, where `wavelength` means the last time point. If only `pwlperiod` is specified and `pwlperiodstart` is undefined, then the period will start at first time point or $(\text{wavelength} - \text{pwlperiod})$, whichever is greater. If only `pwlperiodstart` is specified and `pwlperiod` is undefined, then the period will end at the last time point in the waveform vector. If the value of the waveform specified is not exactly the same at both the period beginning and the period end, then you must provide a nonzero value `twidth`. Before repeating, the waveform changes linearly in an interval of `twidth` from its value at $(\text{period} - \text{twidth})$ to its value at the beginning of the waveform. Thus `twidth` must always be less than `period`.

Bit Type Waveform

Bit type waveform is the analog waveform of a series of digital logic state. It uses the pattern parameters to provide the digital state sequence, and some pulse waveform parameters to define the waveform characteristics.

To define the waveform characteristics, use parameters: `val1`, `val0`, `rise`, `fall`, and `period`. Note that parameter `period` here defines the length of a bit and it must be given. The general parameter `delay` can also be used for bit type to define the delay time from the beginning of the transient interval to the beginning of the first bit. The state during the delay time is the same as the first state specified in `data`.

Pattern parameters are used to specify the digital bit string. The pattern parameters of sources are the same as those of a pattern, except that you can specify `rpttimes` to a negative number for sources but not for patterns. Please do "spectre -h pattern" for details on how to use pattern parameters.

Noise of the source

You can give the excess noise of the source as a file or specify it with a vector of frequency-noise pairs. For a file, give the frequency-noise pairs one pair per line with a space or tab between the frequency and noise values.

Operating-Point Parameters

- | | | |
|---|----------------------|-----------------------------|
| 1 | <code>v</code> (V) | Voltage across the source. |
| 2 | <code>i</code> (A) | Current through the source. |
| 3 | <code>pwr</code> (W) | Power dissipation. |

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Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

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ammodindex	I-39	i	OP-2	pwlbandwidth	I-20	tc1	I-83
ammodoffset	I-40	iqmodfiles	I-35	pwlfilter	I-18	tc2	I-84
ammodphase	I-42	isnoisy	I-76	pwlperiod	I-22	td1	I-48
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fmodindex	I-36	pacphase	I-81	sinedc	I-27	wave	I-13
freq	I-29	period	I-8	sinephase	I-30	width	I-11
freq2	I-32	phase	I-78	sinephase2	I-33	xfmag	I-79
freqvec	I-44	phasevec	I-46	stretch	I-16		
fundname	I-3	pjump	I-60	taps	I-64		

z-Domain Current Controlled Voltage Source (zccvs)

The output is defined with a transfer function given as the ratio of two polynomials in the complex variable z . Each polynomial can be specified using either its coefficients or its roots. The roots of the numerator are the zeros of the transfer function and the roots of the denominator are the poles.

You may specify polynomials either in the complex variable z or $1/z$ by setting optional parameter `polyarg` to `z` or `inversez` respectively. By default, it is set to `inversez`. If you choose to provide the coefficients of a polynomial, enter them as a vector in ascending order of the power of the variable z or $1/z$, starting from the constant term. For example, to specify a denominator of $3z^{-2} + 4z^{-1} + 1$, use `denom=[1 4 3]`. Or to specify a denominator of $4z^2 + 3z - 2$, use `polyarg=z denom=[2 3 4]`.

To specify transfer function in terms of its zeros and poles in z -plane, give them as vectors of complex numbers. You must always give the real and imaginary portions of the root, even when the root is real. You may give either both roots of a complex-conjugate pair or only one. In the latter case the conjugate complex root will be generated automatically. The order of the roots is not important. For example, to specify poles of $z = 1$, $z = 4j$, $z = -4j$, $z = 2 + 2j$, and $z = 2 - 2j$, use `poles=[1 0 0 4 0 -4 2 2 2 -2]` or, omitting conjugate poles, `poles=[1 0 0 4 2 2]`.

Either the numerator or the denominator specification can be omitted. An omitted denominator or numerator is taken to be 1.

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Circuit Components

Transition time (t_t) is an optional parameter that at each sampling point forces linear transition of the output to a new value within the specified time range. By default, it is set to one percent of the sampling period.

The sampling delay (t_d) is another optional parameter, with the default value of 0, that lets you set asynchronous sampling rates.

To use the s to z transformation, set the optional `sxz` parameter to one of the transformation methods - forward differences, backward differences, or bilinear. When the `sxz` parameter is specified, the transfer function specification is assumed to be given in the complex variable s and it will be transformed to the complex variable z using the indicated method.

Notes on gain and gainfactor

The parameter `gain` is interpreted either as the DC gain or, if the function has zeros or poles at the origin, as a constant factor. Note that `gain` has a default value of 1, so if you do not want to specify the DC gain, you should always use parameter `gainfactor` to disable parameter `gain`. When `gainfactor` is specified, `gain` is not valid any more. For example, if the instant statement is:

```
s1 (1 0 control 0) svcvs numer=[1 2] denom=[3 4]
```

the transfer function will be $2*(2s+1)/(4s+3)$. Factor 2 is applied to make the DC gain of the transfer function to be 1. If you just want the transfer function to be $(2s+1)/(4s+3)$, specify `gainfactor=1` to disable the default value of `gain`. In this example, the statement will be:

```
s1 (1 0 control 0) svcvs numer=[1 2] denom=[3 4] gainfactor=1
```

where the transfer function is $1*(2s+1)/(4s+3)$. 1 is the gainfactor.

This device is not supported within altergroup.

Sample Instance Statement

```
va (1 0) vsource type=sine freq=10K
z2 2 0 zccvs probe=va gain=-2 ts=5e-5 tt=1.1e-5 numer=[1 -1]
```

Instance Definition

```
Name p n zccvs parameter=value ...
```

Instance Parameters

1 probe Device through which the controlling current flows.

Virtuoso Simulator Components and Device Models Reference

Circuit Components

2	<code>mprobe</code>	The <code>mprobe</code> functions the same as <code>probe</code> except that it will divide the input current by the <code>mfactor</code> .
3	<code>port=0</code>	Index of the probe port through which the controlling current flows.
4	<code>ts=1 s</code>	Sampling period.
5	<code>td=0 s</code>	Sampling delay.
6	<code>tt=0.01 ts s</code>	Transition time.
7	<code>gain=1</code>	DC gain or constant transfer function factor. See notes on <code>gain</code> and <code>gainfactor</code> for details.
8	<code>gainfactor</code>	Factor applied to transfer function. It overwrites the parameter <code>gain</code> .
9	<code>polyarg=inversez</code>	Polynomial argument. Possible values are <code>z</code> or <code>inversez</code> .
10	<code>sxz=none</code>	<code>s</code> to <code>z</code> transformation. Possible values are <code>none</code> , <code>backward</code> , <code>forward</code> , or <code>bilinear</code> .
11	<code>numer=[...]</code>	Vector of numerator coefficients.
12	<code>denom=[...]</code>	Vector of denominator coefficients.
13	<code>zeros=[...]</code>	Vector of complex zeros.
14	<code>poles=[...]</code>	Vector of complex poles.
15	<code>m=1</code>	Multiplicity factor.
16	<code>tc1=0 1/C</code>	Linear temperature coefficient.
17	<code>tc2=0 C⁻²</code>	Quadratic temperature coefficient.

Operating-Point Parameters

1	<code>i (A)</code>	Output current.
2	<code>v (V)</code>	Output voltage.

Virtuoso Simulator Components and Device Models Reference

Circuit Components

3 `pwr` (W) Power dissipation.

Parameter Index

In the following index, `I` refers to instance parameters, `M` refers to the model parameters section, `O` refers to the output parameters section, and `OP` refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of `M-35` means the 35th model parameter.

<code>denom</code>	I-12	<code>mprobe</code>	I-2	<code>probe</code>	I-1	<code>td</code>	I-5
<code>gain</code>	I-7	<code>numer</code>	I-11	<code>pwr</code>	OP-3	<code>ts</code>	I-4
<code>gainfactor</code>	I-8	<code>poles</code>	I-14	<code>sxz</code>	I-10	<code>tt</code>	I-6
<code>i</code>	OP-1	<code>polyarg</code>	I-9	<code>tc1</code>	I-16	<code>v</code>	OP-2
<code>m</code>	I-15	<code>port</code>	I-3	<code>tc2</code>	I-17	<code>zeros</code>	I-13

z-Domain Voltage Controlled Voltage Source (`zvcvs`)

The output is defined with a transfer function given as the ratio of two polynomials in the complex variable z . Each polynomial can be specified using either its coefficients or its roots. The roots of the numerator are the zeros of the transfer function and the roots of the denominator are the poles.

You may specify polynomials either in the complex variable z or $1/z$ by setting optional parameter `polyarg` to `z` or `inversez` respectively. By default, it is set to `inversez`. If you choose to provide the coefficients of a polynomial, enter them as a vector in ascending order of the power of the variable z or $1/z$, starting from the constant term. For example, to specify a denominator of $3z^{-2} + 4z^{-1} + 1$, use `denom=[1 4 3]`. Or to specify a denominator of $4z^2 + 3z - 2$, use `polyarg=z denom=[2 3 4]`.

To specify transfer function in terms of its zeros and poles in z -plane, give them as vectors of complex numbers. You must always give the real and imaginary portions of the root, even when the root is real. You may give either both roots of a complex-conjugate pair or only one. In the latter case the conjugate complex root will be generated automatically. The order of the roots is not important. For example, to specify poles of $z = 1$, $z = 4j$, $z = -4j$, $z = 2 + 2j$, and z

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Circuit Components

= 2 - 2j, use `poles=[1 0 0 4 0 -4 2 2 2 -2]` or, omitting conjugate poles, `poles=[1 0 0 4 2 2]`.

Either the numerator or the denominator specification can be omitted. An omitted denominator or numerator is taken to be 1.

Transition time (t_t) is an optional parameter that at each sampling point forces linear transition of the output to a new value within the specified time range. By default, it is set to one percent of the sampling period.

The sampling delay (t_d) is another optional parameter, with the default value of 0, that lets you set asynchronous sampling rates.

To use the s to z transformation, set the optional `sxz` parameter to one of the transformation methods - forward differences, backward differences, or bilinear. When the `sxz` parameter is specified, the transfer function specification is assumed to be given in the complex variable s and it will be transformed to the complex variable z using the indicated method.

Notes on gain and gainfactor

The parameter `gain` is interpreted either as the DC gain or, if the function has zeros or poles at the origin, as a constant factor. Note that `gain` has a default value of 1, so if you do not want to specify the DC gain, you should always use parameter `gainfactor` to disable parameter `gain`. When `gainfactor` is specified, `gain` is not valid any more. For example, if the instant statement is:

```
s1 (1 0 control 0) svcvs numer=[1 2] denom=[3 4]
```

the transfer function will be $2*(2s+1)/(4s+3)$. Factor 2 is applied to make the DC gain of the transfer function to be 1. If you just want the transfer function to be $(2s+1)/(4s+3)$, specify `gainfactor=1` to disable the default value of `gain`. In this example, the statement will be:

```
s1 (1 0 control 0) svcvs numer=[1 2] denom=[3 4] gainfactor=1
```

where the transfer function is $1*(2s+1)/(4s+3)$. 1 is the gainfactor.

This device is not supported within altergroup.

Sample Instance Statement:

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Circuit Components

va (1 0) vsource type=sine freq=10K

z3 (3 0 1 0) zvcvs gain=-1 ts=4e-5 tt=1e-5 numer=[-1 -1]

Instance Definition

Name p n ps ns zvcvs parameter=value ...

Instance Parameters

1	ts=1 s	Sampling period.
2	td=0 s	Sampling delay.
3	tt=0.01 ts s	Transition time.
4	gain=1	DC gain or constant transfer function factor. See notes on gain and gainfactor for details.
5	gainfactor	Factor applied to transfer function. It overwrites the parameter gain.
6	polyarg=inversez	Polynomial argument. Possible values are z or inversez.
7	sxz=none	s to z transformation. Possible values are none, backward, forward, or bilinear.
8	numer=[...]	Vector of numerator coefficients.
9	denom=[...]	Vector of denominator coefficients.
10	zeros=[...]	Vector of complex zeros.
11	poles=[...]	Vector of complex poles.
12	m=1	Multiplicity factor.
13	tc1=0 1/C	Linear temperature coefficient.
14	tc2=0 C ⁻²	Quadratic temperature coefficient.

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Circuit Components

Operating-Point Parameters

1	<code>i</code> (A)	Output current.
2	<code>v</code> (V)	Output voltage.
3	<code>pwr</code> (W)	Power dissipation.

Parameter Index

In the following index, `I` refers to instance parameters, `M` refers to the model parameters section, `O` refers to the output parameters section, and `OP` refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of `M-35` means the 35th model parameter.

<code>denom</code>	<code>I-9</code>	<code>numer</code>	<code>I-8</code>	<code>tc1</code>	<code>I-13</code>	<code>v</code>	<code>OP-2</code>
<code>gain</code>	<code>I-4</code>	<code>poles</code>	<code>I-11</code>	<code>tc2</code>	<code>I-14</code>	<code>zeros</code>	<code>I-10</code>
<code>gainfactor</code>	<code>I-5</code>	<code>polyarg</code>	<code>I-6</code>	<code>td</code>	<code>I-2</code>		
<code>i</code>	<code>OP-1</code>	<code>pwr</code>	<code>OP-3</code>	<code>ts</code>	<code>I-1</code>		
<code>m</code>	<code>I-12</code>	<code>sxz</code>	<code>I-7</code>	<code>tt</code>	<code>I-3</code>		

Behavioral Source (bsource)

Behavioral source enables you to model a resistor, inductor, capacitor, voltage or current source as a behavioral component. Using `bsource`, you can express the value of a resistance, capacitance, voltage or current as a combination of device operating points, node voltages, branch currents, and built in Virtuoso[®] Spectre[®] circuit simulator expressions. `bsource` simulation performance has now been improved by compiling the `bsource` devices.

`Bsource` simulation performance has been improved by compiling the `bsource` devices. This is explained in more detail in the `bsource` compilation section below.

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Circuit Components

2	<code>tc2</code>	Quadratic temperature co-efficient. Valid for all behavioral elements. Default value is 0 C ⁻²
3	<code>tnom</code>	Parameters measurement temperature. Valid for all behavioral elements. Default value is 27.0.
4	<code>trise</code>	Temperature rise for ambient. Valid for all behavioral elements. Default value is 0.0.

Clipping Parameters

1	<code>max_val</code>	Maximum value of bsource expression. Valid for all behavioral elements, but generally used with i and v elements for clipping the current or voltage between the specified values.
2	<code>min_val</code>	Minimum value of bsource expression. Valid for all behavioral elements, but generally used with i and v elements for clipping the current or voltage between the specified values.

Noise Parameters

1	<code>af</code>	Flicker noise exponent, Valid for r and g elements Default value is 2.
2	<code>fexp</code>	Flicker noise frequency exponent. Valid for r, g, v, and i elements. Default value is 1.
3	<code>isnoisy</code>	Specifies whether to generate noise. Valid for r, g, i, and v elements Valid values are yes and no. Default value is yes.
4	<code>kf</code>	Flicker noise co-efficient. Valid for r and g elements.
5	<code>white_noise</code>	White noise expression. Valid for v and i elements.
6	<code>flicker_noise</code>	Flicker noise expression. Valid for v and i elements.

DC Mismatch Parameters

<code>mr</code>	DC-Mismatch parameter. Valid for r only. For algorithm in detail, Refer to "Affirma Spectre DC Device Matching Analysis Tutorial."
-----------------	--

Note: All the parameters in the `param_name` table are instance parameters. `white_noise` and `flicker_noise` may be assigned behavioral expressions; the other parameters must be assigned constant or parametric expressions.

Instance Parameters

`bsource` supports the following instance parameters for the Spectre primitives.

- | | |
|-------------|--|
| 1 Resistor | <code>isnoisy, m, r, tc1, tc2, trise, kf, af, fexp, ldexp, wdexp, l, w, mr.</code> |
| 2 Capacitor | <code>c, m, tc1, tc2, trise, ic.</code> |
| 3 Inductor | <code>l, m, tc1, tc2, trise.</code> |

Mathematical Definitions

The `i` and `v` elements are current and voltage sources respectively with the current and voltage values specified by the `generic_expression`.

The `q` and `phi` elements are defined as:

(1-1)

$$i = ddt(q) = ddt(\text{simple_expr})$$

(1-2)

$$v = ddt(phi) = ddt(\text{simple_expr})$$

The `r`, `g`, `c`, and `l` elements are defined as:

(1-3)

$$v = i \times r = i \times (\text{simple_expr})$$

(1-4)

$$i = g \times v = (\text{simple_expr}) \times v$$

(1-5)

$$i = c \times ddt(v) = (\text{simple_expr}) \times ddt(v)$$

(1-6)

$$v = l \times ddt(i) = (simple_expr) \times ddt(i)$$

The elements r , g , c , and l are provided for compatibility reasons. The actual resistance, conductance, capacitance, and inductance are different from the expressions you specify. For example, a non-linear conductance is defined as:

(1-7)

$$g(v) = \frac{di}{dv}$$

where i and v are the conductance branch current and voltage respectively. If we use the conductance element (equation 5-4), and specify the conductance as a function of the branch voltage:

(1-8)

$$g = g_s(v)$$

then the true conductance is given by:

(1-9)

$$g(v) = \frac{d}{dv}(g_s(v) \times v)$$

(1-10)

$$g(v) = g_s(v) + v \left(\frac{d}{dv} g_s(v) \right)$$

Note that the true conductance is different from the specified conductance. The correct way to implement a conductance $g_s(v)$ is to use the i element and specify the current expression as:

(1-11)

$$i = \int g_s(v) dv$$

Noise Model for bsource

Noise sources are implemented for the elements i, v, r, and g.

Noise for Elements i and v

You need to specify the expression for Power Spectral Density (PSD) using the *white_noise* and *flicker_noise* parameters.

(1-12)

$$white_noise = simple_expr$$

(1-13)

$$flicker_noise = simple_expr \quad fexp = constant_expr$$

where *simple_expr* is the power of the flicker noise (or white noise) source at 1Hz and *fexp* is the exponent of the frequency.

(1-14)

$$noisePSD = \frac{simple_expr}{f^{fexp}}$$

The noise source unit is A²/Hz for *i* and V²/Hz for *v*. The following is an example of a noise parameter specification for a current source:

(1-15)

$$white_noise = 4 \times k \times T \times g$$

where *k* is the Boltzman constant (1.380626e-23) and

T is the temperature.

(1-16)

$$flicker_noise = kf \times pow((g \times V(p, n)), af) \quad fexp = 2$$

where *V(p,n)* is the voltage across the *i* element.

The following is an example of a noise parameter specification for a voltage source:

(1-17)

$$white_noise = 4 \times k \times T \times r$$

(1-18)

$$flicker_noise = kf \times (r \times pow(i("inst_name:0), af))^{fexp} = 2$$

Noise for elements g and r

The syntax is:

```
name (node1 node2) bsource { r | g }=simple_expr kf=value af=value fexp=value
    isnoisy={ yes | no }
```

The `white_noise` and `flicker_noise` values are calculated from the above expression. When `isnoisy=no`, noise contributions are turned off. By default the white noise source is on and the flicker noise source is off (default is `kf=0`).

The noise source for `g` is a current source in parallel with the `g` element and the noise power is in units of A^2/Hz . If `x` is the expression for the `g` element,

(1-19)

$$white_noise = 4 \times k \times T \times x$$

(1-20)

$$flicker_noise = \frac{kf \times (x \times v(p, n))^{af}}{freq^{fexp}}$$

where `kf`, `af`, and `fexp` are the values specified for these parameters

`k` is the Boltzman constant (1.380626e-23)

`T` is the temperature and

`v(p,n)` is the voltage across the `g` element.

The noise source for `r` is a current source in parallel with the `r` element and the noise power is in units of V^2/Hz . If `x` is the expression for the `r` element,

(1-21)

$$white_noise = 4 \times k \times T \times x$$

(1-22)

$$flicker_noise = \frac{kf \times (x \times I(relement))^{af}}{freq^{fexp}}$$

where kf , af , and $fexp$ are the values specified for these parameters

k is the Boltzman constant (1.380626e-23)

T is the temperature and

$I(relement)$ is the current through r element.

Temperature Effect on bsource

The equation for calculating temperature effect is:

(1-23)

$$tempFactor = [1 + tc1 \times (temp + trise - tnom) + tc1 \times (temp + trise - tnom)^2]$$

Independent Resistive Source (port)

In time-domain, a port is a resistive source that is tied between `pos` and `neg`. It is equivalent to a voltage source in series with a resistor, and the reference resistance of the port is the value of the resistor. The DC value given for the port voltage specifies the DC voltage across the port when it is terminated in its reference resistance (in other words, the DC voltage of the internal voltage source is double the user specified DC value, `dc`). The same is true for the values for the transient, and PAC signals of the port. However, the amplitude of the sine wave in the transient and PAC analyses can alternatively be specified as the power in dBm delivered by the port when terminated with the reference resistance. In frequency-domain, a port can have complex reference impedance. The value of AC signal of the port specifies the voltage across the port when it is terminated in its complex conjugate reference impedance. The reactance part of the impedance is ignored when the port is used in time-domain analyses.

While generally useful as a stimulus in high frequency circuits, the port has three unique capabilities. First, it acts to define the ports of the circuit to the S-parameter analysis. Second, it has an intrinsic noise source, and so allows the noise analysis to directly compute the noise figure of the circuit. And finally, it is the only source for which the amplitude can be specified in terms of power.

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Circuit Components

You can define 2 or 3 terminal port. if you define 2-terminal port it operates like was described above. In case of 3-terminal port it also includes internal ideal choke inductor and ideal blocking capacitor. They are work like switches to terminate or connect appropriate branch dependent on type of analysis

This device is not supported within altergroup.

The value of the DC voltage as a function of the temperature is given by:

$$V(T) = V * [1 + tc1 * (T - tnom) + tc2 * (T - tnom)^2].$$

Sample Instance Statement

```
p20 (2 0) port num=2 r=50 type=pulse period=1e-9 rise=1e-10 fall=1e-10 vall=1
width=0.5n mag=1
p30 (2 0 choke) port num=1 r=50 lchoke=0.1 cblock=0.00001 type=pulse period=1e-9
rise=1e-10 fall=1e-10
```

Instance Definition

Name p n ... port parameter=value ...

Instance Parameters

1 dc=0 V DC value.

General waveform parameters

2 type=dc Waveform type.
Possible values are dc, pulse, pwl, sine, exp, or bit.

3 fundname Name of the fundamental frequency. Must be specified if the source is active during a pdisto analysis or it is the active clock during an envlp analysis.

4 delay=0 s Waveform delay time.

5 edgetype=linear Type of the rising and falling edges. This is for pulse waveform and pulse-like piecewise linear waveform.
Possible values are linear or halvesine.

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Circuit Components

Pulse waveform parameters

6	<code>val0=0 V</code>	Zero value used in pulse and exponential waveforms.
7	<code>val1=1 V</code>	One value used in pulse and exponential waveforms.
8	<code>period=∞ s</code>	Period of waveform.
9	<code>rise (s)</code>	Rise time for pulse waveform (time for transition from <code>val0</code> to <code>val1</code>). If parameter <code>rise</code> is not given, then the rise time will be the same as fall time; if fall time is not given either, then the rise time will be 1/100 of the waveform period; if the waveform is not periodic, then the rise time will be 1/100 of the simulation interval.
10	<code>fall (s)</code>	Fall time for pulse waveform (time for transition from <code>val1</code> to <code>val0</code>). If parameter <code>fall</code> is not given, then the fall time will be the same as rise time; if rise time is not given either, then the fall time will be 1/100 of the waveform period; if the waveform is not periodic, then the fall time will be 1/100 of the simulation interval.
11	<code>width=∞ s</code>	Pulse width (duration of <code>val1</code>).

PWL waveform parameters

12	<code>file</code>	Name of file containing waveform.
13	<code>wave=[...]</code>	Vector of time/value pairs that defines waveform.
14	<code>offset=0 V</code>	DC offset for the PWL waveform.
15	<code>scale=1</code>	Scale factor for the PWL waveform.
16	<code>pwldbms (dBm)</code>	Power of PWL waveform in dBm (alternative to <code>scale</code>).
17	<code>stretch=1</code>	Scale factor for time given for the PWL waveform.
18	<code>rms</code>	Desired rms(root of mean square) value of the PWL waveform.
19	<code>pwlfilter=none</code>	Add filter to pwl source, where the pwl data should be equal space sampled. Possible values are 'nrc'(normal raised cosine filter) and 'none'. Possible values are <code>none</code> and <code>nrc</code> .

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Circuit Components

20	<code>rolloff</code>	Desired rolloff factor for the raised cosine filter, default value is 0.2. Only valid when 'pwlfilter' is set to nrc.
21	<code>pwlbandwidth</code>	Bandwidth of the pwl input signal. Be used when 'pwlfilter' is set to nrc.
22	<code>allbrkpts</code>	All the points in the PWL waveform are breakpoints if set to yes. Default is yes if the number of points is less than 20. Possible values are <code>no</code> and <code>yes</code> .
23	<code>pwlperiod (s)</code>	Period of the periodic PWL waveform.
24	<code>pwlperiodstart (s)</code>	Period start time of the periodic PWL waveform.
25	<code>twidth=pwlperiod/1000 s</code>	Transition width used when making PWL waveforms periodic.
26	<code>highz=1e12</code>	The impedance of high z state.
27	<code>min_z_transition_width=10e-12 s</code>	Minimum width of transition from z-state to non z-state. The width of transition is set as $1e-3 \cdot (\text{z-state duration})$.

Sinusoidal waveform parameters

28	<code>sinedc=dc V</code>	DC level for sinusoidal waveforms.
29	<code>ampl=1 V</code>	amplitude of sinusoidal waveform.
30	<code>dbm (dBm)</code>	Amplitude of sinusoidal waveform in dBm (alternative to <code>ampl</code>).
31	<code>freq=0 Hz</code>	Frequency of sinusoidal waveform.
32	<code>sinephase=0</code>	Phase of sinusoid when <code>t=delay</code> .
33	<code>ampl2=1 V</code>	amplitude of second sinusoidal waveform.
34	<code>dbm2 (dBm)</code>	Amplitude of second sinusoidal waveform in dBm (alternative to <code>ampl2</code>).
35	<code>freq2=0 Hz</code>	Frequency of second sinusoidal waveform.
36	<code>sinephase2=0</code>	Phase of second sinusoid when <code>t=delay</code> .

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Circuit Components

37	<code>fundname2</code>	Name of the fundamental frequency associated with <code>freq2</code> . Must be specified if <code>freq2</code> is used in a <code>pdisto</code> analysis.
38	<code>iqmodfiles=[...]</code>	Two file names which containing pwl I/Q source waveform.
39	<code>fmodindex=0</code>	FM index of modulation for sinusoidal waveform.
40	<code>fmodfreq=0 Hz</code>	FM modulation frequency for sinusoidal waveform.
41	<code>fmodfiles=[...]</code>	One or two file names: containing FM waveform for one file case, and FM I/Q signals for two files with I file first.
42	<code>ammodindex=0</code>	AM index of modulation for sinusoidal waveform.
43	<code>ammodoffset=1</code>	AM offset of modulation for sinusoidal waveform.
44	<code>ammodfreq=0 Hz</code>	AM modulation frequency for sinusoidal waveform.
45	<code>ammodphase=0</code>	AM phase of modulation for sinusoidal waveform.
46	<code>damp=0 1/s</code>	Damping factor for sinusoidal waveform.
47	<code>freqvec=[...] Hz</code>	Vector of support frequency of sinusoidal channel source.
48	<code>amplvec=[...] V</code>	Vector of amplitude of sinusoidal channel source.
49	<code>dbmvec=[...] dBm</code>	Vector of amplitude of sinusoidal waveform in dBm (alternative to <code>amplvec</code>).
50	<code>phasevec=[...] °</code>	Vector of phase of sinusoidal channel source.
51	<code>maxharms=[...]</code>	Array of number of harmonics of each frequency.

Exponential waveform parameters

52	<code>td1=0 s</code>	Rise start time for exponential wave.
53	<code>tau1 (s)</code>	Rise time constant for exponential wave.
54	<code>td2 (s)</code>	Fall start time for exponential wave.
55	<code>tau2 (s)</code>	Fall time constant for exponential wave.

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56 `expperiod` (s) Period of the periodic EXP waveform.

Pattern parameters

57 `data` The bit string. A string that contains a series of the four states, 1 0 m z. For prbs, it can contain only 0 and 1, and m, z is not supported.

58 `rptstart=1` The starting bit when repeating. The data repeats from the specified bit to the end of the bit string. The parameter should be an integer from 1 to the length of the bit string.

59 `rpttimes=0` The repeat times. The output will maintain the state of the last bit after the last repeat. If its value is negative, the string repeats forever.

Prbs parameters

60 `ref` (V) Sets the crossing reference for the control node. This parameter applies only when the Prbs source operates as a 3 or 4 terminal device. When the voltage across terminals 3 and 4 drops below `ref`, the output of the source is set to 0. If terminal 4 is not specified, it is assumed to be connected to ground.

61 `jitter` (s) The parameter `jitter` is obsolete. It has no effect on the output.

62 `rjseed=1` The seed for random number generator, used in generating random jitter for PRBS sources. The default value is 1.

63 `rjrms` (s) When set for PRBS source or Bit source, the source has a normally distributed random jitter, whose mean is zero and whose standard deviation is `rjrms`.

64 `pjamp=[...]` s When set for PRBS source or Bit source, the source has multiple periodic jitters, whose amplitudes are defined by `pjamp` and frequencies are defined by `pjfreq`.

65 `pjfreq=[...]` Hz When set for PRBS source or Bit source, the source has multiple periodic jitters, whose amplitudes are defined by `pjamp` and whose frequency are defined by `pjfreq`.

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- 66 `pjtype="sine"` For PRBS source or Bit source, `pjtype` defines the types of periodic jitters. Possible values are 'sine', 'sawtooth', or 'square'.
- 67 `seed` This parameter is obsolete but retained for backward compatibility. Set `registerlength=[2 ... 32]` to choose a Maximum Length Sequence or define a custom PRBS by use of the parameters, `lfsrtaps` and `lfsrseed`.
- 68 `taps=[...]` The use of `taps` is discouraged. For PRBS, `taps` is an integer array which sets the locations of the LFSR taps. Please use `lfsrtaps` instead. Please see the section, 'PRBS Type Waveform' below for details of the PRBS operation.
- 69 `lfsrtaps=[...]` For PRBS source, `lfsrtaps` is an integer array which sets the location of LFSR taps. Locations are 1-based and ordered from MSB to LSB of the LFSR. The largest element of the `taps` array is equal to the width of the LFSR. Please see the section, 'PRBS Type Waveform' for details of PRBS source operation.
- 70 `lfsrseed=[...]` For PRBS source, `lfsrseed` is an integer array which sets the initial state of the LFSR. Array elements sets the locations of non-zero bits. Locations are 1-based and ordered from MSB to LSB of the LFSR. For example, assume `lfsrtaps=[6]` and `lfsrseed=[1 3 5]`. The width of the register is then 6 bits and the initial state is '101010'.
- 71 `registerlength` When set for PRBS, the `registerlength` defines the width of the LFSR and the LFSR works in Maximum Length Sequence mode. Please see the section 'PRBS Type Waveform' below for details of MLS setting.
- 72 `triggerthreshold` (V) For PRBS, when `triggerthreshold` is set and the source is instantiated with optional control terminals (terminals 3 and optionally 4; if terminal 4 is unspecified it is assumed to be connected to ground), `triggerthreshold` defines the crossing threshold for the trigger event. The event causes the emission of the next PRBS pulse.
- 73 `triggerdelthresh` (V) For PRBS in external triggering mode, `triggerdelthresh` is used with `triggerthreshold` to define the crossing threshold. For rising edge triggering, the actual threshold is (`triggerthreshold` +

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triggerdelthresh); for falling edge triggering, the threshold is (triggerthreshold - triggerdelthresh). The default value is zero.

74 `triggerdirection="both"`

For PRBS in external triggering mode, trigger direction defines the direction of the control signal at the crossing event. Possible values are 'rise', 'fall', or 'both'.

75 `transitionreference`

Defines the voltage swing for the duration of rise and fall time, as a percentage of val1 - val0. For example, transitionreference =100 means that the output voltage transitions from val0 to val1 in rise seconds. 90 means that it transitions from 0.1*(val1-val0) to 0.9*(val1-val0) in rise seconds, 80 means from 0.2*(val1-val0) to 0.8*(val1-val0), etc. Possible values are 100, 90, 80, 70 and 60. .

Noise Parameters

76 `noisefile`

Name of file containing excess spot noise data in the form of frequency-noise pairs. The noise can be specified as the spectral density in V²/Hz, or as single-sideband phase noise in dBc. The parameter noisetype determines how Spectre interprets the noise data..

77 `noisevec=[...] V2/Hz` Excess spot noise as a function of frequency in the form of frequency-noise pairs. The parameter noisetype determines how Spectre interprets the noise data..

78 `noisetype=noisevoltage`

When set to noisevoltage, the noise data represents the noise spectral density in V²/Hz. When set to ssbphasenoise, the noise data represents single-sideband phase noise in dBc. When set to noisevoltage, the frequencies are absolute. For ssbphasenoise, the frequencies are offset from carrier.. Possible values are noisevoltage and ssbphasenoise.

79 `noiseinterp=linear`

Determine how the specified noise data is interpolated. This parameter only applies to noisetype=noisevoltage. When set to linear, interpolation is linear over both axes. When set to loglog, Spectre uses log interpolation over both axes.. Possible values are linear and loglog.

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80	<code>noisetemp</code> (C)	Noise temperature of port. If not specified, the noise temperature is taken to be 290 K.
81	<code>isnoisy=yes</code>	Should port generate noise. Possible values are <code>no</code> and <code>yes</code> .

Port parameters

82	<code>r=50</code> Ω	Reference resistance.
83	<code>x=0</code> Ω	Reference reactance, ignored for time domain analyses.
84	<code>lchock=0.1</code> H	Choke inductor for network analyser.
85	<code>lchoke=0.1</code> H	Choke inductor for network analyser.
86	<code>cblock=0.0001</code> F	Blocking capacitance for network analyser.
87	<code>num</code>	Port number.
88	<code>m=1</code>	Multiplicity factor.

Small signal parameters

89	<code>mag=0</code> V	Small signal voltage.
90	<code>phase=0</code> °	Small signal phase.
91	<code>xfmag=1</code> V/V	Transfer function analysis magnitude.
92	<code>pacmag=0</code> V	Periodic AC analysis magnitude.
93	<code>pacdbm</code> (dBm)	Periodic AC analysis magnitude in dBm (alternative to <code>pacmag</code>).
94	<code>pacphase=0</code> °	Periodic AC analysis phase.

Temperature effects parameters

95	<code>tc1=0</code> 1/C	First order temperature coefficient.
96	<code>tc2=0</code> C ⁻²	Second order temperature coefficient.

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97 `tnom` (C) Parameters measurement temperature. Default set by options.

Harmonic balance parameters

98 `harmvec`=[...] Harmvec, `rvec`, and `xvec` are considered together, and are only applied in harmonic balance large-signal analyses. Harmvec is a list of harmonics to have impedances set manually. If the input to the circuit has a single frequency, then this is a list of harmonics like [1 3] which would set the first and third harmonic. When there are two inputs, then each harmonic has two indices. An example would be [2 -1 -1 2] which would set the harmonics 2, -1, and 1, -2 manually. When there are three inputs, then each harmonic has three indices, and so on.

99 `rvec`=[...] Ω Rvec is the list of series resistance values that go with the list of harmonics to be set manually. If there are three harmonics in the harmvec, for example [1 4 5] in a single tone analysis, then there must be three resistance values in rvec, like [60 70 80]. The order in the list corresponds to the order of harmvec. In this example, harmonic 5 gets set to 80 Ohms. All values must be specified. There is no default.

100 `xvec`=[...] Ω Xvec is the list of series reactance values that go with the list of harmonics to be set manually. If there are two harmonics in the harmvec, for example [2 -1 1 -2] in a two tone circuit, then xvec must have two values, like [0 25]. The order in the list corresponds to the order of harmvec. In this example, harmonic 1, -2 gets set to 25 Ohms. All values must be specified. There is no default.

101 `ro`=50 Ω Series resistance for all the harmonics that are not set manually. This is also the value used in time-domain (transient and shooting PSS) and AC analyses.

102 `xo`=0 Ω This is used for the frequency-domain analyses only. This specifies the series reactance for all the harmonics that are not set manually. This value is ignored in time-domain analyses. It is used to represent the port impedance at all frequencies in AC analysis.

If you do not specify the DC value, it is assumed to be the `time=0` value of the waveform.

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Sinusoidal waveform in the time interval $0 < t < \text{delay}$ has constant value equal to that at $t = \text{delay}$.

In DC analyses, the only active parameters are `dc`, `m`, and the temperature coefficient parameters. In AC analyses, the only active parameters are `m`, `mag` and `phase`. In transient analyses, all parameters are active except the small signal parameters and the noise parameters. The `type` parameter selects which type of waveform is generated. You may specify parameters for more than one waveform type, and use the `alter` statement to change the waveform type between analyses. There is one exception for type `bit`. You cannot change `bit` type to other types or other types to `bit`.

PWL Type Waveform

A vector of time-value pairs describes the piecewise linear waveform. As an alternative, you can read the waveform from a file. In this case, you give time-value pairs one pair per line with a space or tab between the time and the value.

If you set `allbrkpts` to `yes`, you force the simulator to place time points at each point specified in a PWL waveform during a transient analysis. This can be very expensive for waveforms with many points. If you set `allbrkpts` to `no`, Spectre inspects the waveform, looking for abrupt changes, and forces time points only at those changes.

The PWL waveform is periodic if you specify `pwlperiod` and/or `pwlperiodstart`. If both `pwlperiod` and `pwlperiodstart` are specified, `pwlperiod` should be longer than $(\text{wavelength} - \text{pwlperiodstart})$, where `wavelength` means the last time point. If only `pwlperiod` is specified and `pwlperiodstart` is undefined, then the period will start at first time point or $(\text{wavelength} - \text{pwlperiod})$, whichever is greater. If only `pwlperiodstart` is specified and `pwlperiod` is undefined, then the period will end at the last time point in the waveform vector. If the value of the waveform specified is not exactly the same at both the period beginning and the period end, then you must provide a nonzero value `twidth`. Before repeating, the waveform changes linearly in an interval of `twidth` from its value at $(\text{period} - \text{twidth})$ to its value at the beginning of the waveform. Thus `twidth` must always be less than `period`.

Bit Type Waveform

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Bit type waveform is the analog waveform of a series of digital logic state. It uses the pattern parameters to provide the digital state sequence, and some pulse waveform parameters to define the waveform characteristics.

To define the waveform characteristics, use parameters: `val1`, `val0`, `rise`, `fall`, and `period`. Note that parameter `period` here defines the length of a bit and it must be given. The general parameter `delay` can also be used for bit type to define the delay time from the beginning of the transient interval to the beginning of the first bit. The state during the delay time is the same as the first state specified in `data`.

Pattern parameters are used to specify the digital bit string. The pattern parameters of sources are the same as those of a pattern, except that you can specify `rpttimes` to a negative number for sources but not for patterns. Type `spectre -h pattern` for details on how to use pattern parameters.

Noise of the source

You can give the excess noise of the source as a file or specify it with a vector of frequency-noise pairs. For a file, give the frequency-noise pairs one pair per line with a space or tab between the frequency and noise values.

When computing the noise figure of a circuit driven at its input by a port, the noise temperature (`noisetemp`) of the port should be set to 16.85C (290K) in order to match the standard IEEE definition of noise figure. In addition, all other sources of noise in the port (`noisefile` and `noisevec`) should be disabled. If a noiseless port is desired, set the noise temperature to absolute zero or below, and do not specify a noise file or noise vector.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

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<code>ammodfreq</code>	I-44	<code>fundname2</code>	I-37	<code>phasevec</code>	I-50	<code>stretch</code>	I-17

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ammodphase	I-45	iqmodfiles	I-38	pjtype	I-66	tau2	I-55
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ampl2	I-33	jitter	I-61	pwlbandwidth	I-16	tc2	I-96
amplvec	I-48	lchock	I-84	pwlfilter	I-19	td1	I-52
cblock	I-86	lchoke	I-85	pwlperiod	I-23	td2	I-54
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Linear N Port (nport)

An N-port takes its characteristics from an S, Y or Z-parameter data file. An N-port can have as many ports as there are in the N-port described in the data file. Each pair of terminals in the `nport' instance statement represents one port. Because there is no limit to the number of ports, there is no limit to the number of terminals. However, the terminals must be given in pairs and there must be at least one pair. The order of the pairs is the same as the order of the ports in the data file. Any missing ports should be skipped.

The S, Y or Z-parameter data file specifies the characteristics of the N-port. You can scale the frequency axis with the `scale' parameter. The frequencies in the data file are then multiplied by 'scale' before the simulator uses them. The default scale factor is unity. In addition to Spectre's native format, the S, Y, or Z-parameters can be in Touchstone or CITIfile format, and the data can be given as: real-imag, mag-deg, mag-rad, db-deg, or db-rad.

An internal thermal noise model is used in noise analysis. However, if the user provides frequency-dependent noise data then this data is used to build a noise model. Currently Touchstone format accepts the two-port noise parameters (NFmin, Gamma (Gopt, Bopt) and Rn), while Spectre's native format accepts both two-port noise parameters and noise correlation matrix.

If interp=linear or spline is specified, then impulse response is calculated, and convolution method is used for simulation in time domain. It is assumed that the S, Y or Z-parameter data is complete and smooth enough to be safely interpolated or extrapolated in the frequency range from fdelta to fmax, and to DC. Be aware that N-port can be used to model many different kind of systems, the default setting of the impulse response and convolution algorithm is made for typical N-port applications. See the important notes below on when and how to set some of the controlling parameters.

Linear interpolation or cubic spline is used on the data in polar form. A simple algorithm removes 2 pi jumps in the phase data. Frequency points where the data is measured must therefore be close enough to avoid an excessive number of jumps. Unfortunately, noisy phase

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data can cause unnecessary warning messages. Number of frequency domain samples used for FFT is f_{max}/f_{delta} with upper limit of $maxn$. It might be necessary to increase $maxn$ in the case of extremely large average group delay. When `usewindow` is set to `yes`, the data in frequency domain is multiplied by Kaiser-Bessel window function with smoothing parameter equal to one.

If `interp=rational` is specified, the data is interpolated and extrapolated using a rational function fit to the data. The degree of rational interpolation is automatically selected based on the values of `abserr` and `relerr`, unless `ratorder` is given, in which case `relerr` and `abserr` are ignored in selecting the order of the rational function interpolation. It is usually better to allow the simulator to automatically select the rational interpolation order.

If the S, Y or Z-parameter data contains noise, `abserr` and `relerr` should be set so that the fitting procedure can ignore the noise, for example, by setting `abserr` above the noise floor and/or relaxing `relerr` as necessary.

Because the fitting procedure can take a long time for complicated data, the reduced order model (ROM) file option is available to store and re-use the rational interpolation function in subsequent simulations.

It is not practical to rely on extrapolated data.

If `matrixform` parameter is set to `yes`, then the `nport` becomes a state-space model. A state-space model is a set of state space equations in matrix form describing a linear system. The equations are in the following form:

$$E(dx/dt) = Ax + Bu$$

$$y = Cx + K(du/dt) + Du$$

where u is the input vector, y is the output vector, x is the internal-state vector. A , B , C , D , E and K are coefficient matrices.

Please see notes on state-space models for detailed information on how to use the parameters.

Sample Instance Statement

```
x1 (a1 0 b1 0 b3 0) ndata file="sparam2.data"
```

Sample Model Statement

```
model ndata nport file="sparam.data" scale=1
```

This device is not supported within `altergroup`.

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Circuit Components

Synopsis

```
Name t1 b1 [t2] [b2] ... ModelName <parameter=value> ...
Name t1 b1 [t2] [b2] ... nport <parameter=value> ...
```

Terminals must be given in pairs.

Model Synopsis

```
model ModelName nport <parameter=value> ...
```

Instance Parameters

- | | | |
|---|----------------------------|--|
| 1 | <code>m=1</code> | Multiplicity factor. |
| 2 | <code>file</code> | S-parameter data file name. |
| 3 | <code>datafmt</code> | The format of the S-parameter data file. If this parameter is not given, Spectre will try to detect the format by itself.
Possible values are <code>spectre</code> , <code>touchstone</code> , <code>citi</code> , and <code>rfm</code> . |
| 4 | <code>scale=1</code> | Frequency scale factor. |
| 5 | <code>interp=linear</code> | Method to interpolate s-parameter data.
Possible values are <code>spline</code> , <code>rational</code> , <code>linear</code> , and <code>bbsplice</code> . |
| 6 | <code>matrixform=no</code> | Flag for matrix form input.
Possible values are <code>no</code> and <code>yes</code> . |
| 7 | <code>isnoisy=yes</code> | Should nport generate noise.
Possible values are <code>no</code> and <code>yes</code> . |

Spline/Linear interpolation parameters

- | | | |
|---|--------------------------|--|
| 8 | <code>fmax</code> (Hz) | Maximum frequency of interest. Default is 3 times the highest frequency found in s-parameter file. |
| 9 | <code>fdelta</code> (Hz) | Frequency sampling interval, auto calculated by simulator. If user specified the parameter explicitly, the adaptive sampling is disable. |

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Circuit Components

- 10 `maxn=131072` Maximal order of impulse response. Cannot exceed 262144.
- 11 `imptrunc=1.0e-4` Impulse response truncation threshold relative to the main maximum. The tail of the impulse response below `imptrunc` will be removed. Set `imptrunc=0` to keep the tail.
- 12 `datatrunc=1.0e-4` Relative truncation threshold for the S-parameter data.
- 13 `usewindow=no` Use smooth data windowing function.
Possible values are `no` and `yes`.
- 14 `dcextrap=constant`
Long delay DC extrapolation method.
Possible values are `constant`, `unwrap`, and `hpunwrap`.
- 15 `hfextrap=constant`
Long delay high-frequency extrapolation method.
Possible values are `constant` and `linear`.

Passivity checking and enforcement parameters

- 16 `passivity=check` Check and enforce passivity of s parameters.
Possible values are `no`, `check`, and `enforce`.
- 17 `pabstol=-1.0e-6` Absolute tolerance of passivity criteria.

Causality correction parameters

- 18 `causality=fmax` Correct s parameter data to ensure system is causal. Possible options are `no`, `fmax` and `auto`. The default is 'fmax'. 'auto' will take long time to perform causality correction.
Possible values are `no`, `fmax`, and `auto`.

Rational interpolation parameters

- 19 `relerr=0.01` Maximum relative allowed tolerance for rational interpolation errors. Deviations of the nport model from supplied s-parameter data of relative magnitude less than `relerr` are generally ignored.
- 20 `abserr=1e-4` Maximum absolute allowed tolerance for rational interpolation errors. Deviations of the nport model from supplied s-parameter

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data of absolute magnitude less than `abserr` are generally ignored.

21 `romdatfile` File used for storing time-domain reduced order model (ROM).

22 `ratorder` Order of rational function to use in fitting the s-parameter data. If this argument is given, `relerr` and `abserr` are ignored in selecting the order of the rational function interpolation. If `ratorder` is not specified then the program will attempt to select an order of rational interpolation that satisfies the criteria implied by `abserr` and `relerr`.

Noise parameters

23 `trise` (C) Temperature rise from ambient.

24 `thermalnoise=yes` Should nport generate noise.
Possible values are `no` and `yes`.

25 `noisemodel` To use the internal thermal noise model, or the externally supplied noise data in the S-parameter data file. The default behavior is to use external data whenever it is available. When `interp=bbspice`, externally supplied noise data will be ignored, default will use the broadbandspice rational fitting model to get noise model.
Possible values are `internal` and `external`.

26 `noisecorr=complex` Setting `noisecorr` to `real` forces the nport noise correlation matrix to be real-valued. The parameter is used for backward compatibility only. Its value is now determined automatically and its use is no longer recommended because it can lead to incorrect answer. The simulator will issue a warning if the noise correlation matrix is complex while the value of `noisecorr` is set to `real`.
Possible values are `real` and `complex`.

Matrixform state-space model parameter

27 `porttypes=[...]` A vector of integers that defines types of the ports. Use 0 for input port, 1 for output port and 2 if the port is both input and output.

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Circuit Components

- 28 `portquantities=[...]` A vector of integers that defines quantities of the ports. Use 0 for voltage and 1 for current.
- 29 `matrixfile` Matrix entry data file name.
- 30 `matrixA=[...]` Nonzero entries in coefficient matrix A. Its format is [... row_i col_j value_ij ...].
- 31 `matrixB=[...]` Nonzero entries in coefficient matrix B. Its format is [... row_i col_j value_ij ...].
- 32 `matrixC=[...]` Nonzero entries in coefficient matrix C. Its format is [... row_i col_j value_ij ...].
- 33 `matrixD=[...]` Nonzero entries in coefficient matrix D. Its format is [... row_i col_j value_ij ...].
- 34 `matrixE=[...]` Nonzero entries in coefficient matrix E. Its format is [... row_i col_j value_ij ...].
- 35 `matrixK=[...]` Nonzero entries in coefficient matrix K. Its format is [... row_i col_j value_ij ...].
- 36 `acmodel=freqdomain` Alters nport behaviour in small signal analyses: sp, ac and xf. The default value is `freqdomain`. Possible values are `freqdomain` and `timedomain`.
- 37 `outfile` File used for storing the equivalent s-parameter data based on corresponding time-domain model. The file format is touchstone. The instance name is added as a suffix and the file extension is added automatically.

Model Definition

`model modelName nport parameter=value ...`

Model Parameters

- 1 `file` S-parameter data file name.

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Circuit Components

- 2 `datafmt` The format of the S-parameter data file. If this parameter is not given, Spectre will try to detect the format by itself. Possible values are `spectre`, `touchstone`, `citi`, and `rfm`.
- 3 `scale=1` Frequency scale factor.
- 4 `dcextrap=constant` Long delay DC extrapolation method. Possible values are `constant`, `unwrap`, and `hpunwrap`.
- 5 `matrixform=no` Flag for matrix form input. Possible values are `no` and `yes`.

Spline/Linear interpolation parameters

- 6 `interp=linear` Method to interpolate s-parameter data. Possible values are `spline`, `rational`, `linear`, and `bbspice`.
- 7 `fmax (Hz)` Maximum frequency of interest. Default is 3 times the highest frequency provided in the s-parameter file.
- 8 `fdelta (Hz)` Frequency sampling interval, auto calculated by simulator. If user specified the parameter explicitly, the adaptive sampling is disable.
- 9 `maxn=131072` Maximal order of impulse response. Cannot exceed 262144.
- 10 `imptrunc=1.0e-4` Relative truncation threshold for the impulse response.
- 11 `datatrunc=1.0e-4` Relative truncation threshold for the S-parameter data.
- 12 `usewindow=no` Use smooth data windowing function. Possible values are `no` and `yes`.
- 13 `hfextrap=constant` Long delay high-frequency extrapolation method. Possible values are `constant` and `linear`.

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Passivity checking and enforcement parameters

- 14 `passivity=check` Check and enforce passivity of s parameters.
Possible values are `no`, `check`, and `enforce`.
- 15 `pabstol=-1.0e-6` Absolute tolerance of passivity criteria.

Causality correction parameters

- 16 `causality=fmax` Correct s parameter data to ensure system is causal. The default value is 'fmax'. 'auto' will take long time to perform causality correction.
Possible values are `no`, `fmax`, and `auto`.

Noise parameters

- 17 `trise=0 C` Default temperature rise from ambient.
- 18 `thermalnoise=yes` Should nport generate noise.
Possible values are `no` and `yes`.
- 19 `isnoisy=yes` Should nport generate noise.
Possible values are `no` and `yes`.
- 20 `noisemodel` To use the internal thermal noise model, or the externally supplied noise data in the S-parameter data file. The default behavior is to use external data whenever it is available. When `interp=bb spice`, externally supplied noise data will be ignored, default will use the broadbandspice rational fitting model to get noise model.
Possible values are `internal` and `external`.
- 21 `noisecorr=complex` Setting `noisecorr` to `real` forces the nport noise correlation matrix to be real-valued. The parameter is used for backward compatibility only. Its value is now determined automatically and its use is no longer recommended because it can lead to incorrect answer. The simulator will issue a warning if the noise correlation matrix is complex while the value of `noisecorr` is set to `real`.
Possible values are `real` and `complex`.

Matrixform state-space model parameter

- 22 `porttypes=[...]` A vector of integers that defines types of the ports. Use 0 for input port, 1 for output port and 2 if the port is both input and output.
- 23 `portquantities=[...]` A vector of integers that defines quantities of the ports. Use 0 for voltage and 1 for current.
- 24 `matrixfile` Matrix entry data file name.
- 25 `matrixA=[...]` Nonzero entries in coefficient matrix A. Its format is [... row_i col_j value_ij ...].
- 26 `matrixB=[...]` Nonzero entries in coefficient matrix B. Its format is [... row_i col_j value_ij ...].
- 27 `matrixC=[...]` Nonzero entries in coefficient matrix C. Its format is [... row_i col_j value_ij ...].
- 28 `matrixD=[...]` Nonzero entries in coefficient matrix D. Its format is [... row_i col_j value_ij ...].
- 29 `matrixE=[...]` Nonzero entries in coefficient matrix E. Its format is [... row_i col_j value_ij ...].
- 30 `matrixK=[...]` Nonzero entries in coefficient matrix K. Its format is [... row_i col_j value_ij ...].

Important note about spline and linear interpolation parameters:

`interp`

To calculate impulse response, either linear or spline interpolation is used to sample data points in the frequency domain, based on the S-parameter data file. When the input data points are sufficient, linear and spline interpolation produce comparable model accuracy. However, when the input data points are scarce, linear interpolation is preferred to bound jumps between data points. Interpolation/extrapolation can be avoided all together if s-parameter data is provided from zero frequency to `fmax` with uniform step `fdelta`, and number of samples is a power of 2.

`fmax`

The default of `fmax` is three times the highest frequency in the S-parameter data file. Impulse response is calculated by sampling frequency points between DC and '`fmax`'. The purpose

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Circuit Components

of this extrapolation is to preserve high-frequency model accuracy. However, if user has enough bandwidth in the S-parameter data file, `fmax` needs to be set to the original highest frequency in the S-parameter data file. In general, fmax must be larger than expected signal bandwidth.

fdelta

Frequency sampling interval, with default of `fmax'/1024, or 1/tstop, whichever is smaller. Note that fdelta will be further reduced, so that fmax/fdelta is a power of 2. This is required by FFT algorithm.

maxn

Maximal order of impulse response, or the maximum number of sampling points in the frequency domain. User should only increase this value when modeling a system with large average group delay, such as transmission line. The given value of `maxn' will be reduced to the nearest power of 2. Setting this value unnecessarily large slows down time-domain simulation. Absolute upper limit for maxn is 16384.

imptrunc

Relative truncation threshold for impulse response. The tail of the impulse response with absolute values below `imptrunc' is removed to speed up simulation.

usewindow

Kaiser-Bessel window with smoothing parameter 1 is used to better regulate the stability of S-parameter data. This parameter trades off model accuracy with model stability, particular useful for S-parameter data with insufficient bandwidth. Window must be used for all-pass type systems, where s-parameters are nonzero for the frequencies beyond fmax.

dcextrap

For long delay, the DC extrapolation method can be set to constant, unwrap or hpunwrap. The default is 'constant', where without a dc point, the low-frequency magnitude is held at the lowest data point, the dc phase is set to the real axis near the lowest-frequency data point and interpolated elsewhere. For the 'unwrap' case and without a dc point, the DC magnitude is set based on a regression of some low-frequency data, and the DC phase is set by unwrapping the phase, then setting it onto the real axis. If the dc point is provided, the magnitude is interpolated while the phase is still determined using the unwrapped estimate. 'hpunwrap' is similar to 'unwrap' for DC phase extrapolation but provides an alternative approach for DC magnitude extrapolation which may be preferred for high-pass characteristics.

Important note about parameters for state-space models:

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Circuit Components

porttype and portquantities

Both parameters have the same number of entries as the number of ports, and each entry corresponds to a port. The entries are in the same order as the port order in terminal specification of the instance. `porttype` specifies the type of each port of the nport. A port can be of type input, output or both. `portquantities` specifies whether each input/output is a voltage or current. Each entry of `portquantities` corresponds to one entry in `porttypes`. It specifies the quantity of input for input and both ports and the quantity of output for output port.

matrixfile

=====

Matrix entry data file name.

File format:

Any line beginning with ";", "#", or "%" is treated as a comment and discarded.

Remaining lines should have a first character of A, B, C, D, E, or K, two integers, and a floating-point number. Such a line denotes an entry in the appropriate matrix with given row column indices and matrix element.

For example, a file may look like this:

```
;matrix A, 3x3
```

```
A 1 1 1234.5678
```

```
...
```

```
;
```

```
;matrix E, 3x3
```

```
E 1 1 1.0
```

```
...
```

```
;
```

```
;matrix B, 3x1
```

```
B 2 1 4.28
```

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Circuit Components

```
...  
;  
;matrix C, 2x3  
C 2 1 3.14  
...
```

If a matrix is not specified in the file, it will be treated as zero matrix for A, B, C, D, and K. Matrix E will be treated as identity matrix if it is not specified in the file.

matrixA matrixB matrixC matrixD matrixE matrixK

Coefficient matrices of the state-space model. The syntax of the vector is in sparse form, i.e.

```
[ Row_1, Column_1, Value_11,  
...  
Row_i, Column_j, Value_ij,  
... ]
```

If a matrix is not specified, it will be treated as a zero matrix for A, B, C, D, and K. Matrix E will be treated as identity matrix if it is not specified.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

abserr	I-14	matrixA	I-26	matrixform	I-6	porttypes	I-23
datafmt	I-3	matrixA	M-19	matrixform	M-4	porttypes	M-16
datafmt	M-2	matrixB	I-27	maxn	I-9	ratorder	I-16

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Circuit Components

dcextrap	I-12	matrixB	M-20	maxn	M-7	relerr	I-13
fdelta	I-8	matrixC	I-28	noisecorr	I-22	romdatfile	I-15
fdelta	M-6	matrixC	M-21	noisecorr	M-15	scale	I-4
file	I-2	matrixD	I-29	noisemodel	I-21	scale	M-3
file	M-1	matrixD	M-22	noisemodel	M-15	thermalnoise	I-20
fmax	I-7	matrixE	I-30	pabstol	I-18	thermalnoise	M-13
fmax	M-5	matrixE	M-23	pabstol	M-11	trise	I-19
imptrunc	I-10	matrixK	I-31	passivity	I-17	trise	M-12
imptrunc	M-8	matrixK	M-24	passivity	M-10	usewindow	I-11
interp	I-5	matrixfile	I-25	portquantities	I-24	usewindow	M-9
m	I-1	matrixfile	M-18	portquantities	M-17		

Current Probe (iprobe)

Current through the probe is computed and is defined to be positive if it flows from the input node, through the probe, to the output node. The current variable is given the name of the `iprobe` instance, so you cannot create an `iprobe` with the same name as a circuit node.

This device is not supported within `altergroup`.

Sample Instance Statement

```
ip (1 0) iprobe
```

Instance Definition

```
Name in out iprobe
```

Operating-Point Parameters

1 i (A) current through iprobe.

Circuit Reduced Order Model (cktrom)

The circuit reduced order model is described by a set of partial differential equations in the form of:

$$\dot{x} = Ax + Bu \quad (1)$$

$$y = Cx + Du \quad (2)$$

where Eqn.(1) is the state equation, Eqn.(2) is the output equation, A is nxn matrix, B is nxm, C is mxn, and D is an mxm matrix. x is a vector of state variables. Input u is a vector of voltages at all the ports and output y is a vector of electric current at all the ports. The number of inputs is always equal to the number of outputs. The order of the terminals in the input must be consistent with the matrix equations. In the input file, the matrices A, B, C and D are in the form of long vectors with row order.

This device is not supported within altergroup.

Sample Instance Statement

```
rom3 (net11 0) cktrom a=[ -2.022852e+14 2.583012e+13 9.553125e+13 9.627727e+13
1.533971e+13 9.987851e+13 4.592012e+13 -1.671024e+14 2.296589e+13 -2.719915e+14
7.668472e+12 -1.564519e+14 8.543123e+13 3.395689e+13 -3.863150e+14 -
1.101618e+14 -5.415116e+14 -2.303841e+14 9.627728e+13 -1.711915e+14 -
1.001818e+14 -8.123120e+14 -2.272715e+14 -9.965181e+14 1.514961e+14
7.668372e+12 -6.415116e+14 -3.272715e+14 -2.852751e+15 -3.564466e+14
9.999851e+13 -1.761619e+14 -1.312841e+14 -8.967181e+14 -4.563456e+14 -
4.068747e+15 ]
```

```
b=[3.366776e+06 5.932470e+05 -1.508475e+06 4.349182e+06 -3.128869e+06 -
2.995677e+06 -2.831481e+06 2.708942e+06 -4.968876e+06 -3.338945e+06 -
3.278564e+06 3.925648e+06 ]
```

```
c=[-3.111296e+06 1.593292e+06 3.324594e+06 3.083731e+06 5.887179e+06
3.766094e+06 -5.049263e+05 -4.275158e+06 3.035578e+06 -3.666385e+06
3.424639e+06 -3.832285e+06]
```

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Circuit Components

d=[1.254627e-01 0.000000e+00 0.000000e+00 1.236790e-01]

Instance Definition

Name sink0 src0 [sink1] [src1] [sink2] [src2] [sink3] [src3] ... cktrom
parameter=value ...

Instance Parameters

- | | | |
|---|---------|---|
| 1 | m=1 | Multiplicity factor. |
| 2 | a=[...] | Coefficient matrix A of state equations. |
| 3 | b=[...] | Coefficient Matrix B of state equations. |
| 4 | c=[...] | Coefficient matrix C of output equations. |
| 5 | d=[...] | Coefficient matrix D of output equations. |

Operating-Point Parameters

- | | | |
|---|-----------|--------------------|
| 1 | i=[...] A | Port currents. |
| 2 | v=[...] V | Port voltages. |
| 3 | pwr (W) | Power dissipation. |

Parameter Index

In the following index, I refers to instance parameters, M refers to the model parameters section, O refers to the output parameters section, and OP refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of M-35 means the 35th model parameter.

a	I-2	c	I-4	i	OP-1	pwr	OP-3
b	I-3	d	I-5	m	I-1	v	OP-2

Analog-to-Logic Converter (a2d)

The analog-to-logic converter transfers analog waveforms to a logic simulator.

This device is not supported within altergroup.

Sample Instance Statement

```
da99 (cmp_out 0) a2d dest="99991" vl=0 vh=5 timex=200u
```

```
// 99991 is a digital net in the Verilog netlist.
```

Instance Definition

```
Name p n a2d parameter=value ...
```

Instance Parameters

- | | | |
|---|------------------------|---|
| 1 | <code>dest</code> | The foreign simulator name for the destination of the signal. |
| 2 | <code>nestlev=0</code> | Number of nesting levels to ignore in the hierarchical name. This should be used to skip over extra levels that do not exist in the co-simulator. |
| 3 | <code>vl=0 V</code> | Voltages below this will be logical 0. |
| 4 | <code>vh=5 V</code> | Voltages above this will be logical 1. |
| 5 | <code>timex=1 s</code> | Time signal can linger between <code>vl</code> and <code>vh</code> before the state becomes X. |

device checker (assert)

The assert statement cannot be altered using the alter statement.

This device is supported within altergroups.

Instance Definition

```
Name assert parameter=value ...
```

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Circuit Components

Instance Parameters

1	<code>max=∞</code>	Upper bound of the parameter to be checked.
2	<code>min=∞</code>	Lower bound of the parameter to be checked.
3	<code>duration=0 s</code>	Time period over which the check has been in violation before a message is flagged.
4	<code>mod</code>	Model to be checked.
5	<code>dev</code>	Device or Subcircuit instance to be checked.
6	<code>primitive</code>	Primitive to be checked.
7	<code>sub</code>	Subcircuit master to be checked.
8	<code>param</code>	Any one of input, output, operating point or subcircuit instance parameter to be checked.
9	<code>modelparam</code>	Model parameter to be checked.
10	<code>message</code>	Message to be printed when assertion fails.
11	<code>level=warning</code>	Severity used when assertion fails. Possible values are <code>none</code> , <code>notice</code> , <code>warning</code> , <code>error</code> , or <code>fatal</code> .
12	<code>info=no</code>	When <code>info=yes</code> , parameter will not be checked against min/max, only its value will be printed out. Possible values are <code>no</code> or <code>yes</code> .
13	<code>expr</code>	Expression to be checked for violation (in MDL syntax).
14	<code>values=[...]</code>	List of values for a parameter of the enumerated type. If the parameter has a value outside of the listed ones, a message will be flagged.
15	<code>m=1</code>	Multiplicity factor.
16	<code>boolean=true</code>	Choose behavior and report style for boolean violations. If <code>boolean = true</code> , asserts are issued when <code>boolean</code> is true and reported in old style; If <code>boolean = false</code> , asserts are issued when

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Circuit Components

boolean is false and reported in new style.
Possible values are `false` or `true`.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

boolean	I-16	info	I-12	message	I-10	param	I-8
dev	I-5	level	I-11	min	I-2	primitive	I-6
duration	I-3	m	I-15	mod	I-4	sub	I-7
expr	I-13	max	I-1	modelparam	I-9	values	I-14

Logic-to-Analog Converter (d2a)

The logic-to-analog converter converts a binary signal from a logic simulator to an analog waveform.

This device is not supported within altergroup.

Sample Instance Statement

```
d2a_1 (net1 net2) d2a src="99991" val0=0 val1=2.5 valx=1.25 rise=200p fall=200p m=2
//99991 is an analog net
```

Instance Definition

```
Name p n d2a parameter=value ...
```

Instance Parameters

1 `src` The foreign simulator's name for the source of the analog signal.

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Circuit Components

2	<code>nestlev=0</code>	Number of nesting levels to ignore in the hierarchical name. This should be used skip over extra levels that do not exist in the co-simulator.
3	<code>val0=0 V</code>	Final value for logical 0.
4	<code>val1=5 V</code>	Final value for logical 1.
5	<code>valx (V)</code>	Final value for logical X.
6	<code>valz (V)</code>	Final value for logical Z.
7	<code>rise=1ns s</code>	Time for transition from <code>val0</code> to <code>val1</code> .
8	<code>fall=1ns s</code>	Time for transition from <code>val1</code> to <code>val0</code> .
9	<code>ron=100 Ω</code>	Output resistance when in active state.
10	<code>m=1</code>	Multiplicity factor.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

<code>fall</code>	I-8	<code>rise</code>	I-7	<code>val0</code>	I-3	<code>valz</code>	I-6
<code>m</code>	I-10	<code>ron</code>	I-9	<code>val1</code>	I-4		
<code>nestlev</code>	I-2	<code>src</code>	I-1	<code>valx</code>	I-5		

Ideal Switch (switch)

Ideal switch is a single-pole multiple-throw switch with infinite `off` resistance and zero `on` resistance. The switch is provided to allow you to reconfigure your circuit between analyses.

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Circuit Components

You can only change the switch state between analyses (using the alter statement), not during an analysis.

When the switch is set to position 0 it is open. In other words, no terminal is connected to any other. When the switch is set to position 1, terminal 1 is connected to terminal 0, and all others are unconnected. When the position is set to 2, terminal 2 is connected to terminal 0, etc.

An offset voltage is supported. It is placed in series with the common terminal. The negative side of the source is connected to the common terminal.

The switch can change its position based on which analysis type is being performed using the `xxx_position` parameters. This feature should be used carefully. Careless use can generate discontinuities that result in convergence problems. Once an analysis specific position has been specified using `xxx_position`, it will always dominate over a position given with the `position` parameter. To disable an analysis specific position, alter it to its default value of unspecified.

This device is not supported within altergroup.

Sample Instance Statement

```
sw1 (t1 t2 t3) switch dc_position=0 ac_position=1 tran_position=2
```

Instance Definition

```
Name t0 t1 ... switch parameter=value ...
```

Instance Parameters

1	<code>position=0</code>	Switch position (0, 1, 2, ...).
2	<code>dc_position</code>	Position to which switch is set at start of DC analysis.
3	<code>ac_position</code>	Position to which switch is set at start of AC analysis.
4	<code>tran_position</code>	Position to which switch is set at start of transient analysis.
5	<code>ic_position</code>	Position to which switch is set at start of IC analysis (precedes transient analysis).
6	<code>offset=0</code>	Offset voltage in series with common terminal.
7	<code>m=1.0</code>	Multiplicity factor.

Output Parameters

1 `present_position`
Current switch position.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

<code>ac_position</code>	I-3	<code>ic_position</code>	I-5	<code>offset</code>	I-6	<code>present_position</code>	O-1
<code>dc_position</code>	I-2	<code>m</code>	I-7	<code>position</code>	I-1	<code>tran_position</code>	I-4

Ratiometric Fourier Analyzer (fourier)

The ratiometric Fourier analyzer measures the Fourier coefficients of two different signals at a specified fundamental frequency without loading the circuit. The algorithm used is based on the Fourier integral rather than the discrete Fourier transform and therefore is not subject to aliasing. Even on broad-band signals, it computes a small number of Fourier coefficients accurately and efficiently. Therefore, this Fourier analyzer is suitable on clocked sinusoids generated by sigma-delta converters, pulse-width modulators, digital-to-analog converters, sample-and-holds, and switched-capacitor filters as well as on the traditional low-distortion sinusoids produced by amplifiers or filters.

The analyzer is active only during a transient analysis. For each signal, the analyzer prints the magnitude and phase of the harmonics along with the total harmonic distortion at the end of the transient analysis. The total harmonic distortion is found by summing the power in all of the computed harmonics except DC and the fundamental. Consequently, the distortion is not accurate if you request an insufficient number of harmonics. The Fourier analyzer also prints the ratio the spectrum of the first signal to the fundamental of the second, so you can use the analyzer to compute large signal gains and immittances directly.

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If you are concerned about accuracy, perform an additional Fourier transform on a pure sinusoid generated by an independent source. Because both transforms use the same time points, the relative errors measured with the known pure sinusoid are representative of the errors in the other transforms. In practice, this second Fourier transform is performed on the reference signal. To increase the accuracy of the Fourier transform, use the `points` parameter to increase the number of points. Tightening `reltol` and setting `errpreset=conservative` are two other measures to consider.

The accuracy of the magnitude and phase for each harmonic is independent of the number of harmonics computed. Thus, increasing the number of harmonics (while keeping `points` constant) does not change the magnitude and phase of the low order harmonics, but it does improve the accuracy of the total harmonic distortion computation. However, if you do not specify `points`, you can increase accuracy by requesting more harmonics, which creates more points.

The large number of points required for accurate results is not a result of aliasing. Many points are needed because a quadratic polynomial interpolates the waveform between the time-points. If you use too few time-points the polynomials deviate slightly from the true waveform between time-points and all of the computed Fourier coefficients are slightly in error. The algorithm that computes the Fourier integral does accept unevenly spaced time-points, but because it uses quadratic interpolation, it is usually more accurate using time-steps that are small and nearly evenly spaced.

This device is not supported within `altergroup`.

Sample Instance Statement

```
four1 (1 0) fourmod harms=50
```

Sample Model Statement

```
model fourmod fourier fund=900M points=2500 order=2
```

Instance Definition

```
Name [p] [n] [pr] [nr] ModelName parameter=value ...
```

```
Name [p] [n] [pr] [nr] fourier parameter=value ...
```

The signal between terminals `p` and `n` is the test or numerator signal. The signal between terminals `pr` and `nr` is the reference or denominator signal. Fourier analysis is performed on terminal currents by specifying the `term` or `refterm` parameters. If both `term` and `p` or `n` are specified, then the terminal current becomes the numerator and the node voltages become the denominator. By mixing voltages and currents, it is possible to compute large signal immittances.

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Circuit Components

Instance Parameters

1	<code>fund</code> (Hz)	Fundamental frequency.
2	<code>points=20</code> <code>maxharm</code>	Minimum number of time points.
3	<code>active=yes</code>	Whether Fourier analysis should be performed or skipped. Possible values are <code>no</code> or <code>yes</code> .
4	<code>order=2</code>	Order of interpolation.
5	<code>term</code>	Terminal used to measure current for test (numerator) channel.
6	<code>refterm</code>	Terminal used to measure current for reference (denominator) channel.
7	<code>harmsvec=[...]</code>	Array of desired harmonics for test (numerator) channel.
8	<code>harms=9</code>	Number of harmonics for test (numerator) channel, if an array is not given. The harmonics start from <code>firstharm</code> and go up to <code>firstharm + harms - 1</code> .
9	<code>refharmsvec=[...]</code>	Array of desired harmonics for reference (denominator) channel.
10	<code>refharms=9</code>	Number of harmonics for reference (denominator) channel, if an array is not given. The harmonics start from <code>reffirstharm</code> and go up to <code>reffirstharm + harms - 1</code> .
11	<code>scale=1</code>	Scale factor for ratio results.
12	<code>firstharm=1</code>	First harmonic computed for test (numerator) channel.
13	<code>reffirstharm=1</code>	First harmonic computed for reference (denominator) channel.
14	<code>normharm=1</code>	Normalizing harmonic for test (numerator) channel.
15	<code>refnormharm=1</code>	Normalizing harmonic for reference (denominator) channel.
16	<code>where=logfile</code>	Where Fourier results should be printed. Possible values are <code>screen</code> , <code>logfile</code> or <code>both</code> .

Virtuoso Simulator Components and Device Models Reference

Circuit Components

Model Definition

```
model modelName fourier parameter=value ...
```

Model Parameters

- | | | |
|---|-------------------|---|
| 1 | fund (Hz) | Fundamental frequency. |
| 2 | points=20 maxharm | Minimum number of time points. |
| 3 | harms=9 | Desired number of harmonics. |
| 4 | active=yes | Whether Fourier analysis should be performed or skipped.
Possible values are <code>no</code> or <code>yes</code> . |
| 5 | order=2 | Order of interpolation. |
| 6 | firstharm=1 | First harmonic computed for test (numerator) channel. |
| 7 | reffirstharm=1 | First harmonic computed for reference (denominator) channel. |

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

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IBIS I/O buffer (ibis_buffer)

IBIS buffer model is based on IBIS (I/O Buffer Information Specification) standard, version 3.2. Package and board models, are not included in the buffer, and have to be added as separate subcircuits.

This device is not supported within altergroup.

Driver equations

Current at the `die` terminal is a function of time and voltage:

$$I(\text{die}) = I_{pd}(V(\text{die})-V(\text{gnd})) * W_d(t) + I_{cd}(V(\text{die})-V(\text{gnd}_c)) \\ + I_{pu}(V(\text{die})-V(\text{pwr})) * W_u(t) + I_{cu}(V(\text{die})-V(\text{pwr}_c))$$

$I_{pd}(V)$, $I_{pu}(V)$, $I_{cd}(V)$, and $I_{cu}(V)$ are piece-wise linear transfer functions of pull-down, pull-up, ground clamp, and power clamp voltage controlled current sources. $W_d(t)$ and $W_u(t)$ are switching coefficient functions for pull-up and pull-down sources, defined as follows.

When the buffer is in the high state,

$$W_d(t)=0, W_u(t)=1.$$

When the state of the buffer is low,

$$W_d(t)=1, W_u(t)=0.$$

During a transition from low to high state

$$W_d(t)=W_{dr}(t-t_0), W_u(t)=W_{ur}(t-t_0),$$

during a hi-lo transition

$$W_d(t)=W_{df}(t-t_0), W_u(t)=W_{uf}(t-t_0),$$

where t_0 - is a time when transition was initiated.

For the 3-state or I/O buffer types, driver can be disabled by `en` signal, then both $W_u(t)=W_d(t)=0$.

Virtuoso Simulator Components and Device Models Reference

Circuit Components

$W_{dr}(t)$, $W_{ur}(t)$, $W_{df}(t)$, and $W_{uf}(t)$ are pwl functions of time, derived from the rising and falling test waveforms and loads.

State of the buffer is defined by the voltage on the `out` terminal, and buffer polarity. During DC analysis buffer can be either in high, or low state. For non-inverting buffer the state is high when $V(\text{out}) > 0.5$, and low when $V(\text{out}) \leq 0.5$. For inverting buffer it is other way around. During transient analysis the buffer is turned into transition state at the time t_0 , when $V(\text{out})$ crosses the midpoint $V(\text{out}) = 0.5$. When both $W_d(t)$ and $W_u(t)$ switching coefficient functions reach their final 1 or 0 values, the buffer returns to the static high or low state.

Receiver equations

Voltage at the `in` terminal is a controlled by voltage at the `die` node.

If $V(\text{die}) > V_{th_hi}$, then $V(\text{in}) = 1$, if $V(\text{die}) < V_{th_lo}$, then $V(\text{in}) = 0$.

In between $V_{th_hi} \geq V(\text{die}) \geq V_{th_lo}$, $V(\text{in})$ keeps previously assigned voltage.

For differential input buffers the voltage difference between non-inverting and inverting pins: $V(\text{die}) - V(\text{inv_die})$ is used instead of $V(\text{die})$

Switching coefficients

Switching coefficients, if not given, are calculated from the test waveforms and loads. If two waveforms are available for rising transition (V_{1r} , V_{2r}) and two for falling (V_{1f} , V_{2f}), then linear system of equations is solved for pairs of switching coefficients (W_{dr} , W_{ur}) and (W_{df} , W_{uf}) at each time t :

$$I_{pd}(V_{r1} - V_{gnd}) * W_{dr} + I_{pu}(V_{r1} - V_{pwr}) * W_{ur} = I_0(V_{r1})$$

$$I_{pd}(V_{r2} - V_{gnd}) * W_{dr} + I_{pu}(V_{r2} - V_{pwr}) * W_{ur} = I_0(V_{r2})$$

$$I_{pd}(V_{f1} - V_{gnd}) * W_{df} + I_{pu}(V_{f1} - V_{pwr}) * W_{uf} = I_0(V_{f1})$$

$$I_{pd}(V_{f2} - V_{gnd}) * W_{df} + I_{pu}(V_{f2} - V_{pwr}) * W_{uf} = I_0(V_{f2})$$

Where $I_{pd}(V)$, $I_{pu}(V)$ are pull-down and pull-up current source functions. Load current $I_0(V)$ for each load resistance R_l , voltage V_l , and capacitance C_l is calculated as:

$$I_0(V) = (C_{comp} + C_l) * dV/dt - (V - V_l) / R_l - I_{gc}(V - V_{gndc}) - I_{pc}(V - V_{pwr})$$

If only one waveform is available for each transition, additional equations are used:

$$W_{dr} + W_{ur} = 1$$

$$W_{df} + W_{uf} = 1$$

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Circuit Components

If no waveforms are given, then `ramp` parameters are used to determine the coefficients. In this case they will be linear functions of time with the slope equal to `ramp` value.

Sample Instance Statement

```
pin1 (die in out en gnd vdd gnd_c vdd_c) iobuff1
pin2 (die out en) ibis_buffer file="models.ibs" model="out2"
```

Sample Model Statement

```
model iobuff1 ibis_buffer type=io vrange=3 ccomp=lp polarity=noninv enable=high
  pullup=[-3 30m -2 25m -1 15m 0 0 1 -15m 2 -24m 3 -30m 4 -35m 5 -36m 6 -37m]
  pulldown=[6 40m 5 38m 4 35m 3 30m 2 25m 1 15m 0 0 -1 -15m -2 -24m -3 -30m]
  uprise=[0 0 3n 1]
  downrise=[0 1 3n 0]
  upfall=[0 1 3n 0]
  downfall=[0 0 3n 1]
  gndclamp=[-4 -40 -0.4 0 0 0]
```

Instance Definition

Name `die` [`inp`] [`out`] [`en`] [`gnd`] [`pwr`] [`gnd_c`] [`pwr_c`] [`inv_die`] `ModelName`
parameter=value ...

Name `die` [`inp`] [`out`] [`en`] [`gnd`] [`pwr`] [`gnd_c`] [`pwr_c`] [`inv_die`] `ibis_buffer`
parameter=value ...

Terminal comments

Number of terminals depend on the type of the buffer.

Only one terminal - `die` - is required for terminator.

Terminals `out` and `en` are required for output buffer. They connect to digital signals, which control pullup and pulldown current sources driving the `die`.

Input buffer must have `in` terminal, which is digital signal received from the `die`.

Terminals `gnd`, `pwr`, `gnd_c`, `pwr_c` provide optional ground and power connections for pull-down, pull-up, ground clamp, and power clamp current sources. Opendrain buffers do not require power connections. Opensource have no ground connections. Either none, or all possible reference voltage terminals have to be specified.

For differential input buffers `inv_die` terminal provides input voltage reference. It have to be connected to the die pad of the inverse pin.

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Circuit Components

buffer type	terminals (y-required, n-not, o-optional)									
	die	in	out	en	gnd	pwr	gnd_c	pwr_c	inv	die
terminator	y	n	n	n	n	n	o	o	n	
input	y	y	n	n	n	n	o	o	o	
output	y	n	y	n	o	o	o	o	n	
tristate	y	n	y	y	o	o	o	o	n	
io	y	y	y	y	o	o	o	o	o	
opendrain	y	n	y	n	o	n	o	n	n	
ioopendrain	y	y	y	y	o	n	o	n	o	
opensesource	y	n	y	n	n	o	n	o	n	
ioopensesource	y	y	y	y	n	o	n	o	o	

Buffer type `opensink` is same as `opendrain`, and `ioopensink` is same as `ioopendrain`. Buffer types ending with `ecl` (`inputecl`, `outputecl`, `ioecl`, `tristateecl`) have same terminals as their normal counterparts (`input`, `output`, `io`, `tristate`).

Instance Parameters

- 1 `file` Name of ibis file containing buffer model information.
- 2 `model` Name of the model section in ibis file.
- 3 `corner=0` IBIS model corner. Allowed values are: 0 or `typical`, 1 or `minimal`, 2 or `maximal`.
Possible values are `typical`, `minimal` or `maximal`.

Differential buffer parameters

- 4 `polarity=inv` Polarity of the buffer.
Possible values are `inv` or `noninv`.
- 5 `delay (s)` Relative delay for differential output buffer.
- 6 `vdiff (V)` Threshold voltage for differential input buffer.

Virtuoso Simulator Components and Device Models Reference

Circuit Components

Multistage buffer parameters

7 `delay_schedule=[...]` sDelay schedule. Format: [rise_on_dly rise_off_dly fall_on_dly fall_off_dly].

HSPICE compatibility parameters. Ignored in spectre mode

8 `compatible=spectre`

Selects buffer format - terminal order, parameters.
Possible values are `spectre` or `hspice`.

9 `buffer`

IBIS model type. If given, must correspond to the buffer model type in the IBIS file. Allowed values are: 1 or `input`, 2 or `output`, 3 or `input_output`, 4 or `three_state`, 5 or `open_drain`, 6 or `io_open_drain`, 7 or `open_sink`, 8 or `io_open_sink`, 9 or `open_source`, 10 or `io_open_source`, 11 or `input_ecl`, 12 or `output_ecl`, 13 or `io_ecl`, 14 or `three_state_ecl`, 17 or `terminator`, .
Possible values are `none`, `input`, `output`, `input_output`, `three_state`, `open_drain`, `io_open_drain`, `open_sink`, `io_open_sink`, `open_source`, `io_open_source`, `input_ecl`, `output_ecl`, `io_ecl`, `three_state_ecl`, `series`, `series_switch`, or `terminator`.

10 `power`

Selects internal (on) or external (off) power sources.
Possible values are `on` or `off`.

11 `interpol`

Interpolation method. Possible values: 1, 2.

12 `ramp_rwf`

Use rising waveform, or ramp. Possible values: 0, 1, 2.

13 `ramp_fwf`

Use falling waveform, or ramp. Possible values: 0, 1, 2.

14 `rwf_tune`

Tune value for rising waveform.

15 `fwf_tune`

Tune value for falling waveform.

16 `c_com_pu`

Pull-up portion of die capacitance.

17 `c_com_pd`

Pull-down portion of die capacitance.

18 `c_com_pc`

Power-clamp portion of die capacitance.

Virtuoso Simulator Components and Device Models Reference

Circuit Components

19	<code>c_com_gc</code>	Ground-clamp portion of die capacitance.
20	<code>xv_pu</code>	
21	<code>xv_pd</code>	
22	<code>pu_scal</code>	Pull-up current scale factor.
23	<code>pd_scal</code>	Pull-down current scale factor.
24	<code>pc_scal</code>	Power-clamp current scale factor.
25	<code>gc_scal</code>	Ground-clamp current scale factor.
26	<code>rwf_scal</code>	Rising waveform scale factor.
27	<code>fwf_scal</code>	Falling waveform scale factor.
28	<code>spu_scal</code> (V)	High state voltage.
29	<code>spd_scal</code> (V)	Low state voltage.

Model Definition

```
model modelName ibis_buffer parameter=value ...
```

Model Parameters

1	<code>type=tristate</code>	Type of the buffer. Possible values are <code>input</code> , <code>output</code> , <code>io</code> , <code>tristate</code> , <code>opendrain</code> , <code>ioopendrain</code> , <code>opensource</code> , <code>ioopensource</code> , <code>terminator</code> , <code>inputecl</code> , <code>outputecl</code> , <code>ioecl</code> , <code>tristateecl</code> , <code>opensink</code> , or <code>ioopensink</code> .
2	<code>ccomp=0 F</code>	Node capacitance on the die pad.
3	<code>enable=high</code>	Polarity of the enable signal. Possible values are <code>low</code> or <code>high</code> .
4	<code>polarity=inv</code>	Polarity of the buffer. Possible values are <code>inv</code> or <code>noninv</code> .

Virtuoso Simulator Components and Device Models Reference

Circuit Components

Voltage reference parameters

- 5 `vrange=5.0 V` Reference voltage.
- 6 `vref=[...] V` Reference voltage, format [gnd pwr gnd_c pwr_c].

Voltage controlled current sources (I/V tables)

- 7 `pullup=[...]` Pull-up current source, format [v1 i1 ...].
- 8 `pulldown=[...]` Pull-down current source, format [v1 i1 ...].
- 9 `powerclamp=[...]` Power clamp current source, format [v1 i1 ...].
- 10 `gndclamp=[...]` Gnd clamp current source, format [v1 i1 ...].

Switching coefficients (W/T tables)

- 11 `uprise=[...]` Pull-up source, rising edge, format [t1 w1 ...].
- 12 `upfall=[...]` Pull-up source, falling edge, format [t1 w1 ...].
- 13 `downrise=[...]` Pull-down source, rising edge, format [t1 w1 ...].
- 14 `downfall=[...]` Pull-down source, falling edge, format [t1 w1 ...].

Test waveforms (V/T tables) and loads

- 15 `vtrise1=[...]` Rising waveform, format [t1 v1 ...].
- 16 `loadrise1=[...]` Load for the rising waveform, format [v r c l].
- 17 `vtfall1=[...]` Falling waveform, format [t1 v1 ...].
- 18 `loadfall1=[...]` Load for the falling waveform, format [v r c l].
- 19 `vtrise2=[...]` Rising waveform, format [t1 v1 ...].
- 20 `loadrise2=[...]` Test load for the rising waveform, format [v r c l].
- 21 `vtfall2=[...]` Falling waveform, format [t1 v1 ...].

Virtuoso Simulator Components and Device Models Reference

Circuit Components

22 `loadfall2=[...]` Test load for the falling waveform, format [v r c l].

23 `ramp=[...]` Rise and fall time, format [dv_rise dt_rise dv_fall dt_fall].

Input logic parameters

24 `vth=[...] V` Low and High switching threshold, format [vth_lo vth_hi].

When `file` and `model` parameters are given, buffer model information is read from the `model` section of the `file`. It is assumed that `file` has standard IBIS format if it has extension `.ibs`.

If `vref` is not given, reference voltages are set according to `vrange` value: `vref=[0 vrange 0 vrange]`. If reference voltage terminals are provided for the buffer instance, then both `vref` and `vrange` are ignored.

Multistaged buffers can be modeled as multiple simple `ibis` buffers connected in parallel. Each stage may have different on and off switching delay relatively to the initial transition edge. Driver schedule have to be specified only for the instances, which are parts of multistaged buffer.

Differential buffer can be modeled by a pair of buffers, one for inverting pin, and another for noninverting pin. Instance parameter `polarity` is used to override the buffer model polarity. In the case of output buffer, `delay` sets transition delay for non-inverting pin relatively to the inverting one. For differential input buffer the inverse pin have to be specified, and `vdiff` instance parameter overrides threshold voltages defined in the model.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

<code>buffer</code>	I-9	<code>fwf_scal</code>	I-27	<code>power</code>	I-10	<code>uprise</code>	M-11
<code>c_com_gc</code>	I-19	<code>fwf_tune</code>	I-15	<code>powerclamp</code>	M-9	<code>vdiff</code>	I-6

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Circuit Components

c_com_pc	I-18	gc_scal	I-25	pu_scal	I-22	vrange	M-5
c_com_pd	I-17	gndclamp	M-10	pulldown	M-8	vref	M-6
c_com_pu	I-16	interpol	I-11	pullup	M-7	vtfall1	M-17
ccomp	M-2	loadfall1	M-18	ramp	M-23	vtfall2	M-21
compatible	I-8	loadfall2	M-22	ramp_fwf	I-13	vth	M-24
corner	I-3	loadrise1	M-16	ramp_rwf	I-12	vtrise1	M-15
delay	I-5	loadrise2	M-20	rwf_scal	I-26	vtrise2	M-19
delay_schedule	I-7	model	I-2	rwf_tune	I-14	xv_pd	I-21
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enable	M-3	polarity	I-4	type	M-1		
file	I-1	polarity	M-4	upfall	M-12		

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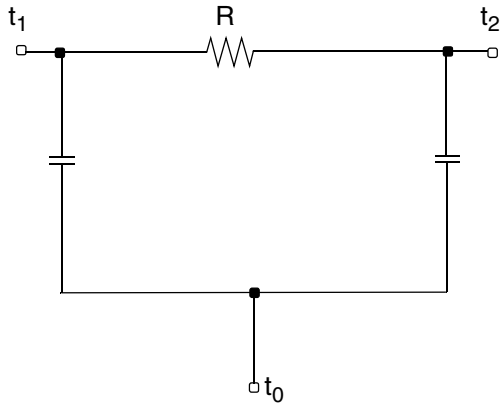
Circuit Components

Passive Components

This chapter contains information on

- [Two Terminal Resistor](#) on page 160
- [Physical Resistor \(phy_res\)](#) on page 173
- [R2 Model \(r2\)](#) on page 183
- [Fractional Impedance/Admittance Pole \(fracpole\)](#) on page 198
- [Two Terminal Capacitor \(capacitor\)](#) on page 202
- [Junction Capacitor \(juncap\)](#) on page 212
- [JUNCAP2 Model \(juncap200\)](#) on page 217
- [Junction Capacitor \(juncap_eldo\)](#) on page 223
- [Two Terminal Inductor \(inductor\)](#) on page 229
- [Mutual Inductor \(mutual_inductor\)](#) on page 232
- [Magnetic Core with Hysteresis \(core\)](#) on page 233
- [Winding for Magnetic Core \(winding\)](#) on page 237
- [Linear Inductance, Reluctance, Resistance, and Capacitance Matrix \(rlck_matrix\)](#) on page 238

Two Terminal Resistor (resistor)



Two Terminal Resistor

If $R(inst)$ is not given and $R(model)$ is given,

$$R(inst) = R(model)$$

Otherwise,

$$R(inst) = Rsh \times \frac{(L - 2 \times etchl)}{(W - 2 \times etch)}$$

If the polynomial coefficients vector ($coeffs=[c1 \ c2 \ \dots]$) is specified, the resistor is nonlinear. When `nonlinform` is set to `g`, the conductance is

$$\begin{aligned} G(V) &= \frac{dI}{dV} \\ &= \frac{(1 + c1 \times V + c2 \times V^2 + \dots)}{R(inst)} \end{aligned}$$

The branch current as a function of applied voltage is

$$I(V) = \left(\frac{V}{R(inst)} \right) \times \left(1 + \frac{1}{2} \times c1 \times V + \frac{1}{3} \times c2 \times V^2 + \dots \right)$$

Virtuoso Simulator Components and Device Models Reference

Passive Components

When `nonlinform` is set to `r`, the resistance is

$$R(V) = \frac{dV}{dI}$$
$$= R(inst) \times (1 + c1 \times V + c2 \times V^2 + \dots)$$

where ck is the k th entry in the coefficient vector.

The value of the resistor as a function of the temperature is given by

$$R(T) = R(tnom) \times [1 + tc1 \times (T - tnom) + tc2 \times (T - tnom)^2]$$

where

$$T = trise(inst) + temp$$

if `trise(inst)` is given, and

$$T = trise(model) + temp$$

`Rac` is an instance or model parameter used in AC analysis.

If `Rac(inst)` is not given and `Rac(model)` is given,

$$Rac(inst) = Rac(model)$$

The final effective value of AC resistance is:

$$Rac_eff = Rac(inst) \times (1.0 + tc1 \times (T - tnom) + tc2 \times (T - tnom)^2)$$

If:

- `Rac` is not specified either in the instance or in the model, `Rac_eff` is the resistor value at operating point.
- `Rac_eff` is less than 1.0e-10 ohms, `Rac_eff`=1.0e-10 ohms.

Noise Model

Thermal Noise:

$$\bar{i}_T = \frac{4kT}{R} \cdot \Delta f$$

where

R is the resistor value and T is the temperature.

Flicker Noise:

$$\bar{i}_f = \frac{KF \cdot I^{AF}}{f^{FEXP}} \cdot \frac{1}{W_{eff}^{WEEXP} \cdot L_{eff}^{LEEXP} \cdot W^{WDEXP} \cdot L^{LDEXP}} \cdot \Delta f$$

where:

KF, AF, FEXP, WEEXP, LEEXP, WDEXP, and LDEXP are model parameters, I is the current, f is the frequency, and W and L are the device width and length.

$W_{eff} = W - 2 \cdot ETCH$ and $L_{eff} = L - 2 \cdot ETCHL$.

Wire RC Model

If you specify the capacitance for a two terminal resistor, the model is a Wire RC model. If you do not specify the capacitance explicitly, it is computed from the physical length and width of the resistor using C_j and C_{jsw} . You can use the model parameter *cratio* to allocate the parasitic capacitance of the wire element between the model's input capacitor and output capacitor.

If $C(inst)$ is not given and $C(model)$ is given

$$C(inst) = C(model)$$

Otherwise,

$$C(inst) = C_j \times (L - 2 \times etch1) \times (W - 2 \times etch) + 2 \times C_{jsw} \times (W + L - 2 \times etch - 2 \times etch1)$$

The parasitic capacitance assigned to the input and output nodes is given by

$$C(1) = C(inst) \times cratio$$

$$C(2) = C(inst) \times (1 - cratio)$$

If C_j is not given, but $thick$ is given and is nonzero, C_j is calculated as follows:

If d_i is given and is nonzero,

$$C_j = \frac{d_i \cdot \epsilon_0}{thick}$$

otherwise

$$C_j = \frac{\epsilon_0 x}{thick}$$

where

$$\epsilon_0 = 8.8542149e-12 \text{ F/meter}$$

$$\epsilon_0 x = 3.453148e-11 \text{ F/meter}$$

The value of each capacitor as a function of the temperature is given by

$$C(T) = C(tnom) \times [1 + tc1c \times (T - tnom) + tc2c \times (T - tnom)^2]$$

Scaling Effects

For scaling effects, see [Scaling Factors \(scale and scalem\)](#) on page 242.

The length and width of the Wire RC model are also scaled by the model parameter *shrink*.

Component Statements

You can give the resistance explicitly or allow it to be computed from the physical length and width of the resistor. In either case, the resistance can be a function of temperature or applied voltage.

This device is supported within altergroups.

Virtuoso Simulator Components and Device Models Reference

Passive Components

If $R(\text{inst})$ is not given and $R(\text{model})$ is given

$$R(\text{inst}) = R(\text{model})$$

otherwise,

$$R(\text{inst}) = R_{\text{sh}} * (L - 2 * \text{etchl}) / (W - 2 * \text{etch})$$

If the polynomial coefficients vector ($\text{coeffs}=[c1 \ c2 \ \dots]$) is specified, the resistor is nonlinear. When nonlinform is set to g , the conductance is

$$\begin{aligned} G(V) &= dI / dV \\ &= (1 + c1 * V + c2 * V^2 + \dots) / R(\text{inst}). \end{aligned}$$

The branch current as a function of applied voltage is

$$I(V) = (V / R(\text{inst})) * (1 + 1/2 * c1 * V + 1/3 * c2 * V^2 + \dots)$$

When nonlinform is set to r , the resistance is

$$\begin{aligned} R(V) &= dV / dI \\ &= R(\text{inst}) * (1 + c1 * V + c2 * V^2 + \dots). \end{aligned}$$

where c_k is the k th entry in the coefficient vector.

For AC analysis, $RAC(\text{inst})$ AC resistance will be used.

If $RAC(\text{inst})$ is not given, and $RAC(\text{model})$ is given,

$$RAC(\text{inst}) = RAC(\text{model})$$

otherwise,

$RAC(\text{inst})$ will use DC resistance.

The value of the resistor as a function of the temperature is given by:

$$R(T) = R(\text{tnom}) * [1 + tc1 * (T - \text{tnom}) + tc2 * (T - \text{tnom})^2]$$

where

$$T = \text{trise}(\text{inst}) + \text{temp}$$

if $\text{trise}(\text{inst})$ is given, and

Virtuoso Simulator Components and Device Models Reference

Passive Components

$$T = \text{trise}(\text{model}) + \text{temp}$$

otherwise.

If you specify capacitance the model is a wire RC model. You can give the capacitance explicitly or allow it to be computed from the physical length and width of the resistor. The model parameter `cratio` can be used to allocate the parasitic capacitance of the wire element between the models input capacitor and output capacitor.

If $C(\text{inst})$ is not given and $C(\text{model})$ is given,

$$C(\text{inst}) = C(\text{model}).$$

Otherwise,

$$C(\text{inst}) = C_j * (L - 2 * \text{etchl}) * (W - 2 * \text{etch}) + 2 * C_{jsw} * (W + L - 2 * \text{etch} - 2 * \text{etchl}).$$

The parasitic capacitance assigned to the input and output nodes is given by:

$$C(1) = C(\text{inst}) * \text{cratio}$$

$$C(2) = C(\text{inst}) * (1 - \text{cratio}).$$

The value of each capacitor as a function of the temperature is given by:

$$C(T) = C(\text{tnom}) * [1 + \text{tc1c} * (T - \text{tnom}) + \text{tc2c} * (T - \text{tnom})^2].$$

Sample Instance Statement

without model:

```
r1 (1 2) resistor r=1.2K rac=100K m=2
```

with model:

```
r1 (1 2) resmod l=8u w=1u
```

Sample Model Statement

```
model resmod resistor rsh=150 l=2u w=2u etch=0.05u tc1=0.1 tnom=27 kf=1
```

This device support behavior expression

Sample behavior Statement

```
r1 (1 0) resistor r=rsh*(1 + v(1,2)*c1 + v(1,2)^2*c2)
```

```
r1 (1 0) resistor r= 100 + sqrt($freq)/1e6
```

Virtuoso Simulator Components and Device Models Reference

Passive Components

Instance Definition

```
Name 1 2 [0] modelName parameter=value ...
Name 1 2 [0] resistor parameter=value ...
```

Instance Parameters

1	<code>r</code>	(Ω)	Resistance.
2	<code>l</code>	(m)	Resistor length.
3	<code>w</code>	(m)	Resistor width.
4	<code>m=1</code>		Multiplicity factor.
5	<code>scale=1</code>		Scale factor.
6	<code>resform</code>		Use the resistance form for this instance. Default is <code>yes</code> if <code>r < thresh</code> . Possible values are <code>no</code> or <code>yes</code> .
7	<code>tc1=0</code>	1/C	Linear temperature coefficient(alias= <code>lv3,tc1r</code>).
8	<code>tc1r=0</code>	1/C	Alias for <code>tc1</code> .
9	<code>tc2=0</code>	C^{-2}	Quadratic temperature coefficient(alias= <code>lv4,tc2r</code>).
10	<code>tc2r=0</code>	C^{-2}	Alias for <code>tc2</code> .
11	<code>trise</code>	(C)	Temperature rise from ambient.
12	<code>isnoisy=yes</code>		Should resistor generate noise. Possible values are <code>no</code> or <code>yes</code> .
13	<code>c</code>	(F)	Capacitance.
14	<code>tc1c=0</code>	1/C	Linear temperature coefficient of capacitor.
15	<code>tc2c=0</code>	C^{-2}	Quadratic temperature coefficient of capacitor.
16	<code>rac</code>	(Ω)	Default AC resistance, (alias= <code>ac</code>).
17	<code>scaler</code>		Resistance scaling factor.

Virtuoso Simulator Components and Device Models Reference

Passive Components

- 18 `scalec` Capacitance scaling factor.
- 19 `dtemp` (C) Alias of Temperature rise from ambient.
- 20 `cap` (F) Alias of capacitance.

The instance parameter `scale`, if specified, overrides the value given by the option parameter `scale`. The `w` and `l` parameters are scaled by the resulting `scale`, and the option parameter `scalem`. The parameters `w` and `l` are scaled also by the model parameter `shrink`. The values of `w` and `l` printed out by `spectre` are those given in the input, and these values might not have the correct units if the scaling factors are not unity. The actual effective resistor dimensions are stored in the output parameters. You can obtain these dimensions by using the `info` statement.

Model Definition

```
model modelName resistor parameter=value ...
```

Model Parameters

Resistance parameters

- 1 `r=0.0` Ω Default resistance.
- 2 `rsh=0.0` Ω/sqr Sheet resistance.
- 3 `thresh=1.0e-3` Ω Resistances smaller than this will use the resistance form, as opposed to the standard conductance form.
- 4 `rthresh=1.0e-3` Ω alias of `thresh`.
- 5 `rac=0.0` Ω Default AC resistance.

Resistor size parameters

- 6 `l=0.0` m Default resistor length.
- 7 `w=1e-6` m Default resistor width.
- 8 `etch=0` m Width narrowing due to etching per side.

Virtuoso Simulator Components and Device Models Reference

Passive Components

9 `etch1=0 m` Length narrowing due to etching per side.

10 `scaler=1` Resistance scaling factor.

Temperature effects parameters

11 `tc1=0 1/C` Linear temperature coefficient.

12 `tc2=0 C-2` Quadratic temperature coefficient.

13 `tnom (C)` Parameters measurement temperature. Default set by `options`.

14 `trise=0 C` Default temperature rise from ambient.

Nonlinear resistance

15 `coeffs=[...]` Vector of polynomial conductance coefficients.

16 `nonlinform=g` The form of the nonlinear resistance.
Possible values are `g` or `r`.

17 `symmetric=none` Use symmetric resistor model.
Possible values are `none`, `absolute` or `smooth`.

Noise model parameters

18 `kf=0` Flicker (1/f) noise coefficient.

19 `af=2` Flicker (1/f) noise exponent.

20 `wdexp=1` Flicker (1/f) noise W exponent.

21 `ldexp=1` Flicker (1/f) noise L exponent.

22 `weexp=0` Flicker (1/f) noise W effective exponent.

23 `leexp=0` Flicker (1/f) noise L effective exponent.

24 `fexp=1` Flicker (1/f) noise frequency exponent.

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Passive Components

DC-mismatch model parameters

- 25 $mr=0.0$ Resistor mismatch dependence.
- 26 $mrl=0.0 \ 1/m^{mrlp}$ Resistor mismatch length dependence.
- 27 $mrlp=0.0$ Resistor mismatch length power dependence.
- 28 $mrw=0.0 \ 1/m^{mrwp}$ Resistor mismatch width dependence.
- 29 $mrwp=0.0$ Resistor mismatch width power dependence.
- 30 $mrlw1=0.0 \ 1/m^{(2 \ mrlw1p)}$
Resistor mismatch area 1 dependence.
- 31 $mrlw1p=0.0$ Resistor mismatch area 1 power dependence.
- 32 $mrlw2=0.0 \ 1/m^{(2 \ mrlw2p)}$
Resistor mismatch area 2 dependence.
- 33 $mrlw2p=0.0$ Resistor mismatch area 2 power dependence.

Wire RC parameters

- 34 $c=0 \ F$ Default capacitance.
- 35 $cj=0 \ F/m^2$ Bottomwall capacitance.
- 36 $cjsw=0 \ F/m$ Sidewall fringing capacitance.
- 37 $thick=0 \ m$ Dielectric thickness.
- 38 $di=0$ Relative dielectric constant.
- 39 $cratio=0.5$ Cratio.
- 40 $tc1c=0 \ C^{-2}$ Linear temperature coefficient of capacitor.
- 41 $tc2c=0 \ C^{-2}$ Quadratic temperature coefficient of capacitor.
- 42 $shrink=1$ Shrink Factor.
- 43 $scalec=1$ Capacitance scaling factor.

Virtuoso Simulator Components and Device Models Reference

Passive Components

44	<code>dtemp=0</code> C	Alias of default temperature rise from ambient.
45	<code>cap=0</code> F	Alias of default capacitance.
46	<code>dw=0</code> m	Alias of width narrowing due to etching per side.
47	<code>d1r=0</code> m	Alias of length narrowing due to etching per side.
48	<code>cox=0</code> F/m ²	Alias of bottomwall capacitance.
49	<code>capsw=0</code> F/m	Alias of sidewall fringing capacitance.
50	<code>res=0</code> Ω	Alias of default resistance.

The instance parameter `resform` and the model parameter `thresh` control whether a resistor is formulated in the standard conductance form, or in the resistance form. If the value of the resistor is smaller than `thresh`, Spectre uses the resistance form; otherwise it uses the conductance form. If `resform` is set on an instance, it overrides the `thresh` parameter. The resistance form is appropriate for very small resistances and the conductance form is intended for larger resistances. Using the conductance form for very small resistances or the resistance form for very large resistances can cause convergence problems.

With the resistance form, the resistance can be zero; with the conductance form, the resistance can be infinite. The resistance form is less efficient than the conductance form. You cannot change the formulation of a resistor once it has been determined. Spectre makes this choice by comparing the initial value of the resistance to `thresh`.

If the polynomial coefficients vector is specified and `symmetric=absolute`, the resistor model is symmetric. When `nonlinform` is set to `g`, the conductance is

$$G(V) = dI / dV$$
$$= (1 + c1 * |V| + c2 * |V|^2 + \dots) / R(\text{inst})$$

where $|V| = \text{ABS}(V(1) - V(2))$ and c_k is the k th entry in the coefficient vector.

When `nonlinform` is set to `r`, the resistance is

$$R(V) = dV / dI$$
$$= R(\text{inst}) * (1 + c1 * |V| + c2 * |V|^2 + \dots)$$

where $|V| = \text{ABS}(V(1) - V(2))$.

If `symmetric=smooth` the smoothing function $f(V)$ is used:

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Passive Components

$$f(V) = V * V / \text{sqrt}(V * V + 0.00001).$$

For nonlinear=g the conductance is

$$G(V) = di / dV$$

$$= (1 + c1 * f(V) + c2 * f(V)^2 + ...) / R(\text{inst}).$$

Modeling AC resistance

In certain situations, a part of a circuit that is required to calculate the DC operating point needs to be removed during a subsequent AC analysis or visa versa. An example of a situation in which this occurs is when measuring the loop gain of a feedback amplifier. In this case the feedback loop must be removed when computing the AC response of the amplifier. In Spectre, the most accurate method of doing this is to use an ideal switch component (see `spectre -h switch`), e.g.

Vin (pin 0) vsource mag=1

OA1 (pin nin out) opamp

Sw1 (nin out 0) switch position=1 ac_position=2

LoopGain ac start=1 stop=1MHz

Another possibility is that the resistance of an instance changes from one analysis to another. The following subcircuit models a resistance whose value is given by the parameter `rac` during AC analyses, and `rdc` for all other analyses.

```
subckt ac_res (a b)
```

```
parameters rdc=1 rac=2
```

```
R1 (a i) resistor r=rdc
```

```
Rac (i b) resistor r=rac-rdc
```

```
Sw (i b) switch position=1 ac_position=0
```

```
ends ac_res
```

Output Parameters

1 leff (m) Effective resistor length.

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Passive Components

2	<code>w_{eff}</code> (m)	Effective resistor width.
3	<code>r_{eff}</code> (Ω)	Effective resistance.
4	<code>c_{eff}</code> (F)	Effective capacitance.

Operating-Point Parameters

1	<code>v</code> (V)	Voltage at operating point.
2	<code>i</code> (A)	Current through the resistor.
3	<code>res</code> (Ω)	Resistance at op point.
4	<code>pwr</code> (W)	Power dissipation.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

<code>af</code>	M-19	<code>i</code>	OP-2	<code>r</code>	I-1	<code>tc1c</code>	M-40
<code>c</code>	I-13	<code>isnoisy</code>	I-12	<code>r</code>	M-1	<code>tc1r</code>	I-8
<code>c</code>	M-34	<code>kf</code>	M-18	<code>rac</code>	I-16	<code>tc2</code>	I-9
<code>cap</code>	I-20	<code>l</code>	I-2	<code>rac</code>	M-5	<code>tc2</code>	M-12
<code>cap</code>	M-45	<code>l</code>	M-6	<code>reff</code>	O-3	<code>tc2c</code>	I-15
<code>capsw</code>	M-49	<code>ldexp</code>	M-21	<code>res</code>	M-50	<code>tc2c</code>	M-41
<code>ceff</code>	O-4	<code>leexp</code>	M-23	<code>res</code>	OP-3	<code>tc2r</code>	I-10
<code>cj</code>	M-35	<code>leff</code>	O-1	<code>resform</code>	I-6	<code>thick</code>	M-37

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Passive Components

cjsw	M-36	m	I-4	rsh	M-2	thresh	M-3
coeffs	M-15	mr	M-25	rthresh	M-4	tnom	M-13
cox	M-48	mrl	M-26	scale	I-5	trise	I-11
cratio	M-39	mrlp	M-27	scalec	I-18	trise	M-14
di	M-38	mrlw1	M-30	scalec	M-43	v	OP-1
dlr	M-47	mrlw1p	M-31	scaler	I-17	w	I-3
dtemp	I-19	mrlw2	M-32	scaler	M-10	w	M-7
dtemp	M-44	mrlw2p	M-33	shrink	M-42	wdexp	M-20
dw	M-46	mrw	M-28	symmetric	M-17	weexp	M-22
etch	M-8	mrwp	M-29	tcl	I-7	weff	O-2
etch1	M-9	nonlinform	M-16	tcl	M-11		
fexp	M-24	pwr	OP-4	tclc	I-14		

Physical Resistor (phy_res)

A physical resistor consists of a two terminal resistor (tied between t_1 and t_2) and two diodes (tied between t_1-t_0 and t_2-t_0). The diodes are junction diodes. Under normal operation, the two diodes are reverse biased, but the parameter `subtype` can reverse the direction of the diodes. If you do not specify t_0 , ground is assumed. The instance parameters always override model parameters. If you do not specify the instance resistance value, it is calculated from the model parameters.

This device is supported within altergroups.

If $R(\text{inst})$ is not given and $R(\text{model})$ is given,

$$R(\text{inst}) = R(\text{model}).$$

Otherwise,

Virtuoso Simulator Components and Device Models Reference

Passive Components

$$R(\text{inst}) = R_{\text{sh}} * (L - 2 * \text{etchl}) / (W - 2 * \text{etch}).$$

If the polynomial coefficients vector (`coeffs=[c1 c2 ...]`) is specified, the resistor is nonlinear. When `nonlinform` is set to `g`, the conductance is

$$\begin{aligned} G(V) &= dI / dV \\ &= (1 + c1 * V + c2 * V^2 + ...) / R(\text{inst}) \end{aligned}$$

where

$$V = V(t1) - V(t2)$$

Here V is the controlling voltage across the resistor. It is also the controlling voltage when the model parameter `polyarg` is set to `diff`. In this form, the physical resistor is symmetric with respect to $V(t1)$ and $V(t2)$. The branch current as a function of the applied voltage is given by

$$I(V) = (V / R(\text{inst})) * (1 + 1/2 * c1 * V + 1/3 * c2 * V^2 + ...)$$

where c_k is the k th entry in the coefficient vector.

If the model parameter `polyarg` is set to `sum`, then the controlling voltage is defined as

$$V_{\text{sum}} = ((V(t1) - V(t0)) + (V(t2) - V(t0))) / 2$$

Here, V_{sum} is the controlling voltage between the resistor and the substrate, t_0 . In this case, the device becomes asymmetric with respect to $V(t1)$ and $V(t2)$. The branch current as a function of the applied voltage for this case is given by

$$I(V_{\text{sum}}) = (V / R(\text{inst})) * (1 + c1 * V_{\text{sum}} + c2 * V_{\text{sum}}^2 + ...)$$

The large-signal conductance is given by

$$G(V_{\text{sum}}) = I/V = (1 + c1 * V_{\text{sum}} + c2 * V_{\text{sum}}^2 + ...) / R(\text{inst})$$

Note, since the device is asymmetrical, the small-signal model is more complicated than a simple conductance.

When `nonlinform` is set to `r`, the resistance is

$$\begin{aligned} R(V) &= dV / dI \\ &= R(\text{inst}) * (1 + c1 * V + c2 * V^2 + ...). \end{aligned}$$

The resistance as a function of temperature is given by:

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Passive Components

$$R(T) = R(t_{nom}) * [1 + tc1 * (T - t_{nom}) + tc2 * (T - t_{nom})^2].$$

where

$$T = trise(inst) + temp$$

if $trise(inst)$ is given, and

$$T = trise(model) + temp$$

otherwise.

If you do not specify the junction leakage current (i_s) and j_s is specified, the leakage current is calculated from j_s and the device dimensions.

$$i_s = j_s * 0.5 * (L - 2 * etchl) * (W - 2 * etchw)$$

If you specify the instance capacitance or the linear model capacitance, linear capacitors are used between t_{1-t0} and t_{2-t0} . Otherwise, nonlinear junction capacitors are used and the zero-bias capacitance values are calculated from the model parameters.

If $C(inst)$ is not given and $C(model)$ is given,

$$C(inst) = C(model).$$

Otherwise,

$$C(inst) = 0.5 * C_j * (L - 2 * etchlc) * (W - 2 * etchw) + C_{jsw} * (W + L - 2 * etchw - 2 * etchlc).$$

If the capacitance is nonlinear, the temperature model for the junction capacitance is used. Otherwise, the following equation is used.

$$C(T) = C(t_{nom}) * [1 + tc1c * (T - t_{nom}) + tc2c * (T - t_{nom})^2].$$

Thermal Noise

$$\overline{i_T} = \frac{4kT}{R} \cdot \Delta f$$

where:

R is the resistor value and T is the temperature.

Shot Noise for the Junctions

$$\bar{i}_S = 2 \cdot q \cdot I \cdot \Delta f$$

Where I is the current flow through the junction.

Flicker Noise for the Resistor

$$\bar{i}_f = \frac{KF \cdot I^{AF}}{f^{FEXP}} \cdot \frac{1}{W_{eff}^{WEEXP} \cdot L_{eff}^{LEEXP} \cdot W^{WDEXP} \cdot L^{LDEXP}} \cdot \Delta f$$

Where KF, AF, FEXP, WEEXP, LEEXP, WDEXP and LDEXP are model parameters, I is the current, W and L are the device width and length, $W_{eff} = W - 2 \cdot ETCH$ and $L_{eff} = L - 2 \cdot ETCHL$.

Flicker Noise for the Junctions

$$\bar{i}_f = \frac{KF \cdot I^{AF}}{f^{FEXP}} \cdot \Delta f$$

Where:

Where KF, AF and FEXP are model parameters, I is the current, and f is the frequency.

Sample Instance Statement

```
res1 (net9 vcc) resphy l=1e-3 w=2e-6
```

Sample Model Statement

```
model resphy phy_res rsh=85 tc1=1.53e-3 tc2=4.67e-7 etch=0 cj=1.33e-3 cjsw=3.15e-10 tc1c=9.26e-4
```

Instance Definition

```
Name 1 2 [0] ModelName parameter=value ...
```


Virtuoso Simulator Components and Device Models Reference

Passive Components

Instance Parameters

1	<code>r</code> (Ω)	Resistance.
2	<code>c</code> (F)	Linear capacitance.
3	<code>l</code> (m)	Line length.
4	<code>w</code> (m)	Line width.
5	<code>region=normal</code>	Estimated operating region. Spectre outputs number (0-1) in a rawfile. Possible values are <code>normal</code> or <code>breakdown</code> .
6	<code>tc1=0</code> 1/C	Linear temperature coefficient of resistor.
7	<code>tc2=0</code> C ⁻²	Quadratic temperature coefficient of resistor.
8	<code>tc1c=0</code> 1/C	Linear temperature coefficient of linear capacitor.
9	<code>tc2c=0</code> C ⁻²	Quadratic temperature coefficient of linear capacitor.
10	<code>trise</code> (C)	Temperature rise from ambient.
11	<code>isnoisy=yes</code>	Should resistor generate noise. Possible values are <code>no</code> or <code>yes</code> .
12	<code>m=1</code>	Multiplicity factor.

The `w` and `l` parameters are scaled by the option parameters `scale` and `scalem`. The values of `w` and `l` printed by Spectre are those given in the input file. These values may not have the correct units if the scaling factors are not unity. The actual effective resistor dimensions are stored in the output parameters. You can obtain these dimensions with the `info` statement. You can delete the diodes from the device by either setting `is=0` or `subtype=poly`. You can also set both `mj` and `mjsw` to zero to make the capacitance linear but still calculated from the device geometry. If `subtype=poly`, the linear capacitors will always be used irrespective of the values of `mj` and `mjsw`.

Model Definition

```
model modelName phy_res parameter=value ...
```

Virtuoso Simulator Components and Device Models Reference

Passive Components

Model Parameters

Substrate type parameters

1 `subtype=p` Substrate type.
Possible values are `n`, `p` or `poly`.

Resistance parameters

2 `r= ∞ Ω` Default resistance.

3 `rsh= ∞ Ω /sqr` Sheet resistance.

4 `minr=0.1 Ω` Minimum resistance.

5 `coeffs=[...]` Vector of polynomial conductance or resistance coefficients.

6 `nonlinform=g` The form of the nonlinear resistance.
Possible values are `g` or `r`.

7 `polyarg=diff` Polynomial model argument type.
Possible values are `sum` or `diff`.

Temperature effects parameters

8 `tc1=0 1/C` Linear temperature coefficient of resistor.

9 `tc2=0 C-2` Quadratic temperature coefficient of resistor.

10 `tc1c=0 C-2` Linear temperature coefficient of linear capacitor.

11 `tc2c=0 C-2` Quadratic temperature coefficient of linear capacitor.

12 `tnom (C)` Parameters measurement temperature. Default set by `options`.

13 `trise=0 C` Temperature rise from ambient.

Junction diode model parameters

14 `is (A)` Saturation current.

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Passive Components

15	$j_s=0$ A/m ²	Saturation current density.
16	$n=1$	Emission coefficient.
17	$e_g=1.11$ V	Band gap.
18	$x_{ti}=3$	Saturation current temperature exponent.
19	$i_{melt}='imax'$ A	Explosion current, diode is linearized beyond this current to aid convergence.
20	$j_{melt}='jmelt'$ A/m ²	Explosion current density, diode is linearized beyond this current to aid convergence.
21	$i_{max}=1$ A	Maximum current, currents above this limit generate a warning.
22	$j_{max}=1e8$ A/m ²	Maximum current density, currents above this limit generate a warning.
23	$dskip=yes$	Use simple piece-wise linear model for diode currents below $0.1*i_{abstol}$. Possible values are <code>no</code> or <code>yes</code> .
24	$b_{vj}=\infty$ V	Junction reverse breakdown voltage.

Junction capacitance model parameters

25	$c=0$ F	Default linear capacitance.
26	$c_j=0$ F/m ²	Zero-bias junction bottom capacitance density.
27	$c_{jsw}=0$ F/m	Zero-bias junction sidewall capacitance density.
28	$m_j=1/2$	Junction bottom grading coefficient.
29	$m_{jsw}=1/3$	Junction sidewall grading coefficient.
30	$p_b=0.8$ V	Junction bottom built-in potential.
31	$p_{bsw}=0.8$ V	Junction sidewall built-in potential.
32	$f_c=0.5$	Junction bottom capacitor forward-bias threshold.

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Passive Components

33 $f_{csw}=0.5$ Junction sidewall capacitor forward-bias threshold.

34 $t_t=0$ s Transit time.

Device size parameters

35 $l=\infty$ m Default line length.

36 $w=1e-6$ m Default line width.

37 $etch=0$ m Narrowing due to etching.

38 $etchl=0$ m Length reduction due to etching.

39 $etchc=etch$ m Narrowing due to etching for capacitances.

40 $etchlc=etchl$ m Length reduction due to etching for capacitances.

41 $scaler=1$ Resistance scaling factor.

42 $scalec=1$ Capacitance scaling factor.

Noise model parameters

43 $k_f=0$ Flicker (1/f) noise coefficient.

44 $a_f=1$ Flicker (1/f) noise exponent.

45 $w_{dexp}=1$ Flicker (1/f) noise W exponent.

46 $l_{dexp}=1$ Flicker (1/f) noise L exponent.

47 $w_{eexp}=0$ Flicker (1/f) noise W effective exponent.

48 $l_{eexp}=0$ Flicker (1/f) noise L effective exponent.

49 $f_{exp}=1$ Flicker (1/f) noise frequency exponent.

DC-mismatch model parameters

50 $m_r=0.0$ Ω^2 Resistor mismatch dependence.

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Passive Components

- 51 `mrl=0.0 Ω^2/m^{mrlp}` Resistor mismatch length dependence.
- 52 `mrlp=0.0` Resistor mismatch length power dependence.
- 53 `mrw=0.0 Ω^2/m^{mrwp}` Resistor mismatch width dependence.
- 54 `mrwp=0.0` Resistor mismatch width power dependence.
- 55 `mrlw1=0.0 $\Omega^2/m^{(2 mrlw1p)}$` Resistor mismatch area 1 dependence.
- 56 `mrlw1p=0.0` Resistor mismatch area 1 power dependence.
- 57 `mrlw2=0.0 $\Omega^2/m^{(2 mrlw2p)}$` Resistor mismatch area 2 dependence.
- 58 `mrlw2p=0.0` Resistor mismatch area 2 power dependence.

Output Parameters

- 1 `leff (m)` Effective line length.
- 2 `weff (m)` Effective line width.
- 3 `iseff (A)` Effective saturation current.
- 4 `reff (Ω)` Effective resistance.
- 5 `ceff (F)` Effective zero-bias capacitance.

Operating-Point Parameters

- 1 `subtype=p` Substrate type.
Possible values are `n`, `p` or `poly`.
- 2 `region=normal` Estimated operating region. Spectre outputs number (0-1) in a rawfile.
Possible values are `normal` or `breakdown`.
- 3 `i (A)` Current through the resistor.

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Passive Components

4	capd1 (F)	Capacitance at the positive node.
5	capd2 (F)	Capacitance at the negative node.
6	id1 (A)	Current between nodes t1 and t0.
7	id2 (A)	Current between nodes t2 and t0.
8	res (Ω)	Resistance between nodes t1 and t2.
9	resd1 (Ω)	Resistance between nodes t1 and t0.
10	resd2 (Ω)	Resistance between nodes t2 and t0.
11	pwr (W)	Power at op point.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

af	M-44	imax	M-21	mrlw1p	M-56	subtype	M-1
bvj	M-24	imelt	M-19	mrlw2	M-57	subtype	OP-1
c	I-2	is	M-14	mrlw2p	M-58	tc1	I-6
c	M-25	iseff	O-3	mrw	M-53	tc1	M-8
capd1	OP-4	isnoisy	I-11	mrwp	M-54	tc1c	I-8
capd2	OP-5	jmax	M-22	n	M-16	tc1c	M-10
ceff	O-5	jmelt	M-20	nonlinform	M-6	tc2	I-7
cj	M-26	js	M-15	pb	M-30	tc2	M-9

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Passive Components

cjsw	M-27	kf	M-43	pbsw	M-31	tc2c	I-9
coeffs	M-5	l	I-3	polyarg	M-7	tc2c	M-11
dskip	M-23	l	M-35	pwr	OP-11	tnom	M-12
eg	M-17	ldexp	M-46	r	I-1	trise	I-10
etch	M-37	leexp	M-48	r	M-2	trise	M-13
etchc	M-39	leff	O-1	reff	O-4	tt	M-34
etchl	M-38	m	I-12	region	I-5	w	I-4
etchlc	M-40	minr	M-4	region	OP-2	w	M-36
fc	M-32	mj	M-28	res	OP-8	wdexp	M-45
fcsw	M-33	mjsw	M-29	resd1	OP-9	weexp	M-47
fexp	M-49	mr	M-50	resd2	OP-10	weff	O-2
i	OP-3	mrl	M-51	rsh	M-3	xti	M-18
idl	OP-6	mrlp	M-52	scalec	M-42		
id2	OP-7	mrlw1	M-55	scaler	M-41		

R2 Model (r2)

The R2 model is a nonlinear 2-terminal resistor model. The model does not include parasitic capacitances. As an option, the model can include self-heating. The nonlinearity form is from Agere Systems, and effectively implements first and second order electric field coefficients of resistance. The R2 model does not have the numerical problems that can arise in polynomial models. Although empirical, the form of the nonlinearity can model data reasonably well, especially for velocity saturation effects which are important in short resistors.

Usage

With model card:

```
r<instanceName> (<node1> <node2>) <modelName> <instanceParameters> .model
<modelName> <modelParameters>
```

Without model card:

```
r<name> (<node1> <node2>) r=<resistanceValue> [tc1=<tc1Value>] [tc2=<tc2Value>]
```

Examples

```
r137 (n1 n2) rnpoly1 w=1u l=10u
.model rnpoly1 r2
+ rsh=100.0 xl=0.2u xw=-0.05u
+ p3=0.12 q3=1.63 p2=0.014 q2=3.79
```

Equivalent Circuit

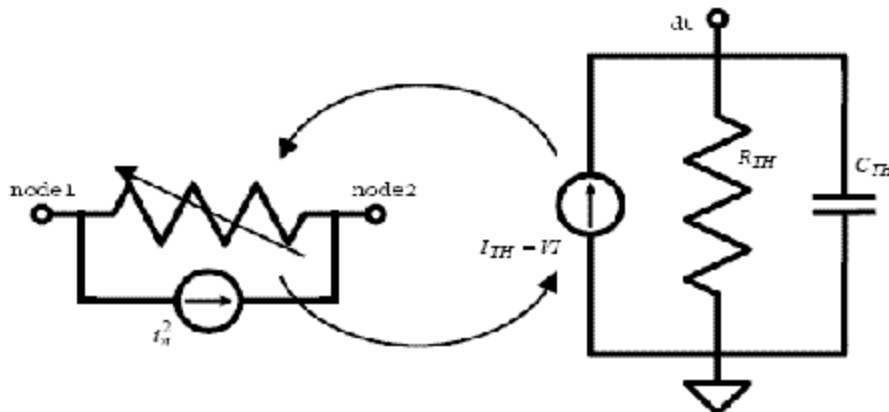


Figure 2-1 Model Equivalent Network (the thermal sub-network is optional)

Bias Dependence

If V is the voltage between the terminals node1 and node2, then the current flowing from node1 to node2 is

(2-1)

$$I = \frac{V}{r_{dc}}$$

the DC bias dependent resistance is

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(2-2)

$$r_{dc} = R_0(T) \cdot rFactor$$

where $R_0(T)$ is the zero-bias resistance at the device temperature (which includes self-heating for the electrothermal version of the model), and the bias-dependent resistance factor is

(2-3)

$$rFactor = 1 - p2 - p3 + p2\sqrt{1 + (q2E)^2} + p3^3\sqrt{1 + |q3E|^3}$$

The electric field E can be calculated based on either the design length or the effective electrical length, depending on the switch parameter `sw_efgeo`. This is because, depending upon how the model is used and the model parameters are characterized, there can be effects in the value of `x1` (the parameter that defines the difference between the design length and the effective electrical length) that are not related to velocity saturation (e.g. if end spreading and/or contact resistance are included in `x1`). If `sw_efgeo` is 1 (`true`), the electric field is calculated from the effective geometry.

(2-4)

$$E = \frac{V}{l_{eff_um} + dxle}$$

otherwise it is calculated from the design geometry,

(2-5)

$$E = \frac{V}{l_{um} + dxle}$$

In both cases, an additional length offset `dxle` is included to allow flexibility and optimization in fitting data by separating the lengths used for resistance and field nonlinearity calculation. Although there is a singularity at $V = E = 0$ because of the absolute value operation in [Equation 2-3](#) on page 185, the derivative of [Equation 2-1](#) on page 184 with respect to voltage is defined and continuous up to third order. The fourth order derivative does not exist at $V = 0$ and its left limit does not equal its right limit there.

For the electrothermal version of the model, the thermal power is calculated as

(2-6)

$$I_{TH} = V \cdot I$$

and the powers that flow through the thermal resistance and thermal capacitance are

(2-7)

$$T(dt) * g_{TH}$$

and

(2-8)

$$ddt(T(dt) * c_{TH})$$

respectively, where $T(dt)$ is the local temperature rise due to self-heating and the thermal conductance and capacitance are g_{TH} and c_{TH} , respectively. The thermal admittance is $Y_{TH} = g_{TH} + j\omega c_{TH}$.

Geometry Dependence

The basic calculation for the (zero bias) resistance of a resistor is $R_0 = r_{sh}L/W$. Because of several physical effects, the length and width used in this calculation differ from the design (or mask) length and width that define the resistor layout.

The `r2` model incorporates a simple, fixed offset between design and effective (electrical) length and width. Because subcircuit models for resistors can consist of multiple resistance sections connected in series, it is desirable to be able to switch on and off the end corrections for length to facilitate implementation of such multi-section models. This is the function of the `c1` and `c2` instance parameters of the `r2` model. The effective length offset is

(2-9)

$$xleff = xl(c1 + c2)/2$$

(which is zero if neither end is contacted, `x1` if both ends are contacted, and `x1/2` if only one end is contacted).

The design length and width, in units of microns, are

(2-10)

$$l_{um} = l \cdot scale \cdot (1 - shrink/100) \cdot 10^6$$

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(2-11)

$$w_{um} = l \cdot scale \cdot (1 - shrink/100) \cdot 10^6$$

where conversions from optical shrinking and unit scale conversion are included. If `scale` is 1 then `l` and `w` should be specified on model instances in meters. If `scale` is `1.0e-6` then `l` and `w` should be specified in units if microns. The effective electrical dimensions are

(2-12)

$$leff_{um} = l_{um} + xleff$$

(2-13)

$$weff_{um} = w_{um} + xw$$

There are three modes of geometric calculation based on the instance parameters `w`, `l`, and `r`. All modes are based on resistance being specified (or calculated), at zero applied bias and at the nominal device temperature specified by the parameter `tnom`. The order of importance of considering the instance parameters is (in order of from most to least important) width, length, and resistance. If all are specified, the instance `r` value is ignored, and resistance is calculated from the specified length and width.

(2-14)

$$R_{0,nom} = r$$

and the effective width is calculated

(2-15)

$$weff_{um} = \frac{rsh}{R_{0,nom}} leff_{um}$$

and possibilities of zero resistance or length, and error conditions of negative length or width, are handled.

If resistance is specified, and length is not specified, then

(2-16)

$$R_{0,nom} = r$$

(2-17)

$$l_{eff_um} = \frac{R_{0,nom}}{rsh} w_{eff_um}$$

and again possibilities of zero resistance and error conditions of negative length or width are handled.

For any other combination of instance parameter specification (resistance is not specified, or if it is then both width and length, which override resistance specification, are also specified), then the resistance is calculated from the geometry,

(2-18)

$$R_{0,nom} = rsh \frac{l_{eff_um}}{w_{eff_um}}$$

and zero resistance or conductance, and negative length or width errors, are handled.

Although end effects, such as spreading resistance and contact resistance, are assumed to be modeled via the `x1` parameter, the temperature coefficients of the end effects may differ from those of the body of the resistor. Simple analysis shows that these different temperature coefficients can be accounted for by introducing inverse length dependence to the temperature coefficients. A width dependence of temperature coefficients of resistance is also included in the model. Therefore in the R2 model,

(2-19)

$$T_{C1}^{eff} = tc1 + \frac{0.5(c1 + c2)tc1l}{l_{eff_um}} + \frac{tc1w}{w_{eff_um}}$$

(2-20)

$$T_{C2}^{eff} = tc2 + \frac{0.5(c1 + c2)tc2l}{l_{eff_um}} + \frac{tc2w}{w_{eff_um}}$$

where the length dependence is switched on, off, or halved, depending on whether the resistor is contacted at both ends, not contacted, or contacted at only one end, respectively. The dependence of the temperature coefficients on whether a resistor is contacted or not enables consistent modeling of temperature coefficients for single or multiple section models.

The thermal conductance and capacitance include area, perimeter, and fixed components. Asymptotically for a large area device, the heat flow is perpendicular to the plane of heat generation in the resistor, and the heat energy stored in a device depends on its volume, hence the area dependent component. For a long resistor, as it becomes narrower, more of

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the heat flow is conducted by a fringe path at the edges of the device, hence the perimeter dependent component. As both length and width decrease, the thermal conditions in the device asymptotically approach that of a point source in an infinite medium, hence the fixed component. The thermal conductance and capacitance are therefore

(2-21)

$$g_{TH} = g_{th0} + g_{thp} \cdot p_{um2} + g_{tha} \cdot a_{um2}$$

(2-22)

$$c_{TH} = c_{th0} + c_{thp} \cdot p_{um2} + c_{tha} \cdot a_{um2}$$

where the area and perimeter are calculated as

(2-23)

$$a_{um2} = l_{um} \cdot w_{um}$$

(2-24)

$$p_{um} = 2l_{um} + (c1 + c2)w_{um}$$

The calculated perimeter therefore depends on whether the ends are contacted or not. Note that often the design dimensions of the body of a resistor differ from the overall dimensions of the device, for example if the design length is considered to be the unsolicited length of a poly resistor, the total resistor length will typically include silicided contact regions. So it is not readily apparent what dimension should be used in calculation of the thermal conductance and capacitance. That is why the design dimensions, rather than some effective dimensions (whose value is calculated to best fit DC electrical data), are used. This turns out to be fine (with the exception that differences between the perimeter components along length and width dimensions are ignored), because if there is some difference Δ between design and effective dimensions for thermal conductance modeling, then for a device contacted at both ends

(2-25)

$$\begin{aligned} g_{TH} &= g_{th0} + g_{thp}(2l_{um} + 2w_{um} + 4\Delta) + g_{tha}(l_{um} + \Delta)(w_{um} + \Delta) \\ &= (g_{th0} + 4g_{thp} \cdot \Delta + g_{tha} \cdot \Delta^2) + (g_{thp} + 0.5g_{tha} \cdot \Delta)p_{um} + g_{tha} \cdot a_{um2} \end{aligned}$$

therefore, any difference between design and effective dimensions can be taken into account by appropriate characterization of the fixed, perimeter, and area component parameters.

Because the local thermal conductance differs between the edge of a device and the center of a device, it is higher at the edge because of fringing conductance, the temperature of a resistor undergoing self-heating is not spatially uniform, but is lower at the edges than in the middle. This is not taken into account in the R2 model.

Temperature Dependence

The zero-bias resistance R_0 varies with temperature as

(2-26)

$$R_0(T) = R_{0, \text{nom}}(1 + T_{C1}^{\text{eff}} dT + T_{C2}^{\text{eff}} dT^2)$$

where $R_{0, \text{nom}}$ is the nominal value of the zero-bias resistance, at the nominal temperature t_{nom} , dT is the temperature difference (including self-heating, if that form of the model is used) with respect to t_{nom} , and

$$T_{C2}^{\text{eff}}$$

and

$$T_{C1}^{\text{eff}}$$

are first (linear) and second (quadratic) order temperature coefficients. These coefficients have both a width dependence and a length dependence, the latter to enable modeling of resistors that have different temperature coefficients for end resistance (which includes contacts and contact enhancement regions) compared to body resistance without having to implement a sectional (subcircuit) model with explicit end and body resistance components. The width and length dependency is detailed in the section on geometry dependence — see [Equation 2-19](#) on page 188 and [Equation 2-20](#) on page 188. Smooth limiting of the resistance temperature coefficient in ([Equation 2-21](#) on page 189) is implemented to limit its lower value to 0.01.

For the isothermal version of the model the temperature difference dT is calculated statically based on the device temperature (which can vary from the circuit ambient temperature by setting the instance parameter `trise`, which is the local device temperature difference with respect to the circuit ambient temperature). For the electrothermal version of the model dT is calculated dynamically and self-consistently with the power dissipation of the device.

The flicker noise coefficient varies with temperature as

(2-27)

$$K_{FN}(T) = kfn(1 + tc1kfnT)$$

where *kfn* and *tc1kfn* are model parameters.

Noise

The noise model comprises two components, a thermal (white) noise component and a flicker ($1/f$) noise component. These components are noise current spectral density (in A_2/Hz) that are implemented as a noise current sources in parallel with the resistance element.

The thermal noise component is based on the DC conductance of the device,

(2-28)

$$i_{thermal}^2 = 4kT_K G_0(T)/rFactor$$

where *k* is Boltzmann's constant, T_K is the device temperature (in Kelvin, including the effect of self-heating), G_0 is the zero-bias conductance of the resistor (at the temperature T), and *rFactor* is the bias-dependent (DC) resistance factor ([Equation 2-3](#) on page 185).

The flicker noise component is DC current dependent ([Equation 2-2](#) on page 185), and scales with geometry per the physical restrictions noted in [Equation 2-3](#) on page 185.

(2-29)

$$i_{flicker}^2 = K_{FN}(T) \left(\frac{I}{W}\right)^{afn} \frac{1}{L} \frac{1}{f^{bfn}}$$

where *f* is frequency (in Hz), *afn* and *bfn* are model parameters, $K_{FN}(T)$ is the temperature dependent flicker noise coefficient ([Equation 2-27](#) on page 191), *I* is the DC current in the resistor, and *W* and *L* are the resistor width and length, respectively, in units of micron. If the switch parameter for flicker noise geometry calculation *sw_fngeo* is 0 (*false*) then *W* and *L* are design geometries, *w_um* and *l_um* respectively, else if it is 1 (*true*) then *W* and *L* are effective geometries, *w_eff_um* and *l_eff_um* respectively.

Note that if self-heating is included, then possibly there is a frequency dependence to the flicker noise because of the thermal time constant. There is no data to verify this at present so a frequency independent noise current spectral density is used.

Description and Details

The voltage nonlinearity of the device resistance is

(2-30)

$$R(E) = R_0 \left((1 - p_2 - p_3) + p_3 \sqrt[3]{1 + |q_3 E|^3} + p_2 \sqrt{1 + (q_2 E)^2} \right)$$

where R_0 is the zero bias resistance of the resistor, $E=V/L$ is the electric field across the device, p_3 and q_3 are parameters of the effective first order (linear) electric field coefficient, and p_2 and q_2 are parameters of the effective second order (quadratic) electric field coefficient. Because the nonlinearity is based on field, rather than voltage, it scales with geometry.

For $q_3 E$ somewhat greater than 1, the cubic component of the model becomes

(2-31)

$$R(E) = R_0(1 + p_3(|q_3 E| - 1))$$

therefore this term approximates a linear (first order) field dependence of resistance with a coefficient of value $p_3 \cdot q_3$.

For $q_2 E$ somewhat less than 1, the quadratic component of the model becomes

(2-32)

$$R(E) = R_0(1 + 0.5 p_2 \cdot q_2^2 E^2)$$

therefore this term approximates a quadratic (second order) field dependence of resistance with a coefficient of value $0.5 p_2 q_2^2$. For high fields this component becomes

(2-33)

$$R(E) = R_0(1 + p_2(|q_2 E| - 1))$$

and it turns out that the behavior embodied in [Equation 2-32](#) on page 192 and [Equation 2-33](#) on page 192 is quite accurate for modeling velocity saturation, which is a significant component of nonlinearity for shorter resistors.

To ensure that the resistance does not become negative,

(2-34)

$$0 \leq p3 < 1$$

and

(2-35)

$$0 \leq p2 < 1 - p3$$

are enforced. This also precludes the model exhibiting a negative differential resistance (NDR). NDR is observed in some devices, but this is from self-heating effects in resistors with positive temperature coefficients. This behavior should therefore be modeled using the electrothermal version of the model.

In SPICE-like simulators, which are based on modified nodal analysis (MNA), it is preferable to formulate models as voltage controlled current sources (VCCS's). This is the default for the R2 model. For small resistance values this can cause numerical problems, and the MNA formulation is not possible for zero valued resistors (which have infinite conductance). For small resistance values it is better to switch to a current controlled voltage source (CCVS) formulation. Implicitly, this increases the matrix size for MNA analysis, as the current through the CCVS becomes a system variable. The R2 model includes a parameter `rthresh`, and if the total (not per segment, but r/m) resistance at zero bias is less than `rthresh`, the model switches to a CCVS formulation for numerical stability and to be able to work properly for zero valued resistors. Note that this makes the model implicit as the formulation is effectively $V = I \cdot R(V)$.

Component Statements

Instance Definition

```
Name 1 2 ModelName parameter=value ...  
Name 1 2 r2 parameter=value ...
```

Instance Parameters

- | | | |
|---|-----------------------|------------------|
| 1 | <code>m=1</code> | Multiply factor. |
| 2 | <code>w=1e-6 m</code> | Default width. |
| 3 | <code>l=1e-6 m</code> | Resistor length. |

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Passive Components

4	<code>r=100.0 Ω</code>	Resistance.
5	<code>c1=1</code>	Contact terminal.
6	<code>c2=1</code>	Contact terminal.
7	<code>trise=0.0 C</code>	Temperature rise.
8	<code>isnoisy=yes</code>	Should resistor generate noise. Possible values are <code>no</code> or <code>yes</code> .
9	<code>sw_et=yes</code>	switch for turning off self-heating.
10	<code>tc1=0.0 /K</code>	resistance linear.
11	<code>tc2=0.0 /K</code>	resistance linear.

Model Definition

```
model modelName r2 parameter=value ...
```

Model Parameters

1	<code>version=1.0</code>	Model version selector. The available versions are 1.0.
2	<code>revision=0.0</code>	Model sub-version selector. The available versions are 0.0.
3	<code>shrink=0.0 %</code>	Shrink factor.
4	<code>tmin=-100 C</code>	The minimal temperature.
5	<code>tmax=500.0 C</code>	The maximal temperature.
6	<code>rthresh=1e-3 Ω</code>	threshold.
7	<code>level=1002</code>	r2 model selector. The available level are 1002.
8	<code>tnom=27.0 C</code>	reference temperature.
9	<code>rsh=∞ Ω/sqr</code>	Sheet resistance.
10	<code>lmin=0.0 μm</code>	Minimum channel length for which the model is valid.

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11	$l_{max}=9.9e99 \mu\text{m}$	Maximum channel length for which the model is valid.
12	$w_{min}=0.0 \mu\text{m}$	Minimum channel width for which the model is valid.
13	$w_{max}=9.9e99 \mu\text{m}$	Maximum channel width for which the model is valid.
14	$xw=0.0 \mu\text{m}$	width offset.
15	$xl=0.0 \mu\text{m}$	length offset.
16	$dxle=0.0 \mu\text{m}$	length delta.
17	$sw_efgeo=no$	Switch for electric field geometry calculation.
18	$q3=0.0 \mu\text{m}/\text{V}$	threshold for the linear field coefficient activities.
19	$p3=0$	coefficient for linear field.
20	$q2=0.0 \mu\text{m}/\text{V}$	threshold for the quadratic field coefficient activities.
21	$p2=0$	coefficient for quadratic field.
22	$kfn=0$	coefficient for flicker noise.
23	$afn=2.0$	flicker noise current exponent.
24	$bfn=1.0$	coefficient for quadratic field.
25	$sw_fngeo=no$	Switch for flicker noise geometry calculation.
26	$j_{max}=100.0 \text{ A}/\mu\text{m}$	Maximum allowable current density.
27	$t_{minclip}=-100.0 \text{ C}$	clip minimum temperature.
28	$t_{maxclip}=500.0 \text{ C}$	clip maximum temperature.
29	$t_{c1}=0.0 /\text{K}$	resistance linear.
30	$t_{c2}=0.0 /\text{K}^2$	resistance quadratic.
31	$t_{c1l}=0.0 \mu\text{m}/\text{K}$	tc length coefficient for resistance linear.
32	$t_{c2l}=0.0 \mu\text{m}/\text{K}^2$	tc length coefficient for resistance quadratic.

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33	$t_{c1w}=0.0 \mu\text{m}/\text{K}$	tc width coefficient for resistance linear.
34	$t_{c2w}=0.0 \mu\text{m}/\text{K}^2$	tc width coefficient for resistance quadratic.
35	$t_{c1kfn}=0$	coefficient for flicker noise linear tc1.
36	$g_{th0}=1.0e6 \text{ W}/\text{K}$	thermal conductance fixed component.
37	$g_{thp}=0.0 \text{ W}/\text{K}\mu\text{m}$	thermal conductance perimeter component.
38	$g_{tha}=0.0 \text{ W}/\text{K}\mu\text{m}^2$	thermal conductance area component.
39	$c_{th0}=0.0 \text{ sW}/\text{K}$	thermal capacitance fixed component.
40	$c_{thp}=0.0 \text{ sW}/\text{K}\mu\text{m}$	thermal capacitance perimeter component.
41	$c_{tha}=0.0 \text{ sW}/\text{K}\mu\text{m}^2$	thermal capacitance area component.
42	$c1=1$	Resistance contact terminal.
43	$c2=1$	Resistance contact terminal.

Operating-Point Parameters

1	v (V)	Voltage at operating point.
2	i (A)	Current through the resistor.
3	power (W)	power dissipated.
4	r_0 (Ω)	zero bias resistance.
5	l_{eff_um} (μm)	effective length in μm .
6	w_{eff_um} (μm)	effective width in μm .
7	r_{dc} (Ω)	DC Resistance.
8	r_{ac} (Ω)	AC Resistance.
9	r_{th} (K/W)	thermal Resistance.
10	c_{th} (sW/K)	thermal capacitance.

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11 dt_et (C) The self-heating temperature rise.

Parameter Index

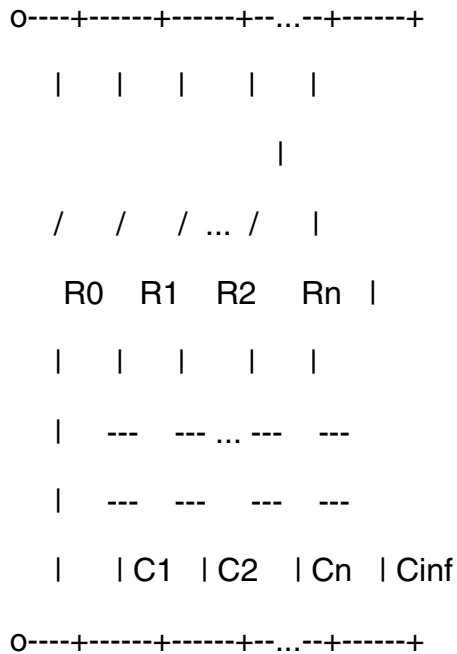
In the following index, I refers to instance parameters, M refers to the model parameters section, O refers to the output parameters section, and OP refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of M-35 means the 35th model parameter.

afn	M-23	jmax	M-26	revision	M-2	tmax	M-5
bfm	M-24	kfn	M-22	rsh	M-9	tmaxclip	M-28
c1	I-5	l	I-3	rth	OP-9	tmin	M-4
c1	M-42	leff_um	OP-5	rthresh	M-6	tminclip	M-27
c2	I-6	level	M-7	shrink	M-3	tnom	M-8
c2	M-43	lmax	M-11	sw_efgeo	M-17	trise	I-7
cth	OP-10	lmin	M-10	sw_et	I-9	v	OP-1
cth0	M-39	m	I-1	sw_fngo	M-25	version	M-1
ctha	M-41	p2	M-21	tc1	I-10	w	I-2
cthp	M-40	p3	M-19	tc1	M-29	weff_um	OP-6
dt_et	OP-11	power	OP-3	tc1kfn	M-35	wmax	M-13
dxle	M-16	q2	M-20	tc1l	M-31	wmin	M-12
gth0	M-36	q3	M-18	tc1w	M-33	x1	M-15
gtha	M-38	r	I-4	tc2	I-11	xw	M-14
gthp	M-37	r0	OP-4	tc2	M-30		

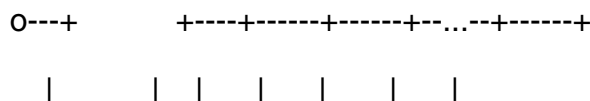
i	OP-2	r_ac	OP-8	tc2l	M-32
isnoisy	I-8	r_dc	OP-7	tc2w	M-34

Fractional Impedance/Admittance Pole (fracpole)

Fractional Impedance Pole takes as input a start frequency, a stop frequency, a negative slope, the unity intercept point, and the number of lumps, and synthesizes a RC circuit that models a fractional impedance pole over the given frequency range. The circuit is a one-port that exhibits poles and zeros that are real and that are spaced evenly in a logarithmic sense over the frequency range. The impedance exhibited by the one port approximates a fractional pole slope between -1 and 0 in the frequency range. In other words, if the impedance is plotted on a log-log scale, it will have a negative slope equal to the fraction specified. The user requested half a pole, the slope will be -1/2, etc. Of course it is a lumped approximation, so the slope will not be exact, but it will slowly oscillate about the desired value.

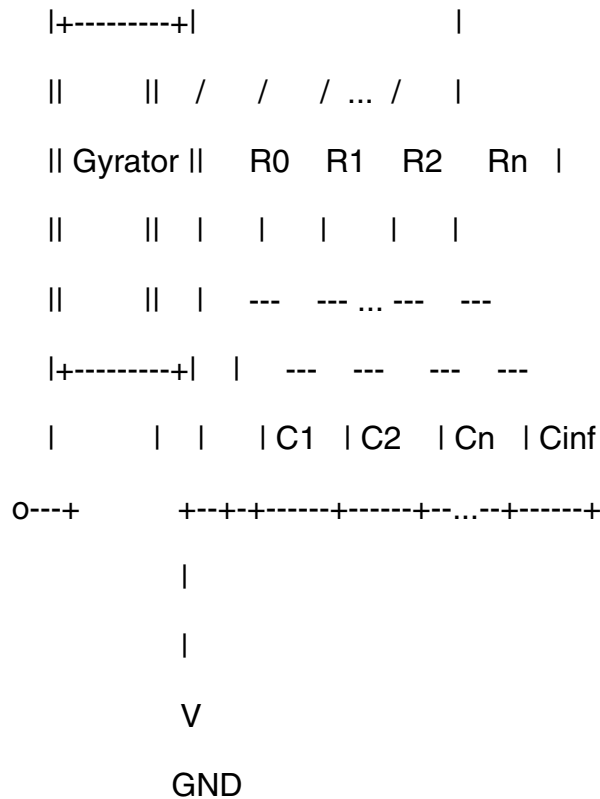


This model is converted to model a Fractional Admittance Pole by combining it with a gyrator.



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It can be used to model skin-effect loss in an inductor and dielectric absorption in a capacitor, and can be used to shape white noise into flicker noise.

Profile

In both fractional impedance/admittance pole cases, what happens outside the range of the approximation is specified by the parameter `profiles` of `fracpole`. It is a code that consists of a pair of letters. The first letter represents the low frequency behavior and the second represents the high frequency behavior. The letters are either f or d , f represents flat or a zero-pole slope, and d represents down or a one-pole slope. Depending on the profile chosen, either R_0 or C_{inf} may or may not be present in the synthesized RC circuit.

Internal Nodes

Internal nodes are created for each RC pair in the synthesized RC circuit, and they are labeled as `InstanceName:int_1`, `InstanceName:int_2`, ... In the case of fractional admittance pole, one more additional internal node, `InstanceName:int_gyr`, is created on the opposite side of gyrator from the terminals of the device.

Current

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The current reported by fracpole device is the static terminal current. In the case of fractional impedance pole, this current does not include the dynamic part. To find the total current of fractional impedance pole, either use current probe in series with it or use the option useprobes=yes.

This device is supported within altergroups.

Fractional Impedance Pole approximates

$$Z(s) = \text{Coef} * s^{\text{Slope}}$$

for $s=2*\pi*\text{freq}*j$ with $f_0 < \text{freq} < f_1$, and $-1 < \text{Slope} < 0$.

Fractional Admittance Pole approximates

$$Z(s) = \text{Coef} * s^{\text{Slope}}$$

$$\text{(or } Y(s) = s^{(-\text{Slope})}/\text{Coef)}$$

for $s=2*\pi*\text{freq}*j$ with $f_0 < \text{freq} < f_1$, and $0 < \text{Slope} < 1$.

Sample Instance Statement

without model:

```
fp (1 2) fracpole f0=1 f1=1M coef=1k dec=1.0 slope=-0.5 profile=ff
```

with model:

```
fp (1 2) fpModel f0=1 f1=1M coef=1.5k lumps=12 slope=-0.5 profile=dd
```

Sample Model Statement

```
model fpModel fracpole f0=1 f1=1M coef=1k dec=1.0 slope=-0.5 profile=ff
```

Instance Definition

```
Name 1 2 ModelName parameter=value ...
```

```
Name 1 2 fracpole parameter=value ...
```

Instance Parameters

1 f0=1.0 Hz Low frequency limit for the approximation.

2 f1=1.0e6 Hz High frequency limit for the approximation.

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Passive Components

3	<code>coef=1.0 Ω</code>	Unity intercept point for ideal impedance at $2*\pi*freq=1$.
4	<code>slope=-0.5</code>	Slope of the impedance when plotted on a log-log scale.
5	<code>lumps</code>	Number of lumps used in the approximation.
6	<code>dec=1.0</code>	Number of lumps per decade used in the approximation.
7	<code>profile=dd if abs(slope)</code>	
8	<code>m=1.0</code>	Multiplicity factor.
9	<code>ic (V)</code>	Initial condition for fractional impedance pole devices with <code>df</code> or <code>dd</code> profile.
10	<code>rforce=1.0 Ω</code>	Resistance used when forcing initial conditions.

Model Definition

```
model modelName fracpole parameter=value ...
```

Model Parameters

1	<code>f0=1.0 Hz</code>	Low frequency limit for the approximation.
2	<code>f1=1.0e6 Hz</code>	High frequency limit for the approximation.
3	<code>coef=1.0 Ω</code>	Unity intercept point for ideal impedance at $2*\pi*freq=1$.
4	<code>slope=-0.5</code>	Slope of the impedance when plotted on a log-log scale.
5	<code>lumps</code>	Number of lumps used in the approximation.
6	<code>dec=1.0</code>	Number of lumps per decade used in the approximation.
7	<code>profile=dd if abs(slope)</code>	

Operating-Point Parameters

1	<code>v (V)</code>	Voltage at operating point.
2	<code>i (A)</code>	Current. See comment on current above.

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Passive Components

3 pwr (W) Power dissipation.

Parameter Index

In the following index, I refers to instance parameters, M refers to the model parameters section, O refers to the output parameters section, and OP refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of M-35 means the 35th model parameter.

coef	I-3	f0	M-1	lumps	I-5	pwr	OP-3
coef	M-3	f1	I-2	lumps	M-5	rforce	I-10
dec	I-6	f1	M-2	m	I-8	slope	I-4
dec	M-6	i	OP-2	profile	I-7	slope	M-4
f0	I-1	ic	I-9	profile	M-7	v	OP-1

Two Terminal Capacitor (capacitor)

You can assign the capacitance or let Spectre compute it from the physical length and width of the capacitor. In either case, the capacitance can be a function of temperature or applied voltage.

This device is supported within altergroups.

If the C(inst) is not given,

$$C(\text{inst}) = C(\text{model})$$

if C(model) is given,

and if Area(inst) or Perim(inst) is given

$$\text{Area_eff} = \text{Area} - (\text{Perim}) \cdot \text{etch} + 4 \cdot \text{etch}^2$$

$$\text{Perim_eff} = \text{Perim} - 8 \cdot \text{etch}$$

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Passive Components

else

$$\text{Area_eff} = (L - 2*\text{etch})*(W - 2*\text{etch})$$

$$\text{Perim_eff} = 2 *(W + L - 4*\text{etch})$$

$$C(\text{inst}) = C_j*\text{Area_eff} + C_{jsw}*\text{Perim_eff}$$

if C(model) is not given.

If the polynomial coefficients vector (coeffs=[c1 c2 ...]) is specified, the capacitor is nonlinear and the capacitance is

$$\begin{aligned} C(V) &= dQ(V) / dV \\ &= C(\text{inst})*(1 + c_1*V + c_2*V^2 + \dots) \end{aligned}$$

or

$$Q(V) = C(\text{inst})*V*(1 + 1/2*c_1*V + 1/3*c_2*V^2 + \dots)$$

where c_k is the k th entry in the coefficient vector.

The value of the capacitor as a function of the temperature is given by:

$$C(T) = C(\text{tnom})*[1 + tc_1*(T - \text{tnom}) + tc_2*(T - \text{tnom})^2].$$

where

$$T = \text{trise}(\text{inst}) + \text{temp}$$

if $\text{trise}(\text{inst})$ is given, and

$$T = \text{trise}(\text{model}) + \text{temp}$$

if $\text{trise}(\text{inst})$ is not given.

Sample Instance Statement

without model:

```
c2 (1 0) capacitor c=2.5u tc1=1e-8
```

with model:

```
c2 (1 0) proc_cap c=2.5u tc1=1e-8
```

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Passive Components

Sample Model Statement

```
model proc_cap capacitor c=2u tc1=1.2e-8 tnom=25
```

This device support behavior expression

Sample Behavior Statement

```
c1 (1 0) capacitor c=c0*(1 + tanh(v(1,2)*c2))
c1 (1 0) capacitor c=1e-12/(1+($freq)/1e9)
```

Instance Definition

```
Name 1 2 ModelName parameter=value ...
Name 1 2 capacitor parameter=value ...
```

Instance Parameters

1	c (F)	Capacitance.
2	w (m)	Capacitor width.
3	l (m)	Capacitor length.
4	m=1	Multiplicity factor.
5	scale=1	Scale factor.
6	trise (C)	Temperature rise from ambient.
7	tc1 (1/C)	Linear temperature coefficient.
8	tc2 (C ⁻²)	Quadratic temperature coefficient.
9	ic (V)	Initial condition(alias=lv2).
10	area=1.0 m ²	Capacitor area.
11	perim=0.0 m	Capacitor perimeter.
12	coeffs=[...]	Vector of polynomial capacitance coefficients.
13	symmetric=none	Use symmetric capacitor model. Possible values are none and absolute.

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Passive Components

14 `bv_max=∞ V` Maximum allowed voltage cross two terminals.

15 `scalec` Capacitance scaling factor.

The instance parameter `scale`, if specified, overrides the value given by the option parameter `scale`. The `w` and `l` parameters are scaled by the resulting `scale`, and the option parameter `scalem`. The values of `w` and `l` printed by Spectre are those given in the input file, and these values might not have the correct units if the scaling factors are not unity. The actual capacitor dimensions are stored in the output parameters. You can obtain these dimensions with the `info` statement.

Model Definition

```
model modelName capacitor parameter=value ...
```

Model Parameters

1 `c=0 F` Default capacitance.

2 `trise=0 C` Default `trise` value for instance.

3 `tnom (C)` Parameters measurement temperature. Default set by `options`.

4 `w=0 m` Default capacitor width.

5 `l=0 m` Default capacitor length.

6 `etch=0 m` Narrowing due to side etching.

7 `cj=0 F/m2` Bottom capacitance density.

8 `cjsw=0 F/m` Sidewall capacitance.

9 `scalec=1` Capacitance scaling factor.

10 `rforce=1 Ω` Resistance used when forcing initial conditions.

11 `di=0` Relative dielectric constant.

12 `thick=0 m` Dielectric thickness.

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Passive Components

Polynomial capacitor parameters

- 13 `coeffs=[...]` Vector of polynomial capacitance coefficients.
- 14 `symmetric=none` Use symmetric resistor model.
Possible values are `none` and `absolute`.
- 15 `min (F)` Minimum capacitance.
- 16 `max (F)` Maximum capacitance.

Temperature effects parameters

- 17 `tc1=0 1/C` Linear temperature coefficient.
- 18 `tc2=0 C-2` Quadratic temperature coefficient.

Shrink Parameters

- 19 `shrink=0.0` Linear shrink parameter.
- 20 `shrink2=0.0` Area shrink parameter.

Safe Operating Areas Parameters

- 21 `bv_max=∞ V` Maximum allowed voltage cross two terminals.

Output Parameters

- 1 `leff (m)` Effective capacitor length.
- 2 `weff (m)` Effective capacitor width.
- 3 `ceff (F)` Effective capacitance(alias=lv1).

Operating-Point Parameters

- 1 `cap (F)` Capacitance at operating point.

Virtuoso Simulator Components and Device Models Reference

Passive Components

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter

area	I-10	coeffs	M-13	perim	I-11	tc1	M-17
bv_max	I-14	di	M-11	rforce	M-10	tc2	I-8
bv_max	M-21	etch	M-6	scale	I-5	tc2	M-18
c	I-1	ic	I-9	scalec	I-15	thick	M-12
c	M-1	l	I-3	scalec	M-9	tnom	M-3
cap	OP-1	l	M-5	shrink	M-19	trise	I-6
ceff	O-3	leff	O-1	shrink2	M-20	trise	M-2
cj	M-7	m	I-4	symmetric	I-13	w	I-2
cjsw	M-8	max	M-16	symmetric	M-14	w	M-4
coeffs	I-12	min	M-15	tc1	I-7	weff	O-2

Interconnect Capacitance (intcap)

Intcap is a model for the calculation of the interconnect capacitance, which takes into account the local layer composition and the tracks spacing width. It is described in the Phillips MOST Modelbook (Dec.96) as INTCAP model.

(c) Phillips Electronics N.V. 1993,1996

The model is extended by the device parameters `lxbelps`, `lxbelin` and `lxbelins`, according to a specification by H.Okel (I&A Hamburg).

This device is supported within altergroups.

Virtuoso Simulator Components and Device Models Reference

Passive Components

This device is dynamically loaded from the shared object `/vobs/spectre_dev/tools.sun4v/cmi/lib/5.0.doc/libphilips_sh.so`

Sample Instance Statement:

```
intc (net9 net12) intconcap m=1 ael=2.5e-15 ain=2e-15 aps=1.8e-15
```

Sample Model Statement:

```
model intconcap intcap cbps=1.5e-13 cebpsm=0.9e-15 cebpsi=0.83e-15 cbin=1.45e-13  
cbins=1.4e-13
```

Instance Definition

```
Name n1 n2 ModelName parameter=value ...
```

Instance Parameters

1	<code>m=1</code>	Multiplicity factor.
2	<code>ael=0.0 m²</code>	The common area of <code>EL</code> track of the reference electrode.
3	<code>ain=0.0 m²</code>	The common area of <code>IN</code> track of the reference electrode.
4	<code>ains=0.0 m²</code>	The common area of <code>INS</code> track of the reference electrode.
5	<code>aps=0.0 m²</code>	The common area of <code>PS</code> track of the reference electrode.
6	<code>lbel=0.0 m</code>	The sum of periphery length of <code>EL</code> -segments common to node <code>n2</code> downwards.
7	<code>lbin=0.0 m</code>	The sum of periphery length of <code>IN</code> -segments to node <code>n2</code> downwards.
8	<code>lbins=0.0 m</code>	The sum of periphery length of <code>INS</code> -segments common to node <code>n2</code> downwards.
9	<code>lbps=0.0 m</code>	The sum of periphery length of <code>PS</code> -segments common to node <code>n2</code> downwards.
10	<code>lfbel=0.0 m</code>	The sum of periphery length-factor products <code>EL</code> downwards.
11	<code>lfbin=0.0 m</code>	The sum of periphery length-factor products <code>IN</code> downwards.

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Passive Components

12	lfbins=0.0 m	The sum of periphery length-factor products INS downwards.
13	lfbps=0.0 m	The sum of periphery length-factor products PS downwards.
14	lftel=0.0 m	The sum of periphery length-factor products EL upwards.
15	lftin=0.0 m	The sum of periphery length-factor products IN upwards.
16	lftins=0.0 m	The sum of periphery length-factor products INS upwards.
17	lftps=0.0 m	The sum of periphery length-factor products PS upwards.
18	ltel=0.0 m	The sum of periphery length of EL -segments common to node n2 upwards.
19	ltin=0.0 m	The sum of periphery length of IN -segments common to node n2 upwards.
20	ltins=0.0 m	The sum of periphery length of INS -segments common to node n2 upwards.
21	ltps=0.0 m	The sum of periphery length of PS -segments common to node n2 upwards.
22	ldsel=0.0 m	The sum of Li/Si quotients for EL tracks.
23	ldsins=0.0 m	The sum of Li/Si quotients for IN tracks.
24	ldsins=0.0 m	The sum of Li/Si quotients for INS tracks.
25	ldsps=0.0 m	The sum of Li/Si quotients for PS tracks.
26	lxbinsps=0.0 m	The sum of Li/Si quotients for an IN track in parallel with an PS track.
27	lxbinsin=0.0 m	The sum of Li/Si quotients for an INS track in parallel with an IN track.
28	lxbinsps=0.0 m	The sum of Li/Si quotients for an INS track in parallel with an PS track.
29	lxbelps=0.0 m	The sum of Li/Si quotients for an EL track in parallel with an PS track.

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Passive Components

30 `lxbelin=0.0 m` The sum of Li/Si quotients for an `EL` track in parallel with an `IN` track.

31 `lxbelins=0.0 m` The sum of Li/Si quotients for an `EL` track in parallel with an `INS` track.

The Spectre option `scale`, default value is 1.0, scales the geometric parameters. The actual areas (parameters starting with letter `a`) are equal

$$axxx * scale ^ 2$$

The actual lengths (parameters starting with letter `l`) are equal

$$lxxx * scale$$

Model Definition

```
model modelName intcap parameter=value ...
```

Model Parameters

- | | | |
|----|--|--|
| 1 | <code>cbps=0.0 F/m²</code> | Bottom capacitance, <code>PS</code> to node <code>n2</code> . |
| 2 | <code>cebpsm=0.0 F/m</code> | Edge to bottom capacitance (<code>PS</code>), 1.0um spacing. |
| 3 | <code>cebpsi=0.0 F/m</code> | Edge to bottom capacitance (<code>PS</code>), single track. |
| 4 | <code>cetpsm=0.0 F/m</code> | Edge to top capacitance (<code>PS</code>), 1.0um spacing. |
| 5 | <code>cetpsi=0.0 F/m</code> | Edge to top capacitance (<code>PS</code>), single track. |
| 6 | <code>cbin=0.0 F/m²</code> | Bottom capacitance, <code>IN</code> to node <code>n2</code> . |
| 7 | <code>cebinm=0.0 F/m</code> | Edge to bottom capacitance (<code>IN</code>), 1.0um spacing. |
| 8 | <code>cebinl=0.0 F/m</code> | Edge to bottom capacitance (<code>IN</code>), single track. |
| 9 | <code>cetinm=0.0 F/m</code> | Edge to top capacitance (<code>IN</code>), 1.0um spacing. |
| 10 | <code>cetini=0.0 F/m</code> | Edge to top capacitance (<code>IN</code>), single track. |
| 11 | <code>cbins=0.0 F/m²</code> | Bottom capacitance, <code>INS</code> to node <code>n2</code> . |

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Passive Components

12	<code>cebinsm=0.0 F/m</code>	Edge to bottom capacitance (INS), 1.0um spacing.
13	<code>cebinsi=0.0 F/m</code>	Edge to bottom capacitance (INS), single track.
14	<code>cetinsm=0.0 F/m</code>	Edge to top capacitance (INS), 1.0um spacing.
15	<code>cetinsi=0.0 F/m</code>	Edge to top capacitance (INS), single track.
16	<code>cbel=0.0 F/m²</code>	Bottom capacitance, EL to node n2.
17	<code>cebelm=0.0 F/m</code>	Edge to bottom capacitance (EL), 1.0um spacing.
18	<code>cebeli=0.0 F/m</code>	Edge to bottom capacitance (EL), single track.
19	<code>cetelm=0.0 F/m</code>	Edge to top capacitance (EL), 1.0um spacing.
20	<code>ceteli=0.0 F/m</code>	Edge to top capacitance (EL), single track.
21	<code>cecps=0.0 F/m</code>	Lateral capacitance (PS), 1.0um spacing.
22	<code>cecin=0.0 F/m</code>	Lateral capacitance (IN), 1.0um spacing.
23	<code>cecins=0.0 F/m</code>	Lateral capacitance (INS), 1.0um spacing.
24	<code>cecel=0.0 F/m</code>	Lateral capacitance (EL), 1.0um spacing.

Output Parameters

1	<code>cap (F)</code>	Total Capacitance.
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Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

`ael` I-2 `cebinsm` M-12 `cetpsm` M-4 `lftin` I-15

Virtuoso Simulator Components and Device Models Reference

Passive Components

ain	I-3	cebpsi	M-3	lbel	I-6	lftins	I-16
ains	I-4	cebpsm	M-2	lbin	I-7	lftps	I-17
aps	I-5	cecel	M-24	lbins	I-8	ltel	I-18
cap	O-1	cecin	M-22	lbsps	I-9	ltin	I-19
cbel	M-16	cecins	M-23	ldsel	I-22	ltins	I-20
cbin	M-6	cecps	M-21	ldsins	I-23	ltps	I-21
cbins	M-11	ceteli	M-20	ldsins	I-24	lxbelin	I-30
cbps	M-1	cetelm	M-19	ldsps	I-25	lxbelins	I-31
cebeli	M-18	cetini	M-10	lfbel	I-10	lxbelps	I-29
cebelm	M-17	cetinm	M-9	lfbins	I-11	lxbinsps	I-26
cebini	M-8	cetinsi	M-15	lfbins	I-12	lxbinsin	I-27
cebinm	M-7	cetinsm	M-14	lfbps	I-13	lxbinsps	I-28
cebinsi	M-13	cetpsi	M-5	lftel	I-14	m	I-1

Junction Capacitor (juncap)

Instance Definition

Name a k ModelName parameter=value ...

Instance Parameters

- 1 $ab=1e-12 \text{ m}^2$ Diffusion area.
- 2 $ls=1e-06 \text{ m}$ Length of the side-wall of the diffusion area AB which is not under the gate.

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Passive Components

3	<code>lg=1e-06 m</code>	Length of the side-wall of the diffusion area AB which is under the gate.
4	<code>mult=1</code>	Number of devices in parallel.
5	<code>region=triode</code>	Estimated DC operating region, used as a convergence aid. Possible values are <code>off</code> , <code>rev</code> , <code>fwd</code> , or <code>brk</code> .
6	<code>m=1</code>	Multiplicity factor.
7	<code>area=1.0e-12 m²</code>	alias of <code>ab</code> .
8	<code>peri=0.0 m</code>	alias of <code>ls</code> .
9	<code>pgate=0.0 m</code>	alias of <code>lg</code> .
10	<code>pj=0.0 m</code>	alias of <code>peri</code> .

Model Definition

```
model modelName juncap parameter=value ...
```

Model Parameters

1	<code>level=1</code>	Level of this model.
2	<code>dta=0 K</code>	Temperature offset of the juncap element with respect to TA.
3	<code>tr=25 C</code>	Temperature at which the parameters have been determined.
4	<code>vr=0 V</code>	Voltage at which the parameters have been determined.
5	<code>jsgbr=0.001 Am⁻²</code>	Bottom saturation-current density due to electron-hole generation at $V=V_R$.
6	<code>jsdbr=0.001 Am⁻²</code>	Bottom saturation-current density due to diffusion from back contact.
7	<code>jsgsr=0.001 Am⁻¹</code>	Sidewall saturation-current density due to electron-hole generation at $V=V_R$.
8	<code>jsdsr=0.001 Am⁻¹</code>	Sidewall saturation-current density due to diffusion from back contact.

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Passive Components

9	$jsggr=0.001 \text{ Am}^{-1}$	Gate edge saturation-current density due to diffusion from back contact.
10	$jsdgr=0.001 \text{ Am}^{-1}$	Gate edge saturation-current density due to diffusion from back contact.
11	$nb=1$	Emission coefficient of the bottom forward current.
12	$ns=1$	Emission coefficient of the sidewall forward current.
13	$ng=1$	Emission coefficient of the gate edge forward current.
14	$vb=0.9 \text{ V}$	Reverse breakdown voltage.
15	$cjbr=1e-12 \text{ Fm}^{-2}$	Bottom junction capacitance at $V=VR$.
16	$cjsr=1e-12 \text{ Fm}^{-1}$	Sidewall junction capacitance at $V=VR$.
17	$cjgr=1e-12 \text{ Fm}^{-1}$	Gate edge junction capacitance at $V=VR$.
18	$vdb=1 \text{ V}$	Diffusion voltage of the bottom junction at $T=TR$.
19	$vdsr=1 \text{ V}$	Diffusion voltage of the sidewall junction at $T=TR$.
20	$vdgr=1 \text{ V}$	Diffusion voltage of the gate edge junction at $T=TR$.
21	$pb=0.4$	Bottom junction grading coefficient.
22	$ps=0.4$	Sidewall junction grading coefficient.
23	$pg=0.4$	Gate edge junction grading coefficient.
24	$imax=1e+03 \text{ A}$	Explosion current.
25	$shrink=0$	Linear shrink factor.
26	$shrink2=0$	Areal shrink factor.
27	$type=n$	Transistor gender. Possible values are <code>n</code> , <code>p</code> , <code>npn</code> , <code>pnv</code> , <code>npnv</code> , <code>pnpl</code> , or <code>pnpl</code> .
28	$tnom \text{ (C)}$	alias of <code>tnom</code> .

Virtuoso Simulator Components and Device Models Reference

Passive Components

29 t_{ref} (C) alias of t_{nom} .

Output Parameters

1	d_{ta} (K)	Temperature offset of the juncap element with respect to T_A .
2	t_r (C)	Temperature at which the parameters have been determined.
3	v_r (V)	Voltage at which the parameters have been determined.
4	i_{sgb} ($A_{m^{-2}}$)	Bottom saturation-current density due to electron-hole generation at $V=V_R$.
5	i_{sdb} ($A_{m^{-2}}$)	Bottom saturation-current density due to diffusion from back contact.
6	i_{sgs} ($A_{m^{-1}}$)	Sidewall saturation-current density due to electron-hole generation at $V=V_R$.
7	i_{sds} ($A_{m^{-1}}$)	Sidewall saturation-current density due to diffusion from back contact.
8	i_{sgg} ($A_{m^{-1}}$)	Gate edge saturation-current density due to electron-hole generation at $V=V_R$.
9	i_{sdg} ($A_{m^{-1}}$)	Gate edge saturation-current density due to diffusion from back contact.
10	n_b	Emission coefficient of the bottom forward current.
11	n_s	Emission coefficient of the sidewall forward current.
12	n_g	Emission coefficient of the gate edge forward current.
13	c_{jb} ($F_{m^{-2}}$)	Bottom junction capacitance at $V=V_R$.
14	c_{js} ($F_{m^{-1}}$)	Sidewall junction capacitance at $V=V_R$.
15	c_{jg} ($F_{m^{-1}}$)	Gate edge junction capacitance at $V=V_R$.
16	v_{db} (V)	Diffusion voltage of the bottom junction at $T=T_R$.
17	v_{ds} (V)	Diffusion voltage of the sidewall junction at $T=T_R$.

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Passive Components

18	vdg (V)	Diffusion voltage of the gate edge junction at T=TR.
19	pb	Bottom junction grading coefficient.
20	ps	Sidewall junction grading coefficient.
21	imax (A)	Explosion current.
22	vexpl (A)	Explosion voltage.
23	pg	Gate edge junction grading coefficient.

Operating-Point Parameters

1	g (S)	Total differential conductance.
2	c (F)	Total capacitance.
3	lx1 (A)	Total current.
4	lx3 (Coul)	Total charge.
5	lx5 (F)	Total capacitance, identical to OP output c.

Parameter Index

In the following index, I refers to instance parameters, M refers to the model parameters section, O refers to the output parameters section, and OP refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of M-35 means the 35th model parameter.

ab	I-1	isgb	O-4	nb	M-11	shrink2	M-26
area	I-7	isgg	O-8	nb	O-10	tnom	M-28
c	OP-2	isgs	O-6	ng	M-13	tr	M-3
cjb	O-13	jsdbr	M-6	ng	O-12	tr	O-2

Virtuoso Simulator Components and Device Models Reference

Passive Components

<code>cjbr</code> M-15	<code>jsdgr</code> M-10	<code>ns</code> M-12	<code>tref</code> M-29
<code>cjg</code> O-15	<code>jsdsr</code> M-8	<code>ns</code> O-11	<code>type</code> M-27
<code>cjgr</code> M-17	<code>jsgbr</code> M-5	<code>pb</code> M-21	<code>vb</code> M-14
<code>cjs</code> O-14	<code>jsggr</code> M-9	<code>pb</code> O-19	<code>vdb</code> O-16
<code>cjsr</code> M-16	<code>jsgsr</code> M-7	<code>peri</code> I-8	<code>vdb</code> M-18
<code>dta</code> M-2	<code>level</code> M-1	<code>pg</code> M-23	<code>vdg</code> O-18
<code>dta</code> O-1	<code>lg</code> I-3	<code>pg</code> O-23	<code>vdgr</code> M-20
<code>g</code> OP-1	<code>ls</code> I-2	<code>pgate</code> I-9	<code>vds</code> O-17
<code>imax</code> M-24	<code>lx1</code> OP-3	<code>pj</code> I-10	<code>vdsr</code> M-19
<code>imax</code> O-21	<code>lx3</code> OP-4	<code>ps</code> M-22	<code>vexpl</code> O-22
<code>isdb</code> O-5	<code>lx5</code> OP-5	<code>ps</code> O-20	<code>vr</code> M-4
<code>isdg</code> O-9	<code>m</code> I-6	<code>region</code> I-5	<code>vr</code> O-3
<code>isds</code> O-7	<code>mult</code> I-4	<code>shrink</code> M-25	

JUNCAP2 Model (juncap200)

This is SiMKit 3.0.2

This device is supported within altergroups.

This device is dynamically loaded from the shared object `/vobs/spectre_dev/tools.lnx86/cmi/lib/5.0.doc/libphilips_sh.so`

Instance Definition

Name `a k` ModelName parameter=value ...

Virtuoso Simulator Components and Device Models Reference

Passive Components

Instance Parameters

1	<code>ab=1e-12 m²</code>	Junction area.
2	<code>ls=1e-06 m</code>	STI-edge part of junction perimeter.
3	<code>lg=1e-06 m</code>	Gate-edge part of junction perimeter.
4	<code>mult=1</code>	Number of devices in parallel.
5	<code>region=triode</code>	Estimated DC operating region, used as a convergence aid. Possible values are <code>off</code> , <code>rev</code> , <code>fwd</code> , or <code>brk</code> .
6	<code>m=1</code>	Multiplicity factor.
7	<code>area=1</code>	alias of <code>mult</code> .

Model Definition

```
model modelName juncap200 parameter=value ...
```

Model Parameters

1	<code>level=200</code>	Model level must be 200.
2	<code>type=n</code>	Type parameter, in output value 1 reflects n-type, -1 reflects p-type. Possible values are <code>n</code> , <code>p</code> , <code>npn</code> , <code>pnv</code> , <code>npnv</code> , <code>npnl</code> , or <code>pnpl</code> .
3	<code>trj=21 C</code>	Reference temperature.
4	<code>dta=0 C</code>	Temperature offset with respect to ambient temperature.
5	<code>imax=1e+03 A</code>	Maximum current up to which forward current behaves exponentially.
6	<code>cjorbot=0.001 Fm⁻²</code>	Zero-bias capacitance per unit-of-area of bottom component.
7	<code>cjorsti=1e-09 Fm⁻¹</code>	Zero-bias capacitance per unit-of-length of STI-edge component.

Virtuoso Simulator Components and Device Models Reference

Passive Components

- 8 `cjorgat=1e-09 Fm-1` Zero-bias capacitance per unit-of-length of gate-edge component.
- 9 `vbirbot=1 V` Built-in voltage at the reference temperature of bottom component.
- 10 `vbirsti=1 V` Built-in voltage at the reference temperature of STI-edge component.
- 11 `vbirgat=1 V` Built-in voltage at the reference temperature of gate-edge component.
- 12 `pbot=0.5` Grading coefficient of bottom component.
- 13 `psti=0.5` Grading coefficient of STI-edge component.
- 14 `pgat=0.5` Grading coefficient of gate-edge component.
- 15 `phigbot=1.16 V` Zero-temperature bandgap voltage of bottom component.
- 16 `phigsti=1.16 V` Zero-temperature bandgap voltage of STI-edge component.
- 17 `phiggat=1.16 V` Zero-temperature bandgap voltage of gate-edge component.
- 18 `idsatrbot=1e-12 Am-2` Saturation current density at the reference temperature of bottom component.
- 19 `idsatrsti=1e-18 Am-1` Saturation current density at the reference temperature of STI-edge component.
- 20 `idsatrgat=1e-18 Am-1` Saturation current density at the reference temperature of gate-edge component.
- 21 `csrhibot=100 Am-3` Shockley-Read-Hall prefactor of bottom component.
- 22 `csrhisti=0.0001 Am-2` Shockley-Read-Hall prefactor of STI-edge component.

Virtuoso Simulator Components and Device Models Reference

Passive Components

- 23 $csr_{hgat}=0.0001 \text{ Am}^{-2}$ Shockley-Read-Hall prefactor of gate-edge component.
- 24 $xj_{unsti}=1e-07 \text{ m}$ Junction depth of STI-edge component.
- 25 $xj_{ungat}=1e-07 \text{ m}$ Junction depth of gate-edge component.
- 26 $ctat_{bot}=100 \text{ Am}^{-3}$ Trap-assisted tunneling prefactor of bottom component.
- 27 $ctat_{sti}=0.0001 \text{ Am}^{-2}$ Trap-assisted tunneling prefactor of STI-edge component.
- 28 $ctat_{gat}=0.0001 \text{ Am}^{-2}$ Trap-assisted tunneling prefactor of gate-edge component.
- 29 $m_{efftatbot}=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of bottom component.
- 30 $m_{efftatsti}=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of STI-edge component.
- 31 $m_{efftatgat}=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of gate-edge component.
- 32 $cbbt_{bot}=1e-12 \text{ AV}^{-3}$ Band-to-band tunneling prefactor of bottom component.
- 33 $cbbt_{sti}=1e-18 \text{ AV}^{-3}_m$ Band-to-band tunneling prefactor of STI-edge component.
- 34 $cbbt_{gat}=1e-18 \text{ AV}^{-3}_m$ Band-to-band tunneling prefactor of gate-edge component.
- 35 $fbbtr_{bot}=1e+09 \text{ Vm}^{-1}$ Normalization field at the reference temperature for band-to-band tunneling of bottom component.
- 36 $fbbtr_{sti}=1e+09 \text{ Vm}^{-1}$ Normalization field at the reference temperature for band-to-band tunneling of STI-edge component.

Virtuoso Simulator Components and Device Models Reference

Passive Components

- 37 `fbttrgat=1e+09 Vm-1` Normalization field at the reference temperature for band-to-band tunneling of gate-edge component.
- 38 `stfbbtbot=-0.001 K-1` Temperature scaling parameter for band-to-band tunneling of bottom component.
- 39 `stfbbtsti=-0.001 K-1` Temperature scaling parameter for band-to-band tunneling of STI-edge component.
- 40 `stfbbtgat=-0.001 K-1` Temperature scaling parameter for band-to-band tunneling of gate-edge component.
- 41 `vbrbot=10 V` Breakdown voltage of bottom component.
- 42 `vbrsti=10 V` Breakdown voltage of STI-edge component.
- 43 `vbrgat=10 V` Breakdown voltage of gate-edge component.
- 44 `pbrbot=4 V` Breakdown onset tuning parameter of bottom component.
- 45 `pbrsti=4 V` Breakdown onset tuning parameter of STI-edge component.
- 46 `pbrgat=4 V` Breakdown onset tuning parameter of gate-edge component.
- 47 `swjunexp=0` Flag for JUNCAP-express; 0=full model, 1=express model.
- 48 `vjunref=2.5` Typical maximum junction voltage; usually about 2*VSUP.
- 49 `fjunq=0.03` Fraction below which junction capacitance components are considered negligible.

Operating-Point Parameters

- 1 `vak (V)` Voltage between anode and cathode.
- 2 `cj (F)` Total source junction capacitance.
- 3 `cjbot (F)` Junction capacitance (bottom component).

Virtuoso Simulator Components and Device Models Reference

Passive Components

4	<code>cjgat</code> (F)	Junction capacitance (gate-edge component).
5	<code>cjsti</code> (F)	Junction capacitance (STI-edge component).
6	<code>ij</code> (A)	Total source junction current.
7	<code>ijbot</code> (A)	Junction current (bottom component).
8	<code>ijgat</code> (A)	Junction current (gate-edge component).
9	<code>ijsti</code> (A)	Junction current (STI-edge component).
10	<code>si</code> (A ² /Hz)	Total junction current noise spectral density.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

<code>ab</code> I-1	<code>ctatsti</code> M-27	<code>m</code> I-6	<code>stfbbtgat</code> M-40
<code>area</code> I-7	<code>dta</code> M-4	<code>mefftatbot</code> M-29	<code>stfbbtsti</code> M-39
<code>cbbtbot</code> M-32	<code>fbbtbot</code> M-35	<code>mefftatgat</code> M-31	<code>swjunexp</code> M-47
<code>cbbtgat</code> M-34	<code>fbbtgat</code> M-37	<code>mefftatsti</code> M-30	<code>trj</code> M-3
<code>cbbtsti</code> M-33	<code>fbbtrsti</code> M-36	<code>mult</code> I-4	<code>type</code> M-2
<code>cj</code> OP-2	<code>fjunq</code> M-49	<code>pbot</code> M-12	<code>vak</code> OP-1
<code>cjbot</code> OP-3	<code>idsatrbot</code> M-18	<code>pbrbot</code> M-44	<code>vbirbot</code> M-9
<code>cjgat</code> OP-4	<code>idsatrgat</code> M-20	<code>pbrgat</code> M-46	<code>vbirgat</code> M-11
<code>cjorbot</code> M-6	<code>idsatrsti</code> M-19	<code>pbrsti</code> M-45	<code>vbirsti</code> M-10

Virtuoso Simulator Components and Device Models Reference

Passive Components

cjorgat	M-8	ij	OP-6	pgat	M-14	vrbot	M-41
cjorsti	M-7	ijbot	OP-7	phigbot	M-15	vbrgat	M-43
cjsti	OP-5	ijgat	OP-8	phiggat	M-17	vbrsti	M-42
csrbot	M-21	ijsti	OP-9	phigsti	M-16	vjunref	M-48
csrbot	M-21	ijsti	OP-9	phigsti	M-16	vjunref	M-48
csrhgat	M-23	imax	M-5	psti	M-13	xjungat	M-25
csrhsti	M-22	level	M-1	region	I-5	xjunsti	M-24
ctatbot	M-26	lg	I-3	si	OP-10		
ctatgat	M-28	ls	I-2	stfbbtbot	M-38		

Junction Capacitor (juncap_eldo)

The juncap model is intended to describe the behavior of the juncaps that are formed by the source, drain or well-to-bulk junctions in MOS devices. It is described in the Phillips MOST Modelbook (Dec.93) as JUNCAP model. Information on how to obtain this document can be found on Source Link by searching for Phillips.

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In extension to the model book description a minimum conductance g_{min} is inserted between the juncap nodes, to aid convergence. The value of g_{min} is set by an options statement, default = 1e-12 S.

The $imax$ parameter is used to aid convergence and to prevent numerical overflow. The junction characteristics of the junction capacitor are accurately modeled for currents up to $imax$. For currents above $imax$, the junction is modeled as a linear resistor and a warning is printed.

This device is supported within altergroups.

This device is dynamically loaded from the shared object /vobs/spectre_dev/tools.lnx86/cmi/lib/5.0.doc/libphilips_sh.so

Virtuoso Simulator Components and Device Models Reference

Passive Components

Sample Instance Statement

```
c2 (1 2) capmod ab=7e-12 lg=5e-6 region=rev
```

Sample Model Statement

```
model capmod juncap type=n cjbr=0.2 cjgr=0.2 cjsr=0.2 tref=25 jsgbr=2e-3  
jsdbr=0.28e-3 jsggr=1e-5 jsdgr=0.33e-6 vdsr=0.8 vdgr=0.8 vdbr=0.8
```

Instance Definition

```
Name n [b] ModelName parameter=value ...
```

Instance Parameters

- | | | |
|---|--|---|
| 1 | ab=1.0 scale ² m ² | Diffusion area. Scale set by option scale. |
| 2 | ls=1.0 scale m | Length of the sidewall of the diffusion area ab which is not under the gate. Scale set by option scale. |
| 3 | lg=1.0 scale m | Length of the sidewall of the diffusion area ab which is under the gate. Scale set by option scale. |
| 4 | m=1.0 | Multiplicity factor. |
| 5 | region=rev | Estimated DC operating region, used as a convergence aid. Possible values are fwd or rev. |

Model Definition

```
model modelName juncap_eldo parameter=value ...
```

Model Parameters

Structural parameters

- | | | |
|---|--------|--|
| 1 | type=n | Type of the juncap device. Possible values are n or p. |
| 2 | vb (V) | Not used for juncap model. |
| 3 | bv (V) | Alias of vb. |

Virtuoso Simulator Components and Device Models Reference

Passive Components

4 level Not used for juncap model.

Current parameters

5 $jsgbr=1.0e-3$ A/m²

Bottom saturation-current density due to electron-hole generation at reference voltage.

6 $jsdbr=1.0e-3$ A/m²

Bottom saturation-current density due to diffusion from back contact.

7 $jsgsr=1.0e-3$ A/m

Sidewall saturation-current density due to electron-hole generation at reference voltage.

8 $jsdsr=1.0e-3$ A/m

Sidewall saturation-current density due to diffusion from back contact.

9 $jsggr=1.0e-3$ A/m

Gate edge saturation-current density due to electron-hole generation at reference voltage.

10 $jsdgr=1.0e-3$ A/m

Gate edge saturation-current density due to diffusion from back contact.

11 $imax=1.0$ A

Explosion current.

Temperature effects parameters

12 $dta=0.0$ K

Temperature offset of the juncap element with respect to ambient temperature.

13 $trise=0.0$ K

Alias of dta .

14 tr (C)

Temperature at which the parameters have been determined. Default set by option t_{nom} .

15 $tref$ (C)

Alias of tr . Default set by option t_{nom} .

16 t_{nom} (C)

Alias of tr . Default set by option t_{nom} .

Virtuoso Simulator Components and Device Models Reference

Passive Components

Junction capacitance parameters

- 17 $c_{jbr}=1.0e-12$ F/m² Bottom junction capacitance at reference voltage.
- 18 $c_{jsr}=1.0e-12$ F/m Sidewall junction capacitance at reference voltage.
- 19 $c_{jgr}=1.0e-12$ F/m Gate edge junction capacitance at reference voltage.

Emission coefficient parameters

- 20 $n_b=1.0$ Emission coefficient of the bottom forward current.
- 21 $n_s=1.0$ Emission coefficient of the sidewall forward current.
- 22 $n_g=1.0$ Emission coefficient of the gate-edge forward current.

Voltage parameters

- 23 $v_r=0.0$ V Voltage at which parameters have been determined.
- 24 $v_{dbr}=1.0$ V Diffusion voltage of the bottom junction at reference temperature.
- 25 $v_{dsr}=1.0$ V Diffusion voltage of the sidewall junction at reference temperature.
- 26 $v_{dgr}=1.0$ V Diffusion voltage of the gate edge junction at reference temperature.

Grading coefficient parameters

- 27 $p_b=0.4$ Bottom-junction grading coefficient.
- 28 $p_s=0.4$ Sidewall-junction grading coefficient.
- 29 $p_g=0.4$ Gate edge-junction grading coefficient.

Virtuoso Simulator Components and Device Models Reference

Passive Components

Compatibility model parameters

30 `compatible=spectre`

Encourage device equations to be compatible with a foreign simulator. This option does not affect input syntax. Possible values are `spectre`, `spice2`, `spice3`, `cdsspice`, `hspice`, or `spiceplus`.

Output Parameters

1	<code>cjb</code> (F)	Capacitance of bottom area <code>ab</code> .
2	<code>cjs</code> (F)	Capacitance of locos-edge <code>ls</code> .
3	<code>cjg</code> (F)	Capacitance of gate-edge <code>lg</code> .
4	<code>isdb</code> (A)	Diffusion saturation-current of bottom area <code>ab</code> .
5	<code>isds</code> (A)	Diffusion saturation-current of locos-edge <code>ls</code> .
6	<code>isdg</code> (A)	Diffusion saturation-current of gate-edge <code>lg</code> .
7	<code>isgb</code> (A)	Generation saturation-current of bottom area <code>ab</code> .
8	<code>isgs</code> (A)	Generation saturation-current of locos-edge <code>ls</code> .
9	<code>isgg</code> (A)	Generation saturation-current of gate-edge <code>lg</code> .
10	<code>vdb</code> (V)	Diffusion voltage of bottom area <code>ab</code> .
11	<code>vds</code> (V)	Diffusion voltage of locos-edge <code>ls</code> .
12	<code>vdg</code> (V)	Diffusion voltage of gate-edge <code>lg</code> .

Operating-Point Parameters

1	<code>v</code> (V)	juncap bias voltage ($v = v_a - v_k$).
2	<code>i</code> (A)	Total resistive current from anode to cathode ($i = i_a = -i_k$).
3	<code>gm</code> (S)	Total differential conductance.

Virtuoso Simulator Components and Device Models Reference

Passive Components

4	q (Coul)	Total junction charge ($q = q_a = -q_k$).
5	c (F)	Total capacitance.
6	pwr (W)	Power.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

ab	I-1	$isdb$	O-4	ls	I-2	$trise$	M-13
bv	M-3	$isdg$	O-6	m	I-4	$type$	M-1
c	OP-5	$isds$	O-5	nb	M-20	v	OP-1
cjb	O-1	$isgb$	O-7	ng	M-22	vb	M-2
$cjbr$	M-17	$isgg$	O-9	ns	M-21	vdb	O-10
cjg	O-3	$isgs$	O-8	pb	M-27	$vdbr$	M-24
$cjgr$	M-19	$jsdbr$	M-6	pg	M-29	vdg	O-12
cjs	O-2	$jsdgr$	M-10	ps	M-28	$vdgr$	M-26
$cjsr$	M-18	$jsdsr$	M-8	pwr	OP-6	vds	O-11
$compatible$	M-30	$jsgbr$	M-5	q	OP-4	$vdsr$	M-25
dta	M-12	$jsggr$	M-9	$region$	I-5	vr	M-23
gm	OP-3	$jsgsr$	M-7	$tnom$	M-16		
i	OP-2	$level$	M-4	tr	M-14		

imax M-11

lg I-3

tref M-15

Two Terminal Inductor (inductor)

The inductance of this component can be a function of temperature or branch current. If you do not specify the inductance in the instance statement, it is taken from the model.

This device is supported within altergroups.

If the polynomial coefficients vector (coeffs=[c1 c2 ...]) is specified, the inductor is nonlinear and the inductance is

$$L(I) = L(\text{inst}) * (1 + c1 * I + c2 * I^2 + \dots).$$

The branch flux as a function of current is

$$\text{Flux}(I) = L(\text{inst}) * I * (1 + 1/2 * c1 * I + 1/3 * c2 * I^2 + \dots)$$

where c_k is the k th entry in the coefficient vector.

The value of the inductor as a function of the temperature is given by:

$$L(T) = L(\text{tnom}) * [1 + tc1 * (T - \text{tnom}) + tc2 * (T - \text{tnom})^2].$$

where

$$T = \text{trise}(\text{inst}) + \text{temp}$$

if $\text{trise}(\text{inst})$ is given, and

$$T = \text{trise}(\text{model}) + \text{temp}$$

otherwise.

Sample Instance Statement

without model:

```
133 (0 net29) inductor l=10e-9 r=1 m=1
```

with model:

```
133 (0 net29) ind l=10e-9 r=1 m=1
```

Virtuoso Simulator Components and Device Models Reference

Passive Components

Sample Model Statement

```
model ind inductor l=6e-9 r=1 tc1=1e-12 tc2=1e-12 tnom=25
```

This device support behavior expression

Sample Behavior Statement

```
l33 (0 net29) inductor l=10*(1 + v(net27, net28)*c1)
l33 (0 net29) inductor l=1e-9+1e-9/(1+($freq)/1e9)
```

Instance Definition

```
Name 1 2 ModelName parameter=value ...
Name 1 2 inductor parameter=value ...
```

Instance Parameters

1	<code>l</code> (H)	Inductance.
2	<code>r</code> (Ω)	Resistance.
3	<code>m=1</code>	Multiplicity factor.
4	<code>trise</code>	Temperature rise from ambient.
5	<code>ic</code> (A)	Initial condition(alias=lv2).
6	<code>isnoisy=yes</code>	Should inductor resistance generate noise. Possible values are <code>no</code> or <code>yes</code> .
7	<code>coeffs=[...]</code>	Vector of polynomial inductance coefficients.
8	<code>tc1=0</code> 1/C	Linear temperature coefficient.
9	<code>tc2=0</code> C ⁻²	Quadratic temperature coefficient.
10	<code>scalei</code>	Inductance scaling factor.

Model Definition

```
model modelName inductor parameter=value ...
```

Virtuoso Simulator Components and Device Models Reference

Passive Components

Model Parameters

1	<code>l=0 H</code>	Default inductance.
2	<code>r=0 Ω</code>	Default resistance.
3	<code>tc1=0 1/C</code>	Linear temperature coefficient.
4	<code>tc2=0 C⁻²</code>	Quadratic temperature coefficient.
5	<code>trise=0 C</code>	Default <code>trise</code> value for instance.
6	<code>tnom (C)</code>	Parameters measurement temperature. Default set by <code>options</code> .
7	<code>rforce=1e9 Ω²</code>	Resistance used when forcing nodesets and initial conditions.
8	<code>coeffs=[...]</code>	Vector of polynomial inductance coefficients.
9	<code>symmetric=none</code>	Use symmetric inductor model. Possible values are <code>none</code> and <code>absolute</code> .
10	<code>scalei=1</code>	Inductance scaling factor.

Noise model parameters

10	<code>kf=0</code>	Flicker (1/f) noise coefficient.
11	<code>af=2</code>	Flicker (1/f) noise exponent.

Output Parameters

1	<code>indef (H)</code>	Effective inductance(alias= <code>lv1</code>).
---	------------------------	---

Operating-Point Parameters

1	<code>ind (H)</code>	Inductance at operating point.
2	<code>i (A)</code>	Current at operating point(alias= <code>lx2</code>).

Virtuoso Simulator Components and Device Models Reference

Passive Components

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

af	M-11	indefeff	O-1	r	I-2	tc1	M-3
coeffs	I-7	isnoisy	I-6	r	M-2	tc2	I-9
coeffs	M-8	kf	M-10	rforce	M-7	tc2	M-4
i	OP-2	l	I-1	scalei	I-10	tnom	M-6
ic	I-5	l	M-1	scalei	M-9	trise	I-4
ind	OP-1	m	I-3	tc1	I-8	trise	M-5

Mutual Inductor (mutual_inductor)

The mutual inductor couples two previously specified inductors. There is no limit to the number of inductors that you can couple or to the number of couplings to a particular inductor, but you must specify separate mutual inductor statements for each coupling. Using the `dot` convention, place a `dot` on the first terminal of each inductor.

This device is supported within altergroups.

The mutual inductor modifies the constitutive equations of two isolated inductors to

$$v1 = L11*di1/dt + M*di2/dt$$

$$v2 = M*di1/dt + L22*di2/dt$$

where the mutual inductance, M , is computed from the coupling coefficient, k , using $k = |M|/\sqrt{L11*L22}$.

Sample Instance Statement with Two Inductors

```
l1 (1 0) inductor
l2 (2 0) inductor
```



```
m1 mutual_inductor coupling=1 ind1=l1 ind2=l2
```

Instance Definition

Name `mutual_inductor` parameter=value ...

Instance Parameters

- | | | |
|---|-------------------------|-------------------------|
| 1 | <code>coupling=0</code> | Coupling coefficient. |
| 2 | <code>k=0</code> | Alias to coupling. |
| 3 | <code>ind1</code> | Inductor to be coupled. |
| 4 | <code>ind2</code> | Inductor to be coupled. |

Operating-Point Parameters

- | | | |
|---|-----------------------|---|
| 1 | <code>mind</code> (H) | Mutual inductance between the inductors(alias=lv1). |
|---|-----------------------|---|

Magnetic Core with Hysteresis (core)

This component models the magnetic hysteresis, with air gap, frequency, and temperature effects. The model is based on the AWB model for magnetic cores and windings. The user has to specify the cores material and geometric parameters to model the hysteresis.

The material parameters to specify are the B_r , B_m and H_c of the core. The geometric parameters are the area, magnetic path length and the air gap of the core.

You can specify the magnetic path length in one of the following ways:

Give the length directly in cm.

Or give the outer and inner diameter of the core.

Cores without terminals represent complete magnetic loops. Cores with terminals are fragments that you can use as building blocks to build models of complicated core structures. For example, you can use the following set of core fragments to model an E core:

```
W1 e1p e1m winding turns=80 core=C1
```

```
W3a e2p e2c winding turns=80 core=C3
```

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```
W3b e2c e2m winding turns=80 core=C3
```

```
C1 m1 0 permalloy area=1 len=2
```

```
C2 m1 0 permalloy area=2 len=2
```

```
C3 m1 0 permalloy area=1 len=2
```

```
model permalloy core ...
```

There are three parallel core fragments representing each of the three fingers on the E. One 80 turn winding is connected to core fragment C1. A center-tapped 160 turn winding (implemented as a pair of windings) are wrapped around core fragment C3. Node m1 is a magnetic node whose value is in magnetomotive force and flow is flux.

You can calculate the frequency and temperature dependency of the core model by specifying the frequency loss parameters and the temperature effects parameters. You can make all the core parameters vary in temperature, including the permeability, saturation flux, and core loss. For frequency losses, a static model refers to a value that you type in for frequency. This model does not adjust the shape of the B-H loop in response to power dissipation or rate of rise of the applied currents and voltages during transient analysis.

This device is not supported within altergroup.

The hysteresis is modeled by different regions whose equations are:

$$\phi = \phi_{ir} + (\phi_{is} - \phi_{ir}) \frac{F}{(F + H_a)} \quad \text{for region number 1}$$
$$\phi = \phi_{is} * \frac{(F - F_c)}{(F - H_b)} \quad \text{for region number 2}$$

where ϕ = flux density

F = magnetomotive force

ϕ_{ir} = residual flux density

ϕ_{is} = Saturated flux density

F_c = Coercive magnetic force

H_a and H_b are shape parameters.

Sample Instance Statement

```
c1 (1 0) core_mod area=1.2 len=8.1 id=0.55 gap=0.25
```

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Passive Components

Sample Model Statement

```
model core_mod core len=7.7 area=0.85 br=1e3 bm=5e3 hc_t1=0.2 p1_f1=2.08 f1=10e3  
p2_f2=50 f2=100K bflux=1e3 density=4.75
```

Instance Definition

```
Name [1] [2] ModelName parameter=value ...
```

Instance Parameters

1	area (cm ²)	Effective magnetic cross-sectional area of core.
2	len (cm)	Effective length of magnetic path.
3	id (cm)	Inner diameter of toroidal core.
4	od (cm)	Outer diameter of toroidal core.
5	gap (cm)	Gap length.
6	m=1	Multiplicity factor.

Model Definition

```
model modelName core parameter=value ...
```

Model Parameters

1	br=1 gauss	Residual flux density.
2	bm=1 gauss	Saturation flux density.
3	hc=1 oersteds	Coercive magnetizing force (value of H where B equals 0).
4	area=1 cm ²	Effective magnetic cross-sectional area of core.
5	len=1 cm	Effective length of magnetic path.
6	id (cm)	Inner diameter of toroidal core.
7	od (cm)	Outer diameter of toroidal core.

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Passive Components

8 `gap=0.0 cm` Gap length.

Initial Conditions

9 `b0 (gauss)` Initial condition for core.

Frequency Loss Parameters

10 `freq (Hz)` Core operating frequency.

11 `p1_f1 (W/Kg)` Core power loss at frequency f_1 .

12 `f1 (Hz)` Reference frequency for power loss.

13 `p2_f2 (W/Kg)` Core power loss at frequency f_2 .

14 `f2 (Hz)` Reference frequency for power loss.

15 `bflux (gauss)` Reference flux density.

16 `density (g/cm3)` Core density.

Temperature Effects Parameters

17 `temp (C)` Core operating temperature.

18 `bm_t1 (gauss)` Saturated flux density B_m at T_1 .

19 `br_t1 (gauss)` Residual flux density B_r at T_1 .

20 `hc_t1 (oersteds)` Coercive force H_c at T_1 .

21 `t1 (C)` Reference temperature.

Operating-Point Parameters

1 `b (gauss)` Flux density of the core.

2 `h (oersteds)` Magnetic field strength.

Virtuoso Simulator Components and Device Models Reference

Passive Components

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

area	I-1	br_t1	M-19	hc	M-3	od	M-7
area	M-4	density	M-16	hc_t1	M-20	p1_f1	M-11
b	OP-1	f1	M-12	id	I-3	p2_f2	M-13
b0	M-9	f2	M-14	id	M-6	t1	M-21
bflux	M-15	freq	M-10	len	I-2	temp	M-17
bm	M-2	gap	I-5	len	M-5		
bm_t1	M-18	gap	M-8	m	I-6		
br	M-1	h	OP-2	od	I-4		

Winding for Magnetic Core (winding)

This winding is used in conjunction with magnetic cores to model coils and transformers with hysteresis. Each winding must be associated with a single core, though a core may have any number of windings.

Winding connects terminals **t1** and **b1**. Current through the winding is computed.

This device is not supported within altergroup.

Sample Instance Statement

```
c1 (1 0) core_mod area=1.2 len=8.1 id=0.45 id=0.55 gap=0.25
y1 (2 0) winding turn=5 core=c1 resis=1m
```

Instance Definition

Name `t b winding parameter=value ...`

Instance Parameters

- | | | |
|---|------------------------|---|
| 1 | <code>turn=1</code> | Number of turns on winding. |
| 2 | <code>resis (Ω)</code> | Resistance of the winding. |
| 3 | <code>m=1</code> | Multiplicity factor. |
| 4 | <code>core</code> | Name of core around which winding is wrapped. |

Initial Conditions

- | | | |
|---|-----------------------|-----------------------------------|
| 5 | <code>ic=0.0 A</code> | Initial condition on the winding. |
|---|-----------------------|-----------------------------------|

Linear Inductance, Reluctance, Resistance, and Capacitance Matrix (`rlck_matrix`)

Matrix device allows to specify a set of coupled inductors, resistors and capacitors in a single device, as opposed to a netlist of individual two-terminal devices and pair couplings. Reluctance matrix can be given instead of inductance matrix.

This device is supported within altergroups.

Device equations can be formulated in terms of inductance matrix L, or reluctance matrix K, defined as inverse of L

Inductance form

$$V_p - V_n = R \cdot I + L \cdot \text{ddt}(I)$$

Reluctance form

$$K \cdot V_p - K \cdot V_n = K \cdot R \cdot I + \text{ddt}(I)$$

where R is resistance matrix, I - vector of branch currents, ddt - time differentiation operator, V_p and V_n are vectors of positive and negative terminal voltages.

Capacitance equations

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Passive Components

$$I_p = I + C_p \cdot \text{ddt}(V_p)$$

$$I_n = -I + C_n \cdot \text{ddt}(V_n)$$

where I_p and I_n are vectors of terminal currents, C_p , C_n are capacitance matrices for positive and negative terminals.

Sample Instance Statement

```
l33 (p1 n1 p2 n2) rick_matrix l=[1 1 10n 1 2 -1n 2 2 5n] r=[1 1 100m 2 2 50m]
```

Instance Definition

```
Name 1 2 ... rick_matrix parameter=value ...
```

Number of terminals is two times dimension of matrix. When capacitance matrix is given, additional terminal can be specified to provide a reference for diagonal capacitors.

Sparse format is used for matrix input. Each matrix element is preceded by its row and column indices. All matrices should have the same dimensions. Matrices are symmetric, so that only upper or lower triangular elements should be specified. At least one of R, L, K matrices must be given. Either L, or K, but not both can be specified.

Instance Parameters

1	<code>l=[...]</code>	H	Inductance matrix.
2	<code>r=[...]</code>	Ω	Resistance matrix.
3	<code>k=[...]</code>	1/H	Reluctance matrix.
4	<code>c1=[...]</code>	F	Capacitance matrix for positive terminals.
5	<code>c2=[...]</code>	F	Capacitance matrix for negative terminals.
6	<code>ignore_coupling=no</code>		Ignore coupling elements in r, l, k, and c matrices. Possible values are <code>no</code> or <code>yes</code> .
7	<code>file</code>		rick matrix data file name.
8	<code>m=1</code>		Multiplicity factor.

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Passive Components

Matrix data file may have several sections - one for each matrix. Each section starts with keyword: inductance (l), reluctance (k), resistance (r), capacitance1 (c1), capacitance2 (c2). If the keyword is not given, the data is assumed to be reluctance matrix. Matrix data is in sparse format, same as on the instance statement. Character + in the first column, as well as =, [, and] are treated as blank space.

Parameter Index

In the following index, I refers to instance parameters, M refers to the model parameters section, O refers to the output parameters section, and OP refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of M-35 means the 35th model parameter.

c1	I-4	file	I-7	k	I-3	m	I-8
c2	I-5	ignore_coupling	I-6	l	I-1	r	I-2

Parameters Common to All Devices

This chapter discusses the following topics:

- Multiplication Factor (m) on page 242
- Scaling Factors (scale and scalem) on page 242
- imelt and imax on page 243
- SPICE Compatibility Flag (compatible) on page 244

Multiplication Factor (*m*)

The multiplication factor (*m*) puts *m* devices in parallel. *m* is an instance parameter and need not be an integer. All devices have the multiplication factor capability.

If you specify *m* in an instance statement, all currents and capacitances of that device are multiplied by *m*, and all resistances are divided by *m*. The multiplication factor, however, does not affect short-channel or narrow-gate effects in MOSFETs. For example, the following two statements might not give you the same simulation results:

```
m1 d g s b my_model w=10u l=1u m=10
m1 d g s b my_model w=100u l=1u m=1
```

You can also specify the multiplication factor on subcircuits. If a multiplication factor is specified in a subcircuit, it applies to all elements in that subcircuit. For example, if the multiplication factor of the subcircuit is 2 and the multiplication factor of an element in the subcircuit is 3, the effective multiplication factor for that element is 6.

Some devices—such as BJT, JFET, and diode—have an area factor parameter (*area*). The *area* parameter has identical effect on devices as the multiplication factor.

Scaling Factors (*scale* and *scalem*)

scale and *scalem* are options that set the scaling factors for instance and model parameters, respectively. You can specify the scaling factors in the `.options` statement. The following devices are affected by *scale* or *scalem*:

- Capacitors
- Diodes
- Resistors
- Physical resistors (*phy_res*)
- All levels of MOSFET models

These scaling factors affect capacitors, resistors, and physical resistors with specified device length (*l*) or width (*w*). *scale* and *scalem* are global options and apply to all instance and model statements for the preceding list of devices.

Parameters are scaled according to the following rules:

- Model (instance) parameters containing units of *m* (meters) are multiplied by *scalem* (*scale*).

Virtuoso Simulator Components and Device Models Reference

Parameters Common to All Devices

- Model (instance) parameters containing units of m^n are multiplied by `scalem` (`scalen`), where n can be a positive integer or a positive real number.
- Model (instance) parameters containing units of $1/m$ are divided by `scalem` (`scale`).
- Model (instance) parameters containing units of $1/m^n$ are divided by `scalemn` (`scalen`), where n can be a positive integer or a positive real number.
- Parameters that use the units `cm` (`1/cm`, `cm2`, ...) and `μm` (`1/μm`, `μm2`, ...) are not scaled. For example, `vmax`, which contains the unit `m/sec`, is scaled by `scalem`, but `ucrit`, which has the unit `V/cm`, is not scaled. Similarly, `nsub`, which has the unit `1/cm3`, is not scaled by `scalem`.
- Parameters with other units are not scaled.

Note: The `diode` model is not scaled by default. To scale the `diode` model, set `allow_scaling` in the model card to `yes`.

imelt and imax

`imelt` and `imax` are used on devices containing p-n junctions. These devices include

- JFETs
- GaAs FETs
- Physical resistors (`phy_res`)
- All MOSFET models
- Diodes
- All BJTs (G-P, VBIC, and HBT)

`imelt` is used to help convergence and to prevent numerical problems. The Virtuoso[®] Spectre[®] circuit simulator uses `imelt` to linearize the junction current. When the junction current is larger than `imelt` (a model parameter), the junction current is calculated as a linear function instead of an exponential function of the junction voltage. Therefore, if the junction current is larger than `imelt`, the current calculated by the Spectre circuit simulator is not what the original junction current model predicts, and the Spectre circuit simulator issues a warning.

`imax` is a warning control parameter. Normally, `imax` does not affect the simulation results. Whenever the junction current is larger than `imax`, the Spectre circuit simulator issues a warning. The default value of `imax` is 1A, and the default value of `imelt` is `imax`. Therefore,

Virtuoso Simulator Components and Device Models Reference

Parameters Common to All Devices

`imax` can affect the simulation results only when `imelt` is not specified and takes its value from `imax`.

Typically, the junction current is much less than 1 A. When `imelt` is 1A, the conductance of the junction at room temperature is about 40 siemens, which is much larger than those of typical semiconductor devices. The Spectre circuit simulator issues a warning message telling you the junction current is linearized when

- The `imelt` value is set too small
- The connection to devices is incorrect
- Temporary voltage overshoot due to capacitive coupling at fast transient transition

If this happens, the warnings can be ignored in most cases unless the voltage overshoot is purposely designed to trigger some circuit functions.

In MOSFETs, you can use `jmelt` instead of `imelt`. The function of `jmelt` is identical to that of `imelt`, except that the junction current is linearized based on the current density specified by `jmelt`. If both `imelt` and `jmelt` are specified, `imelt` takes precedence.

For BJTs, `imelt` and `imax` are used to control the base-emitter and the substrate junctions. `imelt1` and `imax1` are used to control the base-collector junction.

SPICE Compatibility Flag (compatible)

The SPICE compatibility flag (`compatible`) is a parameter you can specify in an `.options` statement. This parameter solves some SPICE compatibility issues. The valid values for `compatible` are `spectre`, `spice2`, `spice3`, and `cdsspice`. This parameter affects two areas:

- Energy band gap

If you set `compatible` to `spectre`, the Spectre simulator uses a more physics-based temperature equation to calculate the energy band gap. For all other values, the Spectre simulator uses the SPICE temperature equation. This different energy gap calculation affects only devices that use the common junction codes such as MOSFET, diode, JFET, and GaAs. BJT is not affected.

- MOSFET Level-2

The MOSFET Level-2 model includes a model parameter `smooth`, which chooses an improved (smoother and faster) model (`smooth = yes`) or the original SPICE Level-2 model (`smooth = no`). The default value of `smooth` is `yes`. If `compatible` is set to a

Virtuoso Simulator Components and Device Models Reference

Parameters Common to All Devices

value other than `spectre`, the Spectre simulator sets `smooth` to `no` regardless of the value you specify.

Virtuoso Simulator Components and Device Models Reference

Parameters Common to All Devices

Diode Model (diode)

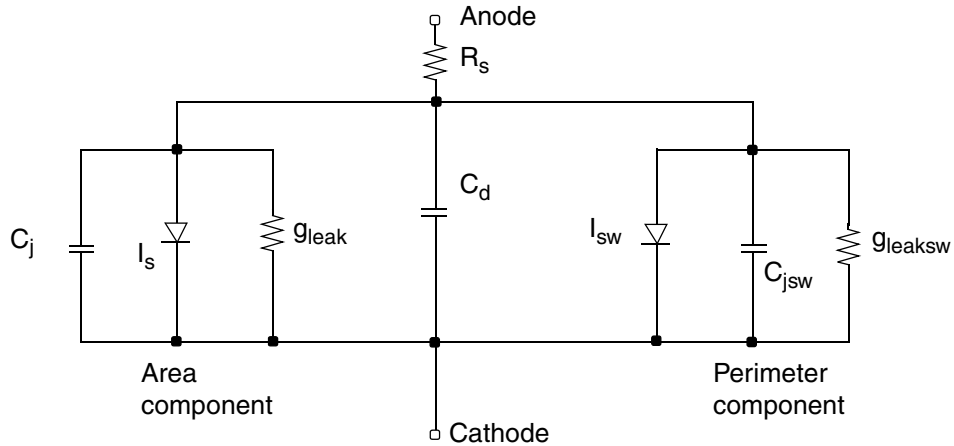
The DIODE level-1 model is based on the junction (Berkeley-spice) model and the level-2 model is based on the Fowler-Nordheim model. This chapter contains the following information about the DIODE model:

- [Level-1 Model](#) on page 248
- [Noise Model](#) on page 255
- [Level-2 Model](#) on page 257
- [Level-3 Model](#) on page 258
- [Component Statements](#) on page 258

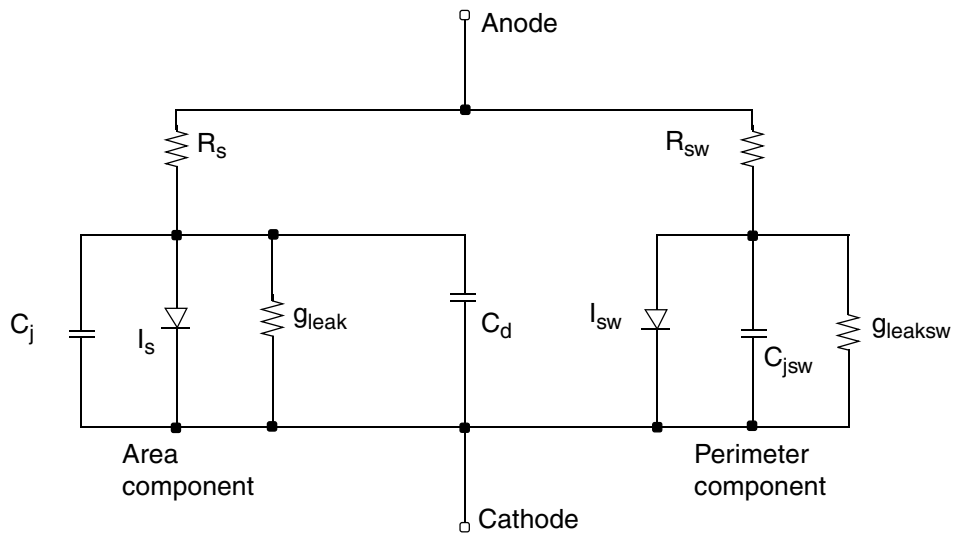
Virtuoso Simulator Components and Device Models Reference

Diode Model (diode)

If R_{sw} is not given, the diode model schematic is given by



If R_{sw} is given, the diode model schematic is given by



Level-1 Model

The following effects are included in the junction diode model: forward characteristics, reverse leakage current, breakdown, parasitic resistance, diffusion capacitance, depletion capacitance, and overlap capacitance.

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Diode Model (diode)

To achieve better scaling, a sidewall (peripheral) diode can also be specified. The peripheral diode shares most model parameters with the main diode except for the following parameters: i_{sw} , n_s , c_{jsw} , m_{jsw} , f_{csw} , r_{sw} , g_{leaksw} , ctp , and ptp . If the sidewall parasitic resistance (r_{sw}) is not specified, the peripheral diode shares the same parasitic resistance with the main diode. That is, both the main and the peripheral diodes are connected to the same internal nodes. If r_{sw} is specified, the peripheral diode creates its own internal node. In this case, the peripheral and main diode are equivalent to connecting two diodes in parallel.

The leakage currents are modeled by putting two small conductances (g_{leak} and g_{leaksw}) in parallel with the intrinsic diodes.

DC Current

$$I_{jtot} = I_j + I_{jsw}$$

where V_t is the thermal voltage given by

$$V_t = \frac{kT}{q}$$

$$I_j = \begin{cases} i_s \left(e^{\frac{V}{nV_t}} - 1 \right) & \text{if } V \leq V_{Expl} \\ I_{offset} + G_{Expl} V & \text{otherwise} \end{cases}$$

$$V_{Expl} = nV_t \ln \left[1 + \frac{imelt}{i_s} \right]$$

is the forward explosion voltage,

$$G_{Expl} = \frac{(imelt + i_s)}{nV_t}$$

is the conductance at V_{Expl} , and

$$I_{offset} = imelt - V_{Expl} G_{Expl}$$

is the current linearly extrapolated to $V = 0$ from V_{Expl} .

Virtuoso Simulator Components and Device Models Reference

Diode Model (diode)

$$I_{j+} = -JTUNeff \times \left(e^{\frac{-vd}{NTUN \times vt}} - 1 \right)$$

If $I_j > 0$ and $I_k > 0$,

$$I_j = I_j / (1 + \sqrt{I_j / (I_k \times Area)})$$

$$I_{jsw} = \begin{cases} isw \left(e^{\frac{V}{n_s V_t}} - 1 \right) & \text{if } V \leq V_{Explsw} \\ I_{offsetsw} + G_{Explsw} V & \text{otherwise} \end{cases}$$

$$V_{Explsw} = n_s V_t \ln \left[1 + \frac{imelt}{is} \right]$$

$$G_{Explsw} = \frac{(imelt + isw)}{n_s V_t}$$

$$I_{offsetsw} = imelt - V_{Explsw} G_{Explsw}$$

If $I_{jsw} > 0$ and $I_{kp} > 0$,

$$I_{jsw} = I_{jsw} / (1 + \sqrt{I_{jsw} / (I_{kp} \times AreaSW)})$$

Junction Capacitance

$$C_j(V) = \begin{cases} \frac{cjo}{\left[1 - \frac{V}{vj} \right]^m} & \text{if } V \leq fc * vj \\ \frac{cjo}{(1 - fc)^m} \left[1 + \frac{m(V - vj * fc)}{vj(1 - fc)} \right] & \text{otherwise} \end{cases}$$

Peripheral Junction Capacitance

$$C_{jsw}(V) = \begin{cases} \frac{c_{jsw}}{\left[1 - \frac{V}{v_{jsw}}\right]^{m_{jsw}}} & \text{if } V \leq f_{csw} * v_{jsw} \\ \frac{c_{jsw}}{(1 - f_{csw})^{m_{jsw}}} \left[1 + \frac{m_{jsw}(V - v_{jsw} * f_{csw})}{v_{jsw}(1 - f_{csw})}\right] & \text{otherwise} \end{cases}$$

Diffusion Capacitance

$$C_{diff} = \frac{tt[I_j + is]}{nV_t} + \frac{tt[I_{jsw} + isw]}{n_s V_t}$$

Total Capacitance

$$C_{tot} = C_j + C_{jsw} + C_{diff} + C_d$$

Breakdown Current

$$I_{zener} = \begin{cases} -ibv \exp\left[-\frac{(V + bv)}{n_z V_t}\right] & \text{if } -(bv + V_{ZenerExpl}) \leq V \\ -[I_{ZenerOffset} - G_{ZenerExpl}(V + bv)] & \text{otherwise} \end{cases}$$

where

$$V_{ZenerExpl} = n_z V_t \ln\left[\frac{imelt}{ibv}\right]$$

is the zener explosion voltage,

$$G_{ZenerExpl} = \frac{(imelt + ibv)}{n_z V_t}$$

Virtuoso Simulator Components and Device Models Reference

Diode Model (diode)

is the conductance at $V_{ZenerExpl}$,

and

$$I_{ZenerOffset} = imelt - V_{ZenerExpl} G_{ZenerExpl}$$

is the current linearly extrapolated to $V = 0$ from $V_{ZenerExpl}$. The breakdown current is not modeled in the peripheral diode.

Temperature Effect

Energy Band Gap

$$E_g(T) = \begin{cases} eg - \frac{gap1 * T^2}{T + gap2} & \text{if } tlev = 2 \\ \left(1.17 - \frac{4.73 \times 10^{-4} T^2}{T + 636}\right) & \text{if } tlev = 0 \text{ or } 1 \\ & \text{and } compatible = spectre \\ \left(1.16 - \frac{7.02 \times 10^{-4} T^2}{T + 1108}\right) & \text{otherwise} \end{cases}$$

Junction Currents

$$is = \begin{cases} is_{nom} \left(\frac{T}{Tnom}\right)^{\frac{xti}{n}} \exp\left[\frac{eg}{V_{t,nom}} - \frac{eg}{V_t}\right] & \text{if } tlev = 0 \text{ or } 1 \text{ and } eg \text{ is} \\ & \text{given, or} \\ & compatible \neq spectre \\ is_{nom} \left(\frac{T}{Tnom}\right)^{\frac{xti}{n}} \exp\left[\frac{E_g(Tnom)}{V_{t,nom}} - \frac{E_g(T)}{V_t}\right] & \text{if } tlev = 2 \text{ or } eg \text{ is not} \\ & \text{given} \end{cases}$$

Note: in the above equation, when eg is not specified, the default band gap is temperature dependent as specified by $E_g(T)$. The temperature dependence can be turned off by

Virtuoso Simulator Components and Device Models Reference

Diode Model (diode)

specifying eg in the model card or by setting the option *compatible* to something other than Virtuoso® Spectre® circuit simulator (for example *compatible = spice*).

$$isw = \begin{cases} isw_{nom} \left(\frac{T}{T_{nom}} \right)^{n_s} \exp \left[\frac{eg}{V_{t,nom}} - \frac{eg}{V_t} \right] & \text{if } tlev = 0 \text{ or } 1 \\ isw_{nom} \left(\frac{T}{T_{nom}} \right)^{n_s} \exp \left[\frac{E_g(T_{nom})}{V_{t,nom}} - \frac{E_g(T)}{V_t} \right] & \text{if } tlev = 2 \end{cases}$$

Breakdown Voltage

$$bv = bv_{nom} (1 + tbv * \Delta T + tbv2 * \Delta T^2)$$

Parasitic Resistance

$$rs = rs_{nom} (1 + trs * \Delta T + trs2 * \Delta T^2)$$

$$rsw = rsw_{nom} (1 + trs * \Delta T + trs2 * \Delta T^2)$$

Leakage Conductance

$$gleak = gleak_{nom} (1 + tgs * \Delta T + tgs2 * \Delta T^2)$$

$$gleaksw = gleaksw_{nom} (1 + tgs * \Delta T + tgs2 * \Delta T^2)$$

Junction Potential

$$v_j = \begin{cases} v_{j_{nom}} \left(\frac{T}{T_{nom}} \right) - \Delta V_j & \text{if } tlevc = 0 \\ v_{j_{nom}} - pta \Delta T & \text{if } tlevc = 1 \text{ or } 2 \\ v_{j_{nom}} - \frac{dV_j}{dT} \Delta T & \text{if } tlevc = 3 \end{cases}$$

$$v_{jsw} = \begin{cases} v_{jsw_{nom}} \left(\frac{T}{T_{nom}} \right) - \Delta V_j & \text{if } tlevc = 0 \\ v_{jsw_{nom}} - ptp \Delta T & \text{if } tlevc = 1 \text{ or } 2 \\ v_{jsw_{nom}} - \frac{dV_{jsw}}{dT} \Delta T & \text{if } tlevc = 3 \end{cases}$$

where

$$\Delta V_j = V_t \left[3 \ln \left(\frac{T}{T_{nom}} \right) + \frac{E_g(T_{nom})}{V_{t,nom}} - \frac{E_g(T)}{V_t} \right]$$

$$\frac{dV_j}{dT} = \begin{cases} \frac{\left[E_g(T_{nom}) + 3V_{t,nom} + (1.16 - E_g(T_{nom})) \left(2 - \frac{T_{nom}}{T_{nom} + 1108} \right) - v_j \right]}{T_{nom}} \\ \frac{\left[E_g(T_{nom}) + 3V_{t,nom} + (eg - E_g(T_{nom})) \left(2 - \frac{T_{nom}}{T_{nom} + gap2} \right) - v_j \right]}{T_{nom}} \end{cases}$$

$$\frac{dV_{jsw}}{dT} = \begin{cases} \frac{\left[E_g(T_{nom}) + 3V_{t,nom} + (1.16 - E_g(T_{nom})) \left(2 - \frac{T_{nom}}{T_{nom} + 1108} \right) - v_{jsw} \right]}{T_{nom}} & \text{if } tlev = 0, 1 \\ \frac{\left[E_g(T_{nom}) + 3V_{t,nom} + (eg - E_g(T_{nom})) \left(2 - \frac{T_{nom}}{T_{nom} + gap2} \right) - v_{jsw} \right]}{T_{nom}} & \text{if } tlev = 2 \end{cases}$$

Junction Capacitance

$$cjo = \begin{cases} cjo_{nom} \left[1 + m \left(0.0004 \Delta T - \frac{vj}{vj_{nom}} + 1 \right) \right] & \text{if } tlevc = 0 \\ cjo_{nom} (1 + cta \Delta T) & \text{if } tlevc = 1 \\ cjo_{nom} \left(\frac{vj_{nom}}{vj} \right)^m & \text{if } tlevc = 2 \\ cjo_{nom} \left(1 - 0.5 \frac{dV_j}{dT} \frac{\Delta T}{vj_{nom}} \right) & \text{if } tlevc = 3 \end{cases}$$

$$cjsw = \begin{cases} cjsw_{nom} \left[1 + m \left(0.0004 \Delta T - \frac{vjsw}{vjsw_{nom}} + 1 \right) \right] & \text{if } tlevc = 0 \\ cjsw_{nom} (1 + ctp \Delta T) & \text{if } tlevc = 1 \\ cjsw_{nom} \left(\frac{vjsw_{nom}}{vjsw} \right)^{mjsw} & \text{if } tlevc = 2 \\ cjsw_{nom} \left(1 - 0.5 \frac{dV_{jsw}}{dT} \frac{\Delta T}{vjsw_{nom}} \right) & \text{if } tlevc = 3 \end{cases}$$

Noise Model

Series Resistance Thermal Noise

$$\overline{i_{R_s}^2} = \frac{4kT}{rs} \Delta f$$

Diode Shot and Flicker Noise

$$\overline{i_D^2} = 2qI_D \Delta f + kf \frac{I_D^{af}}{f} \Delta f$$

where kf and af are constants for a given device. The Spectre[®] circuit simulator defaults for these constants are 0.0 and 1.0, respectively.

Scaling Effects

The following are the Spectre scaling effects:

- is , cjo , cd , and ibv are multiplied by $area$ and m .
- rs is divided by $area$ and m .
- All noises are multiplied by $area$ and m .
- isw and $cjsw$ are multiplied by $perim$ and m for the peripheral diode.
- rsw is divided by $perim$ and m .
- If $area$ is not specified and l and w are specified, $area$ is calculated from l and w as

$$area = L_{eff} \times W_{eff}$$

where

$$W_{eff} = w - etch$$

$$L_{eff} = l - etchl$$

If $area$, w , and l are not specified on the instance line, and $area$ is specified on the model card, then $area = area_{model}$.

Otherwise, $area$ defaults to 1.

- If $perim$ is not specified and l and w are specified, $perim$ is calculated from l and w as

$$perim = 2 \times (L_{eff} + W_{eff})$$

If $perim$, l , and w are not specified on the instance line, and $perim$ is specified on the model card, then $perim = perim_{model}$.

Otherwise, $perim$ defaults to 0.

The model parameter $allow_scaling$ controls scaling of diode geometry parameters ($area$, $perim$, l , and w) by the scale option. If $allow_scaling$ is set to *yes*, then the l , w , and $perim$ device parameters are multiplied by $scale$, while $area$ is multiplied by $scale^2$. By default, $allow_scaling$ is *no*.

If $scale$ is specified on the diode instance line, then this value overrides the value of the scale option for this particular instance, although it is still only used if $allow_scaling$ is *yes* on the corresponding diode model card.

Level-2 Model

The level-2 diode model is used to model the Fowler-Nordheim tunneling current in very thin insulators, such as silicon dioxide, commonly seen in nonvolatile memory. The peripheral diode is not supported for the level-2 model. If *perim* is specified, it is ignored.

DC Current

$$I_j = \begin{cases} if \left(\frac{V}{tox}\right)^{nf} e^{-\frac{ecrf \times tox}{V}} & \text{if } V \geq 0 \\ ir \left(\frac{V}{tox}\right)^{nr} e^{\frac{ecrr \times tox}{V}} & \text{otherwise} \end{cases}$$

Linear Capacitance

$$C_d = cd + \frac{\epsilon_{ox}}{tox}$$

Scaling Effects

The following are the Spectre scaling effects:

- *if*, *ir*, and *cd* are multiplied by *area* and *m*.
- *rs* is divided by *area* and *m*.
- If *area* is not specified and *l* and *w* are specified, *area* is calculated from *l* and *w* as follows:

$$area = L_{eff} \times W_{eff}$$

where

$$W_{eff} = w - etch$$

$$L_{eff} = l - etchl$$

Otherwise, *area* defaults to 1.

Level-3 Model

The level-3 model shares the level-1 model parameters. In addition, the level-3 model supports the following parameters: LM, LP, WM, XM, XP, XOI and XOM.

The poly metal capacitor is calculated by:

If *xoi* is given:

$$C_{poly} = (\text{oxide permittivity} | xoi \times 1.0E - 10) \times (wp + xp) \times (lp + xp)$$

otherwise,

$$C_{poly} = (\text{oxide permittivity} | 7.0E) \times (wp + xp) \times (lp + xp)$$

The metal capacitor is calculated by:

If *xom* is given:

$$C_{metal} = (\text{oxide permittivity} | xoi \times 1.0E - 10) \times (wm + xm) \times (lm + xm)$$

otherwise,

$$C_{metal} = (\text{oxide permittivity} | 1.0E6) \times (wm + xm) \times (lm + xm)$$

Component Statements

The junction diode model includes nonlinear junction capacitance and reverse breakdown.

This device is supported within altergroups.

Sample Instance Statement

```
d0 (dp dn) pdiode l=3e-4 w=2.5e-4 area=1
```

Virtuoso Simulator Components and Device Models Reference

Diode Model (diode)

Sample Model Statement

```
model pdiode diode is=1.8e-5 rs=1.43 n=1.22 nz=2.31 gleak=6.2e-5 rsw=10 isw=6.1e-10
ibv=0.95e-3 tgs=2 ik=1.2e7 fc=0.5 cj=1.43e-3 pb=0.967 mj=0.337 cjsw=2.76e-9
vjsw=0.94 jmax=1e20
```

Instance Definition

Name a c ModelName parameter=value ...

In forward operation, the voltage on the anode (a) is more positive than the voltage on the cathode (c).

Instance Parameters

1	area	Junction area factor (alias=lv1).
2	perim	Junction perimeter factor.
3	l=1e-6 m	Drawn length of junction.
4	w=1e-6 m	Drawn width of junction.
5	m=1	Multiplicity factor.
6	scale=1	Scale factor.
7	region=on	Estimated operating region. Spectre outputs number (0-2) in a rawfile. Possible values are <code>off</code> , <code>on</code> , and <code>breakdown</code> .
8	trise (C)	Temperature rise from ambient.
9	lm=0.0 m	Length of metal capacitor.
10	lp=0.0 m	Length of polysilicon capacitor.
11	wm=0.0 m	Width of metal capacitor.
12	wp=0.0 m	Width of polysilicon capacitor.
13	isnoisy=yes	Should device generate noise. Possible values are <code>no</code> and <code>yes</code> .

Virtuoso Simulator Components and Device Models Reference

Diode Model (diode)

The instance parameter `scale`, if specified, overrides the value given by the option parameter `scale`. If the model parameter `allow_scaling` is set to `yes` then, the `area`, `perim`, `l` and `w` parameters are scaled by `scale`. By default `allow_scaling` is set to `no` and no scaling of geometry parameters will occur. The values of `area`, `perim`, `l` and `w` printed out by `spectre` are those given in the input, and these values might not have the correct units if the scaling factors are not unity.

Model Definition

```
model modelName diode parameter=value ...
```

Model Parameters

Model selector parameters

- | | | |
|---|---------------------------------|---|
| 1 | <code>level=1</code> | Model selector. 1 = Junction ,2 = Fowler-Nordheim, 3 = Junction + additional metal and polysilicon capacitances. |
| 2 | <code>dcap=2</code> | Depletion capacitance equations selector (hspice compatibility flag only). |
| 3 | <code>compatible=spectre</code> | Spice compatible flag.
Possible values are <code>spectre</code> , <code>spice2</code> , <code>spice3</code> , <code>cdsspice</code> , <code>hspice</code> , <code>spiceplus</code> , <code>eldo</code> , <code>spice</code> , or <code>mica</code> . |

Process parameters

- | | | |
|---|------------------------|---|
| 4 | <code>etch=0 m</code> | Narrowing due to etching per side. |
| 5 | <code>etchl=0 m</code> | Length reduction due to etching per side. |
| 6 | <code>l=1e-6 m</code> | Drawn length of junction. |
| 7 | <code>w=1e-6 m</code> | Drawn width of junction. |

Junction diode parameters

- | | | |
|---|------------------------------|----------------------------|
| 8 | <code>js=1e-14 A/Area</code> | Saturation current. |
| 9 | <code>is=`jsA'</code> | Alias to <code>js</code> . |

Virtuoso Simulator Components and Device Models Reference

Diode Model (diode)

10	<code>j_{sw}=0 A/Perim</code>	Sidewall saturation current.
11	<code>isw=`j_{sw}A'</code>	Alias to <code>j_{sw}</code> .
12	<code>isp=`j_{sw}A'</code>	Alias to <code>j_{sw}</code> .
13	<code>n=1</code>	Emission coefficient.
14	<code>ns=1</code>	Sidewall emission coefficient.
15	<code>ik=0.0 A/Area</code>	High-level injection knee current.
16	<code>ikf=0.0 A/Area</code>	High-level injection knee current. For <code>level=1/3</code> , it is an alias to <code>ik</code> .
17	<code>ikp=`ikA/Area'</code>	High-level injection knee current for sidewall.
18	<code>ikr=ik A/Area</code>	Reverse high-level injection knee current (hspice compatibility flag only).
19	<code>area=1</code>	Junction area factor.
20	<code>perim=0</code>	Junction perimeter factor.
21	<code>allow_scaling=no</code>	Allow scale option and instance scale parameter to affect diode instance geometry parameters. Possible values are <code>no</code> and <code>yes</code> .

Capacitive parameters

22	<code>tt=0 s</code>	Transit time.
23	<code>cd=0 F/Area</code>	Linear capacitance.
24	<code>cjo=0 F/Area</code>	Zero-bias junction capacitance.
25	<code>vj=1 V</code>	Junction potential.(For HSPICE, its default value is 0.8).
26	<code>pb=`vjV'</code>	Alias to <code>vj</code> .
27	<code>m=0.5</code>	Grading coefficient.
28	<code>cj_{sw}=0 F/Perim</code>	Zero-bias sidewall junction capacitance.

Virtuoso Simulator Components and Device Models Reference

Diode Model (diode)

29	<code>cjp=`cjswF'</code>	Alias to <code>cjsw</code> .
30	<code>vjsw=1 V</code>	Sidewall junction potential.(For HSPICE, its default value is <code>vj</code>).
31	<code>php=`vjswV'</code>	Alias of <code>vjsw</code> .
32	<code>mjsw=0.33</code>	Sidewall grading coefficient.
33	<code>fc=0.5</code>	Forward-bias depletion capacitance threshold.
34	<code>fcs=`fc'</code>	Coefficient for forward-bias depletion sidewall capacitance.
35	<code>lm=0.0 m</code>	Length of metal capacitor (level=3 only).
36	<code>lp=0.0 m</code>	Length of polysilicon capacitor (level=3 only).
37	<code>wm=0.0 m</code>	Width of metal capacitor (level=3 only).
38	<code>wp=0.0 m</code>	Width of polysilicon capacitor (level=3 only).
39	<code>xm=0.0 m</code>	XM accounts for masking and etching effects (level=3 only).
40	<code>xp=0.0 m</code>	XP accounts for masking and etching effects (level=3 only).
41	<code>xoi=0.0 m</code>	Thickness of the polysilicon to bulk oxide. Units - nAngstrom (level=3 only).
42	<code>xom=0.0 m</code>	Thickness of the metal to bulk oxide. Units - nAngstrom (level=3 only).
43	<code>xw=0.0 m</code>	Accounts for masking and etching effects (level=3 only).
44	<code>vjmin=0.1</code>	Lowest value for build-in junction potential.

Breakdown parameters

45	<code>bv=∞ V</code>	Reverse breakdown voltage. Note: <code>bv=0</code> is not the same as <code>bv=infinity</code> .
46	<code>vb=`bvV'</code>	Alias to <code>bv</code> .
47	<code>ibv=0.001 A/Area</code>	Current at breakdown voltage.

Virtuoso Simulator Components and Device Models Reference

Diode Model (diode)

48	$nz=1$	Emission coefficient for Zener diode.
49	$bvj=\infty$ V	Voltage at which junction breakdown warning is issued.
50	$isr=0$ A/m ²	Recombination current parameter.
51	$ibvl=0$ A/m ²	Low-level reverse breakdown current.
52	$nbv=1$	Reverse breakdown ideality factor.
53	$nbvl=1$	Reverse breakdown ideality factor.

Parasitic resistance parameters

54	$rs=0$ Ω	Series resistance (/area).
55	$rsw=0$ Ω	Sidewall series resistance (/perim).
56	$gleak=0$ S	Bottom junction leakage conductance (*area).
57	$gleaksw=0$ S	Sidewall junction leakage conductance (*perim).
58	$minr=0.1$ Ω	Minimum series resistance.

Temperature effects parameters

59	$tlev=0$	DC temperature selector.
60	$tlevc=0$	AC temperature selector.
61	$eglev=0$	DC temperature selector.
62	$eg=1.11$ V	Band gap. Note: when not specified, the default value is temperature dependent. It is 1.11 at temp=27C.
63	$gap1=7.02e-4$ V/C	Band gap temperature coefficient.
64	$gap2=1108$ C	Band gap temperature offset.
65	$xTi=3$	Saturation current temperature exponent.
66	$tbvl=0$ 1/C	Linear temperature coefficient for bv .

Virtuoso Simulator Components and Device Models Reference

Diode Model (diode)

67	$tcv = `tbv11/C'$	Linear temperature coefficient for bv .
68	$tbv2=0 \text{ } C^{-2}$	Quadratic temperature coefficient for bv .
69	$tikf=0 \text{ } 1/C$	IKF temperature coefficient (linear).
70	$tnom \text{ (C)}$	Parameters measurement temperature. Default set by <code>options</code> .
71	$trise=0 \text{ } C$	Temperature rise from ambient.
72	$trs=0 \text{ } 1/C$	Linear temperature coefficient for parasitic resistance.
73	$trs1=0 \text{ } 1/C$	Alias of <code>trs</code> .
74	$tmod=tnom \text{ } C$	Model temperature.
75	$trs2=0 \text{ } C^{-2}$	Quadratic temperature coefficient for parasitic resistance.
76	$tgs=0 \text{ } 1/C$	Linear temperature coefficient for leakage conductance.
77	$tgs2=0 \text{ } C^{-2}$	Quadratic temperature coefficient for leakage conductance.
78	$cta=0 \text{ } 1/C$	Junction capacitance temperature coefficient.
79	$ctp=0 \text{ } 1/C$	Sidewall junction capacitance temperature coefficient.
80	$pta=0 \text{ } V/C$	Junction potential temperature coefficient.
81	$ptp=0 \text{ } V/C$	Sidewall junction potential temperature coefficient.
82	$ttt1=0.0 \text{ } 1/C$	1st order temp. coeff. for <code>tt hspice</code> .
83	$ttt2=0.0 \text{ } C^{-2}$	2st order temp. coeff. for <code>tt hspice</code> .
84	$tm1=0.0 \text{ } 1/C$	1st order temp. coeff. for <code>Mj hspice</code> .
85	$tm2=0.0 \text{ } C^{-2}$	2st order temp. coeff. for <code>Mj hspice</code> .

Junction diode model control parameters

86	$jmelt = `jmeltA/Area'$	Explosion current.
----	-------------------------	--------------------

Virtuoso Simulator Components and Device Models Reference

Diode Model (diode)

87	<code>imelt=`jmeltA'</code>	Alias to <code>jmelt</code> .
88	<code>expli=`jmeltA'</code>	Alias to <code>jmelt</code> .
89	<code>jmax=1 A/Area</code>	Maximum allowable current.
90	<code>imax=`jmaxA'</code>	Alias to <code>jmax</code> .
91	<code>dskip=yes</code>	Use simple piece-wise linear model for diode currents below $0.1 \cdot i_{abstol}$. Possible values are <code>no</code> or <code>yes</code> .

Fowler-Nordheim diode parameters

92	<code>if=1e-10 A/V^nf</code>	Forward Fowler-Nordheim current coefficient (*area).
93	<code>ir=`ifA/V^nr'</code>	Reverse Fowler-Nordheim current coefficient (*area).
94	<code>ecrf=2.55e10 V/m</code>	Forward critical field (For hspice compatible, the unit is V/cm, default value is $1.0e-8$).
95	<code>ecrr=`ecrfV/m'</code>	Reverse critical field (For hspice compatible, the unit is V/cm).
96	<code>ef=`ecrfV/m'</code>	Alias of <code>ecrf</code> .
97	<code>er=`ecrrV/m'</code>	Alias of <code>ecrr</code> .
98	<code>nf=2</code>	Forward voltage power.
99	<code>nr=`nf'</code>	Reverse voltage power.
100	<code>tox=1e-8 m</code>	Thickness of insulating layer.

TSMC Stand Alone model parameters

101	<code>rod=`rs'Ω</code>	Alias for <code>Rs</code> (Ohmic series resistance).
102	<code>jts=0 A/m²</code>	Bottom trap-assisted saturation current density (with <code>Level=1</code> and <code>StAlone flag=1</code>).
103	<code>jtssw=0 A/m²</code>	Sidewall trap-assisted saturation current density (with <code>Level=1</code> and <code>StAlone flag=1</code>).

Virtuoso Simulator Components and Device Models Reference

Diode Model (diode)

104	<code>mrs=0.4</code>	Fitting parameter for R_{seff} (with Level=1 and StAlone flag=1).
105	<code>njts=60</code>	Non-ideality factor for J_{ts} (with Level=1 and StAlone flag=1).
106	<code>njtssw=60</code>	Non-ideality factor for J_{tssw} (with Level=1 and StAlone flag=1).
107	<code>xts=0.055</code>	Power dependence of J_{ts} on temperature (with Level=1 and StAlone flag=1).
108	<code>xtssw=0.055</code>	Power dependence of J_{tssw} on temperature (with Level=1 and StAlone flag=1).
109	<code>tnjts=0.15</code>	Temperature coefficient for N_{jts} (with Level=1 and StAlone flag=1).
110	<code>tnjtssw=0.15</code>	Temperature coefficient for N_{jtssw} (with Level=1 and StAlone flag=1).
111	<code>trod=0</code>	Temperature coefficient for $R_{od}(R_s)$ (with Level=1 and StAlone flag=1).

Noise model parameters

112	<code>kf=0</code>	Flicker noise (1/f) coefficient.
113	<code>af=1</code>	Flicker noise (1/f) exponent.

Shrink Parameters

114	<code>shrink=1.0</code>	Shrink factor.
115	<code>shrink2=0.0</code>	Area shrink parameter.

Trap-assisted tunneling current parameters

116	<code>jtun=0 A</code>	Tunneling saturation current per area.
117	<code>jtunsw=0 A</code>	Sidewall tunneling saturation current per unit junction periphery.
118	<code>ntun=30</code>	Tunneling emission coefficient.
119	<code>xtitun=3.0</code>	Exponent for the tunneling current temperature.

Virtuoso Simulator Components and Device Models Reference

Diode Model (diode)

120 `egtun=eg` V Parameter for tunneling current at reverse region.

Safe Operating Areas Parameters

121 `bv_max=∞` V Maximum allowed voltage cross two terminals.

122 `fv_max=∞` V Maximum allowed forward voltage cross two terminals.

123 `keg=1.0` V The factor that is multiplied by EG to calculate the tunneling bandgap.

Both of these parameters have current density counterparts, `jmax` and `jmelt`, that you can specify if you want the absolute current values to depend on the device area.

Output Parameters

1 `bveff` (V) Effective reverse breakdown voltage.

Operating-Point Parameters

1 `region=on` Estimated operating region. Spectre outputs number (0-2) in a rawfile.
Possible values are `off`, `on`, and `breakdown`.

2 `v` (V) Extrinsic diode voltage.

3 `i` (A) Resistive diode current (alias=`lx1`).

4 `pwr` (W) Power dissipation.

5 `res` (Ω) Resistance of intrinsic diode.

6 `resp` (Ω) Resistance of intrinsic sidewall diode.

7 `cap` (F) Junction capacitance.

8 `capp` (F) Sidewall junction capacitance.

9 `cd` (F) Total junction capacitance (alias=`lx5`).

10 `ctotal` (F) Total junction capacitance (alias=`lx5`).

Virtuoso Simulator Components and Device Models Reference

Diode Model (diode)

11	gd (S)	Equivalent conductance (alias=lx2).
12	qd (Coul)	Charge of diode capacitor (alias=lx3).
13	vdio (V)	Voltage, across diode (VD), excluding RS (alias=lx0).

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

af	M-113	gleaksw	M-57	mrs	M-104	tm2	M-85
allow_scaling	M-21	i	OP-3	n	M-13	tmod	M-74
area	I-1	ibv	M-47	nbv	M-52	tnjts	M-109
area	M-19	ibvl	M-51	nbvl	M-53	tnjtssw	M-110
bv	M-45	if	M-92	nf	M-98	tnom	M-70
bv_max	M-121	ik	M-15	njts	M-105	tox	M-100
bveff	O-1	ikf	M-16	njtssw	M-106	trise	I-8
bvj	M-49	ikp	M-17	nr	M-99	trise	M-71
cap	OP-7	ikr	M-18	ns	M-14	trod	M-111
capp	OP-8	imax	M-90	ntun	M-118	trs	M-72
cd	M-23	imelt	M-87	nz	M-48	trs1	M-73
cd	OP-9	ir	M-93	pb	M-26	trs2	M-75
cjo	M-24	is	M-9	perim	I-2	tt	M-22

Virtuoso Simulator Components and Device Models Reference

Diode Model (diode)

cjp M-29	isnoisy I-13	perim M-20	ttt1 M-82
cjsw M-28	isp M-12	php M-31	ttt2 M-83
compatible M-3	isr M-50	pta M-80	v OP-2
cta M-78	isw M-11	ptp M-81	vb M-46
ctotal OP-10	jmax M-89	pwr OP-4	vdio OP-13
ctp M-79	jmelt M-86	qd OP-12	vj M-25
dcap M-2	js M-8	region I-7	vjmin M-44
dskip M-91	jsw M-10	region OP-1	vjsw M-30
ecrf M-94	jts M-102	res OP-5	w I-4
ecrr M-95	jtssw M-103	resp OP-6	w M-7
ef M-96	jtun M-116	rod M-101	wm I-11
eg M-62	jtunsw M-117	rs M-54	wm M-37
eglev M-61	keg M-123	rsw M-55	wp I-12
egtun M-120	kf M-112	scale I-6	wp M-38
er M-97	l I-3	shrink M-114	xm M-39
etch M-4	l M-6	shrink2 M-115	xoi M-41
etchl M-5	level M-1	tbv1 M-66	xom M-42
expli M-88	lm I-9	tbv2 M-68	xp M-40
fc M-33	lm M-35	tcv M-67	xti M-65
fcs M-34	lp I-10	tgs M-76	xtitun M-119
fv_max M-122	lp M-36	tgs2 M-77	xts M-107

Virtuoso Simulator Components and Device Models Reference

Diode Model (diode)

gap1	M-63	m	I-5	tikf	M-69	xtssw	M-108
gap2	M-64	m	M-27	tlev	M-59	xw	M-43
gd	OP-11	minr	M-58	tlevc	M-60		

BJT Model (bjt)

The BJT model is based on the Berkeley-Spice Gummel-Poon model. It defaults to the simpler Ebers-Moll model if certain parameters are left unspecified. This model also includes a substrate junction that connects either to the collector or to the base to model vertical and lateral structures.

This chapter contains the following information for the BJT model:

- [Device Regions](#) on page 276
- [DC Current](#) on page 276
- [Nonlinear Base Resistance](#) on page 278
- [Nonlinear Collector Resistance \(If \$r_{cv}\$ Is Specified\)](#) on page 278
- [Collector Leakage Current](#) on page 278
- [Substrate Leakage Current](#) on page 279
- [Charge and Capacitance](#) on page 279
- [Excess Phase](#) on page 280
- [Temperature Effect](#) on page 281
- [Noise Model](#) on page 289
- [Scaling Effects](#) on page 290
- [Device Regions](#) on page 276

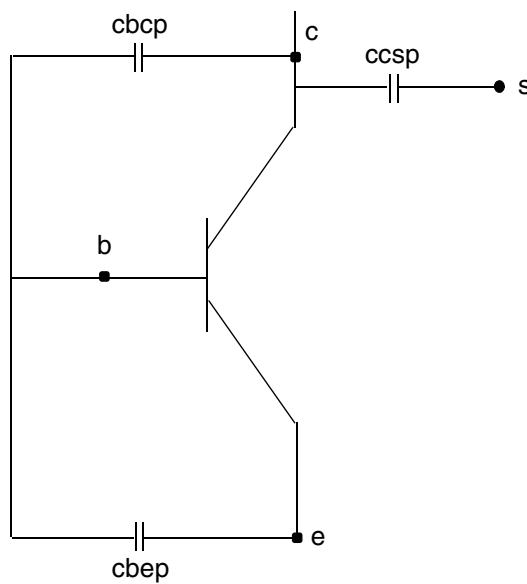
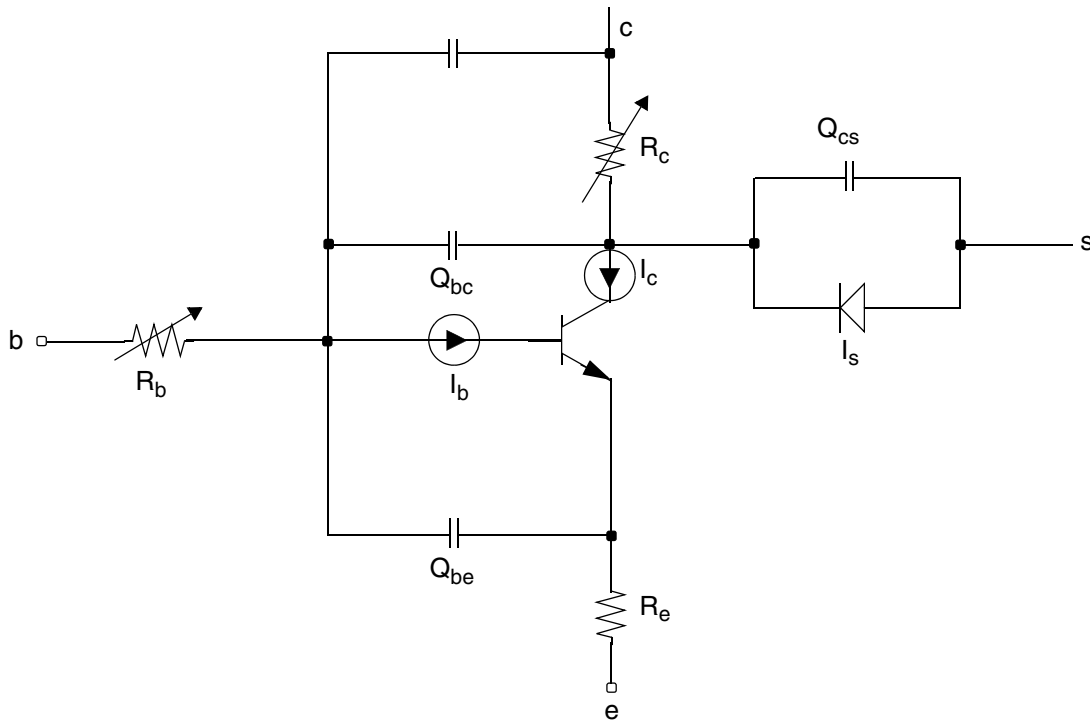
Note: When the Virtuoso® Spectre® circuit simulator option `approx` is set to `yes`, `pow()` in the junction depletion capacitance calculation and `sqrt()` in the BJT and MOSFET level 1-5 models are replaced by a spline-function approximation. For more information, see `spectre -h options`.

Virtuoso Simulator Components and Device Models Reference

BJT Model (bjt)

If `struct=vertical` (the default for NPN), the schematic of the model is given by one of the following figures:

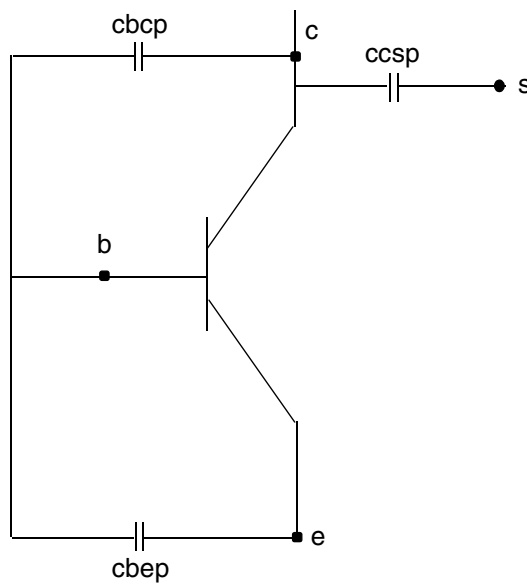
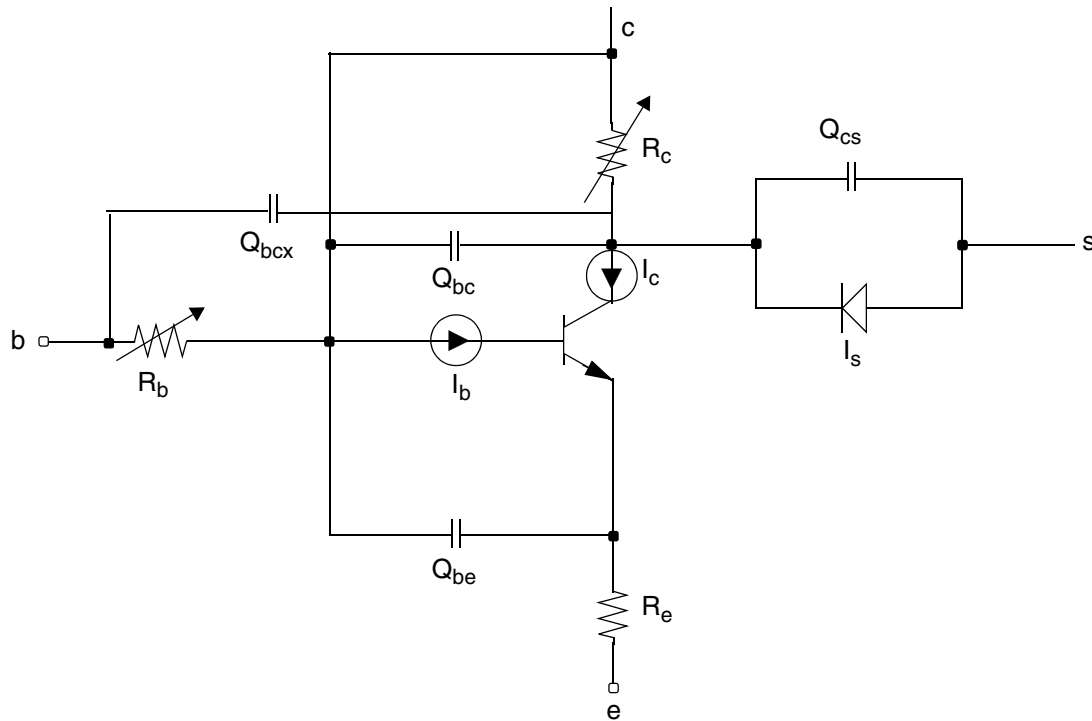
If `Cbcsplit2` or `Cbcsplit` is not specified:



Virtuoso Simulator Components and Device Models Reference

BJT Model (bjt)

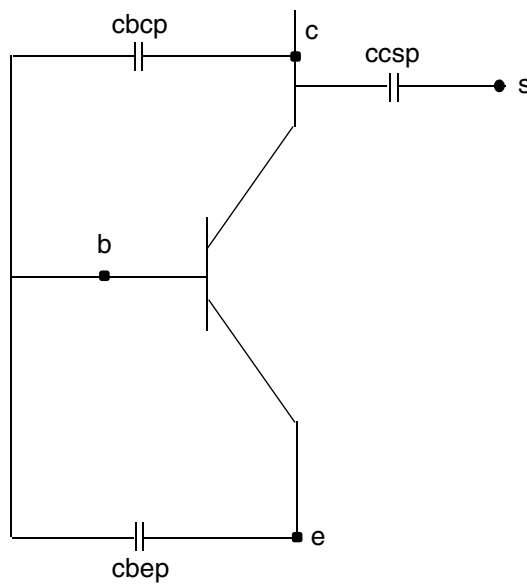
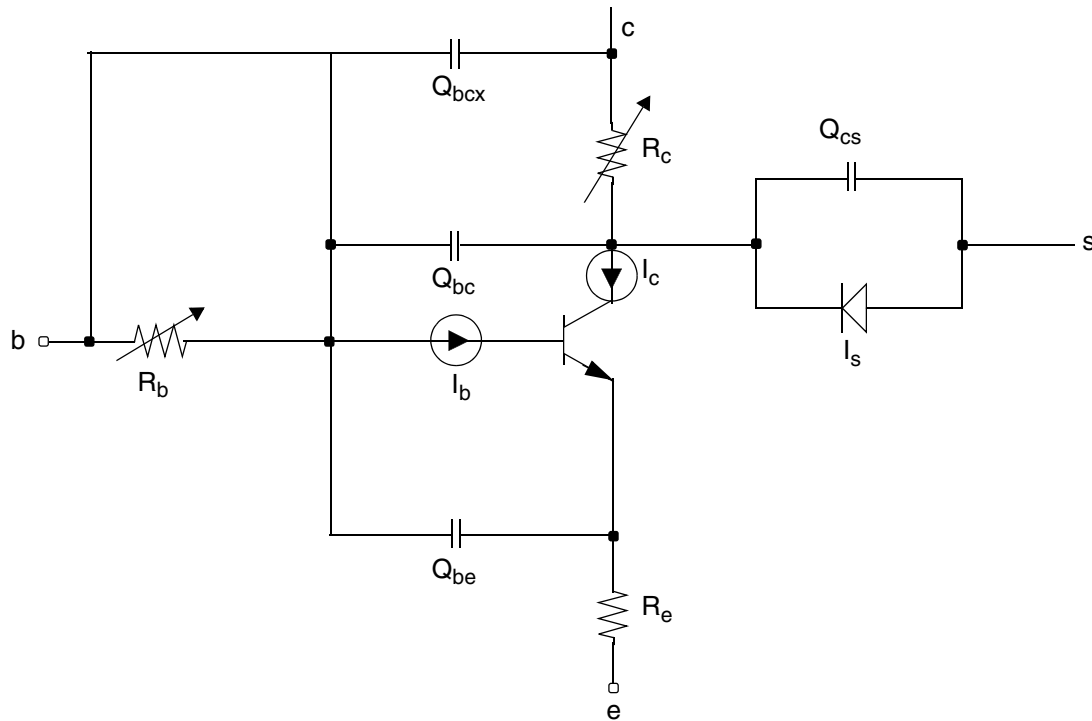
If Cbcsplit=xcjc:



Virtuoso Simulator Components and Device Models Reference

BJT Model (bjt)

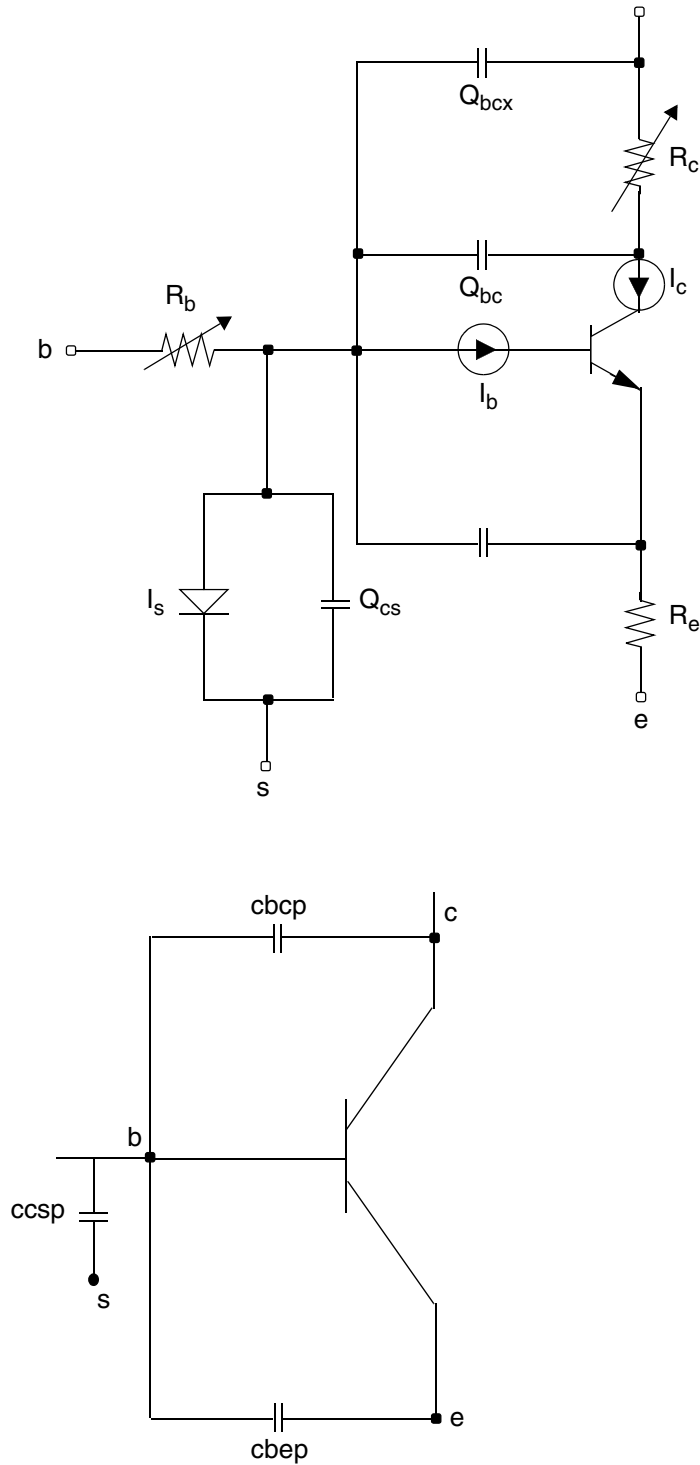
If Cbcsplit2=xcjc2



Virtuoso Simulator Components and Device Models Reference

BJT Model (bjt)

If `struct=lateral` (the default for PNP), the schematic of the model is given by



Device Regions

This section describes device regions for the BJT model.

The device region is	If
breakdown	<ul style="list-style-type: none"> ■ $bvsub$ is given and $V_{CS} \geq bvsub$ ■ $bvbe$ is given and $V_{BE} \leq bvbe$ ■ $bvce$ is given and $V_{CE} \geq bvce$
saturation	$V_{BE} > vbefwd$ and $V_{BC} > vbcfwd$
reverse	$V_{BC} > vbcfwd$ and $V_{BE} \leq vbefwd$
off	none of the above conditions are true

DC Current

$$I_c = \frac{i_s}{Q_B} \left(e^{\frac{V_{BE}}{n_f V_t}} - e^{\frac{V_{BC}}{n_r V_t}} \right) - I_{CB}$$

$$I_b = \frac{i_s}{\beta_f} \left(e^{\frac{V_{BE}}{n_f V_t}} - 1 \right) + i_s e \left(e^{\frac{V_{BE}}{n_e V_t}} - 1 \right) + I_{CB}$$

where V_t is the thermal voltage given by

$$V_t = \frac{kT}{q}$$

$$I_{CB} = \frac{i_s}{\beta_r} \left(e^{\frac{V_{BC}}{n_r V_t}} - 1 \right) + i_s c \left(e^{\frac{V_{BC}}{n_c V_t}} - 1 \right)$$

The intact equation for Q_B and n_kf is:

Virtuoso Simulator Components and Device Models Reference

BJT Model (bjt)

$$Q_B = \frac{Q_1}{2}(1 + (1 + 4Q_2)^{nkf})$$

When $nkf=0.5$, the QB equation is:

$$Q_B = \frac{Q_1}{2}(1 + \sqrt{1 + 4Q_2})$$

$$Q_1 = \begin{cases} \frac{1}{\frac{V_{BC}}{vaf} - \frac{V_{BE}}{var}} & \text{if neither } k_e \text{ or } k_c \text{ is specified} \\ \left(1 + \int_0^{V_{BE}} f_{cj}(k_e, v_{je}, m_{je}) dv + \int_0^{V_{BC}} f_{cj}(k_c, v_{jc}, m_{jc}) dv \right) & \text{otherwise} \end{cases}$$

where f_{cj} is defined as follows:

$$f_{cj}(C, P, M) = \begin{cases} \frac{C}{\left(1 - \frac{v}{P}\right)^M} & \text{if } v \leq fc * P \\ \frac{C}{(1 - fc)^{1+M}} \left[1 - fc(1 + M) + \frac{M}{P}v \right] & \text{otherwise} \end{cases}$$

$$Q_2 = \frac{is}{ikf} \left(e^{\frac{V_{BE}}{nfV_t}} - 1 \right) + \frac{is}{ikr} \left(e^{\frac{V_{BC}}{nrV_t}} - 1 \right)$$

If ise (isc) is not given and $C2$ ($C4$) is specified, ise (isc) is calculated from

$$ise = C2 \times is$$

$$isc = C4 \times is$$

Nonlinear Base Resistance

$$R_B = r_{bm} + \frac{rb - r_{bm}}{Q_B} \quad \text{if } irb \text{ is not given}$$

If irb is given and `rbmod = spice` or SPICE compatibility is required,

$$R_B = r_{bm} + 3(rb - r_{bm}) \frac{\tan(z) - z}{z \tan^2(z)}$$

where

$$z = \frac{-1 + \sqrt{1 + \frac{144I_b}{irb\pi^2}}}{\frac{24}{\pi^2} \sqrt{\frac{I_b}{irb}}}$$

If irb is given and `rbmod = spectre`,

$$R_B = r_{bm} + \frac{rb - r_{bm}}{\sqrt{1 + 3\left(\frac{I_b}{irb}\right)^{0.852}}}$$

Nonlinear Collector Resistance (If rcv Is Specified)

$$R_C = rcv \left[1 + \left(\frac{n_i}{dope} \right)^2 \left(e^{\frac{V_{BC}}{V_t}} \right) \right]^{-1} \left[1 + \left(\frac{I_c}{cco} \right)^{cex} \right] + r_{cm}$$

Collector Leakage Current

If vbo is specified, the collector leakage current I_{CB} for $V_{BC} \leq 0$ is modeled by

$$I_{CB} = (-cbo + gboV_{BC}) \left[1 - e^{\frac{V_{BC}}{vbo}} \right]$$

Note: To make the transition at $V_{BC} = 0$ smooth, vbo must satisfy

$$\frac{cbo}{vbo} = \frac{is}{br} \left(\frac{1}{nrV_t} \right) + \frac{isc}{ncV_t} \quad .$$

Substrate Leakage Current

$$I_S = iss \left(e^{\frac{V_{SC}}{nsV_t}} - 1 \right)$$

where V_{SC} is the substrate-to-collector voltage if `struct=vertical` or the base-to-substrate voltage if `struct=lateral`.

Charge and Capacitance

$$Q_{be} = \frac{tfI_{Fwd}}{Q_B} \left\{ 1 + (xtf)e^{\frac{V_{BC}}{\sqrt{2}vtf}} \left[\frac{I_{Fwd}}{I_{Fwd} + itf} \right]^2 \right\} + \int_0^{V_{BE}} f_{cj} \cdot (cje, vje, mje) dv$$

where

$$I_{Fwd} = is \left(e^{\frac{V_{BE}}{nfV_t}} - 1 \right)$$

Note: If `compatible() spectre`, the equation is as follows

$$Q_{be} = \frac{tfI_{Fwd}}{Q_B} \left\{ 1 + (xtf)e^{\frac{V_{BC}}{1.44vtf}} \left[\frac{I_{Fwd}}{I_{Fwd} + itf} \right]^2 \right\} + \int_0^{V_{BE}} f_{cj} \cdot (cje, vje, mje) dv$$

$$Q_{bc} = tr*is \left(e^{\frac{V_{BC}}{nrV_t}} - 1 \right) + xcjc \int_0^{V_{BC}} f_{cj} (cjc, vjc, mjc) dv$$

$$Q_{bcx} = (1 - xcjc) \int_0^{V_{BCX}} f_{cj} (cjc, vjc, mjc) dv$$

$$Q_{cs} = \begin{cases} \int_0^{V_{CS}} f_{cj} (cjs, vjs, mjs) dv & \text{if } mjs \text{ is specified} \\ cjs V_{CS} & \text{otherwise} \end{cases}$$

Excess Phase

In an actual device, the measured phase shift is often larger than the shift predicted by the lumped model. The excess-phase parameter *ptf* accounts for this extra phase shift at high frequencies. An all-pass, second-order Bessel function filter creates this extra phase shift. The frequency response of this filter is

$$\phi(s) = \frac{3\omega_0^2}{s^2 + 3\omega_0 s + 3\omega_0^2}$$

where

$$\omega_0 = \frac{180}{ptf \times tf \times \pi}$$

and the phase shift due to this filter is

$$\theta = \tan^{-1}(H)$$

$$H = \frac{3\omega\omega_0}{3\omega_0^2 - \omega^2}$$

The value of ptf is usually the excess phase shift of transconductance measured at frequency $f = 1/(2\pi tf)$. The value of ptf should not be less than zero. SPICE does not implement the actual Bessel filter, which requires two more internal nodes for each BJT device. Instead, SPICE uses second-order numerical integration in the device code. This approach sometimes causes convergence problems. However, to remain compatible with SPICE, the Spectre[®] circuit simulator follows the SPICE method.

Temperature Effect

Energy Gap

For $tlev=0, 1, \text{ or } 3$

$$E_{g,ref} = 1.16 - 7.02 \cdot 10^{-4} \cdot \frac{T_{nom}^2}{T_{nom} + 1108}$$

$$E_g = 1.16 - 7.02 \cdot 10^{-4} \cdot \frac{T^2}{T + 1108}$$

$$dV_{je}dT = -\frac{E_{g,ref} + 3V_{T,nom} + (1.16 - E_{g,ref})\left(2 - \frac{T_{nom}}{T_{nom} + 1108}\right) - V_{je}}{T_{nom}}$$

$$dV_{jc}dT = -\frac{E_{g,ref} + 3V_{T,nom} + (1.16 - E_{g,ref})\left(2 - \frac{T_{nom}}{T_{nom} + 1108}\right) - V_{jc}}{T_{nom}}$$

$$dV_{js}dT = -\frac{E_{g,ref} + 3V_{T,nom} + (1.16 - E_{g,ref})\left(2 - \frac{T_{nom}}{T_{nom} + 1108}\right) - V_{js}}{T_{nom}}$$

For $tlev=2$

Virtuoso Simulator Components and Device Models Reference

BJT Model (bjt)

$$E_{g,ref} = E_g - Gap_1 \cdot \frac{T_{nom}^2}{T_{nom} + Gap_2}$$

$$E_g = E_g - Gap_1 \cdot \frac{T^2}{T + Gap_2}$$

$$dV_{je}dT = - \frac{E_{g,ref} + 3V_{T,nom} + (E_g - E_{g,ref}) \left(2 - \frac{T_{nom}}{T_{nom} + Gap_2} \right) - V_{je}}{T_{nom}}$$

$$dV_{jc}dT = - \frac{E_{g,ref} + 3V_{T,nom} + (E_g - E_{g,ref}) \left(2 - \frac{T_{nom}}{T_{nom} + Gap_2} \right) - V_{jc}}{T_{nom}}$$

$$dV_{js}dT = - \frac{E_{g,ref} + 3V_{T,nom} + (E_g - E_{g,ref}) \left(2 - \frac{T_{nom}}{T_{nom} + Gap_2} \right) - V_{js}}{T_{nom}}$$

Saturation Current

For tlev=0 and tlev=2

$$I_{set} = \frac{I_{se}}{\left(\frac{T}{T_{nom}} \right)^{X_{TB}}} \cdot e^{LsT/Ne}$$

$$I_{sct} = \frac{I_{sc}}{\left(\frac{T}{T_{nom}} \right)^{X_{TB}}} \cdot e^{LsT/Nc}$$

Virtuoso Simulator Components and Device Models Reference

BJT Model (bjt)

$$I_{sst} = \frac{I_{ss}}{\left(\frac{T}{T_{nom}}\right)^{X_{TB}}} \cdot e^{LsT/Ns}$$

$$I_{bet} = I_{be} \cdot e^{LsT/Nf}$$

$$I_{bct} = I_{bc} \cdot e^{LsT/Nr}$$

$$I_{sT} = I_s \cdot e^{LsT}$$

For tlev=1

$$I_{set} = \frac{I_{se}}{1 + X_{TB} \cdot \Delta T} \cdot e^{LsT/Nc}$$

$$I_{sct} = \frac{I_{sc}}{1 + X_{TB} \cdot \Delta T} \cdot e^{LsT/Nc}$$

$$I_{sst} = \frac{I_{ss}}{1 + X_{TB} \cdot \Delta T} \cdot e^{LsT/Ns}$$

$$I_{bet} = I_{be} \cdot e^{LsT/Nf}$$

$$I_{bct} = I_{bc} \cdot e^{LsT/Nr}$$

$$I_{st} = I_s \cdot e^{LsT}$$

For tlev=3

$$I_{set} = I_{se}^{(1 + t_{ise1} \cdot \Delta T + t_{ise2} \cdot \Delta T^2)}$$

$$I_{sct} = I_{sc}^{(1 + t_{isc1} \cdot \Delta T + t_{isc2} \cdot \Delta T^2)}$$

Virtuoso Simulator Components and Device Models Reference

BJT Model (bjt)

$$I_{Sst} = I_{SS} (1 + t_{iss1} \cdot \Delta T + t_{iss2} \cdot \Delta T^2)$$

$$I_{bet} = I_{be} (1 + t_{is1} \cdot \Delta T + t_{is2} \cdot \Delta T^2)$$

$$I_{bct} = I_{bc} (1 + t_{is1} \cdot \Delta T + t_{is2} \cdot \Delta T^2)$$

$$I_{St} = I_S (1 + t_{is1} \cdot \Delta T + t_{is2} \cdot \Delta T^2)$$

Parameters I_{kf} , I_{kr} , and I_{rb} are modified as follows.

For $tlev=0$, 1, or 2

$$I_{kfT} = I_{kf} \cdot (1 + t_{ikf1} \Delta T + t_{ikf2} \Delta T^2)$$

$$I_{krT} = I_{kr} \cdot (1 + t_{ikr1} \Delta T + t_{ikr2} \Delta T^2)$$

$$I_{rbT} = I_{rb} \cdot (1 + t_{irb1} \Delta T + t_{irb2} \Delta T^2)$$

For $tlev=3$

$$I_{kfT} = I_{kf}^{1 + t_{ikf1} \Delta T + t_{ikf2} \Delta T^2}$$

$$I_{krT} = I_{kr}^{1 + t_{ikr1} \Delta T + t_{ikr2} \Delta T^2}$$

$$I_{rbT} = I_{rb}^{1 + t_{irb1} \Delta T + t_{irb2} \Delta T^2}$$

Degree Factor

For $tlev=0$, 1, or 3

Virtuoso Simulator Components and Device Models Reference

BJT Model (bjt)

$$L_{sT} = \frac{E_g}{V_{Tnom}} - \frac{E_g}{V_T} + X_{TI} \cdot \ln\left(\frac{T}{Tnom}\right)$$

For tlev=2

$$L_{sT} = \frac{E_{g,ref}}{V_{Tnom}} - \frac{E_g}{V_T} + X_{TI} \cdot \ln\left(\frac{T}{Tnom}\right)$$

Current Gains (B_f , B_r)

For tlev=0, 2, or 3

$$B_{fT} = B_f \cdot \left(\frac{T}{Tnom}\right)^{X_{TB}}$$

$$B_{rT} = B_r \cdot \left(\frac{T}{Tnom}\right)^{X_{TB}}$$

For tlev=1

$$B_{fT} = B_f \cdot (1 + X_{TB}\Delta T)$$

$$B_{rT} = B_r \cdot (1 + X_{TB}\Delta T)$$

If coefficients are specified,

$$B_f(T) = B_{fT} \cdot (1 + t_{Bf1}\Delta T + t_{Bf2}\Delta T^2)$$

$$B_r(T) = B_{rT} \cdot (1 + t_{Br1}\Delta T + t_{Br2}\Delta T^2)$$

$$V_{afT} = V_{af} \cdot (1 + t_{vaf1}\Delta T + t_{vaf2}\Delta T^2)$$

$$V_{arT} = V_{ar} \cdot (1 + t_{var1}\Delta T + t_{var2}\Delta T^2)$$

Virtuoso Simulator Components and Device Models Reference

BJT Model (bjt)

$$t_{fT} = t_f \cdot (1 + t_{tf1}\Delta T + t_{tf2}\Delta T^2)$$

$$t_{rT} = t_r \cdot (1 + t_{tr1}\Delta T + t_{tr2}\Delta T^2)$$

$$N_{fT} = N_f \cdot (1 + t_{nf1}\Delta T + t_{nf2}\Delta T^2)$$

$$N_{rT} = N_r \cdot (1 + t_{nr1}\Delta T + t_{nr2}\Delta T^2)$$

$$N_{eT} = N_e \cdot (1 + t_{ne1}\Delta T + t_{ne2}\Delta T^2)$$

$$N_{cT} = N_c \cdot (1 + t_{nc1}\Delta T + t_{nc2}\Delta T^2)$$

$$N_{sT} = N_s \cdot (1 + t_{ns1}\Delta T + t_{ns2}\Delta T^2)$$

$$M_{jeT} = M_{je} \cdot (1 + t_{mje1}\Delta T + t_{mje2}\Delta T^2)$$

$$M_{jcT} = M_{jc} \cdot (1 + t_{mjc1}\Delta T + t_{mjc2}\Delta T^2)$$

$$M_{jsT} = M_{js} \cdot (1 + t_{mjs1}\Delta T + t_{mjs2}\Delta T^2)$$

$$t_{dT} = t_d \cdot (1 + t_{td1}\Delta T + t_{td2}\Delta T^2)$$

$$I_{tfT} = I_{tf} \cdot (1 + t_{itf1}\Delta T + t_{itf2}\Delta T^2)$$

$$X_{tfT} = X_{tf} \cdot (1 + t_{xtf1}\Delta T + t_{xtf2}\Delta T^2)$$

$$V_{tfT} = V_{tf} \cdot (1 + t_{vtf1}\Delta T + t_{vtf2}\Delta T^2)$$

Junction Capacitors (cjc, cje, and cjs)

For tlevc=0

$$C_{jeT} = C_{je} \left[1 + M_{je} \cdot \left(400 \cdot 10^{-6} \Delta T + 1 - \frac{V_{jeT}}{V_{je}} \right) \right]$$

where

$$V_{jeT} = V_{je} \frac{T}{T_{nom}} - 3V_T \cdot \ln \frac{T}{T_{nom}} + E_{g,ref} \frac{T}{T_{nom}} - E_g$$

$$C_{jcT} = C_{jc} \left[1 + M_{jc} \cdot \left(400 \cdot 10^{-6} \Delta T + 1 - \frac{V_{jcT}}{V_{jc}} \right) \right]$$

where

$$V_{jcT} = V_{jc} \frac{T}{T_{nom}} - 3V_T \cdot \ln \frac{T}{T_{nom}} + E_{g,ref} \frac{T}{T_{nom}} - E_g$$

$$C_{jsT} = C_{js} \left[1 + M_{js} \cdot \left(400 \cdot 10^{-6} \Delta T + 1 - \frac{V_{jsT}}{V_{js}} \right) \right]$$

where

$$V_{jsT} = V_{js} \frac{T}{T_{nom}} - 3V_T \cdot \ln \frac{T}{T_{nom}} + E_{g,ref} \frac{T}{T_{nom}} - E_g$$

For tlevc=1

$$C_{jeT} = C_{je} \cdot (1 + C_{te} \Delta T)$$

where

$$V_{jeT} = V_{je} - t_{vje} \Delta T$$

$$C_{jcT} = C_{jc} \cdot (1 + C_{te} \Delta T)$$

where

Virtuoso Simulator Components and Device Models Reference

BJT Model (bjt)

$$V_{jcT} = V_{jc} - t_{vjc}\Delta T$$

$$C_{jsT} = C_{js} \cdot (1 + C_{ts}\Delta T)$$

where

$$V_{jsT} = V_{js} - t_{vjs}\Delta T$$

For tlevc=2

$$C_{jeT} = C_{je} \cdot \left(\frac{V_{je}}{V_{jeT}} \right)^{M_{je}}$$

where

$$V_{jeT} = V_{je} - t_{vje}\Delta T$$

$$C_{jcT} = C_{jc} \cdot \left(\frac{V_{jc}}{V_{jcT}} \right)^{M_{jc}}$$

where

$$V_{jcT} = V_{jc} - t_{vjc}\Delta T$$

$$C_{jsT} = C_{js} \cdot \left(\frac{V_{js}}{V_{jsT}} \right)^{M_{js}}$$

where

$$V_{jsT} = V_{js} - t_{vjs}\Delta T$$

For tlevc=3

$$C_{jeT} = C_{je} \cdot \left(1 - 0.5 \cdot dV_{je} dT \frac{\Delta T}{V_{je}} \right)$$

where

$$V_{jeT} = V_{je} + dV_{je} dT \Delta T$$

$$C_{jcT} = C_{jc} \cdot \left(1 - 0.5 \cdot dV_{jc} dT \frac{\Delta T}{V_{jc}}\right)$$

where

$$V_{jcT} = V_{jc} + dV_{jc} dT \Delta T$$

$$C_{jsT} = C_{js} \cdot \left(1 - 0.5 \cdot dV_{js} dT \frac{\Delta T}{V_{js}}\right)$$

where

$$V_{jsT} = V_{js} + dV_{js} dT \Delta T$$

Parasitic Resistors (rb, rc, and re)

$$R_{eT} = R_e \cdot (1 + t_{re1} \Delta T + t_{re2} \Delta T^2)$$

$$R_{cT} = R_c \cdot (1 + t_{rc1} \Delta T + t_{rc2} \Delta T^2)$$

$$R_{sT} = R_s \cdot (1 + t_{rs1} \Delta T + t_{rs2} \Delta T^2)$$

$$R_{bmT} = R_{bm} \cdot (1 + t_{rm1} \Delta T + t_{rm2} \Delta T^2)$$

Noise Model

Base Resistance Thermal Noise

$$\overline{i_{R_B}^2} = \begin{cases} \frac{4kT r_{bnoi}}{R_B R_B} \Delta f & \text{if } r_{bnoi} \text{ is specified} \\ \frac{4kt}{R_B} \Delta f & \text{otherwise} \end{cases}$$

Collector Resistance Thermal Noise

$$\overline{i_{R_C}^2} = \frac{4kT}{R_C} \Delta f$$

Emitter Resistance Thermal Noise

$$\overline{i_{R_E}^2} = \frac{4kT}{R_E} \Delta f$$

Collector Shot Noise Source

$$\overline{i_C^2} = 2qI_C \Delta f$$

Base Shot, Flicker, and Burst Noise Sources

$$\overline{i_B^2} = 2qI_B \Delta f + kf \frac{I_B^{af}}{f} \Delta f + kb \frac{I_B}{1 + (f/f_c)^2} \Delta f$$

where kf , af , kb , and fc are constants for a given device. The Spectre defaults for these constants are 0.0, 1.0, 0.0, and 1.0 respectively.

Scaling Effects

This model has the following enhancements over SPICE2G.6:

1. Two base resistance models are provided.
2. Nonlinear collector resistance is implemented.
3. The integral form of the Early voltage effect is available.
4. The substrate junction includes both the diode and the capacitor.

This device is supported within altergroups.

Virtuoso Simulator Components and Device Models Reference

BJT Model (bjt)

Sample Instance Statement:

```
q1 (vcc net3 minus) npn_mod region=fwd area=1 m=1
```

Sample Model Statement:

```
model npn_mod bjt type=npn is=10e-13 bf=200 va=58.8 ikf=5.63e-3 rb=700 rbm=86  
re=3.2 cje=0.352e-12 pe=0.76 me=0.34 tf=249e-12 cjc=0.34e-12 pc=0.55
```

Instance Definition

```
Name c b e [s] ModelName parameter=value ...
```

You do not have to specify the substrate terminal. If you do not specify it, the substrate is connected to ground.

Instance Parameters

1	area=1	Transistor area factor (alias=lv1).
2	areab=1	Transistor areab factor.
3	areac=1	Transistor areac factor.
4	m=1	Multiplicity factor.
5	trise	Temperature rise from ambient.
6	region=fwd	Estimated operating region. Spectre outputs number (0-4) in a rawfile. Possible values are off, fwd, rev, sat, or breakdown.
7	isnoisy=yes	Should device generate noise. Possible values are no or yes.

Model Definition

```
model modelName bjt parameter=value ...
```

Model Parameters

Structural parameters

1	type=npn	Transistor type. Possible values are npn and pnp.
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Virtuoso Simulator Components and Device Models Reference

BJT Model (bjt)

- 2 `struct=vertical` Transistor structure. For pnp, the default is `lateral`. Possible values are `vertical` and `lateral`.
- 3 `subs=1` Transistor structure. 1 for Vertical structure and 0 for lateral structure.

Saturation current parameters

- 4 `is=1e-16 A` Saturation current (*area).
- 5 `ise=0 A` B-E leakage saturation current. Set to $c2 * is$ if not given. (*area).
- 6 `isc=0 A` B-C leakage saturation current. Set to $c4 * is$ if not given. (*area).
- 7 `iss=0 A` Substrate leakage saturation current (*area).
- 8 `c2=0` Forward leakage saturation current coefficient.
- 9 `c4=0` Reverse leakage saturation current coefficient.
- 10 `nkf=0.5` Qb exponent parameter.
- 11 `nk=nkf` Qb exponent parameter, alias of `nkf`.

B-C leakage model parameters

- 12 `cbo=0 A` Extrapolated 0-volt B-C leakage current (*area).
- 13 `gbo=0 S` Slope of I_{cbo} vs. V_{bc} above V_{bo} (*area).
- 14 `vbo=0 V` Slope of I_{cbo} vs. V_{bc} at $V_{bc}=0$.
- 15 `tcbo=0 1/C` Temperature coefficient for `cbo`.
- 16 `tgbo=0 1/C` Temperature coefficient for `gbo`.

Emission coefficient parameters

- 17 `nf=1` Forward emission coefficient.

Virtuoso Simulator Components and Device Models Reference

BJT Model (bjt)

18	$nr=1$	Reverse emission coefficient.
19	$ne=1.5$	B-E leakage emission coefficient.
20	$nc=2$	B-C leakage emission coefficient.
21	$ns=1$	Substrate junction emission coefficient.

Current gain parameters

22	$bf=100$ A/A	Forward current gain (beta).
23	bfm (A/A)	Forward current gain (beta).
24	$br=1$ A/A	Reverse current gain (beta).
25	brm (A/A)	Reverse current gain (beta).
26	$ikf=\infty$ A	High current corner for forward beta (*area).
27	$ik=\infty$ A	High current corner for forward beta (*area).
28	$jbf=\infty$ A	High current corner for forward beta (*area).
29	$ikr=\infty$ A	High current corner for reverse beta (*area).
30	jbr (A)	High current corner for reverse beta (*area).

Early voltage parameters

31	$vaf=\infty$ V	Forward Early voltage.
32	$va=\infty$ V	Forward Early voltage.
33	$var=\infty$ V	Reverse Early voltage.
34	$vb=\infty$ V	Reverse Early voltage.
35	$ke=0$ 1/V	B-E space-charge integral multiplier.
36	$kc=0$ 1/V	B-C space-charge integral multiplier.

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BJT Model (bjt)

Parasitic resistance parameters

37	$r_{b=0} \Omega$	Zero-bias base resistance (/area).
38	$r_{bm}=r_b \Omega$	Minimum base resistance for high currents (/area).
39	$i_{rb}=\infty \text{ A}$	Current at base resistance midpoint (*area).
40	$j_{rb} \text{ (A)}$	Current at base resistance midpoint (*area).
41	$i_{ob} \text{ (A)}$	Current at base resistance midpoint (*area).
42	$r_{bmod}=spice$	Nonlinear R_b model. Possible values are <code>spectre</code> and <code>spice</code> .
43	$r_c=0 \Omega$	Collector resistance (/area).
44	$r_{cv}=0 \Omega$	Variable collector resistance (/area), only works when its value is given.
45	$r_{cm}=0 \Omega$	Minimum collector resistance (/area).
46	$dope=1e15 \text{ cm}^{-3}$	Collector background doping concentration.
47	$cex=1$	Current crowding exponent.
48	$cco=1 \text{ A}$	Current crowding normalization constant (*area).
49	$r_e=0 \Omega$	Emitter resistance (/area).
50	$minr=0.1 \Omega$	Minimum parasitic resistance.

Junction capacitance parameters

51	$dcap=2$	Depletion capacitance model selector.
52	$c_{je}=0 \text{ F}$	B-E zero-bias junction capacitance (*area).
53	$v_{je}=0.75 \text{ V}$	B-E built-in junction potential.
54	$m_{je}=1/3$	B-E junction exponent.
55	$p_e=0.75 \text{ V}$	B-E built-in junction potential.

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BJT Model (bjt)

56	$m_e=1/3$	B-E junction exponent.
57	$c_{jc}=0$ F	B-C zero-bias junction capacitance (*area).
58	$v_{jc}=0.75$ V	B-C built-in junction potential.
59	$m_{jc}=1/3$	B-C junction exponent.
60	$p_c=0.75$ V	B-C built-in junction potential.
61	$m_c=1/3$	B-C junction exponent.
62	$x_{cjc}=1$	Fraction of B-C capacitance tied to internal base node.
63	$x_{cjc2}=1$	Fraction of B-C capacitance tied to collector and fraction of B-C tied to internal node.
64	$c_{js}=0$ F	B-S zero-bias junction capacitance (*area).
65	$c_{cs}=0$ F	B-S zero-bias junction capacitance (*area).
66	c_{sub} (F)	B-S zero-bias junction capacitance (*area).
67	$v_{js}=0.75$ V	B-S built-in junction potential.
68	$m_{js}=0$	B-S junction exponent.
69	$p_s=0.75$ V	B-S built-in junction potential.
70	p_{sub} (V)	B-S built-in junction potential.
71	$m_s=0$	B-S junction exponent.
72	e_{sub}	B-S junction exponent.
73	$f_c=0.5$	Junction capacitor forward-bias threshold.
74	$c_{bcp}=0$ F	B-C parasitic capacitance.
75	$c_{bep}=0$ F	B-E parasitic capacitance.
76	$c_{csp}=0$ F	C-S parasitic capacitance.

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BJT Model (bjt)

Transit time and excess phase parameters

77	$t_f=0$ s	Ideal forward transit time.
78	$t_d=0$ s	Intrinsic base delay time.
79	$x_{tf}=0$	Coefficient for bias dependence of t_f .
80	$v_{tf}=\infty$ V	Voltage describing V_{bc} dependence of t_f .
81	$i_{tf}=0$ A	High current parameter for effect on t_f (*area).
82	j_{tf} (A)	High current parameter for effect on t_f (*area).
83	$t_r=0$ s	Ideal reverse transit time.
84	$p_{tf}=0$ °	Excess phase at freq = $1.0/(t_f*2 \text{ pi})$ Hz.

Temperature effects parameters

85	t_{nom} (C)	Parameters measurement temperature. Default set by <code>options</code> .
86	t_{ref} (C)	TNOMs alias.
87	$t_{rise}=0$ C	Temperature rise from ambient.
88	$e_g=1.11$ V	Band-gap.
89	$x_{tb}=0$	Beta temperature exponent.
90	$x_{ti}=3$	Temperature exponent for effect on i_s .
91	p_t	Temperature exponent for effect on i_s .
92	$t_{rb1}=0$ 1/C	Linear temperature coefficient for the base resistor.
93	$t_{rb2}=0$ C ⁻²	Quadratic temperature coefficient for the base resistor.
94	$t_{rm1}=0$ 1/C	Linear temperature coefficient for the minimum base resistor.
95	$t_{rm2}=0$ C ⁻²	Quadratic temperature coefficient for the minimum base resistor.
96	$t_{rc1}=0$ 1/C	Linear temperature coefficient for the collector resistor.

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BJT Model (bjt)

97	$\text{trc2}=0 \text{ C}^{-2}$	Quadratic temperature coefficient for the collector resistor.
98	$\text{tre1}=0 \text{ 1/C}$	Linear temperature coefficient for the emitter resistor.
99	$\text{tre2}=0 \text{ C}^{-2}$	Quadratic temperature coefficient for the emitter resistor.
100	$\text{tlev}=0$	DC temperature selector.
101	$\text{tlevc}=0$	AC temperature selector.
102	$\text{eglev}=0$	DC temperature selector.
103	$\text{gap1}=7.02\text{e-}4 \text{ V/C}$	Band-gap temperature coefficient.
104	$\text{gap2}=1108 \text{ C}$	Band-gap temperature offset.
105	$\text{tikf1}=0 \text{ 1/C}$	Linear temperature coefficient for i_{kf} .
106	$\text{tikf2}=0 \text{ C}^{-2}$	Quadratic temperature coefficient for i_{kf} .
107	$\text{tikr1}=0 \text{ 1/C}$	Linear temperature coefficient for i_{kr} .
108	$\text{tikr2}=0 \text{ C}^{-2}$	Quadratic temperature coefficient for i_{kr} .
109	$\text{tirb1}=0 \text{ 1/C}$	Linear temperature coefficient for i_{rb} .
110	$\text{tirb2}=0 \text{ C}^{-2}$	Quadratic temperature coefficient for i_{rb} .
111	$\text{tis1}=0 \text{ 1/C}$	Linear temperature coefficient for i_s .
112	$\text{tis2}=0 \text{ C}^{-2}$	Quadratic temperature coefficient for i_s .
113	$\text{tise1}=0 \text{ 1/C}$	Linear temperature coefficient for i_{se} .
114	$\text{tise2}=0 \text{ C}^{-2}$	Quadratic temperature coefficient for i_{se} .
115	$\text{tisc1}=0 \text{ 1/C}$	Linear temperature coefficient for i_{sc} .
116	$\text{tisc2}=0 \text{ C}^{-2}$	Quadratic temperature coefficient for i_{sc} .
117	$\text{tiss1}=0 \text{ 1/C}$	Linear temperature coefficient for i_{ss} .
118	$\text{tiss2}=0 \text{ C}^{-2}$	Quadratic temperature coefficient for i_{ss} .

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BJT Model (bjt)

119	$t_{bf1}=0$	1/C	Linear temperature coefficient for b_f .
120	$t_{bf2}=0$	C^{-2}	Quadratic temperature coefficient for b_f .
121	$t_{br1}=0$	1/C	Linear temperature coefficient for b_r .
122	$t_{br2}=0$	C^{-2}	Quadratic temperature coefficient for b_r .
123	$t_{vaf1}=0$	1/C	Linear temperature coefficient for v_{af} .
124	$t_{vaf2}=0$	C^{-2}	Quadratic temperature coefficient for v_{af} .
125	$t_{var1}=0$	1/C	Linear temperature coefficient for v_{ar} .
126	$t_{var2}=0$	C^{-2}	Quadratic temperature coefficient for v_{ar} .
127	$t_{itf1}=0$	1/C	Linear temperature coefficient for i_{tf} .
128	$t_{itf2}=0$	C^{-2}	Quadratic temperature coefficient for i_{tf} .
129	$t_{tf1}=0$	1/C	Linear temperature coefficient for t_f .
130	$t_{tf2}=0$	C^{-2}	Quadratic temperature coefficient for t_f .
131	$t_{tr1}=0$	1/C	Linear temperature coefficient for t_r .
132	$t_{tr2}=0$	C^{-2}	Quadratic temperature coefficient for t_r .
133	$t_{nf1}=0$	1/C	Linear temperature coefficient for n_f .
134	$t_{nf2}=0$	C^{-2}	Quadratic temperature coefficient for n_f .
135	$t_{nr1}=0$	1/C	Linear temperature coefficient for n_r .
136	$t_{nr2}=0$	C^{-2}	Quadratic temperature coefficient for n_r .
137	$t_{ne1}=0$	1/C	Linear temperature coefficient for n_e .
138	$t_{ne2}=0$	C^{-2}	Quadratic temperature coefficient for n_e .
139	$t_{nc1}=0$	1/C	Linear temperature coefficient for n_c .
140	$t_{nc2}=0$	C^{-2}	Quadratic temperature coefficient for n_c .

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BJT Model (bjt)

141	$t_{ns1}=0$	1/C	Linear temperature coefficient for n_s .
142	$t_{ns2}=0$	C^{-2}	Quadratic temperature coefficient for n_s .
143	$t_{mje1}=0$	1/C	Linear temperature coefficient for m_{j_e} .
144	$t_{mje2}=0$	C^{-2}	Quadratic temperature coefficient for m_{j_e} .
145	$t_{mj_c1}=0$	1/C	Linear temperature coefficient for m_{j_c} .
146	$t_{mj_c2}=0$	C^{-2}	Quadratic temperature coefficient for m_{j_c} .
147	$t_{mjs1}=0$	1/C	Linear temperature coefficient for m_{j_s} .
148	$t_{mjs2}=0$	C^{-2}	Quadratic temperature coefficient for m_{j_s} .
149	$c_{t_e}=0$	1/C	Temperature coefficient for c_{j_e} .
150	$c_{t_c}=0$	1/C	Temperature coefficient for c_{j_c} .
151	$c_{t_s}=0$	1/C	Temperature coefficient for c_{j_s} .
152	$t_{v_{j_e}}=0$	V/C	Temperature coefficient for v_{j_e} .
153	$t_{v_{j_c}}=0$	V/C	Temperature coefficient for v_{j_c} .
154	$t_{v_{j_s}}=0$	V/C	Temperature coefficient for v_{j_s} .
155	$t_{v_{t_f1}}=0$	1/C	Linear temperature coefficient for v_{t_f} .
156	$t_{v_{t_f2}}=0$	C^{-2}	Quadratic temperature coefficient for v_{t_f} .
157	$t_{x_{t_f1}}=0$	1/C	Linear temperature coefficient for x_{t_f} .
158	$t_{x_{t_f2}}=0$	C^{-2}	Quadratic temperature coefficient for x_{t_f} .

Junction diode model control parameters

159	$d_{skip}=yes$		Skip junction calculations if they are reverse-saturated. Possible values are <code>no</code> and <code>yes</code> .
160	$i_{melt}=i_{max}$	A	Junction explosion current (*area).

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BJT Model (bjt)

Operating region warning control parameters

161	$bvbe=\infty$ V	B-E breakdown voltage.
162	$bvbc=\infty$ V	B-C breakdown voltage.
163	$bvce=\infty$ V	C-E breakdown voltage.
164	$bvsub=\infty$ V	Substrate junction breakdown voltage.
165	$vbefwd=0.2$ V	B-E forward voltage.
166	$vbcfwd=0.2$ V	B-C forward voltage.
167	$vsubfwd=0.2$ V	Substrate junction forward voltage.
168	$imax=1e3$ A	Maximum allowable base current (*area).
169	$imax1=imax$ A	Maximum allowable collector current (*area).
170	$alarm=none$	Forbidden operating region. Possible values are <code>none</code> , <code>off</code> , <code>fwd</code> , <code>rev</code> , and <code>sat</code> .

Noise model parameters

171	$kf=0$	Flicker (1/f) noise coefficient.
172	$af=1$	Flicker (1/f) noise exponent.
173	$kb=0$	Burst noise coefficient.
174	$bnoiseFc=1$	Burst noise cutoff frequency.
175	$rbnoi=rb$ Ω	Effective base noise resistance.

DC-mismatch model parameters

176	$mvt0=0.0$ V	Threshold mismatch intercept.
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Compatibility model parameters

- 177 `compatible=spectre` Encourage device equations to be compatible with a foreign simulator. This option does not affect input syntax. Possible values are `spectre`, `spice2`, `spice3`, `cdsspice`, `hspice`, `spiceplus`, `eldo`, `sspice`, and `mica`.
- 178 `updatelevel=0` Model update selector. The available versions are 0, 1.

Shrink Parameters

Safe Operating Areas Parameters

- 179 `vbe_max=∞ V` Maximum allowed voltage cross base and emitter.
- 180 `vbc_max=∞ V` Maximum allowed voltage cross base and collector.
- 181 `vce_max=∞ V` Maximum allowed voltage cross collector and emitter.
- 182 `vcs_max=∞ V` Maximum allowed voltage cross collector and substrate.

Auto Model Selector parameters

- 183 `areamax=0` Maximum transistor area factor for which the model is valid.
- 184 `areamin=1` Minimum transistor area factor for which the model is valid.

Imax and Imelt

The ``imax'` parameter aids convergence and prevents numerical overflow. The junction characteristics of the device are accurately modeled for current up to ``imax'`. If ``imax'` is exceeded during iterations, the linear model is substituted until the current drops below `'imax'` or until convergence is achieved. If convergence is achieved with the current exceeding ``imax'`, the results are inaccurate, and a warning is printed out.

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BJT Model (bjt)

A separate model parameter, ``imelt'`, is used as a limit warning for the junction current. This parameter can be set to the maximum current rating of the device. When any component of the junction current exceeds ``imelt'`, note that base and collector currents are composed of many exponential terms, a warning will be issued and the results become inaccurate. The junction current is linearized above the value of ``imelt'` to prevent arithmetic exception, with the exponential term replaced by a linear equation at ``imelt'`.

Output Parameters

1	<code>ibeeff</code> (Ohm)	The effective reverse saturation current of BE.
2	<code>ibceff</code> (Ohm)	The effective reverse saturation current of BC.
3	<code>iseeff</code> (Ohm)	The effective leakage saturation current of BE.
4	<code>isceff</code> (Ohm)	The effective leakage saturation current of BC.
5	<code>isseff</code> (Ohm)	The effective reverse saturation current of bulk-collector or bulk-base.

Operating Point Parameters

1	<code>type=npn</code>	Transistor type. Possible values are <code>npn</code> and <code>pnp</code> .
2	<code>struct=vertical</code>	Transistor structure. For <code>pnp</code> , default is <code>lateral</code> . Possible values are <code>vertical</code> and <code>lateral</code> .
3	<code>region=fwd</code>	Estimated operating region. Spectre outputs number (0-4) in a rawfile. Possible values are <code>off</code> , <code>fwd</code> , <code>rev</code> , <code>sat</code> , and <code>breakdown</code> .
4	<code>vbe</code> (V)	Base-emitter voltage (alias= <code>lx0</code>).
5	<code>vbc</code> (V)	Base-collector voltage (alias= <code>lx1</code>).
6	<code>vce</code> (V)	Collector-emitter voltage.
7	<code>vsub</code> (V)	Substrate junction voltage (alias= <code>lx24</code>).
8	<code>ic</code> (A)	Resistive collector current (alias= <code>lx2</code>).

Virtuoso Simulator Components and Device Models Reference

BJT Model (bjt)

9	i_b (A)	Resistive base current (alias=lx3).
10	i_{sub} (A)	Resistive substrate current (alias=lv6).
11	pwr (W)	Power dissipation.
12	β_{adc} (A/A)	Ratio of resistive collector current to resistive base current (alias=lv10).
13	β_{aac} (A/A)	Small-signal common-emitter current gain.
14	g_m (S)	Common-emitter transconductance (alias=lx6).
15	r_{pi} (Ω)	Common-emitter input resistance.
16	r_o (Ω)	Common-emitter output resistance.
17	r_b (Ω)	Parasitic base resistance.
18	r_c (Ω)	Parasitic collector resistance.
19	c_{pi} (F)	Common-emitter input capacitance (alias=lx19).
20	c_{mu} (F)	Common-base output capacitance (alias=lx20).
21	c_{mux} (F)	External common-base output capacitance (alias=lx22).
22	c_{sub} (F)	Substrate capacitance (alias=lx21).
23	f_t (Hz)	Unity small-signal current-gain frequency (alias=lv5).
24	g_{pi} (S)	$G_{pi}=i_b/v_{be}$ constant v_{bc} (alias=lx4).
25	g_{mu} (S)	$G_{mu}=i_b/v_{bc}$ constant v_{be} (alias=lx5).
26	g_0 (S)	$G_0=i_c/v_{ce}$ constant v_{be} (alias=lx7).
27	g_b (S)	$1/R_{beff}$ internal conductance (alias=lx16).
28	q_{be}	Base emitter charge (alias=lx8).
29	q_{bc}	Base collector charge (alias=lx10).

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BJT Model (bjt)

30	qsc	Collector substrate charge.
31	grc (S)	Collector conductance (alias=lv16).
32	rbb (Ω)	Base resistance (alias=lv14).
33	log_ic (A)	Log(Ic) (alias=lv8).
34	log_ib (A)	Log(Ib) (alias=lv9).
35	gre (S)	Emitter conductance (alias=lv15).
36	re (Ω)	

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

af	M-172	ib	OP-9	rbmod	M-42	tns2	M-142
alarm	M-170	ic	OP-8	rbnoi	M-175	tr	M-83
area	I-1	ik	M-27	rc	M-43	trb1	M-92
areab	I-2	ikf	M-26	rc	OP-18	trb2	M-93
areac	I-3	ikr	M-29	rcm	M-45	trc1	M-96
areamax	M-183	imax	M-168	rcv	M-44	trc2	M-97
areamin	M-184	imax1	M-169	re	M-49	tre1	M-98
betaac	OP-13	imelt	M-160	re	OP-36	tre2	M-99
betadc	OP-12	iob	M-41	region	I-6	tref	M-86
bf	M-22	irb	M-39	region	OP-3	trise	I-5

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BJT Model (bjt)

bfm	M-23	is	M-4	ro	OP-16	trise	M-87
bnoisefc	M-174	isc	M-6	rpi	OP-15	trm1	M-94
br	M-24	ise	M-5	struct	M-2	trm2	M-95
brm	M-25	isnoisy	I-7	struct	OP-2	ttf1	M-129
bvbc	M-162	iss	M-7	subs	M-3	ttf2	M-130
bvbe	M-161	isub	OP-10	tbf1	M-119	ttr1	M-131
bvce	M-163	itf	M-81	tbf2	M-120	ttr2	M-132
bvsub	M-164	jbf	M-28	tbr1	M-121	tvaf1	M-123
c2	M-8	jbr	M-30	tbr2	M-122	tvaf2	M-124
c4	M-9	jrb	M-40	tcho	M-15	tvar1	M-125
cbcp	M-74	jtf	M-82	td	M-78	tvar2	M-126
cbep	M-75	kb	M-173	tf	M-77	tvjc	M-153
cbo	M-12	kc	M-36	tgbo	M-16	tvje	M-152
cco	M-48	ke	M-35	tikf1	M-105	tvjs	M-154
ccs	M-65	kf	M-171	tikf2	M-106	tvtf1	M-155
ccsp	M-76	log_ib	OP-34	tikr1	M-107	tvtf2	M-156
cex	M-47	log_ic	OP-33	tikr2	M-108	txtf1	M-157
cjc	M-57	m	I-4	tirb1	M-109	txtf2	M-158
cje	M-52	mc	M-61	tirb2	M-110	type	M-1
cjs	M-64	me	M-56	tis1	M-111	type	OP-1
cmu	OP-20	minr	M-50	tis2	M-112	updatelevel	M-178

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BJT Model (bjt)

cmux	OP-21	mjc	M-59	tisc1	M-115	va	M-32
compatible	M-177	mje	M-54	tisc2	M-116	vaf	M-31
cpi	OP-19	mjs	M-68	tise1	M-113	var	M-33
csub	M-66	ms	M-71	tise2	M-114	vb	M-34
csub	OP-22	mvt0	M-176	tiss1	M-117	vbc	OP-5
ctc	M-150	nc	M-20	tiss2	M-118	vbc_max	M-180
cte	M-149	ne	M-19	titf1	M-127	vbcfwd	M-166
cts	M-151	nf	M-17	titf2	M-128	vbe	OP-4
dcap	M-51	nk	M-11	tlev	M-100	vbe_max	M-179
dope	M-46	nkf	M-10	tlevc	M-101	vbefwd	M-165
dskip	M-159	nr	M-18	tmjc1	M-145	vbo	M-14
eg	M-88	ns	M-21	tmjc2	M-146	vce	OP-6
eglev	M-102	pc	M-60	tmje1	M-143	vce_max	M-181
esub	M-72	pe	M-55	tmje2	M-144	vcs_max	M-182
fc	M-73	ps	M-69	tmjs1	M-147	vjc	M-58
ft	OP-23	psub	M-70	tmjs2	M-148	vje	M-53
g0	OP-26	pt	M-91	tnc1	M-139	vjs	M-67
gap1	M-103	ptf	M-84	tnc2	M-140	vsub	OP-7
gap2	M-104	pwr	OP-11	tne1	M-137	vsubfwd	M-167
gb	OP-27	qbc	OP-29	tne2	M-138	vtf	M-80
gbo	M-13	qbe	OP-28	tnf1	M-133	xcjc	M-62

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BJT Model (bjt)

gm	OP-14	qsc	OP-30	tnf2	M-134	xcjc2	M-63
gmu	OP-25	rb	M-37	tnom	M-85	xtb	M-89
gpi	OP-24	rb	OP-17	tnr1	M-135	xtf	M-79
grc	OP-31	rbb	OP-32	tnr2	M-136	xti	M-90
gre	OP-35	rbm	M-38	tns1	M-141		

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BJT Model (bjt)

HiCUM Model (bht)

The HiCUM model was developed by Professor M. Schroter. This chapter contains the following information:

- [Spectre HICUM Model vs. Public HICUM Model](#) on page 310
- [Model Description](#) on page 311
- [DC Equations](#) on page 312
- [Charge and Capacitance Equations](#) on page 315
- [Noise Model](#) on page 318
- [Temperature Effect](#) on page 319
- [Self-Heating](#) on page 320
- [NQS effect](#) on page 321
- [Scaling Effects](#) on page 338
- [Component Statements](#) on page 339

Spectre HICUM Model vs. Public HICUM Model

MMSIM supports HICUM model version = 1.0, 2.1, 2.20, 2.21, 2.22, 2.23, 2.24, 2.3, 2.31, and 2.32. Model parameter “updatelevel” is added by Cadence in order to include some enhancement. The detail information is in the below:

- **updatelevel = 0:** The model is compatible with the original HICUM Fortran code. Temperature dependence is ignored in the model. No fix or enhancement is added to updatelevel=0. The model may show convergence issue. It is not suggested to use it.
- **updatelevel = 1 / 2:** This level has better temperature dependence. It includes some fixes and enhancements. Version 1.0, 2.1, 2.20, 2.21 and 2.22 supports this level.
- **updatelevel = 3:** This level has complete derivatives for current and charge model. And the simulation result is fully compatible with the result from HICUM Verilog-A model (released from TU Dresden, Germany). This level supports version = 2.1, 2.20, 2.21, 2.22, 2.23, 2.24, 2.3, 2.31, and 2.32. It is recommended to use this level. Further enhancement will be focusing on this level. Version = 2.23 and 2.24 support NQS effects.

Self-Heating

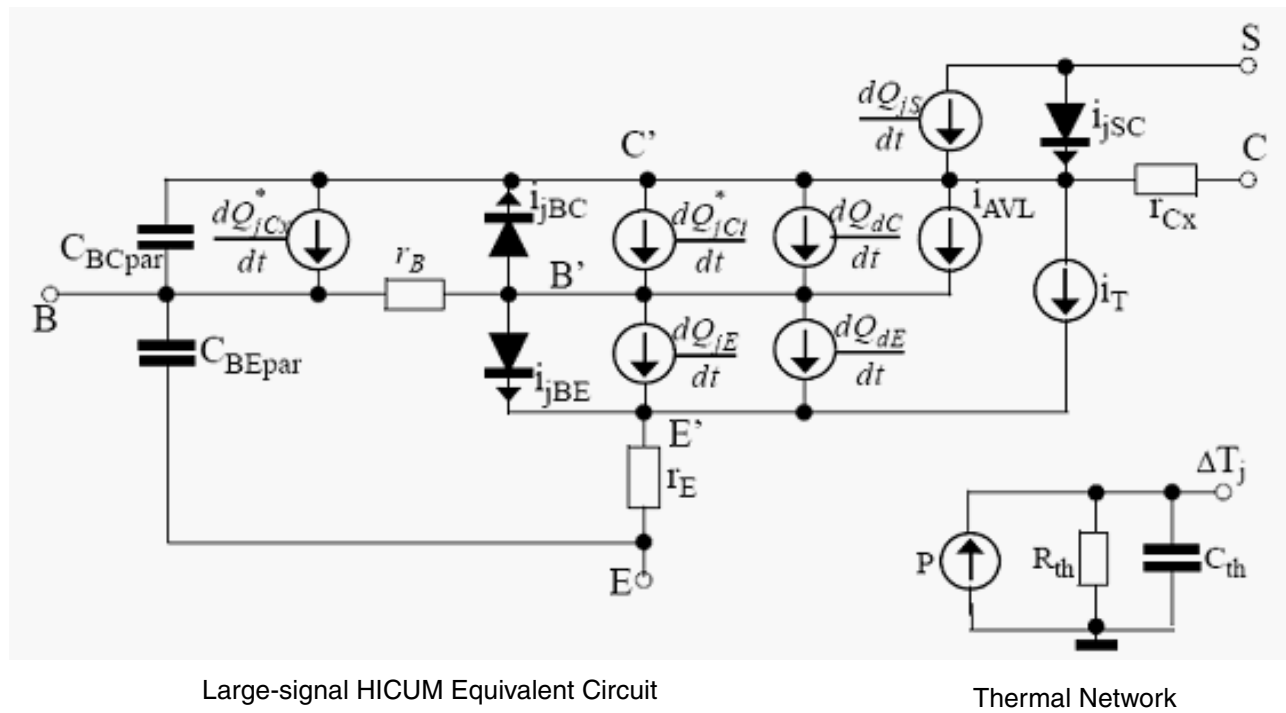
You can set `self_heating=fast` to enable the fast self-heating which has high performance. The result should be identical or very close to normal self-heating result.

Parameter flcomp

When updatelevel=3, if `flcomp=0` or 2.1 the result is consistent with version 2.1, irrespective of the version used in the netlist.

Model Description

The HiCUM model is a semi-physical compact bipolar transistor model. Semi-physical means that for arbitrary transistor configurations, a complete set of model parameters can be calculated from a single set of technology specific electrical and technological data. This model was developed with special emphasis on modeling the operating region at high current densities. The modularity and physics-based approach of this model allows the construction of a model hierarchy without additional effort in parameter extraction.



Large-signal HiCUM Equivalent Circuit

Thermal Network

DC Equations

$$i_T = i_{Tf} - i_{Tr}$$

$$i_{Tf1} = \frac{C_{10}}{Q_{p,T}} \exp\left(\frac{V_{B'E'}}{m_{cf} V_T}\right)$$

$$i_{Tf} = i_{Tf1} \left(1 + \frac{i_{Tf1}}{i_{ch}}\right)$$

$$i_{Tr} = \frac{C_{10}}{Q_{p,T}} \exp\left(\frac{V_{B'C'}}{V_T}\right)$$

$$Q_{p,T} = \frac{Q_{p,low}}{2} + \sqrt{\left(\frac{Q_{p,low}}{2}\right)^2 + \tau_{f0} C_{10} \exp\left(\frac{V_{B'E'}}{V_T}\right) + \tau_r C_{10} \exp\left(\frac{V_{B'C'}}{V_T}\right)}$$

$$Q_{p,1} = Q_{p0} + Q_{jEi} h_{jei} + h_{jci} Q_{jci}$$

$$I_{CK} = \frac{V_{ceff}}{r_{cio}} \frac{1}{\sqrt{1 + \left(\frac{V_{ceff}}{V_{lim}}\right)^2}} \left[1 + \frac{x + \sqrt{x^2 + 10^{-3}}}{2}\right]$$

$$X = (V_{ceff} - V_{lim}) / V_{PT}$$

$$r_{cio} = \frac{w_c}{q \mu_{nc0} N_{ci} A_E f_{cs}}$$

$$V_{lim} = \frac{V_{sn}}{\mu_{nc0}} w_c$$

$$V_{PT} = \frac{q N_{ci} w_c^2}{2E}$$

Virtuoso Simulator Components and Device Models Reference
HiCUM Model (bht)

$$i_{jBEi} = I_{BEis} \left[\exp\left(\frac{V_{B'E'}}{m_{BEi} V_T}\right) - 1 \right] + I_{REis} \left[\exp\left(\frac{V_{B'E'}}{m_{BEi} V_T}\right) - 1 \right]$$

$$i_{jBEp} = I_{BEps} \left[\exp\left(\frac{V_{B'E'}}{m_{BEp} V_T}\right) - 1 \right] + I_{REps} \left[\exp\left(\frac{V_{B'E'}}{m_{REp} V_T}\right) - 1 \right]$$

$$i_{jBCi} = I_{BCis} \left[\exp\left(\frac{V_{B'C'}}{m_{BCi} V_T}\right) - 1 \right]$$

$$i_{jBCx} = I_{BCxs} \left[\exp\left(\frac{V_{B'C'}}{M_{BCx} V_T}\right) - 1 \right]$$

$$r_{Bi} = r_{Bi0} \frac{C_i}{C_i + C_{dEp}}$$

$$r_{Bi0} = r_{SBi0} \frac{b_E}{I_E n_E} g_i$$

$$C_i = C_{jEi} + C_{dEi} + C_{dci}$$

$$C_{dEp} = C_{dE}(1 - f_{Qi})$$

$$i_{AVL} = I_T \frac{f_{AVL} V_{DCi}}{C_c^{1/z_{ci}}} \exp\left(-\frac{q_{AVL}}{C_{jCi0} V_{DCi}} C_c^{(1/z_{ci}-1)}\right)$$

$$C_c = \frac{C_{jci}(V_{B'C'})}{C_{jci0}}$$

*

$$i_{BEt} = I_{BEts} (-V_e) C_e^{1-1/z_E} \exp\left[-a_{BEt} C_e^{1/z_E-1}\right]$$

Virtuoso Simulator Components and Device Models Reference
HiCUM Model (bht)

$$I_{BEts} = 2 \frac{\sqrt{2m^*/E_G} q^3 V_{DE}^2}{h^2 \epsilon_{Si}} C_{jE0}$$

$$a_{BEt} = \frac{8\pi \sqrt{2m^*E_G} E_G W_{BE0}}{3qh} \frac{1}{2V_{DE}}$$

$$C_e = \frac{C_{jE(V)}}{C_{jE0}}$$

$$i_{TS} = I_{TSf} - I_{TSr} = I_{TSS} \left[\exp\left(\frac{V_{B^*C'}}{m_{Sf}V_T}\right) - \exp\left(\frac{V_{S'C'}}{m_{Sr}V_T}\right) \right]$$

$$i_{SC} = I_{SCS} \left[\exp\left(\frac{V_{S'C'}}{m_{SC}V_T}\right) - 1 \right]$$

Charge and Capacitance Equations

$$Q_{P,T} = Q_{p0} + h_{jEi}Q_{jEi} + h_{jCi}Q_{jCi} + Q_{f,T} + Q_{r,T}$$

$$Q_{f,T} = Q_{f0} + \Delta Q_{Ef} + \Delta Q_{fh}$$

$$Q_{f0} = \tau_{f0}i_{Tf}$$

$$\Delta Q_{Ef} = \Delta \tau_{Ef} \frac{i_{Tf}}{1 + g_{\tau E}}$$

$$\Delta \tau_{Ef} = \tau_{Ef0} \left(\frac{i_{Tf}}{I_{CK}} \right)^{g_{\tau E}}$$

$$\tau_{Ef0} = \frac{1}{\beta_0} \left(\frac{W_E}{V_{Ke}} + \frac{W_E^2}{2\mu_{PE}V_T} \right)$$

$$\Delta Q_{fh} = \Delta Q_{Bf} + Q_{cf} = \tau_{hcS}i_{Tf}W^2$$

$$Q_{r,T} = \tau_r i_{Tr}$$

$$C_{jEi} = \frac{C_{jEi0}}{(1 - V_j/V_{DEi})^{2Ei}} \cdot \frac{e}{1 + e} + a_{jEi} C_{jEi0} \frac{1}{1 + e}$$

$$e = \exp\left(\frac{V_f - V_{B'E'}}{V_T}\right)$$

$$V_j = V_f - V_T \ln[1 + e] < V_f$$

$$V_f = V_{DEi} \left[1 - a_{jEi}^{-1/(z_{Ei})} \right]$$

Virtuoso Simulator Components and Device Models Reference
HiCUM Model (bht)

$$Q_{jEi} = \frac{C_{jEi0} V_{DEi}}{1 - Z_{Ei}} \left[1 - \left(1 - \frac{V_j}{V_{DEi}} \right)^{(1/(z_{Ei}))} \right] + a_{jEi} C_{jEi0} (V_{B'E'} - V_j)$$

$$C_{jci} = C_{jci,cl} + C_{jci,PT} + C_{jci,fb}$$

$$C_{jci,cl} = \frac{C_{jci0}}{(1 - V_{j,m}/V_{DCi})^{z_{ci}}} \cdot \frac{Q_{j,r}}{1 + e_{j,r}} \frac{e_{j,m}}{1 + e_{j,m}}$$

$$C_{jci,fb} = a_{jci} C_{jci0} \frac{1}{e_{j,r} + 1}$$

$$C_{jci,PT} = \frac{C_{jci0,r}}{(1 - V_{j,r}/V_{DCi})^{z_{ci,r}}} \cdot \frac{1}{1 + e_{j,m}}$$

$$Q_{jCi} = Q_{jCi,m} + Q_{jCi,r} + a_{jci} C_{jci0} (V_{B'C'} - V_{j,r}) - Q_{jci,c}$$

$$Q_{jCi,m} = \frac{C_{jCi0} V_{DCi}}{1 - z_{Ci}} \left[1 - \left(1 - \frac{V_{j,m}}{V_{DCi}} \right)^{1 - z_{Ci}} \right]$$

$$Q_{jCi,r} = \frac{C_{jCi,r} V_{DCi}}{1 - z_{Ci,r}} \left[1 - \left(1 - \frac{V_{j,r}}{V_{DCi}} \right)^{1 - z_{Ci,r}} \right]$$

$$Q_{jCi,c} = \frac{C_{jCi,r} V_{DCi}}{1 - z_{ci,r}} \left[1 - \left(1 - \frac{V_{j,m}}{V_{DCi}} \right)^{1 - z_{ci,r}} \right]$$

$$C_{jCi0,r} = C_{jCi0} \cdot \left(\frac{V_{DCi}}{V_{PTCi}} \right)^{(z_{ci} - z_{ci,r})}$$

$$C_i = C_{jEi} + C_{jCi} + C_{dE} + C_{dC}$$

$$Q_{dS} = Y_{sf} I_{TSf}$$

Virtuoso Simulator Components and Device Models Reference
HiCUM Model (bht)

$$C_{dE} = \tau_f S_{fb}$$

$$C_{dC} = \tau_r S_{rC} + \tau_f S_{fC}$$

$$C_{dS} = \tau_{sf} S_{TSu, b}$$

$$S_{fb} = \left. \frac{dI_{Tf}}{dV_{B'E'}} \right|_{V_{B'C'}} = \frac{I_{Tf1}}{V_{Tf}} \cdot \frac{Q_{P, T} + \tau_r I_{Tr} - h_{jei} C_{jEi} V_{Tf}}{Q_{P, T} + \tau_r I_{Tr} + \tau_{fT} I_{Tf1} d_{ch}} d_{ch}$$

$$d_{Ch} = 1 + 2I_{Tf1}/I_{Ch}$$

$$S_{fC} = \left. \frac{dI_{Tf}}{dV_{C'E'}} \right|_{V_{B'E'}} = \frac{I_{Tf1}}{V_{Af}} \cdot \frac{d}{1 + d\tau_{f, T} I_{Tf1}/Q_{P, T}}$$

$$V_{Af} = \frac{Q_{P, T}}{h_{jci} C_{jCi} - \left. \frac{dQ_f}{dV_{C'E'}} \right|_{V_{B'E'}}$$

$$d = d_{ch} \frac{e}{1 + e}$$

$$e = \exp\left(\frac{V_c}{V_T} - 1\right)$$

$$S_{rc} = \left. \frac{dI_{Tr}}{dV_{C'E'}} \right|_{V_{B'E'}} = -\frac{I_{Tr}}{V_T} \cdot \frac{Q_{P, T} + (\tau_{f, T} S_{fC} - h_{jci} C_{jci}) V_T}{Q_{P, T} + \tau_r I_{Tr}}$$

$$S_{TSu, b} = \frac{I_{TsS}}{m_{sf} V_T} \exp\left(\frac{V_{B^*C'}}{m_{sf} V_T}\right)$$

Noise Model

$$\overline{i_{RE}^2} = \frac{4K_B T \Delta f}{r_E}$$

$$\overline{i_{RCx}^2} = \frac{4K_B T \Delta f}{r_{cx}}$$

$$\overline{i_{Bx}^2} = \frac{4K_B T \Delta f}{r_{Bx}}$$

$$\overline{i_{Bin}^2} = \frac{4K_B T \Delta f}{r_{Bin}}$$

$$\overline{i_T^2} = 2qI_T \Delta f$$

$$\overline{i_{AVL}^2} = 2qI_{AVL} \Delta f$$

Diode currents $I_{jdiode} = \{BEi, BCi, BEp, BCx, CS\}$:

$$\overline{i_{jdiode}^2} = 2qI_{jdiode} \Delta f$$

$$\overline{i_{BE}^2} = k_F (I_{jBEi} + I_{jBEp})^{\alpha_F} \frac{\Delta f}{f}$$

Correlation between base and collector noise spectral density S_{incinb} :

$$S_{incinb} \approx -2qI_T \times (j\omega\tau_{Bf} \times alit)$$

$$\tau_{Bf} = \frac{I_T}{I_{BEi}}$$

Temperature Effect

$$r_{ci}(T) = r_{ci}(T_0) \left(\frac{T}{T_0} \right)^{\zeta_{ci}}$$

$$V_{lim}(T) = V_{lim}(T_0) (1 - \alpha_{VS} \Delta T) \left(\frac{T}{T_0} \right)^{\zeta_{Ci}}$$

$$V_{C'E's}(T) = V_{C'E's}(T_0) [1 + \alpha_{CEs} \Delta T]$$

$$\tau_0(T) = \tau_0(T_0) [1 + \alpha_{\tau_0} \Delta T + K_{\tau_0} \Delta T^2]$$

$$\tau_{hcs}(T) = \tau_{hcs}(T_0) \left(\frac{T}{T_0} \right)^{(\tau_{ci} - 1)}$$

$$\tau_{Ej0}(T) = \tau_{Ej}(T_0) \frac{T/T_0}{1 + \alpha_B \Delta T}$$

$$V_D(T) = V_D(T_0) \frac{T}{T_0} - V_{Gj} \left(\frac{T}{T_0} - 1 \right) - 3V_T \ln \left(\frac{T}{T_0} \right)$$

$$C_{j0}(T) = C_{j0}(T_0) \left(\frac{V_D(T_0)}{V_D(T)} \right)^2$$

$$\alpha_j(T) = \alpha_j(T_0) \frac{V_D(T)}{V_D(T_0)}$$

$$r_{Bi0}(T) = r_{Bi0}(T_0) \left(\frac{T}{T_0} \right)^{\zeta_{rBi}}$$

$$f_{AVL}(T) = f_{AVL}(T_0) \exp(\alpha_{fav} \Delta T)$$

$$q_{AVL}(T) = q_{AVL}(T_0) \exp(\alpha_{qav} \Delta T)$$

$$I_{BEtsS}(T) = I_{BEtS}(T_0) \sqrt{\frac{V_G(T_0)}{V_G(T)}} \left(\frac{V_{DEp}(T)}{V_{DEp}(T_0)} \right)^2 \frac{C_{jEp0}(T)}{C_{jEp0}(T_0)}$$

$$a_{BEt}(T) = a_{BEt}(T_0) \left(\frac{V_G(T)}{V_G(T_0)} \right)^{3/2} \frac{V_{DEp}(T)}{V_{DEp}(T_0)}$$

When `updatelevel=0`,

$$I_{tss}(T) = I_{tss}(T_0) \quad (\text{No temperature dependence})$$

$$TEF0(T) = TEF0(T_0) \times (T/T_0) / (0.5 \times (A + \sqrt{A \times A + 0.01}))$$

When `updatelevel=1`,

$$I_{tss}(T) = I_{tss}(T_0) \times (T/T_0)^{3/Msf} \times \exp(VGB / (Msf \times Vt) \times (T/T_0 - 1))$$

$$TEF0(T) = TEF0(T_0) \times (T/T_0) / (0.5 \times (A + \sqrt{A \times A + 1e-6}))$$

$$C_{dci} = Tr \times Src$$

where

$$A = 1.0 + Alb \times DeltaT$$

The original HICUM model had simple derivatives for some currents and charges, which sometimes caused convergence issues. There have been some enhancements made to solve this problem, especially for AC analyses.

Self-Heating

You can set `self_heating=fast` to enable the fast self-heating, which is faster than the full self-heating but gives similar results in most cases.

Self-heating for parasitic resistor is given by the following equation:

$$Pwr = V_{cei} \times I_t - V_{bci} \times I_{avl}$$

If `updatelevel=2`,

Virtuoso Simulator Components and Device Models Reference

HiCUM Model (bht)

$$P_{wr} = P_{wr} + (V_{bp} - V_b) \times \frac{(V_{bp} - V_b)}{R_{bi}} \quad \text{if } R_{bi0} \text{ is given}$$

$$P_{wr} = P_{wr} + (V_{bx} - V_{bp}) \times \frac{(V_{bx} - V_{bp})}{R_{bx}} \quad \text{if } R_{bx} \text{ is given}$$

$$P_{wr} = P_{wr} + (V_{cx} - V_c) \times \frac{(V_{cx} - V_c)}{R_{cx}} \quad \text{if } R_{cx} \text{ is given}$$

$$P_{wr} = P_{wr} + (V_e - V_{ex}) \times \frac{(V_e - V_{ex})}{R_e} \quad \text{if } R_e \text{ is given}$$

NQS effect

Lateral NQS

The lateral NQS effect is implemented by an adequate capacitance C_{rBi} in parallel to the resistance r_{Bi} .

$$C_{rBi} = f_{crBi} \times C_{jei} \times C_{jci} \times C_{dei} \times C_{dci}$$

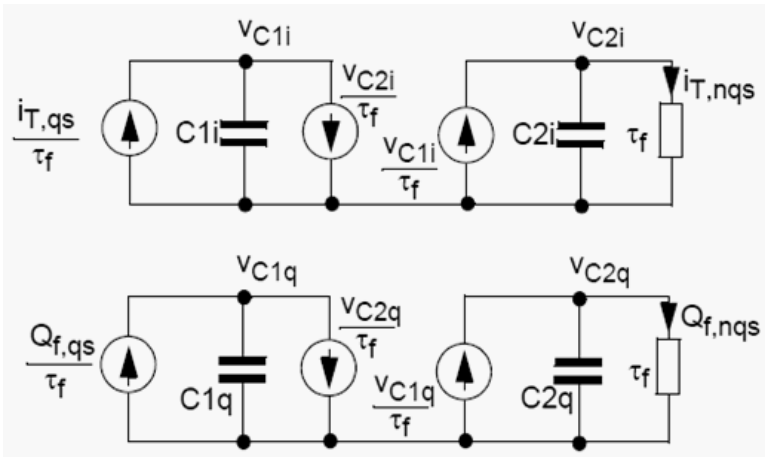
$$Q_{rBi} = C_{rBi} \times V_{B \times B}^{min}$$

Vertical NQS

Vertical NQS effects are implemented through “additional delay times” for both minority charge Q_f and forward transfer current i_{Tf} . The figure below shows the adjunct NQS networks for Transfer Current i_T and Minority Charge Q_r .

Virtuoso Simulator Components and Device Models Reference

HiCUM Model (bht)



$$\frac{I_{T,qs} - V_{C2i}}{\tau_f} = \frac{d \times (alit \times V_{C1i})}{dt}$$

$$\frac{V_{C1i} - V_{C2i}}{\tau_f} = \frac{d \times (alit \times V_{C2i}/3)}{dt}$$

$$I_{T,nqs} = \frac{V_{C2i}}{\tau_f}$$

$$\frac{Q_{T,qs} - V_{C2q}}{\tau_f} = \frac{d \times (alqf \times V_{C1i})}{dt}$$

$$\frac{V_{C1q} - V_{C2q}}{\tau_f} = \frac{d \times (alqf \times V_{C2q}/3)}{dt}$$

$$Q_{T,nqs} = \frac{V_{C2q}}{\tau_f}$$

HiCUM Model Version 2.2

Temperature Dependent Bandgap Voltage

$$V_g(T) = V_g(0) + K_1 T \ln(T) + K_2 T$$

$$V_g(T) = V_{g, cq}(0) - \frac{\alpha_g T^2}{T + T_g}$$

For compact model and application purposes, it is sometimes more convenient to re-write the above equation in terms of a reference temperature T_0 (e.g. for parameter extraction), which gives

$$V_g(T) = V_g(T_0) + k_1 \frac{T}{T_0} \ln\left(\frac{T}{T_0}\right) + k_2 \left(\frac{T}{T_0} - 1\right)$$

with the definitions

$$k_1 = k_1 T_0$$

$$k_2 = k_2 T_0 + k_1 \ln(T_0)$$

and the bandgap voltage at the measurement reference temperature,

$$V_g(T_0) = k_2 + V_g(0)$$

The choice of the bandgap description also influences the formulation of the effective intrinsic carrier density, which now reads

$$n_{ie}^2(T) = n_{ie}^2(T_0) \left(\frac{T}{T_0}\right)^{m_g} \exp\left[\frac{V_{g, eff}(0)}{V_T} \left(\frac{T}{T_0} - 1\right)\right]$$

with the constant

$$m_g = 3 - \frac{k_1}{V_{T0}} = 3 - \frac{qK_1}{K_B}$$

Transfer current

Base Region Reach-Through

$$Q_{pT,j} = Q_{p0} + h_{jEi}Q_{jEi} + h_{jCi}Q_{jCi}$$

$$Q_{pT,low} = Q_{B,rt} \left(1 + \frac{x + \sqrt{x^2 + a}}{2} \right)$$

and $a = 1.921812$.

$$x = \frac{Q_{pT,j}}{Q_{B,rt}} - 1$$

Temperature Dependence

Prefactor

$$c_{10}(T) = c_{10}(T_0) \left(\frac{T}{T_0} \right)^{\zeta_{CT}} \exp \left[\frac{V_{gBeff}(0)}{V_T} \left(\frac{T}{T_0} - 1 \right) \right]$$

$$\zeta_{CT} = m_g + 1 - \zeta_{\mu mB}$$

Zero-Bias Hole Charge

$$Q_{p0}(T) = Q_{p0}(T_0) \left[2 - \left(\frac{V_{DEi}(T)}{V_{DEi}(T_0)} \right)^{Z_{Ei}} \right]$$

Base Currents

Excess Base Current from Recombination at the BC Barrier

$$i_{Bhrec} = \frac{\Delta Q_{Bf}}{\tau_{Bhrec}}$$

Temperature Dependent Junction Current Components

$$I_{BEiS}(T) = I_{BEiS}(T_0) \left(\frac{T}{T_0}\right)^{\zeta_{BET}} \exp\left[\frac{V_{gEeff}(0)}{V_T} \left(\frac{T}{T_0} - 1\right)\right]$$

$$V_{gEeff}(0) = V_{gBEff}(0) - \alpha_{Bf} T_0 V_{T0}$$

$$I_j = I_{jS} \exp\left(\frac{V}{mV_T}\right)$$

$$I_{jS}(T) = I_{jS}(T_0) \left(\frac{T}{T_0}\right)^{\zeta_r} \exp\left[\frac{V_{gEeff}(0)}{V_T} \left(\frac{T}{T_0} - 1\right)\right]$$

$$V_{gBEeff} = \frac{V_{gBEeff} + V_{gEeff}}{2}$$

$$\mu_{Ci}(T) = \mu_{Ci}(T_0) \left(\frac{T}{T_0}\right)^{-\zeta_{Ci}}$$

$$\zeta_{BCiT} = m_g + 1 - \zeta_{Ci}$$

$$\zeta_{BCxT} = m_g + 1 - \zeta_{Cx}$$

$$\zeta_{SCT} = m_g + 1 - \zeta_{\mu pS}$$

Depletion Capacitances and Charges

Bias Dependence of Base-Emitter Component

$$v_j = V_f - V_T \frac{x + \sqrt{x^2 + a_{ff}}}{2} < V_f$$

$$x = \frac{V_f - v_{B'E}}{V_T}$$

$$a_{ff} = 41n^2(2) = 1.921812$$

$$C_{jEi} = \frac{C_{jEi0}}{(1 - v_j/V_{DEi})^{z_{Ei}}} \cdot \frac{dv_j}{dv_{B'E}} + a_{jEi} C_{jEi0} \left(1 - \frac{dv_j}{dv_{B'E}}\right)$$

$$\frac{dv_j}{dv_{B'E}} = \frac{x + \sqrt{x^2 + a_{ff}}}{2\sqrt{x^2 + a_{ff}}}$$

External Depletion Capacitances

The formulation for the depletion capacitances C_{jEp} also has been changed from exponential to hyperbolic smoothing functions.

Temperature Dependence of Built-in Voltages

$$V_{Dj}(T_0) = 2V_{T0} \ln \left[\exp\left(\frac{V_D(T_0)}{2V_{T0}}\right) - \exp\left(\frac{V_D(T_0)}{2V_{T0}}\right) \right]$$

$$V_{Dj}(T) = V_{Dj}(T_0) \frac{T}{T_0} - 3V_T \ln\left(\frac{T}{T_0}\right) + V_{geff}(T) - V_{geff}(T_0) \left(\frac{T}{T_0}\right)$$

For the bandgap voltage formulation, the above equation reads

$$V_{Dj}(T) = V_{Dj}(T_0) \frac{T}{T_0} - m_g V_T \ln\left(\frac{T}{T_0}\right) - V_{geff}(0) \left(\frac{T}{T_0} - 1\right)$$

which reduces to the classical equation (that assumes a linear temperature dependence of V_{geff}) if $m_g = 3$. Finally, the new built-in voltage is calculated as

$$V_D(T) = V_{Dj}(T) + 2V_T \ln\left(\frac{1}{2} \left[1 + \sqrt{1 + 4 \exp\left(-\frac{V_{Dj}(T)}{V_T}\right)} \right]\right)$$

$$V_{geff} \rightarrow V_{g(x,y)eff} = \frac{V_{gxeff} + V_{gyeff}}{2}$$

$$\left. \frac{dV_D(T)}{dT} \right|_{T_0} \cong \left. \frac{dV_{Dj}(T)}{dT} \right|_{T_0}$$

$$\left. \frac{dV_{Dj}(T)}{dT} \right|_{T_0} = \frac{V_{Dj}(T_0) - V_{geff}(0) - m_g V_T}{T_0}$$

Minority Charge

Effective Collector Voltage and Critical Current

$$v_{ceff} = V_T \left[1 + \frac{u + \sqrt{u^2 + a_{vceff}}}{2} \right]$$

$$u = \frac{v_c - V_T}{V_T}$$

$$x = \frac{v_{ceff} - V_{lim}}{V_{PT}}$$

Diffusion Capacitances

$$C_{dCi} = \tau_r S_{rc} + \tau_f S_{fc}$$

has been changed to

$$C_{dCi} = \tau_r S_{rc}$$

$$C_{dEi}^C = \tau_f S_{fc} + \left. \frac{dQ_f}{dV_{CE}} \right|_{T_{TP}, T}$$

$$C_{dEi}^B = \tau_r S_{rb}$$

Temperature Dependence

Critical Voltage V_{lim}

$$V_{lim}(T) = \frac{v_s(T)}{\mu_{nCi0}(T)}$$

$$v_s(T) = v_{s0}(T_0) \left(\frac{T}{T_0} \right)^{-a_{vs}}$$

$$a_{vs} = a_{vs} T_0$$

Inserting the temperature dependence of the collector electron mobility into the $V_{lim}(T)$ equation gives the physics-based formulation

$$V_{lim}(T) = V_{lim}(T_0) \left(\frac{T}{T_0} \right)^{\zeta_{Cl} - a_{vs}}$$

The following equation replaces the formulation used in version 2.1:

$$V_{lim}(T) = V_{lim}(T_0)(1 - a_{vs}\Delta T)\left(\frac{T}{T_0}\right)^{\zeta_{cl}}$$

Emitter Transit Time

$$\tau_{Ef0}(T) = \tau_{Ef0}(T_0)\left(\frac{T}{T_0}\right)^{\zeta_{\tau cl}} \exp\left[-\frac{\Delta V_{geff}(0)}{V_T}\left(\frac{T}{T_0} - 1\right)\right]$$

$$\Delta V_{geff}(0) = V_{gBeff}(0) - V_{gEeff}(0)$$

$$\zeta_{\tau Ef} = \zeta_{BET} - \zeta_{CT} - 0.5$$

Collector Current Spreading

$$f_{ccs} = \frac{\tau_f(I_{CK})}{\tau_{f,ID}(I_{CK})}$$

$$\tau_{hcs} = f_{ccs}\tau_{pCs} + \tau_{Bfvs} = f_{ccs}\frac{w_C^2}{4\mu_{nC0}V_T} + \frac{w_{Bm}w_C}{2G_{\zeta_i}\mu_{nC0}V_T}$$

The original model parameter τ_{hcs} is extracted from measurements together with the partitioning factor

$$f_{thc} = \frac{\tau_{pCs}}{\tau_{hcs,x}}$$

Thus, during preprocessing for model card generation, the modified extracted time constant

$$\tau_{hcs} = (1 - f_{thc})\tau_{hcs,x} + f_{ccs}\tau_{pCs} = [(1 - f_{thc}) + f_{ccs}f_{thc}]\tau_{hcs,x}$$

is calculated and used as a model parameter.

Internal Base Resistance

In Version 2.1, the impact of the minority charge at the emitter periphery during large-signal switching on the lumped internal base resistance was taken into account by the equation

$$r_{Bi}^* = r_{Bi} \frac{\Delta Q_i}{\Delta Q_p} = r_{Bi} \frac{\Delta Q_i}{\Delta Q_i + \Delta Q_{fp}}$$

with

$$\Delta Q_i = Q_{jEi} + Q_{jCi} + Q_{fi}$$

For the case of a large negative BC voltage and a low forward BE voltage

$$\Delta Q_i = Q_{jEi} + Q_{jCi}$$

can become zero, causing a division by zero and a pole in the bias dependent r_{Bi} characteristic. Although this case is rare and is mostly likely caused by bad (non-physical) parameter combinations, it needs to be avoided under any circumstances. Therefore, to ensure numerical stability Q_{jCi} is dropped, leading to the modified formulation of the charge difference

$$\Delta Q_i = Q_{jEi} + Q_{fi}$$

In the corresponding small-signal equation,

$$r_{Bi}^* = r_{Bi} \frac{C_i}{C_i + C_{dEp}}$$

the internal capacitance has also to be modified to

$$C_i = C_{jEi} + C_{dEi}$$

Another change of the formulation for the internal base resistance is that the parameter KRBI is dropped. It was introduced about 10 years ago and intended to be used for changing during h.f. noise analysis due to the many uncertainties in bipolar transistor noise mechanisms and theory. With a better understanding of noise in bipolar transistors and many experimental investigations performed recently for advanced processes, this empirical parameter does not seem to be required anymore.

Base-emitter Tunnelling Component

Location of the Current Source

$$i_{BEt} = I_{BEtS}(-V_e)C_e^{1-1/z_g} \exp\left[-a_{BEt}C_e^{1/z_g-1}\right]$$

Temperature Dependence

$$I_{BEtS}(T) = I_{BEtS}(T_0) \sqrt{\frac{V_g(T_0)}{V_g(T)}} \left(\frac{V_{DE}(T)}{V_{DE}(T_0)}\right)^2 \left(\frac{C_{jE0}(T)}{C_{jE0}(T_0)}\right)$$

$$a_{BEt}(T) = a_{BEt}(T_0) \left(\frac{V_g(T)}{V_g(T_0)}\right)^{3/2} \frac{V_{DE}(T_0) C_{jE0}(T_0)}{V_{DE}(T) C_{jE0}(T)}$$

$$V_g(T) = V_{gBEeff}(T) = \frac{V_{gBEeff}(0T) + V_{gEeff}(T)}{2}$$

Parasitic Base-Emitter Capacitance Partitioning

$$C_{BEpar} = C_{Eox} + C_{BE,metal}$$

$$f_{BEpar} = \frac{C_{BEpar,2}}{C_{BEpar}} = \frac{C_{Eox,2} + C_{BE,metal}}{C_{Eox} + C_{BE,metal}}$$

Substrate Transistor

$$I_{TS}(T) = I_{TSS}(T_0) \left(\frac{T}{T_0}\right)^{\zeta_{BCxT}} \exp\left[\frac{V_g C_{eff}(0)}{V_T} \left(\frac{T}{T_0} - 1\right)\right]$$

$$\tau_{Sf}(T) = \tau_{Sf}(T_0) \left(\frac{T}{T_0}\right)^{(\zeta_{Cx} - 1)}$$

HiCUM Model Version 2.3

HICUM/L2 version 2.30 has been developed to a large extent within the framework of the European DOTFIVE project. This HICUM/L2 version has been improved from its present official version (v2.24) in order to meet the requirements for emerging mm-wave applications. Following is a brief overview of the new improvements and additions in the new model.

Improvements in the model equations

Formulation for the critical current (ICK)

$$I_{ck} = \frac{V_{ceff}}{r_{ci0}} \frac{1}{\left(1 + \left(\frac{V_{ceff}}{V_{lim}}\right)^{\delta_{ck}}\right)^{1/\delta_{ck}}} \left[1 + \frac{\chi + \sqrt{\chi^2 - a_{ickpt}}}{2}\right]$$

where δ_{ck} is the new mode parameter.

Weight factors

Weight factor for low current transit time

A new weight factor hf0 for the low current minority charge has been introduced.

$$Q_{fT} = h_{f0}Q_{f0} + h_{fE}\Delta Q_{Ef} + \Delta Q_{Bf} + h_{fc}\Delta Q_{cf}$$

Note that the default value of hf0 (=1) makes it compatible with the previous version. The temperature dependence of hf0 is given by

$$h_{f0}(T) = h_{f0}(T_0) \exp\left[\frac{\Delta V_{gBE}}{V_T} \left(\frac{T}{T_0} - 1\right)\right]$$

where, ΔV_{gBE} is the new model parameter and defined as the bandgap difference between base and BE-junction, used for h_{jEi0} and hf_0 .

Weight factor of BE depletion charge

In this version, the BE-depletion charge weight factor h_{jEi} is modeled as bias dependent with the following equations:

$$h_{jEi} = h_{jEi0} \frac{\exp(u) - 1}{1}$$

With,

$$u = a_{h_{jEi}} \left(1 - \left(1 - \frac{V_j}{V_{DEi}} \right)^{Z_{Ei}} \right)$$

Where, $a_{h_{jEi}}$ is the new model parameter.

The junction voltage is limited to V_{DEi} and 0 by:

$$\chi_{upp} = \frac{V_{DEi} - V_{BEi}}{r_{h_{jEi}} V_T}$$

and

$$V_{j, upp} = V_{DEi} - r_{h_{jEi}} V_T \frac{\chi_{upp} + \sqrt{\chi_{upp}^2 - a_{fi}}}{2}$$

where, $r_{h_{jEi}}$ is the newly introduced model parameter.

The voltage has been further limited to values greater than zero using the following equations:

$$\chi_{low} = \frac{v_{j, upp} - V_T}{V_T}$$

$$v_j = V_T \left(1 + \frac{\chi_{low} + \sqrt{\chi_{low}^2 + a_{fi}}}{2} \right)$$

The temperature dependence of h_{jEi} and r_{hjEi} is given by:

$$a_{hjEi}(T) = a_{hjEi}(T_0) \left(\frac{T}{T_0} \right)^{\zeta_{hjEi}}$$

$$h_{jEi0}(T) = h_{jEi}(T_0) \exp \left[\left(-\frac{\Delta V_{gBe}}{V_T} \right) \left(\left(\frac{T}{T_0} \right)^{\zeta_{VgBE}} - 1 \right) \right]$$

Where,

ζ_{hjEi} and ζ_{VgBE} are the fitting parameters.

High current weight factors

Temperature dependences for h_{fE} and h_{fC} have been considered in the new model.

$$h_{fE}(T) = h_{fE}(T_0) \exp \left[\frac{V_{gb} - V_{ge}}{V_T} \left(\frac{T}{T_0} - 1 \right) \right]$$

$$h_{fC}(T) = h_{fC}(T_0) \exp \left[\frac{V_{gb} - V_{gc}}{V_T} \left(\frac{T}{T_0} - 1 \right) \right]$$

To enable full backward compatibility to previous versions of HICUM, the parameter `flcomp` needs to be set to 2.3, or more to turn on these models.

Transit Times

Barrier voltage

The barrier related term is calculated by the bias dependent barrier voltage:

$$\Delta V_{cBar} = V_{cBar} \exp\left(\frac{2}{i_{Bar} + \sqrt{i_{Bar}^2 + a_{cBar}}}\right)$$

$$i_{Bar} = \frac{i_{Tf} - I_{CK}}{i_{cBar}}$$

Barrier related minority charge

The high current minority charge expression has been extended by adding the barrier related part:

$$Q_{f,h} = \Delta Q_{Ef} + \Delta Q_{Bf,b} + \Delta Q_{Bf,c} + \Delta Q_{cf,c}$$

The new formulation for the barrier related minority charge reads as follows:

$$\Delta Q_{Bf,b} = \tau_{Bfvs} i_{Tf} \left[\exp\left(\frac{\Delta V_{cBar}}{V_T}\right) - 1 \right]$$

With the already existing parameter:

$$\tau_{Bfvs} = (1 - f_{\tau hc}) \tau_{hCs}$$

High current charges

Considering the “Kirk effect” the following expression can be obtained:

$$\Delta Q_{f_{h,c}} = \tau_{hCs} i_{Tf}^2 \exp\left(\frac{\Delta V_{cBar} - V_{cBar}}{V_T}\right)$$

The high current collector charge including current spreading can be expressed as:

$$\Delta Q_{Cf,c} = \tau_{pCs} i_{Tf} \exp\left(\frac{\Delta V_{cBar} - V_{cBar}}{V_T}\right) \left\{ \begin{array}{ll} 2 \frac{f_{Ci} 1n\left(\frac{1 + \zeta_b w}{1 + \zeta_l w}\right) - f_{Cb} + f_{Cl}}{\zeta_b - \zeta_l} & l_{E0} > b_{E0} \\ \frac{1 + \zeta_{bw}/3}{1 + \zeta_b w} w^2 & l_{E0} = b_{E0} \end{array} \right.$$

Emitter transit time

The temperature dependence of the emitter transit time has been removed. However, by setting `f1comp` to 2.2 or lower, the former existing equation will still be available.

Lateral non-quasi-static (NQS) effect

The formulation has been switched back to that of HICUM/L2 version 2.23.

Temperature dependence of thermal resistance

In this version, the thermal resistance (R_{th}) has been modeled as temperature dependent.

$$R_{th}(T) = R_{th}(T_0) \left(\frac{T}{T_0}\right)^{\zeta_{rth}}$$

where, ζ_{rth} is the temperature coefficient of R_{th} and a new model parameter.

Temperature dependence of internal BE recombination current

The current equation has been modified, within the existing simplifying assumptions, by replacing “1/2” with “1/ m_{REi} ”

$$I_{REiS}(T) = I_{REiS}(T_0) \left(\frac{T}{T_0}\right)^{\frac{m_g}{m_{REi}}} \exp\left[\frac{1}{m_{REi}} \cdot \frac{V_{gBEeff}}{V_T} \left(\frac{T}{T_0} - 1\right)\right]$$

Temperature dependence of peripheral BE recombination current

In the same way the with peripheral BE recombination current has been modified:

$$I_{REpS}(T) = I_{REpS}(T_0) \left(\frac{T}{T_0}\right)^{\frac{m_g}{m_{REp}}} \exp\left[\frac{1}{m_{REp}} \cdot \frac{V_{gBEeff}}{V_T} \left(\frac{T}{T_0} - 1\right)\right]$$

Note: Setting $m_{REi}=2$ and $m_{REp}=2$ yields the formulation of previous model versions.

Noise source of the emitter resistance

Based on measurements presented in an additional flicker noise contribution has been introduced for the series emitter resistance R_E . The total noise contribution becomes:

$$\overline{I_{rE}^2} = \frac{Kf_{rE} \cdot T_E^{A_{f_{rE}}}}{f} + \frac{4KT}{r_E}$$

where, the first component represents the flicker noise and second the thermal noise.

HiCUM Model Version 2.31

Improvements in Model Equations

Temperature Dependence of Thermal Resistance

In this version, the temperature dependence of thermal resistance (R_{th}) has been changed as follows:

$$R_{th}(T) = R_{th}(T_0) \left(\frac{T}{T_0}\right)^{\zeta_{rth}} (1 + alrth \cdot \Delta t)$$

Lateral Non-Quasi-Static (NQS) Effect

In this version, the lateral NQS modeling has been simplified to reduce the number of calculated derivatives.

$$C_{dei} = T(f_0) \cdot itf / V_t$$

$$C_{dci} = tr \cdot itr / V_t$$

Vertical NQS Effect Parameters

The default value of the vertical NQS effect parameters has been changed as follows:

$$alqf = 0.167$$

$$alit = 0.333$$

Noise Correlation

A new noise correlation model has been introduced, which is valid at all frequencies.

HiCUM Model Version 2.32

Improvements in Model Equations

The conditional statement for the barrier term has been changed to transistor-specific values. The original conditional statement `if(icbar<1e-10)` has been changed to `if(icbar<0.05*(vlim/rci0))` where `vlim/rci0` is a rough bias and temperature-independent estimation of `ICK`.

Scaling Effects

For scaling effects, see [Scaling Factors \(scale and scalem\)](#) on page 242.

Component Statements

Instance Definition

Name c b e [s] [t] ModelName parameter=value ...

Specifying the substrate terminal is optional. If not provided, the substrate is connected to ground.

Specifying the thermal node (t) is optional. However, if it is specified then:

- When it is connected, it is parallel with the internal Rth/Cth
- When it is shorted to ground, it disables the self heating effect
- When it is kept floated, it uses the internal Rth/Cth and is equivalent to not being specified.

Instance Parameters

Parameters valid for both modes

- | | | |
|---|------------------|--|
| 1 | region=fwd | Estimated operating region.
Possible values are <code>off</code> , <code>fwd</code> , <code>rev</code> , and <code>sat</code> . |
| 2 | trise (C) | Temperature rise from ambient. |
| 3 | self_heating=yes | Control switch for self-heating. Possible values are <code>no</code> , <code>yes</code> or <code>fast</code> . <code>Fast</code> is Cadence's proprietary approach that is significant faster than the full self-heating yet gives very similar results in most cases.
Possible values are <code>no</code> , <code>yes</code> , and <code>fast</code> . |
| 4 | m=1 | Multiplicity factor (number of devices in parallel). |

Parameters for structure mode

- | | | |
|---|-------------|---|
| 5 | isnoisy=yes | Should device generate noise.
Possible values are <code>no</code> and <code>yes</code> . |
|---|-------------|---|

Structural parameters

6 area=1 Transistor area factor.

Model Definition

model modelName bht parameter=value ...

Model Parameters

Major mode of operation

1 mode=internal Mode for model parameter determination.
Possible values are `internal`.

Parameters for internal mode

Structural parameters

2 type=npn Transistor type.
Possible values are `pnp` and `npn`.

3 latb=0.0 Parameter for lateral scaling (Zeta_b).

4 latl=0.0 Parameter for lateral scaling (Zeta_l).

Internal transistor

5 c10=2.0e-30 A²s Constant for ICCR.

6 qp0=2.0e-14 Coul Zero-bias hole charge.

7 ich=∞ A High current correction (multidimensional ICCR).

8 hjci=1.0 B-C depletion charge weighting factor.

9 hf0=1.0 Weight factor for the low current minority charge.

10 ahjei=0.0 Parameter describing the slope of $h_j E_i(VBE)$.

Virtuoso Simulator Components and Device Models Reference

HiCUM Model (bht)

11	rhjei=1.0	Smoothing parameter for $h_{jEi}(V_{BE})$ at high voltage.
12	hjei=1.0	B-E depletion charge weighting factor.
13	mcf=1.0	Forward non-ideality factor of S_u transfer current.
14	tsf=0.0 s	Transit time (forward operation).
15	hfc=1.0	Collector minority charge weighting factor.
16	hfe=1.0	Emitter minority charge weighting factor.
17	aljt=0.0	Factor for additional delay time of i_T .
18	cjei0=0.0 F	Internal zero-bias BE depletion capacitance.
19	vdei=0.9 V	Internal BE built-in voltage.
20	zei=0.5	Internal BE depletion coefficient.
21	aljei=2.5	Maximum int. depl. cap. divided by C_{jei0} .
22	cjci0=0.0 F	Internal zero-bias BC depletion capacitance.
23	vdci=0.7 V	Internal BC built-in voltage.
24	zci=0.4	Internal BC depletion coefficient.
25	vptci= ∞ V	Punch-through voltage of internal BC junction.
26	t0=0.0 s	Time constant (low current densities).
27	dt0h=0.0 s	Time constant for base and BC space charge layer width modulation.
28	tbvl=0.0 s	Time constant for modeling carrier jam.
29	tef0=0.0 s	Neutral emitter storage time.
30	gtfe=1.0	Current dependence factor for $TEF0$.
31	thcs=0.0 s	Saturation time constant.

Virtuoso Simulator Components and Device Models Reference

HiCUM Model (bht)

32	<code>alhc=0.1</code>	Smoothing factor for base and collector transit time.
33	<code>fthc=0.0</code>	Partitioning factor for base and collector portion.
34	<code>vc_{es}=0.1 V</code>	Internal CE saturation voltage.
35	<code>rci₀=150.0 Ω</code>	Low-field resistance of epitaxial collector.
36	<code>vlim=0.5 V</code>	Limitation voltage.
37	<code>v_{pt}=∞ V</code>	Punch-through voltage. The default value is 100V since version 2.24.
38	<code>tr=0.0 s</code>	Ideal reverse transit time.
39	<code>vc_{bar}=0.0 V</code>	Barrier voltage.
40	<code>ic_{bar}=0.0 A</code>	Normalization parameter.
41	<code>ac_{bar}=0.01</code>	Smoothing parameter for barrier voltage.
42	<code>delck=2.0</code>	fitting factor for critical current.
43	<code>alqf=0.0</code>	Factor for additional delay time of minority charge.
44	<code>ibeis=1.0e-18 A</code>	Internal BE saturation current.
45	<code>mbei=1.0</code>	Internal BE non-ideality factor.
46	<code>ireis=0.0 A</code>	Internal BE saturation current (recombination).
47	<code>mrei=2.0</code>	Internal BE non-ideality factor (recombination).
48	<code>ibcis=1.0e-16 A</code>	Internal BC saturation current.
49	<code>mbci=1.0</code>	Internal BC non-ideality factor.
50	<code>favl=0.0 1/V</code>	Avalanche current factor.
51	<code>qavl=0.0 Coul</code>	Exponent factor for Avalanche current.
52	<code>rbi₀=0.0 Ω</code>	Internal base resistance at zero-bias.

Virtuoso Simulator Components and Device Models Reference

HiCUM Model (bht)

53	<code>fdqr=0.0</code>	Correction factor for modulation.
54	<code>fgeo=0.6557</code>	Geometry factor for current crowding.
55	<code>fqi=1.0</code>	Ratio of internal to total minority charge.
56	<code>fcربی=0.0</code>	Ratio of high frequency shunt to total internal capacitance.
57	<code>dvgbه=0.0 V</code>	Bandgap difference between B and B-E junction used for h_{jEi0} and h_{f0} .
58	<code>zetahjei=1.0</code>	Temperature coefficient for ah_{jEi} .
59	<code>zetavgبه=1.0</code>	Temperature coefficient for h_{jEi0} .
60	<code>zetarth=0.0 K/W</code>	Temperature coefficient for R_{th} .
61	<code>flcono=no</code>	Flag for turning on and off of correlated noise implementation. Possible values are <code>no</code> and <code>yes</code> .
62	<code>alrth=0.0 1/K</code>	First order relative TC of parameter R_{th} .

Peripheral elements

63	<code>cjep0=0.0 F</code>	Peripheral zero-bias BE depletion capacitance.
64	<code>vdep=0.9 V</code>	Peripheral BE built-in voltage.
65	<code>zep=0.5</code>	Peripheral BE depletion coefficient.
66	<code>aljep=2.5</code>	Maximum per. depl. cap. divided by C_{jep0} .
67	<code>ibeps=0.0 A</code>	Peripheral BE saturation current.
68	<code>mbep=1.0</code>	Peripheral BE non-ideality factor.
69	<code>ireps=0.0 A</code>	Periph. BE saturation current (recomb.).
70	<code>mrep=2.0</code>	Periph. BE non-ideality factor (recomb.).

Virtuoso Simulator Components and Device Models Reference

HiCUM Model (bht)

External elements

71	$c_{jcx0}=0.0$ F	External zero-bias BC depletion capacitance.
72	$v_{dcox}=0.7$ V	External BC built-in voltage.
73	$z_{cx}=0.4$	External BC depletion coefficient.
74	$v_{ptcx}=\infty$ V	Punch-through voltage of external BC junction.
75	$c_{cox}=0.0$ F	BC overlap capacitance.
76	$f_{bc}=0.0$	Partitioning factor for C_{jcx} and C_{cox} over r_{Bx} .
77	$i_{bcxs}=0.0$ A	External BC saturation current.
78	$m_{bcx}=1.0$	External BC non-ideality factor.
79	$c_{eox}=0.0$ F	Emitter oxide (overlap) capacitance.
80	$r_{bx}=0.0$ Ω	External base series resistance.
81	$r_e=0.0$ Ω	Emitter series resistance.
82	$r_{cx}=0.0$ Ω	External collector series resistance.

Substrate transistor

83	$c_{js0}=0.0$ F	Zero-bias CS depletion capacitance.
84	$v_{ds}=0.6$ V	CS built-in voltage.
85	$z_s=0.5$	CS depletion coefficient.
86	$v_{pts}=\infty$ V	Punch-through voltage of CS junction.
87	$r_{su}=0.0$ Ω	Substrate resistance.
88	$c_{su}=0.0$ F	Substrate coupling capacitance.
89	$i_{scs}=0.0$ A	CS diode saturation current.
90	$m_{sc}=1.0$	CS diode non-ideality factor.

Virtuoso Simulator Components and Device Models Reference

HiCUM Model (bht)

91	<code>itss=0.0 A</code>	Transfer saturation current of Su transistor.
92	<code>msf=1.0</code>	Forward non-ideality factor of Su transfer current.
93	<code>msr=1.0</code>	Reverse non-ideality factor of Su transfer current.
94	<code>ibets=0.0 A</code>	BE tunneling saturation current.
95	<code>abet=40.0</code>	BE tunneling factor.

Noise parameters

96	<code>kf=0.0</code>	Flicker noise factor.
97	<code>af=2.0</code>	Flicker noise exponent factor.
98	<code>krbi=1.0</code>	Noise factor for internal base resistance.
99	<code>kfre=0.0</code>	Emitter resistance flicker noise coefficient.
100	<code>afre=2.0</code>	Emitter resistance flicker noise exponent facto.

Temperature effect parameters

101	<code>tnom (C)</code>	Parameters measurement temperature. Default set by options.
102	<code>vgb=1.17 V</code>	Bandgap-voltage.
103	<code>alb=5.0e-3 1/K</code>	Rel. temperature coeff. of current gain.
104	<code>alfav=0.0 1/K</code>	Temperature coefficient for FAVL.
105	<code>alqav=0.0 1/K</code>	Temperature coefficient for QAVL.
106	<code>zetaci=0.0</code>	Temper. coeff. (mobility) for epi-collector.
107	<code>alvs=0.0 1/K</code>	Relative temperature coefficient of saturation-drift velocity.
108	<code>alces=0.0 1/K</code>	Relative temperature coefficient of VCEs.
109	<code>zetarbi=0.0</code>	Temperature coefficient. (mobility) for int. base res.

Virtuoso Simulator Components and Device Models Reference

HiCUM Model (bht)

110	<code>zetarbx=0.0</code>	Temper. coeff. (mobility) for ext. base res.
111	<code>zetarcx=0.0</code>	Temper. coeff. (mobility) for ext. collector res.
112	<code>zetare=0.0</code>	Temper. coeff. (mobility) for emitter res.
113	<code>alt0=0.0</code> 1/K	First-order temper. coeff. of temperature T0.
114	<code>kt0=0.0</code>	Second-order temper. coeff. of temperature T0.
115	<code>rth=0.0</code> K/W	Thermal resistance for self-heating.
116	<code>cth=0.0</code> J/K	Thermal capacitance for self-heating.
117	<code>debug=0.0</code>	Debug.
118	<code>version=2.1</code>	The available versions are 1.0, 2.1, 2.20, 2.21, 2.22, 2.23, 2.24, 2.30, 2.31, and 2.32.

Operating region warning control parameters

119	<code>updatelevel=2.0</code>	Model update selector. The available versions are 0, 1, 2, and 3. updatelevel = 0 : This level is compatible with the original HICUM Fortran code. Temperature dependence is ignored. It is not recommended to use this level for convergence issue; updatelevel = 1 OR 2 : This level has better temperature dependence. It includes some fixes and enhancements. Version 1.0, 2.1, 2.21, and 2.22 support this level; updatelevel = 3 : This level has complete derivatives for current and charge model. The simulation result is fully compatible with HICUM Verilog-A model. Version 2.1, 2.20, 2.22, 2.23, and 2.32 support this level.
120	<code>minr=0.001</code> Ω	Minimum resistance.
121	<code>imax=1e3</code>	Maximum current.
122	<code>tmax=500</code> C	Maximum device temperature.
123	<code>tmin=200</code> C	Minimum resistance.
124	<code>alarm=none</code>	Forbidden operating region. Possible values are <code>none</code> , <code>off</code> , <code>fwd</code> , <code>rev</code> , and <code>sat</code> .

Virtuoso Simulator Components and Device Models Reference

HiCUM Model (bht)

DC-mismatch model parameters

125 $mvt0=0.0$ V Threshold mismatch intercept.

Formally released Hicium 2.2 new parameters

126 $v_{gc}=1.17$ V eff. collector bandgap voltage.

127 $v_{ge}=1.17$ V eff. emitter bandgap voltage.

128 $v_{gs}=1.17$ V eff. substrate bandgap voltage.

129 $zeta_{act}=3.0$ Exponent coefficient in transfer current temperature dependence.

130 $zeta_{bet}=3.5$ Exponent coefficient in B-E junction current temperature dependence.

131 $t_{bhrec}=0.0$ s Base current recombination time constant at B-C barrier for high forward injection.

132 $t_{unode}=1$ Specifies the base node connection for the tunneling current. Possible values are 0 and 1, where 1 signifies perimeter node.

133 $c_{bepar}=0.0$ F Total parasitic B-E capacitance.

134 $f_{bepar}=1.0$ Partitioning factor of parasitic B-E cap.

135 $f_{1vg}=-1.02377e-4$ Coefficient K1 in T-dependent band-gap equation.

136 $f_{2vg}=4.3215e-4$ Coefficient K2 in T-dependent band-gap equation.

137 $c_{fbe}=-1$ Flag for determining where to tag the flicker noise source, possible values are -1 and -2.

138 $zeta_{acx}=1.0$ Temperature exponent of mobility in substrate transistor transit time.

139 $c_{bcpar}=0.0$ F Total parasitic B-C capacitance.

140 $f_{bcpar}=0.0$ Partitioning factor of parasitic B-C cap.

141 $a_{jei}=2.5$ Ratio of maximum to zero-bias value of internal B-E capacitance.

Virtuoso Simulator Components and Device Models Reference

HiCUM Model (bht)

142	<code>ajep=2.5</code>	Ratio of maximum to zero-bias value of peripheral B-E capacitance.
143	<code>ahc=0.1</code>	Smoothing factor for current dependence of base and collector transit time.
144	<code>flsh=1</code>	Flag for turning on and off self-heating effect. Possible values are 0,1 and 2, 0 refer to turn off, 2 refer to full selfheating.
145	<code>flcomp=0.0</code>	Flag for compatibility with v2.1 model (0=v2.1).
146	<code>flnqs=1</code>	Flag for allowing to turn on(1) or off(0) NQS effect in a given model parameter set, that included non-zero values for alit and alqf.
147	<code>cornoise_flag=no</code>	Flag for turning on and off of correlated noise implementation. Alias of flcono. Possible values are <code>no</code> and <code>yes</code> .
148	<code>compatible=spectre</code>	Compatible parameters. Possible values are <code>spectre</code> , <code>spice2</code> , <code>spice3</code> , <code>cdsspice</code> , <code>hspice</code> , <code>spiceplus</code> , <code>eldo</code> , <code>sspice</code> , and <code>mica</code> .

Output Parameters

1	<code>tempeff (C)</code>	Effective temperature for a single device.
2	<code>meff</code>	Effective multiplicity factor (m-factor).
3	<code>debug</code>	Debug variable.

Operating-Point Parameters

1	<code>temp (C)</code>	Temperature.
2	<code>ic (A)</code>	Collector current.
3	<code>ib (A)</code>	Base current.
4	<code>vbei (V)</code>	Internal base-emitter voltage.

Virtuoso Simulator Components and Device Models Reference

HiCUM Model (bht)

5	qjei (Coul)	Internal base-emitter space charge.
6	cjei (F)	Internal base-emitter depletion capacitance.
7	vbep (V)	Peripheral base-emitter voltage.
8	qjep (Coul)	Peripheral base-emitter space charge.
9	cjep (F)	Peripheral base-emitter depletion capacitance.
10	vbci (V)	Internal base-collector voltage.
11	qjci (Coul)	Internal base-collector space charge.
12	cjci (F)	Internal base-collector depletion capacitance.
13	vbcp (V)	Vbcp.
14	qjcp (Coul)	Qjcp.
15	cjcp (F)	Cjcp.
16	vbcx (V)	Vbcx.
17	qjcx (Coul)	Qjcx.
18	cjcx (F)	Cjcx.
19	vsc (V)	Vsc.
20	qjs (Coul)	Substrate space charge.
21	cjs (F)	Substrate capacitance.
22	qdsu (Coul)	Substrate diffusion charge.
23	cdsu (F)	Substrate diffusion capacitance.
24	vcei (V)	Internal collector emitter voltage.
25	tf (s)	Transit Time.
26	qf (Coul)	Minority charge.

Virtuoso Simulator Components and Device Models Reference

HiCUM Model (bht)

27	qdei (Coul)	Internal base-emitter diffusion charge.
28	cdei (F)	Internal base-emitter diffusion capacitance.
29	qdc1 (Coul)	Internal base-collector diffusion charge.
30	cdci (F)	Internal base-collector diffusion capacitance.
31	qp (Coul)	Hole charge.
32	it (A)	Transfer current.
33	itf (A)	Transfer current.
34	itr (A)	Transfer current.
35	ibet (A)	Tunneling current.
36	gm (S)	Common-emitter transconductance.
37	si (S)	Common emitter output conductance.
38	sfb	Sfb variable.
39	srb	Srb variable.
40	sfc	Sfc variable.
41	src	Src variable.
42	rbi (Ω)	Internal base resistance.
43	rbx (Ω)	External base resistance.
44	rcx (Ω)	External collector resistance.
45	re (Ω)	Re variable.
46	rsu (Ω)	External collector resistance.
47	is (A)	Substrate current.
48	ft (Hz)	Unity small-signal current-gain frequency.

Virtuoso Simulator Components and Device Models Reference

HiCUM Model (bht)

49	pwr (W)	Power dissipation.
50	iavl (A)	lavl.
51	ibei (A)	lbei.
52	ibci (A)	lbci.
53	ibep (A)	lbep.
54	ijbcx (A)	ljbcx.
55	ijsc (A)	ljsc.
56	ieei (A)	leei.
57	ie (A)	le.
58	cbe (F)	Cbe.
59	cbc (F)	Cbc.
60	betar (A/A)	betar.
61	beta (A/A)	beta.
62	betadc (A/A)	betadc, the alias is beta.
63	betaac	Small signal current gain.
64	gmavl (S)	Transconductance for avalanche current.
65	gms (S)	Transconductance of the parasitic substrate PNP.
66	rpii (Ω)	Intrinsic input resistance.
67	rpix (Ω)	Extrinsic input resistance.
68	rmui (Ω)	Intrinsic feedback resistance.
69	rmux (Ω)	Extrinsic feedback resistance.
70	rmus (Ω)	Intrinsic substrate feedback resistance.

Virtuoso Simulator Components and Device Models Reference

HiCUM Model (bht)

71	<code>ro</code> (Ω)	Output resistance.
72	<code>ros</code> (Ω)	Output resistance for the parasitic substrate PNP.
73	<code>cpii</code> (F)	Total intrinsic BE capacitance.
74	<code>cpix</code> (F)	Total extrinsic BE capacitance.
75	<code>cmui</code> (F)	Total intrinsic BC capacitance.
76	<code>cmux</code> (F)	Total extrinsic BC capacitance.
77	<code>ccs</code> (F)	CS junction capacitance.
78	<code>crbi</code> (F)	Shunt capacitance across RBI.
79	<code>vef</code> (V)	Effective Forward Early voltage.
80	<code>ver</code> (V)	Effective Inverse Early voltage.
81	<code>vbe</code> (V)	External BE voltage.
82	<code>vbc</code> (V)	External BC voltage.
83	<code>vce</code> (V)	External CE voltage.
84	<code>gmi</code> (S)	Internal transconductance, alias of gm.
85	<code>roi</code> (Ω)	Output resistance.
86	<code>rb</code> (Ω)	Total base resistance as calculated in the model.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

`abet` M-95

`dt0h` M-27

`lat1` M-4

`tbv1` M-28

Virtuoso Simulator Components and Device Models Reference

HiCUM Model (bht)

acbar M-41	dvgbe M-57	m I-4	tef0 M-29
af M-97	f1vg M-135	mbci M-49	temp OP-1
afre M-100	f2vg M-136	mbcx M-78	tempeff O-1
ahc M-143	fav1 M-50	mbei M-45	tf OP-25
ahjei M-10	fbc M-76	mbep M-68	thcs M-31
ajei M-141	fbcpa M-140	mcf M-13	tmax M-122
ajep M-142	fbepa M-134	meff O-2	tmin M-123
alarm M-124	fcrbi M-56	minr M-120	tnom M-101
alb M-103	fdqr0 M-53	mode M-1	tr M-38
alces M-108	fgeo M-54	mrei M-47	trise I-2
alfav M-104	flcomp M-145	mrep M-70	tsf M-14
alhc M-32	flcono M-61	msc M-90	tunode M-132
alit M-17	flnqs M-146	msf M-92	type M-2
aljei M-21	flsh M-144	msr M-93	updatelevel M-119
aljep M-66	fqi M-55	mvt0 M-125	vbc OP-82
alqav M-105	ft OP-48	pwr OP-49	vbc1 OP-10
alqf M-43	fthc M-33	qavl M-51	vbc2 OP-13
alrth M-62	gm OP-36	qdc1 OP-29	vbc3 OP-16
alt0 M-113	gmavl OP-64	qdei OP-27	vbe OP-81
alvs M-107	gmi OP-84	qdsu OP-22	vbei OP-4
area I-6	gms OP-65	qf OP-26	vbep OP-7

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HiCUM Model (bht)

beta	OP-61	gtfe	M-30	qjci	OP-11	vcbar	M-39
betaac	OP-63	hf0	M-9	qjcp	OP-14	vce	OP-83
betadc	OP-62	hfc	M-15	qjcx	OP-17	vcei	OP-24
betar	OP-60	hfe	M-16	qjei	OP-5	vces	M-34
c10	M-5	hjci	M-8	qjep	OP-8	vdci	M-23
cbc	OP-59	hjei	M-12	qjs	OP-20	vdcx	M-72
cbcpar	M-139	iavl	OP-50	qp	OP-31	vdei	M-19
cbe	OP-58	ib	OP-3	qp0	M-6	vdep	M-64
cbepar	M-133	ibci	OP-52	rb	OP-86	vds	M-84
ccox	M-75	ibcis	M-48	rbi	OP-42	vef	OP-79
ccs	OP-77	ibcxs	M-77	rbi0	M-52	ver	OP-80
cdci	OP-30	ibei	OP-51	rbx	M-80	version	M-118
cdei	OP-28	ibeis	M-44	rbx	OP-43	vgb	M-102
cdsu	OP-23	ibep	OP-53	rci0	M-35	vgc	M-126
ceox	M-79	ibeps	M-67	rcx	M-82	vge	M-127
cfbe	M-137	ibet	OP-35	rcx	OP-44	vgs	M-128
cjci	OP-12	ibets	M-94	re	M-81	vlim	M-36
cjci0	M-22	ic	OP-2	re	OP-45	vpt	M-37
cjcp	OP-15	icbar	M-40	region	I-1	vptci	M-25
cjcx	OP-18	ich	M-7	rhjei	M-11	vptcx	M-74
cjcx0	M-71	ie	OP-57	rmui	OP-68	vpts	M-86

Virtuoso Simulator Components and Device Models Reference

HiCUM Model (bht)

cjei	OP-6	ieei	OP-56	rmus	OP-70	vsc	OP-19
cjei0	M-18	ijbcx	OP-54	rmux	OP-69	zci	M-24
cjep	OP-9	ijsc	OP-55	ro	OP-71	zcx	M-73
cjep0	M-63	imax	M-121	roi	OP-85	zei	M-20
cjs	OP-21	ireis	M-46	ros	OP-72	zep	M-65
cjs0	M-83	ireps	M-69	rpii	OP-66	zetabet	M-130
cmui	OP-75	is	OP-47	rpix	OP-67	zetaci	M-106
cmux	OP-76	iscs	M-89	rsu	M-87	zetact	M-129
compatible	M-148	isnoisy	I-5	rsu	OP-46	zetacx	M-138
cornoise_flag	M-147	it	OP-32	rth	M-115	zetahjei	M-58
cpii	OP-73	itf	OP-33	self_heating	I-3	zetarbi	M-109
cpix	OP-74	itr	OP-34	sfb	OP-38	zetarbx	M-110
crbi	OP-78	itss	M-91	sfc	OP-40	zetarcx	M-111
csu	M-88	kf	M-96	si	OP-37	zetare	M-112
cth	M-116	kfre	M-99	srb	OP-39	zetarth	M-60
debug	M-117	krbi	M-98	src	OP-41	zetavgbe	M-59
debug	O-3	kt0	M-114	t0	M-26	zs	M-85
delck	M-42	latb	M-3	tbhrec	M-131		

Virtuoso Simulator Components and Device Models Reference

HiCUM Model (bht)

HiCUM Level-0 Model (bht0)

The HiCUM Level0 model was developed by Professor M. Schroter. It combines the simplicity of the Spice Gummel Poon Model (SGPM) in terms of equivalent circuit and some of its model equations with several important features of HiCUM Level2. As a result, BHT0 is a more physics-based and accurate model than the SGPM and also reduces parameter extraction efforts, especially for single transistor sizes, compared to HiCUM Level2 and SGPM. The latest version of this model is 1.31, and all of previous versions are supported with setting model parameter VERSION.

This chapter contains the following information about the BHT0 model:

- [Model Version Updates](#) on page 358
- [Equivalent Circuit](#) on page 360
- [Charge formulation of the internal transistor](#) on page 361
- [Derivation of the simplified transfer current equation](#) on page 362
- [Static base current components](#) on page 365
- [Depletion charges and capacitances](#) on page 365
- [Minority charges and capacitances](#) on page 365
- [Series Resistance](#) on page 367
- [Temperature Dependence](#) on page 368
- [Noise Model](#) on page 370
- [Charge Storage Elements](#) on page 372
- [Series Resistance](#) on page 373
- [Temperature Effects](#) on page 373
- [Models and Equations in Version 1.30](#) on page 375
- [Component Statements](#) on page 378

Model Version Updates

Version 1.2:

- Upper limit of the model parameter FGEO is now infinity.
- Four or five terminals can be used with the latest version model, corresponding "tnode" is set as internal or external.
- Flag FLSH introduced for controlling self-heating calculation.
- All series resistors and RTH are limited to a minimum value.
- ddx() operator used with QJMOD and QJMODF wherever required.
- Substrate transistor transfer current has been added.
- Hyperbolic smoothing is used in rbi computation to avoid divide-by-zero.

Version 1.3

- Modification done at TUD: Third order polynomial is solved for transfer current. It can be turned on by setting `IT_MOD=1`.
- Added voltage dependent Reverse Early voltage. Parameter `aver` describes voltage dependence.
- Parameters `ZETAVER`, `ZETA VGBE`, `VGBE` describe temperature dependence of `VER` and `IQF`.
- Added temperature dependence for `IQFH` and `TFH`. `ALIQFH` and `KIQFH` are used to model a second order temperature model. Parameter `TEF_TEMP=0` turns off the temperature dependence for `TEF0`.
- Corrected SPICE name for `AHQ` and `ZETA IQF`. The original name is `AHQX` and `ZETA IQF`, which are also valid aliases.
- Implemented a `gmin` between nodes `CI` and `EI`.
- `qj` is now limited to positive values to improve convergence at negative bias.
- Resolved a convergence issue for `cc` a calculation of voltage dependence of `t0`

Version 1.3.1

- NQS effects have been added and can be activated by using the flag `FLNQS=1`.

Virtuoso Simulator Components and Device Models Reference

HiCUM Level-0 Model (bht0)

- Some operating point outputs have been added to the Va code.

Equivalent Circuit

Figure 7-1 Large signal equivalent circuit of the simplified HiCUM version, HiCUM/L0

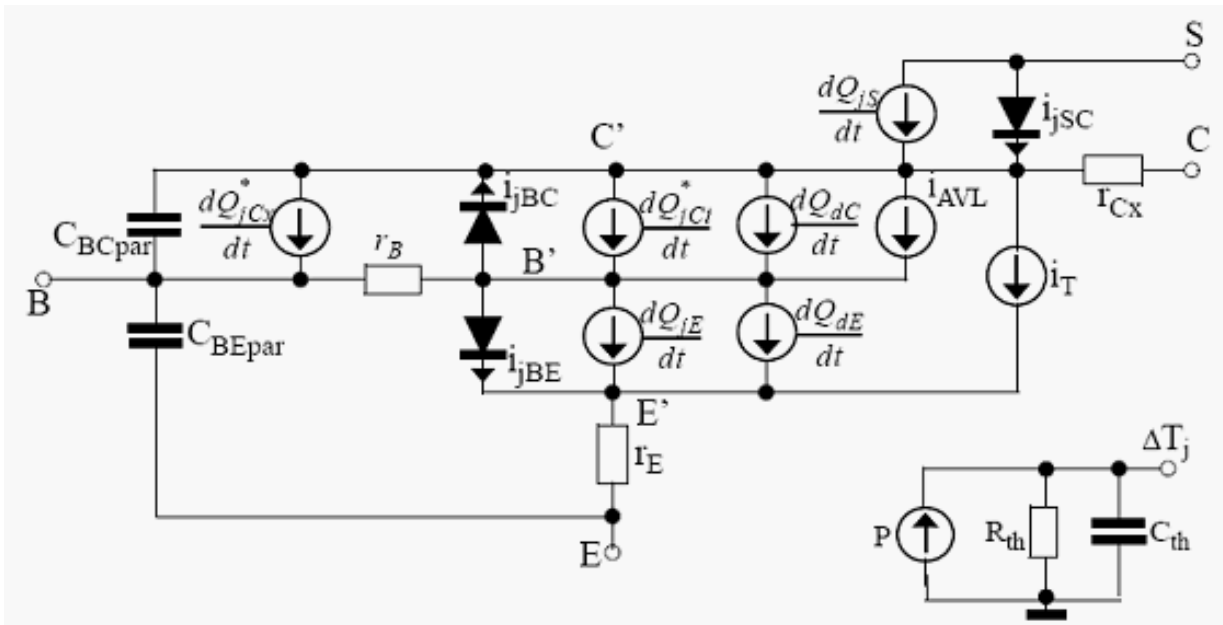


Figure 7-2 Small signal equivalent circuit of HiCUM/L0

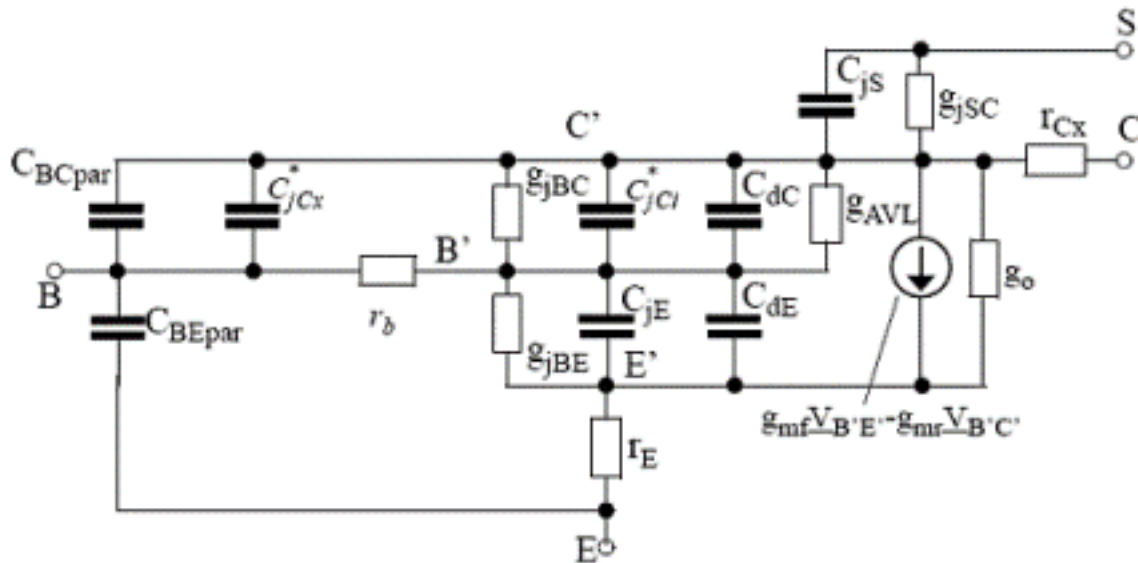
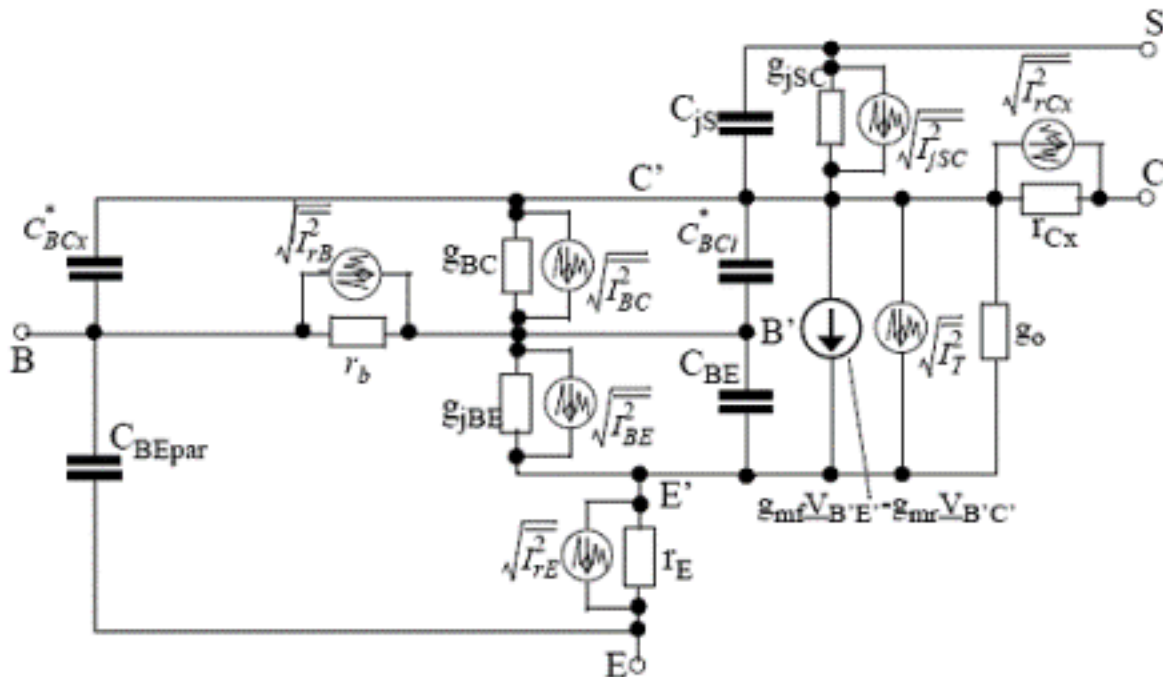


Figure 7-3 Small signal noise equivalent circuit of HiCUM/L0 showing the noise sources with their RMS values used in a circuit simulator



Charge formulation of the internal transistor

All depletion charges and capacitances are described with the same equations as HiCUM/L2. The formulation of forward minority charge Q_f is strongly based on the accurate description of the transit time τ_f . Like in HiCUM/L2, the bias dependent of τ_f is modelled as

$$\tau = \tau_{f0}(v_{B'C'}) + \Delta\tau_{f0}(i_{Tf} v_{C'E'})$$

with the low current component τ_{f0} , the high-current component $\Delta\tau_f$ and the i_{tf} as the forward transfer current. The formulation of τ_{f0} is same as in HiCUM/L2.

$$\Delta\tau_f = \left(\tau_{hcs} w^2 \left(1 + \frac{2I_{CK}}{i_{Tf} \sqrt{\left(1 - \frac{I_{CK}}{i_{Tf}}\right)^2 + a_{hc}}} \right) + \tau_{JE0} \left(\frac{i_{Tf}}{I_{CK}} \right)^{g_{TE}} \right) .$$

The minority charge Q_f used for dynamic transistor operation is then obtained analytically by integrating τ_f over i_{tf} .

$$Q_f = (\tau_{f0} i_{Tf} + \Delta Q_f) ,$$

Derivation of the simplified transfer current equation

$$i_T = \frac{c_{10}}{Q_{p,I}} \left[\exp\left(\frac{v_{BE}}{V_T}\right) - \exp\left(\frac{v_{BC}}{V_T}\right) \right] ,$$

The derivation starts with the transport related charge for low bias:

$$Q_{p,I} = Q_{p0} + h_{jei} Q_{jEi} + h_{jci} Q_{jCi} = Q_{p0} + h_{jei} (Q_{jEi,op} + \Delta Q_{jEi}) + h_{jci} Q_{jCi} .$$

$$Q_{p0}^* = Q_{p0} + h_{jei} Q_{jEi,op} .$$

$$\frac{Q_{p,I}}{Q_{p0}^*} = 1 + \frac{h_{jei} \Delta Q_{jEi}}{Q_{p0}^*} + \frac{h_{jci} Q_{jCi}}{Q_{p0}^*} + \frac{Q_{f,I}}{Q_{p0}^*} + \frac{Q_{r,I}}{Q_{p0}^*}$$

The resulting transfer current expression reads

$$i_{Tf} = \frac{I_S^*}{Q_{p,I}^*/Q_{p0}^*} \exp\left(\frac{v_{BE}}{V_T}\right),$$

with a modified saturation current

$$I_S^* = c_{10}/Q_{p0}^*.$$

The forward transfer current equation can be written in a more familiar form:

$$i_{Tf} = \frac{I_S^*}{1 + \frac{h_{jci}Q_{jci}}{Q_{p0}^*} + \frac{Q_{f,I}}{Q_{p0}^*} + \frac{Q_{r,I}}{Q_{p0}^*}} \exp\left(\frac{v_{BE}}{m_{Cf}V_T}\right).$$

Where

$$m_{Cf} = \frac{i_{Tf}/V_T}{g_m} \cong \left(1 - \frac{h_{jei}C_{jEi,op}V_T}{Q_{p0}^*}\right)^{-1} \cong 1 + \frac{h_{jei}C_{jEi,op}V_T}{Q_{p0}^*},$$

the low-current transconductance at the selected bias point $V_{BE',op}$ is given by

$$g_m = \frac{di_{Tf}}{dv_{BE}} \cong i_{Tf} \left(\frac{1}{V_T} - \frac{h_{jei}C_{jEi,op}}{Q_{p0}^*} \right) = \frac{i_{Tf}}{V_T} \left(1 - \frac{h_{jei}C_{jEi,op}V_T}{Q_{p0}^*} \right).$$

The artificial Early Voltage is defined as:

$$V_{Ef} = \frac{Q_{p0}^*}{h_{jcl} C_{jCl0}} .$$

The critical (or knee) current of the D.C. forward transfer curve is defined as:

$$I_{Qf} = Q_{p0}^* / \tau_{f0} (V_{B'C'} = 0)$$

$$I_{Qf} = Q_{p0}^* / \tau_f$$

Quadratic equation for normalized charge:

$$q_{p,T} = \underbrace{1 + \frac{q_{jCl}}{V_{Ef}}}_{q_j} + \underbrace{\left(\frac{i_{Tf}}{I_{Qf}} + \frac{i_{Tr}}{I_{Qr}} \right)}_{q_m} \cdot \frac{1}{q_{p,T}} .$$

The final formulation for the HICUM/L0 transfer current components:

$$\boxed{i_{Tf} = \frac{i_{Tf}}{1 + \frac{\Delta q_{fn}}{q_{p,T}}}} \quad \text{and} \quad \boxed{i_{Tr} = \frac{i_{Tr}}{1 + \frac{\Delta q_{fn}}{q_{p,T}}}} .$$

The total transfer current in HICUM/L0 reads:

$$i_T = i_{Tf} + i_{Tr} .$$

Static base current components

$$i_{jBE} = I_{BES} \left[\exp\left(\frac{v_{BE}}{m_{BE}V_T}\right) - 1 \right] + I_{RES} \left[\exp\left(\frac{v_{BE}}{m_{RE}V_T}\right) - 1 \right],$$

$$i_{jBC} = I_{jBCS} \left[\exp\left(\frac{v_{BC}}{m_{BC}V_T}\right) - 1 \right]$$

$$i_{AVL} = k_{AVL} \frac{i_{If}}{C_c^{1/z_{ci}}} \exp\left(-e_{AVL} C_c^{\left(\frac{1}{z_{ci}} - 1\right)}\right)$$

$$i_{jSC} = I_{SCS} \left[\exp\left(\frac{v_{SC}}{m_{SC}V_T}\right) - 1 \right]$$

Depletion charges and capacitances

$$C_{jE} = \frac{C_{jE0}}{(1 - v_j/V_{DE})^{z_E}} \frac{dv_j}{dv_{BE'}} + a_{jE} C_{jE0} \left(1 - \frac{dv_j}{dv_{BE'}} \right)$$

$$Q_{jE} = \frac{C_{jE0} V_{DE}}{1 - z_E} \left[1 - \left(1 - \frac{v_j}{V_{DE}} \right)^{(1 - z_E)} \right] + a_{jE} C_{jE0} (v_{BE} - v_j)$$

Minority charges and capacitances

The transit time consists of two components:

$$\tau_f(v_{CE'}, i_{If}) = \tau_f(v_{BC}) + \Delta\tau_f(v_{CE'}, i_{If})$$

Low current densities

The transit time reads:

$$\tau_{f0}(v_{BC}) = \tau_0 + \Delta\tau_{0h}(c-1) + \tau_{Bfvl} \left(\frac{1}{c} - 1 \right)$$

The respective forward minority charge is given by:

$$Q_{f0} = \tau_{f0} i_{Tf}$$

Medium and high current densities

The total increase in the (forward) transit time is given by:

$$\Delta\tau_f(v_{CE}, i_{Tf}) = \Delta\tau_{Ef} + \Delta\tau_{fh}$$

$$\Delta\tau_{fh} = \tau_{hcs} \cdot w^2 \left[1 + \frac{2I_{CK}}{i_{Tf} \sqrt{i^2 + a_{hc}}} \right]$$

$$w = \frac{w_i}{w_C} = \frac{i + \sqrt{i^2 + a_{hc}}}{1 + \sqrt{1 + a_{hc}}}$$

$$i = 1 - \frac{I_{CK}}{I_{Tf}}$$

The critical current I_{CK} is described by the same voltage dependence as for HICUM/L2.:

$$I_{CK} = \frac{v_{ceff}}{r_{Cl0}} \frac{1}{\sqrt{1 + \left(\frac{v_{ceff}}{V_{lim}}\right)^2}} \left[1 + \frac{x + \sqrt{x^2 + 10^{-3}}}{2} \right]$$

$$v_{ceff} = V_T \left[1 + \frac{1}{2} \left\{ u_{vc} + \sqrt{u_{vc}^2 + 1.921812} \right\} \right]$$

$$\Delta Q_{fh} = \tau_{hcs} i_{If} w^2$$

Series Resistance

Internal base resistance

$$r_{Bi} = r_i \psi(\eta)$$

$$\psi(\eta) = \frac{\ln(1 + \eta)}{\eta}$$

$$\eta = f_{geo} \frac{r_i I_{BE}}{V_T}$$

$$r_i = \frac{r_{Bi0}}{f_{Qz}}$$

$$f_{Qz} = \frac{1}{2} \left\{ Q_z + \sqrt{Q_z^2 + 0.01} \right\}$$

$$Q_z = \left(1 + \frac{q_{jE}}{V_{r0E}} + \frac{q_{jCl}}{V_{r0C}} + \frac{I_{If}}{I_{Qf}} + \frac{I_{Ir}}{I_{Qr}} \right)$$

External series resistances

$$r_B = r_{Bi} + r_{Bx}$$

Temperature Dependence

$$V_g(T) = V_g(T_0) + k_1 \frac{T}{T_0} \ln\left(\frac{T}{T_0}\right) + k_2 \left(\frac{T}{T_0} - 1\right)$$

with the definitions

$$k_1 = K_1 T_0 \quad , \quad k_2 = K_2 T_0 + k_1 \ln(T_0)$$

and the bandgap voltage at the measurement reference temperature

$$V_g(T_0) = k_2 + V_g(0)$$

$$I_S^*(T) = I_S^*(T_0) \left(\frac{T}{T_0}\right)^{\zeta_{scr}} \exp\left[\frac{V_{Gb}}{V_T(T)} \left(\frac{T}{T_0} - 1\right)\right]$$

$$I_{BES}(T) = I_{BES}(T_0) \left(\frac{T}{T_0}\right)^{\zeta_{BET}} \exp\left[\frac{V_{Gb}}{V_T(T)} \left(\frac{T}{T_0} - 1\right)\right]$$

$$I_{RES}(T) = I_{RES}(T_0) \left(\frac{T}{T_0}\right)^{m_g/2} \exp\left[\frac{V_{Gb}}{V_T(T)} \left(\frac{T}{T_0} - 1\right)\right]$$

$$I_{BCS}(T) = I_{BCS}(T_0) \left(\frac{T}{T_0}\right)^{\zeta_{BCI}} \exp\left[\frac{V_{GbX}}{V_T(T)} \left(\frac{T}{T_0} - 1\right)\right]$$

with $\zeta_{BET} = m_g + 1 - \zeta_{CT}$ and

$$I_{SCS}(T) = I_{SCS}(T_0) \left(\frac{T}{T_0}\right)^{\zeta_{scr}} \exp\left[\frac{V_{Gsc}}{V_T(T)} \left(\frac{T}{T_0} - 1\right)\right]$$

$$I_{TSS}(T) = I_{TSS}(T_0) \left(\frac{T}{T_0}\right)^{\zeta_{scr}} \exp\left[\frac{V_{Gc}}{V_T(T)} \left(\frac{T}{T_0} - 1\right)\right]$$

with $\zeta_{scr} = m_g - 1.5$

$$C_{j0}(T) = C_{j0}(T_0) \left(\frac{V_D(T_0)}{V_D(T)}\right)^z$$

$$V_{Dj}(T_0) = 2V_{T0} \ln\left[\exp\left(\frac{V_D(T_0)}{2V_{T0}}\right) - \exp\left(-\frac{V_D(T_0)}{2V_{T0}}\right)\right]$$

$$V_{Dj}(T) = V_{Dj}(T_0) \left(\frac{T}{T_0}\right) + V_g \left(1 - \frac{T}{T_0}\right) - m_g V_{T0} \ln\left(\frac{T}{T_0}\right)$$

$$V_D(T) = V_{Dj}(T) + 2V_T \ln \left(\frac{1 + \sqrt{1 + 4 \exp\left(-\frac{V_{Dj}(T)}{V_T}\right)}}{2} \right)$$

$$\tau_0(T) = \tau_0(T_0)[1 + alt0(T - T_0) + kt0(T - T_0)^2]$$

$$r_{Cf0}(T) = r_{Cf0}(T_0) \left(\frac{T}{T_0}\right)^{\zeta_{Cf}}$$

$$V_{CEs}(T) = V_{CEs}(T_0)[1 + (T - T_0)\alpha_{CES}]$$

$$r_{Cx}(T) = r_{Cx}(T_0) \left(\frac{T}{T_0}\right)^{\zeta_{RCX}}$$

$$r_{Bx}(T) = r_{Bx}(T_0) \left(\frac{T}{T_0}\right)^{\zeta_{RBX}}$$

$$r_{Bf0}(T) = r_{Bf0}(T_0) \left(\frac{T}{T_0}\right)^{\zeta_{RBI}}$$

$$r_E(T) = r_E(T_0) \left(\frac{T}{T_0}\right)^{\zeta_{RE}}$$

Noise Model

The equivalent noise current source is used for thermal noise in ohmic resistance:

$$\overline{I_r^2} = \frac{4kT\Delta f}{r}$$

For the transfer current, shot noise is assumed as:

$$\overline{I_T^2} = 2qI_T \Delta f$$

The noise resulting from the current injected across the BE junction into the emitter

$$\overline{I_{BE}^2} = 2qI_{jBE}\Delta f + k_F I_{jBE}^{\alpha_F} \frac{\Delta f}{f}$$

The currents across the other junctions are assumed to have a shot noise component only

$$\overline{I_{jdiode}^2} = 2qI_{jdiode} \Delta f$$

Noise from avalanche generation within the internal BC depletion region is modelled as shot noise

$$\overline{I_{AVL}^2} = 2qI_{AVL} \Delta f$$

giving for the total noise contribution within the BC junction

$$\overline{I_{BC}^2} = \overline{I_{jBC}^2} + \overline{I_{AVL}^2}$$

DC Characteristics

$$i_T = c_{10} \cdot \frac{\exp(V_{B'E'}/V_T) - \exp(V_{B'C'}/V_T)}{Q_{p0} + h_{jei}Q_{jei} + h_{jci}Q_{jCi} + Q_{fT} + Q_{rT}}$$

$$i_{Tf} = \frac{I^*_S}{1 + \frac{h_{jci}Q_{jCi}}{Q_{p0}} + \frac{Q_{fT}}{Q_{p0}} + \frac{Q_{rT}}{Q_{p0}}} \cdot \exp\left(\frac{v_{B'E'}}{m_{Cf}V_T}\right)$$

$$I^*_S = (c_{10}/Q^*_{p0}) \exp((h_{jei}C_{jei,op}v_{B'E',op})/Q^*_{p0})$$

$$V_{Ef} = \frac{Q_{p0}^*}{h_{jci} C_{jCi0}}$$

$$I_{Qf} = Q_{p0}^* / \tau_{f0} (v_{B'C'} = 0)$$

$$I_{Qr} = Q_{p0}^* / \tau_f$$

$$q_{pT} = \frac{1 + q_{jCi} / V_{Ef}}{q_j} + \frac{i_{Tfl} / I_{Qf} + i_{Trl} / I_{Qr}}{q_m' / q_{pT}}$$

$$i_{Trl} = \frac{I_s^*}{q_{pT}} \exp\left(\frac{v_{B'C'}}{m_{Cr} V_T}\right)$$

$$\frac{Q_{fT} - \tau_{f0} i_{Tfl}}{Q_{p0}^*} \cong \Delta q_{fh} = \left(w^2 + t_{fh} \frac{i_{Tfl}}{I_{CK}} \right) \frac{i_{Tfl}}{I_{Qfh}}$$

$$i_T = \frac{i_{Tfl} - i_{Trl}}{1 + \Delta q_{fh} / q_{pT}}$$

Charge Storage Elements

$$\tau_f = \tau_{f0} (V_{B'C'}) + \Delta \tau_f (i_{Tf} V_{C'E'})$$

The current dependence of $\Delta \tau_f$ is simplified by neglecting the bias dependent collector current spreading formulation. However, the bias independent collector current spreading factor fcs remains included in the critical current I_{CK} , resulting in a more physical geometry dependence of the low-field internal (epi-)collector resistance.

$$\Delta \tau_f = \tau_{hcs} w^2 \left(1 + \frac{2l_{CK}}{i_{Tf} \sqrt{(1 - l_{CK} / i_{Tf})^2 + a_{hc}}} \right) + \tau_{fE0} \left(\frac{i_{Tf}}{I_{CK}} \right)^{g_{\tau fE}}$$

$$Q_f = ((Q_{f0} + dQ_{ef}) + dQ_{fh})$$

$$Q_r = \tau_r i_{Tr}$$

Series Resistance

The internal base resistance can be strongly bias dependent and is modeled as

$$r_i = \frac{r_{Bi0}}{1 + \frac{q_{jE}}{V_{r0E}} + \frac{q_{jCi}}{V_{r0C}} + \frac{i_{Tf}}{I_{Qf}} + \frac{l_{Tf}}{I_{Qr}}}$$

where r_{Bi0} is the geometry dependent zero-bias value, and the denominator represents the conductivity modulation. The above equation has been derived from HICUM level-2 by introducing certain simplifications. Note, that V_{r0C} is close to the Early voltage V_{Ef} for BJTs but generally differs from V_{Ef} for HBTs.

Temperature Effects

$$q_{tt0} = T_{dev}/T_{nom}$$

$$I_s(t) = I_S * \exp(ZETA_{CT} * \ln(q_{tt0}) + V_{GB}/VT * (q_{tt0} - 1))$$

$$I_{bes}(t) = I_{BES} * \exp(ZETA_{BET} * \ln(q_{tt0}) + V_{GE}/VT * (q_{tt0} - 1))$$

$$I_{res}(t) = I_{RES} * \exp(ZETA_{BET} * \ln(q_{tt0}) + v_{gbe}/VT * (q_{tt0} - 1))$$

$$I_{bcs}(t) = I_{BCS} * \exp(ZETA_{BCI} * \ln(q_{tt0}) + V_{GC}/VT * (q_{tt0} - 1))$$

$$I_{scs}(t) = I_{SCS} * \exp(ZETA_{SCT} * \ln(q_{tt0}) + V_{GS}/VT * (q_{tt0} - 1))$$

$$vd_{j0} = 2 * VT * \ln(\exp(0.5 * vd/VT) - \exp(-0.5 * vd/VT))$$

$$vd_{jt} = vd_{j0} * q_{tt0} + v_g * (1 - q_{tt0}) - m_g * VT * \ln(q_{tt0})$$

$$vd_t = vd_{jt} + 2 * VT * \ln(0.5 * (1 + \sqrt{1 + 4 * \exp(-vd_{jt}/VT)}))$$

where v_g can be replaced with v_{gbe} , v_{gbc} , or v_{gsc}

$$C_{je0}(t) = C_{JE0} * \exp(ZE * \ln(V_{DE}/vd_t))$$

$$C_{jci0}(t) = C_{JCI0} * \exp(ZCI * \ln(V_{DCI}/vd_t))$$

Virtuoso Simulator Components and Device Models Reference

HiCUM Level-0 Model (bht0)

$$Cjcx0(t) = CJCX0 * \exp(ZCX * \ln(VDCX/vd_t))$$

$$Cjs0(t) = CJS0 * \exp(ZS * \ln(VDS/vd_t))$$

$$Rci0(t) = RCI0 * \exp(ZETACI * \ln(qtt0))$$

$$Vlim(t) = VLIM * \exp((ZETACI - avs) * \ln(qtt0))$$

$$Vces(t) = VCES * (1 + ALCES * dt)$$

$$T0(t) = T0 * (1 + ALT0 * dt + KT0 * dT * dT)$$

$$Thcs(t) = THCS * \exp((ZETACI - 1) * \ln_qtto)$$

$$zetatef = ZETABET - ZETACT - 0.5$$

$$dvg = VGB - VGE$$

$$Tef0(t) = TEF0 * \exp(ZETATEF * \ln(qtt0) - dvg/VT * (qtt0 - 1))$$

$$Rbx(t) = RBX * \exp(ZETARBX * \ln(qtt0))$$

$$Rcx(t) = RCX * \exp(ZETARCX * \ln(qtt0))$$

$$rbi0(t) = RBI0 * \exp(ZETARBI * \ln(qtt0))$$

$$Re(t) = RE * \exp(ZETARE * \ln(qtt0))$$

$$Eavl(t) = EAVL * \exp(ALEAV * dT) \quad /$$

$$Kavl(t) = KAVL * \exp(ALKAV * dT)$$

Noise Model

The equivalent noise current source is used for thermal noise in ohmic resistance:

$$\overline{I_r^2} = \frac{4k_B T \Delta f}{r}, \text{ with } r \rightarrow r_E, r_{Cx}, r_B = r_{Bx} + R_{Bi}$$

Shot noise is assumed for transfer current

$$\overline{I_T^2} = 2qI_T \Delta f$$

Shot noise for current across BE junction is taken into account in the following equation

$$\overline{I_{jBE}^2} = 2qI_{jBE} \Delta f$$

A flicker noise source is implemented for the BE junction

$$\overline{I_{BE}^2} = k_f I_{jBE}^{a_f} \frac{\Delta f}{f}$$

Other Effects

Self-heating is included to overcome one of the most significant deficiencies of the SGPM for advanced processes including III-V HBTs.

Models and Equations in Version 1.30

Improved model formulations for the HiCUM/L0 transfer current

The improvements can be categorized by:

- Bias Dependence
- Temperature Dependence

Bias Dependence

Low and Medium Current Range

The equation for reverse Early voltage is:

$$V_{Er} = \frac{V_{Er0}}{\left(\frac{\exp(u) - 1}{u}\right)}$$

where

$$u = a_{V_{Er}} \left(1 - \left(1 - \frac{v_j}{V_{DE}} \right)^{Z_E} \right)$$

Here, V_{Er0} is the Early voltage for zero volt and $a_{V_{Er}}$ the parameter describing the change of the Early voltage. The junction voltage is limited to the range (0, V_{DEi}) as follows:

$$\chi_{upp} = \frac{V_{DE} - V_{BEi}}{r_{V_{Er}} V_T}$$

$$v_{j,upp} = V_{DE} - r_{V_{Er}} V_T \frac{\chi_{upp} - \sqrt{\chi_{upp}^2 + a_{fi}}}{2}$$

$r_{V_{Er}} V_T$ is used rather than V_T since it allows a smooth transition to voltages larger than V_{DE} .

The limitation to values larger zero is realized by:

$$\chi_{low} = \frac{v_{j,upp} - V_T}{V_T} \quad \text{and} \quad v_j = V_T \left(1 + \frac{\chi_{low} + \sqrt{\chi_{low}^2 + a_{fi}}}{2} \right)$$

The parameters V_{DE} and j used here are the same as for the electrostatic capacitance. For simplification, the parameter $r_{V_{Er}}$ is set to a fixed value of two, which is sufficient for all verifications. However, to allow full backward compatibility the parameter set for the DC charge V_{EDC} , z_{EDC} and a_{jEDC} is still kept separately from that of the AC charge, although the values may be the same. Therefore, the DC-charge formulation can still be used in the new version and the bias dependence of V_{Er} can be turned off by settings $a_{V_{Er}}$ to zero.

High Current

The transfer current equation for high current effects has been changed. In earlier versions, a second order polynomial (with bias dependent coefficients) was used for the whole range. However, a more physical description results in a third order polynomial function (resulting from $g_{tfE}=1$ in HICUM/L2). The third order polynomial reads:

$$q_{pT}^3 - q_j q_{pT}^2 - \left(\frac{I_{Tf0}}{I_{CKf}} + \frac{I_{Tr0}}{I_{CKr}} + \frac{I_{Tf0}}{I_{Qfh}} w^2 \right) q_{pT} - \frac{I_{Tf0}^2 t_{fh}}{I_{CK} I_{Qfh}} = 0$$

The above equation can be solved with respect to q_{pT} .

The following is the transfer current equation for modeling the high current effects:

$$i_{Tf} = \frac{I_s}{q_j + \frac{i_{Tf}}{I_{CKf}} + \frac{i_{Tr}}{I_{CKr}} + w^2 \frac{i_{Tf}}{I_{Qfh}} + \left(\frac{i_{Tf}}{I_{CK}} \right) \frac{i_{Tf}}{I_{QfE}}}$$

t_{fh} can be simply calculated by:

$$t_{fh} = \frac{I_{Qfh}}{I_{QfE}}$$

Temperature Dependence

Medium Bias Range

The medium bias range is dominated by the temperature dependence of the saturation current and reverse Early voltage. The temperature dependence of the saturation current is kept untouched. The reverse Early voltage itself becomes temperature dependent. Two effects need to be taken into account.

First, the Early voltage at zero volt changes due to the different bandgap in the base and the BESC. This bandgap difference is used as a parameter along with a non-ideality parameter. The equation itself reads:

$$V_{Er0}(T) = V_{Er0}(T_0) \exp \left[\frac{-\Delta V_{gBE}}{V_T} \left(\left(\frac{T}{T_0} \right)^{\zeta_{vgBE}} - 1 \right) \right]$$

Additional, the parameter describing the Early voltage change also changes due to the temperature voltage V_T and the temperature induced moving of the SCR-boundary. Both effects are modelled using one temperature coefficient.

$$a_{V_{Er}}(T) = a_{V_{Er}}(T_0) \left(\frac{T}{T_0} \right)^{\zeta_{V_{Er}}}$$

High Current Effects

The temperature dependence of I_{Qf} is given by:

$$I_{Qf}(T) = I_{Qf}(T_0) \left(\frac{T}{T_0} \right)^{\zeta_{IQf}} \exp \left(\frac{-\Delta V_{gBE}}{V_T} \left(\frac{T}{T_0} - 1 \right) \right)$$

Due to different bandgap voltages in the transistor, high current effects may become also temperature dependent. Since for I_{Qfh} , minorities in different regions of the transistor are taken into account, a simple second order polynomial fit is applied, as follows:

$$I_{Qfh}(T) = I_{Qfh}(T_0) \left(1 + \alpha_{IQfh} \Delta T + k_{IQfh} \Delta T^2 \right)$$

$$I_{Qfh} = \frac{Q_{p0}}{((1 - f_{\tau h C}) + f_{\tau h C} h_{fC}) \tau_{hC} s}$$

The temperature dependence of t_{fh} is given by:

$$t_{fh}(T) = t_{fh}(T_0) \frac{I_{Qfh}(T)}{I_{Qfh}(T_0)} \exp \left(\frac{V_{gb} - V_{ge}}{V_T} \left(\frac{T}{T_0} - 1 \right) \right)$$

Component Statements

The device is supported within altergroups.

Instance Definition

Name c b e s [tnode] ModelName parameter=value ...

Virtuoso Simulator Components and Device Models Reference

HiCUM Level-0 Model (bht0)

Instance Parameters

1	<code>dt=0.0 K</code>	Temperature change for particular transistor.
2	<code>m=1</code>	Instance parameter Mfactor.
3	<code>exp_cr=80</code>	Instance parameter <code>exp_cr</code> for <code>limitexp</code> .
4	<code>isnoisy=yes</code>	Should device generate noise. Possible values are <code>no</code> and <code>yes</code> .

Model Definition

```
model modelName bht0 parameter=value ...
```

Model Parameters

1	<code>is=1.0e-16 A</code>	(Modified) saturation current.
2	<code>it_mod=0</code>	Flag for using third order solution for transfer current.
3	<code>mcf=1.00</code>	Non-ideality coefficient of forward collector current.
4	<code>mcr=1.00</code>	Non-ideality coefficient of reverse collector current.
5	<code>vef=1.0e6 V</code>	forward Early voltage (normalization volt.).
6	<code>ver=1.0e6 V</code>	reverse Early voltage (normalization volt.).
7	<code>aver=0.0</code>	bias dependence for reverse Early voltage.
8	<code>iqf=1.0e6 A</code>	forward d.c. high-injection toll-off current.
9	<code>fiqf=0</code>	flag for turning on base related critical current.
10	<code>iqr=1.0e6 A</code>	inverse d.c. high-injection roll-off current.
11	<code>iqfh=1.0e6 A</code>	high-injection correction current.
12	<code>tfh=0.0</code>	high-injection correction factor.
13	<code>ahq=0</code>	Smoothing factor for the d.c. injection width.

Virtuoso Simulator Components and Device Models Reference

HiCUM Level-0 Model (bht0)

14	<code>ibes=1e-18 A</code>	BE saturation current.
15	<code>mbe=1.0</code>	BE non-ideality factor.
16	<code>ires=0.0 A</code>	BE recombination saturation current.
17	<code>mre=2.0</code>	BE recombination non-ideality factor.
18	<code>ibcs=0.0 A</code>	BC saturation current.
19	<code>mbc=1.0</code>	BC non-ideality factor.
20	<code>cje0=1.0e-20 F</code>	Zero-bias BE depletion capacitance.
21	<code>vde=0.9 V</code>	BE built-in voltage.
22	<code>ze=0.5</code>	BE exponent factor.
23	<code>aje=2.5</code>	Ratio of maximum to zero-bias value.
24	<code>vdedc=0.9 V</code>	BE charge built-in voltage for d.c. transfer current.
25	<code>zedc=0.5</code>	charge BE exponent factor for d.c. transfer current.
26	<code>ajedc=2.5</code>	BE capacitance ratio Ratio maximum to zero-bias value for d.c. transfer current.
27	<code>t0=0.0 s</code>	low current transit time at $V_{bici}=0$.
28	<code>dt0h=0.0</code>	model parameter: no description.
29	<code>tbvl=0.0 s</code>	SCR width modulation contribution.
30	<code>tef0=0.0 s</code>	Storage time in neutral emitter.
31	<code>gte=1.0</code>	Exponent factor for emitter transit time.
32	<code>thcs=0.0 s</code>	Saturation time at high current densities.
33	<code>ahc=0.1</code>	Smoothing factor for current dependence.
34	<code>tr=0.0 s</code>	Storage time at inverse operation.

Virtuoso Simulator Components and Device Models Reference

HiCUM Level-0 Model (bht0)

35	$r_{ci0}=150 \ \Omega$	Low-field collector resistance under emitter.
36	$v_{lim}=0.5 \ V$	Voltage dividing ohmic and satur.region.
37	$v_{pt}=100 \ V$	Punch-through voltage.
38	$v_{ces}=0.1 \ V$	Saturation voltage.
39	$c_{jci0}=1.0e-20 \ F$	Total zero-bias BC depletion capacitance.
40	$v_{dci}=0.7 \ V$	BC built-in voltage.
41	$z_{ci}=0.333$	BC exponent factor.
42	$v_{ptci}=100 \ V$	Punch-through voltage of BC junction.
43	$c_{jcx0}=1.0e-20 \ F$	Zero-bias external BC depletion capacitance.
44	$v_{dcx}=0.7 \ V$	External BC built-in voltage.
45	$z_{cx}=0.333$	External BC exponent factor.
46	$v_{ptcx}=100 \ V$	Punch-through voltage.
47	$f_{bc}=1.0$	Split factor = C_{jci0}/C_{jcx0} .
48	$r_{bi0}=0.0 \ \Omega$	Internal base resistance at zero-bias.
49	$v_{r0e}=2.5 \ V$	forward Early voltage (normalization volt.).
50	$v_{r0c}=1.0e6 \ V$	forward Early voltage (normalization volt.).
51	$f_{geo}=0.656$	Geometry factor.
52	$r_{bx}=0.0 \ \Omega$	External base series resistance.
53	$r_{cx}=0.0 \ \Omega$	Emitter series resistance.
54	$r_{e}=0.0 \ \Omega$	External collector series resistance.
55	$i_{tss}=0.0 \ A$	Substrate transistor transfer saturation current.
56	$msf=1.0$	Substrate transistor transfer current non-ideality factor.

Virtuoso Simulator Components and Device Models Reference

HiCUM Level-0 Model (bht0)

57	<code>iscs=0.0 A</code>	SC saturation current.
58	<code>msc=1.0</code>	SC non-ideality factor.
59	<code>cjs0=1.0e-20 F</code>	Zero-bias SC depletion capacitance.
60	<code>vds=0.3 V</code>	SC built-in voltage.
61	<code>zs=0.3</code>	External SC exponent factor.
62	<code>vppts=100 V</code>	SC punch-through voltage.
63	<code>cbcpar=0.0 F</code>	Collector-base isolation (overlap) capacitance.
64	<code>cbepar=0.0 F</code>	Emitter-base oxide capacitance.
65	<code>eavl=0.0</code>	Exponent factor.
66	<code>kavl=0.0</code>	Prefactor.
67	<code>kf=0.0 M^(1-AF)</code>	flicker noise coefficient.
68	<code>af=2.0</code>	flicker noise exponent factor.
69	<code>alqf=0.167</code>	Factor for additional delay time of minority charge.
70	<code>alif=0.333</code>	Factor for additional delay time of transfer current.
71	<code>flnqs=0</code>	Flag for turning on and off of vertical NQS effect.
72	<code>vgb=1.2 V</code>	Bandgap-voltage.
73	<code>vge=1.17 V</code>	Effective emitter bandgap-voltage.
74	<code>vgc=1.17 V</code>	Effective collector bandgap-voltage.
75	<code>vgs=1.17 V</code>	Effective substrate bandgap-voltage.
76	<code>f1vg=(-1.02377e-4) V/K</code>	Coefficient K1 in T-dependent bandgap equation.
77	<code>f2vg=4.3215e-4 V/K</code>	Coefficient K2 in T-dependent bandgap equation.

Virtuoso Simulator Components and Device Models Reference

HiCUM Level-0 Model (bht0)

78	<code>alt0=0.0 1/K</code>	First-order TC of <code>tf0</code> .
79	<code>kt0=0.0 1/K²</code>	Second-order TC of <code>tf0</code> .
80	<code>zetact=3.0</code>	Exponent coefficient in transfer current temperature dependence.
81	<code>zetabet=3.5</code>	Exponent coefficient in BE junction current temperature dependence.
82	<code>zetaci=0.0</code>	TC of epi-collector diffusivity.
83	<code>alvs=0.0 1/K</code>	Relative TC of satur.drift velocity.
84	<code>alces=0.0 1/K</code>	Relative TC of <code>vces</code> .
85	<code>zetarbi=0.0</code>	TC of internal base resistance.
86	<code>zetarbx=0.0</code>	TC of external base resistance.
87	<code>zetarcx=0.0</code>	TC of external collector resistance.
88	<code>zetare=0.0</code>	TC of emitter resistances.
89	<code>zetaiqf=0.0</code>	TC of <code>iqf</code> .
90	<code>alkav=0.0 1/K</code>	TC of avalanche prefactor.
91	<code>aleav=0.0 1/K</code>	TC of avalanche exponential factor.
92	<code>zetarth=0.0</code>	Exponent factor for temperature dependent thermal resistance.
93	<code>tef_temp=1</code>	Flag for turning temperature dependence of <code>tef0</code> on and off.
94	<code>zetaver=(-1.0)</code>	TC of Reverse Early voltage.
95	<code>zetavgbe=1.0</code>	TC of AVER.
96	<code>dvgb=0.0</code>	Bandgap difference between base and BE-junction.
97	<code>aliqfh=0 1/K</code>	First-order TC of <code>iqfh</code> .
98	<code>kiqfh=0 1/K²</code>	Second-order TC of <code>iqfh</code> .

Virtuoso Simulator Components and Device Models Reference

HiCUM Level-0 Model (bht0)

99	flsh=0	Flag for self-heating calculation.
100	rth=0.0 K/W	Thermal resistance.
101	cth=0.0 Ws/K	Thermal capacitance.
102	pnnp=0	model type flag for pnp.
103	nnp=1	model type flag for npn.
104	tnom=27 C	Temperature for which parameters are valid.
105	version=1.2	The available versions are 1.0, 1.11, 1.12, 1.2, 1.3 and 1.31.

Output Parameters

1	meff	Effective multiplicity factor (m-factor).
---	------	---

Operating Point Parameters

1	qjci (C)	B-C internal junction charge.
2	qjei (C)	B-E internal junction charge.
3	cjei (F)	B-E internal junction capacitance.
4	it (A)	Transfer Current.
5	ijbc (A)	Base-collector diode current.
6	iavl (A)	Avalanche current.
7	ijsc (A)	Substrate-collector diode current.
8	ieei (A)	Current through external to internal emitter node.
9	icci (A)	Current through external to internal collector node.
10	ibbi (A)	Current through external to internal base node.
11	ibici (A)	Base-collector diode current minus the avalanche current.

Virtuoso Simulator Components and Device Models Reference

HiCUM Level-0 Model (bht0)

12	<code>ijbe</code> (A)	Base-emitter diode current.
13	<code>vef</code> (V)	Effective forward Early-voltage.
14	<code>ver</code> (V)	Effective inverse Early-voltage.
15	<code>tempeff</code> (C)	Effective temperature for a single device.
16	<code>ib</code>	Base terminal current.
17	<code>ic</code>	Collector terminal current.
18	<code>is</code>	Substrate current.
19	<code>vbe</code>	External BE voltage.
20	<code>vbc</code>	External BC voltage.
21	<code>vce</code>	External CE voltage.
22	<code>vsc</code>	External SC voltage.
23	<code>betadc</code>	Common emitter forward current gain.
24	<code>gmi</code>	Internal transconductance.
25	<code>rpii</code>	Internal input resistance.
26	<code>rmui</code>	Internal feedback resistance.
27	<code>roi</code>	Internal Output resistance.
28	<code>cpii</code>	Total BE capacitance.
29	<code>cmui</code>	Total internal BC capacitance.
30	<code>cbcx</code>	Total external BC capacitance.
31	<code>ccs</code>	CS junction capacitance.
32	<code>rbi</code>	Internal base resistance.
33	<code>rb</code>	Total base resistance.

Virtuoso Simulator Components and Device Models Reference

HiCUM Level-0 Model (bht0)

34	<code>rcx</code>	External (saturated) collector series resistance.
35	<code>re</code>	Emitter series resistance.
36	<code>betaac</code>	Small signal current gain.
37	<code>tf</code>	Total forward transit time.
38	<code>ft</code>	Transit frequency.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

<code>af</code>	M-68	<code>fiqf</code>	M-9	<code>mcr</code>	M-4	<code>vdcx</code>	M-44
<code>ahc</code>	M-33	<code>flnqs</code>	M-71	<code>meff</code>	O-1	<code>vde</code>	M-21
<code>ahq</code>	M-13	<code>flsh</code>	M-99	<code>mre</code>	M-17	<code>vdedc</code>	M-24
<code>aje</code>	M-23	<code>ft</code>	OP-38	<code>msc</code>	M-58	<code>vds</code>	M-60
<code>ajedc</code>	M-26	<code>gmi</code>	OP-24	<code>msf</code>	M-56	<code>vef</code>	M-5
<code>alces</code>	M-84	<code>gte</code>	M-31	<code>npn</code>	M-103	<code>vef</code>	OP-13
<code>aleav</code>	M-91	<code>iavl</code>	OP-6	<code>pnp</code>	M-102	<code>ver</code>	M-6
<code>aliqfh</code>	M-97	<code>ib</code>	OP-16	<code>qjci</code>	OP-1	<code>ver</code>	OP-14
<code>alif</code>	M-70	<code>ibbi</code>	OP-10	<code>qjei</code>	OP-2	<code>version</code>	M-105
<code>alkav</code>	M-90	<code>ibcs</code>	M-18	<code>rb</code>	OP-33	<code>vgb</code>	M-72
<code>alqf</code>	M-69	<code>ibes</code>	M-14	<code>rbi</code>	OP-32	<code>vgc</code>	M-74
<code>alt0</code>	M-78	<code>ibici</code>	OP-11	<code>rbi0</code>	M-48	<code>vge</code>	M-73

Virtuoso Simulator Components and Device Models Reference

HiCUM Level-0 Model (bht0)

alvs M-83	ic OP-17	rbx M-52	vgs M-75
aver M-7	icci OP-9	rci0 M-35	vlim M-36
betaac OP-36	ieei OP-8	rcx M-53	vpt M-37
betadc OP-23	ijbc OP-5	rcx OP-34	vptci M-42
cbcpar M-63	ijbe OP-12	re M-54	vptcx M-46
cbcx OP-30	ijsc OP-7	re OP-35	vpts M-62
cbepar M-64	iqf M-8	rmui OP-26	vr0c M-50
ccs OP-31	iqfh M-11	roi OP-27	vr0e M-49
cjci0 M-39	iqr M-10	rpii OP-25	vsc OP-22
cjcx0 M-43	ires M-16	rth M-100	zci M-41
cje0 M-20	is M-1	t0 M-27	zcx M-45
cjei OP-3	is OP-18	tbv1 M-29	ze M-22
cjs0 M-59	iscs M-57	tef0 M-30	zedc M-25
cmui OP-29	isnoisy I-4	tef_temp M-93	zetabet M-81
cpii OP-28	it OP-4	tempeff OP-15	zetaci M-82
cth M-101	it_mod M-2	tf OP-37	zetact M-80
dt I-1	itss M-55	tfh M-12	zetaiqf M-89
dt0h M-28	kavl M-66	thcs M-32	zetarbi M-85
dvgbe M-96	kf M-67	tnom M-104	zetarbx M-86
eavl M-65	kiqfh M-98	tr M-34	zetarcx M-87
exp_cr I-3	kt0 M-79	vbc OP-20	zetare M-88

Virtuoso Simulator Components and Device Models Reference

HiCUM Level-0 Model (bht0)

f1vg	M-76	m	I-2	vbe	OP-19	zetarth	M-92
f2vg	M-77	mbc	M-19	vce	OP-21	zetaver	M-94
fbc	M-47	mbe	M-15	vces	M-38	zetavgbe	M-95
fgeo	M-51	mcf	M-3	vdci	M-40	zs	M-61

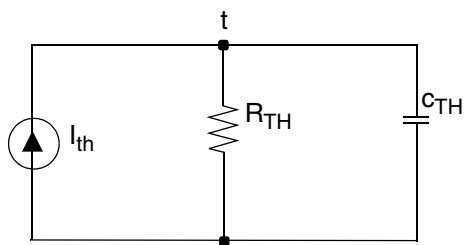
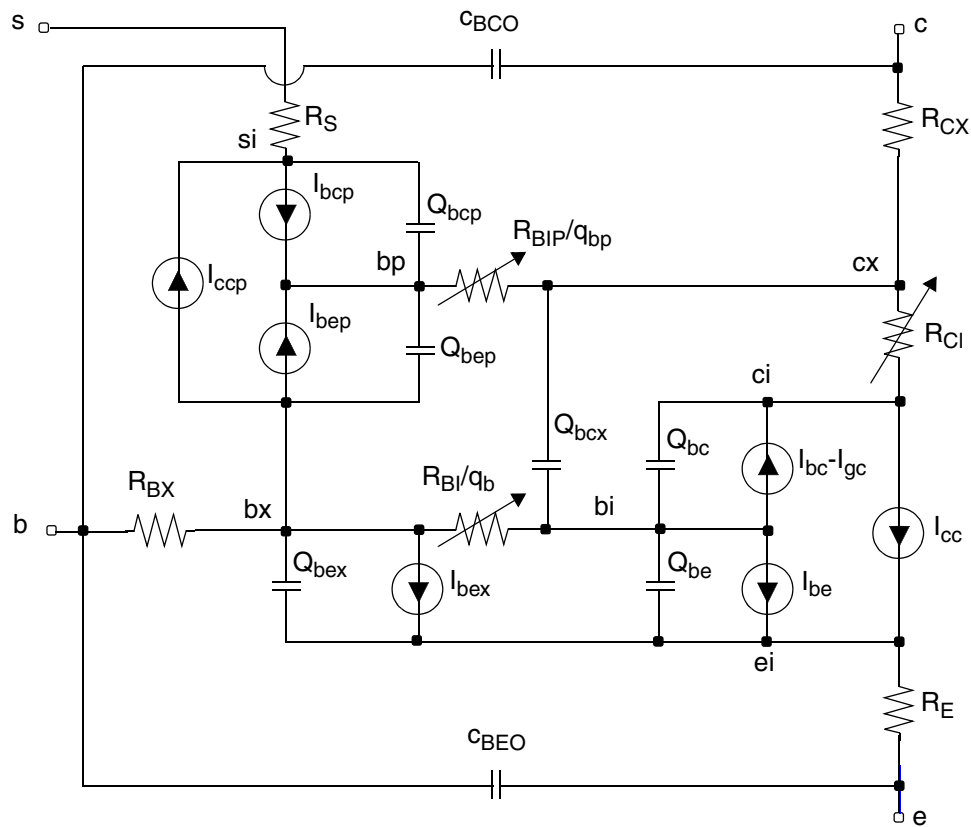
VBIC Model (vbic)

The VBIC model was developed by the Colin McAndrew team at Motorola as a replacement of the Gummel-Poon model. This chapter contains the following information for the VBIC model:

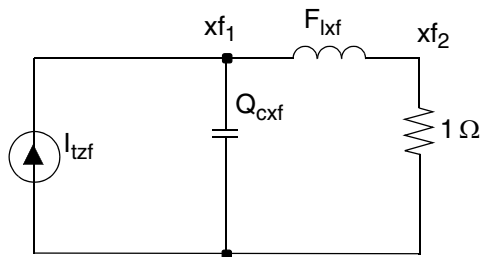
- [VBIC 1.1](#) on page 391
 - [DC Current](#) on page 391
 - [Charge Equations](#) on page 393
 - [Excess Phase](#) on page 396
 - [Small Signal Parameters](#) on page 396
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Virtuoso Simulator Components and Device Models Reference

VBIC Model (vbic)



Thermal network



Excess phase network

VBIC 1.1

DC Current

$$I_{cc} = \frac{I_{tf} - I_{tr}}{Q_b}$$

$$I_{tf} = I_s (e^{V_{bei}/N_f V_{tm}} - 1)$$

$$I_{tr} = I_s (e^{V_{bci}/N_r V_{tm}} - 1)$$

$$Q_b = \frac{1}{2} (Q_1 + \sqrt{Q_1^2 + 4Q_2})$$

$$Q_1 = \frac{1}{2} \sqrt{\left(0.9999 + \frac{Q'_{je}}{V_{er}} + \frac{Q'_{jc}}{V_{ef}}\right)^2 + 10^{-8}} + \frac{1}{2} \left(0.9999 + \frac{Q'_{je}}{V_{er}} + \frac{Q'_{jc}}{V_{ef}}\right) + 10^{-4}$$

$$Q'_{je} = \frac{Q_{je}}{C_{je}}$$

$$Q'_{jc} = \frac{Q_{jc}}{C_{jc}}$$

$$Q_2 = \frac{I_{tf}}{I_{kf}} + \frac{I_{tr}}{I_{kr}}$$

$$I_{be} = W_{be} \left[I_{bei} (e^{V_{bei}/N_{ei} V_{tm}} - 1) + I_{ben} (e^{V_{bei}/N_{en} V_{tm}} - 1) \right]$$

$$I_{bex} = (1 - W_{be}) \left[I_{bei} (e^{V_{bex}/N_{ei} V_{tm}} - 1) + I_{ben} (e^{V_{bex}/N_{en} V_{tm}} - 1) \right]$$

Virtuoso Simulator Components and Device Models Reference

VBIC Model (vbic)

$$I_{bc} = I_{bci} (e^{V_{bci}/N_{ci}V_{tm}} - 1) + I_{bcn} (e^{V_{bci}/N_{cn}V_{tm}} - 1)$$

$$I_{gc} = (I_{cc} - I_{bc}) A_{vc1} V_l e^{-A_{vc2} V_{tm}}$$

$$V_l = \frac{1}{2} \left[\sqrt{(P_c - V_{bc})^2 + 0.01} + (P_c - V_{bc}) \right]$$

$$V_{lm} = V_l^{(M_c - 1)}$$

$$I_{bep} = I_{beip} (e^{V_{bep}/N_{ci}V_{tm}} - 1) + I_{benp} (e^{V_{bep}/(N_{cn}V_{tm})} - 1)$$

$$I_{bcp} = I_{bcip} (e^{V_{bcp}/(N_{cip}V_{tm})} - 1) + I_{bcnp} (e^{V_{bcp}/(N_{cnp}V_{tm})} - 1)$$

$$I_{ccp} = \frac{I_{tfp} - I_{trp}}{Q_{bp}}$$

$$I_{tfp} = W_{sp} I_{sp} (e^{V_{bep}/N_{fp} V_{tm}} - 1) + (1 - W_{sp}) I_{sp} (e^{V_{bci}/N_{fp} V_{tm}} - 1)$$

$$I_{trp} = I_{sp} (e^{V_{bcp}/N_{fp} V_{tm}} - 1)$$

$$Q_{bp} = \frac{1}{2} (1 + \sqrt{1 + 4Q_{2p}})$$

$$Q_{2p} = \frac{I_{tfp}}{I_{kp}}$$

$$R_{bi} = \frac{R_{bi}}{Q_b}$$

$$R_{bp} = \frac{R_{bp}}{Q_{bp}}$$

Virtuoso Simulator Components and Device Models Reference

VBIC Model (vbic)

$$I_{rci} = \frac{V_{rci} + V_{tm}[K_{bci} - K_{bcx} - \ln(R_{kpl})]}{R_{ci}\sqrt{1 + (D_{erf})^2}}$$

$$D_{erf} = \frac{V_{rci} + V_{tm} [K_{bci} - K_{bcx} - \ln(R_{kpl})]}{V_o + \frac{\sqrt{V_{rci}^2 + 0.01}}{2H_{rcf}}}$$

If the backward compatibility flag `imeltrci=no` (the default value), K_{bci} and K_{bcx} are calculated as follows:

$$K_{bci} = \sqrt{1 + G_{amm} e^{V_{bc}/V_{tm}}}$$

$$K_{bcx} = \sqrt{1 + G_{amm} e^{V_{bcx}/V_{tm}}}$$

If `imeltrci=yes`, K_{bci} and K_{bcx} are limited.

$$R_{kpl} = \frac{K_{bci} + 1}{K_{bcx} + 1}$$

$$V_{bcx} = V_{bci} - V_{rci}$$

Charge Equations

$$Q_{be} = W_{be} Q_{je} + T_{ff} I_{tf}$$

$$T_{ff} = \left\{ \begin{array}{l} T_f (1 + Q_{tf} Q_1) \left[1 + X_{tf} e^{V_{bci}/(1.44 V_{tf})} \frac{\left(\frac{I_{tf}(\text{current})}{I_{tf}(\text{modelparameter})} \right)^2}{\left(1 + \frac{I_{tf}}{I_{tf}'} \right)^2} \right] \quad \text{If } I_{tf}(\text{model parameter}) > 0 \\ T_f (1 + Q_{tf} Q_1) \quad \text{otherwise} \end{array} \right.$$

Virtuoso Simulator Components and Device Models Reference

VBIC Model (vbic)

Note: In the above equation, I_{tf} is the current calculated from the equation given under the section DC Current on page 391.

$$Q_{bc} = T_r I_{tr} + Q_{jc} + Q_{co} K_{bci}$$

$$Q_{bex} = (1 - W_{be}) Q_{jex}$$

$$Q_{bcx} = Q_{co} K_{bcx}$$

$$Q_{bep} = T_r I_{tfp} + Q_{jep}$$

$$Q_{bcp} = Q_{jcp}$$

$$Q_{je} = Q_j(C_{je}, P_e, M_e, A_{je}, V_{bei})$$

$$Q_{jc} = Q_j(C_{jc}, P_c, M_c, A_{jc}, V_{bci})$$

$$Q_{jex} = Q_j(C_{je}, P_e, M_e, A_{je}, V_{bex})$$

$$Q_{jep} = Q_j(C_{jep}, P_c, M_c, A_{jc}, V_{bep})$$

$$Q_{jcp} = Q_j(C_{jcp}, P_s, M_s, A_{js}, V_{bcp})$$

If $A_j > 0$, $Q_j(C_j, P, M, A_j, V)$ is calculated as

$$Q_j = \frac{C_j}{2} \left(1 - \frac{D_v}{M_v}\right) \left(1 - \frac{V_l}{P}\right)^{-M} + \frac{C_j}{(1 - F_c)^M} \left[1 - \frac{1}{2} \left(1 - \frac{D_v}{M_v}\right)\right]$$

$$D_v = V - P F_c$$

$$M_v = \sqrt{D_v^2 + A_j}$$

$$V_l = \frac{1}{2}(D_v - M_v) + P F_c$$

Virtuoso Simulator Components and Device Models Reference
VBIC Model (vbic)

$$Q_j = -\frac{C_j P \left(1 - \frac{V_l}{P}\right) \left(1 - \frac{V_l}{P}\right)^{-M}}{1 - M} - Q_0 + \frac{C_j (V - V_l + V_{l0})}{(1 - F_c)^M}$$

$$Q_0 = -\frac{C_j P \left(1 - \frac{V_{l0}}{P}\right)^{1-M}}{1 - M}$$

$$V_{l0} = \frac{1}{2}(D_{v0} - M_{v0}) + P F_c$$

$$D_{v0} = -P F_c$$

$$M_{v0} = \sqrt{D_{v0}^2 + A_j}$$

If $A_j \leq 0$, $Q_j(C_j, P, M, A_j, V)$ is calculated as

$$Q_j = \left\{ \begin{array}{l} C_j P \left[\frac{1 - \left(1 - \frac{V}{P}\right)^{1-M}}{1 - M} \right] \\ \frac{[1 - F_c (1 + M)] (V - F_c P) + \frac{M (V^2 - F_c^2 P^2)}{2P}}{(1 - F_c)^{M+1}} + \frac{P}{1 - M} \left[1 - \frac{1}{(1 - F_c)^{M-1}} \right] \end{array} \right. \begin{array}{l} \text{If} \\ V \leq F_c P \\ \\ \text{otherw} \\ \text{ise} \end{array}$$

otherwise

$$C_j = \left\{ \begin{array}{l} \frac{C_j}{\left(1 - \frac{V}{P}\right)^M} \\ \frac{1}{(1 - F_c)^M \left[1 + \frac{M (V - F_c P)}{P - F_c P} \right]} \end{array} \right. \begin{array}{l} \text{If } V \leq F_c P \\ \\ \text{otherwise} \end{array}$$

Excess Phase

In an actual device, the measured phase shift is often larger than the shift predicted by the lumped model. The excess-phase parameter td accounts for this extra phase shift at high frequencies. An all-pass, second-order Bessel function filter creates this extra phase shift. The frequency response of this filter is

$$\phi(s) = \frac{3\omega_0^2}{s^2 + 3\omega_0 s + 3\omega_0^2}$$

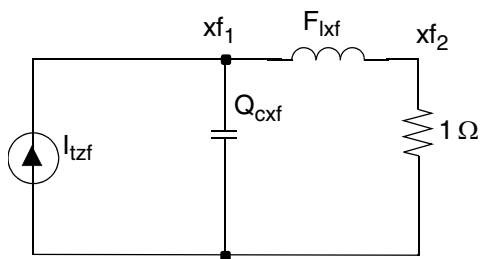
where

$$\omega_0 = \frac{1}{td}$$

and the phase shift due to this filter is

$$\theta = \tan^{-1} \frac{3\omega\omega_0}{3\omega_0^2 - \omega^2}$$

The Bessel filter is implemented with the excess phase network shown below.



Excess phase network

where $L_{xf} = \frac{td}{3}$ and $C_{xf} = td$.

Small Signal Parameters

$$g_m = \frac{dI_{cc}}{dV_{be}} + \frac{dI_{cc}}{dV_{bc}}$$

Virtuoso Simulator Components and Device Models Reference

VBIC Model (vbic)

$$g_{pi} = \frac{dI_{be}}{dV_{be}}$$

$$g_o = -\frac{dI_{cc}}{dV_{bc}}$$

$$g_{mu} = \frac{dI_{bc}}{dV_{bc}}$$

$$betaAC = \frac{g_m}{g_{pi}}$$

$$c_{pi} = \frac{dQ_{be}}{dV_{be}}$$

$$c_{mu} = \frac{dQ_{bc}}{dV_{bc}}$$

$$C_{bcx} = \frac{dQ_{bcx}}{dV_{bcx}}$$

If R_{ci} is given,

$$F_t = \frac{g_m}{2\pi(c_{pi} + g_m \cdot t_f + cb_{cx} + cmu(g_m R_{ci} + 1))}$$

where

$$R_{ci} = \frac{dI_{rci}}{dV_{rci}}$$

and t_f is the model parameter.

If R_{ci} is not given,

$$F_t = \frac{g_m}{2\pi(c_{pi} + c_{bcx} + c_{mu})}$$

Temperature Equations

$$\Delta T = T - T_{nom}$$

$$R_t = \frac{T}{T_{nom}}$$

$$R_{cx} = R_{cxnom} R_t^{X_{rc}}$$

$$R_{ci} = R_{cinom} R_t^{X_{rc}}$$

$$R_{bp} = R_{bpnom} R_t^{X_{rc}}$$

$$R_{bx} = R_{bxnom} R_t^{X_{rb}}$$

$$R_{bi} = R_{binom} R_t^{X_{rb}}$$

$$R_e = R_{enom} R_t^{X_{re}}$$

$$R_s = R_{snom} R_t^{X_{rs}}$$

$$I_s = I_{snom} R_t^{X_{is}/NF_{nom}} e^{-E_a(1-R_t)/NF_{nom}} V_{tm}$$

$$I_{sp} = I_{spnom} R_t^{X_{is}/N_{fp}} e^{-E_a(1-R_t)/N_{fp}} V_{tm}$$

$$I_{bei} = I_{beinom} R_t^{X_{ii}/N_{ei}} e^{-E_{aie}(1-R_t)/N_{ei}} V_{tm}$$

Virtuoso Simulator Components and Device Models Reference

VBIC Model (vbic)

$$I_{ben} = I_{bennom} R_t^{X_{in}/N_{en}} e^{-E_{ane}(1-R_t)/N_{en}} V_{tm}$$

$$I_{bci} = I_{bcinom} R_t^{X_{ii}/N_{ci}} e^{-E_{aic}(1-R_t)/N_{ci}} V_{tm}$$

$$I_{bcn} = I_{bcnnom} R_t^{X_{in}/N_{cn}} e^{-E_{anc}(1-R_t)/N_{cn}} V_{tm}$$

$$I_{beip} = I_{beipnom} R_t^{X_{ii}/N_{ci}} V_{tm} e^{-E_{aic}(1-R_t)/N_{ci}} V_{tm}$$

$$I_{benp} = I_{benpnom} R_t^{X_{in}/N_{cn}} e^{-E_{anc}(1-R_t)/N_{cn}} V_{tm}$$

$$I_{bcip} = I_{bcipnom} R_t^{X_{ii}/N_{cip}} e^{-E_{ais}(1-R_t)/N_{cip}} V_{tm}$$

$$I_{bcnp} = I_{bcnpnom} R_t^{X_{in}/N_{cnp}} e^{-E_{ans}(1-R_t)/N_{cnp}} V_{tm}$$

$$N_f = N_{fnom}(1 + T_{nf} \Delta T)$$

$$N_r = N_{rnom}(1 + T_{nf} \Delta T)$$

$$A_{vc2} = A_{vc2nom}(1 + T_{avc} \Delta T)$$

$$G_{amm} = G_{ammnom} R_t^{X_{is}} e^{-E_a \left(1 - \frac{T}{T_{nom}}\right) / V_{tm}}$$

$$V_o = V_{onom} R_t^{X_{vo}}$$

$$C_{je} = C_{jenom} \left(\frac{P_{enom}}{P_e} \right)^{M_e}$$

Virtuoso Simulator Components and Device Models Reference

VBIC Model (vbic)

$$C_{jc} = C_{jcnom} \left(\frac{P_{cnom}}{P_c} \right)^{M_c}$$

$$C_{jep} = C_{jepnom} \left(\frac{P_{cnom}}{P_c} \right)^{M_c}$$

$$C_{jcp} = C_{jcpnom} \left(\frac{P_{snom}}{P_s} \right)^{M_s}$$

$$P_e = A_e + 2V_{tm} \ln \left[\frac{1}{2} \left(1 + \sqrt{1 + 4e^{-A_e/V_{tm}}} \right) \right]$$

$$A_e = 2V_{tm} \ln \left(e^{PE_{nom}/2V_{tm}} - e^{-PE_{nom}/2V_{tm}} \right) R_t - 3V_{tm} \ln(R_t) - E_{aic}(R_t - 1)$$

$$P_c = A_c + 2V_{tm} \ln \left[\frac{1}{2} \left(1 + \sqrt{1 + 4e^{-A_c/V_{tm}}} \right) \right]$$

$$A_c = 2V_{tm} \ln \left(e^{PC_{nom}/2V_{tm}} - e^{-PC_{nom}/2V_{tm}} \right) R_t - 3V_{tm} \ln(R_t) - E_{aic}(R_t - 1)$$

$$P_s = A_s + 2V_{tm} \ln \left[\frac{1}{2} \left(1 + \sqrt{1 + 4e^{-A_s/V_{tm}}} \right) \right]$$

$$A_s = 2V_{tm} \ln \left(e^{PS_{nom}/2V_{tm}} - e^{-PS_{nom}/2V_{tm}} \right) R_t - 3V_{tm} \ln(R_t) - E_{ais}(R_t - 1)$$

Noise Equations

$$\overline{i_{Icc}^2} = 2 q I_{cc} \Delta f$$

I_{be} shot and flicker noises:

Virtuoso Simulator Components and Device Models Reference

VBIC Model (vbic)

$$\overline{i_{Ibe}^2} = 2 q I_{be} + \frac{K_{fn} I_{be}^{A_{fn}}}{f^{B_{fn}}} \Delta f$$

R_{cx} thermal noise:

$$\overline{i_{Rcx}^2} = \frac{4K_t}{R_{cx}}$$

R_{ci} thermal noise:

$$\overline{i_{Rci}^2} = \frac{4K_t}{dI_{rci}} / (dV_{rci})$$

R_{bx} thermal noise:

$$\overline{i_{Rbx}^2} = \frac{4K_t}{R_{bx}}$$

R_{bi} thermal noise:

$$\overline{i_{Rbi}^2} = \frac{4K_t}{dI_{rbi}} / (dV_{rbi})$$

R_e thermal noise:

$$\overline{i_{RE}^2} = \frac{4K_t}{R_e}$$

R_s thermal noise:

$$\overline{i_{RS}^2} = \frac{4K_t}{R_e}$$

I_{ccp} shot noise:

$$\overline{i_{Rccp}^2} = 2 q I_{ccp}$$

I_{bep} shot and flicker noises:

$$\overline{i_{Rbep}^2} = 2 \cdot q \cdot I_{bep} + \frac{K_{fn} \cdot I_{bep}^{A_{fn}}}{f_{B_{fn}}}$$

R_{bp} thermal noise:

$$\overline{i_{Rbp}^2} = \frac{4K_t}{dI_{rbp}} / (dV_{rbp})$$

VBIC 1.2

This section lists equations new for VBIC 1.2. The rest of the equations remain the same as VBIC 1.15 (previous section).

DC Current

$$I_{tr} = I_s(T) \cdot I_{srr}(T) \cdot \left(e^{V_{bci} / (N_r \cdot V_{tm})} - 1 \right)$$

If $Q_{bm} < \frac{1}{2}$

then

$$Q_b = \frac{1}{2} \cdot \left(Q_1 + \left(Q_1^{1/N_{kf}} + 4 \cdot Q_2 \right)^{N_{kf}} \right)$$

otherwise

$$Q_b = \frac{1}{2} \cdot Q_1 \cdot \left(1 + (1 + 4 \cdot Q_2)^{N_{kf}} \right)$$

If ($V_{be} > 0$)

Virtuoso Simulator Components and Device Models Reference
VBIC Model (vbic)

$$I_{bei} = I_{bei}(T) \left(e^{V_{bei}/(N_{en} \cdot V_{tm})} - 1 \right)$$

$$I_{ben} = I_{ben}(T) \left(e^{V_{bei}/(N_{en} \cdot V_{tm})} - 1 \right)$$

$$I_{bbe} = I_{bbe}(T)_{nom} \cdot \left(e^{(-V_{bbe}(T) - V_{bei})/(N_{bbe}(T) \cdot V_{tm})} - E_{bbe}(T) \right)$$

then

$$I_{be} = W_{be} \cdot I_{bei}(T) + I_{ben}(T) - I_{bbe}(T)$$

If $V_{bex} > 0$

$$I_{bexi} = I_{bexi}(T) \left(e^{V_{bex}/(N_{en} \cdot V_{tm})} - 1 \right)$$

$$I_{bexn} = I_{bexn}(T) \left(e^{V_{bex}/(N_{en} \cdot V_{tm})} - 1 \right)$$

$$I_{bbex} = I_{bbex}(T)_{nom} \cdot \left(e^{(-V_{bbe}(T) - V_{bex})/(N_{bbe}(T) \cdot V_{tm})} - E_{bbe}(T) \right)$$

then

$$I_{bex} = (1 - W_{be}) \cdot (I_{bexi}(T) + I_{bexn}(T) - I_{bbex}(T))$$

If $V_{be} \leq 0$

```
{
  Ibei = - Ibei(T);
  Iben = - Iben(T);
  Ibbe = 0;
}
```

If $V_{bex} \leq 0$

```
{
  Ibexi = - Ibexi(T);
  Ibexn = - Ibexn(T);
}
```

Virtuoso Simulator Components and Device Models Reference

VBIC Model (vbic)

```
Ibbex = 0;
}
```

Charge Equations

If ($A_{je} \leq 0$)

{

If $V \leq F_c P$

$$Q_j = \frac{P}{1-M} \left[1 - \left(1 - \frac{V}{P} \right)^{1-M} \right]$$

Else

$$Q_j = \frac{[1 - F_c(1 + M)] \cdot (V - F_c P) + \frac{M \cdot (V^2 - F_c^2 P^2)}{2P}}{(1 - F_c)^{M+1}} + \frac{P}{1-M} \left[1 - \frac{1}{(1 - F_c)^{M-1}} \right]$$

}

Else

{

$$Q_j = -\frac{P}{1-M} \cdot \left[\left(1 - \frac{T1}{P} \right)^{1-M} - \left(1 + \frac{1}{2P} \cdot \left(-F_c P + \sqrt{F_c^2 P^2 + 4A_j^2} \right) \right)^{1-M} \right] +$$

$$\frac{V_{be} - T1 - \frac{1}{2} \cdot \left(-F_c P + \sqrt{F_c^2 P^2 + 4A_j^2} \right)}{(1 - F_c)^M}$$

and

$$T1 = \frac{1}{2} \left(V - F_c P - \sqrt{(V - F_c P)^2 + 4A_j^2} \right) + F_c P$$

}

Virtuoso Simulator Components and Device Models Reference

VBIC Model (vbic)

If $(A_{jc} > 0)$

If $(V_{rt} > 0) \wedge (A_{rt} > 0)$

then

$$dv0 = -(F_c \cdot P)$$

$$vn0 = \frac{V_{rt} + dv0}{V_{rt} - dv0}$$

$$v_{nl0} = \frac{2 \cdot vn0}{\sqrt{(vn0 - 1)^2 + 4 \cdot A_j^2} + \sqrt{(vn0 + 1)^2 + 4 \cdot A_{rt}^2}}$$

$$v_{l0} = \frac{1}{2} \cdot (v_{nl0} \cdot (V_{rt} - dv0) - V_{rt} - dv0)$$

$$Q_{l0} = P \cdot \frac{\left(1 - \left(1 - \frac{V_{l0}}{P}\right)^{1-M}\right)}{1-M}$$

$$vn = \frac{2 \cdot V + V_{rt} + dv0}{V_{rt} - dv0}$$

$$v_{nl} = \frac{2 \cdot vn}{\sqrt{(vn - 1)^2 + 4 \cdot A \cdot A} + \sqrt{(vn + 1)^2 + 4 \cdot A_{rt} \cdot A_{rt}}}$$

$$v_l = \frac{1}{2} \cdot (v_{nl} \cdot (V_{rt} - dv0) - V_{rt} - dv0)$$

$$Q_{jc0} = P \cdot \frac{\left(1 - \left(1 - \frac{v_l}{P}\right)^{1-M}\right)}{1-M}$$

$$sel = \frac{1}{2} \cdot (v_{nl} + 1)$$

$$crt = \left(1 + \frac{V_{rt}}{P}\right)^{-M}$$

Virtuoso Simulator Components and Device Models Reference

VBIC Model (vbic)

$$cl = (1 - sel) \cdot crt + sel \cdot cmx$$

$$Q_l = (V - vl + vl0) \cdot cl$$

$$Q_{jc} = Q_l + Q_{jc0} - Q_{l0}$$

else

$$vl = \frac{1}{2} \cdot \left(V - F_c \cdot P - \sqrt{(V - (F_c \cdot P))^2 + 4 \cdot A \cdot A} \right) + F_c \cdot P$$

$$vl0 = -\frac{1}{2} \cdot \left(-F_c \cdot P + \sqrt{(F_c \cdot P)^2 + 4 \cdot A \cdot A} \right)$$

$$Q_{j0} = -P \cdot \frac{\left(1 - \frac{vl0}{P}\right)^{1-M}}{1-M}$$

$$Q_{l0} = -P \cdot \frac{\left(1 - \frac{vl}{P}\right)^{1-M}}{1-M}$$

$$Q_{jc} = Q_{l0} + (1 - F_c)^{-M} \cdot (V - vl + vl0) - Q_{j0}$$

Temperature Equations

If self-heating is on, the device temperature is calculated by

$$T = T_{op} + DTEMP + V(rth)$$

If self-heating is off, the device temperature is calculated by

$$T = T_{op} + DTEMP$$

The model parameter extraction temperature is calculated by

$$T_{nom} = TNOM$$

$$R_t = \frac{T}{T_{nom}}$$

$$V_{tm} = \frac{K_B \cdot T}{Q_e}$$

$$\Delta T = T - T_{nom}$$

$$R_{cx}(T) = R_{cx} \cdot R_t^{X_{rcx}}$$

$$R_{bx}(T) = R_{bx} \cdot R_t^{X_{rbx}}$$

$$R_{bp}(T) = R_{bp} \cdot R_t^{X_{rbp}}$$

$$I_{sp}(T) = I_{sp} \cdot R_t^{X_{is}/N_{fp}} \cdot e^{-E_{ap}/N_{fp}} \cdot (1 - R_t)/(V_{tm} \cdot N_{fp})$$

Scaling Effects

For scaling effects, [Scaling Factors \(scale and scalem\)](#) on page 242.

Component Statements

The VBIC model was developed as a replacement for the SPICE G-P model. The model has four electrical terminals, two thermal terminals, and up to nine internal nodes, depending on the model parameters that the user specifies. VBIC 1.1.5 and VBIC 1.2 are implemented and controlled by model parameter version. Default is version=1.1.5. Detailed description of the model and equations are given in the Virtuoso Spectre Circuit Simulator Device Model Equations manual.

This device is supported within altergroups.

Sample Instance Statement

```
q1 (1 2 0 0 0) vbjt area=1
```

Virtuoso Simulator Components and Device Models Reference

VBIC Model (vbic)

Sample Model Statement

```
model vbjt vbic type=npn is=2e-16 iben=4.5e-15 isp=1e-15 gamm=1.55e-11 ikf=0.0021
ikr=0.0021 vef=15 ver=7 rbi=35 rbx=7 re=3 rs=15 cje=1.5e-14 tf=15e-12 selft=yes
rth=1K
```

Instance Definition

```
Name c b e [s] [dt] [t1] ModelName parameter=value ...
```

`t1` node is the local temperature and the `dt` node is the rise above the local temperature caused by the thermal power dissipated by the device being modeled by VBIC. Consequently, the `t1` node can be connected to a thermal network that models heat flow through the substrate and/or between devices. It is not necessary to specify the substrate and the two thermal terminals. If left unspecified, the substrate and the `t1` thermal terminal are connected to ground. But if the self-heating flag is turned on and `dt` is not given, an internal node is created for self-heating. You must specify the substrate terminal if you specify `dt` and both substrate and `dt` must be given if `t1` needs to be specified.

It is strongly recommended to avoid using the `t1` node. It is not fully supported and using it will degrade convergence properties. This node is removed in the VBIC 1.2 version. All thermal effects can be modeled with just the `dt` node.

Instance Parameters

1	<code>area=1</code>	Transistor area factor.
2	<code>m=1</code>	Multiplicity factor.
3	<code>region=fwd</code>	Estimated operating region. Spectre outputs number (0-4) in a rawfile. Possible values are <code>off</code> , <code>fwd</code> , <code>rev</code> , <code>sat</code> , or <code>breakdown</code> .
4	<code>trise</code>	Temperature rise from ambient.
5	<code>dtmp</code>	Alias to <code>trise</code> .
6	<code>dtemp</code>	Alias to <code>trise</code> .
7	<code>isnoisy=yes</code>	Should resistor generate noise. Possible values are <code>no</code> or <code>yes</code> .

Virtuoso Simulator Components and Device Models Reference

VBIC Model (vbic)

small-signal model parameters

Model Definition

```
model modelName vbic parameter=value ...
```

Model Parameters

Structural parameters

- | | | |
|---|---------------------------------|---|
| 1 | <code>type=npn</code> | Transistor type.
Possible values are <code>npn</code> or <code>pnP</code> . |
| 2 | <code>compatible=spectre</code> | Encourage device equations to be compatible with a foreign simulator. This option does not affect input syntax.
Possible values are <code>spectre</code> , <code>spice2</code> , <code>spice3</code> , <code>cdsspice</code> , <code>hspice</code> , <code>spiceplus</code> , <code>eldo</code> , <code>sspice</code> , or <code>mica</code> . |

Saturation current parameters

- | | | |
|----|---------------------------|--|
| 3 | <code>is=1e-16 A</code> | Transport saturation current (*area). |
| 4 | <code>ibei=1e-18 A</code> | Ideal B-E saturation current. (*area). |
| 5 | <code>iben=0 A</code> | Nonideal B-E saturation current (*area). |
| 6 | <code>ibci=1e-16 A</code> | Ideal B-C saturation current. (*area). |
| 7 | <code>ibcn=0 A</code> | Nonideal B-C saturation current (*area). |
| 8 | <code>isp=0 A</code> | Parasitic transport saturation current. (*area). |
| 9 | <code>ibeip=0 A</code> | Ideal parasitic B-E saturation current (*area). |
| 10 | <code>ibenp=0 A</code> | Nonideal parasitic B-E saturation current (*area). |
| 11 | <code>ibcip=0 A</code> | Ideal parasitic B-C saturation current (*area). |
| 12 | <code>ibcnp=0 A</code> | Nonideal parasitic B-C saturation current (*area). |
| 13 | <code>vo=0 V</code> | Epi drift saturation voltage. |

Virtuoso Simulator Components and Device Models Reference

VBIC Model (vbic)

- 14 `gamm=0` V Epi doping parameter.
- 15 `hrcf=1` High current RC factor.
- 16 `wbe=1` Portion of I_{bei} from V_{bei} .
- 17 `wsp=1` Portion of I_{ccp} from V_{bep} .

Emission coefficient parameters

- 18 `nf=1` Forward emission coefficient.
- 19 `nr=1` Reverse emission coefficient.
- 20 `nei=1` Ideal B-E emission coefficient.
- 21 `nen=2` Nonideal B-E emission coefficient.
- 22 `nci=1` Ideal B-C emission coefficient.
- 23 `ncn=2` Nonideal B-C emission coefficient.
- 24 `nfp=1` Parasitic forward emission coefficient.
- 25 `ncip=1` Ideal parasitic B-C emission coefficient.
- 26 `ncnp=2` Nonideal parasitic B-C emission coefficient.

Current gain parameters

- 27 `ikf= ∞` A Forward knee current (*area).
- 28 `ikr= ∞` A Reverse knee current (*area).
- 29 `ikp= ∞` A Parasitic knee current (*area).

Early voltage parameters

- 30 `vef= ∞` V Forward Early voltage.
- 31 `ver= ∞` V Reverse Early voltage.

Virtuoso Simulator Components and Device Models Reference

VBIC Model (vbic)

Breakdown voltage parameters

- 32 `avc1=0` B-C weak avalanche parameter.
- 33 `avc2=0` B-C weak avalanche parameter.

Parasitic resistance parameters

- 34 `rbi=0` Ω Intrinsic base resistance (/area).
- 35 `rbx=0` Ω Extrinsic base resistance (/area).
- 36 `re=0` Ω Emitter resistance (/area).
- 37 `rs=0` Ω Substrate resistance (/area).
- 38 `rbp=0` Ω Parasitic base resistance (/area).
- 39 `rcx=0` Ω Extrinsic collector resistance (/area).
- 40 `rci=0` Ω Intrinsic collector resistance (/area).
- 41 `minr=0.01` Ω Minimum parasitic resistance.

Junction capacitance parameters

- 42 `cje=0` F B-E zero-bias capacitance (*area).
- 43 `pe=0.75` V B-E built-in potential.
- 44 `me=0.33` B-E grading coefficient.
- 45 `aje=-0.5` B-E capacitance smoothing factor.
- 46 `fc=0.9` Forward-bias depletion capacitance limit.
- 47 `cbeo=0` F Extrinsic B-E overlap capacitance (*area).
- 48 `cjc=0` F B-C zero-bias capacitance (*area).
- 49 `cjep=0` F B-C extrinsic zero-bias capacitance (*area).

Virtuoso Simulator Components and Device Models Reference

VBIC Model (vbic)

50	$p_c=0.75$ V	B-C built-in potential.
51	$m_c=0.33$	B-C grading coefficient.
52	$a_{jc}=-0.5$	B-C capacitance smoothing factor.
53	$c_{bco}=0$ F	Extrinsic B-C overlap capacitance (*area).
54	$q_{co}=0$ Coul	Epi charge parameter.
55	$c_{jcp}=0$ F	S-C zero-bias capacitance (*area).
56	$p_s=0.75$ V	S-C built-in potential.
57	$m_s=0.33$	S-C grading coefficient.
58	$a_{js}=-0.5$	S-C capacitance smoothing factor.

Transit time and excess phase parameters

59	$t_f=0$ s	Forward transit time.
60	$t_r=0$ s	Reverse transit time.
61	$t_d=0$ s	Forward excess-phase delay time.
62	$q_{tf}=0$	Variation of t_f with base width modulation.
63	$x_{tf}=0$	Coefficient of t_f with bias dependence.
64	$v_{tf}=0$	Coefficient of t_f dependence on V_{bc} .
65	$i_{tf}=0$	Coefficient of t_f dependence on I_c .

Temperature effects parameters

66	$selft=no$	Flag denoting self-heating. Possible values are <code>no</code> or <code>yes</code> .
67	t_{nom} (C)	Parameters measurement temperature. Default set by options.
68	$t_{rise}=0$ C	Temperature rise from ambient.

Virtuoso Simulator Components and Device Models Reference

VBIC Model (vbic)

69	$r_{th}=0 \ \Omega$	Thermal resistance, must be given for self-heating.
70	$c_{th}=0 \ F$	Thermal capacitance.
71	$x_{is}=3 \ V$	Temperature exponent of I_s .
72	$x_{ii}=3 \ V$	Temperature exponent of I_{bei} , I_{bci} , I_{beip} , and I_{bcip} .
73	$x_{in}=3 \ V$	Temperature exponent of I_{ben} , I_{bcn} , I_{benp} , and I_{bcnp} .
74	$t_{nf}=0 \ V$	Temperature coefficient of N_f .
75	$t_{avc}=0 \ V$	Temperature coefficient of A_{vc2} .
76	$e_a=1.12 \ V$	Activation energy for i_s .
77	$e_{aie}=1.12 \ V$	Activation energy for I_{bei} .
78	$e_{aic}=1.12 \ V$	Activation energy for I_{bci}/I_{beip} .
79	$e_{ais}=1.12 \ V$	Activation energy for I_{bcip} .
80	$e_{ane}=1.12 \ V$	Activation energy for I_{ben} .
81	$e_{anc}=1.12 \ V$	Activation energy for I_{bcn}/I_{benp} .
82	$e_{ans}=1.12 \ V$	Activation energy for I_{bcnp} .
83	$x_{re}=0$	Temperature exponent of r_e .
84	$x_{rb}=0$	Temperature exponent of r_b .
85	$x_{rc}=0$	Temperature exponent of r_c .
86	$x_{rs}=0$	Temperature exponent of r_s .
87	$x_{vo}=0$	Temperature exponent of v_o .
88	$dt_{max}=226.85 \ C$	Maximum expected device temperature. (500 K).

Noise model parameters

89	$k_{fn}=0$	B-E flicker (1/f) noise coefficient.
----	------------	--------------------------------------

Virtuoso Simulator Components and Device Models Reference

VBIC Model (vbic)

90 `afn=1` B-E flicker (1/f) noise exponent.

91 `bfn=1` B-E flicker (1/f) noise dependence.

Junction diode model control parameters

92 `dskip=yes` Skip junction calculations if they are reverse-saturated.
Possible values are `no` or `yes`.

93 `imelt=10 A` Explosion current (*area).

Operating region warning control parameters

94 `bvbe= ∞ V` B-E breakdown voltage.

95 `bvbc= ∞ V` B-C breakdown voltage.

96 `bvce= ∞ V` C-E breakdown voltage.

97 `bvsub= ∞ V` Substrate junction breakdown voltage.

98 `vbefwd=0.2 V` B-E forward voltage.

99 `vbcfwd=0.2 V` B-C forward voltage.

100 `vsubfwd=0.2 V` Substrate junction forward voltage.

101 `imax=1 A` Maximum allowable base current (*area).

102 `imax1='imax' A` Maximum allowable collector current (*area).

103 `alarm=none` Forbidden operating region.
Possible values are `none`, `off`, `fwd`, `rev`, or `sat`.

DC-mismatch model parameters

104 `mvt0=0.0 V` Threshold mismatch intercept.

New model parameter for Vbic 1.2

105 `vrt=0 V` B-C reach-through limiting voltage.

Virtuoso Simulator Components and Device Models Reference

VBIC Model (vbic)

106	<code>art=0.1 V</code>	B-C reach-through limiting smoothing factor .
107	<code>ccso=0 F</code>	Fixed collector-substrate capacitance.
108	<code>qbm=0</code>	Parameter to select SGP qb formulation.
109	<code>nkf=0.5</code>	High current beta rolloff parameter.
110	<code>xikf=0</code>	Parameter of temperature dependence to <code>ikf</code> .
111	<code>xrcx=0</code>	Parameter of temperature dependence to <code>rcx</code> .
112	<code>xrbx=0</code>	Parameter of temperature dependence to <code>rbx</code> .
113	<code>xrbp=0</code>	Parameter of temperature dependence to <code>rbp</code> .
114	<code>isrr=1</code>	Parameter to separate <code>is</code> for forward and reversed parts.
115	<code>xisr=0</code>	Temperature exponent coefficient of <code>isrr</code> .
116	<code>dear=0 V</code>	Activation energy for <code>isrr</code> .
117	<code>eap=1.12 V</code>	Activation energy for <code>isp</code> .
118	<code>vbbe=0 V</code>	B-E breakdown voltage.
119	<code>nbbe=1.0</code>	B-E breakdown emission coefficient.
120	<code>ibbe=1.0e-6 A</code>	B-E breakdown current.
121	<code>tvbbe1=0</code>	First temperature coefficient of <code>vbbe</code> .
122	<code>tvbbe2=0</code>	Second temperature coefficient of <code>vbbe</code> .
123	<code>tnbbe=0</code>	Temperature coefficient for <code>nbbe</code> .
124	<code>vers=1.15</code>	Version control parameter.
125	<code>vrev=0</code>	Revision control parameter.
126	<code>dtmp (C)</code>	Alias to <code>trise</code> .
127	<code>dtemp (C)</code>	Alias to <code>trise</code> .

Virtuoso Simulator Components and Device Models Reference

VBIC Model (vbic)

128 <code>version</code>	Alias to <code>vers</code> .
129 <code>rev</code>	Alias to <code>vrev</code> .
130 <code>xrbi</code>	Alias to <code>xrb</code> .
131 <code>xrci</code>	Alias to <code>xrc</code> .
132 <code>ebbe=0.0</code>	$\exp(-V_{BBE}/(N_{BBE} \cdot V_{tv}))t$.

Shrink Parameters

`Imax` and `Imelt`:

The `imax` parameter aids convergence and prevents numerical overflow. The junction characteristics of the device are accurately modeled for current up to `imax`. If `imax` is exceeded during iterations, the linear model is substituted until the current drops below `imax` or until convergence is achieved. If convergence is achieved with the current exceeding `imax`, the results are inaccurate, and Spectre prints a warning.

A separate model parameter, `imelt`, is used as a limit warning for the junction current. This parameter can be set to the maximum current rating of the device. When any component of the junction current exceeds `imelt`, note that base and collector currents are composed of many exponential terms, Spectre issues a warning and the results become inaccurate. The junction current is linearized above the value of `imelt` to prevent arithmetic exception, with the exponential term replaced by a linear equation at `imelt`.

Operating-Point Parameters

1 <code>type=npn</code>	Transistor type. Possible values are <code>npn</code> or <code>pnP</code> .
2 <code>region=fwd</code>	Estimated operating region. Spectre outputs number (0-4) in a rawfile. Possible values are <code>off</code> , <code>fwd</code> , <code>rev</code> , <code>sat</code> , or <code>breakdown</code> .
3 <code>vbe (V)</code>	Base-emitter voltage.
4 <code>vbc (V)</code>	Base-collector voltage.

Virtuoso Simulator Components and Device Models Reference

VBIC Model (vbic)

5	<code>vce</code> (V)	Collector-emitter voltage.
6	<code>vcs</code> (V)	Collector-substrate voltage.
7	<code>temp</code> (C)	Device temperature.
8	<code>ith</code> (A)	Thermal source.
9	<code>ic</code> (A)	Intrinsic DC collector current. ($I_{cc} - I_{bc} + I_{gc}$).
10	<code>ib</code> (A)	Intrinsic DC base current. ($I_{be} + I_{bc} - I_{gc}$).
11	<code>icc</code> (A)	C-E current.
12	<code>ibe</code> (A)	Intrinsic B-E junction current.
13	<code>ibc</code> (A)	Intrinsic B-C junction current.
14	<code>ibex</code> (A)	BX-E junction current.
15	<code>igc</code> (A)	Breakdown current.
16	<code>iccp</code> (A)	Parasitic transport C-E current.
17	<code>ibep</code> (A)	Parasitic transport B-E current.
18	<code>ibcp</code> (A)	Parasitic transport B-C current.
19	<code>betadc</code> (A/A)	Ratio of external collector current to external base current. (I_{c_ext}/I_{b_ext}).
20	<code>gm</code> (S)	Intrinsic small-signal transconductance. ($g_m = dI_{cc}/dV_{be} + dI_{cc}/dV_{bc}$).
21	<code>gpi</code> (S)	Intrinsic small-signal input conductance. ($g_{pi} = dI_{be}/dV_{be}$).
22	<code>go</code> (S)	Intrinsic small-signal output conductance. ($g_o = -dI_{cc}/dV_{bc}$).
23	<code>gmu</code> (S)	Intrinsic small-signal Collector-Base conductance. ($g_{mu} = dI_{bc}/dV_{bc}$).
24	<code>cpi</code> (F)	Intrinsic small-signal B-E capacitance. Same as <code>cje</code> .

Virtuoso Simulator Components and Device Models Reference

VBIC Model (vbic)

25	<code>cmu</code> (F)	Intrinsic small signal B-C capacitance. Same as <code>cjc</code> .
26	<code>betaac</code> (A/A)	Small-signal common-emitter current gain. (<code>gm/gpi</code>).
27	<code>ft</code> (Hz)	Unity small-signal current-gain frequency.
28	<code>dic_dvbe</code> (S)	Intrinsic <code>dlc/dVbe</code> .
29	<code>dic_dvbc</code> (S)	Intrinsic <code>dlc_dVbc</code> .
30	<code>dib_dvbe</code> (S)	Intrinsic <code>dlb_dVbe</code> .
31	<code>dib_dvbc</code> (S)	Intrinsic <code>dlb_dVbc</code> .
32	<code>rbi</code> (Ω)	Intrinsic base resistance.
33	<code>rci</code> (Ω)	Intrinsic collector resistance.
34	<code>rbp</code> (Ω)	Parasitic transistor base resistance.
35	<code>cje</code> (F)	Intrinsic B-E capacitance.
36	<code>cjc</code> (F)	Intrinsic B-C capacitance.
37	<code>cbex</code> (F)	BX-E junction capacitance.
38	<code>cbcx</code> (F)	B-CX junction capacitance.
39	<code>cbep</code> (F)	Parasitic B-E junction capacitance.
40	<code>cbcp</code> (F)	Parasitic B-C junction capacitance.
41	<code>pwr</code> (W)	Power dissipation.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

Virtuoso Simulator Components and Device Models Reference

VBIC Model (vbic)

afn M-90	eaic M-78	itf M-65	tf M-59
ajc M-52	eaie M-77	ith OP-8	tnbbe M-123
aje M-45	eaiss M-79	kfn M-89	tnf M-74
ajs M-58	eanc M-81	m I-2	tnom M-67
alarm M-103	eane M-80	mc M-51	tr M-60
area I-1	eans M-82	me M-44	trise I-4
art M-106	eap M-117	minr M-41	trise M-68
avc1 M-32	ebbe M-132	ms M-57	tvbbe1 M-121
avc2 M-33	fc M-46	mvt0 M-104	tvbbe2 M-122
betaac OP-26	ft OP-27	nbbe M-119	type M-1
betadc OP-19	gamm M-14	nci M-22	type OP-1
bfm M-91	gm OP-20	ncip M-25	vbbe M-118
bvbc M-95	gmu OP-23	ncn M-23	vbc OP-4
bvbe M-94	go OP-22	ncnp M-26	vbcfwd M-99
bvce M-96	gpi OP-21	nei M-20	vbe OP-3
bvsub M-97	hrcf M-15	nen M-21	vbefwd M-98
cbco M-53	ib OP-10	nf M-18	vce OP-5
cbcp OP-40	ibbe M-120	nfp M-24	vcs OP-6
cbcx OP-38	ibc OP-13	nkf M-109	vef M-30
cbeo M-47	ibci M-6	nr M-19	ver M-31

Virtuoso Simulator Components and Device Models Reference

VBIC Model (vbic)

cbep	OP-39	ibcip	M-11	pc	M-50	vers	M-124
cbex	OP-37	ibcn	M-7	pe	M-43	version	M-128
ccso	M-107	ibcnp	M-12	ps	M-56	vo	M-13
cjc	M-48	ibcp	OP-18	pwr	OP-41	vrev	M-125
cjc	OP-36	ibe	OP-12	qbm	M-108	vrt	M-105
cjcp	M-55	ibei	M-4	qco	M-54	vsubfwd	M-100
cje	M-42	ibeip	M-9	qtf	M-62	vtf	M-64
cje	OP-35	iben	M-5	rbi	M-34	wbe	M-16
cjep	M-49	ibenp	M-10	rbi	OP-32	wsp	M-17
cmu	OP-25	ibep	OP-17	rbp	M-38	xii	M-72
compatible	M-2	ibex	OP-14	rbp	OP-34	xikf	M-110
cpi	OP-24	ic	OP-9	rbx	M-35	xin	M-73
cth	M-70	icc	OP-11	rci	M-40	xis	M-71
dear	M-116	iccp	OP-16	rci	OP-33	xisr	M-115
dib_dvbc	OP-31	igc	OP-15	rcx	M-39	xrb	M-84
dib_dvbe	OP-30	ikf	M-27	re	M-36	xrbi	M-130
dic_dvbc	OP-29	ikp	M-29	region	I-3	xrbp	M-113
dic_dvbe	OP-28	ikr	M-28	region	OP-2	xrbx	M-112
dskip	M-92	imax	M-101	rev	M-129	xrc	M-85
dtemp	I-6	imax1	M-102	rs	M-37	xrci	M-131
dtemp	M-127	imelt	M-93	rth	M-69	xrcx	M-111

Virtuoso Simulator Components and Device Models Reference

VBIC Model (vbic)

dtmax	M-88	is	M-3	selft	M-66	xre	M-83
dtmp	I-5	isnoisy	I-7	tavc	M-75	xrs	M-86
dtmp	M-126	isp	M-8	td	M-61	xtf	M-63
ea	M-76	isrr	M-114	temp	OP-7	xvo	M-87

Virtuoso Simulator Components and Device Models Reference

VBIC Model (vbic)

HBT Model (hbt)

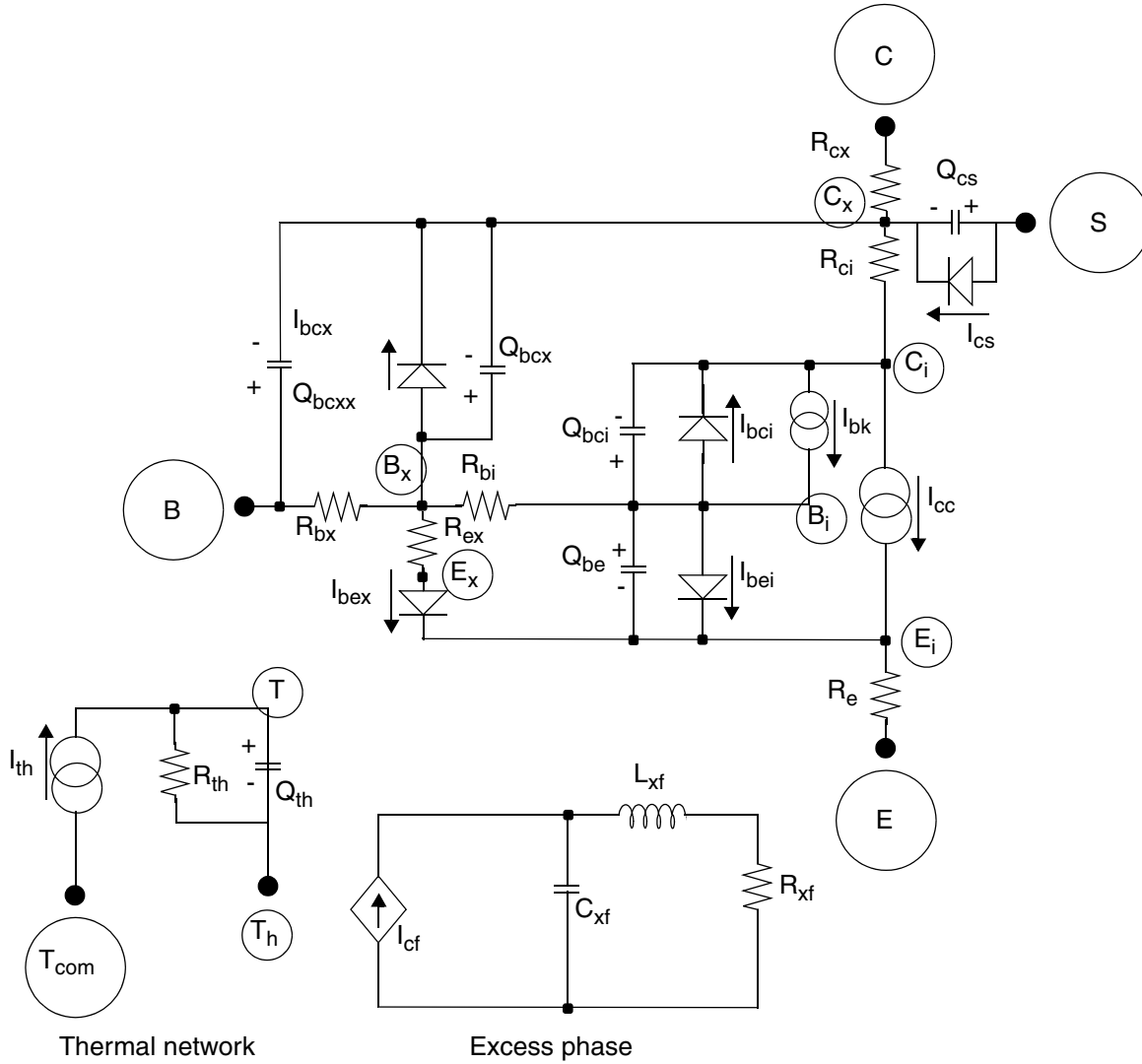
The Hetero-junction Bipolar Transistor (HBT) model was developed by UCSD as part of the ARPA High Speed Circuit Design Program. The model has four external electrical nodes, one thermal node, and up to nine internals depending on the version of the model you specify.

This chapter contains the following information for the HBT model:

- [DC Current](#) on page 424
- [Junction Capacitance](#) on page 426
- [Total Charge](#) on page 427
- [Thermal Current Equations](#) on page 430
- [Temperature Equations](#) on page 430
- [Scaling Effects](#) on page 433
- [Component Statements](#) on page 433

Virtuoso Simulator Components and Device Models Reference

HBT Model (hbt)



DC Current

$$I_{cc} = I_{cf} - I_{cr}$$

$$I_{cf} = \frac{I_S}{\Delta} (e^{V_{be}/N_r(V_{tm})} - 1)$$

Virtuoso Simulator Components and Device Models Reference

HBT Model (hbt)

$$I_{cr} = \frac{I_s}{\Delta} (e^{V_{bc}/N_r(V_{tm})} - 1)$$

$$\Delta = Q_b + \frac{I_s}{I_{sa}} e^{V_{be}/N_a(V_{tm})} + \frac{I_s}{I_{sb}} e^{V_{bc}/N_b(V_{tm})}$$

$$Q_b = \frac{Q_1}{2} (1 + \sqrt{1 + 4Q_2})$$

$$Q_1 = \frac{1}{1 - \frac{V_{bc}}{V_{af}} - \frac{V_{be}}{V_{ar}}}$$

$$Q_2 = \frac{I_s}{I_k} (e^{V_{be}/N_f(V_{tm})} - 1)$$

$$I_{be} = \frac{I_{cf}}{B_f} + I_{se} (e^{V_{be}/N_e(V_{tm})} - 1)$$

$$I_{bex} = I_{sex} (e^{V_{bex}/N_{ex}(V_{tm})} - 1)$$

$$I_{bc} = \frac{I_{cr}}{B_r} + I_{sc} (e^{V_{bc}/N_c(V_{tm})} - 1)$$

$$I_{bcx} = I_{scx} (e^{V_{bcx}/N_{cx}(V_{tmop})} - 1)$$

$$I_{cs} = I_{cs} (e^{-V_{cs}/N_{cs}(V_{tmop})} - 1)$$

$$I_{bk} = \begin{cases} 0 & \text{if } B_{kdn} = 0 \\ (M_f - 1)I_{cf} & \text{otherwise} \end{cases}$$

$$M_f = \begin{cases} \frac{1}{1 - \left(\frac{-V_{bc}}{B_{vc}}\right)^{N_{bc}}} & \text{if } V_{tm} < -V_{bc} < F_a(B_{vc}) \\ 1 & \text{if } -V_{bc} < V_{tm} \\ M_{f1} + g_1(-V_{bc} - F_a(B_{vc})) & -V_{bc} < F_a(B_{vc}) \end{cases}$$

$$M_{f1} = \frac{1}{1 - F_a^{N_{bc}}}$$

$$g_1 = M_{f1}(M_{f1} - 1) \frac{N_{bc}}{F_a(B_{vc})}$$

Junction Capacitance

Define

$$V_{min} = V_j \left[1 - \left(\frac{C_j}{C_{min}} \right)^{1/M_j} \right]$$

If $V < V_{min}$,

$$C_j = C_{min}$$

$$Q_j = C_{min}(V - V_j) + C_{min}(V_j) \left(\frac{M_j}{M_j - 1} \right) \left(\frac{C_j}{C_{min}} \right)^{1/M_j}$$

If $V < F_c(V_j)$,

$$C_j = \frac{C_j}{\left(1 - \frac{V}{V_j}\right)^{M_j}}$$

If $V > F_c(V_j)$ and $C_j \geq C_{min}(1 - F_c)^{M_j}$,

$$C_j = \frac{C_j}{(1 - F_c)^{M_j}} [1 + M_j(V_R)]$$

$$Q_j = \frac{-C_j}{(1 - F_c)^{M_j}} \left[\frac{1}{1 - M_j} - V_r - \frac{M_j(V_R^2)}{2} \right]$$

where

$$V_R = \frac{V - F_c(V_j)}{V_j - F_c(V_j)}$$

If $V > F_c(V_j)$ and $C_j < C_{min}(1 - F_c)^{M_j}$,

$$C_j = C_{min} + \frac{C_j(M_j)(V_R)}{(1 - F_c)^{M_j}}$$

$$Q_j = C_{min} \left(V - V_{min} - \frac{V_j - V_{min}}{1 - M_j} \right) + \frac{C_j(M_j)(V - F_c(V_j))(V_R)}{2(1 - F_c)^{M_j}}$$

Total Charge

$$Q_{be} = Q_{je} + (1 - F_{ex})Q_{fdiff}$$

where Q_{je} is the junction charge Q_j with $V = V_{be}$.

$$Q_{bc} = Q_{jc} + T_r(I_{cr}) + F_{ex}(Q_{fdiff})$$

$$Q_{bcx} = T_{rx}(I_{bcx}) + X_{cjc}(Q_{jcx})$$

Virtuoso Simulator Components and Device Models Reference

HBT Model (hbt)

$$Q_{bcxx} = (1 - X_{cjc})Q_{jcx}$$

$$Q_{cs} = Q_{js}$$

$$Q_{fdiff} = I_{cf}(F_{tt}) \left(T_{fbt} + \frac{T_{fco}}{Q_{cc}} + Q_{bcm} + Q_{krk} \right)$$

where

$$F_{tt} = R_{td}^{X_{ttf}}$$

$$T_{fbt} = T_{fb} \left(1 + \frac{V_{bc}}{V_{af}} + \frac{V_{be}}{V_{ar}} \right) + T_{bexs} (e^{-(V_{be} - V_{je})/N_a(V_{tm})}) + T_{bcxs} (e^{-(V_{bc} - V_{jc})/N_b(V_{tm})})$$

$$Q_{cc} = \frac{1 + (I_{cf})^2}{1 + \left(\frac{I_{cf}}{I_{tc2}} \right)^3 + \left(\frac{V_{jc} - V_{bc}}{V_{tc}} \right)}$$

$$Q_{krk} = T_{krk}(I_{cj}) e^{(V_{bc}/V_{krk} + I_{cf}/I_{krk})}$$

$$Q_{bcm} = Q_{bcf} - Q_{jc}$$

where Q_{bcf} is calculated according to the following rules:

Define

$$I_o = \frac{I_{cf}}{I_{crit}}$$

where

$$I_{crit} = I_{crito} \left(\frac{Q_{cc}}{F_{tt}} \right)$$

Virtuoso Simulator Components and Device Models Reference
HBT Model (hbt)

$$C_{jch} = \begin{cases} C_{jc}((1-I_o)^{M_{jc}}) & \text{If } I_o < 1 \\ -C_{jc}((I_o-1)^{M_{jc}}) & \text{otherwise} \end{cases}$$

If $C_{jch} < 0$,

$$Q_{bcf} = C_{cmin}(V_{bc} - V_{jc}) - \frac{C_{cmin}(V_{jc})(M_{jc})}{M_{jc} - 1} \left(\frac{C_{jch}}{C_{cmin}} \right)^{1/M_{jc}}$$

If $C_{jch} \geq 0$, define

$$V_{min1} = V_{jc} \left[1 - \left(\frac{C_{jch}}{C_{cmin}} \right)^{1/M_{jc}} \right]$$

If $V_{bc} < F_c(V_{jc})$ and $V_{bc} < V_{min1}$,

$$Q_{bcf} = C_{cmin}(V_{bc} - V_{jc}) + \frac{C_{cmin}(V_{jc})(M_{jc})}{M_{jc} - 1} \left(\frac{C_{jch}}{C_{cmin}} \right)^{1/M_{jc}}$$

If $V_{bc} < F_c(V_{jc})$ and $V_{bc} \geq V_{min1}$,

$$Q_{bcf} = -\frac{C_{jch}(V_{jc})}{1 - M_{jc}} \left(1 - \frac{V_{bc}}{V_{jc}} \right)^{1 - M_{jc}}$$

If $V_{bc} \geq F_c(V_{jc})$ and $C_{jch} > C_{min}(1 - F_c)^{M_{jc}}$,

$$Q_{bcf} = \frac{-C_{jch}(V_{jc} - F_c(V_{jc}))}{(1 - F_c)^{M_{jc}}} \left[\frac{1}{1 - M_{jc}} - V_{RC} - \frac{M_{jc}(V_{RC}^2)}{2} \right]$$

where

$$V_{RC} = \frac{V_{bc} - F_c(V_j)}{V_j - F_c(V_j)}$$

If $V_{bc} \geq F_c(V_{jc})$ and $C_{jch} \leq C_{min}(1 - F_c)^{M_{jc}}$,

$$Q_{bcf} = C_{min} \left(V_{bc} - V_{min1} - \frac{V_{jc} - V_{min1}}{1 - M_{jc}} \right) + \frac{C_{jch}(M_{jc})(V_{bc} - F_c(V_{jc}))V_{R_c}}{2(1 - F_c)^{M_{jc}}}$$

Thermal Current Equations

$$I_{th} = I_{cc}(V_{ce}) + I_{be}(V_{be}) + I_{bex}(V_{bex}) + I_{bcx}(V_{bcx}) + (I_{bc} - I_{bk})(V_{bc} - I_{cs})(V_{cs})$$

$$+ \frac{V_{bbx}^2}{R_{bx}} + \frac{V_{bxex}^2}{R_{ex}} + \frac{V_{bxbi}^2}{R_{bi}} + \frac{V_{eei}^2}{R_e} + \frac{V_{ccx}^2}{R_{cx}} + \frac{V_{cxi}^2}{R_{ci}}$$

Temperature Equations

$$\Delta T = T - T_{nom}$$

$$V_{tm} = \frac{kT}{q}$$

$$V_{tmop} = \frac{kT_{op}}{q}$$

$$V_{tmnom} = \frac{kT_{nom}}{q}$$

$$R_{td} = \frac{T}{T_{nom}}$$

$$R_{top} = \frac{T_{op}}{T_{nom}}$$

$$R_{th} = R_{thnom} \left(R_{td}^{X_{rt}} \right)$$

Virtuoso Simulator Components and Device Models Reference

HBT Model (hbt)

$$R_{cx} = R_{cxnom} \left(R_{top}^{X_{rc}} \right)$$

$$R_{ci} = R_{cinom} \left(R_{top}^{X_{rc}} \right)$$

$$R_{bx} = R_{bxnom} \left(R_{top}^{X_{rb}} \right)$$

$$R_{bi} = R_{binom} \left(R_{top}^{X_{rb}} \right)$$

$$R_e = R_{enom} \left(R_{top}^{X_{re}} \right)$$

$$R_{ex} = R_{exnom} \left(R_{top}^{X_{rex}} \right)$$

$$I_s = I_{snom} \left(R_{td}^{X_{ti}} \right) \left(e^{E_g(R_{td}-1)/V_{tm}} \right)$$

$$I_{sa} = I_{sanom} \left(R_{td}^{X_{ti}} \right) \left(e^{(E_g + E_{aa})(R_{td}-1)/V_{tm}} \right)$$

$$I_{sb} = I_{sbnom} \left(R_{td}^{X_{ti}} \right) \left(e^{(E_g + E_{ab})(R_{td}-1)/V_{tm}} \right)$$

$$B_f = B_{fnom} \left(R_{td}^{X_{tb}} \right)$$

$$B_r = B_{rnom} \left(R_{td}^{X_{tb}} \right)$$

$$I_{se} = I_{senom} \left(R_{td}^{(X_{ti}/N_e - X_{tb})} \right) \left(e^{(E_g + E_{ae})/N_e(V_{tm}) - (E_g + E_{ae})/N_{enom}(V_{tmnom})} \right)$$

Virtuoso Simulator Components and Device Models Reference

HBT Model (hbt)

$$N_e = N_{enom} + T_{ne}(\Delta T)$$

$$I_{sc} = I_{scnom} \left(R_{td}^{(X_{ti}/N_c - X_{tb})} \right) \left(e^{(E_g + E_{ac})/N_c(V_{tm}) - (E_g + E_{ac})/N_{cnom}(V_{tmnom})} \right)$$

$$N_c = N_{cnom} + T_{nc}(\Delta T)$$

$$I_{sex} = I_{sexnom} \left(R_{td}^{(X_{ti}/N_{ex} - X_{tb})} \right) \left(e^{(E_g + E_{ax})/N_{ex}(V_{tm}) - (E_g + E_{ax})/N_{exnom}(V_{tmnom})} \right)$$

$$N_{ex} = N_{exnom} + T_{nex}(\Delta T)$$

$$V_j = V_{jnom} - T_{vj}(T_{op} - T_{nom})$$

$$C_j = C_{jnom} \left(\frac{V_{jnom}}{V_j} \right)^{M_j}$$

$$I_{tc} = I_{tcnom} \left(R_{td}^{X_{ticc}} \right)$$

$$I_{tc2} = I_{tc2nom} \left(R_{td}^{X_{ticc2}} \right)$$

$$T_{krk} = T_{krknom} \left(R_{top}^{X_{tkrk}} \right)$$

$$V_{krk} = V_{krknom} \left(R_{top}^{X_{tkrk}} \right)$$

$$I_{krk} = I_{krknom} \left(R_{top}^{X_{tkrk}} \right)$$

Scaling Effects

For scaling effects, see [Scaling Factors \(scale and scalem\)](#) on page 242.

Component Statements

Sample Instance Statement

```
q7 (net5 net2 0) hbtmod m=1 top=25
```

Sample Model Statement

```
model hbtmod hbt type=npn bf=500 br=1000 xtb=-2.4 xti=0 xcjc=0.83 mje=0.34 fc=0.5  
eg=1.2 ise=5.5e-15 vjc=0.84 vaf=40 cjc=5.1e-15
```

Instance Definition

```
Name c b e [t] [s] ModelName parameter=value ...
```

It is not necessary to specify the substrate and thermal terminal. If left unspecified, the substrate node is connected to ground while the thermal node is fixed to the ambient temperature. However, you must specify the thermal node if you specify the substrate node.

Instance Parameters

1	area=1	Transistor area factor.
2	m=1	Multiplicity factor.
3	top (C)	Average device operating temperature.
4	region=fwd	Estimated operating region. Spectre outputs number (0-3) in a rawfile. Possible values are <code>off</code> , <code>fwd</code> , <code>rev</code> , or <code>sat</code> .
5	isnoisy=yes	Should resistor generate noise. Possible values are <code>no</code> or <code>yes</code> .

Model Definition

```
model modelName hbt parameter=value ...
```

Model Parameters

Structural parameters

1 `type=npn` Transistor type.
Possible values are `npn` or `pnP`.

Saturation current parameters

2 `is=1e-25 A` Saturation value for forward collector current (*area).
3 `ise=1e-25 A` Saturation value for nonideal base current. (*area).
4 `isex=1e-25 A` Saturation current for emitter leakage diode (*area).
5 `isc=1e-20 A` Saturation value for intrinsic BC junction current. (*area).
6 `iscx=1e-20 A` Saturation value for extrinsic B-C junction current (*area).
7 `ics=1e-30 A` Saturation value for C-S junction current (*area).

Emission coefficient parameters

8 `nf=1` Forward collector current ideality factor.
9 `nr=1` Reverse ideality factor.
10 `ne=2` Nonideal base forward current ideality factor.
11 `nex=2` Ideality factor for emitter leakage diode.
12 `nc=2` Intrinsic B-C junction ideality factor.
13 `ncx=2` Ideality factor for extrinsic B-C junction.
14 `ncs=2` Ideality factor for C-S junction.

Current gain parameters

15 `bf=1000 A/A` Forward ideal current gain (beta).

Virtuoso Simulator Components and Device Models Reference

HBT Model (hbt)

16	<code>br=1000 A/A</code>	Reverse ideal current gain.
17	<code>isa=1e10 A</code>	Collector E-B barrier limiting current (*area).
18	<code>na=2</code>	Collector E-B barrier ideality factor.
19	<code>isb=1e10 A</code>	Collector B-C barrier limiting current (*area).
20	<code>nb=2</code>	Collector B-C barrier ideality factor.
21	<code>ik=1e10 A</code>	Knee current for dc high-level injection effect (*area).

Early voltage parameters

22	<code>vaf=500 V</code>	Forward Early voltage.
23	<code>var=500 V</code>	Reverse Early voltage.

Breakdown voltage parameters

24	<code>bkdn=no</code>	Flag denoting B-C breakdown should be included. Possible values are <code>no</code> or <code>yes</code> .
25	<code>bvc=50 A</code>	Collector-base breakdown voltage BV_{cbo} .
26	<code>nbcb=8</code>	Exponent for B-C multiplication factor versus voltage.
27	<code>fa=0.9</code>	Factor for specification of avalanche voltage.
28	<code>imax=1 A</code>	Maximum allowable base current (*area).
29	<code>imelt=10 A</code>	Explosion current (*area).

Parasitic resistance parameters

30	<code>rbi=0 Ω</code>	Intrinsic base resistance (/area).
31	<code>rbx=0 Ω</code>	Extrinsic base resistance (/area).
32	<code>rci=0 Ω</code>	Intrinsic collector resistance (/area).

Virtuoso Simulator Components and Device Models Reference

HBT Model (hbt)

- 33 $r_{cx}=0 \ \Omega$ Extrinsic collector resistance (/area).
- 34 $r_e=0 \ \Omega$ Emitter resistance (/area).
- 35 $r_{ex}=0 \ \Omega$ Extrinsic emitter leakage diode series resistance (/area).

Junction capacitance parameters

- 36 $c_{je}=0 \ F$ B-E depletion capacitance at zero bias (*area).
- 37 $v_{je}=1.6 \ V$ B-E built-in potential for C_j .
- 38 $m_{je}=0.5$ Exponent for voltage variation of B-E C_j .
- 39 $c_{emin}=0 \ F$ Minimum B-E capacitance (*area).
- 40 $f_{ce}=0.8$ Factor for start of high bias B-E C_j approximation.
- 41 $c_{jc}=0 \ F$ Intrinsic B-C depletion capacitance at zero bias (*area).
- 42 $v_{jc}=1.4 \ V$ Intrinsic B-C built-in potential for C_j .
- 43 $m_{jc}=0.33$ Exponent for voltage variation of Intrinsic B-C C_j .
- 44 $c_{cmin}=0 \ F$ Minimum B-C capacitance (*area).
- 45 $f_c=0.8$ Factor for start of high bias B-C C_j approximation.
- 46 $c_{jcx}=0 \ F$ Extrinsic B-C depletion capacitance at zero bias (*area).
- 47 $v_{jcx}=1.4 \ V$ Extrinsic B-C built-in potential for C_j .
- 48 $m_{jcx}=0.33$ B-C junction exponent.
- 49 $c_{xmin}=0 \ F$ Minimum extrinsic B-C capacitance (*area).
- 50 $x_{cjc}=0$ Fraction of B-C capacitance tied to external base node.
- 51 $c_{js}=0 \ F$ B-S depletion capacitance at zero bias (*area).
- 52 $v_{js}=1.4 \ V$ B-S built-in potential for C_j .
- 53 $m_{js}=0.5$ Exponent for voltage variation of C-S C_j .

Virtuoso Simulator Components and Device Models Reference

HBT Model (hbt)

Transit time and excess phase parameters

54	<code>tfb=0 s</code>	Base transit time.
55	<code>tbexs=0</code>	Excess B-E heterojunction transit time.
56	<code>tbcxs=0</code>	Excess B-C heterojunction transit time.
57	<code>tfc0=0 s</code>	Collector forward transit time.
58	<code>icrit0=1e3 A</code>	Critical current for intrinsic C_j variation.
59	<code>itc=0 A</code>	Characteristic current for T_{fc} .
60	<code>itc2=0 A</code>	Characteristic current for T_{fc} .
61	<code>vtc=1e3 V</code>	Characteristic voltage for T_{fc} .
62	<code>tkrk=0 s</code>	Forward transit time for Kirk effect.
63	<code>vkrk=1e3 V</code>	Characteristic voltage for Kirk effect.
64	<code>ikrk=1e3 A</code>	Characteristic voltage for Kirk effect.
65	<code>tr=0 s</code>	Reverse charge storage time for intrinsic B-C junction.
66	<code>trx=0 s</code>	Reverse charge storage time for extrinsic B-C junction.
67	<code>fex=0 s</code>	Factor to determine excess phase.

Temperature effects parameters

68	<code>selft=no</code>	Flag denoting self-heating. Possible values are <code>no</code> or <code>yes</code> .
69	<code>tnom (C)</code>	Parameters measurement temperature. Default set by options.
70	<code>top=27 C</code>	Average device operating temperature.
71	<code>rth=0 Ω</code>	Thermal resistance of device.
72	<code>cth=0 F</code>	Thermal capacitance of device.

Virtuoso Simulator Components and Device Models Reference

HBT Model (hbt)

73	$x_{ti}=2$	Exponent for i_s temperature dependence.
74	$x_{tb}=2$	Exponent for beta temperature dependence.
75	$t_{ne}=0$	Coefficient for n_e temperature dependence.
76	$t_{nc}=0$	Coefficient for n_c temperature dependence.
77	$t_{nex}=0$	Coefficient for n_{ex} temperature dependence.
78	$e_{ae}=0$ V	Activation energy for i_{sa} temperature dependence.
79	$e_{ac}=0$ V	Activation energy for i_{sb} temperature dependence.
80	$e_{aa}=0$ V	Activation energy for i_{se} temperature dependence.
81	$e_{ab}=0$ V	Activation energy for i_{sc} temperature dependence.
82	$e_{ax}=0$ V	Activation energy for i_{sex} temperature dependence.
83	$x_{re}=0$	Exponent for r_e temperature dependence.
84	$x_{rex}=0$	Exponent for r_{ex} temperature dependence.
85	$x_{rb}=0$	Exponent for r_b temperature dependence.
86	$x_{rc}=0$	Exponent for r_c temperature dependence.
87	$t_{vje}=0$ V/C	Coefficient for v_{je} temperature dependence.
88	$t_{vjc}=0$ V/C	Coefficient for v_{jc} temperature dependence.
89	$t_{vjcx}=0$ V/C	Coefficient for v_{jcx} temperature dependence.
90	$t_{vjs}=0$ V/C	Coefficient for v_{js} temperature dependence.
91	$x_{titc}=0$	Exponent for i_{tc} temperature dependence.
92	$x_{titc2}=0$	Exponent for i_{tc2} temperature dependence.
93	$x_{ttf}=0$	Exponent for t_f temperature dependence.
94	$x_{ttrk}=0$	Exponent for t_{krk} temperature exponent.

Virtuoso Simulator Components and Device Models Reference

HBT Model (hbt)

95	<code>xtvkrk=0</code>	Exponent for <code>vkrk</code> temperature dependence.
96	<code>xtikrk=0</code>	Exponent for <code>ikrk</code> temperature dependence.
97	<code>xrt=0</code>	Exponent for <code>rth</code> temperature dependence.
98	<code>eg=1.5 V</code>	Activation energy for <code>is</code> temperature dependence.
99	<code>dtmax=1000 C</code>	Maximum expected temperature rise above heat sink.

Noise model parameters

100	<code>kfn=0</code>	Flicker (1/f) noise coefficient.
101	<code>afn=1</code>	Flicker (1/f) noise exponent.
102	<code>bfm=1</code>	Flicker noise frequency exponent.

Imax and Imelt

The `imax` parameter aids convergence and prevents numerical overflow. The junction characteristics of the device are accurately modeled for current up to `imax`. If `imax` is exceeded during iterations, the linear model is substituted until the current drops below `imax` or until convergence is achieved. If convergence is achieved with the current exceeding `imax`, the results are inaccurate, and Spectre prints a warning.

A separate model parameter, `imelt`, is used as a limit warning for the junction current. This parameter can be set to the maximum current rating of the device. When any component of the junction current exceeds `imelt`, note that base and collector currents are composed of many exponential terms, Spectre issues a warning and the results become inaccurate. The junction current is linearized above the value of `imelt` to prevent arithmetic exception, with the exponential term replaced by a linear equation at `imelt`.

Operating-Point Parameters

1	<code>type=npn</code>	Transistor type. Possible values are <code>npn</code> or <code>pnp</code> .
2	<code>region=fwd</code>	Estimated operating region. Spectre outputs number (0-3) in a rawfile. Possible values are <code>off</code> , <code>fwd</code> , <code>rev</code> , or <code>sat</code> .

Virtuoso Simulator Components and Device Models Reference

HBT Model (hbt)

3	vbe (V)	Base-emitter voltage.
4	vbc (V)	Base-collector voltage.
5	vce (V)	Collector-emitter voltage.
6	vcs (V)	XC-substrate voltage.
7	temp (C)	Device temperature.
8	ith (A)	Thermal source.
9	ice (A)	Intrinsic B-C current.
10	ibe (A)	Intrinsic B-E current.
11	ics (A)	C-S junction current.
12	ibei (A)	B-E junction current.
13	ibci (A)	B-C junction current.
14	ibex (A)	XB-E junction current.
15	ibcx (A)	XB-C junction current.
16	ibk (A)	Breakdown current.
17	dice_dvbe (S)	Intrinsic dlce/dVbe.
18	dice_dvbc (S)	Intrinsic dlce_dVbc.
19	dibe_dvbe (S)	Intrinsic dlbe_dVbe.
20	dibe_dvbc (S)	Intrinsic dlbe_dVbc.
21	dqbe_dvbe (F)	Intrinsic dQbe_dVbe.
22	dqbe_dvbc (F)	Intrinsic dQbe_dVbc.
23	dqbc_dvbe (F)	Intrinsic dQbc_dVbe.
24	dqbc_dvbc (F)	Intrinsic dQbc_dVbc.

Virtuoso Simulator Components and Device Models Reference

HBT Model (hbt)

25	<code>cbc_x</code> (F)	XB-C junction capacitance.
26	<code>cbc_{xx}</code> (F)	EXTB-C junction capacitance.
27	<code>ccs</code> (F)	Substrate junction capacitance.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

<code>afn</code> M-101	<code>fc</code> M-45	<code>na</code> M-18	<code>tvjc</code> M-88
<code>area</code> I-1	<code>fce</code> M-40	<code>nb</code> M-20	<code>tvjcx</code> M-89
<code>bf</code> M-15	<code>fex</code> M-67	<code>nbc</code> M-26	<code>tvje</code> M-87
<code>bf_n</code> M-102	<code>ibci</code> OP-13	<code>nc</code> M-12	<code>tvjs</code> M-90
<code>bkdn</code> M-24	<code>ibcx</code> OP-15	<code>ncs</code> M-14	<code>type</code> M-1
<code>br</code> M-16	<code>ibe</code> OP-10	<code>ncx</code> M-13	<code>type</code> OP-1
<code>bvc</code> M-25	<code>ibei</code> OP-12	<code>ne</code> M-10	<code>vaf</code> M-22
<code>cbc_x</code> OP-25	<code>ibex</code> OP-14	<code>nex</code> M-11	<code>var</code> M-23
<code>cbc_{xx}</code> OP-26	<code>ibk</code> OP-16	<code>nf</code> M-8	<code>vbc</code> OP-4
<code>ccmin</code> M-44	<code>ice</code> OP-9	<code>nr</code> M-9	<code>vbe</code> OP-3
<code>ccs</code> OP-27	<code>icrit0</code> M-58	<code>rbi</code> M-30	<code>vce</code> OP-5
<code>cemin</code> M-39	<code>ics</code> M-7	<code>rbx</code> M-31	<code>vcs</code> OP-6
<code>cjc</code> M-41	<code>ics</code> OP-11	<code>rci</code> M-32	<code>vjc</code> M-42

Virtuoso Simulator Components and Device Models Reference

HBT Model (hbt)

cjcx	M-46	ik	M-21	rcx	M-33	vjcx	M-47
cje	M-36	ikrk	M-64	re	M-34	vje	M-37
cjs	M-51	imax	M-28	region	I-4	vjs	M-52
cth	M-72	imelt	M-29	region	OP-2	vkrk	M-63
cxmin	M-49	is	M-2	rex	M-35	vtc	M-61
dibe_dvbc	OP-20	isa	M-17	rth	M-71	xcjc	M-50
dibe_dvbe	OP-19	isb	M-19	selft	M-68	xrb	M-85
dice_dvbc	OP-18	isc	M-5	tbcxs	M-56	xrc	M-86
dice_dvbe	OP-17	iscx	M-6	tbexs	M-55	xre	M-83
dqbc_dvbc	OP-24	ise	M-3	temp	OP-7	xrex	M-84
dqbc_dvbe	OP-23	isex	M-4	tfb	M-54	xrt	M-97
dqbe_dvbc	OP-22	isnoisy	I-5	tfc0	M-57	xtb	M-74
dqbe_dvbe	OP-21	itc	M-59	tkrk	M-62	xti	M-73
dtmax	M-99	itc2	M-60	tnc	M-76	xtikrk	M-96
eea	M-80	ith	OP-8	tne	M-75	xtitc	M-91
eab	M-81	kfn	M-100	tnex	M-77	xtitc2	M-92
eac	M-79	m	I-2	tnom	M-69	xttf	M-93
eae	M-78	mjc	M-43	top	I-3	xttkrk	M-94
eax	M-82	mjcx	M-48	top	M-70	xtvkrk	M-95
eg	M-98	mje	M-38	tr	M-65		
fa	M-27	mjs	M-53	trx	M-66		

Virtuoso Simulator Components and Device Models Reference

HBT Model (hbt)

Virtuoso Simulator Components and Device Models Reference

HBT Model (hbt)

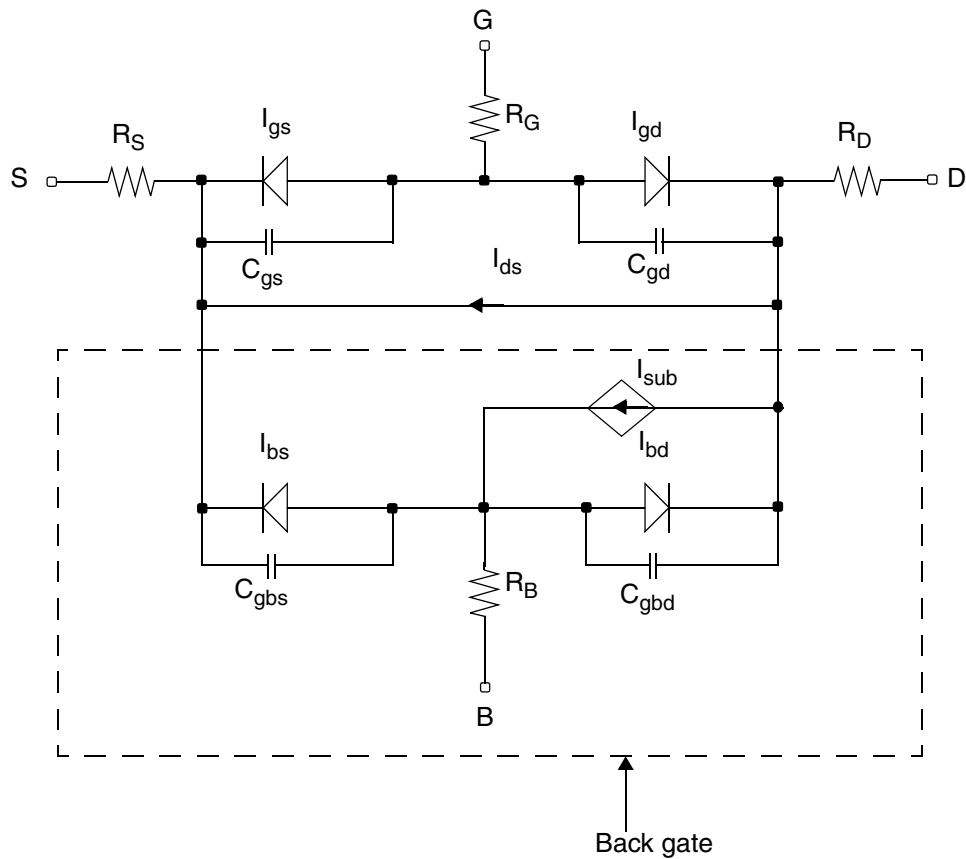
JFET Model (jfet)

The JFET model is derived from the FET model of Shichman and Hodges. This chapter contains the following information for the JFET model:

- [Drain Current for the Subthreshold Region](#) on page 446
- [Drain Current for the Triode Region](#) on page 447
- [Drain Current for the Saturation Region](#) on page 447
- [Gate Junction Currents](#) on page 448
- [Gate Junction Capacitance](#) on page 449
- [Temperature Effect](#) on page 449
- [Noise Model](#) on page 452
- [Scaling Effects](#) on page 453
- [Component Statements](#) on page 453

Virtuoso Simulator Components and Device Models Reference

JFET Model (jfet)



Note: The back gate (enclosed by dotted lines) is available for *level* = 3 only.

$$V_{GST} = V_{GS} - V_{TH}$$

where

$$V_{TH} = \begin{cases} v_{to} & \text{if } level = 1, 2, \text{ or } 4 \\ V_{to4} & \text{if } level = 3 \end{cases}$$

$$V_{to4} = v_{tos}(v_{top} - V_{BS})^{v_{toe}} + v_{toc}$$

Drain Current for the Subthreshold Region

Note: These equations apply when $V_{GST} \leq 0$.

$$I_{DS} = \begin{cases} 0 & \text{if } level = 1 \text{ or } 4 \\ \frac{I_{EXP} I_{LIMIT}}{I_{EXP} + I_{LIMIT}} & \text{otherwise} \end{cases}$$

where

$$I_{LIMIT} = 2betaV_t^2$$

$$I_{EXP} = (io)e^{V_{GST}/nsV_t}(1 - e^{-V_{DS}/V_t})$$

Drain Current for the Triode Region

Note: These equations apply when $V_{GST} \geq 0$ and $V_{DS} \leq V_{GST}$.

$$I_{DS} = \begin{cases} \beta(2V_{GST} - V_{DS})V_{DS}(1 + \lambda V_{DS}) & level = 1 \\ \beta V_{GST}^{np} \tanh\left(\frac{\alpha V_{DS}}{V_{GST}}\right)(1 + \lambda V_{DS}) & level = 2 \\ \beta_4 V_{GST}^{np} \tanh\left(\frac{\alpha V_{DS}}{V_{GST}}\right)(1 + \lambda V_{DS}) & level = 3 \end{cases}$$

where

$$\beta_4 = \beta \left(\frac{vto + vtop}{V_{to4} + vtop} \right)$$

$$\lambda = \lambda(1 + \lambda V_{GST})$$

Drain Current for the Saturation Region

Note: These equations apply when $V_{GST} \geq 0$ and $V_{DS} \geq V_{GST}$.

$$I_{DS} = \begin{cases} \beta V_{GST}^2 (1 + \lambda V_{DS}) & \text{level} = 1 \\ \beta V_{GST}^{np} \tanh\left(\frac{\alpha V_{DS}}{V_{GST}}\right) (1 + \lambda V_{DS}) & \text{level} = 2 \\ \beta_4 V_{GST}^{np} \tanh\left(\frac{\alpha V_{DS}}{V_{GST}}\right) (1 + \lambda V_{DS}) & \text{level} = 3 \end{cases}$$

where

$$Clm = \begin{cases} \frac{V_{GST}}{vto} & \text{if } V_{GS} \leq 0 \\ 1 + \lambda V_{GS} & \text{if } V_{GS} \geq 0 \end{cases}$$

Substrate Leakage Currents

If a_i and b_i are both greater than 0, and $V_{DS} > V_{DSAT}$

$$I_{sub} = I_{DS} \times (V_{DS} - V_{DSAT}) \times \exp\left[\frac{-b}{V_{DS} - V_{DSAT}}\right]$$

For information on bulk junction models I_{BS} , I_{BD} , C_{GBS} , and C_{GBD} , see [Chapter 12, “Common MOSFET Equations.”](#)

Gate Junction Currents

$$I_{GS(GD)} = \begin{cases} \left(i_s \left(e^{\frac{V_{gs(gd)}}{nV_t}} - 1 \right) \right) & \text{if } V_{gs(gd)} \leq V_{Expl} \\ I_{offset} + G_{Expl} V_{gs(gd)} & \text{otherwise} \end{cases}$$

where V_t is the thermal voltage given by

$$V_t = \frac{kT}{q} ,$$

$$V_{Expl} = nV_t \ln \left[1 + \frac{imelt}{is} \right]$$

is the forward explosion voltage,

$$G_{Expl} = \frac{(imelt + is)}{nV_t}$$

is the conductance at V_{Expl} , and

$$I_{offset} = imelt - V_{Expl}G_{Expl}$$

is the current linearly extrapolated to $V = 0$ from V_{Expl} .

Gate Junction Capacitance

$$C_{GS(GD)}(V_{GS(GD)}) = \begin{cases} \frac{cgs(cgd)}{\left[1 - \frac{V_{gs(gd)}}{pb}\right]^{mj}} & \text{if } V_{GS(GD)} \leq fc * pb \\ \frac{cgs(cgd)}{(1-fc)^{mj}} \left[1 + \frac{mj(V_{gs(gd)} - pb * fc)}{pb(1-fc)} \right] & \text{otherwise} \end{cases}$$

Temperature Effect

Gate-Source and Gate-Drain Capacitance

$$C_{gs} = cgs_{nom} \left\{ 1 + mj \left[0.0004(T - Tnom) + \frac{(pb_{nom} - pb)}{pb_{nom}} \right] \right\}$$

Virtuoso Simulator Components and Device Models Reference

JFET Model (jfet)

$$C_{gd} = cgd_{nom} \left\{ 1 + mj \left[0.0004(T - T_{nom}) + \frac{(pb_{nom} - pb)}{pb_{nom}} \right] \right\}$$

Junction Potential

$$pb = pb_{nom} \left(\frac{T}{T_{nom}} \right) - 3V_t \ln \left[\frac{T}{T_{nom}} \right] - E_{g,nom} \left(\frac{T}{T_{nom}} \right) + E_g$$

Transconductance Temperature

$$Beta = Beta \times \left(\frac{T}{T_{nom} + bto} \right)^{bte}$$

$$Lambda = Lambda \times \left(\frac{T}{T_{nom} + lto} \right)^{lte}$$

$$Lambda1 = Lambda1 \times \left(\frac{T}{T_{nom} + lto} \right)^{lte}$$

Gate Junction Current

$$is = is_{nom} \left(\frac{T}{T_{nom}} \right)^{xti} \exp \left[\frac{E_{g,nom}}{V_{t,nom}} - \frac{E_g}{V_t} \right]$$

where, if SPICE-compatibility is required (set by the options),

$$E_g = 1.16 - \frac{7.02 \times 10^{-4} T^2}{1108 + T}$$

$$E_{g,nom} = 1.16 - \frac{7.02 \times 10^{-4} T_{nom}^2}{1108 + T_{nom}}$$

otherwise,

$$E_g = 1.17 - \frac{4.73 \times 10^{-4} T^2}{636 + T}$$

$$E_{g, nom} = 1.17 - \frac{4.73 \times 10^{-4} T_{nom}^2}{636 + T_{nom}}$$

For equations on parameters `tlev`, `tlevc`, `gap1`, and `gap2`, see [Chapter 12, “Common MOSFET Equations.”](#)

Threshold Voltage

For `tcv`,

$$V_{TO} = V_{TO}(model) - tcv \times \text{delta}T$$

$$V_{TOC} = V_{TOC}(model) - tcv \times \text{delta}T$$

Parasitic Resistors

$$\text{tempfactor} = 1.0 + \text{delta}T \times (tc1 \times \text{delta}T + tc2)$$

$$R_{g\text{eff}} = \text{tempfactor} \times R_g$$

$$R_{d\text{eff}} = \text{tempfactor} \times R_d$$

$$R_{s\text{eff}} = \text{tempfactor} \times R_s$$

$$R_{b\text{eff}} = \text{tempfactor} \times R_b$$

Noise Model

Source Series Resistance Thermal Noise

$$\overline{i_{Rs}^2} = \frac{4kT}{r_s} \Delta f$$

Drain Series Resistance Thermal Noise

$$\overline{i_{RD}^2} = \frac{4kT}{r_d} \Delta f$$

Channel Thermal and Flicker Noise

$$\overline{i_{DS}^2} = \frac{8kT(g_m + g_{ds})}{3} \left(\frac{3}{2} - \frac{V'_{DS}}{2V_{DSAT}} \right) + kf \frac{(I_{DS})^{af}}{f} \Delta f$$

where

$$V'_{DS} = \text{MIN}(V_{DS}, V_{DSAT})$$

g_m is the transconductance, g_{ds} is the channel conductance, kf and af are constants for a given device. The Virtuoso[®] Spectre[®] circuit simulator defaults for kf and af are 0.0 and 1.0, respectively.

Gate Junction Noise

$$\overline{i_{gs}^2} = 2qI_{GS} \Delta f + kfd \frac{I_{GS}^{afg}}{f} \Delta f$$

$$\overline{i_{gd}^2} = 2qI_{GD} \Delta f + kfd \frac{I_{GD}^{afg}}{f} \Delta f$$

Scaling Effects

The following are the Spectre scaling effects:

- *is*, *cgs*, *cgd*, and *beta* are multiplied by *area*.
- *rs* and *rd* are divided by *area*.
- All noises are multiplied by *area*.

Component Statements

Sample Instance Statement:

```
jf1 (net1 net2 0) jmod area=1
```

Sample Model Statement

```
model jmod jfet beta=9e-5 lambda=0 type=n vt0=-18.7 rd=10 rs=10 cgs=1.3e-13 pb=0.65
```

Instance Definition

```
Name d g s [b] ModelName parameter=value ...
```

You do not have to specify the back gate terminal when you use the four-terminal model. If left unspecified, the substrate is connected to ground.

Instance Parameters

1	<code>area=1</code>	Junction area factor.
2	<code>m=1</code>	Multiplicity factor.
3	<code>region=triode</code>	Estimated operating region. Spectre outputs number (0-4) in a rawfile. Possible values are <code>off</code> , <code>triode</code> , <code>sat</code> , <code>subth</code> , or <code>breakdown</code> .
4	<code>isnoisy=yes</code>	Should resistor generate noise. Possible values are <code>no</code> or <code>yes</code> .
5	<code>trise=0</code>	Temperature rise from ambient.

Virtuoso Simulator Components and Device Models Reference

JFET Model (jfet)

Model Definition

model modelName jfet parameter=value ...

Model Parameters

Device type parameters

1 type=n Transistor type.
Possible values are n or p.

Drain current model parameters

2 level=1 Drain current model level selector.

3 vto=-2 V Pinchoff voltage.

4 beta=0.0001 A/V² Transconductance parameter.

5 lambda=0 1/V Channel length modulation parameter.

6 lambda1=0 1/V Gate dependence of channel length modulation parameter.

7 np=2 Power-law exponent.

8 alpha=2 Triode-to-saturation transition parameter.

9 io=0 A Subthreshold current parameter.

10 ns=1 Subthreshold swing parameter.

11 ai=0 1/V Impact ionization current coefficient.

12 bi=0 V Impact ionization current exponent.

Four terminal threshold voltage parameters

13 vtop=0.6 V Back gate to channel junction potential.

14 vtos=1.2 V Threshold voltage slope.

Virtuoso Simulator Components and Device Models Reference

JFET Model (jfet)

15 `vt0e=0.33` Threshold voltage exponent.

16 `vt0c=-3.3 V` Threshold voltage constant.

Parasitic resistance parameters

17 `rd=0 Ω` Drain resistance (/area).

18 `rs=0 Ω` Source resistance (/area).

19 `rg=0 Ω` Gate resistance (/area).

20 `rb=0 Ω` Back gate resistance (/area).

21 `minr=0.1 Ω` Minimum source/drain/gate resistance.

Junction diode model parameters

22 `is=1e-14 A` Gate saturation current (*area).

23 `n=1` Emission coefficient for G-D and G-S junctions.

24 `imelt='imax' A` Explosion current (*area).

25 `dskip=yes` Use simple piece-wise linear model for diode currents below $0.1 \cdot i_{abstol}$.
Possible values are `no` or `yes`.

Junction capacitance model parameters

26 `tt=0 s` Transit time.

27 `cgs=0 F` Gate-source zero-bias junction capacitance (*area).

28 `cgd=0 F` Gate-drain zero-bias junction capacitance (*area).

29 `mj=1/2` Junction grading coefficient.

30 `pb=1 V` Gate-junction potential.

31 `fc=0.5` Junction capacitor forward-bias threshold.

Virtuoso Simulator Components and Device Models Reference

JFET Model (jfet)

Four terminal junction parameters

32	<code>isb=1e-14 A</code>	Back gate-saturation current (*area).
33	<code>nb=1</code>	Emission coefficient for back gate-junctions.
34	<code>cgbs=0 F</code>	Back gate-source zero-bias junction capacitance (*area).
35	<code>cgbd=0 F</code>	Back gate-drain zero-bias junction capacitance (*area).
36	<code>mjb=1/2</code>	Back gate-junction grading coefficient.
37	<code>pbb=1 V</code>	Back gate-junction potential.

Temperature effect parameters

38	<code>tnom (C)</code>	Parameters measurement temperature. Default set by <code>options</code> .
39	<code>trise=0 C</code>	Temperature rise from ambient.
40	<code>x_{ti}=3</code>	Temperature exponent for effect on <code>is</code> .
41	<code>tlev=0</code>	DC temperature selector.
42	<code>tlevc=0</code>	AC temperature selector.
43	<code>eg=1.12452 V</code>	Energy band gap.
44	<code>gap1=7.02e-4 V/C</code>	Band gap temperature coefficient.
45	<code>gap2=1108 C</code>	Band gap temperature offset.
46	<code>eglev=0</code>	DC temperature selector.
47	<code>tcv=0 1/C</code>	Threshold voltage temperature coefficient.
48	<code>bto=0 C</code>	Transconductance parameter temperature offset.
49	<code>bte=0</code>	Transconductance parameter temperature exponent.
50	<code>lto=0 C</code>	Channel length modulation parameters temperature offset.
51	<code>lte=0</code>	Channel length modulation parameters temperature exponent.

Virtuoso Simulator Components and Device Models Reference

JFET Model (jfet)

- 52 $t_{c1}=0$ 1/C Linear temperature coefficient for parasitic resistors.
- 53 $t_{c2}=0$ C⁻² Quadratic temperature coefficient for parasitic resistors.
- 54 $p_{ta}=0$ V/C Junction potential temperature coefficient.

Operating region warning control parameters

- 55 $alarm=none$ Forbidden operating region.
Possible values are `none`, `off`, `triode`, `sat`, `subth`, or `rev`.
- 56 $imax=1$ A Maximum allowable current (*area).
- 57 $b_{vj}=\infty$ V Junction reverse breakdown voltage.

Noise parameters

- 58 $k_f=0$ Flicker noise (1/f) coefficient.
- 59 $a_f=1$ Flicker noise (1/f) exponent.
- 60 $k_{fd}=0$ Flicker noise (1/f) coefficient for gate diodes.
- 61 $a_{fg}=1$ Flicker noise (1/f) exponent for gate diodes.

Compatibility model parameters

- 62 $l_{del}=0$ m Difference between drawn and actual or optical device length.
- 63 $w_{del}=0$ m Difference between drawn and actual or optical device Width.
- 64 $r_{sh}=0$ Ω heavily doped region, sheet resistance (ohm/sq).
- 65 $r_{shg}=0$ Ω Gate sheet resistance (ohm/sq).
- 66 $r_{shl}=0$ Ω lightly doped region, sheet resistance (ohm/sq).
- 67 $hdif=0$ m distance of the heavily diffused or low resistance region from source or drain contact to lightly doped region.

Virtuoso Simulator Components and Device Models Reference

JFET Model (jfet)

68	<code>ldif=0 m</code>	distance of the lightly doped region from heavily doped region to transistor edge.
69	<code>trd=0 1/C</code>	temperature coefficient for drain resistance.
70	<code>trs=0 1/C</code>	temperature coefficient for source resistance.
71	<code>acm=0</code>	area calculation method. <code>acm=0</code> <code>area=w/l</code> , <code>acm=1</code> <code>area=w.l</code> .

`Imax` and `Imelt`

The `imax` parameter aids convergence and prevents numerical overflow. The junction characteristics of the device are accurately modeled for current up to `imax`. If `imax` is exceeded during iterations, the linear model is substituted until the current drops below `imax` or until convergence is achieved. If convergence is achieved with the current exceeding `imax`, the results are inaccurate, and Spectre prints a warning.

A separate model parameter, `imelt`, is used as a limit warning for the junction current. This parameter can be set to the maximum current rating of the device. When any component of the junction current exceeds `imelt`, note that base and collector currents are composed of many exponential terms, Spectre issues a warning and the results become inaccurate. The junction current is linearized above the value of `imelt` to prevent arithmetic exception, with the exponential term replaced by a linear equation at `imelt`.

The `bv` parameter is used to detect the junction breakdown only. The breakdown currents of the junctions are not modeled.

Operating-Point Parameters

1	<code>type=n</code>	Transistor type. Possible values are <code>n</code> or <code>p</code> .
2	<code>region=triode</code>	Estimated operating region. Spectre outputs number (0-4) in a rawfile. Possible values are <code>off</code> , <code>triode</code> , <code>sat</code> , <code>subth</code> , or <code>breakdown</code> .
3	<code>ids (A)</code>	Resistive drain current.
4	<code>id (A)</code>	<code>Id</code> drain current.
5	<code>vgs (V)</code>	Gate-source voltage.
6	<code>vds (V)</code>	Drain-source voltage.

Virtuoso Simulator Components and Device Models Reference

JFET Model (jfet)

7	<code>vth</code> (V)	Threshold at op point.
8	<code>vdsat</code> (V)	Drain saturation voltage.
9	<code>gm</code> (S)	Common-source transconductance.
10	<code>gds</code> (S)	Common-source output conductance.
11	<code>cgs</code> (F)	Gate-source capacitance.
12	<code>cgd</code> (F)	Gate-drain capacitance.
13	<code>ig</code> (A)	Resistive gate current.
14	<code>pwr</code> (W)	Power at op point.
15	<code>qd</code> (V)	Threshold at op point.
16	<code>qg</code> (V)	Threshold at op point.
17	<code>qs</code> (V)	Threshold at op point.
18	<code>qb</code> (V)	Threshold at op point.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

<code>acm</code> M-71	<code>gds</code> OP-10	<code>mjb</code> M-36	<code>tcv</code> M-47
<code>af</code> M-59	<code>gm</code> OP-9	<code>n</code> M-23	<code>tlev</code> M-41
<code>afg</code> M-61	<code>hdif</code> M-67	<code>nb</code> M-33	<code>tlevc</code> M-42
<code>ai</code> M-11	<code>id</code> OP-4	<code>np</code> M-7	<code>tnom</code> M-38

Virtuoso Simulator Components and Device Models Reference

JFET Model (jfet)

alarm	M-55	ids	OP-3	ns	M-10	trd	M-69
alpha	M-8	ig	OP-13	pb	M-30	trise	I-5
area	I-1	imax	M-56	pbb	M-37	trise	M-39
beta	M-4	imelt	M-24	pta	M-54	trs	M-70
bi	M-12	io	M-9	pwr	OP-14	tt	M-26
bte	M-49	is	M-22	qj	OP-18	type	M-1
bto	M-48	isb	M-32	qd	OP-15	type	OP-1
bvj	M-57	isnoisy	I-4	qg	OP-16	vds	OP-6
cgbd	M-35	kf	M-58	qs	OP-17	vdsat	OP-8
cgbs	M-34	kfd	M-60	rb	M-20	vgs	OP-5
cgd	M-28	lambda	M-5	rd	M-17	vth	OP-7
cgd	OP-12	lambda1	M-6	region	I-3	vto	M-3
cgs	M-27	ldel	M-62	region	OP-2	vtoc	M-16
cgs	OP-11	ldif	M-68	rg	M-19	vtoe	M-15
dskip	M-25	level	M-2	rs	M-18	vtop	M-13
eg	M-43	lte	M-51	rsh	M-64	vtos	M-14
eglev	M-46	lto	M-50	rshg	M-65	wdel	M-63
fc	M-31	m	I-2	rshl	M-66	xti	M-40
gap1	M-44	minr	M-21	tc1	M-52		
gap2	M-45	mj	M-29	tc2	M-53		

Philips Models

This chapter describes the component statements for the following models:

- [Diode Level 500 \(dio500\)](#) on page 463
- [Lateral PNP Transistor \(bjt301\)](#) on page 466
- [Lateral PNP Transistor \(bjt500\)](#) on page 474
- [Lateral PNP Transistor \(bjt500t\)](#) on page 486
- [Vertical NPN/PNP Transistor \(bjt503\)](#) on page 498
- [Compact Bipolar-Transistor Model \(bjt504\)](#) on page 509
- [Compact Bipolar-Transistor Model \(bjt504t\)](#) on page 524
- [Compact Bipolar-Transistor Model \(bjtd504\)](#) on page 540
- [Compact Bipolar-Transistor Model \(bjtd504t\)](#) on page 553
- [Compact Bipolar-Transistor Model \(bjtd3500\)](#) on page 568
- [Compact Bipolar-Transistor Model \(bjtd3500t\)](#) on page 583
- [Long Channel JFET/MOSFET Model \(mos30\)](#) on page 599
- [MOS Model 40, Level 40 \(mos40t\)](#) on page 604
- [Long Channel JFET/MOSFET Model \(mos3002\)](#) on page 609
- [Compact MOS-Transistor Model \(mos705\)](#) on page 614
- [Compact MOS-Transistor Model \(mos902\)](#) on page 624
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- [Compact MOS-Transistor Distortion Model \(mos1100\)](#) on page 663
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- [MOS Model 11, Level 1101 \(mos11010\)](#) on page 684

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Philips Models

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- [MOS Model 11, Level 1101 \(mos11011\)](#) on page 711
- [MOS Model 11, Level 1101 \(mos11011t\)](#) on page 729
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Diode Level 500 (dio500)

The `dio500` model provides a detailed description of the diode currents in forward and reverse biased Si-diodes. It is described in the Philips Bipolar Modelbook (Dec.93) as `Diode level 500`. Information on how to obtain this document can be found on Source Link by searching for Philips.

(c) Philips Electronics N.V. 1994

In extension to the model book description a minimum conductance `gmin` is inserted between the diode nodes to aid convergence. The value of `gmin` is set by an options statement, default is `gmin = 1.0e-12 S`.

The `imax` parameter is used to aid convergence and to prevent numerical overflow. The junction characteristics of the diode are accurately modeled for currents up to `imax`. For currents above `imax`, the junction is modeled as a linear resistor, and a warning is printed.

This device is supported within altergroups.

This device is dynamically loaded from the shared object `/vobs/spectre_dev/tools.lnx86/cmi/lib/5.0.doc/libphilips_sh.so`

Sample Instance Statement

```
d1 (pnode 0) phdiode area=2
```

Sample Model Statement

```
model phdiode dio500 is=3.5e-12 rs=26.3 n=2.7 imax=1e20 vlc=1.8 vbr=9.63 cj=2.65e-11 dta=12.88 tau=7.5e-10 tnom=25
```

Instance Definition

```
Name a k ModelName parameter=value ...
```

Instance Parameters

- | | | |
|---|-----------------------|------------------------|
| 1 | <code>area=1.0</code> | Multiplication factor. |
| 2 | <code>mult</code> | Alias of area factor. |
| 3 | <code>m=1.0</code> | Multiplicity factor. |

Virtuoso Simulator Components and Device Models Reference

Philips Models

4 `region=fwd` Estimated DC operating region, used as a convergence aid. Possible values are `fwd`, `rev` or `brk`.

Model Definition

```
model modelName dio500 parameter=value ...
```

Model Parameters

1 `is=7.13e-13 A` Saturation current.

2 `n=1.044` Junction emission coefficient.

3 `v1c=0.0 V` Voltage dependence at low forward currents.

4 `vbr=7.459 V` Breakdown voltage.

5 `emvbr=1.36e+06 V/cm` Electric field at breakdown.

6 `csrhh=7.44e-07 A/cm` Shockley-Read-Hall generation.

7 `cbbt=3.255 A/V` Band to band tunneling.

8 `ctat=3.31e-06 A/cm` Trap assisted tunneling.

9 `rs=0.0 Ω` Series resistance.

10 `tau=500.0e-12 s` Transit time.

11 `cj=7.0e-12 F` Zero-bias depletion capacitance.

12 `vd=0.9 V` Diffusion voltage.

13 `p=0.4` Grading coefficient.

14 `tref (C)` Reference temperature. Default set by option `tnom`.

15 `tnom (C)` Alias of `tref`.

16 `tr (C)` Alias of `tref`.

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Philips Models

17	<code>vg=1.206 V</code>	Bandgap voltage.
18	<code>p_{trs}=0.0</code>	Power for temperature dependence of <code>r_s</code> .
19	<code>kf=0.0</code>	Flickernoise coefficient.
20	<code>af=1.0</code>	Flickernoise exponent.
21	<code>d_{ta}=0.0 K</code>	Difference between device temperature and ambient temperature.
22	<code>trise (K)</code>	Alias of <code>d_{ta}</code> .
23	<code>imax=1.0 A</code>	Explosion current.

Operating-Point Parameters

1	<code>v_{ak} (V)</code>	Diode voltage, measured from anode to cathode (including <code>r_s</code>).
2	<code>i_d (A)</code>	Total resistive diode current.
3	<code>q_d (Coul)</code>	Diffusion charge.
4	<code>q_t (Coul)</code>	Depletion charge.
5	<code>r_{st} (Ω)</code>	Series resistance (temperature updated).
6	<code>r_l (Ω)</code>	AC linearized resistance.
7	<code>c_l (F)</code>	AC linearized capacitance.
8	<code>pwr (W)</code>	Power dissipation.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

Virtuoso Simulator Components and Device Models Reference

Philips Models

af	M-20	id	OP-2	pwr	OP-8	tr	M-16
area	I-1	imax	M-23	qd	OP-3	tref	M-14
cbbt	M-7	is	M-1	qt	OP-4	trise	M-22
cj	M-11	kf	M-19	region	I-4	vak	OP-1
cl	OP-7	m	I-3	rl	OP-6	vbr	M-4
csrh	M-6	mult	I-2	rs	M-9	vd	M-12
ctat	M-8	n	M-2	rst	OP-5	vg	M-17
dta	M-21	p	M-13	tau	M-10	vlc	M-3
emvbr	M-5	ptrs	M-18	tnom	M-15		

Lateral PNP Transistor (bjt301)

The bjt301 model provides an extensive description of a lateral integrated circuit junction-isolated PNP transistor. It is described in the Philips Bipolar Modelbook (Dec.93) as TPL level 301.

(c) Philips Electronics N.V. 1993

In extension to the model book description a minimum conductance g_{min} is inserted between the internal base and internal collector node, between the internal base and the internal emitter node, and between the external base and the substrate node to aid convergence. The value of g_{min} is set by an options statement, default = 1e-12 S.

The $imax$ parameter is used to aid convergence and to prevent numerical overflow. The junction characteristics of the transistor are accurately modeled for currents up to $imax$. For currents above $imax$, the junction is modeled as a linear resistor and a warning is printed.

This device is supported within altergroups.

This device is dynamically loaded from the shared object /vobs/spectre_dev/tools.lnx86/cmi/lib/5.0.doc/libphilips_sh.so

Virtuoso Simulator Components and Device Models Reference

Philips Models

Sample Instance Statement:

```
q2 (minus net3 vcc) pnp_mod region=fwd area=1 m=1
```

Sample Model Statement:

```
model pnp_mod bjt301 type=pnp struct=lateral is=1e-14 bf=85 ilf=11e-9 ikf=95e-6  
re=3.2 cje=0.352e-12
```

Instance Definition

```
Name c b e [s] ModelName parameter=value ...
```

Instance Parameters

- | | | |
|---|------------|---|
| 1 | area=1 | Area factor. |
| 2 | mult=1 | Alias of area factor. |
| 3 | m=1 | Multiplicity factor. |
| 4 | region=fwd | Estimated DC operating region, used as a convergence aid.
Possible values are off, fwd, rev, or sat. |

Model Definition

```
model modelName bjt301 parameter=value ...
```

Model Parameters

Structural parameters

- | | | |
|---|----------------|---|
| 1 | type=pnp | Transistor type.
Possible values are pnp or pnp1. |
| 2 | struct=lateral | Transistor structure.
Possible values are lateral. |

Virtuoso Simulator Components and Device Models Reference

Philips Models

Current parameters

3	$i_s=1.0e-15$ A	Saturation current.
4	$i_{max}=1.0$ A	Explosion current.
5	$\beta_f=100.0$ A/A	Ideal forward common-emitter current gain (beta).
6	$i_{lf}=10.0e-9$ A	Low-level knee-current of forward beta.
7	$n_{lf}=2.0$	Emission coefficient of non-ideal forward base current.
8	$i_{kf}=100.0e-6$ A	High-injection knee-current of forward beta.
9	$n_{hf}=1.0$	Basewidening exponent.
10	$v_{eaf}=50.0$ V	Early voltage related to collector junction.
11	$\beta_r=10.0$ A/A	Ideal reverse common-collector current gain (beta).
12	$i_{lr}=10.0e-9$ A	Low-level knee-current of reverse beta.
13	$n_{lr}=2.0$	Emission coefficient of non-ideal reverse base current.
14	$i_{kr}=100.0e-6$ A	High-injection knee-current of reverse beta.
15	$i_{ks}=100.0e-6$ A	High-injection current of substrate effect.
16	$x_{cs}=1.0$	Current fraction of c-b-s transistor.
17	$x_{es}=0.01$	Current fraction of e-b-s transistor.

Parasitic resistance parameters

18	$r_c=1.0$ Ω	Collector resistance.
19	$r_{bc}=10.0$ Ω	Constant part of base resistance.
20	$r_{bv}=10.0$ Ω	Variable part of base resistance.
21	$r_e=1.0$ Ω	Emitter series resistance.

Junction capacitance parameters

22	$\tau_{aub}=25.0e-9$ s	Forward transit time related to neutral base.
23	$\tau_{aune}=1.0e-9$ s	Forward transit time related to neutral emitter in neutral e-b region.
24	$m\tau_{au}=1.0$	Coefficient of current dependence of τ_{aune} .
25	$c_{je}=100.0e-15$ F	Zero bias emitter-base depletion capacitance.
26	$v_{de}=0.55$ V	Emitter-base diffusion voltage.
27	$p_e=0.333$	Emitter-base grading coefficient.
28	$\tau_{aur}=100.0e-9$ s	Ideal reverse transit time.
29	$c_{jc}=200.0e-15$ F	Zero bias collector-base depletion capacitance.
30	$v_{dc}=0.55$ V	Collector-base diffusion voltage.
31	$p_c=0.333$	Collector-base grading coefficient.
32	$c_{js}=1.0e-12$ F	Zero bias substrate junction depletion capacitance.
33	$v_{ds}=0.55$ V	Substrate junction diffusion voltage.
34	$p_s=0.333$	Substrate junction grading coefficient.
35	$exphi=0.3$	Excess phase shift.
36	$f_c=0.95$	Coefficient for forward bias capacitance.

Temperature effects parameters

37	t_{ref} (C)	Reference temperature. Default set by option t_{nom} .
38	t_{nom} (C)	Alias of t_{ref} . Default set by option t_{nom} .
39	$dta=0.0$ K	Difference between device temperature and ambient temperature.
40	$t_{rise}=0.0$ K	Alias of dta .

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Philips Models

41	<code>ptbf=0.0</code>	Power for temperature dependence of <code>b_f</code> .
42	<code>ptbr=0.0</code>	Power for temperature dependence of <code>b_r</code> .
43	<code>ptrc=0.0</code>	Power for temperature dependence of <code>r_c</code> .
44	<code>ptrb=0.0</code>	Power for temperature dependence of <code>r_{bc}</code> and <code>r_{bv}</code> .
45	<code>vg=1.2 V</code>	Band-gap voltage.
46	<code>pt=1.2</code>	Power for temperature dependence of diffusion coefficient.

Noise model parameters

47	<code>kf=0.0</code>	Flicker noise coefficient.
48	<code>af=1.0</code>	Flicker noise exponent.

Output Parameters

1	<code>ist</code> (A)	Saturation current.
2	<code>i_{ole}</code> (A)	Non-ideal forward base saturation current.
3	<code>i_{olc}</code> (A)	Non-ideal reverse base saturation current.
4	<code>b_{ft}</code> (A/A)	Ideal forward common-emitter current gain (beta).
5	<code>b_{rt}</code> (A/A)	Ideal reverse common-collector current gain (beta).
6	<code>r_{ct}</code> (Ω)	Collector resistance.
7	<code>r_{bct}</code> (Ω)	Constant part of base resistance.
8	<code>r_{bvt}</code> (Ω)	Variable part of base resistance.
9	<code>t_{aubt}</code> (s)	Forward transit time related to neutral base.
10	<code>c_{jet}</code> (F)	Zero bias emitter-base depletion capacitance.
11	<code>v_{det}</code> (V)	Emitter-base diffusion voltage.

Virtuoso Simulator Components and Device Models Reference

Philips Models

12	<code>taurt</code> (s)	Ideal reverse transit time.
13	<code>cjct</code> (F)	Zero bias collector-base depletion capacitance.
14	<code>vdct</code> (V)	Collector-base diffusion voltage.
15	<code>cjst</code> (F)	Zero bias substrate junction depletion capacitance.
16	<code>vdst</code> (V)	Substrate junction diffusion voltage.

Operating-Point Parameters

1	<code>ib</code> (A)	Base current.
2	<code>ic</code> (A)	Collector current.
3	<code>ie</code> (A)	Emitter current.
4	<code>isub</code> (A)	Substrate current.
5	<code>vbe</code> (V)	Base-emitter voltage.
6	<code>vbc</code> (V)	Base-collector voltage.
7	<code>vce</code> (V)	Collector-emitter voltage.
8	<code>vsubj</code> (V)	Substrate voltage.
9	<code>betadc</code> (A/A)	Ratio of DC collector current to DC Base current.
10	<code>rb</code> (Ω)	Base resistance at operating point.
11	<code>rc</code> (Ω)	Collector resistance at operating point.
12	<code>re</code> (Ω)	Emitter resistance at operating point.
13	<code>icb</code> (A)	Collector-Base current.
14	<code>ieb</code> (A)	Emitter-Base current.
15	<code>icsub</code> (A)	Collector-Substrate current.
16	<code>iesub</code> (A)	Emitter-Substrate current.

Virtuoso Simulator Components and Device Models Reference

Philips Models

17	<code>pwr</code> (W)	Power.
18	<code>gpi</code> (S)	Conductance emitter-base junction.
19	<code>gmu</code> (S)	Conductance collector-base junction.
20	<code>gf</code> (S)	Forward transconductance.
21	<code>gr</code> (S)	Reverse transconductance.
22	<code>gs</code> (S)	Conductance substrate-base junction.
23	<code>g3</code> (S)	Transconductance (parasitic PNP) c-b-s transistor.
24	<code>g4</code> (S)	Transconductance (parasitic PNP) e-b-s transistor.
25	<code>ced</code> (F)	Emitter diffusion capacitance.
26	<code>ccd</code> (F)	Collector diffusion capacitance.
27	<code>cet</code> (F)	Emitter junction depletion capacitance.
28	<code>cct</code> (F)	Collector junction depletion capacitance.
29	<code>cst</code> (F)	Substrate junction depletion capacitance.
30	<code>betaac</code> (A/A)	Small-signal common-emitter current gain.
31	<code>ft</code> (Hz)	Unity small-signal current-gain frequency.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

<code>af</code>	M-48	<code>gf</code>	OP-20	<code>mtau</code>	M-24	<code>struct</code>	M-2
<code>area</code>	I-1	<code>gmu</code>	OP-19	<code>mult</code>	I-2	<code>taub</code>	M-22

Virtuoso Simulator Components and Device Models Reference

Philips Models

betaac	OP-30	gpi	OP-18	nhf	M-9	taubt	O-9
betadc	OP-9	gr	OP-21	nlf	M-7	taune	M-23
bf	M-5	gs	OP-22	nlr	M-13	taur	M-28
bft	O-4	ib	OP-1	pc	M-31	taurt	O-12
br	M-11	ic	OP-2	pe	M-27	tnom	M-38
brt	O-5	icb	OP-13	ps	M-34	tref	M-37
ccd	OP-26	icsub	OP-15	pt	M-46	trise	M-40
cct	OP-28	ie	OP-3	ptbf	M-41	type	M-1
ced	OP-25	ieb	OP-14	ptbr	M-42	vbc	OP-6
cet	OP-27	iesub	OP-16	ptrb	M-44	vbe	OP-5
cjc	M-29	ikf	M-8	ptrc	M-43	vce	OP-7
cjct	O-13	ikr	M-14	pwr	OP-17	vdc	M-30
cje	M-25	iks	M-15	rb	OP-10	vdct	O-14
cjet	O-10	ilf	M-6	rbc	M-19	vde	M-26
cjs	M-32	ilr	M-12	rbct	O-7	vdet	O-11
cjst	O-15	imax	M-4	rbv	M-20	vds	M-33
cst	OP-29	iolc	O-3	rbvt	O-8	vdst	O-16
dta	M-39	iole	O-2	rc	M-18	veaf	M-10
exphi	M-35	is	M-3	rc	OP-11	vg	M-45
fc	M-36	ist	O-1	rct	O-6	vsubj	OP-8
ft	OP-31	isub	OP-4	re	M-21	xcs	M-16

g3	OP-23	kf	M-47	re	OP-12	xes	M-17
g4	OP-24	m	I-3	region	I-4		

Lateral PNP Transistor (bjt500)

This is SimKit 4.0

This device is supported within altergroups.

This device is dynamically loaded from the shared object /vobs/spectre_dev/tools.lnx86/cmi/lib/5.0.doc/libphilips_sh.so

Instance Definition

```
Name c b e s ModelName parameter=value ...
```

Instance Parameters

- | | | |
|---|------------|--|
| 1 | mult=1 | Area factor. |
| 2 | region=fwd | Estimated DC operating region, used as a convergence aid. Possible values are off, sat, rev, or fwd. |
| 3 | m=1 | Multiplicity factor. |
| 4 | area=1 | alias of mult. |

Model Definition

```
model modelName bjt500 parameter=value ...
```

Model Parameters

- | | | |
|---|--------------|--|
| 1 | level=500 | Bipolar Level. |
| 2 | is=1.8e-16 A | Collector-emitter saturation current. |
| 3 | bf=131 A | Ideal forward common-emitter current gain. |

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Philips Models

4	$ibf=2.6e-14$ A	Saturation current of non-ideal forward base current.
5	$vlf=0.54$ V	Cross-over voltage of non-ideal forward base current.
6	$ik=0.00011$ A	High injection knee current.
7	$xifv=0.43$	Vertical fraction of forward current.
8	$eafl=20.5$ V	Early voltage of the lateral forward current component.
9	$eafv=75$ V	Early voltage of the vertical forward current component.
10	$br=25$ A	Ideal reverse common-emitter current gain.
11	$ibr=1.2e-13$ A	Saturation current of non-ideal reverse base current.
12	$vlr=0.48$ V	Cross-over voltage of non-ideal reverse base current.
13	$xirv=0.43$	Vertical fraction of reverse current.
14	$earl=13.1$ V	Early voltage of the lateral reverse current component.
15	$earv=104$ V	Early voltage of the vertical reverse current component.
16	$xes=0.0027$	Ratio between saturation current of e-b-s transistor and e-b-c transistor.
17	$xhes=0.7$	Fraction of substrate current of e-b-s transistor subject to high injection.
18	$xcs=3$	Ratio between saturation current of c-b-s transistor and c-b-e transistor.
19	$xhcs=1$	Fraction of substrate current of c-b-s transistor subject to high injection.
20	$iss=4e-13$ A	Saturation current of substrate-base diode.
21	$rcex=5$ Ω	External part of the collector resistance.
22	$rcin=47$ Ω	Internal part of the collector resistance.
23	$rbcc=10$ Ω	Constant part of the base resistance rbc .

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Philips Models

24	$r_{bcv}=10 \ \Omega$	Variable part of the base resistance r_{bc} .
25	$r_{bec}=10 \ \Omega$	Constant part of the base resistance r_{be} .
26	$r_{bev}=50 \ \Omega$	Variable part of the base resistance r_{be} .
27	$r_{eex}=27 \ \Omega$	External part of the emitter resistance.
28	$r_{ein}=66 \ \Omega$	Internal part of the emitter resistance.
29	$r_{sb}=1e+15 \ \Omega$	Substrate-base leakage resistance.
30	$t_{lat}=2.4e-09 \ s$	Low injection (forward and reverse) transit time of charge stored in the epilayer between emitter and collector.
31	$t_{fvr}=3e-08 \ s$	Low injection forward transit time due to charge stored in the epilayer under the emitter.
32	$t_{fn}=2e-10 \ s$	Low injection forward transit time due to charge stored in the emitter and the buried layer under the emitter.
33	$c_{je}=6.1e-14 \ F$	Zero-bias emitter-base depletion capacitance.
34	$v_{de}=0.52 \ V$	Emitter-base diffusion voltage.
35	$p_e=0.3$	Emitter-base grading coefficient.
36	$t_{rvr}=1e-09 \ s$	Low injection reverse transit time due to charge stored in the epilayer under the collector.
37	$t_{rn}=3e-09 \ s$	Low injection reverse transit time due to charge stored in the collector and the buried layer under the collector.
38	$c_{jc}=3.9e-13 \ F$	Zero-bias collector-base depletion capacitance.
39	$v_{dc}=0.57 \ V$	Collector-base diffusion voltage.
40	$p_c=0.36$	Collector-base grading coefficient.
41	$c_{js}=1.3e-12 \ F$	Zero-bias substrate-base depletion capacitance.
42	$v_{ds}=0.52 \ V$	Substrate-base diffusion voltage.

Virtuoso Simulator Components and Device Models Reference

Philips Models

43	<code>ps=0.35</code>	Substrate-base grading coefficient.
44	<code>tref=25 C</code>	Reference temperature. Default set by option <code>tnom</code> .
45	<code>dta=0 K</code>	Difference between the device temperature and the ambient analysis temperature.
46	<code>vg_{eb}=1.21 V</code>	Bandgap voltage of the emitter-base depletion region.
47	<code>vg_{cb}=1.21 V</code>	Bandgap voltage of the collector-base depletion region.
48	<code>vg_{sb}=1.21 V</code>	Bandgap voltage of the substrate-base depletion region.
49	<code>vg_b=1.21 V</code>	Bandgap voltage of the base between emitter and collector.
50	<code>vg_e=1.21 V</code>	Bandgap voltage of the emitter.
51	<code>vg_{je}=1.12 V</code>	Bandgap voltage recombination emitter-base junction.
52	<code>ae=4.48</code>	Temperature coefficient of <code>bf</code> .
53	<code>spb=2.85</code>	SC.
54	<code>snb=2.6</code>	Temperature coefficient of the epitaxial base electron mobility.
55	<code>snbn=0.3</code>	Temperature coefficient of buried layer electron mobility.
56	<code>spe=0.73</code>	Temperature coefficient of emitter hole mobility.
57	<code>spc=0.73</code>	Temperature coefficient of collector hole mobility.
58	<code>sx=1</code>	Temperature coefficient of combined minority carrier mobility in emitter and buried layer.
59	<code>kf=0</code>	Flicker noise coefficient.
60	<code>af=1</code>	Flicker noise exponent.
61	<code>exphi=0</code>	Not used in model <code>bjt500</code> .
62	<code>type=n</code>	Transistor gender. Possible values are <code>n</code> , <code>p</code> , <code>nnp</code> , <code>pnnp</code> , <code>nnpv</code> , <code>pnnpv</code> , <code>nnp1</code> , or <code>pnnp1</code> .

Virtuoso Simulator Components and Device Models Reference

Philips Models

63	<code>imax=1.0 A</code>	Explosion current.
64	<code>tnom (C)</code>	alias of <code>tnom</code> .
65	<code>tr (C)</code>	alias of <code>tnom</code> .

Output Parameters

1	<code>is (A)</code>	Collector-emitter saturation current.
2	<code>bf (A)</code>	Ideal forward common-emitter current gain .
3	<code>ibf (A)</code>	Saturation current of non-ideal forward base current.
4	<code>vlf (V)</code>	Cross-over voltage of non-ideal forward base current.
5	<code>ik (A)</code>	High injection knee current.
6	<code>xifv</code>	Vertical fraction of forward current.
7	<code>eaf1 (V)</code>	Early voltage of the lateral forward current component.
8	<code>eafv (V)</code>	Early voltage of the vertical forward current component.
9	<code>br (A)</code>	Ideal reverse common-emitter current gain.
10	<code>ibr (A)</code>	Saturation current of non-ideal reverse base current.
11	<code>v1r (V)</code>	Cross-over voltage of non-ideal reverse base current.
12	<code>xirv</code>	Vertical fraction of reverse current.
13	<code>ear1 (V)</code>	Early voltage of the lateral reverse current component.
14	<code>earv (V)</code>	Early voltage of the vertical reverse current component.
15	<code>xes</code>	Ratio between saturation current of e-b-s transistor and e-b-c transistor.
16	<code>xhes</code>	Fraction of substrate current of e-b-s transistor subject to high injection.

Virtuoso Simulator Components and Device Models Reference

Philips Models

17	x_{cs}	Ratio between saturation current of c-b-s transistor and c-b-e transistor.
18	x_{hcs}	Fraction of substrate current of c-b-s transistor subject to high injection.
19	i_{ss} (A)	Saturation current of substrate-base diode.
20	r_{cex} (Ω)	External part of the collector resistance.
21	r_{cin} (Ω)	Internal part of the collector resistance.
22	r_{bcc} (Ω)	Constant part of the base resistance r_{bc} .
23	r_{bcv} (Ω)	Variable part of the base resistance r_{bc} .
24	r_{bec} (Ω)	Constant part of the base resistance r_{be} .
25	r_{bev} (Ω)	Variable part of the base resistance r_{be} .
26	r_{eex} (Ω)	External part of the emitter resistance.
27	r_{ein} (Ω)	Internal part of the emitter resistance.
28	r_{sb} (Ω)	Substrate-base leakage resistance.
29	t_{lat} (s)	Low injection .
30	t_{fvr} (s)	Low injection forward transit time due to charge stored in the epilayer under the emitter.
31	t_{fn} (s)	Low injection forward transit time due to charge stored in the emitter and the buried layer under the emitter.
32	c_{je} (F)	Zero-bias emitter-base depletion capacitance.
33	v_{de} (V)	Emitter-base diffusion voltage.
34	p_e	Emitter-base grading coefficient.
35	t_{rvr} (s)	Low injection reverse transit time due to charge stored in the epilayer under the collector.

Virtuoso Simulator Components and Device Models Reference

Philips Models

36	<code>trn</code> (s)	Low injection reverse transit time due to charge stored in the collector and the buried layer under the collector.
37	<code>cjc</code> (F)	Zero-bias collector-base depletion capacitance.
38	<code>vdc</code> (V)	Collector-base diffusion voltage.
39	<code>pc</code>	Collector-base grading coefficient.
40	<code>cjs</code> (F)	Zero-bias substrate-base depletion capacitance.
41	<code>vds</code> (V)	Substrate-base diffusion voltage.
42	<code>ps</code>	Substrate-base grading coefficient.
43	<code>vgeb</code> (V)	Bandgap voltage of the emitter-base depletion region.
44	<code>vgcb</code> (V)	Bandgap voltage of the collector-base depletion region.
45	<code>vgsb</code> (V)	Bandgap voltage of the substrate-base depletion region.
46	<code>vgb</code> (V)	Bandgap voltage of the base between emitter and collector.
47	<code>vge</code> (V)	Bandgap voltage of the emitter.
48	<code>vgje</code> (V)	Bandgap voltage recombination emitter-base junction.
49	<code>ae</code>	Temperature coefficient of <code>bf</code> .
50	<code>spb</code>	SC.
51	<code>snb</code>	Temperature coefficient of the epitaxial base electron mobility.
52	<code>snbn</code>	Temperature coefficient of buried layer electron mobility.
53	<code>spe</code>	Temperature coefficient of emitter hole mobility.
54	<code>spc</code>	Temperature coefficient of collector hole mobility.
55	<code>sx</code>	Temperature coefficient of combined minority carrier mobility in emitter and buried layer.
56	<code>kf</code>	Flickernoise coefficient.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 57 `af` Flickernoise exponent.
- 58 `exphi` Not used in model `bjt500`.

Operating-Point Parameters

- 1 `ic` (A) External DC collector current.
- 2 `ib` (A) External DC base current.
- 3 `ie` (A) Resistive emitter current.
- 4 `isub` (A) Resistive substrate current.
- 5 `iflat` (A) Lateral forward current.
- 6 `irlat` (A) Lateral reverse current.
- 7 `ifver` (A) Vertical forward current.
- 8 `irver` (A) Vertical reverse current.
- 9 `ire` (A) ideal forward base current.
- 10 `ile` (A) Non-ideal forward base current.
- 11 `ise` (A) Forward substrate current.
- 12 `irc` (A) Ideal reverse base current.
- 13 `ilc` (A) Non-ideal reverse base current.
- 14 `isc` (A) Reverse substrate current.
- 15 `isf` (A) Reverse leakage current of the substrate-base junction.
- 16 `ip` (A) Main current.
- 17 `betadc` External DC current gain I_c/I_b .
- 18 `vbc` (V) Base-collector voltage.
- 19 `vbe` (V) Base-emitter voltage.

Virtuoso Simulator Components and Device Models Reference

Philips Models

20	vce (V)	Collector-emitter voltage.
21	vsb (V)	Substrate-base voltage.
22	rcex (Ω)	External part of the collector resistance.
23	rcin (Ω)	Internal part of the collector resistance.
24	reex (Ω)	External part of the emitter resistance.
25	rein (Ω)	Internal part of the emitter resistance.
26	rbc (Ω)	Base resistance under the collector.
27	rbe (Ω)	Base resistance under the emitter.
28	rsb (Ω)	Ohmic leakage across the substrate-base junction.
29	pwr (W)	Power.
30	gfl (S)	Forward conductance, lateral path.
31	grl (S)	Reverse conductance, lateral path.
32	g11 (S)	Forward conductance, vertical path.
33	g12 (S)	Collector Early-effect on I_{fver} .
34	g21 (S)	Emitter Early-effect on I_{rver} .
35	g22 (S)	Reverse conductance, vertical path.
36	gpiv (S)	Conductance emitter-base junction.
37	gmuv (S)	Conductance collector-base junction.
38	gbe (S)	Emitter-side: base conductance B1-B.
39	gibe (S)	Emitter Early-effect on I_{b1b} .
40	gbc (S)	Collector-side: base conductance B2-B.
41	gibc (S)	Collector Early-effect on I_{b2b} .

Virtuoso Simulator Components and Device Models Reference

Philips Models

42	<code>gise</code> (S)	Transconductance (parasitic PNP) e-b-s transistor.
43	<code>gisc</code> (S)	Transconductance (parasitic PNP) c-b-s transistor.
44	<code>gsb</code> (S)	Conductance substrate-base junction.
45	<code>cpil</code> (F)	Forward diffusion capacitance, lateral path.
46	<code>cipil</code> (F)	Collector Early-effect on Qflat.
47	<code>cpiv</code> (F)	Forward total capacitance, vertical path.
48	<code>cmul</code> (F)	Reverse diffusion capacitance, lateral path.
49	<code>cimul</code> (F)	Emitter Early-effect on Qrlat.
50	<code>cmuv</code> (F)	Reverse total capacitance, vertical path.
51	<code>csb</code> (F)	Total capacitance substrate-base junction.
52	<code>irbe</code> (A)	Ideal total forward base current.
53	<code>irbc</code> (A)	Ideal total reverse base current.
54	<code>irsb</code> (A)	Substrate base leakage resistance current.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

<code>ae</code>	M-52	<code>gpiv</code>	OP-36	<code>rbcc</code>	M-23	<code>trn</code>	M-37
<code>ae</code>	O-49	<code>grl</code>	OP-31	<code>rbcc</code>	O-22	<code>trn</code>	O-36
<code>af</code>	M-60	<code>gsb</code>	OP-44	<code>rbcv</code>	M-24	<code>trvr</code>	M-36
<code>af</code>	O-57	<code>ib</code>	OP-2	<code>rbcv</code>	O-23	<code>trvr</code>	O-35

Virtuoso Simulator Components and Device Models Reference

Philips Models

area	I-4	ibf	M-4	rbe	OP-27	type	M-62
betadc	OP-17	ibf	O-3	rbec	M-25	vbc	OP-18
bf	M-3	ibr	M-11	rbec	O-24	vbe	OP-19
bf	O-2	ibr	O-10	rbev	M-26	vce	OP-20
br	M-10	ic	OP-1	rbev	O-25	vdc	M-39
br	O-9	ie	OP-3	rcex	M-21	vdc	O-38
cimul	OP-49	iflat	OP-5	rcex	O-20	vde	M-34
cipil	OP-46	ifver	OP-7	rcex	OP-22	vde	O-33
cjc	M-38	ik	M-6	rcin	M-22	vds	M-42
cjc	O-37	ik	O-5	rcin	O-21	vds	O-41
cje	M-33	ilc	OP-13	rcin	OP-23	vgb	M-49
cje	O-32	ile	OP-10	reex	M-27	vgb	O-46
cjs	M-41	imax	M-63	reex	O-26	vgcb	M-47
cjs	O-40	ip	OP-16	reex	OP-24	vgcb	O-44
cmul	OP-48	irbc	OP-53	region	I-2	vge	M-50
cmuv	OP-50	irbe	OP-52	rein	M-28	vge	O-47
cpil	OP-45	irc	OP-12	rein	O-27	vgeb	M-46
cpiv	OP-47	ire	OP-9	rein	OP-25	vgeb	O-43
csb	OP-51	irlat	OP-6	rsb	M-29	vgje	M-51
dta	M-45	irsb	OP-54	rsb	O-28	vgje	O-48
eaf1	M-8	irver	OP-8	rsb	OP-28	vgsb	M-48

Virtuoso Simulator Components and Device Models Reference

Philips Models

eafl	O-7	is	M-2	snb	M-54	vgsb	O-45
eafv	M-9	is	O-1	snb	O-51	vlf	M-5
eafv	O-8	isc	OP-14	snbn	M-55	vlf	O-4
earl	M-14	ise	OP-11	snbn	O-52	vlr	M-12
earl	O-13	isf	OP-15	spb	M-53	vlr	O-11
earv	M-15	iss	M-20	spb	O-50	vsb	OP-21
earv	O-14	iss	O-19	spc	M-57	xcs	M-18
exphi	M-61	isub	OP-4	spc	O-54	xcs	O-17
exphi	O-58	kf	M-59	spe	M-56	xes	M-16
g11	OP-32	kf	O-56	spe	O-53	xes	O-15
g12	OP-33	level	M-1	sx	M-58	xhcs	M-19
g21	OP-34	m	I-3	sx	O-55	xhcs	O-18
g22	OP-35	mult	I-1	tfn	M-32	xhes	M-17
gbc	OP-40	pc	M-40	tfn	O-31	xhes	O-16
gbe	OP-38	pc	O-39	tfvr	M-31	xifv	M-7
gfl	OP-30	pe	M-35	tfvr	O-30	xifv	O-6
gibc	OP-41	pe	O-34	tlat	M-30	xirv	M-13
gibe	OP-39	ps	M-43	tlat	O-29	xirv	O-12
gisc	OP-43	ps	O-42	tnom	M-64		
gise	OP-42	pwr	OP-29	tr	M-65		
gmuv	OP-37	rbc	OP-26	tref	M-44		

Lateral PNP Transistor (bjt500t)

This is SimKit 4.0

This device is supported within altergroups.

This device is dynamically loaded from the shared object /vobs/spectre_dev/tools.lnx86/cmi/lib/5.0.doc/libphilips_sh.so

Instance Definition

```
Name c b e s dt ModelName parameter=value ...
```

Instance Parameters

- | | | |
|---|------------|---|
| 1 | mult=1 | Area factor. |
| 2 | region=fwd | Estimated DC operating region, used as a convergence aid.
Possible values are off, sat, rev, or fwd. |
| 3 | m=1 | Multiplicity factor. |
| 4 | area=1 | alias of mult. |

Model Definition

```
model modelName bjt500t parameter=value ...
```

Model Parameters

- | | | |
|---|---------------|---|
| 1 | level=500 | Bipolar Level. |
| 2 | is=1.8e-16 A | Collector-emitter saturation current. |
| 3 | bf=131 A | Ideal forward common-emitter current gain . |
| 4 | ibf=2.6e-14 A | Saturation current of non-ideal forward base current. |
| 5 | vlf=0.54 V | Cross-over voltage of non-ideal forward base current. |
| 6 | ik=0.00011 A | High injection knee current. |

Virtuoso Simulator Components and Device Models Reference

Philips Models

7	<code>xifv=0.43</code>	Vertical fraction of forward current.
8	<code>eafl=20.5 V</code>	Early voltage of the lateral forward current component.
9	<code>eafv=75 V</code>	Early voltage of the vertical forward current component.
10	<code>br=25 A</code>	Ideal reverse common-emitter current gain.
11	<code>ibr=1.2e-13 A</code>	Saturation current of non-ideal reverse base current.
12	<code>vlr=0.48 V</code>	Cross-over voltage of non-ideal reverse base current.
13	<code>xirv=0.43</code>	Vertical fraction of reverse current.
14	<code>earl=13.1 V</code>	Early voltage of the lateral reverse current component.
15	<code>earv=104 V</code>	Early voltage of the vertical reverse current component.
16	<code>xes=0.0027</code>	Ratio between saturation current of e-b-s transistor and e-b-c transistor.
17	<code>xhes=0.7</code>	Fraction of substrate current of e-b-s transistor subject to high injection.
18	<code>xcs=3</code>	Ratio between saturation current of c-b-s transistor and c-b-e transistor.
19	<code>xhcs=1</code>	Fraction of substrate current of c-b-s transistor subject to high injection.
20	<code>iss=4e-13 A</code>	Saturation current of substrate-base diode.
21	<code>rcex=5 Ω</code>	External part of the collector resistance.
22	<code>rcin=47 Ω</code>	Internal part of the collector resistance.
23	<code>rbcc=10 Ω</code>	Constant part of the base resistance r_{bc} .
24	<code>rbcv=10 Ω</code>	Variable part of the base resistance r_{bc} .
25	<code>rbec=10 Ω</code>	Constant part of the base resistance r_{be} .
26	<code>rbev=50 Ω</code>	Variable part of the base resistance r_{be} .

Virtuoso Simulator Components and Device Models Reference

Philips Models

27	$reex=27 \Omega$	External part of the emitter resistance.
28	$rein=66 \Omega$	Internal part of the emitter resistance.
29	$rsb=1e+15 \Omega$	Substrate-base leakage resistance.
30	$tlat=2.4e-09 s$	Low injection (forward and reverse) transit time of charge stored in the epilayer between emitter and collector.
31	$tfvr=3e-08 s$	Low injection forward transit time due to charge stored in the epilayer under the emitter.
32	$tfn=2e-10 s$	Low injection forward transit time due to charge stored in the emitter and the buried layer under the emitter.
33	$cje=6.1e-14 F$	Zero-bias emitter-base depletion capacitance.
34	$vde=0.52 V$	Emitter-base diffusion voltage.
35	$pe=0.3$	Emitter-base grading coefficient.
36	$trvr=1e-09 s$	Low injection reverse transit time due to charge stored in the epilayer under the collector.
37	$trn=3e-09 s$	Low injection reverse transit time due to charge stored in the collector and the buried layer under the collector.
38	$cjc=3.9e-13 F$	Zero-bias collector-base depletion capacitance.
39	$vdc=0.57 V$	Collector-base diffusion voltage.
40	$pc=0.36$	Collector-base grading coefficient.
41	$cjs=1.3e-12 F$	Zero-bias substrate-base depletion capacitance.
42	$vds=0.52 V$	Substrate-base diffusion voltage.
43	$ps=0.35$	Substrate-base grading coefficient.
44	$tref=25 C$	Reference temperature. Default set by option t_{nom} .
45	$dta=0 K$	Difference between the device temperature and the ambient analysis temperature.

Virtuoso Simulator Components and Device Models Reference

Philips Models

46	<code>vgeb=1.21 V</code>	Bandgap voltage of the emitter-base depletion region.
47	<code>vgcb=1.21 V</code>	Bandgap voltage of the collector-base depletion region.
48	<code>vgsb=1.21 V</code>	Bandgap voltage of the substrate-base depletion region.
49	<code>vgb=1.21 V</code>	Bandgap voltage of the base between emitter and collector.
50	<code>vge=1.21 V</code>	Bandgap voltage of the emitter.
51	<code>vgje=1.12 V</code>	Bandgap voltage recombination emitter-base junction.
52	<code>ae=4.48</code>	Temperature coefficient of <code>bf</code> .
53	<code>spb=2.85</code>	SC.
54	<code>snb=2.6</code>	Temperature coefficient of the epitaxial base electron mobility.
55	<code>snbn=0.3</code>	Temperature coefficient of buried layer electron mobility.
56	<code>spe=0.73</code>	Temperature coefficient of emitter hole mobility.
57	<code>spc=0.73</code>	Temperature coefficient of collector hole mobility.
58	<code>sx=1</code>	Temperature coefficient of combined minority carrier mobility in emitter and buried layer.
59	<code>kf=0</code>	Flickernoise coefficient.
60	<code>af=1</code>	Flickernoise exponent.
61	<code>exphi=0</code>	Not used in model <code>bjt500</code> .
62	<code>rth=300 K/W</code>	Thermal resistance.
63	<code>cth=3e-09 J/K</code>	Thermal capacitance.
64	<code>ath=0</code>	Temperature coefficient of the thermal resistance.
65	<code>type=n</code>	Transistor gender. Possible values are <code>n</code> , <code>p</code> , <code>npn</code> , <code>pnnp</code> , <code>npnv</code> , <code>pnpv</code> , <code>npnl</code> , or <code>pnpl</code> .
66	<code>imax=1.0 A</code>	Explosion current.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 67 `tnom` (C) alias of `tnom`.
- 68 `tr` (C) alias of `tnom`.

Output Parameters

- 1 `is` (A) Collector-emitter saturation current.
- 2 `bf` (A) Ideal forward common-emitter current gain .
- 3 `ibf` (A) Saturation current of non-ideal forward base current.
- 4 `vlf` (V) Cross-over voltage of non-ideal forward base current.
- 5 `ik` (A) High injection knee current.
- 6 `xifv` Vertical fraction of forward current.
- 7 `eaf1` (V) Early voltage of the lateral forward current component.
- 8 `eafv` (V) Early voltage of the vertical forward current component.
- 9 `br` (A) Ideal reverse common-emitter current gain.
- 10 `ibr` (A) Saturation current of non-ideal reverse base current.
- 11 `vlr` (V) Cross-over voltage of non-ideal reverse base current.
- 12 `xirv` Vertical fraction of reverse current.
- 13 `ear1` (V) Early voltage of the lateral reverse current component.
- 14 `earv` (V) Early voltage of the vertical reverse current component.
- 15 `xes` Ratio between saturation current of e-b-s transistor and e-b-c transistor.
- 16 `xhes` Fraction of substrate current of e-b-s transistor subject to high injection.
- 17 `xcs` Ratio between saturation current of c-b-s transistor and c-b-e transistor.

Virtuoso Simulator Components and Device Models Reference

Philips Models

18	<code>xhcs</code>	Fraction of substrate current of c-b-s transistor subject to high injection.
19	<code>iss</code> (A)	Saturation current of substrate-base diode.
20	<code>rcex</code> (Ω)	External part of the collector resistance.
21	<code>rcin</code> (Ω)	Internal part of the collector resistance.
22	<code>rbcc</code> (Ω)	Constant part of the base resistance <code>rbc</code> .
23	<code>rbcv</code> (Ω)	Variable part of the base resistance <code>rbc</code> .
24	<code>rbec</code> (Ω)	Constant part of the base resistance <code>rbe</code> .
25	<code>rbev</code> (Ω)	Variable part of the base resistance <code>rbe</code> .
26	<code>reex</code> (Ω)	External part of the emitter resistance.
27	<code>rein</code> (Ω)	Internal part of the emitter resistance.
28	<code>rsb</code> (Ω)	Substrate-base leakage resistance.
29	<code>tlat</code> (s)	Low injection .
30	<code>tfvr</code> (s)	Low injection forward transit time due to charge stored in the epilayer under the emitter.
31	<code>tfn</code> (s)	Low injection forward transit time due to charge stored in the emitter and the buried layer under the emitter.
32	<code>cje</code> (F)	Zero-bias emitter-base depletion capacitance.
33	<code>vde</code> (V)	Emitter-base diffusion voltage.
34	<code>pe</code>	Emitter-base grading coefficient.
35	<code>trvr</code> (s)	Low injection reverse transit time due to charge stored in the epilayer under the collector.
36	<code>trn</code> (s)	Low injection reverse transit time due to charge stored in the collector and the buried layer under the collector.

Virtuoso Simulator Components and Device Models Reference

Philips Models

37	c_{jc} (F)	Zero-bias collector-base depletion capacitance.
38	v_{dc} (V)	Collector-base diffusion voltage.
39	p_c	Collector-base grading coefficient.
40	c_{js} (F)	Zero-bias substrate-base depletion capacitance.
41	v_{ds} (V)	Substrate-base diffusion voltage.
42	p_s	Substrate-base grading coefficient.
43	v_{geb} (V)	Bandgap voltage of the emitter-base depletion region.
44	v_{gcb} (V)	Bandgap voltage of the collector-base depletion region.
45	v_{gsb} (V)	Bandgap voltage of the substrate-base depletion region.
46	v_{gb} (V)	Bandgap voltage of the base between emitter and collector.
47	v_{ge} (V)	Bandgap voltage of the emitter.
48	v_{gje} (V)	Bandgap voltage recombination emitter-base junction.
49	a_e	Temperature coefficient of b_f .
50	sp_b	SC.
51	sn_b	Temperature coefficient of the epitaxial base electron mobility.
52	sn_{bn}	Temperature coefficient of buried layer electron mobility.
53	sp_e	Temperature coefficient of emitter hole mobility.
54	sp_c	Temperature coefficient of collector hole mobility.
55	sx	Temperature coefficient of combined minority carrier mobility in emitter and buried layer.
56	k_f	Flicker noise coefficient.
57	a_f	Flicker noise exponent.

Virtuoso Simulator Components and Device Models Reference

Philips Models

58 `exphi` Not used in model `bjt500`.

59 `rth` (K/W) Thermal resistance.

60 `cth` (J/K) Thermal capacitance.

Operating-Point Parameters

1 `ic` (A) External DC collector current.

2 `ib` (A) External DC base current.

3 `ie` (A) Resistive emitter current.

4 `isub` (A) Resistive substrate current.

5 `iflat` (A) Lateral forward current.

6 `irlat` (A) Lateral reverse current.

7 `ifver` (A) Vertical forward current.

8 `irver` (A) Vertical reverse current.

9 `ire` (A) ideal forward base current.

10 `ile` (A) Non-ideal forward base current.

11 `ise` (A) Forward substrate current.

12 `irc` (A) Ideal reverse base current.

13 `ilc` (A) Non-ideal reverse base current.

14 `isc` (A) Reverse substrate current.

15 `isf` (A) Reverse leakage current of the substrate-base junction.

16 `ip` (A) Main current.

17 `betadc` External DC current gain I_c/I_b .

18 `vbc` (V) Base-collector voltage.

Virtuoso Simulator Components and Device Models Reference

Philips Models

19	vbe (V)	Base-emitter voltage.
20	vce (V)	Collector-emitter voltage.
21	vsb (V)	Substrate-base voltage.
22	rcex (Ω)	External part of the collector resistance.
23	rcin (Ω)	Internal part of the collector resistance.
24	reex (Ω)	External part of the emitter resistance.
25	rein (Ω)	Internal part of the emitter resistance.
26	rbc (Ω)	Base resistance under the collector.
27	rbe (Ω)	Base resistance under the emitter.
28	rsb (Ω)	Ohmic leakage across the substrate-base junction.
29	pwr (W)	Power.
30	gfl (S)	Forward conductance, lateral path.
31	grl (S)	Reverse conductance, lateral path.
32	g11 (S)	Forward conductance, vertical path.
33	g12 (S)	Collector Early-effect on I_{fver} .
34	g21 (S)	Emitter Early-effect on I_{rver} .
35	g22 (S)	Reverse conductance, vertical path.
36	gpiv (S)	Conductance emitter-base junction.
37	gmuv (S)	Conductance collector-base junction.
38	gbe (S)	Emitter-side: base conductance B1-B.
39	gibe (S)	Emitter Early-effect on I_{b1b} .
40	gbc (S)	Collector-side: base conductance B2-B.

Virtuoso Simulator Components and Device Models Reference

Philips Models

41	<code>gibc</code> (S)	Collector Early-effect on Ib2b.
42	<code>gise</code> (S)	Transconductance (parasitic PNP) e-b-s transistor.
43	<code>gisc</code> (S)	Transconductance (parasitic PNP) c-b-s transistor.
44	<code>gsb</code> (S)	Conductance substrate-base junction.
45	<code>cpil</code> (F)	Forward diffusion capacitance, lateral path.
46	<code>cipil</code> (F)	Collector Early-effect on Qflat.
47	<code>cpiv</code> (F)	Forward total capacitance, vertical path.
48	<code>cmul</code> (F)	Reverse diffusion capacitance, lateral path.
49	<code>cimul</code> (F)	Emitter Early-effect on Qrlat.
50	<code>cmuv</code> (F)	Reverse total capacitance, vertical path.
51	<code>csb</code> (F)	Total capacitance substrate-base junction.
52	<code>irbe</code> (A)	Ideal total forward base current.
53	<code>irbc</code> (A)	Ideal total reverse base current.
54	<code>irsb</code> (A)	Substrate base leakage resistance current.
55	<code>Pdiss</code> (W)	Dissipation.
56	<code>TK</code> (K)	Actual device temperature.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

`Pdiss` OP-55

`gibe` OP-39

`ps` O-42

`tlat` O-29

Virtuoso Simulator Components and Device Models Reference

Philips Models

TK	OP-56	gisc	OP-43	pwr	OP-29	tnom	M-67
ae	M-52	gise	OP-42	rbc	OP-26	tr	M-68
ae	O-49	gmuv	OP-37	rbcc	M-23	tref	M-44
af	M-60	gpiv	OP-36	rbcc	O-22	trn	M-37
af	O-57	grl	OP-31	rbcv	M-24	trn	O-36
area	I-4	gsb	OP-44	rbcv	O-23	trvr	M-36
ath	M-64	ib	OP-2	rbe	OP-27	trvr	O-35
betadc	OP-17	ibf	M-4	rbec	M-25	type	M-65
bf	M-3	ibf	O-3	rbec	O-24	vbc	OP-18
bf	O-2	ibr	M-11	rbev	M-26	vbe	OP-19
br	M-10	ibr	O-10	rbev	O-25	vce	OP-20
br	O-9	ic	OP-1	rcex	M-21	vdc	M-39
cimul	OP-49	ie	OP-3	rcex	O-20	vdc	O-38
cipil	OP-46	iflat	OP-5	rcex	OP-22	vde	M-34
cjc	M-38	ifver	OP-7	rcin	M-22	vde	O-33
cjc	O-37	ik	M-6	rcin	O-21	vds	M-42
cje	M-33	ik	O-5	rcin	OP-23	vds	O-41
cje	O-32	ilc	OP-13	reex	M-27	vgb	M-49
cjs	M-41	ile	OP-10	reex	O-26	vgb	O-46
cjs	O-40	imax	M-66	reex	OP-24	vpcb	M-47
cmul	OP-48	ip	OP-16	region	I-2	vpcb	O-44

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Philips Models

cmuv	OP-50	irbc	OP-53	rein	M-28	vge	M-50
cpil	OP-45	irbe	OP-52	rein	O-27	vge	O-47
cpiv	OP-47	irc	OP-12	rein	OP-25	vgeb	M-46
csb	OP-51	ire	OP-9	rsb	M-29	vgeb	O-43
cth	M-63	irlat	OP-6	rsb	O-28	vgje	M-51
cth	O-60	irsb	OP-54	rsb	OP-28	vgje	O-48
dta	M-45	irver	OP-8	rth	M-62	vgsb	M-48
eaf1	M-8	is	M-2	rth	O-59	vgsb	O-45
eaf1	O-7	is	O-1	snb	M-54	vlf	M-5
eafv	M-9	isc	OP-14	snb	O-51	vlf	O-4
eafv	O-8	ise	OP-11	snbn	M-55	vlr	M-12
ear1	M-14	isf	OP-15	snbn	O-52	vlr	O-11
ear1	O-13	iss	M-20	spb	M-53	vsb	OP-21
earv	M-15	iss	O-19	spb	O-50	xcs	M-18
earv	O-14	isub	OP-4	spc	M-57	xcs	O-17
exphi	M-61	kf	M-59	spc	O-54	xes	M-16
exphi	O-58	kf	O-56	spe	M-56	xes	O-15
g11	OP-32	level	M-1	spe	O-53	xhcs	M-19
g12	OP-33	m	I-3	sx	M-58	xhcs	O-18
g21	OP-34	mult	I-1	sx	O-55	xhes	M-17
g22	OP-35	pc	M-40	tfn	M-32	xhes	O-16

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Philips Models

gbc	OP-40	pc	O-39	tfn	O-31	xifv	M-7
gbe	OP-38	pe	M-35	tfvr	M-31	xifv	O-6
gfl	OP-30	pe	O-34	tfvr	O-30	xirv	M-13
gibc	OP-41	ps	M-43	tlat	M-30	xirv	O-12

Vertical NPN/PNP Transistor (bjt503)

The bjt503 model provides a detailed description of a vertical integrated NPN and PNP transistor. It is described in the Philips Bipolar Modelbook (Dec.95) as TN/TNS and TP/TPS level 503.

The NPN is also described in Nat.Lab. Unclassified Report Nr. 006/94 as Mextram Bipolar Transistor Model. Information on how to obtain this document can be found on Source Link by searching for Philips.

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In addition to the model description a `level` parameter is added. Via the `level` parameter the user can switch between Philips Bipolar Modelbook (Dec.95) and Philips Bipolar Modelbook (Dec.94).

The `imax` parameter is used to aid convergence and to prevent numerical overflow. The junction characteristics of the transistor are accurately modeled for currents up to `imax`. For currents above `imax`, the junction is modeled as a linear resistor and a warning is printed.

The descriptions of the operating point derivatives are given for the NPN type. For the PNP type the terminal voltage in the descriptions has to be exchanged. E.g.:

NPN: $g_x = dI_n/dV_{b2e1}$

PNP: $g_x = dI_n/dV_{e1b2}$

This device is supported within altergroups.

This device is dynamically loaded from the shared object `/vobs/spectre_dev/tools.lnx86/cmi/lib/5.0.doc/libphilips_sh.so`

Sample Instance Statement

```
q4 (vcc net3 minus) npn_mod region=fwd m=1 mult=1
```

Sample Model Statement:

```
model npn_mod bjt503 type=npn level=2 exmod=1 is=1e-14 bf=85 ik=95e-6 rbc=50  
cje=0.352e-12
```

Instance Definition

```
Name c b e [s] ModelName parameter=value ...
```

Instance Parameters

- | | | |
|---|------------|---|
| 1 | area=1 | Area factor. |
| 2 | mult=1 | Alias of area factor. |
| 3 | m=1 | Multiplication factor. |
| 4 | region=fwd | Estimated DC operating region, used as a convergence aid.
Possible values are off, fwd, rev, or sat. |

Model Definition

```
model modelName bjt503 parameter=value ...
```

Model Parameters

- | | | |
|---|--------------|---|
| 1 | type=npn | Transistor type.
Possible values are npn, npnv, pnp, or pnpv. |
| 2 | level=2.0 | Transistor Level. Possible values are 1 (Philips Bipolar Modelbook Dec.94) or 2 (Philips Bipolar Modelbook Dec.95). |
| 3 | exmod=0 | Flag for extended modeling of the reverse current gain. |
| 4 | exphi=0 | Flag for distributed high frequency effects. |
| 5 | exavl=1 | Flag for extended modeling of avalanche currents. |
| 6 | is=5.0e-17 A | Collector-emitter saturation current. |

Virtuoso Simulator Components and Device Models Reference

Philips Models

7	$b_f=140.0$ A/A	Ideal forward current gain.
8	$x_{ibi}=0.0$	Fraction of ideal base current that belongs to the sidewall.
9	$i_{bf}=2.0e-14$ A	Saturation current of the non-ideal forward base current.
10	$v_{lf}=0.5$ V	Cross-over voltage of the non-ideal forward base current.
11	$i_k=15.0e-3$ A	High-injection knee current.
12	$b_{ri}=16.0$ A/A	Ideal reverse current gain.
13	$i_{br}=8.0e-15$ A	Saturation current of the non-ideal reverse base current.
14	$v_{lr}=0.5$ V	Cross-over voltage of the non-ideal reverse base current.
15	$x_{ext}=0.5$	Part of I_{ex} , Q_{ex} , Q_{tex} and I_{sub} that depends on V_{bc1} .
16	$q_{bo}=1.2e-12$ Coul	Base charge at zero bias.
17	$\eta_a=4.0$	Factor of the built-in field of the base.
18	$av_1=50.0$	Weak avalanche parameter.
19	$e_{fi}=0.7$	Electric field intercept (with $ex_{av_1}=1$).
20	$i_{hc}=3.0e-3$ A	Critical current for hot carriers.
21	$r_{cc}=25.0$ Ω	Constant part of the collector resistance.
22	$r_{cv}=750.0$ Ω	Resistance of the unmodulated epilayer.
23	$scr_{cv}=1000.0$ Ω	Space charge resistance of the epilayer.
24	$sf_h=0.6$	Current spreading factor epilayer.
25	$r_{bc}=50.0$ Ω	Constant part of the base resistance.
26	$r_{bv}=100.0$ Ω	Variable part of the base resistance at zero bias.
27	$r_e=2.0$ Ω	Emitter series resistance.
28	$\tau_{aune}=3.0e-10$ s	Minimum delay time of neutral and emitter charge.

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Philips Models

29	$m\tau=1.18$	Non-ideality factor of the neutral and emitter charge.
30	$c_{je}=2.5e-13$ F	Zero bias emitter-base depletion capacitance.
31	$v_{de}=0.9$ V	Emitter-base diffusion voltage.
32	$p_e=0.33$	Emitter-base grading coefficient.
33	$x_{cje}=0.5$	Fraction of the e-b depletion cap. that belongs to the sidewall.
34	$c_{jc}=1.3e-13$ F	Zero bias collector-base depletion capacitance.
35	$v_{dc}=0.6$ V	Collector-base diffusion voltage.
36	$p_c=0.4$	Collector-base grading coefficient variable part.
37	$x_p=0.2$	Constant part of c_{jc} .
38	$m_c=0.5$	Collector current modulation coefficient.
39	$x_{cjc}=0.1$	Fraction of the collector-base depletion cap. under the emitter area.
40	t_{ref} (C)	Reference temperature. Default set by option t_{nom} .
41	t_{nom} (C)	Alias of t_{ref} . Default set by option t_{nom} .
42	t_r (C)	Alias of t_{ref} . Default set by option t_{nom} .
43	$d\tau_a=0.0$ K	Difference of the device temperature to the ambient temperature.
44	$t_{rise}=0.0$ K	Alias of $d\tau_a$.
45	$v_{ge}=1.01$ V	Band-gap voltage of the emitter.
46	$v_{gb}=1.18$ V	Band-gap voltage of the base.
47	$v_{gc}=1.205$ V	Band-gap voltage of the collector.
48	$v_{gj}=1.1$ V	Band-gap voltage recombination emitter-base junction.
49	$v_i=0.04$ V	Ionization voltage base dope.

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Philips Models

50	$na=3.0e17 \text{ cm}^{-3}$	Maximum base dope concentration.
51	$er=2.0e-3$	Temperature coefficient of v_{lf} and v_{lr} .
52	$ab=1.35$	Temperature coefficient resistivity base.
53	$aepi=2.15$	Temperature coefficient resistivity of the epilayer.
54	$aex=1.0$	Temperature coefficient resistivity of the extrinsic base.
55	$ac=0.4$	Temperature coefficient resistivity of the buried layer.
56	$kf=2.0e-16$	Flicker noise coefficient ideal base current.
57	$kfn=2.0e-16$	Flicker noise coefficient non-ideal base current.
58	$af=1.0$	Flicker noise exponent.
59	$iss=6.0e-16 \text{ A}$	Base-substrate saturation current.
60	$iks=5.0e-6 \text{ A}$	Knee current of the substrate.
61	$cjs=1.0e-12 \text{ F}$	Zero bias collector-substrate depletion capacitance.
62	$vds=0.5 \text{ V}$	Collector-substrate diffusion voltage.
63	$ps=0.33$	Collector-substrate grading coefficient.
64	$vgs=1.15 \text{ V}$	Band-gap voltage of the substrate.
65	$as=2.15$	For a closed buried layer: $as=ac$. For an open buried layer: $as=aepi$.
66	$imax=1.0 \text{ A}$	Explosion current.
67	$vers=503$	Version number.
68	$compatible=spectre$	Encourage device equations to be compatible with a foreign simulator. This option does not affect input syntax. Possible values are <code>spectre</code> , <code>spice2</code> , <code>spice3</code> , <code>cdsspice</code> , <code>hspice</code> , or <code>spiceplus</code> .

Virtuoso Simulator Components and Device Models Reference

Philips Models

Output Parameters

1	<code>ist</code> (A)	Collector-Emitter saturation current.
2	<code>bft</code> (A/A)	Ideal forward current gain.
3	<code>ibft</code> (A)	Saturation current of the non-ideal forward base current.
4	<code>vlft</code> (V)	Cross-over voltage of the non-ideal forward base current.
5	<code>ikt</code> (A)	High-injection knee current.
6	<code>ibr</code> (A)	Saturation current of the non-ideal reverse base current.
7	<code>vlr</code> (V)	Cross-over voltage of the non-ideal reverse base current.
8	<code>qbot</code> (Coul)	Base charge at zero bias.
9	<code>avlt</code>	Weak avalanche parameter.
10	<code>rcct</code> (Ω)	Constant part of the collector resistance.
11	<code>rcvt</code> (Ω)	Resistance of the unmodulated epilayer.
12	<code>rbct</code> (Ω)	Constant part of the base resistance.
13	<code>rbvt</code> (Ω)	Variable part of the base resistance at zero bias.
14	<code>taunet</code> (s)	Minimum delay time of neutral and emitter charge.
15	<code>mtaut</code>	Non-ideality factor of the neutral and emitter charge.
16	<code>cjet</code> (F)	Zero bias emitter-base depletion capacitance.
17	<code>vdet</code> (V)	Emitter-base diffusion voltage.
18	<code>cjct</code> (F)	Zero bias collector-base depletion capacitance.
19	<code>vdct</code> (V)	Collector-base diffusion voltage.
20	<code>xpt</code>	Constant part of <code>cjc</code> .
21	<code>isst</code> (A)	Base-substrate saturation current.

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Philips Models

22	$ikst$ (A)	Knee current of the substrate.
23	$cjst$ (F)	Zero bias collector-substrate depletion capacitance.
24	$vdst$ (V)	Collector-substrate diffusion voltage.

Operating-Point Parameters

1	ib (A)	Base current.
2	ic (A)	Collector current.
3	ie (A)	Emitter current.
4	is (A)	Substrate current.
5	vbe (V)	Base-emitter voltage.
6	vbc (V)	Base-collector voltage.
7	vce (V)	Collector-emitter voltage.
8	vsc (V)	Substrate voltage.
9	re (Ω)	Constant emitter resistance.
10	rcc (Ω)	Constant collector resistance.
11	rbc (Ω)	Constant part of base resistance.
12	$betadc$ (A/A)	DC current gain.
13	pwr (W)	Power.
14	$Vb1e1$ (V)	Internal voltage.
15	$Vb2e1$ (V)	Internal voltage.
16	$Vb2c1$ (V)	Internal voltage.
17	$Vb2c2$ (V)	Internal voltage.
18	$Vb1b2$ (V)	Internal voltage.

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Philips Models

19	Vb1c1 (V)	Internal voltage.
20	Vbc1 (V)	Internal voltage.
21	in (A)	Main current.
22	ic1c2 (A)	Variable collector resistance current.
23	ib1 (A)	Bulk component of ideal base current.
24	ib1s (A)	Sidewall component of ideal base current.
25	ib2 (A)	Non-ideal base current.
26	iav1 (A)	Weak avalanche current.
27	ib1b2 (A)	Variable base resistance current.
28	ib3 (A)	Non-ideal reverse base current.
29	iex (A)	Internal extrinsic base current.
30	isub (A)	Internal base-substrate current.
31	isf (A)	Substrate-collector current.
32	xiex (A)	External extrinsic base current.
33	Xisub (A)	External base-substrate current.
34	gx (S)	dI_n/dV_{b2e1} .
35	gy (S)	dI_n/dV_{b2c2} .
36	gz (S)	dI_n/dV_{b2c1} .
37	grcvy (S)	dI_{c1c2}/dV_{b2c2} .
38	grcvz (S)	dI_{c1c2}/dV_{b2c1} .
39	gpi (S)	Conductance floor base-emitter junction: $dI_{b1}/dV_{b2e1} + dI_{b2}/dV_{b2e1}$.

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Philips Models

40	sgpi (S)	Conductance sidewall base-emitter junction: $dlb1S/dVb1e1$.
41	gmux (S)	Dependence avalanche multiplication on internal b-e junction: $-dlavl/dVb2e1$.
42	gmu (S)	Dependence avalanche multiplication on internal b-c junction: $-dlavl/dVb2c2$.
43	gmuz (S)	Dependence avalanche multiplication on external b-c junction: $-dlavl/dVb2c1$.
44	grbv (S)	$dlb1b2/dVb1b2$.
45	grbvX (S)	Emitter Early-effect on $Ib1b2$: $dlb1b2/dVb2e1$.
46	grbvY (S)	Internal collector Early-effect on $Ib1b2$: $dlb1b2/dVb2c2$.
47	grbvZ (S)	External collector Early effect on $Ib1b2$: $dlb1b2/dVb2c1$.
48	gmuex (S)	Conductance floor extrinsic b-c junction: $dlex/dVb1c1 + dIsub/dVb1c1 + dlb3/dVb1c1$.
49	xgmuex (S)	Conductance sidewall extrinsic b-c junction: $dXIlex/dVbc1 + dXIsub/dVbc1$.
50	gsub (S)	Conductance s-c junction: $dIsub/dVsc1$.
51	gpnP (S)	Transconductance floor extrinsic PNP transistor: $dIsub/dVb1c1$.
52	xgpnP (S)	Transconductance sidewall extrinsic PNP transistor: $dXIsub/dVbc1$.
53	cbex (F)	Capacitance floor b-e junction: $dQte/dVb2e1 + dQbe/dVb2e1 + dQn/dVb2e1$.
54	cbey (F)	Internal collector Early-effect on Qbe : $dQbe/dVb2c2$.
55	cbez (F)	External collector Early-effect on Qbe : $dQbe/dVb2c1$.
56	scte (F)	Dependence of $QteS$ on internal b-e junction: $dQteS/dVb2e1$.
57	cbcX (F)	Emitter Early-effect on Qbc : $dQbc/dVb2e1$.

Virtuoso Simulator Components and Device Models Reference

Philips Models

58	<code>cbcy</code> (F)	Capacitance intrinsic b-c junction: $dQ_{tc}/dV_{b2c2} + dQ_{bc}/dV_{b2c2} + dQ_{epi}/dV_{b2c2}$.
59	<code>cbcz</code> (F)	Collector Early-effect on Q_{tc} : $dQ_{tc}/dV_{b2c1} + dQ_{bc}/dV_{b2c1} + dQ_{epi}/dV_{b2c1}$.
60	<code>cb1b2</code> (F)	Capacitance AC current crowding: $dQ_{b1b2}/dV_{b1b2} = C_b$.
61	<code>cb1b2x</code> (F)	Dependence of Q_{b1b2} on internal b-e junction voltage: dQ_{b1b2}/dV_{b2e1} .
62	<code>cbce_x</code> (F)	Capacitance floor extrinsic b-c junction: $dQ_{tex}/dV_{b1c1} + dQ_{ex}/dV_{b1c1}$.
63	<code>xcbce_x</code> (F)	Capacitance sidewall extrinsic b-c junction: $dXQ_{tex}/dV_{bc1} + dXQ_{ex}/dV_{bc1}$.
64	<code>cts</code> (F)	Capacitance s-c junction: $dQ_{tex}/dV_{b1c1} + dQ_{ex}/dV_{b1c1}$.
65	<code>cbe</code> (F)	C_{be} .
66	<code>cbc</code> (F)	C_{bc} .
67	<code>csc</code> (F)	C_{sc} .

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

<code>Vb1b2</code>	OP-18	<code>dta</code>	M-43	<code>ikst</code>	O-22	<code>sfh</code>	M-24
<code>Vb1c1</code>	OP-19	<code>efi</code>	M-19	<code>ikt</code>	O-5	<code>sgpi</code>	OP-40
<code>Vb1e1</code>	OP-14	<code>er</code>	M-51	<code>imax</code>	M-66	<code>taune</code>	M-28
<code>Vb2c1</code>	OP-16	<code>eta</code>	M-17	<code>in</code>	OP-21	<code>taunet</code>	O-14

Virtuoso Simulator Components and Device Models Reference

Philips Models

Vb2c2	OP-17	exavl	M-5	is	M-6	tnom	M-41
Vb2e1	OP-15	exmod	M-3	is	OP-4	tr	M-42
Vbc1	OP-20	exphi	M-4	isf	OP-31	tref	M-40
Xisub	OP-33	gmu	OP-42	iss	M-59	trise	M-44
ab	M-52	gmux	OP-48	isst	O-21	type	M-1
ac	M-55	gmux	OP-41	ist	O-1	vbc	OP-6
aepi	M-53	gmuz	OP-43	isub	OP-30	vbe	OP-5
aex	M-54	gpi	OP-39	kf	M-56	vce	OP-7
af	M-58	gpnv	OP-51	kfn	M-57	vdc	M-35
area	I-1	grbv	OP-44	level	M-2	vdct	O-19
as	M-65	grbvz	OP-45	m	I-3	vde	M-31
avl	M-18	grbvy	OP-46	mc	M-38	vdet	O-17
avlt	O-9	grbvz	OP-47	mtau	M-29	vds	M-62
betadc	OP-12	grcvy	OP-37	mtaut	O-15	vdst	O-24
bf	M-7	grcvz	OP-38	mult	I-2	vers	M-67
bft	O-2	gsub	OP-50	na	M-50	vgb	M-46
bri	M-12	gx	OP-34	pc	M-36	vgc	M-47
cb1b2	OP-60	gy	OP-35	pe	M-32	vge	M-45
cb1b2x	OP-61	gz	OP-36	ps	M-63	vgj	M-48
cbc	OP-66	iavl	OP-26	pwr	OP-13	vgs	M-64
cbcx	OP-62	ib	OP-1	qbo	M-16	vi	M-49

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Philips Models

cbcx	OP-57	ib1	OP-23	qbot	O-8	vlf	M-10
cbcy	OP-58	ib1b2	OP-27	rbc	M-25	vlft	O-4
cbcz	OP-59	ib1s	OP-24	rbc	OP-11	vlr	M-14
cbe	OP-65	ib2	OP-25	rbct	O-12	vlrt	O-7
cbex	OP-53	ib3	OP-28	rbv	M-26	vsc	OP-8
cbey	OP-54	ibf	M-9	rbvt	O-13	xcbcex	OP-63
cbez	OP-55	ibft	O-3	rcc	M-21	xcjc	M-39
cjc	M-34	ibr	M-13	rcc	OP-10	xcje	M-33
cjct	O-18	ibrtr	O-6	rcct	O-10	xext	M-15
cje	M-30	ic	OP-2	rcv	M-22	xgmux	OP-49
cjet	O-16	ic1c2	OP-22	rcvt	O-11	xgpnv	OP-52
cjs	M-61	ie	OP-3	re	M-27	xibi	M-8
cjst	O-23	iex	OP-29	re	OP-9	xiex	OP-32
compatible	M-68	ihc	M-20	region	I-4	xp	M-37
csc	OP-67	ik	M-11	scrcv	M-23	xpt	O-20
cts	OP-64	iks	M-60	scte	OP-56		

Compact Bipolar-Transistor Model (bjt504)

Instance Definition

Name c b e s ModelName parameter=value ...

Virtuoso Simulator Components and Device Models Reference

Philips Models

Instance Parameters

1	<code>mult=1</code>	Number of devices in parallel.
2	<code>region=fwd</code>	Estimated DC operating region, used as a convergence aid. Possible values are <code>off</code> , <code>sat</code> , <code>rev</code> , or <code>fwd</code> .
3	<code>m=1</code>	Multiplicity factor.
4	<code>area=1</code>	alias of <code>mult</code> .

Model Definition

```
model modelName bjt504 parameter=value ...
```

Model Parameters

1	<code>level=504</code>	Bipolar Level.
2	<code>tref=25 deg. C</code>	Reference temperature.
3	<code>dta=0 K</code>	Difference between the local ambient and global ambient temperature.
4	<code>exmod=1</code>	Flag for extended modeling of reverse current gain.
5	<code>exphi=1</code>	Flag for the distributed high-frequency effects in transient.
6	<code>exavl=0</code>	Flag for extended modeling of avalanche currents.
7	<code>is=2.2e-17 A</code>	Collector-emitter saturation current.
8	<code>ik=0.1 A</code>	Collector-emitter high injection knee current.
9	<code>ver=2.5 V</code>	Reverse Early voltage.
10	<code>vef=44 V</code>	Forward Early voltage.
11	<code>bf=215</code>	Ideal forward current gain.
12	<code>ibf=2.7e-15 A</code>	Saturation current of the non-ideal forward base current.
13	<code>m1f=2</code>	Non ideality factor of the non-ideal forward base current.

Virtuoso Simulator Components and Device Models Reference

Philips Models

14	$x_{ibi}=0$	Part of ideal base current that belongs to the sidewall.
15	$b_{ri}=7$	Ideal reverse current gain.
16	$i_{br}=1e-15$ A	Saturation current of the non-ideal reverse base current.
17	$v_{lr}=0.2$ V	Cross-over voltage of the non-ideal reverse base current.
18	$x_{ext}=0.63$	Part of I_{ex} , Q_{tex} , Q_{ex} and I_{sub} that depends on V_{bc1} instead of V_{b1c1} .
19	$w_{avl}=1.1e-06$ m	Epilayer thickness used in weak-avalanche model.
20	$v_{avl}=3$ V	Voltage determining curvature of avalanche current.
21	$sfh=0.3$	Current spreading factor of avalanche model (when $EXAVL=1$).
22	$r_e=5$ Ω	Emitter resistance.
23	$r_{bc}=23$ Ω	Constant part of the base resistance.
24	$r_{bv}=18$ Ω	Zero-bias value of the variable part of the base resistance.
25	$r_{cc}=12$ Ω	Constant part of collector resistance.
26	$r_{cv}=150$ Ω	Resistance of the un-modulated epilayer.
27	$s_{rcv}=1.25e+03$ Ω	Space charge resistance of the epilayer.
28	$i_{hc}=0.004$ A	Critical current for velocity saturation in the epilayer.
29	$axi=0.3$	Smoothness parameter for the onset of quasi-saturation.
30	$c_{je}=7.3e-14$ F	Zero-bias emitter-base depletion capacitance.
31	$v_{de}=0.95$ V	Emitter-base diffusion voltage.
32	$p_e=0.4$	Emitter-base grading coefficient.
33	$x_{cje}=0.4$	Fraction of the emitter-base depletion capacitance that belongs to the sidewall.

Virtuoso Simulator Components and Device Models Reference

Philips Models

34	$c_{beo}=0$	Emitter-base overlap capacitance.
35	$c_{jc}=7.8e-14$ F	Zero-bias collector-base depletion capacitance.
36	$v_{dc}=0.68$ V	Collector-base diffusion voltage.
37	$p_c=0.5$	Collector-base grading coefficient.
38	$x_p=0.35$	Constant part of C_{jc} .
39	$m_c=0.5$	Coefficient for the current modulation of the collector-base depletion capacitance.
40	$x_{cjc}=0.032$	Fraction of the collector-base depletion capacitance under the emitter.
41	$c_{bco}=0$	Collector-base overlap capacitance.
42	$m_{\tau}=1$	Non-ideality factor of the emitter stored charge.
43	$\tau_{aue}=2e-12$ s	Minimum transit time of stored emitter charge.
44	$\tau_{aub}=4.2e-12$ s	Transit time of stored base charge.
45	$\tau_{epi}=4.1e-11$ s	Transit time of stored epilayer charge.
46	$\tau_{aur}=5.2e-10$ s	Transit time of reverse extrinsic base charge.
47	$\delta_{eg}=0$ eV	Bandgap difference over the base.
48	$x_{rec}=0$	Pre-factor of the recombination part of I_{b1} .
49	$a_{qbo}=0.3$	Temperature coefficient of the zero-bias base charge.
50	$a_e=0$	Temperature coefficient of the resistivity of the emitter.
51	$a_b=1$	Temperature coefficient of the resistivity of the base.
52	$d_{ais}=0$	Parameter for fine tuning of temperature dependence of collector-emitter saturation current.
53	$a_{epi}=2.5$	Temperature coefficient of the resistivity of the epilayer.

Virtuoso Simulator Components and Device Models Reference

Philips Models

54	$a_{ex}=0.62$	Temperature coefficient of the resistivity of the extrinsic base.
55	$a_c=2$	Temperature coefficient of the resistivity of the buried layer.
56	$dv_{gbf}=0.05$ V	Bandgap voltage difference of forward current gain.
57	$dv_{gbr}=0.045$ V	Bandgap voltage difference of reverse current gain.
58	$v_{gb}=1.17$ V	Bandgap voltage of the base.
59	$v_{gc}=1.18$ V	Bandgap voltage of the collector.
60	$v_{gj}=1.15$ V	Bandgap voltage recombination emitter-base junction.
61	$dv_{gte}=0.05$ V	Bandgap voltage difference of emitter stored charge.
62	$a_f=2$	Exponent of the Flicker-noise.
63	$k_f=2e-11$	Flicker-noise coefficient of the ideal base current.
64	$k_{fn}=2e-11$	Flicker-noise coefficient of the non-ideal base current.
65	$k_{av1}=0$	Switch for white noise contribution due to avalanche.
66	$i_{ss}=4.8e-17$ A	Base-substrate saturation current.
67	$i_{ks}=0.00025$ A	Base-substrate high injection knee current.
68	$c_{js}=3.15e-13$ F	Zero-bias collector-substrate depletion capacitance.
69	$v_{ds}=0.62$ V	Collector-substrate diffusion voltage.
70	$p_s=0.34$	Collector-substrate grading coefficient.
71	$v_{gs}=1.2$ V	Band-gap voltage of the substrate.
72	$a_s=1.58$	For a closed buried layer: $A_s=A_c$: for an open buried layer: $A_s=A_{epi}$.
73	$type=n$	Transistor gender. Possible values are n, p, npn, pnp, npnv, pnpv, npnl, or pnp1.
74	$i_{max}=1.0$ A	Explosion current.

Virtuoso Simulator Components and Device Models Reference

Philips Models

75 `tnom` (deg. C) alias of `tnom`.

76 `tr` (deg. C) alias of `tnom`.

Output Parameters

1 `tref` (deg. C) Reference temperature.

2 `dta` (K) Difference between the local ambient and global ambient temperatures.

3 `exmod` Flag for extended modeling of reverse current gain.

4 `exphi` Flag for the distributed high-frequency effects in transient.

5 `exavl` Flag for extended modeling of avalanche currents.

6 `is` (A) Collector-emitter saturation current.

7 `ik` (A) Collector-emitter high injection knee current.

8 `ver` (V) Reverse Early voltage.

9 `vef` (V) Forward Early voltage.

10 `bf` Ideal forward current gain.

11 `ibf` (A) Saturation current of the non-ideal forward base current.

12 `mlf` Non ideality factor of the non-ideal forward base current.

13 `xibi` Part of ideal base current that belongs to the sidewall.

14 `bri` Ideal reverse current gain.

15 `ibr` (A) Saturation current of the non-ideal reverse base current.

16 `vlr` (V) Cross-over voltage of the non-ideal reverse base current.

17 `xext` Part of I_{ex} , Q_{tex} , Q_{ex} and I_{sub} that depends on V_{bc1} instead of V_{b1c1} .

18 `wavl` (M) Epilayer thickness used in weak-avalanche model.

Virtuoso Simulator Components and Device Models Reference

Philips Models

19	vavl (V)	Voltage determining curvature of avalanche current.
20	sfh	Current spreading factor of avalanche model (when EXAVL=1).
21	re (Ω)	Emitter resistance.
22	rbc (Ω)	Constant part of the base resistance.
23	rbv (Ω)	Zero-bias value of the variable part of the base resistance.
24	rcc (Ω)	Constant part of collector resistance.
25	rcv (Ω)	Resistance of the un-modulated epilayer.
26	scrcv (Ω)	Space charge resistance of the epilayer.
27	ihc (A)	Critical current for velocity saturation in the epilayer.
28	axi	Smoothness parameter for the onset of quasi-saturation.
29	cje (F)	Zero-bias emitter-base depletion capacitance.
30	vde (V)	Emitter-base diffusion voltage.
31	pe	Emitter-base grading coefficient.
32	xcje	Fraction of the emitter-base depletion capacitance that belongs to the sidewall.
33	cbeo	Emitter-base overlap capacitance.
34	cjc (F)	Zero-bias collector-base depletion capacitance.
35	vdc (V)	Collector-base diffusion voltage.
36	pc	Collector-base grading coefficient.
37	xp	Constant part of Cjc.
38	mc	Coefficient for the current modulation of the collector-base depletion capacitance.

Virtuoso Simulator Components and Device Models Reference

Philips Models

39	<code>xcjc</code>	Fraction of the collector-base depletion capacitance under the emitter.
40	<code>cbco</code>	Collector-base overlap capacitance.
41	<code>mtau</code>	Non-ideality factor of the emitter stored charge.
42	<code>taue (s)</code>	Minimum transit time of stored emitter charge.
43	<code>taub (s)</code>	Transit time of stored base charge.
44	<code>tepi (s)</code>	Transit time of stored epilayer charge.
45	<code>taur (s)</code>	Transit time of reverse extrinsic stored base charge.
46	<code>deg (eV)</code>	Bandgap difference over the base.
47	<code>xrec</code>	Pre-factor of the recombination part of I_{b1} .
48	<code>aqbo</code>	Temperature coefficient of the zero-bias base charge.
49	<code>ae</code>	Temperature coefficient of the resistivity of the emitter.
50	<code>ab</code>	Temperature coefficient of the resistivity of the base.
51	<code>dais</code>	Parameter for fine tuning of temperature dependence of collector-emitter saturation current.
52	<code>aepi</code>	Temperature coefficient of the resistivity of the epilayer.
53	<code>aex</code>	Temperature coefficient of the resistivity of the extrinsic base.
54	<code>ac</code>	Temperature coefficient of the resistivity of the buried layer.
55	<code>dvgbf (V)</code>	Bandgap voltage difference of forward current gain.
56	<code>dvgbr (V)</code>	Bandgap voltage difference of reverse current gain.
57	<code>vgb (V)</code>	Bandgap voltage of the base.
58	<code>vgc (V)</code>	Bandgap voltage of the collector.
59	<code>vgj (V)</code>	Bandgap voltage recombination emitter-base junction.

Virtuoso Simulator Components and Device Models Reference

Philips Models

60	dv_{gte} (V)	Bandgap voltage difference of emitter stored charge.
61	a_f	Exponent of the Flicker-noise.
62	k_f	Flicker-noise coefficient of the ideal base current.
63	k_{fn}	Flicker-noise coefficient of the non-ideal base current.
64	k_{av1}	Switch for white noise contribution due to avalanche.
65	i_{ss} (A)	Base-substrate saturation current.
66	i_{ks} (A)	Base-substrate high injection knee current.
67	c_{js} (F)	Zero-bias collector-substrate depletion capacitance.
68	v_{ds} (V)	Collector-substrate diffusion voltage.
69	p_s	Collector-substrate grading coefficient.
70	v_{gs} (V)	Band-gap voltage of the substrate.
71	a_s	For a closed buried layer: $A_s=A_c$, for an open buried layer: $A_s=A_{epi}$.

Operating-Point Parameters

1	I_c (A)	External DC collector current.
2	I_b (A)	External DC base current.
3	β_{DC}	External DC current gain I_c/I_b .
4	v_{b2e1} (V)	Internal base-emitter bias.
5	v_{b2c2} (V)	Internal base-collector bias.
6	v_{b2c1} (V)	Internal base-collector bias including epilayer.
7	v_{b1c1} (V)	External base-collector bias without contact resistances.
8	v_{e1e} (V)	Bias over emitter resistance.

Virtuoso Simulator Components and Device Models Reference

Philips Models

9	I_n (A)	Main current.
10	I_{c1c2} (A)	Epilayer current.
11	I_{b1b2} (A)	Pinched-base current.
12	I_{b1} (A)	Ideal forward base current.
13	$S I_{b1}$ (A)	Ideal side-wall base current.
14	I_{b2} (A)	Non-ideal forward base current.
15	I_{b3} (A)	Non-ideal reverse base current.
16	I_{ex} (A)	Extrinsic reverse base current.
17	$X I_{ex}$ (A)	Extrinsic reverse base current.
18	I_{av1} (A)	Avalanche current.
19	I_{RE} (A)	Current through emitter resistance.
20	I_{RBC} (A)	Current through constant base resistance.
21	I_{RCC} (A)	Current through constant collector resistance.
22	Q_e (C)	Emitter charge or emitter neutral charge.
23	Q_{te} (C)	Base-emitter depletion charge.
24	$S Q_{te}$ (C)	Sidewall base-emitter depletion charge.
25	Q_{be} (C)	Base-emitter diffusion charge.
26	Q_{bc} (C)	Base-collector diffusion charge.
27	Q_{tc} (C)	Base-collector depletion charge.
28	Q_{epi} (C)	Epilayer diffusion charge.
29	Q_{b1b2} (C)	AC current crowding charge.
30	Q_{tex} (C)	Extrinsic base-collector depletion charge.

Virtuoso Simulator Components and Device Models Reference

Philips Models

31	XQ_{tex} (C)	Extrinsic base-collector depletion charge.
32	Q_{ex} (C)	Extrinsic base-collector diffusion charge.
33	XQ_{ex} (C)	Extrinsic base-collector diffusion charge.
34	g_x (1/Ω)	Forward transconductance.
35	g_y (1/Ω)	Reverse transconductance.
36	g_z (1/Ω)	Reverse transconductance.
37	S_{gpi} (1/Ω)	Conductance sidewall b-e junction.
38	g_{pix} (1/Ω)	Conductance floor b-e junction.
39	g_{piy} (1/Ω)	Early effect on recombination base current.
40	g_{piz} (1/Ω)	Early effect on recombination base current.
41	g_{mux} (1/Ω)	Early effect on avalanche current limiting.
42	g_{muy} (1/Ω)	Conductance of avalanche current.
43	g_{muz} (1/Ω)	Conductance of avalanche current.
44	g_{muex} (1/Ω)	Conductance extrinsic b-c junction.
45	Xg_{muex} (1/Ω)	Conductance extrinsic b-c junction.
46	g_{rcvy} (1/Ω)	Conductance of the epilayer current.
47	g_{rcvz} (1/Ω)	Conductance of the epilayer current.
48	R_{bv} (Ω)	Conductance of the epilayer current.
49	g_{rbvx} (1/Ω)	Early-effect on base resistance.
50	g_{rbvy} (1/Ω)	Early-effect on base resistance.
51	g_{rbvz} (1/Ω)	Early-effect on base resistance:.
52	R_E (Ω)	Early-effect on base resistance:.

Virtuoso Simulator Components and Device Models Reference

Philips Models

53	RBC (Ω)	Early-effect on base resistance:.
54	RCC (Ω)	Early-effect on base resistance:.
55	SCbe (F)	Capacitance sidewall b-e junction.
56	Cbex (F)	Capacitance floor b-e junction.
57	Cbey (F)	Early effect on b-e diffusion charge.
58	Cbez (F)	Early effect on b-e diffusion charge.
59	Cbcx (F)	Early effect on b-c diffusion charge.
60	Cbcy (F)	Capacitance floor b-c junction.
61	Cbcz (F)	Capacitance floor b-c junction.
62	Cbcex (F)	Capacitance extrinsic b-c junction.
63	XCbcex (F)	Capacitance extrinsic b-c junction.
64	Cb1b2 (F)	Capacitance AC current crowding.
65	Cb1b2x (F)	Cross-capacitance AC current crowding .
66	Cb1b2y (F)	Cross-capacitance AC current crowding.
67	Cb1b2z (F)	Cross-capacitance AC current crowding.
68	gm ($1/\Omega$)	Transconductance.
69	beta	Current amplification.
70	gout ($1/\Omega$)	Output conductance.
71	gmu ($1/\Omega$)	Feedback transconductance.
72	RB (Ω)	Base resistance.
73	Cbe (F)	Base-emitter capacitance.
74	Cbc (F)	Base-collector capacitance.

Virtuoso Simulator Components and Device Models Reference

Philips Models

75	f_T (Hz)	Good approximation for cut-off frequency.
76	I_{qs} (A)	Current at onset of quasi-saturation.
77	X_{iWepi} (M)	Thickness of injection layer.
78	$V_{b2c2star}$ (V)	Physical value of internal base-collector bias.
79	P_{diss} (W)	Dissipation.
80	T_K (K)	Actual temperature.
81	I_{sub} (A)	Substrate current.
82	X_{Isub} (A)	Substrate current.
83	I_{sf} (A)	Substrate failure current.
84	Q_{ts} (C)	Collector-substrate depletion charge.
85	g_S ($1/\Omega$)	Conductance parasitic PNP transistor.
86	X_{gS} ($1/\Omega$)	Conductance parasitic PNP transistor.
87	g_{Sf} ($1/\Omega$)	
88	C_{ts} (C)	Capacitance s-c junction:.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

β_{DC}	OP-3	X_{Isub}	OP-82	g_{Sf}	OP-87	r_{cc}	O-24
C_{b1b2}	OP-64	X_{Qex}	OP-33	g_m	OP-68	r_{cv}	M-26

Virtuoso Simulator Components and Device Models Reference

Philips Models

Cb1b2x	OP-65	XQtex	OP-31	gmu	OP-71	rcv	O-25
Cb1b2y	OP-66	XgS	OP-86	gmux	OP-44	re	M-22
Cb1b2z	OP-67	Xgmux	OP-45	gmux	OP-41	re	O-21
Cbc	OP-74	XiWepi	OP-77	gmuy	OP-42	region	I-2
Cbcex	OP-62	ab	M-51	gmuz	OP-43	scrcv	M-27
Cbcx	OP-59	ab	O-50	gout	OP-70	scrcv	O-26
Cbcy	OP-60	ac	M-55	gpix	OP-38	sfh	M-21
Cbcz	OP-61	ac	O-54	gpiy	OP-39	sfh	O-20
Cbe	OP-73	ae	M-50	gpiz	OP-40	taub	M-44
Cbex	OP-56	ae	O-49	grbvz	OP-49	taub	O-43
Cbey	OP-57	aepi	M-53	grbvy	OP-50	taue	M-43
Cbez	OP-58	aepi	O-52	grbvz	OP-51	taue	O-42
Cts	OP-88	aex	M-54	grcvy	OP-46	taur	M-46
IRBC	OP-20	aex	O-53	grcvz	OP-47	taur	O-45
IRCC	OP-21	af	M-62	gx	OP-34	tepi	M-45
IRE	OP-19	af	O-61	gy	OP-35	tepi	O-44
Iavl	OP-18	aqbo	M-49	gz	OP-36	tnom	M-75
Ib	OP-2	aqbo	O-48	ibf	M-12	tr	M-76
Ib1	OP-12	area	I-4	ibf	O-11	tref	M-2
Ib1b2	OP-11	as	M-72	ibr	M-16	tref	O-1
Ib2	OP-14	as	O-71	ibr	O-15	type	M-73

Virtuoso Simulator Components and Device Models Reference

Philips Models

Ib3	OP-15	axi	M-29	ihc	M-28	vavl	M-20
Ic	OP-1	axi	O-28	ihc	O-27	vavl	O-19
Ic1c2	OP-10	beta	OP-69	ik	M-8	vdc	M-36
Iex	OP-16	bf	M-11	ik	O-7	vdc	O-35
In	OP-9	bf	O-10	iks	M-67	vde	M-31
Iqs	OP-76	bri	M-15	iks	O-66	vde	O-30
Isf	OP-83	bri	O-14	imax	M-74	vds	M-69
Isub	OP-81	cbco	M-41	is	M-7	vds	O-68
Pdiss	OP-79	cbco	O-40	is	O-6	vef	M-10
Qb1b2	OP-29	cbeo	M-34	iss	M-66	vef	O-9
Qbc	OP-26	cbeo	O-33	iss	O-65	ver	M-9
Qbe	OP-25	cjc	M-35	kavl	M-65	ver	O-8
Qe	OP-22	cjc	O-34	kavl	O-64	vgb	M-58
Qepi	OP-28	cje	M-30	kf	M-63	vgb	O-57
Qex	OP-32	cje	O-29	kf	O-62	vgc	M-59
Qtc	OP-27	cjs	M-68	kfn	M-64	vgc	O-58
Qte	OP-23	cjs	O-67	kfn	O-63	vgj	M-60
Qtex	OP-30	dais	M-52	level	M-1	vgj	O-59
Qts	OP-84	dais	O-51	m	I-3	vgs	M-71
RB	OP-72	deg	M-47	mc	M-39	vgs	O-70
RBC	OP-53	deg	O-46	mc	O-38	vlr	M-17

Virtuoso Simulator Components and Device Models Reference

Philips Models

RCC	OP-54	dta	M-3	mlf	M-13	vlr	O-16
RE	OP-52	dta	O-2	mlf	O-12	wavl	M-19
Rbv	OP-48	dvgbf	M-56	mtau	M-42	wavl	O-18
SCbe	OP-55	dvgbf	O-55	mtau	O-41	xcjc	M-40
SIb1	OP-13	dvgbr	M-57	mult	I-1	xcjc	O-39
SQte	OP-24	dvgbr	O-56	pc	M-37	xcje	M-33
Sgpi	OP-37	dvgte	M-61	pc	O-36	xcje	O-32
TK	OP-80	dvgte	O-60	pe	M-32	xext	M-18
Vb1c1	OP-7	exavl	M-6	pe	O-31	xext	O-17
Vb2c1	OP-6	exavl	O-5	ps	M-70	xibi	M-14
Vb2c2	OP-5	exmod	M-4	ps	O-69	xibi	O-13
Vb2c2star	OP-78	exmod	O-3	rbc	M-23	xp	M-38
Vb2e1	OP-4	exphi	M-5	rbc	O-22	xp	O-37
Ve1e	OP-8	exphi	O-4	rbv	M-24	xrec	M-48
XCbceX	OP-63	fT	OP-75	rbv	O-23	xrec	O-47
XIex	OP-17	gS	OP-85	rcc	M-25		

Compact Bipolar-Transistor Model (bjt504t)

This is SimKit 4.0

This device is supported within altergroups.

This device is dynamically loaded from the shared object /vobs/spectre_dev/tools.lnx86/cmi/lib/5.0.doc/libphilips_sh.so

Virtuoso Simulator Components and Device Models Reference

Philips Models

Instance Definition

Name c b e s dt ModelName parameter=value ...

Instance Parameters

- | | | |
|---|------------|---|
| 1 | mult=1 | Number of devices in parallel. |
| 2 | region=fwd | Estimated DC operating region, used as a convergence aid.
Possible values are off, sat, rev, or fwd. |
| 3 | m=1 | Multiplicity factor. |
| 4 | area=1 | alias of mult. |

Model Definition

model modelName bjt504t parameter=value ...

Model Parameters

- | | | |
|----|----------------|--|
| 1 | level=504 | Bipolar Level. |
| 2 | tref=25 deg. C | Reference temperature. |
| 3 | dta=0 K | Difference between the local ambient and global ambient temperature. |
| 4 | exmod=1 | Flag for extended modeling of reverse current gain. |
| 5 | exphi=1 | Flag for the distributed high-frequency effects in transient. |
| 6 | exavl=0 | Flag for extended modeling of avalanche currents. |
| 7 | is=2.2e-17 A | Collector-emitter saturation current. |
| 8 | ik=0.1 A | Collector-emitter high injection knee current. |
| 9 | ver=2.5 V | Reverse Early voltage. |
| 10 | vef=44 V | Forward Early voltage. |
| 11 | bf=215 | Ideal forward current gain. |

Virtuoso Simulator Components and Device Models Reference

Philips Models

12	<code>ibf=2.7e-15 A</code>	Saturation current of the non-ideal forward base current.
13	<code>mlf=2</code>	Non ideality factor of the non-ideal forward base current.
14	<code>xibi=0</code>	Part of ideal base current that belongs to the sidewall.
15	<code>bri=7</code>	Ideal reverse current gain.
16	<code>ibr=1e-15 A</code>	Saturation current of the non-ideal reverse base current.
17	<code>vlr=0.2 V</code>	Cross-over voltage of the non-ideal reverse base current.
18	<code>xext=0.63</code>	Part of I_{ex} , Q_{tex} , Q_{ex} and I_{sub} that depends on V_{bc1} instead of V_{b1c1} .
19	<code>wavl=1.1e-06 m</code>	Epilayer thickness used in weak-avalanche model.
20	<code>vavl=3 V</code>	Voltage determining curvature of avalanche current.
21	<code>sfh=0.3</code>	Current spreading factor of avalanche model (when EXAVL=1).
22	<code>re=5 Ω</code>	Emitter resistance.
23	<code>rbc=23 Ω</code>	Constant part of the base resistance.
24	<code>rbv=18 Ω</code>	Zero-bias value of the variable part of the base resistance.
25	<code>rcc=12 Ω</code>	Constant part of collector resistance.
26	<code>rcv=150 Ω</code>	Resistance of the un-modulated epilayer.
27	<code>scrcv=1.25e+03 Ω</code>	Space charge resistance of the epilayer.
28	<code>ihc=0.004 A</code>	Critical current for velocity saturation in the epilayer.
29	<code>axi=0.3</code>	Smoothness parameter for the onset of quasi-saturation.
30	<code>cje=7.3e-14 F</code>	Zero-bias emitter-base depletion capacitance.
31	<code>vde=0.95 V</code>	Emitter-base diffusion voltage.
32	<code>pe=0.4</code>	Emitter-base grading coefficient.

Virtuoso Simulator Components and Device Models Reference

Philips Models

33	$x_{cje}=0.4$	Fraction of the emitter-base depletion capacitance that belongs to the sidewall.
34	$c_{beo}=0$	Emitter-base overlap capacitance.
35	$c_{jc}=7.8e-14$ F	Zero-bias collector-base depletion capacitance.
36	$v_{dc}=0.68$ V	Collector-base diffusion voltage.
37	$p_c=0.5$	Collector-base grading coefficient.
38	$x_p=0.35$	Constant part of C_{jc} .
39	$m_c=0.5$	Coefficient for the current modulation of the collector-base depletion capacitance.
40	$x_{cjc}=0.032$	Fraction of the collector-base depletion capacitance under the emitter.
41	$c_{bco}=0$	Collector-base overlap capacitance.
42	$m_{tau}=1$	Non-ideality factor of the emitter stored charge.
43	$\tau_{aue}=2e-12$ s	Minimum transit time of stored emitter charge.
44	$\tau_{aub}=4.2e-12$ s	Transit time of stored base charge.
45	$\tau_{epi}=4.1e-11$ s	Transit time of stored epilayer charge.
46	$\tau_{aur}=5.2e-10$ s	Transit time of reverse extrinsic base charge.
47	$deg=0$ eV	Bandgap difference over the base.
48	$x_{rec}=0$	Pre-factor of the recombination part of I_{b1} .
49	$a_{qbo}=0.3$	Temperature coefficient of the zero-bias base charge.
50	$a_e=0$	Temperature coefficient of the resistivity of the emitter.
51	$a_b=1$	Temperature coefficient of the resistivity of the base.
52	$d_{ais}=0$	Parameter for fine tuning of temperature dependence of collector-emitter saturation current.

Virtuoso Simulator Components and Device Models Reference

Philips Models

53	$a_{epi}=2.5$	Temperature coefficient of the resistivity of the epilayer.
54	$a_{ex}=0.62$	Temperature coefficient of the resistivity of the extrinsic base.
55	$a_c=2$	Temperature coefficient of the resistivity of the buried layer.
56	$dv_{gbf}=0.05$ V	Bandgap voltage difference of forward current gain.
57	$dv_{gbr}=0.045$ V	Bandgap voltage difference of reverse current gain.
58	$v_{gb}=1.17$ V	Bandgap voltage of the base.
59	$v_{gc}=1.18$ V	Bandgap voltage of the collector.
60	$v_{gj}=1.15$ V	Bandgap voltage recombination emitter-base junction.
61	$dv_{gte}=0.05$ V	Bandgap voltage difference of emitter stored charge.
62	$a_f=2$	Exponent of the Flicker-noise.
63	$k_f=2e-11$	Flicker-noise coefficient of the ideal base current.
64	$k_{fn}=2e-11$	Flicker-noise coefficient of the non-ideal base current.
65	$k_{av1}=0$	Switch for white noise contribution due to avalanche.
66	$i_{ss}=4.8e-17$ A	Base-substrate saturation current.
67	$i_{ks}=0.00025$ A	Base-substrate high injection knee current.
68	$c_{js}=3.15e-13$ F	Zero-bias collector-substrate depletion capacitance.
69	$v_{ds}=0.62$ V	Collector-substrate diffusion voltage.
70	$p_s=0.34$	Collector-substrate grading coefficient.
71	$v_{gs}=1.2$ V	Band-gap voltage of the substrate.
72	$a_s=1.58$	For a closed buried layer: $A_s=A_c$: for an open buried layer: $A_s=A_{epi}$.
73	$r_{th}=300$ K/W	Thermal resistance.

Virtuoso Simulator Components and Device Models Reference

Philips Models

74	<code>cth=3e-09 J/K</code>	Thermal capacitance.
75	<code>ath=0</code>	Temperature coefficient of the thermal resistance.
76	<code>type=n</code>	Transistor gender. Possible values are <code>n</code> , <code>p</code> , <code>npn</code> , <code>pnP</code> , <code>npnv</code> , <code>pnPv</code> , <code>npnl</code> , or <code>pnPl</code> .
77	<code>imax=1.0 A</code>	Explosion current.
78	<code>tnom (deg. C)</code>	alias of <code>tnom</code> .
79	<code>tr (deg. C)</code>	alias of <code>tnom</code> .

Output Parameters

1	<code>tref (deg. C)</code>	Reference temperature.
2	<code>dta (K)</code>	Difference between the local ambient and global ambient temperatures.
3	<code>exmod</code>	Flag for extended modeling of reverse current gain.
4	<code>exphi</code>	Flag for the distributed high-frequency effects in transient.
5	<code>exavl</code>	Flag for extended modeling of avalanche currents.
6	<code>is (A)</code>	Collector-emitter saturation current.
7	<code>ik (A)</code>	Collector-emitter high injection knee current.
8	<code>ver (V)</code>	Reverse Early voltage.
9	<code>vef (V)</code>	Forward Early voltage.
10	<code>bf</code>	Ideal forward current gain.
11	<code>ibf (A)</code>	Saturation current of the non-ideal forward base current.
12	<code>mlf</code>	Non ideality factor of the non-ideal forward base current.
13	<code>xibi</code>	Part of ideal base current that belongs to the sidewall.
14	<code>bri</code>	Ideal reverse current gain.

Virtuoso Simulator Components and Device Models Reference

Philips Models

15	<code>ibr</code> (A)	Saturation current of the non-ideal reverse base current.
16	<code>vlr</code> (V)	Cross-over voltage of the non-ideal reverse base current.
17	<code>xext</code>	Part of <code>lex</code> , <code>Qtex</code> , <code>Qex</code> and <code>lsub</code> that depends on <code>Vbc1</code> instead of <code>Vb1c1</code> .
18	<code>wavl</code> (M)	Epilayer thickness used in weak-avalanche model.
19	<code>vavl</code> (V)	Voltage determining curvature of avalanche current.
20	<code>sfh</code>	Current spreading factor of avalanche model (when <code>EXAVL=1</code>).
21	<code>re</code> (Ω)	Emitter resistance.
22	<code>rbc</code> (Ω)	Constant part of the base resistance.
23	<code>rbv</code> (Ω)	Zero-bias value of the variable part of the base resistance.
24	<code>rcc</code> (Ω)	Constant part of collector resistance.
25	<code>rcv</code> (Ω)	Resistance of the un-modulated epilayer.
26	<code>scrcv</code> (Ω)	Space charge resistance of the epilayer.
27	<code>ihc</code> (A)	Critical current for velocity saturation in the epilayer.
28	<code>axi</code>	Smoothness parameter for the onset of quasi-saturation.
29	<code>cje</code> (F)	Zero-bias emitter-base depletion capacitance.
30	<code>vde</code> (V)	Emitter-base diffusion voltage.
31	<code>pe</code>	Emitter-base grading coefficient.
32	<code>xcje</code>	Fraction of the emitter-base depletion capacitance that belongs to the sidewall.
33	<code>cbeo</code>	Emitter-base overlap capacitance.
34	<code>cjc</code> (F)	Zero-bias collector-base depletion capacitance.
35	<code>vdc</code> (V)	Collector-base diffusion voltage.

Virtuoso Simulator Components and Device Models Reference

Philips Models

36	pc	Collector-base grading coefficient.
37	xp	Constant part of Cjc.
38	mc	Coefficient for the current modulation of the collector-base depletion capacitance.
39	xcjc	Fraction of the collector-base depletion capacitance under the emitter.
40	cbco	Collector-base overlap capacitance.
41	mtau	Non-ideality factor of the emitter stored charge.
42	taue (s)	Minimum transit time of stored emitter charge.
43	taub (s)	Transit time of stored base charge.
44	tepi (s)	Transit time of stored epilayer charge.
45	taur (s)	Transit time of reverse extrinsic stored base charge.
46	deg (eV)	Bandgap difference over the base.
47	xrec	Pre-factor of the recombination part of Ib1.
48	aqbo	Temperature coefficient of the zero-bias base charge.
49	ae	Temperature coefficient of the resistivity of the emitter.
50	ab	Temperature coefficient of the resistivity of the base.
51	dais	Parameter for fine tuning of temperature dependence of collector-emitter saturation current.
52	aepi	Temperature coefficient of the resistivity of the epilayer.
53	aex	Temperature coefficient of the resistivity of the extrinsic base.
54	ac	Temperature coefficient of the resistivity of the buried layer.
55	dvgbf (V)	Bandgap voltage difference of forward current gain.

Virtuoso Simulator Components and Device Models Reference

Philips Models

56	<code>dvgbr</code> (V)	Bandgap voltage difference of reverse current gain.
57	<code>vgb</code> (V)	Bandgap voltage of the base.
58	<code>vgc</code> (V)	Bandgap voltage of the collector.
59	<code>vgj</code> (V)	Bandgap voltage recombination emitter-base junction.
60	<code>dvgte</code> (V)	Bandgap voltage difference of emitter stored charge.
61	<code>af</code>	Exponent of the Flicker-noise.
62	<code>kf</code>	Flicker-noise coefficient of the ideal base current.
63	<code>kfn</code>	Flicker-noise coefficient of the non-ideal base current.
64	<code>kavl</code>	Switch for white noise contribution due to avalanche.
65	<code>iss</code> (A)	Base-substrate saturation current.
66	<code>iks</code> (A)	Base-substrate high injection knee current.
67	<code>cjs</code> (F)	Zero-bias collector-substrate depletion capacitance.
68	<code>vds</code> (V)	Collector-substrate diffusion voltage.
69	<code>ps</code>	Collector-substrate grading coefficient.
70	<code>vgs</code> (V)	Band-gap voltage of the substrate.
71	<code>as</code>	For a closed buried layer: $A_s=A_c$, for an open buried layer: $A_s=A_{epi}$.
72	<code>rth</code> (K/W)	Thermal resistance.
73	<code>cth</code> (J/K)	Thermal capacitance.
74	<code>ath</code>	Temperature coefficient of the thermal resistance.

Operating-Point Parameters

1	<code>Ic</code> (A)	External DC collector current.
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Virtuoso Simulator Components and Device Models Reference

Philips Models

2	I_b (A)	External DC base current.
3	BetaDC	External DC current gain I_c/I_b .
4	V_{b2e1} (V)	Internal base-emitter bias.
5	V_{b2c2} (V)	Internal base-collector bias.
6	V_{b2c1} (V)	Internal base-collector bias including epilayer.
7	V_{b1c1} (V)	External base-collector bias without contact resistances.
8	V_{e1e} (V)	Bias over emitter resistance.
9	I_n (A)	Main current.
10	I_{c1c2} (A)	Epilayer current.
11	I_{b1b2} (A)	Pinched-base current.
12	I_{b1} (A)	Ideal forward base current.
13	$S I_{b1}$ (A)	Ideal side-wall base current.
14	I_{b2} (A)	Non-ideal forward base current.
15	I_{b3} (A)	Non-ideal reverse base current.
16	I_{ex} (A)	Extrinsic reverse base current.
17	$X I_{ex}$ (A)	Extrinsic reverse base current.
18	I_{av1} (A)	Avalanche current.
19	I_{RE} (A)	Current through emitter resistance.
20	I_{RBC} (A)	Current through constant base resistance.
21	I_{RCC} (A)	Current through constant collector resistance.
22	Q_e (C)	Emitter charge or emitter neutral charge.
23	Q_{te} (C)	Base-emitter depletion charge.

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Philips Models

24	sq_{te} (C)	Sidewall base-emitter depletion charge.
25	q_{be} (C)	Base-emitter diffusion charge.
26	q_{bc} (C)	Base-collector diffusion charge.
27	q_{tc} (C)	Base-collector depletion charge.
28	q_{epi} (C)	Epilayer diffusion charge.
29	q_{b1b2} (C)	AC current crowding charge.
30	q_{tex} (C)	Extrinsic base-collector depletion charge.
31	xq_{tex} (C)	Extrinsic base-collector depletion charge.
32	q_{ex} (C)	Extrinsic base-collector diffusion charge.
33	xq_{ex} (C)	Extrinsic base-collector diffusion charge.
34	g_x ($1/\Omega$)	Forward transconductance.
35	g_y ($1/\Omega$)	Reverse transconductance.
36	g_z ($1/\Omega$)	Reverse transconductance.
37	sg_{pi} ($1/\Omega$)	Conductance sidewall b-e junction.
38	gp_{ix} ($1/\Omega$)	Conductance floor b-e junction.
39	gp_{iy} ($1/\Omega$)	Early effect on recombination base current.
40	gp_{iz} ($1/\Omega$)	Early effect on recombination base current.
41	gm_{ux} ($1/\Omega$)	Early effect on avalanche current limiting.
42	gm_{uy} ($1/\Omega$)	Conductance of avalanche current.
43	gm_{uz} ($1/\Omega$)	Conductance of avalanche current.
44	gm_{uex} ($1/\Omega$)	Conductance extrinsic b-c junction.
45	xgm_{uex} ($1/\Omega$)	Conductance extrinsic b-c junction.

Virtuoso Simulator Components and Device Models Reference

Philips Models

46	$grcvy$ ($1/\Omega$)	Conductance of the epilayer current.
47	$grcvz$ ($1/\Omega$)	Conductance of the epilayer current.
48	Rbv (Ω)	Conductance of the epilayer current.
49	$grbv_x$ ($1/\Omega$)	Early-effect on base resistance.
50	$grbv_y$ ($1/\Omega$)	Early-effect on base resistance.
51	$grbv_z$ ($1/\Omega$)	Early-effect on base resistance:.
52	RE (Ω)	Early-effect on base resistance:.
53	RBC (Ω)	Early-effect on base resistance:.
54	RCC (Ω)	Early-effect on base resistance:.
55	$SCbe$ (F)	Capacitance sidewall b-e junction.
56	$Cbex$ (F)	Capacitance floor b-e junction.
57	$Cbey$ (F)	Early effect on b-e diffusion charge.
58	$Cbez$ (F)	Early effect on b-e diffusion charge.
59	$Cbcx$ (F)	Early effect on b-c diffusion charge.
60	$Cbcy$ (F)	Capacitance floor b-c junction.
61	$Cbcz$ (F)	Capacitance floor b-c junction.
62	$Cbcex$ (F)	Capacitance extrinsic b-c junction.
63	$XCbcex$ (F)	Capacitance extrinsic b-c junction.
64	$Cb1b2$ (F)	Capacitance AC current crowding.
65	$Cb1b2x$ (F)	Cross-capacitance AC current crowding .
66	$Cb1b2y$ (F)	Cross-capacitance AC current crowding.
67	$Cb1b2z$ (F)	Cross-capacitance AC current crowding.

Virtuoso Simulator Components and Device Models Reference

Philips Models

68	g_m ($1/\Omega$)	Transconductance.
69	beta	Current amplification.
70	g_{out} ($1/\Omega$)	Output conductance.
71	g_{mu} ($1/\Omega$)	Feedback transconductance.
72	R_B (Ω)	Base resistance.
73	C_{be} (F)	Base-emitter capacitance.
74	C_{bc} (F)	Base-collector capacitance.
75	f_T (Hz)	Good approximation for cut-off frequency.
76	I_{qs} (A)	Current at onset of quasi-saturation.
77	X_{iWepi} (M)	Thickness of injection layer.
78	$V_{b2c2star}$ (V)	Physical value of internal base-collector bias.
79	P_{diss} (W)	Dissipation.
80	T_K (K)	Actual temperature.
81	I_{sub} (A)	Substrate current.
82	X_{Isub} (A)	Substrate current.
83	I_{sf} (A)	Substrate failure current.
84	Q_{ts} (C)	Collector-substrate depletion charge.
85	g_S ($1/\Omega$)	Conductance parasitic PNP transistor.
86	X_{gS} ($1/\Omega$)	Conductance parasitic PNP transistor.
87	g_{Sf} ($1/\Omega$)	
88	C_{ts} (C)	Capacitance s-c junction:.

Virtuoso Simulator Components and Device Models Reference

Philips Models

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

BetaDC	OP-3	XQtex	OP-31	gSf	OP-87	rcv	O-25
Cb1b2	OP-64	XgS	OP-86	gm	OP-68	re	M-22
Cb1b2x	OP-65	Xgmuex	OP-45	gmu	OP-71	re	O-21
Cb1b2y	OP-66	XiWepi	OP-77	gmux	OP-44	region	I-2
Cb1b2z	OP-67	ab	M-51	gmux	OP-41	rth	M-73
Cbc	OP-74	ab	O-50	gmuy	OP-42	rth	O-72
Cbcex	OP-62	ac	M-55	gmuz	OP-43	scrcv	M-27
Cbcx	OP-59	ac	O-54	gout	OP-70	scrcv	O-26
Cbcy	OP-60	ae	M-50	gpix	OP-38	sfh	M-21
Cbcz	OP-61	ae	O-49	gpiy	OP-39	sfh	O-20
Cbe	OP-73	aepi	M-53	gpiz	OP-40	taub	M-44
Cbex	OP-56	aepi	O-52	grbvz	OP-49	taub	O-43
Cbey	OP-57	aex	M-54	grbvy	OP-50	taue	M-43
Cbez	OP-58	aex	O-53	grbvz	OP-51	taue	O-42
Cts	OP-88	af	M-62	grcvy	OP-46	taur	M-46
IRBC	OP-20	af	O-61	grcvz	OP-47	taur	O-45

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Philips Models

IRCC	OP-21	aqbo	M-49	gx	OP-34	tepi	M-45
IRE	OP-19	aqbo	O-48	gy	OP-35	tepi	O-44
Iavl	OP-18	area	I-4	gz	OP-36	tnom	M-78
Ib	OP-2	as	M-72	ibf	M-12	tr	M-79
Ib1	OP-12	as	O-71	ibf	O-11	tref	M-2
Ib1b2	OP-11	ath	M-75	ibr	M-16	tref	O-1
Ib2	OP-14	ath	O-74	ibr	O-15	type	M-76
Ib3	OP-15	axi	M-29	ihc	M-28	vavl	M-20
Ic	OP-1	axi	O-28	ihc	O-27	vavl	O-19
Ic1c2	OP-10	beta	OP-69	ik	M-8	vdc	M-36
Iex	OP-16	bf	M-11	ik	O-7	vdc	O-35
In	OP-9	bf	O-10	iks	M-67	vde	M-31
Iqs	OP-76	bri	M-15	iks	O-66	vde	O-30
Isf	OP-83	bri	O-14	imax	M-77	vds	M-69
Isub	OP-81	cbco	M-41	is	M-7	vds	O-68
Pdiss	OP-79	cbco	O-40	is	O-6	vef	M-10
Qb1b2	OP-29	cbeo	M-34	iss	M-66	vef	O-9
Qbc	OP-26	cbeo	O-33	iss	O-65	ver	M-9
Qbe	OP-25	cjc	M-35	kavl	M-65	ver	O-8
Qe	OP-22	cjc	O-34	kavl	O-64	vgb	M-58
Qepi	OP-28	cje	M-30	kf	M-63	vgb	O-57

Virtuoso Simulator Components and Device Models Reference

Philips Models

Qex	OP-32	cje	O-29	kf	O-62	vgc	M-59
Qtc	OP-27	cjs	M-68	kfn	M-64	vgc	O-58
Qte	OP-23	cjs	O-67	kfn	O-63	vgj	M-60
Qtex	OP-30	cth	M-74	level	M-1	vgj	O-59
Qts	OP-84	cth	O-73	m	I-3	vgc	M-71
RB	OP-72	dais	M-52	mc	M-39	vgc	O-70
RBC	OP-53	dais	O-51	mc	O-38	vlr	M-17
RCC	OP-54	deg	M-47	mlf	M-13	vlr	O-16
RE	OP-52	deg	O-46	mlf	O-12	wavl	M-19
Rbv	OP-48	dta	M-3	mtau	M-42	wavl	O-18
SCbe	OP-55	dta	O-2	mtau	O-41	xcjc	M-40
SIb1	OP-13	dvgbf	M-56	mult	I-1	xcjc	O-39
SQte	OP-24	dvgbf	O-55	pc	M-37	xcje	M-33
Sgpi	OP-37	dvgbr	M-57	pc	O-36	xcje	O-32
TK	OP-80	dvgbr	O-56	pe	M-32	xext	M-18
Vb1c1	OP-7	dvgte	M-61	pe	O-31	xext	O-17
Vb2c1	OP-6	dvgte	O-60	ps	M-70	xibi	M-14
Vb2c2	OP-5	exavl	M-6	ps	O-69	xibi	O-13
Vb2c2star	OP-78	exavl	O-5	rbc	M-23	xp	M-38
Vb2e1	OP-4	exmod	M-4	rbc	O-22	xp	O-37
Ve1e	OP-8	exmod	O-3	rbv	M-24	xrec	M-48

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Philips Models

XCbceX	OP-63	exphi	M-5	rbv	O-23	xrec	O-47
XIex	OP-17	exphi	O-4	rcc	M-25		
XIsub	OP-82	fT	OP-75	rcc	O-24		
XQex	OP-33	gS	OP-85	rcv	M-26		

Compact Bipolar-Transistor Model (bjtd504)

Instance Definition

Name c b e modelName parameter=value ...

Instance Parameters

- 1 mult=1 Number of devices in parallel.
- 2 region=fwd Estimated DC operating region, used as a convergence aid. Possible values are off, sat, rev, or fwd.
- 3 m=1 Multiplicity factor.
- 4 area=1 alias of mult.

Model Definition

model modelName bjtd504 parameter=value ...

Model Parameters

- 1 level=504 Bipolar Level.
- 2 tref=25 deg. C Reference temperature.
- 3 dta=0 K Difference between the local ambient and global ambient temperature.
- 4 exmod=1 Flag for extended modeling of reverse current gain.

Virtuoso Simulator Components and Device Models Reference

Philips Models

5	<code>exphi=1</code>	Flag for the distributed high-frequency effects in transient.
6	<code>exavl=0</code>	Flag for extended modeling of avalanche currents.
7	<code>is=2.2e-17 A</code>	Collector-emitter saturation current.
8	<code>ik=0.1 A</code>	Collector-emitter high injection knee current.
9	<code>ver=2.5 V</code>	Reverse Early voltage.
10	<code>vef=44 V</code>	Forward Early voltage.
11	<code>bf=215</code>	Ideal forward current gain.
12	<code>ibf=2.7e-15 A</code>	Saturation current of the non-ideal forward base current.
13	<code>mlf=2</code>	Non ideality factor of the non-ideal forward base current.
14	<code>xibi=0</code>	Part of ideal base current that belongs to the sidewall.
15	<code>bri=7</code>	Ideal reverse current gain.
16	<code>ibr=1e-15 A</code>	Saturation current of the non-ideal reverse base current.
17	<code>vlr=0.2 V</code>	Cross-over voltage of the non-ideal reverse base current.
18	<code>xext=0.63</code>	Part of I_{ex} , Q_{tex} , Q_{ex} and I_{sub} that depends on V_{bc1} instead of V_{b1c1} .
19	<code>wavl=1.1e-06 m</code>	Epilayer thickness used in weak-avalanche model.
20	<code>vavl=3 V</code>	Voltage determining curvature of avalanche current.
21	<code>sfh=0.3</code>	Current spreading factor of avalanche model (when EXAVL=1).
22	<code>re=5 Ω</code>	Emitter resistance.
23	<code>rbc=23 Ω</code>	Constant part of the base resistance.
24	<code>rbv=18 Ω</code>	Zero-bias value of the variable part of the base resistance.
25	<code>rcc=12 Ω</code>	Constant part of collector resistance.

Virtuoso Simulator Components and Device Models Reference

Philips Models

26	$rcv=150 \ \Omega$	Resistance of the un-modulated epilayer.
27	$scrcv=1.25e+03 \ \Omega$	Space charge resistance of the epilayer.
28	$ihc=0.004 \ A$	Critical current for velocity saturation in the epilayer.
29	$axi=0.3$	Smoothness parameter for the onset of quasi-saturation.
30	$cje=7.3e-14 \ F$	Zero-bias emitter-base depletion capacitance.
31	$vde=0.95 \ V$	Emitter-base diffusion voltage.
32	$pe=0.4$	Emitter-base grading coefficient.
33	$xcje=0.4$	Fraction of the emitter-base depletion capacitance that belongs to the sidewall.
34	$cbeo=0$	Emitter-base overlap capacitance.
35	$cjc=7.8e-14 \ F$	Zero-bias collector-base depletion capacitance.
36	$vdc=0.68 \ V$	Collector-base diffusion voltage.
37	$pc=0.5$	Collector-base grading coefficient.
38	$xp=0.35$	Constant part of C_{jc} .
39	$mc=0.5$	Coefficient for the current modulation of the collector-base depletion capacitance.
40	$xcjc=0.032$	Fraction of the collector-base depletion capacitance under the emitter.
41	$cbco=0$	Collector-base overlap capacitance.
42	$m\tau_{au}=1$	Non-ideality factor of the emitter stored charge.
43	$\tau_{aue}=2e-12 \ s$	Minimum transit time of stored emitter charge.
44	$\tau_{aub}=4.2e-12 \ s$	Transit time of stored base charge.
45	$\tau_{epi}=4.1e-11 \ s$	Transit time of stored epilayer charge.

Virtuoso Simulator Components and Device Models Reference

Philips Models

46	<code>taur=5.2e-10 s</code>	Transit time of reverse extrinsic base charge.
47	<code>deg=0 eV</code>	Bandgap difference over the base.
48	<code>xrec=0</code>	Pre-factor of the recombination part of I_{b1} .
49	<code>aqbo=0.3</code>	Temperature coefficient of the zero-bias base charge.
50	<code>ae=0</code>	Temperature coefficient of the resistivity of the emitter.
51	<code>ab=1</code>	Temperature coefficient of the resistivity of the base.
52	<code>dais=0</code>	Parameter for fine tuning of temperature dependence of collector-emitter saturation current.
53	<code>aepi=2.5</code>	Temperature coefficient of the resistivity of the epilayer.
54	<code>aex=0.62</code>	Temperature coefficient of the resistivity of the extrinsic base.
55	<code>ac=2</code>	Temperature coefficient of the resistivity of the buried layer.
56	<code>dvgbf=0.05 V</code>	Bandgap voltage difference of forward current gain.
57	<code>dvgbr=0.045 V</code>	Bandgap voltage difference of reverse current gain.
58	<code>vgb=1.17 V</code>	Bandgap voltage of the base.
59	<code>vgc=1.18 V</code>	Bandgap voltage of the collector.
60	<code>vgj=1.15 V</code>	Bandgap voltage recombination emitter-base junction.
61	<code>dvgte=0.05 V</code>	Bandgap voltage difference of emitter stored charge.
62	<code>af=2</code>	Exponent of the Flicker-noise.
63	<code>kf=2e-11</code>	Flicker-noise coefficient of the ideal base current.
64	<code>kfn=2e-11</code>	Flicker-noise coefficient of the non-ideal base current.
65	<code>kav1=0</code>	Switch for white noise contribution due to avalanche.
66	<code>type=n</code>	Transistor gender. Possible values are <code>n</code> , <code>p</code> , <code>npn</code> , <code>pnv</code> , <code>npnv</code> , <code>pnpv</code> , <code>npnl</code> , or <code>pnpl</code> .

Virtuoso Simulator Components and Device Models Reference

Philips Models

67 `imax=1.0 A` Explosion current.

68 `tnom (deg. C)` alias of `tnom`.

69 `tr (deg. C)` alias of `tnom`.

Output Parameters

1 `tref (deg. C)` Reference temperature.

2 `dta (K)` Difference between the local ambient and global ambient temperatures.

3 `exmod` Flag for extended modeling of reverse current gain.

4 `exphi` Flag for the distributed high-frequency effects in transient.

5 `exavl` Flag for extended modeling of avalanche currents.

6 `is (A)` Collector-emitter saturation current.

7 `ik (A)` Collector-emitter high injection knee current.

8 `ver (V)` Reverse Early voltage.

9 `vef (V)` Forward Early voltage.

10 `bf` Ideal forward current gain.

11 `ibf (A)` Saturation current of the non-ideal forward base current.

12 `mlf` Non ideality factor of the non-ideal forward base current.

13 `xibi` Part of ideal base current that belongs to the sidewall.

14 `bri` Ideal reverse current gain.

15 `ibr (A)` Saturation current of the non-ideal reverse base current.

16 `vlr (V)` Cross-over voltage of the non-ideal reverse base current.

17 `xext` Part of `Iex`, `Qtex`, `Qex` and `Isub` that depends on `Vbc1` instead of `Vb1c1`.

Virtuoso Simulator Components and Device Models Reference

Philips Models

18	wavl (M)	Epilayer thickness used in weak-avalanche model.
19	vavl (V)	Voltage determining curvature of avalanche current.
20	sfh	Current spreading factor of avalanche model (when EXAVL=1).
21	re (Ω)	Emitter resistance.
22	rbc (Ω)	Constant part of the base resistance.
23	rbv (Ω)	Zero-bias value of the variable part of the base resistance.
24	rcc (Ω)	Constant part of collector resistance.
25	rcv (Ω)	Resistance of the un-modulated epilayer.
26	scrcv (Ω)	Space charge resistance of the epilayer.
27	ihc (A)	Critical current for velocity saturation in the epilayer.
28	axi	Smoothness parameter for the onset of quasi-saturation.
29	cje (F)	Zero-bias emitter-base depletion capacitance.
30	vde (V)	Emitter-base diffusion voltage.
31	pe	Emitter-base grading coefficient.
32	xcje	Fraction of the emitter-base depletion capacitance that belongs to the sidewall.
33	cbeo	Emitter-base overlap capacitance.
34	cjc (F)	Zero-bias collector-base depletion capacitance.
35	vdc (V)	Collector-base diffusion voltage.
36	pc	Collector-base grading coefficient.
37	xp	Constant part of Cjc.
38	mc	Coefficient for the current modulation of the collector-base depletion capacitance.

Virtuoso Simulator Components and Device Models Reference

Philips Models

39	<code>xcjc</code>	Fraction of the collector-base depletion capacitance under the emitter.
40	<code>cbco</code>	Collector-base overlap capacitance.
41	<code>mtau</code>	Non-ideality factor of the emitter stored charge.
42	<code>taue (s)</code>	Minimum transit time of stored emitter charge.
43	<code>taub (s)</code>	Transit time of stored base charge.
44	<code>tepi (s)</code>	Transit time of stored epilayer charge.
45	<code>taur (s)</code>	Transit time of reverse extrinsic stored base charge.
46	<code>deg (eV)</code>	Bandgap difference over the base.
47	<code>xrec</code>	Pre-factor of the recombination part of I_{b1} .
48	<code>aqbo</code>	Temperature coefficient of the zero-bias base charge.
49	<code>ae</code>	Temperature coefficient of the resistivity of the emitter.
50	<code>ab</code>	Temperature coefficient of the resistivity of the base.
51	<code>dais</code>	Parameter for fine tuning of temperature dependence of collector-emitter saturation current.
52	<code>aepi</code>	Temperature coefficient of the resistivity of the epilayer.
53	<code>aex</code>	Temperature coefficient of the resistivity of the extrinsic base.
54	<code>ac</code>	Temperature coefficient of the resistivity of the buried layer.
55	<code>dvgbf (V)</code>	Bandgap voltage difference of forward current gain.
56	<code>dvgbr (V)</code>	Bandgap voltage difference of reverse current gain.
57	<code>vgb (V)</code>	Bandgap voltage of the base.
58	<code>vgc (V)</code>	Bandgap voltage of the collector.
59	<code>vgj (V)</code>	Bandgap voltage recombination emitter-base junction.

Virtuoso Simulator Components and Device Models Reference

Philips Models

60	dv_{gte} (V)	Bandgap voltage difference of emitter stored charge.
61	a_f	Exponent of the Flicker-noise.
62	k_f	Flicker-noise coefficient of the ideal base current.
63	k_{fn}	Flicker-noise coefficient of the non-ideal base current.
64	k_{av1}	Switch for white noise contribution due to avalanche.

Operating-Point Parameters

1	I_c (A)	External DC collector current.
2	I_b (A)	External DC base current.
3	$Beta_{DC}$	External DC current gain I_c/I_b .
4	v_{b2e1} (V)	Internal base-emitter bias.
5	v_{b2c2} (V)	Internal base-collector bias.
6	v_{b2c1} (V)	Internal base-collector bias including epilayer.
7	v_{b1c1} (V)	External base-collector bias without contact resistances.
8	v_{e1e} (V)	Bias over emitter resistance.
9	I_n (A)	Main current.
10	I_{c1c2} (A)	Epilayer current.
11	I_{b1b2} (A)	Pinched-base current.
12	I_{b1} (A)	Ideal forward base current.
13	$S I_{b1}$ (A)	Ideal side-wall base current.
14	I_{b2} (A)	Non-ideal forward base current.
15	I_{b3} (A)	Non-ideal reverse base current.
16	I_{ex} (A)	Extrinsic reverse base current.

Virtuoso Simulator Components and Device Models Reference

Philips Models

17	XI_{ex} (A)	Extrinsic reverse base current.
18	I_{avl} (A)	Avalanche current.
19	I_{RE} (A)	Current through emitter resistance.
20	I_{RBC} (A)	Current through constant base resistance.
21	I_{RCC} (A)	Current through constant collector resistance.
22	Q_e (C)	Emitter charge or emitter neutral charge.
23	Q_{te} (C)	Base-emitter depletion charge.
24	SQ_{te} (C)	Sidewall base-emitter depletion charge.
25	Q_{be} (C)	Base-emitter diffusion charge.
26	Q_{bc} (C)	Base-collector diffusion charge.
27	Q_{tc} (C)	Base-collector depletion charge.
28	Q_{epi} (C)	Epilayer diffusion charge.
29	Q_{b1b2} (C)	AC current crowding charge.
30	Q_{tex} (C)	Extrinsic base-collector depletion charge.
31	XQ_{tex} (C)	Extrinsic base-collector depletion charge.
32	Q_{ex} (C)	Extrinsic base-collector diffusion charge.
33	XQ_{ex} (C)	Extrinsic base-collector diffusion charge.
34	g_x (1/Ω)	Forward transconductance.
35	g_y (1/Ω)	Reverse transconductance.
36	g_z (1/Ω)	Reverse transconductance.
37	S_{gpi} (1/Ω)	Conductance sidewall b-e junction.
38	g_{pix} (1/Ω)	Conductance floor b-e junction.

Virtuoso Simulator Components and Device Models Reference

Philips Models

39	$gpiy$ ($1/\Omega$)	Early effect on recombination base current.
40	$gpiz$ ($1/\Omega$)	Early effect on recombination base current.
41	$gmux$ ($1/\Omega$)	Early effect on avalanche current limiting.
42	$gmuy$ ($1/\Omega$)	Conductance of avalanche current.
43	$gmuz$ ($1/\Omega$)	Conductance of avalanche current.
44	$gmux$ ($1/\Omega$)	Conductance extrinsic b-c junction.
45	$Xgmux$ ($1/\Omega$)	Conductance extrinsic b-c junction.
46	$grcvy$ ($1/\Omega$)	Conductance of the epilayer current.
47	$grcvz$ ($1/\Omega$)	Conductance of the epilayer current.
48	Rbv (Ω)	Conductance of the epilayer current.
49	$grbvz$ ($1/\Omega$)	Early-effect on base resistance.
50	$grbvy$ ($1/\Omega$)	Early-effect on base resistance.
51	$grbvz$ ($1/\Omega$)	Early-effect on base resistance:.
52	RE (Ω)	Early-effect on base resistance:.
53	RBC (Ω)	Early-effect on base resistance:.
54	RCC (Ω)	Early-effect on base resistance:.
55	$SCbe$ (F)	Capacitance sidewall b-e junction.
56	$Cbex$ (F)	Capacitance floor b-e junction.
57	$Cbey$ (F)	Early effect on b-e diffusion charge.
58	$Cbez$ (F)	Early effect on b-e diffusion charge.
59	$Cbcx$ (F)	Early effect on b-c diffusion charge.
60	$Cbcy$ (F)	Capacitance floor b-c junction.

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Philips Models

61	Cbcz (F)	Capacitance floor b-c junction.
62	Cbcex (F)	Capacitance extrinsic b-c junction.
63	XCbcex (F)	Capacitance extrinsic b-c junction.
64	Cb1b2 (F)	Capacitance AC current crowding.
65	Cb1b2x (F)	Cross-capacitance AC current crowding .
66	Cb1b2y (F)	Cross-capacitance AC current crowding.
67	Cb1b2z (F)	Cross-capacitance AC current crowding.
68	gm ($1/\Omega$)	Transconductance.
69	beta	Current amplification.
70	gout ($1/\Omega$)	Output conductance.
71	gm _u ($1/\Omega$)	Feedback transconductance.
72	R _B (Ω)	Base resistance.
73	C _{be} (F)	Base-emitter capacitance.
74	C _{bc} (F)	Base-collector capacitance.
75	f _T (Hz)	Good approximation for cut-off frequency.
76	I _{qs} (A)	Current at onset of quasi-saturation.
77	XiWepi (M)	Thickness of injection layer.
78	Vb2c2star (V)	Physical value of internal base-collector bias.
79	P _{diss} (W)	Dissipation.
80	T _K (K)	Actual temperature.

Virtuoso Simulator Components and Device Models Reference

Philips Models

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

BetaDC	OP-3	XIex	OP-17	gmu	OP-71	re	M-22
Cb1b2	OP-64	XQex	OP-33	gmux	OP-44	re	O-21
Cb1b2x	OP-65	XQtex	OP-31	gmux	OP-41	region	I-2
Cb1b2y	OP-66	Xgmux	OP-45	gmuy	OP-42	scrcv	M-27
Cb1b2z	OP-67	XiWepi	OP-77	gmuz	OP-43	scrcv	O-26
Cbc	OP-74	ab	M-51	gout	OP-70	sfh	M-21
Cbcex	OP-62	ab	O-50	gpix	OP-38	sfh	O-20
Cbcx	OP-59	ac	M-55	gpiy	OP-39	taub	M-44
Cbcy	OP-60	ac	O-54	gpiz	OP-40	taub	O-43
Cbcz	OP-61	ae	M-50	grbvz	OP-49	taue	M-43
Cbe	OP-73	ae	O-49	grbvy	OP-50	taue	O-42
Cbex	OP-56	aepi	M-53	grbvz	OP-51	taur	M-46
Cbey	OP-57	aepi	O-52	grcvy	OP-46	taur	O-45
Cbez	OP-58	aex	M-54	grcvz	OP-47	tepi	M-45
IRBC	OP-20	aex	O-53	gx	OP-34	tepi	O-44
IRCC	OP-21	af	M-62	gy	OP-35	tnom	M-68

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Philips Models

IRE	OP-19	af	O-61	gz	OP-36	tr	M-69
Iavl	OP-18	aqbo	M-49	ibf	M-12	tref	M-2
Ib	OP-2	aqbo	O-48	ibf	O-11	tref	O-1
Ib1	OP-12	area	I-4	ibr	M-16	type	M-66
Ib1b2	OP-11	axi	M-29	ibr	O-15	vavl	M-20
Ib2	OP-14	axi	O-28	ihc	M-28	vavl	O-19
Ib3	OP-15	beta	OP-69	ihc	O-27	vdc	M-36
Ic	OP-1	bf	M-11	ik	M-8	vdc	O-35
Ic1c2	OP-10	bf	O-10	ik	O-7	vde	M-31
Iex	OP-16	bri	M-15	imax	M-67	vde	O-30
In	OP-9	bri	O-14	is	M-7	vef	M-10
Iqs	OP-76	cbco	M-41	is	O-6	vef	O-9
Pdiss	OP-79	cbco	O-40	kavl	M-65	ver	M-9
Qb1b2	OP-29	cbeo	M-34	kavl	O-64	ver	O-8
Qbc	OP-26	cbeo	O-33	kf	M-63	vgb	M-58
Qbe	OP-25	cjc	M-35	kf	O-62	vgb	O-57
Qe	OP-22	cjc	O-34	kfn	M-64	vgc	M-59
Qepi	OP-28	cje	M-30	kfn	O-63	vgc	O-58
Qex	OP-32	cje	O-29	level	M-1	vgj	M-60
Qtc	OP-27	dais	M-52	m	I-3	vgj	O-59
Qte	OP-23	dais	O-51	mc	M-39	vlr	M-17

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Philips Models

Qtex	OP-30	deg	M-47	mc	O-38	vlr	O-16
RB	OP-72	deg	O-46	mlf	M-13	wavl	M-19
RBC	OP-53	dta	M-3	mlf	O-12	wavl	O-18
RCC	OP-54	dta	O-2	mtau	M-42	xcjc	M-40
RE	OP-52	dvgbf	M-56	mtau	O-41	xcjc	O-39
Rbv	OP-48	dvgbf	O-55	mult	I-1	xcje	M-33
SCbe	OP-55	dvgbr	M-57	pc	M-37	xcje	O-32
SIb1	OP-13	dvgbr	O-56	pc	O-36	xext	M-18
SQte	OP-24	dvgte	M-61	pe	M-32	xext	O-17
Sgpi	OP-37	dvgte	O-60	pe	O-31	xibi	M-14
TK	OP-80	exavl	M-6	rbc	M-23	xibi	O-13
Vb1c1	OP-7	exavl	O-5	rbc	O-22	xp	M-38
Vb2c1	OP-6	exmod	M-4	rbv	M-24	xp	O-37
Vb2c2	OP-5	exmod	O-3	rbv	O-23	xrec	M-48
Vb2c2star	OP-78	exphi	M-5	rcc	M-25	xrec	O-47
Vb2e1	OP-4	exphi	O-4	rcc	O-24		
Ve1e	OP-8	fT	OP-75	rcv	M-26		
XCbceX	OP-63	gm	OP-68	rcv	O-25		

Compact Bipolar-Transistor Model (bjtd504t)

this is SimKit 4.0

Virtuoso Simulator Components and Device Models Reference

Philips Models

This device is supported within altergroups.

This device is dynamically loaded from the shared object /vobs/spectre_dev/tools.lnx86/cmi/lib/5.0.doc/libphilips_sh.so

Instance Definition

```
Name c b e dt ModelName parameter=value ...
```

Instance Parameters

- | | | |
|---|------------|--|
| 1 | mult=1 | Number of devices in parallel. |
| 2 | region=fwd | Estimated DC operating region, used as a convergence aid. Possible values are off, sat, rev, or fwd. |
| 3 | m=1 | Multiplicity factor. |
| 4 | area=1 | alias of mult. |

Model Definition

```
model modelName bjtd504t parameter=value ...
```

Model Parameters

- | | | |
|---|----------------|--|
| 1 | level=504 | Bipolar Level. |
| 2 | tref=25 deg. C | Reference temperature. |
| 3 | dta=0 K | Difference between the local ambient and global ambient temperature. |
| 4 | exmod=1 | Flag for extended modeling of reverse current gain. |
| 5 | exphi=1 | Flag for the distributed high-frequency effects in transient. |
| 6 | exavl=0 | Flag for extended modeling of avalanche currents. |
| 7 | is=2.2e-17 A | Collector-emitter saturation current. |
| 8 | ik=0.1 A | Collector-emitter high injection knee current. |

Virtuoso Simulator Components and Device Models Reference

Philips Models

9	<code>ver=2.5 V</code>	Reverse Early voltage.
10	<code>vef=44 V</code>	Forward Early voltage.
11	<code>bf=215</code>	Ideal forward current gain.
12	<code>ibf=2.7e-15 A</code>	Saturation current of the non-ideal forward base current.
13	<code>mlf=2</code>	Non ideality factor of the non-ideal forward base current.
14	<code>xibi=0</code>	Part of ideal base current that belongs to the sidewall.
15	<code>bri=7</code>	Ideal reverse current gain.
16	<code>ibr=1e-15 A</code>	Saturation current of the non-ideal reverse base current.
17	<code>vlr=0.2 V</code>	Cross-over voltage of the non-ideal reverse base current.
18	<code>xext=0.63</code>	Part of I_{ex} , Q_{tex} , Q_{ex} and I_{sub} that depends on V_{bc1} instead of V_{b1c1} .
19	<code>wavl=1.1e-06 m</code>	Epilayer thickness used in weak-avalanche model.
20	<code>vavl=3 V</code>	Voltage determining curvature of avalanche current.
21	<code>sfh=0.3</code>	Current spreading factor of avalanche model (when EXAVL=1).
22	<code>re=5 Ω</code>	Emitter resistance.
23	<code>rbc=23 Ω</code>	Constant part of the base resistance.
24	<code>rbv=18 Ω</code>	Zero-bias value of the variable part of the base resistance.
25	<code>rcc=12 Ω</code>	Constant part of collector resistance.
26	<code>rcv=150 Ω</code>	Resistance of the un-modulated epilayer.
27	<code>scrcv=1.25e+03 Ω</code>	Space charge resistance of the epilayer.
28	<code>ihc=0.004 A</code>	Critical current for velocity saturation in the epilayer.
29	<code>axi=0.3</code>	Smoothness parameter for the onset of quasi-saturation.

Virtuoso Simulator Components and Device Models Reference

Philips Models

30	$c_{je}=7.3e-14$ F	Zero-bias emitter-base depletion capacitance.
31	$v_{de}=0.95$ V	Emitter-base diffusion voltage.
32	$p_e=0.4$	Emitter-base grading coefficient.
33	$x_{cje}=0.4$	Fraction of the emitter-base depletion capacitance that belongs to the sidewall.
34	$c_{beo}=0$	Emitter-base overlap capacitance.
35	$c_{jc}=7.8e-14$ F	Zero-bias collector-base depletion capacitance.
36	$v_{dc}=0.68$ V	Collector-base diffusion voltage.
37	$p_c=0.5$	Collector-base grading coefficient.
38	$x_p=0.35$	Constant part of C_{jc} .
39	$m_c=0.5$	Coefficient for the current modulation of the collector-base depletion capacitance.
40	$x_{cjc}=0.032$	Fraction of the collector-base depletion capacitance under the emitter.
41	$c_{bco}=0$	Collector-base overlap capacitance.
42	$m_{tau}=1$	Non-ideality factor of the emitter stored charge.
43	$\tau_{aue}=2e-12$ s	Minimum transit time of stored emitter charge.
44	$\tau_{aub}=4.2e-12$ s	Transit time of stored base charge.
45	$\tau_{epi}=4.1e-11$ s	Transit time of stored epilayer charge.
46	$\tau_{aur}=5.2e-10$ s	Transit time of reverse extrinsic base charge.
47	$\Delta E_g=0$ eV	Bandgap difference over the base.
48	$x_{rec}=0$	Pre-factor of the recombination part of I_{b1} .
49	$a_{qbo}=0.3$	Temperature coefficient of the zero-bias base charge.

Virtuoso Simulator Components and Device Models Reference

Philips Models

50	$ae=0$	Temperature coefficient of the resistivity of the emitter.
51	$ab=1$	Temperature coefficient of the resistivity of the base.
52	$dais=0$	Parameter for fine tuning of temperature dependence of collector-emitter saturation current.
53	$aepi=2.5$	Temperature coefficient of the resistivity of the epilayer.
54	$aex=0.62$	Temperature coefficient of the resistivity of the extrinsic base.
55	$ac=2$	Temperature coefficient of the resistivity of the buried layer.
56	$dvgbf=0.05$ V	Bandgap voltage difference of forward current gain.
57	$dvgbr=0.045$ V	Bandgap voltage difference of reverse current gain.
58	$vgb=1.17$ V	Bandgap voltage of the base.
59	$vgc=1.18$ V	Bandgap voltage of the collector.
60	$vgj=1.15$ V	Bandgap voltage recombination emitter-base junction.
61	$dvgte=0.05$ V	Bandgap voltage difference of emitter stored charge.
62	$af=2$	Exponent of the Flicker-noise.
63	$kf=2e-11$	Flicker-noise coefficient of the ideal base current.
64	$kfn=2e-11$	Flicker-noise coefficient of the non-ideal base current.
65	$kavl=0$	Switch for white noise contribution due to avalanche.
66	$rth=300$ K/W	Thermal resistance.
67	$cth=3e-09$ J/K	Thermal capacitance.
68	$ath=0$	Temperature coefficient of the thermal resistance.
69	$type=n$	Transistor gender. Possible values are n, p, npn, pnp, npnv, pnpv, npnl, or pnp1.
70	$imax=1.0$ A	Explosion current.

Virtuoso Simulator Components and Device Models Reference

Philips Models

71	<code>tnom</code> (deg. C)	alias of <code>tnom</code> .
72	<code>tr</code> (deg. C)	alias of <code>tnom</code> .

Output Parameters

1	<code>tref</code> (deg. C)	Reference temperature.
2	<code>dta</code> (K)	Difference between the local ambient and global ambient temperatures.
3	<code>exmod</code>	Flag for extended modeling of reverse current gain.
4	<code>exphi</code>	Flag for the distributed high-frequency effects in transient.
5	<code>exavl</code>	Flag for extended modeling of avalanche currents.
6	<code>is</code> (A)	Collector-emitter saturation current.
7	<code>ik</code> (A)	Collector-emitter high injection knee current.
8	<code>ver</code> (V)	Reverse Early voltage.
9	<code>vef</code> (V)	Forward Early voltage.
10	<code>bf</code>	Ideal forward current gain.
11	<code>ibf</code> (A)	Saturation current of the non-ideal forward base current.
12	<code>mlf</code>	Non ideality factor of the non-ideal forward base current.
13	<code>xibi</code>	Part of ideal base current that belongs to the sidewall.
14	<code>bri</code>	Ideal reverse current gain.
15	<code>ibr</code> (A)	Saturation current of the non-ideal reverse base current.
16	<code>vlr</code> (V)	Cross-over voltage of the non-ideal reverse base current.
17	<code>xext</code>	Part of <code>Iex</code> , <code>Qtex</code> , <code>Qex</code> and <code>Isub</code> that depends on <code>Vbc1</code> instead of <code>Vb1c1</code> .
18	<code>wavl</code> (M)	Epilayer thickness used in weak-avalanche model.

Virtuoso Simulator Components and Device Models Reference

Philips Models

19	vavl (V)	Voltage determining curvature of avalanche current.
20	sfh	Current spreading factor of avalanche model (when EXAVL=1).
21	re (Ω)	Emitter resistance.
22	rbc (Ω)	Constant part of the base resistance.
23	rbv (Ω)	Zero-bias value of the variable part of the base resistance.
24	rcc (Ω)	Constant part of collector resistance.
25	rcv (Ω)	Resistance of the un-modulated epilayer.
26	scrcv (Ω)	Space charge resistance of the epilayer.
27	ihc (A)	Critical current for velocity saturation in the epilayer.
28	axi	Smoothness parameter for the onset of quasi-saturation.
29	cje (F)	Zero-bias emitter-base depletion capacitance.
30	vde (V)	Emitter-base diffusion voltage.
31	pe	Emitter-base grading coefficient.
32	xcje	Fraction of the emitter-base depletion capacitance that belongs to the sidewall.
33	cbeo	Emitter-base overlap capacitance.
34	cjc (F)	Zero-bias collector-base depletion capacitance.
35	vdc (V)	Collector-base diffusion voltage.
36	pc	Collector-base grading coefficient.
37	xp	Constant part of Cjc.
38	mc	Coefficient for the current modulation of the collector-base depletion capacitance.

Virtuoso Simulator Components and Device Models Reference

Philips Models

39	<code>xcjc</code>	Fraction of the collector-base depletion capacitance under the emitter.
40	<code>cbco</code>	Collector-base overlap capacitance.
41	<code>mtau</code>	Non-ideality factor of the emitter stored charge.
42	<code>taue (s)</code>	Minimum transit time of stored emitter charge.
43	<code>taub (s)</code>	Transit time of stored base charge.
44	<code>tepi (s)</code>	Transit time of stored epilayer charge.
45	<code>taur (s)</code>	Transit time of reverse extrinsic stored base charge.
46	<code>deg (eV)</code>	Bandgap difference over the base.
47	<code>xrec</code>	Pre-factor of the recombination part of I_{b1} .
48	<code>aqbo</code>	Temperature coefficient of the zero-bias base charge.
49	<code>ae</code>	Temperature coefficient of the resistivity of the emitter.
50	<code>ab</code>	Temperature coefficient of the resistivity of the base.
51	<code>dais</code>	Parameter for fine tuning of temperature dependence of collector-emitter saturation current.
52	<code>aepi</code>	Temperature coefficient of the resistivity of the epilayer.
53	<code>aex</code>	Temperature coefficient of the resistivity of the extrinsic base.
54	<code>ac</code>	Temperature coefficient of the resistivity of the buried layer.
55	<code>dvgbf (V)</code>	Bandgap voltage difference of forward current gain.
56	<code>dvgbr (V)</code>	Bandgap voltage difference of reverse current gain.
57	<code>vgb (V)</code>	Bandgap voltage of the base.
58	<code>vgc (V)</code>	Bandgap voltage of the collector.
59	<code>vgj (V)</code>	Bandgap voltage recombination emitter-base junction.

Virtuoso Simulator Components and Device Models Reference

Philips Models

60	dv_{gte} (V)	Bandgap voltage difference of emitter stored charge.
61	a_f	Exponent of the Flicker-noise.
62	k_f	Flicker-noise coefficient of the ideal base current.
63	k_{fn}	Flicker-noise coefficient of the non-ideal base current.
64	k_{av1}	Switch for white noise contribution due to avalanche.
65	r_{th} (K/W)	Thermal resistance.
66	c_{th} (J/K)	Thermal capacitance.
67	a_{th}	Temperature coefficient of the thermal resistance.

Operating-Point Parameters

1	I_c (A)	External DC collector current.
2	I_b (A)	External DC base current.
3	$Beta_{DC}$	External DC current gain I_c/I_b .
4	V_{b2e1} (V)	Internal base-emitter bias.
5	V_{b2c2} (V)	Internal base-collector bias.
6	V_{b2c1} (V)	Internal base-collector bias including epilayer.
7	V_{b1c1} (V)	External base-collector bias without contact resistances.
8	V_{e1e} (V)	Bias over emitter resistance.
9	I_n (A)	Main current.
10	I_{c1c2} (A)	Epilayer current.
11	I_{b1b2} (A)	Pinched-base current.
12	I_{b1} (A)	Ideal forward base current.
13	$S I_{b1}$ (A)	Ideal side-wall base current.

Virtuoso Simulator Components and Device Models Reference

Philips Models

14	I_{b2} (A)	Non-ideal forward base current.
15	I_{b3} (A)	Non-ideal reverse base current.
16	I_{ex} (A)	Extrinsic reverse base current.
17	XI_{ex} (A)	Extrinsic reverse base current.
18	I_{av1} (A)	Avalanche current.
19	I_{RE} (A)	Current through emitter resistance.
20	I_{RBC} (A)	Current through constant base resistance.
21	I_{RCC} (A)	Current through constant collector resistance.
22	Q_e (C)	Emitter charge or emitter neutral charge.
23	Q_{te} (C)	Base-emitter depletion charge.
24	SQ_{te} (C)	Sidewall base-emitter depletion charge.
25	Q_{be} (C)	Base-emitter diffusion charge.
26	Q_{bc} (C)	Base-collector diffusion charge.
27	Q_{tc} (C)	Base-collector depletion charge.
28	Q_{epi} (C)	Epilayer diffusion charge.
29	Q_{b1b2} (C)	AC current crowding charge.
30	Q_{tex} (C)	Extrinsic base-collector depletion charge.
31	XQ_{tex} (C)	Extrinsic base-collector depletion charge.
32	Q_{ex} (C)	Extrinsic base-collector diffusion charge.
33	XQ_{ex} (C)	Extrinsic base-collector diffusion charge.
34	g_x ($1/\Omega$)	Forward transconductance.
35	g_y ($1/\Omega$)	Reverse transconductance.

Virtuoso Simulator Components and Device Models Reference

Philips Models

36	g_z ($1/\Omega$)	Reverse transconductance.
37	g_{gpi} ($1/\Omega$)	Conductance sidewall b-e junction.
38	g_{pix} ($1/\Omega$)	Conductance floor b-e junction.
39	g_{piy} ($1/\Omega$)	Early effect on recombination base current.
40	g_{piz} ($1/\Omega$)	Early effect on recombination base current.
41	g_{mux} ($1/\Omega$)	Early effect on avalanche current limiting.
42	g_{muy} ($1/\Omega$)	Conductance of avalanche current.
43	g_{muz} ($1/\Omega$)	Conductance of avalanche current.
44	g_{muxe} ($1/\Omega$)	Conductance extrinsic b-c junction.
45	X_{gmuxe} ($1/\Omega$)	Conductance extrinsic b-c junction.
46	g_{rcvy} ($1/\Omega$)	Conductance of the epilayer current.
47	g_{rcvz} ($1/\Omega$)	Conductance of the epilayer current.
48	R_{bv} (Ω)	Conductance of the epilayer current.
49	g_{rbvx} ($1/\Omega$)	Early-effect on base resistance.
50	g_{rbvy} ($1/\Omega$)	Early-effect on base resistance.
51	g_{rbvz} ($1/\Omega$)	Early-effect on base resistance:.
52	R_E (Ω)	Early-effect on base resistance:.
53	R_{BC} (Ω)	Early-effect on base resistance:.
54	R_{CC} (Ω)	Early-effect on base resistance:.
55	SC_{be} (F)	Capacitance sidewall b-e junction.
56	C_{bex} (F)	Capacitance floor b-e junction.
57	C_{bey} (F)	Early effect on b-e diffusion charge.

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Philips Models

58	Cbez (F)	Early effect on b-e diffusion charge.
59	Cbcx (F)	Early effect on b-c diffusion charge.
60	Cbcy (F)	Capacitance floor b-c junction.
61	Cbcz (F)	Capacitance floor b-c junction.
62	Cbcex (F)	Capacitance extrinsic b-c junction.
63	XCbcex (F)	Capacitance extrinsic b-c junction.
64	Cb1b2 (F)	Capacitance AC current crowding.
65	Cb1b2x (F)	Cross-capacitance AC current crowding .
66	Cb1b2y (F)	Cross-capacitance AC current crowding.
67	Cb1b2z (F)	Cross-capacitance AC current crowding.
68	gm ($1/\Omega$)	Transconductance.
69	beta	Current amplification.
70	gout ($1/\Omega$)	Output conductance.
71	gmu ($1/\Omega$)	Feedback transconductance.
72	RB (Ω)	Base resistance.
73	Cbe (F)	Base-emitter capacitance.
74	Cbc (F)	Base-collector capacitance.
75	fT (Hz)	Good approximation for cut-off frequency.
76	Iqs (A)	Current at onset of quasi-saturation.
77	XiWepi (M)	Thickness of injection layer.
78	Vb2c2star (V)	Physical value of internal base-collector bias.
79	Pdiss (W)	Dissipation.

Virtuoso Simulator Components and Device Models Reference

Philips Models

80 TK (K) Actual temperature.

Parameter Index

In the following index, I refers to instance parameters, M refers to the model parameters section, O refers to the output parameters section, and OP refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of M-35 means the 35th model parameter.

BetaDC	OP-3	XQex	OP-33	fT	OP-75	rcv	O-25
Cb1b2	OP-64	XQtex	OP-31	gm	OP-68	re	M-22
Cb1b2x	OP-65	Xgmux	OP-45	gmu	OP-71	re	O-21
Cb1b2y	OP-66	XiWepi	OP-77	gmux	OP-44	region	I-2
Cb1b2z	OP-67	ab	M-51	gmux	OP-41	rth	M-66
Cbc	OP-74	ab	O-50	gmuy	OP-42	rth	O-65
Cbcex	OP-62	ac	M-55	gmuz	OP-43	scrcv	M-27
Cbcx	OP-59	ac	O-54	gout	OP-70	scrcv	O-26
Cbcy	OP-60	ae	M-50	gpix	OP-38	sfh	M-21
Cbcz	OP-61	ae	O-49	gpiy	OP-39	sfh	O-20
Cbe	OP-73	aepi	M-53	gpiz	OP-40	taub	M-44
Cbex	OP-56	aepi	O-52	grbvz	OP-49	taub	O-43
Cbey	OP-57	aex	M-54	grbvy	OP-50	taue	M-43
Cbez	OP-58	aex	O-53	grbvz	OP-51	taue	O-42
IRBC	OP-20	af	M-62	grcvy	OP-46	taur	M-46

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Philips Models

IRCC	OP-21	af	O-61	grcvz	OP-47	taur	O-45
IRE	OP-19	aqbo	M-49	gx	OP-34	tepi	M-45
Iavl	OP-18	aqbo	O-48	gy	OP-35	tepi	O-44
Ib	OP-2	area	I-4	gz	OP-36	tnom	M-71
Ib1	OP-12	ath	M-68	ibf	M-12	tr	M-72
Ib1b2	OP-11	ath	O-67	ibf	O-11	tref	M-2
Ib2	OP-14	axi	M-29	ibr	M-16	tref	O-1
Ib3	OP-15	axi	O-28	ibr	O-15	type	M-69
Ic	OP-1	beta	OP-69	ihc	M-28	vavl	M-20
Ic1c2	OP-10	bf	M-11	ihc	O-27	vavl	O-19
Iex	OP-16	bf	O-10	ik	M-8	vdc	M-36
In	OP-9	bri	M-15	ik	O-7	vdc	O-35
Iqs	OP-76	bri	O-14	imax	M-70	vde	M-31
Pdiss	OP-79	cbco	M-41	is	M-7	vde	O-30
Qb1b2	OP-29	cbco	O-40	is	O-6	vef	M-10
Qbc	OP-26	cbeo	M-34	kavl	M-65	vef	O-9
Qbe	OP-25	cbeo	O-33	kavl	O-64	ver	M-9
Qe	OP-22	cjc	M-35	kf	M-63	ver	O-8
Qepi	OP-28	cjc	O-34	kf	O-62	vgb	M-58
Qex	OP-32	cje	M-30	kfn	M-64	vgb	O-57
Qtc	OP-27	cje	O-29	kfn	O-63	vgc	M-59

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Philips Models

Qte	OP-23	cth	M-67	level	M-1	vgc	O-58
Qtex	OP-30	cth	O-66	m	I-3	vgj	M-60
RB	OP-72	dais	M-52	mc	M-39	vgj	O-59
RBC	OP-53	dais	O-51	mc	O-38	vlr	M-17
RCC	OP-54	deg	M-47	mlf	M-13	vlr	O-16
RE	OP-52	deg	O-46	mlf	O-12	wavl	M-19
Rbv	OP-48	dta	M-3	mtau	M-42	wavl	O-18
SCbe	OP-55	dta	O-2	mtau	O-41	xcjc	M-40
SIb1	OP-13	dvgbf	M-56	mult	I-1	xcjc	O-39
SQte	OP-24	dvgbf	O-55	pc	M-37	xcje	M-33
Sgpi	OP-37	dvgbr	M-57	pc	O-36	xcje	O-32
TK	OP-80	dvgbr	O-56	pe	M-32	xext	M-18
Vb1c1	OP-7	dvgte	M-61	pe	O-31	xext	O-17
Vb2c1	OP-6	dvgte	O-60	rbc	M-23	xibi	M-14
Vb2c2	OP-5	exavl	M-6	rbc	O-22	xibi	O-13
Vb2c2star	OP-78	exavl	O-5	rbv	M-24	xp	M-38
Vb2e1	OP-4	exmod	M-4	rbv	O-23	xp	O-37
Ve1e	OP-8	exmod	O-3	rcc	M-25	xrec	M-48
XCbcex	OP-63	exphi	M-5	rcc	O-24	xrec	O-47
XIex	OP-17	exphi	O-4	rcv	M-26		

Compact Bipolar-Transistor Model (bjtd3500)

This is SimKit 4.0

This device is supported within altergroups.

This device is dynamically loaded from the shared object /vobs/spectre_dev/tools.lnx86/cmi/lib/5.0.doc/libphilips_sh.so

Instance Definition

```
Name c b e modelName parameter=value ...
```

Instance Parameters

- | | | |
|---|------------|--|
| 1 | mult=1 | Number of devices in parallel. |
| 2 | region=fwd | Estimated DC operating region, used as a convergence aid. Possible values are off, sat, rev, or fwd. |
| 3 | m=1 | Multiplicity factor. |
| 4 | area=1 | alias of mult. |

Model Definition

```
model modelName bjtd3500 parameter=value ...
```

Model Parameters

- | | | |
|---|----------------|--|
| 1 | level=3.5e+03 | Bipolar Level. |
| 2 | tref=25 deg. C | Reference temperature. |
| 3 | dta=0 K | Difference between the local ambient and global ambient temperature. |
| 4 | exmod=1 | Flag for extended modeling of reverse current gain. |
| 5 | exphi=1 | Flag for the distributed high-frequency effects in transient. |
| 6 | exavl=0 | Flag for extended modeling of avalanche currents. |

Virtuoso Simulator Components and Device Models Reference

Philips Models

7	$is=2.2e-17$ A	Collector-emitter saturation current.
8	$ik=0.1$ A	Collector-emitter high injection knee current.
9	$ver=2.5$ V	Reverse Early voltage.
10	$vef=44$ V	Forward Early voltage.
11	$bf=215$	Ideal forward current gain.
12	$ibf=2.7e-15$ A	Saturation current of the non-ideal forward base current.
13	$m1f=2$	Non ideality factor of the non-ideal forward base current.
14	$mhf=1$	Non ideality factor of the non-ideal forward base current.
15	$m1r=2$	Non ideality factor of the non-ideal reverse base current.
16	$mhr=1$	Non ideality factor of the ideal reverse base current.
17	$mf=1$	Non ideality factor of main current.
18	$xibi=0$	Part of ideal base current that belongs to the sidewall.
19	$bri=7$	Ideal reverse current gain.
20	$ibr=1e-15$ A	Saturation current of the non-ideal reverse base current.
21	$v1r=0.2$ V	Cross-over voltage of the non-ideal reverse base current.
22	$xext=0.63$	Part of I_{ex} , Q_{tex} , Q_{ex} and I_{sub} that depends on V_{bc1} instead of V_{b1c1} .
23	$wav1=1.1e-06$ m	Epilayer thickness used in weak-avalanche model.
24	$vav1=3$ V	Voltage determining curvature of avalanche current.
25	$sfh=0.3$	Current spreading factor of avalanche model (when $EXAVL=1$).
26	$re=5$ Ω	Emitter resistance.
27	$rbc=23$ Ω	Constant part of the base resistance.

Virtuoso Simulator Components and Device Models Reference

Philips Models

28	$rbv=18 \ \Omega$	Zero-bias value of the variable part of the base resistance.
29	$rcc=12 \ \Omega$	Constant part of collector resistance.
30	$rcv=150 \ \Omega$	Resistance of the un-modulated epilayer.
31	$srcrv=1.25e+03 \ \Omega$	Space charge resistance of the epilayer.
32	$ihc=0.004 \ A$	Critical current for velocity saturation in the epilayer.
33	$axi=0.3$	Smoothness parameter for the onset of quasi-saturation.
34	$cje=7.3e-14 \ F$	Zero-bias emitter-base depletion capacitance.
35	$vde=0.95 \ V$	Emitter-base diffusion voltage.
36	$pe=0.4$	Emitter-base grading coefficient.
37	$xcje=0.4$	Fraction of the emitter-base depletion capacitance that belongs to the sidewall.
38	$cbeo=0$	Emitter-base overlap capacitance.
39	$cjc=7.8e-14 \ F$	Zero-bias collector-base depletion capacitance.
40	$vdc=0.68 \ V$	Collector-base diffusion voltage.
41	$pc=0.5$	Collector-base grading coefficient.
42	$xp=0.35$	Constant part of C_{jc} .
43	$mc=0.5$	Coefficient for the current modulation of the collector-base depletion capacitance.
44	$xcjc=0.032$	Fraction of the collector-base depletion capacitance under the emitter.
45	$cbco=0$	Collector-base overlap capacitance.
46	$vos=0.04 \ V$	Voltage describing overshoot.
47	$isat=0.067 \ A$	Saturation current.

Virtuoso Simulator Components and Device Models Reference

Philips Models

48	<code>repi=6 Ω</code>	Ohmic resistance epilayer.
49	<code>rdmin=0</code>	Minimum relative collector doping.
50	<code>sbn=0.1</code>	Smoothness parameter Qtc model.
51	<code>sbeb=0.1</code>	Smoothness parameter Qtc model.
52	<code>etavdr=0.23</code>	Slope-parameter of Vdrift at high electric field.
53	<code>nvdr=4</code>	Power describing saturation behavior of Qtc.
54	<code>alfaw=0</code>	Smooth switch for reach through modeling.
55	<code>sw=0.1</code>	Smoothness parameter for reach through modeling.
56	<code>mtau=1</code>	Non-ideality factor of the emitter stored charge.
57	<code>taue=2e-12 s</code>	Minimum transit time of stored emitter charge.
58	<code>taub=4.2e-12 s</code>	Transit time of stored base charge.
59	<code>tepi=4.1e-11 s</code>	Transit time of stored epilayer charge.
60	<code>taur=5.2e-10 s</code>	Transit time of reverse extrinsic base charge.
61	<code>deg=0 eV</code>	Bandgap difference over the base.
62	<code>xrec=0</code>	Pre-factor of the recombination part of Ib1.
63	<code>aqbo=0.3</code>	Temperature coefficient of the zero-bias base charge.
64	<code>ae=0</code>	Temperature coefficient of the resistivity of the emitter.
65	<code>ab=1</code>	Temperature coefficient of the resistivity of the base.
66	<code>dais=0</code>	Parameter for fine tuning of temperature dependence of collector-emitter saturation current.
67	<code>aepi=2.5</code>	Temperature coefficient of the resistivity of the epilayer.
68	<code>aex=0.62</code>	Temperature coefficient of the resistivity of the extrinsic base.

Virtuoso Simulator Components and Device Models Reference

Philips Models

69	<code>ac=2</code>	Temperature coefficient of the resistivity of the buried layer.
70	<code>aisat=-0.37</code>	Temperature coefficient of the saturation current.
71	<code>dvgbf=0.05 V</code>	Bandgap voltage difference of forward current gain.
72	<code>dvgbr=0.045 V</code>	Bandgap voltage difference of reverse current gain.
73	<code>vgb=1.17 V</code>	Bandgap voltage of the base.
74	<code>vgc=1.18 V</code>	Bandgap voltage of the collector.
75	<code>vgj=1.15 V</code>	Bandgap voltage recombination emitter-base junction.
76	<code>dvgte=0.05 V</code>	Bandgap voltage difference of emitter stored charge.
77	<code>af=2</code>	Exponent of the Flicker-noise.
78	<code>kf=2e-11</code>	Flicker-noise coefficient of the ideal base current.
79	<code>kfn=2e-11</code>	Flicker-noise coefficient of the non-ideal base current.
80	<code>kav1=0</code>	Switch for white noise contribution due to avalanche.
81	<code>type=n</code>	Transistor gender. Possible values are <code>n</code> , <code>p</code> , <code>npn</code> , <code>pnnp</code> , <code>npnv</code> , <code>pnnpv</code> , <code>npnl</code> , or <code>pnpl</code> .
82	<code>imax=1.0 A</code>	Explosion current.
83	<code>tnom (deg. C)</code>	alias of <code>tnom</code> .
84	<code>tr (deg. C)</code>	alias of <code>tnom</code> .

Output Parameters

1	<code>tref (deg. C)</code>	Reference temperature.
2	<code>dta (K)</code>	Difference between the local ambient and global ambient temperatures.
3	<code>exmod</code>	Flag for extended modeling of reverse current gain.
4	<code>exphi</code>	Flag for the distributed high-frequency effects in transient.

Virtuoso Simulator Components and Device Models Reference

Philips Models

5	exavl	Flag for extended modeling of avalanche currents.
6	is (A)	Collector-emitter saturation current.
7	ik (A)	Collector-emitter high injection knee current.
8	ver (V)	Reverse Early voltage.
9	vef (V)	Forward Early voltage.
10	bf	Ideal forward current gain.
11	ibf (A)	Saturation current of the non-ideal forward base current.
12	mlf	Non ideality factor of the non-ideal forward base current.
13	mhf	Non ideality factor of the ideal forward base current.
14	mlr	Non ideality factor of the non-ideal reverse base current.
15	mhr	Non ideality factor of the ideal reverse base current.
16	mf	Non ideality factor of main current.
17	xibi	Part of ideal base current that belongs to the sidewall.
18	bri	Ideal reverse current gain.
19	ibr (A)	Saturation current of the non-ideal reverse base current.
20	vlr (V)	Cross-over voltage of the non-ideal reverse base current.
21	xext	Part of I_{ex} , Q_{tex} , Q_{ex} and I_{sub} that depends on V_{bc1} instead of V_{b1c1} .
22	wavl (M)	Epilayer thickness used in weak-avalanche model.
23	vavl (V)	Voltage determining curvature of avalanche current.
24	sfh	Current spreading factor of avalanche model (when EXAVL=1).
25	re (Ω)	Emitter resistance.

Virtuoso Simulator Components and Device Models Reference

Philips Models

26	r_{bc} (Ω)	Constant part of the base resistance.
27	r_{bv} (Ω)	Zero-bias value of the variable part of the base resistance.
28	r_{cc} (Ω)	Constant part of collector resistance.
29	r_{cv} (Ω)	Resistance of the un-modulated epilayer.
30	scr_{cv} (Ω)	Space charge resistance of the epilayer.
31	i_{hc} (A)	Critical current for velocity saturation in the epilayer.
32	axi	Smoothness parameter for the onset of quasi-saturation.
33	c_{je} (F)	Zero-bias emitter-base depletion capacitance.
34	v_{de} (V)	Emitter-base diffusion voltage.
35	pe	Emitter-base grading coefficient.
36	xc_{je}	Fraction of the emitter-base depletion capacitance that belongs to the sidewall.
37	c_{beo}	Emitter-base overlap capacitance.
38	c_{jc} (F)	Zero-bias collector-base depletion capacitance.
39	v_{dc} (V)	Collector-base diffusion voltage.
40	pc	Collector-base grading coefficient.
41	x_p	Constant part of C_{jc} .
42	mc	Coefficient for the current modulation of the collector-base depletion capacitance.
43	xc_{jc}	Fraction of the collector-base depletion capacitance under the emitter.
44	$cbco$	Collector-base overlap capacitance.
45	v_{os} (V)	Voltage describing overshoot.

Virtuoso Simulator Components and Device Models Reference

Philips Models

46	isat (A)	Saturation current.
47	repi (Ω)	Ohmic resistance epilayer.
48	rdmin	Minimum relative collector doping.
49	sbjn	Smoothness parameter Qtc model.
50	sbeb	Smoothness parameter Qtc model.
51	etavdr	Slope-parameter of Vdrift at high electric field.
52	nvdr	Power describing saturation behavior of Qtc.
53	alfaw	Smooth switch for reach through modeling.
54	sw	Smoothness parameter for reach through modeling.
55	mtau	Non-ideality factor of the emitter stored charge.
56	taue (s)	Minimum transit time of stored emitter charge.
57	taub (s)	Transit time of stored base charge.
58	tepi (s)	Transit time of stored epilayer charge.
59	taur (s)	Transit time of reverse extrinsic stored base charge.
60	deg (eV)	Bandgap difference over the base.
61	xrec	Pre-factor of the recombination part of Ib1.
62	aqbo	Temperature coefficient of the zero-bias base charge.
63	ae	Temperature coefficient of the resistivity of the emitter.
64	ab	Temperature coefficient of the resistivity of the base.
65	dais	Parameter for fine tuning of temperature dependence of collector-emitter saturation current.
66	aepi	Temperature coefficient of the resistivity of the epilayer.

Virtuoso Simulator Components and Device Models Reference

Philips Models

67	aex	Temperature coefficient of the resistivity of the extrinsic base.
68	ac	Temperature coefficient of the resistivity of the buried layer.
69	aisat	Temperature coefficient of the saturation current.
70	dvgbf (V)	Bandgap voltage difference of forward current gain.
71	dvgbr (V)	Bandgap voltage difference of reverse current gain.
72	vgb (V)	Bandgap voltage of the base.
73	vgc (V)	Bandgap voltage of the collector.
74	vgj (V)	Bandgap voltage recombination emitter-base junction.
75	dvgte (V)	Bandgap voltage difference of emitter stored charge.
76	af	Exponent of the Flicker-noise.
77	kf	Flicker-noise coefficient of the ideal base current.
78	kfn	Flicker-noise coefficient of the non-ideal base current.
79	kav1	Switch for white noise contribution due to avalanche.

Operating-Point Parameters

1	Ic (A)	External DC collector current.
2	Ib (A)	External DC base current.
3	BetaDC	External DC current gain I_c/I_b .
4	Vb2e1 (V)	Internal base-emitter bias.
5	Vb2c2 (V)	Internal base-collector bias.
6	Vb2c1 (V)	Internal base-collector bias including epilayer.
7	Vb1c1 (V)	External base-collector bias without contact resistances.
8	Ve1e (V)	Bias over emitter resistance.

Virtuoso Simulator Components and Device Models Reference

Philips Models

9	I_n (A)	Main current.
10	I_{c1c2} (A)	Epilayer current.
11	I_{b1b2} (A)	Pinched-base current.
12	I_{b1} (A)	Ideal forward base current.
13	$S I_{b1}$ (A)	Ideal side-wall base current.
14	I_{b2} (A)	Non-ideal forward base current.
15	I_{b3} (A)	Non-ideal reverse base current.
16	I_{ex} (A)	Extrinsic reverse base current.
17	$X I_{ex}$ (A)	Extrinsic reverse base current.
18	I_{av1} (A)	Avalanche current.
19	I_{RE} (A)	Current through emitter resistance.
20	I_{RBC} (A)	Current through constant base resistance.
21	I_{RCC} (A)	Current through constant collector resistance.
22	Q_e (C)	Emitter charge or emitter neutral charge.
23	Q_{te} (C)	Base-emitter depletion charge.
24	$S Q_{te}$ (C)	Sidewall base-emitter depletion charge.
25	Q_{be} (C)	Base-emitter diffusion charge.
26	Q_{bc} (C)	Base-collector diffusion charge.
27	Q_{tc} (C)	Base-collector depletion charge.
28	Q_{epi} (C)	Epilayer diffusion charge.
29	Q_{b1b2} (C)	AC current crowding charge.
30	Q_{tex} (C)	Extrinsic base-collector depletion charge.

Virtuoso Simulator Components and Device Models Reference

Philips Models

31	XQ_{tex} (C)	Extrinsic base-collector depletion charge.
32	Q_{ex} (C)	Extrinsic base-collector diffusion charge.
33	XQ_{ex} (C)	Extrinsic base-collector diffusion charge.
34	g_x (1/Ω)	Forward transconductance.
35	g_y (1/Ω)	Reverse transconductance.
36	g_z (1/Ω)	Reverse transconductance.
37	S_{gpi} (1/Ω)	Conductance sidewall b-e junction.
38	g_{pix} (1/Ω)	Conductance floor b-e junction.
39	g_{piy} (1/Ω)	Early effect on recombination base current.
40	g_{piz} (1/Ω)	Early effect on recombination base current.
41	g_{mux} (1/Ω)	Early effect on avalanche current limiting.
42	g_{muy} (1/Ω)	Conductance of avalanche current.
43	g_{muz} (1/Ω)	Conductance of avalanche current.
44	g_{muex} (1/Ω)	Conductance extrinsic b-c junction.
45	Xg_{muex} (1/Ω)	Conductance extrinsic b-c junction.
46	g_{rcvy} (1/Ω)	Conductance of the epilayer current.
47	g_{rcvz} (1/Ω)	Conductance of the epilayer current.
48	R_{bv} (Ω)	Conductance of the epilayer current.
49	g_{rbvx} (1/Ω)	Early-effect on base resistance.
50	g_{rbvy} (1/Ω)	Early-effect on base resistance.
51	g_{rbvz} (1/Ω)	Early-effect on base resistance:.
52	R_E (Ω)	Early-effect on base resistance:.

Virtuoso Simulator Components and Device Models Reference

Philips Models

53	RBC (Ω)	Early-effect on base resistance:.
54	RCC (Ω)	Early-effect on base resistance:.
55	SCbe (F)	Capacitance sidewall b-e junction.
56	Cbex (F)	Capacitance floor b-e junction.
57	Cbey (F)	Early effect on b-e diffusion charge.
58	Cbez (F)	Early effect on b-e diffusion charge.
59	Cbcx (F)	Early effect on b-c diffusion charge.
60	Cbcy (F)	Capacitance floor b-c junction.
61	Cbcz (F)	Capacitance floor b-c junction.
62	Cbcex (F)	Capacitance extrinsic b-c junction.
63	XCbcex (F)	Capacitance extrinsic b-c junction.
64	Cb1b2 (F)	Capacitance AC current crowding.
65	Cb1b2x (F)	Cross-capacitance AC current crowding .
66	Cb1b2y (F)	Cross-capacitance AC current crowding.
67	Cb1b2z (F)	Cross-capacitance AC current crowding.
68	gm ($1/\Omega$)	Transconductance.
69	beta	Current amplification.
70	gout ($1/\Omega$)	Output conductance.
71	gm _u ($1/\Omega$)	Feedback transconductance.
72	RB (Ω)	Base resistance.
73	Cbe (F)	Base-emitter capacitance.
74	Cbc (F)	Base-collector capacitance.

Virtuoso Simulator Components and Device Models Reference

Philips Models

75	f_T (Hz)	Good approximation for cut-off frequency.
76	I_{qs} (A)	Current at onset of quasi-saturation.
77	X_{iWepi} (M)	Thickness of injection layer.
78	$V_{b2c2star}$ (V)	Physical value of internal base-collector bias.
79	P_{diss} (W)	Dissipation.
80	T_K (K)	Actual temperature.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

BetaDC	OP-3	ac	M-69	gpiz	OP-40	re	O-25
Cb1b2	OP-64	ac	O-68	grbvz	OP-49	region	I-2
Cb1b2x	OP-65	ae	M-64	grbvy	OP-50	repi	M-48
Cb1b2y	OP-66	ae	O-63	grbvz	OP-51	repi	O-47
Cb1b2z	OP-67	aepi	M-67	grcvy	OP-46	sbeb	M-51
Cbc	OP-74	aepi	O-66	grcvz	OP-47	sbeb	O-50
Cbcex	OP-62	aex	M-68	gx	OP-34	sbnj	M-50
Cbcx	OP-59	aex	O-67	gy	OP-35	sbnj	O-49
Cbcy	OP-60	af	M-77	gz	OP-36	scrcv	M-31
Cbcz	OP-61	af	O-76	ibf	M-12	scrcv	O-30

Virtuoso Simulator Components and Device Models Reference

Philips Models

Cbe	OP-73	aisat	M-70	ibf	O-11	sfh	M-25
Cbex	OP-56	aisat	O-69	ibr	M-20	sfh	O-24
Cbey	OP-57	alfaw	M-54	ibr	O-19	sw	M-55
Cbez	OP-58	alfaw	O-53	ihc	M-32	sw	O-54
IRBC	OP-20	aqbo	M-63	ihc	O-31	taub	M-58
IRCC	OP-21	aqbo	O-62	ik	M-8	taub	O-57
IRE	OP-19	area	I-4	ik	O-7	taue	M-57
Iavl	OP-18	axi	M-33	imax	M-82	taue	O-56
Ib	OP-2	axi	O-32	is	M-7	taur	M-60
Ib1	OP-12	beta	OP-69	is	O-6	taur	O-59
Ib1b2	OP-11	bf	M-11	isat	M-47	tepi	M-59
Ib2	OP-14	bf	O-10	isat	O-46	tepi	O-58
Ib3	OP-15	bri	M-19	kavl	M-80	tnom	M-83
Ic	OP-1	bri	O-18	kavl	O-79	tr	M-84
Ic1c2	OP-10	cbco	M-45	kf	M-78	tref	M-2
Iex	OP-16	cbco	O-44	kf	O-77	tref	O-1
In	OP-9	cbeo	M-38	kfn	M-79	type	M-81
Iqs	OP-76	cbeo	O-37	kfn	O-78	vavl	M-24
Pdiss	OP-79	cjc	M-39	level	M-1	vavl	O-23
Qb1b2	OP-29	cjc	O-38	m	I-3	vdc	M-40
Qbc	OP-26	cje	M-34	mc	M-43	vdc	O-39

Virtuoso Simulator Components and Device Models Reference

Philips Models

Qbe	OP-25	cje	O-33	mc	O-42	vde	M-35
Qe	OP-22	dais	M-66	mf	M-17	vde	O-34
Qepi	OP-28	dais	O-65	mf	O-16	vef	M-10
Qex	OP-32	deg	M-61	mhf	M-14	vef	O-9
Qtc	OP-27	deg	O-60	mhf	O-13	ver	M-9
Qte	OP-23	dta	M-3	mhr	M-16	ver	O-8
Qtex	OP-30	dta	O-2	mhr	O-15	vgb	M-73
RB	OP-72	dvgbf	M-71	mlf	M-13	vgb	O-72
RBC	OP-53	dvgbf	O-70	mlf	O-12	vgc	M-74
RCC	OP-54	dvgbr	M-72	mlr	M-15	vgc	O-73
RE	OP-52	dvgbr	O-71	mlr	O-14	vgj	M-75
Rbv	OP-48	dvgte	M-76	mtau	M-56	vgj	O-74
SCbe	OP-55	dvgte	O-75	mtau	O-55	vlr	M-21
SIb1	OP-13	etavdr	M-52	mult	I-1	vlr	O-20
SQte	OP-24	etavdr	O-51	nvdr	M-53	vos	M-46
Sgpi	OP-37	exavl	M-6	nvdr	O-52	vos	O-45
TK	OP-80	exavl	O-5	pc	M-41	wavl	M-23
Vb1c1	OP-7	exmod	M-4	pc	O-40	wavl	O-22
Vb2c1	OP-6	exmod	O-3	pe	M-36	xcjc	M-44
Vb2c2	OP-5	exphi	M-5	pe	O-35	xcjc	O-43
Vb2c2star	OP-78	exphi	O-4	rbc	M-27	xcje	M-37

Virtuoso Simulator Components and Device Models Reference

Philips Models

Vb2e1	OP-4	fT	OP-75	rbc	O-26	xcje	O-36
Ve1e	OP-8	gm	OP-68	rbv	M-28	xext	M-22
XCbceX	OP-63	gmu	OP-71	rbv	O-27	xext	O-21
XIex	OP-17	gmueX	OP-44	rcc	M-29	xibi	M-18
XQex	OP-33	gmux	OP-41	rcc	O-28	xibi	O-17
XQtex	OP-31	gmuy	OP-42	rcv	M-30	xp	M-42
XgmueX	OP-45	gmuz	OP-43	rcv	O-29	xp	O-41
XiWepi	OP-77	gout	OP-70	rdmin	M-49	xrec	M-62
ab	M-65	gpix	OP-38	rdmin	O-48	xrec	O-61
ab	O-64	gpiy	OP-39	re	M-26		

Compact Bipolar-Transistor Model (bjtd3500t)

This is SimKit 4.0

This device is supported within altergroups.

This device is dynamically loaded from the shared object /vobs/spectre_dev/tools.lnx86/cmi/lib/5.0.doc/libphilips_sh.so

Instance Definition

```
Name c b e dt ModelName parameter=value ...
```

Instance Parameters

- | | | |
|---|------------|---|
| 1 | mult=1 | Number of devices in parallel. |
| 2 | region=fwd | Estimated DC operating region, used as a convergence aid.
Possible values are off, sat, rev, or fwd. |

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 3 `m=1` Multiplicity factor.
- 4 `area=1` alias of mult.

Model Definition

```
model modelName bjtd3500t parameter=value ...
```

Model Parameters

- 1 `level=3.5e+03` Bipolar Level.
- 2 `tref=25 deg. C` Reference temperature.
- 3 `dta=0 K` Difference between the local ambient and global ambient temperature.
- 4 `exmod=1` Flag for extended modeling of reverse current gain.
- 5 `exphi=1` Flag for the distributed high-frequency effects in transient.
- 6 `exavl=0` Flag for extended modeling of avalanche currents.
- 7 `is=2.2e-17 A` Collector-emitter saturation current.
- 8 `ik=0.1 A` Collector-emitter high injection knee current.
- 9 `ver=2.5 V` Reverse Early voltage.
- 10 `vef=44 V` Forward Early voltage.
- 11 `bf=215` Ideal forward current gain.
- 12 `ibf=2.7e-15 A` Saturation current of the non-ideal forward base current.
- 13 `mlf=2` Non ideality factor of the non-ideal forward base current.
- 14 `mhf=1` Non ideality factor of the non-ideal forward base current.
- 15 `mlr=2` Non ideality factor of the non-ideal reverse base current.
- 16 `mhr=1` Non ideality factor of the ideal reverse base current.

Virtuoso Simulator Components and Device Models Reference

Philips Models

17	$m_f=1$	Non ideality factor of main current.
18	$x_{ibi}=0$	Part of ideal base current that belongs to the sidewall.
19	$b_{ri}=7$	Ideal reverse current gain.
20	$i_{br}=1e-15$ A	Saturation current of the non-ideal reverse base current.
21	$v_{lr}=0.2$ V	Cross-over voltage of the non-ideal reverse base current.
22	$x_{ext}=0.63$	Part of I_{ex} , Q_{tex} , Q_{ex} and I_{sub} that depends on V_{bc1} instead of V_{b1c1} .
23	$w_{avl}=1.1e-06$ m	Epilayer thickness used in weak-avalanche model.
24	$v_{avl}=3$ V	Voltage determining curvature of avalanche current.
25	$s_{fh}=0.3$	Current spreading factor of avalanche model (when $EXAVL=1$).
26	$r_e=5$ Ω	Emitter resistance.
27	$r_{bc}=23$ Ω	Constant part of the base resistance.
28	$r_{bv}=18$ Ω	Zero-bias value of the variable part of the base resistance.
29	$r_{cc}=12$ Ω	Constant part of collector resistance.
30	$r_{cv}=150$ Ω	Resistance of the un-modulated epilayer.
31	$s_{rcv}=1.25e+03$ Ω	Space charge resistance of the epilayer.
32	$i_{hc}=0.004$ A	Critical current for velocity saturation in the epilayer.
33	$a_{xi}=0.3$	Smoothness parameter for the onset of quasi-saturation.
34	$c_{je}=7.3e-14$ F	Zero-bias emitter-base depletion capacitance.
35	$v_{de}=0.95$ V	Emitter-base diffusion voltage.
36	$p_e=0.4$	Emitter-base grading coefficient.

Virtuoso Simulator Components and Device Models Reference

Philips Models

37	$x_{cje}=0.4$	Fraction of the emitter-base depletion capacitance that belongs to the sidewall.
38	$c_{beo}=0$	Emitter-base overlap capacitance.
39	$c_{jc}=7.8e-14$ F	Zero-bias collector-base depletion capacitance.
40	$v_{dc}=0.68$ V	Collector-base diffusion voltage.
41	$p_c=0.5$	Collector-base grading coefficient.
42	$x_p=0.35$	Constant part of C_{jc} .
43	$m_c=0.5$	Coefficient for the current modulation of the collector-base depletion capacitance.
44	$x_{cjc}=0.032$	Fraction of the collector-base depletion capacitance under the emitter.
45	$c_{bco}=0$	Collector-base overlap capacitance.
46	$v_{os}=0.04$ V	Voltage describing overshoot.
47	$i_{sat}=0.067$ A	Saturation current.
48	$r_{epi}=6$ Ω	Ohmic resistance epilayer.
49	$r_{dmin}=0$	Minimum relative collector doping.
50	$s_{bjn}=0.1$	Smoothness parameter Qtc model.
51	$s_{beb}=0.1$	Smoothness parameter Qtc model.
52	$e_{tavdr}=0.23$	Slope-parameter of V_{drift} at high electric field.
53	$n_{vdr}=4$	Power describing saturation behavior of Qtc.
54	$alfaw=0$	Smooth switch for reach through modeling.
55	$sw=0.1$	Smoothness parameter for reach through modeling.
56	$m_{tau}=1$	Non-ideality factor of the emitter stored charge.

Virtuoso Simulator Components and Device Models Reference

Philips Models

57	$\tau_{aue}=2e-12$ s	Minimum transit time of stored emitter charge.
58	$\tau_{aub}=4.2e-12$ s	Transit time of stored base charge.
59	$\tau_{epi}=4.1e-11$ s	Transit time of stored epilayer charge.
60	$\tau_{aur}=5.2e-10$ s	Transit time of reverse extrinsic base charge.
61	$\text{deg}=0$ eV	Bandgap difference over the base.
62	$x_{rec}=0$	Pre-factor of the recombination part of I_{b1} .
63	$a_{qbo}=0.3$	Temperature coefficient of the zero-bias base charge.
64	$a_e=0$	Temperature coefficient of the resistivity of the emitter.
65	$a_b=1$	Temperature coefficient of the resistivity of the base.
66	$d_{ais}=0$	Parameter for fine tuning of temperature dependence of collector-emitter saturation current.
67	$a_{epi}=2.5$	Temperature coefficient of the resistivity of the epilayer.
68	$a_{ex}=0.62$	Temperature coefficient of the resistivity of the extrinsic base.
69	$a_c=2$	Temperature coefficient of the resistivity of the buried layer.
70	$a_{isat}=-0.37$	Temperature coefficient of the saturation current.
71	$d_{vgbf}=0.05$ V	Bandgap voltage difference of forward current gain.
72	$d_{vgbr}=0.045$ V	Bandgap voltage difference of reverse current gain.
73	$v_{gb}=1.17$ V	Bandgap voltage of the base.
74	$v_{gc}=1.18$ V	Bandgap voltage of the collector.
75	$v_{gj}=1.15$ V	Bandgap voltage recombination emitter-base junction.
76	$d_{vgte}=0.05$ V	Bandgap voltage difference of emitter stored charge.
77	$a_f=2$	Exponent of the Flicker-noise.

Virtuoso Simulator Components and Device Models Reference

Philips Models

78	<code>kf=2e-11</code>	Flicker-noise coefficient of the ideal base current.
79	<code>kfn=2e-11</code>	Flicker-noise coefficient of the non-ideal base current.
80	<code>kavl=0</code>	Switch for white noise contribution due to avalanche.
81	<code>rth=300 K/W</code>	Thermal resistance.
82	<code>cth=3e-09 J/K</code>	Thermal capacitance.
83	<code>ath=0</code>	Temperature coefficient of the thermal resistance.
84	<code>dtmax=1e+03 K</code>	Maximal dynamic temperature increase.
85	<code>exrth=0</code>	Flag for extended modeling of non-linear thermal resistance.
86	<code>type=n</code>	Transistor gender. Possible values are <code>n</code> , <code>p</code> , <code>npn</code> , <code>pnnp</code> , <code>nnpv</code> , <code>pnpv</code> , <code>npnl</code> , or <code>pnpl</code> .
87	<code>imax=1.0 A</code>	Explosion current.
88	<code>tnom (deg. C)</code>	alias of <code>tnom</code> .
89	<code>tr (deg. C)</code>	alias of <code>tnom</code> .

Output Parameters

1	<code>tref (deg. C)</code>	Reference temperature.
2	<code>dta (K)</code>	Difference between the local ambient and global ambient temperatures.
3	<code>exmod</code>	Flag for extended modeling of reverse current gain.
4	<code>exphi</code>	Flag for the distributed high-frequency effects in transient.
5	<code>exavl</code>	Flag for extended modeling of avalanche currents.
6	<code>is (A)</code>	Collector-emitter saturation current.
7	<code>ik (A)</code>	Collector-emitter high injection knee current.
8	<code>ver (V)</code>	Reverse Early voltage.

Virtuoso Simulator Components and Device Models Reference

Philips Models

9	v_{ef} (V)	Forward Early voltage.
10	b_f	Ideal forward current gain.
11	i_{bf} (A)	Saturation current of the non-ideal forward base current.
12	m_{lf}	Non ideality factor of the non-ideal forward base current.
13	m_{hf}	Non ideality factor of the ideal forward base current.
14	m_{lr}	Non ideality factor of the non-ideal reverse base current.
15	m_{hr}	Non ideality factor of the ideal reverse base current.
16	m_f	Non ideality factor of main current.
17	x_{ibi}	Part of ideal base current that belongs to the sidewall.
18	b_{ri}	Ideal reverse current gain.
19	i_{br} (A)	Saturation current of the non-ideal reverse base current.
20	v_{lr} (V)	Cross-over voltage of the non-ideal reverse base current.
21	x_{ext}	Part of I_{ex} , Q_{tex} , Q_{ex} and I_{sub} that depends on V_{bc1} instead of V_{b1c1} .
22	w_{avl} (M)	Epilayer thickness used in weak-avalanche model.
23	v_{avl} (V)	Voltage determining curvature of avalanche current.
24	s_{fh}	Current spreading factor of avalanche model (when $EXAVL=1$).
25	r_e (Ω)	Emitter resistance.
26	r_{bc} (Ω)	Constant part of the base resistance.
27	r_{bv} (Ω)	Zero-bias value of the variable part of the base resistance.
28	r_{cc} (Ω)	Constant part of collector resistance.
29	r_{cv} (Ω)	Resistance of the un-modulated epilayer.

Virtuoso Simulator Components and Device Models Reference

Philips Models

30	<code>scrcv</code> (Ω)	Space charge resistance of the epilayer.
31	<code>ihc</code> (A)	Critical current for velocity saturation in the epilayer.
32	<code>axi</code>	Smoothness parameter for the onset of quasi-saturation.
33	<code>cje</code> (F)	Zero-bias emitter-base depletion capacitance.
34	<code>vde</code> (V)	Emitter-base diffusion voltage.
35	<code>pe</code>	Emitter-base grading coefficient.
36	<code>xcje</code>	Fraction of the emitter-base depletion capacitance that belongs to the sidewall.
37	<code>cbeo</code>	Emitter-base overlap capacitance.
38	<code>cjc</code> (F)	Zero-bias collector-base depletion capacitance.
39	<code>vdc</code> (V)	Collector-base diffusion voltage.
40	<code>pc</code>	Collector-base grading coefficient.
41	<code>xp</code>	Constant part of <code>Cjc</code> .
42	<code>mc</code>	Coefficient for the current modulation of the collector-base depletion capacitance.
43	<code>xcjc</code>	Fraction of the collector-base depletion capacitance under the emitter.
44	<code>cbco</code>	Collector-base overlap capacitance.
45	<code>vos</code> (V)	Voltage describing overshoot.
46	<code>isat</code> (A)	Saturation current.
47	<code>repi</code> (Ω)	Ohmic resistance epilayer.
48	<code>rdmin</code>	Minimum relative collector doping.
49	<code>sbn</code>	Smoothness parameter <code>Qtc</code> model.

Virtuoso Simulator Components and Device Models Reference

Philips Models

50	sbeb	Smoothness parameter Qtc model.
51	etavdr	Slope-parameter of Vdrift at high electric field.
52	nvdr	Power describing saturation behavior of Qtc.
53	alfaw	Smooth switch for reach through modeling.
54	sw	Smoothness parameter for reach through modeling.
55	mtau	Non-ideality factor of the emitter stored charge.
56	taue (s)	Minimum transit time of stored emitter charge.
57	taub (s)	Transit time of stored base charge.
58	tepi (s)	Transit time of stored epilayer charge.
59	taur (s)	Transit time of reverse extrinsic stored base charge.
60	deg (eV)	Bandgap difference over the base.
61	xrec	Pre-factor of the recombination part of Ib1.
62	aqbo	Temperature coefficient of the zero-bias base charge.
63	ae	Temperature coefficient of the resistivity of the emitter.
64	ab	Temperature coefficient of the resistivity of the base.
65	dais	Parameter for fine tuning of temperature dependence of collector-emitter saturation current.
66	aepi	Temperature coefficient of the resistivity of the epilayer.
67	aex	Temperature coefficient of the resistivity of the extrinsic base.
68	ac	Temperature coefficient of the resistivity of the buried layer.
69	aisat	Temperature coefficient of the saturation current.
70	dvgbf (V)	Bandgap voltage difference of forward current gain.

Virtuoso Simulator Components and Device Models Reference

Philips Models

71	<code>dvgbr</code> (V)	Bandgap voltage difference of reverse current gain.
72	<code>vgb</code> (V)	Bandgap voltage of the base.
73	<code>vgc</code> (V)	Bandgap voltage of the collector.
74	<code>vgj</code> (V)	Bandgap voltage recombination emitter-base junction.
75	<code>dvgte</code> (V)	Bandgap voltage difference of emitter stored charge.
76	<code>af</code>	Exponent of the Flicker-noise.
77	<code>kf</code>	Flicker-noise coefficient of the ideal base current.
78	<code>kfn</code>	Flicker-noise coefficient of the non-ideal base current.
79	<code>kavl</code>	Switch for white noise contribution due to avalanche.
80	<code>rth</code> (K/W)	Thermal resistance.
81	<code>cth</code> (J/K)	Thermal capacitance.
82	<code>ath</code>	Temperature coefficient of the thermal resistance.
83	<code>dtmax</code> (K)	Maximal dynamic temperature increase.
84	<code>exrth</code>	Flag for extended modeling of non-linear thermal resistance.

Operating-Point Parameters

1	<code>Ic</code> (A)	External DC collector current.
2	<code>Ib</code> (A)	External DC base current.
3	<code>BetaDC</code>	External DC current gain I_c/I_b .
4	<code>Vb2e1</code> (V)	Internal base-emitter bias.
5	<code>Vb2c2</code> (V)	Internal base-collector bias.
6	<code>Vb2c1</code> (V)	Internal base-collector bias including epilayer.
7	<code>Vb1c1</code> (V)	External base-collector bias without contact resistances.

Virtuoso Simulator Components and Device Models Reference

Philips Models

8	V_{e1e} (V)	Bias over emitter resistance.
9	I_n (A)	Main current.
10	I_{c1c2} (A)	Epilayer current.
11	I_{b1b2} (A)	Pinched-base current.
12	I_{b1} (A)	Ideal forward base current.
13	$S I_{b1}$ (A)	Ideal side-wall base current.
14	I_{b2} (A)	Non-ideal forward base current.
15	I_{b3} (A)	Non-ideal reverse base current.
16	I_{ex} (A)	Extrinsic reverse base current.
17	$X I_{ex}$ (A)	Extrinsic reverse base current.
18	I_{av1} (A)	Avalanche current.
19	I_{RE} (A)	Current through emitter resistance.
20	I_{RBC} (A)	Current through constant base resistance.
21	I_{RCC} (A)	Current through constant collector resistance.
22	Q_e (C)	Emitter charge or emitter neutral charge.
23	Q_{te} (C)	Base-emitter depletion charge.
24	$S Q_{te}$ (C)	Sidewall base-emitter depletion charge.
25	Q_{be} (C)	Base-emitter diffusion charge.
26	Q_{bc} (C)	Base-collector diffusion charge.
27	Q_{tc} (C)	Base-collector depletion charge.
28	Q_{epi} (C)	Epilayer diffusion charge.
29	Q_{b1b2} (C)	AC current crowding charge.

Virtuoso Simulator Components and Device Models Reference

Philips Models

30	Q_{tex} (C)	Extrinsic base-collector depletion charge.
31	XQ_{tex} (C)	Extrinsic base-collector depletion charge.
32	Q_{ex} (C)	Extrinsic base-collector diffusion charge.
33	XQ_{ex} (C)	Extrinsic base-collector diffusion charge.
34	g_x ($1/\Omega$)	Forward transconductance.
35	g_y ($1/\Omega$)	Reverse transconductance.
36	g_z ($1/\Omega$)	Reverse transconductance.
37	S_{gpi} ($1/\Omega$)	Conductance sidewall b-e junction.
38	g_{pix} ($1/\Omega$)	Conductance floor b-e junction.
39	g_{piy} ($1/\Omega$)	Early effect on recombination base current.
40	g_{piz} ($1/\Omega$)	Early effect on recombination base current.
41	g_{mux} ($1/\Omega$)	Early effect on avalanche current limiting.
42	g_{muy} ($1/\Omega$)	Conductance of avalanche current.
43	g_{muz} ($1/\Omega$)	Conductance of avalanche current.
44	g_{muex} ($1/\Omega$)	Conductance extrinsic b-c junction.
45	Xg_{muex} ($1/\Omega$)	Conductance extrinsic b-c junction.
46	g_{rcvy} ($1/\Omega$)	Conductance of the epilayer current.
47	g_{rcvz} ($1/\Omega$)	Conductance of the epilayer current.
48	R_{bv} (Ω)	Conductance of the epilayer current.
49	g_{rbvx} ($1/\Omega$)	Early-effect on base resistance.
50	g_{rbvy} ($1/\Omega$)	Early-effect on base resistance.
51	g_{rbvz} ($1/\Omega$)	Early-effect on base resistance:.

Virtuoso Simulator Components and Device Models Reference

Philips Models

52	RE (Ω)	Early-effect on base resistance:.
53	RBC (Ω)	Early-effect on base resistance:.
54	RCC (Ω)	Early-effect on base resistance:.
55	SCbe (F)	Capacitance sidewall b-e junction.
56	Cbex (F)	Capacitance floor b-e junction.
57	Cbey (F)	Early effect on b-e diffusion charge.
58	Cbez (F)	Early effect on b-e diffusion charge.
59	Cbcx (F)	Early effect on b-c diffusion charge.
60	Cbcy (F)	Capacitance floor b-c junction.
61	Cbcz (F)	Capacitance floor b-c junction.
62	Cbcex (F)	Capacitance extrinsic b-c junction.
63	XCbcex (F)	Capacitance extrinsic b-c junction.
64	Cb1b2 (F)	Capacitance AC current crowding.
65	Cb1b2x (F)	Cross-capacitance AC current crowding .
66	Cb1b2y (F)	Cross-capacitance AC current crowding.
67	Cb1b2z (F)	Cross-capacitance AC current crowding.
68	gm ($1/\Omega$)	Transconductance.
69	beta	Current amplification.
70	gout ($1/\Omega$)	Output conductance.
71	gm _u ($1/\Omega$)	Feedback transconductance.
72	RB (Ω)	Base resistance.
73	Cbe (F)	Base-emitter capacitance.

Virtuoso Simulator Components and Device Models Reference

Philips Models

74	Cbc (F)	Base-collector capacitance.
75	fT (Hz)	Good approximation for cut-off frequency.
76	Iqs (A)	Current at onset of quasi-saturation.
77	XiWepi (M)	Thickness of injection layer.
78	Vb2c2star (V)	Physical value of internal base-collector bias.
79	Pdiss (W)	Dissipation.
80	TK (K)	Actual temperature.

Parameter Index

In the following index, I refers to instance parameters, M refers to the model parameters section, O refers to the output parameters section, and OP refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of M-35 means the 35th model parameter.

BetaDC	OP-3	ae	O-63	gpix	OP-38	region	I-2
Cb1b2	OP-64	aepi	M-67	gpiy	OP-39	repi	M-48
Cb1b2x	OP-65	aepi	O-66	gpiz	OP-40	repi	O-47
Cb1b2y	OP-66	aex	M-68	grbvz	OP-49	rth	M-81
Cb1b2z	OP-67	aex	O-67	grbvy	OP-50	rth	O-80
Cbc	OP-74	af	M-77	grbvz	OP-51	sbeb	M-51
Cbcex	OP-62	af	O-76	grcvy	OP-46	sbeb	O-50
Cbcx	OP-59	aisat	M-70	grcvz	OP-47	sbjn	M-50
Cbcy	OP-60	aisat	O-69	gx	OP-34	sbjn	O-49

Virtuoso Simulator Components and Device Models Reference

Philips Models

Cbcz	OP-61	alfaw	M-54	gy	OP-35	scrcv	M-31
Cbe	OP-73	alfaw	O-53	gz	OP-36	scrcv	O-30
Cbex	OP-56	aqbo	M-63	ibf	M-12	sfh	M-25
Cbey	OP-57	aqbo	O-62	ibf	O-11	sfh	O-24
Cbez	OP-58	area	I-4	ibr	M-20	sw	M-55
IRBC	OP-20	ath	M-83	ibr	O-19	sw	O-54
IRCC	OP-21	ath	O-82	ihc	M-32	taub	M-58
IRE	OP-19	axi	M-33	ihc	O-31	taub	O-57
Iavl	OP-18	axi	O-32	ik	M-8	taue	M-57
Ib	OP-2	beta	OP-69	ik	O-7	taue	O-56
Ib1	OP-12	bf	M-11	imax	M-87	taur	M-60
Ib1b2	OP-11	bf	O-10	is	M-7	taur	O-59
Ib2	OP-14	bri	M-19	is	O-6	tepi	M-59
Ib3	OP-15	bri	O-18	isat	M-47	tepi	O-58
Ic	OP-1	cbco	M-45	isat	O-46	tnom	M-88
Ic1c2	OP-10	cbco	O-44	kavl	M-80	tr	M-89
Iex	OP-16	cbeo	M-38	kavl	O-79	tref	M-2
In	OP-9	cbeo	O-37	kf	M-78	tref	O-1
Iqs	OP-76	cjc	M-39	kf	O-77	type	M-86
Pdiss	OP-79	cjc	O-38	kfn	M-79	vavl	M-24
Qb1b2	OP-29	cje	M-34	kfn	O-78	vavl	O-23

Virtuoso Simulator Components and Device Models Reference

Philips Models

Qbc	OP-26	cje	O-33	level	M-1	vdc	M-40
Qbe	OP-25	cth	M-82	m	I-3	vdc	O-39
Qe	OP-22	cth	O-81	mc	M-43	vde	M-35
Qepi	OP-28	dais	M-66	mc	O-42	vde	O-34
Qex	OP-32	dais	O-65	mf	M-17	vef	M-10
Qtc	OP-27	deg	M-61	mf	O-16	vef	O-9
Qte	OP-23	deg	O-60	mhf	M-14	ver	M-9
Qtex	OP-30	dta	M-3	mhf	O-13	ver	O-8
RB	OP-72	dta	O-2	mhr	M-16	vgb	M-73
RBC	OP-53	dtmax	M-84	mhr	O-15	vgb	O-72
RCC	OP-54	dtmax	O-83	mlf	M-13	vgc	M-74
RE	OP-52	dvgbf	M-71	mlf	O-12	vgc	O-73
Rbv	OP-48	dvgbf	O-70	mlr	M-15	vgj	M-75
SCbe	OP-55	dvgbr	M-72	mlr	O-14	vgj	O-74
SIb1	OP-13	dvgbr	O-71	mtau	M-56	vlr	M-21
SQte	OP-24	dvgte	M-76	mtau	O-55	vlr	O-20
Sgpi	OP-37	dvgte	O-75	mult	I-1	vos	M-46
TK	OP-80	etavdr	M-52	nvdr	M-53	vos	O-45
Vb1c1	OP-7	etavdr	O-51	nvdr	O-52	wavl	M-23
Vb2c1	OP-6	exavl	M-6	pc	M-41	wavl	O-22
Vb2c2	OP-5	exavl	O-5	pc	O-40	xcjc	M-44

Virtuoso Simulator Components and Device Models Reference

Philips Models

Vb2c2star	OP-78	exmod	M-4	pe	M-36	xcjc	O-43
Vb2e1	OP-4	exmod	O-3	pe	O-35	xcje	M-37
Ve1e	OP-8	exphi	M-5	rbc	M-27	xcje	O-36
XCbcex	OP-63	exphi	O-4	rbc	O-26	xext	M-22
XIex	OP-17	exrth	M-85	rbv	M-28	xext	O-21
XQex	OP-33	exrth	O-84	rbv	O-27	xibi	M-18
XQtex	OP-31	fT	OP-75	rcc	M-29	xibi	O-17
Xgmux	OP-45	gm	OP-68	rcc	O-28	xp	M-42
XiWepi	OP-77	gmu	OP-71	rcv	M-30	xp	O-41
ab	M-65	gmux	OP-44	rcv	O-29	xrec	M-62
ab	O-64	gmux	OP-41	rdmin	M-49	xrec	O-61
ac	M-69	gmuy	OP-42	rdmin	O-48		
ac	O-68	gmuz	OP-43	re	M-26		
ae	M-64	gout	OP-70	re	O-25		

Long Channel JFET/MOSFET Model (mos30)

This long channel JFET/MOSFET model is specially developed to describe the drift region of LDMOS, EPMOS and VDMOS devices. It is described in the Philips MOST Modelbook (Dec.95) as MOS model, level 30 (Used for DMOS). Information on how to obtain this document can be found on Source Link by searching for Philips.

Note: In noise analysis, mos30 instances will not generate any contribution, since there are no noise sources included in the mos30 model.

Warning: Dont use this model. It is obsolete.

Mos30 will be removed from spectre in the next release.

(c) Philips Electronics N.V. 1993, 1994, 1996

This device is supported within altergroups.

This device is dynamically loaded from the shared object /vobs/spectre_dev/tools.lnx86/cmi/lib/5.0.doc/libphilips_sh.so

Sample Instance Statement

```
mn30 (1 2 0 0) nchmod area=2 mult=1
```

Sample Model Statement

```
model nchmod mos30 type=n tox=1.1e-5 ron=150 rsat=500 psat=2 vsat=1 vsub=0.59  
cgate=1.65e-12 csub=1.1e-9 tref=25
```

Instance Definition

```
Name d g s [b] ModelName parameter=value ...
```

Instance Parameters

- | | | |
|---|---------------|--|
| 1 | mult=1 | Number of devices in parallel. |
| 2 | area=1 | Alias of mult. |
| 3 | region=triode | Estimated DC operating region, used as a convergence aid.
Possible values are off, triode, sat, or subth. |
| 4 | m=1 | Multiplicity factor. |

Model Definition

```
model modelName mos30 parameter=value ...
```

Model Parameters

- | | | |
|---|------------------|---|
| 1 | type=n | Transistor gender.
Possible values are n or p. |
| 2 | ron=1.0 Ω | Ohmic resistance at zero bias. |

Virtuoso Simulator Components and Device Models Reference

Philips Models

3	<code>rsat=1.0 Ω</code>	Space charge resistance at zero bias.
4	<code>vsat=10.0 V</code>	Critical drain-source voltage for hot carriers.
5	<code>psat=1.0</code>	Velocity saturation coefficient.
6	<code>vp=-1.0 V</code>	Pinch off voltage at zero gate and substrate voltages.
7	<code>tox=-1.0 cm</code>	Gate oxide thickness.
8	<code>dch=1.0e15 cm^{-3}</code>	Doping level channel.
9	<code>dsub=1.0e15 cm^{-3}</code>	Doping level substrate.
10	<code>vsub=0.6 V</code>	Substrate diffusion voltage.
11	<code>vgap=1.2 V</code>	Bandgap voltage channel.
12	<code>cgate=0.0 F</code>	Gate capacitance at zero bias.
13	<code>csub=0.0 F</code>	Substrate capacitance at zero bias.
14	<code>tausc=0.0 s</code>	Space charge transit time of the channel.
15	<code>ach=0.0</code>	Temperature coefficient resistivity of the channel.
16	<code>kf=0.0</code>	Flickernoise coefficient.
17	<code>af=1.0</code>	Flickernoise exponent.
18	<code>tr (C)</code>	Reference temperature. Default set by option <code>tnom</code> .
19	<code>tref (C)</code>	Alias of <code>tr</code> . Default set by option <code>tnom</code> .
20	<code>tnom (C)</code>	Alias of <code>tr</code> . Default set by option <code>tnom</code> .
21	<code>dta=0.0 K</code>	Temperature offset of the device.
22	<code>trise=0.0 K</code>	Alias of <code>dta</code> .

Output Parameters

1	<code>ront (Ω)</code>	Ohmic resistance at zero bias.
---	---	--------------------------------

Virtuoso Simulator Components and Device Models Reference

Philips Models

2	r_{sat} (Ω)	Space charge resistance at zero bias.
3	v_{satt} (V)	Critical drain-source voltage for hot carriers.
4	v_{subt} (V)	Substrate diffusion voltage.
5	c_{gate} (F)	Gate capacitance at zero bias.
6	c_{subt} (F)	Substrate capacitance at zero bias.

Operating-Point Parameters

1	pwr (W)	Power.
2	ids (A)	Total current including velocity saturation.
3	qb (Coul)	Substrate charge.
4	qg (Coul)	Gate charge.
5	qds (Coul)	Space charge in the channel.
6	$gdsd$ (S)	Conductance ($d\ ids / d\ vd$).
7	$gdsg$ (S)	Conductance ($d\ ids / d\ vg$).
8	$gdss$ (S)	Conductance ($d\ ids / d\ vs$).
9	$gdsb$ (S)	Conductance ($d\ ids / d\ vb$).
10	cbd (F)	Capacitance ($d\ qb / d\ vd$).
11	cbg (F)	Capacitance ($d\ qb / d\ vg$).
12	cbs (F)	Capacitance ($d\ qb / d\ vs$).
13	cbb (F)	Capacitance ($d\ qb / d\ vb$).
14	cgd (F)	Capacitance ($d\ qg / d\ vd$).
15	cgg (F)	Capacitance ($d\ qg / d\ vg$).
16	cgs (F)	Capacitance ($d\ qg / d\ vs$).

Virtuoso Simulator Components and Device Models Reference

Philips Models

17	cgb (F)	Capacitance (d qg / d vb).
18	cdsd (F)	Capacitance (d qds / d vd).
19	cdsg (F)	Capacitance (d qds / d vg).
20	cdss (F)	Capacitance (d qds / d vs).
21	cdsb (F)	Capacitance (d qds / d vb).

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

ach	M-15	cgd	OP-14	m	I-4	tox	M-7
af	M-17	cgg	OP-15	mult	I-1	tr	M-18
area	I-2	cgs	OP-16	psat	M-5	tref	M-19
cbb	OP-13	csub	M-13	pwr	OP-1	trise	M-22
cbd	OP-10	csubt	O-6	qj	OP-3	type	M-1
cbg	OP-11	dch	M-8	qds	OP-5	vgap	M-11
cbs	OP-12	dsub	M-9	qg	OP-4	vp	M-6
cdsb	OP-21	dta	M-21	region	I-3	vsat	M-4
cdsd	OP-18	gdsb	OP-9	ron	M-2	vsatt	O-3
cdsg	OP-19	gdsg	OP-6	ront	O-1	vsub	M-10
cdss	OP-20	gdsg	OP-7	rsat	M-3	vsubt	O-4

Virtuoso Simulator Components and Device Models Reference

Philips Models

cgate	M-12	gdss	OP-8	rsat	O-2
cgate	O-5	ids	OP-2	tausc	M-14
cgb	OP-17	kf	M-16	tnom	M-20

MOS Model 40, Level 40 (mos40t)

This is SimKit 4.0

This device is supported within altergroups.

This device is dynamically loaded from the shared object /vobs/spectre_dev/tools.lnx86/cmi/lib/5.0.doc/libphilips_sh.so

Instance Definition

```
Name d g s b dt ModelName parameter=value ...
```

Instance Parameters

- | | | |
|---|---------------|---|
| 1 | mult=1 | Number of devices in parallel. |
| 2 | region=triode | Estimated DC operating region, used as a convergence aid. Possible values are off, triode, sat, or subth. |
| 3 | m=1 | Multiplicity factor. |
| 4 | area=1 | alias of mult. |

Model Definition

```
model modelName mos40t parameter=value ...
```

Model Parameters

- | | | |
|---|----------------|--------------------------------|
| 1 | level=40 | Level of this model. |
| 2 | ron=1 Ω | Ohmic resistance at zero bias. |

Virtuoso Simulator Components and Device Models Reference

Philips Models

3	$rsat=1 \Omega$	Space charge resistance at zero bias.
4	$vsat=10 V$	Critical drain-source voltage for hot carriers.
5	$psat=1$	Velocity saturation coefficient.
6	$vp=-1 V$	Pinch off voltage at zero gate and substrate voltages.
7	$tox=-1 m$	Gate oxide thickness.
8	$dch=1e+21 m^{-3}$	Doping level channel.
9	$tbox=-1 m^{-3}$	Box oxide thickness.
10	$cgate=0 F$	Gate capacitance at zero bias.
11	$cbox=0 F$	Wafer capacitance.
12	$tausc=0 s$	Space charge transit time of the channel.
13	$ach=0$	Temperature coefficient resistivity of the channel.
14	$achmod=0$	Parameter to switch to extended temperature scaling.
15	$achron=0$	Temperature coefficient of ohmic resistance at zero bias.
16	$achvsat=0$	Temperature coefficient of critical drain-source voltage for hot carriers.
17	$achrsat=0$	Temperature coefficient of space charge resistance at zero bias.
18	$tref=25 C$	Reference temperature.
19	$dta=0 K$	Temperature offset of the device.
20	$rth=300 K/W$	Thermal resistance.
21	$cth=3e-09 J/K$	Thermal capacitance.
22	$ath=0$	Temperature coefficient of the thermal resistance.
23	$type=n$	Transistor gender. Possible values are n, p, npn, pnp, npnv, pnpv, npnl, or pnp1.

Virtuoso Simulator Components and Device Models Reference

Philips Models

24	<code>imax=1.0 A</code>	Explosion current.
25	<code>tnom (C)</code>	alias of <code>tnom</code> .
26	<code>tr (C)</code>	alias of <code>tnom</code> .

Output Parameters

1	<code>ront (Ω)</code>	Ohmic resistance at zero bias.
2	<code>rsatt (Ω)</code>	Space charge resistance at zero bias.
3	<code>vsatt (V)</code>	Critical drain-source voltage for hot carriers.
4	<code>psat</code>	Velocity saturation coefficient.
5	<code>vp (V)</code>	Pinch off voltage at zero gate and substrate voltages.
6	<code>tox (m)</code>	Gate oxide thickness.
7	<code>dch (m^{-3})</code>	Doping level channel.
8	<code>tbox (m^{-3})</code>	Box oxide thickness.
9	<code>cgate (F)</code>	Gate capacitance at zero bias.
10	<code>cbox (F)</code>	Wafer capacitance.
11	<code>tausc (s)</code>	Space charge transit time of the channel.
12	<code>rth (K/W)</code>	Thermal resistance.
13	<code>cth (J/K)</code>	Thermal capacitance.
14	<code>ath</code>	Temperature coefficient of the thermal resistance.

Operating-Point Parameters

1	<code>ids (A)</code>	Drain source current.
2	<code>vds (V)</code>	Drain source voltage.

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Philips Models

3	v_{gs} (V)	Gate source voltage.
4	v_{bs} (V)	Bulk source voltage.
5	v_p (V)	Channel pinch-off voltage.
6	g_m (A/V)	Transconductance.
7	g_{mb} (A/V)	Bulk transconductance.
8	g_{ds} (A/V)	Output conductance.
9	q_g (C)	Gate charge.
10	c_{gd} (F)	Gate charge dependence on drain voltage.
11	c_{gg} (F)	Gate charge dependence on gate voltage.
12	c_{gs} (F)	Gate charge dependence on substrate voltage.
13	c_{gb} (F)	Gate charge dependence on bulk voltage.
14	q_b (C)	Bulk charge.
15	c_{bd} (F)	Bulk charge dependence on drain voltage.
16	c_{bg} (F)	Bulk charge dependence on gate voltage.
17	c_{bs} (F)	Bulk charge dependence on substrate voltage.
18	c_{bb} (F)	Bulk charge dependence on bulk voltage.
19	q_d (C)	Drain charge.
20	c_{dd} (F)	Drain charge dependence on drain voltage (dQ_d/dV_d).
21	c_{dg} (F)	Drain charge dependence on gate voltage ($-dQ_d/dV_g$).
22	c_{ds} (F)	Drain charge dependence on source voltage ($-dQ_d/dV_s$).
23	c_{db} (F)	Drain charge dependence on bulk voltage ($-dQ_d/dV_b$).
24	q_s (C)	Source charge.

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Philips Models

25	<code>csd</code> (F)	Source charge dependence on drain voltage (-dQs/dVd).
26	<code>csg</code> (F)	Source charge dependence on gate voltage (-dQs/dVg).
27	<code>css</code> (F)	Source charge dependence on source voltage (dQs/dVs).
28	<code>csb</code> (F)	Source charge dependence on bulk voltage (-dQs/dVb).
29	<code>u</code>	Transistor gain.
30	<code>rout</code> (Ω)	Small-signal output resistance.
31	<code>vearly</code> (V)	Equivalent early voltage.
32	<code>iohm</code> (A)	Drain source current excluding velocity saturation.
33	<code>ihc</code> (A)	Critical current for velocity saturation.
34	<code>Pdiss</code> (W)	Dissipation.
35	<code>TK</code> (K)	Actual temperature.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

<code>Pdiss</code>	OP-34	<code>cgate</code>	M-10	<code>imax</code>	M-24	<code>tausc</code>	O-11
<code>TK</code>	OP-35	<code>cgate</code>	O-9	<code>iohm</code>	OP-32	<code>tbox</code>	M-9
<code>ach</code>	M-13	<code>cgb</code>	OP-13	<code>level</code>	M-1	<code>tbox</code>	O-8
<code>achmod</code>	M-14	<code>cgd</code>	OP-10	<code>m</code>	I-3	<code>tnom</code>	M-25
<code>achron</code>	M-15	<code>cgg</code>	OP-11	<code>mult</code>	I-1	<code>tox</code>	M-7

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Philips Models

achrsat	M-17	cgs	OP-12	psat	M-5	tox	O-6
achvsat	M-16	csb	OP-28	psat	O-4	tr	M-26
area	I-4	csd	OP-25	qj	OP-14	tref	M-18
ath	M-22	csg	OP-26	qd	OP-19	type	M-23
ath	O-14	css	OP-27	qg	OP-9	u	OP-29
cbb	OP-18	cth	M-21	qs	OP-24	vbs	OP-4
cbd	OP-15	cth	O-13	region	I-2	vds	OP-2
cbg	OP-16	dch	M-8	ron	M-2	vearly	OP-31
cbox	M-11	dch	O-7	ront	O-1	vgs	OP-3
cbox	O-10	dta	M-19	rout	OP-30	vp	M-6
cbs	OP-17	gds	OP-8	rsat	M-3	vp	O-5
cdb	OP-23	gm	OP-6	rsatt	O-2	vp	OP-5
cdd	OP-20	gmb	OP-7	rth	M-20	vsat	M-4
cdg	OP-21	ids	OP-1	rth	O-12	vsatt	O-3
cds	OP-22	ihc	OP-33	tausc	M-12		

Long Channel JFET/MOSFET Model (mos3002)

This long channel JFET/MOSFET model is specially developed to describe the drift region of LDMOS, EPMOS and VDMOS devices. It is described in the Philips MOST Modelbook (Dec.98) as MOS model, level 3002 (Used for DMOS). Information on how to obtain this document can be found on Source Link by searching for Philips.

Note: In noise analysis, mos3002 instances will not generate any contribution, since there are no noise sources included in the mos3002 model.

(c) Philips Electronics N.V. 1993, 1994, 1996, 1998

This device is supported within altergroups.

This device is dynamically loaded from the shared object /vobs/spectre_dev/tools.lnx86/cmi/lib/5.0.doc/libphilips_sh.so

Sample Instance Statement

```
mn3 (1 2 0 0) nch3002 area=1 m=2
```

Sample Model Statement

```
model nch3002 mos3002 ron=20 rsat=150 vsat=1 tox=1.23e-5 dch=1.1e16 vsub=0.58  
csub=5.43e-13 tausc=1.2e-12 kf=1 tref=27 psat=1 dta=0
```

Instance Definition

```
Name d g s [b] ModelName parameter=value ...
```

Instance Parameters

- | | | |
|---|---------------|--|
| 1 | mult=1 | Number of devices in parallel. |
| 2 | area=1 | Alias of mult. |
| 3 | region=triode | Estimated DC operating region, used as a convergence aid.
Possible values are off, triode, sat, or subth. |
| 4 | m=1 | Multiplicity factor. |

Model Definition

```
model modelName mos3002 parameter=value ...
```

Model Parameters

- | | | |
|---|-------------------|---|
| 1 | type=n | Transistor gender.
Possible values are n or p. |
| 2 | ron=1.0 Ω | Ohmic resistance at zero bias. |
| 3 | rsat=1.0 Ω | Space charge resistance at zero bias. |

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Philips Models

4	<code>vsat=10.0 V</code>	Critical drain-source voltage for hot carriers.
5	<code>psat=1.0</code>	Velocity saturation coefficient.
6	<code>vp=-1.0 V</code>	Pinch off voltage at zero gate and substrate voltages.
7	<code>tox=-1.0 cm</code>	Gate oxide thickness.
8	<code>dch=1.0e15 cm⁻³</code>	Doping level channel.
9	<code>dsub=1.0e15 cm⁻³</code>	Doping level substrate.
10	<code>vsub=0.6 V</code>	Substrate diffusion voltage.
11	<code>vgap=1.2 V</code>	Bandgap voltage channel.
12	<code>cgate=0.0 F</code>	Gate capacitance at zero bias.
13	<code>csub=0.0 F</code>	Substrate capacitance at zero bias.
14	<code>tausc=0.0 s</code>	Space charge transit time of the channel.
15	<code>ach=0.0</code>	Temperature coefficient resistivity of the channel.
16	<code>kf=0.0</code>	Flickernoise coefficient.
17	<code>af=1.0</code>	Flickernoise exponent.
18	<code>tr (C)</code>	Reference temperature. Default set by option <code>tnom</code> .
19	<code>tr_{ref} (C)</code>	Alias of <code>tr</code> . Default set by option <code>tnom</code> .
20	<code>tnom (C)</code>	Alias of <code>tr</code> . Default set by option <code>tnom</code> .
21	<code>dta=0.0 K</code>	Temperature offset of the device.
22	<code>trise=0.0 K</code>	Alias of <code>dta</code> .

Output Parameters

1	<code>ront (Ω)</code>	Ohmic resistance at zero bias.
2	<code>rsat (Ω)</code>	Space charge resistance at zero bias.

Virtuoso Simulator Components and Device Models Reference

Philips Models

3	<code>vsatt</code> (V)	Critical drain-source voltage for hot carriers.
4	<code>vsubt</code> (V)	Substrate diffusion voltage.
5	<code>cgate</code> (F)	Gate capacitance at zero bias.
6	<code>csubt</code> (F)	Substrate capacitance at zero bias.

Operating-Point Parameters

1	<code>pwr</code> (W)	Power.
2	<code>ids</code> (A)	Total current including velocity saturation.
3	<code>qb</code> (Coul)	Substrate charge.
4	<code>qg</code> (Coul)	Gate charge.
5	<code>qds</code> (Coul)	Space charge in the channel.
6	<code>gdsd</code> (S)	Conductance ($d\text{ ids} / d\text{ vd}$).
7	<code>gdsg</code> (S)	Conductance ($d\text{ ids} / d\text{ vg}$).
8	<code>gdss</code> (S)	Conductance ($d\text{ ids} / d\text{ vs}$).
9	<code>gdsb</code> (S)	Conductance ($d\text{ ids} / d\text{ vb}$).
10	<code>cbd</code> (F)	Capacitance ($d\text{ qb} / d\text{ vd}$).
11	<code>cbg</code> (F)	Capacitance ($d\text{ qb} / d\text{ vg}$).
12	<code>cbs</code> (F)	Capacitance ($d\text{ qb} / d\text{ vs}$).
13	<code>cbb</code> (F)	Capacitance ($d\text{ qb} / d\text{ vb}$).
14	<code>cgd</code> (F)	Capacitance ($d\text{ qg} / d\text{ vd}$).
15	<code>cgg</code> (F)	Capacitance ($d\text{ qg} / d\text{ vg}$).
16	<code>cgs</code> (F)	Capacitance ($d\text{ qg} / d\text{ vs}$).
17	<code>cgb</code> (F)	Capacitance ($d\text{ qg} / d\text{ vb}$).

Virtuoso Simulator Components and Device Models Reference

Philips Models

18	<code>cdsd</code> (F)	Capacitance (d qds / d vd).
19	<code>cdsg</code> (F)	Capacitance (d qds / d vg).
20	<code>cdss</code> (F)	Capacitance (d qds / d vs).
21	<code>cdsb</code> (F)	Capacitance (d qds / d vb).

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

<code>ach</code> M-15	<code>cgd</code> OP-14	<code>m</code> I-4	<code>tox</code> M-7
<code>af</code> M-17	<code>cgg</code> OP-15	<code>mult</code> I-1	<code>tr</code> M-18
<code>area</code> I-2	<code>cgs</code> OP-16	<code>psat</code> M-5	<code>tref</code> M-19
<code>cbb</code> OP-13	<code>csub</code> M-13	<code>pwr</code> OP-1	<code>trise</code> M-22
<code>cbd</code> OP-10	<code>csubt</code> O-6	<code>qb</code> OP-3	<code>type</code> M-1
<code>cbg</code> OP-11	<code>dch</code> M-8	<code>qds</code> OP-5	<code>vgap</code> M-11
<code>cbs</code> OP-12	<code>dsub</code> M-9	<code>qg</code> OP-4	<code>vp</code> M-6
<code>cdsb</code> OP-21	<code>dta</code> M-21	<code>region</code> I-3	<code>vsat</code> M-4
<code>cdsd</code> OP-18	<code>gdsb</code> OP-9	<code>ron</code> M-2	<code>vsatt</code> O-3
<code>cdsg</code> OP-19	<code>gdsd</code> OP-6	<code>ront</code> O-1	<code>vsub</code> M-10
<code>cdss</code> OP-20	<code>gdsg</code> OP-7	<code>rsat</code> M-3	<code>vsubt</code> O-4
<code>cgate</code> M-12	<code>gdss</code> OP-8	<code>rsat</code> O-2	

cgate	O-5	ids	OP-2	tausc	M-14
cgb	OP-17	kf	M-16	tnom	M-20

Compact MOS-Transistor Model (mos705)

The mos705 model is a compact MOS-transistor model, intended for the simulation of circuit behavior with emphasis on analog applications. It is described in the Philips MOST Modelbook (Dec.93) as MOS model, level 705.

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In extension to the model book description a minimum conductance `gmin` is inserted between the drain and source node, to aid convergence. The value of `gmin` is set by an options statement, default = 1e-12 S.

This device is supported within altergroups.

This device is dynamically loaded from the shared object `/vobs/spectre_dev/tools.lnx86/cmi/lib/5.0.doc/libphilips_sh.so`

Sample Instance Statement:

```
mn1 (1 2 0 0) mna7 ln=120e-6 wn=12e-6
```

Sample Model Statement:

```
model mna7 mos705 type=n vtn=0.853 betan=77e-6 tox=15e-9 vfb=-850e-3 tref=25  
subthn=3 phi=0.645 lap=100e-9 gkn=-350e-9 th1n=0.15 th2n=0.046 th3n=0.1 fnoise=1e-  
10
```

Instance Definition

```
Name d g s [b] ModelName parameter=value ...
```

Instance Parameters

1	wn=1.0	scale m	Drawn channel width in the lay-out of the actual transistor. Scale set by option scale.
---	--------	---------	---

Virtuoso Simulator Components and Device Models Reference

Philips Models

2	<code>ln=1.0 scale m</code>	Drawn channel length in the lay-out of the actual transistor. Scale set by option <code>scale</code> .
3	<code>w=1.0 scale m</code>	Alias for <code>wn</code> .
4	<code>l=1.0 scale m</code>	Alias for <code>ln</code> .
5	<code>mult=1</code>	Number of devices in parallel.
6	<code>area=1</code>	Alias of <code>mult</code> .
7	<code>region=triode</code>	Estimated DC operating region, used as a convergence aid. Possible values are <code>off</code> , <code>triode</code> , <code>sat</code> , or <code>subth</code> .
8	<code>m=1</code>	Multiplicity factor.

Model Definition

```
model modelName mos705 parameter=value ...
```

Model Parameters

1	<code>type=n</code>	Transistor gender. Possible values are <code>n</code> or <code>p</code> .
2	<code>vtn=0 V</code>	Threshold voltage of the reference transistor at the reference temperature.
3	<code>kon=0 \sqrt{V}</code>	K_0 of the reference transistor.
4	<code>kn=100m \sqrt{V}</code>	K of the reference transistor.
5	<code>vsbxn=0 V</code>	V_{sbx} of the reference transistor.
6	<code>delvx=0 V</code>	D_{vsbx} of the reference transistor.
7	<code>th1n=0 1/V</code>	The_1 of the reference transistor.
8	<code>th2n=0 1/\sqrt{V}</code>	The_2 of the reference transistor.
9	<code>th3n=0 1/V</code>	The_3 of the reference transistor at the reference temperature.
10	<code>gamman=0</code>	Γ_{am} of the reference transistor.

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Philips Models

11	$\text{shiftn}=0 \ V^{(1-n)}$	Sh of the reference transistor.
12	$\text{nn}=0$	N of the reference transistor.
13	$\text{pn}=0 \ 1/V$	P of the reference transistor.
14	$\text{ava}=0$	A of the reference transistor.
15	$\text{avb}=1 \ V$	B of the reference transistor.
16	$\text{avc}=0$	C of the reference transistor.
17	$\text{wref}=100\mu \text{ m}$	Effective width of the reference transistor.
18	$\text{wtol}=0 \text{ m}$	Difference between drawn and effective gate width.
19	$\text{dvtn}=0 \ V \text{ m}$	Narrow-width factor of the threshold voltage at vsbref .
20	$\text{dkon}=0 \ \sqrt{V} \text{ m}$	Narrow-width factor of k_o .
21	$\text{dkn}=0 \ \sqrt{V} \text{ m}$	Narrow-width factor of k .
22	$\text{dvsbxn}=0 \ V \text{ m}$	Narrow-width factor of vsbx .
23	$\text{ddelvx}=0 \ V\text{m}$	Narrow-width factor of dvsbx .
24	$\text{betan}=20\mu \text{ A}/V^2$	Gain factor of a infinite-square transistor at the reference temperature.
25	$\text{dth1n}=0 \ \text{m}/V$	Narrow-width factor of the1 .
26	$\text{dth2n}=0 \ \text{m}/\sqrt{V}$	Narrow-width factor of the2 .
27	$\text{dth3n}=0 \ \text{m}/V$	Narrow-width factor of the3 .
28	$\text{dgamn}=0 \ \text{m}$	Narrow-width factor of gam .
29	$\text{dava}=0 \ \text{m}$	Narrow-width factor of a .
30	$\text{davb}=0 \ V \text{ m}$	Narrow-width factor of b .
31	$\text{davc}=0 \ \text{m}$	Narrow-width factor of c .

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Philips Models

32	$l_{ref}=100\mu\text{ m}$	Effective length of the reference transistor.
33	$l_{tol}=0\text{ m}$	Difference between drawn and actual gate polysilicon length.
34	$g_{vtn}=0\text{ V m}$	Short-channel factor of the threshold voltage at v_{sbref} .
35	$g_{kon}=0\sqrt{V}\text{ m}$	Short-channel factor of k_o .
36	$g_{kn}=0\sqrt{V}\text{ m}$	Short-channel factor of k .
37	$g_{vsbxn}=0\text{ V m}$	Short-channel factor of v_{sbx} .
38	$g_{delvx}=0\text{ V m}$	Short-channel factor of dv_{sbx} .
39	$g_{th1n}=0\text{ m/V}$	Short-channel factor of th_{e1} .
40	$g_{th2n}=0\text{ m}/\sqrt{V}$	Short-channel factor of th_{e2} .
41	$g_{th3n}=0\text{ m/V}$	Short-channel factor of th_{e3} .
42	$g_{gamn}=0\text{ m}$	Short-channel factor of gam .
43	$g_{shift}=0\text{ V}^{(1-n)}\text{ m}^2$	Short-channel factor of sh .
44	$g_{nn}=0\text{ m}$	Short-channel factor of n .
45	$g_{pn}=0\text{ m/V}$	Short-channel factor of p .
46	$g_{ava}=0\text{ m}$	Short-channel factor of a .
47	$g_{avb}=0\text{ V m}$	Short-channel factor of b .
48	$g_{avc}=0\text{ m}$	Short-channel factor of c .
49	$l_{ap}=0\text{ m}$	Half of the effective channel-length reduction due to lateral diffusion.
50	$v_{sbref}=0\text{ V}$	Source to bulk reference voltage for parameter determination.
51	$\phi_i=600\text{m V}$	Diffusion potential at the reference temperature.
52	$tcvt=-1\text{m V/K}$	Temperature coefficient of v_{to} .

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Philips Models

53	$t_{\text{betan}}=1.5$	Power temperature coefficient of bet .
54	$t_{\text{th3n}}=0 \text{ } 1/(\text{V K})$	Temperature coefficient of t_{he3} .
55	$t_{\text{gth3n}}=0 \text{ } \text{m}/(\text{V K})$	Temperature coefficient of the length dependence of t_{he3} .
56	$m=1.0$	Subthreshold-slope factor at reference back bias and at the reference temperature.
57	$\text{subthn}=0$	Weak-inversion factor.
58	$v_{\text{tr}}=0 \text{ V}$	Depletion-MOS-transistor-transition voltage.
59	$\text{ratio}=0$	Depletion-MOS-transistor-gain ratio.
60	$v_{\text{fb}}=0 \text{ V}$	Flat-band voltage.
61	$t_{\text{ox}}=100\text{n m}$	Gate-oxide thickness.
62	$c_{\text{ol}}=0 \text{ F/m}$	Gate/drain or gate/source overlap capacitance per unit length.
63	$f_{\text{noise}}=0 \text{ } \text{m}^2 \text{ V}^2$	Flicker-noise factor.
64	$t_{\text{noise}}=0$	Thermal-noise factor.

Temperature parameters

65	$t_{\text{r}} \text{ (C)}$	Reference temperature. Default set by option t_{nom} .
66	$t_{\text{ref}} \text{ (C)}$	Alias of t_{r} . Default set by option t_{nom} .
67	$t_{\text{nom}} \text{ (C)}$	Alias of t_{r} . Default set by option t_{nom} .
68	$d_{\text{ta}}=0 \text{ K}$	Deviation between the temperature of the transistor and the temperature of the circuit.
69	$t_{\text{rise}}=0 \text{ K}$	Alias of d_{ta} .

Output Parameters

1	$w_{\text{eff}} \text{ (V)}$	Effective channel width of the actual transistor.
---	------------------------------	---

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Philips Models

2	l_{eff} (V)	Effective channel length of the actual transistor.
3	$twophif$ (V)	Diffusion potential.
4	β (A/V^2)	Gain factor of the transistor.
5	k (\sqrt{V})	Body-effect factor.
6	k_0 (\sqrt{V})	Initial body-effect factor for dual k approach.
7	v_{sbx} (V)	Transition voltage for dual k approach.
8	Δv_{sbx} (V)	Transition-voltage range for dual k approach.
9	v_{to} (V)	Threshold voltage.
10	v_{on} (V)	Onset voltage of the superthreshold region.
11	$the1$ ($1/V$)	Gate-bias-controlled transverse-field mobility reduction factor.
12	$the2$ ($1/\sqrt{V}$)	Back-bias-controlled transverse-field mobility reduction factor.
13	$the3$ ($1/V$)	Lateral-field mobility reduction factor (velocity saturation).
14	γ	Static-drain-feedback factor.
15	sh ($V^{(1-n)}$)	Threshold-voltage-shift factor.
16	n	Threshold-voltage-shift exponent.
17	p ($1/V$)	Back-bias-shift factor.
18	m_e (\sqrt{V})	Auxiliary parameter for subthreshold-slope factor.
19	a	Weak-avalanche multiplier.
20	b (V)	Weak-avalanche exponent factor.
21	c	Saturation-voltage reduction factor.
22	c_{ox} (F)	Gate capacitance.
23	c_{gso} (F)	Gate/source-overlap capacitance.

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Philips Models

24	<code>cgdo</code> (F)	Gate/drain-overlap capacitance.
25	<code>vtre</code> (V)	Depletion MOS transistor transition voltage.
26	<code>ratio</code>	Depletion MOS transistor gain ratio.
27	<code>vfbe</code> (V)	Flat band voltage.
28	<code>vtemp</code> (V)	kT/q at actual device temperature.
29	<code>gnoise</code> (V^2)	Coefficient of the flicker noise for the actual transistor.
30	<code>unoise</code> (J)	Coefficient of the thermal noise for the actual transistor.

Operating-Point Parameters

1	<code>ide</code> (A)	Drain current.
2	<code>ige</code> (A)	Gate current.
3	<code>ise</code> (A)	Source current.
4	<code>ibe</code> (A)	Bulk current.
5	<code>vds</code> (V)	Drain-source voltage.
6	<code>vgs</code> (V)	Gate-source voltage.
7	<code>vsb</code> (V)	Source-bulk voltage.
8	<code>ids</code> (A)	Drain-source current.
9	<code>idb</code> (A)	Drain-bulk current.
10	<code>isb</code> (A)	Source-bulk current.
11	<code>pwr</code> (W)	Power.
12	<code>vt_s</code> (V)	V_{to} including back-bias effects.
13	<code>vgt</code> (V)	Effective gate drive including back-bias and drain effects.
14	<code>vd_{ss}</code> (V)	Saturation voltage at actual bias.

Virtuoso Simulator Components and Device Models Reference

Philips Models

15	g_m (S)	Transconductance ($d i_{ds} / d v_{gs}$).
16	g_{mb} (S)	Bulk transconductance ($d i_{ds} / d v_{bs}$).
17	g_{ds} (S)	Output conductance ($d i_{ds} / d v_{ds}$).
18	c_{dd} (F)	Capacitance ($d q_d / d v_d$).
19	c_{dg} (F)	Capacitance ($- d q_d / d v_g$).
20	c_{ds} (F)	Capacitance ($- d q_d / d v_s$).
21	c_{db} (F)	Capacitance ($- d q_d / d v_b$).
22	c_{gd} (F)	Capacitance ($- d q_g / d v_d$).
23	c_{gg} (F)	Capacitance ($d q_g / d v_g$).
24	c_{gs} (F)	Capacitance ($- d q_g / d v_s$).
25	c_{gb} (F)	Capacitance ($- d q_g / d v_b$).
26	c_{sd} (F)	Capacitance ($- d q_s / d v_d$).
27	c_{sg} (F)	Capacitance ($- d q_s / d v_g$).
28	c_{ss} (F)	Capacitance ($d q_s / d v_s$).
29	c_{sb} (F)	Capacitance ($- d q_s / d v_b$).
30	c_{bd} (F)	Capacitance ($- d q_b / d v_d$).
31	c_{bg} (F)	Capacitance ($- d q_b / d v_g$).
32	c_{bs} (F)	Capacitance ($- d q_b / d v_s$).
33	c_{bb} (F)	Capacitance ($d q_b / d v_b$).
34	u	Transistor gain (g_m/g_{ds}).
35	r_{out} (Ω)	Small signal output resistance ($1/g_{ds}$).
36	v_{early} (V)	Equivalent Early voltage ($ I_{ds} /g_{ds}$).

Virtuoso Simulator Components and Device Models Reference

Philips Models

37	k_{eff} (\sqrt{V})	Describes body effect at actual bias.
38	b_{eff} (S/V)	Effective beta at actual bias in the simple MOS model.
39	f_{ug} (Hz)	Unity gain frequency at actual bias ($gm/(2*\pi*cox)$).
40	$sqrtsfw$ (V/\sqrt{Hz})	Input-referred RMS white noise voltage (\sqrt{sth}/gm).
41	$sqrtsff$ (V/\sqrt{Hz})	Input-referred RMS 1/f noise voltage at 1kHz ($\sqrt{gnoise/1000}$).
42	f_{knee} (Hz)	Cross-over frequency above which white noise is dominant.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

a	O-19	dta	M-68	k	O-5	the3	O-13
area	I-6	dth1n	M-25	keff	OP-37	tnoise	M-64
ava	M-14	dth2n	M-26	kn	M-4	tnom	M-67
avb	M-15	dth3n	M-27	ko	O-6	tox	M-61
avc	M-16	dvsbx	O-8	kon	M-3	tr	M-65
b	O-20	dvsbxn	M-22	l	I-4	tref	M-66
b _{eff}	OP-38	dvt _n	M-19	lap	M-49	trise	M-69
bet	O-4	fknee	OP-42	leff	O-2	tth3n	M-54

Virtuoso Simulator Components and Device Models Reference

Philips Models

betan M-24	fnoise M-63	ln I-2	twophif O-3
c O-21	fug OP-39	lref M-32	type M-1
cbb OP-33	gam O-14	ltol M-33	u OP-34
cbd OP-30	gamman M-10	m I-8	unoise O-30
cbg OP-31	gava M-46	m M-56	vds OP-5
cbs OP-32	gavb M-47	me O-18	vdss OP-14
cdb OP-21	gavc M-48	mult I-5	vearly OP-36
cdd OP-18	gdelvx M-38	n O-16	vfb M-60
cdg OP-19	gds OP-17	nn M-12	vfbe O-27
cds OP-20	ggamn M-42	p O-17	vgs OP-6
cgb OP-25	gkn M-36	phi M-51	vgt OP-13
cgd OP-22	gkon M-35	pn M-13	von O-10
cgdo O-24	gm OP-15	pwr OP-11	vsb OP-7
cgg OP-23	gmb OP-16	ratio M-59	vsbref M-50
cgs OP-24	gnn M-44	ratio O-26	vsbx O-7
cgso O-23	gnoise O-29	region I-7	vsbxn M-5
col M-62	gpn M-45	rout OP-35	vtemp O-28
cox O-22	gshift M-43	sh O-15	vtn M-2
csb OP-29	gth1n M-39	shiftn M-11	vto O-9
csd OP-26	gth2n M-40	sqrtsff OP-41	vtr M-58
csg OP-27	gth3n M-41	sqrtsfw OP-40	vtre O-25

Virtuoso Simulator Components and Device Models Reference

Philips Models

css	OP-28	gvsbxn	M-37	subthn	M-57	vts	OP-12
dava	M-29	gvtn	M-34	tbetan	M-53	w	I-3
davb	M-30	ibe	OP-4	tcvt	M-52	weff	O-1
davc	M-31	idb	OP-9	tgth3n	M-55	wn	I-1
ddelvx	M-23	ide	OP-1	th1n	M-7	wref	M-17
delvx	M-6	ids	OP-8	th2n	M-8	wtol	M-18
dgamn	M-28	ige	OP-2	th3n	M-9		
dkn	M-21	isb	OP-10	the1	O-11		
dkon	M-20	ise	OP-3	the2	O-12		

Compact MOS-Transistor Model (mos902)

The mos902 model is a compact MOS-transistor model, intended for the simulation of circuit behavior with emphasis on analog applications. It is described in the Philips MOST Modelbook (Feb.98) as MOS model, level 902. Information on how to obtain this document can be found on Source Link by searching for Philips.

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In extension to the model book description a minimum conductance g_{min} is inserted between the drain and source node, to aid convergence. The value of g_{min} is set by an options statement, default = 1e-12 S.

This device is supported within altergroups.

This device is dynamically loaded from the shared object /vobs/spectre_dev/tools.lnx86/cmi/lib/5.0.doc/libphilips_sh.so

Sample Instance Statement:

```
mp1 (0 1 2 2) mos9pch w=10u l=2u area=1.5
```


Virtuoso Simulator Components and Device Models Reference

Philips Models

Sample Model Statement:

```
model mos9pch mos902 ler=0.93e-6 wer=20e-6 tref=27 vtor=1.11 kr=0.54 phibr=0.66  
vsbxr=100 the1r=0.19 slk=-0.215e-6 swk=98e-9 swthe3=7.8e-9
```

Instance Definition

```
Name d g s [b] ModelName parameter=value ...
```

Instance Parameters

- | | | |
|---|---------------|--|
| 1 | w=1.0 scale m | Drawn channel width in the lay-out. Scale set by option scale. |
| 2 | l=1.0 scale m | Drawn channel length in the lay-out. Scale set by option scale. |
| 3 | mult=1 | Number of devices in parallel. |
| 4 | area=1 | Alias of mult. |
| 5 | region=triode | Estimated DC operating region, used as a convergence aid.
Possible values are off, triode, sat, or subth. |
| 6 | m=1 | Multiplicity factor. |

Model Definition

```
model modelName mos902 parameter=value ...
```

Model Parameters

Device type parameters

- | | | |
|---|--------|---|
| 1 | type=n | Transistor gender.
Possible values are n or p. |
|---|--------|---|

Geometry parameters

- | | | |
|---|--------------|---|
| 2 | ler=2.5e-6 m | Effective channel length of the reference transistor. |
| 3 | wer=25e-6 m | Effective channel width of the reference transistor. |

Virtuoso Simulator Components and Device Models Reference

Philips Models

4	$lvar=0.3e-6$ m	Difference between the actual and the programmed poly-silicon gate length.
5	$lap=0.1e-6$ m	Effective channel length reduction per side.
6	$wvar=3e-6$ m	Difference between the actual and the programmed field-oxide opening.
7	$wot=1e-6$ m	Effective channel width reduction per side.
8	$wdog=0$ m	Characteristic drawn gate width, below which dogboning appears.

Threshold-voltage parameters

9	$v_{tor}=0.8$ V	Threshold voltage at zero back-bias.
10	$stv_{to}=0.01$ V/K	Coefficient of the temperature dependence of v_{to} .
11	$slv_{to}=0.5e-6$ V m	Coefficient of the length dependence of v_{to} .
12	$sl2v_{to}=0$ V m ²	Second coefficient of the length dependence of v_{to} .
13	$swv_{to}=5e-6$ V m	Coefficient of the width dependence of v_{to} .
14	$k_{or}=0.5$ \sqrt{V}	Low-backbias body factor.
15	$slk_o=1e-6$ \sqrt{V} m	Coefficient of the length dependence of k_o .
16	$swk_o=10e-6$ \sqrt{V} m	Coefficient of the width dependence of k_o .
17	$k_r=0.1$ \sqrt{V}	High-backbias body factor.
18	$slk=0.5e-6$ \sqrt{V} m	Coefficient of the length dependence of k .
19	$swk=5e-6$ \sqrt{V} m	Coefficient of the width dependence of k .
20	$phibr=0.65$ V	Surface potential at strong inversion.

Virtuoso Simulator Components and Device Models Reference

Philips Models

21 $v_{sbxr}=0.9$ V Transition voltage for the dual-k-factor model.

22 $slv_{sbx}=0.5e-6$ V m Coefficient of the length dependence of v_{sbx} .

23 $swv_{sbx}=5e-6$ V m Coefficient of the width dependence of v_{sbx} .

Channel-current parameters

24 $betsq=0.1e-3$ A/V² Gain factor for an infinite square transistor.

25 $etabet=0.5$ Exponent of the temperature dependence of the gain factor.

26 $the1r=0.05$ 1/V Coefficient of the mobility reduction due to the gate-induced field.

27 $stthe1r=3e-3$ 1/(V K) Coefficient of the temperature dependence of $the1$.

28 $slthe1r=50e-9$ m/V Coefficient of the length dependence of $the1$.

29 $stlthe1=5e-9$ m/(V K) Coefficient of the temperature dependence of $slthe1$.

30 $swthe1=1e-6$ m/V Coefficient of the width dependence of $the1$.

31 $fthe1=0$ Coefficient describing the width dependence of $the1$ for $w < w_{dog}$.

32 $the2r=17e-3$ 1/ \sqrt{V} Coefficient of the mobility reduction due to the back-bias.

33 $stthe2r=0.1e-3$ 1/(\sqrt{V} K) Coefficient of the temperature dependence of $the2$.

34 $slthe2r=5e-9$ m/ \sqrt{V} Coefficient of the length dependence of $the2$.

35 $stlthe2=0.5e-9$ m/(\sqrt{V} K) Coefficient of the temperature dependence of $slthe2$.

36 $swthe2=0.1e-6$ m/ \sqrt{V} Coefficient of the width dependence of $the2$.

Virtuoso Simulator Components and Device Models Reference

Philips Models

37 $\text{the3r}=37\text{e-}3 \text{ 1/V}$ Coefficient of the mobility reduction due to the lateral field.

38 $\text{stthe3r}=0.1\text{e-}3 \text{ 1/(V K)}$
Coefficient of the temperature dependence of the3 .

39 $\text{slthe3r}=5\text{e-}9 \text{ m/V}$ Coefficient of the length dependence of the3 .

40 $\text{stlthe3}=0.5\text{e-}9 \text{ m/(V K)}$
Coefficient of the temperature dependence of slthe3 .

41 $\text{swthe3}=0.1\text{e-}6 \text{ m/V}$ Coefficient of the width dependence of the3 .

Drain-feedback parameters

42 $\text{gam1r}=40\text{e-}3 \text{ V}^{(1-\text{etads})}$
Coefficient for the drain induced threshold shift for large gate drive.

43 $\text{slgam1}=0.1\text{e-}6 \text{ V}^{(1-\text{etads})} \text{ m}$
Coefficient of the length dependence of gam1 .

44 $\text{swgam1}=1\text{e-}6 \text{ V}^{(1-\text{etads})} \text{ m}$
Coefficient of the width dependence of gam1 .

45 $\text{etadsr}=0.6$ Exponent of the vds dependence of gam1 .

46 $\text{alpr}=4\text{e-}3$ Factor of the channel-length modulation.

47 $\text{etaalp}=0.5$ Exponent of the length dependence of alp .

48 $\text{slalp}=0.14\text{e-}3 \text{ m}^{\text{etaalp}}$
Coefficient of the length dependence of alp .

49 $\text{swalp}=0.1\text{e-}6 \text{ m}$ Coefficient of the width dependence of alp .

50 $\text{vpr}=0.25 \text{ V}$ Characteristic voltage of the channel-length modulation.

Sub-threshold parameters

51 $\text{gamoor}=1.1\text{e-}3$ Coefficient for the drain induced threshold shift at zero gate drive.

Virtuoso Simulator Components and Device Models Reference

Philips Models

52	$slgamoo=10e-15 \text{ m}^2$	Coefficient of the length dependence of $gamoo$.
53	$etagamr=2$	Exponent of the back-bias dependence of $gamoo$.
54	$mor=0.3$	Factor for the subthreshold slope.
55	$stmo=0.01 \text{ 1/K}$	Coefficient of the temperature dependence of mo .
56	$slmo=1.4e-3 \sqrt{m}$	Coefficient of the length dependence of mo .
57	$etamr=2$	Exponent of the back-bias dependence of m .
58	$zet1r=0.7$	Weak-inversion correction factor.
59	$etazet=0.5$	Exponent of the length dependence of $zet1$.
60	$slzet1=0.14e-6 \text{ m}^{etazet}$	Coefficient of the length dependence of $zet1$.
61	$vsbtr=99 \text{ V}$	Limiting voltage of the vsb dependence of m and $gamoo$.
62	$slvsbt=10e-6 \text{ V m}$	Coefficient of the length dependence of $vsbt$.

Weak-avalanche parameters

63	$a1r=22$	Factor of the weak-avalanche current.
64	$sta1=0.1 \text{ 1/K}$	Coefficient of the temperature dependence of $a1$.
65	$sla1=10e-6 \text{ m}$	Coefficient of the length dependence of $a1$.
66	$swa1=0.1e-3 \text{ m}$	Coefficient of the width dependence of $a1$.
67	$a2r=33 \text{ V}$	Exponent of the weak-avalanche current.
68	$sla2=10e-6 \text{ V m}$	Coefficient of the length dependence of $a2$.
69	$swa2=0.1e-3 \text{ V m}$	Coefficient of the width dependence of $a2$.
70	$a3r=0.6$	Factor of the drain-source voltage above which weak-avalanche occurs.

Virtuoso Simulator Components and Device Models Reference

Philips Models

71 $sla3=1e-6$ m Coefficient of the length dependence of $a3$.

72 $swa3=10e-6$ m Coefficient of the width dependence of $a3$.

Charge parameters

73 $tox=20e-9$ m Thickness of the oxide layer.

74 $col=50e-12$ F/m Gate overlap capacitance per unit channel width.

Noise parameters

75 $ntr=21e-21$ J Coefficient of the thermal noise.

76 $nfr=16e-12$ V² Coefficient of the flicker noise.

Temperature parameters

77 tr (C) Reference temperature. Default set by option $tnom$.

78 $tref$ (C) Alias of tr . Default set by option $tnom$.

79 $tnom$ (C) Alias of tr . Default set by option $tnom$.

80 $dta=0$ K Temperature offset of the device.

81 $trise=0$ K Alias of dta .

Output Parameters

1 le (m) Effective channel length.

2 we (m) Effective channel width.

3 vto (V) Threshold voltage at zero back-bias.

4 ko (\sqrt{V}) Low-backbias body factor.

5 k (\sqrt{V}) High-backbias body factor.

Virtuoso Simulator Components and Device Models Reference

Philips Models

6	phib (V)	Surface potential at strong inversion.
7	vsbx (V)	Transition voltage for the dual-k-factor model.
8	bet (A/V^2)	Gain factor (* mult).
9	the1 (1/V)	Coefficient of the mobility reduction due to the gate-induced field.
10	the2 ($1/\sqrt{V}$)	Coefficient of the mobility reduction due to the back-bias.
11	the3 (1/V)	Coefficient of the mobility reduction due to the lateral field.
12	gam1 ($V^{(1-etads)}$)	Coefficient for the drain induced threshold shift for large gate drive.
13	etads	Exponent of the vds dependence of gam1.
14	alp	Factor of the channel-length modulation.
15	vp (V)	Characteristic voltage of the channel-length modulation.
16	gamoo	Coefficient for the drain induced threshold shift at zero gate drive.
17	etagam	Exponent of the back-bias dependence of gamoo.
18	mo	Factor for the subthreshold slope.
19	etam	Exponent of the back-bias dependence of m.
20	phit (V)	Thermal voltage.
21	zet1	Weak-inversion correction factor.
22	vsbt (V)	Limiting voltage of the vsb dependence of m and gamoo.
23	a1	Factor of the weak-avalanche current.
24	a2 (V)	Exponent of the weak-avalanche current.
25	a3	Factor of the drain-source voltage above which weak-avalanche occurs.
26	cox (F)	Gate-to-channel capacitance (* mult).

Virtuoso Simulator Components and Device Models Reference

Philips Models

27	c_{gdo} (F)	Gate-drain overlap capacitance (* mult).
28	c_{gso} (F)	Gate-source overlap capacitance (* mult).
29	n_t (J)	Coefficient of the thermal noise.
30	n_f (V^2)	Coefficient of the flicker noise (/ mult).

Operating-Point Parameters

1	i_{de} (A)	Resistive drain current.
2	i_{ge} (A)	Resistive gate current.
3	i_{se} (A)	Resistive source current.
4	i_{be} (A)	Resistive bulk current.
5	v_{ds} (V)	Drain-source voltage.
6	v_{gs} (V)	Gate-source voltage.
7	v_{sb} (V)	Source-bulk voltage.
8	i_{ds} (A)	Resistive drain-source current.
9	i_{db} (A)	Resistive drain-bulk current.
10	i_{sb} (A)	Resistive source-bulk current.
11	i_{avl} (A)	Substrate current.
12	pwr (W)	Power.
13	v_{t1} (V)	V_{to} including backbias effects.
14	v_{gt2} (V)	Effective gate drive including backbias and drain effects.
15	v_{dss1} (V)	Saturation voltage at actual bias.
16	v_{sat} (V)	Saturation limit.
17	g_m (S)	Transconductance ($d i_{ds} / d v_{gs}$).

Virtuoso Simulator Components and Device Models Reference

Philips Models

18	g_{mb} (S)	Bulk transconductance ($d\ i_{ds} / d\ v_{bs}$).
19	g_{ds} (S)	Output conductance ($d\ i_{ds} / d\ v_{ds}$).
20	c_{dd} (F)	Capacitance ($d\ q_d / d\ v_d$).
21	c_{dg} (F)	Capacitance ($- d\ q_d / d\ v_g$).
22	c_{ds} (F)	Capacitance ($- d\ q_d / d\ v_s$).
23	c_{db} (F)	Capacitance ($- d\ q_d / d\ v_b$).
24	c_{gd} (F)	Capacitance ($- d\ q_g / d\ v_d$).
25	c_{gg} (F)	Capacitance ($d\ q_g / d\ v_g$).
26	c_{gs} (F)	Capacitance ($- d\ q_g / d\ v_s$).
27	c_{gb} (F)	Capacitance ($- d\ q_g / d\ v_b$).
28	c_{sd} (F)	Capacitance ($- d\ q_s / d\ v_d$).
29	c_{sg} (F)	Capacitance ($- d\ q_s / d\ v_g$).
30	c_{ss} (F)	Capacitance ($d\ q_s / d\ v_s$).
31	c_{sb} (F)	Capacitance ($- d\ q_s / d\ v_b$).
32	c_{bd} (F)	Capacitance ($- d\ q_b / d\ v_d$).
33	c_{bg} (F)	Capacitance ($- d\ q_b / d\ v_g$).
34	c_{bs} (F)	Capacitance ($- d\ q_b / d\ v_s$).
35	c_{bb} (F)	Capacitance ($d\ q_b / d\ v_b$).
36	u	Transistor gain (g_m/g_{ds}).
37	r_{out} (Ω)	Small signal output resistance ($1/g_{ds}$).
38	v_{early} (V)	Equivalent Early voltage ($ i_{dl} /g_{ds}$).
39	k_{eff} (\sqrt{V})	Describes body effect at actual bias.

Virtuoso Simulator Components and Device Models Reference

Philips Models

40	beff (S/V)	Effective beta at actual bias in the simple MOS model ($2 \cdot i_{ds} / v_{gt}^2$).
41	fug (Hz)	Unity gain frequency at actual bias ($g_m / (2 \cdot \pi \cdot c_{in})$).
42	sqrtsfw (V/ $\sqrt{\text{Hz}}$)	Input-referred RMS white noise voltage ($\sqrt{\text{sth}} / g_m$).
43	sqrtsff (V/ $\sqrt{\text{Hz}}$)	Input-referred RMS 1/f noise voltage at 1kHz ($\sqrt{\text{nf} / 1000}$).
44	fknee (Hz)	Cross-over frequency above which white noise is dominant.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

a1	O-23	etazet	M-59	region	I-5	swvto	M-13
a1r	M-63	fknee	OP-44	rout	OP-37	the1	O-9
a2	O-24	fthe1	M-31	sl2vto	M-12	the1r	M-26
a2r	M-67	fug	OP-41	sla1	M-65	the2	O-10
a3	O-25	gam1	O-12	sla2	M-68	the2r	M-32
a3r	M-70	gam1r	M-42	sla3	M-71	the3	O-11
alp	O-14	gamoo	O-16	slalp	M-48	the3r	M-37
alpr	M-46	gamoor	M-51	slgam1	M-43	tnom	M-79
area	I-4	gds	OP-19	slgamoo	M-52	tox	M-73

Virtuoso Simulator Components and Device Models Reference

Philips Models

beff	OP-40	gm	OP-17	slk	M-18	tr	M-77
bet	O-8	gmb	OP-18	slko	M-15	tref	M-78
betsq	M-24	iavl	OP-11	slmo	M-56	trise	M-81
cbb	OP-35	ibe	OP-4	slthe1r	M-28	type	M-1
cbd	OP-32	idb	OP-9	slthe2r	M-34	u	OP-36
cbg	OP-33	ide	OP-1	slthe3r	M-39	vds	OP-5
cbs	OP-34	ids	OP-8	slvsbt	M-62	vdss1	OP-15
cdb	OP-23	ige	OP-2	slvsbx	M-22	vearly	OP-38
cdd	OP-20	isb	OP-10	slvto	M-11	vgs	OP-6
cdg	OP-21	ise	OP-3	slzet1	M-60	vgt2	OP-14
cds	OP-22	k	O-5	sqrtsff	OP-43	vp	O-15
cgb	OP-27	keff	OP-39	sqrtsfw	OP-42	vpr	M-50
cgd	OP-24	ko	O-4	stal	M-64	vsat	OP-16
cgdo	O-27	kor	M-14	stlthe1	M-29	vsb	OP-7
cgg	OP-25	kr	M-17	stlthe2	M-35	vsbt	O-22
cgs	OP-26	l	I-2	stlthe3	M-40	vsbtr	M-61
cgso	O-28	lap	M-5	stmo	M-55	vsbx	O-7
col	M-74	le	O-1	stthe1r	M-27	vsbxr	M-21
cox	O-26	ler	M-2	stthe2r	M-33	vt1	OP-13
csb	OP-31	lvar	M-4	stthe3r	M-38	vto	O-3
csd	OP-28	m	I-6	stvto	M-10	vtor	M-9

Virtuoso Simulator Components and Device Models Reference

Philips Models

csg	OP-29	mo	O-18	swa1	M-66	w	I-1
css	OP-30	mor	M-54	swa2	M-69	wdog	M-8
dta	M-80	mult	I-3	swa3	M-72	we	O-2
etaalp	M-47	nf	O-30	swalp	M-49	wer	M-3
etabet	M-25	nfr	M-76	swgam1	M-44	wot	M-7
etads	O-13	nt	O-29	swk	M-19	wvar	M-6
etadsr	M-45	ntr	M-75	swko	M-16	zet1	O-21
etagam	O-17	phib	O-6	swthe1	M-30	zet1r	M-58
etagamr	M-53	phibr	M-20	swthe2	M-36		
etam	O-19	phit	O-20	swthe3	M-41		
etamr	M-57	pwr	OP-12	swvsbx	M-23		

Compact MOS-Transistor Model (mos903)

The mos903 model is a compact MOS-transistor model, intended for the simulation of circuit behavior with emphasis on analog applications. It is described in the Philips MOST Modelbook (Jun.98) as MOS model, level 903. Information on how to obtain this document can be found on Source Link by searching for Philips.

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In extension to the model book description a minimum conductance g_{min} is inserted between the drain and source node, to aid convergence. The value of g_{min} is set by an options statement, default = 1e-12 S.

This device is supported within altergroups.

This device is dynamically loaded from the shared object /vobs/spectre_dev/tools.lnx86/cmi/lib/5.0.doc/libphilips_sh.so

Virtuoso Simulator Components and Device Models Reference

Philips Models

Sample Instance Statement

```
m_1 (1 2 0 0) mos9nch w=0.35e-6 l=0.35e-6
```

Sample Model Statement

```
model mos9nch mos903 ler=3.5e-7 wer=1e-5 lvar=0 lap=2.2e-8 wvar=0 wot=3e-8  
vtor=0.76 the1r=0.67 stthe1r=-1.76e-3 etaalp=0 slalp=0 alpr=0.01
```

Instance Definition

```
Name d g s [b] ModelName parameter=value ...
```

Instance Parameters

1	l=1.5e-06 m	Drawn channel length in the lay-out. Scale set by option scale.
2	w=2e-05 m	Drawn channel width in the lay-out. Scale set by option scale.
3	mult=1	Number of devices in parallel.
4	region=triode	Estimated DC operating region, used as a convergence aid. Possible values are off, triode, sat, or subth.
5	m=1	Multiplicity factor.
6	trise=0	Temperature rise from ambient.
7	area=1	alias of mult.

Model Definition

```
model modelName mos903 parameter=value ...
```

Model Parameters

1	level=903	MOS Level.
2	ler=1.1e-06(n)/1.25e-06(p) m	Effective channel length of the reference transistor.
3	wer=2e-05 m	Effective channel width of the reference transistor.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 4 $lvar=-2.2e-07(n)/-4.6e-07(p)$ m
Difference between the actual and the programmed poly-silicon gate length.
- 5 $lap=1e-07(n)/2.5e-08(p)$ m
Effective channel length reduction per side.
- 6 $wvar=-2.5e-08(n)/-1.3e-07(p)$ m
Difference between the actual and the programmed field-oxide opening.
- 7 $wot=0$ m
Effective channel width reduction per side.
- 8 $tr=21$ unitCELSIUS
Reference temperature. Default set by option `tnom`.
- 9 $vtor=0.73(n)/1.1(p)$ V
Threshold voltage at zero back-bias.
- 10 $stvto=-0.0012(n)/-0.0017(p)$ V/K
Coefficient of the temperature dependence of `vto`.
- 11 $slvto=-1.35e-07(n)/3.5e-08(p)$ V*m
Coefficient of the length dependence of `vto`.
- 12 $sl2vto=0$ V*m²
Second coefficient of the length dependence of `vto`.
- 13 $sl3vto=0$ V
Third coefficient of the length dependence of `vto`.
- 14 $swvto=1.3e-07(n)/5e-08(p)$ V*m
Coefficient of the width dependence of `vto`.
- 15 $kor=0.65(n)/0.47(p)$ sqrt(V)
Low-backbias body factor.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 16 $slko=-1.3e-07(n)/-2e-07(p) \sqrt{V} \cdot m$
Coefficient of the length dependence of `ko'.
- 17 $sl2ko=0 V^{1/2} m^2$ Second coefficient of the length dependence of `ko'.
- 18 $swko=2e-09(n)/1.15e-07(p) \sqrt{V} \cdot m$
Coefficient of the width dependence of `ko'.
- 19 $kr=0.11(n)/0.47(p) \sqrt{V}$
High-backbias body factor.
- 20 $slk=-2.8e-07(n)/-2e-07(p) \sqrt{V} \cdot m$
Coefficient of the length dependence of `k'.
- 21 $sl2k=0 V^{1/2} m^2$ Second coefficient of the length dependence of `k'.
- 22 $swk=2.75e-07(n)/1.15e-07(p) \sqrt{V} \cdot m$
Coefficient of the width dependence of `k'.
- 23 $phibr=0.65 V$ Surface potential at strong inversion.
- 24 $vsbxr=0.66(n)/1e-12(p) V$
Transition voltage for the dual-`k'-factor model.
- 25 $slvsbx=0 V \cdot m$ Coefficient of the length dependence of `vsbx'.
- 26 $swvsbx=-6.75e-07(n)/0(p) V \cdot m$
Coefficient of the width dependence of `vsbx'.
- 27 $betsq=8.3e-05(n)/2.61e-05(p) A/V^2$
Gain factor for an infinite square transistor.
- 28 $etabet=1.6$ Exponent of the temperature dependence of the gain factor.
- 29 $lp1=1e-06 m$ Characteristic length of first profile.

Virtuoso Simulator Components and Device Models Reference

Philips Models

30	$f_{bet1}=0$	Relative mobility decrease due to first profile.
31	$l_{p2}=1e-08$ m	Characteristic length of second profile.
32	$f_{bet2}=0$	Relative mobility decrease due to second profile.
33	$the1r=0.19$ 1/V	Coefficient of the mobility reduction due to the gate-induced field.
34	$stthe1r=0$ 1/(V*K)	Coefficient of the temperature dependence of `the1'.
35	$slthe1r=1.4e-07(n)/7e-08(p)$ m/V	Coefficient of the length dependence of `the1'.
36	$stlthe1=0$ m/(V*K)	Coefficient of the temperature dependence of `slthe1'.
37	$gthe1=0$	Parameter that selects either the old ($gthe1=0$) or the new ($gthe1=1$) scaling rule of the1.
38	$swthe1=-5.8e-08(n)/-8e-08(p)$ m/V	Coefficient of the width dependence of `the1'.
39	$w_{dog}=0$ m	Characteristic drawn gate width, below which dogboning appears.
40	$fthe1=0$	Coefficient describing the width dependence of `the1' for `w' < `wdog'.
41	$the2r=0.012(n)/0.165(p)$ 1/sqrt(V)	Coefficient of the mobility reduction due to the back-bias.
42	$stthe2r=0$ 1/(sqrt(V)*K)	Coefficient of the temperature dependence of `the2'.
43	$slthe2r=-3.3e-08(n)/-7.5e-08(p)$ m/sqrt(V)	

Virtuoso Simulator Components and Device Models Reference

Philips Models

Coefficient of the length dependence of θ_{e2} .

44 $\theta_{l\theta_{e2}} = 0 \text{ m}/(\sqrt{V} \cdot K)$

Coefficient of the temperature dependence of $\theta_{sl\theta_{e2}}$.

45 $\theta_{sw\theta_{e2}} = 3e-08(n)/2e-08(p) \text{ m}/\sqrt{V}$

Coefficient of the width dependence of θ_{e2} .

46 $\theta_{e3r} = 0.145(n)/0.027(p) \text{ 1}/V$

Coefficient of the mobility reduction due to the lateral field.

47 $\theta_{st\theta_{e3r}} = -0.00066(n)/0(p) \text{ 1}/(V \cdot K)$

Coefficient of the temperature dependence of θ_{e3} .

48 $\theta_{sl\theta_{e3r}} = 1.85e-07(n)/2.7e-08(p) \text{ m}/V$

Coefficient of the length dependence of θ_{e3} .

49 $\theta_{st\theta_{e3}} = -6.2e-10(n)/0(p) \text{ m}/(V \cdot K)$

Coefficient of the temperature dependence of $\theta_{sl\theta_{e3}}$.

50 $\theta_{sw\theta_{e3}} = 2e-08(n)/1.1e-08(p) \text{ m}/V$

Coefficient of the width dependence of θ_{e3} .

51 $\theta_{\text{gam}1r} = 0.145(n)/0.077(p) V^{(1-\text{etads})}$

Coefficient for the drain induced threshold shift for large gate drive.

52 $\theta_{sl\text{gam}1} = 1.6e-07(n)/1.05e-07(p) V^{(1-\text{etads})} \cdot \text{m}$

Coefficient of the length dependence of $\theta_{\text{gam}1}$.

53 $\theta_{sw\text{gam}1} = -1e-08(n)/-1.1e-08(p) V^{(1-\text{etads})} \cdot \text{m}$

Coefficient of the width dependence of $\theta_{\text{gam}1}$.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 54 $\text{etadsr}=0.6$ Exponent of the vds dependence of γ_1 .
- 55 $\text{alpr}=0.003(n)/0.044(p)$
Factor of the channel-length modulation.
- 56 $\text{etaalp}=0.15(n)/0.17(p)$
Exponent of the length dependence of α .
- 57 $\text{slalp}=-0.00565(n)/0.009(p) m^{\text{etaalp}}$
Coefficient of the length dependence of α .
- 58 $\text{swalp}=1.67e-09(n)/1.8e-10(p) m$
Coefficient of the width dependence of α .
- 59 $\text{vpr}=0.34(n)/0.235(p) V$
Characteristic voltage of the channel-length modulation.
- 60 $\text{gamoor}=0.018(n)/0.007(p)$
Coefficient for the drain induced threshold shift at zero gate drive.
- 61 $\text{slgamoo}=2e-14(n)/1.1e-14(p) m^2$
Coefficient of the length dependence of γ_{oo} .
- 62 $\text{sl2gamoo}=0$ Second coefficient of the length dependence of γ_{oo} .
- 63 $\text{etagamr}=2(n)/1(p)$
Exponent of the back-bias dependence of γ_{oo} .
- 64 $\text{mor}=0.5(n)/0.375(p)$
Factor for the subthreshold slope.
- 65 $\text{stmo}=0 1/K$ Coefficient of the temperature dependence of μ_0 .
- 66 $\text{slmo}=0.00028(n)/4.7e-05(p) \text{sqrt}(m)$

Virtuoso Simulator Components and Device Models Reference

Philips Models

- Coefficient of the length dependence of μ_0 .
- 67 $etamr=2(n)/1(p)$ Exponent of the back-bias dependence of m .
- 68 $zet1r=0.42(n)/1.3(p)$
- Weak-inversion correction factor.
- 69 $etazet=0.17(n)/0.03(p)$
- Exponent of the length dependence of zet1 .
- 70 $slzet1=-0.39(n)/-2.8(p) m^{etazet}$
- Coefficient of the length dependence of zet1 .
- 71 $vsbtr=2.1(n)/100(p) V$
- Limiting voltage of the vsb dependence of m and γ_0 .
- 72 $slvsbt=-4.4e-06(n)/0(p) V \cdot m$
- Coefficient of the length dependence of $vsbt$.
- 73 $a1r=6(n)/10(p)$ Factor of the weak-avalanche current.
- 74 $sta1=0 1/K$ Coefficient of the temperature dependence of $a1$.
- 75 $sla1=1.3e-06(n)/-1.5e-05(p) m$
- Coefficient of the length dependence of $a1$.
- 76 $swa1=3e-06(n)/3e-05(p) m$
- Coefficient of the width dependence of $a1$.
- 77 $a2r=38(n)/59(p) V$
- Exponent of the weak-avalanche current.
- 78 $sla2=1e-06(n)/-8e-06(p) V \cdot m$
- Coefficient of the length dependence of $a2$.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 79 $swa2=2e-06(n)/1.5e-05(p)$ V*m
Coefficient of the width dependence of a^2 .
- 80 $a3r=0.65(n)/0.52(p)$ Factor of the drain-source voltage above which weak-avalanche occurs.
- 81 $sla3=-5.5e-07(n)/-4.5e-07(p)$ m
Coefficient of the length dependence of a^3 .
- 82 $swa3=0(n)/-1.4e-07(p)$ m
Coefficient of the width dependence of a^3 .
- 83 $tox=2.5e-08$ m Thickness of the oxide layer.
- 84 $col=3.2e-10$ F/m Gate overlap capacitance per unit channel width.
- 85 $ntr=2.44e-20(n)/2.11e-20(p)$ J
Coefficient of the thermal noise.
- 86 $nfmod=0$ Switch that selects either old or new flicker noise model.
- 87 $nfr=7e-11(n)/2.14e-11(p)$ V²
Flicker noise coefficient of the reference transistor (for $nfmod=0$).
- 88 $nfcr=7.15e+22(n)/1.53e+22(p)$ 1/(V*m⁴)
First coefficient of the flicker noise coefficient of the reference transistor (for $nfmod=1$).
- 89 $nfr=2.16e+07(n)/4.06e+06(p)$ 1/(V*m²)
Second coefficient of the flicker noise coefficient of the reference transistor (for $nfmod=1$).
- 90 $nfc=0(n)/2.92e-10(p)$ 1/V
Third coefficient of the flicker noise coefficient of the reference transistor (for $nfmod=1$).

Virtuoso Simulator Components and Device Models Reference

Philips Models

91	th3mod=1	Flag for theta3 clipping.
92	dta=0 K	Temperature offset of the device.
93	type=n	Transistor gender. Possible values are n, p, npn, pnp, npnv, pnpv, npnl, or pnpl.
94	imax=1.0 A	Explosion current.
95	vbox=0.0 V	Oxide breakdown voltage.
96	vbd _s =0.0 V	Drain-source breakdown voltage.
97	tnom (unitCELSIUS)	alias of tnom.
98	tref (unitCELSIUS)	alias of tnom.

Output Parameters

1	vto ()	Threshold voltage at zero back-bias.
2	ko ()	Low-backbias body factor.
3	k ()	High-backbias body factor.
4	phib ()	Surface potential at strong inversion.
5	vsbx ()	Transition voltage for the dual-k-factor model.
6	bet ()	Gain factor (* mult).
7	the1 ()	Coefficient of the mobility reduction due to the gate-induced field.
8	the2 ()	Coefficient of the mobility reduction due to the back-bias.
9	the3 ()	Coefficient of the mobility reduction due to the lateral field.
10	gam1 ()	Coefficient for the drain induced threshold shift for large gate drive.
11	etads	Exponent of the vds dependence of gam1.

Virtuoso Simulator Components and Device Models Reference

Philips Models

12	alp	Factor of the channel-length modulation.
13	vp ()	Characteristic voltage of the channel-length modulation.
14	gamoo	Coefficient of the drain induced threshold shift at zero gate drive for the actual transistor.
15	etagam	Exponent of the back-bias dependence of gamo.
16	mo	Factor for the subthreshold slope.
17	etam	Exponent of the back-bias dependence of m.
18	phit ()	Thermal voltage.
19	zet1	Weak-inversion correction factor.
20	vsbt ()	Limiting voltage of the vsb dependence of m and gamo.
21	a1	Factor of the weak-avalanche current.
22	a2 ()	Exponent of the weak-avalanche current.
23	a3	Factor of the drain-source voltage above which weak-avalanche occurs.
24	cox ()	Gate-to-channel capacitance (* mult).
25	cgdo ()	Gate-drain overlap capacitance (* mult).
26	cgso ()	Gate-source overlap capacitance (* mult).
27	nt ()	Coefficient of the thermal noise.
28	nfmod	Switch that selects either old or new flicker noise model.
29	nf ()	Coefficient of the flicker noise (/ mult) (nfmod = 0).
30	nfa ()	First coefficient of the flickernoise of the actual transistor (nfmod = 1).
31	nfb ()	Second coefficient of the flickernoise of the actual transistor (nfmod = 1).

Virtuoso Simulator Components and Device Models Reference

Philips Models

32	nfc ()	Second coefficient of the flickernoise of the actual transistor (nfmod = 1).
33	th3mod	Flag for theta3 clipping.
34	tox ()	Thickness of the oxide layer.

Operating-Point Parameters

1	ids ()	Resistive drain-source current.
2	iavl ()	Substrate current.
3	vds ()	Drain-source voltage.
4	vgs ()	Gate-source voltage.
5	vsb ()	Source-bulk voltage.
6	vto ()	Threshold voltage at zero back-bias.
7	vts ()	VT0 including backbias effects.
8	vgt ()	Effective gate drive including backbias and drain effects.
9	vdss ()	Saturation voltage at actual bias.
10	vsat ()	Saturation limit.
11	gm ()	Transconductance ($d\text{ ids} / d\text{ vgs}$).
12	gmb ()	Bulk transconductance ($d\text{ ids} / d\text{ vbs}$).
13	gds ()	Output conductance ($d\text{ ids} / d\text{ vds}$).
14	cdd ()	Capacitance ($d\text{ qd} / d\text{ vd}$).
15	cdg ()	Capacitance ($- d\text{ qd} / d\text{ vg}$).
16	cds ()	Capacitance ($- d\text{ qd} / d\text{ vs}$).
17	cdb ()	Capacitance ($- d\text{ qd} / d\text{ vb}$).

Virtuoso Simulator Components and Device Models Reference

Philips Models

18	cgd ()	Capacitance (- d qg / d vd).
19	cgg ()	Capacitance (d qg / d vg).
20	cgs ()	Capacitance (- d qg / d vs).
21	cgb ()	Capacitance (- d qg / d vb).
22	csd ()	Capacitance (- d qs / d vd).
23	csg ()	Capacitance (- d qs / d vg).
24	css ()	Capacitance (d qs / d vs).
25	csb ()	Capacitance (- d qs / d vb).
26	cbd ()	Capacitance (- d qb / d vd).
27	cbg ()	Capacitance (- d qb / d vg).
28	cbs ()	Capacitance (- d qb / d vs).
29	cbb ()	Capacitance (d qb / d vb).
30	cgdol ()	Drain overlap capacitance of the actual transistor.
31	cgsol ()	Gate overlap capacitance of the actual transistor.
32	weff ()	Effective channel width for geometrical models.
33	leff ()	Effective channel length for geometrical models.
34	u	Transistor gain (gm/gds).
35	rout ()	Small signal output resistance (1/gds).
36	vearly ()	Equivalent Early voltage (idl /gds).
37	keff ()	Describes body effect at actual bias.
38	beff ()	Effective beta at actual bias in the simple MOS model ($2 \cdot idl / vgt^2$).

Virtuoso Simulator Components and Device Models Reference

Philips Models

39	fug ()	Unity gain frequency at actual bias ($gm/(2*\pi*cin)$).
40	sqrtsfw ()	Input-referred RMS white noise voltage (\sqrt{sth}/gm).
41	sqrtstff ()	Input-referred RMS 1/f noise voltage at 1kHz ($\sqrt{nf/1000}$).
42	fknee ()	Cross-over frequency above which white noise is dominant.
43	table_ids ()	Channel current.
44	table_isub ()	Substrate current.
45	table_vth ()	Threshold voltage including back-bias and drain-bias effects.
46	table_vdsat ()	Saturation voltage at actual bias.
47	table_qg ()	Charge at g node.
48	table_qd ()	Charge at d node.
49	table_qb ()	Charge at b node.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

a1	O-21	fthe1	M-40	sl2gamoo	M-62	table_qd	OP-48
a1r	M-73	fug	OP-39	sl2k	M-21	table_qg	OP-47
a2	O-22	gam1	O-10	sl2ko	M-17	table_vdsat	OP-46
a2r	M-77	gam1r	M-51	sl2vto	M-12	table_vth	OP-45

Virtuoso Simulator Components and Device Models Reference

Philips Models

a3	O-23	gamoo	O-14	sl3vto	M-13	th3mod	M-91
a3r	M-80	gamoor	M-60	sla1	M-75	th3mod	O-33
alp	O-12	gds	OP-13	sla2	M-78	the1	O-7
alpr	M-55	gm	OP-11	sla3	M-81	the1r	M-33
area	I-7	gmb	OP-12	sla1p	M-57	the2	O-8
beff	OP-38	gthe1	M-37	slgam1	M-52	the2r	M-41
bet	O-6	iavl	OP-2	slgamoo	M-61	the3	O-9
betsq	M-27	ids	OP-1	slk	M-20	the3r	M-46
cbb	OP-29	imax	M-94	slko	M-16	tnom	M-97
cbd	OP-26	k	O-3	slmo	M-66	tox	M-83
cbg	OP-27	keff	OP-37	slthe1r	M-35	tox	O-34
cbs	OP-28	ko	O-2	slthe2r	M-43	tr	M-8
cdb	OP-17	kor	M-15	slthe3r	M-48	tref	M-98
cdd	OP-14	kr	M-19	slvsbt	M-72	trise	I-6
cdg	OP-15	l	I-1	slvsbx	M-25	type	M-93
cds	OP-16	lap	M-5	slvto	M-11	u	OP-34
cgb	OP-21	leff	OP-33	slzet1	M-70	vbds	M-96
cgd	OP-18	ler	M-2	sqrtsff	OP-41	vbox	M-95
cgdo	O-25	level	M-1	sqrtsfw	OP-40	vds	OP-3
cgdo1	OP-30	lp1	M-29	sta1	M-74	vdss	OP-9
cgg	OP-19	lp2	M-31	stlthe1	M-36	vearly	OP-36

Virtuoso Simulator Components and Device Models Reference

Philips Models

cgs	OP-20	lvar	M-4	stlthe2	M-44	vgs	OP-4
cgso	O-26	m	I-5	stlthe3	M-49	vgt	OP-8
cgsol	OP-31	mo	O-16	stmo	M-65	vp	O-13
col	M-84	mor	M-64	stthe1r	M-34	vpr	M-59
cox	O-24	mult	I-3	stthe2r	M-42	vsat	OP-10
csb	OP-25	nf	O-29	stthe3r	M-47	vsb	OP-5
csd	OP-22	nfa	O-30	stvto	M-10	vsbt	O-20
csg	OP-23	nfarc	M-88	swa1	M-76	vsbtr	M-71
css	OP-24	nfb	O-31	swa2	M-79	vsbx	O-5
dta	M-92	nfbr	M-89	swa3	M-82	vsbxr	M-24
etaalp	M-56	nfc	O-32	swalp	M-58	vto	O-1
etabet	M-28	nfcrc	M-90	swgam1	M-53	vto	OP-6
etads	O-11	nfmod	M-86	swk	M-22	vtor	M-9
etadsr	M-54	nfmod	O-28	swko	M-18	vts	OP-7
etagam	O-15	nfr	M-87	swthe1	M-38	w	I-2
etagamr	M-63	nt	O-27	swthe2	M-45	wdog	M-39
etam	O-17	ntr	M-85	swthe3	M-50	weff	OP-32
etamr	M-67	phib	O-4	swvsbx	M-26	wer	M-3
etazet	M-69	phibr	M-23	swvto	M-14	wot	M-7
fbet1	M-30	phit	O-18	table_ids	OP-43	wvar	M-6
fbet2	M-32	region	I-4	table_isub	OP-44	zet1	O-19

Virtuoso Simulator Components and Device Models Reference

Philips Models

fknee OP-42 rout OP-35 table_qb OP-49 zet1r M-68

The mos10.00 model is an experimental model based on the thesis of Ronald van Langevelde: "A compact MOSFET Model for Distortion Analysis in Analog Circuit Design", Technische Universiteit Eindhoven, 1998.

Note: In noise analysis, mos10.00 instances will not generate any contribution, since there are no noise sources included (yet) in the mos10.00 model.

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In extension to the description a minimum conductance g_{min} is inserted between the drain and source node, to aid convergence. The value of g_{min} is set by an options statement, default = 1e-12 S.

This device is supported within altergroups.

This device is dynamically loaded from the shared object /vobs/spectre_dev/tools.sun4v/cmi/lib/5.0.doc/libphilips_sh.so

Instance Definition

```
Name d g s [b] ModelName parameter=value ...
```

Instance Parameters

- | | | |
|---|---------------|---|
| 1 | w=1.0 scale m | Drawn channel width in the lay-out. Scale set by option scale. |
| 2 | l=1.0 scale m | Drawn channel length in the lay-out. Scale set by option scale. |
| 3 | mult=1 | Number of devices in parallel. |
| 4 | area=1 | Alias of mult. |
| 5 | region=triode | Estimated DC operating region, used as a convergence aid. Possible values are off, triode, sat, or subth. |
| 6 | m=1 | Multiplicity factor. |

Virtuoso Simulator Components and Device Models Reference

Philips Models

Model Definition

```
model modelName mos1000 parameter=value ...
```

Model Parameters

Device type parameters

1 `type=n` Transistor gender.
Possible values are n or p.

Geometry parameters

2 `ler=1.0e-6 m` Effective channel length of the reference transistor.

3 `wer=1e-6 m` Effective channel width of the reference transistor.

4 `lvar=0.0 m` Difference between the actual and the programmed poly-silicon gate length.

5 `lap=45.0e-9 m` Effective channel length reduction per side.

6 `wvar=-5.0e-9 m` Difference between the actual and the programmed field-oxide opening.

7 `wot=50.0e-9 m` Effective channel width reduction per side.

Threshold-voltage parameters

8 `vfbr=-518.9e-03 V` Flat-band voltage for reference transistor.

9 `stvfb=-1.2e-03 V/K`
Coefficient of temperature dependence of `vfbr`.

10 `slvfb=24.0e-09 V m`
Coefficient of length dependence of `vfbr`.

11 `sl2vfb=-1.1e-15 V m2`
Second coefficient of length dependence of `vfbr`.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 12 $swvfb=4.400e-09$ V m
Coefficient of the width dependency of v_{fb} .
- 13 $kor=368.0e-03$ \sqrt{V}
Body effect coefficient for the reference transistor.
- 14 $slko=-8.240e-09$ \sqrt{V} m
Coefficient of the length dependence of k_o .
- 15 $sl2ko=-2.260e-15$ \sqrt{V} m²
Second coefficient of the length dependence of k_o .
- 16 $swko=5.86e-09$ \sqrt{V} m
Coefficient of the width dependence of k_o .
- 17 $phibr=0.6$ V
Surface potential at strong inversion.

Channel-current parameters

- 18 $betsq=370.9e-06$ A/V²
Gain factor for an infinite square transistor.
- 19 $etabet=1.6$
Exponent of the temperature dependence of the gain factor.
- 20 $thesrr=16.10e-3$ 1/V²
Mobility degradation parameter due to surface roughness scattering.
- 21 $stthesr=0.0$ 1/(V² K)
Coefficient of the temperature dependence of $thesr$.
- 22 $swthesr=0.0$ 1/(V² m)
Coefficient of the width dependence of $thesr$.
- 23 $thephr=0.055$ 1/V
Mobility degradation parameter due to phonon scattering.
- 24 $sttheph=0.0$ 1/(V K)
Coefficient of the temperature dependence of $theph$.
- 25 $swtheph=0.0$ 1/(V m)
Coefficient of the width dependence of $theph$.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 26 $etamobr=1.6$ Effective field parameter for dependence on depletion charge.
- 27 $swetamob=0.0$ 1/m Coefficient of the width dependence of $etamobr$.
- 28 $thersq=0.155$ 1/V Coefficient of gate voltage independent part of series resistance.
- 29 $swther=0.0$ 1/(V m)
Coefficient of the width dependence of $ther$.
- 30 $ther1=0.0$ V Numerator of gate voltage independent part of series resistance.
- 31 $ther2=1.0$ V Denominator of gate voltage independent part of series resistance.
- 32 $thenr=0.480$ 1/V Velocity saturation parameter due to optical phonon scattering.
- 33 $stthen=0.0$ 1/(V K)
Coefficient of the temperature dependence of $then$.
- 34 $swthen=0.0$ 1/(V m)
Coefficient of the width dependence of $then$.
- 35 $thepr=0.0$ 1/V Velocity saturation parameter due to acoustic phonon scattering.
- 36 $stthep=0.0$ 1/(V K)
Coefficient of the temperature dependence of $thep$.
- 37 $swthep=0.0$ 1/(V m)
Coefficient of the width dependence of $thep$.
- 38 $gthep=1.0$ Velocity saturation factor due to acoustic phonon scattering.
- 39 $thethr=3.227e-3$ 1/V³
Coefficient of self-heating.
- 40 $sltheth=2.460e-9$ 1/(V³ m)
Coefficient of the length dependence of $theth$.
- 41 $swtheth=0.0$ 1/(V³ m)
Coefficient of the width dependence of $theth$.

Sub-threshold parameters

- 42 `sdiblo=2.030e-03` $1/\sqrt{V}$ Drain-induced barrier lowering parameter.
- 43 `sdiblexp=1.340` Exponent of the length dependence of `sdibl`.
- 44 `dphi=0.800` V Parameter for short-channel subthreshold behavior.

Saturation parameters

- 45 `ssfsq=6.250e-03` $1/\sqrt{V}$ Static feedback parameter.
- 46 `swssf=0.0` $1/(\sqrt{V} \text{ m})$ Coefficient of the width dependence of `ssf`.
- 47 `alpsq=0.010` m Characteristic length parameter for channel length modulation.
- 48 `swalp=0.0` m Coefficient of the width dependence of `alp`.
- 49 `vp=0.075` V Characteristic voltage of channel-length modulation.

Smoothing parameters

- 50 `mexpo=0.093` Smoothing factor.
- 51 `mexpl=0.065` Coefficient of the length dependence of `mexp`.

Weak-avalanche parameters

- 52 `a1r=6` Factor of the weak-avalanche current.
- 53 `sta1=0.0` $1/K$ Coefficient of the temperature dependence of `a1`.
- 54 `sla1=1.30e-6` m Coefficient of the length dependence of `a1`.
- 55 `swa1=3.0e-06` m Coefficient of the width dependence of `a1`.
- 56 `a2r=38.0` V Exponent of the weak-avalanche current.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 57 $s_{la2}=1.00e-06$ V m Coefficient of the length dependence of a_2 .
- 58 $s_{wa2}=2.00e-06$ V m Coefficient of the width dependence of a_2 .
- 59 $a_{3r}=0.650$ Factor of the drain-source voltage above which weak-avalanche occurs.
- 60 $s_{la3}=-550.0e-06$ m Coefficient of the length dependence of a_3 .
- 61 $s_{wa3}=0.0$ m Coefficient of the width dependence of a_3 .

Charge parameters

- 62 $t_{ox}=4.5e-09$ m Thickness of the oxide layer.
- 63 $c_{ol}=320e-12$ F/m Gate overlap capacitance per unit channel width.

Temperature parameters

- 64 t_r (C) Reference temperature. Default set by option t_{nom} .
- 65 t_{ref} (C) Alias of t_r . Default set by option t_{nom} .
- 66 t_{nom} (C) Alias of t_r . Default set by option t_{nom} .
- 67 $d_{ta}=0.0$ K Temperature offset of the device.
- 68 $t_{rise}=0.0$ K Alias of d_{ta} .

Output Parameters

- 1 l_e (m) Effective channel length.
- 2 w_e (m) Effective channel width.
- 3 v_{fb} (V) Flat-band voltage.
- 4 k_o (\sqrt{V}) Body effect coefficient.
- 5 ϕ_{hib} (V) Surface potential at strong inversion.

Virtuoso Simulator Components and Device Models Reference

Philips Models

6	bet (A/V ²)	Gain factor.
7	thesr (1/V ²)	Mobility degradation parameter due to surface roughness scattering.
8	theph (1/V)	Mobility degradation parameter due to phonon scattering.
9	etamob	Effective field parameter for dependence on depletion charge.
10	ther (1/V)	Coefficient of gate voltage independent part of series resistance.
11	ther1 (V)	Numerator of gate voltage independent part of series resistance.
12	ther2 (V)	Denominator of gate voltage independent part of series resistance.
13	then (1/V)	Velocity saturation parameter due to optical phonon scattering.
14	thep (1/V)	Velocity saturation parameter due to acoustic phonon scattering.
15	gthep	Velocity saturation factor due to acoustic phonon scattering.
16	theth (1/V ³)	Coefficient of self-heating.
17	sdibl (1/ \sqrt{V})	Drain-induced barrier lowering parameter.
18	dphi (V)	Parameter for short-channel subthreshold behavior.
19	ssf (1/ \sqrt{V})	Static feedback parameter.
20	alp (m)	Characteristic length parameter for channel length modulation.
21	vp (V)	Characteristic voltage of channel-length modulation.
22	mexp	Smoothing factor.
23	phit (V)	Thermal voltage.
24	a1	Factor of the weak-avalanche current.
25	a2 (V)	Exponent of the weak-avalanche current.

Virtuoso Simulator Components and Device Models Reference

Philips Models

26	a3	Factor of the drain-source voltage above which weak-avalanche occurs.
27	cox (F)	Gate-to-channel capacitance (* mult).
28	cgdo (F)	Gate-drain overlap capacitance (* mult).
29	cgso (F)	Gate-source overlap capacitance (* mult).

Operating-Point Parameters

1	ide (A)	Resistive drain current.
2	ige (A)	Resistive gate current.
3	ise (A)	Resistive source current.
4	ibe (A)	Resistive bulk current.
5	vds (V)	Drain-source voltage.
6	vgs (V)	Gate-source voltage.
7	vsb (V)	Source-bulk voltage.
8	ids (A)	Resistive drain current.
9	idb (A)	Resistive drain-bulk current.
10	isb (A)	Resistive source-bulk current.
11	iavl (A)	Substrate current.
12	pwr (W)	Power.
13	vto (V)	Threshold voltage at zero back-bias.
14	vtS (V)	V _{ts} .
15	vgt (V)	Effective gate drive including backbias and drain effects.
16	vdss (V)	Saturation voltage at actual bias.

Virtuoso Simulator Components and Device Models Reference

Philips Models

17	v_{sat} (V)	Saturation limit.
18	g_m (S)	Transconductance ($d i_{ds} / d v_{gs}$).
19	g_{mb} (S)	Bulk transconductance ($d i_{ds} / d v_{bs}$).
20	g_{ds} (S)	Output conductance ($d i_{ds} / d v_{ds}$).
21	c_{dd} (F)	Capacitance ($d q_d / d v_d$).
22	c_{dg} (F)	Capacitance ($- d q_d / d v_g$).
23	c_{ds} (F)	Capacitance ($- d q_d / d v_s$).
24	c_{db} (F)	Capacitance ($- d q_d / d v_b$).
25	c_{gd} (F)	Capacitance ($- d q_g / d v_d$).
26	c_{gg} (F)	Capacitance ($d q_g / d v_g$).
27	c_{gs} (F)	Capacitance ($- d q_g / d v_s$).
28	c_{gb} (F)	Capacitance ($- d q_g / d v_b$).
29	c_{sd} (F)	Capacitance ($- d q_s / d v_d$).
30	c_{sg} (F)	Capacitance ($- d q_s / d v_g$).
31	c_{ss} (F)	Capacitance ($d q_s / d v_s$).
32	c_{sb} (F)	Capacitance ($- d q_s / d v_b$).
33	c_{bd} (F)	Capacitance ($- d q_b / d v_d$).
34	c_{bg} (F)	Capacitance ($- d q_b / d v_g$).
35	c_{bs} (F)	Capacitance ($- d q_b / d v_s$).
36	c_{bb} (F)	Capacitance ($d q_b / d v_b$).
37	u	Transistor gain (g_m/g_{ds}).
38	r_{out} (Ω)	Small signal output resistance ($1/g_{ds}$).

Virtuoso Simulator Components and Device Models Reference

Philips Models

39	vearly (V)	Equivalent Early voltage ($ idl/gds$).
40	keff (\sqrt{V})	Describes body effect at actual bias.
41	beff (S/V)	Effective beta at actual bias in the simple MOS model ($2* idl/vgt^2$).
42	fug (Hz)	Unity gain frequency at actual bias ($gm/(2*pi*cin)$).

Parameter Index

In the following index, I refers to instance parameters, M refers to the model parameters section, O refers to the output parameters section, and OP refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of M-35 means the 35th model parameter.

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a2	O-25	gds	OP-20	sla1	M-54	ther2	O-12
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Virtuoso Simulator Components and Device Models Reference

Philips Models

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cbs	OP-35	keff	OP-40	stvfb	M-9	u	OP-37
cdb	OP-24	ko	O-4	swa1	M-55	vds	OP-5
cdd	OP-21	kor	M-13	swa2	M-58	vdss	OP-16
cdg	OP-22	l	I-2	swa3	M-61	vearly	OP-39
cds	OP-23	lap	M-5	swalp	M-48	vfb	O-3
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Compact MOS-Transistor Distortion Model (mos1100)

Instance Definition

Name d g s b ModelName parameter=value ...

Instance Parameters

- | | | |
|---|---------------|--|
| 1 | l=2e-06 m | Drawn channel length in the layout. Scale set by option scale.. |
| 2 | w=1e-05 m | Drawn channel width in the layout. Scale set by option scale.. |
| 3 | mult=1 | Number of devices in parallel. |
| 4 | region=triode | Estimated DC operating region, used as a convergence aid.
Possible values are off, triode, sat, or subth. |
| 5 | m=1 | Multiplicity factor. |
| 6 | area=1 | alias of mult. |

Model Definition

model modelName mos1100 parameter=value ...

Model Parameters

- | | | |
|---|---------------|------------|
| 1 | level=1.1e+03 | MOS Level. |
|---|---------------|------------|

Virtuoso Simulator Components and Device Models Reference

Philips Models

2	<code>ler=1e-06 m</code>	Effective channel length of the reference transistor.
3	<code>wer=1e-05 m</code>	Effective channel width of the reference transistor.
4	<code>lvar=0 m</code>	Difference between the actual and the programmed poly-silicon gate length.
5	<code>lap=4e-08 m</code>	Effective channel length reduction per side.
6	<code>wvar=0 m</code>	Difference between the actual and the programmed field-oxide opening.
7	<code>wot=0 m</code>	Effective channel width reduction per side.
8	<code>tr=21 C</code>	Reference temperature. Default set by option <code>tnom</code> .
9	<code>vfbr=-1.05 V</code>	Flat-band voltage for reference transistor.
10	<code>stvfb=0.0005 V/K</code>	Coefficient of temperature dependence of <code>vfbr</code> .
11	<code>kor=0.5 \sqrt{V}</code>	Body effect coefficient for the reference transistor.
12	<code>s1ko=0 \sqrt{V} m</code>	Coefficient of the length dependence of <code>ko</code> .
13	<code>s12ko=0 \sqrt{V} m²</code>	Second coefficient of the length dependence of <code>ko</code> .
14	<code>swko=0 \sqrt{V} m</code>	Coefficient of the width dependence of <code>ko</code> .
15	<code>kpinv=0 1/\sqrt{V}</code>	Inverse of body-effect factor of the poly-silicon gate.
16	<code>phibr=0.95 V</code>	Surface potential at strong inversion.
17	<code>s1phib=0 Vm</code>	Coefficient of the length dependence of <code>phib</code> .
18	<code>s12phib=0 Vm²</code>	Second coefficient of the length dependence of <code>phib</code> .
19	<code>swphib=0 Vm</code>	Coefficient of the width dependence of <code>phib</code> .
20	<code>betsq=0.000371(n)/0.000115(p) A/V²</code>	Gain factor for an infinite square transistor.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 21 $etabet=1.3(n)/0.5(p)$ Exponent of the temperature dependence of the gain factor.
- 22 $fbet1=0$ Relative mobility decrease due to first lateral profile.
- 23 $lp1=8e-07$ m Characteristic length of first lateral profile.
- 24 $fbet2=0$ Relative mobility decrease due to second lateral profile.
- 25 $lp2=8e-07$ m Characteristic length of second lateral profile.
- 26 $thesrr=0.4(n)/0.73(p) 1/V$ Coefficient of the mobility reduction due to surface roughness scattering.
- 27 $swthesr=0$ m Coefficient of the width dependence of thesr.
- 28 $thephr=0.0129(n)/0.001(p) 1/V$ Coefficient of the mobility reduction due to phonon scattering.
- 29 $etaph=1.75$ Exponent of the temperature dependence of theph.
- 30 $swtheph=0$ m Coefficient of the width dependence of theph.
- 31 $etamobr=1.4(n)/3(p)$ Effective field parameter for dependence on depletion/inversion charge.
- 32 $stetamob=0 1/K$ Coefficient of the temperature dependence of etamob.
- 33 $swetamob=0$ m Coefficient of the width dependence of etamob.
- 34 $nur=1$ Exponent of the field dependence of the mobility model minus 1.
- 35 $nuexp=5.25(n)/3.23(p)$ Exponent of the temperature dependence of parameter nu.
- 36 $therr=0.155(n)/0.08(p) 1/V$ Coefficient of the series resistance.
- 37 $etar=0.95(n)/0.4(p)$ Exponent of the temperature dependence of ther.

Virtuoso Simulator Components and Device Models Reference

Philips Models

38	swther=0 m	Coefficient of the width dependence of ther.
39	ther1=0 V	Numerator of gate voltage dependent part of series resistance.
40	ther2=1 V	Denominator of gate voltage dependent part of series resistance.
41	thesatr=0.5 (n) / 0.2 (p) $1/V$	Velocity saturation parameter due to optical/acoustic phonon scattering.
42	slthesat=1	Coefficient of length dependence of thesat.
43	thesatexp=1	Exponent of length dependence of thesat.
44	etasat=1.04 (n) / 0.86 (p)	Exponent of the temperature dependence of thesat.
45	swthesat=0 m	Coefficient of the width dependence of thesat.
46	thethr=0.001 (n) / 0.0005 (p) $1/V^3$	Coefficient of self-heating.
47	thethexp=1	Exponent of the length dependence of theth.
48	swtheth=0 m	Coefficient of the width dependence of Theth.
49	sdiblo=0.002 (n) / 0.001 (p) $1/\sqrt{V}$	Drain-induced barrier lowering parameter.
50	sdiblexp=1.35	Exponent of the length dependence of sdibl.
51	mor=0	Parameter for short-channel subthreshold slope.
52	moexp=1.34	Exponent of the length dependence of mo.
53	ssfr=0.00625 $1/\sqrt{V}$	Static feedback parameter.
54	slssf=1e-06 m	Coefficient of the length dependence of ssf.
55	swssf=0 m	Coefficient of the width dependence of ssf.

Virtuoso Simulator Components and Device Models Reference

Philips Models

56	$alpr=0.01$	Factor of the channel length modulation.
57	$sla1p=1$	Coefficient of the length dependence of alp .
58	$alpexp=1$	Exponent of the length dependence of alp .
59	$swalp=0$ m	Coefficient of the width dependence of alp .
60	$vp=0.05$ V	Characteristic voltage of channel-length modulation.
61	$lmin=1.5e-07$ m	Minimum effective channel length in technology, used for calculation of smoothing factor m .
62	$a1r=6$	Factor of the weak-avalanche current.
63	$sta1=0$ 1/K	Coefficient of the temperature dependence of $a1$.
64	$sla1=0$ m	Coefficient of the length dependence of $a1$.
65	$swa1=0$ m	Coefficient of the width dependence of $a1$.
66	$a2r=38$ V	Exponent of the weak-avalanche current.
67	$sla2=0$ V m	Coefficient of the length dependence of $a2$.
68	$swa2=0$ V m	Coefficient of the width dependence of $a2$.
69	$a3r=1$	Factor of the drain-source voltage above which weak-avalanche occurs.
70	$sla3=0$ m	Coefficient of the length dependence of $a3$.
71	$swa3=0$ m	Coefficient of the width dependence of $a3$.
72	$iginvr=0$ A/V ²	Gain factor for intrinsic gate tunnelling current in inversion.
73	$binv=48(n)/87.5(p)$ A/V ²	Probability factor for intrinsic gate tunnelling current in inversion.
74	$igaccr=0$ A/V ²	Gain factor for intrinsic gate tunnelling current in accumulation.
75	$bacc=48$ V	Probability factor for intrinsic gate tunnelling current in accumulation.

Virtuoso Simulator Components and Device Models Reference

Philips Models

76	$v_{fbov}=0$ V	Flat-band voltage for the Source/Drain overlap extensions.
77	$k_{ov}=2.5$ \sqrt{V}	Body-effect factor for the Source/Drain overlap extensions.
78	$i_{govr}=0$ A/ V^2	Gain factor for Source/Drain overlap gate tunnelling current.
79	$t_{ox}=3.2e-09$ m	Thickness of gate oxide layer.
80	$col=3.2e-10$ F/m	Gate overlap capacitance per unit channel width.
81	$gatenoise=0$	Flag for in/exclusion of induced gate thermal noise.
82	$n_{tr}=1.66e-20$ J	Coefficient of the thermal noise.
83	$n_{far}=1.57e+22$ (n) / $3.83e+23$ (p) $1/(V m^4)$	First coefficient of the flicker noise.
84	$n_{fbr}=4.75e+08$ (n) / $1.02e+08$ (p) $1/(V m^2)$	Second coefficient of the flicker noise.
85	$n_{fcr}=0$ (n) / $7.3e-09$ (p) $1/V$	Third coefficient of the flicker noise.
86	$dta=0$ K	Temperature offset of the device.
87	$type=n$	Transistor gender. Possible values are n, p, npn, pnp, npnv, pnpv, npnl, or pnp1.
88	$imax=1.0$ A	Explosion current.
89	t_{nom} (C)	alias of t_{nom} .
90	t_{ref} (C)	alias of t_{nom} .

Output Parameters

1	v_{fb} (V)	Flat-band voltage for the actual transistor.
2	k_o (\sqrt{V})	Body-effect factor.
3	k_{pinv} ($1/\sqrt{V}$)	Inverse of body-effect factor of the poly-silicon gate.
4	ϕ_{ib} (V)	Surface potential at the onset of strong inversion.

Virtuoso Simulator Components and Device Models Reference

Philips Models

5	bet (A/V ²)	Gain factor.
6	thesr (1/V)	Mobility degradation parameter due to surface roughness scattering.
7	theph (1/V)	Mobility degradation parameter due to phonon scattering.
8	etamob	Effective field parameter for dependence on depletion charge.
9	nu	Exponent of field dependence of mobility model.
10	ther (1/V)	Coefficient of series resistance.
11	ther1 (V)	Numerator of gate voltage dependent part of series resistance.
12	ther2 (V)	Denominator of gate voltage dependent part of series resistance.
13	thesat (1/V)	Velocity saturation parameter due to optical/acoustic phonon scattering.
14	theth (1/V ³)	Coefficient of self-heating.
15	sdibl (1/ \sqrt{V})	Drain-induced barrier lowering parameter.
16	mo (V)	Parameter for (short-channel) subthreshold slope.
17	ssf (1/ \sqrt{V})	Static-feedback parameter.
18	alp	Factor of channel length modulation.
19	vp (V)	Characteristic voltage of channel-length modulation.
20	mexp	Smoothing factor.
21	phit (V)	Thermal voltage at the actual temperature.
22	a1	Factor of the weak-avalanche current.
23	a2 (V)	Exponent of the weak-avalanche current.
24	a3	Factor of the drain-source voltage above which weak-avalanche occurs.

Virtuoso Simulator Components and Device Models Reference

Philips Models

25	ig_{inv} (A/V ²)	Gain factor for intrinsic gate tunnelling current in inversion.
26	bi_{inv} (A/V ²)	Probability factor for intrinsic gate tunnelling current in inversion.
27	ig_{acc} (A/V ²)	Gain factor for intrinsic gate tunnelling current in accumulation.
28	ba_{acc} (V)	Probability factor for intrinsic gate tunnelling current in accumulation.
29	vf_{bov} (V)	Flat-band voltage for the Source/Drain overlap extensions.
30	ko_{ov} (\sqrt{V})	Body-effect factor for the Source/Drain overlap extensions.
31	ig_{ov} (A/V ²)	Gain factor for Source/Drain overlap tunnelling current.
32	co_x (F)	Oxide capacitance for the intrinsic channel (* mult).
33	cg_{do} (F)	Oxide capacitance for the gate-drain overlap (* mult).
34	cg_{so} (F)	Oxide capacitance for the gate-source overlap (* mult).
35	$gatenoise$	Flag for in/exclusion of induced gate thermal noise.
36	nt (J)	Thermal noise coefficient.
37	nfa (1/(Vm ⁴))	First coefficient of the flicker noise.
38	nfb (1/(Vm ²))	Second coefficient of the flicker noise.
39	nfc (1/V)	Third coefficient of the flicker noise.
40	tox (m)	Thickness of gate oxide layer.

Operating-Point Parameters

1	ids (A)	Drain current, excl. avalanche and tunnel currents.
2	$iavl$ (A)	Substrate current due to weak-avalanche.
3	igs (A)	Gate-to-source current due to direct tunnelling.
4	igd (A)	Gate-to-drain current due to direct tunnelling.

Virtuoso Simulator Components and Device Models Reference

Philips Models

5	i_{gb} (A)	Gate-to-bulk current due to direct tunnelling.
6	v_{ds} (V)	Drain-source voltage.
7	v_{gs} (V)	Gate-source voltage.
8	v_{sb} (V)	Source-bulk voltage.
9	v_{to} (V)	Zero-bias threshold voltage.
10	v_{ts} (V)	Threshold voltage including back-bias effects.
11	v_{th} (V)	Threshold voltage including back-bias and drain-bias effects.
12	v_{gt} (V)	Effective gate drive voltage including back-bias and drain voltage effects.
13	v_{dss} (V)	Drain saturation voltage at actual bias.
14	v_{sat} (V)	Saturation limit.
15	g_m (A/V)	Transconductance ($d i_{ds} / d v_{gs}$).
16	g_{mb} (A/V)	Substrate-transconductance ($d i_{ds} / d v_{bs}$).
17	g_{ds} (A/V)	Output conductance ($d i_{ds} / d v_{ds}$).
18	c_{dd} (F)	Capacitance ($d q_d / d v_d$).
19	c_{dg} (F)	Capacitance ($- d q_d / d v_g$).
20	c_{ds} (F)	Capacitance ($- d q_d / d v_s$).
21	c_{db} (F)	Capacitance ($- d q_d / d v_b$).
22	c_{gd} (F)	Capacitance ($- d q_g / d v_d$).
23	c_{gg} (F)	Capacitance ($d q_g / d v_g$).
24	c_{gs} (F)	Capacitance ($- d q_g / d v_s$).
25	c_{gb} (F)	Capacitance ($- d q_g / d v_b$).

Virtuoso Simulator Components and Device Models Reference

Philips Models

26	c_{sd} (F)	Capacitance (- d q_s / d v_d).
27	c_{sg} (F)	Capacitance (- d q_s / d v_g).
28	c_{ss} (F)	Capacitance (d q_s / d v_s).
29	c_{sb} (F)	Capacitance (- d q_s / d v_b).
30	c_{bd} (F)	Capacitance (- d q_b / d v_d).
31	c_{bg} (F)	Capacitance (- d q_b / d v_g).
32	c_{bs} (F)	Capacitance (- d q_b / d v_s).
33	c_{bb} (F)	Capacitance (d q_b / d v_b).
34	c_{gdol} (F)	Gate-drain overlap capacitance of the actual transistor.
35	c_{gsol} (F)	Gate-source overlap capacitance of the actual transistor.
36	w_{eff} (m)	Effective channel width for geometrical models.
37	l_{eff} (m)	Effective channel length for geometrical models.
38	u	Transistor gain (gm/gds).
39	r_{out} (Ω)	Small-signal output resistance (1/gds).
40	v_{early} (V)	Equivalent Early voltage ($ l_{idl} /gds$).
41	k_{eff} (\sqrt{V})	Body effect parameter.
42	b_{eff} (A/V ²)	Gain factor.
43	f_{ug} (Hz)	Unity gain frequency at actual bias ($gm/(2*\pi*cin)$).
44	$sqrtsfw$ (V/ \sqrt{Hz})	Input-referred RMS white noise voltage density.
45	$sqrtsff$ (V/ \sqrt{Hz})	Input-referred RMS white noise voltage density at 1 kHz.
46	f_{knee} (Hz)	Cross-over frequency above which white noise is dominant.

Virtuoso Simulator Components and Device Models Reference

Philips Models

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

a1	O-22	fbet1	M-22	nfbr	M-84	theph	O-7
a1r	M-62	fbet2	M-24	nfc	O-39	thephr	M-28
a2	O-23	fknee	OP-46	nfcrr	M-85	ther	O-10
a2r	M-66	fug	OP-43	nt	O-36	ther1	M-39
a3	O-24	gatenoise	M-81	ntr	M-82	ther1	O-11
a3r	M-69	gatenoise	O-35	nu	O-9	ther2	M-40
alp	O-18	gds	OP-17	nuexp	M-35	ther2	O-12
alpexp	M-58	gm	OP-15	nur	M-34	therr	M-36
alpr	M-56	gmb	OP-16	phib	O-4	thesat	O-13
area	I-6	iavl	OP-2	phibr	M-16	thesatexp	M-43
bacc	M-75	ids	OP-1	phit	O-21	thesatr	M-41
bacc	O-28	igacc	O-27	region	I-4	thesr	O-6
beff	OP-42	igaccr	M-74	rout	OP-39	thesrr	M-26
bet	O-5	igb	OP-5	sdibl	O-15	theth	O-14
betsq	M-20	igd	OP-4	sdiblexp	M-50	thethexp	M-47
binv	M-73	iginv	O-25	sdiblo	M-49	thethr	M-46

Virtuoso Simulator Components and Device Models Reference

Philips Models

binv	O-26	iginvr	M-72	sl2ko	M-13	tnom	M-89
cbb	OP-33	igov	O-31	sl2phib	M-18	tox	M-79
cbd	OP-30	igovr	M-78	sla1	M-64	tox	O-40
cbg	OP-31	igs	OP-3	sla2	M-67	tr	M-8
cbs	OP-32	imax	M-88	sla3	M-70	tref	M-90
cdb	OP-21	keff	OP-41	slalp	M-57	type	M-87
cdd	OP-18	ko	O-2	slko	M-12	u	OP-38
cdg	OP-19	kor	M-11	slphib	M-17	vds	OP-6
cds	OP-20	kov	M-77	slssf	M-54	vdss	OP-13
cgb	OP-25	kov	O-30	slthesat	M-42	vearly	OP-40
cgd	OP-22	kpinv	M-15	sqrtsff	OP-45	vfb	O-1
cgdo	O-33	kpinv	O-3	sqrtsfw	OP-44	vfbov	M-76
cgdol	OP-34	l	I-1	ssf	O-17	vfbov	O-29
cgg	OP-23	lap	M-5	ssfr	M-53	vfbr	M-9
cgs	OP-24	leff	OP-37	sta1	M-63	vgs	OP-7
cgso	O-34	ler	M-2	stetamob	M-32	vgt	OP-12
cgso1	OP-35	level	M-1	stvfb	M-10	vp	M-60
col	M-80	lmin	M-61	swa1	M-65	vp	O-19
cox	O-32	lp1	M-23	swa2	M-68	vsat	OP-14
csb	OP-29	lp2	M-25	swa3	M-71	vsb	OP-8
csd	OP-26	lvar	M-4	swalp	M-59	vth	OP-11

Virtuoso Simulator Components and Device Models Reference

Philips Models

csg	OP-27	m	I-5	swetamob	M-33	vto	OP-9
css	OP-28	mexp	O-20	swko	M-14	vts	OP-10
dta	M-86	mo	O-16	swphib	M-19	w	I-2
etabet	M-21	moexp	M-52	swssf	M-55	weff	OP-36
etamob	O-8	mor	M-51	swtheph	M-30	wer	M-3
etamobr	M-31	mult	I-3	swther	M-38	wot	M-7
etaph	M-29	nfa	O-37	swthesat	M-45	wvar	M-6
etar	M-37	nfar	M-83	swthesr	M-27		
etasat	M-44	nfb	O-38	swtheth	M-48		

Compact MOS-Transistor Distortion Model (mos1100e)

This device is supported within altergroups.

This device is dynamically loaded from the shared object `/vobs/spectre_dev/tools.sun4v/cmi/lib/5.0.doc/libphilips_sh.so`

Instance Definition

```
Name d g s b ModelName parameter=value ...
```

Instance Parameters

- | | | |
|---|---------------|--|
| 1 | mult=1 | Number of devices in parallel. |
| 2 | region=triode | Estimated DC operating region, used as a convergence aid.
Possible values are <code>off</code> , <code>triode</code> , <code>sat</code> , or <code>subth</code> . |
| 3 | m=1 | Multiplicity factor. |
| 4 | area=1 | alias of mult. |

Virtuoso Simulator Components and Device Models Reference

Philips Models

Model Definition

model modelName mos1100e parameter=value ...

Model Parameters

- 1 level=1.1e+03 MOS Level.
- 2 vfb=-1.05 V Flat-band voltage for the actual transistor.
- 3 ko=0.5 \sqrt{V} Body-effect factor.
- 4 kpinv=0 $1/\sqrt{V}$ Inverse of body-effect factor of the poly-silicon gate.
- 5 phib=0.95 V Surface potential at the onset of strong inversion.
- 6 bet=0.00192 (n) / 0.000381 (p) A/V^2
Gain factor.
- 7 thesr=0.356 (n) / 0.73 (p) $1/V$
Mobility degradation parameter due to surface roughness scattering.
- 8 theph=0.0129 (n) / 0.001 (p) $1/V$
Mobility degradation parameter due to phonon scattering.
- 9 etamob=1.4 (n) / 3 (p)
Effective field parameter for dependence on depletion charge.
- 10 nu=2 Exponent of field dependence of mobility model.
- 11 ther=0.0812 (n) / 0.079 (p) $1/V$
Coefficient of series resistance.
- 12 ther1=0 V Numerator of gate voltage dependent part of series resistance.
- 13 ther2=1 V Denominator of gate voltage dependent part of series resistance.
- 14 thesat=0.251 (n) / 0.173 (p) $1/V$
Velocity saturation parameter due to optical/acoustic phonon scattering.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 15 $theth=1e-05 (n) / 0 (p) \ 1/V^3$
Coefficient of self-heating.
- 16 $sdibl=0.000853 (n) / 3.55e-05 (p) \ 1/\sqrt{V}$
Drain-induced barrier lowering parameter.
- 17 $mo=0 \ V$
Parameter for (short-channel) subthreshold slope.
- 18 $ssf=0.012 (n) / 0.01 (p) \ 1/\sqrt{V}$
Static-feedback parameter.
- 19 $alp=0.025$
Factor of channel length modulation.
- 20 $vp=0.05 \ V$
Characteristic voltage of channel-length modulation.
- 21 $mexp=5$
Smoothing factor.
- 22 $phit=0.0266 \ V$
Thermal voltage at the actual temperature.
- 23 $a1=6.02 (n) / 6.86 (p)$
Factor of the weak-avalanche current.
- 24 $a2=38 (n) / 57.3 (p) \ V$
Exponent of the weak-avalanche current.
- 25 $a3=0.641 (n) / 0.425 (p)$
Factor of the drain-source voltage above which weak-avalanche occurs.
- 26 $iginv=0 \ A/V^2$
Gain factor for intrinsic gate tunnelling current in inversion.
- 27 $binv=48 (n) / 87.5 (p) \ A/V^2$
Probability factor for intrinsic gate tunnelling current in inversion.
- 28 $igacc=0 \ A/V^2$
Gain factor for intrinsic gate tunnelling current in accumulation.
- 29 $bacc=48 \ V$
Probability factor for intrinsic gate tunnelling current in accumulation.
- 30 $vfbov=0 \ V$
Flat-band voltage for the Source/Drain overlap extensions.
- 31 $kov=2.5 \ \sqrt{V}$
Body-effect factor for the Source/Drain overlap extensions.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 32 $igov=0$ A/V² Gain factor for Source/Drain overlap tunnelling current.
- 33 $cox=2.98e-14$ (n) / $2.72e-14$ (p) F
Oxide capacitance for the intrinsic channel (* mult).
- 34 $cgdo=6.39e-15$ (n) / $6.36e-15$ (p) F
Oxide capacitance for the gate-drain overlap (* mult).
- 35 $cgso=6.39e-15$ (n) / $6.36e-15$ (p) F
Oxide capacitance for the gate-source overlap (* mult).
- 36 $gatenoise=0$ Flag for in/exclusion of induced gate thermal noise.
- 37 $nt=1.66e-20$ J Thermal noise coefficient.
- 38 $nfa=8.32e+22$ (n) / $1.9e+22$ (p) 1/(V^m⁴)
First coefficient of the flicker noise.
- 39 $nfb=2.51e+07$ (n) / $5.04e+06$ (p) 1/(V^m²)
Second coefficient of the flicker noise.
- 40 $nfc=0$ (n) / $3.63e-10$ (p) 1/V
Third coefficient of the flicker noise.
- 41 $tox=3.2e-09$ m Thickness of gate oxide layer.
- 42 $type=n$ Transistor gender.
Possible values are n, p, npn, pnp, npnv, pnpv, npnl, or pnp1.
- 43 $imax=1.0$ A Explosion current.

Output Parameters

- 1 vfb (V) Flat-band voltage for the actual transistor.
- 2 ko (\sqrt{V}) Body-effect factor.
- 3 $kpinv$ ($1/\sqrt{V}$) Inverse of body-effect factor of the poly-silicon gate.
- 4 $phib$ (V) Surface potential at the onset of strong inversion.
- 5 bet (A/V²) Gain factor.

Virtuoso Simulator Components and Device Models Reference

Philips Models

6	thesr (1/V)	Mobility degradation parameter due to surface roughness scattering.
7	theph (1/V)	Mobility degradation parameter due to phonon scattering.
8	etamob	Effective field parameter for dependence on depletion charge.
9	nu	Exponent of field dependence of mobility model.
10	ther (1/V)	Coefficient of series resistance.
11	ther1 (V)	Numerator of gate voltage dependent part of series resistance.
12	ther2 (V)	Denominator of gate voltage dependent part of series resistance.
13	thesat (1/V)	Velocity saturation parameter due to optical/acoustic phonon scattering.
14	theth (1/V ³)	Coefficient of self-heating.
15	sdibl (1/ $\sqrt[3]{V}$)	Drain-induced barrier lowering parameter.
16	mo (V)	Parameter for (short-channel) subthreshold slope.
17	ssf (1/ $\sqrt[3]{V}$)	Static-feedback parameter.
18	alp	Factor of channel length modulation.
19	vp (V)	Characteristic voltage of channel-length modulation.
20	mexp	Smoothing factor.
21	phit (V)	Thermal voltage at the actual temperature.
22	a1	Factor of the weak-avalanche current.
23	a2 (V)	Exponent of the weak-avalanche current.
24	a3	Factor of the drain-source voltage above which weak-avalanche occurs.
25	iginv (A/V ²)	Gain factor for intrinsic gate tunnelling current in inversion.

Virtuoso Simulator Components and Device Models Reference

Philips Models

26	binv (A/V ²)	Probability factor for intrinsic gate tunnelling current in inversion.
27	igacc (A/V ²)	Gain factor for intrinsic gate tunnelling current in accumulation.
28	bacc (V)	Probability factor for intrinsic gate tunnelling current in accumulation.
29	vfbov (V)	Flat-band voltage for the Source/Drain overlap extensions.
30	kov (\sqrt{V})	Body-effect factor for the Source/Drain overlap extensions.
31	igov (A/V ²)	Gain factor for Source/Drain overlap tunnelling current.
32	cox (F)	Oxide capacitance for the intrinsic channel (* mult).
33	cgdo (F)	Oxide capacitance for the gate-drain overlap (* mult).
34	cgso (F)	Oxide capacitance for the gate-source overlap (* mult).
35	gatenoise	Flag for in/exclusion of induced gate thermal noise.
36	nt (J)	Thermal noise coefficient.
37	nfa (1/(Vm ⁴))	First coefficient of the flicker noise.
38	nfb (1/(Vm ²))	Second coefficient of the flicker noise.
39	nfc (1/V)	Third coefficient of the flicker noise.
40	tox (m)	Thickness of gate oxide layer.

Operating-Point Parameters

1	ids (A)	Drain current, excl. avalanche and tunnel currents.
2	iavl (A)	Substrate current due to weak-avalanche.
3	igs (A)	Gate-to-source current due to direct tunnelling.
4	igd (A)	Gate-to-drain current due to direct tunnelling.
5	igb (A)	Gate-to-bulk current due to direct tunnelling.

Virtuoso Simulator Components and Device Models Reference

Philips Models

6	v_{ds} (V)	Drain-source voltage.
7	v_{gs} (V)	Gate-source voltage.
8	v_{sb} (V)	Source-bulk voltage.
9	v_{to} (V)	Zero-bias threshold voltage.
10	v_{ts} (V)	Threshold voltage including back-bias effects.
11	v_{th} (V)	Threshold voltage including back-bias and drain-bias effects.
12	v_{gt} (V)	Effective gate drive voltage including back-bias and drain voltage effects.
13	v_{dss} (V)	Drain saturation voltage at actual bias.
14	v_{sat} (V)	Saturation limit.
15	g_m (A/V)	Transconductance ($d i_{ds} / d v_{gs}$).
16	g_{mb} (A/V)	Substrate-transconductance ($d i_{ds} / d v_{bs}$).
17	g_{ds} (A/V)	Output conductance ($d i_{ds} / d v_{ds}$).
18	c_{dd} (F)	Capacitance ($d q_d / d v_d$).
19	c_{dg} (F)	Capacitance ($- d q_d / d v_g$).
20	c_{ds} (F)	Capacitance ($- d q_d / d v_s$).
21	c_{db} (F)	Capacitance ($- d q_d / d v_b$).
22	c_{gd} (F)	Capacitance ($- d q_g / d v_d$).
23	c_{gg} (F)	Capacitance ($d q_g / d v_g$).
24	c_{gs} (F)	Capacitance ($- d q_g / d v_s$).
25	c_{gb} (F)	Capacitance ($- d q_g / d v_b$).
26	c_{sd} (F)	Capacitance ($- d q_s / d v_d$).

Virtuoso Simulator Components and Device Models Reference

Philips Models

27	c_{sg} (F)	Capacitance ($-d q_s / d v_g$).
28	c_{ss} (F)	Capacitance ($d q_s / d v_s$).
29	c_{sb} (F)	Capacitance ($-d q_s / d v_b$).
30	c_{bd} (F)	Capacitance ($-d q_b / d v_d$).
31	c_{bg} (F)	Capacitance ($-d q_b / d v_g$).
32	c_{bs} (F)	Capacitance ($-d q_b / d v_s$).
33	c_{bb} (F)	Capacitance ($d q_b / d v_b$).
34	c_{gdol} (F)	Gate-drain overlap capacitance of the actual transistor.
35	c_{gsol} (F)	Gate-source overlap capacitance of the actual transistor.
36	u	Transistor gain (g_m/g_{ds}).
37	r_{out} (Ω)	Small-signal output resistance ($1/g_{ds}$).
38	v_{early} (V)	Equivalent Early voltage ($ i_d /g_{ds}$).
39	k_{eff} (\sqrt{V})	Body effect parameter.
40	b_{eff} (A/V^2)	Gain factor.
41	f_{ug} (Hz)	Unity gain frequency at actual bias ($g_m/(2*\pi*c_{in})$).
42	$sqrtsfw$ (V/\sqrt{Hz})	Input-referred RMS white noise voltage density.
43	$sqrtsff$ (V/\sqrt{Hz})	Input-referred RMS white noise voltage density at 1 kHz.
44	f_{knee} (Hz)	Cross-over frequency above which white noise is dominant.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the

Virtuoso Simulator Components and Device Models Reference

Philips Models

description for that parameter. For example, a reference of M-35 means the 35th model parameter.

a1	M-23	cgsol	OP-35	kpinv	M-4	ther	M-11
a1	O-22	cox	M-33	kpinv	O-3	ther	O-10
a2	M-24	cox	O-32	level	M-1	ther1	M-12
a2	O-23	csb	OP-29	m	I-3	ther1	O-11
a3	M-25	csd	OP-26	mexp	M-21	ther2	M-13
a3	O-24	csg	OP-27	mexp	O-20	ther2	O-12
alp	M-19	css	OP-28	mo	M-17	thesat	M-14
alp	O-18	etamob	M-9	mo	O-16	thesat	O-13
area	I-4	etamob	O-8	mult	I-1	thesr	M-7
bacc	M-29	fknee	OP-44	nfa	M-38	thesr	O-6
bacc	O-28	fug	OP-41	nfa	O-37	theth	M-15
beff	OP-40	gatenoise	M-36	nfb	M-39	theth	O-14
bet	M-6	gatenoise	O-35	nfb	O-38	tox	M-41
bet	O-5	gds	OP-17	nfc	M-40	tox	O-40
binv	M-27	gm	OP-15	nfc	O-39	type	M-42
binv	O-26	gmb	OP-16	nt	M-37	u	OP-36
cbb	OP-33	iavl	OP-2	nt	O-36	vds	OP-6
cbd	OP-30	ids	OP-1	nu	M-10	vdss	OP-13
cbg	OP-31	igacc	M-28	nu	O-9	yearly	OP-38

Virtuoso Simulator Components and Device Models Reference

Philips Models

cbs	OP-32	igacc	O-27	phib	M-5	vfb	M-2
cdb	OP-21	igb	OP-5	phib	O-4	vfb	O-1
cdd	OP-18	igd	OP-4	phit	M-22	vfbov	M-30
cdg	OP-19	iginv	M-26	phit	O-21	vfbov	O-29
cds	OP-20	iginv	O-25	region	I-2	vgs	OP-7
cgb	OP-25	igov	M-32	rout	OP-37	vgt	OP-12
cgd	OP-22	igov	O-31	sdibl	M-16	vp	M-20
cgdo	M-34	igs	OP-3	sdibl	O-15	vp	O-19
cgdo	O-33	imax	M-43	sqrtsff	OP-43	vsat	OP-14
cgdol	OP-34	keff	OP-39	sqrtsfw	OP-42	vsb	OP-8
cgg	OP-23	ko	M-3	ssf	M-18	vth	OP-11
cgs	OP-24	ko	O-2	ssf	O-17	vto	OP-9
cgso	M-35	kov	M-31	theph	M-8	vts	OP-10
cgso	O-34	kov	O-30	theph	O-7		

MOS Model 11, Level 1101 (mos11010)

This is SimKit 4.0

This device is supported within altergroups.

This device is dynamically loaded from the shared object /vobs/spectre_dev/tools.lnx86/cmi/lib/5.0.doc/libphilips_sh.so

Instance Definition

Name d g s b ModelName parameter=value ...

Virtuoso Simulator Components and Device Models Reference

Philips Models

Instance Parameters

1	<code>l=2e-06 m</code>	Drawn channel length in the layout. Scale set by option scale..
2	<code>w=1e-05 m</code>	Drawn channel width in the layout. Scale set by option scale..
3	<code>mult=1</code>	Number of devices in parallel.
4	<code>region=triode</code>	Estimated DC operating region, used as a convergence aid. Possible values are <code>off</code> , <code>triode</code> , <code>sat</code> , or <code>subth</code> .
5	<code>m=1</code>	Multiplicity factor.
6	<code>area=1</code>	alias of <code>mult</code> .

Model Definition

```
model modelName mos11010 parameter=value ...
```

Model Parameters

1	<code>level=1.1e+04</code>	Transistor Level.
2	<code>lvar=0 m</code>	Difference between the actual and the programmed poly-silicon gate length.
3	<code>lap=4e-08 m</code>	Effective channel length reduction per side.
4	<code>wvar=0 m</code>	Difference between the actual and the programmed field-oxide opening.
5	<code>wot=0 m</code>	Effective channel width reduction per side.
6	<code>tr=21 C</code>	Reference temperature.
7	<code>vfb=-1.05 V</code>	Flat-band voltage at reference temperature.
8	<code>stvfb=0.0005 V/K</code>	Coefficient of temperature dependence of VFB.
9	<code>kor=0.5 \sqrt{V}</code>	Body effect coefficient for the reference transistor.
10	<code>slko=0</code>	Coefficient of the length dependence of KO.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 11 $sl2ko=0$ Second coefficient of the length dependence of KO.
- 12 $swko=0$ Coefficient of the width dependence of KO.
- 13 $kpinv=0 \ 1/\sqrt{V}$ Inverse of body-effect factor of the poly-silicon gate.
- 14 $phibr=0.95 \ V$ Surface potential at strong inversion.
- 15 $stphib=-0.00085 \ V/K$ Coefficient of the temperature dependency of PHIB.
- 16 $slphib=0$ Coefficient of the length dependence of PHIB.
- 17 $sl2phib=0$ Second coefficient of the length dependence of PHIB.
- 18 $swphib=0$ Coefficient of the width dependence of PHIB.
- 19 $betsq=0.000371 \ (n) / 0.000115 \ (p) \ A/V^2$ Gain factor for an infinite square transistor.
- 20 $etabetr=1.3 \ (n) / 0.5 \ (p)$ Exponent of the temperature dependence of the gain factor.
- 21 $sletabet=0$ Coefficient of length dependence of ETABETR.
- 22 $fbet1=0$ Relative mobility decrease due to first lateral profile.
- 23 $lp1=8e-07 \ m$ Characteristic length of first lateral profile.
- 24 $fbet2=0$ Relative mobility decrease due to second lateral profile.
- 25 $lp2=8e-07 \ m$ Characteristic length of second lateral profile.
- 26 $thesrr=0.4 \ (n) / 0.73 \ (p) \ 1/V$ Coefficient of the mobility reduction due to surface roughness scattering.
- 27 $etasr=0.65 \ (n) / 0.5 \ (p)$ Exponent of the temperature dependence of THESR.
- 28 $swthesr=0$ Coefficient of the width dependence of THESR.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 29 $\text{thephr}=0.0129 (n) / 0.001 (p) \ 1/V$
Coefficient of the mobility reduction due to phonon scattering.
- 30 $\text{etaph}=1.35 (n) / 3.75 (p)$
Exponent of the temperature dependence of THEPH.
- 31 $\text{swtheph}=0$
Coefficient of the width dependence of THEPH.
- 32 $\text{etamobr}=1.4 (n) / 3 (p)$
Effective field parameter for dependence on depletion/inversion charge.
- 33 $\text{stetamob}=0 \ 1/K$
Coefficient of the temperature dependence of ETAMOB.
- 34 $\text{swetamob}=0$
Coefficient of the width dependence of ETAMOB.
- 35 $\text{nu}=2$
Exponent of field dependence of mobility model.
- 36 $\text{nuexp}=5.25 (n) / 3.23 (p)$
Exponent of the temperature dependence of parameter NU.
- 37 $\text{therr}=0.155 (n) / 0.08 (p) \ 1/V$
Coefficient of the series resistance.
- 38 $\text{etar}=0.95 (n) / 0.4 (p)$
Exponent of the temperature dependence of THER.
- 39 $\text{swther}=0$
Coefficient of the width dependence of THER.
- 40 $\text{ther1}=0 \ V$
Numerator of gate voltage dependent part of series resistance.
- 41 $\text{ther2}=1 \ V$
Denominator of gate voltage dependent part of series resistance.
- 42 $\text{thesatr}=0.5 (n) / 0.2 (p) \ 1/V$
Velocity saturation parameter due to optical/acoustic phonon scattering.
- 43 $\text{etasat}=1.04 (n) / 0.86 (p)$
Exponent of the temperature dependence of THESAT.
- 44 $\text{slthesat}=1$
Coefficient of length dependence of THESAT.

Virtuoso Simulator Components and Device Models Reference

Philips Models

45	<code>thesatexp=1</code>	Exponent of length dependence of THESAT.
46	<code>swthesat=0</code>	Coefficient of the width dependence of THESAT.
47	<code>thethr=0.001(n)/0.0005(p) 1/V³</code>	Coefficient of self-heating.
48	<code>thethexp=1</code>	Exponent of the length dependence of THETH.
49	<code>swtheth=0</code>	Coefficient of the width dependence of THETH.
50	<code>sdiblo=0.0001 1/√V</code>	Drain-induced barrier lowering parameter.
51	<code>sdiblexp=1.35</code>	Exponent of the length dependence of SDIBL.
52	<code>mo=0</code>	Parameter for short-channel subthreshold slope.
53	<code>mor=0</code>	Parameter for short-channel subthreshold slope per unit length.
54	<code>moexp=1.34</code>	Exponent of the length dependence of MO.
55	<code>ssfr=0.00625 1/√V</code>	Static feedback parameter.
56	<code>slssf=1</code>	Coefficient of the length dependence of SSF.
57	<code>swssf=0</code>	Coefficient of the width dependence of SSF.
58	<code>alpr=0.01</code>	Factor of the channel length modulation.
59	<code>slalp=1</code>	Coefficient of the length dependence of ALP.
60	<code>alpexp=1</code>	Exponent of the length dependence of ALP.
61	<code>swalp=0</code>	Coefficient of the width dependence of ALP.
62	<code>vp=0.05 V</code>	Characteristic voltage of channel-length modulation.
63	<code>lmin=1.5e-07 m</code>	Minimum effective channel length in technology, used for calculation of smoothing factor m.
64	<code>a1r=6</code>	Factor of the weak-avalanche current.

Virtuoso Simulator Components and Device Models Reference

Philips Models

65	$sta1=0$	$1/K$	Coefficient of the temperature dependence of A1.
66	$sla1=0$		Coefficient of the length dependence of A1.
67	$swa1=0$		Coefficient of the width dependence of A1.
68	$a2r=38$	V	Exponent of the weak-avalanche current.
69	$sla2=0$		Coefficient of the length dependence of A2.
70	$swa2=0$		Coefficient of the width dependence of A2.
71	$a3r=1$		Factor of the drain-source voltage above which weak-avalanche occurs.
72	$sla3=0$		Coefficient of the length dependence of A3.
73	$swa3=0$		Coefficient of the width dependence of A3.
74	$iginvr=0$	A/V^2	Gain factor for intrinsic gate tunnelling current in inversion.
75	$binv=48$	$(n)/87.5(p)$	V Probability factor for intrinsic gate tunnelling current in inversion.
76	$igaccr=0$	A/V^2	Gain factor for intrinsic gate tunnelling current in accumulation.
77	$bacc=48$	V	Probability factor for intrinsic gate tunnelling current in accumulation.
78	$vfbov=0$	V	Flat-band voltage for the Source/Drain overlap extensions.
79	$kov=2.5$	\sqrt{V}	Body-effect factor for the Source/Drain overlap extensions.
80	$igovr=0$	A/V^2	Gain factor for Source/Drain overlap gate tunnelling current.
81	$agidlr=0$	A/V^3	Gain factor for gate-induced leakage current.
82	$bgidl=41$	V	Probability factor for gate-induced drain leakage current at reference temperature.
83	$stbgidl=-0.000364$	V/K	Coefficient of the temperature dependence of BGIDL.

Virtuoso Simulator Components and Device Models Reference

Philips Models

84	<code>cgidl=0</code>	Factor for the lateral field dependence of the gate-induced leakage current.
85	<code>tox=3.2e-09 m</code>	Thickness of gate oxide layer.
86	<code>col=3.2e-16 F</code>	Gate overlap capacitance for a channel width of 1 μm .
87	<code>gatenoise=0</code>	Flag for in/exclusion of induced gate thermal noise.
88	<code>nt=1.62e-20 J</code>	Thermal noise coefficient.
89	<code>nfar=1.57e+23 (n) / 3.83e+24 (p) 1/(Vm⁴)</code>	First coefficient of the flicker noise for a channel area of 1 μm^2 .
90	<code>nfbr=4.75e+09 (n) / 1.02e+09 (p) 1/(Vm²)</code>	Second coefficient of the flicker noise for a channel area of 1 μm^2 .
91	<code>nfcr=0 (n) / 7.3e-08 (p) 1/V</code>	Third coefficient of the flicker noise for a channel area of 1 μm^2 .
92	<code>dta=0 K</code>	Temperature offset of the device.
93	<code>type=n</code>	Transistor gender. Possible values are n, p, npn, pnp, npnv, pnpv, npnl, or pnp1.
94	<code>imax=1.0 A</code>	Explosion current.
95	<code>tnom (C)</code>	alias of <code>tnom</code> .
96	<code>tref (C)</code>	alias of <code>tnom</code> .

Output Parameters

1	<code>vfb (V)</code>	Flat-band voltage at reference temperature.
2	<code>ko (\sqrt{V})</code>	Body-effect factor.
3	<code>kpinv (1/\sqrt{V})</code>	Inverse of body-effect factor of the poly-silicon gate.
4	<code>phib (V)</code>	Surface potential at the onset of strong inversion.
5	<code>bet (A/V²)</code>	Gain factor.

Virtuoso Simulator Components and Device Models Reference

Philips Models

6	thesr (1/V)	Mobility degradation parameter due to surface roughness scattering.
7	theph (1/V)	Mobility degradation parameter due to phonon scattering.
8	etamob	Effective field parameter for dependence on depletion charge.
9	nu	Exponent of field dependence of mobility model.
10	ther (1/V)	Coefficient of series resistance.
11	ther1 (V)	Numerator of gate voltage dependent part of series resistance.
12	ther2 (V)	Denominator of gate voltage dependent part of series resistance.
13	thesat (1/V)	Velocity saturation parameter due to optical/acoustic phonon scattering.
14	theth (1/V ³)	Coefficient of self-heating.
15	sdibl (1/ \sqrt{V})	Drain-induced barrier lowering parameter.
16	mo	Parameter for (short-channel) subthreshold slope.
17	ssf (1/ \sqrt{V})	Static-feedback parameter.
18	alp	Factor of channel length modulation.
19	vp (V)	Characteristic voltage of channel-length modulation.
20	mexp	Smoothing factor.
21	a1	Factor of the weak-avalanche current.
22	a2 (V)	Exponent of the weak-avalanche current.
23	a3	Factor of the drain-source voltage above which weak-avalanche occurs.
24	iginv (A/V ²)	Gain factor for intrinsic gate tunnelling current in inversion.
25	binv (V)	Probability factor for intrinsic gate tunnelling current in inversion.

Virtuoso Simulator Components and Device Models Reference

Philips Models

26	$igacc$ (A/V ²)	Gain factor for intrinsic gate tunnelling current in accumulation.
27	$bacc$ (V)	Probability factor for intrinsic gate tunnelling current in accumulation.
28	$vfbov$ (V)	Flat-band voltage for the Source/Drain overlap extensions.
29	kov (\sqrt{V})	Body-effect factor for the Source/Drain overlap extensions.
30	$igov$ (A/V ²)	Gain factor for Source/Drain overlap tunnelling current.
31	$agidl$ (A/V ³)	Gain factor for gate-induced leakage current.
32	$bgidl$ (V)	Probability factor for gate-induced drain leakage current at reference temperature.
33	$cgidl$	Factor for the lateral field dependence of the gate-induced leakage current.
34	cox (F)	Oxide capacitance for the intrinsic channel (* mult).
35	$cgdo$ (F)	Oxide capacitance for the gate-drain overlap (* mult).
36	$cgso$ (F)	Oxide capacitance for the gate-source overlap (* mult).
37	$gatenoise$	Flag for in/exclusion of induced gate thermal noise.
38	nt (J)	Thermal noise coefficient.
39	nfa (1/(Vm ⁴))	First coefficient of the flicker noise.
40	nfb (1/(Vm ²))	Second coefficient of the flicker noise.
41	nfc (1/V)	Third coefficient of the flicker noise.
42	tox (m)	Thickness of gate oxide layer.

Operating-Point Parameters

1	ids (A)	Drain current, excl. avalanche and tunnel currents.
2	$iavl$ (A)	Substrate current due to weak-avalanche.

Virtuoso Simulator Components and Device Models Reference

Philips Models

3	i_{gs} (A)	Gate-to-source current due to direct tunnelling.
4	i_{gd} (A)	Gate-to-drain current due to direct tunnelling.
5	i_{gb} (A)	Gate-to-bulk current due to direct tunnelling.
6	v_{ds} (V)	Drain-source voltage.
7	v_{gs} (V)	Gate-source voltage.
8	v_{sb} (V)	Source-bulk voltage.
9	v_{to} (V)	Zero-bias threshold voltage.
10	v_{ts} (V)	Threshold voltage including back-bias effects.
11	v_{th} (V)	Threshold voltage including back-bias and drain-bias effects.
12	v_{gt} (V)	Effective gate drive voltage including back-bias and drain voltage effects.
13	v_{dss} (V)	Drain saturation voltage at actual bias.
14	v_{sat} (V)	Saturation limit.
15	g_m (A/V)	Transconductance ($d i_{ds} / d v_{gs}$).
16	g_{mb} (A/V)	Substrate-transconductance ($d i_{ds} / d v_{bs}$).
17	g_{ds} (A/V)	Output conductance ($d i_{ds} / d v_{ds}$).
18	c_{dd} (F)	Capacitance ($d q_d / d v_d$).
19	c_{dg} (F)	Capacitance ($- d q_d / d v_g$).
20	c_{ds} (F)	Capacitance ($- d q_d / d v_s$).
21	c_{db} (F)	Capacitance ($- d q_d / d v_b$).
22	c_{gd} (F)	Capacitance ($- d q_g / d v_d$).
23	c_{gg} (F)	Capacitance ($d q_g / d v_g$).

Virtuoso Simulator Components and Device Models Reference

Philips Models

24	c_{gs} (F)	Capacitance ($-d qg / d vs$).
25	c_{gb} (F)	Capacitance ($-d qg / d vb$).
26	c_{sd} (F)	Capacitance ($-d qs / d vd$).
27	c_{sg} (F)	Capacitance ($-d qs / d vg$).
28	c_{ss} (F)	Capacitance ($d qs / d vs$).
29	c_{sb} (F)	Capacitance ($-d qs / d vb$).
30	c_{bd} (F)	Capacitance ($-d qb / d vd$).
31	c_{bg} (F)	Capacitance ($-d qb / d vg$).
32	c_{bs} (F)	Capacitance ($-d qb / d vs$).
33	c_{bb} (F)	Capacitance ($d qb / d vb$).
34	c_{gdol} (F)	Gate-drain overlap capacitance of the actual transistor.
35	c_{gsol} (F)	Gate-source overlap capacitance of the actual transistor.
36	w_{eff} (m)	Effective channel width for geometrical models.
37	l_{eff} (m)	Effective channel length for geometrical models.
38	u	Transistor gain (gm/gds).
39	r_{out} (Ω)	Small-signal output resistance ($1/gds$).
40	v_{early} (V)	Equivalent Early voltage ($ idl /gds$).
41	k_{eff} (\sqrt{V})	Body effect parameter.
42	b_{eff} (A/V^2)	Gain factor.
43	f_{ug} (Hz)	Unity gain frequency at actual bias ($gm/(2*\pi*cin)$).
44	$sqrt_{sfw}$ (V/\sqrt{Hz})	Input-referred RMS white noise voltage density.

Virtuoso Simulator Components and Device Models Reference

Philips Models

45 `sqrtsff` (V/ $\sqrt{\text{Hz}}$)

Input-referred RMS white noise voltage density at 1 kHz.

46 `fknee` (Hz)

Cross-over frequency above which white noise is dominant.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

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<code>a1r</code>	M-64	<code>etaph</code>	M-30	<code>nfars</code>	M-89	<code>swthesr</code>	M-28
<code>a2</code>	O-22	<code>etar</code>	M-38	<code>nfb</code>	O-40	<code>swtheth</code>	M-49
<code>a2r</code>	M-68	<code>etasat</code>	M-43	<code>nfbr</code>	M-90	<code>theph</code>	O-7
<code>a3</code>	O-23	<code>etasr</code>	M-27	<code>nfc</code>	O-41	<code>thephr</code>	M-29
<code>a3r</code>	M-71	<code>fbet1</code>	M-22	<code>nfcrc</code>	M-91	<code>ther</code>	O-10
<code>agidl</code>	O-31	<code>fbet2</code>	M-24	<code>nt</code>	M-88	<code>ther1</code>	M-40
<code>agidlr</code>	M-81	<code>fknee</code>	OP-46	<code>nt</code>	O-38	<code>ther1</code>	O-11
<code>alp</code>	O-18	<code>fug</code>	OP-43	<code>nu</code>	M-35	<code>ther2</code>	M-41
<code>alpexp</code>	M-60	<code>gatenoise</code>	M-87	<code>nu</code>	O-9	<code>ther2</code>	O-12
<code>alpr</code>	M-58	<code>gatenoise</code>	O-37	<code>nuexp</code>	M-36	<code>therr</code>	M-37
<code>area</code>	I-6	<code>gds</code>	OP-17	<code>phib</code>	O-4	<code>thesat</code>	O-13
<code>bacc</code>	M-77	<code>gm</code>	OP-15	<code>phibr</code>	M-14	<code>thesatexp</code>	M-45

Virtuoso Simulator Components and Device Models Reference

Philips Models

bacc	O-27	gmb	OP-16	region	I-4	thesatr	M-42
beff	OP-42	iavl	OP-2	rout	OP-39	thesr	O-6
bet	O-5	ids	OP-1	sdibl	O-15	thesrr	M-26
betsq	M-19	igacc	O-26	sdiblexp	M-51	theth	O-14
bgidl	M-82	igaccr	M-76	sdiblo	M-50	thethexp	M-48
bgidl	O-32	igb	OP-5	sl2ko	M-11	thethr	M-47
binv	M-75	igd	OP-4	sl2phib	M-17	tnom	M-95
binv	O-25	iginv	O-24	sla1	M-66	tox	M-85
cbb	OP-33	iginvr	M-74	sla2	M-69	tox	O-42
cbd	OP-30	igov	O-30	sla3	M-72	tr	M-6
cbg	OP-31	igovr	M-80	slalp	M-59	tref	M-96
cbs	OP-32	igs	OP-3	sletabet	M-21	type	M-93
cdb	OP-21	imax	M-94	slko	M-10	u	OP-38
cdd	OP-18	keff	OP-41	slphib	M-16	vds	OP-6
cdg	OP-19	ko	O-2	slssf	M-56	vdss	OP-13
cds	OP-20	kor	M-9	slthesat	M-44	vearly	OP-40
cgb	OP-25	kov	M-79	sqrtsff	OP-45	vfb	M-7
cgd	OP-22	kov	O-29	sqrtsfw	OP-44	vfb	O-1
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Virtuoso Simulator Components and Device Models Reference

Philips Models

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cgidl O-33	leff OP-37	stetamob M-33	vp M-62
cgs OP-24	level M-1	stphib M-15	vp O-19
cgso O-36	lmin M-63	stvfb M-8	vsat OP-14
cgso1 OP-35	lp1 M-23	swa1 M-67	vsb OP-8
col M-86	lp2 M-25	swa2 M-70	vth OP-11
cox O-34	lvar M-2	swa3 M-73	vto OP-9
csb OP-29	m I-5	swalp M-61	vts OP-10
csd OP-26	mexp O-20	swetamob M-34	w I-2
csg OP-27	mo O-16	swko M-12	weff OP-36
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etamob O-8	mult I-3	swther M-39	

MOS Model 11, Level 1101 (mos11010t)

This is SimKit 4.0

This device is supported within altergroups.

This device is dynamically loaded from the shared object /vobs/spectre_dev/tools.lnx86/cmi/lib/5.0.doc/libphilips_sh.so

Instance Definition

Name d g s b dt ModelName parameter=value ...

Virtuoso Simulator Components and Device Models Reference

Philips Models

Instance Parameters

1	<code>l=2e-06 m</code>	Drawn channel length in the layout. Scale set by option scale..
2	<code>w=1e-05 m</code>	Drawn channel width in the layout. Scale set by option scale..
3	<code>mult=1</code>	Number of devices in parallel.
4	<code>region=triode</code>	Estimated DC operating region, used as a convergence aid. Possible values are <code>off</code> , <code>triode</code> , <code>sat</code> , or <code>subth</code> .
5	<code>m=1</code>	Multiplicity factor.
6	<code>area=1</code>	alias of <code>mult</code> .

Model Definition

```
model modelName mos11010t parameter=value ...
```

Model Parameters

1	<code>level=1.1e+04</code>	Transistor Level.
2	<code>lvar=0 m</code>	Difference between the actual and the programmed poly-silicon gate length.
3	<code>lap=4e-08 m</code>	Effective channel length reduction per side.
4	<code>wvar=0 m</code>	Difference between the actual and the programmed field-oxide opening.
5	<code>wot=0 m</code>	Effective channel width reduction per side.
6	<code>tr=21 C</code>	Reference temperature.
7	<code>vfb=-1.05 V</code>	Flat-band voltage at reference temperature.
8	<code>stvfb=0.0005 V/K</code>	Coefficient of temperature dependence of VFB.
9	<code>kor=0.5 \sqrt{V}</code>	Body effect coefficient for the reference transistor.
10	<code>slko=0</code>	Coefficient of the length dependence of KO.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 11 $sl2ko=0$ Second coefficient of the length dependence of KO.
- 12 $swko=0$ Coefficient of the width dependence of KO.
- 13 $kpinv=0 \ 1/\sqrt{V}$ Inverse of body-effect factor of the poly-silicon gate.
- 14 $phibr=0.95 \ V$ Surface potential at strong inversion.
- 15 $stphib=-0.00085 \ V/K$ Coefficient of the temperature dependency of PHIB.
- 16 $slphib=0$ Coefficient of the length dependence of PHIB.
- 17 $sl2phib=0$ Second coefficient of the length dependence of PHIB.
- 18 $swphib=0$ Coefficient of the width dependence of PHIB.
- 19 $betsq=0.000371 \ (n) / 0.000115 \ (p) \ A/V^2$ Gain factor for an infinite square transistor.
- 20 $etabetr=1.3 \ (n) / 0.5 \ (p)$ Exponent of the temperature dependence of the gain factor.
- 21 $sletabet=0$ Coefficient of length dependence of ETABETR.
- 22 $fbet1=0$ Relative mobility decrease due to first lateral profile.
- 23 $lp1=8e-07 \ m$ Characteristic length of first lateral profile.
- 24 $fbet2=0$ Relative mobility decrease due to second lateral profile.
- 25 $lp2=8e-07 \ m$ Characteristic length of second lateral profile.
- 26 $thesrr=0.4 \ (n) / 0.73 \ (p) \ 1/V$ Coefficient of the mobility reduction due to surface roughness scattering.
- 27 $etasr=0.65 \ (n) / 0.5 \ (p)$ Exponent of the temperature dependence of THESR.
- 28 $swthesr=0$ Coefficient of the width dependence of THESR.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 29 $\text{thephr}=0.0129 (n) / 0.001 (p) \ 1/V$
Coefficient of the mobility reduction due to phonon scattering.
- 30 $\text{etaph}=1.35 (n) / 3.75 (p)$
Exponent of the temperature dependence of THEPH.
- 31 $\text{swtheph}=0$
Coefficient of the width dependence of THEPH.
- 32 $\text{etamobr}=1.4 (n) / 3 (p)$
Effective field parameter for dependence on depletion/inversion charge.
- 33 $\text{stetamob}=0 \ 1/K$
Coefficient of the temperature dependence of ETAMOB.
- 34 $\text{swetamob}=0$
Coefficient of the width dependence of ETAMOB.
- 35 $\text{nu}=2$
Exponent of field dependence of mobility model.
- 36 $\text{nuexp}=5.25 (n) / 3.23 (p)$
Exponent of the temperature dependence of parameter NU.
- 37 $\text{therr}=0.155 (n) / 0.08 (p) \ 1/V$
Coefficient of the series resistance.
- 38 $\text{etar}=0.95 (n) / 0.4 (p)$
Exponent of the temperature dependence of THER.
- 39 $\text{swther}=0$
Coefficient of the width dependence of THER.
- 40 $\text{ther1}=0 \ V$
Numerator of gate voltage dependent part of series resistance.
- 41 $\text{ther2}=1 \ V$
Denominator of gate voltage dependent part of series resistance.
- 42 $\text{thesatr}=0.5 (n) / 0.2 (p) \ 1/V$
Velocity saturation parameter due to optical/acoustic phonon scattering.
- 43 $\text{etasat}=1.04 (n) / 0.86 (p)$
Exponent of the temperature dependence of THESAT.
- 44 $\text{slthesat}=1$
Coefficient of length dependence of THESAT.

Virtuoso Simulator Components and Device Models Reference

Philips Models

45	<code>thesatexp=1</code>	Exponent of length dependence of THESAT.
46	<code>swthesat=0</code>	Coefficient of the width dependence of THESAT.
47	<code>thethr=0.001(n)/0.0005(p) 1/V³</code>	Coefficient of self-heating.
48	<code>thethexp=1</code>	Exponent of the length dependence of THETH.
49	<code>swtheth=0</code>	Coefficient of the width dependence of THETH.
50	<code>sdiblo=0.0001 1/√V</code>	Drain-induced barrier lowering parameter.
51	<code>sdiblexp=1.35</code>	Exponent of the length dependence of SDIBL.
52	<code>moo=0</code>	Parameter for short-channel subthreshold slope.
53	<code>mor=0</code>	Parameter for short-channel subthreshold slope per unit length.
54	<code>moexp=1.34</code>	Exponent of the length dependence of MO.
55	<code>ssfr=0.00625 1/√V</code>	Static feedback parameter.
56	<code>slssf=1</code>	Coefficient of the length dependence of SSF.
57	<code>swssf=0</code>	Coefficient of the width dependence of SSF.
58	<code>alpr=0.01</code>	Factor of the channel length modulation.
59	<code>slalp=1</code>	Coefficient of the length dependence of ALP.
60	<code>alpexp=1</code>	Exponent of the length dependence of ALP.
61	<code>swalp=0</code>	Coefficient of the width dependence of ALP.
62	<code>vp=0.05 V</code>	Characteristic voltage of channel-length modulation.
63	<code>lmin=1.5e-07 m</code>	Minimum effective channel length in technology, used for calculation of smoothing factor <i>m</i> .
64	<code>a1r=6</code>	Factor of the weak-avalanche current.

Virtuoso Simulator Components and Device Models Reference

Philips Models

65	$sta1=0$	$1/K$	Coefficient of the temperature dependence of A1.
66	$s1a1=0$		Coefficient of the length dependence of A1.
67	$swa1=0$		Coefficient of the width dependence of A1.
68	$a2r=38$	V	Exponent of the weak-avalanche current.
69	$s1a2=0$		Coefficient of the length dependence of A2.
70	$swa2=0$		Coefficient of the width dependence of A2.
71	$a3r=1$		Factor of the drain-source voltage above which weak-avalanche occurs.
72	$s1a3=0$		Coefficient of the length dependence of A3.
73	$swa3=0$		Coefficient of the width dependence of A3.
74	$iginvr=0$	A/V^2	Gain factor for intrinsic gate tunnelling current in inversion.
75	$binv=48$	$(n)/87.5(p)$	V Probability factor for intrinsic gate tunnelling current in inversion.
76	$igaccr=0$	A/V^2	Gain factor for intrinsic gate tunnelling current in accumulation.
77	$bacc=48$	V	Probability factor for intrinsic gate tunnelling current in accumulation.
78	$vfbov=0$	V	Flat-band voltage for the Source/Drain overlap extensions.
79	$kov=2.5$	\sqrt{V}	Body-effect factor for the Source/Drain overlap extensions.
80	$igovr=0$	A/V^2	Gain factor for Source/Drain overlap gate tunnelling current.
81	$agidlr=0$	A/V^3	Gain factor for gate-induced leakage current.
82	$bgidl=41$	V	Probability factor for gate-induced drain leakage current at reference temperature.
83	$stbgidl=-0.000364$	V/K	Coefficient of the temperature dependence of BGIDL.

Virtuoso Simulator Components and Device Models Reference

Philips Models

84	<code>cgidl=0</code>	Factor for the lateral field dependence of the gate-induced leakage current.
85	<code>tox=3.2e-09 m</code>	Thickness of gate oxide layer.
86	<code>col=3.2e-16 F</code>	Gate overlap capacitance for a channel width of 1 μm .
87	<code>gatenoise=0</code>	Flag for in/exclusion of induced gate thermal noise.
88	<code>nt=1.62e-20 J</code>	Thermal noise coefficient.
89	<code>nfar=1.57e+23 (n) / 3.83e+24 (p) 1 / (Vm⁴)</code>	First coefficient of the flicker noise for a channel area of 1 μm^2 .
90	<code>nfbr=4.75e+09 (n) / 1.02e+09 (p) 1 / (Vm²)</code>	Second coefficient of the flicker noise for a channel area of 1 μm^2 .
91	<code>nfcr=0 (n) / 7.3e-08 (p) 1/V</code>	Third coefficient of the flicker noise for a channel area of 1 μm^2 .
92	<code>dta=0 K</code>	Temperature offset of the device.
93	<code>rth=300 K/W</code>	Thermal resistance.
94	<code>cth=3e-09 J/K</code>	Thermal capacitance.
95	<code>ath=0</code>	Temperature coefficient of the thermal resistance.
96	<code>type=n</code>	Transistor gender. Possible values are n, p, npn, pnp, npnv, pnpv, npnl, or pnp1.
97	<code>imax=1.0 A</code>	Explosion current.
98	<code>tnom (C)</code>	alias of <code>tnom</code> .
99	<code>tref (C)</code>	alias of <code>tnom</code> .

Output Parameters

1	<code>vfb (V)</code>	Flat-band voltage at reference temperature.
2	<code>ko (\sqrt{V})</code>	Body-effect factor.

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Philips Models

3	$kpinv$ ($1/\sqrt{V}$)	Inverse of body-effect factor of the poly-silicon gate.
4	$phib$ (V)	Surface potential at the onset of strong inversion.
5	bet (A/V^2)	Gain factor.
6	$thesr$ ($1/V$)	Mobility degradation parameter due to surface roughness scattering.
7	$theph$ ($1/V$)	Mobility degradation parameter due to phonon scattering.
8	$etamob$	Effective field parameter for dependence on depletion charge.
9	nu	Exponent of field dependence of mobility model.
10	$ther$ ($1/V$)	Coefficient of series resistance.
11	$ther1$ (V)	Numerator of gate voltage dependent part of series resistance.
12	$ther2$ (V)	Denominator of gate voltage dependent part of series resistance.
13	$thesat$ ($1/V$)	Velocity saturation parameter due to optical/acoustic phonon scattering.
14	$theth$ ($1/V^3$)	Coefficient of self-heating.
15	$sdibl$ ($1/\sqrt{V}$)	Drain-induced barrier lowering parameter.
16	mo	Parameter for (short-channel) subthreshold slope.
17	ssf ($1/\sqrt{V}$)	Static-feedback parameter.
18	alp	Factor of channel length modulation.
19	vp (V)	Characteristic voltage of channel-length modulation.
20	$mexp$	Smoothing factor.
21	$a1$	Factor of the weak-avalanche current.
22	$a2$ (V)	Exponent of the weak-avalanche current.

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Philips Models

23	a3	Factor of the drain-source voltage above which weak-avalanche occurs.
24	iginv (A/V ²)	Gain factor for intrinsic gate tunnelling current in inversion.
25	binv (V)	Probability factor for intrinsic gate tunnelling current in inversion.
26	igacc (A/V ²)	Gain factor for intrinsic gate tunnelling current in accumulation.
27	bacc (V)	Probability factor for intrinsic gate tunnelling current in accumulation.
28	vfbov (V)	Flat-band voltage for the Source/Drain overlap extensions.
29	kov (\sqrt{V})	Body-effect factor for the Source/Drain overlap extensions.
30	igov (A/V ²)	Gain factor for Source/Drain overlap tunnelling current.
31	agidl (A/V ³)	Gain factor for gate-induced leakage current.
32	bgidl (V)	Probability factor for gate-induced drain leakage current at reference temperature.
33	cgidl	Factor for the lateral field dependence of the gate-induced leakage current.
34	cox (F)	Oxide capacitance for the intrinsic channel (* mult).
35	cgdo (F)	Oxide capacitance for the gate-drain overlap (* mult).
36	cgso (F)	Oxide capacitance for the gate-source overlap (* mult).
37	gatenoise	Flag for in/exclusion of induced gate thermal noise.
38	nt (J)	Thermal noise coefficient.
39	nfa (1/(Vm ⁴))	First coefficient of the flicker noise.
40	nfb (1/(Vm ²))	Second coefficient of the flicker noise.
41	nfc (1/V)	Third coefficient of the flicker noise.
42	tox (m)	Thickness of gate oxide layer.

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Philips Models

- 43 r_{th} (K/W) Thermal resistance.
- 44 c_{th} (J/K) Thermal capacitance.

Operating-Point Parameters

- 1 i_{ds} (A) Drain current, excl. avalanche and tunnel currents.
- 2 i_{avl} (A) Substrate current due to weak-avalanche.
- 3 i_{gs} (A) Gate-to-source current due to direct tunnelling.
- 4 i_{gd} (A) Gate-to-drain current due to direct tunnelling.
- 5 i_{gb} (A) Gate-to-bulk current due to direct tunnelling.
- 6 v_{ds} (V) Drain-source voltage.
- 7 v_{gs} (V) Gate-source voltage.
- 8 v_{sb} (V) Source-bulk voltage.
- 9 v_{to} (V) Zero-bias threshold voltage.
- 10 v_{ts} (V) Threshold voltage including back-bias effects.
- 11 v_{th} (V) Threshold voltage including back-bias and drain-bias effects.
- 12 v_{gt} (V) Effective gate drive voltage including back-bias and drain voltage effects.
- 13 v_{dss} (V) Drain saturation voltage at actual bias.
- 14 v_{sat} (V) Saturation limit.
- 15 g_m (A/V) Transconductance ($d i_{ds} / d v_{gs}$).
- 16 g_{mb} (A/V) Substrate-transconductance ($d i_{ds} / d v_{sb}$).
- 17 g_{ds} (A/V) Output conductance ($d i_{ds} / d v_{ds}$).
- 18 c_{dd} (F) Capacitance ($d q_d / d v_d$).

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Philips Models

19	c_{dg} (F)	Capacitance ($-d qd / d v_g$).
20	c_{ds} (F)	Capacitance ($-d qd / d v_s$).
21	c_{db} (F)	Capacitance ($-d qd / d v_b$).
22	c_{gd} (F)	Capacitance ($-d qg / d v_d$).
23	c_{gg} (F)	Capacitance ($d qg / d v_g$).
24	c_{gs} (F)	Capacitance ($-d qg / d v_s$).
25	c_{gb} (F)	Capacitance ($-d qg / d v_b$).
26	c_{sd} (F)	Capacitance ($-d qs / d v_d$).
27	c_{sg} (F)	Capacitance ($-d qs / d v_g$).
28	c_{ss} (F)	Capacitance ($d qs / d v_s$).
29	c_{sb} (F)	Capacitance ($-d qs / d v_b$).
30	c_{bd} (F)	Capacitance ($-d qb / d v_d$).
31	c_{bg} (F)	Capacitance ($-d qb / d v_g$).
32	c_{bs} (F)	Capacitance ($-d qb / d v_s$).
33	c_{bb} (F)	Capacitance ($d qb / d v_b$).
34	c_{gdol} (F)	Gate-drain overlap capacitance of the actual transistor.
35	c_{gsol} (F)	Gate-source overlap capacitance of the actual transistor.
36	w_{eff} (m)	Effective channel width for geometrical models.
37	l_{eff} (m)	Effective channel length for geometrical models.
38	u	Transistor gain (g_m/g_{ds}).
39	r_{out} (Ω)	Small-signal output resistance ($1/g_{ds}$).
40	v_{early} (V)	Equivalent Early voltage ($ I_{d1} /g_{ds}$).

Virtuoso Simulator Components and Device Models Reference

Philips Models

41	k_{eff} (\sqrt{V})	Body effect parameter.
42	b_{eff} (A/V^2)	Gain factor.
43	f_{ug} (Hz)	Unity gain frequency at actual bias ($g_m/(2\pi C_{in})$).
44	$sqrtsfw$ (V/\sqrt{Hz})	Input-referred RMS white noise voltage density.
45	$sqrtsff$ (V/\sqrt{Hz})	Input-referred RMS white noise voltage density at 1 kHz.
46	f_{knee} (Hz)	Cross-over frequency above which white noise is dominant.
47	P_{diss} (W)	Dissipation.
48	T_K (K)	Actual device temperature.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

P_{diss}	OP-47	d_{ta}	M-92	$mult$	I-3	$swther$	M-39
T_K	OP-48	$etabetr$	M-20	nfa	O-39	$swthesat$	M-46
a_1	O-21	$etamob$	O-8	$nfars$	M-89	$swthesr$	M-28
a_{1r}	M-64	$etamobr$	M-32	nfb	O-40	$swtheth$	M-49
a_2	O-22	$etaph$	M-30	nfb_r	M-90	$theph$	O-7
a_{2r}	M-68	$etar$	M-38	nfc	O-41	$theph_r$	M-29
a_3	O-23	$etasat$	M-43	nfc_r	M-91	$ther$	O-10

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Philips Models

a3r M-71	etasr M-27	nt M-88	ther1 M-40
agidl O-31	fbet1 M-22	nt O-38	ther1 O-11
agidlr M-81	fbet2 M-24	nu M-35	ther2 M-41
alp O-18	fknee OP-46	nu O-9	ther2 O-12
alpexp M-60	fug OP-43	nuexp M-36	therr M-37
alpr M-58	gatenoise M-87	phib O-4	thesat O-13
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ath M-95	gds OP-17	region I-4	thesatr M-42
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bacc O-27	gmb OP-16	rth M-93	thesrr M-26
beff OP-42	iavl OP-2	rth O-43	theth O-14
bet O-5	ids OP-1	sdibl O-15	thethexp M-48
betsq M-19	igacc O-26	sdiblexp M-51	thethr M-47
bgidl M-82	igaccr M-76	sdiblo M-50	tnom M-98
bgidl O-32	igb OP-5	sl2ko M-11	tox M-85
binv M-75	igd OP-4	sl2phib M-17	tox O-42
binv O-25	iginv O-24	sla1 M-66	tr M-6
cbb OP-33	iginvr M-74	sla2 M-69	tref M-99
cbd OP-30	igov O-30	sla3 M-72	type M-96
cbg OP-31	igovr M-80	slalp M-59	u OP-38
cbs OP-32	igs OP-3	sletabet M-21	vds OP-6

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Philips Models

cdb	OP-21	imax	M-97	slko	M-10	vdss	OP-13
cdd	OP-18	keff	OP-41	slphib	M-16	vearly	OP-40
cdg	OP-19	ko	O-2	slssf	M-56	vfb	M-7
cds	OP-20	kor	M-9	slthesat	M-44	vfb	O-1
cgb	OP-25	kov	M-79	sqrtsff	OP-45	vfbov	M-78
cgd	OP-22	kov	O-29	sqrtsfw	OP-44	vfbov	O-28
cgdo	O-35	kpinv	M-13	ssf	O-17	vgs	OP-7
cgdol	OP-34	kpinv	O-3	ssfr	M-55	vgt	OP-12
cgg	OP-23	l	I-1	stal	M-65	vp	M-62
cgidl	M-84	lap	M-3	stbgidl	M-83	vp	O-19
cgidl	O-33	leff	OP-37	stetamob	M-33	vsat	OP-14
cgs	OP-24	level	M-1	stphib	M-15	vsb	OP-8
cgso	O-36	lmin	M-63	stvfb	M-8	vth	OP-11
cgsol	OP-35	lp1	M-23	swa1	M-67	vto	OP-9
col	M-86	lp2	M-25	swa2	M-70	vts	OP-10
cox	O-34	lvar	M-2	swa3	M-73	w	I-2
csb	OP-29	m	I-5	swalp	M-61	weff	OP-36
csd	OP-26	mexp	O-20	swetamob	M-34	wot	M-5
csg	OP-27	mo	O-16	swko	M-12	wvar	M-4
css	OP-28	moexp	M-54	swphib	M-18		
cth	M-94	moo	M-52	swssf	M-57		

cth O-44

mor M-53

swtheph M-31

MOS Model 11, Level 1101 (mos11011)

Instance Definition

Name d g s b ModelName parameter=value ...

Instance Parameters

- | | | |
|---|----------------------------|--|
| 1 | <code>l=2e-06 m</code> | Drawn channel length in the layout. Scale set by option scale.. |
| 2 | <code>w=1e-05 m</code> | Drawn channel width in the layout. Scale set by option scale.. |
| 3 | <code>mult=1</code> | Number of devices in parallel. |
| 4 | <code>region=triode</code> | Estimated DC operating region, used as a convergence aid.
Possible values are <code>off</code> , <code>triode</code> , <code>sat</code> , or <code>subth</code> . |
| 5 | <code>m=1</code> | Multiplicity factor. |
| 6 | <code>area=1</code> | alias of <code>mult</code> . |

Model Definition

model modelName mos11011 parameter=value ...

Model Parameters

- | | | |
|---|----------------------------|--|
| 1 | <code>level=1.1e+04</code> | Transistor Level. |
| 2 | <code>lvar=0 m</code> | Difference between the actual and the programmed poly-silicon gate length. |
| 3 | <code>lap=4e-08 m</code> | Effective channel length reduction per side. |
| 4 | <code>wvar=0 m</code> | Difference between the actual and the programmed field-oxide opening. |

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Philips Models

5	<code>wot=0 m</code>	Effective channel width reduction per side.
6	<code>tr=21 C</code>	Reference temperature.
7	<code>lmin=0 m</code>	Device length low limit for binning selection.
8	<code>lmax=1 m</code>	Device length high limit for binning selection.
9	<code>wmin=0 m</code>	Device width low limit for binning selection.
10	<code>wmax=1 m</code>	Device width high limit for binning selection.
11	<code>vfb=-1.05 V</code>	Flat-band voltage at reference temperature.
12	<code>poko=0.5 \sqrt{V}</code>	Coefficient for the geometry independent part of KO.
13	<code>plko=0 \sqrt{V}</code>	Coefficient for the length dependence of KO.
14	<code>pwko=0 \sqrt{V}</code>	Coefficient for the width dependence of KO.
15	<code>plwko=0 \sqrt{V}</code>	Coefficient for the length times width dependence of KO.
16	<code>kpinv=0 $1/\sqrt{V}$</code>	Inverse of body-effect factor of the poly-silicon gate.
17	<code>pophib=0.95 V</code>	Coefficient for the geometric independent part of PHIB.
18	<code>plphib=0 V</code>	Coefficient for the length dependence of PHIB.
19	<code>pwphib=0 V</code>	Coefficient for the width dependence of PHIB.
20	<code>plwphib=0 V</code>	Coefficient for the length times width dependence of PHIB.
21	<code>pobet=0.00192 (n) / 0.000381 (p) A/V^2</code>	Coefficient for the geometry independent part of BET.
22	<code>plbet=0 A/V^2</code>	Coefficient for the length dependence of BET.
23	<code>pwbet=0 A/V^2</code>	Coefficient for the width dependence of BET.
24	<code>plwbet=0 A/V^2</code>	Coefficient for the width over length dependence of BET.
25	<code>pothesr=0.356 (n) / 0.73 (p) $1/V$</code>	Coefficient of the geometry independent part of THESR.

Virtuoso Simulator Components and Device Models Reference

Philips Models

26	$plthesr=0 \ 1/V$	Coefficient of the length dependence of THESR.
27	$pwthesr=0 \ 1/V$	Coefficient of the width dependence of THESR.
28	$plwthesr=0 \ 1/V$	Coefficient of the length times width dependence of THESR.
29	$potheph=0.0129 (n) / 0.001 (p) \ 1/V$	Coefficient of the geometry independent part of THEPH.
30	$pltheph=0 \ 1/V$	Coefficient of the length dependence of THEPH.
31	$pwtheph=0 \ 1/V$	Coefficient of the width dependence of THEPH.
32	$plwtheph=0 \ 1/V$	Coefficient of the length times width dependence of THEPH.
33	$poetamob=1.4 (n) / 3 (p)$	Coefficient of the geometry independent part of ETAMOB.
34	$pletamob=0$	Coefficient of the length dependence of ETAMOB.
35	$pwetamob=0$	Coefficient of the width dependence of ETAMOB.
36	$plwetamob=0$	Coefficient of the length times width dependence of ETAMOB.
37	$pothether=0.0812 (n) / 0.079 (p) \ 1/V$	Coefficient of the geometry independent part of THER.
38	$plther=0 \ 1/V$	Coefficient of the length dependence of THER.
39	$pwther=0 \ 1/V$	Coefficient of the width dependence of THER.
40	$plwther=0 \ 1/V$	Coefficient of the length times width dependence of THER.
41	$ther1=0 \ V$	Numerator of gate voltage dependent part of series resistance.
42	$ther2=1 \ V$	Denominator of gate voltage dependent part of series resistance.
43	$pothesat=0.251 (n) / 0.173 (p) \ 1/V$	Coefficient of the geometry independent part of THESAT.
44	$plthesat=0 \ 1/V$	Coefficient of the length dependence of THESAT.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 45 $p_{wthemat}=0 \ 1/V$ Coefficient of the width dependence of THESAT.
- 46 $pl_{wthemat}=0 \ 1/V$ Coefficient of the length times width dependence of THESAT.
- 47 $po_{theth}=1e-05 (n) / 0 (p) \ 1/V^3$
Coefficient of the geometry independent part of THETH.
- 48 $pl_{theth}=0 \ 1/V^3$ Coefficient of the length dependence of THETH.
- 49 $pw_{theth}=0 \ 1/V^3$ Coefficient of the width dependence of THETH.
- 50 $pl_{wtheth}=0 \ 1/V^3$ Coefficient of the length times width dependence of THETH.
- 51 $posdibl=0.000853 (n) / 3.55e-05 (p) \ 1/\sqrt{V}$
Coefficient of the geometry independent part of SDIBL.
- 52 $pls_{dibl}=0 \ 1/\sqrt{V}$
Coefficient of the length dependence of SDIBL.
- 53 $pws_{dibl}=0 \ 1/\sqrt{V}$
Coefficient of the width dependence of SDIBL.
- 54 $plws_{dibl}=0 \ 1/\sqrt{V}$
Coefficient of the length times width dependence of SDIBL.
- 55 $p_{omo}=0$ Coefficient of the geometry independent part of MO.
- 56 $pl_{mo}=0$ Coefficient of the length dependence of MO.
- 57 $pw_{mo}=0$ Coefficient of the width dependence of MO.
- 58 $pl_{wmo}=0$ Coefficient of the length times width dependence of MO.
- 59 $possf=0.012 (n) / 0.01 (p) \ 1/\sqrt{V}$
Coefficient of the geometry independent part of SSF.
- 60 $pl_{ssf}=0 \ 1/\sqrt{V}$ Coefficient of the length dependence of SSF.
- 61 $pw_{ssf}=0 \ 1/\sqrt{V}$ Coefficient of the width dependence of SSF.
- 62 $pl_{wssf}=0 \ 1/\sqrt{V}$
Coefficient of the length times width dependence of SSF.

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Philips Models

63	$poalp=0.025$	Coefficient of the geometry independent part of ALP.
64	$plalp=0$	Coefficient of the length dependence of ALP.
65	$pwalp=0$	Coefficient of the width dependence of ALP.
66	$plwalp=0$	Coefficient of the length times width dependence of ALP.
67	$vp=0.05 \text{ V}$	Characteristic voltage of channel-length modulation.
68	$pomexp=0.2$	Coefficient of the geometry independent part of MEXP.
69	$plmexp=0$	Coefficient of the length dependence of MEXP.
70	$pwmexp=0$	Coefficient of the width dependence of MEXP.
71	$plwmexp=0$	Coefficient of the length times width dependence of MEXP.
72	$poa1=6.02(n)/6.86(p)$	Coefficient of the geometry independent part of A1.
73	$pla1=0$	Coefficient of the length dependence of A1.
74	$pwa1=0$	Coefficient of the width dependence of A1.
75	$plwa1=0$	Coefficient of the length times width dependence of A1.
76	$poa2=38(n)/57.3(p) \text{ V}$	Coefficient of the geometry independent part of A2.
77	$pla2=0 \text{ V}$	Coefficient of the length dependence of A2.
78	$pwa2=0 \text{ V}$	Coefficient of the width dependence of A2.
79	$plwa2=0 \text{ V}$	Coefficient of the length times width dependence of A2.
80	$poa3=0.641(n)/0.425(p)$	Coefficient of the geometry independent part of A3.
81	$pla3=0$	Coefficient of the length dependence of A3.
82	$pwa3=0$	Coefficient of the width dependence of A3.

Virtuoso Simulator Components and Device Models Reference

Philips Models

83	$plwa3=0$	Coefficient of the length times width dependence of A3.
84	$poiginv=0 \ A/V^2$	Coefficient of the geometry independent part of IGINV.
85	$pliginv=0 \ A/V^2$	Coefficient of the length dependence of IGINV.
86	$pwiginv=0 \ A/V^2$	Coefficient of the width dependence of IGINV.
87	$plwiginv=0 \ A/V^2$	Coefficient of the length times width dependence of IGINV.
88	$pobinv=48 \ (n) / 87.5 \ (p) \ V$	Coefficient of the geometry independent part of BINV.
89	$plbinv=0 \ V$	Coefficient of the length dependence of BINV.
90	$pwbinv=0 \ V$	Coefficient of the width dependence of BINV.
91	$plwbinv=0 \ V$	Coefficient of the length times width dependence of BINV.
92	$poigacc=0 \ A/V^2$	Coefficient of the geometry independent part of IGACC.
93	$pligacc=0 \ A/V^2$	Coefficient of the length dependence of IGACC.
94	$pwigacc=0 \ A/V^2$	Coefficient of the width dependence of IGACC.
95	$plwigacc=0 \ A/V^2$	Coefficient of the length times width dependence of IGACC.
96	$pobacc=48 \ V$	Coefficient of the geometry independent part of BACC.
97	$plbacc=0 \ V$	Coefficient of the length dependence of BACC.
98	$pwbacc=0 \ V$	Coefficient of the width dependence of BACC.
99	$plwbacc=0 \ V$	Coefficient of the length times width dependence of BACC.
100	$vfbov=0 \ V$	Flat-band voltage for the Source/Drain overlap extensions.
101	$kov=2.5 \ \sqrt{V}$	Body-effect factor for the Source/Drain overlap extensions.
102	$poigov=0 \ A/V^2$	Coefficient of the geometry independent part of IGOV.
103	$pligov=0 \ A/V^2$	Coefficient of the length dependence of IGOV.

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104	$p_{wigov}=0 \text{ A/V}^2$	Coefficient of the width dependence of IGOV.
105	$p_{lwigov}=0 \text{ A/V}^2$	Coefficient of the length times width dependence of IGOV.
106	$p_{oagidl}=0 \text{ A/V}^3$	Coefficient of the geometry independent part of AGIDL.
107	$p_{lagidl}=0 \text{ A/V}^3$	Coefficient of the length dependence of AGIDL.
108	$p_{wagidl}=0 \text{ A/V}^3$	Coefficient of the width dependence of AGIDL.
109	$p_{lwagidl}=0 \text{ A/V}^3$	Coefficient of the length times width dependence of AGIDL.
110	$p_{obgidl}=41 \text{ V}$	Coefficient of the geometry independent part of BGIDL.
111	$p_{lbgidl}=0 \text{ V}$	Coefficient of the length dependence of BGIDL.
112	$p_{wbgidl}=0 \text{ V}$	Coefficient of the width dependence of BGIDL.
113	$p_{lwbgidl}=0 \text{ V}$	Coefficient of the length times width dependence of BGIDL.
114	$p_{ocgidl}=0$	Coefficient of the geometry independent part of CGIDL.
115	$p_{lccgidl}=0$	Coefficient of the length dependence of CGIDL.
116	$p_{wccgidl}=0$	Coefficient of the width dependence of CGIDL.
117	$p_{lwcgidl}=0$	Coefficient of the length times width dependence of CGIDL.
118	$t_{ox}=3.2e-09 \text{ m}$	Thickness of gate oxide layer.
119	$p_{ocox}=2.98e-14 \text{ (n)} / 2.72e-14 \text{ (p)} \text{ F}$	Coefficient of the geometry independent part of COX.
120	$p_{lcox}=0 \text{ F}$	Coefficient of the length dependence of COX.
121	$p_{wcox}=0 \text{ F}$	Coefficient of the width dependence of COX.
122	$p_{lwccox}=0 \text{ F}$	Coefficient of the length times width dependence of COX.
123	$p_{ocgdo}=6.39e-15 \text{ (n)} / 6.36e-15 \text{ (p)} \text{ F}$	Coefficient of the geometry independent part of CGDO.
124	$p_{lccgdo}=0 \text{ F}$	Coefficient of the length dependence of CGDO.

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125	$p_{w\text{cgdo}}=0$	F	Coefficient of the width dependence of CGDO.
126	$p_{l\text{w}\text{cgdo}}=0$	F	Coefficient of the length time width dependence of CGDO.
127	$p_{o\text{cgso}}=6.39\text{e-}15$	$(n) / 6.36\text{e-}15$	(p) F Coefficient of the geometry independent part of CGSO.
128	$p_{l\text{cgso}}=0$	F	Coefficient of the length dependence of CGSO.
129	$p_{w\text{cgso}}=0$	F	Coefficient of the width dependence of CGSO.
130	$p_{l\text{w}\text{cgso}}=0$	F	Coefficient of the length times width dependence of CGSO.
131	$g\text{atenoise}=0$		Flag for in/exclusion of induced gate thermal noise.
132	$n\text{t}=1.62\text{e-}20$	J	Thermal noise coefficient.
133	$p_{o\text{nfa}}=8.32\text{e+}22$	$(n) / 1.9\text{e+}22$	(p) $1/V$ m^4 Coefficient of the geometry independent part of NFA.
134	$p_{l\text{nfa}}=0$	$1/V$ m^4	Coefficient of the length dependence of NFA.
135	$p_{w\text{nfa}}=0$	$1/V$ m^4	Coefficient of the width dependence of NFA.
136	$p_{l\text{w}\text{nfa}}=0$	$1/V$ m^4	Coefficient of the length times width dependence of NFA.
137	$p_{o\text{nfb}}=2.51\text{e+}07$	$(n) / 5.04\text{e+}06$	(p) $1/V$ m^2 Coefficient of the geometry independent part of NFB.
138	$p_{l\text{nfb}}=0$	$1/V$ m^2	Coefficient of the length dependence of NFB.
139	$p_{w\text{nfb}}=0$	$1/V$ m^2	Coefficient of the width dependence of NFB.
140	$p_{l\text{w}\text{nfb}}=0$	$1/V$ m^2	Coefficient of the length times width dependence of NFB.
141	$p_{o\text{nfc}}=0$	$(n) / 3.63\text{e-}10$	(p) $1/V$ Coefficient of the geometry independent part of NFC.
142	$p_{l\text{nfc}}=0$	$1/V$	Coefficient of the length dependence of NFC.
143	$p_{w\text{nfc}}=0$	$1/V$	Coefficient of the width dependence of NFC.
144	$p_{l\text{w}\text{nfc}}=0$	$1/V$	Coefficient of the length times width dependence of NFC.

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- 145 $\text{potvfb}=0.0005 \text{ V/K}$ Coefficient of the geometry independent part of STVFB.
- 146 $\text{pltvfb}=0 \text{ V/K}$ Coefficient of the length dependence of STVFB.
- 147 $\text{pwtvfb}=0 \text{ V/K}$ Coefficient of the width dependence of STVFB.
- 148 $\text{plwtvfb}=0 \text{ V/K}$ Coefficient of the length times width dependence of STVFB.
- 149 $\text{potphib}=-0.00085 \text{ V/K}$ Coefficient of the geometry independent part of STPHIB.
- 150 $\text{pltphib}=0 \text{ V/K}$ Coefficient of the length dependence of STPHIB.
- 151 $\text{pwtphib}=0 \text{ V/K}$ Coefficient of the width dependence of STPHIB.
- 152 $\text{plwtphib}=0 \text{ V/K}$ Coefficient of the length times width dependence of STPHIB.
- 153 $\text{potetabet}=1.3 (n) / 0.5 (p)$ Coefficient of the geometry independent part of ETABET.
- 154 $\text{pltetabet}=0$ Coefficient of the length dependence of ETABET.
- 155 $\text{pwtetabet}=0$ Coefficient of the width dependence of ETABET.
- 156 $\text{plwtetabet}=0$ Coefficient of the length times width dependence of ETABET.
- 157 $\text{potetasr}=0.65 (n) / 0.5 (p)$ Coefficient of the geometry independent part of ETASR.
- 158 $\text{pltetasr}=0$ Coefficient of the length dependence of ETASR.
- 159 $\text{pwtetasr}=0$ Coefficient of the width dependence of ETASR.
- 160 $\text{plwtetasr}=0$ Coefficient of the length times width dependence of ETASR.
- 161 $\text{potetaph}=1.35 (n) / 3.75 (p)$ Coefficient of the geometry independent part of ETAPH.
- 162 $\text{pltetaph}=0$ Coefficient of the length dependence of ETAPH.
- 163 $\text{pwtetaph}=0$ Coefficient of the width dependence of ETAPH.
- 164 $\text{plwtetaph}=0$ Coefficient of the length times width dependence of ETAPH.

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165	$\text{potetamob}=0 \ 1/K$	Coefficient of the geometry independent part of STETAMOB.
166	$\text{pltetamob}=0 \ 1/K$	Coefficient of the length dependence of STETAMOB.
167	$\text{pwtetamob}=0 \ 1/K$	Coefficient of the width dependence of STETAMOB.
168	$\text{plwtetamob}=0 \ 1/K$	Coefficient of the length times width dependence of STETAMOB.
169	$\text{nu}=2$	Exponent of field dependence of mobility model.
170	$\text{potnuexp}=5.25 \ (n) / 3.23 \ (p)$	Coefficient of the geometry independent part of NUEXP.
171	$\text{pltnuexp}=0$	Coefficient of the length dependence of NUEXP.
172	$\text{pwtnuexp}=0$	Coefficient of the width dependence of NUEXP.
173	$\text{plwtnuexp}=0$	Coefficient of the length times width dependence of NUEXP.
174	$\text{potetar}=0.95 \ (n) / 0.4 \ (p)$	Coefficient of the geometry independent part of ETAR.
175	$\text{pltetar}=0$	Coefficient of the length dependence of ETAR.
176	$\text{pwtetar}=0$	Coefficient of the width dependence of ETAR.
177	$\text{plwtetar}=0$	Coefficient of the length times width dependence of ETAR.
178	$\text{potetasat}=1.04 \ (n) / 0.86 \ (p)$	Coefficient of the geometry independent part of ETASAT.
179	$\text{pltetasat}=0$	Coefficient of the length dependence of ETASAT.
180	$\text{pwtetasat}=0$	Coefficient of the width dependence of ETASAT.
181	$\text{plwtetasat}=0$	Coefficient of the length times width dependence of ETASAT.
182	$\text{pota1}=0 \ 1/K$	Coefficient of the geometry independent part of STA1.
183	$\text{plta1}=0 \ 1/K$	Coefficient of the length dependence of STA1.
184	$\text{pwta1}=0 \ 1/K$	Coefficient of the width dependence of STA1.

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185	<code>plwta1=0</code>	1/K	Coefficient of the length times width dependence of STA1.
186	<code>potbgidl=-0.000364</code>	V/K	Coefficient of the geometry independent part of STBGIDL.
187	<code>pltbgidl=0</code>	V/K	Coefficient of the length dependence of STBGIDL.
188	<code>pwtbgidl=0</code>	V/K	Coefficient of the width dependence of STBGIDL.
189	<code>plwtbgidl=0</code>	V/K	Coefficient of the length times width dependence of STBGIDL.
190	<code>dta=0</code>	K	Temperature offset of the device.
191	<code>type=n</code>		Transistor gender. Possible values are n, p, npn, pnp, npnv, pnpv, npnl, or pnp1.
192	<code>imax=1.0</code>	A	Explosion current.
193	<code>tnom</code>	(C)	alias of tnom.
194	<code>tref</code>	(C)	alias of tnom.

Output Parameters

1	<code>vfb</code>	(V)	Flat-band voltage at reference temperature.
2	<code>ko</code>	(\sqrt{V})	Body-effect factor.
3	<code>kpinv</code>	($1/\sqrt{V}$)	Inverse of body-effect factor of the poly-silicon gate.
4	<code>phib</code>	(V)	Surface potential at the onset of strong inversion.
5	<code>bet</code>	(A/V^2)	Gain factor.
6	<code>thesr</code>	(1/V)	Mobility degradation parameter due to surface roughness scattering.
7	<code>theph</code>	(1/V)	Mobility degradation parameter due to phonon scattering.
8	<code>etamob</code>		Effective field parameter for dependence on depletion charge.
9	<code>nu</code>		Exponent of field dependence of mobility model.

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10	ther (1/V)	Coefficient of series resistance.
11	ther1 (V)	Numerator of gate voltage dependent part of series resistance.
12	ther2 (V)	Denominator of gate voltage dependent part of series resistance.
13	thesat (1/V)	Velocity saturation parameter due to optical/acoustic phonon scattering.
14	theth (1/V ³)	Coefficient of self-heating.
15	sdibl (1/ \sqrt{V})	Drain-induced barrier lowering parameter.
16	mo	Parameter for (short-channel) subthreshold slope.
17	ssf (1/ \sqrt{V})	Static-feedback parameter.
18	alp	Factor of channel length modulation.
19	vp (V)	Characteristic voltage of channel-length modulation.
20	mexp	Smoothing factor.
21	a1	Factor of the weak-avalanche current.
22	a2 (V)	Exponent of the weak-avalanche current.
23	a3	Factor of the drain-source voltage above which weak-avalanche occurs.
24	iginv (A/V ²)	Gain factor for intrinsic gate tunnelling current in inversion.
25	binv (V)	Probability factor for intrinsic gate tunnelling current in inversion.
26	igacc (A/V ²)	Gain factor for intrinsic gate tunnelling current in accumulation.
27	bacc (V)	Probability factor for intrinsic gate tunnelling current in accumulation.
28	vfbov (V)	Flat-band voltage for the Source/Drain overlap extensions.
29	kov (\sqrt{V})	Body-effect factor for the Source/Drain overlap extensions.

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30	$igov$ (A/V ²)	Gain factor for Source/Drain overlap tunnelling current.
31	$agidl$ (A/V ³)	Gain factor for gate-induced leakage current.
32	$bgidl$ (V)	Probability factor for gate-induced drain leakage current at reference temperature.
33	$cgidl$	Factor for the lateral field dependence of the gate-induced leakage current.
34	cox (F)	Oxide capacitance for the intrinsic channel (* mult).
35	$cgdo$ (F)	Oxide capacitance for the gate-drain overlap (* mult).
36	$cgso$ (F)	Oxide capacitance for the gate-source overlap (* mult).
37	$gatenoise$	Flag for in/exclusion of induced gate thermal noise.
38	nt (J)	Thermal noise coefficient.
39	nfa (1/(Vm ⁴))	First coefficient of the flicker noise.
40	nfb (1/(Vm ²))	Second coefficient of the flicker noise.
41	nfc (1/V)	Third coefficient of the flicker noise.
42	tox (m)	Thickness of gate oxide layer.

Operating-Point Parameters

1	ids (A)	Drain current, excl. avalanche and tunnel currents.
2	$iavl$ (A)	Substrate current due to weak-avalanche.
3	igs (A)	Gate-to-source current due to direct tunnelling.
4	igd (A)	Gate-to-drain current due to direct tunnelling.
5	igb (A)	Gate-to-bulk current due to direct tunnelling.
6	vds (V)	Drain-source voltage.
7	vgs (V)	Gate-source voltage.

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8	v_{sb} (V)	Source-bulk voltage.
9	v_{to} (V)	Zero-bias threshold voltage.
10	v_{ts} (V)	Threshold voltage including back-bias effects.
11	v_{th} (V)	Threshold voltage including back-bias and drain-bias effects.
12	v_{gt} (V)	Effective gate drive voltage including back-bias and drain voltage effects.
13	v_{dss} (V)	Drain saturation voltage at actual bias.
14	v_{sat} (V)	Saturation limit.
15	g_m (A/V)	Transconductance ($d i_{ds} / d v_{gs}$).
16	g_{mb} (A/V)	Substrate-transconductance ($d i_{ds} / d v_{bs}$).
17	g_{ds} (A/V)	Output conductance ($d i_{ds} / d v_{ds}$).
18	c_{dd} (F)	Capacitance ($d q_d / d v_d$).
19	c_{dg} (F)	Capacitance ($- d q_d / d v_g$).
20	c_{ds} (F)	Capacitance ($- d q_d / d v_s$).
21	c_{db} (F)	Capacitance ($- d q_d / d v_b$).
22	c_{gd} (F)	Capacitance ($- d q_g / d v_d$).
23	c_{gg} (F)	Capacitance ($d q_g / d v_g$).
24	c_{gs} (F)	Capacitance ($- d q_g / d v_s$).
25	c_{gb} (F)	Capacitance ($- d q_g / d v_b$).
26	c_{sd} (F)	Capacitance ($- d q_s / d v_d$).
27	c_{sg} (F)	Capacitance ($- d q_s / d v_g$).
28	c_{ss} (F)	Capacitance ($d q_s / d v_s$).

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29	c_{sb} (F)	Capacitance (- d q_s / d v_b).
30	c_{bd} (F)	Capacitance (- d q_b / d v_d).
31	c_{bg} (F)	Capacitance (- d q_b / d v_g).
32	c_{bs} (F)	Capacitance (- d q_b / d v_s).
33	c_{bb} (F)	Capacitance (d q_b / d v_b).
34	c_{gdol} (F)	Gate-drain overlap capacitance of the actual transistor.
35	c_{gsol} (F)	Gate-source overlap capacitance of the actual transistor.
36	w_{eff} (m)	Effective channel width for geometrical models.
37	l_{eff} (m)	Effective channel length for geometrical models.
38	u	Transistor gain (gm/gds).
39	r_{out} (Ω)	Small-signal output resistance (1/gds).
40	v_{early} (V)	Equivalent Early voltage ($ l_{dl} /gds$).
41	k_{eff} (\sqrt{V})	Body effect parameter.
42	b_{eff} (A/V ²)	Gain factor.
43	f_{ug} (Hz)	Unity gain frequency at actual bias ($gm/(2*\pi*cin)$).
44	$sqrtsfw$ (V/ \sqrt{Hz})	Input-referred RMS white noise voltage density.
45	$sqrtsff$ (V/ \sqrt{Hz})	Input-referred RMS white noise voltage density at 1 kHz.
46	f_{knee} (Hz)	Cross-over frequency above which white noise is dominant.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the

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description for that parameter. For example, a reference of M-35 means the 35th model parameter.

a1	O-21	nt	O-38	plwta1	M-185	pwigacc	M-94
a2	O-22	nu	M-169	plwtbgidl	M-189	pwiginv	M-86
a3	O-23	nu	O-9	plwtetabet	M-156	pwigov	M-104
agidl	O-31	phib	O-4	plwtetamob	M-168	pwko	M-14
alp	O-18	pla1	M-73	plwtetaph	M-164	pwmexp	M-70
area	I-6	pla2	M-77	plwtetar	M-177	pwm0	M-57
bacc	O-27	pla3	M-81	plwtetasat	M-181	pwnfa	M-135
beff	OP-42	plagidl	M-107	plwtetasr	M-160	pwnfb	M-139
bet	O-5	plalp	M-64	plwtheph	M-32	pwnfc	M-143
bgidl	O-32	plbacc	M-97	plwther	M-40	pwphib	M-19
binv	O-25	plbet	M-22	plwthesat	M-46	pwsdibl	M-53
cbb	OP-33	plbgidl	M-111	plwthesr	M-28	pwsst	M-61
cbd	OP-30	plbinv	M-89	plwtheth	M-50	pwta1	M-184
cbg	OP-31	plcgdo	M-124	plwtneuexp	M-173	pwtbgidl	M-188
cbs	OP-32	plcgidl	M-115	plwtphib	M-152	pwtetabet	M-155
cdb	OP-21	plcgso	M-128	plwtvfb	M-148	pwtetamob	M-167
cdd	OP-18	plcox	M-120	poa1	M-72	pwtetaph	M-163
cdg	OP-19	pletamob	M-34	poa2	M-76	pwtetar	M-176
cds	OP-20	pligacc	M-93	poa3	M-80	pwtetasat	M-180

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cgb	OP-25	plginv	M-85	poagidl	M-106	pwtetasr	M-159
cgd	OP-22	pligov	M-103	poalp	M-63	pwtheph	M-31
cgdo	O-35	plko	M-13	pobacc	M-96	pwther	M-39
cgdol	OP-34	plmexp	M-69	pobet	M-21	pwthesat	M-45
cgg	OP-23	plmo	M-56	pobgidl	M-110	pwthesr	M-27
cgidl	O-33	plnfa	M-134	pobinv	M-88	pwtheth	M-49
cgs	OP-24	plnfb	M-138	pocgdo	M-123	pwtnuexp	M-172
cgso	O-36	plnfc	M-142	pocgidl	M-114	pwtphib	M-151
cgsol	OP-35	plphib	M-18	pocgso	M-127	pwtvfb	M-147
cox	O-34	plsdibl	M-52	pocox	M-119	region	I-4
csb	OP-29	plssf	M-60	poetamob	M-33	rout	OP-39
csd	OP-26	plta1	M-183	poigacc	M-92	sdibl	O-15
csg	OP-27	pltbgidl	M-187	poiginv	M-84	sqrtsff	OP-45
css	OP-28	pltetabet	M-154	poigov	M-102	sqrtsfw	OP-44
dta	M-190	pltetamob	M-166	poko	M-12	ssf	O-17
etamob	O-8	pltetaph	M-162	pomexp	M-68	theph	O-7
fknee	OP-46	pltetar	M-175	pomo	M-55	ther	O-10
fug	OP-43	pltetasat	M-179	ponfa	M-133	ther1	M-41
gatenoise	M-131	pltetasr	M-158	ponfb	M-137	ther1	O-11
gatenoise	O-37	pltheph	M-30	ponfc	M-141	ther2	M-42
gds	OP-17	plther	M-38	pophib	M-17	ther2	O-12

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gm	OP-15	plthesat	M-44	posdibl	M-51	thesat	O-13
gmb	OP-16	plthesr	M-26	possf	M-59	thesr	O-6
iavl	OP-2	pltheth	M-48	potal	M-182	theth	O-14
ids	OP-1	pltnuexp	M-171	potbgidl	M-186	tnom	M-193
igacc	O-26	pltphib	M-150	potetabet	M-153	tox	M-118
igb	OP-5	pltvfb	M-146	potetamob	M-165	tox	O-42
igd	OP-4	plwa1	M-75	potetaph	M-161	tr	M-6
iginv	O-24	plwa2	M-79	potetar	M-174	tref	M-194
igov	O-30	plwa3	M-83	potetasat	M-178	type	M-191
igs	OP-3	plwagidl	M-109	potetasr	M-157	u	OP-38
imax	M-192	plwalp	M-66	potheph	M-29	vds	OP-6
keff	OP-41	plwbacc	M-99	pother	M-37	vdss	OP-13
ko	O-2	plwbet	M-24	pothesat	M-43	vearly	OP-40
kov	M-101	plwbgidl	M-113	pothesr	M-25	vfb	M-11
kov	O-29	plwbinv	M-91	potheth	M-47	vfb	O-1
kpinv	M-16	plwcgdo	M-126	potnuexp	M-170	vfbov	M-100
kpinv	O-3	plwcgidl	M-117	potphib	M-149	vfbov	O-28
l	I-1	plwcgso	M-130	potvfb	M-145	vgs	OP-7
lap	M-3	plwcox	M-122	pwa1	M-74	vgt	OP-12
leff	OP-37	plwetamob	M-36	pwa2	M-78	vp	M-67
level	M-1	plwigacc	M-95	pwa3	M-82	vp	O-19

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lmax	M-8	plwiginv	M-87	pwagidl	M-108	vsat	OP-14
lmin	M-7	plwigov	M-105	pwalp	M-65	vsb	OP-8
lvar	M-2	plwko	M-15	pwbacc	M-98	vth	OP-11
m	I-5	plwmexp	M-71	pwbet	M-23	vto	OP-9
mexp	O-20	plwmo	M-58	pwbgidl	M-112	vts	OP-10
mo	O-16	plwnfa	M-136	pwbinv	M-90	w	I-2
mult	I-3	plwnfb	M-140	pwcgdo	M-125	weff	OP-36
nfa	O-39	plwnfc	M-144	pwcgidl	M-116	wmax	M-10
nfb	O-40	plwphib	M-20	pwcgso	M-129	wmin	M-9
nfc	O-41	plwsdibl	M-54	pwcox	M-121	wot	M-5
nt	M-132	plwssf	M-62	pwetamob	M-35	wvar	M-4

MOS Model 11, Level 1101 (mos11011t)

This is SimKit 4.0

This device is supported within altergroups.

This device is dynamically loaded from the shared object /vobs/spectre_dev/tools.lnx86/cmi/lib/5.0.doc/libphilips_sh.so

Instance Definition

Name d g s b dt ModelName parameter=value ...

Instance Parameters

- 1 l=2e-06 m Drawn channel length in the layout. Scale set by option scale..
- 2 w=1e-05 m Drawn channel width in the layout. Scale set by option scale..

Virtuoso Simulator Components and Device Models Reference

Philips Models

3	<code>mult=1</code>	Number of devices in parallel.
4	<code>region=triode</code>	Estimated DC operating region, used as a convergence aid. Possible values are <code>off</code> , <code>triode</code> , <code>sat</code> , or <code>subth</code> .
5	<code>m=1</code>	Multiplicity factor.
6	<code>area=1</code>	alias of <code>mult</code> .

Model Definition

```
model modelName mos11011t parameter=value ...
```

Model Parameters

1	<code>level=1.1e+04</code>	Transistor Level.
2	<code>lvar=0 m</code>	Difference between the actual and the programmed poly-silicon gate length.
3	<code>lap=4e-08 m</code>	Effective channel length reduction per side.
4	<code>wvar=0 m</code>	Difference between the actual and the programmed field-oxide opening.
5	<code>wot=0 m</code>	Effective channel width reduction per side.
6	<code>tr=21 C</code>	Reference temperature.
7	<code>lmin=0 m</code>	Device length low limit for binning selection.
8	<code>lmax=1 m</code>	Device length high limit for binning selection.
9	<code>wmin=0 m</code>	Device width low limit for binning selection.
10	<code>wmax=1 m</code>	Device width high limit for binning selection.
11	<code>vfb=-1.05 V</code>	Flat-band voltage at reference temperature.
12	<code>poko=0.5 \sqrt{V}</code>	Coefficient for the geometry independent part of KO.
13	<code>plko=0 \sqrt{V}</code>	Coefficient for the length dependence of KO.

Virtuoso Simulator Components and Device Models Reference

Philips Models

14	$p_{wko}=0 \sqrt{V}$	Coefficient for the width dependence of KO.
15	$p_{lwko}=0 \sqrt{V}$	Coefficient for the length times width dependence of KO.
16	$k_{pinv}=0 1/\sqrt{V}$	Inverse of body-effect factor of the poly-silicon gate.
17	$p_{ophib}=0.95 V$	Coefficient for the geometric independent part of PHIB.
18	$p_{lphib}=0 V$	Coefficient for the length dependence of PHIB.
19	$p_{wphib}=0 V$	Coefficient for the width dependence of PHIB.
20	$p_{lwphib}=0 V$	Coefficient for the length times width dependence of PHIB.
21	$p_{obet}=0.00192 (n) / 0.000381 (p) A/V^2$	Coefficient for the geometry independent part of BET.
22	$p_{lbet}=0 A/V^2$	Coefficient for the length dependence of BET.
23	$p_{wbet}=0 A/V^2$	Coefficient for the width dependence of BET.
24	$p_{lwbet}=0 A/V^2$	Coefficient for the width over length dependence of BET.
25	$p_{othesr}=0.356 (n) / 0.73 (p) 1/V$	Coefficient of the geometry independent part of THESR.
26	$p_{lthesr}=0 1/V$	Coefficient of the length dependence of THESR.
27	$p_{wthesr}=0 1/V$	Coefficient of the width dependence of THESR.
28	$p_{lwthesr}=0 1/V$	Coefficient of the length times width dependence of THESR.
29	$p_{otheph}=0.0129 (n) / 0.001 (p) 1/V$	Coefficient of the geometry independent part of THEPH.
30	$p_{ltheeph}=0 1/V$	Coefficient of the length dependence of THEPH.
31	$p_{wtheph}=0 1/V$	Coefficient of the width dependence of THEPH.
32	$p_{lwtheeph}=0 1/V$	Coefficient of the length times width dependence of THEPH.
33	$p_{oetamob}=1.4 (n) / 3 (p)$	Coefficient of the geometry independent part of ETAMOB.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 34 $p_{letamob}=0$ Coefficient of the length dependence of ETAMOB.
- 35 $p_{wetamob}=0$ Coefficient of the width dependence of ETAMOB.
- 36 $p_{lwetamob}=0$ Coefficient of the length times width dependence of ETAMOB.
- 37 $p_{other}=0.0812 (n) / 0.079 (p) \ 1/V$
Coefficient of the geometry independent part of THER.
- 38 $p_{lther}=0 \ 1/V$ Coefficient of the length dependence of THER.
- 39 $p_{wthther}=0 \ 1/V$ Coefficient of the width dependence of THER.
- 40 $p_{lwthther}=0 \ 1/V$ Coefficient of the length times width dependence of THER.
- 41 $ther1=0 \ V$ Numerator of gate voltage dependent part of series resistance.
- 42 $ther2=1 \ V$ Denominator of gate voltage dependent part of series resistance.
- 43 $p_{thesat}=0.251 (n) / 0.173 (p) \ 1/V$
Coefficient of the geometry independent part of THESAT.
- 44 $p_{lthesat}=0 \ 1/V$ Coefficient of the length dependence of THESAT.
- 45 $p_{wththesat}=0 \ 1/V$ Coefficient of the width dependence of THESAT.
- 46 $p_{lwththesat}=0 \ 1/V$ Coefficient of the length times width dependence of THESAT.
- 47 $p_{theth}=1e-05 (n) / 0 (p) \ 1/V^3$
Coefficient of the geometry independent part of THETH.
- 48 $p_{ltheth}=0 \ 1/V^3$ Coefficient of the length dependence of THETH.
- 49 $p_{wththeth}=0 \ 1/V^3$ Coefficient of the width dependence of THETH.
- 50 $p_{lwththeth}=0 \ 1/V^3$ Coefficient of the length times width dependence of THETH.
- 51 $p_{osdibl}=0.000853 (n) / 3.55e-05 (p) \ 1/\sqrt{V}$
Coefficient of the geometry independent part of SDIBL.
- 52 $p_{lsdibl}=0 \ 1/\sqrt{V}$
Coefficient of the length dependence of SDIBL.

Virtuoso Simulator Components and Device Models Reference

Philips Models

53	$pwsdibl=0 \ 1/\sqrt{V}$	Coefficient of the width dependence of SDIBL.
54	$plwsdibl=0 \ 1/\sqrt{V}$	Coefficient of the length times width dependence of SDIBL.
55	$pomo=0$	Coefficient of the geometry independent part of MO.
56	$plmo=0$	Coefficient of the length dependence of MO.
57	$pwm=0$	Coefficient of the width dependence of MO.
58	$plwm=0$	Coefficient of the length times width dependence of MO.
59	$possf=0.012(n)/0.01(p) \ 1/\sqrt{V}$	Coefficient of the geometry independent part of SSF.
60	$plssf=0 \ 1/\sqrt{V}$	Coefficient of the length dependence of SSF.
61	$pwssf=0 \ 1/\sqrt{V}$	Coefficient of the width dependence of SSF.
62	$plwssf=0 \ 1/\sqrt{V}$	Coefficient of the length times width dependence of SSF.
63	$poalp=0.025$	Coefficient of the geometry independent part of ALP.
64	$plalp=0$	Coefficient of the length dependence of ALP.
65	$pwalp=0$	Coefficient of the width dependence of ALP.
66	$plwalp=0$	Coefficient of the length times width dependence of ALP.
67	$vp=0.05 \ V$	Characteristic voltage of channel-length modulation.
68	$pomexp=0.2$	Coefficient of the geometry independent part of MEXP.
69	$plmexp=0$	Coefficient of the length dependence of MEXP.
70	$pwmexp=0$	Coefficient of the width dependence of MEXP.
71	$plwmexp=0$	Coefficient of the length times width dependence of MEXP.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 72 $poa1=6.02(n)/6.86(p)$ Coefficient of the geometry independent part of A1.
- 73 $pla1=0$ Coefficient of the length dependence of A1.
- 74 $pwa1=0$ Coefficient of the width dependence of A1.
- 75 $plwa1=0$ Coefficient of the length times width dependence of A1.
- 76 $poa2=38(n)/57.3(p) \ V$ Coefficient of the geometry independent part of A2.
- 77 $pla2=0 \ V$ Coefficient of the length dependence of A2.
- 78 $pwa2=0 \ V$ Coefficient of the width dependence of A2.
- 79 $plwa2=0 \ V$ Coefficient of the length times width dependence of A2.
- 80 $poa3=0.641(n)/0.425(p)$ Coefficient of the geometry independent part of A3.
- 81 $pla3=0$ Coefficient of the length dependence of A3.
- 82 $pwa3=0$ Coefficient of the width dependence of A3.
- 83 $plwa3=0$ Coefficient of the length times width dependence of A3.
- 84 $poiginv=0 \ A/V^2$ Coefficient of the geometry independent part of IGINV.
- 85 $pliginv=0 \ A/V^2$ Coefficient of the length dependence of IGINV.
- 86 $pwiginv=0 \ A/V^2$ Coefficient of the width dependence of IGINV.
- 87 $plwiginv=0 \ A/V^2$ Coefficient of the length times width dependence of IGINV.
- 88 $pobinv=48(n)/87.5(p) \ V$ Coefficient of the geometry independent part of BINV.
- 89 $plbinv=0 \ V$ Coefficient of the length dependence of BINV.
- 90 $pwbinv=0 \ V$ Coefficient of the width dependence of BINV.
- 91 $plwbinv=0 \ V$ Coefficient of the length times width dependence of BINV.

Virtuoso Simulator Components and Device Models Reference

Philips Models

92	$poigacc=0 \text{ A/V}^2$	Coefficient of the geometry independent part of IGACC.
93	$pligacc=0 \text{ A/V}^2$	Coefficient of the length dependence of IGACC.
94	$pwigacc=0 \text{ A/V}^2$	Coefficient of the width dependence of IGACC.
95	$plwigacc=0 \text{ A/V}^2$	Coefficient of the length times width dependence of IGACC.
96	$pobacc=48 \text{ V}$	Coefficient of the geometry independent part of BACC.
97	$plbacc=0 \text{ V}$	Coefficient of the length dependence of BACC.
98	$pwbacc=0 \text{ V}$	Coefficient of the width dependence of BACC.
99	$plwbacc=0 \text{ V}$	Coefficient of the length times width dependence of BACC.
100	$vfbov=0 \text{ V}$	Flat-band voltage for the Source/Drain overlap extensions.
101	$kov=2.5 \sqrt{V}$	Body-effect factor for the Source/Drain overlap extensions.
102	$poigov=0 \text{ A/V}^2$	Coefficient of the geometry independent part of IGOV.
103	$pligov=0 \text{ A/V}^2$	Coefficient of the length dependence of IGOV.
104	$pwigov=0 \text{ A/V}^2$	Coefficient of the width dependence of IGOV.
105	$plwigov=0 \text{ A/V}^2$	Coefficient of the length times width dependence of IGOV.
106	$poagidl=0 \text{ A/V}^3$	Coefficient of the geometry independent part of AGIDL.
107	$plagidl=0 \text{ A/V}^3$	Coefficient of the length dependence of AGIDL.
108	$pwagidl=0 \text{ A/V}^3$	Coefficient of the width dependence of AGIDL.
109	$plwagidl=0 \text{ A/V}^3$	Coefficient of the length times width dependence of AGIDL.
110	$pobgidl=41 \text{ V}$	Coefficient of the geometry independent part of BGIDL.
111	$plbgidl=0 \text{ V}$	Coefficient of the length dependence of BGIDL.
112	$pwbgidl=0 \text{ V}$	Coefficient of the width dependence of BGIDL.
113	$plwbgidl=0 \text{ V}$	Coefficient of the length times width dependence of BGIDL.

Virtuoso Simulator Components and Device Models Reference

Philips Models

114	<code>pocgidl=0</code>	Coefficient of the geometry independent part of CGIDL.
115	<code>plcgidl=0</code>	Coefficient of the length dependence of CGIDL.
116	<code>pwcgidl=0</code>	Coefficient of the width dependence of CGIDL.
117	<code>plwcgidl=0</code>	Coefficient of the length times width dependence of CGIDL.
118	<code>tox=3.2e-09 m</code>	Thickness of gate oxide layer.
119	<code>pocox=2.98e-14 (n) / 2.72e-14 (p) F</code>	Coefficient of the geometry independent part of COX.
120	<code>plcox=0 F</code>	Coefficient of the length dependence of COX.
121	<code>pwcox=0 F</code>	Coefficient of the width dependence of COX.
122	<code>plwcox=0 F</code>	Coefficient of the length times width dependence of COX.
123	<code>pocgdo=6.39e-15 (n) / 6.36e-15 (p) F</code>	Coefficient of the geometry independent part of CGDO.
124	<code>plcgdo=0 F</code>	Coefficient of the length dependence of CGDO.
125	<code>pwcgdo=0 F</code>	Coefficient of the width dependence of CGDO.
126	<code>plwcgdo=0 F</code>	Coefficient of the length time width dependence of CGDO.
127	<code>pocgso=6.39e-15 (n) / 6.36e-15 (p) F</code>	Coefficient of the geometry independent part of CGSO.
128	<code>plcgso=0 F</code>	Coefficient of the length dependence of CGSO.
129	<code>pwcgso=0 F</code>	Coefficient of the width dependence of CGSO.
130	<code>plwcgso=0 F</code>	Coefficient of the length times width dependence of CGSO.
131	<code>gatenoise=0</code>	Flag for in/exclusion of induced gate thermal noise.
132	<code>nt=1.62e-20 J</code>	Thermal noise coefficient.
133	<code>ponfa=8.32e+22 (n) / 1.9e+22 (p) 1/V m⁴</code>	Coefficient of the geometry independent part of NFA.

Virtuoso Simulator Components and Device Models Reference

Philips Models

134	$p_{lnfa}=0 \ 1/V \ m^4$	Coefficient of the length dependence of NFA.
135	$p_{wnfa}=0 \ 1/V \ m^4$	Coefficient of the width dependence of NFA.
136	$p_{lwnfa}=0 \ 1/V \ m^4$	Coefficient of the length times width dependence of NFA.
137	$p_{onfb}=2.51e+07 (n) / 5.04e+06 (p) \ 1/V \ m^2$	Coefficient of the geometry independent part of NFB.
138	$p_{lnfb}=0 \ 1/V \ m^2$	Coefficient of the length dependence of NFB.
139	$p_{wnfb}=0 \ 1/V \ m^2$	Coefficient of the width dependence of NFB.
140	$p_{lwnfb}=0 \ 1/V \ m^2$	Coefficient of the length times width dependence of NFB.
141	$p_{onfc}=0 (n) / 3.63e-10 (p) \ 1/V$	Coefficient of the geometry independent part of NFC.
142	$p_{lnfc}=0 \ 1/V$	Coefficient of the length dependence of NFC.
143	$p_{wnfc}=0 \ 1/V$	Coefficient of the width dependence of NFC.
144	$p_{lwnfc}=0 \ 1/V$	Coefficient of the length times width dependence of NFC.
145	$p_{otvfb}=0.0005 \ V/K$	Coefficient of the geometry independent part of STVFB.
146	$p_{ltvfb}=0 \ V/K$	Coefficient of the length dependence of STVFB.
147	$p_{wtvfb}=0 \ V/K$	Coefficient of the width dependence of STVFB.
148	$p_{lwtvfb}=0 \ V/K$	Coefficient of the length times width dependence of STVFB.
149	$p_{otphib}=-0.00085 \ V/K$	Coefficient of the geometry independent part of STPHIB.
150	$p_{ltphib}=0 \ V/K$	Coefficient of the length dependence of STPHIB.
151	$p_{wtphib}=0 \ V/K$	Coefficient of the width dependence of STPHIB.
152	$p_{lwtphib}=0 \ V/K$	Coefficient of the length times width dependence of STPHIB.
153	$p_{otetabet}=1.3 (n) / 0.5 (p)$	Coefficient of the geometry independent part of ETABET.

Virtuoso Simulator Components and Device Models Reference

Philips Models

154	<code>pltetabet=0</code>	Coefficient of the length dependence of ETABET.
155	<code>pwtetabet=0</code>	Coefficient of the width dependence of ETABET.
156	<code>plwtetabet=0</code>	Coefficient of the length times width dependence of ETABET.
157	<code>potetasr=0.65 (n) / 0.5 (p)</code>	Coefficient of the geometry independent part of ETASR.
158	<code>pltetasr=0</code>	Coefficient of the length dependence of ETASR.
159	<code>pwtetasr=0</code>	Coefficient of the width dependence of ETASR.
160	<code>plwtetasr=0</code>	Coefficient of the length times width dependence of ETASR.
161	<code>potetaph=1.35 (n) / 3.75 (p)</code>	Coefficient of the geometry independent part of ETAPH.
162	<code>pltetaph=0</code>	Coefficient of the length dependence of ETAPH.
163	<code>pwtetaph=0</code>	Coefficient of the width dependence of ETAPH.
164	<code>plwtetaph=0</code>	Coefficient of the length times width dependence of ETAPH.
165	<code>potetamob=0 1/K</code>	Coefficient of the geometry independent part of STETAMOB.
166	<code>pltetamob=0 1/K</code>	Coefficient of the length dependence of STETAMOB.
167	<code>pwtetamob=0 1/K</code>	Coefficient of the width dependence of STETAMOB.
168	<code>plwtetamob=0 1/K</code>	Coefficient of the length times width dependence of STETAMOB.
169	<code>nu=2</code>	Exponent of field dependence of mobility model.
170	<code>potnuexp=5.25 (n) / 3.23 (p)</code>	Coefficient of the geometry independent part of NUEXP.
171	<code>pltnuexp=0</code>	Coefficient of the length dependence of NUEXP.
172	<code>pwtnuexp=0</code>	Coefficient of the width dependence of NUEXP.
173	<code>plwtnuexp=0</code>	Coefficient of the length times width dependence of NUEXP.

Virtuoso Simulator Components and Device Models Reference

Philips Models

174	$\text{potetar}=0.95(n)/0.4(p)$	Coefficient of the geometry independent part of ETAR.
175	$\text{pltetar}=0$	Coefficient of the length dependence of ETAR.
176	$\text{pwtetar}=0$	Coefficient of the width dependence of ETAR.
177	$\text{plwtetar}=0$	Coefficient of the length times width dependence of ETAR.
178	$\text{potetasat}=1.04(n)/0.86(p)$	Coefficient of the geometry independent part of ETASAT.
179	$\text{pltetasat}=0$	Coefficient of the length dependence of ETASAT.
180	$\text{pwtetasat}=0$	Coefficient of the width dependence of ETASAT.
181	$\text{plwtetasat}=0$	Coefficient of the length times width dependence of ETASAT.
182	$\text{pota1}=0 \text{ 1/K}$	Coefficient of the geometry independent part of STA1.
183	$\text{plta1}=0 \text{ 1/K}$	Coefficient of the length dependence of STA1.
184	$\text{pwta1}=0 \text{ 1/K}$	Coefficient of the width dependence of STA1.
185	$\text{plwta1}=0 \text{ 1/K}$	Coefficient of the length times width dependence of STA1.
186	$\text{potbgidl}=-0.000364 \text{ V/K}$	Coefficient of the geometry independent part of STBGIDL.
187	$\text{pltbgidl}=0 \text{ V/K}$	Coefficient of the length dependence of STBGIDL.
188	$\text{pwtbgidl}=0 \text{ V/K}$	Coefficient of the width dependence of STBGIDL.
189	$\text{plwtbgidl}=0 \text{ V/K}$	Coefficient of the length times width dependence of STBGIDL.
190	$\text{dta}=0 \text{ K}$	Temperature offset of the device.
191	$\text{rth}=300 \text{ K/W}$	Thermal resistance.
192	$\text{cth}=3e-09 \text{ J/K}$	Thermal capacitance.
193	$\text{ath}=0$	Temperature coefficient of the thermal resistance.

Virtuoso Simulator Components and Device Models Reference

Philips Models

194	<code>type=n</code>	Transistor gender. Possible values are n, p, npn, pnp, npnv, pnpv, npnl, or pnp1.
195	<code>imax=1.0 A</code>	Explosion current.
196	<code>tnom (C)</code>	alias of <code>tnom</code> .
197	<code>tref (C)</code>	alias of <code>tnom</code> .

Output Parameters

1	<code>vfb (V)</code>	Flat-band voltage at reference temperature.
2	<code>ko (\sqrt{V})</code>	Body-effect factor.
3	<code>kpinv ($1/\sqrt{V}$)</code>	Inverse of body-effect factor of the poly-silicon gate.
4	<code>phib (V)</code>	Surface potential at the onset of strong inversion.
5	<code>bet (A/V^2)</code>	Gain factor.
6	<code>thesr ($1/V$)</code>	Mobility degradation parameter due to surface roughness scattering.
7	<code>theph ($1/V$)</code>	Mobility degradation parameter due to phonon scattering.
8	<code>etamob</code>	Effective field parameter for dependence on depletion charge.
9	<code>nu</code>	Exponent of field dependence of mobility model.
10	<code>ther ($1/V$)</code>	Coefficient of series resistance.
11	<code>ther1 (V)</code>	Numerator of gate voltage dependent part of series resistance.
12	<code>ther2 (V)</code>	Denominator of gate voltage dependent part of series resistance.
13	<code>thesat ($1/V$)</code>	Velocity saturation parameter due to optical/acoustic phonon scattering.
14	<code>theth ($1/V^3$)</code>	Coefficient of self-heating.
15	<code>sdibl ($1/\sqrt{V}$)</code>	Drain-induced barrier lowering parameter.

Virtuoso Simulator Components and Device Models Reference

Philips Models

16	mo	Parameter for (short-channel) subthreshold slope.
17	ssf (1/ \sqrt{V})	Static-feedback parameter.
18	alp	Factor of channel length modulation.
19	vp (V)	Characteristic voltage of channel-length modulation.
20	mexp	Smoothing factor.
21	a1	Factor of the weak-avalanche current.
22	a2 (V)	Exponent of the weak-avalanche current.
23	a3	Factor of the drain-source voltage above which weak-avalanche occurs.
24	iginv (A/V ²)	Gain factor for intrinsic gate tunnelling current in inversion.
25	binv (V)	Probability factor for intrinsic gate tunnelling current in inversion.
26	igacc (A/V ²)	Gain factor for intrinsic gate tunnelling current in accumulation.
27	bacc (V)	Probability factor for intrinsic gate tunnelling current in accumulation.
28	vfbov (V)	Flat-band voltage for the Source/Drain overlap extensions.
29	kov (\sqrt{V})	Body-effect factor for the Source/Drain overlap extensions.
30	igov (A/V ²)	Gain factor for Source/Drain overlap tunnelling current.
31	agidl (A/V ³)	Gain factor for gate-induced leakage current.
32	bgidl (V)	Probability factor for gate-induced drain leakage current at reference temperature.
33	cgidl	Factor for the lateral field dependence of the gate-induced leakage current.
34	cox (F)	Oxide capacitance for the intrinsic channel (* mult).
35	cgdo (F)	Oxide capacitance for the gate-drain overlap (* mult).

Virtuoso Simulator Components and Device Models Reference

Philips Models

36	<code>cgso</code> (F)	Oxide capacitance for the gate-source overlap (* mult).
37	<code>gatenoise</code>	Flag for in/exclusion of induced gate thermal noise.
38	<code>nt</code> (J)	Thermal noise coefficient.
39	<code>nfa</code> ($1/(V_m^4)$)	First coefficient of the flicker noise.
40	<code>nfb</code> ($1/(V_m^2)$)	Second coefficient of the flicker noise.
41	<code>nfc</code> (1/V)	Third coefficient of the flicker noise.
42	<code>tox</code> (m)	Thickness of gate oxide layer.
43	<code>rth</code> (K/W)	Thermal resistance.
44	<code>cth</code> (J/K)	Thermal capacitance.

Operating-Point Parameters

1	<code>ids</code> (A)	Drain current, excl. avalanche and tunnel currents.
2	<code>iavl</code> (A)	Substrate current due to weak-avalanche.
3	<code>igs</code> (A)	Gate-to-source current due to direct tunnelling.
4	<code>igd</code> (A)	Gate-to-drain current due to direct tunnelling.
5	<code>igb</code> (A)	Gate-to-bulk current due to direct tunnelling.
6	<code>vds</code> (V)	Drain-source voltage.
7	<code>vgs</code> (V)	Gate-source voltage.
8	<code>vsb</code> (V)	Source-bulk voltage.
9	<code>vto</code> (V)	Zero-bias threshold voltage.
10	<code>vtb</code> (V)	Threshold voltage including back-bias effects.
11	<code>vth</code> (V)	Threshold voltage including back-bias and drain-bias effects.

Virtuoso Simulator Components and Device Models Reference

Philips Models

12	v_{gt} (V)	Effective gate drive voltage including back-bias and drain voltage effects.
13	v_{dss} (V)	Drain saturation voltage at actual bias.
14	v_{sat} (V)	Saturation limit.
15	g_m (A/V)	Transconductance ($d i_{ds} / d v_{gs}$).
16	g_{mb} (A/V)	Substrate-transconductance ($d i_{ds} / d v_{bs}$).
17	g_{ds} (A/V)	Output conductance ($d i_{ds} / d v_{ds}$).
18	c_{dd} (F)	Capacitance ($d q_d / d v_d$).
19	c_{dg} (F)	Capacitance ($- d q_d / d v_g$).
20	c_{ds} (F)	Capacitance ($- d q_d / d v_s$).
21	c_{db} (F)	Capacitance ($- d q_d / d v_b$).
22	c_{gd} (F)	Capacitance ($- d q_g / d v_d$).
23	c_{gg} (F)	Capacitance ($d q_g / d v_g$).
24	c_{gs} (F)	Capacitance ($- d q_g / d v_s$).
25	c_{gb} (F)	Capacitance ($- d q_g / d v_b$).
26	c_{sd} (F)	Capacitance ($- d q_s / d v_d$).
27	c_{sg} (F)	Capacitance ($- d q_s / d v_g$).
28	c_{ss} (F)	Capacitance ($d q_s / d v_s$).
29	c_{sb} (F)	Capacitance ($- d q_s / d v_b$).
30	c_{bd} (F)	Capacitance ($- d q_b / d v_d$).
31	c_{bg} (F)	Capacitance ($- d q_b / d v_g$).
32	c_{bs} (F)	Capacitance ($- d q_b / d v_s$).

Virtuoso Simulator Components and Device Models Reference

Philips Models

33	c_{bb} (F)	Capacitance ($d q_b / d v_b$).
34	c_{gdol} (F)	Gate-drain overlap capacitance of the actual transistor.
35	c_{gsol} (F)	Gate-source overlap capacitance of the actual transistor.
36	w_{eff} (m)	Effective channel width for geometrical models.
37	l_{eff} (m)	Effective channel length for geometrical models.
38	u	Transistor gain (g_m/g_{ds}).
39	r_{out} (Ω)	Small-signal output resistance ($1/g_{ds}$).
40	v_{early} (V)	Equivalent Early voltage ($ i_{dl} /g_{ds}$).
41	k_{eff} (\sqrt{V})	Body effect parameter.
42	b_{eff} (A/V^2)	Gain factor.
43	f_{ug} (Hz)	Unity gain frequency at actual bias ($g_m/(2*\pi*c_{in})$).
44	$sqrtsfw$ (V/\sqrt{Hz})	Input-referred RMS white noise voltage density.
45	$sqrtsff$ (V/\sqrt{Hz})	Input-referred RMS white noise voltage density at 1 kHz.
46	f_{knee} (Hz)	Cross-over frequency above which white noise is dominant.
47	p_{diss} (W)	Dissipation.
48	T_K (K)	Actual device temperature.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

Virtuoso Simulator Components and Device Models Reference

Philips Models

Pdiss	OP-47	nfb	O-40	plwssf	M-62	pwiginv	M-86
TK	OP-48	nfc	O-41	plwta1	M-185	pwigov	M-104
a1	O-21	nt	M-132	plwtbgidl	M-189	pwko	M-14
a2	O-22	nt	O-38	plwtetabet	M-156	pwmexp	M-70
a3	O-23	nu	M-169	plwtetamob	M-168	pwmo	M-57
agidl	O-31	nu	O-9	plwtetaph	M-164	pwnfa	M-135
alp	O-18	phib	O-4	plwtetar	M-177	pwnfb	M-139
area	I-6	pla1	M-73	plwtetasat	M-181	pwnfc	M-143
ath	M-193	pla2	M-77	plwtetasr	M-160	pwphib	M-19
bacc	O-27	pla3	M-81	plwtheph	M-32	pwsdibl	M-53
beff	OP-42	plagidl	M-107	plwther	M-40	pwssf	M-61
bet	O-5	plalp	M-64	plwthesat	M-46	pwtal	M-184
bgidl	O-32	plbacc	M-97	plwthesr	M-28	pwtbgidl	M-188
binv	O-25	plbet	M-22	plwtheth	M-50	pwtetabet	M-155
cbb	OP-33	plbgidl	M-111	plwtuexp	M-173	pwtetamob	M-167
cbd	OP-30	plbinv	M-89	plwtphib	M-152	pwtetaph	M-163
cbg	OP-31	plcgdo	M-124	plwtvfb	M-148	pwtetar	M-176
cbs	OP-32	plcgidl	M-115	poa1	M-72	pwtetasat	M-180
cdb	OP-21	plcgso	M-128	poa2	M-76	pwtetasr	M-159
cdd	OP-18	plcox	M-120	poa3	M-80	pwtheph	M-31

Virtuoso Simulator Components and Device Models Reference

Philips Models

cdg	OP-19	pletamob	M-34	poagidl	M-106	pwther	M-39
cds	OP-20	pligacc	M-93	poalp	M-63	pwthesat	M-45
cgb	OP-25	pliginv	M-85	pobacc	M-96	pwthesr	M-27
cgd	OP-22	pligov	M-103	pobet	M-21	pwtheth	M-49
cgdo	O-35	plko	M-13	pobgidl	M-110	pwtnuexp	M-172
cgdol	OP-34	plmexp	M-69	pobinv	M-88	pwtphib	M-151
cgg	OP-23	plmo	M-56	pocgdo	M-123	pwtvfb	M-147
cgidl	O-33	plnfa	M-134	pocgidl	M-114	region	I-4
cgs	OP-24	plnfb	M-138	pocgso	M-127	rout	OP-39
cgso	O-36	plnfc	M-142	pocox	M-119	rth	M-191
cgsol	OP-35	plphib	M-18	poetamob	M-33	rth	O-43
cox	O-34	plsdibl	M-52	poigacc	M-92	sdibl	O-15
csb	OP-29	plssf	M-60	poiginv	M-84	sqrtsff	OP-45
csd	OP-26	plta1	M-183	poigov	M-102	sqrtsfw	OP-44
csg	OP-27	pltbgidl	M-187	poko	M-12	ssf	O-17
css	OP-28	pltetabet	M-154	pomexp	M-68	theph	O-7
cth	M-192	pltetamob	M-166	pomo	M-55	ther	O-10
cth	O-44	pltetaph	M-162	ponfa	M-133	ther1	M-41
dta	M-190	pltetar	M-175	ponfb	M-137	ther1	O-11
etamob	O-8	pltetasat	M-179	ponfc	M-141	ther2	M-42
fknee	OP-46	pltetasr	M-158	pophib	M-17	ther2	O-12

Virtuoso Simulator Components and Device Models Reference

Philips Models

fug	OP-43	pltheph	M-30	posdibl	M-51	thesat	O-13
gatenoise	M-131	plther	M-38	possf	M-59	thesr	O-6
gatenoise	O-37	plthesat	M-44	potal	M-182	theth	O-14
gds	OP-17	plthesr	M-26	potbgidl	M-186	tnom	M-196
gm	OP-15	pltheth	M-48	potetabet	M-153	tox	M-118
gmb	OP-16	pltnuexp	M-171	potetamob	M-165	tox	O-42
iavl	OP-2	pltphib	M-150	potetaph	M-161	tr	M-6
ids	OP-1	pltvfb	M-146	potetar	M-174	tref	M-197
igacc	O-26	plwa1	M-75	potetasat	M-178	type	M-194
igb	OP-5	plwa2	M-79	potetasr	M-157	u	OP-38
igd	OP-4	plwa3	M-83	potheph	M-29	vds	OP-6
iginv	O-24	plwagidl	M-109	pother	M-37	vdss	OP-13
igov	O-30	plwalp	M-66	pothesat	M-43	vearly	OP-40
igs	OP-3	plwbacc	M-99	pothesr	M-25	vfb	M-11
imax	M-195	plwbet	M-24	potheth	M-47	vfb	O-1
keff	OP-41	plwbgidl	M-113	potnuexp	M-170	vfbov	M-100
ko	O-2	plwbinv	M-91	potphib	M-149	vfbov	O-28
kov	M-101	plwcgdo	M-126	potvfb	M-145	vgs	OP-7
kov	O-29	plwcgidl	M-117	pwa1	M-74	vgt	OP-12
kpinv	M-16	plwcgso	M-130	pwa2	M-78	vp	M-67
kpinv	O-3	plwcox	M-122	pwa3	M-82	vp	O-19

Virtuoso Simulator Components and Device Models Reference

Philips Models

l	I-1	plwetamob	M-36	pwagidl	M-108	vsat	OP-14
lap	M-3	plwigacc	M-95	pwalp	M-65	vsb	OP-8
leff	OP-37	plwiginv	M-87	pwbacc	M-98	vth	OP-11
level	M-1	plwigov	M-105	pwbet	M-23	vto	OP-9
lmax	M-8	plwko	M-15	pwbgidl	M-112	vts	OP-10
lmin	M-7	plwmexp	M-71	pwbinv	M-90	w	I-2
lvar	M-2	plwmo	M-58	pwcgdo	M-125	weff	OP-36
m	I-5	plwnfa	M-136	pwcgidl	M-116	wmax	M-10
mexp	O-20	plwnfb	M-140	pwcgso	M-129	wmin	M-9
mo	O-16	plwnfc	M-144	pwcox	M-121	wot	M-5
mult	I-3	plwphib	M-20	pwetamob	M-35	wvar	M-4
nfa	O-39	plwsdibl	M-54	pwigacc	M-94		

MOS Model 11, Level 1101 (mos1101e)

This is SimKit 4.0

This device is supported within altergroups.

This device is dynamically loaded from the shared object /vobs/spectre_dev/tools.lnx86/cmi/lib/5.0.doc/libphilips_sh.so

Instance Definition

Name d g s b ModelName parameter=value ...

Instance Parameters

1 mult=1 Number of devices in parallel.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 2 `region=triode` Estimated DC operating region, used as a convergence aid. Possible values are `off`, `triode`, `sat`, or `subth`.
- 3 `m=1` Multiplicity factor.
- 4 `area=1` alias of `mult`.

Model Definition

`model modelName mos1101e parameter=value ...`

Model Parameters

- 1 `level=1.1e+03` Transistor Level.
- 2 `tr=21 C` Reference temperature.
- 3 `vfb=-1.05 V` Flat-band voltage at reference temperature.
- 4 `stvfb=0.0005 V/K` Coefficient of temperature dependence of VFB.
- 5 `ko=0.5 \sqrt{V}` Body-effect factor.
- 6 `kpinv=0 $1/\sqrt{V}$` Inverse of body-effect factor of the poly-silicon gate.
- 7 `phib=0.95 V` Surface potential at the onset of strong inversion.
- 8 `stphib=-0.00085 V/K`
Coefficient of the temperature dependency of PHIB.
- 9 `bet=0.00192 (n) / 0.000381 (p) A/V^2`
Gain factor.
- 10 `etabet=1.3 (n) / 0.5 (p)`
Exponent of the temperature dependence of the gain factor.
- 11 `thesr=0.356 (n) / 0.73 (p) $1/V$`
Mobility degradation parameter due to surface roughness scattering.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 12 $etasr=0.65(n)/0.5(p)$
Exponent of the temperature dependence of THESR.
- 13 $theph=0.0129(n)/0.001(p) \ 1/V$
Mobility degradation parameter due to phonon scattering.
- 14 $etaph=1.35(n)/3.75(p)$
Exponent of the temperature dependence of THEPH.
- 15 $etamob=1.4(n)/3(p)$
Effective field parameter for dependence on depletion charge.
- 16 $stetamob=0 \ 1/K$
Coefficient of the temperature dependence of ETAMOB.
- 17 $nu=2$
Exponent of field dependence of mobility model.
- 18 $nuexp=5.25(n)/3.23(p)$
Exponent of the temperature dependence of parameter NU.
- 19 $ther=0.0812(n)/0.079(p) \ 1/V$
Coefficient of series resistance.
- 20 $etar=0.95(n)/0.4(p)$
Exponent of the temperature dependence of THER.
- 21 $ther1=0 \ V$
Numerator of gate voltage dependent part of series resistance.
- 22 $ther2=1 \ V$
Denominator of gate voltage dependent part of series resistance.
- 23 $thesat=0.251(n)/0.173(p) \ 1/V$
Velocity saturation parameter due to optical/acoustic phonon scattering.
- 24 $etasat=1.04(n)/0.86(p)$
Exponent of the temperature dependence of THESAT.
- 25 $theth=1e-05(n)/0(p) \ 1/V^3$
Coefficient of self-heating.
- 26 $sdibl=0.000853(n)/3.55e-05(p) \ 1/\sqrt{V}$
Drain-induced barrier lowering parameter.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 27 $m_0=0$ Parameter for (short-channel) subthreshold slope.
- 28 $ssf=0.012(n)/0.01(p) 1/\sqrt{V}$ Static-feedback parameter.
- 29 $alp=0.025$ Factor of channel length modulation.
- 30 $v_p=0.05 V$ Characteristic voltage of channel-length modulation.
- 31 $m_{exp}=5$ Smoothing factor.
- 32 $a1=6.02(n)/6.86(p)$ Factor of the weak-avalanche current.
- 33 $sta1=0 1/K$ Coefficient of the temperature dependence of A1.
- 34 $a2=38(n)/57.3(p) V$ Exponent of the weak-avalanche current.
- 35 $a3=0.641(n)/0.425(p)$ Factor of the drain-source voltage above which weak-avalanche occurs.
- 36 $ig_{inv}=0 A/V^2$ Gain factor for intrinsic gate tunnelling current in inversion.
- 37 $binv=48(n)/87.5(p) V$ Probability factor for intrinsic gate tunnelling current in inversion.
- 38 $ig_{acc}=0 A/V^2$ Gain factor for intrinsic gate tunnelling current in accumulation.
- 39 $b_{acc}=48 V$ Probability factor for intrinsic gate tunnelling current in accumulation.
- 40 $v_{fbov}=0 V$ Flat-band voltage for the Source/Drain overlap extensions.
- 41 $k_{ov}=2.5 \sqrt{V}$ Body-effect factor for the Source/Drain overlap extensions.
- 42 $ig_{ov}=0 A/V^2$ Gain factor for Source/Drain overlap tunnelling current.
- 43 $ag_{idl}=0 A/V^3$ Gain factor for gate-induced leakage current.
- 44 $bg_{idl}=41 V$ Probability factor for gate-induced drain leakage current at reference temperature.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 45 `stbgidl=-0.000364` V/K
Coefficient of the temperature dependence of BGIDL.
- 46 `cgidl=0`
Factor for the lateral field dependence of the gate-induced leakage current.
- 47 `cox=2.98e-14 (n) / 2.72e-14 (p)` F
Oxide capacitance for the intrinsic channel (* mult).
- 48 `cgdo=6.39e-15 (n) / 6.36e-15 (p)` F
Oxide capacitance for the gate-drain overlap (* mult).
- 49 `cgso=6.39e-15 (n) / 6.36e-15 (p)` F
Oxide capacitance for the gate-source overlap (* mult).
- 50 `gatenoise=0`
Flag for in/exclusion of induced gate thermal noise.
- 51 `nt=1.62e-20` J
Thermal noise coefficient.
- 52 `nfa=8.32e+22 (n) / 1.9e+22 (p)` $1 / (\text{Vm}^4)$
First coefficient of the flicker noise.
- 53 `nfb=2.51e+07 (n) / 5.04e+06 (p)` $1 / (\text{Vm}^2)$
Second coefficient of the flicker noise.
- 54 `nfc=0 (n) / 3.63e-10 (p)` $1 / \text{V}$
Third coefficient of the flicker noise.
- 55 `tox=3.2e-09` m
Thickness of gate oxide layer.
- 56 `dta=0` K
Temperature offset of the device.
- 57 `type=n`
Transistor gender.
Possible values are n, p, npn, pnp, npnv, pnpv, npnl, or pnp1.
- 58 `imax=1.0` A
Explosion current.
- 59 `tnom` (C)
alias of `tnom`.
- 60 `tref` (C)
alias of `tnom`.

Virtuoso Simulator Components and Device Models Reference

Philips Models

Output Parameters

1	v_{fb} (V)	Flat-band voltage at reference temperature.
2	k_o (\sqrt{V})	Body-effect factor.
3	k_{pinv} ($1/\sqrt{V}$)	Inverse of body-effect factor of the poly-silicon gate.
4	ϕ_{ib} (V)	Surface potential at the onset of strong inversion.
5	β_{et} (A/V^2)	Gain factor.
6	θ_{esr} ($1/V$)	Mobility degradation parameter due to surface roughness scattering.
7	θ_{eph} ($1/V$)	Mobility degradation parameter due to phonon scattering.
8	ϵ_{tamob}	Effective field parameter for dependence on depletion charge.
9	ν	Exponent of field dependence of mobility model.
10	θ_{er} ($1/V$)	Coefficient of series resistance.
11	θ_{er1} (V)	Numerator of gate voltage dependent part of series resistance.
12	θ_{er2} (V)	Denominator of gate voltage dependent part of series resistance.
13	θ_{esat} ($1/V$)	Velocity saturation parameter due to optical/acoustic phonon scattering.
14	θ_{eth} ($1/V^3$)	Coefficient of self-heating.
15	s_{dibl} ($1/\sqrt{V}$)	Drain-induced barrier lowering parameter.
16	m_o	Parameter for (short-channel) subthreshold slope.
17	s_{sf} ($1/\sqrt{V}$)	Static-feedback parameter.
18	α_p	Factor of channel length modulation.
19	v_p (V)	Characteristic voltage of channel-length modulation.

Virtuoso Simulator Components and Device Models Reference

Philips Models

20	mexp	Smoothing factor.
21	a1	Factor of the weak-avalanche current.
22	a2 (V)	Exponent of the weak-avalanche current.
23	a3	Factor of the drain-source voltage above which weak-avalanche occurs.
24	iginv (A/V ²)	Gain factor for intrinsic gate tunnelling current in inversion.
25	binv (V)	Probability factor for intrinsic gate tunnelling current in inversion.
26	igacc (A/V ²)	Gain factor for intrinsic gate tunnelling current in accumulation.
27	bacc (V)	Probability factor for intrinsic gate tunnelling current in accumulation.
28	vfbov (V)	Flat-band voltage for the Source/Drain overlap extensions.
29	kov (\sqrt{V})	Body-effect factor for the Source/Drain overlap extensions.
30	igov (A/V ²)	Gain factor for Source/Drain overlap tunnelling current.
31	agidl (A/V ³)	Gain factor for gate-induced leakage current.
32	bgidl (V)	Probability factor for gate-induced drain leakage current at reference temperature.
33	cgidl	Factor for the lateral field dependence of the gate-induced leakage current.
34	cox (F)	Oxide capacitance for the intrinsic channel (* mult).
35	cgdo (F)	Oxide capacitance for the gate-drain overlap (* mult).
36	cgso (F)	Oxide capacitance for the gate-source overlap (* mult).
37	gatenoise	Flag for in/exclusion of induced gate thermal noise.
38	nt (J)	Thermal noise coefficient.
39	nfa (1/(V _m ⁴))	First coefficient of the flicker noise.

Virtuoso Simulator Components and Device Models Reference

Philips Models

40	nfb ($1/(V_m^2)$)	Second coefficient of the flicker noise.
41	nfc ($1/V$)	Third coefficient of the flicker noise.
42	tox (m)	Thickness of gate oxide layer.

Operating-Point Parameters

1	ids (A)	Drain current, excl. avalanche and tunnel currents.
2	$iavl$ (A)	Substrate current due to weak-avalanche.
3	igs (A)	Gate-to-source current due to direct tunnelling.
4	igd (A)	Gate-to-drain current due to direct tunnelling.
5	igb (A)	Gate-to-bulk current due to direct tunnelling.
6	vds (V)	Drain-source voltage.
7	vgs (V)	Gate-source voltage.
8	vsb (V)	Source-bulk voltage.
9	vto (V)	Zero-bias threshold voltage.
10	vt_s (V)	Threshold voltage including back-bias effects.
11	vth (V)	Threshold voltage including back-bias and drain-bias effects.
12	vgt (V)	Effective gate drive voltage including back-bias and drain voltage effects.
13	$vdss$ (V)	Drain saturation voltage at actual bias.
14	$vsat$ (V)	Saturation limit.
15	gm (A/V)	Transconductance ($d\,ids / d\,vgs$).
16	gmb (A/V)	Substrate-transconductance ($d\,ids / d\,vbs$).
17	gds (A/V)	Output conductance ($d\,ids / d\,vds$).

Virtuoso Simulator Components and Device Models Reference

Philips Models

18	c_{dd} (F)	Capacitance ($d q_d / d v_d$).
19	c_{dg} (F)	Capacitance ($- d q_d / d v_g$).
20	c_{ds} (F)	Capacitance ($- d q_d / d v_s$).
21	c_{db} (F)	Capacitance ($- d q_d / d v_b$).
22	c_{gd} (F)	Capacitance ($- d q_g / d v_d$).
23	c_{gg} (F)	Capacitance ($d q_g / d v_g$).
24	c_{gs} (F)	Capacitance ($- d q_g / d v_s$).
25	c_{gb} (F)	Capacitance ($- d q_g / d v_b$).
26	c_{sd} (F)	Capacitance ($- d q_s / d v_d$).
27	c_{sg} (F)	Capacitance ($- d q_s / d v_g$).
28	c_{ss} (F)	Capacitance ($d q_s / d v_s$).
29	c_{sb} (F)	Capacitance ($- d q_s / d v_b$).
30	c_{bd} (F)	Capacitance ($- d q_b / d v_d$).
31	c_{bg} (F)	Capacitance ($- d q_b / d v_g$).
32	c_{bs} (F)	Capacitance ($- d q_b / d v_s$).
33	c_{bb} (F)	Capacitance ($d q_b / d v_b$).
34	c_{gdol} (F)	Gate-drain overlap capacitance of the actual transistor.
35	c_{gsol} (F)	Gate-source overlap capacitance of the actual transistor.
36	u	Transistor gain (g_m/g_{ds}).
37	r_{out} (Ω)	Small-signal output resistance ($1/g_{ds}$).
38	v_{early} (V)	Equivalent Early voltage ($ I_d /g_{ds}$).
39	k_{eff} (\sqrt{V})	Body effect parameter.

Virtuoso Simulator Components and Device Models Reference

Philips Models

40	b_{eff} (A/V ²)	Gain factor.
41	f_{ug} (Hz)	Unity gain frequency at actual bias ($g_m/(2\pi C_{in})$).
42	$sqrtsfw$ (V/ $\sqrt{\text{Hz}}$)	Input-referred RMS white noise voltage density.
43	$sqrtsff$ (V/ $\sqrt{\text{Hz}}$)	Input-referred RMS white noise voltage density at 1 kHz.
44	f_{knee} (Hz)	Cross-over frequency above which white noise is dominant.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

a1	M-32	cgso	O-36	kov	M-41	theph	O-7
a1	O-21	cgsol	OP-35	kov	O-29	ther	M-19
a2	M-34	cox	M-47	kpinv	M-6	ther	O-10
a2	O-22	cox	O-34	kpinv	O-3	ther1	M-21
a3	M-35	csb	OP-29	level	M-1	ther1	O-11
a3	O-23	csd	OP-26	m	I-3	ther2	M-22
agidl	M-43	csg	OP-27	mexp	M-31	ther2	O-12
agidl	O-31	css	OP-28	mexp	O-20	thesat	M-23
alp	M-29	dta	M-56	mo	M-27	thesat	O-13
alp	O-18	etabet	M-10	mo	O-16	thesr	M-11

Virtuoso Simulator Components and Device Models Reference

Philips Models

area	I-4	etamob	M-15	mult	I-1	thesr	O-6
bacc	M-39	etamob	O-8	nfa	M-52	theth	M-25
bacc	O-27	etaph	M-14	nfa	O-39	theth	O-14
beff	OP-40	etar	M-20	nfb	M-53	tnom	M-59
bet	M-9	etasat	M-24	nfb	O-40	tox	M-55
bet	O-5	etasr	M-12	nfc	M-54	tox	O-42
bgidl	M-44	fknee	OP-44	nfc	O-41	tr	M-2
bgidl	O-32	fug	OP-41	nt	M-51	tref	M-60
binv	M-37	gatenoise	M-50	nt	O-38	type	M-57
binv	O-25	gatenoise	O-37	nu	M-17	u	OP-36
cbb	OP-33	gds	OP-17	nu	O-9	vds	OP-6
cbd	OP-30	gm	OP-15	nuexp	M-18	vdss	OP-13
cbg	OP-31	gmb	OP-16	phib	M-7	vearly	OP-38
cbs	OP-32	iavl	OP-2	phib	O-4	vfb	M-3
cdb	OP-21	ids	OP-1	region	I-2	vfb	O-1
cdd	OP-18	igacc	M-38	rout	OP-37	vfbov	M-40
cdg	OP-19	igacc	O-26	sdibl	M-26	vfbov	O-28
cds	OP-20	igb	OP-5	sdibl	O-15	vgs	OP-7
cgb	OP-25	igd	OP-4	sqrtsff	OP-43	vgt	OP-12
cgd	OP-22	iginv	M-36	sqrtsfw	OP-42	vp	M-30
cgdo	M-48	iginv	O-24	ssf	M-28	vp	O-19

Virtuoso Simulator Components and Device Models Reference

Philips Models

cgdo	O-35	igov	M-42	ssf	O-17	vsat	OP-14
cgdol	OP-34	igov	O-30	stal	M-33	vsb	OP-8
cgg	OP-23	igs	OP-3	stbgidl	M-45	vth	OP-11
cgidl	M-46	imax	M-58	stetamob	M-16	vto	OP-9
cgidl	O-33	keff	OP-39	stphib	M-8	vts	OP-10
cgs	OP-24	ko	M-5	stvfb	M-4		
cgso	M-49	ko	O-2	theph	M-13		

MOS Model 11, Level 1101 (mos1101et)

This is SimKit 4.0

This device is supported within altergroups.

This device is dynamically loaded from the shared object /vobs/spectre_dev/tools.lnx86/cmi/lib/5.0.doc/libphilips_sh.so

Instance Definition

Name d g s b dt ModelName parameter=value ...

Instance Parameters

- | | | |
|---|---------------|---|
| 1 | mult=1 | Number of devices in parallel. |
| 2 | region=triode | Estimated DC operating region, used as a convergence aid. Possible values are off, triode, sat, or subth. |
| 3 | m=1 | Multiplicity factor. |
| 4 | area=1 | alias of mult. |

Virtuoso Simulator Components and Device Models Reference

Philips Models

Model Definition

```
model modelName mos1101et parameter=value ...
```

Model Parameters

- 1 `level=1.1e+03` Transistor Level.
- 2 `tr=21 C` Reference temperature.
- 3 `vfb=-1.05 V` Flat-band voltage at reference temperature.
- 4 `stvfb=0.0005 V/K` Coefficient of temperature dependence of VFB.
- 5 `ko=0.5 \sqrt{V}` Body-effect factor.
- 6 `kpinv=0 $1/\sqrt{V}$` Inverse of body-effect factor of the poly-silicon gate.
- 7 `phib=0.95 V` Surface potential at the onset of strong inversion.
- 8 `stphib=-0.00085 V/K`
Coefficient of the temperature dependency of PHIB.
- 9 `bet=0.00192 (n) / 0.000381 (p) A/V^2`
Gain factor.
- 10 `etabet=1.3 (n) / 0.5 (p)`
Exponent of the temperature dependence of the gain factor.
- 11 `thesr=0.356 (n) / 0.73 (p) $1/V$`
Mobility degradation parameter due to surface roughness scattering.
- 12 `etasr=0.65 (n) / 0.5 (p)`
Exponent of the temperature dependence of THESR.
- 13 `theph=0.0129 (n) / 0.001 (p) $1/V$`
Mobility degradation parameter due to phonon scattering.
- 14 `etaph=1.35 (n) / 3.75 (p)`
Exponent of the temperature dependence of THEPH.
- 15 `etamob=1.4 (n) / 3 (p)`
Effective field parameter for dependence on depletion charge.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 16 $stetamob=0 \text{ 1/K}$ Coefficient of the temperature dependence of ETAMOB.
- 17 $nu=2$ Exponent of field dependence of mobility model.
- 18 $nuexp=5.25(n)/3.23(p)$ Exponent of the temperature dependence of parameter NU.
- 19 $ther=0.0812(n)/0.079(p) \text{ 1/V}$ Coefficient of series resistance.
- 20 $etar=0.95(n)/0.4(p)$ Exponent of the temperature dependence of THER.
- 21 $ther1=0 \text{ V}$ Numerator of gate voltage dependent part of series resistance.
- 22 $ther2=1 \text{ V}$ Denominator of gate voltage dependent part of series resistance.
- 23 $thesat=0.251(n)/0.173(p) \text{ 1/V}$ Velocity saturation parameter due to optical/acoustic phonon scattering.
- 24 $etasat=1.04(n)/0.86(p)$ Exponent of the temperature dependence of THESAT.
- 25 $theth=1e-05(n)/0(p) \text{ 1/V}^3$ Coefficient of self-heating.
- 26 $sdibl=0.000853(n)/3.55e-05(p) \text{ 1/V}$ Drain-induced barrier lowering parameter.
- 27 $mo=0$ Parameter for (short-channel) subthreshold slope.
- 28 $ssf=0.012(n)/0.01(p) \text{ 1/V}$ Static-feedback parameter.
- 29 $alp=0.025$ Factor of channel length modulation.
- 30 $vp=0.05 \text{ V}$ Characteristic voltage of channel-length modulation.
- 31 $mexp=5$ Smoothing factor.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 32 $a1=6.02 (n) / 6.86 (p)$ Factor of the weak-avalanche current.
- 33 $sta1=0 \text{ } 1/K$ Coefficient of the temperature dependence of A1.
- 34 $a2=38 (n) / 57.3 (p) \text{ } V$ Exponent of the weak-avalanche current.
- 35 $a3=0.641 (n) / 0.425 (p)$ Factor of the drain-source voltage above which weak-avalanche occurs.
- 36 $iginv=0 \text{ } A/V^2$ Gain factor for intrinsic gate tunnelling current in inversion.
- 37 $binv=48 (n) / 87.5 (p) \text{ } V$ Probability factor for intrinsic gate tunnelling current in inversion.
- 38 $igacc=0 \text{ } A/V^2$ Gain factor for intrinsic gate tunnelling current in accumulation.
- 39 $bacc=48 \text{ } V$ Probability factor for intrinsic gate tunnelling current in accumulation.
- 40 $vfbov=0 \text{ } V$ Flat-band voltage for the Source/Drain overlap extensions.
- 41 $kov=2.5 \text{ } \sqrt{V}$ Body-effect factor for the Source/Drain overlap extensions.
- 42 $igov=0 \text{ } A/V^2$ Gain factor for Source/Drain overlap tunnelling current.
- 43 $agidl=0 \text{ } A/V^3$ Gain factor for gate-induced leakage current.
- 44 $bgidl=41 \text{ } V$ Probability factor for gate-induced drain leakage current at reference temperature.
- 45 $stbgidl=-0.000364 \text{ } V/K$ Coefficient of the temperature dependence of BGIDL.
- 46 $cgidl=0$ Factor for the lateral field dependence of the gate-induced leakage current.
- 47 $cox=2.98e-14 (n) / 2.72e-14 (p) \text{ } F$ Oxide capacitance for the intrinsic channel (* mult).

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 48 $cgdo=6.39e-15$ (n) / $6.36e-15$ (p) F
Oxide capacitance for the gate-drain overlap (* mult).
- 49 $cgso=6.39e-15$ (n) / $6.36e-15$ (p) F
Oxide capacitance for the gate-source overlap (* mult).
- 50 $gatenoise=0$
Flag for in/exclusion of induced gate thermal noise.
- 51 $nt=1.62e-20$ J
Thermal noise coefficient.
- 52 $nfa=8.32e+22$ (n) / $1.9e+22$ (p) $1/(V\text{m}^4)$
First coefficient of the flicker noise.
- 53 $nfb=2.51e+07$ (n) / $5.04e+06$ (p) $1/(V\text{m}^2)$
Second coefficient of the flicker noise.
- 54 $nfc=0$ (n) / $3.63e-10$ (p) $1/V$
Third coefficient of the flicker noise.
- 55 $tox=3.2e-09$ m
Thickness of gate oxide layer.
- 56 $dta=0$ K
Temperature offset of the device.
- 57 $rth=300$ K/W
Thermal resistance.
- 58 $cth=3e-09$ J/K
Thermal capacitance.
- 59 $ath=0$
Temperature coefficient of the thermal resistance.
- 60 $type=n$
Transistor gender.
Possible values are n, p, npn, pnp, npnv, pnpv, npnl, or pnp1.
- 61 $imax=1.0$ A
Explosion current.
- 62 $tnom$ (C)
alias of $tnom$.
- 63 $tref$ (C)
alias of $tnom$.

Output Parameters

- 1 vfb (V)
Flat-band voltage at reference temperature.
- 2 ko (\sqrt{V})
Body-effect factor.

Virtuoso Simulator Components and Device Models Reference

Philips Models

3	$kpinv$ ($1/\sqrt{V}$)	Inverse of body-effect factor of the poly-silicon gate.
4	$phib$ (V)	Surface potential at the onset of strong inversion.
5	bet (A/V^2)	Gain factor.
6	$thesr$ ($1/V$)	Mobility degradation parameter due to surface roughness scattering.
7	$theph$ ($1/V$)	Mobility degradation parameter due to phonon scattering.
8	$etamob$	Effective field parameter for dependence on depletion charge.
9	nu	Exponent of field dependence of mobility model.
10	$ther$ ($1/V$)	Coefficient of series resistance.
11	$ther1$ (V)	Numerator of gate voltage dependent part of series resistance.
12	$ther2$ (V)	Denominator of gate voltage dependent part of series resistance.
13	$thesat$ ($1/V$)	Velocity saturation parameter due to optical/acoustic phonon scattering.
14	$theth$ ($1/V^3$)	Coefficient of self-heating.
15	$sdibl$ ($1/\sqrt{V}$)	Drain-induced barrier lowering parameter.
16	mo	Parameter for (short-channel) subthreshold slope.
17	ssf ($1/\sqrt{V}$)	Static-feedback parameter.
18	alp	Factor of channel length modulation.
19	vp (V)	Characteristic voltage of channel-length modulation.
20	$mexp$	Smoothing factor.
21	$a1$	Factor of the weak-avalanche current.
22	$a2$ (V)	Exponent of the weak-avalanche current.

Virtuoso Simulator Components and Device Models Reference

Philips Models

23	a3	Factor of the drain-source voltage above which weak-avalanche occurs.
24	iginv (A/V ²)	Gain factor for intrinsic gate tunnelling current in inversion.
25	binv (V)	Probability factor for intrinsic gate tunnelling current in inversion.
26	igacc (A/V ²)	Gain factor for intrinsic gate tunnelling current in accumulation.
27	bacc (V)	Probability factor for intrinsic gate tunnelling current in accumulation.
28	vfbov (V)	Flat-band voltage for the Source/Drain overlap extensions.
29	kov (\sqrt{V})	Body-effect factor for the Source/Drain overlap extensions.
30	igov (A/V ²)	Gain factor for Source/Drain overlap tunnelling current.
31	agidl (A/V ³)	Gain factor for gate-induced leakage current.
32	bgidl (V)	Probability factor for gate-induced drain leakage current at reference temperature.
33	cgidl	Factor for the lateral field dependence of the gate-induced leakage current.
34	cox (F)	Oxide capacitance for the intrinsic channel (* mult).
35	cgdo (F)	Oxide capacitance for the gate-drain overlap (* mult).
36	cgso (F)	Oxide capacitance for the gate-source overlap (* mult).
37	gatenoise	Flag for in/exclusion of induced gate thermal noise.
38	nt (J)	Thermal noise coefficient.
39	nfa (1/(Vm ⁴))	First coefficient of the flicker noise.
40	nfb (1/(Vm ²))	Second coefficient of the flicker noise.
41	nfc (1/V)	Third coefficient of the flicker noise.
42	tox (m)	Thickness of gate oxide layer.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 43 r_{th} (K/W) Thermal resistance.
- 44 c_{th} (J/K) Thermal capacitance.

Operating-Point Parameters

- 1 i_{ds} (A) Drain current, excl. avalanche and tunnel currents.
- 2 i_{avl} (A) Substrate current due to weak-avalanche.
- 3 i_{gs} (A) Gate-to-source current due to direct tunnelling.
- 4 i_{gd} (A) Gate-to-drain current due to direct tunnelling.
- 5 i_{gb} (A) Gate-to-bulk current due to direct tunnelling.
- 6 v_{ds} (V) Drain-source voltage.
- 7 v_{gs} (V) Gate-source voltage.
- 8 v_{sb} (V) Source-bulk voltage.
- 9 v_{to} (V) Zero-bias threshold voltage.
- 10 v_{ts} (V) Threshold voltage including back-bias effects.
- 11 v_{th} (V) Threshold voltage including back-bias and drain-bias effects.
- 12 v_{gt} (V) Effective gate drive voltage including back-bias and drain voltage effects.
- 13 v_{dss} (V) Drain saturation voltage at actual bias.
- 14 v_{sat} (V) Saturation limit.
- 15 g_m (A/V) Transconductance ($d i_{ds} / d v_{gs}$).
- 16 g_{mb} (A/V) Substrate-transconductance ($d i_{ds} / d v_{sb}$).
- 17 g_{ds} (A/V) Output conductance ($d i_{ds} / d v_{ds}$).
- 18 c_{dd} (F) Capacitance ($d q_d / d v_d$).

Virtuoso Simulator Components and Device Models Reference

Philips Models

19	c_{dg} (F)	Capacitance (- d qd / d vg).
20	c_{ds} (F)	Capacitance (- d qd / d vs).
21	c_{db} (F)	Capacitance (- d qd / d vb).
22	c_{gd} (F)	Capacitance (- d qg / d vd).
23	c_{gg} (F)	Capacitance (d qg / d vg).
24	c_{gs} (F)	Capacitance (- d qg / d vs).
25	c_{gb} (F)	Capacitance (- d qg / d vb).
26	c_{sd} (F)	Capacitance (- d qs / d vd).
27	c_{sg} (F)	Capacitance (- d qs / d vg).
28	c_{ss} (F)	Capacitance (d qs / d vs).
29	c_{sb} (F)	Capacitance (- d qs / d vb).
30	c_{bd} (F)	Capacitance (- d qb / d vd).
31	c_{bg} (F)	Capacitance (- d qb / d vg).
32	c_{bs} (F)	Capacitance (- d qb / d vs).
33	c_{bb} (F)	Capacitance (d qb / d vb).
34	c_{gdol} (F)	Gate-drain overlap capacitance of the actual transistor.
35	c_{gsol} (F)	Gate-source overlap capacitance of the actual transistor.
36	u	Transistor gain (gm/gds).
37	r_{out} (Ω)	Small-signal output resistance (1/gds).
38	v_{early} (V)	Equivalent Early voltage (lidl/gds).
39	k_{eff} (\sqrt{V})	Body effect parameter.
40	b_{eff} (A/V ²)	Gain factor.

Virtuoso Simulator Components and Device Models Reference

Philips Models

41	fug (Hz)	Unity gain frequency at actual bias ($gm/(2*\pi*cin)$).
42	sqrtsfw (V/\sqrt{Hz})	Input-referred RMS white noise voltage density.
43	sqrtsff (V/\sqrt{Hz})	Input-referred RMS white noise voltage density at 1 kHz.
44	fknee (Hz)	Cross-over frequency above which white noise is dominant.
45	Pdiss (W)	Dissipation.
46	TK (K)	Actual device temperature.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

Pdiss	OP-45	cgso	M-49	ko	O-2	theph	M-13
TK	OP-46	cgso	O-36	kov	M-41	theph	O-7
a1	M-32	cgso1	OP-35	kov	O-29	ther	M-19
a1	O-21	cox	M-47	kpinv	M-6	ther	O-10
a2	M-34	cox	O-34	kpinv	O-3	ther1	M-21
a2	O-22	csb	OP-29	level	M-1	ther1	O-11
a3	M-35	csd	OP-26	m	I-3	ther2	M-22
a3	O-23	csg	OP-27	mexp	M-31	ther2	O-12
agidl	M-43	css	OP-28	mexp	O-20	thesat	M-23

Virtuoso Simulator Components and Device Models Reference

Philips Models

agidl O-31	cth M-58	mo M-27	thesat O-13
alp M-29	cth O-44	mo O-16	thesr M-11
alp O-18	dta M-56	mult I-1	thesr O-6
area I-4	etabet M-10	nfa M-52	theth M-25
ath M-59	etamob M-15	nfa O-39	theth O-14
bacc M-39	etamob O-8	nfb M-53	tnom M-62
bacc O-27	etaph M-14	nfb O-40	tox M-55
beff OP-40	etar M-20	nfc M-54	tox O-42
bet M-9	etasat M-24	nfc O-41	tr M-2
bet O-5	etasr M-12	nt M-51	tref M-63
bgidl M-44	fknee OP-44	nt O-38	type M-60
bgidl O-32	fug OP-41	nu M-17	u OP-36
binv M-37	gatenoise M-50	nu O-9	vds OP-6
binv O-25	gatenoise O-37	nuexp M-18	vdss OP-13
cbb OP-33	gds OP-17	phib M-7	vearly OP-38
cbd OP-30	gm OP-15	phib O-4	vfb M-3
cbg OP-31	gmb OP-16	region I-2	vfb O-1
cbs OP-32	iavl OP-2	rout OP-37	vfbov M-40
cdb OP-21	ids OP-1	rth M-57	vfbov O-28
cdd OP-18	igacc M-38	rth O-43	vgs OP-7
cdg OP-19	igacc O-26	sdibl M-26	vgt OP-12

Virtuoso Simulator Components and Device Models Reference

Philips Models

cds	OP-20	igb	OP-5	sdibl	O-15	vp	M-30
cgb	OP-25	igd	OP-4	sqrtsff	OP-43	vp	O-19
cgd	OP-22	iginv	M-36	sqrtsfw	OP-42	vsat	OP-14
cgdo	M-48	iginv	O-24	ssf	M-28	vsb	OP-8
cgdo	O-35	igov	M-42	ssf	O-17	vth	OP-11
cgdol	OP-34	igov	O-30	stal	M-33	vto	OP-9
cgg	OP-23	igs	OP-3	stbgidl	M-45	vts	OP-10
cgidl	M-46	imax	M-61	stetamob	M-16		
cgidl	O-33	keff	OP-39	stphib	M-8		
cgs	OP-24	ko	M-5	stvfb	M-4		

MOS Model 11, Level 1102 (mos11020)

This is SimKit 4.0

This device is supported within altergroups.

This device is dynamically loaded from the shared object /vobs/spectre_dev/tools.lnx86/cmi/lib/5.0.doc/libphilips_sh.so

Instance Definition

Name d g s b ModelName parameter=value ...

Instance Parameters

- 1 `l=2e-06 m` Drawn channel length in the layout. Scale set by option scale..
- 2 `w=1e-05 m` Drawn channel width in the layout. Scale set by option scale..
- 3 `mult=1` Number of devices in parallel.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- | | | |
|---|----------------------------|---|
| 4 | <code>region=triode</code> | Estimated DC operating region, used as a convergence aid. Possible values are <code>off</code> , <code>triode</code> , <code>sat</code> , or <code>subth</code> . |
| 5 | <code>m=1</code> | Multiplicity factor. |
| 6 | <code>area=1</code> | alias of <code>mult</code> . |

Model Definition

```
model modelName mos11020 parameter=value ...
```

Model Parameters

- | | | |
|----|--|--|
| 1 | <code>level=1.1e+04</code> | Transistor Level. |
| 2 | <code>lvar=0 m</code> | Difference between the actual and the programmed poly-silicon gate length. |
| 3 | <code>lap=4e-08 m</code> | Effective channel length reduction per side. |
| 4 | <code>wvar=0 m</code> | Difference between the actual and the programmed field-oxide opening. |
| 5 | <code>wot=0 m</code> | Effective channel width reduction per side. |
| 6 | <code>tr=21 C</code> | Reference temperature. |
| 7 | <code>vfb=-1.05 V</code> | Flat-band voltage at reference temperature. |
| 8 | <code>stvfb=0.0005 V/K</code> | Coefficient of temperature dependence of VFB. |
| 9 | <code>kor=0.5 \sqrt{V}</code> | Body effect coefficient for the reference transistor. |
| 10 | <code>s1ko=0</code> | Coefficient of the length dependence of KO. |
| 11 | <code>s12ko=0</code> | Second coefficient of the length dependence of KO. |
| 12 | <code>swko=0</code> | Coefficient of the width dependence of KO. |
| 13 | <code>kpinv=0 $1/\sqrt{V}$</code> | Inverse of body-effect factor of the poly-silicon gate. |
| 14 | <code>phibr=0.95 V</code> | Surface potential at strong inversion. |

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 15 $stphib=-0.00085 \text{ V/K}$ Coefficient of the temperature dependency of PHIB.
- 16 $slphib=0$ Coefficient of the length dependence of PHIB.
- 17 $sl2phib=0$ Second coefficient of the length dependence of PHIB.
- 18 $swphib=0$ Coefficient of the width dependence of PHIB.
- 19 $betsq=0.000371(n)/0.000115(p) \text{ A/V}^2$ Gain factor for an infinite square transistor.
- 20 $etabetr=1.3(n)/0.5(p)$ Exponent of the temperature dependence of the gain factor.
- 21 $sletabet=0$ Coefficient of length dependence of ETABETR.
- 22 $fbet1=0$ Relative mobility decrease due to first lateral profile.
- 23 $lp1=8e-07 \text{ m}$ Characteristic length of first lateral profile.
- 24 $fbet2=0$ Relative mobility decrease due to second lateral profile.
- 25 $lp2=8e-07 \text{ m}$ Characteristic length of second lateral profile.
- 26 $thesrr=0.4(n)/0.73(p) \text{ 1/V}$ Coefficient of the mobility reduction due to surface roughness scattering.
- 27 $etasr=0.65(n)/0.5(p)$ Exponent of the temperature dependence of THESR.
- 28 $swthesr=0$ Coefficient of the width dependence of THESR.
- 29 $thephr=0.0129(n)/0.001(p) \text{ 1/V}$ Coefficient of the mobility reduction due to phonon scattering.
- 30 $etaph=1.35(n)/3.75(p)$ Exponent of the temperature dependence of THEPH.
- 31 $swtheph=0$ Coefficient of the width dependence of THEPH.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 32 $etamobr=1.4(n)/3(p)$ Effective field parameter for dependence on depletion/inversion charge.
- 33 $stetamob=0\ 1/K$ Coefficient of the temperature dependence of ETAMOB.
- 34 $swetamob=0$ Coefficient of the width dependence of ETAMOB.
- 35 $nu=2$ Exponent of field dependence of mobility model.
- 36 $nuexp=5.25(n)/3.23(p)$ Exponent of the temperature dependence of parameter NU.
- 37 $therr=0.155(n)/0.08(p)\ 1/V$ Coefficient of the series resistance.
- 38 $etar=0.95(n)/0.4(p)$ Exponent of the temperature dependence of THER.
- 39 $swther=0$ Coefficient of the width dependence of THER.
- 40 $ther1=0\ V$ Numerator of gate voltage dependent part of series resistance.
- 41 $ther2=1\ V$ Denominator of gate voltage dependent part of series resistance.
- 42 $thesatr=0.5(n)/0.2(p)\ 1/V$ Velocity saturation parameter due to optical/acoustic phonon scattering.
- 43 $etasat=1.04(n)/0.86(p)$ Exponent of the temperature dependence of THESAT.
- 44 $slthesat=1$ Coefficient of length dependence of THESAT.
- 45 $thesatexp=1$ Exponent of length dependence of THESAT.
- 46 $swthesat=0$ Coefficient of the width dependence of THESAT.
- 47 $thethr=0.001(n)/0.0005(p)\ 1/V^3$ Coefficient of self-heating.
- 48 $thethexp=1$ Exponent of the length dependence of THETH.

Virtuoso Simulator Components and Device Models Reference

Philips Models

49	<code>swtheth=0</code>	Coefficient of the width dependence of THETH.
50	<code>sdiblo=0.0001</code> $1/\sqrt{V}$	Drain-induced barrier lowering parameter.
51	<code>sdiblexp=1.35</code>	Exponent of the length dependence of SDIBL.
52	<code>mo=0</code>	Parameter for short-channel subthreshold slope.
53	<code>mor=0</code>	Parameter for short-channel subthreshold slope per unit length.
54	<code>moexp=1.34</code>	Exponent of the length dependence of MO.
55	<code>ssfr=0.00625</code> $1/\sqrt{V}$	Static feedback parameter.
56	<code>slssf=1</code>	Coefficient of the length dependence of SSF.
57	<code>swssf=0</code>	Coefficient of the width dependence of SSF.
58	<code>alpr=0.01</code>	Factor of the channel length modulation.
59	<code>slalp=1</code>	Coefficient of the length dependence of ALP.
60	<code>alpexp=1</code>	Exponent of the length dependence of ALP.
61	<code>swalp=0</code>	Coefficient of the width dependence of ALP.
62	<code>vp=0.05</code> V	Characteristic voltage of channel-length modulation.
63	<code>lmin=1.5e-07</code> m	Minimum effective channel length in technology, used for calculation of smoothing factor m.
64	<code>a1r=6</code>	Factor of the weak-avalanche current.
65	<code>sta1=0</code> $1/K$	Coefficient of the temperature dependence of A1.
66	<code>sla1=0</code>	Coefficient of the length dependence of A1.
67	<code>swa1=0</code>	Coefficient of the width dependence of A1.
68	<code>a2r=38</code> V	Exponent of the weak-avalanche current.

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69	$s1a2=0$	Coefficient of the length dependence of A2.
70	$swa2=0$	Coefficient of the width dependence of A2.
71	$a3r=1$	Factor of the drain-source voltage above which weak-avalanche occurs.
72	$s1a3=0$	Coefficient of the length dependence of A3.
73	$swa3=0$	Coefficient of the width dependence of A3.
74	$iginvr=0 \text{ A/V}^2$	Gain factor for intrinsic gate tunnelling current in inversion.
75	$binv=48(n)/87.5(p) \text{ V}$	Probability factor for intrinsic gate tunnelling current in inversion.
76	$igaccr=0 \text{ A/V}^2$	Gain factor for intrinsic gate tunnelling current in accumulation.
77	$bacc=48 \text{ V}$	Probability factor for intrinsic gate tunnelling current in accumulation.
78	$vfbov=0 \text{ V}$	Flat-band voltage for the Source/Drain overlap extensions.
79	$kov=2.5 \sqrt{V}$	Body-effect factor for the Source/Drain overlap extensions.
80	$igovr=0 \text{ A/V}^2$	Gain factor for Source/Drain overlap gate tunnelling current.
81	$agidlr=0 \text{ A/V}^3$	Gain factor for gate-induced leakage current.
82	$bgidl=41 \text{ V}$	Probability factor for gate-induced drain leakage current at reference temperature.
83	$stbgidl=-0.000364 \text{ V/K}$	Coefficient of the temperature dependence of BGIDL.
84	$cgidl=0$	Factor for the lateral field dependence of the gate-induced leakage current.
85	$tox=3.2e-09 \text{ m}$	Thickness of gate oxide layer.
86	$col=3.2e-16 \text{ F}$	Gate overlap capacitance for a channel width of 1 μm .
87	$gatenoise=0$	Flag for in/exclusion of induced gate thermal noise.

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Philips Models

- 88 $n_t=1.62e-20$ J Thermal noise coefficient.
- 89 $n_{far}=1.57e+23$ (n) / $3.83e+24$ (p) $1/(V_m^4)$
First coefficient of the flicker noise for a channel area of $1 \mu m^2$.
- 90 $n_{fbr}=4.75e+09$ (n) / $1.02e+09$ (p) $1/(V_m^2)$
Second coefficient of the flicker noise for a channel area of $1 \mu m^2$.
- 91 $n_{fcr}=0$ (n) / $7.3e-08$ (p) $1/V$
Third coefficient of the flicker noise for a channel area of $1 \mu m^2$.
- 92 $dta=0$ K Temperature offset of the device.
- 93 $csr=0$ Factor of the Coulomb scattering.
- 94 $slcs=0$ Coefficient of the length dependence of CS.
- 95 $csexp=1$ Exponent of the length dependence of CS.
- 96 $swcs=0$ Coefficient of the width dependence of CS.
- 97 $etacs=0$ Exponent of the temperature dependence of CS.
- 98 $type=n$ Transistor gender.
Possible values are n, p, npn, pnp, npnv, pnpv, npnl, or pnp1.
- 99 $imax=1.0$ A Explosion current.
- 100 $mbeo=0.0$ DCmatch parameter.
- 101 $mvto=0.0$ DCmatch parameter.
- 102 t_{nom} (C) alias of t_{nom} .
- 103 t_{ref} (C) alias of t_{nom} .

Output Parameters

- 1 v_{fb} (V) Flat-band voltage at reference temperature.
- 2 k_o (\sqrt{V}) Body-effect factor.

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Philips Models

3	k_{pinv} ($1/\sqrt{V}$)	Inverse of body-effect factor of the poly-silicon gate.
4	ϕ_{ib} (V)	Surface potential at the onset of strong inversion.
5	β (A/V^2)	Gain factor.
6	θ_{sr} ($1/V$)	Mobility degradation parameter due to surface roughness scattering.
7	θ_{ph} ($1/V$)	Mobility degradation parameter due to phonon scattering.
8	ϵ_{amob}	Effective field parameter for dependence on depletion charge.
9	ν	Exponent of field dependence of mobility model.
10	c_s	Coefficient of Coulomb scattering.
11	θ_{er} ($1/V$)	Coefficient of series resistance.
12	θ_{er1} (V)	Numerator of gate voltage dependent part of series resistance.
13	θ_{er2} (V)	Denominator of gate voltage dependent part of series resistance.
14	θ_{sat} ($1/V$)	Velocity saturation parameter due to optical/acoustic phonon scattering.
15	θ_{eth} ($1/V^3$)	Coefficient of self-heating.
16	s_{dibl} ($1/\sqrt{V}$)	Drain-induced barrier lowering parameter.
17	m_o	Parameter for (short-channel) subthreshold slope.
18	s_{sf} ($1/\sqrt{V}$)	Static-feedback parameter.
19	α_p	Factor of channel length modulation.
20	v_p (V)	Characteristic voltage of channel-length modulation.
21	m_{exp}	Smoothing factor.
22	a_1	Factor of the weak-avalanche current.

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23	a2 (V)	Exponent of the weak-avalanche current.
24	a3	Factor of the drain-source voltage above which weak-avalanche occurs.
25	iginv (A/V ²)	Gain factor for intrinsic gate tunnelling current in inversion.
26	binv (V)	Probability factor for intrinsic gate tunnelling current in inversion.
27	igacc (A/V ²)	Gain factor for intrinsic gate tunnelling current in accumulation.
28	bacc (V)	Probability factor for intrinsic gate tunnelling current in accumulation.
29	vfbov (V)	Flat-band voltage for the Source/Drain overlap extensions.
30	kov (\sqrt{V})	Body-effect factor for the Source/Drain overlap extensions.
31	igov (A/V ²)	Gain factor for Source/Drain overlap tunnelling current.
32	agidl (A/V ³)	Gain factor for gate-induced leakage current.
33	bgidl (V)	Probability factor for gate-induced drain leakage current at reference temperature.
34	cgidl	Factor for the lateral field dependence of the gate-induced leakage current.
35	cox (F)	Oxide capacitance for the intrinsic channel (* mult).
36	cgdo (F)	Oxide capacitance for the gate-drain overlap (* mult).
37	cgso (F)	Oxide capacitance for the gate-source overlap (* mult).
38	gatenoise	Flag for in/exclusion of induced gate thermal noise.
39	nt (J)	Thermal noise coefficient.
40	nfa (1/(Vm ⁴))	First coefficient of the flicker noise.
41	nfb (1/(Vm ²))	Second coefficient of the flicker noise.
42	nfc (1/V)	Third coefficient of the flicker noise.

43 t_{ox} (m) Thickness of gate oxide layer.

Operating-Point Parameters

1	i_{ds} (A)	Drain current, excl. avalanche and tunnel currents.
2	i_{avl} (A)	Substrate current due to weak-avalanche.
3	i_{gs} (A)	Gate-to-source current due to direct tunnelling.
4	i_{gd} (A)	Gate-to-drain current due to direct tunnelling.
5	i_{gb} (A)	Gate-to-bulk current due to direct tunnelling.
6	v_{ds} (V)	Drain-source voltage.
7	v_{gs} (V)	Gate-source voltage.
8	v_{sb} (V)	Source-bulk voltage.
9	v_{to} (V)	Zero-bias threshold voltage.
10	v_{ts} (V)	Threshold voltage including back-bias effects.
11	v_{th} (V)	Threshold voltage including back-bias and drain-bias effects.
12	v_{gt} (V)	Effective gate drive voltage including back-bias and drain voltage effects.
13	v_{dss} (V)	Drain saturation voltage at actual bias.
14	v_{sat} (V)	Saturation limit.
15	g_m (A/V)	Transconductance ($d i_{ds} / d v_{gs}$).
16	g_{mb} (A/V)	Substrate-transconductance ($d i_{ds} / d v_{bs}$).
17	g_{ds} (A/V)	Output conductance ($d i_{ds} / d v_{ds}$).
18	c_{dd} (F)	Capacitance ($d q_d / d v_d$).
19	c_{dg} (F)	Capacitance ($- d q_d / d v_g$).

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20	c_{ds} (F)	Capacitance (- d qd / d vs).
21	c_{db} (F)	Capacitance (- d qd / d vb).
22	c_{gd} (F)	Capacitance (- d qg / d vd).
23	c_{gg} (F)	Capacitance (d qg / d vg).
24	c_{gs} (F)	Capacitance (- d qg / d vs).
25	c_{gb} (F)	Capacitance (- d qg / d vb).
26	c_{sd} (F)	Capacitance (- d qs / d vd).
27	c_{sg} (F)	Capacitance (- d qs / d vg).
28	c_{ss} (F)	Capacitance (d qs / d vs).
29	c_{sb} (F)	Capacitance (- d qs / d vb).
30	c_{bd} (F)	Capacitance (- d qb / d vd).
31	c_{bg} (F)	Capacitance (- d qb / d vg).
32	c_{bs} (F)	Capacitance (- d qb / d vs).
33	c_{bb} (F)	Capacitance (d qb / d vb).
34	c_{gdol} (F)	Gate-drain overlap capacitance of the actual transistor.
35	c_{gsol} (F)	Gate-source overlap capacitance of the actual transistor.
36	w_{eff} (m)	Effective channel width for geometrical models.
37	l_{eff} (m)	Effective channel length for geometrical models.
38	u	Transistor gain (gm/gds).
39	r_{out} (Ω)	Small-signal output resistance (1/gds).
40	v_{early} (V)	Equivalent Early voltage ($ idl /gds$).
41	k_{eff} (\sqrt{V})	Body effect parameter.

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Philips Models

42	$beff$ (A/V ²)	Gain factor.
43	fug (Hz)	Unity gain frequency at actual bias ($gm/(2*\pi*cin)$).
44	$sqrtsfw$ (V/ \sqrt{Hz})	Input-referred RMS white noise voltage density.
45	$sqrtsff$ (V/ \sqrt{Hz})	Input-referred RMS white noise voltage density at 1 kHz.
46	$fknee$ (Hz)	Cross-over frequency above which white noise is dominant.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

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$a2$	O-23	$etamobr$	M-32	nfa	O-40	$swthesat$	M-46
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Philips Models

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cgdol	OP-34	kov	O-30	sqrtsff	OP-45	vfb	O-1
cgg	OP-23	kpinv	M-13	sqrtsfw	OP-44	vfbov	M-78
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cgidl	O-34	l	I-1	ssfr	M-55	vgs	OP-7
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MOS Model 11, Level 1102 (mos11020t)

This is SimKit 4.0

This device is supported within altergroups.

This device is dynamically loaded from the shared object /vobs/spectre_dev/tools.lnx86/cmi/lib/5.0.doc/libphilips_sh.so

Instance Definition

```
Name d g s b dt ModelName parameter=value ...
```

Instance Parameters

1	<code>l=2e-06 m</code>	Drawn channel length in the layout. Scale set by option scale..
2	<code>w=1e-05 m</code>	Drawn channel width in the layout. Scale set by option scale..
3	<code>mult=1</code>	Number of devices in parallel.
4	<code>region=triode</code>	Estimated DC operating region, used as a convergence aid. Possible values are <code>off</code> , <code>triode</code> , <code>sat</code> , or <code>subth</code> .
5	<code>m=1</code>	Multiplicity factor.
6	<code>area=1</code>	alias of <code>mult</code> .

Model Definition

```
model modelName mos11020t parameter=value ...
```

Model Parameters

1	<code>level=1.1e+04</code>	Transistor Level.
2	<code>lvar=0 m</code>	Difference between the actual and the programmed poly-silicon gate length.
3	<code>lap=4e-08 m</code>	Effective channel length reduction per side.

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4	$wvar=0$ m	Difference between the actual and the programmed field-oxide opening.
5	$wot=0$ m	Effective channel width reduction per side.
6	$tr=21$ C	Reference temperature.
7	$vfb=-1.05$ V	Flat-band voltage at reference temperature.
8	$stvfb=0.0005$ V/K	Coefficient of temperature dependence of VFB.
9	$kor=0.5$ \sqrt{V}	Body effect coefficient for the reference transistor.
10	$slko=0$	Coefficient of the length dependence of KO.
11	$sl2ko=0$	Second coefficient of the length dependence of KO.
12	$swko=0$	Coefficient of the width dependence of KO.
13	$kpinv=0$ $1/\sqrt{V}$	Inverse of body-effect factor of the poly-silicon gate.
14	$phibr=0.95$ V	Surface potential at strong inversion.
15	$stphib=-0.00085$ V/K	Coefficient of the temperature dependency of PHIB.
16	$slphib=0$	Coefficient of the length dependence of PHIB.
17	$sl2phib=0$	Second coefficient of the length dependence of PHIB.
18	$swphib=0$	Coefficient of the width dependence of PHIB.
19	$betsq=0.000371(n)/0.000115(p)$ A/V ²	Gain factor for an infinite square transistor.
20	$etabetr=1.3(n)/0.5(p)$	Exponent of the temperature dependence of the gain factor.
21	$sletabet=0$	Coefficient of length dependence of ETABETR.
22	$fbet1=0$	Relative mobility decrease due to first lateral profile.
23	$lp1=8e-07$ m	Characteristic length of first lateral profile.

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Philips Models

- 24 $f_{bet2}=0$ Relative mobility decrease due to second lateral profile.
- 25 $l_{p2}=8e-07$ m Characteristic length of second lateral profile.
- 26 $t_{hesrr}=0.4$ (n) / 0.73 (p) $1/V$
Coefficient of the mobility reduction due to surface roughness scattering.
- 27 $e_{tasr}=0.65$ (n) / 0.5 (p)
Exponent of the temperature dependence of THESR.
- 28 $sw_{thesr}=0$ Coefficient of the width dependence of THESR.
- 29 $t_{hephr}=0.0129$ (n) / 0.001 (p) $1/V$
Coefficient of the mobility reduction due to phonon scattering.
- 30 $e_{taph}=1.35$ (n) / 3.75 (p)
Exponent of the temperature dependence of THEPH.
- 31 $sw_{theph}=0$ Coefficient of the width dependence of THEPH.
- 32 $e_{tamobr}=1.4$ (n) / 3 (p)
Effective field parameter for dependence on depletion/inversion charge.
- 33 $st_{etamob}=0$ $1/K$ Coefficient of the temperature dependence of ETAMOB.
- 34 $sw_{etamob}=0$ Coefficient of the width dependence of ETAMOB.
- 35 $\nu=2$ Exponent of field dependence of mobility model.
- 36 $\nu_{exp}=5.25$ (n) / 3.23 (p)
Exponent of the temperature dependence of parameter NU.
- 37 $t_{herr}=0.155$ (n) / 0.08 (p) $1/V$
Coefficient of the series resistance.
- 38 $e_{tar}=0.95$ (n) / 0.4 (p)
Exponent of the temperature dependence of THER.
- 39 $sw_{ther}=0$ Coefficient of the width dependence of THER.
- 40 $t_{her1}=0$ V Numerator of gate voltage dependent part of series resistance.

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Philips Models

41	<code>ther2=1 V</code>	Denominator of gate voltage dependent part of series resistance.
42	<code>thesatr=0.5(n)/0.2(p) 1/V</code>	Velocity saturation parameter due to optical/acoustic phonon scattering.
43	<code>etasat=1.04(n)/0.86(p)</code>	Exponent of the temperature dependence of THESAT.
44	<code>slthesat=1</code>	Coefficient of length dependence of THESAT.
45	<code>thesatexp=1</code>	Exponent of length dependence of THESAT.
46	<code>swthesat=0</code>	Coefficient of the width dependence of THESAT.
47	<code>thethr=0.001(n)/0.0005(p) 1/V³</code>	Coefficient of self-heating.
48	<code>thethexp=1</code>	Exponent of the length dependence of THETH.
49	<code>swtheth=0</code>	Coefficient of the width dependence of THETH.
50	<code>sdiblo=0.0001 1/√V</code>	Drain-induced barrier lowering parameter.
51	<code>sdiblexp=1.35</code>	Exponent of the length dependence of SDIBL.
52	<code>mo=0</code>	Parameter for short-channel subthreshold slope.
53	<code>mor=0</code>	Parameter for short-channel subthreshold slope per unit length.
54	<code>moexp=1.34</code>	Exponent of the length dependence of MO.
55	<code>ssfr=0.00625 1/√V</code>	Static feedback parameter.
56	<code>slssf=1</code>	Coefficient of the length dependence of SSF.
57	<code>swssf=0</code>	Coefficient of the width dependence of SSF.
58	<code>alpr=0.01</code>	Factor of the channel length modulation.

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Philips Models

59	<code>slalp=1</code>	Coefficient of the length dependence of ALP.
60	<code>alpexp=1</code>	Exponent of the length dependence of ALP.
61	<code>swalp=0</code>	Coefficient of the width dependence of ALP.
62	<code>vp=0.05 V</code>	Characteristic voltage of channel-length modulation.
63	<code>lmin=1.5e-07 m</code>	Minimum effective channel length in technology, used for calculation of smoothing factor m .
64	<code>a1r=6</code>	Factor of the weak-avalanche current.
65	<code>sta1=0 1/K</code>	Coefficient of the temperature dependence of A1.
66	<code>sla1=0</code>	Coefficient of the length dependence of A1.
67	<code>swa1=0</code>	Coefficient of the width dependence of A1.
68	<code>a2r=38 V</code>	Exponent of the weak-avalanche current.
69	<code>sla2=0</code>	Coefficient of the length dependence of A2.
70	<code>swa2=0</code>	Coefficient of the width dependence of A2.
71	<code>a3r=1</code>	Factor of the drain-source voltage above which weak-avalanche occurs.
72	<code>sla3=0</code>	Coefficient of the length dependence of A3.
73	<code>swa3=0</code>	Coefficient of the width dependence of A3.
74	<code>iginvr=0 A/V²</code>	Gain factor for intrinsic gate tunnelling current in inversion.
75	<code>binv=48(n)/87.5(p) V</code>	Probability factor for intrinsic gate tunnelling current in inversion.
76	<code>igaccr=0 A/V²</code>	Gain factor for intrinsic gate tunnelling current in accumulation.
77	<code>bacc=48 V</code>	Probability factor for intrinsic gate tunnelling current in accumulation.
78	<code>vfbov=0 V</code>	Flat-band voltage for the Source/Drain overlap extensions.

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Philips Models

79	$k_{ov}=2.5 \sqrt{V}$	Body-effect factor for the Source/Drain overlap extensions.
80	$igovr=0 \text{ A/V}^2$	Gain factor for Source/Drain overlap gate tunnelling current.
81	$agidlr=0 \text{ A/V}^3$	Gain factor for gate-induced leakage current.
82	$bgidl=41 \text{ V}$	Probability factor for gate-induced drain leakage current at reference temperature.
83	$stbgidl=-0.000364 \text{ V/K}$	Coefficient of the temperature dependence of BGIDL.
84	$cgidl=0$	Factor for the lateral field dependence of the gate-induced leakage current.
85	$tox=3.2e-09 \text{ m}$	Thickness of gate oxide layer.
86	$col=3.2e-16 \text{ F}$	Gate overlap capacitance for a channel width of 1 μm .
87	$gatenoise=0$	Flag for in/exclusion of induced gate thermal noise.
88	$nt=1.62e-20 \text{ J}$	Thermal noise coefficient.
89	$nfar=1.57e+23 \text{ (n)} / 3.83e+24 \text{ (p)} \text{ } 1 / (\text{Vm}^4)$	First coefficient of the flicker noise for a channel area of 1 μm^2 .
90	$nfbr=4.75e+09 \text{ (n)} / 1.02e+09 \text{ (p)} \text{ } 1 / (\text{Vm}^2)$	Second coefficient of the flicker noise for a channel area of 1 μm^2 .
91	$nfcr=0 \text{ (n)} / 7.3e-08 \text{ (p)} \text{ } 1 / \text{V}$	Third coefficient of the flicker noise for a channel area of 1 μm^2 .
92	$dta=0 \text{ K}$	Temperature offset of the device.
93	$csr=0$	Factor of the Coulomb scattering.
94	$slcs=0$	Coefficient of the length dependence of CS.
95	$csexp=1$	Exponent of the length dependence of CS.
96	$swcs=0$	Coefficient of the width dependence of CS.

Virtuoso Simulator Components and Device Models Reference

Philips Models

97	<code>etacs=0</code>	Exponent of the temperature dependence of CS.
98	<code>rth=300 K/W</code>	Thermal resistance.
99	<code>cth=3e-09 J/K</code>	Thermal capacitance.
100	<code>ath=0</code>	Temperature coefficient of the thermal resistance.
101	<code>type=n</code>	Transistor gender. Possible values are n, p, npn, pnp, npnv, pnpv, npnl, or pnp1.
102	<code>imax=1.0 A</code>	Explosion current.
103	<code>mbeo=0.0</code>	DCmatch parameter.
104	<code>mvto=0.0</code>	DCmatch parameter.
105	<code>tnom (C)</code>	alias of <code>tnom</code> .
106	<code>tref (C)</code>	alias of <code>tnom</code> .

Output Parameters

1	<code>vfb (V)</code>	Flat-band voltage at reference temperature.
2	<code>ko (\sqrt{V})</code>	Body-effect factor.
3	<code>kpinv ($1/\sqrt{V}$)</code>	Inverse of body-effect factor of the poly-silicon gate.
4	<code>phib (V)</code>	Surface potential at the onset of strong inversion.
5	<code>bet (A/V^2)</code>	Gain factor.
6	<code>thesr ($1/V$)</code>	Mobility degradation parameter due to surface roughness scattering.
7	<code>theph ($1/V$)</code>	Mobility degradation parameter due to phonon scattering.
8	<code>etamob</code>	Effective field parameter for dependence on depletion charge.
9	<code>nu</code>	Exponent of field dependence of mobility model.
10	<code>cs</code>	Coefficient of Coulomb scattering.

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Philips Models

11	ther (1/V)	Coefficient of series resistance.
12	ther1 (V)	Numerator of gate voltage dependent part of series resistance.
13	ther2 (V)	Denominator of gate voltage dependent part of series resistance.
14	thesat (1/V)	Velocity saturation parameter due to optical/acoustic phonon scattering.
15	theth (1/V ³)	Coefficient of self-heating.
16	sdibl (1/ \sqrt{V})	Drain-induced barrier lowering parameter.
17	mo	Parameter for (short-channel) subthreshold slope.
18	ssf (1/ \sqrt{V})	Static-feedback parameter.
19	alp	Factor of channel length modulation.
20	vp (V)	Characteristic voltage of channel-length modulation.
21	mexp	Smoothing factor.
22	a1	Factor of the weak-avalanche current.
23	a2 (V)	Exponent of the weak-avalanche current.
24	a3	Factor of the drain-source voltage above which weak-avalanche occurs.
25	iginv (A/V ²)	Gain factor for intrinsic gate tunnelling current in inversion.
26	binv (V)	Probability factor for intrinsic gate tunnelling current in inversion.
27	igacc (A/V ²)	Gain factor for intrinsic gate tunnelling current in accumulation.
28	bacc (V)	Probability factor for intrinsic gate tunnelling current in accumulation.
29	vfbov (V)	Flat-band voltage for the Source/Drain overlap extensions.
30	kov (\sqrt{V})	Body-effect factor for the Source/Drain overlap extensions.

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Philips Models

31	$igov$ (A/V ²)	Gain factor for Source/Drain overlap tunnelling current.
32	$agidl$ (A/V ³)	Gain factor for gate-induced leakage current.
33	$bgidl$ (V)	Probability factor for gate-induced drain leakage current at reference temperature.
34	$cgidl$	Factor for the lateral field dependence of the gate-induced leakage current.
35	cox (F)	Oxide capacitance for the intrinsic channel (* mult).
36	$cgdo$ (F)	Oxide capacitance for the gate-drain overlap (* mult).
37	$cgso$ (F)	Oxide capacitance for the gate-source overlap (* mult).
38	$gatenoise$	Flag for in/exclusion of induced gate thermal noise.
39	nt (J)	Thermal noise coefficient.
40	nfa (1/(Vm ⁴))	First coefficient of the flicker noise.
41	nfb (1/(Vm ²))	Second coefficient of the flicker noise.
42	nfc (1/V)	Third coefficient of the flicker noise.
43	tox (m)	Thickness of gate oxide layer.
44	rth (K/W)	Thermal resistance.
45	cth (J/K)	Thermal capacitance.

Operating-Point Parameters

1	ids (A)	Drain current, excl. avalanche and tunnel currents.
2	$iavl$ (A)	Substrate current due to weak-avalanche.
3	igs (A)	Gate-to-source current due to direct tunnelling.
4	igd (A)	Gate-to-drain current due to direct tunnelling.
5	igb (A)	Gate-to-bulk current due to direct tunnelling.

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Philips Models

6	v_{ds} (V)	Drain-source voltage.
7	v_{gs} (V)	Gate-source voltage.
8	v_{sb} (V)	Source-bulk voltage.
9	v_{to} (V)	Zero-bias threshold voltage.
10	v_{ts} (V)	Threshold voltage including back-bias effects.
11	v_{th} (V)	Threshold voltage including back-bias and drain-bias effects.
12	v_{gt} (V)	Effective gate drive voltage including back-bias and drain voltage effects.
13	v_{dss} (V)	Drain saturation voltage at actual bias.
14	v_{sat} (V)	Saturation limit.
15	g_m (A/V)	Transconductance ($d i_{ds} / d v_{gs}$).
16	g_{mb} (A/V)	Substrate-transconductance ($d i_{ds} / d v_{bs}$).
17	g_{ds} (A/V)	Output conductance ($d i_{ds} / d v_{ds}$).
18	c_{dd} (F)	Capacitance ($d q_d / d v_d$).
19	c_{dg} (F)	Capacitance ($- d q_d / d v_g$).
20	c_{ds} (F)	Capacitance ($- d q_d / d v_s$).
21	c_{db} (F)	Capacitance ($- d q_d / d v_b$).
22	c_{gd} (F)	Capacitance ($- d q_g / d v_d$).
23	c_{gg} (F)	Capacitance ($d q_g / d v_g$).
24	c_{gs} (F)	Capacitance ($- d q_g / d v_s$).
25	c_{gb} (F)	Capacitance ($- d q_g / d v_b$).
26	c_{sd} (F)	Capacitance ($- d q_s / d v_d$).

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Philips Models

27	c_{sg} (F)	Capacitance ($-d q_s / d v_g$).
28	c_{ss} (F)	Capacitance ($d q_s / d v_s$).
29	c_{sb} (F)	Capacitance ($-d q_s / d v_b$).
30	c_{bd} (F)	Capacitance ($-d q_b / d v_d$).
31	c_{bg} (F)	Capacitance ($-d q_b / d v_g$).
32	c_{bs} (F)	Capacitance ($-d q_b / d v_s$).
33	c_{bb} (F)	Capacitance ($d q_b / d v_b$).
34	c_{gdol} (F)	Gate-drain overlap capacitance of the actual transistor.
35	c_{gsol} (F)	Gate-source overlap capacitance of the actual transistor.
36	w_{eff} (m)	Effective channel width for geometrical models.
37	l_{eff} (m)	Effective channel length for geometrical models.
38	u	Transistor gain (g_m/g_{ds}).
39	r_{out} (Ω)	Small-signal output resistance ($1/g_{ds}$).
40	v_{early} (V)	Equivalent Early voltage ($ l_{id} /g_{ds}$).
41	k_{eff} (\sqrt{V})	Body effect parameter.
42	b_{eff} (A/V^2)	Gain factor.
43	f_{ug} (Hz)	Unity gain frequency at actual bias ($g_m/(2*\pi*c_{in})$).
44	$sqrtsfw$ (V/\sqrt{Hz})	Input-referred RMS white noise voltage density.
45	$sqrtsff$ (V/\sqrt{Hz})	Input-referred RMS white noise voltage density at 1 kHz.
46	f_{knee} (Hz)	Cross-over frequency above which white noise is dominant.
47	P_{diss} (W)	Dissipation.

Virtuoso Simulator Components and Device Models Reference

Philips Models

48 TK (K) Actual device temperature.

Parameter Index

In the following index, I refers to instance parameters, M refers to the model parameters section, O refers to the output parameters section, and OP refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of M-35 means the 35th model parameter.

Pdiss	OP-47	cth	O-45	mor	M-53	swssf	M-57
TK	OP-48	dta	M-92	mult	I-3	swtheph	M-31
a1	O-22	etabetr	M-20	mvto	M-104	swther	M-39
a1r	M-64	etacs	M-97	nfa	O-40	swthesat	M-46
a2	O-23	etamob	O-8	nfarc	M-89	swthesr	M-28
a2r	M-68	etamobr	M-32	nfb	O-41	swtheth	M-49
a3	O-24	etaph	M-30	nfbr	M-90	theph	O-7
a3r	M-71	etar	M-38	nfc	O-42	thephr	M-29
agidl	O-32	etasat	M-43	nfcrc	M-91	ther	O-11
agidlr	M-81	etasr	M-27	nt	M-88	ther1	M-40
alp	O-19	fbet1	M-22	nt	O-39	ther1	O-12
alpexp	M-60	fbet2	M-24	nu	M-35	ther2	M-41
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area	I-6	fug	OP-43	nuexp	M-36	therr	M-37
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Philips Models

bacc M-77	gatenoise O-38	phibr M-14	thesatexp M-45
bacc O-28	gds OP-17	region I-4	thesatr M-42
beff OP-42	gm OP-15	rout OP-39	thesr O-6
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bgidl M-82	ids OP-1	sdibl O-16	thethexp M-48
bgidl O-33	igacc O-27	sdiblexp M-51	thethr M-47
binv M-75	igaccr M-76	sdiblo M-50	tnom M-105
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cbb OP-33	igd OP-4	sl2phib M-17	tox O-43
cbd OP-30	iginv O-25	sla1 M-66	tr M-6
cbg OP-31	iginvr M-74	sla2 M-69	tref M-106
cbs OP-32	igov O-31	sla3 M-72	type M-101
cdb OP-21	igovr M-80	slalp M-59	u OP-38
cdd OP-18	igs OP-3	slcs M-94	vds OP-6
cdg OP-19	imax M-102	sletabet M-21	vdss OP-13
cds OP-20	keff OP-41	slko M-10	vearly OP-40
cgb OP-25	ko O-2	slphib M-16	vfb M-7
cgd OP-22	kor M-9	slssf M-56	vfb O-1
cgdo O-36	kov M-79	slthesat M-44	vfbov M-78
cgdol OP-34	kov O-30	sqrtsff OP-45	vfbov O-29

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Philips Models

cgg	OP-23	kpinv	M-13	sqrtsfw	OP-44	vgs	OP-7
cgidl	M-84	kpinv	O-3	ssf	O-18	vgt	OP-12
cgidl	O-34	l	I-1	ssfr	M-55	vp	M-62
cgs	OP-24	lap	M-3	sta1	M-65	vp	O-20
cgso	O-37	leff	OP-37	stbgidl	M-83	vsat	OP-14
cgsol	OP-35	level	M-1	stetamob	M-33	vsb	OP-8
col	M-86	lmin	M-63	stphib	M-15	vth	OP-11
cox	O-35	lp1	M-23	stvfb	M-8	vto	OP-9
cs	O-10	lp2	M-25	swa1	M-67	vts	OP-10
csb	OP-29	lvar	M-2	swa2	M-70	w	I-2
csd	OP-26	m	I-5	swa3	M-73	weff	OP-36
csexp	M-95	mbeo	M-103	swalp	M-61	wot	M-5
csg	OP-27	mexp	O-21	swcs	M-96	wvar	M-4
csr	M-93	mo	O-17	swetamob	M-34		
css	OP-28	moexp	M-54	swko	M-12		
cth	M-99	moo	M-52	swphib	M-18		

MOS Model 11, Level 1102 (mos11021)

This is SimKit 4.0

This device is supported within altergroups.

This device is dynamically loaded from the shared object /vobs/spectre_dev/tools.lnx86/cmi/lib/5.0.doc/libphilips_sh.so

Virtuoso Simulator Components and Device Models Reference

Philips Models

Instance Definition

Name d g s b ModelName parameter=value ...

Instance Parameters

- | | | |
|---|----------------------------|--|
| 1 | <code>l=2e-06 m</code> | Drawn channel length in the layout. Scale set by option scale.. |
| 2 | <code>w=1e-05 m</code> | Drawn channel width in the layout. Scale set by option scale.. |
| 3 | <code>mult=1</code> | Number of devices in parallel. |
| 4 | <code>region=triode</code> | Estimated DC operating region, used as a convergence aid.
Possible values are <code>off</code> , <code>triode</code> , <code>sat</code> , or <code>subth</code> . |
| 5 | <code>m=1</code> | Multiplicity factor. |
| 6 | <code>area=1</code> | alias of <code>mult</code> . |

Model Definition

model modelName mos11021 parameter=value ...

Model Parameters

- | | | |
|---|----------------------------|--|
| 1 | <code>level=1.1e+04</code> | Transistor Level. |
| 2 | <code>lvar=0 m</code> | Difference between the actual and the programmed poly-silicon gate length. |
| 3 | <code>lap=4e-08 m</code> | Effective channel length reduction per side. |
| 4 | <code>wvar=0 m</code> | Difference between the actual and the programmed field-oxide opening. |
| 5 | <code>wot=0 m</code> | Effective channel width reduction per side. |
| 6 | <code>tr=21 C</code> | Reference temperature. |
| 7 | <code>lmin=0 m</code> | Device length low limit for binning selection. |
| 8 | <code>lmax=1 m</code> | Device length high limit for binning selection. |

Virtuoso Simulator Components and Device Models Reference

Philips Models

9	$w_{min}=0$ m	Device width low limit for binning selection.
10	$w_{max}=1$ m	Device width high limit for binning selection.
11	$v_{fb}=-1.05$ V	Flat-band voltage at reference temperature.
12	$p_{oko}=0.5$ \sqrt{V}	Coefficient for the geometry independent part of KO.
13	$pl_{ko}=0$ \sqrt{V}	Coefficient for the length dependence of KO.
14	$pw_{ko}=0$ \sqrt{V}	Coefficient for the width dependence of KO.
15	$plw_{ko}=0$ \sqrt{V}	Coefficient for the length times width dependence of KO.
16	$kp_{inv}=0$ $1/\sqrt{V}$	Inverse of body-effect factor of the poly-silicon gate.
17	$p_{ophib}=0.95$ V	Coefficient for the geometric independent part of PHIB.
18	$pl_{phib}=0$ V	Coefficient for the length dependence of PHIB.
19	$pw_{phib}=0$ V	Coefficient for the width dependence of PHIB.
20	$plw_{phib}=0$ V	Coefficient for the length times width dependence of PHIB.
21	$p_{obet}=0.00192$ (n) / 0.000381 (p) A/V^2	Coefficient for the geometry independent part of BET.
22	$pl_{bet}=0$ A/V^2	Coefficient for the length dependence of BET.
23	$pw_{bet}=0$ A/V^2	Coefficient for the width dependence of BET.
24	$plw_{bet}=0$ A/V^2	Coefficient for the width over length dependence of BET.
25	$p_{othesr}=0.356$ (n) / 0.73 (p) $1/V$	Coefficient of the geometry independent part of THESR.
26	$pl_{thesr}=0$ $1/V$	Coefficient of the length dependence of THESR.
27	$pw_{thesr}=0$ $1/V$	Coefficient of the width dependence of THESR.
28	$plw_{thesr}=0$ $1/V$	Coefficient of the length times width dependence of THESR.

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Philips Models

- 29 $potheph=0.0129 (n) / 0.001 (p) \ 1/V$
Coefficient of the geometry independent part of THEPH.
- 30 $pltheph=0 \ 1/V$
Coefficient of the length dependence of THEPH.
- 31 $pwtheph=0 \ 1/V$
Coefficient of the width dependence of THEPH.
- 32 $plwtheph=0 \ 1/V$
Coefficient of the length times width dependence of THEPH.
- 33 $poetamob=1.4 (n) / 3 (p)$
Coefficient of the geometry independent part of ETAMOB.
- 34 $pletamob=0$
Coefficient of the length dependence of ETAMOB.
- 35 $pwetamob=0$
Coefficient of the width dependence of ETAMOB.
- 36 $plwetamob=0$
Coefficient of the length times width dependence of ETAMOB.
- 37 $pothether=0.0812 (n) / 0.079 (p) \ 1/V$
Coefficient of the geometry independent part of THER.
- 38 $plther=0 \ 1/V$
Coefficient of the length dependence of THER.
- 39 $pwther=0 \ 1/V$
Coefficient of the width dependence of THER.
- 40 $plwther=0 \ 1/V$
Coefficient of the length times width dependence of THER.
- 41 $ther1=0 \ V$
Numerator of gate voltage dependent part of series resistance.
- 42 $ther2=1 \ V$
Denominator of gate voltage dependent part of series resistance.
- 43 $pothesat=0.251 (n) / 0.173 (p) \ 1/V$
Coefficient of the geometry independent part of THESAT.
- 44 $plthesat=0 \ 1/V$
Coefficient of the length dependence of THESAT.
- 45 $pwthesat=0 \ 1/V$
Coefficient of the width dependence of THESAT.
- 46 $plwthesat=0 \ 1/V$
Coefficient of the length times width dependence of THESAT.
- 47 $potheth=1e-05 (n) / 0 (p) \ 1/V^3$
Coefficient of the geometry independent part of THETH.

Virtuoso Simulator Components and Device Models Reference

Philips Models

48	$pltheth=0 \ 1/V^3$	Coefficient of the length dependence of THETH.
49	$pwtheth=0 \ 1/V^3$	Coefficient of the width dependence of THETH.
50	$plwtheth=0 \ 1/V^3$	Coefficient of the length times width dependence of THETH.
51	$posdibl=0.000853(n)/3.55e-05(p) \ 1/\sqrt{V}$	Coefficient of the geometry independent part of SDIBL.
52	$plsdibl=0 \ 1/\sqrt{V}$	Coefficient of the length dependence of SDIBL.
53	$pwsdibl=0 \ 1/\sqrt{V}$	Coefficient of the width dependence of SDIBL.
54	$plwsdibl=0 \ 1/\sqrt{V}$	Coefficient of the length times width dependence of SDIBL.
55	$pomo=0$	Coefficient of the geometry independent part of MO.
56	$plmo=0$	Coefficient of the length dependence of MO.
57	$pwmo=0$	Coefficient of the width dependence of MO.
58	$plwmo=0$	Coefficient of the length times width dependence of MO.
59	$possf=0.012(n)/0.01(p) \ 1/\sqrt{V}$	Coefficient of the geometry independent part of SSF.
60	$plssf=0 \ 1/\sqrt{V}$	Coefficient of the length dependence of SSF.
61	$pwssf=0 \ 1/\sqrt{V}$	Coefficient of the width dependence of SSF.
62	$plwssf=0 \ 1/\sqrt{V}$	Coefficient of the length times width dependence of SSF.
63	$poalp=0.025$	Coefficient of the geometry independent part of ALP.
64	$plalp=0$	Coefficient of the length dependence of ALP.
65	$pwalp=0$	Coefficient of the width dependence of ALP.
66	$plwalp=0$	Coefficient of the length times width dependence of ALP.

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67	$v_p=0.05 \text{ V}$	Characteristic voltage of channel-length modulation.
68	$p_{omexp}=0.2$	Coefficient of the geometry independent part of MEXP.
69	$p_{lmexp}=0$	Coefficient of the length dependence of MEXP.
70	$p_{wmexp}=0$	Coefficient of the width dependence of MEXP.
71	$p_{lwmexp}=0$	Coefficient of the length times width dependence of MEXP.
72	$p_{oa1}=6.02 \text{ (n)} / 6.86 \text{ (p)}$	Coefficient of the geometry independent part of A1.
73	$p_{la1}=0$	Coefficient of the length dependence of A1.
74	$p_{wa1}=0$	Coefficient of the width dependence of A1.
75	$p_{lwa1}=0$	Coefficient of the length times width dependence of A1.
76	$p_{oa2}=38 \text{ (n)} / 57.3 \text{ (p)} \text{ V}$	Coefficient of the geometry independent part of A2.
77	$p_{la2}=0 \text{ V}$	Coefficient of the length dependence of A2.
78	$p_{wa2}=0 \text{ V}$	Coefficient of the width dependence of A2.
79	$p_{lwa2}=0 \text{ V}$	Coefficient of the length times width dependence of A2.
80	$p_{oa3}=0.641 \text{ (n)} / 0.425 \text{ (p)}$	Coefficient of the geometry independent part of A3.
81	$p_{la3}=0$	Coefficient of the length dependence of A3.
82	$p_{wa3}=0$	Coefficient of the width dependence of A3.
83	$p_{lwa3}=0$	Coefficient of the length times width dependence of A3.
84	$p_{oiginv}=0 \text{ A/V}^2$	Coefficient of the geometry independent part of IGINV.
85	$p_{liginv}=0 \text{ A/V}^2$	Coefficient of the length dependence of IGINV.
86	$p_{wiginv}=0 \text{ A/V}^2$	Coefficient of the width dependence of IGINV.

Virtuoso Simulator Components and Device Models Reference

Philips Models

87	$plwginv=0 \text{ A}/V^2$	Coefficient of the length times width dependence of IGINV.
88	$pobinv=48(n)/87.5(p) \text{ V}$	Coefficient of the geometry independent part of BINV.
89	$plbinv=0 \text{ V}$	Coefficient of the length dependence of BINV.
90	$pwbinv=0 \text{ V}$	Coefficient of the width dependence of BINV.
91	$plwbinv=0 \text{ V}$	Coefficient of the length times width dependence of BINV.
92	$poigacc=0 \text{ A}/V^2$	Coefficient of the geometry independent part of IGACC.
93	$pligacc=0 \text{ A}/V^2$	Coefficient of the length dependence of IGACC.
94	$pwigacc=0 \text{ A}/V^2$	Coefficient of the width dependence of IGACC.
95	$plwigacc=0 \text{ A}/V^2$	Coefficient of the length times width dependence of IGACC.
96	$pobacc=48 \text{ V}$	Coefficient of the geometry independent part of BACC.
97	$plbacc=0 \text{ V}$	Coefficient of the length dependence of BACC.
98	$pwbacc=0 \text{ V}$	Coefficient of the width dependence of BACC.
99	$plwbacc=0 \text{ V}$	Coefficient of the length times width dependence of BACC.
100	$vfbov=0 \text{ V}$	Flat-band voltage for the Source/Drain overlap extensions.
101	$kov=2.5 \sqrt{V}$	Body-effect factor for the Source/Drain overlap extensions.
102	$poigov=0 \text{ A}/V^2$	Coefficient of the geometry independent part of IGOV.
103	$pligov=0 \text{ A}/V^2$	Coefficient of the length dependence of IGOV.
104	$pwigov=0 \text{ A}/V^2$	Coefficient of the width dependence of IGOV.
105	$plwigov=0 \text{ A}/V^2$	Coefficient of the length times width dependence of IGOV.
106	$poagidl=0 \text{ A}/V^3$	Coefficient of the geometry independent part of AGIDL.
107	$plagidl=0 \text{ A}/V^3$	Coefficient of the length dependence of AGIDL.

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108	$pwagidl=0$	A/V^3	Coefficient of the width dependence of AGIDL.
109	$plwagidl=0$	A/V^3	Coefficient of the length times width dependence of AGIDL.
110	$pobgidl=41$	V	Coefficient of the geometry independent part of BGIDL.
111	$plbgidl=0$	V	Coefficient of the length dependence of BGIDL.
112	$pwbgidl=0$	V	Coefficient of the width dependence of BGIDL.
113	$plwbgidl=0$	V	Coefficient of the length times width dependence of BGIDL.
114	$pocgidl=0$		Coefficient of the geometry independent part of CGIDL.
115	$plcgidl=0$		Coefficient of the length dependence of CGIDL.
116	$pwcgidl=0$		Coefficient of the width dependence of CGIDL.
117	$plwcgidl=0$		Coefficient of the length times width dependence of CGIDL.
118	$tox=3.2e-09$	m	Thickness of gate oxide layer.
119	$pocox=2.98e-14$	$(n) / 2.72e-14 (p)$	F Coefficient of the geometry independent part of COX.
120	$plcox=0$	F	Coefficient of the length dependence of COX.
121	$pwcox=0$	F	Coefficient of the width dependence of COX.
122	$plwcox=0$	F	Coefficient of the length times width dependence of COX.
123	$pocgdo=6.39e-15$	$(n) / 6.36e-15 (p)$	F Coefficient of the geometry independent part of CGDO.
124	$plcgdo=0$	F	Coefficient of the length dependence of CGDO.
125	$pwcgdo=0$	F	Coefficient of the width dependence of CGDO.
126	$plwcgdo=0$	F	Coefficient of the length time width dependence of CGDO.
127	$pocgso=6.39e-15$	$(n) / 6.36e-15 (p)$	F Coefficient of the geometry independent part of CGSO.

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128	<code>plcgso=0</code>	F	Coefficient of the length dependence of CGSO.
129	<code>pwcgso=0</code>	F	Coefficient of the width dependence of CGSO.
130	<code>plwcgso=0</code>	F	Coefficient of the length times width dependence of CGSO.
131	<code>gatenoise=0</code>		Flag for in/exclusion of induced gate thermal noise.
132	<code>nt=1.62e-20</code>	J	Thermal noise coefficient.
133	<code>ponfa=8.32e+22</code>	(n) / 1.9e+22 (p)	$1/V \text{ m}^4$ Coefficient of the geometry independent part of NFA.
134	<code>plnfa=0</code>	$1/V \text{ m}^4$	Coefficient of the length dependence of NFA.
135	<code>pwnfa=0</code>	$1/V \text{ m}^4$	Coefficient of the width dependence of NFA.
136	<code>plwnfa=0</code>	$1/V \text{ m}^4$	Coefficient of the length times width dependence of NFA.
137	<code>ponfb=2.51e+07</code>	(n) / 5.04e+06 (p)	$1/V \text{ m}^2$ Coefficient of the geometry independent part of NFB.
138	<code>plnfb=0</code>	$1/V \text{ m}^2$	Coefficient of the length dependence of NFB.
139	<code>pwnfb=0</code>	$1/V \text{ m}^2$	Coefficient of the width dependence of NFB.
140	<code>plwnfb=0</code>	$1/V \text{ m}^2$	Coefficient of the length times width dependence of NFB.
141	<code>ponfc=0</code>	(n) / 3.63e-10 (p)	$1/V$ Coefficient of the geometry independent part of NFC.
142	<code>plnfc=0</code>	$1/V$	Coefficient of the length dependence of NFC.
143	<code>pwnfc=0</code>	$1/V$	Coefficient of the width dependence of NFC.
144	<code>plwnfc=0</code>	$1/V$	Coefficient of the length times width dependence of NFC.
145	<code>potvfb=0.0005</code>	V/K	Coefficient of the geometry independent part of STVFB.
146	<code>pltvfb=0</code>	V/K	Coefficient of the length dependence of STVFB.
147	<code>pwtvfb=0</code>	V/K	Coefficient of the width dependence of STVFB.

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148	$plwtvfb=0$	V/K	Coefficient of the length times width dependence of STVFB.
149	$potphib=-0.00085$	V/K	Coefficient of the geometry independent part of STPHIB.
150	$pltphib=0$	V/K	Coefficient of the length dependence of STPHIB.
151	$pwtphib=0$	V/K	Coefficient of the width dependence of STPHIB.
152	$plwtphib=0$	V/K	Coefficient of the length times width dependence of STPHIB.
153	$potetabet=1.3$	$(n) / 0.5$	(p) Coefficient of the geometry independent part of ETABET.
154	$pltetabet=0$		Coefficient of the length dependence of ETABET.
155	$pwtetabet=0$		Coefficient of the width dependence of ETABET.
156	$plwtetabet=0$		Coefficient of the length times width dependence of ETABET.
157	$potetasr=0.65$	$(n) / 0.5$	(p) Coefficient of the geometry independent part of ETASR.
158	$pltetasr=0$		Coefficient of the length dependence of ETASR.
159	$pwtetasr=0$		Coefficient of the width dependence of ETASR.
160	$plwtetasr=0$		Coefficient of the length times width dependence of ETASR.
161	$potetaph=1.35$	$(n) / 3.75$	(p) Coefficient of the geometry independent part of ETAPH.
162	$pltetaph=0$		Coefficient of the length dependence of ETAPH.
163	$pwtetaph=0$		Coefficient of the width dependence of ETAPH.
164	$plwtetaph=0$		Coefficient of the length times width dependence of ETAPH.
165	$potetamob=0$	1/K	Coefficient of the geometry independent part of STETAMOB.
166	$pltetamob=0$	1/K	Coefficient of the length dependence of STETAMOB.
167	$pwtetamob=0$	1/K	Coefficient of the width dependence of STETAMOB.

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Philips Models

168	$plwtetamob=0 \ 1/K$	Coefficient of the length times width dependence of STETAMOB.
169	$nu=2$	Exponent of field dependence of mobility model.
170	$potnuexp=5.25 \ (n) / 3.23 \ (p)$	Coefficient of the geometry independent part of NUEXP.
171	$pltnuexp=0$	Coefficient of the length dependence of NUEXP.
172	$pwtenuexp=0$	Coefficient of the width dependence of NUEXP.
173	$plwtenuexp=0$	Coefficient of the length times width dependence of NUEXP.
174	$potetar=0.95 \ (n) / 0.4 \ (p)$	Coefficient of the geometry independent part of ETAR.
175	$pltetar=0$	Coefficient of the length dependence of ETAR.
176	$pwtetar=0$	Coefficient of the width dependence of ETAR.
177	$plwtetar=0$	Coefficient of the length times width dependence of ETAR.
178	$potetasat=1.04 \ (n) / 0.86 \ (p)$	Coefficient of the geometry independent part of ETASAT.
179	$pltetasat=0$	Coefficient of the length dependence of ETASAT.
180	$pwtetasat=0$	Coefficient of the width dependence of ETASAT.
181	$plwtetasat=0$	Coefficient of the length times width dependence of ETASAT.
182	$potat1=0 \ 1/K$	Coefficient of the geometry independent part of STA1.
183	$pltat1=0 \ 1/K$	Coefficient of the length dependence of STA1.
184	$pwtat1=0 \ 1/K$	Coefficient of the width dependence of STA1.
185	$plwtat1=0 \ 1/K$	Coefficient of the length times width dependence of STA1.
186	$potbgidl=-0.000364 \ V/K$	Coefficient of the geometry independent part of STBGIDL.
187	$pltbgidl=0 \ V/K$	Coefficient of the length dependence of STBGIDL.

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Philips Models

188	<code>pwtbgidl=0</code>	V/K	Coefficient of the width dependence of STBGIDL.
189	<code>plwtbgidl=0</code>	V/K	Coefficient of the length times width dependence of STBGIDL.
190	<code>dta=0</code>	K	Temperature offset of the device.
191	<code>pocs=0</code>		Coefficient of the geometry independent part of CS.
192	<code>plcs=0</code>		Coefficient of the length dependence of CS.
193	<code>pwcs=0</code>		Coefficient of the width dependence of CS.
194	<code>plwcs=0</code>		Coefficient of the length times width dependence of CS.
195	<code>potetacs=0</code>		Coefficient of the geometry independent part of ETACS.
196	<code>pltetacs=0</code>		Coefficient of the length dependence of ETACS.
197	<code>pwtetacs=0</code>		Coefficient of the width dependence of ETACS.
198	<code>plwtetacs=0</code>		Coefficient of the length times width dependence of ETACS.
199	<code>type=n</code>		Transistor gender. Possible values are n, p, npn, pnp, npnv, pnpv, npnl, or pnp1.
200	<code>imax=1.0</code>	A	Explosion current.
201	<code>mbeo=0.0</code>		DCmatch parameter.
202	<code>mvto=0.0</code>		DCmatch parameter.
203	<code>tnom</code>	(C)	alias of <code>tnom</code> .
204	<code>tref</code>	(C)	alias of <code>tnom</code> .

Output Parameters

1	<code>vfb</code>	(V)	Flat-band voltage at reference temperature.
2	<code>ko</code>	(\sqrt{V})	Body-effect factor.
3	<code>kpinv</code>	($1/\sqrt{V}$)	Inverse of body-effect factor of the poly-silicon gate.

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Philips Models

4	phib (V)	Surface potential at the onset of strong inversion.
5	bet (A/V^2)	Gain factor.
6	thesr ($1/V$)	Mobility degradation parameter due to surface roughness scattering.
7	theph ($1/V$)	Mobility degradation parameter due to phonon scattering.
8	etamob	Effective field parameter for dependence on depletion charge.
9	nu	Exponent of field dependence of mobility model.
10	cs	Coefficient of Coulomb scattering.
11	ther ($1/V$)	Coefficient of series resistance.
12	ther1 (V)	Numerator of gate voltage dependent part of series resistance.
13	ther2 (V)	Denominator of gate voltage dependent part of series resistance.
14	thesat ($1/V$)	Velocity saturation parameter due to optical/acoustic phonon scattering.
15	theth ($1/V^3$)	Coefficient of self-heating.
16	sdibl ($1/\sqrt{V}$)	Drain-induced barrier lowering parameter.
17	mo	Parameter for (short-channel) subthreshold slope.
18	ssf ($1/\sqrt{V}$)	Static-feedback parameter.
19	alp	Factor of channel length modulation.
20	vp (V)	Characteristic voltage of channel-length modulation.
21	mexp	Smoothing factor.
22	a1	Factor of the weak-avalanche current.
23	a2 (V)	Exponent of the weak-avalanche current.

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24	a3	Factor of the drain-source voltage above which weak-avalanche occurs.
25	iginv (A/V ²)	Gain factor for intrinsic gate tunnelling current in inversion.
26	binv (V)	Probability factor for intrinsic gate tunnelling current in inversion.
27	igacc (A/V ²)	Gain factor for intrinsic gate tunnelling current in accumulation.
28	bacc (V)	Probability factor for intrinsic gate tunnelling current in accumulation.
29	vfbov (V)	Flat-band voltage for the Source/Drain overlap extensions.
30	kov (\sqrt{V})	Body-effect factor for the Source/Drain overlap extensions.
31	igov (A/V ²)	Gain factor for Source/Drain overlap tunnelling current.
32	agidl (A/V ³)	Gain factor for gate-induced leakage current.
33	bgidl (V)	Probability factor for gate-induced drain leakage current at reference temperature.
34	cgidl	Factor for the lateral field dependence of the gate-induced leakage current.
35	cox (F)	Oxide capacitance for the intrinsic channel (* mult).
36	cgdo (F)	Oxide capacitance for the gate-drain overlap (* mult).
37	cgso (F)	Oxide capacitance for the gate-source overlap (* mult).
38	gatenoise	Flag for in/exclusion of induced gate thermal noise.
39	nt (J)	Thermal noise coefficient.
40	nfa (1/(Vm ⁴))	First coefficient of the flicker noise.
41	nfb (1/(Vm ²))	Second coefficient of the flicker noise.
42	nfc (1/V)	Third coefficient of the flicker noise.
43	tox (m)	Thickness of gate oxide layer.

Operating-Point Parameters

1	i_{ds} (A)	Drain current, excl. avalanche and tunnel currents.
2	i_{avl} (A)	Substrate current due to weak-avalanche.
3	i_{gs} (A)	Gate-to-source current due to direct tunnelling.
4	i_{gd} (A)	Gate-to-drain current due to direct tunnelling.
5	i_{gb} (A)	Gate-to-bulk current due to direct tunnelling.
6	v_{ds} (V)	Drain-source voltage.
7	v_{gs} (V)	Gate-source voltage.
8	v_{sb} (V)	Source-bulk voltage.
9	v_{to} (V)	Zero-bias threshold voltage.
10	v_{ts} (V)	Threshold voltage including back-bias effects.
11	v_{th} (V)	Threshold voltage including back-bias and drain-bias effects.
12	v_{gt} (V)	Effective gate drive voltage including back-bias and drain voltage effects.
13	v_{dss} (V)	Drain saturation voltage at actual bias.
14	v_{sat} (V)	Saturation limit.
15	g_m (A/V)	Transconductance ($d i_{ds} / d v_{gs}$).
16	g_{mb} (A/V)	Substrate-transconductance ($d i_{ds} / d v_{sb}$).
17	g_{ds} (A/V)	Output conductance ($d i_{ds} / d v_{ds}$).
18	c_{dd} (F)	Capacitance ($d q_d / d v_d$).
19	c_{dg} (F)	Capacitance ($- d q_d / d v_g$).
20	c_{ds} (F)	Capacitance ($- d q_d / d v_s$).

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21	c_{db} (F)	Capacitance ($-d q_d / d v_b$).
22	c_{gd} (F)	Capacitance ($-d q_g / d v_d$).
23	c_{gg} (F)	Capacitance ($d q_g / d v_g$).
24	c_{gs} (F)	Capacitance ($-d q_g / d v_s$).
25	c_{gb} (F)	Capacitance ($-d q_g / d v_b$).
26	c_{sd} (F)	Capacitance ($-d q_s / d v_d$).
27	c_{sg} (F)	Capacitance ($-d q_s / d v_g$).
28	c_{ss} (F)	Capacitance ($d q_s / d v_s$).
29	c_{sb} (F)	Capacitance ($-d q_s / d v_b$).
30	c_{bd} (F)	Capacitance ($-d q_b / d v_d$).
31	c_{bg} (F)	Capacitance ($-d q_b / d v_g$).
32	c_{bs} (F)	Capacitance ($-d q_b / d v_s$).
33	c_{bb} (F)	Capacitance ($d q_b / d v_b$).
34	c_{gdol} (F)	Gate-drain overlap capacitance of the actual transistor.
35	c_{gsol} (F)	Gate-source overlap capacitance of the actual transistor.
36	w_{eff} (m)	Effective channel width for geometrical models.
37	l_{eff} (m)	Effective channel length for geometrical models.
38	u	Transistor gain (g_m/g_{ds}).
39	r_{out} (Ω)	Small-signal output resistance ($1/g_{ds}$).
40	v_{early} (V)	Equivalent Early voltage (l_{idl}/g_{ds}).
41	k_{eff} (\sqrt{V})	Body effect parameter.
42	b_{eff} (A/V^2)	Gain factor.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 43 `fug` (Hz) Unity gain frequency at actual bias ($gm/(2*\pi*cin)$).
- 44 `sqrtsw` (V/\sqrt{Hz}) Input-referred RMS white noise voltage density.
- 45 `sqrtfff` (V/\sqrt{Hz}) Input-referred RMS white noise voltage density at 1 kHz.
- 46 `fknee` (Hz) Cross-over frequency above which white noise is dominant.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

<code>a1</code>	O-22	<code>nt</code>	O-39	<code>plwta1</code>	M-185	<code>pwetamob</code>	M-35
<code>a2</code>	O-23	<code>nu</code>	M-169	<code>plwtbgidl</code>	M-189	<code>pwigacc</code>	M-94
<code>a3</code>	O-24	<code>nu</code>	O-9	<code>plwtetabet</code>	M-156	<code>pwiginv</code>	M-86
<code>agidl</code>	O-32	<code>phib</code>	O-4	<code>plwtetacs</code>	M-198	<code>pwigov</code>	M-104
<code>alp</code>	O-19	<code>pla1</code>	M-73	<code>plwtetamob</code>	M-168	<code>pwko</code>	M-14
<code>area</code>	I-6	<code>pla2</code>	M-77	<code>plwtetaph</code>	M-164	<code>pwmexp</code>	M-70
<code>bacc</code>	O-28	<code>pla3</code>	M-81	<code>plwtetar</code>	M-177	<code>pwm0</code>	M-57
<code>beff</code>	OP-42	<code>plagidl</code>	M-107	<code>plwtetasat</code>	M-181	<code>pwnfa</code>	M-135
<code>bet</code>	O-5	<code>plalp</code>	M-64	<code>plwtetasr</code>	M-160	<code>pwnfb</code>	M-139
<code>bgidl</code>	O-33	<code>plbacc</code>	M-97	<code>plwtheph</code>	M-32	<code>pwnfc</code>	M-143
<code>binv</code>	O-26	<code>plbet</code>	M-22	<code>plwther</code>	M-40	<code>pwphib</code>	M-19

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Philips Models

cbb	OP-33	plbgidl	M-111	plwthesat	M-46	pwsdibl	M-53
cbd	OP-30	plbinv	M-89	plwthesr	M-28	pwssf	M-61
cbg	OP-31	plcgdo	M-124	plwtheth	M-50	pwtal	M-184
cbs	OP-32	plcgidl	M-115	plwtnuexp	M-173	pwtbgidl	M-188
cdb	OP-21	plcgso	M-128	plwtphib	M-152	pwtetabet	M-155
cdd	OP-18	plcox	M-120	plwtvfb	M-148	pwtetacs	M-197
cdg	OP-19	plcs	M-192	poal	M-72	pwtetamob	M-167
cds	OP-20	pletamob	M-34	poa2	M-76	pwtetaph	M-163
cgb	OP-25	pligacc	M-93	poa3	M-80	pwtetar	M-176
cgd	OP-22	pliginv	M-85	poagidl	M-106	pwtetasat	M-180
cgdo	O-36	pligov	M-103	poalp	M-63	pwtetasr	M-159
cgdol	OP-34	plko	M-13	pobacc	M-96	pwtheph	M-31
cgg	OP-23	plmexp	M-69	pobet	M-21	pwthether	M-39
cgidl	O-34	plmo	M-56	pobgidl	M-110	pwthesat	M-45
cgs	OP-24	plnfa	M-134	pobinv	M-88	pwthesr	M-27
cgso	O-37	plnfb	M-138	pocgdo	M-123	pwtheth	M-49
cgsol	OP-35	plnfc	M-142	pocgidl	M-114	pwtnuexp	M-172
cox	O-35	plphib	M-18	pocgso	M-127	pwtphib	M-151
cs	O-10	plsdibl	M-52	pocox	M-119	pwtvfb	M-147
csb	OP-29	plssf	M-60	pocs	M-191	region	I-4
csd	OP-26	pltal	M-183	poetamob	M-33	rout	OP-39

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csg	OP-27	pltbgidl	M-187	poigacc	M-92	sdibl	O-16
css	OP-28	pltetabet	M-154	poiginv	M-84	sqrtsff	OP-45
dta	M-190	pltetacs	M-196	poigov	M-102	sqrtsfw	OP-44
etamob	O-8	pltetamob	M-166	poko	M-12	ssf	O-18
fknee	OP-46	pltetaph	M-162	pomexp	M-68	theph	O-7
fug	OP-43	pltetar	M-175	pomo	M-55	ther	O-11
gatenoise	M-131	pltetasat	M-179	ponfa	M-133	ther1	M-41
gatenoise	O-38	pltetasr	M-158	ponfb	M-137	ther1	O-12
gds	OP-17	pltheph	M-30	ponfc	M-141	ther2	M-42
gm	OP-15	plther	M-38	pophib	M-17	ther2	O-13
gmb	OP-16	plthesat	M-44	posdibl	M-51	thesat	O-14
iavl	OP-2	plthesr	M-26	possf	M-59	thesr	O-6
ids	OP-1	pltheth	M-48	potal	M-182	theth	O-15
igacc	O-27	pltnuexp	M-171	potbgidl	M-186	tnom	M-203
igb	OP-5	pltphib	M-150	potetabet	M-153	tox	M-118
igd	OP-4	pltvfb	M-146	potetacs	M-195	tox	O-43
iginv	O-25	plwa1	M-75	potetamob	M-165	tr	M-6
igov	O-31	plwa2	M-79	potetaph	M-161	tref	M-204
igs	OP-3	plwa3	M-83	potetar	M-174	type	M-199
imax	M-200	plwagidl	M-109	potetasat	M-178	u	OP-38
keff	OP-41	plwalp	M-66	potetasr	M-157	vds	OP-6

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Philips Models

ko	O-2	plwbacc	M-99	potheph	M-29	vdss	OP-13
kov	M-101	plwbet	M-24	pother	M-37	vearly	OP-40
kov	O-30	plwbgidl	M-113	pothesat	M-43	vfb	M-11
kpinv	M-16	plwbinv	M-91	pothesr	M-25	vfb	O-1
kpinv	O-3	plwcgdo	M-126	potheth	M-47	vfbov	M-100
l	I-1	plwcgidl	M-117	potnuexp	M-170	vfbov	O-29
lap	M-3	plwcgso	M-130	potphib	M-149	vgs	OP-7
leff	OP-37	plwcox	M-122	potvfb	M-145	vgt	OP-12
level	M-1	plwcs	M-194	pwa1	M-74	vp	M-67
lmax	M-8	plwetamob	M-36	pwa2	M-78	vp	O-20
lmin	M-7	plwigacc	M-95	pwa3	M-82	vsat	OP-14
lvar	M-2	plwiginv	M-87	pwagidl	M-108	vsb	OP-8
m	I-5	plwigov	M-105	pwalp	M-65	vth	OP-11
mbeo	M-201	plwko	M-15	pwbacc	M-98	vto	OP-9
mexp	O-21	plwmexp	M-71	pwbet	M-23	vts	OP-10
mo	O-17	plwmo	M-58	pwbgidl	M-112	w	I-2
mult	I-3	plwnfa	M-136	pwbinv	M-90	weff	OP-36
mvto	M-202	plwnfb	M-140	pwcgdo	M-125	wmax	M-10
nfa	O-40	plwnfc	M-144	pwcgidl	M-116	wmin	M-9
nfb	O-41	plwphib	M-20	pwcgso	M-129	wot	M-5
nfc	O-42	plwsdibl	M-54	pwcox	M-121	wvar	M-4

nt M-132 plwssf M-62 pwcs M-193

MOS Model 11, Level 1102 (mos11021t)

This is SimKit 4.0

This device is supported within altergroups.

This device is dynamically loaded from the shared object /vobs/spectre_dev/tools.lnx86/cmi/lib/5.0.doc/libphilips_sh.so

Instance Definition

Name d g s b dt modelName parameter=value ...

Instance Parameters

- | | | |
|---|----------------------------|--|
| 1 | <code>l=2e-06 m</code> | Drawn channel length in the layout. Scale set by option scale.. |
| 2 | <code>w=1e-05 m</code> | Drawn channel width in the layout. Scale set by option scale.. |
| 3 | <code>mult=1</code> | Number of devices in parallel. |
| 4 | <code>region=triode</code> | Estimated DC operating region, used as a convergence aid.
Possible values are <code>off</code> , <code>triode</code> , <code>sat</code> , or <code>subth</code> . |
| 5 | <code>m=1</code> | Multiplicity factor. |
| 6 | <code>area=1</code> | alias of <code>mult</code> . |

Model Definition

model modelName mos11021t parameter=value ...

Model Parameters

- | | | |
|---|----------------------------|-------------------|
| 1 | <code>level=1.1e+04</code> | Transistor Level. |
|---|----------------------------|-------------------|

Virtuoso Simulator Components and Device Models Reference

Philips Models

2	<code>lvar=0 m</code>	Difference between the actual and the programmed poly-silicon gate length.
3	<code>lap=4e-08 m</code>	Effective channel length reduction per side.
4	<code>wvar=0 m</code>	Difference between the actual and the programmed field-oxide opening.
5	<code>wot=0 m</code>	Effective channel width reduction per side.
6	<code>tr=21 C</code>	Reference temperature.
7	<code>lmin=0 m</code>	Device length low limit for binning selection.
8	<code>lmax=1 m</code>	Device length high limit for binning selection.
9	<code>wmin=0 m</code>	Device width low limit for binning selection.
10	<code>wmax=1 m</code>	Device width high limit for binning selection.
11	<code>vfb=-1.05 V</code>	Flat-band voltage at reference temperature.
12	<code>poko=0.5 \sqrt{V}</code>	Coefficient for the geometry independent part of KO.
13	<code>plko=0 \sqrt{V}</code>	Coefficient for the length dependence of KO.
14	<code>pwko=0 \sqrt{V}</code>	Coefficient for the width dependence of KO.
15	<code>plwko=0 \sqrt{V}</code>	Coefficient for the length times width dependence of KO.
16	<code>kpinv=0 $1/\sqrt{V}$</code>	Inverse of body-effect factor of the poly-silicon gate.
17	<code>pophib=0.95 V</code>	Coefficient for the geometric independent part of PHIB.
18	<code>plphib=0 V</code>	Coefficient for the length dependence of PHIB.
19	<code>pwphib=0 V</code>	Coefficient for the width dependence of PHIB.
20	<code>plwphib=0 V</code>	Coefficient for the length times width dependence of PHIB.
21	<code>pobet=0.00192 (n) / 0.000381 (p) A/V^2</code>	Coefficient for the geometry independent part of BET.

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22	$plbet=0 \ A/V^2$	Coefficient for the length dependence of BET.
23	$pwbet=0 \ A/V^2$	Coefficient for the width dependence of BET.
24	$plwbet=0 \ A/V^2$	Coefficient for the width over length dependence of BET.
25	$pothesr=0.356 (n) / 0.73 (p) \ 1/V$	Coefficient of the geometry independent part of THESR.
26	$plthesr=0 \ 1/V$	Coefficient of the length dependence of THESR.
27	$pwthesr=0 \ 1/V$	Coefficient of the width dependence of THESR.
28	$plwthesr=0 \ 1/V$	Coefficient of the length times width dependence of THESR.
29	$potheph=0.0129 (n) / 0.001 (p) \ 1/V$	Coefficient of the geometry independent part of THEPH.
30	$pltheph=0 \ 1/V$	Coefficient of the length dependence of THEPH.
31	$pwtheph=0 \ 1/V$	Coefficient of the width dependence of THEPH.
32	$plwtheph=0 \ 1/V$	Coefficient of the length times width dependence of THEPH.
33	$poetamob=1.4 (n) / 3 (p)$	Coefficient of the geometry independent part of ETAMOB.
34	$pletamob=0$	Coefficient of the length dependence of ETAMOB.
35	$pwetamob=0$	Coefficient of the width dependence of ETAMOB.
36	$plwetamob=0$	Coefficient of the length times width dependence of ETAMOB.
37	$pother=0.0812 (n) / 0.079 (p) \ 1/V$	Coefficient of the geometry independent part of THER.
38	$plther=0 \ 1/V$	Coefficient of the length dependence of THER.
39	$pwther=0 \ 1/V$	Coefficient of the width dependence of THER.
40	$plwther=0 \ 1/V$	Coefficient of the length times width dependence of THER.
41	$ther1=0 \ V$	Numerator of gate voltage dependent part of series resistance.

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- 42 $ther2=1 \text{ V}$ Denominator of gate voltage dependent part of series resistance.
- 43 $pothesat=0.251(n)/0.173(p) \text{ 1/V}$ Coefficient of the geometry independent part of THESAT.
- 44 $plthesat=0 \text{ 1/V}$ Coefficient of the length dependence of THESAT.
- 45 $pwthesat=0 \text{ 1/V}$ Coefficient of the width dependence of THESAT.
- 46 $plwthesat=0 \text{ 1/V}$ Coefficient of the length times width dependence of THESAT.
- 47 $potheth=1e-05(n)/0(p) \text{ 1/V}^3$ Coefficient of the geometry independent part of THETH.
- 48 $pltheth=0 \text{ 1/V}^3$ Coefficient of the length dependence of THETH.
- 49 $pwtheth=0 \text{ 1/V}^3$ Coefficient of the width dependence of THETH.
- 50 $plwtheth=0 \text{ 1/V}^3$ Coefficient of the length times width dependence of THETH.
- 51 $posdibl=0.000853(n)/3.55e-05(p) \text{ 1/\sqrt{V}}$ Coefficient of the geometry independent part of SDIBL.
- 52 $plsdibl=0 \text{ 1/\sqrt{V}}$ Coefficient of the length dependence of SDIBL.
- 53 $pwsdibl=0 \text{ 1/\sqrt{V}}$ Coefficient of the width dependence of SDIBL.
- 54 $plwsdibl=0 \text{ 1/\sqrt{V}}$ Coefficient of the length times width dependence of SDIBL.
- 55 $pomo=0$ Coefficient of the geometry independent part of MO.
- 56 $plmo=0$ Coefficient of the length dependence of MO.
- 57 $pwmo=0$ Coefficient of the width dependence of MO.
- 58 $plwmo=0$ Coefficient of the length times width dependence of MO.
- 59 $possf=0.012(n)/0.01(p) \text{ 1/\sqrt{V}}$ Coefficient of the geometry independent part of SSF.

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60	$p_{lssf}=0 \ 1/\sqrt{V}$	Coefficient of the length dependence of SSF.
61	$p_{wssf}=0 \ 1/\sqrt{V}$	Coefficient of the width dependence of SSF.
62	$p_{lwssf}=0 \ 1/\sqrt{V}$	Coefficient of the length times width dependence of SSF.
63	$p_{oa1p}=0.025$	Coefficient of the geometry independent part of ALP.
64	$p_{la1p}=0$	Coefficient of the length dependence of ALP.
65	$p_{wa1p}=0$	Coefficient of the width dependence of ALP.
66	$p_{lwa1p}=0$	Coefficient of the length times width dependence of ALP.
67	$v_p=0.05 \ V$	Characteristic voltage of channel-length modulation.
68	$p_{omexp}=0.2$	Coefficient of the geometry independent part of MEXP.
69	$p_{lmexp}=0$	Coefficient of the length dependence of MEXP.
70	$p_{wmexp}=0$	Coefficient of the width dependence of MEXP.
71	$p_{lwmexp}=0$	Coefficient of the length times width dependence of MEXP.
72	$p_{oa1}=6.02 (n) / 6.86 (p)$	Coefficient of the geometry independent part of A1.
73	$p_{la1}=0$	Coefficient of the length dependence of A1.
74	$p_{wa1}=0$	Coefficient of the width dependence of A1.
75	$p_{lwa1}=0$	Coefficient of the length times width dependence of A1.
76	$p_{oa2}=38 (n) / 57.3 (p) \ V$	Coefficient of the geometry independent part of A2.
77	$p_{la2}=0 \ V$	Coefficient of the length dependence of A2.
78	$p_{wa2}=0 \ V$	Coefficient of the width dependence of A2.
79	$p_{lwa2}=0 \ V$	Coefficient of the length times width dependence of A2.

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80	$poa3=0.641(n)/0.425(p)$	Coefficient of the geometry independent part of A3.
81	$pla3=0$	Coefficient of the length dependence of A3.
82	$pwa3=0$	Coefficient of the width dependence of A3.
83	$plwa3=0$	Coefficient of the length times width dependence of A3.
84	$poiginv=0 A/V^2$	Coefficient of the geometry independent part of IGINV.
85	$pliginv=0 A/V^2$	Coefficient of the length dependence of IGINV.
86	$pwiginv=0 A/V^2$	Coefficient of the width dependence of IGINV.
87	$plwiginv=0 A/V^2$	Coefficient of the length times width dependence of IGINV.
88	$pobinv=48(n)/87.5(p) V$	Coefficient of the geometry independent part of BINV.
89	$plbinv=0 V$	Coefficient of the length dependence of BINV.
90	$pwbinv=0 V$	Coefficient of the width dependence of BINV.
91	$plwbinv=0 V$	Coefficient of the length times width dependence of BINV.
92	$poigacc=0 A/V^2$	Coefficient of the geometry independent part of IGACC.
93	$pligacc=0 A/V^2$	Coefficient of the length dependence of IGACC.
94	$pwigacc=0 A/V^2$	Coefficient of the width dependence of IGACC.
95	$plwigacc=0 A/V^2$	Coefficient of the length times width dependence of IGACC.
96	$pobacc=48 V$	Coefficient of the geometry independent part of BACC.
97	$plbacc=0 V$	Coefficient of the length dependence of BACC.
98	$pwbacc=0 V$	Coefficient of the width dependence of BACC.
99	$plwbacc=0 V$	Coefficient of the length times width dependence of BACC.
100	$vfbov=0 V$	Flat-band voltage for the Source/Drain overlap extensions.

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101	$k_{ov}=2.5 \sqrt{V}$	Body-effect factor for the Source/Drain overlap extensions.
102	$p_{oigov}=0 \ A/V^2$	Coefficient of the geometry independent part of IGOV.
103	$p_{ligov}=0 \ A/V^2$	Coefficient of the length dependence of IGOV.
104	$p_{wigov}=0 \ A/V^2$	Coefficient of the width dependence of IGOV.
105	$p_{lwigov}=0 \ A/V^2$	Coefficient of the length times width dependence of IGOV.
106	$p_{oagidl}=0 \ A/V^3$	Coefficient of the geometry independent part of AGIDL.
107	$p_{lagidl}=0 \ A/V^3$	Coefficient of the length dependence of AGIDL.
108	$p_{wagidl}=0 \ A/V^3$	Coefficient of the width dependence of AGIDL.
109	$p_{lwagidl}=0 \ A/V^3$	Coefficient of the length times width dependence of AGIDL.
110	$p_{obgidl}=41 \ V$	Coefficient of the geometry independent part of BGIDL.
111	$p_{lbgidl}=0 \ V$	Coefficient of the length dependence of BGIDL.
112	$p_{wbgidl}=0 \ V$	Coefficient of the width dependence of BGIDL.
113	$p_{lwbgidl}=0 \ V$	Coefficient of the length times width dependence of BGIDL.
114	$p_{ocgidl}=0$	Coefficient of the geometry independent part of CGIDL.
115	$p_{lccgidl}=0$	Coefficient of the length dependence of CGIDL.
116	$p_{wccgidl}=0$	Coefficient of the width dependence of CGIDL.
117	$p_{lwcgidl}=0$	Coefficient of the length times width dependence of CGIDL.
118	$t_{ox}=3.2e-09 \ m$	Thickness of gate oxide layer.
119	$p_{ocox}=2.98e-14 \ (n) / 2.72e-14 \ (p) \ F$	Coefficient of the geometry independent part of COX.
120	$p_{lcox}=0 \ F$	Coefficient of the length dependence of COX.
121	$p_{wcox}=0 \ F$	Coefficient of the width dependence of COX.

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122	$p_{lwcox}=0$	F	Coefficient of the length times width dependence of COX.
123	$p_{ocgdo}=6.39e-15$	$(n)/6.36e-15$	F Coefficient of the geometry independent part of CGDO.
124	$p_{lchgdo}=0$	F	Coefficient of the length dependence of CGDO.
125	$p_{wchgdo}=0$	F	Coefficient of the width dependence of CGDO.
126	$p_{lwcgdo}=0$	F	Coefficient of the length time width dependence of CGDO.
127	$p_{ocgso}=6.39e-15$	$(n)/6.36e-15$	F Coefficient of the geometry independent part of CGSO.
128	$p_{lchgso}=0$	F	Coefficient of the length dependence of CGSO.
129	$p_{wchgso}=0$	F	Coefficient of the width dependence of CGSO.
130	$p_{lwcgso}=0$	F	Coefficient of the length times width dependence of CGSO.
131	$gatenoise=0$		Flag for in/exclusion of induced gate thermal noise.
132	$nt=1.62e-20$	J	Thermal noise coefficient.
133	$p_{onfa}=8.32e+22$	$(n)/1.9e+22$	$1/V$ m^4 Coefficient of the geometry independent part of NFA.
134	$p_{lnfa}=0$	$1/V$ m^4	Coefficient of the length dependence of NFA.
135	$p_{wnfa}=0$	$1/V$ m^4	Coefficient of the width dependence of NFA.
136	$p_{lwnfa}=0$	$1/V$ m^4	Coefficient of the length times width dependence of NFA.
137	$p_{onfb}=2.51e+07$	$(n)/5.04e+06$	$1/V$ m^2 Coefficient of the geometry independent part of NFB.
138	$p_{lnfb}=0$	$1/V$ m^2	Coefficient of the length dependence of NFB.
139	$p_{wnfb}=0$	$1/V$ m^2	Coefficient of the width dependence of NFB.
140	$p_{lwnfb}=0$	$1/V$ m^2	Coefficient of the length times width dependence of NFB.

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- 141 $\text{ponfc}=0(n)/3.63e-10(p) \ 1/V$ Coefficient of the geometry independent part of NFC.
- 142 $\text{plnfc}=0 \ 1/V$ Coefficient of the length dependence of NFC.
- 143 $\text{pwnfc}=0 \ 1/V$ Coefficient of the width dependence of NFC.
- 144 $\text{plwnfc}=0 \ 1/V$ Coefficient of the length times width dependence of NFC.
- 145 $\text{potvfb}=0.0005 \ V/K$ Coefficient of the geometry independent part of STVFB.
- 146 $\text{pltvfb}=0 \ V/K$ Coefficient of the length dependence of STVFB.
- 147 $\text{pwtvfb}=0 \ V/K$ Coefficient of the width dependence of STVFB.
- 148 $\text{plwtvfb}=0 \ V/K$ Coefficient of the length times width dependence of STVFB.
- 149 $\text{potphib}=-0.00085 \ V/K$ Coefficient of the geometry independent part of STPHIB.
- 150 $\text{pltphib}=0 \ V/K$ Coefficient of the length dependence of STPHIB.
- 151 $\text{pwtphib}=0 \ V/K$ Coefficient of the width dependence of STPHIB.
- 152 $\text{plwtphib}=0 \ V/K$ Coefficient of the length times width dependence of STPHIB.
- 153 $\text{potetabet}=1.3(n)/0.5(p)$ Coefficient of the geometry independent part of ETABET.
- 154 $\text{pltetabet}=0$ Coefficient of the length dependence of ETABET.
- 155 $\text{pwtetabet}=0$ Coefficient of the width dependence of ETABET.
- 156 $\text{plwtetabet}=0$ Coefficient of the length times width dependence of ETABET.
- 157 $\text{potetasr}=0.65(n)/0.5(p)$ Coefficient of the geometry independent part of ETASR.
- 158 $\text{pltetasr}=0$ Coefficient of the length dependence of ETASR.
- 159 $\text{pwtetasr}=0$ Coefficient of the width dependence of ETASR.
- 160 $\text{plwtetasr}=0$ Coefficient of the length times width dependence of ETASR.

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161	$\text{potetaph}=1.35 \text{ (n)} / 3.75 \text{ (p)}$	Coefficient of the geometry independent part of ETAPH.
162	$\text{pltetaph}=0$	Coefficient of the length dependence of ETAPH.
163	$\text{pwtetaph}=0$	Coefficient of the width dependence of ETAPH.
164	$\text{plwtetaph}=0$	Coefficient of the length times width dependence of ETAPH.
165	$\text{potetamob}=0 \text{ 1/K}$	Coefficient of the geometry independent part of STETAMOB.
166	$\text{pltetamob}=0 \text{ 1/K}$	Coefficient of the length dependence of STETAMOB.
167	$\text{pwtetamob}=0 \text{ 1/K}$	Coefficient of the width dependence of STETAMOB.
168	$\text{plwtetamob}=0 \text{ 1/K}$	Coefficient of the length times width dependence of STETAMOB.
169	$\text{nu}=2$	Exponent of field dependence of mobility model.
170	$\text{potnuexp}=5.25 \text{ (n)} / 3.23 \text{ (p)}$	Coefficient of the geometry independent part of NUEXP.
171	$\text{pltnuexp}=0$	Coefficient of the length dependence of NUEXP.
172	$\text{pwtnuexp}=0$	Coefficient of the width dependence of NUEXP.
173	$\text{plwtnuexp}=0$	Coefficient of the length times width dependence of NUEXP.
174	$\text{potetar}=0.95 \text{ (n)} / 0.4 \text{ (p)}$	Coefficient of the geometry independent part of ETAR.
175	$\text{pltetar}=0$	Coefficient of the length dependence of ETAR.
176	$\text{pwtetar}=0$	Coefficient of the width dependence of ETAR.
177	$\text{plwtetar}=0$	Coefficient of the length times width dependence of ETAR.
178	$\text{potetasat}=1.04 \text{ (n)} / 0.86 \text{ (p)}$	Coefficient of the geometry independent part of ETASAT.
179	$\text{pltetasat}=0$	Coefficient of the length dependence of ETASAT.
180	$\text{pwtetasat}=0$	Coefficient of the width dependence of ETASAT.

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181	<code>plwtetasat=0</code>	Coefficient of the length times width dependence of ETASAT.
182	<code>pota1=0 1/K</code>	Coefficient of the geometry independent part of STA1.
183	<code>plta1=0 1/K</code>	Coefficient of the length dependence of STA1.
184	<code>pwtta1=0 1/K</code>	Coefficient of the width dependence of STA1.
185	<code>plwta1=0 1/K</code>	Coefficient of the length times width dependence of STA1.
186	<code>potbgidl=-0.000364 V/K</code>	Coefficient of the geometry independent part of STBGIDL.
187	<code>pltbgidl=0 V/K</code>	Coefficient of the length dependence of STBGIDL.
188	<code>pwtbgidl=0 V/K</code>	Coefficient of the width dependence of STBGIDL.
189	<code>plwtbgidl=0 V/K</code>	Coefficient of the length times width dependence of STBGIDL.
190	<code>dta=0 K</code>	Temperature offset of the device.
191	<code>pocs=0</code>	Coefficient of the geometry independent part of CS.
192	<code>plcs=0</code>	Coefficient of the length dependence of CS.
193	<code>pwcs=0</code>	Coefficient of the width dependence of CS.
194	<code>plwcs=0</code>	Coefficient of the length times width dependence of CS.
195	<code>potetacs=0</code>	Coefficient of the geometry independent part of ETACS.
196	<code>pltetacs=0</code>	Coefficient of the length dependence of ETACS.
197	<code>pwtetacs=0</code>	Coefficient of the width dependence of ETACS.
198	<code>plwtetacs=0</code>	Coefficient of the length times width dependence of ETACS.
199	<code>rth=300 K/W</code>	Thermal resistance.
200	<code>cth=3e-09 J/K</code>	Thermal capacitance.
201	<code>ath=0</code>	Temperature coefficient of the thermal resistance.

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202	type=n	Transistor gender. Possible values are n, p, npn, pnp, npnv, pnpv, npnl, or pnp1.
203	imax=1.0 A	Explosion current.
204	mbeo=0.0	DCmatch parameter.
205	mvto=0.0	DCmatch parameter.
206	tnom (C)	alias of tnom.
207	tref (C)	alias of tnom.

Output Parameters

1	vfb (V)	Flat-band voltage at reference temperature.
2	ko (\sqrt{V})	Body-effect factor.
3	kpinv ($1/\sqrt{V}$)	Inverse of body-effect factor of the poly-silicon gate.
4	phib (V)	Surface potential at the onset of strong inversion.
5	bet (A/V^2)	Gain factor.
6	thesr ($1/V$)	Mobility degradation parameter due to surface roughness scattering.
7	theph ($1/V$)	Mobility degradation parameter due to phonon scattering.
8	etamob	Effective field parameter for dependence on depletion charge.
9	nu	Exponent of field dependence of mobility model.
10	cs	Coefficient of Coulomb scattering.
11	ther ($1/V$)	Coefficient of series resistance.
12	ther1 (V)	Numerator of gate voltage dependent part of series resistance.
13	ther2 (V)	Denominator of gate voltage dependent part of series resistance.

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14	thesat (1/V)	Velocity saturation parameter due to optical/acoustic phonon scattering.
15	theth (1/V ³)	Coefficient of self-heating.
16	sdibl (1/ \sqrt{V})	Drain-induced barrier lowering parameter.
17	mo	Parameter for (short-channel) subthreshold slope.
18	ssf (1/ \sqrt{V})	Static-feedback parameter.
19	alp	Factor of channel length modulation.
20	vp (V)	Characteristic voltage of channel-length modulation.
21	mexp	Smoothing factor.
22	a1	Factor of the weak-avalanche current.
23	a2 (V)	Exponent of the weak-avalanche current.
24	a3	Factor of the drain-source voltage above which weak-avalanche occurs.
25	iginv (A/V ²)	Gain factor for intrinsic gate tunnelling current in inversion.
26	binv (V)	Probability factor for intrinsic gate tunnelling current in inversion.
27	igacc (A/V ²)	Gain factor for intrinsic gate tunnelling current in accumulation.
28	bacc (V)	Probability factor for intrinsic gate tunnelling current in accumulation.
29	vfbov (V)	Flat-band voltage for the Source/Drain overlap extensions.
30	kov (\sqrt{V})	Body-effect factor for the Source/Drain overlap extensions.
31	igov (A/V ²)	Gain factor for Source/Drain overlap tunnelling current.
32	agidl (A/V ³)	Gain factor for gate-induced leakage current.
33	bgidl (V)	Probability factor for gate-induced drain leakage current at reference temperature.

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34	<code>cgidl</code>	Factor for the lateral field dependence of the gate-induced leakage current.
35	<code>cox</code> (F)	Oxide capacitance for the intrinsic channel (* mult).
36	<code>cgdo</code> (F)	Oxide capacitance for the gate-drain overlap (* mult).
37	<code>cgso</code> (F)	Oxide capacitance for the gate-source overlap (* mult).
38	<code>gatenoise</code>	Flag for in/exclusion of induced gate thermal noise.
39	<code>nt</code> (J)	Thermal noise coefficient.
40	<code>nfa</code> ($1/(V_m^4)$)	First coefficient of the flicker noise.
41	<code>nfb</code> ($1/(V_m^2)$)	Second coefficient of the flicker noise.
42	<code>nfc</code> (1/V)	Third coefficient of the flicker noise.
43	<code>tox</code> (m)	Thickness of gate oxide layer.
44	<code>rth</code> (K/W)	Thermal resistance.
45	<code>cth</code> (J/K)	Thermal capacitance.

Operating-Point Parameters

1	<code>ids</code> (A)	Drain current, excl. avalanche and tunnel currents.
2	<code>iavl</code> (A)	Substrate current due to weak-avalanche.
3	<code>igs</code> (A)	Gate-to-source current due to direct tunnelling.
4	<code>igd</code> (A)	Gate-to-drain current due to direct tunnelling.
5	<code>igb</code> (A)	Gate-to-bulk current due to direct tunnelling.
6	<code>vds</code> (V)	Drain-source voltage.
7	<code>vgs</code> (V)	Gate-source voltage.
8	<code>vsb</code> (V)	Source-bulk voltage.

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9	v_{to} (V)	Zero-bias threshold voltage.
10	v_{ts} (V)	Threshold voltage including back-bias effects.
11	v_{th} (V)	Threshold voltage including back-bias and drain-bias effects.
12	v_{gt} (V)	Effective gate drive voltage including back-bias and drain voltage effects.
13	v_{dss} (V)	Drain saturation voltage at actual bias.
14	v_{sat} (V)	Saturation limit.
15	g_m (A/V)	Transconductance ($d i_{ds} / d v_{gs}$).
16	g_{mb} (A/V)	Substrate-transconductance ($d i_{ds} / d v_{bs}$).
17	g_{ds} (A/V)	Output conductance ($d i_{ds} / d v_{ds}$).
18	c_{dd} (F)	Capacitance ($d q_d / d v_d$).
19	c_{dg} (F)	Capacitance ($- d q_d / d v_g$).
20	c_{ds} (F)	Capacitance ($- d q_d / d v_s$).
21	c_{db} (F)	Capacitance ($- d q_d / d v_b$).
22	c_{gd} (F)	Capacitance ($- d q_g / d v_d$).
23	c_{gg} (F)	Capacitance ($d q_g / d v_g$).
24	c_{gs} (F)	Capacitance ($- d q_g / d v_s$).
25	c_{gb} (F)	Capacitance ($- d q_g / d v_b$).
26	c_{sd} (F)	Capacitance ($- d q_s / d v_d$).
27	c_{sg} (F)	Capacitance ($- d q_s / d v_g$).
28	c_{ss} (F)	Capacitance ($d q_s / d v_s$).
29	c_{sb} (F)	Capacitance ($- d q_s / d v_b$).

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30	c_{bd} (F)	Capacitance ($-d q_b / d v_d$).
31	c_{bg} (F)	Capacitance ($-d q_b / d v_g$).
32	c_{bs} (F)	Capacitance ($-d q_b / d v_s$).
33	c_{bb} (F)	Capacitance ($d q_b / d v_b$).
34	c_{gdol} (F)	Gate-drain overlap capacitance of the actual transistor.
35	c_{gsol} (F)	Gate-source overlap capacitance of the actual transistor.
36	w_{eff} (m)	Effective channel width for geometrical models.
37	l_{eff} (m)	Effective channel length for geometrical models.
38	u	Transistor gain (g_m/g_{ds}).
39	r_{out} (Ω)	Small-signal output resistance ($1/g_{ds}$).
40	v_{early} (V)	Equivalent Early voltage ($ i_d /g_{ds}$).
41	k_{eff} (\sqrt{V})	Body effect parameter.
42	b_{eff} (A/V^2)	Gain factor.
43	f_{ug} (Hz)	Unity gain frequency at actual bias ($g_m/(2*\pi*c_{in})$).
44	$sqrt_{sfw}$ (V/\sqrt{Hz})	Input-referred RMS white noise voltage density.
45	$sqrt_{sff}$ (V/\sqrt{Hz})	Input-referred RMS white noise voltage density at 1 kHz.
46	f_{knee} (Hz)	Cross-over frequency above which white noise is dominant.
47	P_{diss} (W)	Dissipation.
48	T_K (K)	Actual device temperature.

Virtuoso Simulator Components and Device Models Reference

Philips Models

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

Pdiss	OP-47	nfb	O-41	plwssf	M-62	pwigacc	M-94
TK	OP-48	nfc	O-42	plwta1	M-185	pwiginv	M-86
a1	O-22	nt	M-132	plwtbgidl	M-189	pwigov	M-104
a2	O-23	nt	O-39	plwtetabet	M-156	pwko	M-14
a3	O-24	nu	M-169	plwtetacs	M-198	pwmexp	M-70
agidl	O-32	nu	O-9	plwtetamob	M-168	pwmo	M-57
alp	O-19	phib	O-4	plwtetaph	M-164	pwnfa	M-135
area	I-6	pla1	M-73	plwtetar	M-177	pwnfb	M-139
ath	M-201	pla2	M-77	plwtetasat	M-181	pwnfc	M-143
bacc	O-28	pla3	M-81	plwtetasr	M-160	pwphib	M-19
beff	OP-42	plagidl	M-107	plwtheph	M-32	psdibl	M-53
bet	O-5	plalp	M-64	plwther	M-40	pwssf	M-61
bgidl	O-33	plbacc	M-97	plwthesat	M-46	pwtal	M-184
binv	O-26	plbet	M-22	plwthesr	M-28	pwtbgidl	M-188
cbb	OP-33	plbgidl	M-111	plwtheth	M-50	pwtetabet	M-155
cbd	OP-30	plbinv	M-89	plwtuexp	M-173	pwtetacs	M-197

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Philips Models

cbg	OP-31	plcgdo	M-124	plwtphib	M-152	pwtetamob	M-167
cbs	OP-32	plcgidl	M-115	plwtvfb	M-148	pwtetaph	M-163
cdb	OP-21	plcgso	M-128	poa1	M-72	pwtetar	M-176
cdd	OP-18	plcox	M-120	poa2	M-76	pwtetasat	M-180
cdg	OP-19	plcs	M-192	poa3	M-80	pwtetasr	M-159
cds	OP-20	pletamob	M-34	poagidl	M-106	pwtheph	M-31
cgb	OP-25	pligacc	M-93	poalp	M-63	pwther	M-39
cgd	OP-22	pliginv	M-85	pobacc	M-96	pwthesat	M-45
cgdo	O-36	pligov	M-103	pobet	M-21	pwthesr	M-27
cgdol	OP-34	plko	M-13	pobgidl	M-110	pwtheth	M-49
cgg	OP-23	plmexp	M-69	pobinv	M-88	pwtuexp	M-172
cgidl	O-34	plmo	M-56	pocgdo	M-123	pwtphib	M-151
cgs	OP-24	plnfa	M-134	pocgidl	M-114	pwtvfb	M-147
cgso	O-37	plnfb	M-138	pocgso	M-127	region	I-4
cgsol	OP-35	plnfc	M-142	pocox	M-119	rout	OP-39
cox	O-35	plphib	M-18	pocs	M-191	rth	M-199
cs	O-10	plsdibl	M-52	poetamob	M-33	rth	O-44
csb	OP-29	plssf	M-60	poigacc	M-92	sdibl	O-16
csd	OP-26	plta1	M-183	poiginv	M-84	sqrtsff	OP-45
csg	OP-27	pltbgidl	M-187	poigov	M-102	sqrtsfw	OP-44
css	OP-28	pltetabet	M-154	poko	M-12	ssf	O-18

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cth M-200	pltetacs M-196	pomexp M-68	theph O-7
cth O-45	pltetamob M-166	pomo M-55	ther O-11
dta M-190	pltetaph M-162	ponfa M-133	ther1 M-41
etamob O-8	pltetar M-175	ponfb M-137	ther1 O-12
fknee OP-46	pltetasat M-179	ponfc M-141	ther2 M-42
fug OP-43	pltetasr M-158	pophib M-17	ther2 O-13
gatenoise M-131	pltheph M-30	posdibl M-51	thesat O-14
gatenoise O-38	plther M-38	possf M-59	thesr O-6
gds OP-17	plthesat M-44	potal M-182	theth O-15
gm OP-15	plthesr M-26	potbgidl M-186	tnom M-206
gmb OP-16	pltheth M-48	potetabet M-153	tox M-118
iavl OP-2	pltnuexp M-171	potetacs M-195	tox O-43
ids OP-1	pltphib M-150	potetamob M-165	tr M-6
igacc O-27	pltvfb M-146	potetaph M-161	tref M-207
igb OP-5	plwa1 M-75	potetar M-174	type M-202
igd OP-4	plwa2 M-79	potetasat M-178	u OP-38
iginv O-25	plwa3 M-83	potetasr M-157	vds OP-6
igov O-31	plwagidl M-109	potheph M-29	vdss OP-13
igs OP-3	plwalp M-66	pother M-37	vearly OP-40
imax M-203	plwbacc M-99	pothesat M-43	vfb M-11
keff OP-41	plwbet M-24	pothesr M-25	vfb O-1

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Philips Models

ko	O-2	plwbgidl	M-113	potheth	M-47	vfbov	M-100
kov	M-101	plwbinv	M-91	potnuexp	M-170	vfbov	O-29
kov	O-30	plwcgdo	M-126	potphib	M-149	vgs	OP-7
kpinv	M-16	plwcgidl	M-117	potvfb	M-145	vgt	OP-12
kpinv	O-3	plwcgso	M-130	pwa1	M-74	vp	M-67
l	I-1	plwcox	M-122	pwa2	M-78	vp	O-20
lap	M-3	plwcs	M-194	pwa3	M-82	vsat	OP-14
leff	OP-37	plwetamob	M-36	pwagidl	M-108	vsb	OP-8
level	M-1	plwigacc	M-95	pwalp	M-65	vth	OP-11
lmax	M-8	plwiginv	M-87	pwbacc	M-98	vto	OP-9
lmin	M-7	plwigov	M-105	pwbet	M-23	vts	OP-10
lvar	M-2	plwko	M-15	pwbgidl	M-112	w	I-2
m	I-5	plwmexp	M-71	pwbinv	M-90	weff	OP-36
mbeo	M-204	plwmo	M-58	pwcgdo	M-125	wmax	M-10
mexp	O-21	plwnfa	M-136	pwcgidl	M-116	wmin	M-9
mo	O-17	plwnfb	M-140	pwcgso	M-129	wot	M-5
mult	I-3	plwnfc	M-144	pwcox	M-121	wvar	M-4
mvto	M-205	plwphib	M-20	pwcs	M-193		
nfa	O-40	plwsdibl	M-54	pwetamob	M-35		

MOS Model 11, Level 1102 (mos1102e)

This device is supported within altergroups.

This device is dynamically loaded from the shared object /vobs/spectre_dev/tools.lnx86/cmi/lib/5.0.doc/libphilips_sh.so

Instance Definition

```
Name d g s b ModelName parameter=value ...
```

Instance Parameters

- | | | |
|---|---------------|---|
| 1 | mult=1 | Number of devices in parallel. |
| 2 | region=triode | Estimated DC operating region, used as a convergence aid. Possible values are off, triode, sat, or subth. |
| 3 | m=1 | Multiplicity factor. |
| 4 | area=1 | alias of mult. |

Model Definition

```
model modelName mos1102e parameter=value ...
```

Model Parameters

- | | | |
|---|----------------------|---|
| 1 | level=1.1e+03 | Transistor Level. |
| 2 | tr=21 C | Reference temperature. |
| 3 | vfb=-1.05 V | Flat-band voltage at reference temperature. |
| 4 | stvfb=0.0005 V/K | Coefficient of temperature dependence of VFB. |
| 5 | ko=0.5 \sqrt{V} | Body-effect factor. |
| 6 | kpinv=0 $1/\sqrt{V}$ | Inverse of body-effect factor of the poly-silicon gate. |
| 7 | phib=0.95 V | Surface potential at the onset of strong inversion. |

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 8 $stphib = -0.00085 \text{ V/K}$
Coefficient of the temperature dependency of PHIB.
- 9 $bet = 0.00192 (n) / 0.000381 (p) \text{ A/V}^2$
Gain factor.
- 10 $etabet = 1.3 (n) / 0.5 (p)$
Exponent of the temperature dependence of the gain factor.
- 11 $thesr = 0.356 (n) / 0.73 (p) \text{ 1/V}$
Mobility degradation parameter due to surface roughness scattering.
- 12 $etasr = 0.65 (n) / 0.5 (p)$
Exponent of the temperature dependence of THESR.
- 13 $theph = 0.0129 (n) / 0.001 (p) \text{ 1/V}$
Mobility degradation parameter due to phonon scattering.
- 14 $etaph = 1.35 (n) / 3.75 (p)$
Exponent of the temperature dependence of THEPH.
- 15 $etamob = 1.4 (n) / 3 (p)$
Effective field parameter for dependence on depletion charge.
- 16 $stetamob = 0 \text{ 1/K}$
Coefficient of the temperature dependence of ETAMOB.
- 17 $nu = 2$
Exponent of field dependence of mobility model.
- 18 $nuexp = 5.25 (n) / 3.23 (p)$
Exponent of the temperature dependence of parameter NU.
- 19 $ther = 0.0812 (n) / 0.079 (p) \text{ 1/V}$
Coefficient of series resistance.
- 20 $etar = 0.95 (n) / 0.4 (p)$
Exponent of the temperature dependence of THER.
- 21 $ther1 = 0 \text{ V}$
Numerator of gate voltage dependent part of series resistance.
- 22 $ther2 = 1 \text{ V}$
Denominator of gate voltage dependent part of series resistance.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 23 $\text{thesat}=0.251(n)/0.173(p) \ 1/V$
Velocity saturation parameter due to optical/acoustic phonon scattering.
- 24 $\text{etasat}=1.04(n)/0.86(p)$
Exponent of the temperature dependence of THESAT.
- 25 $\text{theth}=1e-05(n)/0(p) \ 1/V^3$
Coefficient of self-heating.
- 26 $\text{sdibl}=0.000853(n)/3.55e-05(p) \ 1/\sqrt{V}$
Drain-induced barrier lowering parameter.
- 27 $\text{mo}=0$
Parameter for (short-channel) subthreshold slope.
- 28 $\text{ssf}=0.012(n)/0.01(p) \ 1/\sqrt{V}$
Static-feedback parameter.
- 29 $\text{alp}=0.025$
Factor of channel length modulation.
- 30 $\text{vp}=0.05 \ V$
Characteristic voltage of channel-length modulation.
- 31 $\text{mexp}=5$
Smoothing factor.
- 32 $\text{a1}=6.02(n)/6.86(p)$
Factor of the weak-avalanche current.
- 33 $\text{sta1}=0 \ 1/K$
Coefficient of the temperature dependence of A1.
- 34 $\text{a2}=38(n)/57.3(p) \ V$
Exponent of the weak-avalanche current.
- 35 $\text{a3}=0.641(n)/0.425(p)$
Factor of the drain-source voltage above which weak-avalanche occurs.
- 36 $\text{iginv}=0 \ A/V^2$
Gain factor for intrinsic gate tunnelling current in inversion.
- 37 $\text{binv}=48(n)/87.5(p) \ V$
Probability factor for intrinsic gate tunnelling current in inversion.
- 38 $\text{igacc}=0 \ A/V^2$
Gain factor for intrinsic gate tunnelling current in accumulation.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- | | | |
|----|---|---|
| 39 | $b_{acc}=48 \text{ V}$ | Probability factor for intrinsic gate tunnelling current in accumulation. |
| 40 | $v_{fbov}=0 \text{ V}$ | Flat-band voltage for the Source/Drain overlap extensions. |
| 41 | $k_{ov}=2.5 \sqrt{V}$ | Body-effect factor for the Source/Drain overlap extensions. |
| 42 | $i_{gov}=0 \text{ A/V}^2$ | Gain factor for Source/Drain overlap tunnelling current. |
| 43 | $a_{gidl}=0 \text{ A/V}^3$ | Gain factor for gate-induced leakage current. |
| 44 | $b_{gidl}=41 \text{ V}$ | Probability factor for gate-induced drain leakage current at reference temperature. |
| 45 | $stb_{gidl}=-0.000364 \text{ V/K}$ | Coefficient of the temperature dependence of BGIDL. |
| 46 | $c_{gidl}=0$ | Factor for the lateral field dependence of the gate-induced leakage current. |
| 47 | $cox=2.98e-14 \text{ (n) / } 2.72e-14 \text{ (p) F}$ | Oxide capacitance for the intrinsic channel (* mult). |
| 48 | $cgdo=6.39e-15 \text{ (n) / } 6.36e-15 \text{ (p) F}$ | Oxide capacitance for the gate-drain overlap (* mult). |
| 49 | $cgso=6.39e-15 \text{ (n) / } 6.36e-15 \text{ (p) F}$ | Oxide capacitance for the gate-source overlap (* mult). |
| 50 | $gatenoise=0$ | Flag for in/exclusion of induced gate thermal noise. |
| 51 | $nt=1.62e-20 \text{ J}$ | Thermal noise coefficient. |
| 52 | $nfa=8.32e+22 \text{ (n) / } 1.9e+22 \text{ (p) } 1 / (\text{Vm}^4)$ | First coefficient of the flicker noise. |
| 53 | $nfb=2.51e+07 \text{ (n) / } 5.04e+06 \text{ (p) } 1 / (\text{Vm}^2)$ | Second coefficient of the flicker noise. |
| 54 | $nfc=0 \text{ (n) / } 3.63e-10 \text{ (p) } 1 / \text{V}$ | Third coefficient of the flicker noise. |
| 55 | $tox=3.2e-09 \text{ m}$ | Thickness of gate oxide layer. |

Virtuoso Simulator Components and Device Models Reference

Philips Models

56	<code>dta=0</code> K	Temperature offset of the device.
57	<code>cs=0</code>	Coefficient of Coulomb scattering.
58	<code>etacs=0</code>	Exponent of the temperature dependence of CS.
59	<code>type=n</code>	Transistor gender. Possible values are n, p, npn, pnp, npnv, pnpv, npnl, or pnp1.
60	<code>imax=1.0</code> A	Explosion current.
61	<code>mbe=0.0</code>	DCmatch parameter.
62	<code>mvt=0.0</code>	DCmatch parameter.
63	<code>tnom</code> (C)	alias of <code>tnom</code> .
64	<code>tref</code> (C)	alias of <code>tnom</code> .

Output Parameters

1	<code>vfb</code> (V)	Flat-band voltage at reference temperature.
2	<code>ko</code> (\sqrt{V})	Body-effect factor.
3	<code>kpinv</code> ($1/\sqrt{V}$)	Inverse of body-effect factor of the poly-silicon gate.
4	<code>phib</code> (V)	Surface potential at the onset of strong inversion.
5	<code>bet</code> (A/V^2)	Gain factor.
6	<code>thesr</code> ($1/V$)	Mobility degradation parameter due to surface roughness scattering.
7	<code>theph</code> ($1/V$)	Mobility degradation parameter due to phonon scattering.
8	<code>etamob</code>	Effective field parameter for dependence on depletion charge.
9	<code>nu</code>	Exponent of field dependence of mobility model.
10	<code>cs</code>	Coefficient of Coulomb scattering.
11	<code>ther</code> ($1/V$)	Coefficient of series resistance.

Virtuoso Simulator Components and Device Models Reference

Philips Models

12	ther1 (V)	Numerator of gate voltage dependent part of series resistance.
13	ther2 (V)	Denominator of gate voltage dependent part of series resistance.
14	thesat (1/V)	Velocity saturation parameter due to optical/acoustic phonon scattering.
15	theth (1/V ³)	Coefficient of self-heating.
16	sdibl (1/ \sqrt{V})	Drain-induced barrier lowering parameter.
17	mo	Parameter for (short-channel) subthreshold slope.
18	ssf (1/ \sqrt{V})	Static-feedback parameter.
19	alp	Factor of channel length modulation.
20	vp (V)	Characteristic voltage of channel-length modulation.
21	mexp	Smoothing factor.
22	a1	Factor of the weak-avalanche current.
23	a2 (V)	Exponent of the weak-avalanche current.
24	a3	Factor of the drain-source voltage above which weak-avalanche occurs.
25	iginv (A/V ²)	Gain factor for intrinsic gate tunnelling current in inversion.
26	binv (V)	Probability factor for intrinsic gate tunnelling current in inversion.
27	igacc (A/V ²)	Gain factor for intrinsic gate tunnelling current in accumulation.
28	bacc (V)	Probability factor for intrinsic gate tunnelling current in accumulation.
29	vfbov (V)	Flat-band voltage for the Source/Drain overlap extensions.
30	kov (\sqrt{V})	Body-effect factor for the Source/Drain overlap extensions.
31	igov (A/V ²)	Gain factor for Source/Drain overlap tunnelling current.

Virtuoso Simulator Components and Device Models Reference

Philips Models

32	$agidl$ (A/V^3)	Gain factor for gate-induced leakage current.
33	$bgidl$ (V)	Probability factor for gate-induced drain leakage current at reference temperature.
34	$cgidl$	Factor for the lateral field dependence of the gate-induced leakage current.
35	cox (F)	Oxide capacitance for the intrinsic channel (* mult).
36	$cgdo$ (F)	Oxide capacitance for the gate-drain overlap (* mult).
37	$cgso$ (F)	Oxide capacitance for the gate-source overlap (* mult).
38	$gatenoise$	Flag for in/exclusion of induced gate thermal noise.
39	nt (J)	Thermal noise coefficient.
40	nfa ($1/(Vm^4)$)	First coefficient of the flicker noise.
41	nfb ($1/(Vm^2)$)	Second coefficient of the flicker noise.
42	nfc ($1/V$)	Third coefficient of the flicker noise.
43	tox (m)	Thickness of gate oxide layer.

Operating-Point Parameters

1	ids (A)	Drain current, excl. avalanche and tunnel currents.
2	$iavl$ (A)	Substrate current due to weak-avalanche.
3	igs (A)	Gate-to-source current due to direct tunnelling.
4	igd (A)	Gate-to-drain current due to direct tunnelling.
5	igb (A)	Gate-to-bulk current due to direct tunnelling.
6	vds (V)	Drain-source voltage.
7	vgs (V)	Gate-source voltage.
8	vsb (V)	Source-bulk voltage.

Virtuoso Simulator Components and Device Models Reference

Philips Models

9	v_{to} (V)	Zero-bias threshold voltage.
10	v_{ts} (V)	Threshold voltage including back-bias effects.
11	v_{th} (V)	Threshold voltage including back-bias and drain-bias effects.
12	v_{gt} (V)	Effective gate drive voltage including back-bias and drain voltage effects.
13	v_{dss} (V)	Drain saturation voltage at actual bias.
14	v_{sat} (V)	Saturation limit.
15	g_m (A/V)	Transconductance ($d i_{ds} / d v_{gs}$).
16	g_{mb} (A/V)	Substrate-transconductance ($d i_{ds} / d v_{bs}$).
17	g_{ds} (A/V)	Output conductance ($d i_{ds} / d v_{ds}$).
18	c_{dd} (F)	Capacitance ($d q_d / d v_d$).
19	c_{dg} (F)	Capacitance ($- d q_d / d v_g$).
20	c_{ds} (F)	Capacitance ($- d q_d / d v_s$).
21	c_{db} (F)	Capacitance ($- d q_d / d v_b$).
22	c_{gd} (F)	Capacitance ($- d q_g / d v_d$).
23	c_{gg} (F)	Capacitance ($d q_g / d v_g$).
24	c_{gs} (F)	Capacitance ($- d q_g / d v_s$).
25	c_{gb} (F)	Capacitance ($- d q_g / d v_b$).
26	c_{sd} (F)	Capacitance ($- d q_s / d v_d$).
27	c_{sg} (F)	Capacitance ($- d q_s / d v_g$).
28	c_{ss} (F)	Capacitance ($d q_s / d v_s$).
29	c_{sb} (F)	Capacitance ($- d q_s / d v_b$).

Virtuoso Simulator Components and Device Models Reference

Philips Models

30	c_{bd} (F)	Capacitance (- d qb / d vd).
31	c_{bg} (F)	Capacitance (- d qb / d vg).
32	c_{bs} (F)	Capacitance (- d qb / d vs).
33	c_{bb} (F)	Capacitance (d qb / d vb).
34	c_{gdol} (F)	Gate-drain overlap capacitance of the actual transistor.
35	c_{gsol} (F)	Gate-source overlap capacitance of the actual transistor.
36	u	Transistor gain (gm/gds).
37	r_{out} (Ω)	Small-signal output resistance (1/gds).
38	v_{early} (V)	Equivalent Early voltage ($ idl /gds$).
39	k_{eff} (\sqrt{V})	Body effect parameter.
40	b_{eff} (A/V^2)	Gain factor.
41	f_{ug} (Hz)	Unity gain frequency at actual bias ($gm/(2*\pi*cin)$).
42	$sqrtsfw$ (V/\sqrt{Hz})	Input-referred RMS white noise voltage density.
43	$sqrtsff$ (V/\sqrt{Hz})	Input-referred RMS white noise voltage density at 1 kHz.
44	f_{knee} (Hz)	Cross-over frequency above which white noise is dominant.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

Virtuoso Simulator Components and Device Models Reference

Philips Models

a1	M-32	cgsol	OP-35	ko	O-2	stvfb	M-4
a1	O-22	cox	M-47	kov	M-41	theph	M-13
a2	M-34	cox	O-35	kov	O-30	theph	O-7
a2	O-23	cs	M-57	kpinv	M-6	ther	M-19
a3	M-35	cs	O-10	kpinv	O-3	ther	O-11
a3	O-24	csb	OP-29	level	M-1	ther1	M-21
agidl	M-43	csd	OP-26	m	I-3	ther1	O-12
agidl	O-32	csg	OP-27	mbe	M-61	ther2	M-22
alp	M-29	css	OP-28	mexp	M-31	ther2	O-13
alp	O-19	dta	M-56	mexp	O-21	thesat	M-23
area	I-4	etabet	M-10	mo	M-27	thesat	O-14
bacc	M-39	etacs	M-58	mo	O-17	thesr	M-11
bacc	O-28	etamob	M-15	mult	I-1	thesr	O-6
beff	OP-40	etamob	O-8	mvt	M-62	theth	M-25
bet	M-9	etaph	M-14	nfa	M-52	theth	O-15
bet	O-5	etar	M-20	nfa	O-40	tnom	M-63
bgidl	M-44	etasat	M-24	nfb	M-53	tox	M-55
bgidl	O-33	etasr	M-12	nfb	O-41	tox	O-43
binv	M-37	fknee	OP-44	nfc	M-54	tr	M-2
binv	O-26	fug	OP-41	nfc	O-42	tref	M-64

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Philips Models

cbb	OP-33	gatenoise	M-50	nt	M-51	type	M-59
cbd	OP-30	gatenoise	O-38	nt	O-39	u	OP-36
cbg	OP-31	gds	OP-17	nu	M-17	vds	OP-6
cbs	OP-32	gm	OP-15	nu	O-9	vdss	OP-13
cdb	OP-21	gmb	OP-16	nuexp	M-18	vearly	OP-38
cdd	OP-18	iavl	OP-2	phib	M-7	vfb	M-3
cdg	OP-19	ids	OP-1	phib	O-4	vfb	O-1
cds	OP-20	igacc	M-38	region	I-2	vfbov	M-40
cgb	OP-25	igacc	O-27	rout	OP-37	vfbov	O-29
cgd	OP-22	igb	OP-5	sdibl	M-26	vgs	OP-7
cgdo	M-48	igd	OP-4	sdibl	O-16	vgt	OP-12
cgdo	O-36	iginv	M-36	sqrtsff	OP-43	vp	M-30
cgdol	OP-34	iginv	O-25	sqrtsfw	OP-42	vp	O-20
cgg	OP-23	igov	M-42	ssf	M-28	vsat	OP-14
cgidl	M-46	igov	O-31	ssf	O-18	vsb	OP-8
cgidl	O-34	igs	OP-3	stal	M-33	vth	OP-11
cgs	OP-24	imax	M-60	stbgidl	M-45	vto	OP-9
cgso	M-49	keff	OP-39	stetamob	M-16	vts	OP-10
cgso	O-37	ko	M-5	stphib	M-8		

MOS Model 11, Level 1102 (mos1102et)

This is SimKit 4.0

This device is supported within altergroups.

This device is dynamically loaded from the shared object /vobs/spectre_dev/tools.lnx86/cmi/lib/5.0.doc/libphilips_sh.so

Instance Definition

```
Name d g s b dt ModelName parameter=value ...
```

Instance Parameters

- | | | |
|---|---------------|---|
| 1 | mult=1 | Number of devices in parallel. |
| 2 | region=triode | Estimated DC operating region, used as a convergence aid. Possible values are off, triode, sat, or subth. |
| 3 | m=1 | Multiplicity factor. |
| 4 | area=1 | alias of mult. |

Model Definition

```
model modelName mos1102et parameter=value ...
```

Model Parameters

- | | | |
|---|----------------------|---|
| 1 | level=1.1e+03 | Transistor Level. |
| 2 | tr=21 C | Reference temperature. |
| 3 | vfb=-1.05 V | Flat-band voltage at reference temperature. |
| 4 | stvfb=0.0005 V/K | Coefficient of temperature dependence of VFB. |
| 5 | ko=0.5 \sqrt{V} | Body-effect factor. |
| 6 | kpinv=0 $1/\sqrt{V}$ | Inverse of body-effect factor of the poly-silicon gate. |

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 7 $\text{phib}=0.95 \text{ V}$ Surface potential at the onset of strong inversion.
- 8 $\text{stphib}=-0.00085 \text{ V/K}$ Coefficient of the temperature dependency of PHIB.
- 9 $\text{bet}=0.00192 \text{ (n)}/0.000381 \text{ (p)} \text{ A/V}^2$ Gain factor.
- 10 $\text{etabet}=1.3 \text{ (n)}/0.5 \text{ (p)}$ Exponent of the temperature dependence of the gain factor.
- 11 $\text{thesr}=0.356 \text{ (n)}/0.73 \text{ (p)} \text{ 1/V}$ Mobility degradation parameter due to surface roughness scattering.
- 12 $\text{etasr}=0.65 \text{ (n)}/0.5 \text{ (p)}$ Exponent of the temperature dependence of THESR.
- 13 $\text{theph}=0.0129 \text{ (n)}/0.001 \text{ (p)} \text{ 1/V}$ Mobility degradation parameter due to phonon scattering.
- 14 $\text{etaph}=1.35 \text{ (n)}/3.75 \text{ (p)}$ Exponent of the temperature dependence of THEPH.
- 15 $\text{etamob}=1.4 \text{ (n)}/3 \text{ (p)}$ Effective field parameter for dependence on depletion charge.
- 16 $\text{stetamob}=0 \text{ 1/K}$ Coefficient of the temperature dependence of ETAMOB.
- 17 $\text{nu}=2$ Exponent of field dependence of mobility model.
- 18 $\text{nuexp}=5.25 \text{ (n)}/3.23 \text{ (p)}$ Exponent of the temperature dependence of parameter NU.
- 19 $\text{ther}=0.0812 \text{ (n)}/0.079 \text{ (p)} \text{ 1/V}$ Coefficient of series resistance.
- 20 $\text{etar}=0.95 \text{ (n)}/0.4 \text{ (p)}$ Exponent of the temperature dependence of THER.
- 21 $\text{ther1}=0 \text{ V}$ Numerator of gate voltage dependent part of series resistance.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 22 $ther2=1$ V Denominator of gate voltage dependent part of series resistance.
- 23 $thesat=0.251(n)/0.173(p)$ $1/V$ Velocity saturation parameter due to optical/acoustic phonon scattering.
- 24 $etasat=1.04(n)/0.86(p)$ Exponent of the temperature dependence of THESAT.
- 25 $theth=1e-05(n)/0(p)$ $1/V^3$ Coefficient of self-heating.
- 26 $sdibl=0.000853(n)/3.55e-05(p)$ $1/\sqrt{V}$ Drain-induced barrier lowering parameter.
- 27 $mo=0$ Parameter for (short-channel) subthreshold slope.
- 28 $ssf=0.012(n)/0.01(p)$ $1/\sqrt{V}$ Static-feedback parameter.
- 29 $alp=0.025$ Factor of channel length modulation.
- 30 $vp=0.05$ V Characteristic voltage of channel-length modulation.
- 31 $mexp=5$ Smoothing factor.
- 32 $a1=6.02(n)/6.86(p)$ Factor of the weak-avalanche current.
- 33 $sta1=0$ $1/K$ Coefficient of the temperature dependence of A1.
- 34 $a2=38(n)/57.3(p)$ V Exponent of the weak-avalanche current.
- 35 $a3=0.641(n)/0.425(p)$ Factor of the drain-source voltage above which weak-avalanche occurs.
- 36 $iginv=0$ A/V^2 Gain factor for intrinsic gate tunnelling current in inversion.
- 37 $binv=48(n)/87.5(p)$ V Probability factor for intrinsic gate tunnelling current in inversion.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 38 $igacc=0$ A/V² Gain factor for intrinsic gate tunnelling current in accumulation.
- 39 $bacc=48$ V Probability factor for intrinsic gate tunnelling current in accumulation.
- 40 $vfbov=0$ V Flat-band voltage for the Source/Drain overlap extensions.
- 41 $kov=2.5$ \sqrt{V} Body-effect factor for the Source/Drain overlap extensions.
- 42 $igov=0$ A/V² Gain factor for Source/Drain overlap tunnelling current.
- 43 $agidl=0$ A/V³ Gain factor for gate-induced leakage current.
- 44 $bgidl=41$ V Probability factor for gate-induced drain leakage current at reference temperature.
- 45 $stbgidl=-0.000364$ V/K Coefficient of the temperature dependence of BGIDL.
- 46 $cgidl=0$ Factor for the lateral field dependence of the gate-induced leakage current.
- 47 $cox=2.98e-14$ (n) / $2.72e-14$ (p) F Oxide capacitance for the intrinsic channel (* mult).
- 48 $cgdo=6.39e-15$ (n) / $6.36e-15$ (p) F Oxide capacitance for the gate-drain overlap (* mult).
- 49 $cgso=6.39e-15$ (n) / $6.36e-15$ (p) F Oxide capacitance for the gate-source overlap (* mult).
- 50 $gatenoise=0$ Flag for in/exclusion of induced gate thermal noise.
- 51 $nt=1.62e-20$ J Thermal noise coefficient.
- 52 $nfa=8.32e+22$ (n) / $1.9e+22$ (p) $1/(V\text{m}^4)$ First coefficient of the flicker noise.
- 53 $nfb=2.51e+07$ (n) / $5.04e+06$ (p) $1/(V\text{m}^2)$ Second coefficient of the flicker noise.
- 54 $nfc=0$ (n) / $3.63e-10$ (p) $1/V$ Third coefficient of the flicker noise.

Virtuoso Simulator Components and Device Models Reference

Philips Models

55	$t_{ox}=3.2e-09$ m	Thickness of gate oxide layer.
56	$dta=0$ K	Temperature offset of the device.
57	$cs=0$	Coefficient of Coulomb scattering.
58	$etacs=0$	Exponent of the temperature dependence of CS.
59	$rth=300$ K/W	Thermal resistance.
60	$cth=3e-09$ J/K	Thermal capacitance.
61	$ath=0$	Temperature coefficient of the thermal resistance.
62	$type=n$	Transistor gender. Possible values are n, p, npn, pnp, npnv, pnpv, npnl, or pnp1.
63	$imax=1.0$ A	Explosion current.
64	$mbe=0.0$	DCmatch parameter.
65	$mvt=0.0$	DCmatch parameter.
66	t_{nom} (C)	alias of t_{nom} .
67	t_{ref} (C)	alias of t_{nom} .

Output Parameters

1	v_{fb} (V)	Flat-band voltage at reference temperature.
2	k_o (\sqrt{V})	Body-effect factor.
3	k_{pinv} ($1/\sqrt{V}$)	Inverse of body-effect factor of the poly-silicon gate.
4	ϕ_{ib} (V)	Surface potential at the onset of strong inversion.
5	β_{et} (A/V^2)	Gain factor.
6	t_{hesr} ($1/V$)	Mobility degradation parameter due to surface roughness scattering.
7	t_{heph} ($1/V$)	Mobility degradation parameter due to phonon scattering.

Virtuoso Simulator Components and Device Models Reference

Philips Models

8	etamob	Effective field parameter for dependence on depletion charge.
9	nu	Exponent of field dependence of mobility model.
10	cs	Coefficient of Coulomb scattering.
11	ther (1/V)	Coefficient of series resistance.
12	ther1 (V)	Numerator of gate voltage dependent part of series resistance.
13	ther2 (V)	Denominator of gate voltage dependent part of series resistance.
14	thesat (1/V)	Velocity saturation parameter due to optical/acoustic phonon scattering.
15	theth (1/V ³)	Coefficient of self-heating.
16	sdibl (1/ \sqrt{V})	Drain-induced barrier lowering parameter.
17	mo	Parameter for (short-channel) subthreshold slope.
18	ssf (1/ \sqrt{V})	Static-feedback parameter.
19	alp	Factor of channel length modulation.
20	vp (V)	Characteristic voltage of channel-length modulation.
21	mexp	Smoothing factor.
22	a1	Factor of the weak-avalanche current.
23	a2 (V)	Exponent of the weak-avalanche current.
24	a3	Factor of the drain-source voltage above which weak-avalanche occurs.
25	iginv (A/V ²)	Gain factor for intrinsic gate tunnelling current in inversion.
26	binv (V)	Probability factor for intrinsic gate tunnelling current in inversion.
27	igacc (A/V ²)	Gain factor for intrinsic gate tunnelling current in accumulation.

Virtuoso Simulator Components and Device Models Reference

Philips Models

28	bacc (V)	Probability factor for intrinsic gate tunnelling current in accumulation.
29	vfbov (V)	Flat-band voltage for the Source/Drain overlap extensions.
30	kov (\sqrt{V})	Body-effect factor for the Source/Drain overlap extensions.
31	igov (A/V^2)	Gain factor for Source/Drain overlap tunnelling current.
32	agidl (A/V^3)	Gain factor for gate-induced leakage current.
33	bgidl (V)	Probability factor for gate-induced drain leakage current at reference temperature.
34	cgidl	Factor for the lateral field dependence of the gate-induced leakage current.
35	cox (F)	Oxide capacitance for the intrinsic channel (* mult).
36	cgdo (F)	Oxide capacitance for the gate-drain overlap (* mult).
37	cgso (F)	Oxide capacitance for the gate-source overlap (* mult).
38	gatenoise	Flag for in/exclusion of induced gate thermal noise.
39	nt (J)	Thermal noise coefficient.
40	nfa ($1/(V_m^4)$)	First coefficient of the flicker noise.
41	nfb ($1/(V_m^2)$)	Second coefficient of the flicker noise.
42	nfc ($1/V$)	Third coefficient of the flicker noise.
43	tox (m)	Thickness of gate oxide layer.
44	rth (K/W)	Thermal resistance.
45	cth (J/K)	Thermal capacitance.

Operating-Point Parameters

1	ids (A)	Drain current, excl. avalanche and tunnel currents.
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Virtuoso Simulator Components and Device Models Reference

Philips Models

2	i_{avl} (A)	Substrate current due to weak-avalanche.
3	i_{gs} (A)	Gate-to-source current due to direct tunnelling.
4	i_{gd} (A)	Gate-to-drain current due to direct tunnelling.
5	i_{gb} (A)	Gate-to-bulk current due to direct tunnelling.
6	v_{ds} (V)	Drain-source voltage.
7	v_{gs} (V)	Gate-source voltage.
8	v_{sb} (V)	Source-bulk voltage.
9	v_{to} (V)	Zero-bias threshold voltage.
10	v_{ts} (V)	Threshold voltage including back-bias effects.
11	v_{th} (V)	Threshold voltage including back-bias and drain-bias effects.
12	v_{gt} (V)	Effective gate drive voltage including back-bias and drain voltage effects.
13	v_{dss} (V)	Drain saturation voltage at actual bias.
14	v_{sat} (V)	Saturation limit.
15	g_m (A/V)	Transconductance ($d i_{ds} / d v_{gs}$).
16	g_{mb} (A/V)	Substrate-transconductance ($d i_{ds} / d v_{bs}$).
17	g_{ds} (A/V)	Output conductance ($d i_{ds} / d v_{ds}$).
18	c_{dd} (F)	Capacitance ($d q_d / d v_d$).
19	c_{dg} (F)	Capacitance ($- d q_d / d v_g$).
20	c_{ds} (F)	Capacitance ($- d q_d / d v_s$).
21	c_{db} (F)	Capacitance ($- d q_d / d v_b$).
22	c_{gd} (F)	Capacitance ($- d q_g / d v_d$).

Virtuoso Simulator Components and Device Models Reference

Philips Models

23	c_{gg} (F)	Capacitance ($d q_g / d v_g$).
24	c_{gs} (F)	Capacitance ($- d q_g / d v_s$).
25	c_{gb} (F)	Capacitance ($- d q_g / d v_b$).
26	c_{sd} (F)	Capacitance ($- d q_s / d v_d$).
27	c_{sg} (F)	Capacitance ($- d q_s / d v_g$).
28	c_{ss} (F)	Capacitance ($d q_s / d v_s$).
29	c_{sb} (F)	Capacitance ($- d q_s / d v_b$).
30	c_{bd} (F)	Capacitance ($- d q_b / d v_d$).
31	c_{bg} (F)	Capacitance ($- d q_b / d v_g$).
32	c_{bs} (F)	Capacitance ($- d q_b / d v_s$).
33	c_{bb} (F)	Capacitance ($d q_b / d v_b$).
34	c_{gdol} (F)	Gate-drain overlap capacitance of the actual transistor.
35	c_{gsol} (F)	Gate-source overlap capacitance of the actual transistor.
36	u	Transistor gain (g_m/g_{ds}).
37	r_{out} (Ω)	Small-signal output resistance ($1/g_{ds}$).
38	v_{early} (V)	Equivalent Early voltage ($ I_D /g_{ds}$).
39	k_{eff} (\sqrt{V})	Body effect parameter.
40	b_{eff} (A/V^2)	Gain factor.
41	f_{ug} (Hz)	Unity gain frequency at actual bias ($g_m/(2*\pi*c_{in})$).
42	$sqrtsfw$ (V/\sqrt{Hz})	Input-referred RMS white noise voltage density.
43	$sqrtsff$ (V/\sqrt{Hz})	Input-referred RMS white noise voltage density at 1 kHz.

Virtuoso Simulator Components and Device Models Reference

Philips Models

44	<code>fknee</code> (Hz)	Cross-over frequency above which white noise is dominant.
45	<code>Pdiss</code> (W)	Dissipation.
46	<code>TK</code> (K)	Actual device temperature.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

<code>Pdiss</code>	OP-45	<code>cgso</code>	O-37	<code>ko</code>	M-5	<code>stphib</code>	M-8
<code>TK</code>	OP-46	<code>cgsol</code>	OP-35	<code>ko</code>	O-2	<code>stvfb</code>	M-4
<code>a1</code>	M-32	<code>cox</code>	M-47	<code>kov</code>	M-41	<code>theph</code>	M-13
<code>a1</code>	O-22	<code>cox</code>	O-35	<code>kov</code>	O-30	<code>theph</code>	O-7
<code>a2</code>	M-34	<code>cs</code>	M-57	<code>kpinv</code>	M-6	<code>ther</code>	M-19
<code>a2</code>	O-23	<code>cs</code>	O-10	<code>kpinv</code>	O-3	<code>ther</code>	O-11
<code>a3</code>	M-35	<code>csb</code>	OP-29	<code>level</code>	M-1	<code>ther1</code>	M-21
<code>a3</code>	O-24	<code>csd</code>	OP-26	<code>m</code>	I-3	<code>ther1</code>	O-12
<code>agidl</code>	M-43	<code>csg</code>	OP-27	<code>mbe</code>	M-64	<code>ther2</code>	M-22
<code>agidl</code>	O-32	<code>css</code>	OP-28	<code>mexp</code>	M-31	<code>ther2</code>	O-13
<code>alp</code>	M-29	<code>cth</code>	M-60	<code>mexp</code>	O-21	<code>thesat</code>	M-23
<code>alp</code>	O-19	<code>cth</code>	O-45	<code>mo</code>	M-27	<code>thesat</code>	O-14
<code>area</code>	I-4	<code>dta</code>	M-56	<code>mo</code>	O-17	<code>thesr</code>	M-11

Virtuoso Simulator Components and Device Models Reference

Philips Models

ath	M-61	etabet	M-10	mult	I-1	thesr	O-6
bacc	M-39	etacs	M-58	mvt	M-65	theth	M-25
bacc	O-28	etamob	M-15	nfa	M-52	theth	O-15
beff	OP-40	etamob	O-8	nfa	O-40	tnom	M-66
bet	M-9	etaph	M-14	nfb	M-53	tox	M-55
bet	O-5	etar	M-20	nfb	O-41	tox	O-43
bgidl	M-44	etasat	M-24	nfc	M-54	tr	M-2
bgidl	O-33	etasr	M-12	nfc	O-42	tref	M-67
binv	M-37	fknee	OP-44	nt	M-51	type	M-62
binv	O-26	fug	OP-41	nt	O-39	u	OP-36
cbb	OP-33	gatenoise	M-50	nu	M-17	vds	OP-6
cbd	OP-30	gatenoise	O-38	nu	O-9	vdss	OP-13
cbg	OP-31	gds	OP-17	nuexp	M-18	vearly	OP-38
cbs	OP-32	gm	OP-15	phib	M-7	vfb	M-3
cdb	OP-21	gmb	OP-16	phib	O-4	vfb	O-1
cdd	OP-18	iavl	OP-2	region	I-2	vfbov	M-40
cdg	OP-19	ids	OP-1	rout	OP-37	vfbov	O-29
cds	OP-20	igacc	M-38	rth	M-59	vgs	OP-7
cgb	OP-25	igacc	O-27	rth	O-44	vgt	OP-12
cgd	OP-22	igb	OP-5	sdibl	M-26	vp	M-30
cgdo	M-48	igd	OP-4	sdibl	O-16	vp	O-20

Virtuoso Simulator Components and Device Models Reference

Philips Models

cgdo	O-36	iginv	M-36	sqrtsff	OP-43	vsat	OP-14
cgdol	OP-34	iginv	O-25	sqrtsfw	OP-42	vsb	OP-8
cgg	OP-23	igov	M-42	ssf	M-28	vth	OP-11
cgidl	M-46	igov	O-31	ssf	O-18	vto	OP-9
cgidl	O-34	igs	OP-3	stal	M-33	vts	OP-10
cgs	OP-24	imax	M-63	stbgidl	M-45		
cgso	M-49	keff	OP-39	stetamob	M-16		

Lateral Double-diffused MOS Model (MOS Model Level 2001) (mos2001)

This is SimKit 4.0

This device is supported within altergroups.

This device is dynamically loaded from the shared object /vobs/spectre_dev/tools.lnx86/cmi/lib/5.0.doc/libphilips_sh.so

Instance Definition

Name d g s b ModelName parameter=value ...

Instance Parameters

- | | | |
|---|---------------|---|
| 1 | w=2e-05 m | Drawn width of the channel region. |
| 2 | wd=2e-05 m | Drawn width of the drift region. |
| 3 | mult=1 | Number of devices in parallel. |
| 4 | region=triode | Estimated DC operating region, used as a convergence aid. Possible values are off, triode, sat, or subth. |

Virtuoso Simulator Components and Device Models Reference

Philips Models

5 `m=1` Multiplicity factor.

6 `area=1` alias of mult.

Model Definition

```
model modelName mos2001 parameter=value ...
```

Model Parameters

1 `level=2e+03` Must be 2001.

2 `wvar=0 m` Width offset of the channel region.

3 `wdvar=0 m` Width offset of the drift region.

4 `tref=25 deg. C` Reference temperature.

5 `vfb=-1 V` Flatband voltage of the channel region, at reference temperature.

6 `stvfb=0 V/K` Temperature scaling coefficient for VFB.

7 `vfbd=-0.1 V` Flatband voltage of the drift region, at reference temperature.

8 `stvfbd=0 V/K` Temperature scaling coefficient for the flatband voltage of the drift region.

9 `kor=1.6 V^(1/2)` Body factor of the channel region of an infinitely wide transistor.

10 `swko=0` Width scaling coefficient for KO.

11 `kodr=1 V^-1/2` Body factor of the drift region of an infinitely wide transistor.

12 `swkod=0` Width scaling coefficient for the body factor of the drift region.

13 `phib=0.86 V` Surface potential at the onset of strong inversion in the channel region, at reference temperature.

14 `stphib=-0.0012 V/K` Temperature scaling coefficient for PHIB.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 15 $\text{phibd}=0.78 \text{ V}$ Surface potential at the onset of strong inversion in the drift region, at reference temperature.
- 16 $\text{stphibd}=-0.0012 \text{ V/K}$ Temperature scaling coefficient for PHIBD.
- 17 $\text{betw}=7\text{e}-05 \text{ A/V}^2$ Gain factor of a channel region of 1 μm wide, at reference temperature.
- 18 $\text{etabet}=1.6$ Temperature scaling exponent for BET.
- 19 $\text{betaccw}=7\text{e}-05 \text{ A/V}^{-2}$ Gain factor of drift region of 1 μm wide, at reference temperature.
- 20 $\text{etabetacc}=1.5$ Temperature scaling exponent for BETACC.
- 21 $\text{rdw}=4\text{e}+03 \text{ }\Omega$ On-resistance of a drift region of 1 μm wide, at reference temperature.
- 22 $\text{etard}=1.5$ Temperature scaling exponent for RD.
- 23 $\text{lamd}=0.2$ Quotient of the depletion layer thickness to the effective thickness of the drift region at $\text{VSB} = 0 \text{ V}$.
- 24 $\text{the1r}=0.09 \text{ V}^{-1}$ Mobility reduction coefficient of infinitely wide transistor, due to vertical strong-inversion field in a channel region.
- 25 $\text{swthe1}=0$ Width scaling coefficient for THE1.
- 26 $\text{the1acc}=0.02 \text{ V}^{-1}$ Mobility reduction coefficient in the drift region due to the vertical electrical field caused by accumulation.
- 27 $\text{the2r}=0.03 \text{ V}^{(-1/2)}$ Mobility reduction coefficient for $\text{VSB} > 0$ of an infinitely wide transistor, due to vertical depletion field in channel region.
- 28 $\text{swthe2}=0$ Width scaling coefficient for THE2.
- 29 $\text{the3r}=0.4 \text{ V}^{-1}$ Mobility reduction coefficient in a channel region of an infinitely wide transistor due to velocity saturation.
- 30 $\text{etathe3}=1$ Temperature scaling exponent for THE3.

Virtuoso Simulator Components and Device Models Reference

Philips Models

31	<code>swthe3=0</code>	Width scaling coefficient for THE3.
32	<code>mexp=2</code>	Smoothing factor for transition from linear to saturation regime.
33	<code>alp=0.002</code>	Factor for channel length modulation.
34	<code>vp=0.05 V</code>	Characteristic voltage of channel length modulation.
35	<code>sdibl=0.001 V^(-1/2)</code>	Factor for drain-induced barrier lowering.
36	<code>msdibl=3</code>	Exponent for the drain-induced barrier lowering dependence on the backgate bias.
37	<code>mo=0 V</code>	Parameter for the (short-channel) sub-threshold slope.
38	<code>ssf=1e-12 V^(-1/2)</code>	Factor for static feedback.
39	<code>a1r=15</code>	Factor of weak avalanche current of an infinitely wide transistor, at reference temperature.
40	<code>sta1=0 K⁻¹</code>	Temperature scaling coefficient for A1.
41	<code>swa1=0</code>	Width scaling coefficient for A1.
42	<code>a2=73 V</code>	Exponent of weak avalanche current.
43	<code>a3=0.8</code>	Factor of the drain-source voltage above which weak avalanche occurs.
44	<code>coxw=7.5e-16 F</code>	Oxide capacitance for an intrinsic channel region of 1um wide.
45	<code>coxdw=7.5e-16 F</code>	Oxide capacitance for an intrinsic drift region of 1um wide.
46	<code>cgdow=0 F</code>	Gate-to-drain overlap capacitance for a drift region of 1 um wide.
47	<code>cgsow=0 F</code>	Gate-to-source overlap capacitance for a channel region of 1 um wide.
48	<code>nt=1.65e-20 J</code>	Coefficient of thermal noise, at reference temperature.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 49 $nfaw=1.4e+25 \text{ V}^{-1} \text{ m}^{-4}$ First coefficient of flicker noise for a channel region of 1 μm wide.
- 50 $nfbw=2e+08 \text{ V}^{-1} \text{ m}^{-2}$ Second coefficient of flicker noise for a channel region of 1 μm wide.
- 51 $nfcw=0 \text{ V}^{-1}$ Third coefficient of flicker noise for a channel region of 1 μm wide.
- 52 $tox=3.8e-08 \text{ m}$ Thickness of the oxide above the channel region.
- 53 $dta=0 \text{ K}$ Temperature offset to the ambient temperature.
- 54 $type=n$ Transistor gender.
Possible values are n, p, npn, pnp, npnv, pnpv, npnl, or pnp1.
- 55 $imax=1.0 \text{ A}$ Explosion current.
- 56 $tnom$ (deg. C) alias of $tnom$.
- 57 tr (deg. C) alias of $tnom$.

Output Parameters

- 1 vfb (V) Flatband voltage of the channel region, at reference temperature.
- 2 $vfbd$ (V) Flatband voltage of the drift region.
- 3 ko ($\text{V}^{1/2}$) Body factor of the channel region.
- 4 kod ($\text{V}^{-1/2}$) Body factor of the drift region.
- 5 $phib$ (V) Surface potential at the onset of strong inversion in the channel region, at reference temperature.
- 6 $phibd$ (V) Surface potential at the onset of strong inversion in the drift region, at reference temperature.
- 7 bet (A/V^2) Gain factor of the channel region, at reference temperature.
- 8 $betacc$ (A/V^2) Gain factor for accumulation in the drift region, at reference temperature.

Virtuoso Simulator Components and Device Models Reference

Philips Models

9	r_d (Ω)	On-resistance of the drift region, at reference temperature.
10	λ_{amd}	Quotient of the depletion layer thickness to the effective thickness of the drift region at $V_{SB} = 0$ V.
11	θ_{e1} (V^{-1})	Mobility reduction coefficient in the channel region due to vertical electrical field caused by strong inversion.
12	θ_{e1acc} (V^{-1})	Mobility reduction coefficient in the drift region due to the vertical electrical field caused by accumulation.
13	θ_{e2} ($V^{-1/2}$)	Mobility reduction coefficient for $V_{SB} > 0$ in the channel region due to the vertical electrical field caused by depletion.
14	θ_{e3} (V^{-1})	Mobility reduction coefficient in the channel region due to the horizontal electrical field caused by velocity saturation.
15	m_{exp}	Smoothing factor for transition from linear to saturation regime.
16	α_p	Factor for channel length modulation.
17	v_p (V)	Characteristic voltage of channel length modulation.
18	s_{dibl} ($V^{-1/2}$)	Factor for drain-induced barrier lowering.
19	m_{sdibl}	Exponent for the drain-induced barrier lowering dependence on the backgate bias.
20	m_0 (V)	Parameter for the (short-channel) sub-threshold slope.
21	s_{sf} ($V^{-1/2}$)	Factor for static feedback.
22	a_1	Factor of weak avalanche current, at reference temperature.
23	a_2 (V)	Exponent of weak avalanche current.
24	a_3	Factor of the drain-source voltage above which weak avalanche occurs.
25	c_{ox} (F)	Oxide capacitance for the intrinsic channel region.
26	c_{oxd} (F)	Oxide capacitance for the intrinsic drift region.

Virtuoso Simulator Components and Device Models Reference

Philips Models

27	$cgdo$ (F)	Gate-to-drain overlap capacitance.
28	$cgso$ (F)	Gate-to-source overlap capacitance.
29	nt (J)	Coefficient of thermal noise, at reference temperature.
30	nfa ($V^{-1} m^{-4}$)	First coefficient of flicker noise.
31	nfb ($V^{-1} m^{-2}$)	Second coefficient of flicker noise.
32	nfc (V^{-1})	Third coefficient of flicker noise.
33	tox (m)	Thickness of the oxide above the channel region.

Operating-Point Parameters

1	ids (A)	Drain current, excl. avalanche and tunnel currents.
2	$iavl$ (A)	Substrate current due to weak-avalanche.
3	vds (V)	Drain-source voltage.
4	vgs (V)	Gate-source voltage.
5	vsb (V)	Source-bulk voltage.
6	vto (V)	Zero-bias threshold voltage.
7	vtb (V)	Threshold voltage including back-bias effects.
8	vth (V)	Threshold voltage including back-bias and drain-bias effects.
9	vgt (V)	Effective gate drive voltage including back-bias and drain voltage effects.
10	$vtod$ (V)	Threshold voltage of the drift region.
11	$vdiseff$ (V)	Effective internal drain-to-source voltage at actual bias.
12	$vdissat$ (V)	Internal drain saturation voltage at actual bias.
13	$vdssat$ (V)	Drain-source saturation voltage at actual bias.

Virtuoso Simulator Components and Device Models Reference

Philips Models

14	g_m (A/V)	Transconductance ($d i_{ds} / d v_{gs}$).
15	g_{mb} (A/V)	Substrate-transconductance ($d i_{ds} / d v_{bs}$).
16	g_{ds} (A/V)	Output conductance ($d i_{ds} / d v_{ds}$).
17	c_{dd} (F)	Capacitance ($d q_d / d v_d$).
18	c_{dg} (F)	Capacitance ($- d q_d / d v_g$).
19	c_{ds} (F)	Capacitance ($- d q_d / d v_s$).
20	c_{db} (F)	Capacitance ($- d q_d / d v_b$).
21	c_{gd} (F)	Capacitance ($- d q_g / d v_d$).
22	c_{gg} (F)	Capacitance ($d q_g / d v_g$).
23	c_{gs} (F)	Capacitance ($- d q_g / d v_s$).
24	c_{gb} (F)	Capacitance ($- d q_g / d v_b$).
25	c_{sd} (F)	Capacitance ($- d q_s / d v_d$).
26	c_{sg} (F)	Capacitance ($- d q_s / d v_g$).
27	c_{ss} (F)	Capacitance ($d q_s / d v_s$).
28	c_{sb} (F)	Capacitance ($- d q_s / d v_b$).
29	c_{bd} (F)	Capacitance ($- d q_b / d v_d$).
30	c_{bg} (F)	Capacitance ($- d q_b / d v_g$).
31	c_{bs} (F)	Capacitance ($- d q_b / d v_s$).
32	c_{bb} (F)	Capacitance ($d q_b / d v_b$).
33	w_{eff} (m)	Effective channel width for geometrical models.
34	w_{defl} (m)	Effective drift region width for geometrical model.
35	u	Transistor gain (g_m/g_{ds}).

Virtuoso Simulator Components and Device Models Reference

Philips Models

36	<code>rout</code> (Ω)	Small-signal output resistance (1/gds).
37	<code>vearly</code> (V)	Equivalent Early voltage ($ idl /gds$).
38	<code>bef</code> (A/V^2)	Gain factor.
39	<code>fug</code> (Hz)	Unity gain frequency at actual bias ($gm/(2*\pi*cin)$).
40	<code>gmmos</code> (A/V)	Transconductance of channel region.
41	<code>sqrtsfw</code> ($V/Hz^{1/2}$)	Input-referred RMS white noise voltage density.
42	<code>sqrtsff</code> ($V/Hz^{1/2}$)	Input-referred RMS white noise voltage density at 1 kHz.
43	<code>fknee</code> (Hz)	Cross-over frequency above which white noise is dominant.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

<code>a1</code>	<code>O-22</code>	<code>csd</code>	<code>OP-25</code>	<code>nfbw</code>	<code>M-50</code>	<code>the2r</code>	<code>M-27</code>
<code>a1r</code>	<code>M-39</code>	<code>csg</code>	<code>OP-26</code>	<code>nfc</code>	<code>O-32</code>	<code>the3</code>	<code>O-14</code>
<code>a2</code>	<code>M-42</code>	<code>css</code>	<code>OP-27</code>	<code>nfcw</code>	<code>M-51</code>	<code>the3r</code>	<code>M-29</code>
<code>a2</code>	<code>O-23</code>	<code>dta</code>	<code>M-53</code>	<code>nt</code>	<code>M-48</code>	<code>tnom</code>	<code>M-56</code>
<code>a3</code>	<code>M-43</code>	<code>etabet</code>	<code>M-18</code>	<code>nt</code>	<code>O-29</code>	<code>tox</code>	<code>M-52</code>
<code>a3</code>	<code>O-24</code>	<code>etabetacc</code>	<code>M-20</code>	<code>phib</code>	<code>M-13</code>	<code>tox</code>	<code>O-33</code>
<code>alp</code>	<code>M-33</code>	<code>etard</code>	<code>M-22</code>	<code>phib</code>	<code>O-5</code>	<code>tr</code>	<code>M-57</code>

Virtuoso Simulator Components and Device Models Reference

Philips Models

alp O-16	etathe3 M-30	phibd M-15	tref M-4
area I-6	fknee OP-43	phibd O-6	type M-54
beff OP-38	fug OP-39	rd O-9	u OP-35
bet O-7	gds OP-16	rdw M-21	vdiseff OP-11
betacc O-8	gm OP-14	region I-4	vdissat OP-12
betaccw M-19	gmb OP-15	rout OP-36	vds OP-3
betw M-17	gmmos OP-40	sdibl M-35	vdssat OP-13
cbb OP-32	iavl OP-2	sdibl O-18	vearly OP-37
cbd OP-29	ids OP-1	sqrtsff OP-42	vfb M-5
cbg OP-30	imax M-55	sqrtsfw OP-41	vfb O-1
cbs OP-31	ko O-3	ssf M-38	vfbd M-7
cdb OP-20	kod O-4	ssf O-21	vfbd O-2
cdd OP-17	kodr M-11	stal M-40	vgs OP-4
cdg OP-18	kor M-9	stphib M-14	vgt OP-9
cds OP-19	lamd M-23	stphibd M-16	vp M-34
cgb OP-24	lamd O-10	stvfb M-6	vp O-17
cgd OP-21	level M-1	stvfbd M-8	vsb OP-5
cgdo O-27	m I-5	swal M-41	vth OP-8
cgdow M-46	mexp M-32	swko M-10	vto OP-6
cgg OP-22	mexp O-15	swkod M-12	vtod OP-10
cgs OP-23	mo M-37	swthel M-25	vts OP-7

Virtuoso Simulator Components and Device Models Reference

Philips Models

cgso	O-28	mo	O-20	swthe2	M-28	w	I-1
cgsow	M-47	msdibl	M-36	swthe3	M-31	wd	I-2
cox	O-25	msdibl	O-19	the1	O-11	wdeff	OP-34
coxd	O-26	mult	I-3	the1acc	M-26	wdvar	M-3
coxdw	M-45	nfa	O-30	the1acc	O-12	weff	OP-33
coxw	M-44	nfaw	M-49	the1r	M-24	wvar	M-2
csb	OP-28	nfb	O-31	the2	O-13		

Lateral Double-diffused MOS Model (MOS Model Level 2001) (mos2001e)

This is SimKit 4.0

This device is supported within altergroups.

This device is dynamically loaded from the shared object /vobs/spectre_dev/tools.lnx86/cmi/lib/5.0.doc/libphilips_sh.so

Instance Definition

Name d g s b ModelName parameter=value ...

Instance Parameters

- 1 mult=1 Number of devices in parallel.
- 2 region=triode Estimated DC operating region, used as a convergence aid. Possible values are off, triode, sat, or subth.
- 3 m=1 Multiplicity factor.
- 4 area=1 alias of mult.

Virtuoso Simulator Components and Device Models Reference

Philips Models

Model Definition

```
model modelName mos2001e parameter=value ...
```

Model Parameters

- | | | |
|----|---------------------------------|---|
| 1 | level=2e+03 | Must be 2001. |
| 2 | tref=25 deg. C | Reference temperature. |
| 3 | vfb=-1 V | Flatband voltage of the channel region, at reference temperature. |
| 4 | stvfb=0 V/K | Temperature scaling coefficient for VFB. |
| 5 | vfbd=-0.1 V | Flatband voltage of the drift region, at reference temperature. |
| 6 | stvfbd=0 V/K | Temperature scaling coefficient for the flatband voltage of the drift region. |
| 7 | ko=1.6 V ^(1/2) | Body factor of the channel region. |
| 8 | kod=1 V ^{-1/2} | Body factor of the drift region. |
| 9 | phib=0.86 V | Surface potential at the onset of strong inversion in the channel region, at reference temperature. |
| 10 | stphib=-0.0012 V/K | Temperature scaling coefficient for PHIB. |
| 11 | phibd=0.78 V | Surface potential at the onset of strong inversion in the drift region, at reference temperature. |
| 12 | stphibd=-0.0012 V/K | Temperature scaling coefficient for PHIBD. |
| 13 | bet=0.0014 A/V ² | Gain factor of the channel region, at reference temperature. |
| 14 | etabet=1.6 | Temperature scaling exponent for BET. |
| 15 | betacc=0.0014 A/V ⁻² | Gain factor for accumulation in the drift region, at reference temperature. |

Virtuoso Simulator Components and Device Models Reference

Philips Models

16	$etabetacc=1.5$	Temperature scaling exponent for BETACC.
17	$rd=200 \Omega$	On-resistance of the drift region, at reference temperature.
18	$etard=1.5$	Temperature scaling exponent for RD.
19	$lamd=0.2$	Quotient of the depletion layer thickness to the effective thickness of the drift region at $V_{SB} = 0$ V.
20	$the1=0.09 V^{-1}$	Mobility reduction coefficient in the channel region due to vertical electrical field caused by strong inversion.
21	$the1acc=0.02 V^{-1}$	Mobility reduction coefficient in the drift region due to the vertical electrical field caused by accumulation.
22	$the2=0.03 V^{(-1/2)}$	Mobility reduction coefficient for $V_{SB} > 0$ in the channel region due to the vertical electrical field caused by depletion.
23	$the3=0.4 V^{-1}$	Mobility reduction coefficient in the channel region due to the horizontal electrical field caused by velocity saturation.
24	$etathe3=1$	Temperature scaling exponent for THE3.
25	$mexp=2$	Smoothing factor for transition from linear to saturation regime.
26	$alp=0.002$	Factor for channel length modulation.
27	$vp=0.05 V$	Characteristic voltage of channel length modulation.
28	$sdibl=0.001 V^{(-1/2)}$	Factor for drain-induced barrier lowering.
29	$msdibl=3$	Exponent for the drain-induced barrier lowering dependence on the backgate bias.
30	$mo=0 V$	Parameter for the (short-channel) sub-threshold slope.
31	$ssf=1e-12 V^{(-1/2)}$	Factor for static feedback.
32	$a1=15$	Factor of weak avalanche current, at reference temperature.

Virtuoso Simulator Components and Device Models Reference

Philips Models

33	$sta1=0 \text{ K}^{-1}$	Temperature scaling coefficient for A1.
34	$a2=73 \text{ V}$	Exponent of weak avalanche current.
35	$a3=0.8$	Factor of the drain-source voltage above which weak avalanche occurs.
36	$cox=1.5e-14 \text{ F}$	Oxide capacitance for the intrinsic channel region.
37	$coxd=1.5e-14 \text{ F}$	Oxide capacitance for the intrinsic drift region.
38	$cgdo=0 \text{ F}$	Gate-to-drain overlap capacitance.
39	$cgso=0 \text{ F}$	Gate-to-source overlap capacitance.
40	$nt=1.65e-20 \text{ J}$	Coefficient of thermal noise, at reference temperature.
41	$nfa=7e+23 \text{ V}^{-1} \text{ m}^{-4}$	First coefficient of flicker noise.
42	$nfb=1e+07 \text{ V}^{-1} \text{ m}^{-2}$	Second coefficient of flicker noise.
43	$nfc=0 \text{ V}^{-1}$	Third coefficient of flicker noise.
44	$tox=3.8e-08 \text{ m}$	Thickness of the oxide above the channel region.
45	$dta=0 \text{ K}$	Temperature offset to the ambient temperature.
46	$type=n$	Transistor gender. Possible values are n, p, npn, pnp, npnv, pnpv, npnl, or pnp1.
47	$imax=1.0 \text{ A}$	Explosion current.
48	$tnom \text{ (deg. C)}$	alias of tnom.
49	$tr \text{ (deg. C)}$	alias of tnom.

Output Parameters

1	$vfb \text{ (V)}$	Flatband voltage of the channel region, at reference temperature.
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Virtuoso Simulator Components and Device Models Reference

Philips Models

2	v_{fbd} (V)	Flatband voltage of the drift region.
3	k_o ($V^{1/2}$)	Body factor of the channel region.
4	k_{od} ($V^{-1/2}$)	Body factor of the drift region.
5	ϕ_{ib} (V)	Surface potential at the onset of strong inversion in the channel region, at reference temperature.
6	ϕ_{ibd} (V)	Surface potential at the onset of strong inversion in the drift region, at reference temperature.
7	β_{et} (A/V^2)	Gain factor of the channel region, at reference temperature.
8	β_{etacc} (A/V^2)	Gain factor for accumulation in the drift region, at reference temperature.
9	r_d (Ω)	On-resistance of the drift region, at reference temperature.
10	λ_{md}	Quotient of the depletion layer thickness to the effective thickness of the drift region at $V_{SB} = 0$ V.
11	θ_{e1} (V^{-1})	Mobility reduction coefficient in the channel region due to vertical electrical field caused by strong inversion.
12	θ_{e1acc} (V^{-1})	Mobility reduction coefficient in the drift region due to the vertical electrical field caused by accumulation.
13	θ_{e2} ($V^{-1/2}$)	Mobility reduction coefficient for $V_{SB} > 0$ in the channel region due to the vertical electrical field caused by depletion.
14	θ_{e3} (V^{-1})	Mobility reduction coefficient in the channel region due to the horizontal electrical field caused by velocity saturation.
15	m_{exp}	Smoothing factor for transition from linear to saturation regime.
16	α_p	Factor for channel length modulation.
17	v_p (V)	Characteristic voltage of channel length modulation.
18	s_{dibl} ($V^{-1/2}$)	Factor for drain-induced barrier lowering.

Virtuoso Simulator Components and Device Models Reference

Philips Models

19	$msdibl$	Exponent for the drain-induced barrier lowering dependence on the backgate bias.
20	mo (V)	Parameter for the (short-channel) sub-threshold slope.
21	ssf ($V^{-1/2}$)	Factor for static feedback.
22	$a1$	Factor of weak avalanche current, at reference temperature.
23	$a2$ (V)	Exponent of weak avalanche current.
24	$a3$	Factor of the drain-source voltage above which weak avalanche occurs.
25	cox (F)	Oxide capacitance for the intrinsic channel region.
26	cox_d (F)	Oxide capacitance for the intrinsic drift region.
27	$cgdo$ (F)	Gate-to-drain overlap capacitance.
28	$cgso$ (F)	Gate-to-source overlap capacitance.
29	nt (J)	Coefficient of thermal noise, at reference temperature.
30	nfa ($V^{-1} m^{-4}$)	First coefficient of flicker noise.
31	nfb ($V^{-1} m^{-2}$)	Second coefficient of flicker noise.
32	nfc (V^{-1})	Third coefficient of flicker noise.
33	tox (m)	Thickness of the oxide above the channel region.

Operating-Point Parameters

1	ids (A)	Drain current, excl. avalanche and tunnel currents.
2	$iavl$ (A)	Substrate current due to weak-avalanche.
3	vds (V)	Drain-source voltage.
4	vgs (V)	Gate-source voltage.
5	vsb (V)	Source-bulk voltage.

Virtuoso Simulator Components and Device Models Reference

Philips Models

6	v_{to} (V)	Zero-bias threshold voltage.
7	v_{ts} (V)	Threshold voltage including back-bias effects.
8	v_{th} (V)	Threshold voltage including back-bias and drain-bias effects.
9	v_{gt} (V)	Effective gate drive voltage including back-bias and drain voltage effects.
10	v_{tod} (V)	Threshold voltage of the drift region.
11	$v_{dis\text{eff}}$ (V)	Effective internal drain-to-source voltage at actual bias.
12	v_{dissat} (V)	Internal drain saturation voltage at actual bias.
13	v_{dssat} (V)	Drain-source saturation voltage at actual bias.
14	g_m (A/V)	Transconductance ($d\ i_{ds} / d\ v_{gs}$).
15	g_{mb} (A/V)	Substrate-transconductance ($d\ i_{ds} / d\ v_{bs}$).
16	g_{ds} (A/V)	Output conductance ($d\ i_{ds} / d\ v_{ds}$).
17	c_{dd} (F)	Capacitance ($d\ q_d / d\ v_d$).
18	c_{dg} (F)	Capacitance ($- d\ q_d / d\ v_g$).
19	c_{ds} (F)	Capacitance ($- d\ q_d / d\ v_s$).
20	c_{db} (F)	Capacitance ($- d\ q_d / d\ v_b$).
21	c_{gd} (F)	Capacitance ($- d\ q_g / d\ v_d$).
22	c_{gg} (F)	Capacitance ($d\ q_g / d\ v_g$).
23	c_{gs} (F)	Capacitance ($- d\ q_g / d\ v_s$).
24	c_{gb} (F)	Capacitance ($- d\ q_g / d\ v_b$).
25	c_{sd} (F)	Capacitance ($- d\ q_s / d\ v_d$).
26	c_{sg} (F)	Capacitance ($- d\ q_s / d\ v_g$).

Virtuoso Simulator Components and Device Models Reference

Philips Models

27	c_{ss} (F)	Capacitance ($d q_s / d v_s$).
28	c_{sb} (F)	Capacitance ($- d q_s / d v_b$).
29	c_{bd} (F)	Capacitance ($- d q_b / d v_d$).
30	c_{bg} (F)	Capacitance ($- d q_b / d v_g$).
31	c_{bs} (F)	Capacitance ($- d q_b / d v_s$).
32	c_{bb} (F)	Capacitance ($d q_b / d v_b$).
33	u	Transistor gain (g_m/g_{ds}).
34	r_{out} (Ω)	Small-signal output resistance ($1/g_{ds}$).
35	v_{early} (V)	Equivalent Early voltage ($ i_d /g_{ds}$).
36	b_{eff} (A/V^2)	Gain factor.
37	f_{ug} (Hz)	Unity gain frequency at actual bias ($g_m/(2*\pi*c_{in})$).
38	g_{mmos} (A/V)	Transconductance of channel region.
39	$sqrtsfw$ ($V/Hz^{1/2}$)	Input-referred RMS white noise voltage density.
40	$sqrtsff$ ($V/Hz^{1/2}$)	Input-referred RMS white noise voltage density at 1 kHz.
41	f_{knee} (Hz)	Cross-over frequency above which white noise is dominant.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

Virtuoso Simulator Components and Device Models Reference

Philips Models

a1	M-32	coxd	M-37	msdibl	M-29	thelacc	M-21
a1	O-22	coxd	O-26	msdibl	O-19	thelacc	O-12
a2	M-34	csb	OP-28	mult	I-1	the2	M-22
a2	O-23	csd	OP-25	nfa	M-41	the2	O-13
a3	M-35	csg	OP-26	nfa	O-30	the3	M-23
a3	O-24	css	OP-27	nfb	M-42	the3	O-14
alp	M-26	dta	M-45	nfb	O-31	tnom	M-48
alp	O-16	etabet	M-14	nfc	M-43	tox	M-44
area	I-4	etabetacc	M-16	nfc	O-32	tox	O-33
beff	OP-36	etard	M-18	nt	M-40	tr	M-49
bet	M-13	etathe3	M-24	nt	O-29	tref	M-2
bet	O-7	fknee	OP-41	phib	M-9	type	M-46
betacc	M-15	fug	OP-37	phib	O-5	u	OP-33
betacc	O-8	gds	OP-16	phibd	M-11	vdisseff	OP-11
cbb	OP-32	gm	OP-14	phibd	O-6	vdissat	OP-12
cbd	OP-29	gmb	OP-15	rd	M-17	vds	OP-3
cbg	OP-30	gmмос	OP-38	rd	O-9	vdssat	OP-13
cbs	OP-31	iavl	OP-2	region	I-2	vearly	OP-35
cdb	OP-20	ids	OP-1	rout	OP-34	vfb	M-3
cdd	OP-17	imax	M-47	sdibl	M-28	vfb	O-1

Virtuoso Simulator Components and Device Models Reference

Philips Models

cdg	OP-18	ko	M-7	sdibl	O-18	vfbd	M-5
cds	OP-19	ko	O-3	sqrtsff	OP-40	vfbd	O-2
cgb	OP-24	kod	M-8	sqrtsfw	OP-39	vgs	OP-4
cgd	OP-21	kod	O-4	ssf	M-31	vgt	OP-9
cgdo	M-38	lamd	M-19	ssf	O-21	vp	M-27
cgdo	O-27	lamd	O-10	stal	M-33	vp	O-17
cgg	OP-22	level	M-1	stphib	M-10	vsb	OP-5
cgs	OP-23	m	I-3	stphibd	M-12	vth	OP-8
cgso	M-39	mexp	M-25	stvfb	M-4	vto	OP-6
cgso	O-28	mexp	O-15	stvfbd	M-6	vtod	OP-10
cox	M-36	mo	M-30	thel	M-20	vts	OP-7
cox	O-25	mo	O-20	thel	O-11		

Lateral Double-diffused MOS Model (MOS Model Level 2001) (mos2001et)

This is SimKit 4.0

This device is supported within altergroups.

This device is dynamically loaded from the shared object /vobs/spectre_dev/tools.lnx86/cmi/lib/5.0.doc/libphilips_sh.so

Instance Definition

Name d g s b dt ModelName parameter=value ...

Virtuoso Simulator Components and Device Models Reference

Philips Models

Instance Parameters

- | | | |
|---|----------------------------|---|
| 1 | <code>mult=1</code> | Number of devices in parallel. |
| 2 | <code>region=triode</code> | Estimated DC operating region, used as a convergence aid. Possible values are <code>off</code> , <code>triode</code> , <code>sat</code> , or <code>subth</code> . |
| 3 | <code>m=1</code> | Multiplicity factor. |
| 4 | <code>area=1</code> | alias of <code>mult</code> . |

Model Definition

```
model modelName mos2001et parameter=value ...
```

Model Parameters

- | | | |
|----|---------------------------------|---|
| 1 | <code>level=2e+03</code> | Must be 2001. |
| 2 | <code>tref=25 deg. C</code> | Reference temperature. |
| 3 | <code>vfb=-1 V</code> | Flatband voltage of the channel region, at reference temperature. |
| 4 | <code>stvfb=0 V/K</code> | Temperature scaling coefficient for VFB. |
| 5 | <code>vfbd=-0.1 V</code> | Flatband voltage of the drift region, at reference temperature. |
| 6 | <code>stvfbd=0 V/K</code> | Temperature scaling coefficient for the flatband voltage of the drift region. |
| 7 | <code>ko=1.6 V^(1/2)</code> | Body factor of the channel region. |
| 8 | <code>kod=1 V^-1/2</code> | Body factor of the drift region. |
| 9 | <code>phib=0.86 V</code> | Surface potential at the onset of strong inversion in the channel region, at reference temperature. |
| 10 | <code>stphib=-0.0012 V/K</code> | Temperature scaling coefficient for PHIB. |
| 11 | <code>phibd=0.78 V</code> | Surface potential at the onset of strong inversion in the drift region, at reference temperature. |

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 12 $stphibd=-0.0012 \text{ V/K}$ Temperature scaling coefficient for PHIBD.
- 13 $bet=0.0014 \text{ A/V}^2$ Gain factor of the channel region, at reference temperature.
- 14 $etabet=1.6$ Temperature scaling exponent for BET.
- 15 $betacc=0.0014 \text{ A/V}^{-2}$ Gain factor for accumulation in the drift region, at reference temperature.
- 16 $etabetacc=1.5$ Temperature scaling exponent for BETACC.
- 17 $rd=200 \text{ } \Omega$ On-resistance of the drift region, at reference temperature.
- 18 $etard=1.5$ Temperature scaling exponent for RD.
- 19 $lamd=0.2$ Quotient of the depletion layer thickness to the effective thickness of the drift region at $V_{SB} = 0 \text{ V}$.
- 20 $the1=0.09 \text{ V}^{-1}$ Mobility reduction coefficient in the channel region due to vertical electrical field caused by strong inversion.
- 21 $the1acc=0.02 \text{ V}^{-1}$ Mobility reduction coefficient in the drift region due to the vertical electrical field caused by accumulation.
- 22 $the2=0.03 \text{ V}^{(-1/2)}$ Mobility reduction coefficient for $V_{SB} > 0$ in the channel region due to the vertical electrical field caused by depletion.
- 23 $the3=0.4 \text{ V}^{-1}$ Mobility reduction coefficient in the channel region due to the horizontal electrical field caused by velocity saturation.
- 24 $etathe3=1$ Temperature scaling exponent for THE3.
- 25 $mexp=2$ Smoothing factor for transition from linear to saturation regime.
- 26 $alp=0.002$ Factor for channel length modulation.
- 27 $vp=0.05 \text{ V}$ Characteristic voltage of channel length modulation.
- 28 $sdibl=0.001 \text{ V}^{(-1/2)}$ Factor for drain-induced barrier lowering.

Virtuoso Simulator Components and Device Models Reference

Philips Models

29	$msdibl=3$	Exponent for the drain-induced barrier lowering dependence on the backgate bias.
30	$mo=0$ V	Parameter for the (short-channel) sub-threshold slope.
31	$ssf=1e-12$ V ^(-1/2)	Factor for static feedback.
32	$a1=15$	Factor of weak avalanche current, at reference temperature.
33	$sta1=0$ K ⁻¹	Temperature scaling coefficient for A1.
34	$a2=73$ V	Exponent of weak avalanche current.
35	$a3=0.8$	Factor of the drain-source voltage above which weak avalanche occurs.
36	$cox=1.5e-14$ F	Oxide capacitance for the intrinsic channel region.
37	$coxd=1.5e-14$ F	Oxide capacitance for the intrinsic drift region.
38	$cgdo=0$ F	Gate-to-drain overlap capacitance.
39	$cgso=0$ F	Gate-to-source overlap capacitance.
40	$nt=1.65e-20$ J	Coefficient of thermal noise, at reference temperature.
41	$nfa=7e+23$ V ⁻¹ m ⁻⁴	First coefficient of flicker noise.
42	$nfb=1e+07$ V ⁻¹ m ⁻²	Second coefficient of flicker noise.
43	$nfc=0$ V ⁻¹	Third coefficient of flicker noise.
44	$tox=3.8e-08$ m	Thickness of the oxide above the channel region.
45	$dta=0$ K	Temperature offset to the ambient temperature.
46	$rth=300$ K/W	Thermal resistance.
47	$cth=3e-09$ J/K	Thermal capacitance.

Virtuoso Simulator Components and Device Models Reference

Philips Models

48	<code>ath=0</code>	Temperature coefficient of the thermal resistance.
49	<code>type=n</code>	Transistor gender. Possible values are <code>n</code> , <code>p</code> , <code>npn</code> , <code>pnv</code> , <code>npnv</code> , <code>pnpl</code> , or <code>pnpl</code> .
50	<code>imax=1.0 A</code>	Explosion current.
51	<code>tnom (deg. C)</code>	alias of <code>tnom</code> .
52	<code>tr (deg. C)</code>	alias of <code>tnom</code> .

Output Parameters

1	<code>vfb (V)</code>	Flatband voltage of the channel region, at reference temperature.
2	<code>vfbd (V)</code>	Flatband voltage of the drift region.
3	<code>ko (V^{1/2})</code>	Body factor of the channel region.
4	<code>kod (V^{-1/2})</code>	Body factor of the drift region.
5	<code>phib (V)</code>	Surface potential at the onset of strong inversion in the channel region, at reference temperature.
6	<code>phibd (V)</code>	Surface potential at the onset of strong inversion in the drift region, at reference temperature.
7	<code>bet (A/V²)</code>	Gain factor of the channel region, at reference temperature.
8	<code>betacc (A/V²)</code>	Gain factor for accumulation in the drift region, at reference temperature.
9	<code>rd (Ω)</code>	On-resistance of the drift region, at reference temperature.
10	<code>lamd</code>	Quotient of the depletion layer thickness to the effective thickness of the drift region at $V_{SB} = 0$ V.
11	<code>the1 (V⁻¹)</code>	Mobility reduction coefficient in the channel region due to vertical electrical field caused by strong inversion.
12	<code>the1acc (V⁻¹)</code>	Mobility reduction coefficient in the drift region due to the vertical electrical field caused by accumulation.

Virtuoso Simulator Components and Device Models Reference

Philips Models

13	the2 ($V^{-1/2}$)	Mobility reduction coefficient for $V_{SB} > 0$ in the channel region due to the vertical electrical field caused by depletion.
14	the3 (V^{-1})	Mobility reduction coefficient in the channel region due to the horizontal electrical field caused by velocity saturation.
15	mexp	Smoothing factor for transition from linear to saturation regime.
16	alp	Factor for channel length modulation.
17	vp (V)	Characteristic voltage of channel length modulation.
18	sdibl ($V^{-1/2}$)	Factor for drain-induced barrier lowering.
19	msdibl	Exponent for the drain-induced barrier lowering dependence on the backgate bias.
20	mo (V)	Parameter for the (short-channel) sub-threshold slope.
21	ssf ($V^{-1/2}$)	Factor for static feedback.
22	a1	Factor of weak avalanche current, at reference temperature.
23	a2 (V)	Exponent of weak avalanche current.
24	a3	Factor of the drain-source voltage above which weak avalanche occurs.
25	cox (F)	Oxide capacitance for the intrinsic channel region.
26	$\text{cox}\bar{d}$ (F)	Oxide capacitance for the intrinsic drift region.
27	cgdo (F)	Gate-to-drain overlap capacitance.
28	cgso (F)	Gate-to-source overlap capacitance.
29	nt (J)	Coefficient of thermal noise, at reference temperature.
30	nfa ($V^{-1} m^{-4}$)	First coefficient of flicker noise.
31	nfb ($V^{-1} m^{-2}$)	Second coefficient of flicker noise.
32	nfc (V^{-1})	Third coefficient of flicker noise.

Virtuoso Simulator Components and Device Models Reference

Philips Models

33	t_{ox} (m)	Thickness of the oxide above the channel region.
34	r_{th} (K/W)	Thermal resistance.
35	c_{th} (J/K)	Thermal capacitance.

Operating-Point Parameters

1	i_{ds} (A)	Drain current, excl. avalanche and tunnel currents.
2	i_{avl} (A)	Substrate current due to weak-avalanche.
3	v_{ds} (V)	Drain-source voltage.
4	v_{gs} (V)	Gate-source voltage.
5	v_{sb} (V)	Source-bulk voltage.
6	v_{to} (V)	Zero-bias threshold voltage.
7	v_{ts} (V)	Threshold voltage including back-bias effects.
8	v_{th} (V)	Threshold voltage including back-bias and drain-bias effects.
9	v_{gt} (V)	Effective gate drive voltage including back-bias and drain voltage effects.
10	v_{tod} (V)	Threshold voltage of the drift region.
11	$v_{disseff}$ (V)	Effective internal drain-to-source voltage at actual bias.
12	v_{dissat} (V)	Internal drain saturation voltage at actual bias.
13	v_{dssat} (V)	Drain-source saturation voltage at actual bias.
14	g_m (A/V)	Transconductance ($d i_{ds} / d v_{gs}$).
15	g_{mb} (A/V)	Substrate-transconductance ($d i_{ds} / d v_{sb}$).
16	g_{ds} (A/V)	Output conductance ($d i_{ds} / d v_{ds}$).
17	c_{dd} (F)	Capacitance ($d q_d / d v_d$).

Virtuoso Simulator Components and Device Models Reference

Philips Models

18	c_{dg} (F)	Capacitance ($-d q_d / d v_g$).
19	c_{ds} (F)	Capacitance ($-d q_d / d v_s$).
20	c_{db} (F)	Capacitance ($-d q_d / d v_b$).
21	c_{gd} (F)	Capacitance ($-d q_g / d v_d$).
22	c_{gg} (F)	Capacitance ($d q_g / d v_g$).
23	c_{gs} (F)	Capacitance ($-d q_g / d v_s$).
24	c_{gb} (F)	Capacitance ($-d q_g / d v_b$).
25	c_{sd} (F)	Capacitance ($-d q_s / d v_d$).
26	c_{sg} (F)	Capacitance ($-d q_s / d v_g$).
27	c_{ss} (F)	Capacitance ($d q_s / d v_s$).
28	c_{sb} (F)	Capacitance ($-d q_s / d v_b$).
29	c_{bd} (F)	Capacitance ($-d q_b / d v_d$).
30	c_{bg} (F)	Capacitance ($-d q_b / d v_g$).
31	c_{bs} (F)	Capacitance ($-d q_b / d v_s$).
32	c_{bb} (F)	Capacitance ($d q_b / d v_b$).
33	u	Transistor gain (g_m/g_{ds}).
34	r_{out} (Ω)	Small-signal output resistance ($1/g_{ds}$).
35	v_{early} (V)	Equivalent Early voltage ($ I_{d1} /g_{ds}$).
36	b_{eff} (A/V^2)	Gain factor.
37	f_{ug} (Hz)	Unity gain frequency at actual bias ($g_m/(2*\pi*c_{in})$).
38	g_{mmos} (A/V)	Transconductance of channel region.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 39 `sqrtsfw` (V/Hz^{1/2}) Input-referred RMS white noise voltage density.
- 40 `sqrtsff` (V/Hz^{1/2}) Input-referred RMS white noise voltage density at 1 kHz.
- 41 `fknee` (Hz) Cross-over frequency above which white noise is dominant.
- 42 `Pdiss` (W) Dissipation.
- 43 `TK` (K) Actual temperature.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

<code>Pdiss</code>	OP-42	<code>cox</code>	O-25	<code>mo</code>	O-20	<code>the1</code>	O-11
<code>TK</code>	OP-43	<code>coxd</code>	M-37	<code>msdibl</code>	M-29	<code>the1acc</code>	M-21
<code>a1</code>	M-32	<code>coxd</code>	O-26	<code>msdibl</code>	O-19	<code>the1acc</code>	O-12
<code>a1</code>	O-22	<code>csb</code>	OP-28	<code>mult</code>	I-1	<code>the2</code>	M-22
<code>a2</code>	M-34	<code>csd</code>	OP-25	<code>nfa</code>	M-41	<code>the2</code>	O-13
<code>a2</code>	O-23	<code>csg</code>	OP-26	<code>nfa</code>	O-30	<code>the3</code>	M-23
<code>a3</code>	M-35	<code>css</code>	OP-27	<code>nfb</code>	M-42	<code>the3</code>	O-14
<code>a3</code>	O-24	<code>cth</code>	M-47	<code>nfb</code>	O-31	<code>tnom</code>	M-51
<code>alp</code>	M-26	<code>cth</code>	O-35	<code>nfc</code>	M-43	<code>tox</code>	M-44
<code>alp</code>	O-16	<code>dta</code>	M-45	<code>nfc</code>	O-32	<code>tox</code>	O-33

Virtuoso Simulator Components and Device Models Reference

Philips Models

area	I-4	etabet	M-14	nt	M-40	tr	M-52
ath	M-48	etabetacc	M-16	nt	O-29	tref	M-2
beff	OP-36	etard	M-18	phib	M-9	type	M-49
bet	M-13	etathe3	M-24	phib	O-5	u	OP-33
bet	O-7	fknee	OP-41	phibd	M-11	vdiseff	OP-11
betacc	M-15	fug	OP-37	phibd	O-6	vdissat	OP-12
betacc	O-8	gds	OP-16	rd	M-17	vds	OP-3
cbb	OP-32	gm	OP-14	rd	O-9	vdssat	OP-13
cbd	OP-29	gmb	OP-15	region	I-2	vearly	OP-35
cbg	OP-30	gmmos	OP-38	rout	OP-34	vfb	M-3
cbs	OP-31	iavl	OP-2	rth	M-46	vfb	O-1
cdb	OP-20	ids	OP-1	rth	O-34	vfbd	M-5
cdd	OP-17	imax	M-50	sdibl	M-28	vfbd	O-2
cdg	OP-18	ko	M-7	sdibl	O-18	vgs	OP-4
cds	OP-19	ko	O-3	sqrtsff	OP-40	vgt	OP-9
cgb	OP-24	kod	M-8	sqrtsfw	OP-39	vp	M-27
cgd	OP-21	kod	O-4	ssf	M-31	vp	O-17
cgdo	M-38	lamd	M-19	ssf	O-21	vsb	OP-5
cgdo	O-27	lamd	O-10	stal	M-33	vth	OP-8
cgg	OP-22	level	M-1	stphib	M-10	vto	OP-6
cgs	OP-23	m	I-3	stphibd	M-12	vtod	OP-10

Virtuoso Simulator Components and Device Models Reference

Philips Models

cgso	M-39	mexp	M-25	stvfb	M-4	vtb	OP-7
cgso	O-28	mexp	O-15	stvfbd	M-6		
cox	M-36	mo	M-30	thel	M-20		

Lateral Double-diffused MOS Model (MOS Model Level 2001) (mos2001t)

This is SimKit 4.0

This device is supported within altergroups.

This device is dynamically loaded from the shared object /vobs/spectre_dev/tools.lnx86/cmi/lib/5.0.doc/libphilips_sh.so

Instance Definition

```
Name d g s b dt ModelName parameter=value ...
```

Instance Parameters

- | | | |
|---|---------------|---|
| 1 | w=2e-05 m | Drawn width of the channel region. |
| 2 | wd=2e-05 m | Drawn width of the drift region. |
| 3 | mult=1 | Number of devices in parallel. |
| 4 | region=triode | Estimated DC operating region, used as a convergence aid. Possible values are off, triode, sat, or subth. |
| 5 | m=1 | Multiplicity factor. |
| 6 | area=1 | alias of mult. |

Model Definition

```
model modelName mos2001t parameter=value ...
```


Virtuoso Simulator Components and Device Models Reference

Philips Models

Model Parameters

1	<code>level=2e+03</code>	Must be 2001.
2	<code>wvar=0 m</code>	Width offset of the channel region.
3	<code>wdvar=0 m</code>	Width offset of the drift region.
4	<code>tref=25 deg. C</code>	Reference temperature.
5	<code>vfb=-1 V</code>	Flatband voltage of the channel region, at reference temperature.
6	<code>stvfb=0 V/K</code>	Temperature scaling coefficient for VFB.
7	<code>vfbd=-0.1 V</code>	Flatband voltage of the drift region, at reference temperature.
8	<code>stvfbd=0 V/K</code>	Temperature scaling coefficient for the flatband voltage of the drift region.
9	<code>kor=1.6 V^(1/2)</code>	Body factor of the channel region of an infinitely wide transistor.
10	<code>swko=0</code>	Width scaling coefficient for KO.
11	<code>kodr=1 V^-1/2</code>	Body factor of the drift region of an infinitely wide transistor.
12	<code>swkod=0</code>	Width scaling coefficient for the body factor of the drift region.
13	<code>phib=0.86 V</code>	Surface potential at the onset of strong inversion in the channel region, at reference temperature.
14	<code>stphib=-0.0012 V/K</code>	Temperature scaling coefficient for PHIB.
15	<code>phibd=0.78 V</code>	Surface potential at the onset of strong inversion in the drift region, at reference temperature.
16	<code>stphibd=-0.0012 V/K</code>	Temperature scaling coefficient for PHIBD.
17	<code>betw=7e-05 A/V²</code>	Gain factor of a channel region of 1 μm wide, at reference temperature.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 18 $etabet=1.6$ Temperature scaling exponent for BET.
- 19 $betaccw=7e-05 \text{ A/V}^{-2}$ Gain factor of drift region of 1 μm wide, at reference temperature.
- 20 $etabetacc=1.5$ Temperature scaling exponent for BETACC.
- 21 $rdw=4e+03 \text{ } \Omega$ On-resistance of a drift region of 1 μm wide, at reference temperature.
- 22 $etard=1.5$ Temperature scaling exponent for RD.
- 23 $lamd=0.2$ Quotient of the depletion layer thickness to the effective thickness of the drift region at $V_{SB} = 0 \text{ V}$.
- 24 $the1r=0.09 \text{ V}^{-1}$ Mobility reduction coefficient of infinitely wide transistor, due to vertical strong-inversion field in a channel region.
- 25 $swthe1=0$ Width scaling coefficient for THE1.
- 26 $the1acc=0.02 \text{ V}^{-1}$ Mobility reduction coefficient in the drift region due to the vertical electrical field caused by accumulation.
- 27 $the2r=0.03 \text{ V}^{-1/2}$ Mobility reduction coefficient for $V_{SB} > 0$ of an infinitely wide transistor, due to vertical depletion field in channel region.
- 28 $swthe2=0$ Width scaling coefficient for THE2.
- 29 $the3r=0.4 \text{ V}^{-1}$ Mobility reduction coefficient in a channel region of an infinitely wide transistor due to velocity saturation.
- 30 $etathe3=1$ Temperature scaling exponent for THE3.
- 31 $swthe3=0$ Width scaling coefficient for THE3.
- 32 $mexp=2$ Smoothing factor for transition from linear to saturation regime.
- 33 $alp=0.002$ Factor for channel length modulation.
- 34 $vp=0.05 \text{ V}$ Characteristic voltage of channel length modulation.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 35 $sdibl=0.001 V^{-1/2}$ Factor for drain-induced barrier lowering.
- 36 $msdibl=3$ Exponent for the drain-induced barrier lowering dependence on the backgate bias.
- 37 $mo=0 V$ Parameter for the (short-channel) sub-threshold slope.
- 38 $ssf=1e-12 V^{-1/2}$ Factor for static feedback.
- 39 $a1r=15$ Factor of weak avalanche current of an infinitely wide transistor, at reference temperature.
- 40 $sta1=0 K^{-1}$ Temperature scaling coefficient for A1.
- 41 $swa1=0$ Width scaling coefficient for A1.
- 42 $a2=73 V$ Exponent of weak avalanche current.
- 43 $a3=0.8$ Factor of the drain-source voltage above which weak avalanche occurs.
- 44 $coxw=7.5e-16 F$ Oxide capacitance for an intrinsic channel region of 1um wide.
- 45 $coxdw=7.5e-16 F$ Oxide capacitance for an intrinsic drift region of 1um wide.
- 46 $cgdow=0 F$ Gate-to-drain overlap capacitance for a drift region of 1 um wide.
- 47 $cgsow=0 F$ Gate-to-source overlap capacitance for a channel region of 1 um wide.
- 48 $nt=1.65e-20 J$ Coefficient of thermal noise, at reference temperature.
- 49 $nfaw=1.4e+25 V^{-1} m^{-4}$ First coefficient of flicker noise for a channel region of 1 um wide.
- 50 $nfbw=2e+08 V^{-1} m^{-2}$ Second coefficient of flicker noise for a channel region of 1 um wide.
- 51 $nfcw=0 V^{-1}$ Third coefficient of flicker noise for a channel region of 1 um wide.

Virtuoso Simulator Components and Device Models Reference

Philips Models

52	$t_{ox}=3.8e-08$ m	Thickness of the oxide above the channel region.
53	$d_{ta}=0$ K	Temperature offset to the ambient temperature.
54	$r_{th}=300$ K/W	Thermal resistance.
55	$c_{th}=3e-09$ J/K	Thermal capacitance.
56	$a_{th}=0$	Temperature coefficient of the thermal resistance.
57	$type=n$	Transistor gender. Possible values are n, p, npn, pnp, npnv, pnpv, npnl, or pnp1.
58	$i_{max}=1.0$ A	Explosion current.
59	t_{nom} (deg. C)	alias of t_{nom} .
60	t_r (deg. C)	alias of t_{nom} .

Output Parameters

1	v_{fb} (V)	Flatband voltage of the channel region, at reference temperature.
2	v_{fbd} (V)	Flatband voltage of the drift region.
3	k_o ($V^{1/2}$)	Body factor of the channel region.
4	k_{od} ($V^{-1/2}$)	Body factor of the drift region.
5	ϕ_{ib} (V)	Surface potential at the onset of strong inversion in the channel region, at reference temperature.
6	ϕ_{ibd} (V)	Surface potential at the onset of strong inversion in the drift region, at reference temperature.
7	β_{et} (A/V^2)	Gain factor of the channel region, at reference temperature.
8	β_{etacc} (A/V^2)	Gain factor for accumulation in the drift region, at reference temperature.
9	r_d (Ω)	On-resistance of the drift region, at reference temperature.

Virtuoso Simulator Components and Device Models Reference

Philips Models

10	lamd	Quotient of the depletion layer thickness to the effective thickness of the drift region at $V_{SB} = 0$ V.
11	$\text{the1} (V^{-1})$	Mobility reduction coefficient in the channel region due to vertical electrical field caused by strong inversion.
12	$\text{the1acc} (V^{-1})$	Mobility reduction coefficient in the drift region due to the vertical electrical field caused by accumulation.
13	$\text{the2} (V^{-1/2})$	Mobility reduction coefficient for $V_{SB} > 0$ in the channel region due to the vertical electrical field caused by depletion.
14	$\text{the3} (V^{-1})$	Mobility reduction coefficient in the channel region due to the horizontal electrical field caused by velocity saturation.
15	mexp	Smoothing factor for transition from linear to saturation regime.
16	alp	Factor for channel length modulation.
17	$\text{vp} (V)$	Characteristic voltage of channel length modulation.
18	$\text{sdibl} (V^{-1/2})$	Factor for drain-induced barrier lowering.
19	msdibl	Exponent for the drain-induced barrier lowering dependence on the backgate bias.
20	$\text{mo} (V)$	Parameter for the (short-channel) sub-threshold slope.
21	$\text{ssf} (V^{-1/2})$	Factor for static feedback.
22	a1	Factor of weak avalanche current, at reference temperature.
23	$\text{a2} (V)$	Exponent of weak avalanche current.
24	a3	Factor of the drain-source voltage above which weak avalanche occurs.
25	$\text{cox} (F)$	Oxide capacitance for the intrinsic channel region.
26	$\text{cox\bar{d}} (F)$	Oxide capacitance for the intrinsic drift region.
27	$\text{cgdo} (F)$	Gate-to-drain overlap capacitance.

Virtuoso Simulator Components and Device Models Reference

Philips Models

28	c_{gso} (F)	Gate-to-source overlap capacitance.
29	n_t (J)	Coefficient of thermal noise, at reference temperature.
30	n_{fa} ($V^{-1} m^{-4}$)	First coefficient of flicker noise.
31	n_{fb} ($V^{-1} m^{-2}$)	Second coefficient of flicker noise.
32	n_{fc} (V^{-1})	Third coefficient of flicker noise.
33	t_{ox} (m)	Thickness of the oxide above the channel region.
34	r_{th} (K/W)	Thermal resistance.
35	c_{th} (J/K)	Thermal capacitance.

Operating-Point Parameters

1	i_{ds} (A)	Drain current, excl. avalanche and tunnel currents.
2	i_{avl} (A)	Substrate current due to weak-avalanche.
3	v_{ds} (V)	Drain-source voltage.
4	v_{gs} (V)	Gate-source voltage.
5	v_{sb} (V)	Source-bulk voltage.
6	v_{to} (V)	Zero-bias threshold voltage.
7	v_{ts} (V)	Threshold voltage including back-bias effects.
8	v_{th} (V)	Threshold voltage including back-bias and drain-bias effects.
9	v_{gt} (V)	Effective gate drive voltage including back-bias and drain voltage effects.
10	v_{tod} (V)	Threshold voltage of the drift region.
11	v_{diseff} (V)	Effective internal drain-to-source voltage at actual bias.
12	v_{dissat} (V)	Internal drain saturation voltage at actual bias.

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Philips Models

13	v_{dssat} (V)	Drain-source saturation voltage at actual bias.
14	g_m (A/V)	Transconductance ($d i_{ds} / d v_{gs}$).
15	g_{mb} (A/V)	Substrate-transconductance ($d i_{ds} / d v_{bs}$).
16	g_{ds} (A/V)	Output conductance ($d i_{ds} / d v_{ds}$).
17	c_{dd} (F)	Capacitance ($d q_d / d v_d$).
18	c_{dg} (F)	Capacitance ($- d q_d / d v_g$).
19	c_{ds} (F)	Capacitance ($- d q_d / d v_s$).
20	c_{db} (F)	Capacitance ($- d q_d / d v_b$).
21	c_{gd} (F)	Capacitance ($- d q_g / d v_d$).
22	c_{gg} (F)	Capacitance ($d q_g / d v_g$).
23	c_{gs} (F)	Capacitance ($- d q_g / d v_s$).
24	c_{gb} (F)	Capacitance ($- d q_g / d v_b$).
25	c_{sd} (F)	Capacitance ($- d q_s / d v_d$).
26	c_{sg} (F)	Capacitance ($- d q_s / d v_g$).
27	c_{ss} (F)	Capacitance ($d q_s / d v_s$).
28	c_{sb} (F)	Capacitance ($- d q_s / d v_b$).
29	c_{bd} (F)	Capacitance ($- d q_b / d v_d$).
30	c_{bg} (F)	Capacitance ($- d q_b / d v_g$).
31	c_{bs} (F)	Capacitance ($- d q_b / d v_s$).
32	c_{bb} (F)	Capacitance ($d q_b / d v_b$).
33	w_{eff} (m)	Effective channel width for geometrical models.
34	w_{def} (m)	Effective drift region width for geometrical model.

Virtuoso Simulator Components and Device Models Reference

Philips Models

35	<code>u</code>	Transistor gain (gm/gds).
36	<code>rout</code> (Ω)	Small-signal output resistance (1/gds).
37	<code>vearly</code> (V)	Equivalent Early voltage (idl /gds).
38	<code>beff</code> (A/V^2)	Gain factor.
39	<code>fug</code> (Hz)	Unity gain frequency at actual bias (gm/(2*pi*cin)).
40	<code>gmmos</code> (A/V)	Transconductance of channel region.
41	<code>sqrtsfw</code> ($V/Hz^{1/2}$)	Input-referred RMS white noise voltage density.
42	<code>sqrtsff</code> ($V/Hz^{1/2}$)	Input-referred RMS white noise voltage density at 1 kHz.
43	<code>fknee</code> (Hz)	Cross-over frequency above which white noise is dominant.
44	<code>Pdiss</code> (W)	Dissipation.
45	<code>TK</code> (K)	Actual temperature.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

<code>Pdiss</code>	OP-44	<code>csb</code>	OP-28	<code>nfb</code>	O-31	<code>the2</code>	O-13
<code>TK</code>	OP-45	<code>csd</code>	OP-25	<code>nfbw</code>	M-50	<code>the2r</code>	M-27
<code>a1</code>	O-22	<code>csg</code>	OP-26	<code>nfc</code>	O-32	<code>the3</code>	O-14
<code>a1r</code>	M-39	<code>css</code>	OP-27	<code>nfcw</code>	M-51	<code>the3r</code>	M-29

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Philips Models

a2	M-42	cth	M-55	nt	M-48	tnom	M-59
a2	O-23	cth	O-35	nt	O-29	tox	M-52
a3	M-43	dta	M-53	phib	M-13	tox	O-33
a3	O-24	etabet	M-18	phib	O-5	tr	M-60
alp	M-33	etabetacc	M-20	phibd	M-15	tref	M-4
alp	O-16	etard	M-22	phibd	O-6	type	M-57
area	I-6	etathe3	M-30	rd	O-9	u	OP-35
ath	M-56	fknee	OP-43	rdw	M-21	vdiseff	OP-11
beff	OP-38	fug	OP-39	region	I-4	vdissat	OP-12
bet	O-7	gds	OP-16	rout	OP-36	vds	OP-3
betacc	O-8	gm	OP-14	rth	M-54	vdssat	OP-13
betaccw	M-19	gmb	OP-15	rth	O-34	vearly	OP-37
betw	M-17	gmмос	OP-40	sdibl	M-35	vfb	M-5
cbb	OP-32	iavl	OP-2	sdibl	O-18	vfb	O-1
cbd	OP-29	ids	OP-1	sqrtsff	OP-42	vfbd	M-7
cbg	OP-30	imax	M-58	sqrtsfw	OP-41	vfbd	O-2
cbs	OP-31	ko	O-3	ssf	M-38	vgs	OP-4
cdb	OP-20	kod	O-4	ssf	O-21	vgt	OP-9
cdd	OP-17	kodr	M-11	stal	M-40	vp	M-34
cdg	OP-18	kor	M-9	stphib	M-14	vp	O-17
cds	OP-19	lamd	M-23	stphibd	M-16	vsb	OP-5

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Philips Models

cgb	OP-24	lamd	O-10	stvfb	M-6	vth	OP-8
cgd	OP-21	level	M-1	stvfbd	M-8	vto	OP-6
cgdo	O-27	m	I-5	swal	M-41	vtod	OP-10
cgdow	M-46	mexp	M-32	swko	M-10	vts	OP-7
cgg	OP-22	mexp	O-15	swkod	M-12	w	I-1
cgs	OP-23	mo	M-37	swthe1	M-25	wd	I-2
cgso	O-28	mo	O-20	swthe2	M-28	wdeff	OP-34
cgsow	M-47	msdibl	M-36	swthe3	M-31	wdvar	M-3
cox	O-25	msdibl	O-19	the1	O-11	weff	OP-33
coxd	O-26	mult	I-3	the1acc	M-26	wvar	M-2
coxdw	M-45	nfa	O-30	the1acc	O-12		
coxw	M-44	nfaw	M-49	the1r	M-24		

Lateral Double-diffused MOS Model (MOS Model Level 2002) (mos2002)

This is SimKit 4.0

This device is supported within altergroups.

This device is dynamically loaded from the shared object /vobs/spectre_dev/tools.lnx86/cmi/lib/5.0.doc/libphilips_sh.so

Instance Definition

Name d g s b ModelName parameter=value ...

Virtuoso Simulator Components and Device Models Reference

Philips Models

Instance Parameters

1	<code>w=2e-05 m</code>	Drawn width of the channel region.
2	<code>wd=2e-05 m</code>	Drawn width of the drift region.
3	<code>mult=1</code>	Number of devices in parallel.
4	<code>region=triode</code>	Estimated DC operating region, used as a convergence aid. Possible values are <code>off</code> , <code>triode</code> , <code>sat</code> , or <code>subth</code> .
5	<code>m=1</code>	Multiplicity factor.
6	<code>area=1</code>	alias of <code>mult</code> .

Model Definition

```
model modelName mos2002 parameter=value ...
```

Model Parameters

1	<code>level=2e+03</code>	Must be 2002.
2	<code>wvar=0 m</code>	Width offset of the channel region.
3	<code>wdvar=0 m</code>	Width offset of the drift region.
4	<code>tref=25 deg. C</code>	Reference temperature.
5	<code>vfb=-1 V</code>	Flatband voltage of the channel region, at reference temperature.
6	<code>stvfb=0 V/K</code>	Temperature scaling coefficient for VFB.
7	<code>vfbd=-0.1 V</code>	Flatband voltage of the drift region, at reference temperature.
8	<code>stvfbd=0 V/K</code>	Temperature scaling coefficient for the flatband voltage of the drift region.
9	<code>kor=1.6 V^(1/2)</code>	Body factor of the channel region of an infinitely wide transistor.
10	<code>swko=0</code>	Width scaling coefficient for KO.

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Philips Models

- 11 $kod_r=1 \text{ V}^{(1/2)}$ Body factor of the drift region of an infinitely wide transistor.
- 12 $swkod=0$ Width scaling coefficient for the body factor of the drift region.
- 13 $phib=0.86 \text{ V}$ Surface potential at the onset of strong inversion in the channel region, at reference temperature.
- 14 $stphib=-0.0012 \text{ V/K}$ Temperature scaling coefficient for PHIB.
- 15 $phibd=0.78 \text{ V}$ Surface potential at the onset of strong inversion in the drift region, at reference temperature.
- 16 $stphibd=-0.0012 \text{ V/K}$ Temperature scaling coefficient for PHIBD.
- 17 $betw=7e-05 \text{ A/V}^2$ Gain factor of a channel region of 1 μm wide, at reference temperature.
- 18 $etabet=1.6$ Temperature scaling exponent for BET.
- 19 $betaccw=7e-05 \text{ A/V}^{-2}$ Gain factor of drift region of 1 μm wide, at reference temperature.
- 20 $etabetacc=1.5$ Temperature scaling exponent for BETACC.
- 21 $rdw=4e+03 \text{ }\Omega$ On-resistance of a drift region of 1 μm wide, at reference temperature.
- 22 $etard=1.5$ Temperature scaling exponent for RD.
- 23 $lamd=0.2$ Quotient of the depletion layer thickness to the effective thickness of the drift region at $V_{SB} = 0 \text{ V}$.
- 24 $the1r=0.09 \text{ V}^{-1}$ Mobility reduction coefficient of infinitely wide transistor, due to vertical strong-inversion field in a channel region.
- 25 $swthe1=0$ Width scaling coefficient for THE1.
- 26 $the1acc=0.02 \text{ V}^{-1}$ Mobility reduction coefficient in the drift region due to the vertical electrical field caused by accumulation.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 27 $the2r=0.03 V^{-1/2}$ Mobility reduction coefficient for $V_{SB} > 0$ of an infinitely wide transistor, due to vertical depletion field in channel region.
- 28 $swthe2=0$ Width scaling coefficient for THE2.
- 29 $the3r=0.4 V^{-1}$ Mobility reduction coefficient in a channel region of an infinitely wide transistor due to velocity saturation.
- 30 $etathe3=1$ Temperature scaling exponent for THE3.
- 31 $swthe3=0$ Width scaling coefficient for THE3.
- 32 $mexp=2$ Smoothing factor for transition from linear to saturation regime.
- 33 $the3dr=0 V^{-1}$ Mobility reduction coefficient in a channel region of an infinitely wide transistor due to velocity saturation.
- 34 $etathe3d=1$ Temperature scaling exponent for THE3D.
- 35 $swthe3d=0$ Width scaling coefficient for THE3D.
- 36 $mexpd=2$ Smoothing factor for transition from linear to quasi-saturation regime.
- 37 $alp=0.002$ Factor for channel length modulation.
- 38 $vp=0.05 V$ Characteristic voltage of channel length modulation.
- 39 $sdibl=0.001 V^{-1/2}$ Factor for drain-induced barrier lowering.
- 40 $msdibl=3$ Exponent for the drain-induced barrier lowering dependence on the backgate bias.
- 41 $mo=0 V$ Parameter for the (short-channel) sub-threshold slope.
- 42 $ssf=1e-12 V^{-1/2}$ Factor for static feedback.
- 43 $a1chr=15$ Factor of channel weak avalanche current of an infinitely wide transistor, at reference temperature.

Virtuoso Simulator Components and Device Models Reference

Philips Models

44	$sta1ch=0 \text{ K}^{-1}$	Temperature scaling coefficient for A1CH.
45	$swa1ch=0$	Width scaling coefficient for A1CH.
46	$a2ch=73 \text{ V}$	Exponent of channel weak avalanche current.
47	$a3ch=0.8$	Factor of the drain-source voltage above which channel weak avalanche occurs.
48	$a1dr=15$	Factor of drift weak avalanche current of an infinitely wide transistor, at reference temperature.
49	$sta1dr=0 \text{ K}^{-1}$	Temperature scaling coefficient for A1DR.
50	$swa1dr=0$	Width scaling coefficient for A1DR.
51	$a2dr=73 \text{ V}$	Exponent of drift weak avalanche current.
52	$a3dr=0.8$	Factor of the drain-source voltage above which drift weak avalanche occurs.
53	$coxw=7.5e-16 \text{ F}$	Oxide capacitance for an intrinsic channel region of 1um wide.
54	$coxdr=7.5e-16 \text{ F}$	Oxide capacitance for an intrinsic drift region of 1um wide.
55	$cgdow=0 \text{ F}$	Gate-to-drain overlap capacitance for a drift region of 1 um wide.
56	$cgsow=0 \text{ F}$	Gate-to-source overlap capacitance for a channel region of 1 um wide.
57	$nt=1.65e-20 \text{ J}$	Coefficient of thermal noise, at reference temperature.
58	$nfaw=1.4e+25 \text{ V}^{-1} \text{ m}^{-4}$	First coefficient of flicker noise for a channel region of 1 um wide.
59	$nfbw=2e+08 \text{ V}^{-1} \text{ m}^{-2}$	Second coefficient of flicker noise for a channel region of 1 um wide.
60	$nfCW=0 \text{ V}^{-1}$	Third coefficient of flicker noise for a channel region of 1 um wide.
61	$tox=3.8e-08 \text{ m}$	Thickness of the oxide above the channel region.

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Philips Models

62	<code>dta=0 K</code>	Temperature offset to the ambient temperature.
63	<code>type=n</code>	Transistor gender. Possible values are <code>n</code> , <code>p</code> , <code>npn</code> , <code>pnv</code> , <code>npnv</code> , <code>pnpl</code> , or <code>pnpl</code> .
64	<code>imax=1.0 A</code>	Explosion current.
65	<code>tnom (deg. C)</code>	alias of <code>tnom</code> .
66	<code>tr (deg. C)</code>	alias of <code>tnom</code> .

Output Parameters

1	<code>vfb (V)</code>	Flatband voltage of the channel region, at reference temperature.
2	<code>vfbd (V)</code>	Flatband voltage of the drift region.
3	<code>ko (V^{1/2})</code>	Body factor of the channel region.
4	<code>kod (V^{1/2})</code>	Body factor of the drift region.
5	<code>phib (V)</code>	Surface potential at the onset of strong inversion in the channel region, at reference temperature.
6	<code>phibd (V)</code>	Surface potential at the onset of strong inversion in the drift region, at reference temperature.
7	<code>bet (A/V²)</code>	Gain factor of the channel region, at reference temperature.
8	<code>betacc (A/V²)</code>	Gain factor for accumulation in the drift region, at reference temperature.
9	<code>rd (Ω)</code>	On-resistance of the drift region, at reference temperature.
10	<code>lamd</code>	Quotient of the depletion layer thickness to the effective thickness of the drift region at $V_{SB} = 0$ V.
11	<code>the1 (V⁻¹)</code>	Mobility reduction coefficient in the channel region due to vertical electrical field caused by strong inversion.
12	<code>the1acc (V⁻¹)</code>	Mobility reduction coefficient in the drift region due to the vertical electrical field caused by accumulation.

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Philips Models

13	the2 ($V^{-1/2}$)	Mobility reduction coefficient for $V_{SB} > 0$ in the channel region due to the vertical electrical field caused by depletion.
14	the3 (V^{-1})	Mobility reduction coefficient in the channel region due to the horizontal electrical field caused by velocity saturation.
15	mexp	Smoothing factor for transition from linear to saturation regime.
16	the3d (V^{-1})	Mobility reduction coefficient in the drift region due to the horizontal electrical field caused by velocity saturation.
17	etathe3d	Temperature scaling exponent for THE3D.
18	mexpd	Smoothing factor for transition from linear to quasi-saturation regime.
19	alp	Factor for channel length modulation.
20	vp (V)	Characteristic voltage of channel length modulation.
21	sdibl ($V^{-1/2}$)	Factor for drain-induced barrier lowering.
22	msdibl	Exponent for the drain-induced barrier lowering dependence on the backgate bias.
23	mo (V)	Parameter for the (short-channel) sub-threshold slope.
24	ssf ($V^{-1/2}$)	Factor for static feedback.
25	a1ch	Factor of channel weak avalanche current, at reference temperature.
26	a2ch (V)	Exponent of channel weak avalanche current.
27	a3ch	Factor of the drain-source voltage above which channel weak avalanche occurs.
28	a1dr	Factor of drift weak avalanche current, at reference temperature.
29	a2dr (V)	Exponent of drift weak avalanche current.
30	a3dr	Factor of the drain-source voltage above which drift weak avalanche occurs.

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Philips Models

31	c_{ox} (F)	Oxide capacitance for the intrinsic channel region.
32	c_{oxd} (F)	Oxide capacitance for the intrinsic drift region.
33	c_{gdo} (F)	Gate-to-drain overlap capacitance.
34	c_{gso} (F)	Gate-to-source overlap capacitance.
35	n_t (J)	Coefficient of thermal noise, at reference temperature.
36	n_{fa} ($V^{-1} m^{-4}$)	First coefficient of flicker noise.
37	n_{fb} ($V^{-1} m^{-2}$)	Second coefficient of flicker noise.
38	n_{fc} (V^{-1})	Third coefficient of flicker noise.
39	t_{ox} (m)	Thickness of the oxide above the channel region.

Operating-Point Parameters

1	i_{ds} (A)	Drain current, excl. avalanche and tunnel currents.
2	i_{avl} (A)	Substrate current due to weak-avalanche.
3	v_{ds} (V)	Drain-source voltage.
4	v_{gs} (V)	Gate-source voltage.
5	v_{sb} (V)	Source-bulk voltage.
6	v_{to} (V)	Zero-bias threshold voltage.
7	v_{ts} (V)	Threshold voltage including back-bias effects.
8	v_{th} (V)	Threshold voltage including back-bias and drain-bias effects.
9	v_{gt} (V)	Effective gate drive voltage including back-bias and drain voltage effects.
10	v_{tod} (V)	Threshold voltage of the drift region.
11	v_{diseff} (V)	Effective internal drain-to-source voltage at actual bias.

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12	<code>vdissat</code> (V)	Saturation voltage of channel region at actual bias.
13	<code>vddisat</code> (V)	Saturation voltage of drift region at actual bias.
14	<code>gm</code> (A/V)	Transconductance ($d\text{ ids} / d\text{ vgs}$).
15	<code>gmb</code> (A/V)	Substrate-transconductance ($d\text{ ids} / d\text{ vbs}$).
16	<code>gds</code> (A/V)	Output conductance ($d\text{ ids} / d\text{ vds}$).
17	<code>cdd</code> (F)	Capacitance ($d\text{ qd} / d\text{ vd}$).
18	<code>cdg</code> (F)	Capacitance ($- d\text{ qd} / d\text{ vg}$).
19	<code>cds</code> (F)	Capacitance ($- d\text{ qd} / d\text{ vs}$).
20	<code>cdb</code> (F)	Capacitance ($- d\text{ qd} / d\text{ vb}$).
21	<code>cgd</code> (F)	Capacitance ($- d\text{ qg} / d\text{ vd}$).
22	<code>cgg</code> (F)	Capacitance ($d\text{ qg} / d\text{ vg}$).
23	<code>cgs</code> (F)	Capacitance ($- d\text{ qg} / d\text{ vs}$).
24	<code>cgb</code> (F)	Capacitance ($- d\text{ qg} / d\text{ vb}$).
25	<code>csd</code> (F)	Capacitance ($- d\text{ qs} / d\text{ vd}$).
26	<code>csg</code> (F)	Capacitance ($- d\text{ qs} / d\text{ vg}$).
27	<code>css</code> (F)	Capacitance ($d\text{ qs} / d\text{ vs}$).
28	<code>csb</code> (F)	Capacitance ($- d\text{ qs} / d\text{ vb}$).
29	<code>cbd</code> (F)	Capacitance ($- d\text{ qb} / d\text{ vd}$).
30	<code>cbg</code> (F)	Capacitance ($- d\text{ qb} / d\text{ vg}$).
31	<code>cbs</code> (F)	Capacitance ($- d\text{ qb} / d\text{ vs}$).
32	<code>cbb</code> (F)	Capacitance ($d\text{ qb} / d\text{ vb}$).
33	<code>weff</code> (m)	Effective channel width for geometrical models.

Virtuoso Simulator Components and Device Models Reference

Philips Models

34	wdeff (m)	Effective drift region width for geometrical model.
35	u	Transistor gain (gm/gds).
36	rout (Ω)	Small-signal output resistance (1/gds).
37	vearly (V)	Equivalent Early voltage (idl /gds).
38	beff (A/V ²)	Gain factor.
39	fug (Hz)	Unity gain frequency at actual bias (gm/(2*pi*cin)).
40	gmmos (A/V)	Transconductance of channel region.
41	sqrtsw (V/Hz ^{1/2})	Input-referred RMS white noise voltage density.
42	sqrtfff (V/Hz ^{1/2})	Input-referred RMS white noise voltage density at 1 kHz.
43	fknee (Hz)	Cross-over frequency above which white noise is dominant.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

a1ch O-25	coxw M-53	nfaw M-58	the2 O-13
a1chr M-43	csb OP-28	nfb O-37	the2r M-27
a1dr O-28	csd OP-25	nfbw M-59	the3 O-14
a1drr M-48	csg OP-26	nfc O-38	the3d O-16
a2ch M-46	css OP-27	nfcw M-60	the3dr M-33

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a2ch	O-26	dta	M-62	nt	M-57	the3r	M-29
a2dr	M-51	etabet	M-18	nt	O-35	tnom	M-65
a2dr	O-29	etabetacc	M-20	phib	M-13	tox	M-61
a3ch	M-47	etard	M-22	phib	O-5	tox	O-39
a3ch	O-27	etathe3	M-30	phibd	M-15	tr	M-66
a3dr	M-52	etathe3d	M-34	phibd	O-6	tref	M-4
a3dr	O-30	etathe3d	O-17	rd	O-9	type	M-63
alp	M-37	fknee	OP-43	rdw	M-21	u	OP-35
alp	O-19	fug	OP-39	region	I-4	vddisat	OP-13
area	I-6	gds	OP-16	rout	OP-36	vdiseff	OP-11
beff	OP-38	gm	OP-14	sdibl	M-39	vdissat	OP-12
bet	O-7	gmb	OP-15	sdibl	O-21	vds	OP-3
betacc	O-8	gmмос	OP-40	sqrtsff	OP-42	vearly	OP-37
betaccw	M-19	iavl	OP-2	sqrtsfw	OP-41	vfb	M-5
betw	M-17	ids	OP-1	ssf	M-42	vfb	O-1
cbb	OP-32	imax	M-64	ssf	O-24	vfbd	M-7
cbd	OP-29	ko	O-3	stalch	M-44	vfbd	O-2
cbg	OP-30	kod	O-4	staldr	M-49	vgs	OP-4
cbs	OP-31	kodr	M-11	stphib	M-14	vgt	OP-9
cdb	OP-20	kor	M-9	stphibd	M-16	vp	M-38
cdd	OP-17	lamd	M-23	stvfb	M-6	vp	O-20

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Philips Models

cdg	OP-18	lamd	O-10	stvfbd	M-8	vsb	OP-5
cds	OP-19	level	M-1	swalch	M-45	vth	OP-8
cgb	OP-24	m	I-5	swaldr	M-50	vto	OP-6
cgd	OP-21	mexp	M-32	swko	M-10	vtod	OP-10
cgdo	O-33	mexp	O-15	swkod	M-12	vts	OP-7
cgdow	M-55	mexpd	M-36	swthe1	M-25	w	I-1
cgg	OP-22	mexpd	O-18	swthe2	M-28	wd	I-2
cgs	OP-23	mo	M-41	swthe3	M-31	wdeff	OP-34
cgso	O-34	mo	O-23	swthe3d	M-35	wdvar	M-3
cgsow	M-56	msdibl	M-40	the1	O-11	weff	OP-33
cox	O-31	msdibl	O-22	the1acc	M-26	wvar	M-2
coxd	O-32	mult	I-3	the1acc	O-12		
coxdw	M-54	nfa	O-36	the1r	M-24		

Lateral Double-diffused MOS Model (MOS Model Level 2002) (mos2002e)

This is SimKit 4.0.

This device is supported within altergroups.

This device is dynamically loaded from the shared object /vobs/spectre_dev/tools.lnx86/cmi/lib/5.0.doc/libphilips_sh.so

Instance Definition

Name d g s b ModelName parameter=value ...

Virtuoso Simulator Components and Device Models Reference

Philips Models

Instance Parameters

- | | | |
|---|----------------------------|---|
| 1 | <code>mult=1</code> | Number of devices in parallel. |
| 2 | <code>region=triode</code> | Estimated DC operating region, used as a convergence aid. Possible values are <code>off</code> , <code>triode</code> , <code>sat</code> , or <code>subth</code> . |
| 3 | <code>m=1</code> | Multiplicity factor. |
| 4 | <code>area=1</code> | alias of <code>mult</code> . |

Model Definition

```
model modelName mos2002e parameter=value ...
```

Model Parameters

- | | | |
|----|---------------------------------|---|
| 1 | <code>level=2e+03</code> | Must be 2002. |
| 2 | <code>tref=25 deg. C</code> | Reference temperature. |
| 3 | <code>vfb=-1 V</code> | Flatband voltage of the channel region, at reference temperature. |
| 4 | <code>stvfb=0 V/K</code> | Temperature scaling coefficient for VFB. |
| 5 | <code>vfbd=-0.1 V</code> | Flatband voltage of the drift region, at reference temperature. |
| 6 | <code>stvfbd=0 V/K</code> | Temperature scaling coefficient for the flatband voltage of the drift region. |
| 7 | <code>ko=1.6 V^(1/2)</code> | Body factor of the channel region. |
| 8 | <code>kod=1 V^(1/2)</code> | Body factor of the drift region. |
| 9 | <code>phib=0.86 V</code> | Surface potential at the onset of strong inversion in the channel region, at reference temperature. |
| 10 | <code>stphib=-0.0012 V/K</code> | Temperature scaling coefficient for PHIB. |
| 11 | <code>phibd=0.78 V</code> | Surface potential at the onset of strong inversion in the drift region, at reference temperature. |

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 12 $stphibd=-0.0012 \text{ V/K}$ Temperature scaling coefficient for PHIBD.
- 13 $bet=0.0014 \text{ A/V}^2$ Gain factor of the channel region, at reference temperature.
- 14 $etabet=1.6$ Temperature scaling exponent for BET.
- 15 $betacc=0.0014 \text{ A/V}^{-2}$ Gain factor for accumulation in the drift region, at reference temperature.
- 16 $etabetacc=1.5$ Temperature scaling exponent for BETACC.
- 17 $rd=200 \text{ } \Omega$ On-resistance of the drift region, at reference temperature.
- 18 $etard=1.5$ Temperature scaling exponent for RD.
- 19 $lamd=0.2$ Quotient of the depletion layer thickness to the effective thickness of the drift region at $V_{SB} = 0 \text{ V}$.
- 20 $the1=0.09 \text{ V}^{-1}$ Mobility reduction coefficient in the channel region due to vertical electrical field caused by strong inversion.
- 21 $the1acc=0.02 \text{ V}^{-1}$ Mobility reduction coefficient in the drift region due to the vertical electrical field caused by accumulation.
- 22 $the2=0.03 \text{ V}^{(-1/2)}$ Mobility reduction coefficient for $V_{SB} > 0$ in the channel region due to the vertical electrical field caused by depletion.
- 23 $the3=0.4 \text{ V}^{-1}$ Mobility reduction coefficient in the channel region due to the horizontal electrical field caused by velocity saturation.
- 24 $etathe3=1$ Temperature scaling exponent for THE3.
- 25 $mexp=2$ Smoothing factor for transition from linear to saturation regime.
- 26 $the3d=0 \text{ V}^{-1}$ Mobility reduction coefficient in the drift region due to the horizontal electrical field caused by velocity saturation.
- 27 $etathe3d=1$ Temperature scaling exponent for THE3D.

Virtuoso Simulator Components and Device Models Reference

Philips Models

28	$m_{expd}=2$	Smoothing factor for transition from linear to quasi-saturation regime.
29	$alp=0.002$	Factor for channel length modulation.
30	$v_p=0.05 \text{ V}$	Characteristic voltage of channel length modulation.
31	$sdibl=0.001 \text{ V}^{-1/2}$	Factor for drain-induced barrier lowering.
32	$msdibl=3$	Exponent for the drain-induced barrier lowering dependence on the backgate bias.
33	$m_o=0 \text{ V}$	Parameter for the (short-channel) sub-threshold slope.
34	$ssf=1e-12 \text{ V}^{-1/2}$	Factor for static feedback.
35	$a1ch=15$	Factor of channel weak avalanche current, at reference temperature.
36	$sta1ch=0 \text{ K}^{-1}$	Temperature scaling coefficient for A1CH.
37	$a2ch=73 \text{ V}$	Exponent of channel weak avalanche current.
38	$a3ch=0.8$	Factor of the drain-source voltage above which channel weak avalanche occurs.
39	$a1dr=15$	Factor of drift weak avalanche current, at reference temperature.
40	$sta1dr=0 \text{ K}^{-1}$	Temperature scaling coefficient for A1DR.
41	$a2dr=73 \text{ V}$	Exponent of drift weak avalanche current.
42	$a3dr=0.8$	Factor of the drain-source voltage above which drift weak avalanche occurs.
43	$cox=1.5e-14 \text{ F}$	Oxide capacitance for the intrinsic channel region.
44	$cox_d=1.5e-14 \text{ F}$	Oxide capacitance for the intrinsic drift region.
45	$cgdo=0 \text{ F}$	Gate-to-drain overlap capacitance.

Virtuoso Simulator Components and Device Models Reference

Philips Models

46	$cgso=0$ F	Gate-to-source overlap capacitance.
47	$nt=1.65e-20$ J	Coefficient of thermal noise, at reference temperature.
48	$nfa=7e+23$ V ⁻¹ m ⁻⁴	First coefficient of flicker noise.
49	$nfb=1e+07$ V ⁻¹ m ⁻²	Second coefficient of flicker noise.
50	$nfc=0$ V ⁻¹	Third coefficient of flicker noise.
51	$tox=3.8e-08$ m	Thickness of the oxide above the channel region.
52	$dta=0$ K	Temperature offset to the ambient temperature.
53	$type=n$	Transistor gender. Possible values are n, p, npn, pnp, npnv, pnpv, npnl, or pnp1.
54	$imax=1.0$ A	Explosion current.
55	$tnom$ (deg. C)	alias of $tnom$.
56	tr (deg. C)	alias of $tnom$.

Output Parameters

1	vfb (V)	Flatband voltage of the channel region, at reference temperature.
2	$vfbd$ (V)	Flatband voltage of the drift region.
3	ko (V ^{1/2})	Body factor of the channel region.
4	kod (V ^{1/2})	Body factor of the drift region.
5	$phib$ (V)	Surface potential at the onset of strong inversion in the channel region, at reference temperature.
6	$phibd$ (V)	Surface potential at the onset of strong inversion in the drift region, at reference temperature.
7	bet (A/V ²)	Gain factor of the channel region, at reference temperature.

Virtuoso Simulator Components and Device Models Reference

Philips Models

8	<code>betacc</code> (A/V^2)	Gain factor for accumulation in the drift region, at reference temperature.
9	<code>rd</code> (Ω)	On-resistance of the drift region, at reference temperature.
10	<code>lamd</code>	Quotient of the depletion layer thickness to the effective thickness of the drift region at $V_{SB} = 0$ V.
11	<code>the1</code> (V^{-1})	Mobility reduction coefficient in the channel region due to vertical electrical field caused by strong inversion.
12	<code>the1acc</code> (V^{-1})	Mobility reduction coefficient in the drift region due to the vertical electrical field caused by accumulation.
13	<code>the2</code> ($V^{-1/2}$)	Mobility reduction coefficient for $V_{SB} > 0$ in the channel region due to the vertical electrical field caused by depletion.
14	<code>the3</code> (V^{-1})	Mobility reduction coefficient in the channel region due to the horizontal electrical field caused by velocity saturation.
15	<code>mexp</code>	Smoothing factor for transition from linear to saturation regime.
16	<code>the3d</code> (V^{-1})	Mobility reduction coefficient in the drift region due to the horizontal electrical field caused by velocity saturation.
17	<code>etathe3d</code>	Temperature scaling exponent for THE3D.
18	<code>mexpd</code>	Smoothing factor for transition from linear to quasi-saturation regime.
19	<code>alp</code>	Factor for channel length modulation.
20	<code>vp</code> (V)	Characteristic voltage of channel length modulation.
21	<code>sdibl</code> ($V^{-1/2}$)	Factor for drain-induced barrier lowering.
22	<code>msdibl</code>	Exponent for the drain-induced barrier lowering dependence on the backgate bias.
23	<code>mo</code> (V)	Parameter for the (short-channel) sub-threshold slope.
24	<code>ssf</code> ($V^{-1/2}$)	Factor for static feedback.

Virtuoso Simulator Components and Device Models Reference

Philips Models

25	a1ch	Factor of channel weak avalanche current, at reference temperature.
26	a2ch (V)	Exponent of channel weak avalanche current.
27	a3ch	Factor of the drain-source voltage above which channel weak avalanche occurs.
28	a1dr	Factor of drift weak avalanche current, at reference temperature.
29	a2dr (V)	Exponent of drift weak avalanche current.
30	a3dr	Factor of the drain-source voltage above which drift weak avalanche occurs.
31	cox (F)	Oxide capacitance for the intrinsic channel region.
32	coxd (F)	Oxide capacitance for the intrinsic drift region.
33	cgdo (F)	Gate-to-drain overlap capacitance.
34	cgso (F)	Gate-to-source overlap capacitance.
35	nt (J)	Coefficient of thermal noise, at reference temperature.
36	nfa ($V^{-1} m^{-4}$)	First coefficient of flicker noise.
37	nfb ($V^{-1} m^{-2}$)	Second coefficient of flicker noise.
38	nfc (V^{-1})	Third coefficient of flicker noise.
39	tox (m)	Thickness of the oxide above the channel region.

Operating-Point Parameters

1	ids (A)	Drain current, excl. avalanche and tunnel currents.
2	iavl (A)	Substrate current due to weak-avalanche.
3	vds (V)	Drain-source voltage.
4	vgs (V)	Gate-source voltage.

Virtuoso Simulator Components and Device Models Reference

Philips Models

5	v_{sb} (V)	Source-bulk voltage.
6	v_{to} (V)	Zero-bias threshold voltage.
7	v_{ts} (V)	Threshold voltage including back-bias effects.
8	v_{th} (V)	Threshold voltage including back-bias and drain-bias effects.
9	v_{gt} (V)	Effective gate drive voltage including back-bias and drain voltage effects.
10	v_{tod} (V)	Threshold voltage of the drift region.
11	$v_{dis\text{eff}}$ (V)	Effective internal drain-to-source voltage at actual bias.
12	v_{dissat} (V)	Saturation voltage of channel region at actual bias.
13	v_{ddisat} (V)	Saturation voltage of drift region at actual bias.
14	g_m (A/V)	Transconductance ($d\ i_{ds} / d\ v_{gs}$).
15	g_{mb} (A/V)	Substrate-transconductance ($d\ i_{ds} / d\ v_{bs}$).
16	g_{ds} (A/V)	Output conductance ($d\ i_{ds} / d\ v_{ds}$).
17	c_{dd} (F)	Capacitance ($d\ q_d / d\ v_d$).
18	c_{dg} (F)	Capacitance ($- d\ q_d / d\ v_g$).
19	c_{ds} (F)	Capacitance ($- d\ q_d / d\ v_s$).
20	c_{db} (F)	Capacitance ($- d\ q_d / d\ v_b$).
21	c_{gd} (F)	Capacitance ($- d\ q_g / d\ v_d$).
22	c_{gg} (F)	Capacitance ($d\ q_g / d\ v_g$).
23	c_{gs} (F)	Capacitance ($- d\ q_g / d\ v_s$).
24	c_{gb} (F)	Capacitance ($- d\ q_g / d\ v_b$).
25	c_{sd} (F)	Capacitance ($- d\ q_s / d\ v_d$).

Virtuoso Simulator Components and Device Models Reference

Philips Models

26	c_{sg} (F)	Capacitance ($-d q_s / d v_g$).
27	c_{ss} (F)	Capacitance ($d q_s / d v_s$).
28	c_{sb} (F)	Capacitance ($-d q_s / d v_b$).
29	c_{bd} (F)	Capacitance ($-d q_b / d v_d$).
30	c_{bg} (F)	Capacitance ($-d q_b / d v_g$).
31	c_{bs} (F)	Capacitance ($-d q_b / d v_s$).
32	c_{bb} (F)	Capacitance ($d q_b / d v_b$).
33	u	Transistor gain (g_m/g_{ds}).
34	r_{out} (Ω)	Small-signal output resistance ($1/g_{ds}$).
35	v_{early} (V)	Equivalent Early voltage ($ I_{D1} /g_{ds}$).
36	b_{eff} (A/V^2)	Gain factor.
37	f_{ug} (Hz)	Unity gain frequency at actual bias ($g_m/(2\pi C_{in})$).
38	g_{mos} (A/V)	Transconductance of channel region.
39	sqrt_{sfw} ($V/Hz^{1/2}$)	Input-referred RMS white noise voltage density.
40	sqrt_{sff} ($V/Hz^{1/2}$)	Input-referred RMS white noise voltage density at 1 kHz.
41	f_{knee} (Hz)	Cross-over frequency above which white noise is dominant.

Parameter Index

In the following index, I refers to instance parameters, M refers to the model parameters section, O refers to the output parameters section, and OP refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of $M-35$ means the 35th model parameter.

Virtuoso Simulator Components and Device Models Reference

Philips Models

a1ch	M-35	cgso	O-34	mexpd	M-28	the1	M-20
a1ch	O-25	cox	M-43	mexpd	O-18	the1	O-11
a1dr	M-39	cox	O-31	mo	M-33	the1acc	M-21
a1dr	O-28	coxd	M-44	mo	O-23	the1acc	O-12
a2ch	M-37	coxd	O-32	msdibl	M-32	the2	M-22
a2ch	O-26	csb	OP-28	msdibl	O-22	the2	O-13
a2dr	M-41	csd	OP-25	mult	I-1	the3	M-23
a2dr	O-29	csg	OP-26	nfa	M-48	the3	O-14
a3ch	M-38	css	OP-27	nfa	O-36	the3d	M-26
a3ch	O-27	dta	M-52	nfb	M-49	the3d	O-16
a3dr	M-42	etabet	M-14	nfb	O-37	tnom	M-55
a3dr	O-30	etabetacc	M-16	nfc	M-50	tox	M-51
alp	M-29	etard	M-18	nfc	O-38	tox	O-39
alp	O-19	etathe3	M-24	nt	M-47	tr	M-56
area	I-4	etathe3d	M-27	nt	O-35	tref	M-2
beff	OP-36	etathe3d	O-17	phib	M-9	type	M-53
bet	M-13	fknee	OP-41	phib	O-5	u	OP-33
bet	O-7	fug	OP-37	phibd	M-11	vddisat	OP-13
betacc	M-15	gds	OP-16	phibd	O-6	vdiseff	OP-11
betacc	O-8	gm	OP-14	rd	M-17	vdissat	OP-12

Virtuoso Simulator Components and Device Models Reference

Philips Models

cbb	OP-32	gmb	OP-15	rd	O-9	vds	OP-3
cbd	OP-29	gmмос	OP-38	region	I-2	vearly	OP-35
cbg	OP-30	iavl	OP-2	rout	OP-34	vfb	M-3
cbs	OP-31	ids	OP-1	sdibl	M-31	vfb	O-1
cdb	OP-20	imax	M-54	sdibl	O-21	vfbд	M-5
cdd	OP-17	ko	M-7	sqrtsff	OP-40	vfbд	O-2
cdg	OP-18	ko	O-3	sqrtsfw	OP-39	vgs	OP-4
cds	OP-19	kod	M-8	ssf	M-34	vgt	OP-9
cgb	OP-24	kod	O-4	ssf	O-24	vp	M-30
cgd	OP-21	lamд	M-19	stalch	M-36	vp	O-20
cgdo	M-45	lamд	O-10	staldr	M-40	vsb	OP-5
cgdo	O-33	level	M-1	stphib	M-10	vth	OP-8
cgg	OP-22	m	I-3	stphibd	M-12	vto	OP-6
cgs	OP-23	mexp	M-25	stvfb	M-4	vtod	OP-10
cgso	M-46	mexp	O-15	stvfbд	M-6	vts	OP-7

Lateral Double-diffused MOS Model (MOS Model Level 2002) (mos2002et)

This is SimKit 4.0

This device is supported within altergroups.

This device is dynamically loaded from the shared object /vobs/spectre_dev/tools.lnx86/cmi/lib/5.0.doc/libphilips_sh.so

Virtuoso Simulator Components and Device Models Reference

Philips Models

Instance Definition

```
Name d g s b dt ModelName parameter=value ...
```

Instance Parameters

- | | | |
|---|----------------------------|---|
| 1 | <code>mult=1</code> | Number of devices in parallel. |
| 2 | <code>region=triode</code> | Estimated DC operating region, used as a convergence aid. Possible values are <code>off</code> , <code>triode</code> , <code>sat</code> , or <code>subth</code> . |
| 3 | <code>m=1</code> | Multiplicity factor. |
| 4 | <code>area=1</code> | alias of <code>mult</code> . |

Model Definition

```
model modelName mos2002et parameter=value ...
```

Model Parameters

- | | | |
|---|-----------------------------|---|
| 1 | <code>level=2e+03</code> | Must be 2002. |
| 2 | <code>tref=25 deg. C</code> | Reference temperature. |
| 3 | <code>vfb=-1 V</code> | Flatband voltage of the channel region, at reference temperature. |
| 4 | <code>stvfb=0 V/K</code> | Temperature scaling coefficient for VFB. |
| 5 | <code>vfbd=-0.1 V</code> | Flatband voltage of the drift region, at reference temperature. |
| 6 | <code>stvfbd=0 V/K</code> | Temperature scaling coefficient for the flatband voltage of the drift region. |
| 7 | <code>ko=1.6 V^(1/2)</code> | Body factor of the channel region. |
| 8 | <code>kod=1 V^(1/2)</code> | Body factor of the drift region. |
| 9 | <code>phib=0.86 V</code> | Surface potential at the onset of strong inversion in the channel region, at reference temperature. |

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 10 $stphib=-0.0012$ V/K Temperature scaling coefficient for PHIB.
- 11 $phibd=0.78$ V Surface potential at the onset of strong inversion in the drift region, at reference temperature.
- 12 $stphibd=-0.0012$ V/K Temperature scaling coefficient for PHIBD.
- 13 $bet=0.0014$ A/V² Gain factor of the channel region, at reference temperature.
- 14 $etabet=1.6$ Temperature scaling exponent for BET.
- 15 $betacc=0.0014$ A/V⁻² Gain factor for accumulation in the drift region, at reference temperature.
- 16 $etabetacc=1.5$ Temperature scaling exponent for BETACC.
- 17 $rd=200$ Ω On-resistance of the drift region, at reference temperature.
- 18 $etard=1.5$ Temperature scaling exponent for RD.
- 19 $lamd=0.2$ Quotient of the depletion layer thickness to the effective thickness of the drift region at VSB = 0 V.
- 20 $the1=0.09$ V⁻¹ Mobility reduction coefficient in the channel region due to vertical electrical field caused by strong inversion.
- 21 $the1acc=0.02$ V⁻¹ Mobility reduction coefficient in the drift region due to the vertical electrical field caused by accumulation.
- 22 $the2=0.03$ V^(-1/2) Mobility reduction coefficient for VSB > 0 in the channel region due to the vertical electrical field caused by depletion.
- 23 $the3=0.4$ V⁻¹ Mobility reduction coefficient in the channel region due to the horizontal electrical field caused by velocity saturation.
- 24 $etathe3=1$ Temperature scaling exponent for THE3.
- 25 $mexp=2$ Smoothing factor for transition from linear to saturation regime.

Virtuoso Simulator Components and Device Models Reference

Philips Models

26	$the3d=0 \text{ V}^{-1}$	Mobility reduction coefficient in the drift region due to the horizontal electrical field caused by velocity saturation.
27	$etathe3d=1$	Temperature scaling exponent for THE3D.
28	$mexpd=2$	Smoothing factor for transition from linear to quasi-saturation regime.
29	$alp=0.002$	Factor for channel length modulation.
30	$vp=0.05 \text{ V}$	Characteristic voltage of channel length modulation.
31	$sdibl=0.001 \text{ V}^{-1/2}$	Factor for drain-induced barrier lowering.
32	$msdibl=3$	Exponent for the drain-induced barrier lowering dependence on the backgate bias.
33	$mo=0 \text{ V}$	Parameter for the (short-channel) sub-threshold slope.
34	$ssf=1e-12 \text{ V}^{-1/2}$	Factor for static feedback.
35	$a1ch=15$	Factor of channel weak avalanche current, at reference temperature.
36	$sta1ch=0 \text{ K}^{-1}$	Temperature scaling coefficient for A1CH.
37	$a2ch=73 \text{ V}$	Exponent of channel weak avalanche current.
38	$a3ch=0.8$	Factor of the drain-source voltage above which channel weak avalanche occurs.
39	$a1dr=15$	Factor of drift weak avalanche current, at reference temperature.
40	$sta1dr=0 \text{ K}^{-1}$	Temperature scaling coefficient for A1DR.
41	$a2dr=73 \text{ V}$	Exponent of drift weak avalanche current.
42	$a3dr=0.8$	Factor of the drain-source voltage above which drift weak avalanche occurs.
43	$cox=1.5e-14 \text{ F}$	Oxide capacitance for the intrinsic channel region.

Virtuoso Simulator Components and Device Models Reference

Philips Models

44	$\text{cox}\bar{d}=1.5\text{e-}14$ F	Oxide capacitance for the intrinsic drift region.
45	$\text{cgdo}=0$ F	Gate-to-drain overlap capacitance.
46	$\text{cgso}=0$ F	Gate-to-source overlap capacitance.
47	$\text{nt}=1.65\text{e-}20$ J	Coefficient of thermal noise, at reference temperature.
48	$\text{nfa}=7\text{e+}23$ V ⁻¹ m ⁻⁴	First coefficient of flicker noise.
49	$\text{nfb}=1\text{e+}07$ V ⁻¹ m ⁻²	Second coefficient of flicker noise.
50	$\text{nfc}=0$ V ⁻¹	Third coefficient of flicker noise.
51	$\text{tox}=3.8\text{e-}08$ m	Thickness of the oxide above the channel region.
52	$\text{dta}=0$ K	Temperature offset to the ambient temperature.
53	$\text{rth}=300$ K/W	Thermal resistance.
54	$\text{cth}=3\text{e-}09$ J/K	Thermal capacitance.
55	$\text{ath}=0$	Temperature coefficient of the thermal resistance.
56	$\text{type}=\text{n}$	Transistor gender. Possible values are n, p, npn, pnp, npnv, pnpv, npnl, or pnp1.
57	$\text{imax}=1.0$ A	Explosion current.
58	tnom (deg. C)	alias of tnom .
59	tr (deg. C)	alias of tnom .

Output Parameters

1	vfb (V)	Flatband voltage of the channel region, at reference temperature.
2	$\text{vfb}\bar{d}$ (V)	Flatband voltage of the drift region.
3	ko (V ^{1/2})	Body factor of the channel region.

Virtuoso Simulator Components and Device Models Reference

Philips Models

4	kod ($V^{1/2}$)	Body factor of the drift region.
5	$phib$ (V)	Surface potential at the onset of strong inversion in the channel region, at reference temperature.
6	$phibd$ (V)	Surface potential at the onset of strong inversion in the drift region, at reference temperature.
7	bet (A/V^2)	Gain factor of the channel region, at reference temperature.
8	$betacc$ (A/V^2)	Gain factor for accumulation in the drift region, at reference temperature.
9	rd (Ω)	On-resistance of the drift region, at reference temperature.
10	$lamd$	Quotient of the depletion layer thickness to the effective thickness of the drift region at $V_{SB} = 0$ V.
11	$the1$ (V^{-1})	Mobility reduction coefficient in the channel region due to vertical electrical field caused by strong inversion.
12	$the1acc$ (V^{-1})	Mobility reduction coefficient in the drift region due to the vertical electrical field caused by accumulation.
13	$the2$ ($V^{-1/2}$)	Mobility reduction coefficient for $V_{SB} > 0$ in the channel region due to the vertical electrical field caused by depletion.
14	$the3$ (V^{-1})	Mobility reduction coefficient in the channel region due to the horizontal electrical field caused by velocity saturation.
15	$mexp$	Smoothing factor for transition from linear to saturation regime.
16	$the3d$ (V^{-1})	Mobility reduction coefficient in the drift region due to the horizontal electrical field caused by velocity saturation.
17	$etathe3d$	Temperature scaling exponent for THE3D.
18	$mexpd$	Smoothing factor for transition from linear to quasi-saturation regime.
19	alp	Factor for channel length modulation.
20	vp (V)	Characteristic voltage of channel length modulation.

Virtuoso Simulator Components and Device Models Reference

Philips Models

21	$sdibl$ ($V^{-1/2}$)	Factor for drain-induced barrier lowering.
22	$msdibl$	Exponent for the drain-induced barrier lowering dependence on the backgate bias.
23	mo (V)	Parameter for the (short-channel) sub-threshold slope.
24	ssf ($V^{-1/2}$)	Factor for static feedback.
25	$a1ch$	Factor of channel weak avalanche current, at reference temperature.
26	$a2ch$ (V)	Exponent of channel weak avalanche current.
27	$a3ch$	Factor of the drain-source voltage above which channel weak avalanche occurs.
28	$a1dr$	Factor of drift weak avalanche current, at reference temperature.
29	$a2dr$ (V)	Exponent of drift weak avalanche current.
30	$a3dr$	Factor of the drain-source voltage above which drift weak avalanche occurs.
31	cox (F)	Oxide capacitance for the intrinsic channel region.
32	$coxd$ (F)	Oxide capacitance for the intrinsic drift region.
33	$cgdo$ (F)	Gate-to-drain overlap capacitance.
34	$cgso$ (F)	Gate-to-source overlap capacitance.
35	nt (J)	Coefficient of thermal noise, at reference temperature.
36	nfa ($V^{-1} m^{-4}$)	First coefficient of flicker noise.
37	nfb ($V^{-1} m^{-2}$)	Second coefficient of flicker noise.
38	nfc (V^{-1})	Third coefficient of flicker noise.
39	tox (m)	Thickness of the oxide above the channel region.
40	rth (K/W)	Thermal resistance.

41 c_{th} (J/K) Thermal capacitance.

Operating-Point Parameters

1 i_{ds} (A) Drain current, excl. avalanche and tunnel currents.

2 i_{avl} (A) Substrate current due to weak-avalanche.

3 v_{ds} (V) Drain-source voltage.

4 v_{gs} (V) Gate-source voltage.

5 v_{sb} (V) Source-bulk voltage.

6 v_{to} (V) Zero-bias threshold voltage.

7 v_{ts} (V) Threshold voltage including back-bias effects.

8 v_{th} (V) Threshold voltage including back-bias and drain-bias effects.

9 v_{gt} (V) Effective gate drive voltage including back-bias and drain voltage effects.

10 v_{tod} (V) Threshold voltage of the drift region.

11 $v_{dis\text{eff}}$ (V) Effective internal drain-to-source voltage at actual bias.

12 v_{dissat} (V) Saturation voltage of channel region at actual bias.

13 v_{ddisat} (V) Saturation voltage of drift region at actual bias.

14 g_m (A/V) Transconductance ($d i_{ds} / d v_{gs}$).

15 g_{mb} (A/V) Substrate-transconductance ($d i_{ds} / d v_{sb}$).

16 g_{ds} (A/V) Output conductance ($d i_{ds} / d v_{ds}$).

17 c_{dd} (F) Capacitance ($d q_d / d v_d$).

18 c_{dg} (F) Capacitance ($- d q_d / d v_g$).

19 c_{ds} (F) Capacitance ($- d q_d / d v_s$).

Virtuoso Simulator Components and Device Models Reference

Philips Models

20	c_{db} (F)	Capacitance ($-d q_d / d v_b$).
21	c_{gd} (F)	Capacitance ($-d q_g / d v_d$).
22	c_{gg} (F)	Capacitance ($d q_g / d v_g$).
23	c_{gs} (F)	Capacitance ($-d q_g / d v_s$).
24	c_{gb} (F)	Capacitance ($-d q_g / d v_b$).
25	c_{sd} (F)	Capacitance ($-d q_s / d v_d$).
26	c_{sg} (F)	Capacitance ($-d q_s / d v_g$).
27	c_{ss} (F)	Capacitance ($d q_s / d v_s$).
28	c_{sb} (F)	Capacitance ($-d q_s / d v_b$).
29	c_{bd} (F)	Capacitance ($-d q_b / d v_d$).
30	c_{bg} (F)	Capacitance ($-d q_b / d v_g$).
31	c_{bs} (F)	Capacitance ($-d q_b / d v_s$).
32	c_{bb} (F)	Capacitance ($d q_b / d v_b$).
33	u	Transistor gain (g_m/g_{ds}).
34	r_{out} (Ω)	Small-signal output resistance ($1/g_{ds}$).
35	v_{early} (V)	Equivalent Early voltage ($ I_{D1} /g_{ds}$).
36	b_{eff} (A/V^2)	Gain factor.
37	f_{ug} (Hz)	Unity gain frequency at actual bias ($g_m/(2*\pi*c_{in})$).
38	g_{mos} (A/V)	Transconductance of channel region.
39	$sqrtsfw$ ($V/Hz^{1/2}$)	Input-referred RMS white noise voltage density.
40	$sqrtsff$ ($V/Hz^{1/2}$)	Input-referred RMS white noise voltage density at 1 kHz.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 41 f_{knee} (Hz) Cross-over frequency above which white noise is dominant.
- 42 P_{diss} (W) Dissipation.
- 43 T_K (K) Actual temperature.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

P_{diss} OP-42	c_{gso} M-46	m_{exp} O-15	$stvfbd$ M-6
T_K OP-43	c_{gso} O-34	m_{expd} M-28	$the1$ M-20
$a1ch$ M-35	c_{ox} M-43	m_{expd} O-18	$the1$ O-11
$a1ch$ O-25	c_{ox} O-31	mo M-33	$the1acc$ M-21
$a1dr$ M-39	c_{oxd} M-44	mo O-23	$the1acc$ O-12
$a1dr$ O-28	c_{oxd} O-32	$msdibl$ M-32	$the2$ M-22
$a2ch$ M-37	c_{sb} OP-28	$msdibl$ O-22	$the2$ O-13
$a2ch$ O-26	c_{sd} OP-25	$mult$ I-1	$the3$ M-23
$a2dr$ M-41	c_{sg} OP-26	nfa M-48	$the3$ O-14
$a2dr$ O-29	c_{ss} OP-27	nfa O-36	$the3d$ M-26
$a3ch$ M-38	c_{th} M-54	nfb M-49	$the3d$ O-16
$a3ch$ O-27	c_{th} O-41	nfb O-37	$tnom$ M-58
$a3dr$ M-42	d_{ta} M-52	nfc M-50	tox M-51

Virtuoso Simulator Components and Device Models Reference

Philips Models

a3dr	O-30	etabet	M-14	nfc	O-38	tox	O-39
alp	M-29	etabetacc	M-16	nt	M-47	tr	M-59
alp	O-19	etard	M-18	nt	O-35	tref	M-2
area	I-4	etathe3	M-24	phib	M-9	type	M-56
ath	M-55	etathe3d	M-27	phib	O-5	u	OP-33
beff	OP-36	etathe3d	O-17	phibd	M-11	vddisat	OP-13
bet	M-13	fknee	OP-41	phibd	O-6	vdiseff	OP-11
bet	O-7	fug	OP-37	rd	M-17	vdissat	OP-12
betacc	M-15	gds	OP-16	rd	O-9	vds	OP-3
betacc	O-8	gm	OP-14	region	I-2	vearly	OP-35
cbb	OP-32	gmb	OP-15	rout	OP-34	vfb	M-3
cbd	OP-29	gmмос	OP-38	rth	M-53	vfb	O-1
cbg	OP-30	iavl	OP-2	rth	O-40	vfbд	M-5
cbs	OP-31	ids	OP-1	sdibl	M-31	vfbд	O-2
cdb	OP-20	imax	M-57	sdibl	O-21	vgs	OP-4
cdd	OP-17	ko	M-7	sqrtsff	OP-40	vgt	OP-9
cdg	OP-18	ko	O-3	sqrtsfw	OP-39	vp	M-30
cds	OP-19	kod	M-8	ssf	M-34	vp	O-20
cgb	OP-24	kod	O-4	ssf	O-24	vsb	OP-5
cgd	OP-21	lamd	M-19	stalch	M-36	vth	OP-8
cgdo	M-45	lamd	O-10	staldr	M-40	vto	OP-6

Virtuoso Simulator Components and Device Models Reference

Philips Models

cgdo	O-33	level	M-1	stphib	M-10	vtod	OP-10
cgg	OP-22	m	I-3	stphibd	M-12	vtb	OP-7
cgs	OP-23	mexp	M-25	stvfb	M-4		

Lateral Double-diffused MOS Model (MOS Model Level 2002) (mos2002t)

This is SimKit 4.0

This device is supported within altergroups.

This device is dynamically loaded from the shared object /vobs/spectre_dev/tools.lnx86/cmi/lib/5.0.doc/libphilips_sh.so

Instance Definition

```
Name d g s b dt ModelName parameter=value ...
```

Instance Parameters

- | | | |
|---|---------------|---|
| 1 | w=2e-05 m | Drawn width of the channel region. |
| 2 | wd=2e-05 m | Drawn width of the drift region. |
| 3 | mult=1 | Number of devices in parallel. |
| 4 | region=triode | Estimated DC operating region, used as a convergence aid. Possible values are off, triode, sat, or subth. |
| 5 | m=1 | Multiplicity factor. |
| 6 | area=1 | alias of mult. |

Model Definition

```
model modelName mos2002t parameter=value ...
```

Virtuoso Simulator Components and Device Models Reference

Philips Models

Model Parameters

1	<code>level=2e+03</code>	Must be 2002.
2	<code>wvar=0 m</code>	Width offset of the channel region.
3	<code>wdvar=0 m</code>	Width offset of the drift region.
4	<code>tref=25 deg. C</code>	Reference temperature.
5	<code>vfb=-1 V</code>	Flatband voltage of the channel region, at reference temperature.
6	<code>stvfb=0 V/K</code>	Temperature scaling coefficient for VFB.
7	<code>vfbd=-0.1 V</code>	Flatband voltage of the drift region, at reference temperature.
8	<code>stvfbd=0 V/K</code>	Temperature scaling coefficient for the flatband voltage of the drift region.
9	<code>kor=1.6 V^(1/2)</code>	Body factor of the channel region of an infinitely wide transistor.
10	<code>swko=0</code>	Width scaling coefficient for KO.
11	<code>kodr=1 V^(1/2)</code>	Body factor of the drift region of an infinitely wide transistor.
12	<code>swkod=0</code>	Width scaling coefficient for the body factor of the drift region.
13	<code>phib=0.86 V</code>	Surface potential at the onset of strong inversion in the channel region, at reference temperature.
14	<code>stphib=-0.0012 V/K</code>	Temperature scaling coefficient for PHIB.
15	<code>phibd=0.78 V</code>	Surface potential at the onset of strong inversion in the drift region, at reference temperature.
16	<code>stphibd=-0.0012 V/K</code>	Temperature scaling coefficient for PHIBD.
17	<code>betw=7e-05 A/V²</code>	Gain factor of a channel region of 1 μm wide, at reference temperature.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 18 $etabet=1.6$ Temperature scaling exponent for BET.
- 19 $betaccw=7e-05 \text{ A/V}^{-2}$ Gain factor of drift region of 1 μm wide, at reference temperature.
- 20 $etabetacc=1.5$ Temperature scaling exponent for BETACC.
- 21 $rdw=4e+03 \text{ } \Omega$ On-resistance of a drift region of 1 μm wide, at reference temperature.
- 22 $etard=1.5$ Temperature scaling exponent for RD.
- 23 $lamd=0.2$ Quotient of the depletion layer thickness to the effective thickness of the drift region at $V_{SB} = 0 \text{ V}$.
- 24 $the1r=0.09 \text{ V}^{-1}$ Mobility reduction coefficient of infinitely wide transistor, due to vertical strong-inversion field in a channel region.
- 25 $swthe1=0$ Width scaling coefficient for THE1.
- 26 $the1acc=0.02 \text{ V}^{-1}$ Mobility reduction coefficient in the drift region due to the vertical electrical field caused by accumulation.
- 27 $the2r=0.03 \text{ V}^{(-1/2)}$ Mobility reduction coefficient for $V_{SB} > 0$ of an infinitely wide transistor, due to vertical depletion field in channel region.
- 28 $swthe2=0$ Width scaling coefficient for THE2.
- 29 $the3r=0.4 \text{ V}^{-1}$ Mobility reduction coefficient in a channel region of an infinitely wide transistor due to velocity saturation.
- 30 $etathe3=1$ Temperature scaling exponent for THE3.
- 31 $swthe3=0$ Width scaling coefficient for THE3.
- 32 $mexp=2$ Smoothing factor for transition from linear to saturation regime.
- 33 $the3dr=0 \text{ V}^{-1}$ Mobility reduction coefficient in a channel region of an infinitely wide transistor due to velocity saturation.
- 34 $etathe3d=1$ Temperature scaling exponent for THE3D.

Virtuoso Simulator Components and Device Models Reference

Philips Models

35	<code>swthe3d=0</code>	Width scaling coefficient for THE3D.
36	<code>mexpd=2</code>	Smoothing factor for transition from linear to quasi-saturation regime.
37	<code>alp=0.002</code>	Factor for channel length modulation.
38	<code>vp=0.05 V</code>	Characteristic voltage of channel length modulation.
39	<code>sdibl=0.001 V^(-1/2)</code>	Factor for drain-induced barrier lowering.
40	<code>msdibl=3</code>	Exponent for the drain-induced barrier lowering dependence on the backgate bias.
41	<code>mo=0 V</code>	Parameter for the (short-channel) sub-threshold slope.
42	<code>ssf=1e-12 V^(-1/2)</code>	Factor for static feedback.
43	<code>a1chr=15</code>	Factor of channel weak avalanche current of an infinitely wide transistor, at reference temperature.
44	<code>sta1ch=0 K⁻¹</code>	Temperature scaling coefficient for A1CH.
45	<code>swa1ch=0</code>	Width scaling coefficient for A1CH.
46	<code>a2ch=73 V</code>	Exponent of channel weak avalanche current.
47	<code>a3ch=0.8</code>	Factor of the drain-source voltage above which channel weak avalanche occurs.
48	<code>a1drr=15</code>	Factor of drift weak avalanche current of an infinitely wide transistor, at reference temperature.
49	<code>sta1dr=0 K⁻¹</code>	Temperature scaling coefficient for A1DR.
50	<code>swa1dr=0</code>	Width scaling coefficient for A1DR.
51	<code>a2dr=73 V</code>	Exponent of drift weak avalanche current.
52	<code>a3dr=0.8</code>	Factor of the drain-source voltage above which drift weak avalanche occurs.

Virtuoso Simulator Components and Device Models Reference

Philips Models

53	$\text{coxw}=7.5\text{e-}16$ F	Oxide capacitance for an intrinsic channel region of 1um wide.
54	$\text{coxdw}=7.5\text{e-}16$ F	Oxide capacitance for an intrinsic drift region of 1um wide.
55	$\text{cgdow}=0$ F	Gate-to-drain overlap capacitance for a drift region of 1 um wide.
56	$\text{cgsow}=0$ F	Gate-to-source overlap capacitance for a channel region of 1 um wide.
57	$\text{nt}=1.65\text{e-}20$ J	Coefficient of thermal noise, at reference temperature.
58	$\text{nfaw}=1.4\text{e+}25$ $\text{V}^{-1} \text{m}^{-4}$	First coefficient of flicker noise for a channel region of 1 um wide.
59	$\text{nfbw}=2\text{e+}08$ $\text{V}^{-1} \text{m}^{-2}$	Second coefficient of flicker noise for a channel region of 1 um wide.
60	$\text{nfcw}=0$ V^{-1}	Third coefficient of flicker noise for a channel region of 1 um wide.
61	$\text{tox}=3.8\text{e-}08$ m	Thickness of the oxide above the channel region.
62	$\text{dta}=0$ K	Temperature offset to the ambient temperature.
63	$\text{rth}=300$ K/W	Thermal resistance.
64	$\text{cth}=3\text{e-}09$ J/K	Thermal capacitance.
65	$\text{ath}=0$	Temperature coefficient of the thermal resistance.
66	$\text{type}=\text{n}$	Transistor gender. Possible values are n, p, npn, pnp, npnv, pnpv, npnl, or pnp1.
67	$\text{imax}=1.0$ A	Explosion current.
68	tnom (deg. C)	alias of tnom.
69	tr (deg. C)	alias of tnom.

Output Parameters

1	vfb (V)	Flatband voltage of the channel region, at reference temperature.
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Virtuoso Simulator Components and Device Models Reference

Philips Models

2	v_{fbd} (V)	Flatband voltage of the drift region.
3	k_o ($V^{1/2}$)	Body factor of the channel region.
4	k_{od} ($V^{1/2}$)	Body factor of the drift region.
5	ϕ_{ib} (V)	Surface potential at the onset of strong inversion in the channel region, at reference temperature.
6	ϕ_{ibd} (V)	Surface potential at the onset of strong inversion in the drift region, at reference temperature.
7	β_{et} (A/V^2)	Gain factor of the channel region, at reference temperature.
8	β_{etacc} (A/V^2)	Gain factor for accumulation in the drift region, at reference temperature.
9	r_d (Ω)	On-resistance of the drift region, at reference temperature.
10	λ_{md}	Quotient of the depletion layer thickness to the effective thickness of the drift region at $V_{SB} = 0$ V.
11	θ_{e1} (V^{-1})	Mobility reduction coefficient in the channel region due to vertical electrical field caused by strong inversion.
12	θ_{e1acc} (V^{-1})	Mobility reduction coefficient in the drift region due to the vertical electrical field caused by accumulation.
13	θ_{e2} ($V^{-1/2}$)	Mobility reduction coefficient for $V_{SB} > 0$ in the channel region due to the vertical electrical field caused by depletion.
14	θ_{e3} (V^{-1})	Mobility reduction coefficient in the channel region due to the horizontal electrical field caused by velocity saturation.
15	m_{exp}	Smoothing factor for transition from linear to saturation regime.
16	θ_{e3d} (V^{-1})	Mobility reduction coefficient in the drift region due to the horizontal electrical field caused by velocity saturation.
17	$e_{\theta_{e3d}}$	Temperature scaling exponent for THE3D.
18	m_{expd}	Smoothing factor for transition from linear to quasi-saturation regime.

Virtuoso Simulator Components and Device Models Reference

Philips Models

19	alp	Factor for channel length modulation.
20	vp (V)	Characteristic voltage of channel length modulation.
21	sdibl ($V^{-1/2}$)	Factor for drain-induced barrier lowering.
22	msdibl	Exponent for the drain-induced barrier lowering dependence on the backgate bias.
23	mo (V)	Parameter for the (short-channel) sub-threshold slope.
24	ssf ($V^{-1/2}$)	Factor for static feedback.
25	a1ch	Factor of channel weak avalanche current, at reference temperature.
26	a2ch (V)	Exponent of channel weak avalanche current.
27	a3ch	Factor of the drain-source voltage above which channel weak avalanche occurs.
28	a1dr	Factor of drift weak avalanche current, at reference temperature.
29	a2dr (V)	Exponent of drift weak avalanche current.
30	a3dr	Factor of the drain-source voltage above which drift weak avalanche occurs.
31	cox (F)	Oxide capacitance for the intrinsic channel region.
32	cox \bar{d} (F)	Oxide capacitance for the intrinsic drift region.
33	cgdo (F)	Gate-to-drain overlap capacitance.
34	cgso (F)	Gate-to-source overlap capacitance.
35	nt (J)	Coefficient of thermal noise, at reference temperature.
36	nfa ($V^{-1} m^{-4}$)	First coefficient of flicker noise.
37	nfb ($V^{-1} m^{-2}$)	Second coefficient of flicker noise.
38	nfc (V^{-1})	Third coefficient of flicker noise.

Virtuoso Simulator Components and Device Models Reference

Philips Models

39	t_{ox} (m)	Thickness of the oxide above the channel region.
40	r_{th} (K/W)	Thermal resistance.
41	c_{th} (J/K)	Thermal capacitance.

Operating-Point Parameters

1	i_{ds} (A)	Drain current, excl. avalanche and tunnel currents.
2	i_{avl} (A)	Substrate current due to weak-avalanche.
3	v_{ds} (V)	Drain-source voltage.
4	v_{gs} (V)	Gate-source voltage.
5	v_{sb} (V)	Source-bulk voltage.
6	v_{to} (V)	Zero-bias threshold voltage.
7	v_{ts} (V)	Threshold voltage including back-bias effects.
8	v_{th} (V)	Threshold voltage including back-bias and drain-bias effects.
9	v_{gt} (V)	Effective gate drive voltage including back-bias and drain voltage effects.
10	v_{tod} (V)	Threshold voltage of the drift region.
11	$v_{dis\text{eff}}$ (V)	Effective internal drain-to-source voltage at actual bias.
12	v_{dissat} (V)	Saturation voltage of channel region at actual bias.
13	v_{ddisat} (V)	Saturation voltage of drift region at actual bias.
14	g_m (A/V)	Transconductance ($d i_{ds} / d v_{gs}$).
15	g_{mb} (A/V)	Substrate-transconductance ($d i_{ds} / d v_{sb}$).
16	g_{ds} (A/V)	Output conductance ($d i_{ds} / d v_{ds}$).
17	c_{dd} (F)	Capacitance ($d q_d / d v_d$).

Virtuoso Simulator Components and Device Models Reference

Philips Models

18	c_{dg} (F)	Capacitance (- d qd / d vg).
19	c_{ds} (F)	Capacitance (- d qd / d vs).
20	c_{db} (F)	Capacitance (- d qd / d vb).
21	c_{gd} (F)	Capacitance (- d qg / d vd).
22	c_{gg} (F)	Capacitance (d qg / d vg).
23	c_{gs} (F)	Capacitance (- d qg / d vs).
24	c_{gb} (F)	Capacitance (- d qg / d vb).
25	c_{sd} (F)	Capacitance (- d qs / d vd).
26	c_{sg} (F)	Capacitance (- d qs / d vg).
27	c_{ss} (F)	Capacitance (d qs / d vs).
28	c_{sb} (F)	Capacitance (- d qs / d vb).
29	c_{bd} (F)	Capacitance (- d qb / d vd).
30	c_{bg} (F)	Capacitance (- d qb / d vg).
31	c_{bs} (F)	Capacitance (- d qb / d vs).
32	c_{bb} (F)	Capacitance (d qb / d vb).
33	w_{eff} (m)	Effective channel width for geometrical models.
34	w_{deff} (m)	Effective drift region width for geometrical model.
35	u	Transistor gain (gm/gds).
36	r_{out} (Ω)	Small-signal output resistance (1/gds).
37	v_{early} (V)	Equivalent Early voltage (lidl/gds).
38	b_{eff} (A/V ²)	Gain factor.
39	f_{ug} (Hz)	Unity gain frequency at actual bias (gm/(2*pi*cin)).

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 40 `gmmos` (A/V) Transconductance of channel region.
- 41 `sqrtsfw` (V/Hz^{1/2}) Input-referred RMS white noise voltage density.
- 42 `sqrtsff` (V/Hz^{1/2}) Input-referred RMS white noise voltage density at 1 kHz.
- 43 `fknee` (Hz) Cross-over frequency above which white noise is dominant.
- 44 `Pdiss` (W) Dissipation.
- 45 `TK` (K) Actual temperature.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

<code>P_{diss}</code>	OP-44	<code>cox_{dw}</code>	M-54	<code>nfa</code>	O-36	<code>the1r</code>	M-24
<code>TK</code>	OP-45	<code>cox_w</code>	M-53	<code>nfaw</code>	M-58	<code>the2</code>	O-13
<code>a1ch</code>	O-25	<code>csb</code>	OP-28	<code>nf_b</code>	O-37	<code>the2r</code>	M-27
<code>a1chr</code>	M-43	<code>csd</code>	OP-25	<code>nf_{bw}</code>	M-59	<code>the3</code>	O-14
<code>a1dr</code>	O-28	<code>csg</code>	OP-26	<code>nfc</code>	O-38	<code>the3d</code>	O-16
<code>a1drr</code>	M-48	<code>css</code>	OP-27	<code>nfc_w</code>	M-60	<code>the3dr</code>	M-33
<code>a2ch</code>	M-46	<code>cth</code>	M-64	<code>nt</code>	M-57	<code>the3r</code>	M-29
<code>a2ch</code>	O-26	<code>cth</code>	O-41	<code>nt</code>	O-35	<code>tnom</code>	M-68
<code>a2dr</code>	M-51	<code>dta</code>	M-62	<code>phib</code>	M-13	<code>tox</code>	M-61

Virtuoso Simulator Components and Device Models Reference

Philips Models

a2dr	O-29	etabet	M-18	phib	O-5	tox	O-39
a3ch	M-47	etabetacc	M-20	phibd	M-15	tr	M-69
a3ch	O-27	etard	M-22	phibd	O-6	tref	M-4
a3dr	M-52	etathe3	M-30	rd	O-9	type	M-66
a3dr	O-30	etathe3d	M-34	rdw	M-21	u	OP-35
alp	M-37	etathe3d	O-17	region	I-4	vddisat	OP-13
alp	O-19	fknee	OP-43	rout	OP-36	vdiseff	OP-11
area	I-6	fug	OP-39	rth	M-63	vdissat	OP-12
ath	M-65	gds	OP-16	rth	O-40	vds	OP-3
beff	OP-38	gm	OP-14	sdibl	M-39	vearly	OP-37
bet	O-7	gmb	OP-15	sdibl	O-21	vfb	M-5
betacc	O-8	gmms	OP-40	sqrtsff	OP-42	vfb	O-1
betaccw	M-19	iavl	OP-2	sqrtsfw	OP-41	vfbd	M-7
betw	M-17	ids	OP-1	ssf	M-42	vfbd	O-2
cbb	OP-32	imax	M-67	ssf	O-24	vgs	OP-4
cbd	OP-29	ko	O-3	stalch	M-44	vgt	OP-9
cbg	OP-30	kod	O-4	staldr	M-49	vp	M-38
cbs	OP-31	kodr	M-11	stphib	M-14	vp	O-20
cdb	OP-20	kor	M-9	stphibd	M-16	vsb	OP-5
cdd	OP-17	lamd	M-23	stvfb	M-6	vth	OP-8
cdg	OP-18	lamd	O-10	stvfbd	M-8	vto	OP-6

Virtuoso Simulator Components and Device Models Reference

Philips Models

cds	OP-19	level	M-1	swalch	M-45	vtod	OP-10
cgb	OP-24	m	I-5	swaldr	M-50	vts	OP-7
cgd	OP-21	mexp	M-32	swko	M-10	w	I-1
cgdo	O-33	mexp	O-15	swkod	M-12	wd	I-2
cgdow	M-55	mexpd	M-36	swthe1	M-25	wdeff	OP-34
cgg	OP-22	mexpd	O-18	swthe2	M-28	wdvar	M-3
cgs	OP-23	mo	M-41	swthe3	M-31	weff	OP-33
cgso	O-34	mo	O-23	swthe3d	M-35	wvar	M-2
cgsow	M-56	msdibl	M-40	the1	O-11		
cox	O-31	msdibl	O-22	the1acc	M-26		
coxd	O-32	mult	I-3	the1acc	O-12		

MOS Model 31, Level 3100 (mos3100)

This is SimKit 4.0

This device is supported within altergroups.

This device is dynamically loaded from the shared object /vobs/spectre_dev/tools.lnx86/cmi/lib/5.0.doc/libphilips_sh.so

Instance Definition

```
Name d g s b ModelName parameter=value ...
```

Instance Parameters

1 mult=1 Number of devices in parallel.

Virtuoso Simulator Components and Device Models Reference

Philips Models

2	<code>region=triode</code>	Estimated DC operating region, used as a convergence aid. Possible values are <code>off</code> , <code>triode</code> , <code>sat</code> , or <code>subth</code> .
3	<code>m=1</code>	Multiplicity factor.
4	<code>area=1</code>	alias of <code>mult</code> .

Model Definition

```
model modelName mos3100 parameter=value ...
```

Model Parameters

1	<code>level=3.1e+03</code>	Transistor level.
2	<code>ron=1 Ω</code>	Ohmic resistance at zero bias.
3	<code>rsat=1 Ω</code>	Space charge resistance at zero bias.
4	<code>vsat=10 V</code>	Critical drain-source voltage for hot carriers.
5	<code>psat=1</code>	Velocity saturation coefficient.
6	<code>vp=-1 V</code>	Pinch off voltage at zero gate and substrate voltages.
7	<code>tox=-1 m</code>	Gate oxide thickness.
8	<code>dch=1e+21 m⁻³</code>	Doping level channel.
9	<code>dsub=1e+21 m⁻³</code>	Doping level substrate.
10	<code>vsub=0.6 V</code>	Substrate diffusion voltage.
11	<code>vgap=1.2 V</code>	Bandgap voltage channel.
12	<code>cgate=0 F</code>	Gate capacitance at zero bias.
13	<code>csub=0 F</code>	Substrate capacitance at zero bias.
14	<code>tausc=0 s</code>	Space charge transit time of the channel.
15	<code>ach=0</code>	Temperature coefficient resistivity of the channel.

Virtuoso Simulator Components and Device Models Reference

Philips Models

16	<code>achmod=0</code>	Parameter to switch to extended temperature scaling.
17	<code>achron=0</code>	Temperature coefficient of ohmic resistance at zero bias.
18	<code>achvsat=0</code>	Temperature coefficient of critical drain-source voltage for hot carriers.
19	<code>achrsat=0</code>	Temperature coefficient of space charge resistance at zero bias.
20	<code>tref=25 deg. C</code>	Reference temperature.
21	<code>dta=0 deg. C</code>	Temperature offset of the device.
22	<code>type=n</code>	Transistor gender. Possible values are n, p, npn, pnp, npnv, pnpv, npnl, or pnp1.
23	<code>imax=1.0 A</code>	Explosion current.
24	<code>tnom (deg. C)</code>	alias of <code>tnom</code> .
25	<code>tr (deg. C)</code>	alias of <code>tnom</code> .

Output Parameters

1	<code>ront (Ω)</code>	Ohmic resistance at zero bias.
2	<code>rsatt (Ω)</code>	Space charge resistance at zero bias.
3	<code>vsatt (V)</code>	Critical drain-source voltage for hot carriers.
4	<code>psat</code>	Velocity saturation coefficient.
5	<code>vp (V)</code>	Pinch off voltage at zero gate and substrate voltages.
6	<code>tox (m)</code>	Gate oxide thickness.
7	<code>dch (m^{-3})</code>	Doping level channel.
8	<code>dsub (m^{-3})</code>	Doping level substrate.
9	<code>vsubt (V)</code>	Substrate diffusion voltage.
10	<code>cgate (F)</code>	Gate capacitance at zero bias.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 11 c_{subt} (F) Substrate capacitance at zero bias.
- 12 τ_{ausc} (s) Space charge transit time of the channel.

Operating-Point Parameters

- 1 i_{ds} (A) Drain source current (including velocity saturation).
- 2 v_{ds} (V) Drain source voltage.
- 3 v_{gs} (V) Gate source voltage.
- 4 v_{bs} (V) Bulk source voltage.
- 5 v_p (V) Channel pinch off voltage.
- 6 g_m (A/V) Transconductance (di_{ds}/dV_g).
- 7 g_{mb} (A/V) Bulk transconductance (di_{ds}/dV_b).
- 8 g_{ds} (A/V) Output conductance (di_{ds}/dV_d).
- 9 q_g (C) Gate charge.
- 10 c_{gd} (F) Gate charge dependence on drain voltage ($-dQ_g/dV_d$).
- 11 c_{gg} (F) Gate charge dependence on gate voltage (dQ_g/dV_g).
- 12 c_{gs} (F) Gate charge dependence on source voltage ($-dQ_g/dV_s$).
- 13 c_{gb} (F) Gate charge dependence on bulk voltage ($-dQ_g/dV_b$).
- 14 q_b (C) Bulk charge.
- 15 c_{bd} (F) Bulk charge dependence on drain voltage ($-dQ_b/dV_d$).
- 16 c_{bg} (F) Bulk charge dependence on gate voltage ($-dQ_b/dV_g$).
- 17 c_{bs} (F) Bulk charge dependence on source voltage ($-dQ_b/dV_s$).
- 18 c_{bb} (F) Bulk charge dependence on bulk voltage (dQ_b/dV_b).
- 19 q_d (C) Drain charge.

Virtuoso Simulator Components and Device Models Reference

Philips Models

20	c_{dd} (F)	Drain charge dependence on drain voltage (dQ_d/dV_d).
21	c_{dg} (F)	Drain charge dependence on gate voltage ($-dQ_d/dV_g$).
22	c_{ds} (F)	Drain charge dependence on source voltage ($-dQ_d/dV_s$).
23	c_{db} (F)	Drain charge dependence on bulk voltage ($-dQ_d/dV_b$).
24	q_s (C)	Source charge.
25	c_{sd} (F)	Source charge dependence on drain voltage ($-dQ_s/dV_d$).
26	c_{sg} (F)	Source charge dependence on gate voltage ($-dQ_s/dV_g$).
27	c_{ss} (F)	Source charge dependence on source voltage (dQ_s/dV_s).
28	c_{sb} (F)	Source charge dependence on bulk voltage ($-dQ_s/dV_b$).
29	u	Transistor gain (g_m/g_{ds}).
30	r_{out} (Ω)	Small signal output resistance ($1/g_{ds}$).
31	v_{early} (V)	Equivalent early voltage ($ I_{ds} /g_{ds}$).
32	i_{ohm} (A)	Drain source current excluding velocity saturation.
33	i_{hc} (A)	Critical current for velocity saturation.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

ach M-15	cgs OP-12	$level$ M-1	tox O-6
$achmod$ M-16	csb OP-28	m I-3	tr M-25

Virtuoso Simulator Components and Device Models Reference

Philips Models

achron	M-17	csd	OP-25	mult	I-1	tref	M-20
achrsat	M-19	csg	OP-26	psat	M-5	type	M-22
achvsat	M-18	css	OP-27	psat	O-4	u	OP-29
area	I-4	csub	M-13	qj	OP-14	vbs	OP-4
cbb	OP-18	csubt	O-11	qd	OP-19	vds	OP-2
cbd	OP-15	dch	M-8	qg	OP-9	vearly	OP-31
cbg	OP-16	dch	O-7	qs	OP-24	vgap	M-11
cbs	OP-17	dsub	M-9	region	I-2	vgs	OP-3
cdb	OP-23	dsub	O-8	ron	M-2	vp	M-6
cdd	OP-20	dta	M-21	ront	O-1	vp	O-5
cdg	OP-21	gds	OP-8	rout	OP-30	vp	OP-5
cds	OP-22	gm	OP-6	rsat	M-3	vsat	M-4
cgate	M-12	gmb	OP-7	rsatt	O-2	vsatt	O-3
cgate	O-10	ids	OP-1	tausc	M-14	vsub	M-10
cgb	OP-13	ihc	OP-33	tausc	O-12	vsubt	O-9
cgd	OP-10	imax	M-23	tnom	M-24		
cgg	OP-11	iohm	OP-32	tox	M-7		

MOS Model 31, Level 3100 (mos3100t)

This is SimKit 4.0

This device is supported within altergroups.

Virtuoso Simulator Components and Device Models Reference

Philips Models

This device is dynamically loaded from the shared object /vobs/spectre_dev/tools.lnx86/cmi/lib/5.0.doc/libphilips_sh.so

Instance Definition

```
Name d g s b dt modelName parameter=value ...
```

Instance Parameters

- | | | |
|---|---------------|---|
| 1 | mult=1 | Number of devices in parallel. |
| 2 | region=triode | Estimated DC operating region, used as a convergence aid. Possible values are off, triode, sat, or subth. |
| 3 | m=1 | Multiplicity factor. |
| 4 | area=1 | alias of mult. |

Model Definition

```
model modelName mos3100t parameter=value ...
```

Model Parameters

- | | | |
|---|----------------------------|--|
| 1 | level=3.1e+03 | Transistor level. |
| 2 | ron=1 Ω | Ohmic resistance at zero bias. |
| 3 | rsat=1 Ω | Space charge resistance at zero bias. |
| 4 | vsat=10 V | Critical drain-source voltage for hot carriers. |
| 5 | psat=1 | Velocity saturation coefficient. |
| 6 | vp=-1 V | Pinch off voltage at zero gate and substrate voltages. |
| 7 | tox=-1 m | Gate oxide thickness. |
| 8 | dch=1e+21 m ⁻³ | Doping level channel. |
| 9 | dsub=1e+21 m ⁻³ | Doping level substrate. |

Virtuoso Simulator Components and Device Models Reference

Philips Models

10	<code>vsub=0.6 V</code>	Substrate diffusion voltage.
11	<code>vgap=1.2 V</code>	Bandgap voltage channel.
12	<code>cgate=0 F</code>	Gate capacitance at zero bias.
13	<code>csub=0 F</code>	Substrate capacitance at zero bias.
14	<code>tausc=0 s</code>	Space charge transit time of the channel.
15	<code>ach=0</code>	Temperature coefficient resistivity of the channel.
16	<code>achmod=0</code>	Parameter to switch to extended temperature scaling.
17	<code>achron=0</code>	Temperature coefficient of ohmic resistance at zero bias.
18	<code>achvsat=0</code>	Temperature coefficient of critical drain-source voltage for hot carriers.
19	<code>achrsat=0</code>	Temperature coefficient of space charge resistance at zero bias.
20	<code>tref=25 deg. C</code>	Reference temperature.
21	<code>dta=0 deg. C</code>	Temperature offset of the device.
22	<code>rth=300 K/W</code>	Thermal resistance.
23	<code>cth=3e-09 J/K</code>	Thermal capacitance.
24	<code>ath=0</code>	Temperature coefficient of the thermal resistance.
25	<code>type=n</code>	Transistor gender. Possible values are n, p, npn, pnp, npnv, pnpv, npnl, or pnp1.
26	<code>imax=1.0 A</code>	Explosion current.
27	<code>tnom (deg. C)</code>	alias of tnom.
28	<code>tr (deg. C)</code>	alias of tnom.

Output Parameters

1	<code>ront (Ω)</code>	Ohmic resistance at zero bias.
---	---	--------------------------------

Virtuoso Simulator Components and Device Models Reference

Philips Models

2	<code>rsatt</code> (Ω)	Space charge resistance at zero bias.
3	<code>vsatt</code> (V)	Critical drain-source voltage for hot carriers.
4	<code>psat</code>	Velocity saturation coefficient.
5	<code>vp</code> (V)	Pinch off voltage at zero gate and substrate voltages.
6	<code>tox</code> (m)	Gate oxide thickness.
7	<code>dch</code> (m^{-3})	Doping level channel.
8	<code>dsub</code> (m^{-3})	Doping level substrate.
9	<code>vsubt</code> (V)	Substrate diffusion voltage.
10	<code>cgate</code> (F)	Gate capacitance at zero bias.
11	<code>csubt</code> (F)	Substrate capacitance at zero bias.
12	<code>tausc</code> (s)	Space charge transit time of the channel.
13	<code>rth</code> (K/W)	Thermal resistance.
14	<code>cth</code> (J/K)	Thermal capacitance.

Operating-Point Parameters

1	<code>ids</code> (A)	Drain source current (including velocity saturation).
2	<code>vds</code> (V)	Drain source voltage.
3	<code>vgs</code> (V)	Gate source voltage.
4	<code>vbs</code> (V)	Bulk source voltage.
5	<code>vp</code> (V)	Channel pinch off voltage.
6	<code>gm</code> (A/V)	Transconductance (dI_{ds}/dV_g).
7	<code>gmb</code> (A/V)	Bulk transconductance (dI_{ds}/dV_b).
8	<code>gds</code> (A/V)	Output conductance (dI_{ds}/dV_d).

Virtuoso Simulator Components and Device Models Reference

Philips Models

9	qg (C)	Gate charge.
10	cgd (F)	Gate charge dependence on drain voltage ($-dQg/dVd$).
11	cgg (F)	Gate charge dependence on gate voltage (dQg/dVg).
12	cgs (F)	Gate charge dependence on source voltage ($-dQg/dVs$).
13	cgb (F)	Gate charge dependence on bulk voltage ($-dQg/dVb$).
14	qb (C)	Bulk charge.
15	cbd (F)	Bulk charge dependence on drain voltage ($-dQb/dVd$).
16	cbg (F)	Bulk charge dependence on gate voltage ($-dQb/dVg$).
17	cbs (F)	Bulk charge dependence on source voltage ($-dQb/dVs$).
18	bbb (F)	Bulk charge dependence on bulk voltage (dQb/dVb).
19	qd (C)	Drain charge.
20	ddd (F)	Drain charge dependence on drain voltage (dQd/dVd).
21	cdg (F)	Drain charge dependence on gate voltage ($-dQd/dVg$).
22	cds (F)	Drain charge dependence on source voltage ($-dQd/dVs$).
23	cdb (F)	Drain charge dependence on bulk voltage ($-dQd/dVb$).
24	qs (C)	Source charge.
25	csd (F)	Source charge dependence on drain voltage ($-dQs/dVd$).
26	csg (F)	Source charge dependence on gate voltage ($-dQs/dVg$).
27	css (F)	Source charge dependence on source voltage (dQs/dVs).
28	csb (F)	Source charge dependence on bulk voltage ($-dQs/dVb$).
29	u	Transistor gain (gm/gds).
30	rou (Ω)	Small signal output resistance ($1/gds$).

Virtuoso Simulator Components and Device Models Reference

Philips Models

31	vearly (V)	Equivalent early voltage (I _{ds1} /g _{ds}).
32	iohm (A)	Drain source current excluding velocity saturation.
33	ihc (A)	Critical current for velocity saturation.
34	Pdiss (W)	Dissipation.
35	TK (K)	Actual temperature.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

Pdiss	OP-34	cgg	OP-11	iohm	OP-32	tox	M-7
TK	OP-35	cgs	OP-12	level	M-1	tox	O-6
ach	M-15	csb	OP-28	m	I-3	tr	M-28
achmod	M-16	csd	OP-25	mult	I-1	tref	M-20
achron	M-17	csg	OP-26	psat	M-5	type	M-25
achrsat	M-19	css	OP-27	psat	O-4	u	OP-29
achvsat	M-18	csub	M-13	qb	OP-14	vbs	OP-4
area	I-4	csubt	O-11	qd	OP-19	vds	OP-2
ath	M-24	cth	M-23	qg	OP-9	vearly	OP-31
cbb	OP-18	cth	O-14	qs	OP-24	vgap	M-11
cbd	OP-15	dch	M-8	region	I-2	vgs	OP-3

Virtuoso Simulator Components and Device Models Reference

Philips Models

cbg	OP-16	dch	O-7	ron	M-2	vp	M-6
cbs	OP-17	dsub	M-9	ront	O-1	vp	O-5
cdb	OP-23	dsub	O-8	rout	OP-30	vp	OP-5
cdd	OP-20	dta	M-21	rsat	M-3	vsat	M-4
cdg	OP-21	gds	OP-8	rsatt	O-2	vsatt	O-3
cds	OP-22	gm	OP-6	rth	M-22	vsub	M-10
cgate	M-12	gmb	OP-7	rth	O-13	vsubt	O-9
cgate	O-10	ids	OP-1	tausc	M-14		
cgb	OP-13	ihc	OP-33	tausc	O-12		
cgd	OP-10	imax	M-26	tnom	M-27		

Common MOSFET Equations

This chapter discusses the following topics:

- [Parameters Common to BSIM1 and BSIM2 Models](#) on page 954
- [Parameters Common to Levels 1-3 Only](#) on page 954
- [Source/Drain Bulk Junction Models](#) on page 956
- [Temperature Effect on Model Parameters](#) on page 962
- [Noise Model](#) on page 973

Spectre[®] circuit simulator has the following public-domain MOSFET models: Level-1, Level-2, Level-3, EKV, BSIM1 (Level-4), BSIM2 (Level-5), BSIM3v2, and 7BSIM3v3.

When the Spectre option `approx` is set to `yes`, `pow()` in the junction depletion capacitance calculation and `sqrt()` in the BJT and MOSFET level 1-5 models are replaced by a spline-function approximation. For more information, see `spectre -h options`.

Parameters Common to BSIM1 and BSIM2 Models

Electrical parameters that you specify override electrical parameters calculated with process parameters. The Spectre circuit simulator selects the default parameter value if you do not specify an electrical or a process parameter.

Channel Width and Length

(12-1)

$$W_{scaled} = w \times scale + xw \times scalem$$

(12-2)

$$W_{eff} = \begin{cases} w \times scale + xw \times scalem - 2wd \times scalem & \text{Level 1-3} \\ w \times scale + xw \times scalem - dw \times scalem & \text{BSIM 1-2} \end{cases}$$

(12-3)

$$L_{eff} = \begin{cases} l \times scale + xl \times scalem - 2ld \times scalem & \text{Level 1-3} \\ l \times scale + xl \times scalem - ld \times scalem & \text{BSIM 1-2} \end{cases}$$

Parameters Common to Levels 1-3 Only

This section discusses parameters that are common to levels 1-3 only.

- If you do not give *vto* and *nsub* is specified, *vto* is calculated from

(12-4)

$$vto = V_{FB} + phi + gamma \sqrt{phi}$$

where

(12-5)

$$V_{FB} = \phi_{MS} - \frac{q(nss)}{C_{ox}}$$

Virtuoso Simulator Components and Device Models Reference

Common MOSFET Equations

is the flat-band voltage and ϕ_{MS} is the work function difference between the gate material and the silicon substrate. With the following equations, the tpg (tps) parameter determines the value of ϕ_{MS} .

(12-6)

$$\phi_{MS} = \begin{cases} -0.5(E_g + phi) & \text{if } tpg = 1 \\ 0.5(E_g - phi) & \text{if } tpg = -1 \\ -0.05 - 0.5(E_g + phi) & \text{if } tpg = 0 \end{cases}$$

E_g is the energy gap whose equation is given later.

- If vto is specified, V_{FB} is calculated from

(12-7)

$$V_{FB} = vto - phi - gamma \sqrt{phi}$$

- If you do not give phi and $nsub$ is specified, phi is calculated from

(12-8)

$$phi = 2V_t \ln \left[\frac{nsub}{n_i} \right]$$

where n_i is the intrinsic carrier concentration of silicon and V_t is the thermal voltage given by kT/q .

- If you do not give $gamma$ and $nsub$ is specified, $gamma$ is calculated from

(12-9)

$$gamma = \frac{\sqrt{2q\epsilon_{si}nsub}}{C_{ox}}$$

- The consistency between kp , uo , and C_{ox} ($kp = uoC_{ox}$) is checked according to the following rules:

- If tox is not given, C_{ox} is calculated from the default value of tox .
- If kp is given, uo is calculated from $uo = kp/C_{ox}$, whether uo is given or not. If this uo value is different from that specified in the model, a warning message tells you that the specified kp and uo values are inconsistent.

Virtuoso Simulator Components and Device Models Reference

Common MOSFET Equations

- If you do not give kp and u_0 is specified, kp is calculated from $kp = u_0 * C_{ox}$.
- If neither kp nor u_0 is given, their default values are used.

In SPICE, if you give kp but not u_0 , u_0 is not calculated from kp . The default value of u_0 (600) is used. If you specify both kp and u_0 , SPICE does not check the consistency between them. In the Spectre circuit simulator, kp and u_0 are always consistent. This can cause the simulation results of the Spectre and SPICE simulators to be different. SPICE uses kp to evaluate the drain current (through the b term) while it uses u_0 to evaluate the drain saturation voltage V_{DSAT} (if $vmax$ is also specified).

Often only kp is specified in the model. SPICE then assigns a default value (600) to u_0 , but Spectre calculates u_0 from kp . This usually causes drain currents to be smaller in the Spectre simulator than in SPICE. If you need SPICE compatibility, you can set `compatible` to any option other than `spectre` (for example, `spice2`, `spice3`, `cdsspace`, or `spiceplus`) in the `.options` card, and the Spectre simulator does not force u_0 to be consistent with kp . In SPICE, V_{DSAT} is a function of $(u_0/vmax)$ rather than u_0 alone. Therefore, you can still make u_0 consistent with kp by proportionally adjusting the $vmax$ value without changing the results. However, you should check the parameter extraction program to find out how u_0 and $vmax$ are extracted before comparing SPICE and Spectre results or changing any of the model parameters.

- If tox is not indicated in the Level-1 model, the intrinsic MOSFET gate capacitances are not calculated.

Source/Drain Bulk Junction Models

Junction Leakage Current

(12-10)

$$I_{BS(BD)} = \begin{cases} i_s \left(e^{\frac{V_{BS(BD)}}{V_t}} - 1 \right) & \text{if } V_{BS(BD)} \leq V_{Expl} \\ I_{offset} + G_{Expl} V_{BS(BD)} & \text{otherwise} \end{cases}$$

where

(12-11)

$$V_{Expl} = V_t \ln \left[1 + \frac{imax}{is} \right]$$

is the forward explosion voltage,

(12-12)

$$G_{Expl} = V_t(imax + is)$$

is the conductance at V_{Expl} , and

(12-13)

$$I_{offset} = imax - V_{Expl}G_{Expl}$$

is the linear extrapolated current at $V_{BS(BD)} = 0$ from V_{Expl} .

Bulk-Junction Bottom (Sidewall) Capacitance

(12-14)

$$C_{BS(BD)} = \begin{cases} \frac{cbs(cbd)}{\left(1 - \frac{V_{BS(BD)}}{pb}\right)^{mj}} & \text{if } V_{BS(BD)} \leq fc \times pb \\ \frac{cbs(cbd)}{(1-fc)^{mj}} \left[1 + \frac{mj(V_{BS(BD)} - pb*fc)}{pb(1-fc)} \right] & \text{otherwise} \end{cases}$$

These equations also apply to the sidewall capacitances with pb and fc replaced by $fcsw$ and $pbsw$. If $fcsw$ is not given, fc is used. If $pbsw$ is not given, pb is used.

Drain and Source Area

The drain and source areas are calculated in the order shown in the following equations:

Virtuoso Simulator Components and Device Models Reference

Common MOSFET Equations

(12-15)

Drain area =	$\left. \begin{array}{l} ad \\ 2hdif*scale*m*W_{scaled} \\ W_{eff}*ld \\ W_{eff}*ldd \\ 0 \end{array} \right\}$	<p>if ad is given</p> <p>if $hdif$ is given</p> <p>if ld is given</p> <p>if ldd is given</p> <p>otherwise</p>
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(12-16)

Source area =	$\left. \begin{array}{l} as \\ 2hdif*scale*m*W_{scaled} \\ W_{eff}*ls \\ W_{eff}*lds \\ 0 \end{array} \right\}$	<p>if as is given</p> <p>if $hdif$ is given</p> <p>if ls is given</p> <p>if lds is given</p> <p>otherwise</p>
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Note: The ld (length of drain) parameter is an instance parameter that is different from the model parameter ld (lateral diffusion) used in calculating L_{eff} .

Drain and Source Perimeters

The drain and source perimeters are calculated in the order shown in the following equations:

(12-17)

Drain perimeter =	$\left. \begin{array}{l} pd \\ 4hdif*scale*m + 2W_{scaled} \\ W_{eff} + 2ld \\ W_{eff} + 2ldd \\ 0 \end{array} \right\}$	<p>if pd is given</p> <p>if $hdif$ is given</p> <p>if ld is given</p> <p>if ldd is given</p> <p>otherwise</p>
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(12-18)

$$\text{Source perimeter} = \begin{cases} p_s & \text{if } p_s \text{ is given} \\ 4hdif * scale_m + 2W_{scaled} & \text{if } hdif \text{ is given} \\ W_{eff} + 2l_s & \text{if } l_s \text{ is given} \\ W_{eff} + 2l_{ds} & \text{if } l_{ds} \text{ is given} \\ 0 & \text{otherwise} \end{cases}$$

Note: The l_d (length of drain) parameter is an instance parameter that is different from the model parameter l_d (lateral diffusion) used in calculating L_{eff} .

Drain and Source Squares

The number of drain and source squares is calculated in the order shown in the following equations:

(12-19)

$$\text{Number of drain squares} = \begin{cases} nrd & \text{if } nrd \text{ is given} \\ hdif / W_{scaled} & \text{if } hdif \text{ is given} \\ l_{gcd} / W_{eff} & \text{if } l_{gcd} \text{ is given} \\ 0 & \text{otherwise} \end{cases}$$

(12-20)

$$\text{Number of source squares} = \begin{cases} nrs & \text{if } nrs \text{ is given} \\ hdif / W_{scaled} & \text{if } hdif \text{ is given} \\ l_{gcs} / W_{eff} & \text{if } l_{gcs} \text{ is given} \\ 0 & \text{otherwise} \end{cases}$$

Junction Saturation Current

i_s always overrides j_s . If you give j_s but not i_s , the saturation currents are calculated from j_s and the source and drain areas.

(12-21)

$$\text{Drain saturation current} = \begin{cases} i_s & \text{if } i_s \text{ is given} \\ j_s * a_d & \text{otherwise} \end{cases}$$

(12-22)

$$\text{Source saturation current} = \begin{cases} i_s & \text{if } i_s \text{ is given} \\ j_s * a_s & \text{otherwise} \end{cases}$$

Junction Capacitance

c_{bs} (c_{bd}) always overrides c_j . If you do not give c_{bs} (c_{bd}) and c_j is specified, c_{bs} (c_{bd}) is calculated from c_j and the source (drain) area.

(12-23)

$$\text{Drain capacitance} = \begin{cases} c_{bd} & \text{if } c_{bd} \text{ is specified} \\ c_j * a_d & \text{otherwise} \end{cases}$$

(12-24)

$$\text{Source capacitance} = \begin{cases} c_{bs} & \text{if } c_{bs} \text{ is specified} \\ c_j * a_s & \text{otherwise} \end{cases}$$

Drain and Source Parasitic Resistance

For MSOFET models except EKV,

Virtuoso Simulator Components and Device Models Reference

Common MOSFET Equations

(12-25)

$$\text{Drain Resistance (R}_{\text{Deff}}) = \begin{cases} nrd * rsh + \frac{rdc}{N_{SC}} + \frac{rd(ld + ldif)scalem}{W_{scaled}} & \text{if } ldif \text{ is given} \\ nrd * rsh + \frac{rdc}{N_{SC}} + rd + \frac{rdd}{W_{eff}} & \text{otherwise} \end{cases}$$

(12-26)

$$\text{Source Resistance (R}_{\text{Seff}}) = \begin{cases} nrs * rsh + \frac{rsc}{N_{SC}} + \frac{rs(ld + ldif)scalem}{W_{scaled}} & \text{if } ldif \text{ is given} \\ nrs * rsh + \frac{rsc}{N_{SC}} + rs + \frac{rss}{W_{eff}} & \text{otherwise} \end{cases} \quad Z$$

(12-27)

$$N_{SC} = \begin{cases} 1 & \text{if } sc \text{ is infinity or negative (default)} \\ W_{eff} & \text{if } sc = 0 \\ \text{MAX}\left[\text{INT}\left(\frac{W_{eff}}{sc}\right), 1\right] & \text{otherwise} \end{cases}$$

For EKV,

(12-28)

$$\text{Drain Resistance (rdeff)} = \begin{cases} nrd * rsh + \frac{rdc}{W_{eff}} + \frac{rd(ld + ldif)scalem}{W_{scaled}} & \text{if } ldif \text{ is given} \\ nrd * rsh + \frac{rdc}{W_{eff}} + rd + \frac{rdd}{Width} & \text{otherwise} \end{cases}$$

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Common MOSFET Equations

(12-29)

$$\text{Source Resistance (rseff)} = \begin{cases} nrs*rsh + \frac{rsc}{W_{eff}} + \frac{rs(ld + ldif)scalem}{W_{scaled}} & \text{if } ldif \text{ is given} \\ nrs*rsh + \frac{rsc}{W_{eff}} + rs + \frac{rdd}{Width} & \text{otherwise} \end{cases}$$

Overlap Capacitance

(12-30)

$$C_{gd} = \begin{cases} cgdo/scalem*W_{eff} & \text{if } cgdo \text{ is given} \\ W_{scaled}(ld + meto)scalem*C_{ox} & \text{if } meto \text{ is given} \end{cases}$$

(12-31)

$$C_{gs} = \begin{cases} cgso/scalem*W_{eff} & \text{if } cgso \text{ is given} \\ W_{scaled}(ld + meto)scalem*C_{ox} & \text{if } meto \text{ is given} \end{cases}$$

(12-32)

$$C_{gb} = \begin{cases} cgbo/scalem*L_{eff} & \text{if } cgbo \text{ is given} \\ 2L_{eff}(ld + meto)scalem*C_{ox} & \text{if } meto \text{ is given} \end{cases}$$

where

(12-33)

$$C_{ox} = \frac{\epsilon_{ox}}{tox*scalem}$$

Temperature Effect on Model Parameters

You can set both the model and the instance temperatures with the *trise* parameter. If the instance *trise* is specified, it overrides the model *trise*. The device temperature *T* is calculated by

Virtuoso Simulator Components and Device Models Reference

Common MOSFET Equations

(12-34)

$$T = trise + T_{ambient}$$

where $T_{ambient}$ is the global temperature set by the simulator.

Mobility and Transconductance Parameters

(12-35)

$$u_o = u_{o_{nom}} \left(\frac{T}{T_{nom}} \right)^{ute}$$

(12-36)

$$k_p = k_{p_{nom}} \left(\frac{T}{T_{nom}} \right)^{ute}$$

where *ute* is the exponent parameter. Default value of *ute* is -1.5.

Energy Band Gap

(12-37)

$$E_g(T) = \begin{cases} e_g - \frac{gap1 * T^2}{T + gap2} & \text{if } tlev = 2 \\ \left(1.17 - \frac{4.73 \times 10^{-4} T^2}{T + 636} \right) & \text{if } tlev = 0 \text{ or } 1 \\ & \text{and } compatible = spectre \\ \left(1.16 - \frac{7.02 \times 10^{-4} T^2}{T + 1108} \right) & \text{otherwise} \end{cases}$$

Surface Potential

(12-38)

$$\phi(T) = \begin{cases} \phi_{nom}\left(\frac{T}{T_{nom}}\right) - \Delta\phi & \text{if } tlevc = 0 \\ \phi_{nom} - ptc\Delta T & \text{if } tlevc = 1 \text{ or } 2 \\ \phi_{nom} - \frac{d\phi}{dT}\Delta T & \text{if } tlevc = 3 \end{cases}$$

where

(12-39)

$$\Delta\phi = V_t(T) \left\{ 3 \ln \left[\frac{T}{T_{nom}} \right] + \frac{E_{g,nom}}{V_{t,nom}} - \frac{E_g(T)}{V_t(T)} \right\}$$

(12-40)

$$E_{g,nom} = E_g(T_{nom})$$

(12-41)

$$V_{t,nom} = \frac{k(T_{nom})}{q}$$

(12-42)

$$\Delta T = T - T_{nom}$$

(12-43)

$$n_i = 1.45 \times 10^{10} \left(\frac{T}{300} \right)^{1.5} \exp \left[\frac{1.12}{0.0516} - \frac{E_g(T)}{2V_t(T)} \right]$$

(12-44)

$$\frac{d\phi}{dT} = \begin{cases} \frac{-\left[\Delta E_{phi} + (1.16 - E_{g,nom}) * \left(2 - \frac{T_{nom}}{T_{nom} + 1108}\right)\right]}{T_{nom}} & \text{if } tlev = 0, 1 \\ \frac{-\left[\Delta E_{phi} + (eg - E_{g,nom}) * \left(2 - \frac{T_{nom}}{T_{nom} + gap2}\right)\right]}{T_{nom}} & \text{if } tlev = 2 \end{cases}$$

where

(12-45) $\Delta E_{phi} = E_{g,nom} + 3V_{t,nom} - phi_{nom}$

Built-in Voltage of Source/Drain Junctions

If $tlevc = 0$,

(12-46)

$$pb(T) = pb_{nom} \left(\frac{T}{T_{nom}} \right) - \Delta\phi$$

(12-47)

$$pbsw(T) = pbsw_{nom} \left(\frac{T}{T_{nom}} \right) - \Delta\phi$$

If $tlevc = 1,2$,

(12-48)

$$pb(T) = pb_{nom} - pta\Delta T$$

(12-49)

$$pbsw(T) = pbsw_{nom} - ptp\Delta T$$

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Common MOSFET Equations

If $tlev = 3$,

(12-50)

$$pb(T) = pb_{nom} + \left(\frac{d\phi_B}{dT}\right)\Delta T$$

(12-51)

$$pbsw(T) = pbsw_{nom} + \left(\frac{d\phi_{sw}}{dT}\right)\Delta T$$

where

(12-52)

$$\frac{d\phi_B}{dT} = \begin{cases} \frac{-\left[\Delta E_{PB} + (1.16 - E_{g,nom}) * \left(2 - \frac{Tnom}{Tnom + 1108}\right)\right]}{Tnom} & \text{if } tlev = 0, 1 \\ \frac{-\left[\Delta E_{PB} + (eg - E_{g,nom}) * \left(2 - \frac{Tnom}{Tnom + gap2}\right)\right]}{Tnom} & \text{if } tlev = 2 \end{cases}$$

(12-53)

$$\frac{d\phi_{BSW}}{dT} = \begin{cases} \frac{-\left[\Delta E_{PBSW} + (1.16 - E_{g,nom}) * \left(2 - \frac{Tnom}{Tnom + 1108}\right)\right]}{Tnom} & \text{if } tlev = 0, 1 \\ \frac{-\left[\Delta E_{PBSW} + (eg - E_{g,nom}) * \left(2 - \frac{Tnom}{Tnom + gap2}\right)\right]}{Tnom} & \text{if } tlev = 2 \end{cases}$$

where

(12-54)

$$\Delta E_{PB} = E_{g,nom} + 3V_{t,nom} - pb_{nom}$$

(12-55)

$$\Delta E_{PBSW} = E_{g,nom} + 3V_{t,nom} - pbsw_{nom}$$

Junction Leakage Currents

(12-56)

$$is(T) = is_{nom} e^{Fact/n}$$

(12-57)

$$js(T) = js_{nom} e^{Fact/n}$$

where

(12-58)

$$Fact = \frac{E_{g,nom}}{V_{t,nom}} - \frac{E_g(T)}{V_t} + xti \ln \left[\frac{T}{Tnom} \right]$$

Junction Capacitances

If $tlevc = 0$

(12-59)

$$cbd(T) = cbd_{nom} \left[1 + mj \left(0.0004 \Delta T - \frac{pb(T)}{pb_{nom}} + 1 \right) \right]$$

(12-60)

$$cbs(T) = cbs_{nom} \left[1 + mj \left(0.0004 \Delta T - \frac{pb(T)}{pb_{nom}} + 1 \right) \right]$$

Virtuoso Simulator Components and Device Models Reference
Common MOSFET Equations

(12-61)

$$c_j(T) = c_{j_{nom}} \left[1 + m_j \left(0.0004 \Delta T - \frac{pb(T)}{pb_{nom}} + 1 \right) \right]$$

(12-62)

$$c_{jsw}(T) = c_{jsw_{nom}} \left[1 + m_{jsw} \left(0.0004 \Delta T - \frac{pb_{sw}(T)}{pb_{sw_{nom}}} + 1 \right) \right]$$

If $tlevc = 1$

(12-63)

$$cbd(T) = cbd_{nom} (1 + cta \Delta T)$$

(12-64)

$$cbs(T) = cbs_{nom} (1 + cta \Delta T)$$

(12-65)

$$c_j(T) = c_{j_{nom}} (1 + cta \Delta T)$$

(12-66)

$$c_{jsw}(T) = c_{jsw_{nom}} (1 + ctp \Delta T)$$

If $tlevc = 2$,

(12-67)

$$cbd(T) = cbd_{nom} \left(\frac{pb_{nom}}{pb(T)} \right)^{m_j}$$

(12-68)

$$cbs(T) = cbs_{nom} \left(\frac{pb_{nom}}{pb(T)} \right)^{m_j}$$

Virtuoso Simulator Components and Device Models Reference

Common MOSFET Equations

(12-69)

$$c_j(T) = c_{j_{nom}} \left(\frac{pb_{nom}}{pb(T)} \right)^{m_j}$$

(12-70)

$$c_{jsw}(T) = c_{jsw_{nom}} \left(\frac{pbsw_{nom}}{pbsw(T)} \right)^{m_{jsw}}$$

If $tlevc = 3$,

(12-71)

$$cbd(T) = cbd_{nom} \left[1 - 0.5 \left(\frac{d\phi_B}{dT} \right) \left(\frac{\Delta T}{pb_{nom}} \right) \right]$$

(12-72)

$$cbs(T) = cbs_{nom} \left[1 - 0.5 \left(\frac{d\phi_B}{dT} \right) \left(\frac{\Delta T}{pb_{nom}} \right) \right]$$

(12-73)

$$c_j(T) = c_{j_{nom}} \left[1 - 0.5 \left(\frac{d\phi_B}{dT} \right) \left(\frac{\Delta T}{pb_{nom}} \right) \right]$$

(12-74)

$$c_{jsw}(T) = c_{jsw_{nom}} \left[1 - 0.5 \left(\frac{d\phi_{SW}}{dT} \right) \left(\frac{\Delta T}{pbsw_{nom}} \right) \right]$$

Channel Length Modulation

(12-75)

$$\lambda(T) = \lambda_{nom}(1 + \lambda_{ex}\Delta T)$$

(12-76)

$$\kappa(T) = \kappa_{nom}(1 + \lambda_{ex}\Delta T)$$

Threshold Voltage

If $tlev = 0$,

(12-77)

$$V_{bi}(T) = vto_{nom} - \gamma \sqrt{\phi_{nom}} + \frac{\phi(T) - \phi_{nom}}{2} + \frac{E_{g,nom} - E_g(T)}{2}$$

(12-78)

$$vto(T) = V_{bi}(T) + \gamma \sqrt{\phi(T)}$$

If $tlev = 1$,

(12-79)

$$vto(T) = vto_{nom} - tcv\Delta T$$

Note: tcv is negative.

(12-80)

$$V_{bi}(T) = vto(T) - \gamma \sqrt{\phi(T)}$$

If $tlev = 2$,

(12-81)

$$vto(T) = vto_{nom} + \left(1 + \frac{gamma}{2\sqrt{phi_{nom}}}\right) \frac{d\phi}{dT} \Delta T$$

(12-82)

$$V_{bi}(T) = vto(T) - gamma\sqrt{phi(T)}$$

Drain and Source Parasitic Resistance

(12-83)

$$rd(T) = rd_{nom}(1 + trd\Delta T)$$

(12-84)

$$rs(T) = rs_{nom}(1 + trs\Delta T)$$

Critical Field

(12-85)

$$ucrit(T) = ucrit_{nom} \left(\frac{T}{T_{nom}}\right)^{f1ex}$$

Noise Model

This section contains model equations for the noise model.

Drain Resistance Thermal Noise

(12-86)

$$\overline{i_{Rd}^2} = \frac{4kT}{R_d} \Delta f$$

Source Resistance Thermal Noise

(12-87)

$$\overline{i_{Rs}^2} = \frac{4kT}{R_s} \Delta f$$

Channel Thermal and Flicker Noise

(12-88)

$$\overline{i_{DS}^2} = \overline{i_{n, thermal}^2} + \frac{kfI_{DS}^{af} \Delta f}{C_{ox} W_{eff} L_{eff} f^{ef}}$$

where

(12-89)

$$\overline{i_{n, thermal}^2} = \frac{8kT(g_m + g_{mb} + g_{ds}) \Delta f}{3} \left[\frac{3}{2} - \frac{V_{DS}}{2V_{DSAT}} \right]$$

Virtuoso Simulator Components and Device Models Reference

Common MOSFET Equations

(12-90)

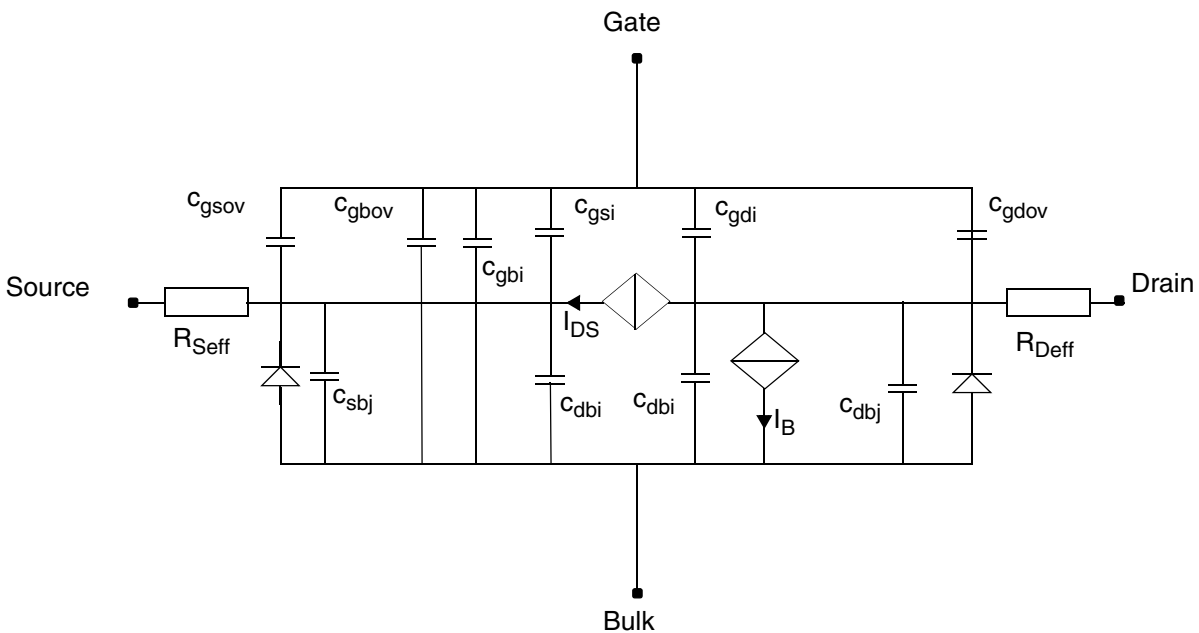
$$V_{DS} = \text{MIN}(V_{DS}, V_{DSAT})$$

g_m is the transconductance, g_{ds} is the channel conductance, and g_{mb} is the body transconductance. The Spectre[®] circuit simulator default values for kf , af , and ef are 0.0, 1.0, and 1.0, respectively.

MOS Capacitance Model

This chapter contains model equations for the MOS capacitance model, including the following:

- [Modified Meyer Model](#) on page 976
- [Yang-Chatterjee Model](#) on page 980
- [BSIM Charge Model with 0/100 Partitioning \(xpart=1\)](#) on page 983
- [BSIM Charge Model with 40/60 Partitioning \(xpart=0\)](#) on page 983
- [BSIM Charge Model with 50/50 Partitioning \(xpart=0.5\)](#) on page 987
- [Scaling Effects](#) on page 990



Virtuoso Simulator Components and Device Models Reference

MOS Capacitance Model

The Virtuoso® Spectre® circuit simulator has three charge-based MOS capacitance models that you can select with the model parameter `capmod`:

- The modified Meyer model

The modified Meyer model is a first-order model with 40/60 channel charge partitioning in the saturation region. This model does not include any short-channel effects.

- The Yang-Chatterjee model

The Yang-Chatterjee model uses a 0/100 channel charge partitioning method and includes some short-channel effects.

- The BSIM charge model

The BSIM charge model provides three methods for partitioning. You choose the method you want with the `xpart` parameter:

- 40/60 for `xpart = 0` (or `xpart < 0.5`)

For `xpart = 0`, the BSIM charge model is similar to the modified Meyer model, but it includes short-channel effects.

- 50/50 for `xpart = 0.5`

- 0/100 for `xpart = 1.0` (or `xpart > 0.5`)

For `xpart = 1`, the BSIM charge model is identical to the Yang-Chatterjee model.

Modified Meyer Model

$$V_{TH} = V_{FB} + \phi + \gamma \sqrt{\phi - V_{BS}}$$

$$V_{DSAT} = V_{GS} - V_{TH}$$

$$V_{GST} = V_{GS} - V_{TH}$$

$$V_{GDT} = V_{GS} - V_{TH} - V_{DS}$$

$$C_o = C_{ox} W_{eff} L_{eff}$$

$$C_{ij} \equiv \frac{dQ_i}{dV_j} \quad i, j = g, d, s, b$$

Accumulation Region

Note: These equations apply when $V_{GS} - V_{BS} \leq V_{FB}$.

$$C_{gg} = C_{bb} = C_o$$

$$C_{gb} = C_{bg} = -C_o$$

All other capacitances are zero.

Subthreshold Region

Note: These equations apply when $V_{GS} \leq V_{TH}$.

$$C_{gg} = C_{bb} = \frac{C_o \text{gamma}}{2 \sqrt{\left(\frac{\text{gamma}}{2}\right)^2 + V_{GS} - V_{BS} - V_{FB}}}$$

$$C_{gb} = C_{bg} = -C_{gg}$$

All other capacitances are zero.

Saturation Region

These equations apply when $V_{GS} \geq V_{TH}$ and $V_{DS} \geq V_{DSAT}$.

$$C_{gg} = \frac{2}{3} C_o$$

$$C_{gb} = \frac{1}{3} C_o \frac{dV_{TH}}{dV_{BS}}$$

$$C_{gs} = -(C_{gg} + C_{gb})$$

Virtuoso Simulator Components and Device Models Reference

MOS Capacitance Model

$$C_{bb} = -C_o \frac{dV_{TH}}{dV_{BS}}$$

$$C_{bs} = -C_{bb}$$

$$C_{dg} = -\frac{4}{15}C_o$$

$$C_{db} = \frac{4}{15}C_o \frac{dV_{TH}}{dV_{BS}}$$

$$C_{ds} = -(C_{dg} + C_{db})$$

$$C_{sg} = -\frac{6}{15}C_o$$

$$C_{sb} = \frac{6}{15}C_o \frac{dV_{TH}}{dV_{BS}}$$

$$C_{ss} = -(C_{sg} + C_{sb})$$

All other capacitances are zero.

Triode Region

Note: These equations apply when $V_{GS} \geq V_{TH}$ and $V_{DS} \leq V_{DSAT}$

$$C_{gg} = \frac{2}{3}C_o \left[1 + \frac{2V_{GST}V_{GDT}}{(V_{GST} + V_{GDT})^2} \right]$$

$$C_{gd} = -\frac{2}{3}C_o \left[1 - \frac{V_{GST}^2}{(V_{GST} + V_{GDT})^2} \right]$$

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MOS Capacitance Model

$$C_{gb} = \frac{1}{3}C_o \left[1 - \frac{4V_{GST}V_{GDT}}{(V_{gst} + V_{GDT})^2} \right]$$

$$C_{gs} = -(C_{gg} + C_{gd} + C_{gb})$$

$$C_{bb} = -C_o \frac{dV_{TH}}{dV_{BS}}$$

$$C_{bs} = -C_{bb}$$

$$C_{dg} = -\frac{1}{3}C_o \left[1 + \frac{2V_{GST}V_{GDT}}{(V_{GST} + V_{GDT})^2} + \frac{1(V_{GDT} - V_{GST})^3}{5(V_{GST} + V_{GDT})^3} \right]$$

$$C_{dd} = \frac{2}{15}C_o \left[3 - \left(\frac{V_{GST}^2}{(V_{GST} + V_{GDT})^2} - \frac{2V_{GST}^3}{(V_{GST} + V_{GDT})^3} \right) \right]$$

$$C_{db} = \frac{1}{3}C_o \frac{dV_{TH}}{dV_{BS}} \left[1 + 2V_{GST}V_{GDT}(V_{GST} + V_{GDT})^2 + \frac{1(V_{GDT} - V_{GST})^3}{5(V_{GST} + V_{GDT})^3} \right]$$

$$C_{ds} = -(C_{dg} + C_{dd} + C_{ds})$$

$$C_{sg} = -(C_{gg} + C_{dg}) = -\frac{1}{3}C_o \left[1 + \frac{2V_{GST}V_{GDT}}{(V_{GST} + V_{GDT})^2} + \frac{1(V_{GST} - V_{GDT})^3}{5(V_{GST} + V_{GDT})^3} \right]$$

$$C_{sg} = -(C_{gg} + C_{dg}) = \frac{4}{15}C_o \left(\frac{V_{GDT}}{(V_{GST} + V_{GDT})} \left[1 + \frac{V_{GST}V_{GDT}}{(V_{GST} + V_{GDT})^2} \right] \right)$$

$$C_{sb} = -(C_{gs} + C_{db} + C_{bb}) = \frac{1}{3}C_o \frac{dV_{TH}}{dV_{BS}} \left[1 + \frac{2V_{GST}V_{GDT}}{(V_{GST} + V_{GDT})^2} + \frac{1(V_{GST} - V_{GDT})^3}{5(V_{GST} + V_{GDT})^3} \right]$$

$$C_{ss} = -(C_{gs} + C_{ds} + C_{bs}) = -(C_{sg} + C_{sd} + C_{sb})$$

Yang-Chatterjee Model

$$V_{TH} = V_{FB} + \phi + \gamma \sqrt{\phi - V_{BS}}$$

$$V_{GST} = V_{GS} - V_{TH}$$

$$V_{GDT} = V_{GS} - V_{TH} - V_{DS}$$

$$C_o = C_{ox} W_{eff} L_{eff}$$

$$\alpha_x = \frac{V_{GST}}{V_{DSAT}}$$

$$C_{ij} \equiv \frac{dQ_i}{dV_j} \quad i, j = g, d, s, b$$

Accumulation Region

Note: These equations apply when $V_{GS} - V_{BS} \leq V_{FB}$.

$$C_{gg} = C_{bb} = C_o$$

$$C_{gb} = C_{bg} = -C_o$$

All other capacitances are zero.

Subthreshold Region

Note: These equations apply when $V_{GS} \leq V_{TH}$.

$$C_{gg} = C_{bb} = \frac{C_o \gamma}{2 \sqrt{\left(\frac{\gamma}{2}\right)^2 + V_{GS} - V_{BS} - V_{FB}}}$$

Virtuoso Simulator Components and Device Models Reference

MOS Capacitance Model

$$C_{gb} = C_{bg} = -C_{gg}$$

All other capacitances are zero.

Saturation Region

Note: These equations apply when $V_{GS} \geq V_{TH}$ and $V_{DS} \geq V_{DSAT}$

$$C_{gg} = C_o \left[1 - \frac{1}{3\alpha_x} + \frac{V_{GST}}{3\alpha_x^2} \frac{d\alpha_x}{dV_{GS}} \right]$$

$$C_{gb} = C_o \left[\frac{1}{3\alpha_x} \frac{dV_{TH}}{dV_{BS}} + \frac{V_{GST}}{3\alpha_x^2} \frac{d\alpha_x}{dV_{BS}} \right]$$

$$C_{gs} = -(C_{gg} + C_{gb})$$

$$C_{bg} = C_o \left[\frac{V_{GST}}{3\alpha_x} \frac{d\alpha_x}{dV_{GS}} - \frac{(1-\alpha_x)}{3\alpha_x} + \frac{(1-\alpha_x)V_{GST}}{3\alpha_x^2} \frac{d\alpha_x}{dV_{GS}} \right]$$

$$C_{bb} = C_o \left[-\frac{dV_{TH}}{dV_{BS}} + \frac{V_{GST}}{3\alpha_x} \frac{d\alpha_x}{dV_{BS}} + \frac{(1-\alpha_x)}{3\alpha_x} \frac{d\alpha_x}{dV_{BS}} + \frac{(1-\alpha_x)V_{GST}}{3\alpha_x^2} \frac{d\alpha_x}{dV_{BS}} \right]$$

$$C_{bs} = -(C_{bg} + C_{bb})$$

$$C_{sg} = -\frac{2}{3}C_o$$

$$C_{sb} = \frac{2}{3}C_o \frac{dV_{TH}}{dV_{BS}}$$

$$C_{ss} = -(C_{sg} + C_{sb})$$

All other capacitances are zero.

Triode Region

Note: These equations apply when $V_{GS} \geq V_{TH}$ and $V_{DS} \leq V_{DSAT}$

$$Fac \equiv \left(V_{GST} - \frac{1}{2} \alpha_x V_{DS} \right)$$

$$C_{gg} = C_o \left[1 + \frac{V_{DS}^2}{12Fac} \frac{d\alpha_x}{dV_{GS}} - \frac{\alpha_x V_{DS}^2}{12Fac^2} \left(1 - \frac{V_{DS}}{2} \frac{d\alpha_x}{dV_{GS}} \right) \right]$$

$$C_{gd} = C_o \left[-\frac{1}{2} + \frac{V_{DS}^2}{12Fac} \frac{d\alpha_x}{dV_{DS}} + \frac{\alpha_x V_{DS}}{6Fac} + \frac{\alpha_x^2 V_{DS}^2}{24Fac^2} \right]$$

$$C_{gb} = C_o \left[\frac{V_{DS}^2}{12Fac} \frac{d\alpha_x}{dV_{BS}} + \frac{\alpha_x V_{DS}^2}{12Fac^2} \left(\frac{dV_{TH}}{dV_{BS}} + \frac{V_{DS}}{2} \frac{d\alpha_x}{dV_{BS}} \right) \right]$$

$$C_{gs} = -(C_{gg} + C_{gd} + C_{gb})$$

$$C_{bg} = C_o \left[-\frac{V_{DS}}{2} \frac{d\alpha_x}{dV_{GS}} - \frac{(1-2\alpha_x)V_{DS}^2}{12Fac} \frac{d\alpha_x}{dV_{GS}} + \frac{(1-\alpha_x)\alpha_x V_{DS}^2}{12Fac^2} \left(1 - \frac{V_{DS}}{2} \frac{d\alpha_x}{dV_{GS}} \right) \right]$$

$$C_{bb} = C_o \left[-\frac{dV_{TH}}{dV_{BS}} - \frac{V_{DS}}{2} \frac{d\alpha_x}{dV_{BS}} - \frac{(1-2\alpha_x)V_{DS}^2}{12Fac} \frac{d\alpha_x}{dV_{BS}} - \frac{(1-\alpha_x)\alpha_x V_{DS}^2}{12Fac^2} \left(\frac{dV_{TH}}{dV_{BS}} + \frac{V_{DS}}{2} \frac{d\alpha_x}{dV_{BS}} \right) \right]$$

$$C_{bd} = C_o \left[\frac{(1-\alpha_x)}{2} - \frac{(1-\alpha_x)\alpha_x V_{DS}}{6Fac} - \frac{(1-\alpha_x)\alpha_x^2 V_{DS}^2}{24Fac^2} \right]$$

$$C_{bs} = -(C_{bg} + C_{bd} + C_{bb})$$

$$C_{dg} = -C_o \left[\frac{1}{2} - \frac{V_{DS}}{4} \left(3 - \frac{\alpha_x V_{DS}}{Fac} \right) \frac{d\alpha_x}{dV_{GS}} - \frac{\alpha_x^2 V_{DS}^2}{8Fac} \left(1 - \frac{V_{DS}}{2} \right) \frac{d\alpha_x}{dV_{GS}} \right]$$

Virtuoso Simulator Components and Device Models Reference
MOS Capacitance Model

$$C_{db} = -C_o \left[-\frac{1}{2} \frac{dV_{TH}}{dV_{BS}} - \frac{V_{DS}}{4} \left(3 - \frac{\alpha_x V_{DS}}{Fac} \right) \frac{d\alpha_x}{dV_{BS}} - \frac{\alpha_x^2 V_{DS}^2}{8Fac} \left(1 - \frac{V_{DS}}{2} \right) \frac{d\alpha_x}{dV_{BS}} \right]$$

$$C_{dd} = -C_o \left[-\frac{3}{4} \alpha_x + \frac{\alpha_x^2 V_{DS}}{4Fac} + \frac{\alpha_x^3 V_{DS}^2}{16Fac^2} \right]$$

$$C_{ds} = -(C_{dg} + C_{dd} + C_{ds})$$

$$C_{sg} = -(C_{gg} + C_{dg} + C_{bg})$$

$$C_{sd} = -(C_{gd} + C_{dd} + C_{bd})$$

$$C_{sb} = -(C_{gb} + C_{db} + C_{bb})$$

$$C_{ss} = -(C_{gs} + C_{ds} + C_{bs})$$

BSIM Charge Model with 0/100 Partitioning (xpart=1)

This model is the same as the Yang-Chatterjee model.

BSIM Charge Model with 40/60 Partitioning (xpart=0)

$$V_{TH} = V_{FB} + phi + gamma \sqrt{phi - V_{BS}}$$

$$V_{GST} = V_{GS} - V_{TH}$$

$$V_{GDT} = V_{GS} - V_{TH} - V_{DS}$$

$$C_o = C_{ox} W_{eff} L_{eff}$$

$$\alpha_x = \frac{V_{GST}}{V_{DSAT}}$$

Virtuoso Simulator Components and Device Models Reference

MOS Capacitance Model

$$C_{ij} \equiv \frac{dQ_i}{dV_j} \quad i, j = g, d, s, b$$

Accumulation Region

Note: These equations apply when $V_{GS} - V_{BS} \leq V_{FB}$.

$$C_{gg} = C_{bb} = C_o$$

$$C_{gb} = C_{bg} = -C_o$$

All other capacitances are zero.

Subthreshold Region

Note: These equations apply when $V_{GS} \leq V_{TH}$.

$$C_{gg} = C_{bb} = \frac{C_o \text{gamma}}{2 \sqrt{\left(\frac{\text{gamma}}{2}\right)^2 + V_{GS} - V_{BS} - V_{FB}}}$$

$$C_{gb} = C_{bg} = -C_{gg}$$

All other capacitances are zero.

Saturation Region

Note: These equations apply when $V_{GS} \geq V_{TH}$ and $V_{DS} \geq V_{DSAT}$.

$$C_{gg} = C_o \left[1 - \frac{1}{3\alpha_x} + \frac{V_{GST}}{3\alpha_x^2} \frac{d\alpha_x}{dV_{GS}} \right]$$

$$C_{gb} = C_o \left[\frac{1}{3\alpha_x} \frac{dV_{TH}}{dV_{BS}} + \frac{V_{GST}}{3\alpha_x^2} \frac{d\alpha_x}{dV_{BS}} \right]$$

Virtuoso Simulator Components and Device Models Reference

MOS Capacitance Model

$$C_{gs} = -(C_{gg} + C_{gb})$$

$$C_{bg} = C_o \left[\frac{V_{GST} d\alpha_x}{3\alpha_x dV_{gs}} - \frac{(1-\alpha_x)}{3\alpha_x} + \frac{(1-\alpha_x)V_{GST} d\alpha_x}{3\alpha_x^2 dV_{GS}} \right]$$

$$C_{bb} = C_o \left[-\frac{dV_{TH}}{dV_{BS}} + \frac{V_{GST} d\alpha_x}{3\alpha_x dV_{BS}} + \frac{(1-\alpha_x) d\alpha_x}{3\alpha_x dV_{BS}} + \frac{(1-\alpha_x)V_{GST} d\alpha_x}{3\alpha_x^2 dV_{BS}} \right]$$

$$C_{bs} = -(C_{bg} + C_{bb})$$

$$C_{sg} = -\frac{6}{15}C_o$$

$$C_{sb} = \frac{6}{15}C_o \frac{dV_{TH}}{dV_{BS}}$$

$$C_{ss} = -(C_{sg} + C_{sb})$$

$$C_{dg} = -\frac{4}{15}C_o$$

$$C_{db} = \frac{4}{15}C_o \frac{dV_{TH}}{dV_{BS}}$$

$$C_{ds} = -(C_{dg} + C_{db})$$

All other capacitances are zero.

Triode Region

Note: These equations apply when $V_{GS} \geq V_{TH}$ and $V_{DS} \leq V_{DSAT}$

$$Fac \equiv (2V_{DSAT} - V_{DS})$$

Virtuoso Simulator Components and Device Models Reference
MOS Capacitance Model

$$C_{gg} = C_o \left[1 + \frac{V_{DS}^2}{6\alpha_x Fac} \frac{d\alpha_x}{dV_{GS}} - \frac{V_{DS}^2}{3\alpha_x Fac^2} \left(1 - \frac{V_{DS}}{2} \frac{d\alpha_x}{dV_{GS}} \right) \right]$$

$$C_{gd} = C_o \left[-\frac{1}{2} + \frac{V_{DS}^2}{6\alpha_x Fac} \frac{d\alpha_x}{dV_{DS}} + \frac{V_{DS}}{3Fac} + \frac{V_{DS}^2}{6Fac^2} \right]$$

$$C_{gb} = C_o \left[\frac{V_{DS}^2}{6\alpha_x Fac} \frac{d\alpha_x}{dV_{BS}} + \frac{V_{DS}^2}{3\alpha_x Fac^2} \left(\frac{dV_{TH}}{dV_{BS}} + \frac{V_{DS}}{2} \frac{d\alpha_x}{dV_{BS}} \right) \right]$$

$$C_{gs} = -(C_{gg} + C_{gd} + C_{gb})$$

$$C_{bg} = C_o \left[-\frac{V_{DS}}{2} \frac{d\alpha_x}{dV_{GS}} - \frac{(1-2\alpha_x)V_{DS}^2}{6\alpha_x Fac} \frac{d\alpha_x}{dV_{GS}} + \frac{(1-\alpha_x)V_{DS}^2}{3\alpha_x Fac^2} \left(1 - \frac{V_{DS}}{2} \frac{d\alpha_x}{dV_{GS}} \right) \right]$$

$$C_{bd} = C_o \left[\frac{(1-\alpha_x)}{2} - \frac{(1-\alpha_x)V_{DS}}{3Fac} - \frac{(1-\alpha_x)V_{DS}^2}{12Fac^2} \right]$$

$$C_{bs} = -(C_{bg} + C_{bd} + C_{bb})$$

$$C_{dg} = -\frac{C_o}{4} \left[2V_{DSAT} - 2V_{DS} + \frac{V_{DS}}{3Fac^2} \left(8V_{DSAT}^2 - 6V_{DSAT}V_{DS} + \frac{6}{5}V_{DS}^2 \right) \right] \frac{d\alpha_x}{dV_{GS}}$$

$$-\frac{\alpha_x}{4} C_o \left[2 - \frac{4V_{DS}}{3Fac^3} \left(8V_{DSAT}^2 - 6V_{DSAT}V_{DS} + \frac{6}{5}V_{DS}^2 \right) + \frac{V_{DS}(16V_{DSAT} - 6V_{DS})}{3Fac^2} \right] \frac{dV_{DSAT}}{dV_{GS}}$$

$$C_{db} = -\frac{C_o}{4} \left[2V_{DSAT} - 2V_{DS} + \frac{V_{DS}}{3Fac^2} \left(8V_{DSAT}^2 - 6V_{DSAT}V_{DS} + \frac{6}{5}V_{DS}^2 \right) \right] \frac{d\alpha_x}{dV_{BS}}$$

$$-\frac{\alpha_x}{4} C_o \left[2 - \frac{4V_{DS}}{3Fac^3} \left(8V_{DSAT}^2 - 6V_{DSAT}V_{DS} + \frac{6}{5}V_{DS}^2 \right) + \frac{V_{DS}(16V_{DSAT} - 6V_{DS})}{3Fac^2} \right] \frac{dV_{DSAT}}{dV_{BS}}$$

Virtuoso Simulator Components and Device Models Reference
MOS Capacitance Model

$$C_{dd} = \frac{\alpha_x}{4} C_o \left[\left(2 + \left(\frac{1}{3Fac^2} + \frac{2V_{DS}}{3Fac^3} \right) \left(8V_{DSAT}^2 - 6V_{DSAT}V_{DS} + \frac{6}{5}V_{DS}^2 \right) \right) \right. \\ \left. + \frac{V_{DS} \left(\frac{12}{5}V_{DS} - 6V_{DSAT} \right)}{2Fac^2} \right]$$

$$C_{ds} = -(C_{dg} + C_{dd} + C_{ds})$$

$$C_{sg} = -(C_{gg} + C_{dg} + C_{bg})$$

$$C_{sd} = -(C_{gd} + C_{dd} + C_{bd})$$

$$C_{sb} = -(C_{gb} + C_{db} + C_{bb})$$

$$C_{ss} = -(C_{gs} + C_{ds} + C_{bs})$$

BSIM Charge Model with 50/50 Partitioning (xpart=0.5)

$$V_{TH} = V_{FB} + phi + gamma \sqrt{phi - V_{BS}}$$

$$V_{GST} = V_{GS} - V_{TH}$$

$$V_{GDT} = V_{GS} - V_{TH} - V_{DS}$$

$$C_o = C_{ox} W_{eff} L_{eff}$$

$$\alpha_x = \frac{V_{GST}}{V_{DSAT}}$$

$$C_{ij} \equiv \frac{dQ_i}{dV_j} \quad i, j = g, d, s, b$$

Accumulation Region

Note: These equations apply when $V_{GS} - V_{BS} \leq V_{FB}$.

$$C_{gg} = C_{bb} = C_o$$

$$C_{gb} = C_{bg} = -C_o$$

All other capacitances are zero.

Subthreshold Region

Note: These equations apply when $V_{GS} \leq V_{TH}$.

$$C_{gg} = C_{bb} = \frac{C_o \text{gamma}}{2 \sqrt{\left(\frac{\text{gamma}}{2}\right)^2 + V_{GS} - V_{BS} - V_{FB}}}$$

$$C_{gb} = C_{bg} = -C_{gg}$$

All other capacitances are zero.

Saturation Region

Note: These equations apply when $V_{GS} \geq V_{TH}$ and $V_{DS} \geq V_{DSAT}$.

$$C_{gg} = C_o \left[1 - \frac{1}{3\alpha_x} + \frac{V_{GST}}{3\alpha_x^2} \frac{d\alpha_x}{dV_{GS}} \right]$$

$$C_{gb} = C_o \left[\frac{1}{3\alpha_x} \frac{dV_{TH}}{dV_{BS}} + \frac{V_{GST}}{3\alpha_x^2} \frac{d\alpha_x}{dV_{BS}} \right]$$

$$C_{gs} = -(C_{gg} + C_{gb})$$

Virtuoso Simulator Components and Device Models Reference

MOS Capacitance Model

$$C_{bg} = C_o \left[\frac{V_{GST} d\alpha_x}{3\alpha_x dV_{gs}} - \frac{(1-\alpha_x)}{3\alpha_x} + \frac{(1-\alpha_x)V_{GST} d\alpha_x}{3\alpha_x^2 dV_{GS}} \right]$$

$$C_{bb} = C_o \left[-\frac{dV_{TH}}{dV_{BS}} + \frac{V_{GST} d\alpha_x}{3\alpha_x dV_{BS}} + \frac{(1-\alpha_x) d\alpha_x}{3\alpha_x dV_{BS}} + \frac{(1-\alpha_x)V_{GST} d\alpha_x}{3\alpha_x^2 dV_{BS}} \right]$$

$$C_{bs} = -(C_{bg} + C_{bb})$$

$$C_{sg} = C_{dg} = -\frac{1}{3}C_o$$

$$C_{sb} = C_{db} = \frac{1}{3}C_o \frac{dV_{TH}}{dV_{BS}}$$

$$C_{ss} = C_{ds} = -(C_{sg} + C_{sb})$$

All other capacitances are zero.

Triode Region

Note: These equations apply when $V_{GS} \geq V_{TH}$ and $V_{DS} \leq V_{DSAT}$.

$$Fac \equiv (2V_{DSAT} - V_{DS})$$

$$C_{gg} = C_o \left[1 + \frac{V_{DS}^2 d\alpha_x}{6\alpha_x Fac dV_{GS}} - \frac{V_{DS}^2}{3\alpha_x Fac^2} \left(1 - \frac{V_{DS} d\alpha_x}{2 dV_{GS}} \right) \right]$$

$$C_{gd} = C_o \left[-\frac{1}{2} + \frac{V_{DS}^2 d\alpha_x}{6\alpha_x Fac dV_{DS}} + \frac{V_{DS}}{3Fac} + \frac{V_{DS}^2}{6Fac^2} \right]$$

$$C_{gb} = C_o \left[\frac{V_{DS}^2 d\alpha_x}{6\alpha_x Fac dV_{BS}} + \frac{V_{DS}^2}{3\alpha_x Fac^2} \left(\frac{dV_{TH}}{dV_{BS}} + \frac{V_{DS} d\alpha_x}{2 dV_{BS}} \right) \right]$$

Virtuoso Simulator Components and Device Models Reference

MOS Capacitance Model

$$C_{gs} = -(C_{gg} + C_{gd} + C_{gb})$$

$$C_{bg} = C_o \left[-\frac{V_{DS}}{2} \frac{d\alpha_x}{dV_{GS}} - \frac{(1-2\alpha_x)V_{DS}^2}{6\alpha_x Fac} \frac{d\alpha_x}{dV_{GS}} + \frac{(1-\alpha_x)V_{DS}^2}{3\alpha_x Fac^2} \left(1 - \frac{V_{DS}}{2} \frac{d\alpha_x}{dV_{GS}} \right) \right]$$

$$C_{bb} = C_o \left[\frac{dV_{TH}}{dV_{BS}} - \frac{V_{DS}}{2} \frac{d\alpha_x}{dV_{BS}} - \frac{(1-2\alpha_x)V_{DS}^2}{6\alpha_x Fac} \frac{d\alpha_x}{dV_{BS}} - \frac{(1-\alpha_x)V_{DS}^2}{3\alpha_x Fac^2} \left(\frac{dV_{TH}}{dV_{BS}} + \frac{V_{DS}}{2} \frac{d\alpha_x}{dV_{BS}} \right) \right]$$

$$C_{bd} = C_o \left[\frac{(1-\alpha_x)}{2} - \frac{(1-\alpha_x)V_{DS}}{3Fac} - \frac{(1-\alpha_x)V_{DS}^2}{12Fac^2} \right]$$

$$C_{bs} = -(C_{bg} + C_{bd} + C_{bb})$$

$$C_{sg} = C_{dg} = -\frac{1}{4}C_o \left(2V_{DSAT} - V_{DS} + \frac{V_{DS}}{3Fac} \right) \frac{d\alpha_x}{dV_{GS}} - \frac{\alpha_x}{4}C_o \left(2 - \frac{2V_{DS}^2}{3Fac^2} \right) \frac{dV_{DSAT}}{dV_{GS}}$$

$$C_{sb} = C_{db} = -\frac{1}{4}C_o \left(2V_{DSAT} - V_{DS} + \frac{V_{DS}}{3Fac} \right) \frac{d\alpha_x}{dV_{BS}} - \frac{\alpha_x}{4}C_o \left(2 - \frac{2V_{DS}^2}{3Fac^2} \right) \frac{dV_{DSAT}}{dV_{BS}}$$

$$C_{sd} = C_{dd} = \frac{\alpha_x}{4}C_o \left(1 - \frac{2V_{DS}}{3Fac} - \frac{V_{DS}^2}{3Fac^2} \right)$$

$$C_{ss} = C_{ds} = -(C_{sg} + C_{sd} + C_{sb})$$

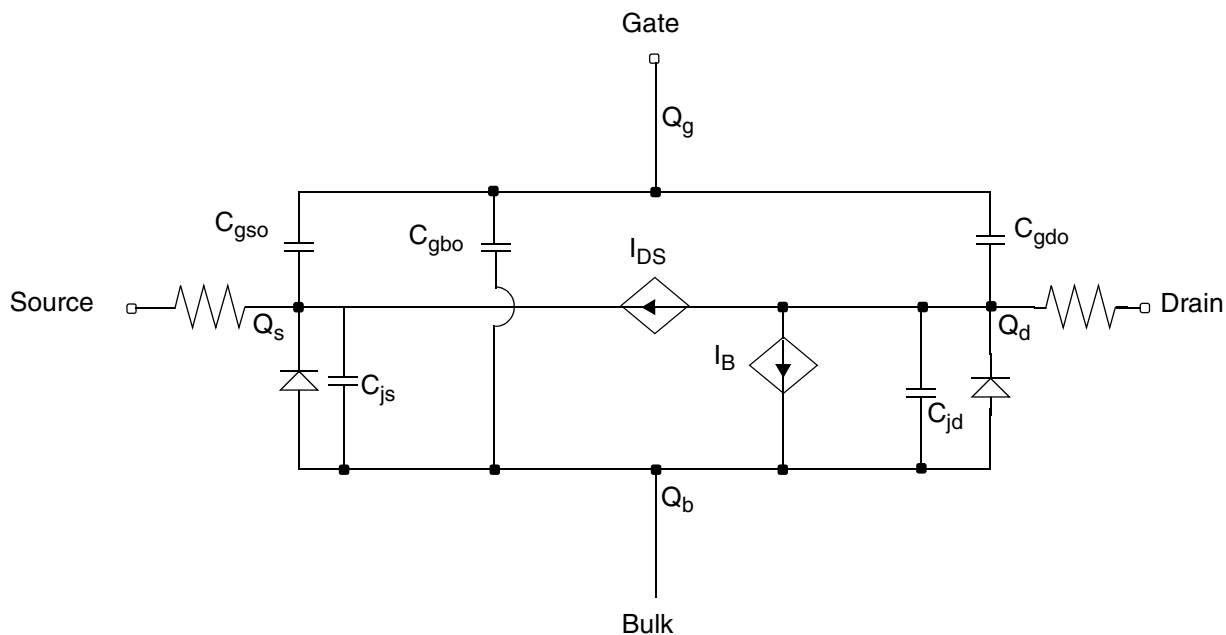
Scaling Effects

For scaling effects, see [Scaling Factors \(scale and scalem\)](#) on page 242.

MOS Level-1 Model (mos1)

The MOS1 model is derived from the FET model of Shichman and Hodges. Velocity saturation and the mobility variation effects can also be incorporated into this model. This chapter contains the following information about the MOS1 model:

- [Channel Width and Length](#) on page 992
- [Threshold Voltage](#) on page 992
- [Drain Saturation Voltage](#) on page 993
- [Drain Current for the Subthreshold Region](#) on page 993
- [Drain Current for the Triode Region](#) on page 993
- [Drain Current for the Saturation Region](#) on page 994
- [Drain Saturation Voltage \(Modified Level-1 Model\)](#) on page 994
- [Drain Current for the Triode Region \(Modified Level-1 Model\)](#) on page 995
- [Drain Current for the Saturation Region \(Modified Level-1 Model\)](#) on page 995
- [Substrate Current](#) on page 995
- [Scaling Effects](#) on page 996
- [Component Statements](#) on page 996



Channel Width and Length

$$W_{scaled} = w*scale + xw*scalem$$

$$W_{eff} = \begin{cases} w*scale + xw*scalem - 2wd*scalem & \text{(Level 1-3)} \\ w*scale + xw*scalem - dw*scalem & \text{(BSIM 1-2)} \end{cases}$$

$$L_{eff} = \begin{cases} l*scale + xl*scalem - 2ld*scalem & \text{(Level 1-3)} \\ l*scale + xl*scalem - dl*scalem & \text{(BSIM 1-2)} \end{cases}$$

Threshold Voltage

$$V_{TH} = vto + gamma(\sqrt{phi} - V_{BS} - \sqrt{phi})$$

Drain Saturation Voltage

$$V_{DSAT} = V_{GS} - V_{TH} \equiv V_{GST}$$

Drain Current for the Subthreshold Region

Note: These equations apply when $V_{GS} - V_{ON} \leq 0$.

You cannot use the subthreshold current equations without nfs .

$$V_{ON} = \begin{cases} V_{TH} + nV_t & \text{if } nfs \text{ is specified} \\ V_{TH} & \text{otherwise} \end{cases}$$

where

$$n = 1 + \frac{C_{FS} + C_D}{C_{ox}}$$

$$C_{FS} = q \times (nfs)$$

$$C_D = \frac{\text{gamma } C_{ox}}{2\sqrt{\text{phi} - V_{BS}}}$$

$$I_{DS} = I_{DS,ON} e^{(V_{GS} - V_{ON})/nV_t}$$

where $I_{DS,ON}$ is the drain current evaluated at $V_{GS} = V_{ON}$.

Drain Current for the Triode Region

Note: These equations apply when $V_{GS} \geq V_{ON}$ and $V_{DS} \leq V_{DSAT}$.

$$I_{DS} = \beta \left(V_{GST} - \frac{1}{2} V_{DS} \right) V_{DS} (1 + \text{lambda} * V_{DS})$$

where

$$\beta = \frac{kp * W_{eff}}{L_{eff}}$$

The mobility temperature offset parameter u_{to} affects both u_{eff} and kp_{eff} , as shown below.

$$u_{eff} = u_o * \text{pow}(T / (T_{nom} + u_{to}), u_{te})$$

$$kp_{eff} = kp * \text{pow}(T / (T_{nom} + u_{to}), u_{te})$$

Drain Current for the Saturation Region

Note: This equation applies when $V_{GS} \geq V_{ON}$ and $V_{DS} \geq V_{DSAT}$.

$$I_{DS} = \frac{\beta V_{GST}^2}{2} (1 + \lambda * V_{DS})$$

Because the standard SPICE Level-1 model does not include any of the short-channel phenomena, such as mobility modulation and velocity-saturation effects, the uses for this model are limited. To retain high computational efficiency and improve accuracy, the Virtuoso[®] Spectre[®] circuit simulator incorporates two parameters, θ and v_{max} , into the Level-1 model. The meanings of θ and v_{max} are the same as those in the Level-3 model. The modified Level-1 model is like a simplified Level-3 model. Spectre uses the modified Level-1 model if θ or v_{max} (or both) is specified. The drain current equations for the modified Level-1 model are shown in the following section.

Drain Saturation Voltage (Modified Level-1 Model)

$$V_{DSAT} = \frac{V_{GST}}{\sqrt{K}}$$

where

$$K = \frac{1 + V_c + \sqrt{1 + 2V_c}}{2}$$

$$V_c = \frac{V_{GST}u_o}{vmax * L_{eff}}$$

Drain Current for the Triode Region (Modified Level-1 Model)

$$I_{DS} = \frac{\beta \left(V_{GST} - \frac{1}{2} V_{DS} \right) V_{DS} [1 + lambda * V_{DS}]}{(1 + theta * V_{GST})(1 + V_{DS}/(E_c L_{eff}))}$$

where

$$E_c = \frac{vmax}{u_o}$$

The mobility temperature offset parameter u_{to} affects both u_{eff} and kp_{eff} , as shown below.

$$u_{eff} = u_0 * pow(T / (Tnom + u_{to}), u_{te})$$

$$kp_{eff} = kp * pow(T / (Tnom + u_{to}), u_{te})$$

Drain Current for the Saturation Region (Modified Level-1 Model)

$$I_{DS} = \frac{\beta \left(V_{GST} - \frac{1}{2} V_{DSAT} \right) V_{DSAT} [1 + lambda * V_{DS}]}{(1 + theta * V_{GST})(1 + V_{DSAT}/E_c L_{eff})}$$

Substrate Current

The substrate current is the result of impact ionization in the velocity saturation region near the drain. This impact-ionization induced current (I_{DB}) flows between the drain and the substrate. You need both aio and bio to use the impact-ionization model.

Virtuoso Simulator Components and Device Models Reference

MOS Level-1 Model (mos1)

$$I_{DB} = \begin{cases} I_{DS} A_i (V_{DS} - V_{DSAT}) e^{-B_i / (V_{DS} - V_{DSAT})} & \text{if } V_{DS} < V_{DSAT} \\ 0 & \text{otherwise} \end{cases}$$

where

$$A_i = a_{io} + \frac{l_{aio} \times 10^{-6}}{L_{eff}} + \frac{w_{aio} \times 10^{-6}}{W_{eff}}$$

$$B_i = b_{io} + \frac{l_{bio} \times 10^{-6}}{L_{eff}} + \frac{w_{bio} \times 10^{-6}}{W_{eff}}$$

Scaling Effects

For scaling effects, see [Scaling Factors \(scale and scalem\)](#) on page 242.

Component Statements

This device is supported within altergroups.

Sample Instance Statement

```
nch1 (1 2 0 0) nchmod1 l=2u w=15u ad=60p as=37.5p pd=23u ps=6u
```

Sample Model Statement

```
model nchmod1 mos1 vto=0.78 gamma=0.56 kp=0.8675e-4 tox=0.21e-7 nsub=0.21e17  
ld=0.55e-6 capmod=yang vmax=4e5 theta=0.19 cbs=11e-15 cbd=10e-15 lambda=0.1
```

Instance Definition

```
Name d g s b ModelName parameter=value ...
```

Instance Parameters

- | | | |
|---|-------|-----------------|
| 1 | w (m) | Channel width. |
| 2 | l (m) | Channel length. |

Virtuoso Simulator Components and Device Models Reference

MOS Level-1 Model (mos1)

3	<code>as</code> (m ²)	Area of source diffusion.
4	<code>ad</code> (m ²)	Area of drain diffusion.
5	<code>ps</code> (m)	Perimeter of source diffusion.
6	<code>pd</code> (m)	Perimeter of drain diffusion.
7	<code>nrd</code> (m/m)	Number of squares of drain diffusion.
8	<code>nrs</code> (m/m)	Number of squares of source diffusion.
9	<code>ld</code> (m)	Length of drain diffusion region.
10	<code>ls</code> (m)	Length of source diffusion region.
11	<code>m=1</code>	Multiplicity factor (number of MOSFETs in parallel).
12	<code>region=triode</code>	Estimated operating region. Spectre outputs number (0-4) in a rawfile. Possible values are <code>off</code> , <code>triode</code> , <code>sat</code> , <code>subth</code> , or <code>breakdown</code> .
13	<code>trise</code>	Temperature rise from ambient.
14	<code>isnoisy=yes</code>	Should resistor generate noise. Possible values are <code>no</code> or <code>yes</code> .
15	<code>degradation=no</code>	Hot-electron degradation flag. Possible values are <code>no</code> or <code>yes</code> .

Model Definition

```
model modelName mos1 parameter=value ...
```

Model Parameters

Device type parameters

1	<code>type=n</code>	Transistor type. Possible values are <code>n</code> or <code>p</code> .
---	---------------------	--

Virtuoso Simulator Components and Device Models Reference

MOS Level-1 Model (mos1)

Drain current model parameters

2	$v_{to}=0$ V	Threshold voltage at zero body bias.
3	$k_p=2.0718e-5$ A/V ²	Transconductance parameter.
4	$\lambda=0$ 1/V	Channel length modulation parameter.
5	$\phi=0.7$ V	Surface potential at strong inversion.
6	$\gamma=0$ \sqrt{V}	Body-effect parameter.
7	$\mu_0=600$ cm ² /V s	Carrier surface mobility.
8	$v_{max}=\infty$ m/s	Carrier saturation velocity.
9	$\theta=0$ 1/V	Mobility modulation coefficient.

Process parameters

10	$n_{sub}=1.13e16$ cm ⁻³	Channel doping concentration.
11	$n_{ss}=0$ cm ⁻²	Surface state density.
12	$n_{fs}=0$ cm ⁻²	Fast surface state density.
13	$t_{pg}=+1$	Type of gate (+1 = opposite of substrate, -1 = same as substrate, 0 = aluminum).
14	$l_d=0$ m	Lateral diffusion.
15	$w_d=0$ m	Field-oxide encroachment.
16	$x_w=0$ m	Width variation due to masking and etching.
17	$x_l=0$ m	Length variation due to masking and etching.
18	$t_{ox}=1e-7$ m	Gate oxide thickness.

Virtuoso Simulator Components and Device Models Reference

MOS Level-1 Model (mos1)

Impact ionization parameters

19	$a_{i0}=0$	1/V	Impact ionization current coefficient.
20	$l_{a_{i0}}=0$	$\mu\text{m}/\text{V}$	Length sensitivity of a_{i0} .
21	$w_{a_{i0}}=0$	$\mu\text{m}/\text{V}$	Width sensitivity of a_{i0} .
22	$b_{i0}=0$	V	Impact ionization current exponent.
23	$l_{b_{i0}}=0$	μm	Length sensitivity of b_{i0} .
24	$w_{b_{i0}}=0$	μm	Width sensitivity of b_{i0} .

Overlap capacitance parameters

25	$c_{gso}=0$	F/m	Gate-source overlap capacitance.
26	$c_{gdo}=0$	F/m	Gate-drain overlap capacitance.
27	$c_{gbo}=0$	F/m	Gate-bulk overlap capacitance.
28	$meto=0$	m	Metal overlap in fringing field.

Charge model selection parameters

29	$capmod=bsim$		Intrinsic charge model. Possible values are <code>none</code> , <code>meyer</code> , <code>yang</code> , or <code>bsim</code> .
30	$xpart=1$		Drain/source channel charge partition in saturation for BSIM charge model, use 0.0 for 40/60, 0.5 for 50/50, or 1.0 for 0/100.
31	$xqc=0$		Drain/source channel charge partition in saturation for charge models, e.g. use 0.4 for 40/60, 0.5 for 50/50, 0 for 0/100.

Parasitic resistance parameters

32	$r_s=0$	Ω	Source resistance.
33	$r_d=0$	Ω	Drain resistance.

Virtuoso Simulator Components and Device Models Reference

MOS Level-1 Model (mos1)

34	<code>rss=0</code>	$\Omega \text{ m}$	Scalable source resistance.
35	<code>rdd=0</code>	$\Omega \text{ m}$	Scalable drain resistance.
36	<code>rsh=0</code>	Ω/sqr	Source/drain diffusion sheet resistance.
37	<code>rsc=0</code>	Ω	Source contact resistance.
38	<code>rdc=0</code>	Ω	Drain contact resistance.
39	<code>minr=0.1</code>	Ω	Minimum source/drain resistance.
40	<code>ldif=0</code>	m	Lateral diffusion beyond the gate.
41	<code>hdif=0</code>	m	Length of heavily doped diffusion.
42	<code>lgcs=0</code>	m	Gate-to-contact length of source side.
43	<code>lgcd=0</code>	m	Gate-to-contact length of drain side.
44	<code>sc=∞</code>	m	Spacing between contacts.

Junction diode model parameters

45	<code>js</code>	(A/m^2)	Bulk junction reverse saturation current density.
46	<code>is=1e-14</code>	A	Bulk junction reverse saturation current.
47	<code>n=1</code>		Junction emission coefficient.
48	<code>dskip=yes</code>		Use simple piece-wise linear model for diode currents below $0.1 \cdot i_{\text{abstol}}$. Possible values are <code>no</code> or <code>yes</code> .
49	<code>imelt=<code>'imax'</code></code>	A	Explosion current, diode is linearized beyond this current to aid convergence.
50	<code>jmelt=<code>'jmax'</code></code>	A/m^2	Explosion current density, diode is linearized beyond this current to aid convergence.

Virtuoso Simulator Components and Device Models Reference

MOS Level-1 Model (mos1)

Junction capacitance model parameters

51	$cbs=0$ F	Bulk-source zero-bias junction capacitance.
52	$cbd=0$ F	Bulk-drain zero-bias junction capacitance.
53	$cj=0$ F/m ²	Zero-bias junction bottom capacitance density.
54	$mj=1/2$	Bulk junction bottom grading coefficient.
55	$pb=0.8$ V	Bulk junction built-in potential.
56	$fc=0.5$	Forward-bias depletion capacitance threshold.
57	$cjsw=0$ F/m	Zero-bias junction sidewall capacitance density.
58	$mjsw=1/3$	Bulk junction sidewall grading coefficient.
59	$pbsw=0.8$ V	Side-wall junction built-in potential.
60	$fcsw=0.5$	Side-wall forward-bias depletion capacitance threshold.

Operating region warning control parameters

61	$alarm=none$	Forbidden operating region. Possible values are <code>none</code> , <code>off</code> , <code>triode</code> , <code>sat</code> , <code>subth</code> , or <code>rev</code> .
62	$imax=1$ A	Maximum current, currents above this limit generate a warning.
63	$jmax=1e8$ A/m ²	Maximum current density, currents above this limit generate a warning.
64	$bvj=\infty$ V	Junction reverse breakdown voltage.
65	$vbox=1e9$ tox V	Oxide breakdown voltage.

Temperature effects parameters

66	$tnom$ (C)	Parameters measurement temperature. Default set by <code>options</code> .
67	$trise=0$ C	Temperature rise from ambient.

Virtuoso Simulator Components and Device Models Reference

MOS Level-1 Model (mos1)

68	$uto=0$ C	Mobility temperature offset.
69	$ute=-1.5$	Mobility temperature exponent.
70	$tlev=0$	DC temperature selector.
71	$tlevc=0$	AC temperature selector.
72	$eg=1.12452$ V	Energy band gap.
73	$gap1=7.02e-4$ V/C	Band gap temperature coefficient.
74	$gap2=1108$ C	Band gap temperature offset.
75	$f1ex=0$	Temperature exponent for $ucrit$.
76	$lamex=0$ 1/C	Temperature parameter for $lambda$ and $kappa$.
77	$trs=0$ 1/C	Temperature parameter for source resistance.
78	$trd=0$ 1/C	Temperature parameter for drain resistance.
79	$xTi=3$	Saturation current temperature exponent.
80	$ptc=0$ V/C	Surface potential temperature coefficient.
81	$tcv=0$ V/C	Threshold voltage temperature coefficient.
82	$pta=0$ V/C	Junction potential temperature coefficient.
83	$ptp=0$ V/C	Sidewall junction potential temperature coefficient.
84	$cta=0$ 1/C	Junction capacitance temperature coefficient.
85	$ctp=0$ 1/C	Sidewall junction capacitance temperature coefficient.

Default instance parameters

86	$w=3e-6$ m	Default channel width.
87	$l=3e-6$ m	Default channel length.
88	$as=0$ m ²	Default area of source diffusion.

Virtuoso Simulator Components and Device Models Reference

MOS Level-1 Model (mos1)

89	<code>ad=0</code> m ²	Default area of drain diffusion.
90	<code>ps=0</code> m	Default perimeter of source diffusion.
91	<code>pd=0</code> m	Default perimeter of drain diffusion.
92	<code>nrd=0</code> m/m	Default number of squares of drain diffusion.
93	<code>nrs=0</code> m/m	Default number of squares of source diffusion.
94	<code>ldd=0</code> m	Default length of drain diffusion region.
95	<code>lds=0</code> m	Default length of source diffusion region.

Noise model parameters

96	<code>noisemod=1</code>	Noise model selector.
97	<code>kf=0</code>	Flicker (1/f) noise coefficient.
98	<code>af=1</code>	Flicker (1/f) noise exponent.
99	<code>ef=1</code>	Flicker (1/f) noise frequency exponent.
100	<code>wnoi=1e-5</code> m	Channel width at which noise parameters were extracted.

Auto Model Selector parameters

101	<code>wmax=1.0</code> m	Maximum channel width for which the model is valid.
102	<code>wmin=0.0</code> m	Minimum channel width for which the model is valid.
103	<code>lmax=1.0</code> m	Maximum channel length for which the model is valid.
104	<code>lmin=0.0</code> m	Minimum channel length for which the model is valid.

Degradation parameters

105	<code>degramod=spectre</code>	Degradation model selector. Possible values are <code>spectre</code> or <code>bert</code> .
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Virtuoso Simulator Components and Device Models Reference

MOS Level-1 Model (mos1)

106	<code>degradation=no</code>	Hot-electron degradation flag. Possible values are <code>no</code> or <code>yes</code> .
107	<code>dvthc=1</code> V	Degradation coefficient for threshold voltage.
108	<code>dvthe=1</code>	Degradation exponent for threshold voltage.
109	<code>duoc=1</code> S	Degradation coefficient for transconductance.
110	<code>duoe=1</code>	Degradation exponent for transconductance.
111	<code>crivth=0.1</code> V	Maximum allowable threshold voltage shift.
112	<code>criuo=10%</code>	Maximum allowable normalized mobility change.
113	<code>crigm=10%</code>	Maximum allowable normalized transconductance change.
114	<code>criids=10%</code>	Maximum allowable normalized drain current change.
115	<code>wnom=5e-6</code> m	Nominal device width in degradation calculation.
116	<code>lnom=1e-6</code> m	Nominal device length in degradation calculation.
117	<code>vbsn=0</code> V	Substrate voltage in degradation calculation.
118	<code>vdsni=0.1</code> V	Drain voltage in I_{ds} degradation calculation.
119	<code>vgsni=5</code> V	Gate voltage in I_{ds} degradation calculation.
120	<code>vdsng=0.1</code> V	Drain voltage in G_m degradation calculation.
121	<code>vgsng=5</code> V	Gate voltage in G_m degradation calculation.

Spectre stress parameters

122	<code>esat=1.1e7</code> V/m	Critical field in V_{dsat} calculation.
123	<code>esatg=2.5e6</code> 1/m	Gate voltage dependence of $esat$.
124	<code>vpg=-0.25</code>	Gate voltage modifier.
125	<code>vpb=-0.13</code>	Gate voltage modifier.

Virtuoso Simulator Components and Device Models Reference

MOS Level-1 Model (mos1)

126 $\text{subc1}=2.24\text{e-}5$ Substrate current coefficient.

127 $\text{subc2}=-0.1\text{e-}5$ 1/V Substrate current coefficient.

128 $\text{sube}=6.4$ Substrate current exponent.

129 $\text{strc}=1$ Stress coefficient.

130 $\text{stre}=1$ Stress exponent.

BERT stress parameters

131 $\text{h0}=1$ Aging coefficient.

132 $\text{hgd}=0$ 1/V Bias dependence of h0 .

133 $\text{m0}=1$ Aging exponent.

134 $\text{mgd}=0$ 1/V Bias dependence of m0 .

135 $\text{ecrit0}=1.1\text{e}5$ V/cm Critical electric field.

136 $\text{lecrit0}=0$ μm V/cm Length dependence of ecrit0 .

137 $\text{wecrit0}=0$ μm V/cm Width dependence of ecrit0 .

138 $\text{ecritg}=0$ 1/cm Gate voltage dependence of ecrit0 .

139 $\text{lecritg}=0$ $\mu\text{m}/\text{cm}$ Length dependence of ecritg .

140 $\text{wecritg}=0$ $\mu\text{m}/\text{cm}$ Width dependence of ecritg .

141 $\text{ecritb}=0$ 1/cm Substrate voltage dependence of ecrit0 .

142 $\text{lecritb}=0$ $\mu\text{m}/\text{cm}$ Length dependence of ecritb .

143 $\text{wecritb}=0$ $\mu\text{m}/\text{cm}$ Width dependence of ecritb .

144 $\text{lc0}=1$ Substrate current coefficient.

145 $\text{llc0}=0$ μm Length dependence of lc0 .

146 $\text{wlc0}=0$ μm Width dependence of lc0 .

Virtuoso Simulator Components and Device Models Reference

MOS Level-1 Model (mos1)

147	$lc1=1$	Substrate current coefficient.
148	$llc1=0$ μm	Length dependence of $lc1$.
149	$wlc1=0$ μm	Width dependence of $lc1$.
150	$lc2=1$	Substrate current coefficient.
151	$llc2=0$ μm	Length dependence of $lc2$.
152	$wlc2=0$ μm	Width dependence of $lc2$.
153	$lc3=1$	Substrate current coefficient.
154	$llc3=0$ μm	Length dependence of $lc3$.
155	$wlc3=0$ μm	Width dependence of $lc3$.
156	$lc4=1$	Substrate current coefficient.
157	$llc4=0$ μm	Length dependence of $lc4$.
158	$wlc4=0$ μm	Width dependence of $lc4$.
159	$lc5=1$	Substrate current coefficient.
160	$llc5=0$ μm	Length dependence of $lc5$.
161	$wlc5=0$ μm	Width dependence of $lc5$.
162	$lc6=1$	Substrate current coefficient.
163	$llc6=0$ μm	Length dependence of $lc6$.
164	$wlc6=0$ μm	Width dependence of $lc6$.
165	$lc7=1$	Substrate current coefficient.
166	$llc7=0$ μm	Length dependence of $lc7$.
167	$wlc7=0$ μm	Width dependence of $lc7$.

Virtuoso Simulator Components and Device Models Reference

MOS Level-1 Model (mos1)

Shrink Parameters

I_{max} and I_{melt} :

The i_{max} parameter aids convergence and prevents numerical overflow. The junction characteristics of the device are accurately modeled for current up to i_{max} . If i_{max} is exceeded during iterations, the linear model is substituted until the current drops below i_{max} or until convergence is achieved. If convergence is achieved with the current exceeding i_{max} , the results are inaccurate, and Spectre prints a warning.

A separate model parameter, i_{melt} , is used as a limit warning for the junction current. This parameter can be set to the maximum current rating of the device. When any component of the junction current exceeds i_{melt} , note that base and collector currents are composed of many exponential terms, Spectre issues a warning and the results become inaccurate. The junction current is linearized above the value of i_{melt} to prevent arithmetic exception, with the exponential term replaced by a linear equation at i_{melt} .

Both of these parameters have current density counterparts, j_{max} and j_{melt} , that you can specify if you want the absolute current values to depend on the device area.

Auto Model Selection

Many models need to be characterized for different geometries in order to obtain accurate results for model development. The model selector program automatically searches for a model with the length and width range specified in the instance statement and uses this model in the simulations.

For the auto model selector program to find a specific model, the models to be searched should be grouped together within braces. Such a group is called a model group. An opening brace is required at the end of the line defining each model group. Every model in the group is given a name followed by a colon and the list of parameters. Also, the four geometric parameters l_{max} , l_{min} , w_{max} , and w_{min} should be given. The selection criteria to choose a model is as follows:

$$l_{min} \leq inst_length < l_{max} \quad \text{and} \quad w_{min} \leq inst_width < w_{max}$$

Example:

```
model ModelName ModelType {
```

```
1: <model parameters> lmin=2 lmax=4 wmin=1 wmax=2
```

```
2: <model parameters> lmin=1 lmax=2 wmin=2 wmax=4
```

Virtuoso Simulator Components and Device Models Reference

MOS Level-1 Model (mos1)

```
3:  <model parameters> lmin=2 lmax=4 wmin=4 wmax=6
}
```

Then for a given instance

```
M1 1 2 3 4 ModelName w=3 l=1.5
```

the program would search all the models in the model group with the name `ModelName` and then pick the first model whose geometric range satisfies the selection criteria. In the preceding example, the auto model selector program would choose `ModelName.2`.

You must specify both length (l) and width (w) on the device instance line to enable automatic model selection.

Output Parameters

1	<code>w_{eff}</code> (m)	Effective channel width.
2	<code>l_{eff}</code> (m)	Effective channel length.
3	<code>r_{seff}</code> (Ω)	Effective source resistance.
4	<code>r_{deff}</code> (Ω)	Effective drain resistance.
5	<code>a_{seff}</code> (m ²)	Effective area of source diffusion.
6	<code>a_{deff}</code> (m ²)	Effective area of drain diffusion.
7	<code>p_{seff}</code> (m)	Effective perimeter of source diffusion.
8	<code>p_{deff}</code> (m)	Effective perimeter of source diffusion.
9	<code>i_{sseff}</code> (A)	Effective source-bulk junction reverse saturation current.
10	<code>i_{sdeff}</code> (A)	Effective drain-bulk junction reverse saturation current.
11	<code>cb_{seff}</code> (F)	Effective zero-bias source-bulk junction capacitance.
12	<code>cb_{deff}</code> (F)	Effective zero-bias drain-bulk junction capacitance.

Virtuoso Simulator Components and Device Models Reference

MOS Level-1 Model (mos1)

Operating-Point Parameters

1	<code>type=n</code>	Transistor type. Possible values are <code>n</code> or <code>p</code> .
2	<code>region=triode</code>	Estimated operating region. Spectre outputs number (0-4) in a rawfile. Possible values are <code>off</code> , <code>triode</code> , <code>sat</code> , <code>subth</code> , or <code>breakdown</code> .
3	<code>degradation=no</code>	Hot-electron degradation flag. Possible values are <code>no</code> or <code>yes</code> .
4	<code>reversed</code>	Reverse mode indicator. Possible values are <code>no</code> or <code>yes</code> .
5	<code>ids (A)</code>	Resistive drain-to-source current.
6	<code>vgs (V)</code>	Gate-source voltage.
7	<code>vds (V)</code>	Drain-source voltage.
8	<code>vbs (V)</code>	Bulk-source voltage.
9	<code>vth (V)</code>	Threshold voltage.
10	<code>vdsat (V)</code>	Drain-source saturation voltage.
11	<code>gm (S)</code>	Common-source transconductance.
12	<code>gds (S)</code>	Common-source output conductance.
13	<code>gmbs (S)</code>	Body-transconductance.
14	<code>gameff (\sqrt{V})</code>	Effective body effect coefficient.
15	<code>betaeff (A/V^2)</code>	Effective <code>beta</code> .
16	<code>cbd (F)</code>	Drain-bulk junction capacitance.
17	<code>cbs (F)</code>	Source-bulk junction capacitance.
18	<code>cgs (F)</code>	Gate-source capacitance.

Virtuoso Simulator Components and Device Models Reference

MOS Level-1 Model (mos1)

19	<code>cgd</code> (F)	Gate-drain capacitance.
20	<code>cgb</code> (F)	Gate-bulk capacitance.
21	<code>ron</code> (Ω)	On-resistance.
22	<code>id</code> (A)	Resistive drain current.
23	<code>ibulk</code> (A)	Resistive bulk current.
24	<code>pwr</code> (W)	Power at op point.
25	<code>gmoverid</code> (1/V)	Gm/Ids.
26	<code>isub</code> (A)	Substrate current.
27	<code>stress</code>	Hot-electron stress.
28	<code>age</code> (s)	Device age.
29	<code>he_vdsat</code> (V)	Hot Electron V_{dsat} .

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

<code>ad</code>	I-4	<code>gap2</code>	M-74	<code>llc7</code>	M-166	<code>tlev</code>	M-70
<code>ad</code>	M-89	<code>gds</code>	OP-12	<code>lmax</code>	M-103	<code>tlevc</code>	M-71
<code>adef</code>	O-6	<code>gm</code>	OP-11	<code>lmin</code>	M-104	<code>tnom</code>	M-66
<code>af</code>	M-98	<code>gmbs</code>	OP-13	<code>lnom</code>	M-116	<code>tox</code>	M-18
<code>age</code>	OP-28	<code>gmoverid</code>	OP-25	<code>ls</code>	I-10	<code>tpg</code>	M-13

Virtuoso Simulator Components and Device Models Reference

MOS Level-1 Model (mos1)

ai0	M-19	h0	M-131	m	I-11	trd	M-78
alarm	M-61	hdif	M-41	m0	M-133	trise	I-13
as	I-3	he_vdsat	OP-29	meto	M-28	trise	M-67
as	M-88	hgd	M-132	mgd	M-134	trs	M-77
aseff	O-5	ibulk	OP-23	minr	M-39	type	M-1
betaeff	OP-15	id	OP-22	mj	M-54	type	OP-1
bi0	M-22	ids	OP-5	mjsw	M-58	uo	M-7
bvj	M-64	imax	M-62	n	M-47	ute	M-69
capmod	M-29	imelt	M-49	nfs	M-12	uto	M-68
cbd	M-52	is	M-46	noisemod	M-96	vbox	M-65
cbd	OP-16	isdeff	O-10	nrd	I-7	vbs	OP-8
cbdeff	O-12	isnoisy	I-14	nrd	M-92	vbsn	M-117
cbs	M-51	isseff	O-9	nrs	I-8	vds	OP-7
cbs	OP-17	isub	OP-26	nrs	M-93	vdsat	OP-10
cbseff	O-11	jmax	M-63	nss	M-11	vdsng	M-120
cgb	OP-20	jmelt	M-50	nsub	M-10	vdsni	M-118
cgbo	M-27	js	M-45	pb	M-55	vgs	OP-6
cgd	OP-19	kf	M-97	pbsw	M-59	vgsng	M-121
cgdo	M-26	kp	M-3	pd	I-6	vgsni	M-119
cgs	OP-18	l	I-2	pd	M-91	vmax	M-8
cgso	M-25	l	M-87	pdeff	O-8	vpb	M-125

Virtuoso Simulator Components and Device Models Reference

MOS Level-1 Model (mos1)

cj	M-53	lai0	M-20	phi	M-5	vpg	M-124
cjsw	M-57	lambda	M-4	ps	I-5	vth	OP-9
crigm	M-113	lamex	M-76	ps	M-90	vto	M-2
criids	M-114	lbi0	M-23	pseff	O-7	w	I-1
criuo	M-112	lc0	M-144	pta	M-82	w	M-86
crivth	M-111	lc1	M-147	ptc	M-80	wai0	M-21
cta	M-84	lc2	M-150	ptp	M-83	wbi0	M-24
ctp	M-85	lc3	M-153	pwr	OP-24	wd	M-15
degradation	I-15	lc4	M-156	rd	M-33	wecrit0	M-137
degradation	M-106	lc5	M-159	rdc	M-38	wecritb	M-143
degradation	OP-3	lc6	M-162	rdd	M-35	wecritg	M-140
degramod	M-105	lc7	M-165	rdeff	O-4	weff	O-1
dskip	M-48	ld	I-9	region	I-12	wlc0	M-146
duoc	M-109	ld	M-14	region	OP-2	wlc1	M-149
duoe	M-110	ldd	M-94	reversed	OP-4	wlc2	M-152
dvthc	M-107	ldif	M-40	ron	OP-21	wlc3	M-155
dvthe	M-108	lds	M-95	rs	M-32	wlc4	M-158
ecrit0	M-135	lecrit0	M-136	rsc	M-37	wlc5	M-161
ecritb	M-141	lecritb	M-142	rseff	O-3	wlc6	M-164
ecritg	M-138	lecritg	M-139	rsh	M-36	wlc7	M-167

Virtuoso Simulator Components and Device Models Reference

MOS Level-1 Model (mos1)

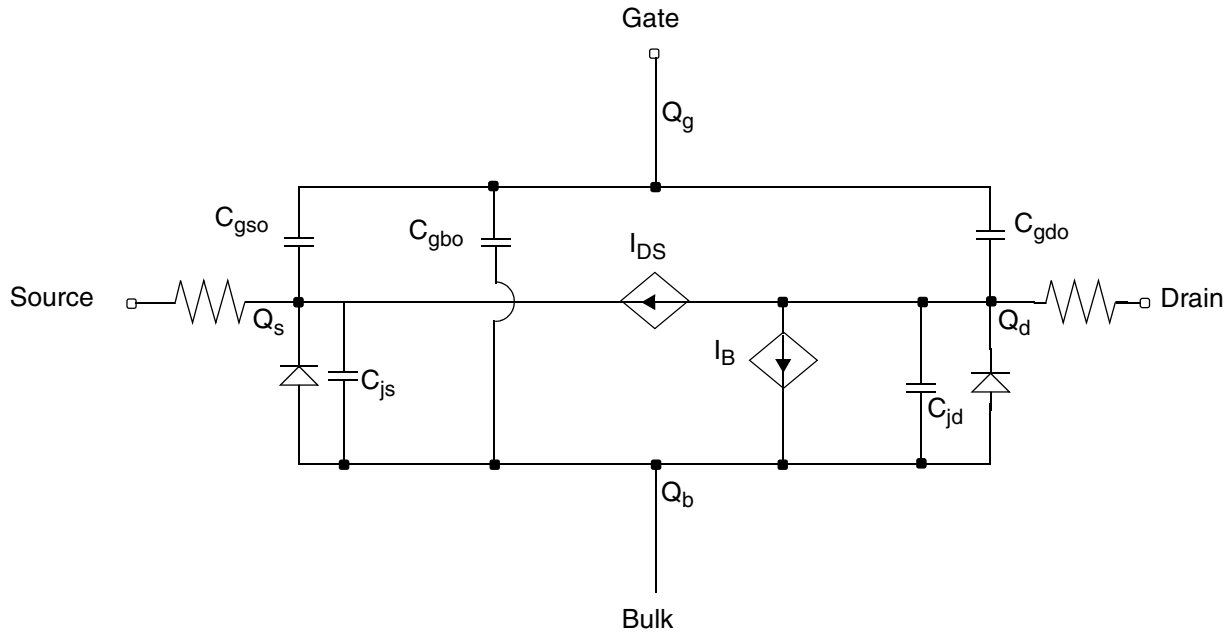
ef	M-99	leff	O-2	rss	M-34	wmax	M-101
eg	M-72	lgcd	M-43	sc	M-44	wmin	M-102
esat	M-122	lgcs	M-42	strc	M-129	wnoi	M-100
esatg	M-123	llc0	M-145	stre	M-130	wnom	M-115
flex	M-75	llc1	M-148	stress	OP-27	x1	M-17
fc	M-56	llc2	M-151	subc1	M-126	xpart	M-30
fcsw	M-60	llc3	M-154	subc2	M-127	xqc	M-31
gameff	OP-14	llc4	M-157	sube	M-128	xti	M-79
gamma	M-6	llc5	M-160	tcv	M-81	xw	M-16
gap1	M-73	llc6	M-163	theta	M-9		

Virtuoso Simulator Components and Device Models Reference
MOS Level-1 Model (mos1)

MOS Level-2 Model (mos2)

The MOS2 model is the level-2 model from Berkeley SPICE. The MOS2 model is an analytical, one-dimensional model that incorporates most of the second-order small-size effects. A smoother version of the level-2 model (with continuous G_{ds} at V_{dsat}) as well as three charge models are also available. This chapter contains the following information about the MOS2 model:

- [Channel Width and Length](#) on page 1016
- [Threshold Voltage](#) on page 1016
- [Drain Saturation Voltage](#) on page 1017
- [Drain Current for the Subthreshold Region](#) on page 1018
- [Drain Current for the Triode Region](#) on page 1019
- [Drain Current for the Saturation Region](#) on page 1020
- [Substrate Current](#) on page 1020
- [Scaling Effects](#) on page 1021
- [Component Statements table](#) on page 1021



Channel Width and Length

$$W_{scaled} = w*scale + xw*scale_m$$

$$W_{eff} = \begin{cases} w*scale + xw*scale_m - 2wd*scale_m & \text{(Level 1-3)} \\ w*scale + xw*scale_m - dw*scale_m & \text{(BSIM 1-2)} \end{cases}$$

$$L_{eff} = \begin{cases} l*scale + xl*scale_m - 2ld*scale_m & \text{(Level 1-3)} \\ l*scale + xl*scale_m - dl*scale_m & \text{(BSIM 1-2)} \end{cases}$$

Threshold Voltage

$$V_{TH} = V_{BI} + \gamma_s \sqrt{phi - V_{BS}} + (\eta - 1)(phi - V_{BS})$$

where

Virtuoso Simulator Components and Device Models Reference

MOS Level-2 Model (mos2)

$$V_{BI} = v_{to} - \gamma_s \sqrt{\phi_i}$$

$$\gamma_s = \gamma_s (1 - \alpha_S - \alpha_D)$$

$$\alpha_S = \frac{x_j}{2L_{eff}} \left[\sqrt{1 + \frac{2W_S}{x_j}} - 1 \right]$$

$$\alpha_D = \frac{x_j}{2L_{eff}} \left[\sqrt{1 + \frac{2W_D}{x_j}} - 1 \right]$$

$$W_S = X_D \sqrt{\phi_i - V_{BS}}$$

$$W_D = X_D \sqrt{\phi_i - V_{BS} + V_{DS}}$$

$$X_D = \begin{cases} \sqrt{\frac{2\epsilon_{si}}{q*(nsub)}} & \text{if } v_{max} \text{ is not specified} \\ \sqrt{\frac{2\epsilon_{si}}{q*neff*nsub}} & \text{otherwise} \end{cases}$$

$$\eta = 1 + \frac{\text{delta}\pi\epsilon_{si}}{4C_{ox}W_{eff}}$$

If x_j or $nsub$ is zero, the short-channel effects on threshold voltage are not evaluated (that is, $\gamma_s = \gamma_s$).

Drain Saturation Voltage

If v_{max} is not specified, V_{DSAT} is determined by the pinchoff condition and is given by

Virtuoso Simulator Components and Device Models Reference
MOS Level-2 Model (mos2)

$$V_{DSAT} = \frac{V_{GS} - V_{BIN}}{\eta} + \frac{1}{2} \left(\frac{\gamma_s}{\eta} \right)^2 (1 - Fac)$$

where

$$V_{BIN} = V_{BI} + \frac{\text{delta}\pi\epsilon_{si}}{4C_{ox}W_{eff}}(\text{phi} - V_{BS})$$

$$Fac = \sqrt{1 + 4 \left(\frac{\eta}{\gamma_s} \right)^2 \left(\frac{V_{GS} - V_{BIN}}{\eta} + \text{phi} - V_{BS} \right)}$$

If v_{max} is specified, V_{DSAT} is determined by the velocity saturation effect.

$$v_{max} = \frac{I_{DSAT}}{W_{eff}Q_{chan}}$$

where

$$Q_{chan} = W_{eff}C_{ox}[V_{GS} - V_{BIN} - \eta V_{DSAT} - \gamma_s \sqrt{\text{phi} - V_{BS} + V_{DSAT}}]$$

μ_{eff} is the effective mobility, defined later. V_{DSAT} can be calculated by solving the preceding equations.

Drain Current for the Subthreshold Region

Note: These equations apply when $V_{GS} \leq V_{ON}$.

You cannot use the subthreshold current equations without nfs .

$$V_{ON} = \begin{cases} V_{TH} + nV_t & \text{if } nfs \text{ is specified} \\ V_{TH} & \text{otherwise} \end{cases}$$

where

$$n = 1 + \frac{C_{FS} + C_D}{C_{ox}}$$

$$C_{FS} = q \times (nfs)$$

$$C_D = \left[\frac{\gamma_s}{2\sqrt{\phi_i - V_{BS}}} - \frac{d\gamma_s}{dV_{BS}} \sqrt{\phi_i - V_{BS}} + (\eta - 1) \right] C_{ox}$$

$$I_{DS} = I_{DS, ON} e^{(V_{GS} - V_{ON})/nV_t}$$

where $I_{DS, ON}$ is the drain current evaluated at $V_{GS} = V_{ON}$.

Drain Current for the Triode Region

Note: These equations apply when $V_{GS} \geq V_{ON}$ and $V_{DS} \leq V_{DSAT}$.

$$I_{DS} = \beta \left\{ \left(V_{GS} - V_{BIN} - \frac{\eta V_{DS}}{2} \right) V_{DS} - \frac{2}{3} \gamma_s \left[(\phi_i - V_{BS} + V_{DS})^{3/2} - (\phi_i - V_{BS})^{3/2} \right] \right\}$$

where

$$\beta = \frac{\mu_{eff} C_{ox} W_{eff}}{L_{eff} - \Delta L}$$

$$\mu_{eff} = uo \left[\frac{ucrit \epsilon_{si}}{C_{ox} (V_{GS} - V_{TH} - \text{utra} * V_{DS})} \right]^{uexp}$$

SPICE does not implement the *utra* effect. Also, if $(V_{GS} - V_{TH}) \leq (ucrit \epsilon_{si} / C_{ox})$, μ_{eff} is clipped to uo . This creates a discontinuity in the first derivatives of the drain current. The Virtuoso[®] Spectre[®] circuit simulator does not have this clipping effect.

$$\Delta L = \begin{cases} \lambda L_{eff} V_{DS} & \text{if } \lambda \text{ is given} \\ 0 & \text{if } n_{sub} \text{ is not given} \\ X_D \sqrt{\left(\frac{V_{DS} - V_{DSAT}}{4}\right) + \sqrt{1 + \left(\frac{V_{DS} - V_{DSAT}}{4}\right)^2}} & \text{if } v_{max} \text{ is not given} \\ X_D \left\{ \sqrt{\left(\frac{X_D v_{max}}{2\mu_{eff}}\right)^2 + V_{DS} - V_{DSAT}} - \frac{X_D v_{max}}{2\mu_{eff}} \right\} & \text{if } V_{DS} \geq V_{DSAT} \end{cases}$$

If $\Delta L \geq (L_{eff} - W_B)$, β is calculated from the following equation to avoid device punchthrough:

$$\beta = \frac{\mu_{eff} C_{ox} W_{eff} (L_{eff})^2}{L_{eff}} \left(\frac{2W_B}{L_{eff}} + \frac{\Delta L}{L_{eff}} - 1 \right)$$

where

$$W_B = X_D \sqrt{p\beta}$$

Drain Current for the Saturation Region

Note: This equation applies when $V_{GS} \geq V_{ON}$ and $V_{DS} \geq V_{DSAT}$.

$$I_{DS} = \beta \left\{ \left(V_{GS} - V_{BIN} - \frac{\eta V_{DSAT}}{2} \right) V_{DSAT} - \frac{2}{3} \gamma_s [(phi - V_{BS} + V_{DSAT})^{3/2} - (phi - V_{BS})^{3/2}] \right\}$$

Substrate Current

The substrate current results from impact ionization in the velocity saturation region near the drain. This impact-ionization induced current (I_{DB}) flows between the drain and the substrate. You need both *aio* and *bio* to use the impact-ionization model.

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MOS Level-2 Model (mos2)

$$I_{DB} = \begin{cases} I_{DS} A_i (V_{DS} - V_{DSAT}) e^{-B_i / (V_{DS} - V_{DSAT})} & \text{if } V_{DS} \leq V_{DSAT} \\ 0 & \text{otherwise} \end{cases}$$

where

$$A_i = a_{io} + \frac{l_{aio} \times 10^{-6}}{L_{eff}} + \frac{w_{aio} \times 10^{-6}}{W_{eff}}$$

$$B_i = b_{io} + \frac{l_{bio} \times 10^{-6}}{L_{eff}} + \frac{w_{bio} \times 10^{-6}}{W_{eff}}$$

Scaling Effects

For scaling effects, see [Scaling Factors \(scale and scalem\)](#) on page 242.

Component Statements

This device is supported within altergroups.

Sample Instance Statement:

```
mn2 (1 2 0 0) nch2 w=10u ad=20p as=20p ps=24u pd=24u
```

Sample Model Statement:

```
model nch2 mos2 type=n vto=0.66 lambda=0.018 gamma=0.6 nsub=0.213e16 kp=0.978e-4  
tpg=-1 vmax=6e4 ucrit=1e7 utra=0.1 uexp=0.2 is=0
```

Sample Instance Statement

```
mn2 (1 2 0 0) nch2 w=10u ad=20p as=20p ps=24u pd=24u
```

Sample Model Statement

```
model nch2 mos2 type=n vto=0.66 lambda=0.018 gamma=0.6 nsub=0.213e16 kp=0.978e-4  
tpg=-1 vmax=6e4 ucrit=1e7 utra=0.1 uexp=0.2 is=0
```

Virtuoso Simulator Components and Device Models Reference

MOS Level-2 Model (mos2)

Instance Definition

Name d g s b ModelName parameter=value ...

Instance Parameters

1	w (m)	Channel width.
2	l (m)	Channel length.
3	as (m ²)	Area of source diffusion.
4	ad (m ²)	Area of drain diffusion.
5	ps (m)	Perimeter of source diffusion.
6	pd (m)	Perimeter of drain diffusion.
7	nrd (m/m)	Number of squares of drain diffusion.
8	nrs (m/m)	Number of squares of source diffusion.
9	ld (m)	Length of drain diffusion region.
10	ls (m)	Length of source diffusion region.
11	m=1	Multiplicity factor (number of MOSFETs in parallel).
12	region=triode	Estimated operating region. Spectre outputs number (0-4) in a rawfile. Possible values are off, triode, sat, subth, or breakdown.
13	trise	Temperature rise from ambient.
14	isnoisy=yes	Should resistor generate noise. Possible values are no or yes.
15	degradation=no	Hot-electron degradation flag. Possible values are no or yes.

Model Definition

model modelName mos2 parameter=value ...

Virtuoso Simulator Components and Device Models Reference

MOS Level-2 Model (mos2)

Model Parameters

Device type parameters

1 type=n Transistor type.
Possible values are n or p.

Drain current model parameters

2 vto=0 V Threshold voltage at zero body bias.

3 kp=2.0718e-5 A/V² Transconductance parameter.

4 lambda=0 1/V Channel length modulation parameter.

5 phi=0.7 V Surface potential at strong inversion.

6 gamma=0 \sqrt{V} Body-effect parameter.

7 uo=600 cm²/V s Carrier surface mobility.

8 vmax=∞ m/s Carrier saturation velocity.

9 ucrit=0 V/cm Critical field for mobility degradation.

10 uexp=0 Critical field exponent for mobility degradation.

11 utra=0 1/V Transverse field for mobility.

12 neff=1 Total channel charge coefficient.

13 delta=0 Width effect on threshold voltage.

14 smooth=yes Drain current smoothing flag.
Possible values are no or yes.

Process parameters

15 nsub=1.13e16 cm⁻³ Channel doping concentration.

Virtuoso Simulator Components and Device Models Reference

MOS Level-2 Model (mos2)

16	$n_{ss}=0 \text{ cm}^{-2}$	Surface state density.
17	$n_{fs}=0 \text{ cm}^{-2}$	Fast surface state density.
18	$t_{pg}=+1$	Type of gate (+1 = opposite of substrate, -1 = same as substrate, 0 = aluminum).
19	$t_{ox}=1e-7 \text{ m}$	Gate oxide thickness.
20	$l_d=0 \text{ m}$	Lateral diffusion.
21	$w_d=0 \text{ m}$	Field-oxide encroachment.
22	$x_w=0 \text{ m}$	Width variation due to masking and etching.
23	$x_l=0 \text{ m}$	Length variation due to masking and etching.
24	$x_j=0 \text{ m}$	Source/drain junction depth.

Impact ionization parameters

25	$a_{i0}=0 \text{ 1/V}$	Impact ionization current coefficient.
26	$l_{a_{i0}}=0 \text{ } \mu\text{m/V}$	Length sensitivity of a_{i0} .
27	$w_{a_{i0}}=0 \text{ } \mu\text{m/V}$	Width sensitivity of a_{i0} .
28	$b_{i0}=0 \text{ V}$	Impact ionization current exponent.
29	$l_{b_{i0}}=0 \text{ } \mu\text{m V}$	Length sensitivity of b_{i0} .
30	$w_{b_{i0}}=0 \text{ } \mu\text{m V}$	Width sensitivity of b_{i0} .

Overlap capacitance parameters

31	$c_{gso}=0 \text{ F/m}$	Gate-source overlap capacitance.
32	$c_{gdo}=0 \text{ F/m}$	Gate-drain overlap capacitance.
33	$c_{gbo}=0 \text{ F/m}$	Gate-bulk overlap capacitance.
34	$meto=0 \text{ m}$	Metal overlap in fringing field.

Virtuoso Simulator Components and Device Models Reference

MOS Level-2 Model (mos2)

Charge model selection parameters

- 35 `capmod=bsim` Intrinsic charge model.
Possible values are `none`, `meyer`, `yang`, or `bsim`.
- 36 `xpart=1` Drain/source channel charge partition in saturation for BSIM
charge model, use 0.0 for 40/60, 0.5 for 50/50, or 1.0 for 0/100.
- 37 `xqc=0` Drain/source channel charge partition in saturation for charge
models, e.g. use 0.4 for 40/60, 0.5 for 50/50, 0 for 0/100.

Parasitic resistance parameters

- 38 `rs=0` Ω Source resistance.
- 39 `rd=0` Ω Drain resistance.
- 40 `rsh=0` Ω/sqr Source/drain diffusion sheet resistance.
- 41 `rss=0` $\Omega \text{ m}$ Scalable source resistance.
- 42 `rdd=0` $\Omega \text{ m}$ Scalable drain resistance.
- 43 `rsc=0` Ω Source contact resistance.
- 44 `rdc=0` Ω Drain contact resistance.
- 45 `minr=0.1` Ω Minimum source/drain resistance.
- 46 `ldif=0` m Lateral diffusion beyond the gate.
- 47 `hdif=0` m Length of heavily doped diffusion.
- 48 `lgcs=0` m Gate-to-contact length of source side.
- 49 `lgcd=0` m Gate-to-contact length of drain side.
- 50 `sc= ∞` m Spacing between contacts.

Junction diode model parameters

- 51 `js` (A/m^2) Bulk junction reverse saturation current density.

Virtuoso Simulator Components and Device Models Reference

MOS Level-2 Model (mos2)

52	<code>is=1e-14 A</code>	Bulk junction reverse saturation current.
53	<code>n=1</code>	Junction emission coefficient.
54	<code>dskip=yes</code>	Use simple piece-wise linear model for diode currents below $0.1 \cdot i_{abstol}$. Possible values are <code>no</code> or <code>yes</code> .
55	<code>imelt='imax' A</code>	Explosion current, diode is linearized beyond this current to aid convergence.
56	<code>jmelt='jmax' A/m²</code>	Explosion current density, diode is linearized beyond this current to aid convergence.

Junction capacitance model parameters

57	<code>cbs=0 F</code>	Bulk-source zero-bias junction capacitance.
58	<code>cbd=0 F</code>	Bulk-drain zero-bias junction capacitance.
59	<code>cj=0 F/m²</code>	Zero-bias junction bottom capacitance density.
60	<code>mj=1/2</code>	Bulk junction bottom grading coefficient.
61	<code>pb=0.8 V</code>	Bulk junction built-in potential.
62	<code>fc=0.5</code>	Forward-bias depletion capacitance threshold.
63	<code>cjsw=0 F/m</code>	Zero-bias junction sidewall capacitance density.
64	<code>mjsw=1/3</code>	Bulk junction sidewall grading coefficient.
65	<code>pbsw=0.8 V</code>	Side-wall junction built-in potential.
66	<code>fcsw=0.5</code>	Side-wall forward-bias depletion capacitance threshold.

Operating region warning control parameters

67	<code>alarm=none</code>	Forbidden operating region. Possible values are <code>none</code> , <code>off</code> , <code>triode</code> , <code>sat</code> , <code>subth</code> , or <code>rev</code> .
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Virtuoso Simulator Components and Device Models Reference

MOS Level-2 Model (mos2)

68	$i_{max}=1$ A	Maximum current, currents above this limit generate a warning.
69	$j_{max}=1e8$ A/m ²	Maximum current density, currents above this limit generate a warning.
70	$b_{vj}=\infty$ V	Junction reverse breakdown voltage.
71	$v_{box}=1e9$ t_{ox} V	Oxide breakdown voltage.

Temperature effects parameters

72	t_{nom} (C)	Parameters measurement temperature. Default set by <code>options</code> .
73	$t_{rise}=0$ C	Temperature rise from ambient.
74	$u_{to}=0$ C	Mobility temperature offset.
75	$u_{te}=-1.5$	Mobility temperature exponent.
76	$t_{lev}=0$	DC temperature selector.
77	$t_{levc}=0$	AC temperature selector.
78	$e_g=1.12452$ V	Energy band gap.
79	$gap1=7.02e-4$ V/C	Band gap temperature coefficient.
80	$gap2=1108$ C	Band gap temperature offset.
81	$f_{lex}=0$	Temperature exponent for <code>ucrit</code> .
82	$lamex=0$ 1/C	Temperature parameter for <code>lambda</code> and <code>kappa</code> .
83	$tr_s=0$ 1/C	Temperature parameter for source resistance.
84	$tr_d=0$ 1/C	Temperature parameter for drain resistance.
85	$x_{ti}=3$	Saturation current temperature exponent.
86	$p_{tc}=0$ V/C	Surface potential temperature coefficient.
87	$t_{cv}=0$ V/C	Threshold voltage temperature coefficient.

Virtuoso Simulator Components and Device Models Reference

MOS Level-2 Model (mos2)

88	$p_{ta}=0$ V/C	Junction potential temperature coefficient.
89	$p_{tp}=0$ V/C	Sidewall junction potential temperature coefficient.
90	$c_{ta}=0$ 1/C	Junction capacitance temperature coefficient.
91	$c_{tp}=0$ 1/C	Sidewall junction capacitance temperature coefficient.

Default instance parameters

92	$w=3e-6$ m	Default channel width.
93	$l=3e-6$ m	Default channel length.
94	$a_s=0$ m ²	Default area of source diffusion.
95	$a_d=0$ m ²	Default area of drain diffusion.
96	$p_s=0$ m	Default perimeter of source diffusion.
97	$p_d=0$ m	Default perimeter of drain diffusion.
98	$n_{rd}=0$ m/m	Default number of squares of drain diffusion.
99	$n_{rs}=0$ m/m	Default number of squares of source diffusion.
100	$l_{dd}=0$ m	Default length of drain diffusion region.
101	$l_{ds}=0$ m	Default length of source diffusion region.

Noise model parameters

102	$noisemod=1$	Noise model selector.
103	$k_f=0$	Flicker (1/f) noise coefficient.
104	$a_f=1$	Flicker (1/f) noise exponent.
105	$e_f=1$	Flicker (1/f) noise frequency exponent.
106	$w_{noi}=1e-5$ m	Channel width at which noise parameters were extracted.

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MOS Level-2 Model (mos2)

Auto Model Selector parameters

107	<code>wmax=1.0 m</code>	Maximum channel width for which the model is valid.
108	<code>wmin=0.0 m</code>	Minimum channel width for which the model is valid.
109	<code>lmax=1.0 m</code>	Maximum channel length for which the model is valid.
110	<code>lmin=0.0 m</code>	Minimum channel length for which the model is valid.

Degradation parameters

111	<code>degramod=spectre</code>	Degradation model selector. Possible values are <code>spectre</code> or <code>bert</code> .
112	<code>degradation=no</code>	Hot-electron degradation flag. Possible values are <code>no</code> or <code>yes</code> .
113	<code>dvthc=1 V</code>	Degradation coefficient for threshold voltage.
114	<code>dvthe=1</code>	Degradation exponent for threshold voltage.
115	<code>duoc=1 S</code>	Degradation coefficient for transconductance.
116	<code>duoe=1</code>	Degradation exponent for transconductance.
117	<code>crivth=0.1 V</code>	Maximum allowable threshold voltage shift.
118	<code>criuo=10%</code>	Maximum allowable normalized mobility change.
119	<code>crigm=10%</code>	Maximum allowable normalized transconductance change.
120	<code>criids=10%</code>	Maximum allowable normalized drain current change.
121	<code>wnom=5e-6 m</code>	Nominal device width in degradation calculation.
122	<code>lnom=1e-6 m</code>	Nominal device length in degradation calculation.
123	<code>vbsn=0 V</code>	Substrate voltage in degradation calculation.
124	<code>vdsni=0.1 V</code>	Drain voltage in I_{ds} degradation calculation.
125	<code>vgsni=5 V</code>	Gate voltage in I_{ds} degradation calculation.

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MOS Level-2 Model (mos2)

126 $v_{dsng}=0.1$ V Drain voltage in G_m degradation calculation.

127 $v_{gsng}=5$ V Gate voltage in G_m degradation calculation.

Spectre stress parameters

128 $esat=1.1e7$ V/m Critical field in V_{dsat} calculation.

129 $esatg=2.5e6$ 1/m Gate voltage dependence of $esat$.

130 $v_{pg}=-0.25$ Gate voltage modifier.

131 $v_{pb}=-0.13$ Gate voltage modifier.

132 $subc1=2.24e-5$ Substrate current coefficient.

133 $subc2=-0.1e-5$ 1/V Substrate current coefficient.

134 $sube=6.4$ Substrate current exponent.

135 $strc=1$ Stress coefficient.

136 $stre=1$ Stress exponent.

BERT stress parameters

137 $h_0=1$ Aging coefficient.

138 $hg_d=0$ 1/V Bias dependence of h_0 .

139 $m_0=1$ Aging exponent.

140 $mg_d=0$ 1/V Bias dependence of m_0 .

141 $ecrit_0=1.1e5$ V/cm Critical electric field.

142 $lecrit_0=0$ μm V/cm Length dependence of $ecrit_0$.

143 $wecrit_0=0$ μm V/cm Width dependence of $ecrit_0$.

144 $ecritg=0$ 1/cm Gate voltage dependence of $ecrit_0$.

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MOS Level-2 Model (mos2)

145	$l_{critg}=0$	$\mu\text{m}/\text{cm}$	Length dependence of e_{critg} .
146	$w_{critg}=0$	$\mu\text{m}/\text{cm}$	Width dependence of e_{critg} .
147	$e_{critb}=0$	$1/\text{cm}$	Substrate voltage dependence of e_{crit0} .
148	$l_{critb}=0$	$\mu\text{m}/\text{cm}$	Length dependence of e_{critb} .
149	$w_{critb}=0$	$\mu\text{m}/\text{cm}$	Width dependence of e_{critb} .
150	$l_{c0}=1$		Substrate current coefficient.
151	$l_{lc0}=0$	μm	Length dependence of l_{c0} .
152	$w_{lc0}=0$	μm	Width dependence of l_{c0} .
153	$l_{c1}=1$		Substrate current coefficient.
154	$l_{lc1}=0$	μm	Length dependence of l_{c1} .
155	$w_{lc1}=0$	μm	Width dependence of l_{c1} .
156	$l_{c2}=1$		Substrate current coefficient.
157	$l_{lc2}=0$	μm	Length dependence of l_{c2} .
158	$w_{lc2}=0$	μm	Width dependence of l_{c2} .
159	$l_{c3}=1$		Substrate current coefficient.
160	$l_{lc3}=0$	μm	Length dependence of l_{c3} .
161	$w_{lc3}=0$	μm	Width dependence of l_{c3} .
162	$l_{c4}=1$		Substrate current coefficient.
163	$l_{lc4}=0$	μm	Length dependence of l_{c4} .
164	$w_{lc4}=0$	μm	Width dependence of l_{c4} .
165	$l_{c5}=1$		Substrate current coefficient.
166	$l_{lc5}=0$	μm	Length dependence of l_{c5} .

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MOS Level-2 Model (mos2)

167	$wlc5=0 \mu\text{m}$	Width dependence of $lc5$.
168	$lc6=1$	Substrate current coefficient.
169	$llc6=0 \mu\text{m}$	Length dependence of $lc6$.
170	$wlc6=0 \mu\text{m}$	Width dependence of $lc6$.
171	$lc7=1$	Substrate current coefficient.
172	$llc7=0 \mu\text{m}$	Length dependence of $lc7$.
173	$wlc7=0 \mu\text{m}$	Width dependence of $lc7$.

Shrink Parameters

Imax and Imelt

The $imax$ parameter aids convergence and prevents numerical overflow. The junction characteristics of the device are accurately modeled for current up to $imax$. If $imax$ is exceeded during iterations, the linear model is substituted until the current drops below $imax$ or until convergence is achieved. If convergence is achieved with the current exceeding $imax$, the results are inaccurate, and Spectre prints a warning.

A separate model parameter, $imelt$, is used as a limit warning for the junction current. This parameter can be set to the maximum current rating of the device. When any component of the junction current exceeds $imelt$, note that base and collector currents are composed of many exponential terms, Spectre issues a warning and the results become inaccurate. The junction current is linearized above the value of $imelt$ to prevent arithmetic exception, with the exponential term replaced by a linear equation at $imelt$.

Both of these parameters have current density counterparts, $jmax$ and $jmelt$, that you can specify if you want the absolute current values to depend on the device area.

Auto Model Selection

Many models need to be characterized for different geometries in order to obtain accurate results for model development. The model selector program automatically searches for a model with the length and width range specified in the instance statement and uses this model in the simulations.

For the auto model selector program to find a specific model, the models to be searched should be grouped together within braces. Such a group is called a model group. An opening

Virtuoso Simulator Components and Device Models Reference

MOS Level-2 Model (mos2)

brace is required at the end of the line defining each model group. Every model in the group is given a name followed by a colon and the list of parameters. Also, the four geometric parameters `lmax`, `lmin`, `wmax`, and `wmin` should be given. The selection criteria to choose a model is as follows:

`lmin <= inst_length < lmax` and `wmin <= inst_width < wmax`

Example:

```
model ModelName ModelType {  
    1: <model parameters> lmin=2 lmax=4 wmin=1 wmax=2  
    2: <model parameters> lmin=1 lmax=2 wmin=2 wmax=4  
    3: <model parameters> lmin=2 lmax=4 wmin=4 wmax=6  
}
```

Then for a given instance

```
M1 1 2 3 4 ModelName w=3 l=1.5
```

the program would search all the models in the model group with the name `ModelName` and then pick the first model whose geometric range satisfies the selection criteria. In the preceding example, the auto model selector program would choose `ModelName.2`.

You must specify both length (`l`) and width (`w`) on the device instance line to enable automatic model selection.

Output Parameters

1	<code>w_{eff}</code> (m)	Effective channel width.
2	<code>l_{eff}</code> (m)	Effective channel length.
3	<code>r_{seff}</code> (Ω)	Effective source resistance.
4	<code>r_{deff}</code> (Ω)	Effective drain resistance.
5	<code>a_{seff}</code> (m ²)	Effective area of source diffusion.
6	<code>a_{deff}</code> (m ²)	Effective area of drain diffusion.

Virtuoso Simulator Components and Device Models Reference

MOS Level-2 Model (mos2)

7	<code>pseff</code> (m)	Effective perimeter of source diffusion.
8	<code>pdeff</code> (m)	Effective perimeter of source diffusion.
9	<code>isseff</code> (A)	Effective source-bulk junction reverse saturation current.
10	<code>isdeff</code> (A)	Effective drain-bulk junction reverse saturation current.
11	<code>cbseff</code> (F)	Effective zero-bias source-bulk junction capacitance.
12	<code>cbdeff</code> (F)	Effective zero-bias drain-bulk junction capacitance.

Operating-Point Parameters

1	<code>type=n</code>	Transistor type. Possible values are <code>n</code> or <code>p</code> .
2	<code>region=triode</code>	Estimated operating region. Spectre outputs number (0-4) in a rawfile. Possible values are <code>off</code> , <code>triode</code> , <code>sat</code> , <code>subth</code> , or <code>breakdown</code> .
3	<code>degradation=no</code>	Hot-electron degradation flag. Possible values are <code>no</code> or <code>yes</code> .
4	<code>reversed</code>	Reverse mode indicator. Possible values are <code>no</code> or <code>yes</code> .
5	<code>ids</code> (A)	Resistive drain-to-source current.
6	<code>vgs</code> (V)	Gate-source voltage.
7	<code>vds</code> (V)	Drain-source voltage.
8	<code>vbs</code> (V)	Bulk-source voltage.
9	<code>vth</code> (V)	Threshold voltage.
10	<code>vdsat</code> (V)	Drain-source saturation voltage.
11	<code>gm</code> (S)	Common-source transconductance.
12	<code>gds</code> (S)	Common-source output conductance.

Virtuoso Simulator Components and Device Models Reference

MOS Level-2 Model (mos2)

13	gmbs (S)	Body-transconductance.
14	gameff (\sqrt{V})	Effective body effect coefficient.
15	betaeff (A/V ²)	Effective beta.
16	cbd (F)	Drain-bulk junction capacitance.
17	cbs (F)	Source-bulk junction capacitance.
18	cgs (F)	Gate-source capacitance.
19	cgd (F)	Gate-drain capacitance.
20	cgb (F)	Gate-bulk capacitance.
21	ron (Ω)	On-resistance.
22	id (A)	Resistive drain current.
23	ibulk (A)	Resistive bulk current.
24	pwr (W)	Power at op point.
25	gmoverid (1/V)	Gm/Ids.
26	isub (A)	Substrate current.
27	stress	Hot-electron stress.
28	age (s)	Device age.
29	he_vdsat (V)	Hot Electron Vdsat.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

Virtuoso Simulator Components and Device Models Reference

MOS Level-2 Model (mos2)

ad	I-4	gds	OP-12	lnom	M-122	tpg	M-18
ad	M-95	gm	OP-11	ls	I-10	trd	M-84
adeff	O-6	gmbs	OP-13	m	I-11	trise	I-13
af	M-104	gmoverid	OP-25	m0	M-139	trise	M-73
age	OP-28	h0	M-137	meto	M-34	trs	M-83
ai0	M-25	hdif	M-47	mgd	M-140	type	M-1
alarm	M-67	he_vdsat	OP-29	minr	M-45	type	OP-1
as	I-3	hgd	M-138	mj	M-60	ucrit	M-9
as	M-94	ibulk	OP-23	mjsw	M-64	uexp	M-10
aseff	O-5	id	OP-22	n	M-53	uo	M-7
betaeff	OP-15	ids	OP-5	neff	M-12	ute	M-75
bi0	M-28	imax	M-68	nfs	M-17	uto	M-74
bvj	M-70	imelt	M-55	noisemod	M-102	utra	M-11
capmod	M-35	is	M-52	nrd	I-7	vbox	M-71
cbd	M-58	isdeff	O-10	nrd	M-98	vbs	OP-8
cbd	OP-16	isnoisy	I-14	nrs	I-8	vbsn	M-123
cbdeff	O-12	isseff	O-9	nrs	M-99	vds	OP-7
cbs	M-57	isub	OP-26	nss	M-16	vdsat	OP-10
cbs	OP-17	jmax	M-69	nsub	M-15	vdsng	M-126
cbseff	O-11	jmelt	M-56	pb	M-61	vdsni	M-124

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MOS Level-2 Model (mos2)

cgb	OP-20	js	M-51	pbsw	M-65	vgs	OP-6
cgbo	M-33	kf	M-103	pd	I-6	vgsng	M-127
cgd	OP-19	kp	M-3	pd	M-97	vgsni	M-125
cgdo	M-32	l	I-2	pdeff	O-8	vmax	M-8
cgs	OP-18	l	M-93	phi	M-5	vpb	M-131
cgso	M-31	lai0	M-26	ps	I-5	vpg	M-130
cj	M-59	lambda	M-4	ps	M-96	vth	OP-9
cjsw	M-63	lamex	M-82	pseff	O-7	vto	M-2
crigm	M-119	lbi0	M-29	pta	M-88	w	I-1
criids	M-120	lc0	M-150	ptc	M-86	w	M-92
criuo	M-118	lc1	M-153	ptp	M-89	wai0	M-27
crivth	M-117	lc2	M-156	pwr	OP-24	wbi0	M-30
cta	M-90	lc3	M-159	rd	M-39	wd	M-21
ctp	M-91	lc4	M-162	rdc	M-44	wecrit0	M-143
degradation	I-15	lc5	M-165	rdd	M-42	wecritb	M-149
degradation	M-112	lc6	M-168	rdeff	O-4	wecritg	M-146
degradation	OP-3	lc7	M-171	region	I-12	weff	O-1
degramod	M-111	ld	I-9	region	OP-2	wlc0	M-152
delta	M-13	ld	M-20	reversed	OP-4	wlc1	M-155
dskip	M-54	ldd	M-100	ron	OP-21	wlc2	M-158

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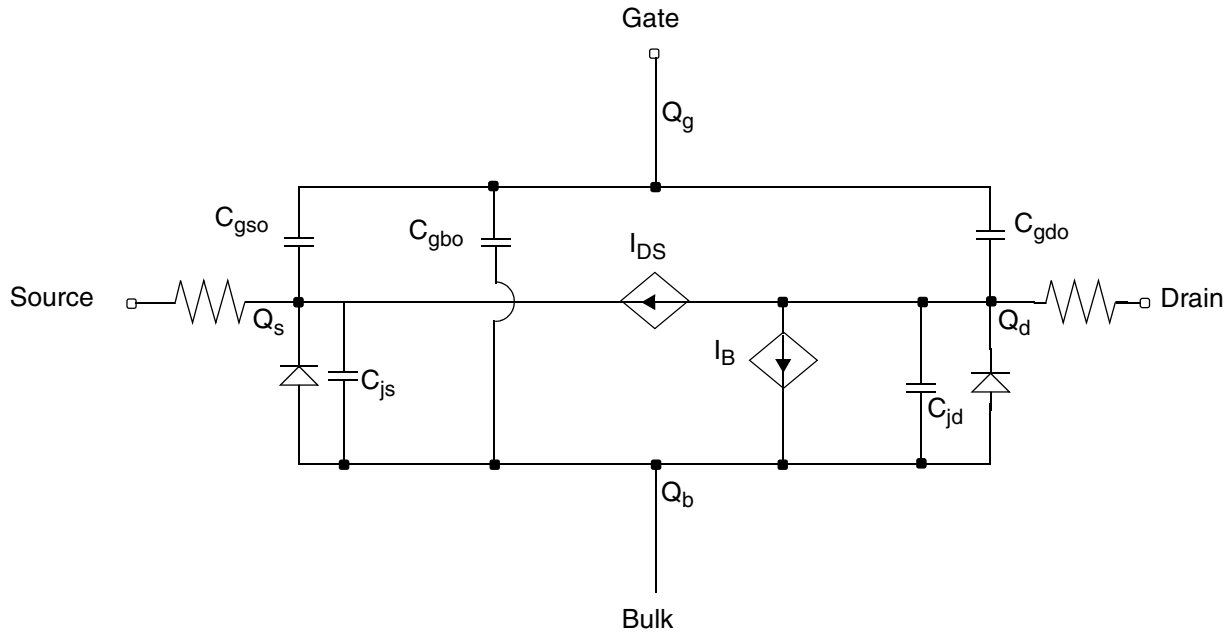
MOS Level-2 Model (mos2)

duoc	M-115	ldif	M-46	rs	M-38	wlc3	M-161
duoe	M-116	lds	M-101	rsc	M-43	wlc4	M-164
dvthc	M-113	lecrit0	M-142	rseff	O-3	wlc5	M-167
dvthe	M-114	lecritb	M-148	rsh	M-40	wlc6	M-170
ecrit0	M-141	lecritg	M-145	rss	M-41	wlc7	M-173
ecritb	M-147	leff	O-2	sc	M-50	wmax	M-107
ecritg	M-144	lgcd	M-49	smooth	M-14	wmin	M-108
ef	M-105	lgcs	M-48	strc	M-135	wnoi	M-106
eg	M-78	llc0	M-151	stre	M-136	wnom	M-121
esat	M-128	llc1	M-154	stress	OP-27	xj	M-24
esatg	M-129	llc2	M-157	subc1	M-132	x1	M-23
flex	M-81	llc3	M-160	subc2	M-133	xpart	M-36
fc	M-62	llc4	M-163	sube	M-134	xqc	M-37
fcsw	M-66	llc5	M-166	tcv	M-87	xti	M-85
gameff	OP-14	llc6	M-169	tlev	M-76	xw	M-22
gamma	M-6	llc7	M-172	tlevc	M-77		
gap1	M-79	lmax	M-109	tnom	M-72		
gap2	M-80	lmin	M-110	tox	M-19		

MOS Level-3 Model (mos3)

The MOS3 model is the level-3 model from Berkeley SPICE, and is a semi-empirical model. Three charge models are available. This chapter contains the following information for the MOS3 model:

- [Channel Width and Length](#) on page 1040
- [Threshold Voltage](#) on page 1040
- [Drain Saturation Voltage](#) on page 1041
- [Drain Current for the Subthreshold Region](#) on page 1042
- [Drain Current for the Triode Region](#) on page 1043
- [Drain Current for the Saturation Region](#) on page 1043
- [Substrate Current](#) on page 1044
- [Scaling Effects](#) on page 1044
- [Component Statements](#) table on page 1044



Channel Width and Length

$$W_{scaled} = w*scale + xw*scalem$$

$$W_{eff} = \begin{cases} w*scale + xw*scalem - 2wd*scalem & \text{(Level 1-3)} \\ w*scale + xw*scalem - dw*scalem & \text{(BSIM 1-2)} \end{cases}$$

$$L_{eff} = \begin{cases} l*scale + xl*scalem - 2ld*scalem & \text{(Level 1-3)} \\ l*scale + xl*scalem - dl*scalem & \text{(BSIM 1-2)} \end{cases}$$

Threshold Voltage

$$V_{TH} = V_{BI} + gamma F_S \sqrt{phi - V_{BS}} - \sigma V_{DS} + F_N(phi - V_{BS})$$

where

$$V_{BI} = v_{to} - \gamma \sqrt{\phi_i}$$

$$\sigma = \frac{8.15 \times 10^{-22} \eta a}{C_{ox} L_{eff}^3}$$

$$F_S = 1 - \frac{x_j}{L_{eff}} \left\{ \left(\frac{ld}{x_j} + \frac{W_C}{x_j} \right) \sqrt{1 - \left(\frac{W_p}{1 + W_p} \right)^2} - \frac{ld}{x_j} \right\}$$

$$W_p = \frac{X_D}{x_j} \sqrt{\phi_i - V_{BS}}$$

$$X_D = \sqrt{\frac{2\epsilon_{si}}{q * n_{sub}}}$$

$$\frac{W_c}{x_j} = 0.0631353 + 0.8013292 W_p - 0.01110777 W_p^2$$

$$F_N = \frac{\delta * \pi * \epsilon_{si}}{2 C_{ox} W_{eff}}$$

If either x_j or n_{sub} is zero, the short-channel effects on threshold voltage are not evaluated; that is, $F_S = 1$.

Drain Saturation Voltage

If v_{max} is not input, V_{DSAT} is determined by the pinchoff condition and is given by

$$V_{DSAT} = \frac{V_{GST}}{1 + F_B}$$

where

$$V_{GST} = V_{GS} - V_{TH}$$

$$F_B = \frac{\gamma_s F_S}{4\sqrt{\phi_i - V_{BS}}} + F_N$$

If v_{max} is specified, V_{DSAT} is determined by the velocity saturation effect.

$$V_{DSAT} = \frac{V_{GST}}{1 + F_B} + E_c L_{eff} - \sqrt{\left(\frac{V_{GST}}{1 + F_B}\right)^2 + (E_c L_{eff})^2}$$

where

$$E_c = \frac{v_{max}}{\mu_{eff}}$$

μ_{eff} is the effective mobility that is defined later.

Drain Current for the Subthreshold Region

Note: These equations apply when $V_{GS} \leq V_{ON}$.

You cannot use the subthreshold current equations without nfs .

$$V_{ON} = \begin{cases} V_{TH} + nV_t & \text{if } nfs \text{ is specified} \\ V_{TH} & \text{otherwise} \end{cases}$$

where

$$n = 1 + \frac{C_{FS} + C_D}{C_{ox}}$$

$$C_{FS} = q(nfs)$$

$$C_D = \left[\frac{\gamma_s}{2\sqrt{\phi_i - V_{BS}}} - \frac{d\gamma_s}{dV_{BS}} \sqrt{\phi_i - V_{BS}} + F_N \right] C_{ox}$$

$$I_{DS} = I_{DS, ON} e^{(V_{GS} - V_{ON})/nV_t}$$

where $I_{DS,ON}$ is the drain current evaluated at $V_{GS} = V_{ON}$.

Drain Current for the Triode Region

Note: These equations apply when $V_{GS} \geq V_{ON}$ and $V_{DS} \leq V_{DSAT}$.

$$I_{DS} = \frac{\beta \left[V_{GS} - V_{TH} - \frac{(1 + F_B)}{2} V_{DS} \right] V_{DS}}{1 + \frac{\mu_{eff} V_{DS}}{v_{max} L_{eff}}} \quad \setminus$$

where

$$\beta = \frac{\mu_{eff} C_{ox} W_{eff}}{L_{eff}} \quad \setminus$$

$$\mu_{eff} = \frac{u_0}{1 + \theta(V_{GS} - V_{TH})}$$

Drain Current for the Saturation Region

Note: These equations apply when $V_{GS} \geq V_{ON}$ and $V_{DS} \geq V_{DSAT}$.

$$I_{DS} = \frac{\beta \left[V_{GS} - V_{TH} - \frac{(1 + F_B)}{2} V_{DSAT} \right] V_{DSAT}}{1 + \frac{\mu_{eff} V_{DSAT}}{v_{max} L_{eff}}}$$

where

$$\beta = \frac{\mu_{eff} C_{ox} W_{eff}}{L_{eff} - \Delta L}$$

$$\Delta L = \begin{cases} \sqrt{kappa X_D^2 (V_{DS} - V_{DSAT})} & \text{if } v_{max} \text{ is not specified} \\ \sqrt{E_x^2 + kappa X_D^2 (V_{DS} - V_{DSAT})} - E_x & \text{otherwise} \end{cases}$$

If $\Delta L \geq L_{eff}/2$, a new value of ΔL (ΔL_{new}) is calculated to avoid device punchthrough.

$$\Delta L_{new} = L_{eff} - \frac{L_{eff}^2}{4\Delta L}$$

Substrate Current

The substrate current results from impact ionization in the velocity saturation region near the drain. This impact-ionization induced current (I_{DB}) flows between the drain and the substrate. You need both *aio* and *bio* to use the impact-ionization model.

$$I_{DB} = \begin{cases} I_{DS} A_i (V_{DS} - V_{DSAT}) e^{-B_i / (V_{DS} - V_{DSAT})} & \text{if } V_{DS} \leq V_{DSAT} \\ 0 & \text{otherwise} \end{cases}$$

where

$$A_i = aio + \frac{lai0 \times 10^{-6}}{L_{eff}} + \frac{wai0 \times 10^{-6}}{W_{eff}}$$

$$B_i = bio + \frac{lbio \times 10^{-6}}{L_{eff}} + \frac>wbio \times 10^{-6}}{W_{eff}}$$

Scaling Effects

For scaling effects, see [Scaling Factors \(scale and scalem\)](#) on page 242.

Component Statements

This device is supported within altergroups.

Virtuoso Simulator Components and Device Models Reference

MOS Level-3 Model (mos3)

Sample Instance Statement:

```
mp3 (0 1 2 2) pchmos3 l=2u w=30u ad=120p as=75p pd=36u ps=6u
```

Sample Model Statement:

```
model pchmos3 mos3 type=p vto=-0.83 gamma=0.4511 kappa=5 ld=0.45e-6 kp=0.334e-4  
tox=0.3e-7 nsub=0.2e17 capmod=yang vmax=4.5e5 theta=0.25 cbs=10e-15 cbd=10e-15
```

Instance Definition

```
Name d g s b ModelName parameter=value ...
```

Instance Parameters

1	w (m)	Channel width.
2	l (m)	Channel length.
3	as (m ²)	Area of source diffusion.
4	ad (m ²)	Area of drain diffusion.
5	ps (m)	Perimeter of source diffusion.
6	pd (m)	Perimeter of drain diffusion.
7	nrd (m/m)	Number of squares of drain diffusion.
8	nrs (m/m)	Number of squares of source diffusion.
9	ld (m)	Length of drain diffusion region.
10	ls (m)	Length of source diffusion region.
11	m=1	Multiplicity factor (number of MOSFETs in parallel).
12	region=triode	Estimated operating region. Spectre outputs number (0-4) in a rawfile. Possible values are off, triode, sat, subth, or breakdown.
13	trise	Temperature rise from ambient.

Virtuoso Simulator Components and Device Models Reference

MOS Level-3 Model (mos3)

- 14 `isnoisy=yes` Should resistor generate noise.
Possible values are `no` or `yes`.
- 15 `degradation=no` Hot-electron degradation flag.
Possible values are `no` or `yes`.

Model Definition

```
model modelName mos3 parameter=value ...
```

Model Parameters

Device type parameters

- 1 `type=n` Transistor type.
Possible values are `n` or `p`.

Drain current model parameters

- 2 `vto=0 V` Threshold voltage at zero body bias.
- 3 `kp=2.0718e-5 A/V2` Transconductance parameter.
- 4 `theta=0 1/V` Mobility modulation coefficient.
- 5 `phi=0.7 V` Surface potential at strong inversion.
- 6 `gamma=0 \sqrt{V}` Body-effect parameter.
- 7 `uo=600 cm2/V s` Carrier surface mobility.
- 8 `vmax= ∞ m/s` Carrier saturation velocity.
- 9 `eta=0 1/V` Static feedback coefficient.
- 10 `kappa=0.2` Saturation field factor.
- 11 `delta=0` Width effect on threshold voltage.

Virtuoso Simulator Components and Device Models Reference

MOS Level-3 Model (mos3)

Process parameters

- 12 $n_{sub}=1.13e16 \text{ cm}^{-3}$ Channel doping concentration.
- 13 $n_{ss}=0 \text{ cm}^{-2}$ Surface state density.
- 14 $n_{fs}=0 \text{ cm}^{-2}$ Fast surface state density.
- 15 $tpg=+1$ Type of gate (+1 = opposite of substrate, -1 = same as substrate, 0 = aluminum).
- 16 $tox=1e-7 \text{ m}$ Gate oxide thickness.
- 17 $ld=0 \text{ m}$ Lateral diffusion.
- 18 $wd=0 \text{ m}$ Field-oxide encroachment.
- 19 $xw=0 \text{ m}$ Width variation due to masking and etching.
- 20 $xl=0 \text{ m}$ Length variation due to masking and etching.
- 21 $xj=0 \text{ m}$ Source/drain junction depth.

Impact ionization parameters

- 22 $ai0=0 \text{ 1/V}$ Impact ionization current coefficient.
- 23 $lai0=0 \text{ }\mu\text{m/V}$ Length sensitivity of $ai0$.
- 24 $wai0=0 \text{ }\mu\text{m/V}$ Width sensitivity of $ai0$.
- 25 $bi0=0 \text{ V}$ Impact ionization current exponent.
- 26 $lbi0=0 \text{ }\mu\text{m V}$ Length sensitivity of $bi0$.
- 27 $wbi0=0 \text{ }\mu\text{m V}$ Width sensitivity of $bi0$.

Overlap capacitance parameters

- 28 $cgso=0 \text{ F/m}$ Gate-source overlap capacitance.

Virtuoso Simulator Components and Device Models Reference

MOS Level-3 Model (mos3)

- 29 $cgdo=0$ F/m Gate-drain overlap capacitance.
- 30 $cgbo=0$ F/m Gate-bulk overlap capacitance.
- 31 $meto=0$ m Metal overlap in fringing field.

Charge model selection parameters

- 32 $capmod=bsim$ Intrinsic charge model.
Possible values are `none`, `meyer`, `yang`, or `bsim`.
- 33 $xpart=1$ Drain/source channel charge partition in saturation for BSIM charge model, use 0.0 for 40/60, 0.5 for 50/50, or 1.0 for 0/100.
- 34 $xqc=0$ Drain/source channel charge partition in saturation for charge models, for example, use 0.4 for 40/60, 0.5 for 50/50, 0 for 0/100.

Parasitic resistance parameters

- 35 $rs=0$ Ω Source resistance.
- 36 $rd=0$ Ω Drain resistance.
- 37 $rsh=0$ Ω/sqr Source/drain diffusion sheet resistance.
- 38 $rss=0$ Ω m Scalable source resistance.
- 39 $rdd=0$ Ω m Scalable drain resistance.
- 40 $rsc=0$ Ω Source contact resistance.
- 41 $rdc=0$ Ω Drain contact resistance.
- 42 $minr=0.1$ Ω Minimum source/drain resistance.
- 43 $ldif=0$ m Lateral diffusion beyond the gate.
- 44 $hdif=0$ m Length of heavily doped diffusion.
- 45 $lgcs=0$ m Gate-to-contact length of source side.
- 46 $lgcd=0$ m Gate-to-contact length of drain side.

Virtuoso Simulator Components and Device Models Reference

MOS Level-3 Model (mos3)

47 $s_c = \infty$ m Spacing between contacts.

Junction diode model parameters

48 j_s (A/m²) Bulk junction reverse saturation current density.

49 $i_s = 1e-14$ A Bulk junction reverse saturation current.

50 $n = 1$ Junction emission coefficient.

51 $dskip = yes$ Use simple piece-wise linear model for diode currents below $0.1 * i_{abstol}$.
Possible values are `no` or `yes`.

52 $imelt = 'imax'$ A Explosion current, diode is linearized beyond this current to aid convergence.

53 $jmelt = 'jmax'$ A/m² Explosion current density, diode is linearized beyond this current to aid convergence.

Junction capacitance model parameters

54 $c_{bs} = 0$ F Bulk-source zero-bias junction capacitance.

55 $c_{bd} = 0$ F Bulk-drain zero-bias junction capacitance.

56 $c_j = 0$ F/m² Zero-bias junction bottom capacitance density.

57 $m_j = 1/2$ Bulk junction bottom grading coefficient.

58 $p_b = 0.8$ V Bulk junction built-in potential.

59 $f_c = 0.5$ Forward-bias depletion capacitance threshold.

60 $c_{jsw} = 0$ F/m Zero-bias junction sidewall capacitance density.

61 $m_{jsw} = 1/3$ Bulk junction sidewall grading coefficient.

62 $p_{bsw} = 0.8$ V Side-wall junction built-in potential.

63 $f_{csw} = 0.5$ Side-wall forward-bias depletion capacitance threshold.

Virtuoso Simulator Components and Device Models Reference

MOS Level-3 Model (mos3)

Operating region warning control parameters

64	alarm=none	Forbidden operating region. Possible values are none, off, triode, sat, subth, or rev.
65	imax=1 A	Maximum current, currents above this limit generate a warning.
66	jmax=1e8 A/m ²	Maximum current density, currents above this limit generate a warning.
67	bvj= ∞ V	Junction reverse breakdown voltage.
68	vbox=1e9 tox V	Oxide breakdown voltage.

Temperature effects parameters

69	tnom (C)	Parameters measurement temperature. Default set by options.
70	trise=0 C	Temperature rise from ambient.
71	uto=0 C	Mobility temperature offset.
72	ute=-1.5	Mobility temperature exponent.
73	tlev=0	DC temperature selector.
74	tlevc=0	AC temperature selector.
75	eg=1.12452 V	Energy band gap.
76	gap1=7.02e-4 V/C	Band gap temperature coefficient.
77	gap2=1108 C	Band gap temperature offset.
78	f1ex=0	Temperature exponent for ucrit.
79	lamex=0 1/C	Temperature parameter for lambda and kappa.
80	trs=0 1/C	Temperature parameter for source resistance.
81	trd=0 1/C	Temperature parameter for drain resistance.
82	xti=3	Saturation current temperature exponent.

Virtuoso Simulator Components and Device Models Reference

MOS Level-3 Model (mos3)

83	$p_{tc}=0$ V/C	Surface potential temperature coefficient.
84	$t_{cv}=0$ V/C	Threshold voltage temperature coefficient.
85	$p_{ta}=0$ V/C	Junction potential temperature coefficient.
86	$p_{tp}=0$ V/C	Sidewall junction potential temperature coefficient.
87	$c_{ta}=0$ 1/C	Junction capacitance temperature coefficient.
88	$c_{tp}=0$ 1/C	Sidewall junction capacitance temperature coefficient.

Default instance parameters

89	$w=3e-6$ m	Default channel width.
90	$l=3e-6$ m	Default channel length.
91	$a_s=0$ m ²	Default area of source diffusion.
92	$a_d=0$ m ²	Default area of drain diffusion.
93	$p_s=0$ m	Default perimeter of source diffusion.
94	$p_d=0$ m	Default perimeter of drain diffusion.
95	$n_{rd}=0$ m/m	Default number of squares of drain diffusion.
96	$n_{rs}=0$ m/m	Default number of squares of source diffusion.
97	$l_{dd}=0$ m	Default length of drain diffusion region.
98	$l_{ds}=0$ m	Default length of source diffusion region.

Noise model parameters

99	$noisemod=1$	Noise model selector.
100	$k_f=0$	Flicker (1/f) noise coefficient.
101	$a_f=1$	Flicker (1/f) noise exponent.

Virtuoso Simulator Components and Device Models Reference

MOS Level-3 Model (mos3)

- 102 `ef=1` Flicker (1/f) noise frequency exponent.
- 103 `wnoi=1e-5 m` Channel width at which noise parameters were extracted.

Auto Model Selector parameters

- 104 `wmax=1.0 m` Maximum channel width for which the model is valid.
- 105 `wmin=0.0 m` Minimum channel width for which the model is valid.
- 106 `lmax=1.0 m` Maximum channel length for which the model is valid.
- 107 `lmin=0.0 m` Minimum channel length for which the model is valid.

Degradation parameters

- 108 `degramod=spectre` Degradation model selector.
Possible values are `spectre` or `bert`.
- 109 `degradation=no` Hot-electron degradation flag.
Possible values are `no` or `yes`.
- 110 `dvthc=1 V` Degradation coefficient for threshold voltage.
- 111 `dvthe=1` Degradation exponent for threshold voltage.
- 112 `duoc=1 S` Degradation coefficient for transconductance.
- 113 `duoe=1` Degradation exponent for transconductance.
- 114 `crivth=0.1 V` Maximum allowable threshold voltage shift.
- 115 `criuo=10%` Maximum allowable normalized mobility change.
- 116 `crigm=10%` Maximum allowable normalized transconductance change.
- 117 `criids=10%` Maximum allowable normalized drain current change.
- 118 `wnom=5e-6 m` Nominal device width in degradation calculation.
- 119 `lnom=1e-6 m` Nominal device length in degradation calculation.

Virtuoso Simulator Components and Device Models Reference

MOS Level-3 Model (mos3)

120	$vbsn=0$ V	Substrate voltage in degradation calculation.
121	$vdsni=0.1$ V	Drain voltage in I_{ds} degradation calculation.
122	$vgsni=5$ V	Gate voltage in I_{ds} degradation calculation.
123	$vdsng=0.1$ V	Drain voltage in G_m degradation calculation.
124	$vgsng=5$ V	Gate voltage in G_m degradation calculation.

Spectre stress parameters

125	$esat=1.1e7$ V/m	Critical field in V_{dsat} calculation.
126	$esatg=2.5e6$ 1/m	Gate voltage dependence of $esat$.
127	$vpg=-0.25$	Gate voltage modifier.
128	$vpb=-0.13$	Gate voltage modifier.
129	$subc1=2.24e-5$	Substrate current coefficient.
130	$subc2=-0.1e-5$ 1/V	Substrate current coefficient.
131	$sube=6.4$	Substrate current exponent.
132	$strc=1$	Stress coefficient.
133	$stre=1$	Stress exponent.

BERT stress parameters

134	$h0=1$	Aging coefficient.
135	$hgd=0$ 1/V	Bias dependence of $h0$.
136	$m0=1$	Aging exponent.
137	$mgd=0$ 1/V	Bias dependence of $m0$.
138	$ecrit0=1.1e5$ V/cm	Critical electric field.

Virtuoso Simulator Components and Device Models Reference

MOS Level-3 Model (mos3)

- 139 $l_{crit0}=0$ $\mu\text{m V/cm}$ Length dependence of $ecrit0$.
- 140 $w_{crit0}=0$ $\mu\text{m V/cm}$ Width dependence of $ecrit0$.
- 141 $ecritg=0$ $1/\text{cm}$ Gate voltage dependence of $ecrit0$.
- 142 $l_{critg}=0$ $\mu\text{m/cm}$ Length dependence of $ecritg$.
- 143 $w_{critg}=0$ $\mu\text{m/cm}$ Width dependence of $ecritg$.
- 144 $ecritb=0$ $1/\text{cm}$ Substrate voltage dependence of $ecrit0$.
- 145 $l_{critb}=0$ $\mu\text{m/cm}$ Length dependence of $ecritb$.
- 146 $w_{critb}=0$ $\mu\text{m/cm}$ Width dependence of $ecritb$.
- 147 $lc0=1$ Substrate current coefficient.
- 148 $llc0=0$ μm Length dependence of $lc0$.
- 149 $wlc0=0$ μm Width dependence of $lc0$.
- 150 $lc1=1$ Substrate current coefficient.
- 151 $llc1=0$ μm Length dependence of $lc1$.
- 152 $wlc1=0$ μm Width dependence of $lc1$.
- 153 $lc2=1$ Substrate current coefficient.
- 154 $llc2=0$ μm Length dependence of $lc2$.
- 155 $wlc2=0$ μm Width dependence of $lc2$.
- 156 $lc3=1$ Substrate current coefficient.
- 157 $llc3=0$ μm Length dependence of $lc3$.
- 158 $wlc3=0$ μm Width dependence of $lc3$.
- 159 $lc4=1$ Substrate current coefficient.
- 160 $llc4=0$ μm Length dependence of $lc4$.

Virtuoso Simulator Components and Device Models Reference

MOS Level-3 Model (mos3)

161	$wlc4=0 \mu\text{m}$	Width dependence of $lc4$.
162	$lc5=1$	Substrate current coefficient.
163	$llc5=0 \mu\text{m}$	Length dependence of $lc5$.
164	$wlc5=0 \mu\text{m}$	Width dependence of $lc5$.
165	$lc6=1$	Substrate current coefficient.
166	$llc6=0 \mu\text{m}$	Length dependence of $lc6$.
167	$wlc6=0 \mu\text{m}$	Width dependence of $lc6$.
168	$lc7=1$	Substrate current coefficient.
169	$llc7=0 \mu\text{m}$	Length dependence of $lc7$.
170	$wlc7=0 \mu\text{m}$	Width dependence of $lc7$.

Shrink Parameters

Imax and Imelt

The $imax$ parameter aids convergence and prevents numerical overflow. The junction characteristics of the device are accurately modeled for current up to $imax$. If $imax$ is exceeded during iterations, the linear model is substituted until the current drops below $imax$ or until convergence is achieved. If convergence is achieved with the current exceeding $imax$, the results are inaccurate, and Spectre prints a warning.

A separate model parameter, $imelt$, is used as a limit warning for the junction current. This parameter can be set to the maximum current rating of the device. When any component of the junction current exceeds $imelt$, note that base and collector currents are composed of many exponential terms, Spectre issues a warning and the results become inaccurate. The junction current is linearized above the value of $imelt$ to prevent arithmetic exception, with the exponential term replaced by a linear equation at $imelt$.

Both of these parameters have current density counterparts, $jmax$ and $jmelt$, that you can specify if you want the absolute current values to depend on the device area.

Auto Model Selection

Virtuoso Simulator Components and Device Models Reference

MOS Level-3 Model (mos3)

Many models need to be characterized for different geometries in order to obtain accurate results for model development. The model selector program automatically searches for a model with the length and width range specified in the instance statement and uses this model in the simulations.

For the auto model selector program to find a specific model, the models to be searched should be grouped together within braces. Such a group is called a model group. An opening brace is required at the end of the line defining each model group. Every model in the group is given a name followed by a colon and the list of parameters. Also, the four geometric parameters `lmax`, `lmin`, `wmax`, and `wmin` should be given. The selection criteria to choose a model is as follows:

$$lmin \leq inst_length < lmax \text{ and } wmin \leq inst_width < wmax$$

Example:

```
model ModelName ModelType {  
    1: <model parameters> lmin=2 lmax=4 wmin=1 wmax=2  
    2: <model parameters> lmin=1 lmax=2 wmin=2 wmax=4  
    3: <model parameters> lmin=2 lmax=4 wmin=4 wmax=6  
}
```

Then for a given instance

```
M1 1 2 3 4 ModelName w=3 l=1.5
```

the program would search all the models in the model group with the name `ModelName` and then pick the first model whose geometric range satisfies the selection criteria. In the preceding example, the auto model selector program would choose `ModelName.2`.

You must specify both length (`l`) and width (`w`) on the device instance line to enable automatic model selection.

Output Parameters

- | | | |
|---|--|------------------------------|
| 1 | <code>w_{eff}</code> (m) | Effective channel width. |
| 2 | <code>l_{eff}</code> (m) | Effective channel length. |
| 3 | <code>r_{seff}</code> (Ω) | Effective source resistance. |

Virtuoso Simulator Components and Device Models Reference

MOS Level-3 Model (mos3)

4	<code>rdef</code> (Ω)	Effective drain resistance.
5	<code>aseff</code> (m^2)	Effective area of source diffusion.
6	<code>adef</code> (m^2)	Effective area of drain diffusion.
7	<code>pseff</code> (m)	Effective perimeter of source diffusion.
8	<code>pdef</code> (m)	Effective perimeter of drain diffusion.
9	<code>isseff</code> (A)	Effective source-bulk junction reverse saturation current.
10	<code>isdef</code> (A)	Effective drain-bulk junction reverse saturation current.
11	<code>cbseff</code> (F)	Effective zero-bias source-bulk junction capacitance.
12	<code>cbdef</code> (F)	Effective zero-bias drain-bulk junction capacitance.

Operating-Point Parameters

1	<code>type=n</code>	Transistor type. Possible values are <code>n</code> or <code>p</code> .
2	<code>region=triode</code>	Estimated operating region. Spectre outputs number (0-4) in a rawfile. Possible values are <code>off</code> , <code>triode</code> , <code>sat</code> , <code>subth</code> , or <code>breakdown</code> .
3	<code>degradation=no</code>	Hot-electron degradation flag. Possible values are <code>no</code> or <code>yes</code> .
4	<code>reversed</code>	Reverse mode indicator. Possible values are <code>no</code> or <code>yes</code> .
5	<code>ids</code> (A)	Resistive drain-to-source current.
6	<code>vgs</code> (V)	Gate-source voltage.
7	<code>vds</code> (V)	Drain-source voltage.
8	<code>vbs</code> (V)	Bulk-source voltage.
9	<code>vth</code> (V)	Threshold voltage.

Virtuoso Simulator Components and Device Models Reference

MOS Level-3 Model (mos3)

10	v_{dsat} (V)	Drain-source saturation voltage.
11	g_m (S)	Common-source transconductance.
12	g_{ds} (S)	Common-source output conductance.
13	g_{mbs} (S)	Body-transconductance.
14	$g_{m\text{eff}}$ (\sqrt{V})	Effective body effect coefficient.
15	β_{eff} (A/V^2)	Effective β .
16	c_{bd} (F)	Drain-bulk junction capacitance.
17	c_{bs} (F)	Source-bulk junction capacitance.
18	c_{gs} (F)	Gate-source capacitance.
19	c_{gd} (F)	Gate-drain capacitance.
20	c_{gb} (F)	Gate-bulk capacitance.
21	r_{on} (Ω)	On-resistance.
22	i_d (A)	Resistive drain current.
23	i_{bulk} (A)	Resistive bulk current.
24	pwr (W)	Power at op point.
25	$g_{m\text{over}i_d}$ (1/V)	G_m/I_{ds} .
26	i_{sub} (A)	Substrate current.
27	$stress$	Hot-electron stress.
28	age (s)	Device age.
29	he_v_{dsat} (V)	Hot Electron v_{dsat} .

Virtuoso Simulator Components and Device Models Reference

MOS Level-3 Model (mos3)

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

ad	I-4	gap1	M-76	llc7	M-169	tlevc	M-74
ad	M-92	gap2	M-77	lmax	M-106	tnom	M-69
adefeff	O-6	gds	OP-12	lmin	M-107	tox	M-16
af	M-101	gm	OP-11	lnom	M-119	tpg	M-15
age	OP-28	gmbs	OP-13	ls	I-10	trd	M-81
ai0	M-22	gmoverid	OP-25	m	I-11	trise	I-13
alarm	M-64	h0	M-134	m0	M-136	trise	M-70
as	I-3	hdif	M-44	meto	M-31	trs	M-80
as	M-91	he_vdsat	OP-29	mgd	M-137	type	M-1
aseff	O-5	hgd	M-135	minr	M-42	type	OP-1
betaeff	OP-15	ibulk	OP-23	mj	M-57	uo	M-7
bi0	M-25	id	OP-22	mjsw	M-61	ute	M-72
bvj	M-67	ids	OP-5	n	M-50	uto	M-71
capmod	M-32	imax	M-65	nfs	M-14	vbox	M-68
cbd	M-55	imelt	M-52	noisemod	M-99	vbs	OP-8
cbd	OP-16	is	M-49	nrd	I-7	vbsn	M-120

Virtuoso Simulator Components and Device Models Reference

MOS Level-3 Model (mos3)

cbdeff	O-12	isdeff	O-10	nrd	M-95	vds	OP-7
cbs	M-54	isnoisy	I-14	nrs	I-8	vdsat	OP-10
cbs	OP-17	isseff	O-9	nrs	M-96	vdsng	M-123
cbseff	O-11	isub	OP-26	nss	M-13	vdsni	M-121
cgb	OP-20	jmax	M-66	nsub	M-12	vgs	OP-6
cgbo	M-30	jmelt	M-53	pb	M-58	vgsng	M-124
cgd	OP-19	js	M-48	pbsw	M-62	vgsni	M-122
cgdo	M-29	kappa	M-10	pd	I-6	vmax	M-8
cgs	OP-18	kf	M-100	pd	M-94	vpb	M-128
cgso	M-28	kp	M-3	pdeff	O-8	vpg	M-127
cj	M-56	l	I-2	phi	M-5	vth	OP-9
cjsw	M-60	l	M-90	ps	I-5	vto	M-2
crigm	M-116	lai0	M-23	ps	M-93	w	I-1
criids	M-117	lamex	M-79	pseff	O-7	w	M-89
criuo	M-115	lbi0	M-26	pta	M-85	wai0	M-24
crivth	M-114	lc0	M-147	ptc	M-83	wbi0	M-27
cta	M-87	lc1	M-150	ptp	M-86	wd	M-18
ctp	M-88	lc2	M-153	pwr	OP-24	wecrit0	M-140
degradation	I-15	lc3	M-156	rd	M-36	wecritb	M-146
degradation	M-109	lc4	M-159	rdc	M-41	wecritg	M-143

Virtuoso Simulator Components and Device Models Reference

MOS Level-3 Model (mos3)

degradation	OP-3	lc5	M-162	rdd	M-39	weff	O-1
degramod	M-108	lc6	M-165	rdeff	O-4	wlc0	M-149
delta	M-11	lc7	M-168	region	I-12	wlc1	M-152
dskip	M-51	ld	I-9	region	OP-2	wlc2	M-155
duoc	M-112	ld	M-17	reversed	OP-4	wlc3	M-158
duoe	M-113	ldd	M-97	ron	OP-21	wlc4	M-161
dvthc	M-110	ldif	M-43	rs	M-35	wlc5	M-164
dvthe	M-111	lds	M-98	rsc	M-40	wlc6	M-167
ecrit0	M-138	lecrit0	M-139	rseff	O-3	wlc7	M-170
ecritb	M-144	lecritb	M-145	rsh	M-37	wmax	M-104
ecritg	M-141	lecritg	M-142	rss	M-38	wmin	M-105
ef	M-102	leff	O-2	sc	M-47	wnoi	M-103
eg	M-75	lgcd	M-46	strc	M-132	wnom	M-118
esat	M-125	lgcs	M-45	stre	M-133	xj	M-21
esatg	M-126	llc0	M-148	stress	OP-27	xl	M-20
eta	M-9	llc1	M-151	subc1	M-129	xpart	M-33
flex	M-78	llc2	M-154	subc2	M-130	xqc	M-34
fc	M-59	llc3	M-157	sube	M-131	xti	M-82
fcsw	M-63	llc4	M-160	tcv	M-84	xw	M-19
gameff	OP-14	llc5	M-163	theta	M-4		
gamma	M-6	llc6	M-166	tlev	M-73		

Virtuoso Simulator Components and Device Models Reference

MOS Level-3 Model (mos3)

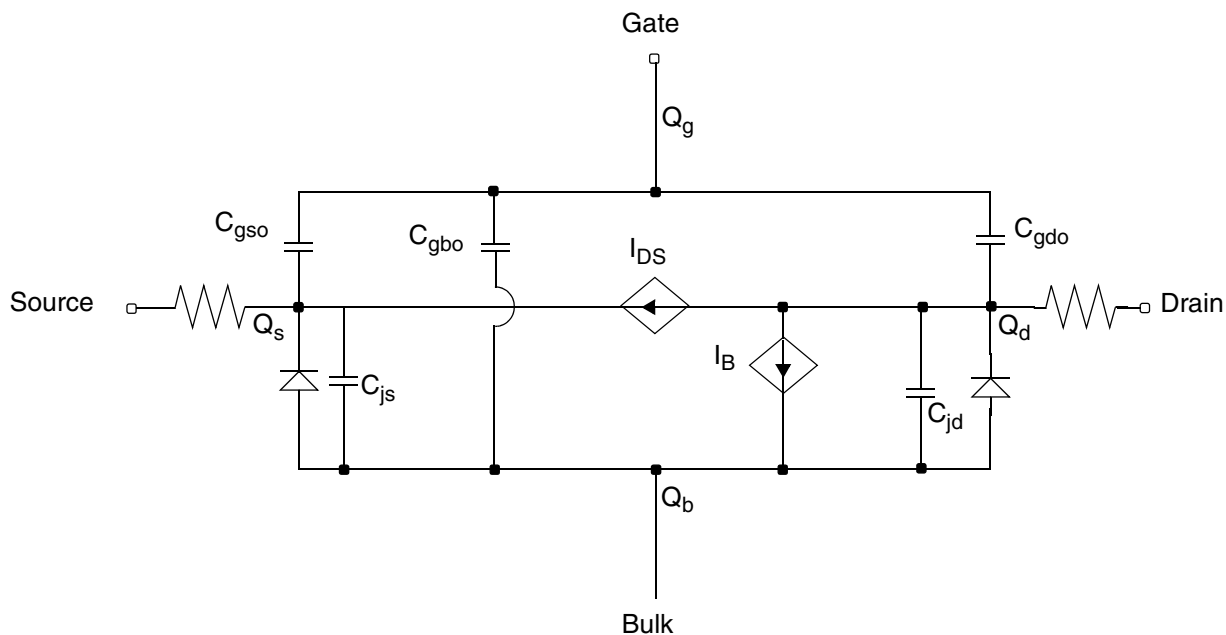
BSIM1 Level-4 Model (bsim1)

The BSIM1 model is based on the industry standard efforts of the Compact Modeling Counsel (CMC) and the BSIM modeling group at the University of California, Berkeley. This chapter contains the following information for the BSIM1 model:

- [Parameter Calculation](#) on page 1065
- [Drain Current Model](#) on page 1066
- [Scaling Effects](#) on page 1069
- [Component Statements](#) on page 1069

Virtuoso Simulator Components and Device Models Reference

BSIM1 Level-4 Model (bsim1)



BSIM1 stands for Berkeley Short-Channel IGFET Model version-1. The BSIM1 model is a semiempirical model suitable for devices with channel length from long channel to about 0.8 μm . This model extracts all model parameters directly from physical devices. You can obtain an automated parameter extraction program, based on the HP9836 and HP4145 systems, from the ILP office, Department of EECS, University of California, Berkeley. The following table shows the correspondence between the input parameter names and the equation symbols for the BSIM1 model.

Parameter	Symbol	Parameter	Symbol	Parameter	Symbol
vfb	$V_{FB,0}$	lvfb	$V_{FB,L}$	wvfb	$V_{FB,W}$
phi	ϕ_0	lphi	ϕ_L	wphi	ϕ_W
k1	K_1	lk1	$K_{1,L}$	wk1	$K_{1,W}$
k2	K_2	lk2	$K_{2,L}$	wk2	$K_{2,W}$
eta	η_0	leta	η_L	weta	η_W
muz	μ_0	d1	d_l	dw	d_w
u0	$U_{0,0}$	lu0	$U_{0,L}$	wu0	$U_{0,W}$
u1	$U_{1,0}$	lu1	$U_{1,L}$	wu1	$U_{1,W}$

Virtuoso Simulator Components and Device Models Reference
BSIM1 Level-4 Model (bsim1)

Parameter	Symbol	Parameter	Symbol	Parameter	Symbol
x2mz	$\mu_{0B,0}$	lx2mz	$\mu_{0B,L}$	wx2mz	$\mu_{0B,W}$
x2e	$\eta_{B,0}$	lx2e	$\eta_{B,L}$	wx2e	$\eta_{B,W}$
x3e	$\eta_{D,0}$	lx3e	$\eta_{D,L}$	wx3e	$\eta_{D,W}$
x2u0	$U_{0B,0}$	lx2u0	$U_{0B,L}$	wx2u0	$U_{0B,W}$
x2u1	$U_{1B,0}$	lx2u1	$U_{1B,L}$	wx2u1	$U_{1B,W}$
mus	μ_s	lmus	$\mu_{s,L}$	wmus	$\mu_{s,W}$
x2ms	$\mu_{sB,0}$	lx2ms	$\mu_{sB,L}$	wx2ms	$\mu_{sB,W}$
x3ms	$\mu_{sD,0}$	lx3ms	$\mu_{sD,L}$	wx3ms	$\mu_{sD,W}$
x3u1	$U_{1D,0}$	lx3u1	$U_{1D,L}$	wx3u1	$U_{1D,W}$
n0	$N_{0,0}$	ln0	$N_{0,L}$	wn0	$N_{0,W}$
nb	$N_{B,0}$	lnb	$N_{B,L}$	wnb	$N_{B,W}$
nd	$N_{D,0}$	lnd	$N_{D,L}$	wnd	$N_{D,W}$
aio	Ai_0	laio	$Ai_{0,L}$	waio	$Ai_{0,W}$
bio	Bi_0	lbio	$Bi_{0,L}$	wbio	$Bi_{0,W}$
vdd	V_{DD}				

Parameter Calculation

Except for muz , dl , and dw , all device parameters are calculated from the following equation:

$$P_i = P_{i,0} + \frac{P_{i,L}}{L_{eff}} + \frac{P_{i,W}}{W_{eff}}$$

where P_i is any device parameter, $P_{i,0}$ is the parameter value for very long channel length and width, and $P_{i,L}$ and $P_{i,W}$ are the channel length and width dependencies of the parameter, respectively. The following example shows how the flat-band voltage for a device with $l = 2 \mu\text{m}$ and $w = 5 \mu\text{m}$ is calculated from the model parameters:

$$V_{FB} = V_{FB,0} + \frac{V_{FB,L}}{2 - dl} + \frac{V_{FB,W}}{5 - dw}$$

Drain Current Model

Channel Width and Length

$$W_{scaled} = w*scale + xw*scale_m$$

$$W_{eff} = \begin{cases} w*scale + xw*scale_m - 2wd*scale_m & \text{(Level 1-3)} \\ w*scale + xw*scale_m - dw*scale_m & \text{(BSIM 1-2)} \end{cases}$$

$$L_{eff} = \begin{cases} l*scale + xl*scale_m - 2ld*scale_m & \text{(Level 1-3)} \\ l*scale + xl*scale_m - dl*scale_m & \text{(BSIM 1-2)} \end{cases}$$

Threshold Voltage

$$V_{TH} = V_{FB} + \phi + K_1\sqrt{\phi - V_{BS}} - K_2(\phi - V_{BS}) - \eta V_{DS}$$

where

$$\eta = \eta_0 + \eta_B V_{BS} + \eta_D (V_{DS} - V_{DD})$$

Drain Saturation Voltage

$$V_{DSAT} = \frac{V_{GS} - V_{TH}}{a\sqrt{K}}$$

where

$$a = 1 + \frac{gK_1}{2\sqrt{\phi - V_{BS}}}$$

$$g = 1 - \frac{1}{1.744 + 0.8364(\phi - V_{BS})}$$

$$K = \frac{1 + V_c + \sqrt{1 + 2V_c}}{2}$$

$$V_c = \frac{U_{1S}(V_{GS} - V_{TH})}{a}$$

Drain Current for the Subthreshold Region

Note: These equations apply when $V_{GS} \leq V_{TH}$.

If you specify that N_0 is less than 10, the subthreshold current is calculated and added to the drain current.

$$I_{subth} = \frac{I_{EXP} I_{LIMIT}}{I_{EXP} + I_{LIMIT}}$$

where

$$I_{EXP} = \beta_0 V_t^2 e^{1.8 + (V_{GS} - V_{TH})/nV_t} (1 - e^{-V_{DS}/V_t})$$

$$I_{LIMIT} = 4.5\beta_0 V_t^2$$

$$n = N_0 + N_B V_{BS} + N_D V_{DS}$$

The subthreshold current is added to the drain current.

$$I_{DS,tot} = I_{DS} + I_{subth}$$

Drain Current for the Triode Region

Note: These equations apply when $V_{GS} \geq V_{ON}$ and $V_{DS} \leq V_{DSAT}$.

$$I_{DS} = \frac{\beta_0 \left(V_{GS} - V_{TH} - \frac{a}{2} V_{DS} \right) V_{DS}}{(1 + U_{1S} V_{DS}) [1 + \theta (V_{GS} - V_{TH})]}$$

where

$$\theta = U_0 + U_{0B}V_{BS}$$

$$U_{1S} = \frac{U_1 + U_{1B}V_{BS} + U_{1D}(V_{DS} - V_{DD})}{L_{eff}}$$

$$\beta_0 = \beta_1 \left(\frac{V_{DS}}{V_{DD}} - 1 \right)^2 + \beta_2 \left(2 - \frac{V_{DS}}{V_{DD}} \right) \frac{V_{DS}}{V_{DD}} + \beta_{sD} V_{DS} \left(\frac{V_{DS}}{V_{DD}} - 1 \right)$$

$$\beta_1 = \frac{C_{ox}W_{eff}}{L_{eff}} (\mu_0 + \mu_{0B}V_{BS})$$

$$\beta_2 = \frac{C_{ox}W_{eff}}{L_{eff}} (\mu_s + \mu_{sB}V_{BS})$$

$$\beta_{sD} = \frac{C_{ox}W_{eff}}{L_{eff}} \mu_{sD}$$

Drain Current for the Saturation Region

Note: This equation applies when $V_{GS} \geq V_{ON}$ and $V_{DS} \geq V_{DSAT}$.

$$I_{DS} = \frac{\beta(V_{GS} - V_{TH})^2}{2aK}$$

Substrate Current

The substrate current results from impact ionization in the velocity saturation region near the drain. This impact-ionization induced current (I_{DB}) flows between the drain and the substrate. You need both A_i and B_i to use the impact-ionization model.

$$I_{DB} = \begin{cases} I_{DS} A_i (V_{DS} - V_{DSAT}) e^{-B_i / (V_{DS} - V_{DSAT})} & \text{if } V_{DS} \leq V_{DSAT} \\ 0 & \text{otherwise} \end{cases}$$

where

$$A_i = A_{io} + \frac{A_{io,L} \times 10^{-6}}{L_{eff}} + \frac{A_{io,W} \times 10^{-6}}{W_{eff}}$$

$$B_i = B_{io} + \frac{B_{io,L} \times 10^{-6}}{L_{eff}} + \frac{B_{io,W} \times 10^{-6}}{W_{eff}}$$

Scaling Effects

For scaling effects, see [Scaling Factors \(scale and scalem\)](#) on page 242.

Component Statements

This device is supported within altergroups.

Sample Instance Statement

```
m1 (1 2 0 0) nchmod l=5u w=10u as=40u ad=40u pd=28u ps=28u m=1
```

Sample Model Statement

```
model nchmod bsim1 vfb0=-0.5 lvfb=0.5 wvfb=0.3 phi0=0.8 eta0=0.056 k1=0.5 muz=454  
eg=0.99 gap1=5.5e-04 trs=1e-3 trd=1e-3 xpart=0.5 rs=10 rd=10
```

Instance Definition

```
Name d g s b ModelName parameter=value ...
```

Instance Parameters

- | | | |
|---|----------------------|---------------------------|
| 1 | w (m) | Channel width. |
| 2 | l (m) | Channel length. |
| 3 | as (m ²) | Area of source diffusion. |
| 4 | ad (m ²) | Area of drain diffusion. |

Virtuoso Simulator Components and Device Models Reference

BSIM1 Level-4 Model (bsim1)

5	<code>ps</code> (m)	Perimeter of source diffusion.
6	<code>pd</code> (m)	Perimeter of drain diffusion.
7	<code>nrd</code> (m/m)	Number of squares of drain diffusion.
8	<code>nrs</code> (m/m)	Number of squares of source diffusion.
9	<code>ld</code> (m)	Drain diffusion length.
10	<code>ls</code> (m)	Source diffusion length.
11	<code>m=1</code>	Multiplicity factor (number of MOSFETs in parallel).
12	<code>region=triode</code>	Estimated operating region. Spectre outputs number (0-4) in a rawfile. Possible values are <code>off</code> , <code>triode</code> , <code>sat</code> , <code>subth</code> , or <code>breakdown</code> .
13	<code>trise</code> (C)	Temperature rise from ambient.
14	<code>degradation=no</code>	Hot-electron degradation flag. Possible values are <code>no</code> or <code>yes</code> .
15	<code>isnoisy=yes</code>	Should resistor generate noise. Possible values are <code>no</code> or <code>yes</code> .

Model Definition

```
model modelName bsim1 parameter=value ...
```

Model Parameters

Device type parameters

1	<code>type=n</code>	Transistor type. Possible values are <code>n</code> or <code>p</code> .
---	---------------------	--

Threshold voltage parameters

2	<code>vfb0=-0.8 V</code>	Flat-band voltage.
---	--------------------------	--------------------

Virtuoso Simulator Components and Device Models Reference

BSIM1 Level-4 Model (bsim1)

3	$lvfb=0$ V μm	Length dependence of v_{fb} .
4	$wvfb=0$ V μm	Width dependence of v_{fb} .
5	$pvfb=0$ V μm	Width-length dependence of v_{fb} .
6	$\phi_0=0.75$ V	Surface potential.
7	$l\phi_0=0$ V μm	Length dependence of ϕ_0 .
8	$w\phi_0=0$ V μm	Width dependence of ϕ_0 .
9	$p\phi_0=0$ V μm	Width-length dependence of ϕ_0 .
10	$k_1=0.7$ \sqrt{V}	Body-effect coefficient.
11	$lk_1=0$ \sqrt{V} μm	Length dependence of k_1 .
12	$wk_1=0$ \sqrt{V} μm	Width dependence of k_1 .
13	$pk_1=0$ \sqrt{V} μm	Width-length dependence of k_1 .
14	$k_2=0$	Charge-sharing parameter.
15	$lk_2=0$ μm	Length dependence of k_2 .
16	$wk_2=0$ μm	Width dependence of k_2 .
17	$pk_2=0$ μm	Width-length dependence of k_2 .
18	$\eta_0=0$	Drain-induced barrier-lowering coefficient.
19	$l\eta_0=0$ μm	Length dependence of η_0 .
20	$w\eta_0=0$ μm	Width dependence of η_0 .
21	$p\eta_0=0$ μm	Width-length dependence of η_0 .
22	$x_{2e}=0$ $1/V$	Body-bias dependence of η_0 .
23	$lx_{2e}=0$ $\mu\text{m}/V$	Length dependence of x_{2e} .
24	$wx_{2e}=0$ $\mu\text{m}/V$	Width dependence of x_{2e} .

Virtuoso Simulator Components and Device Models Reference
BSIM1 Level-4 Model (bsim1)

- 25 $\text{px}2\text{e}=0 \text{ } \mu\text{m}/\text{V}$ Width-length dependence of $\text{x}2\text{e}$.
- 26 $\text{x}3\text{e}=0 \text{ } 1/\text{V}$ Drain-bias dependence of eta .
- 27 $\text{l}\text{x}3\text{e}=0 \text{ } \mu\text{m}/\text{V}$ Length dependence of $\text{x}3\text{e}$.
- 28 $\text{w}\text{x}3\text{e}=0 \text{ } \mu\text{m}/\text{V}$ Width dependence of $\text{x}3\text{e}$.
- 29 $\text{p}\text{x}3\text{e}=0 \text{ } \mu\text{m}/\text{V}$ Width-length dependence of $\text{x}3\text{e}$.

Mobility parameters

- 30 $\text{muz}=400 \text{ cm}^2/\text{V s}$ Low-field mobility.
- 31 $\text{l}\text{muz}=0 \text{ cm}^2/\text{V s}$ Length dependence of muz .
- 32 $\text{w}\text{muz}=0 \text{ cm}^2/\text{V s}$ Width dependence of muz .
- 33 $\text{p}\text{muz}=0 \text{ cm}^2/\text{V s}$ Width-length dependence of muz .
- 34 $\text{x}2\text{mz}=0 \text{ cm}^2/\text{V}^2 \text{ s}$ Body-bias dependence of muz .
- 35 $\text{l}\text{x}2\text{mz}=0 \text{ cm}^2 \text{ } \mu\text{m}/\text{V}^2 \text{ s}$
Length dependence of $\text{x}2\text{mz}$.
- 36 $\text{w}\text{x}2\text{mz}=0 \text{ cm}^2 \text{ } \mu\text{m}/\text{V}^2 \text{ s}$
Width dependence of $\text{x}2\text{mz}$.
- 37 $\text{p}\text{x}2\text{mz}=0 \text{ cm}^2 \text{ } \mu\text{m}/\text{V}^2 \text{ s}$
Width-length dependence of $\text{x}2\text{mz}$.
- 38 $\text{mus}=450 \text{ cm}^2/\text{V s}$ Mobility in the saturation region.
- 39 $\text{l}\text{mus}=0 \text{ cm}^2 \text{ } \mu\text{m}/\text{V s}$
Length dependence of mus .
- 40 $\text{w}\text{mus}=0 \text{ cm}^2 \text{ } \mu\text{m}/\text{V s}$
Width dependence of mus .
- 41 $\text{p}\text{mus}=0 \text{ cm}^2 \text{ } \mu\text{m}/\text{V s}$
Width-length dependence of mus .
- 42 $\text{x}2\text{ms}=0 \text{ cm}^2/\text{V}^2 \text{ s}$ Body-bias dependence of mus .

Virtuoso Simulator Components and Device Models Reference

BSIM1 Level-4 Model (bsim1)

- 43 $lx2ms=0$ $cm^2 \mu m/V^2 s$ Length dependence of $x2ms$.
- 44 $wx2ms=0$ $cm^2 \mu m/V^2 s$ Width dependence of $x2ms$.
- 45 $px2ms=0$ $cm^2 \mu m/V^2 s$ Width-length dependence of $x2ms$.
- 46 $x3ms=0$ $cm^2/V^2 s$ Drain-bias dependence of mu_s .
- 47 $lx3ms=0$ $cm^2 \mu m/V^2 s$ Length dependence of $x3ms$.
- 48 $wx3ms=0$ $cm^2 \mu m/V^2 s$ Width dependence of $x3ms$.
- 49 $px3ms=0$ $cm^2 \mu m/V^2 s$ Width-length dependence of $x3ms$.

Mobility modulation parameters

- 50 $u00=0$ $1/V$ Gate voltage dependence of mobility.
- 51 $lu0=0$ $\mu m/V$ Length dependence of $u0$.
- 52 $wu0=0$ $\mu m/V$ Width dependence of $u0$.
- 53 $pu0=0$ $\mu m/V$ Width-length dependence of $u0$.
- 54 $x2u0=0$ $1/V^2$ Body-bias dependence of $u0$.
- 55 $lx2u0=0$ $\mu m/V^2$ Length dependence of $x2u0$.
- 56 $wx2u0=0$ $\mu m/V^2$ Width dependence of $x2u0$.
- 57 $px2u0=0$ $\mu m/V^2$ Width-length dependence of $x2u0$.

Velocity saturation parameters

- 58 $u10=0$ $1/V$ Velocity saturation coefficient.

Virtuoso Simulator Components and Device Models Reference
BSIM1 Level-4 Model (bsim1)

59	$l_{u1=0}$	$\mu\text{m}/V$	Length dependence of $u1$.
60	$w_{u1=0}$	$\mu\text{m}/V$	Width dependence of $u1$.
61	$p_{u1=0}$	$\mu\text{m}/V$	Width-length dependence of $u1$.
62	$x_{2u1=0}$	$1/V^2$	Body-bias dependence of $u1$.
63	$l_{x2u1=0}$	$\mu\text{m}/V^2$	Length dependence of x_{2u1} .
64	$w_{x2u1=0}$	$\mu\text{m}/V^2$	Width dependence of x_{2u1} .
65	$p_{x2u1=0}$	$\mu\text{m}/V^2$	Width-length dependence of x_{2u1} .
66	$x_{3u1=0}$	$1/V^2$	Drain-bias dependence of $u1$.
67	$l_{x3u1=0}$	$\mu\text{m}/V^2$	Length dependence of x_{3u1} .
68	$w_{x3u1=0}$	$\mu\text{m}/V^2$	Width dependence of x_{3u1} .
69	$p_{x3u1=0}$	$\mu\text{m}/V^2$	Width-length dependence of x_{3u1} .

Subthreshold parameters

70	$n0=0$		Subthreshold swing parameter.
71	$l_{n0=0}$	μm	Length dependence of subthreshold swing parameter.
72	$w_{n0=0}$	μm	Width dependence of subthreshold swing parameter.
73	$p_{n0=0}$	μm	Width-length dependence of subthreshold swing parameter.
74	$n_b=0$	\sqrt{V}	Body-bias dependence of $n0$.
75	$l_{n_b=0}$	$\sqrt{V} \mu\text{m}$	Length dependence of n_b .
76	$w_{n_b=0}$	$\sqrt{V} \mu\text{m}$	Width dependence of n_b .
77	$p_{n_b=0}$	$\sqrt{V} \mu\text{m}$	Width-length dependence of n_b .
78	$n_d=0$	$1/V$	Drain-bias dependence of $n0$.
79	$l_{n_d=0}$	$\mu\text{m}/V$	Length dependence of n_d .

Virtuoso Simulator Components and Device Models Reference

BSIM1 Level-4 Model (bsim1)

- 80 $wnd=0$ $\mu\text{m}/\text{V}$ Width dependence of n_d .
- 81 $pnd=0$ $\mu\text{m}/\text{V}$ Width-length dependence of n_d .
- 82 $subthmod=2$ Subthreshold model selector.

Impact ionization parameters

- 83 $ai0=0$ $1/\text{V}$ Hot-electron effect on R_{out} parameter.
- 84 $lai0=0$ $\mu\text{m}/\text{V}$ Length dependence of $ai0$.
- 85 $wai0=0$ $\mu\text{m}/\text{V}$ Width dependence of $ai0$.
- 86 $pai0=0$ $\mu\text{m}/\text{V}$ Width-length dependence of $ai0$.
- 87 $bi0=0$ V Hot-electron effect on R_{out} exponent.
- 88 $lbi0=0$ $\text{V } \mu\text{m}$ Length dependence of $bi0$.
- 89 $wbi0=0$ $\text{V } \mu\text{m}$ Width dependence of $bi0$.
- 90 $pbi0=0$ $\text{V } \mu\text{m}$ Width-length dependence of $bi0$.

Length and width modulation parameters

- 91 $d10=0$ μm Lateral diffusion.
- 92 $dw0=0$ μm Field oxide encroachment.
- 93 $lref=\infty$ m Reference channel length.
- 94 $wref=\infty$ m Reference channel width.
- 95 $xw=0$ m Width variation due to masking and etching.
- 96 $xl=0$ m Length variation due to masking and etching.

Temperature effects parameters

- 97 $temp$ (C) Parameters measurement temperature. Default set by options.

Virtuoso Simulator Components and Device Models Reference

BSIM1 Level-4 Model (bsim1)

98	<code>trise=0 C</code>	Temperature rise from ambient.
99	<code>tempmod=432</code>	Temperature model selector.
100	<code>version=432</code>	Version selector.
101	<code>uto=0 C</code>	Mobility temperature offset.
102	<code>ute=-1.5</code>	Mobility temperature exponent.
103	<code>tlev=0</code>	DC temperature selector.
104	<code>tlevc=0</code>	AC temperature selector.
105	<code>eg=1.12452 V</code>	Energy band gap.
106	<code>gap1=7.02e-4 V/C²</code>	Band gap temperature coefficient.
107	<code>gap2=1108 K</code>	Band gap temperature offset.
108	<code>trs=0 1/C</code>	Temperature coefficient for source resistance.
109	<code>trd=0 1/C</code>	Temperature coefficient for drain resistance.
110	<code>x_{ti}=3</code>	Saturation current temperature exponent.

Overlap capacitance parameters

111	<code>cgso=0 F/m</code>	Gate-source overlap capacitance.
112	<code>cgdo=0 F/m</code>	Gate-drain overlap capacitance.
113	<code>cgbo=0 F/m</code>	Gate-bulk overlap capacitance.
114	<code>meto=0 m</code>	Metal overlap in fringing field.

Charge model selection parameters

115	<code>capmod=bsim</code>	Intrinsic charge model. Possible values are <code>none</code> , <code>meyer</code> , <code>yang</code> , or <code>bsim</code> .
-----	--------------------------	--

Virtuoso Simulator Components and Device Models Reference

BSIM1 Level-4 Model (bsim1)

- 116 $x_{part}=1$ Drain/source channel charge partition in saturation for BSIM charge model, use 0.0 for 40/60, 0.5 for 50/50, or 1.0 for 0/100.
- 117 $x_{qc}=0$ Drain/source channel charge partition in saturation for charge models, e.g. use 0.4 for 40/60, 0.5 for 50/50, or 0 for 0/100.

Parasitic resistance parameters

- 118 $r_s=0 \ \Omega$ Source resistance.
- 119 $r_d=0 \ \Omega$ Drain resistance.
- 120 $r_{sh}=0 \ \Omega/\text{sqr}$ Source/drain diffusion sheet resistance.
- 121 $r_{sc}=0 \ \Omega$ Source contact resistance.
- 122 $r_{dc}=0 \ \Omega$ Drain contact resistance.
- 123 $r_{ss}=0 \ \Omega \ \text{m}$ Scalable source resistance.
- 124 $r_{dd}=0 \ \Omega \ \text{m}$ Scalable drain resistance.
- 125 $\text{min}r=0.1 \ \Omega$ Minimum source/drain resistance.
- 126 $h_{dif}=0 \ \text{m}$ Length of heavily doped diffusion.
- 127 $l_{dif}=0 \ \text{m}$ Lateral diffusion beyond the gate.
- 128 $l_{gcs}=0 \ \text{m}$ Gate-to-contact length of source side.
- 129 $l_{gcd}=0 \ \text{m}$ Gate-to-contact length of drain side.
- 130 $s_c=\infty \ \text{m}$ Spacing between contacts.

Junction diode parameters

- 131 $j_s \ (\text{A}/\text{m}^2)$ Bulk junction reverse saturation current density.
- 132 $i_s=1e-14 \ \text{A}$ Bulk junction reverse saturation current.
- 133 $n=1$ Junction emission coefficient.

Virtuoso Simulator Components and Device Models Reference

BSIM1 Level-4 Model (bsim1)

- 134 $imelt=\text{'imax'}$ A Explosion current, diode is linearized beyond this current to aid convergence.
- 135 $jmelt=\text{'jmax'}$ A/m² Explosion current density, diode is linearized beyond this current to aid convergence.
- 136 $dskip=yes$ Use simple piece-wise linear model for diode currents below $0.1 \cdot iabstol$.
Possible values are `no` or `yes`.

Junction capacitance model parameters

- 137 $cbs=0$ F Bulk-source zero-bias junction capacitance.
- 138 $cbd=0$ F Bulk-drain zero-bias junction capacitance.
- 139 $cj=0$ F/m² Zero-bias junction bottom capacitance density.
- 140 $mj=1/2$ Bulk junction bottom grading coefficient.
- 141 $pb=0.8$ V Bulk junction potential.
- 142 $fc=0.5$ Forward-bias depletion capacitance threshold.
- 143 $cjsw=0$ F/m Zero-bias junction sidewall capacitance density.
- 144 $mjsw=1/3$ Bulk junction sidewall grading coefficient.
- 145 $pbsw=0.8$ V Side-wall junction potential.
- 146 $fcsw=0.5$ Side-wall forward-bias depletion capacitance threshold.

Operating region warning control parameters

- 147 $alarm=none$ Forbidden operating region.
Possible values are `none`, `off`, `triode`, `sat`, `subth`, or `rev`.
- 148 $imax=1$ A Maximum current, currents above this limit generate a warning.
- 149 $jmax=1e8$ A/m² Maximum current density, currents above this limit generate a warning.

Virtuoso Simulator Components and Device Models Reference

BSIM1 Level-4 Model (bsim1)

150 $b_{vj}=\infty$ V Junction reverse breakdown voltage.

151 $v_{box}=1e9$ t_{ox} V Oxide breakdown voltage.

Process and power supply parameters

152 $t_{ox}=4e-8$ m Gate oxide thickness.

153 $v_{dd}=5$ V Drain voltage at which parameters are extracted.

Default device parameters

154 $w=3e-6$ m Channel width.

155 $l=3e-6$ m Channel length.

156 $a_s=0$ m² Area of source diffusion.

157 $a_d=0$ m² Area of drain diffusion.

158 $p_s=0$ m Perimeter of source diffusion.

159 $p_d=0$ m Perimeter of drain diffusion.

160 $n_{rd}=0$ m/m Number of squares of drain diffusion.

161 $n_{rs}=0$ m/m Number of squares of source diffusion.

162 $l_{dd}=0$ m Drain diffusion length.

163 $l_{ds}=0$ m Source diffusion length.

Noise model parameters

164 $noisemod=1$ Noise model selector.

165 $k_f=0$ Flicker (1/f) noise coefficient.

166 $a_f=1$ Flicker (1/f) noise exponent.

167 $e_f=1$ Flicker (1/f) noise frequency exponent.

Virtuoso Simulator Components and Device Models Reference

BSIM1 Level-4 Model (bsim1)

168 `wnoi=1e-5 m` Channel width at which noise parameters were extracted.

Auto Model Selector parameters

169 `wmax=1.0 m` Maximum channel width for which the model is valid.

170 `wmin=0.0 m` Minimum channel width for which the model is valid.

171 `lmax=1.0 m` Maximum channel length for which the model is valid.

172 `lmin=0.0 m` Minimum channel length for which the model is valid.

Degradation parameters

173 `degramod=spectre` Degradation model selector.
Possible values are `spectre` or `bert`.

174 `degradation=no` Hot-electron degradation flag.
Possible values are `no` or `yes`.

175 `dvthc=1 V` Degradation coefficient for threshold voltage.

176 `dvthe=1` Degradation exponent for threshold voltage.

177 `duoc=1 S` Degradation coefficient for transconductance.

178 `duoe=1` Degradation exponent for transconductance.

179 `crivth=0.1 V` Maximum allowable threshold voltage shift.

180 `criuo=10%` Maximum allowable normalized mobility change.

181 `crigm=10%` Maximum allowable normalized transconductance change.

182 `criids=10%` Maximum allowable normalized drain current change.

183 `wnom=5e-6 m` Nominal device width in degradation calculation.

184 `lnom=1e-6 m` Nominal device length in degradation calculation.

185 `vbsn=0 V` Substrate voltage in degradation calculation.

Virtuoso Simulator Components and Device Models Reference

BSIM1 Level-4 Model (bsim1)

186	$v_{dsni}=0.1$ V	Drain voltage in I_{ds} degradation calculation.
187	$v_{gsni}=5$ V	Gate voltage in I_{ds} degradation calculation.
188	$v_{dsng}=0.1$ V	Drain voltage in G_m degradation calculation.
189	$v_{gsng}=5$ V	Gate voltage in G_m degradation calculation.

Spectre stress parameters

190	$esat=1.1e7$ V/m	Critical field in V_{dsat} calculation.
191	$esatg=2.5e6$ 1/m	Gate voltage dependence of $esat$.
192	$vpg=-0.25$	Gate voltage modifier.
193	$vpb=-0.13$	Gate voltage modifier.
194	$subc1=2.24e-5$	Substrate current coefficient.
195	$subc2=-0.1e-5$ 1/V	Substrate current coefficient.
196	$sube=6.4$	Substrate current exponent.
197	$strc=1$	Stress coefficient.
198	$stre=1$	Stress exponent.

BERT stress parameters

199	$h0=1$	Aging coefficient.
200	$hgd=0$ 1/V	Bias dependence of $h0$.
201	$m0=1$	Aging exponent.
202	$mgd=0$ 1/V	Bias dependence of $m0$.
203	$ecrit0=1.1e5$ V/cm	Critical electric field.
204	$lecrit0=0$ μm V/cm	Length dependence of $ecrit0$.

Virtuoso Simulator Components and Device Models Reference

BSIM1 Level-4 Model (bsim1)

205	$w_{crit0}=0$	$\mu\text{m V/cm}$	Width dependence of e_{crit0} .
206	$e_{critg}=0$	$1/\text{cm}$	Gate voltage dependence of e_{crit0} .
207	$l_{critg}=0$	$\mu\text{m/cm}$	Length dependence of e_{critg} .
208	$w_{critg}=0$	$\mu\text{m/cm}$	Width dependence of e_{critg} .
209	$e_{critb}=0$	$1/\text{cm}$	Substrate voltage dependence of e_{crit0} .
210	$l_{critb}=0$	$\mu\text{m/cm}$	Length dependence of e_{critb} .
211	$w_{critb}=0$	$\mu\text{m/cm}$	Width dependence of e_{critb} .
212	$lc0=1$		Substrate current coefficient.
213	$llc0=0$	μm	Length dependence of $lc0$.
214	$wlc0=0$	μm	Width dependence of $lc0$.
215	$lc1=1$		Substrate current coefficient.
216	$llc1=0$	μm	Length dependence of $lc1$.
217	$wlc1=0$	μm	Width dependence of $lc1$.
218	$lc2=1$		Substrate current coefficient.
219	$llc2=0$	μm	Length dependence of $lc2$.
220	$wlc2=0$	μm	Width dependence of $lc2$.
221	$lc3=1$		Substrate current coefficient.
222	$llc3=0$	μm	Length dependence of $lc3$.
223	$wlc3=0$	μm	Width dependence of $lc3$.
224	$lc4=1$		Substrate current coefficient.
225	$llc4=0$	μm	Length dependence of $lc4$.
226	$wlc4=0$	μm	Width dependence of $lc4$.

Virtuoso Simulator Components and Device Models Reference

BSIM1 Level-4 Model (bsim1)

227	$lc5=1$	Substrate current coefficient.
228	$llc5=0$ μm	Length dependence of $lc5$.
229	$wlc5=0$ μm	Width dependence of $lc5$.
230	$lc6=1$	Substrate current coefficient.
231	$llc6=0$ μm	Length dependence of $lc6$.
232	$wlc6=0$ μm	Width dependence of $lc6$.
233	$lc7=1$	Substrate current coefficient.
234	$llc7=0$ μm	Length dependence of $lc7$.
235	$wlc7=0$ μm	Width dependence of $lc7$.

I_{max} and I_{melt} :

The i_{max} parameter aids convergence and prevents numerical overflow. The junction characteristics of the device are accurately modeled for current up to i_{max} . If i_{max} is exceeded during iterations, the linear model is substituted until the current drops below i_{max} or until convergence is achieved. If convergence is achieved with the current exceeding i_{max} , the results are inaccurate, and Spectre prints a warning.

A separate model parameter, i_{melt} , is used as a limit warning for the junction current. This parameter can be set to the maximum current rating of the device. When any component of the junction current exceeds i_{melt} , note that base and collector currents are composed of many exponential terms, Spectre issues a warning and the results become inaccurate. The junction current is linearized above the value of i_{melt} to prevent arithmetic exception, with the exponential term replaced by a linear equation at i_{melt} .

Both of these parameters have current density counterparts, j_{max} and j_{melt} , that you can specify if you want the absolute current values to depend on the device area.

Auto Model Selection:

Many models need to be characterized for different geometries in order to obtain accurate results for model development. The model selector program automatically searches for a model with the length and width range specified in the instance statement and uses this model in the simulations.

Virtuoso Simulator Components and Device Models Reference

BSIM1 Level-4 Model (bsim1)

For the auto model selector program to find a specific model, the models to be searched should be grouped together within braces. Such a group is called a model group. An opening brace is required at the end of the line defining each model group. Every model in the group is given a name followed by a colon and the list of parameters. Also, the four geometric parameters `lmax`, `lmin`, `wmax`, and `wmin` should be given. The selection criteria to choose a model is as follows:

$$l_{min} \leq inst_length < l_{max} \quad \text{and} \quad w_{min} \leq inst_width < w_{max}$$

Example:

```
model ModelName ModelType {  
    1: <model parameters> lmin=2 lmax=4 wmin=1 wmax=2  
    2: <model parameters> lmin=1 lmax=2 wmin=2 wmax=4  
    3: <model parameters> lmin=2 lmax=4 wmin=4 wmax=6  
}
```

Then for a given instance

```
M1 1 2 3 4 ModelName w=3 l=1.5
```

the program would search all the models in the model group with the name `ModelName` and then pick the first model whose geometric range satisfies the selection criteria. In the preceding example, the auto model selector program would choose `ModelName.2`.

You must specify both length (`l`) and width (`w`) on the device instance line to enable automatic model selection.

Output Parameters

1	<code>w_{eff}</code> (m)	Effective channel width.
2	<code>l_{eff}</code> (m)	Effective channel length.
3	<code>r_{seff}</code> (Ω)	Effective source resistance.
4	<code>r_{deff}</code> (Ω)	Effective drain resistance.
5	<code>a_{seff}</code> (m ²)	Effective area of source diffusion.

Virtuoso Simulator Components and Device Models Reference

BSIM1 Level-4 Model (bsim1)

6	<code>adeff</code> (m ²)	Effective area of drain diffusion.
7	<code>pseff</code> (m)	Effective perimeter of source diffusion.
8	<code>pdeff</code> (m)	Effective perimeter of source diffusion.
9	<code>isseff</code> (A)	Effective source-bulk junction reverse saturation current.
10	<code>isdeff</code> (A)	Effective drain-bulk junction reverse saturation current.
11	<code>cbseff</code> (F)	Effective zero-bias source-bulk junction capacitance.
12	<code>cbdeff</code> (F)	Effective zero-bias drain-bulk junction capacitance.
13	<code>vt0</code> (V)	Effective zero-bias threshold voltage.
14	<code>vfb</code> (V)	Effective flat-band voltage.
15	<code>phi</code> (V)	Effective surface potential.
16	<code>k1</code> (\sqrt{V})	Effective body-effect coefficient.
17	<code>k2</code>	Effective charge-sharing parameter.
18	<code>eta</code>	Effective DIBL coefficient.

Operating-Point Parameters

1	<code>type=n</code>	Transistor type. Possible values are <code>n</code> or <code>p</code> .
2	<code>region=triode</code>	Estimated operating region. Spectre outputs number (0-4) in a rawfile. Possible values are <code>off</code> , <code>triode</code> , <code>sat</code> , <code>subth</code> , or <code>breakdown</code> .
3	<code>degradation=no</code>	Hot-electron degradation flag. Possible values are <code>no</code> or <code>yes</code> .
4	<code>reversed</code>	Reverse mode indicator. Possible values are <code>no</code> or <code>yes</code> .
5	<code>ids</code> (A)	Resistive drain-to-source current.

Virtuoso Simulator Components and Device Models Reference

BSIM1 Level-4 Model (bsim1)

6	v_{gs} (V)	Gate-source voltage.
7	v_{ds} (V)	Drain-source voltage.
8	v_{bs} (V)	Bulk-source voltage.
9	v_{th} (V)	Threshold voltage.
10	v_{dsat} (V)	Drain-source saturation voltage.
11	β_{eff} (A/V ²)	Effective beta.
12	g_m (S)	Common-source transconductance.
13	g_{ds} (S)	Common-source output conductance.
14	g_{mbs} (S)	Body-transconductance.
15	c_{bd} (F)	Drain-bulk junction capacitance.
16	c_{bs} (F)	Source-bulk junction capacitance.
17	c_{gs} (F)	Gate-source capacitance.
18	c_{gd} (F)	Gate-drain capacitance.
19	c_{gb} (F)	Gate-bulk capacitance.
20	r_{on} (Ω)	ON-resistance.
21	i_d (A)	Resistive drain current.
22	i_{bulk} (A)	Resistive bulk current.
23	pwr (W)	Power at op point.
24	$g_{moverid}$ (1/V)	Gm/Ids.
25	i_{sub} (A)	Substrate current.
26	$stress$	Hot-electron stress.
27	age (s)	Device age.

Virtuoso Simulator Components and Device Models Reference

BSIM1 Level-4 Model (bsim1)

28 he_vdsat (V) hot electron vdsat.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

ad	I-4	jmax	M-149	nb	M-74	ute	M-102
ad	M-157	jmelt	M-135	nd	M-78	uto	M-101
adefeff	O-6	js	M-131	noisemod	M-164	vbox	M-151
af	M-166	k1	M-10	nrd	I-7	vbs	OP-8
age	OP-27	k1	O-16	nrd	M-160	vbsn	M-185
ai0	M-83	k2	M-14	nrs	I-8	vdd	M-153
alarm	M-147	k2	O-17	nrs	M-161	vds	OP-7
as	I-3	kf	M-165	pai0	M-86	vdsat	OP-10
as	M-156	l	I-2	pb	M-141	vdsng	M-188
aseff	O-5	l	M-155	pbi0	M-90	vdsni	M-186
betaeff	OP-11	lai0	M-84	pbsw	M-145	version	M-100
bi0	M-87	lbi0	M-88	pd	I-6	vfb	O-14
bvj	M-150	lc0	M-212	pd	M-159	vfb0	M-2
capmod	M-115	lc1	M-215	pdeff	O-8	vgs	OP-6
cbd	M-138	lc2	M-218	peta	M-21	vgsng	M-189

Virtuoso Simulator Components and Device Models Reference

BSIM1 Level-4 Model (bsim1)

cbd	OP-15	lc3	M-221	phi	O-15	vgsni	M-187
cbdeff	O-12	lc4	M-224	phi0	M-6	vpb	M-193
cbs	M-137	lc5	M-227	pk1	M-13	vpg	M-192
cbs	OP-16	lc6	M-230	pk2	M-17	vth	OP-9
cbseff	O-11	lc7	M-233	pmus	M-41	vto	O-13
cgb	OP-19	ld	I-9	pmuz	M-33	w	I-1
cgbo	M-113	ldd	M-162	pn0	M-73	w	M-154
cgd	OP-18	ldif	M-127	pnb	M-77	wai0	M-85
cgdo	M-112	lds	M-163	pnd	M-81	wbi0	M-89
cgs	OP-17	lecrit0	M-204	pphi	M-9	wecrit0	M-205
cgso	M-111	lecritb	M-210	ps	I-5	wecritb	M-211
cj	M-139	lecritg	M-207	ps	M-158	wecritg	M-208
cjsw	M-143	leff	O-2	pseff	O-7	weff	O-1
crigm	M-181	leta	M-19	pu0	M-53	weta	M-20
criids	M-182	lgcd	M-129	pu1	M-61	wk1	M-12
criuo	M-180	lgcs	M-128	pvfb	M-5	wk2	M-16
crivth	M-179	lk1	M-11	pwr	OP-23	wlc0	M-214
degradation	I-14	lk2	M-15	px2e	M-25	wlc1	M-217
degradation	M-174	llc0	M-213	px2ms	M-45	wlc2	M-220
degradation	OP-3	llc1	M-216	px2mz	M-37	wlc3	M-223

Virtuoso Simulator Components and Device Models Reference

BSIM1 Level-4 Model (bsim1)

degramod	M-173	llc2	M-219	px2u0	M-57	wlc4	M-226
dl0	M-91	llc3	M-222	px2u1	M-65	wlc5	M-229
dskip	M-136	llc4	M-225	px3e	M-29	wlc6	M-232
duoc	M-177	llc5	M-228	px3ms	M-49	wlc7	M-235
duoe	M-178	llc6	M-231	px3u1	M-69	wmax	M-169
dvthc	M-175	llc7	M-234	rd	M-119	wmin	M-170
dvthe	M-176	lmax	M-171	rdc	M-122	wmus	M-40
dw0	M-92	lmin	M-172	rdd	M-124	wmuz	M-32
ecrit0	M-203	lmus	M-39	rdeff	O-4	wn0	M-72
ecritb	M-209	lmuz	M-31	region	I-12	wnb	M-76
ecritg	M-206	ln0	M-71	region	OP-2	wnd	M-80
ef	M-167	lnb	M-75	reversed	OP-4	wnoi	M-168
eg	M-105	lnd	M-79	ron	OP-20	wnom	M-183
esat	M-190	lnom	M-184	rs	M-118	wphi	M-8
esatg	M-191	lphi	M-7	rsc	M-121	wref	M-94
eta	O-18	lref	M-93	rseff	O-3	wu0	M-52
eta0	M-18	ls	I-10	rsh	M-120	wu1	M-60
fc	M-142	lu0	M-51	rss	M-123	wvfb	M-4
fcsw	M-146	lu1	M-59	sc	M-130	wx2e	M-24
gap1	M-106	lvfb	M-3	strc	M-197	wx2ms	M-44
gap2	M-107	lx2e	M-23	stre	M-198	wx2mz	M-36

Virtuoso Simulator Components and Device Models Reference

BSIM1 Level-4 Model (bsim1)

gds	OP-13	lx2ms	M-43	stress	OP-26	wx2u0	M-56
gm	OP-12	lx2mz	M-35	subc1	M-194	wx2u1	M-64
gmbs	OP-14	lx2u0	M-55	subc2	M-195	wx3e	M-28
gmoverid	OP-24	lx2u1	M-63	sube	M-196	wx3ms	M-48
h0	M-199	lx3e	M-27	subthmod	M-82	wx3u1	M-68
hdif	M-126	lx3ms	M-47	temp	M-97	x2e	M-22
he_vdsat	OP-28	lx3u1	M-67	tempmod	M-99	x2ms	M-42
hgd	M-200	m	I-11	tlev	M-103	x2mz	M-34
ibulk	OP-22	m0	M-201	tlevc	M-104	x2u0	M-54
id	OP-21	meto	M-114	tox	M-152	x2u1	M-62
ids	OP-5	mgd	M-202	trd	M-109	x3e	M-26
imax	M-148	minr	M-125	trise	I-13	x3ms	M-46
imelt	M-134	mj	M-140	trise	M-98	x3u1	M-66
is	M-132	mjsw	M-144	trs	M-108	x1	M-96
isdeff	O-10	mus	M-38	type	M-1	xpart	M-116
isnoisy	I-15	muz	M-30	type	OP-1	xqc	M-117
isseff	O-9	n	M-133	u00	M-50	xti	M-110
isub	OP-25	n0	M-70	u10	M-58	xw	M-95

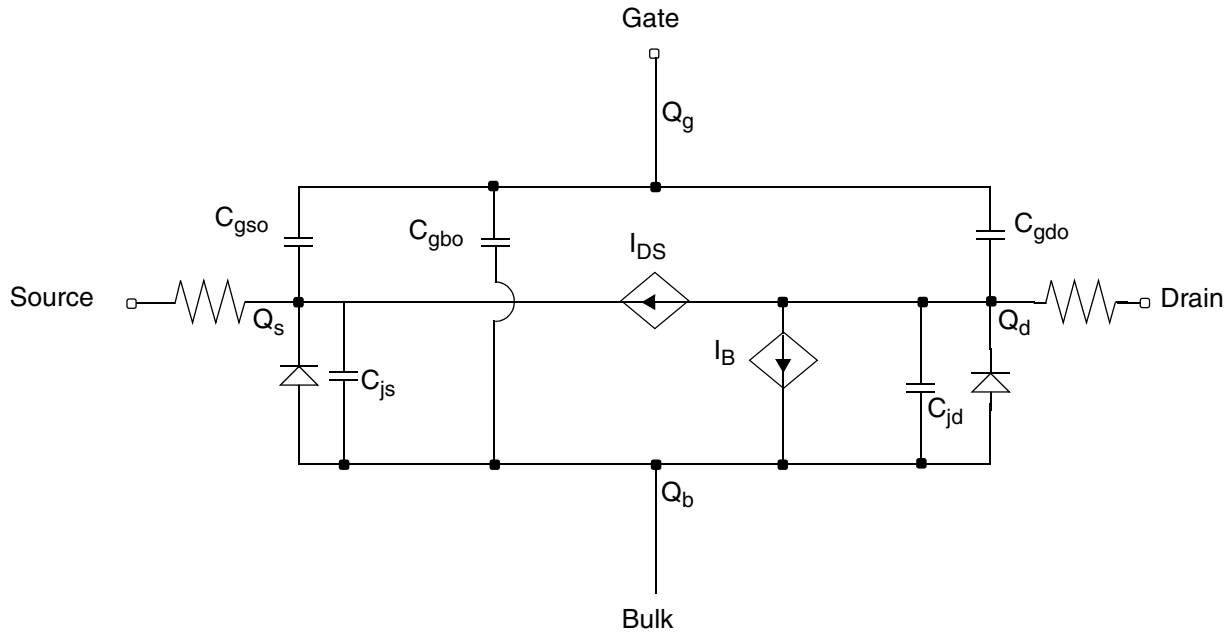
BSIM2 Level-5 Model (bsim2)

The BSIM2 model is based on the industry standard efforts of the Compact Modeling Counsel (CMC) and the BSIM modeling group at the University of California, Berkeley. This chapter contains the following information about the BSIM2 model:

- [Parameter Calculation](#) on page 1094
- [Drain Current Model](#) on page 1094
- [Scaling Effects](#) on page 1098
- [Component Statements](#) on page 1098

Virtuoso Simulator Components and Device Models Reference

BSIM2 Level-5 Model (bsim2)



BSIM2 stands for Berkeley Short-Channel IGFET Model version-2. The BSIM2 is a semi empirical model suitable for devices with channel length from long channel to about 0.2 μm . Because it also models the output resistance, BSIM2 is suitable for both digital and analog applications. BSIM2 extracts all model parameters directly from physical devices. You can obtain an automated parameter extraction program, based on the IBM PC and HP4145 system, from the ILP office, Department of EECS, University of California, Berkeley. The following table shows the correspondence between the input parameter names and the equation symbols for the BSIM2 model.

Parameter	Symbol	Parameter	Symbol	Parameter	Symbol
vfb	$V_{FB,0}$	lvfb	$V_{FB,L}$	wvfb	$V_{FB,W}$
phi	ϕ_0	lphi	ϕ_L	wphi	ϕ_W
k1	K_1	lk1	$K_{1,L}$	wk1	$K_{1,W}$
k2	K_2	lk2	$K_{2,L}$	wk2	$K_{2,W}$
eta0	$\eta_{0,0}$	leta0	$\eta_{0,L}$	weta0	$\eta_{0,W}$
mu0	$\mu_{0,0}$	d1	dI	dw	dW
ua0	$U_{a0,0}$	lua0	$U_{a0,L}$	wua0	$U_{a0,W}$

Virtuoso Simulator Components and Device Models Reference
BSIM2 Level-5 Model (bsim2)

Parameter	Symbol	Parameter	Symbol	Parameter	Symbol
uab	$U_{aB,0}$	luab	$U_{aB,L}$	wuab	$U_{aB,W}$
ub0	$U_{b0,0}$	lub0	$U_{b0,L}$	wub0	$U_{b0,W}$
ubb	$U_{bB,0}$	lubb	$U_{bB,L}$	wubb	$U_{bB,W}$
u10	$U_{10,0}$	lu10	$U_{10,L}$	wu10	$U_{10,W}$
u1b	$U_{1B,0}$	lu1b	$U_{1B,L}$	wu1b	$U_{1B,W}$
u1d	$U_{1D,0}$	lu1d	$U_{1D,L}$	wu1d	$U_{1D,W}$
mu0b	$\mu_{0B,0}$	lmu0b	$\mu_{0B,L}$	mu0b	$\mu_{0B,W}$
mus0	$\mu_{s0,0}$	lmus0	$\mu_{s0,L}$	wmus0	$\mu_{s0,W}$
musb	$\mu_{sB,0}$	lmusb	$\mu_{sB,L}$	wmusb	$\mu_{sB,W}$
mu20	$\mu_{20,0}$	lmu20	$\mu_{20,L}$	wmu20	$\mu_{20,W}$
mu2b	$\mu_{2B,0}$	lmu2b	$\mu_{2B,L}$	wmu2b	$\mu_{2B,W}$
mu2g	$\mu_{2G,0}$	lmu2g	$\mu_{2G,L}$	wmu2g	$\mu_{2G,W}$
mu30	$\mu_{30,0}$	lmu30	$\mu_{30,L}$	wmu30	$\mu_{30,W}$
mu3b	$\mu_{3B,0}$	lmu3b	$\mu_{3B,L}$	wmu3b	$\mu_{3B,W}$
mu3g	$\mu_{3G,0}$	lmu3g	$\mu_{3G,L}$	wmu3g	$\mu_{3G,W}$
mu40	$\mu_{40,0}$	lmu40	$\mu_{40,L}$	wmu40	$\mu_{40,W}$
mu4b	$\mu_{4B,0}$	lmu4b	$\mu_{4B,L}$	wmu4b	$\mu_{4B,W}$
mu4g	$\mu_{4G,0}$	lmu4g	$\mu_{4G,L}$	wmu4g	$\mu_{4G,W}$
etab	$\eta_{B,0}$	letab	$\eta_{B,L}$	wetab	$\eta_{B,W}$
n0	$N_{0,0}$	ln0	$N_{0,L}$	wn0	$N_{0,W}$
nb	$N_{B,0}$	lnb	$N_{B,L}$	wnb	$N_{B,W}$
nd	$N_{D,0}$	lnd	$N_{D,L}$	wnd	$N_{D,W}$
vof0	$V_{offset0,0}$	lvof0	$V_{offset0,L}$	wvof0	$V_{offset0,W}$
vofb	$V_{offsetB,0}$	lvofb	$V_{offsetB,L}$	wvofb	$V_{offsetB,W}$
vofd	$V_{offsetD,0}$	lvofd	$V_{offsetD,L}$	wvofd	$V_{offsetD,W}$
ai0	$A_{i0,0}$	lai0	$A_{i0,L}$	wai0	$A_{i0,W}$
aib	$A_{iB,0}$	laib	$A_{iB,L}$	waib	$A_{iB,W}$

Virtuoso Simulator Components and Device Models Reference
BSIM2 Level-5 Model (bsim2)

Parameter	Symbol	Parameter	Symbol	Parameter	Symbol
bi0	$B_{i0,0}$	lbi0	$B_{i0,L}$	wbi0	$B_{i0,W}$
bib	$B_{iB,0}$	lbib	$B_{iB,L}$	wbib	$B_{iB,W}$
vdd	V_{DD}	vgg	V_{GG}	vbb	V_{BB}
vghigh	$V_{G,high}$	vglow	$V_{G,low}$		

Parameter Calculation

Except for μ_{i0} , d_l , and d_w , all device parameters are calculated from the following equation:

$$P_i = P_{i,0} + \frac{P_{i,L}}{L_{eff}} + \frac{P_{i,W}}{W_{eff}}$$

where P_i is any device parameter, $P_{i,0}$ is the parameter value for very long channel length and width, and $P_{i,L}$ and $P_{i,W}$ are the channel length and width dependencies of the parameter, respectively. The following is an example showing how the flat-band voltage for a device with $l = 2\mu\text{m}$ and $w = 5\mu\text{m}$ is calculated from the model parameters.

$$V_{FB} = V_{FB,0} + \frac{V_{FB,L}}{2.0 - dl} + \frac{V_{FB,W}}{5.0 - dw}$$

Drain Current Model

Channel Width and Length

$$W_{scaled} = w*scale + xw*scalem$$

$$W_{eff} = \begin{cases} w*scale + xw*scalem - 2wd*scalem & \text{(Level 1-3)} \\ w*scale + xw*scalem - dw*scalem & \text{(BSIM 1-2)} \end{cases}$$

$$L_{eff} = \begin{cases} l*scale + xl*scalem - 2ld*scalem & \text{(Level 1-3)} \\ l*scale + xl*scalem - dl*scalem & \text{(BSIM 1-2)} \end{cases}$$

Threshold Voltage

$$V_{TH} = V_{FB} + \phi + K_1 \sqrt{\phi - V_{BS}} K_2 (\phi - V_{BS}) - \eta V_{DS}$$

where

$$\eta = \eta_0 + \eta_B V_{BS}$$

Drain Saturation Voltage

$$V_{DSAT} = \frac{V_{GST}}{a\sqrt{K}}$$

where

$$V_{GST} = V_{GS} - V_{TH}$$

$$a = 1 + \frac{gK_1}{2\sqrt{\phi - V_{BS}}}$$

$$g = 1 - \frac{1}{1.744 + 0.8364(\phi - V_{BS})}$$

$$K = \frac{1 + V_c + \sqrt{1 + 2V_c}}{2}$$

$$V_c = \frac{U_{1S} V_{GST}}{a[1 + U_a V_{GST} + U_b V_{GST}^2]}$$

$$U_{1S} = \begin{cases} U_1 \left[1 - \frac{U_{1D} (V_{DS} - V_{DSAT})^2}{V_{DSAT}^2} \right] & \text{if } V_{DS} \leq V_{DSAT} \\ U_1 & \text{otherwise} \end{cases}$$

$$U_1 = U_{10} + U_{1B}V_{BS}$$

Drain Current for the Subthreshold Region

Note: These equations apply when $V_{GST} \leq V_{glow}$.

$$I_{subth} = \beta V_t^2 e^{V_{offset} + V_{GST}/nV_t} \left[1 - e^{-V_{DS}/V_t} \right]$$

where

$$n = N_0 + \frac{N_B}{\sqrt{\phi - V_{BS}}} + N_D V_{DS}$$

$$V_{offset} = V_{offset0} + V_{offsetB}V_{BS} + V_{offsetD}V_{DS}$$

Drain Current for the Triode Region

Note: These equations apply when $V_{GST} \geq 0$ and $V_{DS} \leq V_{SAT}$.

$$I_{DS} = \frac{\beta_0 \left(V_{GST} - \frac{a}{2} V_{DS} \right) V_{DS}}{\left[1 + U_a V_{GST} + U_b V_{GST}^2 + U_{1S} V_{DS} \right]}$$

where

$$U_a = U_{a0} + U_{a0B}V_{BS}$$

$$U_b = U_{b0} + U_{b0B}V_{BS}$$

$$\beta_0 = \beta_{0lin} + \beta_1 \tanh \left[\frac{\beta_2 V_{DS}}{V_{DSAT}} \right] + \beta_3 V_{DS} - \beta_4 V_{DS}^2$$

$$\beta_{0lin} = \frac{C_{ox} W_{eff}}{L_{eff}} (\mu_0 + \mu_{0B} V_{BS})$$

$$\beta_1 = \beta_s - (\beta_{0lin} + \beta_3 V_{DD} - \beta_4 V_{DD}^2)$$

$$\beta_s = \frac{C_{ox} W_{eff}}{L_{eff}} (\mu_{s0} + \mu_{sB} V_{BS})$$

$$\beta_2 = \mu_{20} + \mu_{2B} V_{BS} + \mu_{2G} V_{GS}$$

$$\beta_3 = \frac{C_{ox} W_{eff}}{L_{eff}} (\mu_{30} + \mu_{3B} V_{BS} + \mu_{3G} V_{GS})$$

$$\beta_4 = \frac{C_{ox} W_{eff}}{L_{eff}} (\mu_{40} + \mu_{4b} V_{BS} + \mu_{4G} V_{GS})$$

Drain Current for the Saturation Region

Note: These equations apply when $V_{GST} \geq V_{ghigh}$ and $V_{DS} \geq V_{DSAT}$.

$$I_{DS} = \frac{\beta V_{GST}^2}{2aK} \left(1 + A_i e^{\frac{-B_i}{V_{DS} - V_{DSAT}}} \right)$$

where

$$\beta = \frac{\beta_0}{1 + U_a V_{GST} + U_b V_{GST}^2}$$

$$A_i = A_{i0} + A_{iB} V_{BS}$$

$$B_i = B_{i0} + B_{iB} V_{BS}$$

Drain Current for the Transition Region

Note: These equations apply when $V_{glow} \leq V_{GST} \leq V_{ghigh}$.

Virtuoso Simulator Components and Device Models Reference

BSIM2 Level-5 Model (bsim2)

Drain current equations are the same as those for the strong-inversion region, except that V'_{GST} replaces all V_{GST} terms. V'_{GST} is calculated from a cubic spline function to match the drain current and its first derivative at the upper and lower bounds (V_{ghigh} and V_{glow}).

$$V'_{GST} = C_0 + C_1 V_{GST} + C_2 V_{GST}^2 + C_3 V_{GST}^3$$

All the coefficients, C_i s, are automatically calculated during

$$V_{glow} = V_{TH} + V_{offset} + nV_t \ln\left(\frac{C_{ox}}{10C_d}\right)$$

$$V_{ghigh} = V_{TH} + nV_t \ln\left(\frac{10C_{ox}}{C_d}\right)$$

$$C_d = \sqrt{\frac{q\epsilon_{si}N_{sub}}{2\phi}}$$

Scaling Effects

For scaling effects, see [Scaling Factors \(scale and scalem\)](#) on page 242.

Component Statements

This device is supported within altergroups.

Sample Instance Statement:

```
m2 (0 2 1 1) pchmod l=5u w=10u as=40u ad=40u pd=28u ps=28u m=1
```

Sample Model Statement:

```
model pchmod bsim2 type=p vfb0=-0.5 lvfb=0.5 wvfb=0.3 phi0=0.8 eta0=0.056 k1=0.5  
eg=0.99 gap1=5.5e-04 trs=1e-3 trd=1e-3 xpart=0.5 rs=10 rd=10
```

Instance Definition

```
Name d g s b ModelName parameter=value ...
```

Virtuoso Simulator Components and Device Models Reference

BSIM2 Level-5 Model (bsim2)

Instance Parameters

1	w (m)	Channel width.
2	l (m)	Channel length.
3	as (m ²)	Area of source diffusion.
4	ad (m ²)	Area of drain diffusion.
5	ps (m)	Perimeter of source diffusion.
6	pd (m)	Perimeter of drain diffusion.
7	nrd (m/m)	Number of squares of drain diffusion.
8	nrs (m/m)	Number of squares of source diffusion.
9	ld (m)	Drain diffusion length.
10	ls (m)	Source diffusion length.
11	m=1	Multiplicity factor (number of MOSFETs in parallel).
12	region=triode	Estimated operating region. Spectre outputs number (0-4) in a rawfile. Possible values are <code>off</code> , <code>triode</code> , <code>sat</code> , <code>subth</code> , or <code>breakdown</code> .
13	trise (C)	Temperature rise from ambient.
14	degradation=no	Hot-electron degradation flag. Possible values are <code>no</code> or <code>yes</code> .
15	isnoisy=yes	Should resistor generate noise. Possible values are <code>no</code> or <code>yes</code> .

Model Definition

```
model modelName bsim2 parameter=value ...
```

Virtuoso Simulator Components and Device Models Reference

BSIM2 Level-5 Model (bsim2)

Model Parameters

Device type parameters

1 `type=n` Transistor type.
Possible values are n or p.

Threshold voltage parameters

2 `vfb0=-0.8 V` Flat-band voltage.

3 `lvfb=0 V μm` Length dependence of `vfb`.

4 `wvfb=0 V μm` Width dependence of `vfb`.

5 `pvfb=0 V μm` Width-length dependence of `vfb`.

6 `phi0=0.75 V` Surface potential.

7 `lphi=0 V μm` Length dependence of `phi`.

8 `wphi=0 V μm` Width dependence of `phi`.

9 `pphi=0 V μm` Width-length dependence of `phi`.

10 `k1=0.7 $\sqrt{\text{V}}$` Body-effect coefficient.

11 `lk1=0 $\sqrt{\text{V}}$ μm` Length dependence of `k1`.

12 `wk1=0 $\sqrt{\text{V}}$ μm` Width dependence of `k1`.

13 `pk1=0 $\sqrt{\text{V}}$ μm` Width-length dependence of `k1`.

14 `k2=0` Charge-sharing parameter.

15 `lk2=0 μm` Length dependence of `k2`.

16 `wk2=0 μm` Width dependence of `k2`.

17 `pk2=0 μm` Width-length dependence of `k2`.

18 `eta0=0` Drain-induced barrier-lowering coefficient.

Virtuoso Simulator Components and Device Models Reference
BSIM2 Level-5 Model (bsim2)

- 19 $l\eta a0=0$ μm Length dependence of $\eta a0$.
- 20 $w\eta a0=0$ μm Width dependence of $\eta a0$.
- 21 $p\eta a0=0$ μm Width-length dependence of $\eta a0$.
- 22 $\eta ab=0$ $1/V$ Body-bias dependence of $\eta a0$.
- 23 $l\eta ab=0$ $\mu\text{m}/V$ Length dependence of ηab .
- 24 $w\eta ab=0$ $\mu\text{m}/V$ Width dependence of ηab .
- 25 $p\eta ab=0$ $\mu\text{m}/V$ Width-length dependence of ηab .

Mobility parameters

- 26 $\mu 0=400$ cm^2/V s Low-field mobility.
- 27 $l\mu 0=0$ cm^2/V s Length dependence of $\mu 0$.
- 28 $w\mu 0=0$ cm^2/V s Width dependence of $\mu 0$.
- 29 $p\mu 0=0$ cm^2/V s Width-length dependence of $\mu 0$.
- 30 $\mu 0b=0$ cm^2/V^2 s Body-bias dependence of μz .
- 31 $l\mu 0b=0$ cm^2 $\mu\text{m}/V^2$ s
Length dependence of $x2mz$.
- 32 $w\mu 0b=0$ cm^2 $\mu\text{m}/V^2$ s
Width dependence of $x2mz$.
- 33 $p\mu 0b=0$ cm^2 $\mu\text{m}/V^2$ s
Width-length dependence of $x2mz$.
- 34 $\mu s0=450$ cm^2/V s Mobility in the saturation region.
- 35 $l\mu s0=0$ cm^2 $\mu\text{m}/V$ s
Length dependence of $\mu s0$.
- 36 $w\mu s0=0$ cm^2 $\mu\text{m}/V$ s
Width dependence of $\mu s0$.

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BSIM2 Level-5 Model (bsim2)

37	$p_{\text{mus0}}=0$ $\text{cm}^2 \mu\text{m}/\text{V}$ s	Width-length dependence of mus0 .
38	$\text{musb}=0$ cm^2/V^2 s	Body-bias dependence of mus0 .
39	$l_{\text{musb}}=0$ $\text{cm}^2 \mu\text{m}/\text{V}^2$ s	Length dependence of mus0 .
40	$w_{\text{musb}}=0$ $\text{cm}^2 \mu\text{m}/\text{V}^2$ s	Length dependence of mus0 .
41	$p_{\text{musb}}=0$ $\text{cm}^2 \mu\text{m}/\text{V}^2$ s	Length dependence of mus0 .
42	$\text{mu20}=1$	Empirical channel length modulation parameter.
43	$l_{\text{mu20}}=0$ μm	Length dependence of mu20 .
44	$w_{\text{mu20}}=0$ μm	Width dependence of mu20 .
45	$p_{\text{mu20}}=0$ μm	Width-length dependence of mu20 .
46	$\text{mu2b}=0$ $1/\text{V}$	Body-bias dependence of mu20 .
47	$l_{\text{mu2b}}=0$ $\mu\text{m}/\text{V}$	Length dependence of mu2b .
48	$w_{\text{mu2b}}=0$ $\mu\text{m}/\text{V}$	Width dependence of mu2b .
49	$p_{\text{mu2b}}=0$ $\mu\text{m}/\text{V}$	Width-length dependence of mu2b .
50	$\text{mu2g}=0$ $1/\text{V}$	Gate-bias dependence of mu20 .
51	$l_{\text{mu2g}}=0$ $\mu\text{m}/\text{V}$	Length dependence of mu2g .
52	$w_{\text{mu2g}}=0$ $\mu\text{m}/\text{V}$	Width dependence of mu2g .
53	$p_{\text{mu2g}}=0$ $\mu\text{m}/\text{V}$	Width-length dependence of mu2g .
54	$\text{mu30}=5$ cm^2/V^2 s	Empirical output resistance parameter.
55	$l_{\text{mu30}}=0$ $\text{cm}^2 \mu\text{m}/\text{V}^2$ s	Length dependence of mu30 .

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BSIM2 Level-5 Model (bsim2)

- 56 $w\mu_{30}=0$ $\text{cm}^2 \mu\text{m}/\text{V}^2$ s Width dependence of μ_{30} .
- 57 $p\mu_{30}=0$ $\text{cm}^2 \mu\text{m}/\text{V}^2$ s Width-length dependence of μ_{30} .
- 58 $\mu_{3b}=0$ cm^2/V^3 s Body-bias dependence of μ_{30} .
- 59 $l\mu_{3b}=0$ $\text{cm}^2 \mu\text{m}/\text{V}^3$ s Length dependence of μ_{3b} .
- 60 $w\mu_{3b}=0$ $\text{cm}^2 \mu\text{m}/\text{V}^3$ s Width dependence of μ_{3b} .
- 61 $p\mu_{3b}=0$ $\text{cm}^2 \mu\text{m}/\text{V}^3$ s Width-length dependence of μ_{3b} .
- 62 $\mu_{3g}=0$ cm^2/V^3 s Gate-bias dependence of μ_{30} .
- 63 $l\mu_{3g}=0$ $\text{cm}^2 \mu\text{m}/\text{V}^3$ s Length dependence of μ_{3g} .
- 64 $w\mu_{3g}=0$ $\text{cm}^2 \mu\text{m}/\text{V}^3$ s Width dependence of μ_{3g} .
- 65 $p\mu_{3g}=0$ $\text{cm}^2 \mu\text{m}/\text{V}^3$ s Width-length dependence of μ_{3g} .
- 66 $\mu_{40}=0$ cm^2/V^3 s Empirical output resistance parameter.
- 67 $l\mu_{40}=0$ $\text{cm}^2 \mu\text{m}/\text{V}^3$ s Length dependence of μ_{40} .
- 68 $w\mu_{40}=0$ $\text{cm}^2 \mu\text{m}/\text{V}^3$ s Width dependence of μ_{40} .
- 69 $p\mu_{40}=0$ $\text{cm}^2 \mu\text{m}/\text{V}^3$ s Width-length dependence of μ_{40} .
- 70 $\mu_{4b}=0$ cm^2/V^3 s Empirical output resistance parameter.
- 71 $l\mu_{4b}=0$ $\text{cm}^2 \mu\text{m}/\text{V}^3$ s Length dependence of μ_{4b} .

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BSIM2 Level-5 Model (bsim2)

- 72 $w_{\mu 4b=0}$ $\text{cm}^2 \mu\text{m}/\text{V}^3 \text{ s}$ Width dependence of μ_{4b} .
- 73 $p_{\mu 4b=0}$ $\text{cm}^2 \mu\text{m}/\text{V}^3 \text{ s}$ Width-length dependence of μ_{4b} .
- 74 $\mu_{4g=0}$ $\text{cm}^2/\text{V}^3 \text{ s}$ Gate-bias dependence of μ_{4g} .
- 75 $l_{\mu 4g=0}$ $\text{cm}^2 \mu\text{m}/\text{V}^3 \text{ s}$ Length dependence of μ_{4g} .
- 76 $w_{\mu 4g=0}$ $\text{cm}^2 \mu\text{m}/\text{V}^3 \text{ s}$ Width dependence of μ_{4g} .
- 77 $p_{\mu 4g=0}$ $\text{cm}^2 \mu\text{m}/\text{V}^3 \text{ s}$ Width-length dependence of μ_{4g} .

Mobility modulation parameters

- 78 $u_{a0=0}$ $1/\text{V}$ Gate voltage dependence of mobility.
- 79 $l_{u_{a0=0}}$ $\mu\text{m}/\text{V}$ Length dependence of u_{a0} .
- 80 $w_{u_{a0=0}}$ $\mu\text{m}/\text{V}$ Width dependence of u_{a0} .
- 81 $p_{u_{a0=0}}$ $\mu\text{m}/\text{V}$ Width-length dependence of u_{a0} .
- 82 $u_{ab=0}$ $1/\text{V}^2$ Body-bias dependence of u_a .
- 83 $l_{u_{ab=0}}$ $\mu\text{m}/\text{V}^2$ Length dependence of u_{ab} .
- 84 $w_{u_{ab=0}}$ $\mu\text{m}/\text{V}^2$ Width dependence of u_{ab} .
- 85 $p_{u_{ab=0}}$ $\mu\text{m}/\text{V}^2$ Width-length dependence of u_{ab} .
- 86 $u_{b0=0}$ $1/\text{V}^2$ Second-order effect of gate voltage dependence of mobility.
- 87 $l_{u_{b0=0}}$ $\mu\text{m}/\text{V}^2$ Length dependence of u_{b0} .
- 88 $w_{u_{b0=0}}$ $\mu\text{m}/\text{V}^2$ Width dependence of u_{b0} .
- 89 $p_{u_{b0=0}}$ $\mu\text{m}/\text{V}^2$ Width-length dependence of u_{b0} .

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BSIM2 Level-5 Model (bsim2)

- 90 $u_{bb=0} \text{ } 1/V^3$ Body-bias dependence of u_b .
- 91 $l_{ubb=0} \text{ } \mu\text{m}/V^3$ Length dependence of u_{bb} .
- 92 $w_{ubb=0} \text{ } \mu\text{m}/V^3$ Width dependence of u_{bb} .
- 93 $p_{ubb=0} \text{ } \mu\text{m}/V^3$ Width-length dependence of u_{bb} .

Velocity saturation parameters

- 94 $u_{10=0} \text{ } 1/V$ Velocity saturation coefficient.
- 95 $l_{u10=0} \text{ } \mu\text{m}/V$ Length dependence of u_1 .
- 96 $w_{u10=0} \text{ } \mu\text{m}/V$ Width dependence of u_1 .
- 97 $p_{u10=0} \text{ } \mu\text{m}/V$ Width-length dependence of u_1 .
- 98 $u_{1b=0} \text{ } 1/V^2$ Body-bias dependence of u_1 .
- 99 $l_{u1b=0} \text{ } \mu\text{m}/V^2$ Length dependence of u_{1b} .
- 100 $w_{u1b=0} \text{ } \mu\text{m}/V^2$ Width dependence of u_{1b} .
- 101 $p_{u1b=0} \text{ } \mu\text{m}/V^2$ Width-length dependence of u_{1b} .
- 102 $u_{1d=0} \text{ } 1/V^2$ Drain-bias dependence of u_1 .
- 103 $l_{u1d=0} \text{ } \mu\text{m}/V^2$ Length dependence of u_{1d} .
- 104 $w_{u1d=0} \text{ } \mu\text{m}/V^2$ Width dependence of u_{1d} .
- 105 $p_{u1d=0} \text{ } \mu\text{m}/V^2$ Width-length dependence of u_{1d} .

Subthreshold parameters

- 106 $n_0=0$ Subthreshold swing parameter.
- 107 $l_{n0=0} \text{ } \mu\text{m}$ Length dependence of subthreshold swing parameter.
- 108 $w_{n0=0} \text{ } \mu\text{m}$ Width dependence of subthreshold swing parameter.

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BSIM2 Level-5 Model (bsim2)

109	$p_{n0}=0$	μm	Width-length dependence of subthreshold swing parameter.	
110	$n_{b=0}$	\sqrt{V}	Body-bias dependence of n_0 .	
111	$l_{nb=0}$	\sqrt{V}	μm	Length dependence of n_b .
112	$w_{nb=0}$	\sqrt{V}	μm	Width dependence of n_b .
113	$p_{nb=0}$	\sqrt{V}	μm	Width-length dependence of n_b .
114	$n_{d=0}$	$1/V$	Drain-bias dependence of n_0 .	
115	$l_{nd=0}$	$\mu\text{m}/V$	Length dependence of n_d .	
116	$w_{nd=0}$	$\mu\text{m}/V$	Width dependence of n_d .	
117	$p_{nd=0}$	$\mu\text{m}/V$	Width-length dependence of n_d .	
118	$v_{of0}=1$	V	Threshold voltage offset in the subthreshold region.	
119	$l_{vof0}=0$	V	μm	Length dependence of v_{of} .
120	$w_{vof0}=0$	V	μm	Width dependence of v_{of} .
121	$p_{vof0}=0$	V	μm	Width-length dependence of v_{of} .
122	$v_{ofb}=0$		Body-bias dependence of v_{of0} .	
123	$l_{vofb}=0$	μm	Length dependence of v_{ofb} .	
124	$w_{vofb}=0$	μm	Width dependence of v_{ofb} .	
125	$p_{vofb}=0$	μm	Width-length dependence of v_{ofb} .	
126	$v_{ofd}=0$		Drain-bias dependence of v_{of0} .	
127	$l_{vofd}=0$	μm	Length dependence of v_{ofd} .	
128	$w_{vofd}=0$	μm	Width dependence of v_{ofd} .	
129	$p_{vofd}=0$	μm	Width-length dependence of v_{ofd} .	
130	$subthmod=2$		Subthreshold model selector.	

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BSIM2 Level-5 Model (bsim2)

Impact ionization parameters

131	$ai0=0$	$1/V$	Hot-electron effect on R_{out} parameter.
132	$lai0=0$	$\mu m/V$	Length dependence of $ai0$.
133	$wai0=0$	$\mu m/V$	Width dependence of $ai0$.
134	$pai0=0$	$\mu m/V$	Width-length dependence of $ai0$.
135	$aib=0$	$1/V^2$	Body-bias dependence of $ai0$.
136	$laib=0$	$\mu m/V^2$	Length dependence of aib .
137	$waib=0$	$\mu m/V^2$	Width dependence of aib .
138	$paib=0$	$\mu m/V^2$	Width-length dependence of aib .
139	$bi0=0$	V	Hot-electron effect on R_{out} exponent.
140	$lbi0=0$	$V \mu m$	Length dependence of $bi0$.
141	$wbi0=0$	$V \mu m$	Width dependence of $bi0$.
142	$pbi0=0$	$V \mu m$	Width-length dependence of $bi0$.
143	$bib=0$		Body-bias dependence of $bi0$.
144	$lbib=0$	μm	Length dependence of bib .
145	$wbib=0$	μm	Width dependence of bib .
146	$pbib=0$	μm	Width-length dependence of bib .

Transition region bound parameters

147	$vghigh=0.2$	V	Upper bound of the transition region.
148	$lvghigh=0$	$V \mu m$	Length dependence of V_{ghigh} .
149	$wvghigh=0$	$V \mu m$	Width dependence of V_{ghigh} .
150	$pvghigh=0$	$V \mu m$	Width-length dependence of V_{ghigh} .

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BSIM2 Level-5 Model (bsim2)

151	$v_{glow} = -0.15$ V	Lower bound of the transition region.
152	$lv_{glow} = 0$ V μm	Length dependence of v_{glow} .
153	$wv_{glow} = 0$ V μm	Width dependence of v_{glow} .
154	$pv_{glow} = 0$ V μm	Width-length dependence of v_{glow} .

Length and width modulation parameters

155	$dl0 = 0$ μm	Lateral diffusion.
156	$dw0 = 0$ μm	Field oxide encroachment.
157	$l_{ref} = \infty$ m	Reference channel length.
158	$w_{ref} = \infty$ m	Reference channel width.
159	$xw = 0$ m	Width variation due to masking and etching.
160	$xl = 0$ m	Length variation due to masking and etching.

Temperature effects parameters

161	$temp$ (C)	Parameters measurement temperature. Default set by options.
162	$trise = 0$ C	Temperature rise from ambient.
163	$tempmod = 432$	Temperature model selector.
164	$version = 432$	Version selector.
165	$uto = 0$ C	Mobility temperature offset.
166	$ute = -1.5$	Mobility temperature exponent.
167	$tlev = 0$	DC temperature selector.
168	$tlevc = 0$	AC temperature selector.
169	$ptc = 0$ V/C	Surface potential temperature coefficient.

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BSIM2 Level-5 Model (bsim2)

170	$eg=1.12452 \text{ V}$	Energy band gap.
171	$gap1=7.02e-4 \text{ V/C}^2$	Band gap temperature coefficient.
172	$gap2=1108 \text{ K}$	Band gap temperature offset.
173	$trs=0 \text{ 1/C}$	Temperature coefficient for source resistance.
174	$trd=0 \text{ 1/C}$	Temperature coefficient for drain resistance.
175	$x_{ti}=3$	Saturation current temperature exponent.

Overlap capacitance parameters

176	$cgso=0 \text{ F/m}$	Gate-source overlap capacitance.
177	$cgdo=0 \text{ F/m}$	Gate-drain overlap capacitance.
178	$cgbo=0 \text{ F/m}$	Gate-bulk overlap capacitance.
179	$meto=0 \text{ m}$	Metal overlap in fringing field.

Charge model selection parameters

180	$capmod=bsim$	Intrinsic charge model. Possible values are <i>none</i> , <i>meyer</i> , <i>yang</i> , or <i>bsim</i> .
181	$xpart=1$	Drain/source channel charge partition in saturation for BSIM charge model, use 0.0 for 40/60, 0.5 for 50/50, or 1.0 for 0/100.
182	$xqc=0$	Drain/source channel charge partition in saturation for charge models, e.g. use 0.4 for 40/60, 0.5 for 50/50, or 0 for 0/100.

Parasitic resistance parameters

183	$rs=0 \text{ } \Omega$	Source resistance.
184	$rd=0 \text{ } \Omega$	Drain resistance.
185	$rsh=0 \text{ } \Omega/\text{sqr}$	Source/drain diffusion sheet resistance.

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BSIM2 Level-5 Model (bsim2)

186	$r_{sc}=0 \ \Omega$	Source contact resistance.
187	$r_{dc}=0 \ \Omega$	Drain contact resistance.
188	$r_{ss}=0 \ \Omega \ m$	Scalable source resistance.
189	$r_{dd}=0 \ \Omega \ m$	Scalable drain resistance.
190	$minr=0.1 \ \Omega$	Minimum source/drain resistance.
191	$hdif=0 \ m$	Length of heavily doped diffusion.
192	$ldif=0 \ m$	Lateral diffusion beyond the gate.
193	$lgcs=0 \ m$	Gate-to-contact length of source side.
194	$lgcd=0 \ m$	Gate-to-contact length of drain side.
195	$sc=\infty \ m$	Spacing between contacts.

Junction diode parameters

196	$j_s \ (A/m^2)$	Bulk junction reverse saturation current density.
197	$i_s=1e-14 \ A$	Bulk junction reverse saturation current.
198	$n=1$	Junction emission coefficient.
199	$dskip=yes$	Use simple piece-wise linear model for diode currents below $0.1*i_{abstol}$. Possible values are <code>no</code> or <code>yes</code> .
200	$imelt='imax' \ A$	Explosion current, diode is linearized beyond this current to aid convergence.
201	$jmelt='jmax' \ A/m^2$	Explosion current density, diode is linearized beyond this current to aid convergence.

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Operating region warning control parameters

202	alarm=none	Forbidden operating region. Possible values are none, off, triode, sat, subth, or rev.
203	imax=1 A	Maximum current, currents above this limit generate a warning.
204	jmax=1e8 A/m ²	Maximum current density, currents above this limit generate a warning.
205	bvj= ∞ V	Junction reverse breakdown voltage.
206	vbox=1e9 tox V	Oxide breakdown voltage.

Junction capacitance model parameters

207	cbs=0 F	Bulk-source zero-bias junction capacitance.
208	cbd=0 F	Bulk-drain zero-bias junction capacitance.
209	cj=0 F/m ²	Zero-bias junction bottom capacitance density.
210	mj=1/2	Bulk junction bottom grading coefficient.
211	pb=0.8 V	Bulk junction potential.
212	fc=0.5	Forward-bias depletion capacitance threshold.
213	cjsw=0 F/m	Zero-bias junction sidewall capacitance density.
214	mjsw=1/3	Bulk junction sidewall grading coefficient.
215	pbsw=0.8 V	Side-wall junction potential.
216	fcsw=0.5	Side-wall forward-bias depletion capacitance threshold.

Process and power supply parameters

217	tox=4e-8 m	Gate oxide thickness.
218	vdd=5 V	Drain voltage at which parameters are extracted.

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BSIM2 Level-5 Model (bsim2)

219 $v_{gg}=5$ V Gate voltage at which parameters are extracted.

220 $v_{bb}=-5$ V Body voltage at which parameters are extracted.

Default device parameters

221 $w=3e-6$ m Channel width.

222 $l=3e-6$ m Channel length.

223 $a_s=0$ m² Area of source diffusion.

224 $a_d=0$ m² Area of drain diffusion.

225 $p_s=0$ m Perimeter of source diffusion.

226 $p_d=0$ m Perimeter of drain diffusion.

227 $n_{rd}=0$ m/m Number of squares of drain diffusion.

228 $n_{rs}=0$ m/m Number of squares of source diffusion.

229 $l_{dd}=0$ m Drain diffusion length.

230 $l_{ds}=0$ m Source diffusion length.

Noise model parameters

231 $noisemod=1$ Noise model selector.

232 $k_f=0$ Flicker (1/f) noise coefficient.

233 $a_f=1$ Flicker (1/f) noise exponent.

234 $e_f=1$ Flicker (1/f) noise frequency exponent.

235 $w_{noi}=1e-5$ m Channel width at which noise parameters were extracted.

Auto Model Selector parameters

236 $w_{max}=1.0$ m Maximum channel width for which the model is valid.

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BSIM2 Level-5 Model (bsim2)

237	<code>wmin=0.0 m</code>	Minimum channel width for which the model is valid.
238	<code>lmax=1.0 m</code>	Maximum channel length for which the model is valid.
239	<code>lmin=0.0 m</code>	Minimum channel length for which the model is valid.

Degradation parameters

240	<code>degramod=spectre</code>	Degradation model selector. Possible values are <code>spectre</code> or <code>bert</code> .
241	<code>degradation=no</code>	Hot-electron degradation flag. Possible values are <code>no</code> or <code>yes</code> .
242	<code>dvthc=1 V</code>	Degradation coefficient for threshold voltage.
243	<code>dvthe=1</code>	Degradation exponent for threshold voltage.
244	<code>duoc=1 S</code>	Degradation coefficient for transconductance.
245	<code>duoe=1</code>	Degradation exponent for transconductance.
246	<code>crivth=0.1 V</code>	Maximum allowable threshold voltage shift.
247	<code>criuo=10%</code>	Maximum allowable normalized mobility change.
248	<code>crigm=10%</code>	Maximum allowable normalized transconductance change.
249	<code>criids=10%</code>	Maximum allowable normalized drain current change.
250	<code>wnom=5e-6 m</code>	Nominal device width in degradation calculation.
251	<code>lnom=1e-6 m</code>	Nominal device length in degradation calculation.
252	<code>vbsn=0 V</code>	Substrate voltage in degradation calculation.
253	<code>vdsni=0.1 V</code>	Drain voltage in I_{ds} degradation calculation.
254	<code>vgsni=5 V</code>	Gate voltage in I_{ds} degradation calculation.
255	<code>vdsng=0.1 V</code>	Drain voltage in G_m degradation calculation.
256	<code>vgsng=5 V</code>	Gate voltage in G_m degradation calculation.

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Spectre stress parameters

257	$esat=1.1e7$	V/m	Critical field in V_{dsat} calculation.
258	$esatg=2.5e6$	1/m	Gate voltage dependence of $esat$.
259	$vpg=-0.25$		Gate voltage modifier.
260	$vpb=-0.13$		Gate voltage modifier.
261	$subc1=2.24e-5$		Substrate current coefficient.
262	$subc2=-0.1e-5$	1/V	Substrate current coefficient.
263	$sube=6.4$		Substrate current exponent.
264	$strc=1$		Stress coefficient.
265	$stre=1$		Stress exponent.

BERT stress parameters

266	$h0=1$		Aging coefficient.
267	$hgd=0$	1/V	Bias dependence of $h0$.
268	$m0=1$		Aging exponent.
269	$mgd=0$	1/V	Bias dependence of $m0$.
270	$ecrit0=1.1e5$	V/cm	Critical electric field.
271	$lecrit0=0$	μm V/cm	Length dependence of $ecrit0$.
272	$wecrit0=0$	μm V/cm	Width dependence of $ecrit0$.
273	$ecritg=0$	1/cm	Gate voltage dependence of $ecrit0$.
274	$lecritg=0$	$\mu\text{m}/\text{cm}$	Length dependence of $ecritg$.
275	$wecritg=0$	$\mu\text{m}/\text{cm}$	Width dependence of $ecritg$.
276	$ecritb=0$	1/cm	Substrate voltage dependence of $ecrit0$.

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BSIM2 Level-5 Model (bsim2)

277	$l_{critb}=0$	$\mu\text{m}/\text{cm}$	Length dependence of e_{critb} .
278	$w_{critb}=0$	$\mu\text{m}/\text{cm}$	Width dependence of e_{critb} .
279	$l_{c0}=1$		Substrate current coefficient.
280	$l_{lc0}=0$	μm	Length dependence of l_{c0} .
281	$w_{lc0}=0$	μm	Width dependence of l_{c0} .
282	$l_{c1}=1$		Substrate current coefficient.
283	$l_{lc1}=0$	μm	Length dependence of l_{c1} .
284	$w_{lc1}=0$	μm	Width dependence of l_{c1} .
285	$l_{c2}=1$		Substrate current coefficient.
286	$l_{lc2}=0$	μm	Length dependence of l_{c2} .
287	$w_{lc2}=0$	μm	Width dependence of l_{c2} .
288	$l_{c3}=1$		Substrate current coefficient.
289	$l_{lc3}=0$	μm	Length dependence of l_{c3} .
290	$w_{lc3}=0$	μm	Width dependence of l_{c3} .
291	$l_{c4}=1$		Substrate current coefficient.
292	$l_{lc4}=0$	μm	Length dependence of l_{c4} .
293	$w_{lc4}=0$	μm	Width dependence of l_{c4} .
294	$l_{c5}=1$		Substrate current coefficient.
295	$l_{lc5}=0$	μm	Length dependence of l_{c5} .
296	$w_{lc5}=0$	μm	Width dependence of l_{c5} .
297	$l_{c6}=1$		Substrate current coefficient.
298	$l_{lc6}=0$	μm	Length dependence of l_{c6} .

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BSIM2 Level-5 Model (bsim2)

299	$wlc6=0 \mu\text{m}$	Width dependence of $lc6$.
300	$lc7=1$	Substrate current coefficient.
301	$llc7=0 \mu\text{m}$	Length dependence of $lc7$.
302	$wlc7=0 \mu\text{m}$	Width dependence of $lc7$.

I_{max} and I_{melt} :

The i_{max} parameter aids convergence and prevents numerical overflow. The junction characteristics of the device are accurately modeled for current up to i_{max} . If i_{max} is exceeded during iterations, the linear model is substituted until the current drops below i_{max} or until convergence is achieved. If convergence is achieved with the current exceeding i_{max} , the results are inaccurate, and Spectre prints a warning.

A separate model parameter, i_{melt} , is used as a limit warning for the junction current. This parameter can be set to the maximum current rating of the device. When any component of the junction current exceeds i_{melt} , note that base and collector currents are composed of many exponential terms, Spectre issues a warning and the results become inaccurate. The junction current is linearized above the value of i_{melt} to prevent arithmetic exception, with the exponential term replaced by a linear equation at i_{melt} .

Both of these parameters have current density counterparts, j_{max} and j_{melt} , that you can specify if you want the absolute current values to depend on the device area.

Auto Model Selection:

Many models need to be characterized for different geometries in order to obtain accurate results for model development. The model selector program automatically searches for a model with the length and width range specified in the instance statement and uses this model in the simulations.

For the auto model selector program to find a specific model, the models to be searched should be grouped together within braces. Such a group is called a model group. An opening brace is required at the end of the line defining each model group. Every model in the group is given a name followed by a colon and the list of parameters. Also, the four geometric parameters l_{max} , l_{min} , w_{max} , and w_{min} should be given. The selection criteria to choose a model is as follows:

$$l_{min} \leq inst_length < l_{max} \quad \text{and} \quad w_{min} \leq inst_width < w_{max}$$

Example:

```
model ModelName ModelType {
```

Virtuoso Simulator Components and Device Models Reference

BSIM2 Level-5 Model (bsim2)

- 1: <model parameters> lmin=2 lmax=4 wmin=1 wmax=2
- 2: <model parameters> lmin=1 lmax=2 wmin=2 wmax=4
- 3: <model parameters> lmin=2 lmax=4 wmin=4 wmax=6

}

Then for a given instance

```
M1 1 2 3 4 ModelName w=3 l=1.5
```

the program would search all the models in the model group with the name `ModelName` and then pick the first model whose geometric range satisfies the selection criteria. In the preceding example, the auto model selector program would choose `ModelName.2`.

You must specify both length (l) and width (w) on the device instance line to enable automatic model selection.

Output Parameters

- | | | |
|----|---|--|
| 1 | <code>w_{eff}</code> (m) | Effective channel width. |
| 2 | <code>l_{eff}</code> (m) | Effective channel length. |
| 3 | <code>r_{seff}</code> (Ω) | Effective source resistance. |
| 4 | <code>r_{deff}</code> (Ω) | Effective drain resistance. |
| 5 | <code>a_{seff}</code> (m ²) | Effective area of source diffusion. |
| 6 | <code>a_{deff}</code> (m ²) | Effective area of drain diffusion. |
| 7 | <code>p_{seff}</code> (m) | Effective perimeter of source diffusion. |
| 8 | <code>p_{deff}</code> (m) | Effective perimeter of drain diffusion. |
| 9 | <code>i_{sseff}</code> (A) | Effective source-bulk junction reverse saturation current. |
| 10 | <code>i_{sdeff}</code> (A) | Effective drain-bulk junction reverse saturation current. |
| 11 | <code>cb_{seff}</code> (F) | Effective zero-bias source-bulk junction capacitance. |
| 12 | <code>cb_{deff}</code> (F) | Effective zero-bias drain-bulk junction capacitance. |

Virtuoso Simulator Components and Device Models Reference

BSIM2 Level-5 Model (bsim2)

13	<code>vto</code> (V)	Effective zero-bias threshold voltage.
14	<code>vfb</code> (V)	Effective flat-band voltage.
15	<code>phi</code> (V)	Effective surface potential.
16	<code>k1</code> (\sqrt{V})	Effective body-effect coefficient.
17	<code>k2</code>	Effective charge-sharing parameter.
18	<code>eta</code>	Effective DIBL coefficient.

Operating-Point Parameters

1	<code>type=n</code>	Transistor type. Possible values are <code>n</code> or <code>p</code> .
2	<code>region=triode</code>	Estimated operating region. Spectre outputs number (0-4) in a rawfile. Possible values are <code>off</code> , <code>triode</code> , <code>sat</code> , <code>subth</code> , or <code>breakdown</code> .
3	<code>degradation=no</code>	Hot-electron degradation flag. Possible values are <code>no</code> or <code>yes</code> .
4	<code>reversed</code>	Reverse mode indicator. Possible values are <code>no</code> or <code>yes</code> .
5	<code>ids</code> (A)	Resistive drain-to-source current.
6	<code>vgs</code> (V)	Gate-source voltage.
7	<code>vds</code> (V)	Drain-source voltage.
8	<code>vbs</code> (V)	Bulk-source voltage.
9	<code>vth</code> (V)	Threshold voltage.
10	<code>vdsat</code> (V)	Drain-source saturation voltage.
11	<code>betaeff</code> (A/V^2)	Effective beta.
12	<code>gm</code> (S)	Common-source transconductance.

Virtuoso Simulator Components and Device Models Reference

BSIM2 Level-5 Model (bsim2)

13	g_{ds} (S)	Common-source output conductance.
14	g_{mbs} (S)	Body-transconductance.
15	c_{bd} (F)	Drain-bulk junction capacitance.
16	c_{bs} (F)	Source-bulk junction capacitance.
17	c_{gs} (F)	Gate-source capacitance.
18	c_{gd} (F)	Gate-drain capacitance.
19	c_{gb} (F)	Gate-bulk capacitance.
20	r_{on} (Ω)	ON-resistance.
21	i_d (A)	Resistive drain current.
22	i_{bulk} (A)	Resistive bulk current.
23	pwr (W)	Power at op point.
24	$g_{moverid}$ (1/V)	Gm/Ids.
25	i_{sub} (A)	Substrate current.
26	$stress$	Hot-electron stress.
27	age (s)	Device age.
28	he_vdsat (V)	hot electron vdsat.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

Virtuoso Simulator Components and Device Models Reference

BSIM2 Level-5 Model (bsim2)

ad	I-4	lc0	M-279	nrd	M-227	ubb	M-90
ad	M-224	lc1	M-282	nrs	I-8	ute	M-166
adefeff	O-6	lc2	M-285	nrs	M-228	uto	M-165
af	M-233	lc3	M-288	pai0	M-134	vbb	M-220
age	OP-27	lc4	M-291	paib	M-138	vbox	M-206
ai0	M-131	lc5	M-294	pb	M-211	vbs	OP-8
aib	M-135	lc6	M-297	pbi0	M-142	vbsn	M-252
alarm	M-202	lc7	M-300	pbib	M-146	vdd	M-218
as	I-3	ld	I-9	pbsw	M-215	vds	OP-7
as	M-223	ldd	M-229	pd	I-6	vdsat	OP-10
aseff	O-5	ldif	M-192	pd	M-226	vdsng	M-255
betaeff	OP-11	lds	M-230	pdeff	O-8	vdsni	M-253
bi0	M-139	lecrit0	M-271	peta0	M-21	version	M-164
bib	M-143	lecritb	M-277	petab	M-25	vfb	O-14
bvj	M-205	lecritg	M-274	phi	O-15	vfb0	M-2
capmod	M-180	leff	O-2	phi0	M-6	vgg	M-219
cbd	M-208	leta0	M-19	pk1	M-13	vghigh	M-147
cbd	OP-15	letab	M-23	pk2	M-17	vglow	M-151
cbdefeff	O-12	lgcd	M-194	pmu0	M-29	vgs	OP-6
cbs	M-207	lgcs	M-193	pmu0b	M-33	vgsng	M-256

Virtuoso Simulator Components and Device Models Reference

BSIM2 Level-5 Model (bsim2)

cbs	OP-16	lk1	M-11	pmu20	M-45	vgsni	M-254
cbseff	O-11	lk2	M-15	pmu2b	M-49	vof0	M-118
cgb	OP-19	llc0	M-280	pmu2g	M-53	vofb	M-122
cgbo	M-178	llc1	M-283	pmu30	M-57	vofd	M-126
cgd	OP-18	llc2	M-286	pmu3b	M-61	vpb	M-260
cgdo	M-177	llc3	M-289	pmu3g	M-65	vpg	M-259
cgs	OP-17	llc4	M-292	pmu40	M-69	vth	OP-9
cgso	M-176	llc5	M-295	pmu4b	M-73	vto	O-13
cj	M-209	llc6	M-298	pmu4g	M-77	w	I-1
cjsw	M-213	llc7	M-301	pmus0	M-37	w	M-221
crigm	M-248	lmax	M-238	pmusb	M-41	wai0	M-133
criids	M-249	lmin	M-239	pn0	M-109	waib	M-137
criuo	M-247	lmu0	M-27	pnb	M-113	wbi0	M-141
crivth	M-246	lmu0b	M-31	pnd	M-117	wbib	M-145
degradation	I-14	lmu20	M-43	pphi	M-9	wecrit0	M-272
degradation	M-241	lmu2b	M-47	ps	I-5	wecritb	M-278
degradation	OP-3	lmu2g	M-51	ps	M-225	wecritg	M-275
degramod	M-240	lmu30	M-55	pseff	O-7	weff	O-1
d10	M-155	lmu3b	M-59	ptc	M-169	weta0	M-20
dskip	M-199	lmu3g	M-63	pul0	M-97	wetab	M-24

Virtuoso Simulator Components and Device Models Reference

BSIM2 Level-5 Model (bsim2)

duoc	M-244	lmu40	M-67	publ	M-101	wk1	M-12
duoe	M-245	lmu4b	M-71	pu1d	M-105	wk2	M-16
dvthc	M-242	lmu4g	M-75	pua0	M-81	wlc0	M-281
dvthe	M-243	lmus0	M-35	puab	M-85	wlc1	M-284
dw0	M-156	lmusb	M-39	pub0	M-89	wlc2	M-287
ecrit0	M-270	ln0	M-107	pubb	M-93	wlc3	M-290
ecritb	M-276	lnb	M-111	pvfb	M-5	wlc4	M-293
ecritg	M-273	lnd	M-115	pvghigh	M-150	wlc5	M-296
ef	M-234	lnom	M-251	pvglow	M-154	wlc6	M-299
eg	M-170	lphi	M-7	pvofo	M-121	wlc7	M-302
esat	M-257	lref	M-157	pvoffb	M-125	wmax	M-236
esatg	M-258	ls	I-10	pvoofd	M-129	wmin	M-237
eta	O-18	lu10	M-95	pwr	OP-23	wmu0	M-28
eta0	M-18	lu1b	M-99	rd	M-184	wmu0b	M-32
etab	M-22	lu1d	M-103	rdc	M-187	wmu20	M-44
fc	M-212	lua0	M-79	rdd	M-189	wmu2b	M-48
fcsw	M-216	luab	M-83	rdeff	O-4	wmu2g	M-52
gap1	M-171	lub0	M-87	region	I-12	wmu30	M-56
gap2	M-172	lubb	M-91	region	OP-2	wmu3b	M-60
gds	OP-13	lvfb	M-3	reversed	OP-4	wmu3g	M-64
gm	OP-12	lvghigh	M-148	ron	OP-20	wmu40	M-68

Virtuoso Simulator Components and Device Models Reference

BSIM2 Level-5 Model (bsim2)

gmbs	OP-14	lvglow	M-152	rs	M-183	wmu4b	M-72
gmoverid	OP-24	lvof0	M-119	rsc	M-186	wmu4g	M-76
h0	M-266	lvofb	M-123	rseff	O-3	wmus0	M-36
hdif	M-191	lvofd	M-127	rsh	M-185	wmusb	M-40
he_vdsat	OP-28	m	I-11	rss	M-188	wn0	M-108
hgd	M-267	m0	M-268	sc	M-195	wnb	M-112
ibulk	OP-22	meto	M-179	strc	M-264	wnd	M-116
id	OP-21	mgd	M-269	stre	M-265	wnoi	M-235
ids	OP-5	minr	M-190	stress	OP-26	wnom	M-250
imax	M-203	mj	M-210	subc1	M-261	wphi	M-8
imelt	M-200	mjsw	M-214	subc2	M-262	wref	M-158
is	M-197	mu0	M-26	sube	M-263	wu10	M-96
isdeff	O-10	mu0b	M-30	subthmod	M-130	wu1b	M-100
isnoisy	I-15	mu20	M-42	temp	M-161	wu1d	M-104
isseff	O-9	mu2b	M-46	tempmod	M-163	wua0	M-80
isub	OP-25	mu2g	M-50	tlev	M-167	wuab	M-84
jmax	M-204	mu30	M-54	tlevc	M-168	wub0	M-88
jmelt	M-201	mu3b	M-58	tox	M-217	wubb	M-92
js	M-196	mu3g	M-62	trd	M-174	wvfb	M-4
k1	M-10	mu40	M-66	trise	I-13	wvghigh	M-149
k1	O-16	mu4b	M-70	trise	M-162	wvglow	M-153

Virtuoso Simulator Components and Device Models Reference

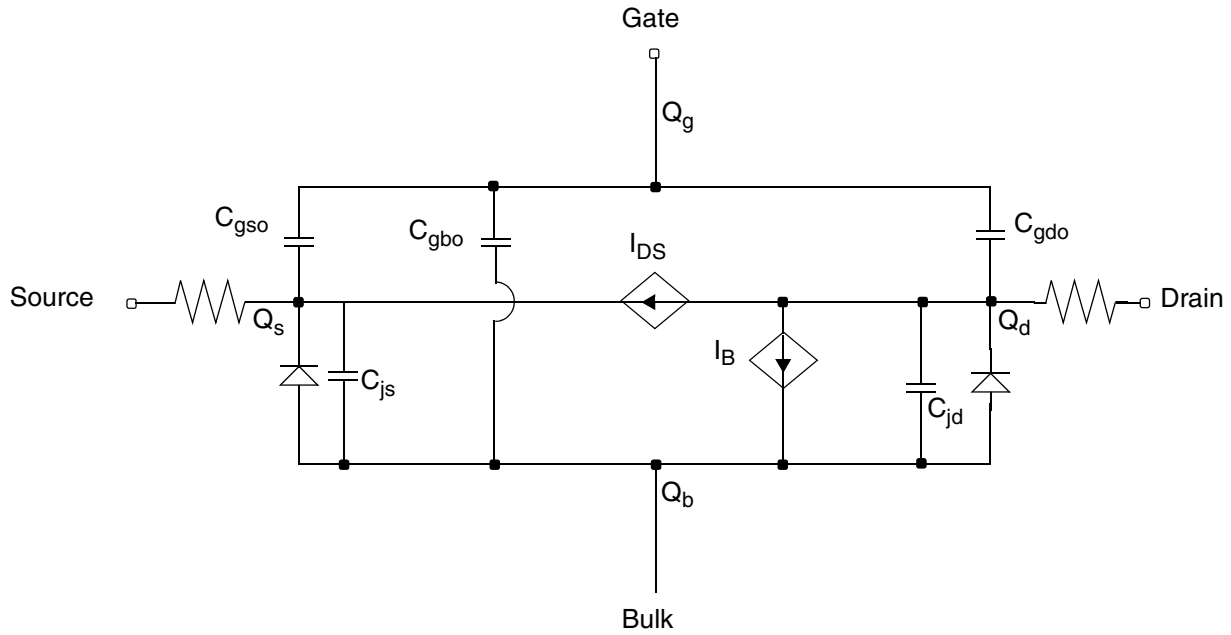
BSIM2 Level-5 Model (bsim2)

k2	M-14	mu4g	M-74	trs	M-173	wvof0	M-120
k2	O-17	mus0	M-34	type	M-1	wvofb	M-124
kf	M-232	musb	M-38	type	OP-1	wvofd	M-128
l	I-2	n	M-198	u10	M-94	x1	M-160
l	M-222	n0	M-106	u1b	M-98	xpart	M-181
lai0	M-132	nb	M-110	uld	M-102	xqc	M-182
laib	M-136	nd	M-114	ua0	M-78	xti	M-175
lbi0	M-140	noisemod	M-231	uab	M-82	xw	M-159
lbib	M-144	nrd	I-7	ub0	M-86		

BSIM3v2 Level-10 Model (bsim3)

The BSIM3 model is based on the industry standard efforts of the Compact Modeling Counsel (CMC) and the BSIM modeling group at the University of California, Berkeley. It is suitable for both digital and analog applications. This chapter contains the following information for the BSIM3v2 model:

- [Threshold Voltage](#) on page 1126
- [Subthreshold Current](#) on page 1127
- [Drain Saturation Voltage](#) on page 1129
- [Drain Current for the Triode Region](#) on page 1130
- [Drain Current for the Saturation Region](#) on page 1131
- [Default Model Parameter Value Calculation](#) on page 1132
- [Scaling Effects](#) on page 1135
- [New Features in BSIM3 Version 3.2.4](#) on page 1135
- [Component Statements](#) on page 1135



Threshold Voltage

$$V_{TH} = vtho + k1(\sqrt{\phi_{hi} - V_{BS}} - \sqrt{\phi_{hi}}) - k2 * V_{BS} - \Delta V_{TH} +$$

$$k1 \left[\sqrt{1 + \frac{nlx}{L_{eff}} \sqrt{\frac{\phi_{hi}}{\phi_{hi} - V_{BS}}}} - 1 \right] \sqrt{\phi_{hi}} + \frac{k3 * tox * \phi_{hi}}{W_{eff} + w0} + (kt1 + kt2 V_{BS}) \left(\frac{T}{tnom} - 1 \right)$$

where

$$\Delta V_{TH} = \theta(vbi - \phi_{hi})$$

$$\theta = dvt0 * \theta_0$$

$$\theta_0 = e^{-dvt1 * L_{eff}/2l_0} + 2e^{-dvt1 * L_{eff}/l_0}$$

L_{eff} is the effective channel length, and I_0 is given by

$$l_0 = \sqrt{\frac{\epsilon_{si}^{tox} X_{dep}}{\epsilon_{ox}}} (1 + dvt2 * V_{BS})$$

and

$$X_{dep} = \sqrt{\frac{2\epsilon_{si}(phi - V_{BS})}{q * n_{peak}}}$$

Subthreshold Current

There are two subthreshold current models that you can select with the `subthmod` parameter. If you set `subthmod` to 0, none of the subthreshold current models are used. For example, the drain current is zero when the gate voltage is less than the threshold voltage. If you set `subthmod` to 1, the summation approach is used. For example, the subthreshold current is always calculated and added to the drain current for the strong-inversion region, regardless of the operating region.

If you set `subthmod` to 2, a transition region between the subthreshold regions and the strong-inversion regions is created. This transition region provides smooth switching between the subthreshold and the strong-inversion regions. The following equations are model equations for the subthreshold and transition regions.

subthmod = 1

$$I_{subth} = \frac{I_{exp} I_{limit}}{I_{exp} + I_{limit}} (1 - e^{-V_{DS}/V_{im}})$$

where

$$I_{limit} = 4.5\beta_0 V_{im}^2$$

$$I_{exp} = \beta_{subth} V_{im}^2 e^{(V'_{GST}/nV_{im})}$$

$$V'_{GST} = V_{GST} - voff + V_{dibl}$$

$$V_{dibl} = (\eta a0 + \eta ab * V_{BS}) * \theta_d * V_{DS}$$

Virtuoso Simulator Components and Device Models Reference
BSIM3v2 Level-10 Model (bsim3)

$$\theta_d = pdibl1[e^{-drouT*L_{eff}/2l_{00}} + 2e^{-drouT*L_{eff}/l_{00}}]$$

$$l_{00} = \sqrt{\frac{\epsilon_{si}toxX_{dep0}}{\epsilon_{ox}}}$$

$$X_{dep0} = \sqrt{\frac{2\epsilon_{si}phi}{q* npeak}}$$

$$V_{GST} = V_{GS} - V_{TH}$$

$$\beta_{subth} = \frac{u_0 C_{d0} W_{eff}}{L_{eff}}$$

$$n = 1 + \frac{C_d}{C_{ox}} nfactor + \frac{(cdsc + cdsc1 * V_{BS})}{C_{ox}} \theta_0 + \frac{C_{it}}{C_{ox}}$$

subthmod = 2

If $V_{GST} \leq V_{glow} - V_{dibl}$, the drain current is given by current.

$$I_{DS} = I_{subth} = \beta_0 V_{tm}^2 e^{(V_{GST}/nV_{tm})} (1 - e^{-V_{DS}/V_{tm}})$$

If $V_{glow} - V_{dibl} \leq V_{GST} \leq V_{ghigh} + V_{dibl}$, the device is operated in the transition region and the drain current is given by

$$I_{DS} = (1-t)^2 I_{dlow} + 2t(1-t)I_p + t^2 I_{dhigh}$$

where I_{dlow} is the subthreshold current evaluated at $V_{GST} = V_{glow} - V_{dibl}$, and I_{dhigh} is the strong-inversion drain current evaluated at $V_{GST} = V_{ghigh} + V_{dibl}$.

$$t = \left(\frac{V_p - V_{glow}}{Y} \right) \left[\sqrt{1 + \frac{Y(V_{GST} - V_{glow})}{(V_p - V_{glow})^2}} - 1 \right]$$

$$Y = V_{glow} - 2V_p + V_{ghigh}$$

$$I_p = I_{dlow} + g_{mlow}(V_p - V_{glow})$$

$$V_p = \frac{(g_{mhigh}V_{ghigh} - g_{mlow}V_{glow}) - (I_{dhigh} - I_{dlow})}{g_{mhigh} - g_{mlow}}$$

g_{mhigh} and g_{mlow} are the transconductances evaluated at $V_{GST} = V_{ghigh} + V_{dibl}$.

Drain Saturation Voltage

If $R_{ds} = 0$,

$$V_{DSAT} = \frac{V_{GST}E_{SAT}L_{eff}}{V_{GST} + A_{bulk}E_{SAT}L_{eff}}$$

otherwise

$$V_{DSAT} = \frac{C_B - \sqrt{C_B^2 - 4C_A C_C}}{2C_A}$$

where

$$R_{ds} = rds0 + \frac{rds0 * 10^{-6}}{W_{eff}}$$

$$E_{SAT} = \frac{2v_{sat}}{\mu_{eff}}$$

$$\mu_{eff} = \frac{u_0}{U_{vert}}$$

$$U_{vert} = 1 + ua \left(\frac{V_{GS} + V_{TH}}{tox} \right) + ub \left(\frac{V_{GS} + V_{TH}}{tox} \right)^2 + uc * V_{BS}$$

If $keta = 0$,

$$A_{bulk} = 1 + \frac{k1*a0*L_{eff}}{2(L_{eff} + 2\sqrt{xjX_{dep}})\sqrt{\phi_i - V_{BS}}}$$

otherwise,

$$A_{bulk} = \left(1 + \frac{k1*a0*L_{eff}}{2(L_{eff} + 2\sqrt{xjX_{dep}})\sqrt{\phi_i}} \right) \frac{1}{1 + keta*V_{BS}/L_{eff}}$$

$$C_A = A_{bulk}^2 R_{vcw}$$

$$C_B = V_{GST} + A_{bulk} E_{SAT} L_{eff} + 3A_{bulk} R_{vcw} V_{GST}$$

$$C_C = E_{SAT} L_{eff} V_{GST} + 2R_{vcw} V_{GST}^2$$

$$R_{vcw} = V_{SAT} * R_{ds} C_{ox} W_{eff}$$

Drain Current for the Triode Region

Note: These equations apply to $V_{GST} \geq 0$ and $V_{DS} \leq V_{DSAT}$.

$$I_{DS} = \frac{I_{dslin0}}{1 + R_{ds} * I_{dslin0} / V_{DS}} \quad \setminus$$

where I_{dslin0} is the drain current in the triode region without the presence of source and drain parasitic resistance.

$$I_{dslin0} = \frac{\beta_{effs} \left(V_{GST} - \frac{1}{2} A_{bulk} V_{DS} \right) V_{DS}}{1 + V_{DS} / E_{SAT} L_{eff}}$$

$$\beta_{eff} = \frac{\mu_{eff} C_{ox} W_{eff}}{L_{eff}}$$

Drain Current for the Saturation Region

Note: These equations apply to $V_{GST} > 0$ and $V_{DS} \geq V_{DSAT}$.

$$I_{DSAT} = I_{DSAT0} \left(1 + \frac{V'_{DS}}{V_a} \right) * \left[1 + \frac{pscbe2}{L_{eff}} V'_{DS} e^{(-pscbe1 * litl / V'_{DS})} \right]$$

where

$$I_{DSAT0} = W_{eff} C_{ox} v_{sat} (V_{GST} - A_{bulk} V_{DSAT})$$

$$V'_{DS} = V_{DS} - V_{DSAT}$$

satmod = 1

$$V_a = V_{aa} + \left(1 + \frac{eta * ldd}{litl} \right) * \left[\frac{(E_{SAT} L_{eff} + V_{GST}) V'_{DS}}{alpha * litl * E_{SAT}} \right] \left(1 - \frac{V'_{DS}}{2 litl * em} \right)$$

$$V_{aa} = \frac{E_{SAT} L_{eff} + V_{DSAT} + 2 R_{vcw} (V_{GST} - 0.5 A_{bulk} V_{DSAT})}{1 + A_{bulk} R_{vcw}}$$

satmod = 2

$$V_a = V_{aa} + \left(1 + \frac{eta * ldd}{litl} \right) \left(\frac{V_{aclm} * V_{dibl}}{V_{aclm} + V_{adibl}} \right) * pvag$$

$$V_{aclm} = \frac{(E_{SAT} L_{eff} A_{bulk} + V_{GST}) V'_{DS}}{litl * pclm * E_{SAT} A_{bulk}}$$

$$V_{adibl} = \left(\frac{V_{GST} - \frac{V_{GST} A_{bulk} V_{DSAT}}{V_{GST} + A_{bulk} V_{DSAT}}}{\theta_{rout}} \right)$$

where

$$\theta_{rout} = pdibli[e^{-drou* L_{eff}/2l_0} + 2e^{-drou* L_{eff}/l_0}] + pdibl2$$

Default Model Parameter Value Calculation

The following are the calculation methods for default model parameter values under various conditions:

- If $vtho$ is not given, it is calculated from

$$vtho = vfb + phi + k1\sqrt{phi}$$

- If phi is not given, it is calculated from

$$phi = 2V_{tm} \ln\left(\frac{n_{peak}}{n_i}\right)$$

where V_{tm} is the thermal voltage given by

$$V_{tm} = \frac{kT}{q}$$

$$n_i = 1.45 \times 10^{10} \left(\frac{T}{300}\right)^{1.5} \exp\left(\frac{1.12}{0.0516} - \frac{E_g(T)}{2V_{tm}}\right)$$

where $E_g(T)$ is the energy band gap at temperature T . The equation for E_g is shown in [Chapter 12, "Common MOSFET Equations."](#)

- If $k1$ is not given, it is calculated from

$$k1 = gamma2 + 2k2\sqrt{phi - vbm}$$

- If $k2$ is not given, it is calculated from

Virtuoso Simulator Components and Device Models Reference
BSIM3v2 Level-10 Model (bsim3)

$$k2 = \frac{(\text{gamma}2 - \text{gamma}1)(\sqrt{\text{phi} - \text{vbx}} - \sqrt{\text{phi}})}{2\sqrt{\text{phi}}(\sqrt{\text{phi}} - \text{vbm} - \sqrt{\text{phi}}) + \text{vbm}}$$

- If *gamma1* is not given, it is calculated from

$$\text{gamma}1 = \frac{\sqrt{2q\epsilon_{si}n_{peak}}}{C_{ox}}$$

- If *gamma2* is not given, it is calculated from

$$\text{gamma}2 = \frac{\sqrt{2q\epsilon_{si}n_{sub}}}{C_{ox}}$$

- If *litl* is not given, it is calculated from

$$\text{litl} = \sqrt{\frac{\epsilon_{si}x_j}{C_{ox}}}$$

- If *vtho* is not given, *vfb* is always calculated from

$$\text{vfb} = \text{vtho} - \text{phi} - k1\sqrt{\text{phi}} + k2*\text{phi}$$

regardless of any value you specify.

- If V_{bi} is not given, it is calculated from

$$V_{bi} = V_{tm} \ln\left(\frac{10^{22}n_{peak}}{n_i^2}\right)$$

- If V_{bx} is not given, it is calculated from

$$V_{bx} = \text{phi} - \frac{q*n_{peak}*x_l^2}{2\epsilon_{si}}$$

- If *gamma1* is given, *npeak* is calculated from

$$n_{peak} = \frac{\text{gamma}1^2 C_{ox}^2}{2q\epsilon_{si}}$$

regardless of any value you specify.

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BSIM3v2 Level-10 Model (bsim3)

If neither γ_{a1} nor n_{peak} is specified, n_{peak} defaults to 1.7e1.7, and γ_{a1} is calculated from n_{peak} .

- The default value for u_0 is 670 cm²/V sec for NMOS and 250 cm²/V sec for PMOS.
- The temperature-dependent mobility is calculated as

$$U_o(T) = U_o \left(\frac{T}{T_{nom}} \right)^{ute}$$

- The temperature-dependent saturation velocity is calculated as

$$V_{sat}(T) = V_{sat} - at(T - T_{nom})$$

- The temperature-dependent mobility degradation parameters are calculated as

$$U_a(T) = U_a - U_{a1} \left(\frac{T}{T_{nom}} - 1 \right)$$

$$U_b(T) = U_b - U_{b1} \left(\frac{T}{T_{nom}} - 1 \right)$$

$$U_c(T) = U_c - U_{c1} \left(\frac{T}{T_{nom}} - 1 \right)$$

- If V_{ghigh} is not given, it is calculated from

$$V_{ghigh} = n_0 V_{tm} \left[\ln \left(\frac{10 C_{ox}}{C_d} \right) + 3 \right]$$

where

$$C_d = \sqrt{\frac{q \epsilon_{si} n_{peak}}{2 \phi}}$$

- If V_{glow} is not given, it is calculated from

$$V_{glow} = v_{off} + n_0 V_{tm} \ln \left(\frac{C_{ox}}{10 C_d} \right) - \theta * v_{dd}$$

- If $cgdo$ ($cgso$) is not given, it is calculated from

$$cgdo(cgso) = \begin{cases} (dl + meto) * C_{ox} & \text{if } dl \text{ is given} \\ 0.5xj * C_{ox} & \text{otherwise} \end{cases}$$

Also, if $cgdo(cgso)$ is zero, $10^{-7} \times C_{ox}$ is used.

If $cgbo$ is not given, it is calculated from

$$cgbo = 2dw * C_{ox}$$

Scaling Effects

For more information about scaling effects, see [Scaling Factors \(scale and scalem\)](#) on page 242.

New Features in BSIM3 Version 3.2.4

The following features have been added to BSIM3v3.2.4:

1. A Spectre circuit simulator thermal noise model with the noise coefficient varying smoothly between 4 to 8/3 when the device moves from linear region to saturation region.
2. A BSIM4 ACNQS model that enables the NQS effect in AC simulations.
3. A new parameter *lintnoi* introducing an offset to the length reduction parameter (*lint*) to improve the accuracy of the flicker noise model

With the capacitance bug fix in this version, the transcapacitance CGG for capmod=3 is now smooth from the subthreshold region to strong inversion with no negative value.

BSIM3v3.2.4 is backward compatible with the previous versions of the model.

Component Statements

This device is supported within altergroups.

Sample Instance Statement:

```
m3 (1 2 0 0) nchmod l=1.5u w=100u as=450p ad=450p pd=209u ps=209u nrd=207m nrs=207m  
m=1
```

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BSIM3v2 Level-10 Model (bsim3)

Sample Model Statement:

```
model nchmod bsim3 vtho=5.94e-01 phi=0.69 k1=0.72 k2=0 w0=1.3e-07 tox=5.9e-09
rdsw=80 uo=499 xj=2e-07 vsat=600e+04 at=3.4e+04 a0=0.8 cdsc=1.4e-03 nfactor=1.03
```

Instance Definition

```
Name d g s b ModelName parameter=value ...
```

Instance Parameters

1	w (m)	Channel width.
2	l (m)	Channel length.
3	as (m ²)	Area of source diffusion.
4	ad (m ²)	Area of drain diffusion.
5	ps (m)	Perimeter of source diffusion.
6	pd (m)	Perimeter of drain diffusion.
7	nrd (m/m)	Number of squares of drain diffusion.
8	nrs (m/m)	Number of squares of source diffusion.
9	isnoisy=yes	Should resistor generate noise. Possible values are no or yes.
10	m=1	Multiplicity factor (number of MOSFETs in parallel).
11	region=triode	Estimated operating region. Spectre outputs number (0-4) in a rawfile. Possible values are off, triode, sat, subth, or breakdown.
12	trise	Temperature rise from ambient.
13	geo=0	Geometry selector.

Model Definition

```
model modelName bsim3 parameter=value ...
```


Virtuoso Simulator Components and Device Models Reference

BSIM3v2 Level-10 Model (bsim3)

Model Parameters

Device type parameters

1 `type=n` Transistor type.
Possible values are n or p.

Threshold voltage parameters

2 `vtho=0 V` Threshold voltage at zero body bias.

3 `phi=0.7 V` Surface potential at strong inversion.

4 `k1=0.53 \sqrt{V}` Body-effect coefficient.

5 `k2=-0.0186` Charge-sharing parameter.

6 `k3=80` Narrow width coefficient.

7 `k3b=0 1/V` Narrow width coefficient.

8 `w0=2.5e-6 m` Narrow width coefficient.

9 `n1x=1.74e-7 m` Lateral nonuniform doping coefficient.

10 `gamma1=0 \sqrt{V}` Body-effect coefficient near the surface.

11 `gamma2=0 \sqrt{V}` Body-effect coefficient in the bulk.

12 `theta=0.02 1/V` Drain-induced barrier lowering coefficient.

13 `eta=0.3 1/V` Effective drain voltage coefficient.

14 `litl (m)` Depth of current path.

15 `vfb (V)` Flat-band voltage.

16 `vbx (V)` Threshold voltage transition body voltage.

17 `vbi (V)` Substrate junction built-in potential.

18 `vbm=-5 V` Maximum applied body voltage.

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BSIM3v2 Level-10 Model (bsim3)

- 19 $dvt0=2.2$ First coefficient of short-channel effects.
- 20 $dvt1=0.53$ Second coefficient of short-channel effects.
- 21 $dvt2=-0.032$ $1/V$ Body-bias coefficient of short-channel effects.
- 22 $a0=1$ for nmos and 4.4 for pmos
Nonuniform depletion width effect coefficient.
- 23 $a1=0$ for nmos, 0.23 for pmos
No-saturation coefficient.
- 24 $a2=1$ for nmos, 0.08 for pmos
No-saturation coefficient.
- 25 $keta=-0.047$ $1/V$ Body-bias coefficient for non-uniform depletion width effect.

Process parameters

- 26 $nsub=2e15$ cm^{-3} Substrate doping concentration.
- 27 $npeak=1.7e17$ cm^{-3} Peak channel doping concentration.
- 28 $ngate$ (cm^{-3}) Poly-gate doping concentration.
- 29 $xj=0.15e-6$ m Source/drain junction depth.
- 30 $dl=0$ m Lateral diffusion for one side.
- 31 $dw=0$ m Width reduction for one side.
- 32 $tox=1.5e-8$ m Gate oxide thickness.
- 33 $vdd=5$ V Maximum drain voltage.
- 34 $xt=1.55e-7$ m Doping depth.
- 35 $ldd=0$ m Total length of lightly doped drain region.
- 36 $rds0=0$ Ω Total drain-source resistance.
- 37 $rds0=0$ Ω μm Width dependence of drain-source resistance.

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BSIM3v2 Level-10 Model (bsim3)

Mobility parameters

- 38 $u_0=670 \text{ cm}^2/\text{V s}$ Low-field surface mobility at t_{nom} . Default is 250 for PMOS.
- 39 $vsat=9.58e4 \text{ m/s}$ Carrier saturation velocity at t_{nom} .
- 40 $ua=2.25e-9 \text{ m/v}$ First-order mobility reduction coefficient.
- 41 $ub=5.87e-19 \text{ m}^2/\text{v}^2$ Second-order mobility reduction coefficient.
- 42 $uc=0.0465 \text{ 1/V}$ Body-bias dependence of mobility.
- 43 $uc0=0$ Mobility coefficient.

Output resistance parameters

- 44 $satmod=2$ Saturation model selector.
- 45 $bulkmod=1$ Bulk-charge effect model selector.
- 46 $drout=0.56$ DIBL effect on output resistance coefficient.
- 47 $alpha=1.9$ Reference voltage multiplication factor.
- 48 $em=4.1e7 \text{ V/m}$ Maximum electric field.
- 49 $pclm=1.3$ Channel length modulation coefficient.
- 50 $pdibl1=0.39$ First coefficient of drain-induced barrier lowering.
- 51 $pdibl2=8.6e-3$ Second coefficient of drain-induced barrier lowering.
- 52 $pscbe1=4.24e8 \text{ V/m}$ First coefficient of substrate current body effect.
- 53 $pscbe2=1e-5 \text{ m/v}$ Second coefficient of substrate current body effect.
- 54 $pvag=0$ Gate dependence of Early voltage.

Subthreshold parameters

- 55 $subthmod=2$ Subthreshold model selector.

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BSIM3v2 Level-10 Model (bsim3)

56	$v_{ghigh}=0.12$ V	Upper bound of transition region.
57	$v_{glow}=-0.12$ V	Lower bound of transition region.
58	$cdsc=2.4e-4$ F/m ²	Source/drain and channel coupling capacitance.
59	$cdscb=0$ F/m ² V	Body-bias dependence of $cdsc$.
60	$nfactor=1$	Subthreshold swing coefficient.
61	$cit=0$ F	Interface trap parameter for subthreshold swing.
62	$voff=-0.11$ V	Threshold voltage offset.
63	$dsub=drout$	DIBL effect in subthreshold region.
64	$eta0=0.08$	DIBL coefficient subthreshold region.
65	$etab=-0.07$ 1/V	Body-bias dependence of $et0$.

Parasitic resistance parameters

66	$rsh=0$ Ω/sqr	Source/drain diffusion sheet resistance.
67	$rs=0$ Ω	Source resistance.
68	$rd=0$ Ω	Drain resistance.
69	$lgcs=0$ m	Gate-to-contact length of source side.
70	$lgcd=0$ m	Gate-to-contact length of drain side.
71	$rsc=0$ Ω	Source contact resistance.
72	$rdc=0$ Ω	Drain contact resistance.
73	$rss=0$ Ω m	Scalable source resistance.
74	$rdd=0$ Ω m	Scalable drain resistance.
75	$sc=\infty$ m	Spacing between contacts.
76	$ldif=0$ m	Lateral diffusion beyond the gate.

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BSIM3v2 Level-10 Model (bsim3)

77 `hdif=0` m Length of heavily doped diffusion.

78 `minr=0.1` Ω Minimum source/drain resistance.

Junction diode model parameters

79 `js` (A/m²) Bulk junction reverse saturation current density.

80 `is=1e-14` A Bulk junction reverse saturation current.

81 `n=1` Junction emission coefficient.

82 `dskip=yes` Use simple piece-wise linear model for diode currents below $0.1 \cdot i_{abstol}$.
Possible values are `no` or `yes`.

83 `imelt='imax'` A Explosion current.

84 `jmelt='jmax'` A/m² Explosion current density.

Overlap capacitance parameters

85 `cgso` (F/m) Gate-source overlap capacitance.

86 `cgdo` (F/m) Gate-drain overlap capacitance.

87 `cgbo` (F/m) Gate-bulk overlap capacitance.

88 `meto=0` m Metal overlap in fringing field.

Junction capacitance model parameters

89 `cbs=0` F Bulk-source zero-bias junction capacitance.

90 `cbd=0` F Bulk-drain zero-bias junction capacitance.

91 `cj=5e-4` F/m² Zero-bias junction bottom capacitance density.

92 `mj=1/2` Bulk junction bottom grading coefficient.

93 `pb=0.8` V Bulk junction built-in potential.

Virtuoso Simulator Components and Device Models Reference

BSIM3v2 Level-10 Model (bsim3)

- 94 $f_c=0.5$ Forward-bias depletion capacitance threshold.
- 95 $c_{jsw}=5e-10$ F/m Zero-bias junction sidewall capacitance density.
- 96 $m_{jsw}=1/3$ Bulk junction sidewall grading coefficient.
- 97 $p_{bsw}=0.8$ V Side-wall junction built-in potential.
- 98 $f_{csw}=0.5$ Side-wall forward-bias depletion capacitance threshold.

Charge model selection parameters

- 99 $capmod=yang$ Intrinsic charge model.
Possible values are `none`, `meyer`, `yang`, or `bsim`.
- 100 $xpart=1$ Drain/source channel charge partition in saturation for BSIM charge model, use 0.0 for 40/60, 0.5 for 50/50, or 1.0 for 0/100.
- 101 $xqc=0$ Drain/source channel charge partition in saturation for charge models, e.g. use 0.4 for 40/60, 0.5 for 50/50, 0 for 0/100.

Default instance parameters

- 102 $w=5e-6$ m Default channel width.
- 103 $l=5e-6$ m Default channel length.
- 104 $a_s=0$ m² Default area of source diffusion.
- 105 $a_d=0$ m² Default area of drain diffusion.
- 106 $p_s=0$ m Default perimeter of source diffusion.
- 107 $p_d=0$ m Default perimeter of drain diffusion.
- 108 $nrd=0$ m/m Default number of squares of drain diffusion.
- 109 $nrs=0$ m/m Default number of squares of source diffusion.

Temperature effects parameters

- 110 t_{nom} (C) Parameters measurement temperature. Default set by `options`.

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BSIM3v2 Level-10 Model (bsim3)

111	$\text{trise}=0$	C	Temperature rise from ambient.
112	$\text{tlev}=0$		DC temperature selector.
113	$\text{tlevc}=0$		AC temperature selector.
114	$\text{eg}=1.12452$	V	Energy band gap.
115	$\text{gap1}=7.02\text{e-}4$	V/C	Band gap temperature coefficient.
116	$\text{gap2}=1108$	C	Band gap temperature offset.
117	$\text{kt1}=-0.11$	V	Temperature coefficient for threshold voltage.
118	$\text{kt11}=-1.86\text{e-}7$	v m	Temperature coefficient for threshold voltage.
119	$\text{kt2}=0.022$		Temperature coefficient for threshold voltage.
120	$\text{at}=3.3\text{e}4$	m/s	Temperature coefficient for v_{sat} .
121	$\text{ua1}=4.31\text{e-}9$	m/v	Temperature coefficient for u_a .
122	$\text{ub1}=-7.61\text{e-}18$	m^2/v^2	Temperature coefficient for u_b .
123	$\text{uc1}=-0.056$	1/V	Temperature coefficient for u_c .
124	$\text{trs}=0$	1/C	Temperature parameter for source resistance.
125	$\text{trd}=0$	1/C	Temperature parameter for drain resistance.
126	$\text{ute}=-1.5$		Mobility temperature exponent.
127	$\text{xti}=3$		Saturation current temperature exponent.
128	$\text{ptc}=0$	V/C	Surface potential temperature coefficient.
129	$\text{tcv}=0$	V/C	Threshold voltage temperature coefficient.
130	$\text{pta}=0$	V/C	Junction potential temperature coefficient.
131	$\text{ptp}=0$	V/C	Sidewall junction potential temperature coefficient.

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BSIM3v2 Level-10 Model (bsim3)

- 132 `cta=0 1/C` Junction capacitance temperature coefficient.
- 133 `ctp=0 1/C` Sidewall junction capacitance temperature coefficient.

Noise model parameters

- 134 `noisemod=1` Noise model selector.
- 135 `kf=0` Flicker (1/f) noise coefficient.
- 136 `af=1` Flicker (1/f) noise exponent.
- 137 `ef=1` Flicker (1/f) noise frequency exponent.
- 138 `wnoi=1e-5 m` Channel width at which noise parameters were extracted.
- 139 `a=1e16 for nmos and 9.9e14 for pmos`
Oxide trap density coefficient.
- 140 `b=5e4 for nmos and 2.4e3 for pmos`
Oxide trap density coefficient.
- 141 `c=-1.4e-8 for nmos and 1.4e-8 for pmos`
Oxide trap density coefficient.

Operating region warning control parameters

- 142 `alarm=none` Forbidden operating region.
Possible values are `none, off, triode, sat, subth, or rev`.
- 143 `imax=1 A` Maximum allowable current.
- 144 `jmax=1e8 A/m2` Maximum allowable current density.
- 145 `bvj= ∞ V` Junction reverse breakdown voltage.
- 146 `vbox=1e9 tox V` Oxide breakdown voltage.
- 147 `maxvp=1.12 V` Maximum allowable voltage across the gate poly layer.

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BSIM3v2 Level-10 Model (bsim3)

Compatibility model parameters

148 `compatible=spectre`
Encourage device equations to be compatible with a foreign simulator. This option does not affect input syntax.
Possible values are `spectre`, `spice2`, `spice3`, `cdsspice`, `hspice`, `spiceplus`, `eldo`, `sspice`, or `mica`.

Auto Model Selector parameters

149 `wmax=1.0 m` Maximum channel width for which the model is valid.
150 `wmin=0.0 m` Minimum channel width for which the model is valid.
151 `lmax=1.0 m` Maximum channel length for which the model is valid.
152 `lmin=0.0 m` Minimum channel length for which the model is valid.

HSPICE junction model

153 `acm=12` HSPICE junction area calculation method selector.
154 `jsw=0.0 A/m` Sidewall bulk junction saturation current density.
155 `nds=1.0` Reverse bias slope coefficient.
156 `vnds=-1.0 V` Reverse diode current transition point.
157 `cjgate=`cjswF/m'` Zero bias gate-edge sidewall bulk junction capacitance density.
158 `php= pb V` Bulk junction sidewall contact potential.
159 `tt=0.0 s` Transit time.
160 `ld (m)` Lateral diffusion into the channel from the source and drain diffusion.
161 `wmlt=1.0` Width diffusion layer shrink reduction factor.
162 `ijth=1.0 A` Explosion current.

`Imax` and `Imelt`:

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BSIM3v2 Level-10 Model (bsim3)

The `imax` parameter aids convergence and prevents numerical overflow. The junction characteristics of the device are accurately modeled for current up to `imax`. If `imax` is exceeded during iterations, the linear model is substituted until the current drops below `imax` or until convergence is achieved. If convergence is achieved with the current exceeding `imax`, the results are inaccurate, and Spectre prints a warning.

A separate model parameter, `imelt`, is used as a limit warning for the junction current. This parameter can be set to the maximum current rating of the device. When any component of the junction current exceeds `imelt`, note that base and collector currents are composed of many exponential terms, Spectre issues a warning and the results become inaccurate. The junction current is linearized above the value of `imelt` to prevent arithmetic exception, with the exponential term replaced by a linear equation at `imelt`.

Both of these parameters have current density counterparts, `jmax` and `jmel`, that you can specify if you want the absolute current values to depend on the device area.

Auto Model Selection:

Many models need to be characterized for different geometries in order to obtain accurate results for model development. The model selector program automatically searches for a model with the length and width range specified in the instance statement and uses this model in the simulations.

For the auto model selector program to find a specific model, the models to be searched should be grouped together within braces. Such a group is called a model group. An opening brace is required at the end of the line defining each model group. Every model in the group is given a name followed by a colon and the list of parameters. Also, the four geometric parameters `lmax`, `lmin`, `wmax`, and `wmin` should be given. The selection criteria to choose a model is as follows:

$$lmin \leq inst_length < lmax \quad \text{and} \quad wmin \leq inst_width < wmax$$

Example:

```
model ModelName ModelType {  
    1: <model parameters> lmin=2 lmax=4 wmin=1 wmax=2  
    2: <model parameters> lmin=1 lmax=2 wmin=2 wmax=4  
    3: <model parameters> lmin=2 lmax=4 wmin=4 wmax=6  
}
```

Then for a given instance

Virtuoso Simulator Components and Device Models Reference

BSIM3v2 Level-10 Model (bsim3)

M1 1 2 3 4 ModelName w=3 l=1.5

the program would search all the models in the model group with the name `ModelName` and then pick the first model whose geometric range satisfies the selection criteria. In the preceding example, the auto model selector program would choose `ModelName.2`.

You must specify both length (*l*) and width (*w*) on the device instance line to enable automatic model selection.

Output Parameters

- | | | |
|---|--|------------------------------|
| 1 | <code>w_{eff}</code> (m) | Effective channel width. |
| 2 | <code>l_{eff}</code> (m) | Effective channel length. |
| 3 | <code>r_{seff}</code> (Ω) | Effective source resistance. |
| 4 | <code>r_{deff}</code> (Ω) | Effective drain resistance. |

Operating-Point Parameters

- | | | |
|---|----------------------------|--|
| 1 | <code>type=n</code> | Transistor type.
Possible values are <code>n</code> or <code>p</code> . |
| 2 | <code>region=triode</code> | Estimated operating region. Spectre outputs number (0-4) in a rawfile.
Possible values are <code>off</code> , <code>triode</code> , <code>sat</code> , <code>subth</code> , or <code>breakdown</code> . |
| 3 | <code>reversed</code> | Reverse mode indicator.
Possible values are <code>no</code> or <code>yes</code> . |
| 4 | <code>ids</code> (A) | Resistive drain-to-source current. |
| 5 | <code>vgs</code> (V) | Gate-source voltage. |
| 6 | <code>vds</code> (V) | Drain-source voltage. |
| 7 | <code>vbs</code> (V) | Bulk-source voltage. |
| 8 | <code>vth</code> (V) | Threshold voltage. |
| 9 | <code>vdsat</code> (V) | Drain-source saturation voltage. |

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BSIM3v2 Level-10 Model (bsim3)

10	g_m (S)	Common-source transconductance.
11	g_{ds} (S)	Common-source output conductance.
12	g_{mbs} (S)	Body-transconductance.
13	β_{eff} (A/V ²)	Effective β .
14	c_{bd} (F)	Drain-bulk junction capacitance.
15	c_{bs} (F)	Source-bulk junction capacitance.
16	c_{gs} (F)	Gate-source capacitance.
17	c_{gd} (F)	Gate-drain capacitance.
18	c_{gb} (F)	Gate-bulk capacitance.
19	r_{on} (Ω)	On-resistance.
20	i_d (A)	Resistive drain current.
21	i_{bulk} (A)	Resistive bulk current.
22	pwr (W)	Power at op point.
23	$g_{moverid}$ (1/V)	Gm/Ids.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

a	M-139	etab	M-65	n	M-81	tlevc	M-113
a0	M-22	fc	M-94	nds	M-155	tnom	M-110

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BSIM3v2 Level-10 Model (bsim3)

a1	M-23	fcsw	M-98	nfactor	M-60	tox	M-32
a2	M-24	gamma1	M-10	ngate	M-28	trd	M-125
acm	M-153	gamma2	M-11	nlx	M-9	trise	I-12
ad	I-4	gap1	M-115	noisemod	M-134	trise	M-111
ad	M-105	gap2	M-116	npeak	M-27	trs	M-124
af	M-136	gds	OP-11	nrd	I-7	tt	M-159
alarm	M-142	geo	I-13	nrd	M-108	type	M-1
alpha	M-47	gm	OP-10	nrs	I-8	type	OP-1
as	I-3	gmbs	OP-12	nrs	M-109	ua	M-40
as	M-104	gmoverid	OP-23	nsub	M-26	ua1	M-121
at	M-120	hdif	M-77	pb	M-93	ub	M-41
b	M-140	ibulk	OP-21	pbsw	M-97	ub1	M-122
betaeff	OP-13	id	OP-20	pclm	M-49	uc	M-42
bulkmod	M-45	ids	OP-4	pd	I-6	uc0	M-43
bvj	M-145	ijth	M-162	pd	M-107	uc1	M-123
c	M-141	imax	M-143	pdibl1	M-50	uo	M-38
capmod	M-99	imelt	M-83	pdibl2	M-51	ute	M-126
cbd	M-90	is	M-80	phi	M-3	vbi	M-17
cbd	OP-14	isnoisy	I-9	php	M-158	vbm	M-18
cbs	M-89	jmax	M-144	ps	I-5	vbox	M-146
cbs	OP-15	jmelt	M-84	ps	M-106	vbs	OP-7

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BSIM3v2 Level-10 Model (bsim3)

cdsc	M-58	js	M-79	pscbe1	M-52	vbx	M-16
cdscb	M-59	jsw	M-154	pscbe2	M-53	vdd	M-33
cgb	OP-18	k1	M-4	pta	M-130	vds	OP-6
cgbo	M-87	k2	M-5	ptc	M-128	vdsat	OP-9
cgd	OP-17	k3	M-6	ptp	M-131	vfb	M-15
cgdo	M-86	k3b	M-7	pvag	M-54	vghigh	M-56
cgs	OP-16	keta	M-25	pwr	OP-22	vglow	M-57
cgso	M-85	kf	M-135	rd	M-68	vgs	OP-5
cit	M-61	kt1	M-117	rdc	M-72	vnds	M-156
cj	M-91	kt11	M-118	rdd	M-74	voff	M-62
cjgate	M-157	kt2	M-119	rdeff	O-4	vsat	M-39
cjsw	M-95	l	I-2	rds0	M-36	vth	OP-8
compatible	M-148	l	M-103	rds1	M-37	vtho	M-2
cta	M-132	ld	M-160	region	I-11	w	I-1
ctp	M-133	ldd	M-35	region	OP-2	w	M-102
dl	M-30	ldif	M-76	reversed	OP-3	w0	M-8
drout	M-46	leff	O-2	ron	OP-19	weff	O-1
dskip	M-82	lgcd	M-70	rs	M-67	wmax	M-149
dsub	M-63	lgcs	M-69	rsc	M-71	wmin	M-150
dvt0	M-19	lit1	M-14	rseff	O-3	wmlt	M-161
dvt1	M-20	lmax	M-151	rsh	M-66	wnoi	M-138

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BSIM3v2 Level-10 Model (bsim3)

dvt2	M-21	lmin	M-152	rss	M-73	xj	M-29
dw	M-31	m	I-10	satmod	M-44	xpart	M-100
ef	M-137	maxvp	M-147	sc	M-75	xqc	M-101
eg	M-114	meto	M-88	subthmod	M-55	xt	M-34
em	M-48	minr	M-78	tcv	M-129	xti	M-127
eta	M-13	mj	M-92	theta	M-12		
eta0	M-64	mjsw	M-96	tlev	M-112		

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BSIM3v2 Level-10 Model (bsim3)

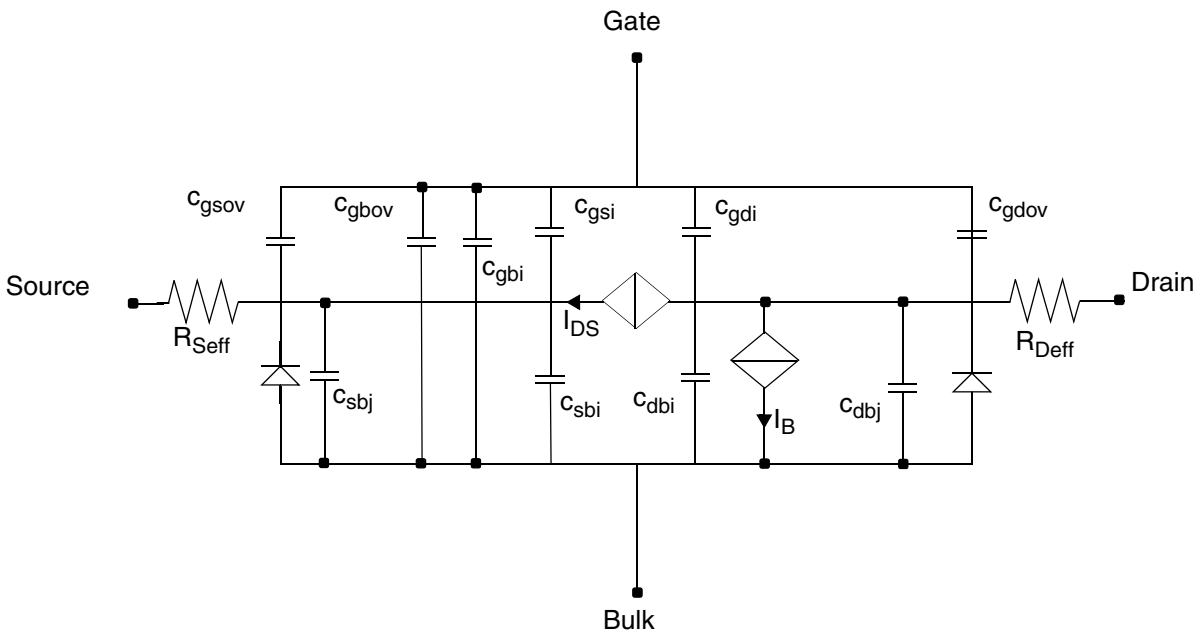
BSIM3v3 Level-11 Model (bsim3v3)

The BSIM3v3 model is based on the industry standard efforts of the Compact Modeling Counsel (CMC) and the BSIM modeling group at the University of California, Berkeley. The available versions for BSIM3v3 model are 3.1, 3.2, 3.21, 3.22, 3.23, 3.24, and 3.3. This chapter contains the following information:

- [Spectre-Specific Parameters](#) on page 1154
- [I-V Model](#) on page 1159
- [Capacitance Model](#) on page 1166
- [Nonquasi-static \(NQS\) Model](#) on page 1185
- [SPICE3 Junction Diode Model](#) on page 1186
- [Flicker Noise](#) on page 1186
- [Channel Thermal Noise](#) on page 1188
- [Default Model Parameter Value Calculation](#) on page 1189
- [Gate Leak Currents](#) on page 1191
- [LOD Model](#) on page 1195
- [Differences between BSIM3v3 Subversions](#) on page 1198
- [Parameter Differences between BSIM3v3 Levels](#) on page 1201
- [Scaling Effects](#) on page 1202
- [Component Statements](#) on page 1203
- [Binning Parameters](#) on page 1256

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BSIM3v3 Level-11 Model (bsim3v3)



Spectre-Specific Parameters

Some of the following parameters are left in the model for backward compatibility to other Virtuoso[®] Spectre[®] circuit simulator models.

Instance Parameters

The instance parameters mentioned in the table below help you in performing mismatch analyses. They represent the statistical variation of the threshold voltage (v_{th0}), the mobility (μ_0), the body bias coefficient (k_1) and the subthreshold swing factor (N_{factor}). These parameters are implemented in the following manner:

Parameter	Unit	Description
Delvto	v	shift in zero-bias threshold voltage v_{th0} . Default value is 0.0.
Nulmu0		Mobility multiplier. Default value is 1.0.
Delk1	$v^{1/2}$	shift in body bias coefficient k_1 . Default value is 0.0.
Delnfct		Shift in subthreshold swing factor. Default value is 0.0.

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BSIM3v3 Level-11 Model (bsim3v3)

The checking of these parameters is as follows:

- If $Mulmu0 < 0.0$ and Paramchk returns a warning message, reset Mulmu0 to 1.0.
- If $Delk1 < -K1$ (after binning) and Paramchk returns a warning message, reset Delk1 to 0.0.

The parameters are added whether V_{to} and $K1$ are given (specified by you or computed internally when not specified). Mulmu0 is multiplied after binning.

Model Parameters

Parameter	Description
ad	Area of drain diffusion. This is an instance parameter in Spice, but may be specified as a model parameter in Spectre.
alarm	Forbidden operating region. Can be set to <code>none</code> , <code>off</code> , <code>triode</code> , <code>sat</code> , <code>subth</code> , or <code>rev</code> . Spectre will issue a warning if your device's operating point enters this region.
as	Area of source diffusion. This is an instance parameter in Spice, but may be specified as a model parameter in Spectre.
bvj	The junction reverse breakdown voltage. Spectre checks this at the DC operating point, and also on each step of the transient simulation. Spectre issues a warning if the bulk-drain voltage exceeds this voltage.
cbd	Bulk-drain zero bias junction capacitance.
cbs	Bulk-drain zero bias junction capacitance.
cta	Junction capacitance temperature coefficient.
ctp	Sidewall junction capacitance temperature coefficient.
diomod	Controls the junction models. If $diomod=1$ (default value), the Spectre junction model is used. The equations are described in <i>Chapter 12: Common MOSFET Equations</i> . If $diomod=0$, the Berkeley BSIM3v3 junction model is used.
drout	DIBL effect on rout coefficient.
dskip	Allows the substitution of a simple <code>pwl</code> model for the diode current if it falls below $0.1 \cdot iabstol$.
eg	Energy band gap.

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BSIM3v3 Level-11 Model (bsim3v3)

<code>fc</code>	Forward bias depletion capacitance threshold.
<code>fcsw</code>	Sidewall forward bias depletion capacitance threshold.
<code>gap1</code>	Band gap temperature coefficient.
<code>gap2</code>	Bandgap temp offset.
<code>hdif</code>	Length of heavily doped diffusion.
<code>imax</code>	Maximum current.
<code>imelt</code>	Explosion current. The junction current is linearized after this current is exceeded.
<code>jmax</code>	Maximum current density.
<code>jmelt</code>	Explosion current density.
<code>is</code>	Bulk-junction reverse saturation current.
<code>l</code>	Default channel length, if not specified on the instance.
<code>ldif</code>	Lateral diffusion beyond the gate.
<code>lgcs</code>	Gate to contact length of source.
<code>lgcd</code>	Gate to contact length of drain.
<code>meto</code>	Metal overlap in fringing field.
<code>minr</code>	Minimum resistance.
<code>nrd</code>	Default number of drain squares. This is an instance parameter also.
<code>nrs</code>	Default number of source squares. This is an instance parameter also.
<code>pd</code>	Drain perimeter. This is an instance parameter also.
<code>ps</code>	Source perimeter. This is an instance parameter also.
<code>pta</code>	Junction potential temperature coefficient.
<code>ptp</code>	Sidewall junction potential temperature coefficient.
<code>rd</code>	Drain resistance.
<code>rdc</code>	Drain contact resistance.
<code>rdd</code>	Scalable drain resistance.
<code>rs</code>	Source resistance.
<code>rsc</code>	Source contact resistance.

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BSIM3v3 Level-11 Model (bsim3v3)

<code>rss</code>	Scalable source resistance.
<code>sc</code>	Contact spacing.
<code>tlev</code>	DC temperature selector.
<code>tlevc</code>	AC temperature selector.
<code>trd</code>	Temperature param for drain resistance.
<code>trise</code>	Temperature rise from ambient.
<code>trs</code>	Temperature param for source resistance.
<code>type</code>	Specifies <code>nmos</code> or <code>pmos</code> , since the primitive name is <code>bsim3v3</code> .
<code>xl</code>	Length variation from masking and etching.
<code>xw</code>	Width variation from masking and etching.
<code>w</code>	Default channel width, if not specified on the instance.
<code>warn</code>	Parameter to turn warnings off and on.
<code>wnoi</code>	Channel width at which noise parameters extracted.
<code>vbox</code>	Oxide breakdown voltage.

Note: `n` in the Spectre® circuit simulator is `nj` in Berkeley. `nqsmod` is an instance parameter for Berkeley, but both an instance and model parameter for the Spectre circuit simulator. `level=11` in the Spectre simulator, but `level=8` in Berkeley. The `ijth` parameter (diode-limiting current) is aliased to the Spectre simulator's `imelt` parameter. Some of the Spectre-specific parameters can affect the behavior of the model in such a way to make the model incompatible with other simulators. Cadence recommends that care be taken when using these parameters.

See `spectre -h bsim3v3` for more details about these parameters.

Drain and Source Area

The drain and source areas are calculated in the order shown in the following equations.

Drain and Source Perimeters

The drain and source perimeters are calculated in the order shown in the following equations:

$$\text{Drain perimeter} = \begin{cases} pd & \text{if } pd \text{ is given} \\ 4hidif*scalem + 2W_{scaled} & \text{if } hidif \text{ is given} \\ 2 \cdot (W_{eff} + ld) & \text{if } ld \text{ is given} \\ 0 & \text{otherwise} \end{cases}$$

$$\text{Source perimeter} = \begin{cases} ps & \text{if } ps \text{ is given} \\ 4hidif*scalem + 2W_{scaled} & \text{if } hidif \text{ is given} \\ 2 \cdot (W_{eff} + ls) & \text{if } ls \text{ is given} \\ 0 & \text{otherwise} \end{cases}$$

Note: The ld (length of drain) parameter is an instance parameter that is different from the model parameter ld (lateral diffusion) used in calculating L_{eff} .

Drain and Source Parasitic Resistance

$$\text{Drain area} = \begin{cases} ad & \text{if } ad \text{ is given} \\ 2hidif*scalem*W_{scaled} & \text{if } hidif \text{ is given} \\ W_{eff}*ld & \text{if } ld \text{ is given} \\ 0 & \text{otherwise} \end{cases}$$

$$\text{Source area} = \begin{cases} \phi_s & \text{if } as \text{ is given} \\ 2hidif * scalem * W_{scaled} & \text{if } hidif \text{ is given} \\ W_{eff} * l_s & \text{if } l_s \text{ is given} \\ 0 & \text{otherwise} \end{cases}$$

Note: The ld (length of drain) parameter is an instance parameter that is different from the model parameter ld (lateral diffusion) used in calculating L_{eff} .

I-V Model

Threshold Voltage

$$\begin{aligned} V_{TH} = & V_{tho} + K_1(\sqrt{\Phi_s - V_{bseff}} - \sqrt{\Phi_s}) - K_2 V_{bseff} \\ & + K_1 \left(\sqrt{1 + \frac{N_{Lx}}{L_{eff}}} - 1 \right) \sqrt{\Phi_s} + (K_3 + K_{3b} V_{bseff}) \times \frac{T_{ox}}{W_{eff} + W_0} \Phi_s - \\ & - D_{vtow} \left(\exp\left(-D_{vt1w} \frac{W_{eff} L_{eff}}{2l_{tw}}\right) + 2 \exp\left(-D_{vt1w} \frac{W_{eff} L_{eff}}{l_{tw}}\right) \right) (V_{bi} - \Phi_s) \\ & - D_{vto} \left(\exp\left(-D_{vt1} \frac{L_{eff}}{2l_t}\right) + 2 \exp\left(-D_{vt1} \frac{L_{eff}}{l_t}\right) \right) (V_{bi} - \Phi_s) \\ & - \left(\exp\left(-D_{sub} \frac{L_{eff}}{2l_{to}}\right) + 2 \exp\left(-D_{sub} \frac{L_{eff}}{l_{to}}\right) \right) (E_{tao} + E_{tab} V_{bseff}) V_{ds} \end{aligned}$$

where

$$l_t = \sqrt{\epsilon_{si} X_{dep} / C_{ox}} (1 + D_{vt2} V_{bseff})$$

$$l_{tw} = \sqrt{\epsilon_{si} X_{dep} / C_{ox}} (1 + D_{vt2w} V_{bseff})$$

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$$l_{to} = \sqrt{\varepsilon_{si} X_{dep0} / C_{ox}}$$

$$X_{dep} = \sqrt{\frac{2\varepsilon_{si}(\Phi_s - V_{bseff})}{qN_{ch}}}$$

$$X_{dep0} = \sqrt{\frac{2\varepsilon_{si}\Phi_s}{qN_{ch}}}$$

$$V_{bseff} = V_{bc} + 0.5 \left[V_{bs} - V_{bc} - \delta_1 + \sqrt{(V_{bs} - V_{bc} - \delta_1)^2 - 4\delta_1 V_{bc}} \right]$$

($\delta_1 = 0.001$)

$$V_{bc} = 0.9 \left(\Phi_s - \frac{K_1^2}{4K_2} \right)$$

$$V_{bi} = V_t \times \ln \left[\frac{N_{ch} N_{DS}}{n_i^2} \right]$$

$$N_{DS} = 10^{20}, V_t = \frac{kT}{q}, \text{ the thermal voltage}$$

Effective Vgs-Vthc

$$V_{gsteff} = \frac{2nv_t \ln \left[1 + \exp \left(\frac{V_{gs} - V_{th}}{2nv_t} \right) \right]}{1 + 2nC_{ox} \sqrt{\frac{2\Phi_s}{q\varepsilon_{si}N_{ch}}} \exp \left(-\frac{V_{gs} - V_{th} - 2V_{off}}{2nv_t} \right)}$$

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$$n = 1 + N_{factor} \frac{C_d}{C_{ox}} + \frac{(C_{dsc} + C_{dscd} V_{ds} + C_{dscb} V_{bseff}) \left(\exp\left(-D_{vt1} \frac{L_{eff}}{2l_t}\right) + 2 \exp\left(-D_{vt1} \frac{L_{eff}}{l_t}\right) \right)}{C_{ox}} + \frac{C_{it}}{C_{ox}}$$

$$C_d = \frac{\epsilon_{si}}{X_{dep}}$$

Mobility

For Mobmod=1,

$$\mu_{eff} = \frac{\mu_o}{1 + (U_a + U_c V_{bseff}) \left(\frac{V_{gsteff} + 2V_{th}}{T_{ox}} \right) + U_b \left(\frac{V_{gsteff} + 2V_{th}}{T_{ox}} \right)^2}$$

For Mobmod=2,

$$\mu_{eff} = \frac{\mu_o}{1 + (U_a + U_c V_{bseff}) \left(\frac{V_{gsteff}}{T_{ox}} \right) + U_b \left(\frac{V_{gsteff}}{T_{ox}} \right)^2}$$

For Mobmod=3,

$$\mu_{eff} = \frac{\mu_o}{1 + \left[U_a \left(\frac{V_{gsteff} + 2V_{th}}{T_{ox}} \right) + U_b \left(\frac{V_{gsteff} + 2V_{th}}{T_{ox}} \right)^2 \right] (1 + U_c V_{bseff})}$$

Drain Saturation Voltage

For $R_{ds} > 0$ or $\lambda \neq 1$,

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$$V_{DSAT} = \frac{-b - \sqrt{b^2 - 4ac}}{2a}$$

$$a = A_{bulk}^2 W_{eff} v_{sat} C_{ox} R_{ds} + \left(\frac{1}{\lambda} - 1\right) A_{bulk}$$

$$b = -\left((V_{gsteff} + 2v_t)\left(\frac{2}{\lambda} - 1\right) + A_{bulk} E_{sat} L_{eff} + 3A_{bulk}(V_{gsteff} + 2v_t)W_{eff} v_{sat} C_{ox} R_{ds}\right)$$

$$c = (V_{gsteff} + 2v_t)E_{sat} L_{eff} + 2(V_{gsteff} + 2v_t)^2 W_{eff} v_{sat} C_{ox} R_{ds}$$

$$\lambda = A_1 V_{gsteff} + A_2$$

For $R_{ds} = 0$ and $\lambda = 1$,

$$V_{DSAT} = \frac{E_{sat} L_{eff} (V_{gsteff} + 2v_t)}{A_{bulk} E_{sat} L_{eff} + (V_{gsteff} + 2v_t)}$$

$$A_{bulk} = \left(1 + \frac{K_1}{2\sqrt{\Phi_s - V_{bseff}}}\left\{\frac{A_o L_{eff}}{L_{eff} + 2\sqrt{X_j X_{dep}}}\left[1 - A_{gs} V_{gsteff}\right.\right.\right. \\ \left.\left.\left.\left(\frac{L_{eff}}{L_{eff} + 2\sqrt{X_j X_{dep}}}\right)^2 \frac{B_o}{W_{eff} B_1}\right]\right\}\right) \frac{1}{1 + K_{eta} V_{bseff}}$$

$$E_{sat} = \frac{2v_{sat}}{\mu_{eff}}$$

Effective Vds

$$V_{dseff} = V_{dsat} - \frac{1}{2}\left(V_{dsat} - V_{ds} - \delta + \sqrt{(V_{dsat} - V_{ds} - \delta)^2 + 4\delta V_{dsat}}\right)$$

Drain Current Expression

$$I_{DS} = \frac{I_{dso}(V_{dseff})}{1 + \frac{R_{ds} I_{dso}(V_{dseff})}{V_{dseff}}} \left(1 + \frac{V_{ds} - V_{dseff}}{V_a}\right) \left(1 + \frac{V_{ds} - V_{dseff}}{V_{asce}}\right)$$

$$I_{dso} = I_{dso} = \frac{W_{eff} \mu_{eff} C_{ox} V_{gsteff} \left(1 - A_{bulk} \frac{V_{dseff}}{2(V_{gsteff} + 2v_t)}\right) V_{dseff}}{L_{eff} [1 + V_{dseff}/(E_{sat} L_{eff})]}$$

$$V_a = V_{asat} + \left(1 + \frac{P_{vag} V_{gsteff}}{E_{sat} L_{eff}}\right) \left(\frac{1}{V_{aclm}} + \frac{1}{V_{adiblc}}\right)^{-1}$$

$$V_{aclm} = \frac{A_{bulk} E_{sat} L_{eff} + V_{gsteff}}{P_{clm} A_{bulk} E_{sat} L_{itl}} (V_{ds} - V_{dseff})$$

$$V_{adiblc} = \frac{(V_{gsteff} + 2v_t)}{\theta_{rout} (1 + P_{diblc} V_{bseff})} \left(1 - \frac{A_{bulk} V_{dsat}}{A_{bulk} V_{dsat} + V_{gsteff} + 2v_t}\right)$$

$$\theta_{rout} = P_{diblc1} \left[\exp\left(-D_{rout} \frac{L_{eff}}{2l_{t0}}\right) + 2 \exp\left(-D_{rout} \frac{L_{eff}}{l_{t0}}\right) \right] + P_{diblc2}$$

$$\frac{1}{V_{asce}} = \frac{P_{scke2}}{L_{eff}} \exp\left(\frac{-P_{scke1} L_{itl}}{V_{ds} - V_{dseff}}\right)$$

$$V_{asat} = \frac{E_{sat} L_{eff} + V_{dsat} + 2R_{ds} v_{sat} C_{ox} W_{eff} V_{gsteff} \left[1 - \frac{A_{bulk} V_{dsat}}{2(V_{gsteff} + 2v_t)}\right]}{2/\lambda - 1 + R_{ds} v_{sat} C_{ox} W_{eff} A_{bulk}}$$

$$L_{itl} = \sqrt{\frac{\epsilon_{si} T_{ox} X_j}{\epsilon_{ox}}}$$

Substrate Current

$$I_{sub} = \frac{\alpha}{L_{eff}}(V_{ds} - V_{dseff}) \exp\left(-\frac{\beta_o}{V_{ds} - V_{dseff}}\right) \frac{I_{dso}}{1 + \frac{R_{ds} I_{dso}}{V_{dseff}}} \left(1 + \frac{V_{ds} - V_{dseff}}{V_a}\right)$$

$$\alpha = \alpha_0 + \alpha_1 L_{eff}$$

Junction Saturation Current

i_s always overrides j_s . If you give j_s but not i_s , the saturation currents are calculated from j_s and the source and drain areas.

$$\text{Drain saturation current} = \begin{cases} i_s & \text{if } i_s \text{ is given} \\ j_s * ad + j_{sw} \times pd & \text{otherwise} \end{cases}$$

$$\text{Source saturation current} = \begin{cases} i_s & \text{if } i_s \text{ is given} \\ j_s * as + j_{sw} \times ps & \text{otherwise} \end{cases}$$

Polysilicon Depletion Effect

$$V_{poly} = \frac{1}{2} X_{poly} E_{poly} = \frac{q N_{gate} X_{poly}^2}{2 \epsilon_{si}}$$

$$\epsilon_{ox} E_{ox} = \epsilon_{si} E_{poly} = \sqrt{2q \epsilon_{si} N_{gate} V_{poly}}$$

$$V_{gs} - V_{fb} - \Phi_s = V_{poly} + V_{ox}$$

$$a(V_{gs} - V_{fb} - \Phi_s - V_{poly})^2 - V_{poly} = 0$$

$$a = \frac{\varepsilon_{ox}^2}{2q\varepsilon_{si}N_{gate}T_{ox}^2}$$

$$V_{gs_eff} = V_{fb} + \Phi_s + \frac{q\varepsilon_{si}N_{gate}T_{ox}^2}{\varepsilon_{ox}^2} \left(\sqrt{1 + \frac{2\varepsilon_{ox}^2(V_{gs} - V_{FB} - \Phi_s)}{q\varepsilon_{si}N_{gate}T_{ox}^2}} - 1 \right)$$

Effective Channel Length and Width

$$L_{eff} = L_{drawn} - 2dL$$

where

$$L_{drawn} = L(\text{given}) \times \text{scale} + xl \times \text{scalem}$$

$$W_{eff} = W_{drawn} - 2dW$$

$$W_{eff}' = W_{drawn} - 2dW'$$

$$dW = dW' + dW_g V_{gsteff} + dW_b (\sqrt{\Phi_s - V_{bseff}} - \sqrt{\Phi_s})$$

$$dW' = W_{int} + \frac{W_l}{L^{L_{ln}}} + \frac{W_w}{W^{L_{wn}}} + \frac{W_{wl}}{L^{L_{ln}} W^{L_{wn}}}$$

$$dL = L_{int} + \frac{L_l}{L^{L_{ln}}} + \frac{L_w}{W^{L_{wn}}} + \frac{L_{wl}}{L^{L_{ln}} W^{L_{wn}}}$$

$$W_{effc} = W_{drawn} - dWC$$

Drain/Source Resistance

$$R_{ds} = \frac{R_{dsw} [1 + P_{rwg} V_{gseff} + P_{rwb} (\sqrt{\Phi_s - V_{bseff}} - \sqrt{\Phi_s})]}{(10^6 W_{eff}')^{Wr}}$$

Temperature Effects

$$V_{th(T)} = V_{th}(T_{nom}) + (K_{t1} + K_{t1l}/L_{eff} + K_{t2} V_{bseff}) \left(\frac{T}{T_{nom}} - 1 \right)$$

$$\mu_{o(T)} = \mu_o(T_{nom}) \left(\frac{T}{T_{nom}} \right)^{U_{te}}$$

$$v_{sat(T)} = v_{sat}(T_{nom}) - A_t \left(\frac{T}{T_{nom}} - 1 \right)$$

$$R_{dsw(T)} = R_{dsw}(T_{nom}) + P_{rt} \left(\frac{T}{T_{nom}} - 1 \right)$$

$$U_{a(T)} = U_a(T_{nom}) + U_{a1} \left(\frac{T}{T_{nom}} - 1 \right)$$

$$U_{b(T)} = U_b(T_{nom}) + U_{b1} \left(\frac{T}{T_{nom}} - 1 \right)$$

$$U_{c(T)} = U_c(T_{nom}) + U_{c1} \left(\frac{T}{T_{nom}} - 1 \right)$$

Capacitance Model

Dimension Dependence

$$L_{active} = L_{drawn} - 2\delta L_{eff}$$

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$$\delta L_{eff} = D_{lc} + \frac{L_{lc}}{L_{ln}} + \frac{L_{wc}}{W_{wn}} + \frac{L_{wlc}}{L_{ln} W_{wn}}$$

$$W_{active} = W_{drawn} - 2\delta W_{eff}$$

$$\delta W_{eff} = D_{wc} + \frac{W_{lc}}{W_{ln}} + \frac{W_{wc}}{W_{wn}} + \frac{W_{wlc}}{L_{ln} W_{wn}}$$

Junction Capacitance

If $pd > W_{eff}$,

$$cd = ad \times cjbs + pd \times cjbssw - W_{eff} \times cjbssw + W_{eff} \times cjbsswg$$

otherwise

$$cd = ad \times cjbs + pd \times cjbssw$$

where

$cjbs$ is a function of cj , mj , and pb

$cjbssw$ is a function of $cjsw$, $mjsw$, and $pbsw$

$cjbsswg$ is a function of $cjswg$, $mjswg$, and $pbswg$

Overlap Capacitance (for NMOS)

$$OverlapCgs = \begin{cases} C_{gso} & \text{if } cgso \text{ is given} \\ (dlc + meto) \times C_{ox} - C_{gsl} & \text{if } dlc \text{ is given and } dlc > 0 \\ 0.6 \times X_j \times C_{ox} & \text{otherwise} \end{cases}$$

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$$OverlapCgd = \begin{cases} C_{gdo} & \text{if } cgdo \text{ is given} \\ (dlc + meto) \times C_{ox} - C_{gdl} & \text{if } dlc \text{ is given and } dlc > 0 \\ 0.6 \times X_j \times C_{ox} & \text{otherwise} \end{cases}$$

$$OverlapCgb = \begin{cases} C_{gbo} & \text{if } cgso \text{ is given} \\ 2.0 \times dwc \times C_{ox} & \text{otherwise} \end{cases}$$

If $OverlapCgs/OverlapCgd < 0$, $OverlapCgs/OverlapCgd = 1.0e-7 \times Tox$

$OverlapCgb < 0$, $OverlapCgb = 0$

Source Overlap Capacitance

For $capmod=0$,

$$Q_{overlap,s} = C_{gso} V_{gs} W_{active}$$

For $capmod=1$,

if ($V_{gs} < 0$),

$$Q_{overlap,s} = \left[C_{gso} V_{gs} + \frac{C_{kappa} C_{gsl}}{2} \left(-1 + \sqrt{1 - \frac{4V_{gs}}{C_{kappa}}} \right) \right] W_{active}$$

else

$$Q_{overlap,s} = [(C_{gso} + C_{kappa} C_{gsl}) V_{gs}] W_{active}$$

For $capmod=2$,

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$$Q_{overlap, s} = \left[C_{gso} V_{gs} + C_{gsl} \left\{ V_{gs} - V_{gs, overlap} + \frac{C_{kappa}}{2} \left(-1 + \sqrt{1 + \frac{4V_{gs, overlap}}{C_{kappa}}} \right) \right\} \right] W_{active}$$

$$V_{gs, overlap} = \frac{1}{2} \left\{ (V_{gs} + \delta_1) - \sqrt{(V_{gs} + \delta_1)^2 + 4\delta_1} \right\} \quad \text{where } \delta_1 = 0.02$$

Drain Overlap Capacitance

For capmod=0,

$$Q_{overlap, d} = C_{gdo} V_{gd} W_{active}$$

For capmod=1,

if ($V_{gd} < 0$),

$$Q_{overlap, d} = \left[C_{gdo} V_{gd} + \frac{C_{kappa} C_{gdl}}{2} \left(-1 + \sqrt{1 - \frac{4V_{gd}}{C_{kappa}}} \right) \right] W_{active}$$

else

$$\frac{Q_{overlap, d}}{W_{active}} = (C_{gdo} + C_{kappa} C_{gdl}) V_{gd}$$

For capmod=2 or 3,

$$Q_{Q_{overlap,d}} = \left[C_{gdo} V_{gd} + C_{gdl} \left\{ V_{gd} - V_{gd,overlap} + \frac{C_{kappa}}{2} \left(-1 + \sqrt{1 + \frac{4V_{gd,overlap}}{C_{kappa}}} \right) \right\} \right] W_{active}$$

$$V_{gd,overlap} = \frac{1}{2} \left\{ (V_{gd} + \delta_1) - \sqrt{(V_{gd} + \delta_1)^2 + 4\delta_1} \right\} \quad \text{where } \delta_1 = 0.02$$

Gate Overlap Charge

$$Q_{overlap,g} = -(Q_{overlap,s} + Q_{overlap,d})$$

Intrinsic Charges

For capmod=0

Accumulation region ($V_{gs} < V_{fb} + V_{bs}$)

$$Q_g = W_{active} L_{active} C_{ox} (V_{gs} - V_{bs} - V_{fbcv})$$

$$Q_{sub} = -Q_g$$

$$Q_{inv} = 0$$

Subthreshold region ($V_{gs} < V_{th}$)

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$$Q_b = -W_{active} L_{active} C_{ox} \frac{K_1^2}{2} \left(-1 + \sqrt{1 + \frac{4(V_{gs} - V_{fbcv} - V_{bs})}{K_1^2}} \right)$$

$$Q_g = -Q_b$$

$$Q_{inv} = 0$$

Strong inversion ($V_{gs} > V_{th}$)

$$V_{dsat, cv} = \frac{V_{gs} - V_{th}}{A_{bulk}'}$$

$$A_{bulk}' = \begin{cases} A_{bulk0} \left(1 + \left(\frac{C_{lc}}{L_{eff}} \right)^{C_{le}} \right) & \text{if version} \leq 3.1 \\ A_{bulk0} \left(1 + \left(\frac{C_{lc}}{L_{active}} \right)^{C_{le}} \right) & \text{if version} > 3.1 \end{cases}$$

$$A_{bulk0} = \left(1 + \frac{K_1}{2\sqrt{\Phi_s - V_{bs}}} \left\{ \frac{A_0 L_{eff}}{L_{eff} + 2\sqrt{X_j X_{dep}}} + \frac{B_o}{W_{eff}' + B_1} \right\} \right) \frac{1}{1 + K_{eta} V_{bs}}$$

$$V_{TH} = V_{fbcv} + \Phi_s + K_1 \sqrt{\Phi_s - V_{bs}}$$

50/50 Charge Partition

If $V_{ds} < V_{dsat}'$

$$Q_g = C_{ox} W_{active} L_{active} \left[V_{gs} - V_{fbcv} - \Phi_s - \frac{V_{ds}}{2} + \frac{A_{bulk}' \times V_{ds}^2}{12 \left(V_{gs} - V_{th} - \frac{A_{bulk}' V_{ds}}{2} \right)} \right]$$

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$$Q_{inv} = -W_{active}L_{active}C_{ox} \left(V_{gs} - V_{th} - \frac{A_{bulk}' \times V_{ds}}{2} + \frac{A_{bulk}'^2 V_{ds}^2}{12 \left(V_{gs} - V_{th} + \frac{A_{bulk}' V_{ds}}{2} \right)} \right)$$

$$Q_b = W_{active}L_{active}C_{ox} \left[V_{fbcv} - V_{th} + \Phi_s + \frac{(1 - A_{bulk}')V_{ds}}{2} - \frac{(1 - A_{bulk}')A_{bulk}'V_{ds}^2}{12 \left(V_{gs} - V_{th} - \frac{A_{bulk}' V_{ds}}{2} \right)} \right]$$

$$Q_s = Q_d = 0.5Q_{inv}$$

$$0.5Q_{inv} = -W_{active}L_{active}C_{ox} \left[V_{gs} - V_{th} - \frac{A_{bulk}' V_{ds}}{2} + \frac{A_{bulk}'^2 V_{ds}^2}{12 \left(V_{gs} - V_{th} - \frac{A_{bulk}' V_{ds}}{2} \right)} \right]$$

otherwise,

$$Q_g = W_{active}L_{active}C_{ox} \left(V_{gs} - V_{fbcv} - \Phi_s - \frac{V_{dsat}}{3} \right)$$

$$Q_s = Q_d = -\frac{1}{3}W_{active}L_{active}C_{ox}(V_{gs} - V_{th})$$

$$Q_b = -W_{active}L_{active}C_{ox} \left(V_{fbcv} + \Phi_s - V_{th} + \frac{(1 - A_{bulk}')V_{dsat}}{3} \right)$$

40/60 Channel-Charge Partition

If $V_{ds} < V_{dsat}$,

$$Q_g = C_{ox}W_{active}L_{active} \left[V_{gs} - V_{fbcv} - \Phi_s - \frac{V_{ds}}{2} + \frac{A_{bulk}'V_{ds}^2}{12 \left(V_{gs} - V_{th} - \frac{A_{bulk}' V_{ds}}{2} \right)} \right]$$

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$$Q_{inv} = -W_{active}L_{active}C_{ox} \left[V_{gs} - V_{th} - \frac{A_{bulk}'V_{ds}}{2} + \frac{A_{bulk}'^2V_{ds}^2}{12\left(V_{gs} - V_{th} - \frac{A_{bulk}'V_{ds}}{2}\right)} \right]$$

$$Q_b = W_{active}L_{active}C_{ox} \left[V_{fbcv} - V_{th} + \Phi_s + \frac{(1 - A_{bulk}')V_{ds}}{2} - \frac{(1 - A_{bulk}')A_{bulk}'V_{ds}^2}{12\left(V_{gs} - V_{th} - \frac{A_{bulk}'V_{ds}}{2}\right)} \right]$$

$$Q_d = -W_{active}L_{active}C_{ox} \times$$

$$\left[\frac{V_{gs} - V_{th}}{2} - \frac{A_{bulk}'V_{ds}}{2} + \frac{A_{bulk}'V_{ds} \times \left[\frac{(V_{gs} - V_{th})^2}{6} - \frac{A_{bulk}'V_{ds}(V_{gs} - V_{th})}{8} + \frac{A_{bulk}'^2V_{ds}^2}{40} \right]}{\left(V_{gs} - V_{th} - \frac{A_{bulk}'V_{ds}}{2}\right)^2} \right]$$

$$Q_s = -(Q_g + Q_b + Q_d)$$

otherwise,

$$Q_g = W_{active}L_{active}C_{ox} \left(V_{gs} - V_{fbcv} - \Phi_s - \frac{V_{dsat}}{3} \right)$$

$$Q_d = -\frac{4}{15}W_{active}L_{active}C_{ox}(V_{gs} - V_{th})$$

$$Q_s = -(Q_g + Q_b + Q_d)$$

$$Q_b = -W_{active}L_{active}C_{ox} \left(V_{fbcv} + \Phi_s - V_{th} + \frac{(1 - A_{bulk}')V_{dsat}}{3} \right)$$

0/100 Channel-Charge Partition

If $V_{ds} < V_{dsat}$,

$$Q_g = C_{ox} W_{active} L_{active} \left[V_{gs} - V_{fbcv} - \Phi_s - \frac{V_{ds}}{2} + \frac{A_{bulk}' V_{ds}^2}{12 \Delta \left(V_{gs} - V_{th} - \frac{A_{bulk}' V_{ds}}{2} \right)} \right]$$

$$Q_{inv} = -W_{active} L_{active} C_{ox} \left[V_{gs} - V_{th} - \frac{A_{bulk}' V_{ds}}{2} + \frac{A_{bulk}'^2 V_{ds}^2}{12 \left(V_{gs} - V_{th} - \frac{A_{bulk}' V_{ds}}{2} \right)} \right]$$

$$Q_b = W_{active} L_{active} C_{ox} \left[V_{fbcv} - V_{th} + \Phi_s + \frac{(1 - A_{bulk}') V_{ds}}{2} - \frac{(1 - A_{bulk}') A_{bulk}' V_{ds}^2}{12 \left(V_{gs} - V_{th} - \frac{A_{bulk}' V_{ds}}{2} \right)} \right]$$

$$Q_d = -W_{active} L_{active} C_{ox} \left[\frac{V_{gs} - V_{th}}{2} + \frac{A_{bulk}' V_{ds}}{4} - \frac{(A_{bulk}' V_{ds})^2}{24 \left(V_{gs} - V_{th} - \frac{A_{bulk}' V_{ds}}{2} \right)} \right]$$

$$Q_s = -(Q_g + Q_b + Q_d)$$

otherwise,

$$Q_g = W_{active} L_{active} C_{ox} \left(V_{gs} - V_{fbcv} - \Phi_s - \frac{V_{dsat}}{3} \right)$$

$$Q_b = -W_{active} L_{active} C_{ox} \left(V_{fbcv} + \Phi_s - V_{th} + \frac{(1 - A_{bulk}') V_{dsat}}{3} \right)$$

$$Q_d = 0$$

$$Q_s = -(Q_g + Q_b)$$

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For capmod=1

if $V_{gs} < V_{fb} + V_{bs} + V_{gsteffcv}$

$$Q_{g1} = -W_{active} L_{active} C_{ox} (V_{gs} - V_{fb} - V_{bs} - V_{gsteffcv})$$

else

$$Q_{g1} = W_{active} L_{active} C_{ox} \frac{K_1^2}{2} \left(-1 + \sqrt{1 + \frac{4(V_{gs} - V_{FB} - V_{gsteffcv} - V_{bs})}{K_1^2}} \right)$$

$$Q_{b1} = -Q_{g1}$$

$$V_{fb} = \begin{cases} V_{th} - \Phi_s - K_1 \sqrt{\Phi_s} & \text{if version} \leq 3.1 \text{ and version} = 3.2.1 \\ V_{th}(V_{bs} = 0) - \Phi_s - K_1 \sqrt{\Phi_s} & \text{if version} = 3.2 \text{ and version} = 3.2.2 \end{cases}$$

$$V_{dsat, cv} = \frac{V_{gsteffcv}}{A_{bulk}'}$$

$$A_{bulk}' = \begin{cases} A_{bulk0} \left(1 + \left(\frac{C_{lc}}{L_{eff}} \right)^{C_{le}} \right) & \text{if version} \leq 3.1 \\ A_{bulk0} \left(1 + \left(\frac{C_{lc}}{L_{active}} \right)^{C_{le}} \right) & \text{if version} > 3.1 \end{cases}$$

$$A_{bulk0} = \left(1 + \frac{K_1}{2\sqrt{\Phi_s - V_{bseff}}} \left\{ \frac{A_0 L_{eff}}{L_{eff} + 2\sqrt{X_j X_{dep}}} + \frac{B_o}{W_{eff}' + B_1} \right\} \right) \frac{1}{1 + K_{eta} V_{bseff}}$$

$$V_{gsteffcv} = n \times N_{off} \times V_t \ln \left[1 + \exp \left(\frac{V_{gs} - V_{th} - V_{offcv}}{n \times N_{off} \times V_t} \right) \right]$$

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If $V_{ds} \leq V_{dsat}$,

$$Q_g = Q_{g1} + W_{active} L_{active} C_{ox} \left(V_{gsteffcv} - \frac{V_{ds}}{2} + \frac{A_{bulk}' V_{ds}^2}{12 \left(V_{gsteffcv} - \frac{A_{bulk}'}{2} V_{ds} \right)} \right)$$

$$Q_b = Q_{b1} + W_{active} L_{active} C_{ox} \left[\frac{(1 - A_{bulk}') V_{ds}}{2} - \frac{(1 - A_{bulk}') A_{bulk}' V_{ds}^2}{12 \left(V_{gsteffcv} - \frac{A_{bulk}'}{2} V_{ds} \right)} \right]$$

50/50 Charge-Channel Partition

$$Q_s = Q_d = -\frac{W_{active} L_{active} C_{ox}}{2} \left(V_{gsteffcv} - \frac{A_{bulk}'}{2} V_{ds} + \frac{A_{bulk}'^2 V_{ds}^2}{12 \left(V_{gsteffcv} - \frac{A_{bulk}'}{2} V_{ds} \right)} \right)$$

40/60 Channel-Charge Partition

$$Q_s = -\frac{W_{active} L_{active} C_{ox}}{2 \left(V_{gsteffcv} - \frac{A_{bulk}'}{2} V_{ds} \right)^2} \times \left(V_{gsteffcv}^3 - \frac{4}{3} V_{gsteffcv}^2 (A_{bulk}' V_{ds}) + \frac{2}{3} V_{gsteffcv} (A_{bulk}' V_{ds})^2 - \frac{2}{15} (A_{bulk}' V_{ds})^3 \right)$$

$$Q_d = -(Q_g + Q_b + Q_s)$$

0/100 Channel-Charge Partition

$$Q_s = -W_{active} L_{active} C_{ox} \left(\frac{V_{gsteffcv}}{2} + \frac{A_{bulk}' V_{ds}}{4} - \frac{(A_{bulk}' V_{ds})^2}{24 \left(V_{gsteffcv} - \frac{A_{bulk}'}{2} V_{ds} \right)} \right)$$

$$Q_d = -(Q_g + Q_b + Q_s)$$

If $V_{ds} > V_{dsat}$,

$$Q_g = Q_{g1} + W_{active} L_{active} C_{ox} \left(V_{gsteffcv} - \frac{V_{dsat}}{3} \right)$$

$$Q_b = Q_{b1} - W_{active} L_{active} C_{ox} \left[\frac{V_{gsteffcv} - V_{dsat}}{3} \right]$$

50/50 Channel-Charge Partition

$$Q_s = Q_d = -\frac{W_{active} L_{active} C_{ox}}{3} (V_{gsteffcv})$$

40/60 Channel-Charge Partition

$$Q_s = -\frac{2W_{active} L_{active} C_{ox}}{5} (V_{gsteffcv})$$

$$Q_d = -(Q_g + Q_b + Q_s)$$

0/100 Channel-Charge Partition

$$Q_s = -W_{active} L_{active} C_{ox} \left(\frac{2V_{gsteffcv}}{3} \right)$$

$$Q_d = -(Q_g + Q_b + Q_s)$$

For capmod=2

$$Q_g = -(Q_{inv} + Q_{acc} + Q_{sub0} + \delta Q_{sub})$$

$$Q_b = Q_{acc} + Q_{sub0} + \delta Q_{sub}$$

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$$Q_{inv} = Q_s + Q_d$$

$$V_{FBeff} = V_{fb} - 0.5 \left\{ V_3 + \sqrt{V_3^2 + 4\delta_3 V_{fb}} \right\} \text{ where } V_3 = V_{fb} - V_{gb} - \delta_3 ; \delta_3 = 0.02$$

$$V_{fb} = \begin{cases} V_{th} - \Phi_s - K_1 \sqrt{\Phi_s} & \text{if version } \leq 3.1 \text{ or version } = 3v3.2.1 \\ V_{th}(V_{bs} = 0) - \Phi_s - K_1 \sqrt{\Phi_s} & \text{otherwise} \end{cases}$$

$$Q_{acc} = -W_{active} L_{active} C_{ox} (V_{fb} - V_{fb})$$

$$Q_{sub0} = -W_{active} L_{active} C_{ox} \frac{K_1^2}{2} \left(-1 + \sqrt{1 + \frac{4(V_{gs} - V_{fb} - V_{gst} - V_{bseff})}{K_1^2}} \right)$$

$$V_{dsat, cv} = \frac{V_{gst}}{A_{bulk}'}$$

$$A_{bulk}' = \begin{cases} A_{bulk0} \left(1 + \left(\frac{C_{lc}}{L_{eff}} \right)^{C_{le}} \right) & \text{if version } \leq 3.1 \\ A_{bulk0} \left(1 + \left(\frac{C_{lc}}{L_{active}} \right)^{C_{le}} \right) & \text{if version } > 3.1 \end{cases}$$

$$A_{bulk0} = \left(1 + \frac{K_1}{2\sqrt{\Phi_s - V_{bseff}}} \left\{ \frac{A_0 L_{eff}}{L_{eff} + 2\sqrt{X_j X_{dep}}} + \frac{B_o}{W_{eff}' + B_1} \right\} \right) \frac{1}{1 + K_{eta} V_{bseff}}$$

$$V_{gst} = n \times N_{off} \times V_t \ln \left[1 + \exp \left(\frac{V_{gs} - V_{th} - V_{off}}{n \times N_{off} \times V_t} \right) \right]$$

$$V_{cveff} = V_{dsat, cv} - 0.5 \left\{ V_4 + \sqrt{V_4^2 + 4\delta_4 V_{dsat, cv}} \right\}$$

where $V_4 = V_{dsat, cv} - V_{ds} - \delta_4$; $\delta_4 = 0.02$

$$Q_{inv} = -W_{active} L_{active} C_{ox} \left(\left(V_{gsteffcv} - \frac{A_{bulk}'}{2} V_{cveff} \right) + \frac{A_{bulk}'^2 V_{cveff}^2}{12 \left(V_{gsteffcv} - \frac{A_{bulk}'}{2} V_{cveff} \right)} \right)$$

$$\delta Q_{sub} = W_{active} L_{active} C_{ox} \left(\frac{1 - A_{bulk}'}{2} V_{cveff} - \frac{(1 - A_{bulk}') A_{bulk}' V_{cveff}^2}{12 \left(V_{gsteffcv} - \frac{A_{bulk}'}{2} V_{cveff} \right)} \right)$$

50/50 Charge Partition

$$Q_s = Q_d = 0.5 Q_{inv} =$$

$$(-1) \frac{W_{active} L_{active} C_{ox}}{2} \left(V_{gsteffcv} - \frac{A_{bulk}'}{2} V_{cveff} + \frac{A_{bulk}'^2 V_{cveff}^2}{12 \left(V_{gsteffcv} - \frac{A_{bulk}'}{2} V_{cveff} \right)} \right)$$

40/60 Channel-Charge Partition

$$Q_s = \left(-\frac{W_{active} L_{active} C_{ox}}{2 \left(V_{gsteffcv} - \frac{A_{bulk}'}{2} V_{cveff} \right)^2} \right) \left(V_{gsteffcv}^3 - \frac{4}{3} V_{gsteffcv}^2 (A_{bulk}' V_{cveff}) \right. \\ \left. + \frac{2}{3} V_{gsteffcv} (A_{bulk}' V_{cveff})^2 - \frac{2}{15} (A_{bulk}' V_{cveff})^3 \right)$$

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$$Q_d = \left(-\frac{W_{active} L_{active} C_{ox}}{2 \left(V_{gsteffcv} - \frac{A_{bulk}' V_{cveff}}{2} \right)^2} \right) \left(V_{gsteffcv}^3 - \frac{5}{3} V_{gsteffcv}^2 (A_{bulk}' V_{cveff}) + \right. \\ \left. V_{gsteffcv} (A_{bulk}' V_{cveff})^2 - \frac{1}{5} (A_{bulk}' V_{cveff})^3 \right)$$

0/100 Charge Partition

$$Q_s = -W_{active} L_{active} C_{ox} \left(\frac{V_{gsteffcv}}{2} + \frac{A_{bulk}' V_{cveff}}{4} - \frac{(A_{bulk}' V_{cveff})^2}{24 \left(V_{gsteffcv} - \frac{A_{bulk}' V_{cveff}}{2} \right)} \right)$$

$$Q_d = -W_{active} L_{active} C_{ox} \left(\frac{V_{gsteffcv}}{2} - \frac{3A_{bulk}' V_{cveff}}{4} + \frac{(A_{bulk}' V_{cveff})^2}{8 \left(V_{gsteffcv} - \frac{A_{bulk}' V_{cveff}}{2} \right)} \right)$$

For capmod = 3

capmod = 3 supports only zero-bias V_{fp} ; that is, V_{fb} is calculated from bias-independent V_{th} , regardless of the version number. This is different from capmod = 1 and 2.

$$Q_g = -(Q_{inv} + Q_{acc} + Q_{sub0} + \delta Q_{sub})$$

$$Q_b = Q_{acc} + Q_{sub0} + \delta Q_{sub}$$

$$Q_{inv} = Q_d + Q_s$$

$$V_{FB_{eff}} = V_{fb} - 0.5 \left(V_3 + \sqrt{V_3^2 + 4\delta_3 V_{fb}} \right)$$

where

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$$V_3 = V_{fb} - V_{gb} - \delta_3$$

$$\delta_3 = 0.02$$

$$V_{fb} = V_{th}(V_{bs} = 0) - \phi_s - K_1 \sqrt{\phi_s}$$

$$Q_{acc} = -W_{active} L_{active} C_{oxeff} (V_{fb} - V_{fb})$$

$$C_{oxeff} = \frac{C_{ox} C_{cen}}{C_{ox} + C_{cen}}$$

$$C_{ox} = \frac{E_{ox}}{t_{ox} - dt_{oxcv}}$$

$$C_{cen} = \frac{\epsilon_{si}}{T_{cen}}$$

$$T_{cen} = L_{deb} - 0.5 \times \left(T_3 + \sqrt{T_3^2 + 4 \times 10^{-3} L_{deb} T_{ox}} \right)$$

$$T_3 = L_{deb} \left\{ 1 - \exp \left[\frac{A_{cde} \times (V_{gs} - V_{bseff} - V_{fb})}{10^8 T_{ox}} \right] \right\} - 10^{-3} T_{ox}$$

$$Q_{sub} = -W_{active} L_{active} C_{oxeff} K_1 \left[\sqrt{\frac{K_1^2}{4} + V_{gs} - V_{fb} - V_{bseff} - V_{gsteffcv}} - \frac{K_1}{2} \right]$$

$$V_{gsteffcv} = n N_{off} V_t \ln \left[1 + \exp \left(\frac{V_{gs} - V_{th} - V_{offcv}}{n N_{off} V_t} \right) \right]$$

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$$Q_{inv} = -W_{active} L_{active} C_{oxeff} \left[V_{gsteffcv} - \delta\phi_s - \frac{A'_{bulk}}{2} V_{cveff} + \frac{A'^2_{bulk} V_{cveff}^2}{12 \left(V_{gsteffcv} - \delta\phi_s - \frac{A'_{bulk}}{2} V_{cveff} \right)} \right]$$

$$\delta Q_{sub} = W_{active} L_{active} C_{oxeff} \left[\frac{1 - A'_{bulk}}{2} V_{cveff} - \frac{(1 - A'_{bulk}) A'_{bulk} V_{cveff}^2}{12 \left(V_{gsteffcv} - \delta\phi_s - \frac{A'_{bulk}}{2} V_{cveff} \right)} \right]$$

$$C_{oxeff} = \frac{C_{ox} C_{cen}}{C_{ox} + C_{cen}}$$

$$C_{cen} = \frac{\epsilon_{si}}{T_{cen}}$$

$$T_{cen} = \frac{1.9 \times 10^{-9}}{1 + \left[\frac{4(V_{th} - V_{fb} - \phi_s) + V_{gsteffcv}}{2 \times 10^8 T_{ox}} \right]^{0.7}}$$

$$\delta\phi_s = V_t \log \left(1 + \frac{2K_1 \sqrt{\phi_s} V_{gsteffcv}}{M_{oin} V_t K_1^2} \right)$$

$$V_{dsat, cv} = \frac{V_{gsteffcv} - \delta\phi_s}{A'_{bulk}}$$

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$$A_{bulk}' = \begin{cases} A_{bulk0} \left(1 + \left(\frac{C_{lc}}{L_{eff}} \right)^{C_{le}} \right) & \text{if version} \leq 3.1 \\ A_{bulk0} \left(1 + \left(\frac{C_{lc}}{L_{active}} \right)^{C_{le}} \right) & \text{if version} > 3.1 \end{cases}$$

$$A_{bulk0} = \left[1 + \frac{K_1}{2\sqrt{\phi_s - V_{bseff}}} \left(\frac{A_0 L_{eff}}{L_{eff} + 2\sqrt{X_j X_{dep}}} + \frac{B_0}{W_{eff} + B_1} \right) \right] \times \frac{1}{1 + K_{eta} V_{bseff}}$$

$$V_{cveff} = V_{dsat, cv} - 0.5 \left(V_4 + \sqrt{V_4^2 + 4\delta_4 V_{dsat, cv}} \right)$$

$$V_4 = V_{dsat, cv} - V_{ds} - \delta_4$$

$$\delta_4 = 0.02$$

50/50 Charge Partition

$$Q_s = Q_d = 0.5Q_{inv}$$

40/60 Charge Partition

$$Q_s = -\frac{W_{active} L_{active} C_{oxeff}}{2 \left(V_{gsteffcv} - \delta\phi_s - \frac{A'_{bulk}}{2} V_{cveff} \right)^2} [(V_{gsteffcv} - \delta\phi_s)^3 - \frac{4}{3} (V_{gsteffcv} - \delta\phi_s)^2 A'_{bulk} V_{cveff} + \frac{2}{3} (V_{gsteffcv} - \delta\phi_s) (A'_{bulk} V_{cveff})^2 - \frac{2}{15} (A'_{bulk} V_{cveff})^3]$$

$$Q_d = Q_{inv} - Q_s$$

0/100 Charge Partition

$$Q_s = -W_{active} L_{active} C_{oxeff} \left[\frac{V_{gsteffcv} - \delta\phi_s}{2} + \frac{A'_{bulk} V_{cveff}}{4} \left(-\frac{(A'_{bulk} V_{cveff})^2}{24(V_{gsteffcv} - \delta\phi_s - \frac{A'_{bulk} V_{cveff}}{2})} \right) \right]$$

$$Q_d = Q_{inv} - Q_s$$

Intrinsic Capacitances (with Body Bias and DIBL)

$$C_{(s, d, g, b), g} = \frac{\partial Q_{s, d, g, b}}{\partial V_{gsteffcv}} \frac{\partial V_{gsteffcv}}{\partial V_{gt}}$$

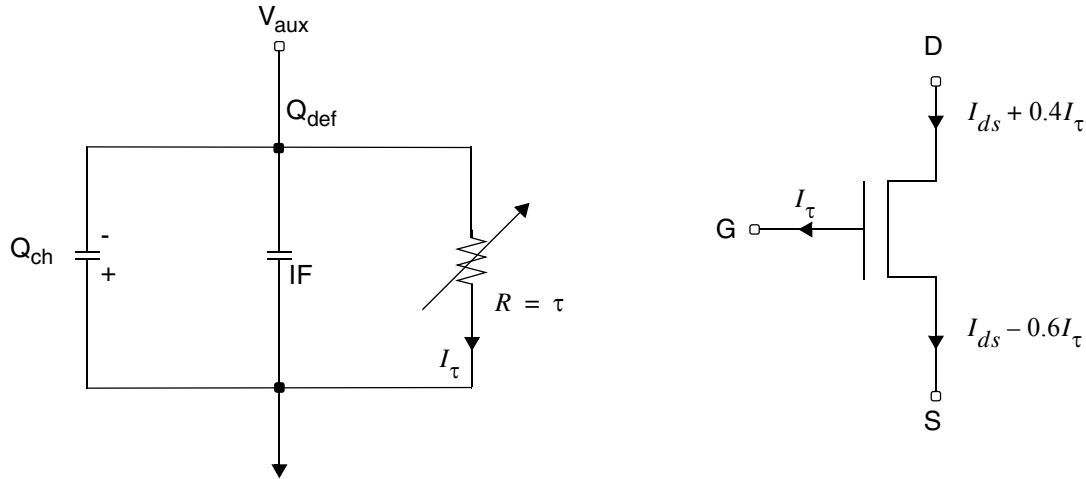
$$C_{(s, d, g, b), s} = -\frac{\partial Q_{s, d, g, b}}{\partial V_{ds}} + \frac{\partial Q_{s, d, g, b}}{\partial V_{gsteffcv}} \frac{\partial V_{gsteffcv}}{\partial V_{gt}} \left(\frac{\partial V_{th}}{\partial V_{ds}} + \frac{\partial V_{th}}{\partial V_{bs}} \right)$$

$$C_{(s, d, g, b), d} = \frac{\partial Q_{s, d, g, b}}{\partial V_{ds}} - \frac{\partial Q_{s, d, g, b}}{\partial (V_{gsteffcv})} \frac{\partial V_{gsteffcv}}{\partial V_{gt}} \frac{\partial V_{th}}{\partial V_{ds}}$$

$$C_{(s, d, g, b), b} = \frac{\partial Q_{s, d, g, b}}{\partial V_{bs}} - \frac{\partial Q_{s, d, g, b}}{\partial V_{gsteffcv}} \frac{\partial V_{gsteffcv}}{\partial V_{gt}} \frac{\partial V_{th}}{\partial V_{bs}}$$

Nonquasi-static (NQS) Model

The following equivalent circuit is used if `nqsmod = 1`. (Only the intrinsic transistor is affected by NQS. The extrinsic components remain the same).



Quasi-static equilibrium channel charge:

$$Q_{eq} = -(Q_g + Q_b)$$

Actual channel charge and Q_{def} obtained from subcircuit:

$$Q_{ch} = Q_{eq} - Q_{def}$$

$$g_\tau = \frac{1}{\tau} = \frac{1}{\tau_{drift}} + \frac{1}{\tau_{diff}}$$

$$\tau_{drift} = \frac{C_{ox} W_{eff} L_{eff}^3}{\mu_{eff} \varepsilon |Q_{eq} - \alpha Q_{def}|} \approx \frac{\zeta}{|Q_{eq}|}$$

where

$\varepsilon \equiv$ Elmore Constant (default = 5)

$0.0 \leq \alpha \leq 1.0$ (default = 0.5)

and

$$\zeta = \frac{C_{ox} W_{eff} L_{eff}^3}{\mu_{eff} \epsilon}$$

$$\tau_{diff} = \frac{L_{eff}^2}{16 \mu_{eff} V_{tm}}$$

SPICE3 Junction Diode Model

There are two junction models in the BSIM3v3 device model. The `diomod` parameter determines the model to be used in a given simulation:

- If `diomod=1` (default value), the model uses the equations described in the chapter *Common MOSFET Equations*.
- If `diomod=0`, the model uses the equations described in *Chapter 9* of the BSIM3v3.2.2 MOSFET Model-Users' Manual available at:

<http://www-device.EECS.Berkeley.EDU/~bsim3/get.html>

The BSIM3v3 device model uses the same equations when `tlev=1`.

Starting with MMSIM1211ISR17, bsim3v3 supports the trap-assisted tunneling current, if `diomod!=100`. For more information, refer to the equations described in the *Total Junction Source/Drain Diode Including Tunneling* section in chapter *BSIM4 Level-14 Model (bsim4)*.

Flicker Noise

Two models exist for flicker noise. Each of these can be toggled by the `noimod` flag.

For `noimod = 1` and `4`

If `wnoi` is given

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$$FlickerNoise = \frac{K_f I_{ds}^{A_f}}{C_{ox} L_{eff}^2 f^{E_f}} \times (wnoi)/(weff)$$

otherwise

$$FlickerNo = \frac{K_f I_{ds}^{A_f}}{C_{ox} L_{eff}^2 f^{E_f}}$$

For noimod = 2 and 3

$$V_{gs} > V_{th} + 0.1:$$

where V_{tm} is the thermal voltage, μ_{eff} is the effective mobility at the given bias condition, L_{eff} and W_{eff} are the effective channel length and width, respectively. The parameter N_0 is the charge density at the source given by

$$N_0 = \frac{C_{ox}(V_{gs} - V_{th})}{q}$$

$$FlickerNoise = \frac{V_{tm} q^2 I_{ds} \mu_{eff}}{f^{E_f} L_{eff}^2 C_{ox} \times 10^8} \left[N_{oia} \log \left(\frac{N_0 + 2 \times 10^{14}}{N_l + 2 \times 10^{14}} \right) + N_{oib} \times (N_0 - N_l) \right. \\ \left. + 0.5 \times N_{oic} (N_0^2 - N_l^2) \right] + \frac{V_{tm} I_{ds}^2 \Delta L_{clm}}{f^{E_f} L_{eff}^2 W_{eff} 10^8} \times \frac{N_{oia} + N_{oib} N_l + N_{oic} N_l^2}{(N_l + N_{oid})^2}$$

The parameter N_l is the charge density at the drain given by

$$N_l = \begin{cases} C_{ox} \left(\frac{V_{gs} - V_{th} - V_{ds}}{q} \right) & \text{if version} < 3.2.4 \\ \left(C_{OX} \cdot V_{gsteff} \cdot \left(1 - \frac{A_{bulk} V_{dseff}}{V_{gsteff} + 2V_t} \right) \right) / q & \text{if version} \geq 3.2.4 \end{cases}$$

$$V_{ds} = \text{MIN}(V_{ds}, V_{dsat})$$

ΔL_{CLM} refers to channel length reduction due to *CLM* and is given by

$$\Delta L_{clm} = \begin{cases} L_{itl} \times \log \left(\frac{V_{ds} - V_{dsat} + E_m}{L_{itl} E_{sat}} \right) & \text{if } V_{DS} > V_{DSAT} \\ 0 & \text{otherwise} \end{cases}$$

$$E_{sat} = \frac{2 \times V_{sat}}{U_{eff}}$$

Otherwise,

$$\text{FlickerNoise} = \frac{S_{limit} \times S_{wi}}{S_{limit} + S_{wi}}$$

where S_{limit} is the flicker noise calculated at $V_{gs} = V_{th} + 0.1$ and S_{wi} is given by

$$S_{wi} = \frac{N_{oia} V_{tm} \times I_{ds}^2}{W_{eff} \times L_{eff} \times f^{E_f} \times 10^8 \times N_{oid}^2}$$

Channel Thermal Noise

Two models exist for channel thermal noise. Each of these can be toggled by the `noimod` flag.

For `noimod=1` and `3`,

$$\overline{i_D^2} = \frac{4kT}{3} \times \text{gamma} \times (g_m + g_{ds} + g_{mb})$$

where `gamma` is a new model parameter introduced to model short channel device thermal noise. The default value for `gamma` is `2/3`.

The standard Berkeley BSIM3v3 equation is

$$\bar{i}_D^2 = \frac{8kT}{3}(g_m + g_{ds} + g_{mb})$$

For noimod=2 and 4,

$$\bar{i}_d^2 = \frac{4kTu_{eff}}{L_{eff}^2 + u_{eff}|Q_{inv}| \cdot R_{ds}} |Q_{inv}| \quad \text{if version} = 3.2.4$$

$$\bar{i}_d^2 = \left(\frac{4kTu_{eff}}{L_{eff}^2} \cdot |Q_{inv}| \right) \quad \text{if version} > \text{ or } < 3.2.4$$

where Q_{inv} is the channel inversion charge, and is calculated as follows:

- For version 3.1:

$$Q_{inv} = -W_{eff}L_{eff}C_{ox}V_{gsteff} \left(1 - \frac{A_{bulk}}{2(V_{gsteff} + 2V_{tm})} V_{dseff} \right)$$

- For version 3.2, the Q_{inv} equations are described in [Intrinsic Charges](#) on page 1170.

Default Model Parameter Value Calculation

- If $vtho$ is not given, it is calculated from

$$vtho = vfb + phi + k1\sqrt{phi}$$

- If phi is not given, it is calculated from

$$phi = 2V_{tm} \ln\left(\frac{nc}{n_i}\right)$$

where V_{tm} is the thermal voltage given by

$$V_{tm} = \frac{kT}{q}$$

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$$n_i = 1.45 \times 10^{10} \left(\frac{T}{300}\right)^{1.5} \exp\left(21.5565981 - \frac{E_g(T)}{2V_{tm}}\right)$$

where $E_g(T)$ is the energy band gap at temperature T . The equation for E_g is shown in *Chapter 12 Common MOSFET Equations*.

- If $k1$ is not given, it is calculated from

$$k1 = \text{gamma}2 - 2k2\sqrt{\text{phi} - vbm}$$

- If $k2$ is not given, it is calculated from

$$k2 = \frac{(\text{gamma}1 - \text{gamma}2)(\sqrt{\text{phi} - vbx} - \sqrt{\text{phi}})}{2\sqrt{\text{phi}}(\sqrt{\text{phi} - vbm} - \sqrt{\text{phi}}) + vbm}$$

- If $\text{gamma}1$ is not given, it is calculated from

$$\text{gamma}1 = \frac{\sqrt{2q\epsilon_{si}nch}}{C_{ox}}$$

- If $\text{gamma}2$ is not given, it is calculated from

$$\text{gamma}2 = \frac{\sqrt{2q\epsilon_{si}nsub}}{C_{ox}}$$

- If Version ≤ 3.1 or version = 3.21, and capmod < 3

$$vfb = vth - \text{phi} - k1 \times \sqrt{\text{phi} - vbs}$$

otherwise

$$vfb = vth0z - \text{phi} - k1\sqrt{\text{phi}}$$

- If V_{bi} is not given, it is calculated from

$$V_{bi} = V_{tm} \ln\left(\frac{1.0e20 \times nch}{n_i^2}\right)$$

- If V_{bx} is not given, it is calculated from

$$V_{bx} = \phi_i - \frac{q \cdot n_{ch} \cdot x_i^2}{2 \epsilon_{si}}$$

- If *cgso* is not given, *dlc* is given, and *dlc* > 0

$$cgso = (dlc + meto) \times cox - cgsl$$

otherwise

$$cgso = 0.6 \times x_j \times cox$$

- If *cgdo* not given, *dlc* given, and *dlc* > 0

$$cgdo = (dlc + meto) \times cox - cgdl$$

otherwise

$$cgdo = 0.6 \times x_j \times cox$$

Gate Leak Currents

This section describes the parameters and equations for gate leak currents.

Instance Parameters

Parameter	Description
<i>Aforward</i>	Forward gate leakage current coefficient. Default value is 0 . 0.
<i>Areverse</i>	Reverse gate leakage current coefficient. Default value is 0 . 0.

If *Aforward* and *Areverse* are both 0.0, gate leak current is also 0.0.

Model Parameters

Parameter	Description
<i>Bforward</i>	Forward gate leakage current coefficient in <code>pow()</code> . Default value is 0 . 0.

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Parameter	Description
Breverse	Reverse gate leakage current coefficient in <code>pow()</code> . Default value is 0.0.
Cforward	Forward gate leakage current coefficient in <code>exp()</code> . Default value is 0.0.
Creverse	Reverse gate leakage current coefficient in <code>exp()</code> . Default value is 0.0.
Tcc	Gate leakage current temperature coefficient. Default value is 0.0.

Leak current between Gate and Drain

If $V_{gd} > 0$

$$I_{gd} = A_{forward} \times (1.0 + Tcc \times (Temp - Tnom)) \times pow(V_{gd}, B_{forward}) \times \exp(C_{forward} \times V_{gd})$$

If $V_{gd} < 0$

$$I_{gd} = -A_{reverse} \times (1.0 + Tcc \times (Temp - Tnom)) \times pow(-V_{gd}, B_{reverse}) \times \exp(C_{reverse} \times V_{gd})$$

If $V_{gd} = 0$

$I_{gd} = 0.0$

Leak current between Gate and Source

- If $I_{gcModel} = 0$ and $I_{gbModel} = 0$,

If $V_{gs} > 0$

$$I_{gs} = A_{forward} \times (1.0 + Tcc \times (Temp - Tnom)) \times pow(V_{gs}, B_{forward}) \times \exp(C_{forward} \times V_{gs})$$

If $V_{gs} < 0$

$$I_{gs} = -A_{reverse} \times (1.0 + Tcc \times (Temp - Tnom)) \times pow(-V_{gs}, B_{reverse}) \times \exp(C_{reverse} \times V_{gs})$$

If $V_{gs} = 0$

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$I_{gs}=0.0$

- Otherwise,

I_{gc}

If $I_{gcModel}=0$ and $I_{gbmodel}=0$, the above equations apply.

Otherwise, the following equations apply.

$I_{gc}=I_{gcs}+I_{gcd}$

$$I_{gc0} = W_{eff} L_{eff}^A \cdot T_{oxratio} V_{gse} V_{aux} \cdot \exp(-B \cdot Toxe(A_{igc} - B_{igc} \cdot V_{oxdepinv}))(1 + C_{igc} \cdot V_{oxdepinv})$$

For $I_{gcmod}=1$

$$V_{aux} = N_{igc} \cdot vt \cdot \log\left(1 + \exp\left(\frac{V_{gse} - V_{th0}}{N_{igc} \cdot vt}\right)\right)$$

For $I_{gcmod}=2$

$$V_{aux} = N_{igc} \cdot vt \cdot \log\left(1 + \exp\left(\frac{V_{gse} - V_{th}}{N_{igc} \cdot vt}\right)\right)$$

$$T_{oxratio} = \left(\frac{T_{oxref}}{Toxe}\right)^{N_{tox}} \frac{1}{Toxe^2}$$

$$V_{oxdepinv} = K1_{ox} \sqrt{\phi_s} + V_{gsteff}$$

Then

$$I_{gcs} = I_{gc0} \frac{P_{igcd} \cdot V_{dseff} + \exp(-P_{igcd} \cdot V_{dseff}) - 1 + 1.0e-4}{P_{igcd}^2 V_{dseff}^2 + 2.0e-4}$$

$$I_{gcd} = I_{gc0} \frac{1 - (P_{igcd} \cdot V_{dseff} + 1) \exp(-P_{igcd} \cdot V_{dseff}) + 1.0e-4}{P_{igcd}^2 V_{dseff}^2 + 2.0e-4}$$

Igs and Igd

Igs represents the gate tunneling current between the gate and source diffusion region, while Igd represents the gate tunneling current between the gate and the drain diffusion region.

$$I_{gs} = W_{eff} D_{lcig} \cdot A_{echvb} \cdot T_{oxratioedge} V_{gs} V_{gs}' \exp(-Bechvb \cdot Toxe \cdot Poxedge \cdot (A_{igsd} - B_{igsd} \cdot V_{gs}'))$$

$$I_{gd} = W_{eff} D_{lcig} \cdot A_{echvb} \cdot T_{oxratioedge} V_{gd} V_{gd}' \exp(-Bechvb \cdot Toxe \cdot Poxedge \cdot (A_{igsd} - B_{igsd} \cdot V_{gd}'))$$

where

$$T_{oxratioedge} = \left(\frac{T_{oxref}}{T_{oxe} P_{oxedge}} \right) \frac{1}{(T_{oxe} P_{oxedge})^2}$$

Igb

Igb=Igbacc+Igbinv

Igbacc is determined by ECB (Electronic tunneling from Conduction band) and is significant in accumulation and given by:

$$I_{gbacc} = W_{eff} L_{eff} A_{echve} \cdot T_{oxratio} V_{gb} V_{aux} \cdot \exp(-Bechvb \cdot Toxe (A_{igbacc} - B_{igbacc} \cdot V_{oxacc}) (1 + C_{igbac} \cdot V_{oxacc}))$$

Where

$$V_{oxacc} = V_{fbsb} - V_{fb\text{eff}}$$

$$V_{fbsb} = V_{th} \Big|_{V_{bs} = V_{ds} = 0q} - \phi_s - K1 \sqrt{\phi_s}$$

$$V_{aux} = N_{igbacc} \cdot vt \cdot \log \left(1 + \exp \left(\frac{V_{gb} - V_{fbsb}}{N_{igbacc} \cdot vt} \right) \right)$$

I_{gbinv} is determined by EVB (Electron tunneling from valence band) and is significant in inversion and given by:

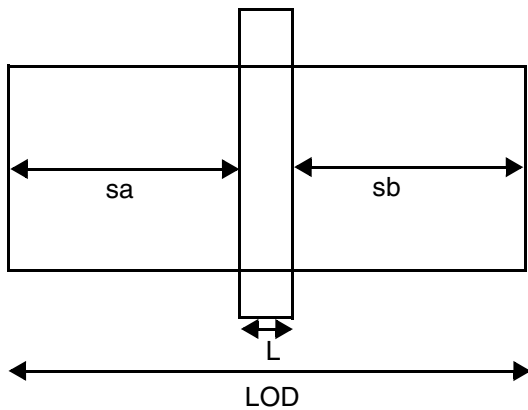
$$I_{gbinv} = W_{eff} L_{eff} A_{echve} \cdot T_{oxratio} V_{gb} V_{aux} \cdot \exp(-Bechvb \cdot Toxe(Aigbinv - Bigbinv \cdot V_{oxdepinv})(1 + Cigbinv \cdot V_{oxdepinv}))$$

Where

$$V_{aux} = Nigbinv \cdot vt \cdot \log\left(1 + \exp\left(\frac{V_{oxdepinv} - Eigbinv}{Nigbinv \cdot vt}\right)\right)$$

LOD Model

The following diagram displays the LOD instance geometry parameters sa and sb .



$$\rho_{\mu eff} = \frac{ku0}{Kstress_u0} \cdot (Inv_sa + Inv_sb)$$

$$Inv_sa = \frac{1}{SA + 0.5 \cdot L_{drawn}}$$

$$Inv_sb = \frac{1}{SB + 0.5 \cdot L_{drawn}}$$

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$$Kstress_u0 = \left(1 + \frac{LKU0}{(L_{drawn} + XL)^{LLODKU0}} + \frac{WKU0}{(W_{drawn} + XW + WLOD)^{WLODKU0}} + \frac{PKU0}{(L_{drawn} + XL)^{LLODKU0} \cdot (W_{drawn} + XW + WLOD)^{WLODKU0}} \right) \times \left(1 + TKU0 \cdot \left(\frac{Temperature}{TNOM} - 1 \right) \right)$$

For irregular LOD device,

$$\frac{1}{SA_{eff} + 0.5 \cdot L_{drawn}} = \sum_{i=1}^n \frac{SW_i}{W_{drawn}} \cdot \frac{1}{sa_i + 0.5 \cdot L_{drawn}}$$

$$\frac{1}{SB_{eff} + 0.5 \cdot L_{drawn}} = \sum_{i=1}^n \frac{SW_i}{W_{drawn}} \cdot \frac{1}{sb_i + 0.5 \cdot L_{drawn}}$$

Stress Effect

$$\mu_{eff} = \frac{1 + \rho_{\mu_{eff}}(SA, SB)}{1 + \rho_{\mu_{eff}}(SA_{ref}, SB_{ref})} \mu_{eff0}$$

$$v_{sat} = \frac{1 + K \cdot \rho_{\mu_{eff}}(SA, SB)}{1 + K \cdot \rho_{\mu_{eff}}(SA_{ref}, SB_{ref})} v_{sato}$$

where μ_{eff0} , v_{sato} are low field mobility, saturation velocity at SA_{ref} , SB_{ref} .

$$Kstress_vth0 = 1 + \frac{LKVTH0}{(L_{drawn} + XL)^{LLODKVTH}} + \frac{WKVTH0}{(W_{drawn} + XW + WLOD)^{WLODKVTH}} + \frac{PKVTH0}{(L_{drawn} + XL)^{LLODKVTH} \cdot (W_{drawn} + XW + WLOD)^{WLODKVTH}}$$

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$$VTH0 = VTH0_{original} + \frac{KVTH0}{Kstress_vth0} \cdot (Inv_sa + Inv_sb - Inv_sa_{ref} - Inv_sb_{ref})$$

$$K2 = K2_{original} + \frac{STK2}{Kstress_vth0} \cdot \frac{LODK2}{LODK2} \cdot (Inv_sa + Inv_sb - Inv_sa_{ref} - Inv_sb_{ref})$$

$$ETA0 = ETA0_{original} + \frac{STETA0}{Kstress_vth0} \cdot \frac{LODETO}{LODETO} \cdot (Inv_sa + Inv_sb - Inv_sa_{ref} - Inv_sb_{ref})$$

Well Proximity Effect

$$Vth0 = Vth0_{org} + KVth0we \cdot (Sca + Web \cdot Scb + Wec \cdot Scc)$$

$$K2 = K2_{org} + K2we \cdot (Sca + Web \cdot Scb + Wec \cdot Scc)$$

$$\mu_{eff} = \mu_{eff,org} \cdot (1 + Ku0we \cdot (Sca + Web \cdot Scb + Wec \cdot Scc))$$

SC is defined as the distance to a single well edge used in calculations of SCA, SCB, and SCC when layout information is not available. If SCA, SCB, and SCC are not given, their estimation is as follows:

$$Sca = \frac{Scref^2}{W_{drawn}} \left(\frac{1}{Sc} - \frac{1}{Sc + W_{drawn}} \right)$$

$$Scb = \frac{1}{W_{drawn} Scref} \left[\begin{array}{l} \frac{Scref Sc \cdot \exp\left(-10 \frac{Sc}{Scref}\right) + \frac{Scref^2}{400} \exp\left(-10 \frac{Sc}{Scref}\right)}{10} \\ - \frac{Scref (Sc + W_{drawn}) \exp\left(-10 \frac{Sc + W_{drawn}}{Scref}\right)}{10} \\ - \frac{Scref^2}{400} \exp\left(-10 \frac{Sc + W_{drawn}}{Scref}\right) \end{array} \right]$$

$$S_{cc} = \frac{1}{W_{drawn} S_{cref}} \left(\begin{array}{l} \frac{S_{cref} S_c \cdot \exp\left(-20 \frac{S_c}{S_{cref}}\right) + \frac{S_{cref}^2}{400} \exp\left(-20 \frac{S_c}{S_{cref}}\right)}{-\frac{S_{cref}}{20} (S_c + W_{drawn}) \exp\left(-20 \frac{S_c + W_{drawn}}{S_{cref}}\right)} \\ -\frac{S_{cref}^2}{400} \exp\left(-20 \frac{S_c + W_{drawn}}{S_{cref}}\right) \end{array} \right)$$

Differences between BSIM3v3 Subversions

1. Intrinsic Charges

When **The equations are**
capmod=0

$$A_{bulk}' = \begin{cases} A_{bulk0} \left(1 + \left(\frac{C_{lc}}{L_{eff}} \right)^{C_{le}} \right) & \text{if version } \leq 3.1 \\ A_{bulk0} \left(1 + \left(\frac{C_{lc}}{L_{active}} \right)^{C_{le}} \right) & \text{if version } > 3.1 \end{cases}$$

capmod=1

$$V_{fb} = \begin{cases} V_{th} - \Phi_s - K_1 \sqrt{\Phi_s} & \text{if version } \leq 3.1 \text{ and version } = 3.2.1 \\ V_{th}(V_{bs} = 0) - \Phi_s - K_1 \sqrt{\Phi_s} & \text{if version } = 3.2 \text{ and version } = 3.2.2 \end{cases}$$

$$A_{bulk}' = \begin{cases} A_{bulk0} \left(1 + \left(\frac{C_{lc}}{L_{eff}} \right)^{C_{le}} \right) & \text{if version } \leq 3.1 \\ A_{bulk0} \left(1 + \left(\frac{C_{lc}}{L_{active}} \right)^{C_{le}} \right) & \text{if version } > 3.1 \end{cases}$$

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When **The equations are**

capmod=2

$$V_{fb} = \begin{cases} V_{th} - \Phi_s - K_1 \sqrt{\Phi_s} & \text{if version } \leq 3.1 \text{ or version} = 3.2.1 \\ V_{th}(V_{bs} = 0) - \Phi_s - K_1 \sqrt{\Phi_s} & \text{otherwise} \end{cases}$$

$$A_{bulk}' = \begin{cases} A_{bulk0} \left(1 + \left(\frac{C_{lc}}{L_{eff}} \right)^{C_{le}} \right) & \text{if version } \leq 3.1 \\ A_{bulk0} \left(1 + \left(\frac{C_{lc}}{L_{active}} \right)^{C_{le}} \right) & \text{if version} > 3.1 \end{cases}$$

capmod=3

$$A_{bulk}' = \begin{cases} A_{bulk0} \left(1 + \left(\frac{C_{lc}}{L_{eff}} \right)^{C_{le}} \right) & \text{if version } \leq 3.1 \\ A_{bulk0} \left(1 + \left(\frac{C_{lc}}{L_{active}} \right)^{C_{le}} \right) & \text{if version} > 3.1 \end{cases}$$

2. Flicker noise

For noimod=2 and 3

$$N_l = \begin{cases} C_{ox} \left(\frac{V_{gs} - V_{th} - V_{ds}}{q} \right) & \text{if version} < 3.2.4 \\ \left(C_{OX} \cdot V_{gsteff} \cdot \left(1 - \frac{A_{bulk} V_{dseff}}{V_{gsteff} + 2V_{\nu}} \right) \right) / q_0 & \text{if version } \geq 3.2.4 \end{cases}$$

3. Channel Thermal Noise

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$$\bar{i}_d^2 = \frac{4kTu_{eff}}{L_{eff}^2 + u_{eff}|Q_{inv}| \cdot R_{ds}} |Q_{inv}|$$

if version = 3.2.4

$$\bar{i}_d^2 = \left(\frac{4kTu_{eff}}{L_{eff}^2} \cdot |Q_{inv}| \right)$$

if version < or > 3.2.4

4. If vto is not given

$$vto = \begin{cases} -1.0 + Phi + K1 \times SqrtPhi + Delvto \\ Vfb + Phi + K1 \times SqrtPhi + Delvto \end{cases}$$

if version ≤ 3.1

if version > 3.1

5. Overlap Capacitance

- If OverlapCgs < 0

For BSIM3v3 version < 3.1

$$OverlapCgs = 1.0e - 7 \times T_{ox}$$

For BSIM3v3 version ≥ 3.1

$$OverlapCgs = 0$$

- If OverlapCgd < 0

For BSIM3v3 version < 3.1

$$OverlapCgd = 1.0e - 7 \times T_{ox}$$

For BSIM3v3 version ≥ 3.1

$$OverlapCgs = 0$$

- If OverlapCgb is not given

For BSIM3v3 version < 3.1

$$OverlapCgb = 0$$

For BSIM3v3 version ≥ 3.1

$$OverlapCgb = 2.0 \times dwc \times C_{ox}$$

Parameter Differences between BSIM3v3 Levels

The following table lists the parameters whose default value depends on the level of the BSIM3v3 model.

Parameter Name	Default Value for each Level	Description
k1	0.53V ^{1/2} (LEVEL=49/53) 1.90923V ^{1/2} (LEVEL=11)	Body-effect coefficient
k2	0.0186 (LEVEL=49/53) -0.33 (LEVEL=11)	Charge-sharing parameter
vfbflag	0 (LEVEL=49/53)	Vfb selector
binflag	0 (LEVEL=49/53)	Binning factor
lref	1.0e20 (LEVEL=49/53)	Binning length factor
minr	0.1 Ohm (LEVEL=11) 1e-5 Ohm (LEVEL=49/53)	Minimum source/drain resistance
js	0A/m ² (LEVEL=49) 1e-4A/m ² (LEVEL=53)	Bulk junction reverse saturation current density
f	1.0e20 (LEVEL=49/53)	Binning width factor
is	1e-14 (LEVEL=11)	Bulk junction reverse saturation current
pb	1V (LEVEL=11/53) 0.8V (LEVEL=49)	Bulk junction built-in potential
cjsw	5e-10F/m (LEVEL=11/53) 0F/m (LEVEL=49)	Zero-bias junction sidewall capacitance density
capmod	2 (LEVEL=11) 3 (LEVEL=49/53)	Intrinsic charge model
xpart	0 (LEVEL=11/53) 1 (LEVEL=49)	Drain/source channel charge partition in saturation for BSIM charge model. Use 0.0 for 40/60, 0.5 for 50/50, or 1.0 for 0/100.
version	3.1(LEVEL=11) 3.2(LEVEL=49/53)	Model version selector. The available versions are 3.1, 3.2, 3.21,3.22, 3.23, 3.24 and 3.3.

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

Parameter Name	Default Value for each Level	Description
paramchk	1 (LEVEL=11) 0 (LEVEL=49/53)	Model parameter checking selector
acm	0 (LEVEL=11/49) 10 (LEVEL=53)	BSIM3v3 area calculation method selector
calcacm	0 (LEVEL=49/53)	geometry factor
eg	1.12452V (LEVEL=11) 1.16V (LEVEL=49/53)	Energy band gap
diomod	1 (LEVEL=11/49) 0 (LEVEL=53)	Flag to select junction model: When diomod=1, the junction model described in Common MOSFET Equations section is used. When diomod=0, the Berkeley junction model is used. When diomod=100, the TSMC special diode model is used.
xti	3 (LEVEL=11/53) 0 (LEVEL=49)	Saturation current temperature exponent
nlev	2.0 (LEVEL=49/53)	Noise selector
gdsnoi	1.0 (LEVEL=49/53)	Channel thermal noise coefficient for 49 noise

Scaling Effects

`scale` and `scalem` are options that set the scaling factors for instance and model parameters, respectively. You can specify the scaling factors in the `.options` statement.

The following sections describe the parameters that are scaled.

Instance Parameters

Channel Width

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

$$w = w \times scale$$

Channel length

$$l = l \times scale$$

Source area

$$as = as \times scale \times scale$$

Drain area

$$ad = ad \times scale \times scale$$

Source perimeter

$$ps = ps \times scale \times scale$$

Drain perimeter

$$pd = pd \times scale$$

Component Statements

This device is supported within altergroups.

Sample Instance Statement

```
m4 (0 2 1 1) pchmod w=2u l=0.8u as=250p ad=250p pd=168p ps=168p m=1
```

Sample Model Statement

```
model pchmod bsim3v3 type=p mobmod=1 capmod=2 version=3.1 tox=9e-5 cdsc=1e-3  
cdscb=-4.36889e-4 cdscd=0 cit=0 nfactor=1.79 xj=1.5e-7 vsat=1.5737e5 at=1e5  
a0=1.2522809 ags=0.2912413 a1=1.01222e-4 a2=0.996841 keta=0 nch=4.06263e17  
ngate=7.6e19 k1=0.823562
```

Instance Definition

```
Name d g s b ModelName parameter=value ...
```

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

Instance Parameters

1	w (m)	Channel width.
2	l (m)	Channel length.
3	as (m ²)	Area of source diffusion.
4	ad (m ²)	Area of drain diffusion.
5	ps (m)	Perimeter of source diffusion.
6	pd (m)	Perimeter of drain diffusion.
7	nrd (m/m)	Number of squares of drain diffusion.
8	nrs (m/m)	Number of squares of source diffusion.
9	m=1	Multiplicity factor (number of MOSFETs in parallel).
10	region=triode	Estimated operating region. Spectre outputs number (0-4) in a rawfile. Possible values are <code>off</code> , <code>triode</code> , <code>sat</code> , <code>subth</code> , and <code>breakdown</code> .
11	nqsmod	NQS flag.
12	acnqsmod	AC NQS flag.
13	isnoisy=yes	Should device generate noise. Possible values are <code>no</code> and <code>yes</code> .
14	trise (C)	Temperature rise from ambient.
15	aforward=0	Forward gate leakage current coefficient.
16	areverse=0	Reverse gate leakage current coefficient.
17	delvto=0 V	shift in zero-bias threshold voltage vth0.
18	mulmu0=1	mobility multiplier.
19	mulu0=1	mobility multiplier.

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BSIM3v3 Level-11 Model (bsim3v3)

20	<code>delk1=0</code>	<code> v</code>	shift in body bias coefficient <code>k1</code> .
21	<code>delnfc1=0</code>		shift in subthreshold swing factor <code>nfactor</code> .
22	<code>geo=0</code>		Geometry selector.
23	<code>rdc=0</code>		Drain contact resistance.
24	<code>rsc=0</code>		Source contact resistance.
25	<code>sa=0</code>	<code>m</code>	Distance between OD edge to poly of one side.
26	<code>sb=0</code>	<code>m</code>	Distance between OD edge to poly of the other side.
27	<code>sa1=0</code>	<code>m</code>	Distance between OD edge to poly of one side 1.
28	<code>sa2=0</code>	<code>m</code>	Distance between OD edge to poly of one side 2.
29	<code>sa3=0</code>	<code>m</code>	Distance between OD edge to poly of one side 3.
30	<code>sa4=0</code>	<code>m</code>	Distance between OD edge to poly of one side 4.
31	<code>sa5=0</code>	<code>m</code>	Distance between OD edge to poly of one side 5.
32	<code>sa6=0</code>	<code>m</code>	Distance between OD edge to poly of one side 6.
33	<code>sa7=0</code>	<code>m</code>	Distance between OD edge to poly of one side 7.
34	<code>sa8=0</code>	<code>m</code>	Distance between OD edge to poly of one side 8.
35	<code>sa9=0</code>	<code>m</code>	Distance between OD edge to poly of one side 9.
36	<code>sa10=0</code>	<code>m</code>	Distance between OD edge to poly of one side 10.
37	<code>sb1=0</code>	<code>m</code>	Distance between OD edge to poly of the other side 1.
38	<code>sb2=0</code>	<code>m</code>	Distance between OD edge to poly of the other side 2.
39	<code>sb3=0</code>	<code>m</code>	Distance between OD edge to poly of the other side 3.
40	<code>sb4=0</code>	<code>m</code>	Distance between OD edge to poly of the other side 4.
41	<code>sb5=0</code>	<code>m</code>	Distance between OD edge to poly of the other side 5.

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

42	<code>sb6=0</code>	m	Distance between OD edge to poly of the other side 6.
43	<code>sb7=0</code>	m	Distance between OD edge to poly of the other side 7.
44	<code>sb8=0</code>	m	Distance between OD edge to poly of the other side 8.
45	<code>sb9=0</code>	m	Distance between OD edge to poly of the other side 9.
46	<code>sb10=0</code>	m	Distance between OD edge to poly of the other side 10.
47	<code>sw1=0</code>	m	Width of SA1/SB1.
48	<code>sw2=0</code>	m	Width of SA2/SB2.
49	<code>sw3=0</code>	m	Width of SA3/SB3.
50	<code>sw4=0</code>	m	Width of SA4/SB4.
51	<code>sw5=0</code>	m	Width of SA5/SB5.
52	<code>sw6=0</code>	m	Width of SA6/SB6.
53	<code>sw7=0</code>	m	Width of SA7/SB7.
54	<code>sw8=0</code>	m	Width of SA8/SB8.
55	<code>sw9=0</code>	m	Width of SA9/SB9.
56	<code>sw10=0</code>	m	Width of SA10/SB10.
57	<code>stimod</code>		LOD stress effect model selector.
58	<code>sca=0.0</code>		Integral of the first distribution function for scattered well dopant.
59	<code>scb=0.0</code>		Integral of the second distribution function for scattered well dopant.
60	<code>scc=0.0</code>	V	Integral of the third distribution function for scattered well dopant.
61	<code>sc=0.0</code>	m	Distance to a single well edge .
62	<code>mulid0=1.0</code>		Ids multiplier.

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

Model Definition

```
model modelName bsim3v3 parameter=value ...
```

Model Parameters

Device type parameters

1 `type=n` Transistor type.
Possible values are `n` and `p`.

Threshold voltage parameters

2 `vtho (V)` Threshold voltage at zero body bias for long-channel devices. For enhancement-mode devices, $v_{tho} > 0$ for n-channel and $v_{th} < 0$ for p-channel. Default value is calculated from other model parameters.

3 `vfb=-1 V` Flat-band voltage.

4 `k1=0.5 |V` Body-effect coefficient.

5 `k2=-0.0186` Charge-sharing parameter.

6 `k3=80` Narrow width coefficient.

7 `k3b=0 1/V` Narrow width coefficient.

8 `w0=2.5e-6 m` Narrow width coefficient.

9 `n1x=1.74e-7 m` Lateral nonuniform doping coefficient.

10 `gamma1 (|V)` Body-effect coefficient near the surface.

11 `gamma2 (|V)` Body-effect coefficient in the bulk.

12 `vbx (V)` Threshold voltage transition body voltage.

13 `vbm=-3 V` Maximum applied body voltage.

14 `dvt0=2.2` First coefficient of short-channel effects.

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

15	$dvt1=0.53$	Second coefficient of short-channel effects.
16	$dvt2=-0.032$ 1/V	Body-bias coefficient of short-channel effects.
17	$dvt0w=0$ 1/m	First coefficient of narrow-width effects.
18	$dvt1w=5.3e6$ 1/m	Second coefficient of narrow-width effects.
19	$dvt2w=-0.032$ 1/V	Body-bias coefficient of narrow-width effects.
20	$a0=1$	Nonuniform depletion width effect coefficient.
21	$b0=0$ m	Bulk charge coefficient due to narrow width effect.
22	$b1=0$ m	Bulk charge coefficient due to narrow width effect.
23	$a1=0$ 1/V	No-saturation coefficient.
24	$a2=1$	No-saturation coefficient.
25	$ags=0$ 1/v	Gate-bias dependence of A_{bulk} .
26	$keta=-0.047$ 1/V	Body-bias coefficient for non-uniform depletion width effect.
27	$vfbflag=0$	49 Vfb selector.
28	$vthmod$	Vth output selector. 'std' outputs model equation Vth. 'vthcc' outputs constant current Vth, and may impact simulation performance. The default value is taken from the options parameter 'vthmod'. Possible values are <code>std</code> and <code>vthcc</code> .
29	$ivth$ (A)	Vth current parameter. The default value is taken from the options parameter 'ivthn' or 'ivthp', depending on the type of the model.
30	$ivthw$ (m)	Width offset for constant current Vth. The default value is taken from the options parameter 'ivthw'.
31	$ivthl$ (m)	Length offset for constant current Vth. The default value is taken from the options parameter 'ivthl'.

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

32 `ivth_vdsmin` (V) Minimum Vds in constant current Vth calculating. The default value is taken from the options parameter 'ivth_vdsmin'.

Process parameters

33 `nsub=6e16` cm⁻³ Substrate doping concentration.

34 `nch=1.7e17` cm⁻³ Peak channel doping concentration.

35 `ngate=0` cm⁻³ Poly-gate doping concentration.

36 `xj=0.15e-6` m Source/drain junction depth.

37 `lint=0` m Lateral diffusion for one side.

38 `wint=0` m Width reduction for one side.

39 `ll=0` m¹¹ⁿ Length dependence of delta L.

40 `lln=1` Length exponent of delta L.

41 `lw=0` m^{1wn} Width dependence of delta L.

42 `lwn=1` Width exponent of delta L.

43 `lwl=0` m^{1wn+11n} Area dependence of delta L.

44 `wl=0` m^{wln} Length dependence of delta W.

45 `wln=1` Length exponent of delta W.

46 `ww=0` m^{wwn} Width dependence of delta W.

47 `wwn=1` Width exponent of delta W.

48 `wwl=0` m^{wwn+wln} Area dependence of delta W.

49 `dwg=0` m/v Gate-bias dependence of channel width.

50 `dwb=0` m/|v Body-bias dependence of channel width.

51 `tox=1.5e-8` m Gate oxide thickness.

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BSIM3v3 Level-11 Model (bsim3v3)

52	$dtoxcv=0.0$ m	Delta oxide thickness.
53	$tox_m=tox$ m	Tox at which parameters were extracted.
54	$toxe=tox$ m	Electrical gate equivalent oxide thickness.
55	$xt=1.55e-7$ m	Doping depth.
56	$rdsw=0$ ohm μm^{wr}	Width dependence of drain-source resistance.
57	$prwb=0$ 1/ v	Body-effect coefficient for Rds.
58	$prwg=0$ 1/V	Gate-effect coefficient for Rds.
59	$wr=1$	Width offset for parasitic resistance.
60	$binunit=1$	Bin parameter unit selector. 1 for microns and 2 for meters.
61	$binflag=0$	49 binning factor.
62	$lref=1.0e20$	49 binning length factor.
63	$wref=1.0e20$	49 binning width factor.
<i>Mobility parameters</i>		
64	$mobmod=1$	Mobility model selector.
65	$u0=670$	Low-field surface mobility at t_{nom} . Default is 250 for PMOS Mobility can also be specified in M2/Vs.
66	$vsat=8e4$ m/s	Carrier saturation velocity at t_{nom} .
67	$ua=2.25e-9$ m/v	First-order mobility reduction coefficient.
68	$ub=5.87e-19$ m ² /v ²	Second-order mobility reduction coefficient.
69	$uc=-4.65e-11$ m/v ²	Body-bias dependence of mobility. Default is -0.046 and unit is 1/ V for $mobmod=3$.

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

Output resistance parameters

70	<code>drout=0.56</code>	DIBL effect on output resistance coefficient.
71	<code>pclm=1.3</code>	Channel length modulation coefficient.
72	<code>pdiblc1=0.39</code>	First coefficient of drain-induced barrier lowering.
73	<code>pdiblc2=8.6e-3</code>	Second coefficient of drain-induced barrier lowering.
74	<code>pdiblcb=0 1/V</code>	Body-effect coefficient for DIBL.
75	<code>pscbe1=4.24e8 V/m</code>	First coefficient of substrate current body effect.
76	<code>pscbe2=1e-5 m/v</code>	Second coefficient of substrate current body effect.
77	<code>pvag=0</code>	Gate dependence of Early voltage.
78	<code>delta=0.01 V</code>	Effective drain voltage smoothing parameter.

Subthreshold parameters

79	<code>cdsc=2.4e-4 F/m²</code>	Source/drain and channel coupling capacitance.
80	<code>cdscb=0 F/m² V</code>	Body-bias dependence of <code>cdsc</code> .
81	<code>cdscd=0 F/m² V</code>	Drain-bias dependence of <code>cdsc</code> .
82	<code>nfactor=1</code>	Subthreshold swing coefficient.
83	<code>cit=0 F/m²</code>	Interface trap parameter for subthreshold swing.
84	<code>voff=-0.08 V</code>	Threshold voltage offset.
85	<code>dsub=drout</code>	DIBL effect in subthreshold region.
86	<code>eta0=0.08</code>	DIBL coefficient subthreshold region.
87	<code>etab=-0.07 1/V</code>	Body-bias dependence of <code>et0</code> .

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

Substrate current parameters

- 88 $\alpha_0=0$ m/v Substrate current impact ionization coefficient.
- 89 $\alpha_1=0$ 1/V Substrate current impact ionization coefficient.
- 90 $\beta_0=30$ V Substrate current impact ionization exponent.

Parasitic resistance parameters

- 91 $r_{sh}=0$ Ω/sqr Source/drain diffusion sheet resistance.
- 92 $r_s=0$ Ω Source resistance.
- 93 $r_d=0$ Ω Drain resistance.
- 94 $lgcs=0$ m Gate-to-contact length of source side.
- 95 $lgcd=0$ m Gate-to-contact length of drain side.
- 96 $r_{sc}=0$ Ω Source contact resistance.
- 97 $r_{dc}=0$ Ω Drain contact resistance.
- 98 $r_{ss}=0$ Ω m Scalable source resistance.
- 99 $r_{dd}=0$ Ω m Scalable drain resistance.
- 100 $sc=\text{infinity}$ m Spacing between contacts.
- 101 $ldif=0$ m Lateral diffusion beyond the gate.
- 102 $hdif=0$ m Length of heavily doped diffusion.
- 103 $minr=0.001$ Ω Minimum source/drain resistance.

Junction diode model parameters

- 104 j_s (A/m^2) Bulk junction reverse saturation current density.
- 105 $j_{sw}=0$ A/m Sidewall junction reverse saturation current density.

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

106	$j_{ssw}=0$ A/m	Alias of j_{sw} .
107	$i_s=1e-14$ A	Bulk junction reverse saturation current.
108	$n=1$	Junction emission coefficient.
109	$n_j=1$	Junction emission coefficient.
110	$dskip=yes$	Use simple piece-wise linear model for diode currents below $0.1 \cdot i_{abstol}$. Possible values are <code>no</code> and <code>yes</code> .
111	$imelt='imaxA'$	Explosion current.
112	$ijth$ (A)	Alias to $imelt$.
113	$jmelt='jmaxA/m'^2$	Explosion current density.
114	$vnds=-1$	Reverse diode current transition point.
115	$nds=1$	Reverse bias slope coefficient.
116	$tt=0.0$ s	Transit time, spice compatible parameter.

Overlap capacitance parameters

117	$cgso$ (F/m)	Gate-source overlap capacitance.
118	$cgdo$ (F/m)	Gate-drain overlap capacitance.
119	$cgbo=2$ D_{wc} C_{ox} F/m	Gate-bulk overlap capacitance. The default value is 0 if <code>version=3.0</code> .
120	$meto=0$ m	Metal overlap in fringing field.
121	$cgsl=0$ F/m	Gate-source overlap capacitance in LDD region.
122	$cgdl=0$ F/m	Gate-drain overlap capacitance in LDD region.
123	$ckappa=0.6$ V	Overlap capacitance fitting parameter.

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BSIM3v3 Level-11 Model (bsim3v3)

Junction capacitance model parameters

124	$c_{bs}=0$ F	Bulk-source zero-bias junction capacitance.
125	$c_{bd}=0$ F	Bulk-drain zero-bias junction capacitance.
126	$c_j=5e-4$ F/m ²	Zero-bias junction bottom capacitance density.
127	$m_j=1/2$	Bulk junction bottom grading coefficient.
128	$p_b=1$ V	Bulk junction built-in potential.
129	$f_c=0.5$	Forward-bias depletion capacitance threshold.
130	$c_{jsw}=5e-10$ F/m	Zero-bias junction sidewall capacitance density.
131	$m_{jsw}=0.33$	Bulk junction sidewall grading coefficient.
132	$p_{bsw}=1$ V	Side-wall junction built-in potential.
133	$c_{jswg}=c_{jsw}$ F/m	Zero-bias gate-side junction capacitance density.
134	$m_{jswg}=m_{jsw}$	Gate-side junction grading coefficient.
135	$p_{bswg}=p_{bsw}$ V	Gate-side junction built-in potential.
136	$f_{csw}=0.5$	Side-wall forward-bias depletion capacitance threshold.

Charge model selection parameters

137	$capmod=2$	Intrinsic charge model.
138	$nqsmod=0$	Non-quasi static model selector. Set to 1 to turn on nqs.
139	$acnqsmod=0$	AC Non-quasi static model selector. Set to 1 to turn on nqs.
140	$dwc=wint$ m	Delta W for capacitance model.
141	$dlc=lint$ m	Delta L for capacitance model.
142	$clc=1e-7$ m	Intrinsic capacitance fitting parameter.
143	$cle=0.6$	Intrinsic capacitance fitting parameter.

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BSIM3v3 Level-11 Model (bsim3v3)

144	cf (F/m)	Fringe capacitance parameter.
145	$elm=5$	Elmore constant of the channel.
146	$vfbcv=-1$	Flat-band voltage for $capmod=0$.
147	$acde=1$ m/v	CV parameter.
148	$moin=15$	CV parameter.
149	$noff=1$	Transition parameter.
150	$voffcv=0$	Transition parameter.
151	$xpart=0$	Drain/source channel charge partition in saturation for BSIM charge model, use 0.0 for 40/60, 0.5 for 50/50, or 1.0 for 0/100.
152	$llc=ll$ m ^{lln}	Length dependence of delta L for CV.
153	$lwc=lw$ m ^{lwn}	Width dependence of delta L for CV.
154	$lwlc=lwl$ m ^{lwn+lln}	Area dependence of delta L for CV.
155	$wlc=wl$ m ^{wln}	Length dependence of delta W for CV.
156	$wwc=ww$ m ^{wwn}	Width dependence of delta W for CV.
157	$wwlc=wwl$ m ^{wln+wwn}	Area dependence of delta W for CV.
158	$wmlt=1.0$	Width shrink reduction factor.
159	$lmlt=1.0$	Length shrink reduction factor.

Default for instance parameters

160	$w=5e-6$ m	Default channel width.
161	$l=5e-6$ m	Default channel length.
162	$as=0$ m ²	Default area of source diffusion.

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BSIM3v3 Level-11 Model (bsim3v3)

163	$ad=0$ m ²	Default area of drain diffusion.
164	$ps=0$ m	Default perimeter of source diffusion.
165	$pd=0$ m	Default perimeter of drain diffusion.
166	$nrd=0$ m/m	Default number of squares of drain diffusion.
167	$nrs=0$ m/m	Default number of squares of source diffusion.
168	$version=3.1$	Model parameter "version" only accepts real number value, like 3.21 for version=3.2.1. The available versions are 3.1(3.1.0), 3.2(3.2.0), 3.21(3.2.1), 3.22(3.2.2), 3.23(3.2.3), 3.24(3.2.4) and 3.3(3.3.0)..
169	$paramchk=1$	Model parameter checking selector.
170	$fullreinit=0$	Model parameter full reinit selector.
171	$level=11$	BSIM3v3 model selector. The available level are 11, 49 and 53.
172	$acm=0$	BSIM3v3 area calculation method selector.
173	$geo=0$	geometry selector.
174	$calcacm=0$	49 geometry factor.

Temperature effects parameters

175	$tnom$ (C)	Parameters measurement temperature. Default set by <code>options</code> .
176	$trise=0$ C	Temperature rise from ambient.
177	$tlev=0$	DC temperature selector.
178	$tlevc=0$	AC temperature selector.
179	$eg=1.12452$ V	Energy band gap. Defaulted as 1.16 when spice compatible and 1.11 when <code>tlev</code> is 0 or 1 for spice.
180	$gap1=7.02e-4$ V/C	Band gap temperature coefficient.
181	$gap2=1108$ C	Band gap temperature offset.

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BSIM3v3 Level-11 Model (bsim3v3)

182	$eglev=0$	DC temperature selector.
183	$diomod=1$	a flag to select junction model. $diomod=1$ junction model described in Common MOSFET Equations section will be used. $diomod=0$ Berkeley junction model is used. $diomod=100$ TSMC special diode model .
184	$kt1=-0.11$ V	Temperature coefficient for threshold voltage.
185	$kt11=0$ v m	Temperature coefficient for threshold voltage.
186	$kt2=0.022$	Temperature coefficient for threshold voltage.
187	$at=3.3e4$ m/s	Temperature coefficient for v_{sat} .
188	$ua1=4.31e-9$ m/v	Temperature coefficient for u_a .
189	$ub1=-7.61e-18$ m^2/v^2	Temperature coefficient for u_b .
190	$uc1=-5.5e-11$ m/v^2	Temperature coefficient for u_c . Default is -0.056 for $mobmod=3$.
191	$prt=0$ Ω	Temperature coefficient for R_{ds} .
192	$trs=0$ 1/C	Temperature parameter for source resistance.
193	$trd=0$ 1/C	Temperature parameter for drain resistance.
194	$ute=-1.5$	Mobility temperature exponent.
195	$x_{ti}=3$	Saturation current temperature exponent.
196	$pta=0$ V/C	Junction potential temperature coefficient.
197	$tpb=0$ V/C	Temperature coefficient for p_b .
198	$ptp=0$ V/C	Sidewall junction potential temperature coefficient.
199	$tpbsw=0$ V/C	Temperature coefficient for p_{bsw} .
200	$tpbswg=0$ V/C	Temperature coefficient for p_{bswg} .

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BSIM3v3 Level-11 Model (bsim3v3)

201	$c_{ta}=0$	1/C	Junction capacitance temperature coefficient.
202	$t_{cj}=0$	1/C	Temperature coefficient for c_j .
203	$c_{tp}=0$	1/C	Sidewall junction capacitance temperature coefficient.
204	$t_{cjsw}=0$	1/C	Temperature coefficient for c_{jsw} .
205	$t_{cjswg}=0$	1/C	Temperature coefficient for c_{jswg} .

Noise model parameters

206	$noimod=1$		Noise model selector.
207	$k_f=0$		Flicker (1/f) noise coefficient.
208	$a_f=1$		Flicker (1/f) noise exponent.
209	$e_f=1$		Flicker (1/f) noise frequency exponent.
210	$noia=1e20$		Oxide trap density coefficient. Default is $9.9e18$ for pmos.
211	$noib=5e4$		Oxide trap density coefficient. Default is $2.4e3$ for pmos.
212	$noic=-1.4e-12$		Oxide trap density coefficient. Default is $1.4e-12$ for pmos.
213	$noid=2e14$		flicker noise subthreshold-above threshold transition coefficient.
214	$w_{noi}=1e-5$	m	Channel width at which noise parameters were extracted.
215	$e_m=4.1e7$	V/m	Maximum electric field.
216	$flkmod=0$		Flicker noise model (0 for I_{ds} based model, 1 for gm based model).
217	$\gamma=2.0/3.0$		Thermal noise coefficient.
218	$nlev=2.0$		49 noise selector.
219	$gdsnoi=1.0$		Channel thermal noise coefficient for 49 noise.
220	$lintnoi=0$	m	Lint offset for noise calculation.

Gate-Induced drain leakage parameters

221	$agidl=0.0$	$1/\Omega$	Pre-exponential coefficient for GIDL.
222	$bgidl=2.3e9$	V/m	Exponential coefficient for GIDL.
223	$cgidl=0.5$	V^3	Parameter for body-bias effect on GIDL.
224	$egidl=0.8$	V	Fitting parameter for band bending for GIDL.
225	$agisl=agidl$	$1/\Omega$	Pre-exponential coefficient for GISL.
226	$bgisl=bgidl$	V/m	Exponential coefficient for GISL.
227	$cgisl=cgidl$	V^3	Parameter for body-bias effect on GISL.
228	$egisl=egidl$	V	Fitting parameter for band bending for GISL.

Gate leak current parameters

229	$bforward=0$		Forward gate leakage current coefficient in $pow()$.
230	$breverse=0$		Reverse gate leakage current coefficient in $pow()$.
231	$cforward=0$		Forward gate leakage current coefficient in $exp()$.
232	$creverse=0$		Reverse gate leakage current coefficient in $exp()$.
233	$tcc=0$		Gate leakage current temperature coefficient.
234	$aigbinv=1.11e-2$	$ F/g \quad s/m$	Parameter for I_{gb} in inversion.
235	$bigbinv=9.49e-4$	$ F/g \quad s/(m \cdot V)$	Parameter for I_{gb} in inversion.
236	$cigbinv=0.006$	$1/V$	Parameter for I_{gb} in inversion.
237	$eigbinv=1.1$	V	Parameter for I_{gb} in inversion.
238	$nigbinv=3.0$		Parameter for I_{gb} in inversion.

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

- 239 $aigbacc=1.36e-2$ $|F/g$ s/m
Parameter for I_{gb} in accumulation.
- 240 $bigbacc=1.71e-3$ $|F/g$ s/(m V)
Parameter for I_{gb} in accumulation.
- 241 $cigbacc=0.075$ 1/V
Parameter for I_{gb} in accumulation.
- 242 $nigbacc=1.0$
Parameter for I_{gb} in accumulation.
- 243 $aigsd=1.36e-2$ (nmos) / $9.80e-3$ (pmos) $|F/g$ s/m
Parameter for I_{gs} and I_{gd} .
- 244 $bigsd=1.71e-3$ (nmos) / $7.59e-4$ (pmos) $|F/g$ s/(m V)
Parameter for I_{gs} and I_{gd} .
- 245 $cigsd=0.075$ (nmos) / 0.03 (pmos) 1/V
Parameter for I_{gs} and I_{gd} .
- 246 $aigc=1.36e-2$ (nmos) / $9.80e-3$ (pmos) $|F/g$ s/m
Parameter for I_{gcs} and I_{gcd} .
- 247 $bigc=1.71e-3$ (nmos) / $7.59e-4$ (pmos) $|F/g$ s/(m V)
Parameter for I_{gcs} and I_{gcd} .
- 248 $cigc=0.075$ (nmos) / 0.03 (pmos) 1/V
Parameter for I_{gcs} and I_{gcd} .
- 249 $nigc=1.0$
Parameter for I_{gcs} , I_{gcd} , I_{gs} and I_{gd} .
- 250 $pigcd=1.0$
Vds dependence of I_{gcs} and I_{gcd} .
- 251 $dlcig='Lintm'$
Source/drain overlap length for I_{gs} and I_{gd} .
- 252 $ntox=1.0$
Exponent for the gate oxide ratio.
- 253 $toxref=3.0e-9$ m
Nominal gate oxide thickness for gate dielectric tunneling current model only.
- 254 $poxedg=1.0$
Factor for the gate oxide thickness in source/drain overlap regions.

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

255 `igcm0d=0` Gate-to-channel and gate-to-source, gate-to-drain tunneling model selector.

256 `igbmod=0` Gate-to-substrate tunneling model selector.

Auto Model Selector parameters

257 `wmax=1 m` Maximum channel width for which the model is valid.

258 `wmin=0 m` Minimum channel width for which the model is valid.

259 `lmax=1 m` Maximum channel length for which the model is valid.

260 `lmin=0 m` Minimum channel length for which the model is valid.

Operating region warning control parameters

261 `alarm=none` Forbidden operating region.
Possible values are `none`, `off`, `triode`, `sat`, `subth`, and `rev`.

262 `imax=1 A` Maximum allowable current.

263 `jmax=1e8 A/m2` Maximum allowable current density.

264 `bvj=infinity V` Junction reverse breakdown voltage.

265 `vbox=3e9 tox V` Oxide breakdown voltage.

266 `warn=on` Parameter to turn warnings on and off.
Possible values are `off` and `on`.

267 `apwarn=0` Warning message flag.

Safe Operating Areas Parameters

268 `vds_max=infinity V`
Maximum allowed voltage cross source and drain.

269 `vgd_max=infinity V`
Maximum allowed voltage cross gate and drain.

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

- 270 `vgs_max=infinity` V
Maximum allowed voltage cross gate and source/bulk.
- 271 `vbd_max=infinity` V
Maximum allowed voltage cross source/drain and bulk.
- 272 `vbs_max=vbd_max` V
Maximum allowed voltage cross source and bulk.
- 273 `vgb_max=infinity` V
Maximum allowed voltage cross gate and bulk.
- 274 `vgdr_max=vgd_max` V
Maximum allowed reverse voltage cross gate and drain.
- 275 `vgdr_max=vgd_max` V
Maximum allowed reverse voltage cross gate and source.
- 276 `vgbr_max=vgb_max` V
Maximum allowed reverse voltage cross gate and bulk.
- 277 `vbsr_max=vbs_max` V
Maximum allowed reverse voltage cross bulk and source.
- 278 `vbdr_max=vbd_max` V
Maximum allowed reverse voltage cross bulk and drain.

Length dependent parameters

- 279 `lvtho=0` Length dependence of V_{th0} .
- 280 `lvth0` Alias of `lvtho`.
- 281 `lk1=0` Length dependence of k_1 .
- 282 `lk2=0` Length dependence of k_2 .
- 283 `lk3=0` Length dependence of k_3 .
- 284 `lk3b=0` Length dependence of k_{3b} .
- 285 `lw0=0` Length dependence of w_0 .
- 286 `lnlx=0` Length dependence of n_{lx} .

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

287	$l_{\text{gamma1}}=0$	Length dependence of gamma1 .
288	$l_{\text{gamma2}}=0$	Length dependence of gamma2 .
289	$l_{\text{vbx}}=0$	Length dependence of vbx .
290	$l_{\text{vbm}}=0$	Length dependence of vbm .
291	$l_{\text{dvt0}}=0$	Length dependence of dvt0 .
292	$l_{\text{dvt1}}=0$	Length dependence of dvt1 .
293	$l_{\text{dvt2}}=0$	Length dependence of dvt2 .
294	$l_{\text{dvt0w}}=0$	Length dependence of dvt0w .
295	$l_{\text{dvt1w}}=0$	Length dependence of dvt1w .
296	$l_{\text{dvt2w}}=0$	Length dependence of dvt2w .
297	$l_{\text{a0}}=0$	Length dependence of a0 .
298	$l_{\text{b0}}=0$	Length dependence of b0 .
299	$l_{\text{b1}}=0$	Length dependence of b1 .
300	$l_{\text{a1}}=0$	Length dependence of a1 .
301	$l_{\text{a2}}=0$	Length dependence of a2 .
302	$l_{\text{ags}}=0$	Length dependence of ags .
303	$l_{\text{keta}}=0$	Length dependence of keta .
304	$l_{\text{nsub}}=0$	Length dependence of nsub .
305	$l_{\text{nch}}=0$	Length dependence of nch .
306	$l_{\text{ngate}}=0$	Length dependence of ngate .
307	$l_{\text{xj}}=0$	Length dependence of xj .
308	$l_{\text{dwg}}=0$	Length dependence of dwg .

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

309	ldwb=0	Length dependence of dwb.
310	lxt=0	Length dependence of xt.
311	lrds=0	Length dependence of rds.
312	lprwb=0	Length dependence of prwb.
313	lprwg=0	Length dependence of prwg.
314	lwr=0	Length dependence of wr.
315	lu0=0	Length dependence of u0.
316	lvsat=0	Length dependence of vsat.
317	lua=0	Length dependence of ua.
318	lub=0	Length dependence of ub.
319	luc=0	Length dependence of uc.
320	ldrout=0	Length dependence of drout.
321	lpclm=0	Length dependence of pclm.
322	lpdiblc1=0	Length dependence of pdiblc1.
323	lpdiblc2=0	Length dependence of pdiblc2.
324	lpdiblcb=0	Length dependence of pdiblcb.
325	lpscbe1=0	Length dependence of pscbe1.
326	lpscbe2=0	Length dependence of pscbe2.
327	lpvag=0	Length dependence of pvag.
328	ldelta=0	Length dependence of delta.
329	lcdsc=0	Length dependence of cdsc.
330	lcdscb=0	Length dependence of cdscb.

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BSIM3v3 Level-11 Model (bsim3v3)

331	lcdscd=0	Length dependence of cdsd.
332	lnfactor=0	Length dependence of nfactor.
333	lcit=0	Length dependence of cit.
334	lvoff=0	Length dependence of voff.
335	ldsub=0	Length dependence of dsub.
336	leta0=0	Length dependence of eta0.
337	letab=0	Length dependence of etab.
338	lalpha0=0	Length dependence of alpha0.
339	lalpha1=0	Length dependence of alpha1.
340	lbeta0=0	Length dependence of beta0.
341	lcgsl=0	Length dependence of cgsl.
342	lcgdl=0	Length dependence of cgdl.
343	lckappa=0	Length dependence of ckappa.
344	lclc=0	Length dependence of clc.
345	lcle=0	Length dependence of cle.
346	lcf=0	Length dependence of cf.
347	lelm=0	Length dependence of elm.
348	lvfbcv=0	Length-dependence of vfbc.
349	lvfb=0	Length dependence of lvfb.
350	lacde=0	Length dependence of acde.
351	lmoin=0	Length dependence of moin.
352	lnoff=0	Length dependence of noff.

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

353	lvoffcv=0	Length dependence of voffcv.
354	lkt1=0	Length dependence of kt1.
355	lkt1l=0	Length dependence of kt1l.
356	lkt2=0	Length dependence of kt2.
357	lat=0	Length dependence of at.
358	lua1=0	Length dependence of ua1.
359	lub1=0	Length dependence of ub1.
360	luc1=0	Length dependence of uc1.
361	lprt=0	Length dependence of prt.
362	lute=0	Length dependence of ute.
363	xl=0 m	Length variation due to masking and etching.
364	xlref=0 m	Length variation due to masking and etching.
365	lagidl=0.0	Length dependence of agidl.
366	lbgidl=0.0	Length dependence of bgidl.
367	lcgidl=0.0	Length dependence of cgidl.
368	legidl=0.0	Length dependence of egidl.

Width dependent parameters

369	wvtho=0	Width dependence of Vth0.
370	wvth0	Alias of wvtho.
371	wk1=0	Width dependence of k1.
372	wk2=0	Width dependence of k2.
373	wk3=0	Width dependence of k3.

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

374	$wk3b=0$	Width dependence of $k3b$.
375	$ww0=0$	Width dependence of $w0$.
376	$wnlx=0$	Width dependence of nlx .
377	$wgamma1=0$	Width dependence of $gamma1$.
378	$wgamma2=0$	Width dependence of $gamma2$.
379	$wvbx=0$	Width dependence of vbx .
380	$wvbm=0$	Width dependence of vbm .
381	$wdvt0=0$	Width dependence of $dvt0$.
382	$wdvt1=0$	Width dependence of $dvt1$.
383	$wdvt2=0$	Width dependence of $dvt2$.
384	$wdvt0w=0$	Width dependence of $dvt0$.
385	$wdvt1w=0$	Width dependence of $dvt1w$.
386	$wdvt2w=0$	Width dependence of $dvt2w$.
387	$wa0=0$	Width dependence of $a0$.
388	$wb0=0$	Width dependence of $b0$.
389	$wb1=0$	Width dependence of $b1$.
390	$wa1=0$	Width dependence of $a1$.
391	$wa2=0$	Width dependence of $a2$.
392	$wags=0$	Width dependence of ags .
393	$wketa=0$	Width dependence of $keta$.
394	$wnsub=0$	Width dependence of $nsub$.
395	$wnch=0$	Width dependence of nch .

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

396	wngate=0	Width dependence of ngate.
397	wxj=0	Width dependence of xj.
398	wdwg=0	Width dependence of dwg.
399	wdwb=0	Width dependence of dwb.
400	wxt=0	Width dependence of xt.
401	wrdsw=0	Width dependence of rdsw.
402	wprwb=0	Width dependence of prwb.
403	wprwg=0	Width dependence of prwg.
404	wwr=0	Width dependence of wr.
405	wu0=0	Width dependence of u0.
406	wvsat=0	Width dependence of vsat.
407	wua=0	Width dependence of ua.
408	wub=0	Width dependence of ub.
409	wuc=0	Width dependence of uc.
410	wdrout=0	Width dependence of drout.
411	wpclm=0	Width dependence of pclm.
412	wpdiblc1=0	Width dependence of pdiblc1.
413	wpdiblc2=0	Width dependence of pdiblc2.
414	wpdiblcb=0	Width dependence of pdiblcb.
415	wpscbe1=0	Width dependence of pscbe1.
416	wpscbe2=0	Width dependence of pscbe2.
417	wpvag=0	Width dependence of pvag.

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

418	wdelta=0	Width dependence of delta.
419	wcdsc=0	Width dependence of cdsc.
420	wcdscb=0	Width dependence of cdscb.
421	wcdscd=0	Width dependence of cdscd.
422	wnfactor=0	Width dependence of nfactor.
423	wcit=0	Width dependence of cit.
424	wvoff=0	Width dependence of voff.
425	wdsub=0	Width dependence of dsub.
426	weta0=0	Width dependence of eta0.
427	wetab=0	Width dependence of etab.
428	walpha0=0	Width dependence of alpha0.
429	walpha1=0	Width dependence of alpha1.
430	wbeta0=0	Width dependence of beta0.
431	wcgsl=0	Width dependence of cgsl.
432	wcgdl=0	Width dependence of cgdl.
433	wckappa=0	Width dependence of ckappa.
434	wclc=0	Width dependence of clc.
435	wcle=0	Width dependence of cle.
436	wcf=0	Width dependence of cf.
437	welm=0	Width dependence of el.
438	wvfbcv=0	Width-dependence of vfbcv.
439	wvfb=0	Width dependence of lvfb.

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

440	wacde=0	Width dependence of acde.
441	wmoin=0	Width dependence of moin.
442	wnoff=0	Width dependence of noff.
443	wvoffcv=0	Width dependence of voffcv.
444	wkt1=0	Width dependence of kt1.
445	wkt1l=0	Width dependence of kt1l.
446	wkt2=0	Width dependence of kt2.
447	wat=0	Width dependence of at.
448	wua1=0	Width dependence of ua1.
449	wub1=0	Width dependence of ub1.
450	wuc1=0	Width dependence of uc1.
451	wprt=0	Width dependence of prt.
452	wute=0	Width dependence of ute.
453	xw=0 m	Width variation due to masking and etching.
454	xwref=0 m	Width variation due to masking and etching.
455	wagidl=0.0	Width dependence of agidl.
456	wbgidl=0.0	Width dependence of bgidl.
457	wcgidl=0.0	Width dependence of cgidl.
458	wegidl=0.0	Width dependence of egidl.

Cross-term dependent parameters (Not listed)

459	pvtho=0	Product dependence of Vth0.
460	pvth0	Alias of pvtho.

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

461	$p_{k1=0}$	Product dependence of $k1$.
462	$p_{k2=0}$	Product dependence of $k2$.
463	$p_{k3=0}$	Product dependence of $k3$.
464	$p_{k3b=0}$	Product dependence of $k3b$.
465	$p_{w0=0}$	Product dependence of $w0$.
466	$p_{nlx=0}$	Product dependence of nlx .
467	$p_{\gamma1=0}$	Product dependence of $\gamma1$.
468	$p_{\gamma2=0}$	Product dependence of $\gamma2$.
469	$p_{vbx=0}$	Product dependence of vbx .
470	$p_{vbm=0}$	Product dependence of vbm .
471	$p_{dvt0=0}$	Product dependence of $dvt0$.
472	$p_{dvt1=0}$	Product dependence of $dvt1$.
473	$p_{dvt2=0}$	Product dependence of $dvt2$.
474	$p_{dvt0w=0}$	Product dependence of $dvt0w$.
475	$p_{dvt1w=0}$	Product dependence of $dvt1w$.
476	$p_{dvt2w=0}$	Product dependence of $dvt2w$.
477	$p_{a0=0}$	Product dependence of $a0$.
478	$p_{b0=0}$	Product dependence of $b0$.
479	$p_{b1=0}$	Product dependence of $b1$.
480	$p_{a1=0}$	Product dependence of $a1$.
481	$p_{a2=0}$	Product dependence of $a2$.
482	$p_{ags=0}$	Product dependence of ags .

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

483	pketa=0	Product dependence of keta.
484	pnsb=0	Product dependence of nsub.
485	pnch=0	Product dependence of nch.
486	pngate=0	Product dependence of ngate.
487	pxj=0	Product dependence of xj.
488	pdwg=0	Product dependence of dwg.
489	pdwb=0	Product dependence of dwb.
490	pxt=0	Product dependence of xt.
491	prdsb=0	Product dependence of rdsb.
492	pprwb=0	Product dependence of prwb.
493	pprwb=0	Product dependence of prwb.
493	pprwb=0	Product dependence of prwb.
493	pprwb=0	Product dependence of prwb.
493	pprwb=0	Product dependence of prwb.
494	pwr=0	Product dependence of wr.
495	pu0=0	Product dependence of u0.
496	pvsat=0	Product dependence of vsat.
497	pua=0	Product dependence of ua.
498	pub=0	Product dependence of ub.
499	puc=0	Product dependence of uc.
500	pdrout=0	Product dependence of drout.
501	ppclm=0	Product dependence of pclm.
502	ppdiblc1=0	Product dependence of pdiblc1.
503	ppdiblc2=0	Product dependence of pdiblc2.
504	ppdiblc3=0	Product dependence of pdiblc3.

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

505	ppscbe1=0	Product dependence of pscbe1.
506	ppscbe2=0	Product dependence of pscbe2.
507	ppvag=0	Product dependence of pvag.
508	pdelta=0	Product dependence of delta.
509	pcdsc=0	Product dependence of cdsc.
510	pcdscb=0	Product dependence of cdsb.
511	pcdscd=0	Product dependence of cdsd.
512	pnfactor=0	Product dependence of nfactor.
513	pcit=0	Product dependence of cit.
514	pvoff=0	Product dependence of voff.
515	pdsb=0	Product dependence of dsb.
516	peta0=0	Product dependence of eta0.
517	petab=0	Product dependence of etab.
518	palpha0=0	Product dependence of alpha0.
519	palpha1=0	Product dependence of alpha1.
520	pbeta0=0	Product dependence of beta0.
521	pcgsl=0	Product dependence of cgsl.
522	pcgdl=0	Product dependence of cgdl.
523	pckappa=0	Product dependence of ckappa.
524	pclc=0	Product dependence of clc.
525	pcle=0	Product dependence of cle.
526	pcf=0	Product dependence of cf.

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

527	pelm=0	Product dependence of elm.
528	pvfbcv=0	Product dependence of vfbcv.
529	pvfb=0	Product dependence of lvfb.
530	pacde=0	Product dependence of acde.
531	pmoin=0	Product dependence of moin.
532	pnoff=0	Product dependence of noff.
533	pvoffcv=0	Product dependence of voffcv.
534	pkt1=0	Product dependence of kt1.
535	pkt11=0	Product dependence of kt11.
536	pkt2=0	Product dependence of kt2.
537	pat=0	Product dependence of at.
538	pua1=0	Product dependence of ua1.
539	pub1=0	Product dependence of ub1.
540	puc1=0	Product dependence of uc1.
541	pprt=0	Product dependence of prt.
542	pute=0	Product dependence of ute.
543	pagidl=0.0	Cross-term dependence of agidl.
544	pbgidl=0.0	Cross-term dependence of bgidl.
545	pcgidl=0.0	Cross-term dependence of cgidl.
546	pegidl=0.0	Cross-term dependence of egidl.

DC-mismatch dependent parameters

547	mvtwl=0.0 v m	Threshold mismatch area dependence.
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Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

548	<code>mvtwl2=0.0 v m^1.5</code>	Threshold mismatch area square dependence.
549	<code>mvt0=0.0 V</code>	Threshold mismatch intercept.
550	<code>mbewl=0.0 m</code>	Beta mismatch area dependence.
551	<code>mbe0=0.0</code>	Beta mismatch intercept.
552	<code>mismatchmod=0</code>	select Mismatch mode. The available modes are 0, 1, 2 and 3.
553	<code>mismatchdist=0 m</code>	Mismatch Distance.

LOD model parameters

554	<code>stimod=1</code>	LOD stress effect model selector. 0 for no LOD, 1 for UCB LOD, 2 for TSMC LOD.
555	<code>sa0=1e-6 m</code>	reference distance between od edge to poly of one side.
556	<code>saref (m)</code>	Alias to Sa0.
557	<code>sb0=1e-6 m</code>	reference distance between od edge to poly of the other side.
558	<code>sbref (m)</code>	Alias to sb0.
559	<code>wlod=0 m</code>	length parameter for stress effect.
560	<code>ku0=0 m</code>	mobility degradation/enhancement coefficient for stress effect.
561	<code>kvsat=0</code>	saturation velocity degradation/enhancement parameter for stress effect.
562	<code>kvth0=0 v m</code>	threshold shift parameter for stress effect.
563	<code>tku0=0</code>	temperature coefficient of ku0.
564	<code>llodku0=0</code>	length parameter for u0 stress effect.
565	<code>wlodku0=0</code>	width parameter for u0 stress effect.
566	<code>llodvth=0</code>	length parameter for vth stress effect.

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

567	$w_{lodvth}=0$	width parameter for vth stress effect.
568	$l_{ku0}=0$ $m^{l_{lodku0}}$	length dependence of $ku0$.
569	$w_{ku0}=0$ $m^{w_{lodku0}}$	width dependence of $ku0$.
570	$p_{ku0}=0$ $m^{(l_{lodku0}+w_{lodku0})}$	cross-term dependence of $ku0$.
571	$l_{kvth0}=0$ v $m^{l_{lodku0}}$	length dependence of $kvth0$.
572	$w_{kvth0}=0$ v $m^{w_{lodku0}}$	width dependence of $kvth0$.
573	$p_{kvth0}=0$ v $m^{(l_{lodku0}+w_{lodku0})}$	cross-term dependence of $kvth0$.
574	$stk2=0$ m	$k2$ shift factor related to $vth0$ change.
575	$lodk2=0$	$k2$ shift modification factor for stress effect.
576	$steta0=0$ m	$eta0$ shift factor related to $vth0$ change.
577	$lodeta0=0$	$eta0$ shift modification factor for stress effect.
578	$wpemod=0$	Flag for WPE model (WPEMOD=1 to activate this model) .
579	$web=0.0$	Coefficient for SCB.
580	$wec=0.0$	Coefficient for SCC.
581	$kvth0we=0.0$ V	Threshold shift factor for well proximity effect .
582	$k2we=0.0$	$K2$ shift factor for well proximity effect.
583	$l_{kvth0we}=0.0$ V	Length dependence of $kvth0we$.
584	$w_{kvth0we}=0.0$ V	Width dependence of $kvth0we$.
585	$p_{kvth0we}=0.0$ V	Cross-term dependence of $kvth0we$.
586	$lk2we=0.0$	Length dependence of $k2we$.

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BSIM3v3 Level-11 Model (bsim3v3)

587	$wk_{2we}=0.0$	Width dependence of k_{2we} .
588	$pk_{2we}=0.0$	Cross-term dependence of k_{2we} .
589	$ku_{0we}=0.0$	Mobility degradation factor for well proximity effect .
590	$lku_{0we}=0.0$	Length dependence of ku_{0we} .
591	$wku_{0we}=0.0$	Width dependence of ku_{0we} .
592	$pku_{0we}=0.0$	Cross-term dependence of ku_{0we} .
593	$scref=1.0e-6$ m	Reference distance to calculate SCA, SCB and SCC .

TSMC junction diode model parameters

594	$jt_{ss}=0$ A/m ²	Source bottom trap-assisted saturation current density.
595	$jt_{sd}=0$ A/m ²	Drain bottom trap-assisted saturation current density.
596	$jt_{ssws}=0$ A/m	Source isolation-edge sidewall trap-assisted saturation current density.
597	$jt_{sswd}=0$ A/m	Drain isolation-edge sidewall trap-assisted saturation current density.
598	$jt_{sswgs}=0$ A/m	Source Gate-edge isolation-edge sidewall trap-assisted saturation current density.
599	$jt_{sswgd}=0$ A/m	Drain isolation-edge sidewall trap-assisted saturation current density.
600	$n_{jts}=60$	Non-ideality factor for J_{tss} and J_{tsd} .
601	$n_{jtssw}=60$	Non-ideality factor for J_{tssws} and J_{tsswd} .
602	$n_{jtsswg}=60$	Non-ideality factor for J_{tsswgs} and J_{tsswgd} .
603	$n_{jt_{sd}}=n_{jts}$	Non-ideality factor for jt_{sd} .
604	$n_{jt_{sswd}}=n_{jt_{ssw}}$	Non-ideality factor for jt_{sswd} .
605	$n_{jt_{sswgd}}=n_{jt_{sswg}}$	Non-ideality factor for jt_{sswgd} .

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606	$mnr=21$	Fitting parameter for resistance induced non-ideality factor.
607	$bnr=0$	Fitting parameter for resistance induced non-ideality factor.
608	$cnr=0$ $1/v$ m	Fitting parameter for resistance induced non-ideality factor.
609	$dnr=0$ $1/v$	Fitting parameter for resistance induced non-ideality factor.
610	$xtss=0.02$	Power dependence of J_{tss} on temperature.
611	$xtsd=0.02$	Power dependence of J_{tsd} on temperature.
612	$xtssws=0.02$	Power dependence of J_{tssws} on temperature.
613	$xtsswd=0.02$	Power dependence of J_{tsswd} on temperature.
614	$xtsswgs=0.02$	Power dependence of J_{tsswgs} on temperature.
615	$xtsswgd=0.02$	Power dependence of J_{tsswgd} on temperature.
616	$tnjts=0$	Temperature coefficient for NJTS.
617	$tnjtssw=0$	Temperature coefficient for $njtssw$.
618	$tnjtsswg=0$	Temperature coefficient for $njtsswg$.
619	$tnjtsd=tnjts$	Temperature coefficient for $njtsd$.
620	$tnjtsswd=tnjtssw$	Temperature coefficient for $njtsswd$.
621	$tnjtsswgd=tnjtsswg$	Temperature coefficient for $njtsswgd$.
622	$tmnr=0$	Temperature coefficient for mnr .
623	$tcnr=0$	Temperature coefficient for cnr .
624	$tdnr=0$	Temperature coefficient for dnr .
625	$jsswg=0$	Sidewall-gate junction reverse saturation current density.
626	$xjbv=1.0$	Fitting parameter for diodes breakdown.

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627	<code>ijthrev=0.1</code>	Reverse maximum allowable current.
628	<code>nrfwd=1.0</code>	Nominal value of <code>Nr</code> for forward linearization.
629	<code>vtss=10.0 V</code>	Source bottom trap-assisted voltage dependent parameter.
630	<code>vtsd=`vtssV'</code>	Drain bottom trap-assisted voltage dependent parameter.
631	<code>vtssws=10.0 V</code>	Source STI sidewall trap-assisted voltage dependent parameter.
632	<code>vtsswd=`vtsswsV'</code>	Drain STI sidewall trap-assisted voltage dependent parameter.
633	<code>vtsswgs=10.0 V</code>	Source gate-edge sidewall trap-assisted voltage dependent parameter.
634	<code>vtsswgd=`vtsswgsV'</code>	Drain gate-edge sidewall trap-assisted voltage dependent parameter.

Shrink Parameters

635	<code>shrink=0</code>	linear shrink parameter.
636	<code>shrink2=0</code>	area shrink parameter.
637	<code>msgskip=off</code>	Skip some warning message customer requested. Possible values are <code>off</code> and <code>on</code> .
638	<code>compatible=spectre</code>	Encourage device equations to be compatible with a foreign simulator. This option does not affect input syntax. Possible values are <code>spectre</code> , <code>spice2</code> , <code>spice3</code> , <code>cdsspice</code> , <code>hspice</code> , <code>spiceplus</code> , <code>eldo</code> , <code>sspice</code> , <code>mica</code> , <code>tispice</code> , and <code>pspice</code> .

Imax and Imelt

The `imax` parameter aids convergence and prevents numerical overflow. The junction characteristics of the device are accurately modeled for current up to `imax`. If `imax` is exceeded during iterations, the linear model is substituted until the current drops below '`imax`' or until convergence is achieved. If convergence is achieved with the current exceeding `imax`, the results are inaccurate, and a warning is printed out.

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A separate model parameter, i_{melt} , is used as a limit warning for the junction current. This parameter can be set to the maximum current rating of the device. When any component of the junction current exceeds i_{melt} , note that base and collector currents are composed of many exponential terms, a warning will be issued and the results become inaccurate. The junction current is linearized above the value of i_{melt} to prevent arithmetic exception, with the exponential term replaced by a linear equation at i_{melt} .

Both of these parameters have current density counterparts, j_{max} and j_{melt} , that you can specify if you want the absolute current values to depend on the device area.

Auto Model Selection

Many models need to be characterized for different geometries in order to obtain accurate results for model development. The model selector program automatically searches for a model with the length and width range specified in the instance statement and uses this model in the simulations.

For the auto model selector program to find a specific model, the models to be searched should be grouped together within braces. Such a group is called a model group. An opening brace is required at the end of the line defining each model group. Every model in the group is given a name followed by a colon and the list of parameters. Also, the four geometric parameters l_{max} , l_{min} , w_{max} , and w_{min} should be given. The selection criteria to choose a model is as follows:

$$l_{min} \leq inst_length < l_{max} \quad \text{and} \quad w_{min} \leq inst_width < w_{max}$$

Example:

```
model ModelName ModelType {  
    1: <model parameters> lmin=2 lmax=4 wmin=1 wmax=2  
    2: <model parameters> lmin=1 lmax=2 wmin=2 wmax=4  
    3: <model parameters> lmin=2 lmax=4 wmin=4 wmax=6  
}
```

Then for a given instance

```
M1 1 2 3 4 ModelName w=3 l=1.5
```


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BSIM3v3 Level-11 Model (bsim3v3)

the program would search all the models in the model group with the name `ModelName` and then pick the first model whose geometric range satisfies the selection criteria. In the preceding example, the auto model selector program would choose `ModelName.2`.

You must specify both length (l) and width (w) on the device instance line to enable automatic model selection.

Output Parameters

1	<code>tempeff</code> (C)	Effective temperature for a single device.
2	<code>meff</code>	Effective multiplicity factor (m-factor).
3	<code>weff</code> (m)	Effective channel width (alias=lv2).
4	<code>leff</code> (m)	Effective channel length (alias=lv1).
5	<code>rseff</code> (Ω)	Effective source resistance (alias=lv17).
6	<code>rdeff</code> (Ω)	Effective drain resistance (alias=lv16).
7	<code>aseff</code> (m ²)	Effective source area (alias=lv4).
8	<code>adef</code> (m ²)	Effective drain area (alias=lv3).
9	<code>pseff</code> (m)	Effective source perimeter (alias=lv12).
10	<code>pdeff</code> (m)	Effective drain perimeter (alias=lv11).

Operating-Point Parameters

1	<code>type=n</code>	Transistor type. Possible values are <code>n</code> and <code>p</code> .
2	<code>region=triode</code>	Estimated operating region. Spectre outputs number (0-4) in a rawfile. Possible values are <code>off</code> , <code>triode</code> , <code>sat</code> , <code>subth</code> , and <code>breakdown</code> .
3	<code>reversed</code>	Reverse mode indicator. Possible values are <code>no</code> and <code>yes</code> .

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

4	i_{ds} (A)	Resistive drain-to-source current (alias=lx4).
5	i_{sub} (A)	substrate current (alias=lx50).
6	v_{gs} (V)	Gate-source voltage.
7	v_{ds} (V)	Drain-source voltage (alias=lx3).
8	v_{bs} (V)	Bulk-source voltage.
9	v_{gb} (V)	gate-bulk voltage.
10	v_{db} (V)	Drain-bulk voltage.
11	v_{gd} (V)	Gate-Drain voltage.
12	v_{th} (V)	Threshold voltage (alias=lv9).
13	v_{dsat} (V)	Drain-source saturation voltage (alias=lv10).
14	$v_{fb\text{eff}}$ (V)	Vfb effective (alias=lv26).
15	g_m (S)	Common-source transconductance (alias=lx7).
16	g_{ds} (S)	Common-source output conductance (alias=lx8).
17	g_{mbs} (S)	Body-transconductance (alias=lx9).
18	β_{eff} (A/V ²)	Effective beta.
19	c_{jd} (F)	Drain-bulk junction capacitance (alias=lx29).
20	c_{js} (F)	Source-bulk junction capacitance (alias=lx28).
21	q_b (Coul)	total bulk charge (alias=lx12).
22	q_g (Coul)	Total gate charge (alias=lx14).
23	q_d (Coul)	Total drain charge (alias=lx16).
24	q_{bd} (Coul)	Drain-bulk charge (alias=lx24).
25	q_{bs} (Coul)	Source-bulk charge (alias=lx26).

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BSIM3v3 Level-11 Model (bsim3v3)

26	c_{gg} (F)	dQg_dVg (alias=lx18).
27	c_{gd} (F)	dQg_dVd (alias=lx19).
28	c_{gs} (F)	dQg_dVs (alias=lx20).
29	c_{gb} (F)	dQg_dVbk .
30	c_{dg} (F)	dQd_dVg (alias=lx32).
31	c_{dd} (F)	Total drain capacitance (including intrinsic, overlap and fringing components, and junction capacitance) (alias=lx33).
32	c_{ds} (F)	dQd_dVs (alias=lx34).
33	c_{db} (F)	dQd_dVb .
34	c_{sg} (F)	dQs_dVg .
35	c_{sd} (F)	dQs_dVd .
36	c_{ss} (F)	dQs_dVs .
37	c_{sb} (F)	dQs_dVb .
38	c_{bg} (F)	dQb_dVg (alias=lx21).
39	c_{bd} (F)	dQb_dVd (alias=lx22).
40	c_{bs} (F)	dQb_dVs (alias=lx23).
41	c_{bb} (F)	dQb_dVb .
42	r_{on} (Ω)	On-resistance.
43	i_d (A)	Resistive drain current (alias=i1).
44	i_s (A)	Resistive source current (alias=i3).
45	i_{bulk} (A)	Resistive bulk current (alias=i4).
46	i_{bs} (A)	Source-bulk diode current (alias=lx5).

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BSIM3v3 Level-11 Model (bsim3v3)

47	ibd (A)	Drain-bulk diode current (alias=lx6).
48	pwr (W)	Power at op point.
49	gmoverid (1/V)	Gm/Ids.
50	ueff	ueff.
51	cgsovl (F)	Gate-source overlap and fringing capacitance (alias=lv36).
52	cgdovl (F)	Gate-drain overlap and fringing capacitance (alias=lv37).
53	cgbovl (F)	Gate-bulk overlap capacitance (alias=lv38).
54	i1 (A)	Alias for id.
55	i3 (A)	Alias of Resistive source current.
56	i4 (A)	Alias of Resistive bulk current.
57	gbd (S)	Conductance of the drain diode (alias=lx10).
58	gbs (S)	Conductance of the source diode (alias=lx11).
59	vgsteff (V)	effective vgs.
60	qinv (Coul)	inversion charge.
61	igd (A)	Gate-to-drain leakage current.
62	igs (A)	Gate-to-source leakage current.
63	igb (A)	Gate-to-bulk tunneling current.
64	igcs (A)	Gate-to-channel (source side) tunneling current.
65	igcd (A)	Gate-to-channel (drain side) tunneling current.
66	igidl (A)	Gate-induced drain leakage current.
67	igisl (A)	Gate-induced source leakage current.
68	ggi (Coul)	Intrinsic Gate charge.

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BSIM3v3 Level-11 Model (bsim3v3)

69	qsi (Coul)	Intrinsic Source charge.
70	qdi (Coul)	Intrinsic Drain charge.
71	qbi (Coul)	Intrinsic Bulk charge.
72	cddbi (F)	Intrinsic drain capacitance.
73	cssbi (F)	Intrinsic source capacitance.
74	cggbi (F)	Intrinsic gate capacitance.
75	cgsbi (F)	Intrinsic gate-to-source capacitance.
76	cgdbi (F)	Intrinsic gate-to-drain capacitance.
77	cbdbi (F)	Intrinsic bulk-to-drain capacitance.
78	cbsbi (F)	Intrinsic bulk-to-source capacitance.
79	qsarco (Coul)	Total Source charge (Charge Conservation: $Q_S = -(Q_G + Q_D + Q_B)$).
80	ide (A)	Total DC drain current .
81	ige (A)	Total DC gate current .
82	ise (A)	Total DC source current .
83	ibe (A)	Total DC bulk current .
84	idb (A)	DC drain-bulk current .
85	isb (A)	DC source-bulk current .
86	vsb (V)	Source-Bulk DC voltage .
87	gmb (S)	DC bulk transconductance .
88	vgt (V)	Effective gate drive voltage including back bias drain bias effects .
89	vdss (V)	Drain saturation voltage at actual bias .

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BSIM3v3 Level-11 Model (bsim3v3)

90	vsat_marg (V)	Vds margin .
91	self_gain	Transistor self gain .
92	rout (Ω)	AC output resistor .
93	bef _{ff} (A/V ²)	Gain factor in saturation .
94	fug (Hz)	Unity current gain frequency at actual bias .
95	vearly (V)	Equivalent early voltage .

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

a0	M-20	jtsswgs	M-598	pbgidl	M-544	toxref	M-253
a1	M-23	jtssws	M-596	pbsw	M-132	tpb	M-197
a2	M-24	k1	M-4	pbswg	M-135	tpbsw	M-199
acde	M-147	k2	M-5	pcdsc	M-509	tpbswg	M-200
acm	M-172	k2we	M-582	pcdscb	M-510	trd	M-193
acnqsmod	I-12	k3	M-6	pcdscd	M-511	trise	I-14
acnqsmod	M-139	k3b	M-7	pcf	M-526	trise	M-176
ad	I-4	keta	M-26	pcgdl	M-522	trs	M-192
ad	M-163	kf	M-207	pcgidl	M-545	tt	M-116
adef _f	O-8	kt1	M-184	pcgsl	M-521	type	M-1

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af	M-208	kt11	M-185	pcit	M-513	type	OP-1
aforward	I-15	kt2	M-186	pckappa	M-523	u0	M-65
agidl	M-221	ku0	M-560	pcic	M-524	ua	M-67
agisl	M-225	ku0we	M-589	pcle	M-525	ua1	M-188
ags	M-25	kvsat	M-561	pcim	M-71	ub	M-68
aigbacc	M-239	kvth0	M-562	pd	I-6	ub1	M-189
aigbinv	M-234	kvth0we	M-581	pd	M-165	uc	M-69
aigc	M-246	l	I-2	pdeff	O-10	uc1	M-190
aigsd	M-243	l	M-161	pdelta	M-508	ueff	OP-50
alarm	M-261	la0	M-297	pdiblc1	M-72	ute	M-194
alpha0	M-88	la1	M-300	pdiblc2	M-73	vbd_max	M-271
alpha1	M-89	la2	M-301	pdiblc3	M-74	vbd_max	M-278
apwarn	M-267	lacde	M-350	pdROUT	M-500	vbm	M-13
areverse	I-16	lagidl	M-365	pdsUB	M-515	vbox	M-265
as	I-3	lags	M-302	pdvt0	M-471	vbs	OP-8
as	M-162	lalpha0	M-338	pdvt0w	M-474	vbs_max	M-272
aseff	O-7	lalpha1	M-339	pdvt1	M-472	vbsr_max	M-277
at	M-187	lat	M-357	pdvt1w	M-475	vbx	M-12
b0	M-21	lb0	M-298	pdvt2	M-473	vdb	OP-10
b1	M-22	lb1	M-299	pdvt2w	M-476	vds	OP-7
beff	OP-93	lbeta0	M-340	pdwb	M-489	vds_max	M-268

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beta0	M-90	lbgidl	M-366	pdwg	M-488	vdsat	OP-13
betaeff	OP-18	lcdsc	M-329	pegidl	M-546	vdss	OP-89
bforward	M-229	lcdscb	M-330	pelm	M-527	vearly	OP-95
bgidl	M-222	lcdscd	M-331	peta0	M-516	version	M-168
bgis1	M-226	lcf	M-346	petab	M-517	vfb	M-3
bigbacc	M-240	lcgdl	M-342	pgamma1	M-467	vfbcv	M-146
bigbinv	M-235	lcgidl	M-367	pgamma2	M-468	vfbeff	OP-14
bigc	M-247	lcgs1	M-341	pigcd	M-250	vfbflag	M-27
bigsd	M-244	lcit	M-333	pk1	M-461	vgb	OP-9
binflag	M-61	lckappa	M-343	pk2	M-462	vgb_max	M-273
binunit	M-60	lclc	M-344	pk2we	M-588	vgbr_max	M-276
bnr	M-607	lcle	M-345	pk3	M-463	vgd	OP-11
breverse	M-230	ldelta	M-328	pk3b	M-464	vgd_max	M-269
bvj	M-264	ldif	M-101	pketa	M-483	vgdr_max	M-274
calcacm	M-174	ldrout	M-320	pkt1	M-534	vgs	OP-6
capmod	M-137	ldsub	M-335	pkt1l	M-535	vgs_max	M-270
cbb	OP-41	ldvt0	M-291	pkt2	M-536	vgsr_max	M-275
cbd	M-125	ldvt0w	M-294	pku0	M-570	vgsteff	OP-59
cbd	OP-39	ldvt1	M-292	pku0we	M-592	vgt	OP-88
cbdbi	OP-77	ldvt1w	M-295	pkvth0	M-573	vnds	M-114
cbg	OP-38	ldvt2	M-293	pkvth0we	M-585	voff	M-84

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cbs M-124	ldvt2w M-296	pmoin M-531	voffcv M-150
cbs OP-40	ldwb M-309	pnch M-485	vsat M-66
cbsbi OP-78	ldwg M-308	pnfactor M-512	vsat_marg OP-90
cdb OP-33	leff O-4	pngate M-486	vsb OP-86
cdd OP-31	legidl M-368	pnlx M-466	vth OP-12
cddb1 OP-72	lelm M-347	pnoff M-532	vthmod M-28
cdg OP-30	leta0 M-336	pnsb M-484	vtho M-2
cds OP-32	letab M-337	poxedge M-254	vtsd M-630
cdsc M-79	level M-171	ppclm M-501	vtss M-629
cdscb M-80	lgamma1 M-287	ppdiblc1 M-502	vtsswd M-632
cdscd M-81	lgamma2 M-288	ppdiblc2 M-503	vtsswd M-634
cf M-144	lgcd M-95	ppdiblc3 M-504	vtsswgs M-633
cforward M-231	lgcs M-94	pprt M-541	vtssws M-631
cgb OP-29	lint M-37	pprwb M-492	w I-1
cgbo M-119	lintnoi M-220	pprwb M-493	w M-160
cgbovl OP-53	lk1 M-281	ppscbe1 M-505	w0 M-8
cgd OP-27	lk2 M-282	ppscbe2 M-506	wa0 M-387
cgdbi OP-76	lk2we M-586	ppvag M-507	wa1 M-390
cgdl M-122	lk3 M-283	prds M-491	wa2 M-391
cgdo M-118	lk3b M-284	prt M-191	wacde M-440
cgdovl OP-52	lketa M-303	prwb M-57	wagidl M-455

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cgg	OP-26	lkt1	M-354	prwg	M-58	wags	M-392
cggbi	OP-74	lkt11	M-355	ps	I-5	walpha0	M-428
cgidl	M-223	lkt2	M-356	ps	M-164	walpha1	M-429
cgisl	M-227	lku0	M-568	pscbe1	M-75	warn	M-266
cgs	OP-28	lku0we	M-590	pscbe2	M-76	wat	M-447
cgsbi	OP-75	lkvth0	M-571	pseff	O-9	wb0	M-388
cgs1	M-121	lkvth0we	M-583	pta	M-196	wb1	M-389
cgso	M-117	ll	M-39	ptp	M-198	wbeta0	M-430
cgsov1	OP-51	llc	M-152	pu0	M-495	wbgidl	M-456
cigbacc	M-241	lln	M-40	pua	M-497	wcdsc	M-419
cigbinv	M-236	llodku0	M-564	pua1	M-538	wcdscb	M-420
cigc	M-248	llodvth	M-566	pub	M-498	wcdscd	M-421
cigsd	M-245	lmax	M-259	pub1	M-539	wcf	M-436
cit	M-83	lmin	M-260	puc	M-499	wcgdl	M-432
cj	M-126	lmlt	M-159	puc1	M-540	wcgidl	M-457
cjd	OP-19	lmoin	M-351	pute	M-542	wcgs1	M-431
cjs	OP-20	lnch	M-305	pvag	M-77	wcit	M-423
cjsw	M-130	lnfactor	M-332	pvb1	M-470	wckappa	M-433
cjswg	M-133	lngate	M-306	pvb1x	M-469	wclc	M-434
ckappa	M-123	lnlx	M-286	pvfb	M-529	wcle	M-435
clc	M-142	lnoff	M-352	pvfbcv	M-528	wdelta	M-418

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

cle	M-143	lnsub	M-304	pvoff	M-514	wdrout	M-410
cnr	M-608	lodeta0	M-577	pvoffcvcv	M-533	wdsub	M-425
compatible	M-638	lodk2	M-575	pvsat	M-496	wdvt0	M-381
creverse	M-232	lpclm	M-321	pvth0	M-460	wdvt0w	M-384
csb	OP-37	lpdiblc1	M-322	pvtho	M-459	wdvt1	M-382
csd	OP-35	lpdiblc2	M-323	pw0	M-465	wdvt1w	M-385
csq	OP-34	lpdiblc3	M-324	pwr	M-494	wdvt2	M-383
css	OP-36	lpprt	M-361	pwr	OP-48	wdvt2w	M-386
cssbi	OP-73	lprwb	M-312	pxj	M-487	wdwb	M-399
cta	M-201	lprwg	M-313	pxt	M-490	wdwg	M-398
ctp	M-203	lpscbe1	M-325	qjb	OP-21	web	M-579
delk1	I-20	lpscbe2	M-326	qbd	OP-24	wec	M-580
delnfct	I-21	lpvag	M-327	qbi	OP-71	weff	O-3
delta	M-78	lrdsw	M-311	qbs	OP-25	wegidl	M-458
delvto	I-17	lref	M-62	qd	OP-23	welm	M-437
diomod	M-183	lu0	M-315	qdi	OP-70	weta0	M-426
dlc	M-141	lua	M-317	qg	OP-22	wetab	M-427
dlcig	M-251	lua1	M-358	qgi	OP-68	wgamma1	M-377
dnr	M-609	lub	M-318	qinv	OP-60	wgamma2	M-378
drout	M-70	lub1	M-359	qsi	OP-69	wint	M-38
dskip	M-110	luc	M-319	qsrco	OP-79	wk1	M-371

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

dsub	M-85	luc1	M-360	rd	M-93	wk2	M-372
dtoxcv	M-52	lute	M-362	rdc	I-23	wk2we	M-587
dvt0	M-14	lvbm	M-290	rdc	M-97	wk3	M-373
dvt0w	M-17	lvbx	M-289	rdd	M-99	wk3b	M-374
dvt1	M-15	lvfb	M-349	rdeff	O-6	wketa	M-393
dvt1w	M-18	lvfbcv	M-348	rdsb	M-56	wkt1	M-444
dvt2	M-16	lvoff	M-334	region	I-10	wkt11	M-445
dvt2w	M-19	lvoffcv	M-353	region	OP-2	wkt2	M-446
dwb	M-50	lvsat	M-316	reversed	OP-3	wku0	M-569
dwc	M-140	lvth0	M-280	ron	OP-42	wku0we	M-591
dwg	M-49	lvtho	M-279	rout	OP-92	wkvth0	M-572
ef	M-209	lw	M-41	rs	M-92	wkvth0we	M-584
eg	M-179	lw0	M-285	rsc	I-24	wl	M-44
egidl	M-224	lwc	M-153	rsc	M-96	wlc	M-155
egisl	M-228	lwl	M-43	rseff	O-5	wln	M-45
eglev	M-182	lwlc	M-154	rsh	M-91	wlod	M-559
eigbinv	M-237	lwn	M-42	rss	M-98	wlodku0	M-565
elm	M-145	lwr	M-314	sa	I-25	wlodvth	M-567
em	M-215	lxj	M-307	sa0	M-555	wmax	M-257
eta0	M-86	lxt	M-310	sa1	I-27	wmin	M-258
etab	M-87	m	I-9	sa10	I-36	wmlt	M-158

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

fc	M-129	mbe0	M-551	sa2	I-28	wmoin	M-441
fcs	M-136	mbewl	M-550	sa3	I-29	wnch	M-395
flkmod	M-216	meff	O-2	sa4	I-30	wnfactor	M-422
fug	OP-94	meto	M-120	sa5	I-31	wngate	M-396
fullreinit	M-170	minr	M-103	sa6	I-32	wnlx	M-376
gamma	M-217	mismatchdist	M-553	sa7	I-33	wnoff	M-442
gamma1	M-10	mismatchmod	M-552	sa8	I-34	wnoi	M-214
gamma2	M-11	mj	M-127	sa9	I-35	wnsub	M-394
gap1	M-180	mjsw	M-131	saref	M-556	wpclm	M-411
gap2	M-181	mjswg	M-134	sb	I-26	wpdiblc1	M-412
gbd	OP-57	mnr	M-606	sb0	M-557	wpdiblc2	M-413
gbs	OP-58	mobmod	M-64	sb1	I-37	wpdiblcb	M-414
gds	OP-16	moin	M-148	sb10	I-46	wpemod	M-578
gdsnoi	M-219	msgskip	M-637	sb2	I-38	wprt	M-451
geo	I-22	mulid0	I-62	sb3	I-39	wprwb	M-402
geo	M-173	mulmu0	I-18	sb4	I-40	wprwg	M-403
gm	OP-15	mulu0	I-19	sb5	I-41	wpscbe1	M-415
gmb	OP-87	mvt0	M-549	sb6	I-42	wpscbe2	M-416
gmbs	OP-17	mvtw1	M-547	sb7	I-43	wpvag	M-417
gmoverid	OP-49	mvtw12	M-548	sb8	I-44	wr	M-59

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

hdif	M-102	n	M-108	sb9	I-45	wrdsw	M-401
i1	OP-54	nch	M-34	sbref	M-558	wref	M-63
i3	OP-55	nds	M-115	sc	I-61	wu0	M-405
i4	OP-56	nfactor	M-82	sc	M-100	wua	M-407
ibd	OP-47	ngate	M-35	sca	I-58	wua1	M-448
ibe	OP-83	nigbacc	M-242	scb	I-59	wub	M-408
ibs	OP-46	nigbinv	M-238	scc	I-60	wub1	M-449
ibulk	OP-45	nigc	M-249	scref	M-593	wuc	M-409
id	OP-43	nj	M-109	self_gain	OP-91	wuc1	M-450
idb	OP-84	njts	M-600	shrink	M-635	wute	M-452
ide	OP-80	njtssd	M-603	shrink2	M-636	wvbm	M-380
ids	OP-4	njtssw	M-601	steta0	M-576	wvbx	M-379
igb	OP-63	njtsswd	M-604	stimod	I-57	wvfb	M-439
igbmod	M-256	njtsswg	M-602	stimod	M-554	wvfbcv	M-438
igcd	OP-65	njtsswgd	M-605	stk2	M-574	wvoff	M-424
igcmmod	M-255	nlev	M-218	sw1	I-47	wvoffcv	M-443
igcs	OP-64	nlx	M-9	sw10	I-56	wvsat	M-406
igd	OP-61	noff	M-149	sw2	I-48	wvth0	M-370
ige	OP-81	noia	M-210	sw3	I-49	wvtho	M-369
igidl	OP-66	noib	M-211	sw4	I-50	ww	M-46
igisl	OP-67	noic	M-212	sw5	I-51	ww0	M-375

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

igs	OP-62	noid	M-213	sw6	I-52	wwc	M-156
ijth	M-112	noimod	M-206	sw7	I-53	wwl	M-48
ijthrev	M-627	nqsmod	I-11	sw8	I-54	wwlc	M-157
imax	M-262	nqsmod	M-138	sw9	I-55	wnn	M-47
imelt	M-111	nrd	I-7	tcc	M-233	wwr	M-404
is	M-107	nrd	M-166	tcj	M-202	wxj	M-397
is	OP-44	nrfwd	M-628	tcjsw	M-204	wxt	M-400
isb	OP-85	nrs	I-8	tcjswg	M-205	xj	M-36
ise	OP-82	nrs	M-167	tcnr	M-623	xjbv	M-626
isnoisy	I-13	nsub	M-33	tdnr	M-624	xl	M-363
isub	OP-5	ntox	M-252	tempeff	O-1	xlref	M-364
ivth	M-29	pa0	M-477	tku0	M-563	xpart	M-151
ivth_vdsmin	M-32	pa1	M-480	tlev	M-177	xt	M-55
ivthl	M-31	pa2	M-481	tlevc	M-178	xti	M-195
ivthw	M-30	pacde	M-530	tmnr	M-622	xtsd	M-611
jmax	M-263	pagidl	M-543	tnjts	M-616	xtss	M-610
jmelt	M-113	pags	M-482	tnjtsd	M-619	xtsswd	M-613
js	M-104	palpha0	M-518	tnjtssw	M-617	xtsswgd	M-615
jssw	M-106	palpha1	M-519	tnjtsswd	M-620	xtsswgs	M-614
jsswg	M-625	paramchk	M-169	tnjtsswg	M-618	xtssws	M-612
jsw	M-105	pat	M-537	tnjtsswgd	M-621	xw	M-453

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BSIM3v3 Level-11 Model (bsim3v3)

jtscd M-595	pb M-128	tnom M-175	xwref M-454
jtss M-594	pb0 M-478	tox M-51	
jtsswd M-597	pb1 M-479	toxe M-54	
jtsswd M-599	pbeta0 M-520	toxm M-53	

Binning Parameters

The table below lists geometry sensitivity factors.

The value of a parameter is calculated from the following equation:

If `binunit = 1`,

$$P = p0 + 1e-6 * wp0 / Weff + 1e-6 * lp0 / Leff + 1e-12 * pp0 / (Weff * Leff)$$

else

$$P = p0 + wp0 / Weff + lp0 / Leff + pp0 / (Weff * Leff)$$

where P is the parameter name.

Table 20-1 Binning Parameters

Parameter Name	Description
LVTO	VTO length sensitivity
WVTO	VTO width sensitivity
PVTO	VTO length and width sensitivity
LK1	K1 length sensitivity
WK1	K1 width sensitivity
PK1	K1 length and width sensitivity
LK2	K2 length sensitivity
WK2	K2 width sensitivity

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

Parameter Name	Description
PK2	K2 length and width sensitivity
LDVT0	DVT0 length sensitivity
WDVT0	DVT0 width sensitivity
PDVT0	DVT0 length and width sensitivity
LDVT1	DVT1 length sensitivity
WDVT1	DVT1 width sensitivity
PDVT1	DVT1 length and width sensitivity
LDVT2	DVT2 length sensitivity
WDVT2	DVT2 width sensitivity
PDVT2	DVT2 length and width sensitivity
LDVT0W	DVT0W length sensitivity
WDVT0W	DVT0W width sensitivity
PDVT0W	DVT0W length and width sensitivity
LDVT1W	DVT1W length sensitivity
WDVT1W	DVT1W width sensitivity
PDVT1W	DVT1W length and width sensitivity
LDVT2W	DVT2W length sensitivity
WDVT2W	DVT2W width sensitivity
PDVT2W	VFB length and width sensitivity
LLETA0	LETA0 length sensitivity
WLETA0	LETA0 width sensitivity
PLETA0	LETA0 length and width sensitivity
LETAB	ETAB length sensitivity
WETAB	ETAB width sensitivity
PETAB	ETAB length and width sensitivity
LNSUB	NSUB length sensitivity
WNSUB	NSUB width sensitivity

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

Parameter Name	Description
PNSUB	NSUB length and width sensitivity
LNCH	NCH length sensitivity
WNCH	NCH width sensitivity
PNCH	NCH length and width sensitivity
LNGATE	NGATE length sensitivity
WNGATE	NGATE width sensitivity
PNGATE	NGATE length and width sensitivity
LXJ	XJ length sensitivity
WXJ	XJ width sensitivity
PXJ	XJ length and width sensitivity
LU0	U0 length sensitivity
WU0	U0 width sensitivity
PU0	U0 length and width sensitivity
LVSAT	VSAT length sensitivity
WVSAT	VSAT width sensitivity
PVSAT	VSAT length and width sensitivity
LUA	UA length sensitivity
WUA	UA width sensitivity
PUA	UA length and width sensitivity
LUB	UB length sensitivity
WUB	UB width sensitivity
PUB	UB length and width sensitivity
LUC	UC length sensitivity
WUC	UC width sensitivity
PUC	UC length and width sensitivity
LPCLM	PCLM length sensitivity
WPCLM	PCLM width sensitivity

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

Parameter Name	Description
PPCLM	PCLM length and width sensitivity
LPDIBLC1	PDIBLC1 length sensitivity
WPDIBLC1	PDIBLC1 width sensitivity
PPDIBLC1	PDIBLC1 length and width sensitivity
LPDIBLC2	PDIBLC2 length sensitivity
WPDIBLC2	PDIBLC2 width sensitivity
PPDIBLC2	PDIBLC2 length and width sensitivity
LPDIBLCB	PDIBLCB length sensitivity
WPDIBLCB	PDIBLCB width sensitivity
PPDIBLCB	PDIBLCB length and width sensitivity
LPSCBE2	PSCBE2 length sensitivity
WPSCBE2	PSCBE2 width sensitivity
PPSCBE2	PSCBE2 length and width sensitivity
LVOFF	VOFF length sensitivity
WVOFF	VOFF width sensitivity
PVOFF	VOFF length and width sensitivity
LRDSW	RDSW length sensitivity
WRDSW	RDSW width sensitivity
PRDSW	RDSW length and width sensitivity
LPRWB	PRWB length sensitivity
WPRWB	PRWB width sensitivity
PPRWB	PRWB length and width sensitivity
LPRWG	PRWG length sensitivity
WPRWG	PRWG width sensitivity
PPRWG	PRWG length and width sensitivity
LPRT	PRT length sensitivity
WPRT	PRT width sensitivity

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

Parameter Name	Description
PPRT	PRT length and width sensitivity
LAGS	AGS length sensitivity
WAGS	AGS width sensitivity
PAGS	AGS length and width sensitivity
LPVAG	PVAG length sensitivity
WPVAG	PVAG width sensitivity
PPVAG	PVAG length and width sensitivity
LKETA	KETA length sensitivity
WKETA	KETA width sensitivity
PKETA	KETA length and width sensitivity
LELM	ELM length sensitivity
WELM	ELM width sensitivity
PELM	ELM length and width sensitivity
LUTE	UTE length sensitivity
WUTE	UTE width sensitivity
PUTE	UTE length and width sensitivity
LCDSC	CDSC length sensitivity
WCDSC	CDSC width sensitivity
PCDSC	CDSC length and width sensitivity
LCDSCB	CDSCB length sensitivity
WCDSCB	CDSCB width sensitivity
PCDSCB	CDSCB length and width sensitivity
LCDSCD	CDSCD length sensitivity
WCDSCD	CDSCD width sensitivity
PCDSCD	CDSCD length and width sensitivity
LNFACTOR	NFACTOR length sensitivity
WNFACTOR	NFACTOR width sensitivity

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

Parameter Name	Description
PNFACTOR	NFACTOR length and width sensitivity
LCIT	CIT length sensitivity
WCIT	CIT width sensitivity
PCIT	CIT length and width sensitivity
LAT	AT length sensitivity
WAT	AT width sensitivity
PAT	AT length and width sensitivity
LA0	A0 length sensitivity
WA0	A0 width sensitivity
PA0	A0 length and width sensitivity
LA1	A1 length sensitivity
WA1	A1 width sensitivity
PA1	A1 length and width sensitivity
LA2	A2 length sensitivity
WA2	A2 width sensitivity
PA2	A2 length and width sensitivity
LKT1	KT1 length sensitivity
WKT1	KT1 width sensitivity
PKT1	KT1 length and width sensitivity
LKT1L	KT1L length sensitivity
WKT1L	KT1L width sensitivity
PKT1L	KT1L length and width sensitivity
LKT2	KT2 length sensitivity
WKT2	KT2 width sensitivity
PKT2	KT2 length and width sensitivity
LK3	K3 length sensitivity
WK3	K3 width sensitivity

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

Parameter Name	Description
PK3	K3 length and width sensitivity
LK3B	K3B length sensitivity
WK3B	K3B width sensitivity
PK3B	K3B length and width sensitivity
LW0	W0 length sensitivity
WW0	W0 width sensitivity
PW0	W0 length and width sensitivity
LNLX	NLX length sensitivity
WNLX	NLX width sensitivity
PNLX	NLX length and width sensitivity
LDROUT	DROUT length sensitivity
WDROUT	DROUT width sensitivity
PDROUT	DROUT length and width sensitivity
LDSUB	DSUB length sensitivity
WDSUB	DSUB width sensitivity
PDSUB	DSUB length and width sensitivity
LUA1	UA1 length sensitivity
WUA1	UA1 width sensitivity
PUA1	UA1 length and width sensitivity
LUB1	UB1 length sensitivity
WUB1	UB1 width sensitivity
PUB1	UB1 length and width sensitivity
LUC1	UC1 length sensitivity
WUC1	UC1 width sensitivity
PUC1	UC1 length and width sensitivity
LDELTA	DELTA length sensitivity
WDELTA	DELTA width sensitivity

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

Parameter Name	Description
PDELTA	DELTA length and width sensitivity
LB0	B0 length sensitivity
WB0	B0 width sensitivity
PB0	B0 length and width sensitivity
LB1	B1 length sensitivity
WB1	B1 width sensitivity
PB1	B1 length and width sensitivity
LWR	WR length sensitivity
WWR	WR width sensitivity
PWR	WR length and width sensitivity
LDWG	DWG length sensitivity
WDWG	DWG width sensitivity
PDWG	DWG length and width sensitivity
LDWB	DWB length sensitivity
WDWB	DWB width sensitivity
PDWB	DWB length and width sensitivity
LALPHA0	ALPHA0 length sensitivity
WALPHA0	ALPHA0 width sensitivity
PALPHA0	ALPHA0 length and width sensitivity
LALPHA1	ALPHA1 length sensitivity
WALPHA1	ALPHA1 width sensitivity
PALPHA1	ALPHA1 length and width sensitivity
LBETA0	BETA0 length sensitivity
WBETA0	BETA0 width sensitivity
PBETA0	BETA0 length and width sensitivity
LDWC	DWC length sensitivity
WDWC	DWC width sensitivity

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

Parameter Name	Description
PDWC	DWC length and width sensitivity
LDLC	DLC length sensitivity
WDLC	DLC width sensitivity
PDLC	DLC length and width sensitivity
LCGSL	CGSL length sensitivity
WCGSL	CGSL width sensitivity
PCGSL	CGSL length and width sensitivity
LCGDL	CGDL length sensitivity
WCGDL	CGDL width sensitivity
PCGDL	CGDL length and width sensitivity
LCKAPPA	CKAPPA length sensitivity
WCKAPPA	CKAPPA width sensitivity
PCKAPPA	CKAPPA length and width sensitivity
LCLC	CLC length sensitivity
WCLC	CLC width sensitivity
PCLC	CLC length and width sensitivity
LCLE	CLE length sensitivity
WCLE	CLE width sensitivity
PCLE	CLE length and width sensitivity
LCF	CF length sensitivity
WCF	CF width sensitivity
PCF	CF length and width sensitivity
LACDE	ACDE length sensitivity
WACDE	ACDE width sensitivity
PACDE	ACDE length and width sensitivity
LMOIN	MOIN length sensitivity
WMOIN	MOIN width sensitivity

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

Parameter Name	Description
PMOIN	MOIN length and width sensitivity
LNOFF	NOFF length sensitivity
WNOFF	NOFF width sensitivity
PNOFF	NOFF length and width sensitivity
LVOFFCV	VOFFCV length sensitivity
WVOFFCV	VOFFCV width sensitivity
PVOFFCV	VOFFCV length and width sensitivity
LGAMMA1	GAMMA1 length sensitivity
WGAMMA1	GAMMA1 width sensitivity
PGAMMA1	GAMMA1 length and width sensitivity
LGAMMA2	GAMMA2 length sensitivity
WGAMMA2	GAMMA2 width sensitivity
PGAMMA2	GAMMA2 length and width sensitivity
LVFB	VFB length sensitivity
WVFB	VFB width sensitivity
PVFB	VFB length and width sensitivity
LVFBCV	VFBCV length sensitivity
WVFBCV	VFBCV width sensitivity
PVFBCV	VFBCV length and width sensitivity
LVBX	VBX length sensitivity
WVBX	VBX width sensitivity
PVBX	VBX length and width sensitivity
LVBM	VBM length sensitivity
WVBM	VBM width sensitivity
PVBM	VBM length and width sensitivity
LXT	XT length sensitivity
WXT	XT width sensitivity

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

Parameter Name	Description
PXT	XT length and width sensitivity

BSIM4 Level-14 Model (bsim4)

BSIM4 model, as the extension of BSIM3v3 model, addresses more physical effects for MOSFET device of 100 nm and beyond. Gate leakage, layout dependent effects, high-K, etc. are modeled in BSIM4.

This chapter contains the following information about the BSIM4 model:

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 - [Instance syntax](#) on page 1269
- [Model](#) on page 1269
 - [Model syntax](#) on page 1269
 - [Auto Model Selection](#) on page 1270
- [Equivalent Circuit](#) on page 1270
- [Device Regions](#) on page 1271
- [Global Control Options](#) on page 1271
- [TMI 1.0 Model](#) on page 1272
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BSIM4 Level-14 Model (bsim4)

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- [Model Equations](#) on page 1277
 - ❑ [Effective Oxide Thickness, Channel Length and Channel Width](#) on page 1277
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 - ❑ [Gate Direct Tunneling Current Model](#) on page 1282
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- [Component Statements](#) on page 1357

Instance

Instance syntax

BSIM4 instance have 4 terminals. To specify BSIM4 instance element, the ModelName has to be associated with a BSIM4 model card.

```
InstanceName (d g s b) ModelName <parameter=value> ...
```

Sample Instance Statement

```
m4 (0 2 1 1) pchmod w=2u l=0.8u as=250p ad=250p pd=168p ps=168p m=1
```

Note: For detailed list of Instance Parameters, see section [Component Statements](#) on page 1357.

Model

Model syntax

The following syntax specifies BSIM4 model:

```
model ModelName bsim4 <parameter=value> ...
```

The third parameter, “bsim4”, is the master to indicate this model card is a BSIM4 model card.

Sample Model Statement

```
model pchmod bsim4 type=p mobmod=0 capmod=2 version=4.21 tox=3e-9 cdsc=2.58e-4  
cdscb=0 cdscd=6.1e-8 cit=0 nfactor=1.1 xj=9e-8 vfb=0.76vsat=9.2e4 at=3.3e4 a0=1.1  
ags=1.0e-20 a1=0 ngate=9e19 vth0=-0.42a1=0 a2=1 delta=0.014 pvag=1e-20 pclm=6.28e-  
4 pdits=0.2 pditsl=2.3e6pditsd=0.23 fprout=0.2 pdiblcb=3.4e-8 pdiblc1=0.81  
drou=0.56pdiblc2=9.84e-6 psobe1=8.14e8 psobe2=9.58e-07 lint=5e-9 wint=5e-9  
dmcg=5e-6 dmci=5e-6 dmdg=5e-6 dmcgt=6e-7 dwj=4.5e-8 rsh=6cgso=7.43e-10 cgdo=7.43e-  
10 cgbo=2.56e-11 cgsl=1e-14 cgdl=1e-14ckappas=0.5 ckappad=0.5 noff=0.9 voffcv=0.02  
acde=1 moin=15 xpart=0kt1l=0 kt2=2.2e-2 lpe0=5.75e-8 lpeb=2.3e-10 dvt0=2.89  
dvt1=0.53dvt2=-3.2e-2 dvt0w=0 dvt1w=0 dvt2w=0 dvtp0=7.32e-7 dvtp1=0.12dsub=0.058  
eta0=0.001 u0=4.19e-2 ua=8.7e-16 ub=3.06e-18 k1=0.33uc=4.6e-13 ute=-1.5 ual=4.31e-  
9 ub1=7.61e-18 uc1=-5.6e-11 k2=-1.87e-2 rdsw=369.4 rdw=184.7 rsw=184.7 prwg=3.22e-  
8 prwb=6.8e-11 wr=1 rdswmin=0 rdwmin=0 rswmin=0 prt=0 b0=-1e-20 k3=80 k3b=0  
w0=2.5e-6b1=0 keta=-0.047 alpha0=7.4e-2 alpha1=0.005 beta0=30
```

Note: For detailed list of Model Parameters, see section [Component Statements](#) on page 1357.

Auto Model Selection

BSIM4 supports dependent model parameters; users can tune these parameters to make a single model card to fit all sizes of devices. But with device geometry shrinks, device needs all kinds of optimization, there are very complicated physical effects. It is very hard to use a single model card to fit all devices. An alternative approach is binning option that uses interpolation to calculate model parameters covered by inside that bin. The binning equation is given by

$$P = P_0 + P_l / L_{eff} + P_w / W_{eff} + P_p / (L_{eff} * W_{eff})$$

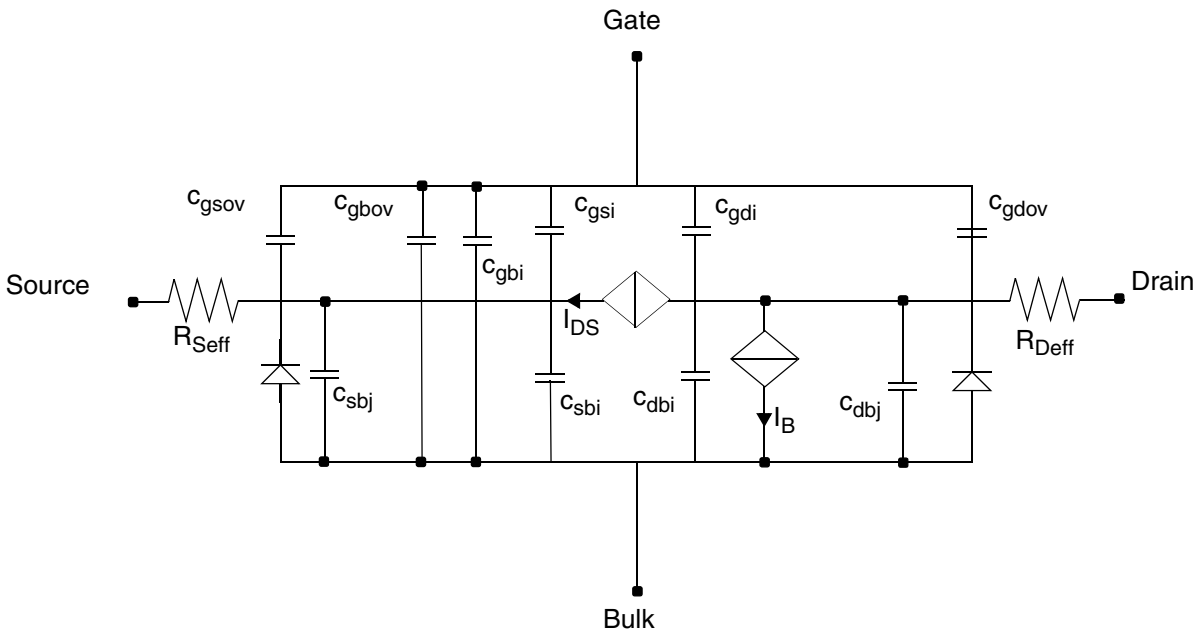
The names of P_l , P_w , and P_p are identical to that of P_0 but with a prefix of l, w, and p, respectively.

Bin selection criteria are as follows:

$$l_{min} \leq inst_length < l_{max} \quad \text{and} \quad w_{min} \leq inst_width < w_{max}$$

Equivalent Circuit

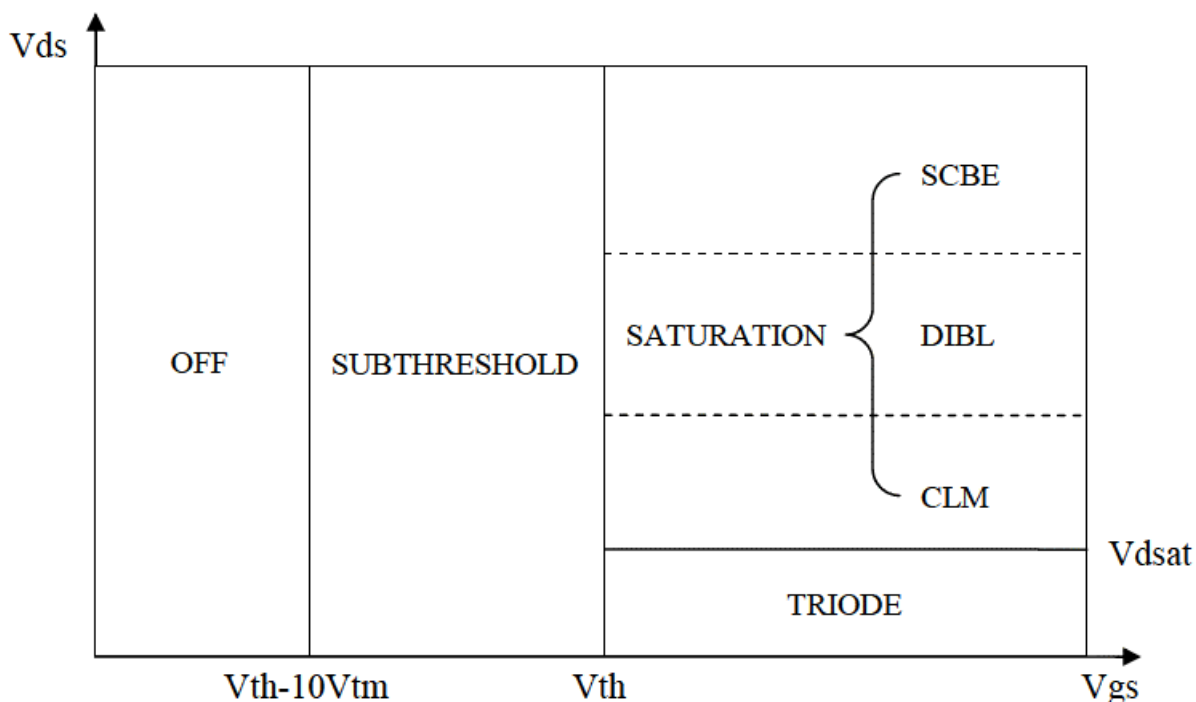
The followings show the equivalent circuits for BSIM4 devices:



Device Regions

Device region is determined by both V_{ds} and V_{gs} . The following figure shows the region of N-type BSIM4 device. Saturation region can be splitted to three regions corresponding to different dominant physical mechanism: channel length modulation (CLM) effect, drain-induced barrier lowering (DIBL) effect, and the substrate current induced body effect (SCBE).

For P-type device, all the voltage in figure is negative. V_{tm} is the thermal voltage which is about 0.026V for 300K temperature.



Global Control Options

The following global options affect BSIM4 model.

1. **GMIN:** GMIN helps solver convergence. It places a conductance in parallel with both the channel and source junction. The default GMIN is 1.0e-12.
2. **MINR:** Source, drain and gate parasitic resistors inside devices less than minr will be removed. The order of checking inside devices is:
 - Check if resistors are smaller than local minr, if so then remove the parasitic resistors, give warning message.

- ❑ Check global minr, parasitic resistors less than global minr will be removed and warning message will be issued.

Note: Local minr is specified by model parameter minr. The default value is 0.1

3. COMPATIBLE: Encourage device equations to be compatible with a foreign simulator. This option does not affect input syntax.

TMI 1.0 Model

TMI, TSMC Model Interface, is supported in MMSIM7.1.0.

In order to support customized model equations for advanced technologies, TMI is proposed to provide an alternative approach for this request in addition to adding more macro models.

TMI provides both good flexibility as macro model and good simulation efficiency as build-in standard model at the same time.

TMI 2.0 Model

The TMI 2.0 model feature is released in MMSIM10.1, provides the following new capabilities:

Flexible device topology with customized model formulations

With MMSIM 10.1 release, additional component(s) and/or internal node(s) can be added on top of existing standard public domain model topology. This allows the simulator to evaluate (during runtime), the customized model as well as the standard core model formulations, gather/scatter device information and conduct matrix stamping for various type of circuit analysis.

Support for reliability aging modeling and analysis for simulators with and without aging capability

With this feature, the user can add customized aging algorithms for all age integration, extrapolation and mapping. The Safe Operating Areas (SOA) check is also supported.

Model Version Update

Version 4.30

1. Introduced a stress effect model for process induced stress effect;
2. Introduced a temperature model format to predict temperature effects on saturation velocity, mobility, and S/D resistances;
3. Introduced a unified current saturation model that includes all mechanisms of current saturation- velocity saturation, velocity overshoot and source end velocity limit and quasi-ballistic transport;
4. Enhanced holistic thermal noise model;
5. Enhanced forward body bias model;
6. Extended gate direct tunneling model to multiple-layer gate stacks.
7. Fixed minor bugs.

Version 4.40

1. Introduced a trap-assisted tunneling and recombination current model, which is applicable to gate-edge side-wall, STI-edge side-wall and bottom junction;
2. Introduced a flatband voltage offset parameter (vfbsdoff) to improve gate overlap tunneling current;
3. Introduced an offset parameter (lintnoi) to length reduction parameter (lint) to improve the accuracy of the flicker noise model;
4. Fixed minor bugs.

Version 4.50

1. Introduced a mobility model which accounts for Coulomb scattering and the channel length dependence of mobility due to heavy halo-doping;
2. Introduced a substrate resistance model (rbodymod = 2), which is scalable with channel length, channel width and number of fingers;
3. Specified gate resistance parameters xgw and ngcon as instance parameters;
4. Improved temperature dependence for model parameters voff and vfbsdoff;

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

5. Enhanced temperature model ($\text{tempmod} = 2$), where V_{th} (DITS) and gate tunneling models are functions of nominal temperature and the temperature dependence of flat-band voltage is added;
6. Introduced a new instance parameter delvto to represent threshold voltage variation;
7. Enhanced well-proximity effect model, enable some device parameters to vary with distance from the edge of well-implantation mask due to ion-scattering;
8. Implemented a full BSIM4 V_{th} model into the I_{gc} equation which enables accurate prediction of the V_{bs} dependence of I_{gc} .
9. Fixed minor bugs.

Version 4.60

1. Introduced separated model parameters for the GIDL and GISL leakage current modules.
2. Introduced separated parameters for the source and drain side junction diode current due to the trap-assisted tunneling current in space-charge region.
3. Introduced separated parameters for the gate tunneling current in the S/D overlap diffusion regions (I_{gs}/I_{gd}).
4. Modified the coulomb scattering term in mobility model to avoid the possibility of non-monotonicity in drain current trend with respect to gate voltage.
5. Improved the accuracy for $\text{rgatemod} = 2$ by accounting correctly the contribution from R_{gate} to overall noise.
6. Set the default value of the parameter vfb to $-1.0V$.

Version 4.61

1. Introduced new material model (by setting $\text{mtrlmod}=1$) for predictive modeling of non-SiO₂ insulator, non-poly Silicon gate and non-silicon channel. Add new parameters including new material model selector (mtrlmod), non-poly silicon gate parameters (phig and epsrgate), non-SiO₂ gate dielectric (eot and vddeot), and non-silicon channel parameters (easub , epsrsub , ni0sub , bg0sub , tbgasub , tbgbsub , ados , and bdos).
2. Improved mobility model ($\text{mobmod} = 0$ and 1) through predictive modeling of vertical electric field. The improved mobility model is selected through $\text{mtrlmod} = 1$ for backward compatibility.

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

3. Improved GIDL/GISL models through an improved definition of flatband voltages at S/D ends. The improved GISL/GIDL model is selected through `mtrlmod = 1` for backward compatibility.
4. Modified poly-depletion model to account for new gate and gate-insulator materials.
5. Introduced a new `VgsteffCV` definition into C-V model (by setting `cvchargemod = 1`) to improve sub-threshold fitting. Add six new parameters including `cvchargemod`, `minvcv`, `lminvcv`, `wminvcv`, `pminvcv` and `voffcvl`.
6. Fixed an error in the derivative calculation of `dVdseffCV_dVb` for `capmod = 1` and 2.
7. Removed warning messages for the limits of `noff` and `voffcv`.

Version 4.62

1. Included the width dependence in trap assisted tunneling (TAT) model. Introduce a new model parameter `jtweff` and set it to zero to maintain the backward compatibility.
2. Introduced mobility model (`mobmod = 3`) to enhance the modeling of Coulomb scattering in the high-k/metal gate transistors.
3. Fixed minor bugs in:
 - Output conductance model: `vascbe`;
 - Thermal noise model (`tnoimod=0`);
 - Negative thermal noise (`tnoimod=1`);
 - Source/drain bulk junction capacitance;
 - Derivative issue in capacitance model (`capmod=0`);
 - `Toxp` calculation (`mtrlmod=1`);
 - Source/drain resistance;
 - Drain/body breakdown voltage.

Version 4.63

Fixed minor bug in `litl` calculation.

Version 4.64

1. Fixed bug in thermal noise model when `tnoimod=1`.
2. Removed duplicate counting of temperature coefficient when `mobmod=3`.
3. Updated Esat after EsatL calculation.

Version 4.65

1. Set `Pseff` and `Pdeff` to zero when they are negative and give a warning message.
2. Turn off source side diode by setting `sourceSaturationCurrent=0.0` when `Aseff` and `Pseff` are zero. Turn off drain side diode by setting `DrainSaturationCurrent=0.0` when `Adeff` and `Pdeff` are zero.

Version 4.70

1. Improved GIDL/GISL model from BIMSOI.
 - ❑ Add new model with flag `gidlmod=1`.
 - ❑ New binnable parameters `rgidl` (`lrgidl`, `wrgidl`, `prgidl`)/`rgisl`, `kgidl`/`kgisl`, and `fgidl`/`fgisl` have been introduced.
 - ❑ The previous GIDL/GISL model is in `gidlmod=0`.
 - ❑ Impacts `igidl` and `igisl`.
2. Improved DIBL/Rout model from BIMSOI.
 - ❑ Existing DIBL/Rout model in BSIM is proposed to enhance with additional term `DVTP5` (with parameters `DVTP2`, `DVTP3`, `DVTP4`, `DVTP5`), to better capture V_{ds} effect in long channel device.
 - ❑ Impacts `Vth`.
3. Improved sub-threshold temperature dependence.
 - ❑ Improve formulations to capture temperature dependence of Leakage Current with new parameters `tnfactor`, `teta0`, and `tvoffcv`.
4. Improved thermal noise model (`tnoimod=2`).
 - ❑ New noise models have been introduced as `tnoimod=2`. Added new parameters `tnoic` and `rnoic`. Correlated noise is considered.
5. Limiting of diode ideality factor (`NJS,NJD`).

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

6. New parameter `mtrlCompatMod` to ensure consistent results of `mtrlMod=0` versus `mtrlMod=1`.
7. BugFix of `Toxm`.
 - Corrected `Toxm` setting in `Initialize()`.
8. BugFix of `igc`.
 - Removed redundant `toxe` term appearing in the `Igc` formulation

Version 4.80

1. Three new mobility models `mobmod=4`, `mobmod=5`, and `mobmod=6` have been introduced.
2. The derivative bugs in `igcmod=2` have been fixed.
3. Some unused lines have been removed.
4. Parameter check on `toxp` has been adjusted.
5. The default value of `fgidl` has been changed to 1.0 for version 4.80.
6. Computational efficiency of `rbsbx`, `rbsby`, `rbdby`, `rbpbx`, `rbpby`, `rbps0`, and `rbpd0` has been improved.

Model Equations

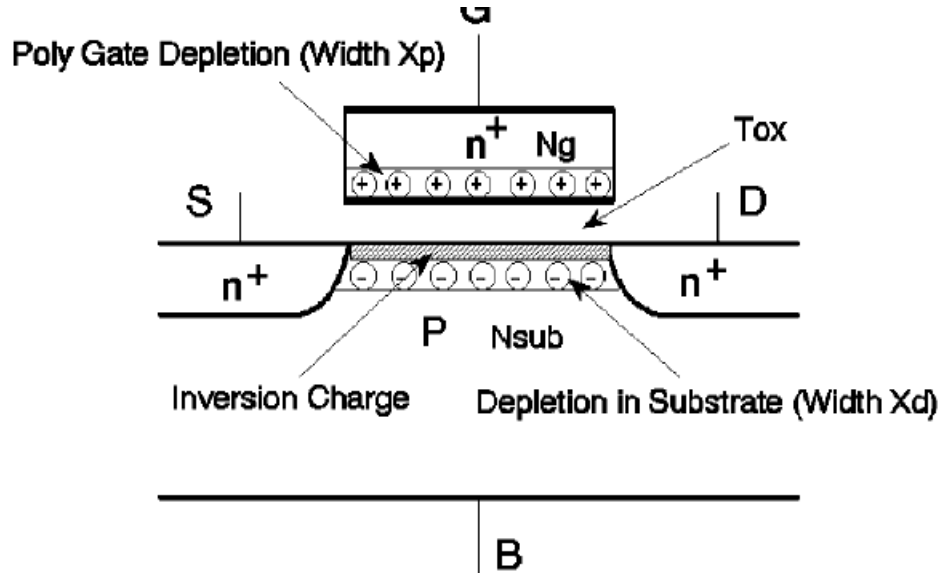
Effective Oxide Thickness, Channel Length and Channel Width

Gate Dielectric Model

The finite chargelayer thickness cannot be ignored when the gate oxide thickness is vigorously scaled down. There are two ways in BSIM4 for modeling this effect in both IV and CV, which can be selected by `mtrlmod`. When `mtrlmod=0` (for SiO₂ gate), the input parameters includes `toxe`, `toxp` and `dtox`. When `mtrlmod=1` (for high-k dielectric gate), the input parameters includes `eot`, `weffeot`, `leffeot`, `tempeot` and `vddeot`. `toxe` is equal to `eot`, and `toxp` could be calculated by the input parameters.

Poly-Silicon Gate Depletion

Charge distribution in a MOSFET with the poly gate depletion effect is shown in the following figure. The device is in the strong inversion region.



The effective gate voltage V_{gse} is

For $mtrlmod=0$

(21-1)

$$V_{gse} = VFB + \Phi_s + \frac{q\epsilon_{si}NGATE \cdot T_{oxe}^2}{EPSROX^2} \left(\sqrt{1 + \frac{2EPSROX^2(V_{gs} - VFB - \Phi_s)}{q\epsilon_{si}NGATE \cdot T_{oxe}^2}} \right)$$

For $mtrlmod=1$ (the non-silicon channel or high -k gate insulator)

(21-2)

$$V_{gse} = VFB + \Phi_s + \frac{q\epsilon_{gate}NGATE}{C_{oxe}^2} \left(\sqrt{1 + \frac{2C_{oxe}^2(V_{gs} - VFB - \Phi_s)}{q\epsilon_{gate}NGATE}} - 1 \right)$$

Effective Channel Length and Width

(21-3)

$$L_{eff} = L_{drawn} + XL - 2dL$$

(21-4)

$$W_{eff} = \frac{W_{drawn}}{NF} + XW - 2dW$$

(21-5)

$$W_{eff}' = \frac{W_{drawn}}{NF} + XW - 2dW'$$

(21-6)

$$dW = dW' + DWG \cdot V_{gsteff} + DWB(\sqrt{\Phi_s - V_{bseff}} - \sqrt{\Phi_s})$$

(21-7)

$$dW' = WINT + \frac{WL}{L^{WLN}} + \frac{WW}{W^{WWN}} + \frac{WWL}{L^{WLN}W^{WWN}}$$

(21-8)

$$dL = LINT + \frac{LL}{L^{LLN}} + \frac{LW}{W^{LWN}} + \frac{LWL}{L^{LLN}W^{LWN}}$$

WINT represents the traditional manner from which "delta *W*" is extracted (from the intercept of straight lines on a $1/R_{ds} \sim W_{drawn}$ plot). The parameters *DWG* and *DWB* are used to account for the contribution of both gate and substrate bias effects. For *dL*, *LINT* represents the traditional manner from which "delta *L*" is extracted from the intercept of lines on a $R_{ds} \sim L_{drawn}$ plot.

The remaining terms in *dW* and *dL* are provided for your convenience. They are meant to allow you to model each parameter as a function of W_{drawn} , L_{drawn} , and their product term. By default, the above geometrical dependencies for *dW* and *dL* are turned off.

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

MOSFET capacitances can be divided into intrinsic and extrinsic components. The intrinsic capacitance is associated with the region between the metallurgical source and drain junction, which is defined by the effective length (L_{active}) and width (W_{active}) when the gate to source/drain regions are under flat-band condition. L_{active} and W_{active} are defined as

(21-9)

$$L_{active} = L_{drawn} + XL - 2dL$$

(21-10)

$$W_{active} = \frac{W_{drawn}}{NF} + XW - 2dW$$

(21-11)

$$dL = DLC + \frac{LLC}{L^{LLN}} + \frac{LWC}{W^{LWN}} + \frac{LWLC}{L^{LLN} W^{LWN}}$$

(21-12)

$$dW = DWC + \frac{WLC}{L^{WLN}} + \frac{WWC}{W^{WWN}} + \frac{WWLC}{L^{WLN} W^{WWN}}$$

The meanings of DWC and DLC are different from those of $WINT$ and $LINT$ in the I-V model. Unlike the case of I-V, these dimensions are bias-dependent. The parameter δL_{eff} is equal to the source/drain to gate overlap length plus the difference between drawn and actual POLY CD due to processing (gate patterning, etching, and oxidation) on one side.

The effective channel length L_{eff} for the I-V model does not necessarily carry a physical meaning. It is just a parameter used in the I-V formulation. This L_{eff} is therefore very sensitive to the I-V equations and also to the conduction characteristics of the LDD region relative to the channel region. A device with a large L_{eff} and a small parasitic resistance can have a similar current drive as another with a smaller L_{eff} but larger R_{ds} .

The L_{active} parameter extracted from capacitance is a closer representation of the metallurgical junction length (physical length). Due to the graded source/drain junction profile, the source to drain length can have a very strong bias dependence. L_{active} is measured at flat-band voltage between gate to source/drain. If DWC , DLC and the length/width dependence parameters (LLC , LWC , $LWLC$, WLC , WWC and $WWLC$) are not specified in technology files, BSIM4 assumes that the DC bias-independent L_{eff} and W_{eff} will be used for

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

the capacitance models, and *DWC*, *DLC*, *LLC*, *LWC*, *LWLC*, *WLC*, *WWC*, and *WWLC* will be set to the values of their DC counterparts.

BSIM4 uses the effective source/drain diffusion width W_{effcj} for modeling parasitics, such as source/drain resistance, gate electrode resistance, and gate induced drain leakage (GIDL) current. W_{effcj} is defined as:

(21-13)

$$W_{effcj} = \frac{W_{drawn}}{NF} - 2 \cdot \left(DWJ + \frac{WLC}{L_{WLN}} + \frac{WWC}{W_{WWN}} + \frac{WWLC}{L_{WLN} W_{WWN}} \right)$$

Threshold Voltage Model

Considering non-uniform doping, short-channel effect, DIBL effect, and narrow-width effect, the complete V_{th} model is:

(21-14)

$$\begin{aligned} V_{th} = & VTH0 + (K_{10x} \cdot \sqrt{\Phi_s - V_{bseff}} - K1 \cdot \sqrt{\Phi_s}) \sqrt{1 + \frac{LPEB}{L_{eff}}} - K_{2ox} V_{bseff} \\ & + K_{1ox} \left(\sqrt{1 + \frac{LPE0}{L_{eff}}} - 1 \right) \sqrt{\Phi_s} + (K3 + K3B \cdot V_{bseff}) \frac{TOXE}{W_{eff}' + W0} \Phi_s \\ & - 0.5 \cdot \left[\frac{DVT0W}{\cosh\left(DVT1W \frac{L_{eff} W_{eff}'}{l_{tw}}\right) - 1} + \frac{DVT0}{\cosh\left(DVT1 \frac{L_{eff}}{l_t}\right) - 1} \right] (V_{bi} - \Phi_s) \\ & - \frac{0.5}{\cosh\left(DSUB \frac{L_{eff}}{l_{t0}}\right) - 1} (ETA0 + ETAB \cdot V_{bseff}) \cdot V_{ds} \\ & - n v_t \cdot 1 n \left(\frac{L_{eff}}{L_{eff} + DVTP0 \cdot \left(1 + e^{-DVTP1 \cdot V_{DS}}\right)} \right) \end{aligned}$$

Channel Charge and Subthreshold Swing Models

A unified expression for channel charge from subthreshold to strong inversion regions is

(21-15)

$$Q_{ch}(y) = C_{oxeff} \cdot V_{gsteff} \cdot \left(1 - \frac{V_F(y)}{V_b} \right)$$

In the above equation, V_{gsteff} (the effective V_{gst} ($V_{gse} - V_{th}$)) used to describe the channel charge densities from subthreshold to strong inversion is modeled by:

$$V_{gsteff} = \frac{n_{vt} \ln \left\{ 1 + \exp \left[\frac{m^*(V_{gse} - V_{th})}{n_{vt}} \right] \right\}}{m^* + nC_{oxe} \cdot \sqrt{\frac{2\Phi_s}{qNDEP\epsilon_{si}}} \exp \left[-\frac{(1 - m^*)(V_{gse} - V_{th}) - V'_{off}}{n_{vt}} \right]}$$

The drain current equation in the subthreshold region can be expressed as:

(21-16)

$$I_{ds} = I_0 \left[1 - \exp \left(-\frac{V_{ds}}{v_t} \right) \right] \cdot \exp \left(\frac{V_{gs} - V_{th} - V'_{off}}{n_{vt}} \right)$$

(21-17)

$$I_0 = \mu \frac{W}{L} \sqrt{\frac{q\epsilon_{si}NDEP}{2\Phi_s}} v_t^2$$

Gate Direct Tunneling Current Model

In BSIM4, the gate tunneling current components include the tunneling current between gate and substrate (I_{gb}), and the current between gate and channel (I_{gc}), which is partitioned between the source and drain terminals by $I_{gc} = I_{gcs} + I_{gcd}$. The third component happens between gate and source/drain diffusion regions (I_{gs} and I_{gd}). Following figure shows the schematic gate tunneling current flows.

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

I_{gc} , I_{gs} , and I_{gd} are turned on when $igcmod = 1, 2$; I_{gb} is turned on when $igbmod = 1$; no gate tunneling currents are modeled when $igcmod = 0$. $V_t (= kT/q)$ is replaced by $V_{tnom}(=kTnom/q)$ when $tempmod = 2$. The gate tunneling current components are expressed as following:

(21-18)

$$\begin{aligned}
 I_{gb} &= I_{gbacc} + I_{gbinv} \\
 &= W_{eff} L_{eff} \cdot A \cdot T_{oxRatio} \cdot V_{gb} \cdot V_{aux} \\
 &\quad \left[\exp(-B \cdot TOXE(AIGBACC - BIGBACC \cdot V_{oxacc}) \cdot (1 + CIGBACC \cdot V_{oxacc})) + \right. \\
 &\quad \left. \exp(-B \cdot TOXE(AIGBINV - BIGBINV \cdot V_{oxdepinv}) \cdot (1 + CIGBINV \cdot V_{oxdepinv})) \right]
 \end{aligned}$$

(21-19)

$$\begin{aligned}
 I_{gs} &= \frac{W_{eff} \cdot DLCIG \cdot A \cdot T_{oxRatioEdge} \cdot V_{gs} \cdot V'_{gs}}{\exp[-B \cdot TOXE \cdot POXEDGE \cdot (AIGS - BIGS \cdot V'_{gs}) \cdot (1 + CIGS \cdot V'_{gs})]}
 \end{aligned}$$

(21-20)

$$\begin{aligned}
 I_{gd} &= \frac{W_{eff} \cdot DLCIGD \cdot A \cdot T_{oxRatioEdge} \cdot V_{gd} \cdot V'_{gd}}{\exp[-B \cdot TOXE \cdot POXEDGE \cdot (AIGD - BIGD \cdot V'_{gd}) \cdot (1 + CIGD \cdot V'_{gd})]}
 \end{aligned}$$

(21-21)

$$I_{gc} = I_{gcs} + I_{gcd}$$

(21-22)

$$I_{gcs} = I_{gc0} \cdot \frac{PIGCD \cdot V_{dseff} + \exp(-PIGCD \cdot V_{dseff}) - 1 + 1.0e - 4}{PIGCD^2 \cdot V_{dseff}^2 + 2.0e - 4}$$

(21-23)

$$I_{gcd} = I_{gc0} \cdot \frac{1 + -(PIGCD \cdot V_{dseff} + 1) \cdot \exp(-PIGCD \cdot V_{dseff}) + 1.0e-4}{PIGCD^2 \cdot V_{dseff}^2 + 2.0e-4}$$

(21-24)

$$I_{gc0} = \frac{W_{eff} L_{eff} \cdot A \cdot T_{oxRatio} \cdot V_{gse} \cdot V_{aux}}{\exp[-B \cdot TOXE(AIGC - BIGC \cdot V_{oxdepinv}) \cdot (1 + CIGC \cdot V_{oxdepinv})]}$$

Drain Current Model

Bulk Charge Effect

The bulk charge effect caused by non-zero V_{ds} is modeled as

(21-25)

$$A_{bulk} = \left\{ 1 \pm F_{doping} \cdot \left[\begin{array}{l} \frac{A0 L_{eff}}{L_{eff} + 2\sqrt{XJ \cdot X_{dep}}} \\ \left(1 - AGSV_{gsteff} \left(\frac{L_{eff}}{L_{eff} + 2\sqrt{XJ \cdot X_{dep}}} \right)^2 \right) \right. \\ \left. + \frac{B0}{W'_{eff} + B1} \right] \right\} \cdot \frac{1}{1 + KETA V_{bseff}}$$

(21-26)

$$F_{doping} = \frac{\sqrt{1 + (LPEB) L_{eff}} K_{1ox}}{2\sqrt{\Phi_s - V_{bseff}}} + K_{2ox} - K3B \frac{TOXE}{W'_{eff} + W0} \Phi_s$$

Mobility Model

Several mobility models are provided in BSIM4. For $mtr1mod = 0$, $mobmod = 0$ and 1 models are from BSIM3v3.2.2, $mobmod = 2$ is a universal mobility model, which is more accurate and suitable. For $mtr1mod = 1$, a new expression of the vertical field in channel is adopted (introduced by BSIM4.6.1). The mobility model is modified as following:

$mobmod=0$

(21-27)

$$\mu_{eff} = \frac{U0 \cdot f(L_{eff})}{1 + (UA + UCV_{bseff})E_{eff} + UB \cdot E_{eff}^2 + UD \left(\frac{V_{th} \cdot EOT}{V_{gsteff} + 2\sqrt{V_{th}^2 + 0.0001}} \right)^2}$$

$mobmod=1$

(21-28)

$$\mu_{eff} = \frac{U0 \cdot f(L_{eff})}{1 + (UAE_{eff} + UBE_{eff}^2)(1 + UCV_{bseff}) + UD \left(\frac{V_{th} \cdot EOT}{V_{gsteff} + 2\sqrt{V_{th}^2 + 0.0001}} \right)^2}$$

$mobmod=2$

(21-29)

$$\mu_{eff} = \frac{U0 \cdot f(L_{eff})}{1 + (UA + UCV_{bseff}) + \left[\frac{V_{gsteff} + C_0 \cdot (V_{THO} - V_{FB} - \Phi_s)}{TOXE} \right]^{EU} + UD \left(\frac{V_{th} \cdot TOXE}{V_{gsteff} + 2\sqrt{V_{th}^2 + 0.0001}} \right)^2}$$

$mobmod=3$ for high k/metal gate structure (introduced by BSIM4..2):

Virtuoso Simulator Components and Device Models Reference
BSIM4 Level-14 Model (bsim4)

(21-30)

$$\mu_{eff} = \frac{U0 \cdot f(L_{eff})}{1 + (UA + UC V_{bseff}) + \left[\frac{V_{gsteff} + C_0 \cdot (V_{THO} - V_{FB} - \Phi_s)}{6 \cdot TOXE} \right]^{EU} + \frac{UD}{0.5 [1 + V_{gsteff} / V_{gsteff} \cdot V_{th}]^{UCS}}$$

BSIM4.80 introduces three new mobility models, mobmod=4, mobmod=5, and mobmod=6 as modified versions of mobmod=0, mobmod=1, and mobmod=2 respectively.

mobmod=4

(21-31)

$$\mu_{eff} = \frac{U0 \cdot f(L_{eff})}{1 + (UA + UC V_{bseff}) \left[\frac{V_{gsteff} + C_0 \cdot (V_{THO} - V_{FB} - \Phi_s)}{TOXE} \right] + UB \left(\frac{V_{gsteff} + C_0 \cdot (V_{THO} - V_{FB} - \Phi_s)}{TOXE} \right)^2 + UD \left(\frac{C_0 \cdot (V_{THO} - V_{FB} - \Phi_s) \cdot TOXE}{V_{gseff} + 2 \sqrt{C_0^2 \cdot (V_{THO} - V_{FB} - \Phi_s)^2 + 0.0001}} \right)^2}$$

mobmod=5

(21-32)

$$\mu_{eff} = \frac{U0 \cdot f(L_{eff})}{1 + \left[UA \left(\frac{V_{gsteff} + C_0 \cdot (V_{THO} - V_{FB} - \Phi_s)}{TOXE} \right) + UB \left(\frac{V_{gsteff} + C_0 \cdot (V_{THO} - V_{FB} - \Phi_s)}{TOXE} \right)^2 \right] (1 + UC \cdot V_{eff}) + UD \left(\frac{C_0 \cdot (V_{THO} - V_{FB} - \Phi_s) \cdot TOXE}{V_{gseff} + 2 \sqrt{C_0^2 \cdot (V_{THO} - V_{FB} - \Phi_s)^2 + 0.0001}} \right)^2}$$

mobmod=6

(21-33)

$$\mu_{eff} = \frac{U_0 \cdot f(L_{eff})}{1 + (UA + UC \cdot V_{bseff}) \left[\frac{V_{gsteff} + C_0 \cdot (V_{THO} - V_{FB} - \Phi_s)}{TOXE} \right]^{EU} + UD \left(\frac{C_0 \cdot (V_{THO} - V_{FB} - \Phi_s) \cdot TOXE}{V_{gsteff} + 2 \sqrt{C_0^2 \cdot (V_{THO} - V_{FB} - \Phi_s)^2 + 0.0001}} \right)^2}$$

Bias-Dependant Source/Drain-Resistance Model

rdsMod=0 (Internal R_{ds} (V))

(21-34)

$$R_{ds}(V) = \left\{ \left[\begin{aligned} &RDSWMIN + RDSW \cdot \\ &\left[PRWB \cdot (\sqrt{\Phi_s - V_{bseff}} - \sqrt{\Phi_s}) + \frac{1}{1 + PRWG \cdot V_{gsteff}} \right] \end{aligned} \right\} / (1e6 \cdot W_{effcj})^{WR}$$

rdsMod=1 (External $R_d(V)$ and $R_s(V)$)

(21-35)

$$R_d(V) = \left\{ \left[\begin{aligned} &RDWMIN + RDW \cdot \\ &\left[-PRWB V_{bd} + \frac{1}{1 + PRWG \cdot (V_{gd} - V_{fbsd})} \right] \end{aligned} \right\} / (1e6 \cdot W_{effcj})^{WR} \cdot NF$$

(21-36)

$$R_s(V) = \left\{ \left[\begin{aligned} &RSWMIN + RSW \cdot \\ &\left[-PRWB V_{bs} + \frac{1}{1 + PRWG \cdot (V_{gs} - V_{fbsd})} \right] \end{aligned} \right\} / (1e6 \cdot W_{effcj})^{WR} \cdot NF$$

Saturation Voltage V_{dsat}

Intrinsic Case

Virtuoso Simulator Components and Device Models Reference
BSIM4 Level-14 Model (bsim4)

(21-37)

$$V_{dsat} = \frac{E_{sat}L(V_{gsteff} + 2v_t)}{A_{bulk}E_{sat}L + V_{gsteff} + 2v_t}$$

Extrinsic Case

(21-38)

$$V_{dsat} = \frac{-b - \sqrt{b^2 - 4ac}}{2a}$$

where

(21-39)

$$a = A_{bulk}^2 W_{eff} V_{SATC_{oxe}} R_{ds} + A_{bulk} \left(\frac{1}{\lambda} - 1 \right)$$

(21-40)

$$b = - \left[(V_{gsteff} + 2v_t) \left(\frac{2}{\lambda} - 1 \right) + A_{bulk} E_{sat} L_{eff} \right. \\ \left. + 3A_{bulk} (V_{gsteff} + 2v_t) W_{eff} V_{SATC_{oxe}} R_{ds} \right]$$

(21-41)

$$c = (V_{gsteff} + 2v_t) E_{sat} L_{eff} + 2(V_{gsteff} + 2v_t)^2 W_{eff} V_{SATC_{oxe}} R_{ds}$$

(21-42)

$$\lambda = A1 V_{gsteff} + A2$$

Drain Current

Considering only the channel current, the I-V curve can be divided into two parts: the linear region and the saturation region. In the linear region, carrier velocity is not saturated and the drain current has a strong dependence on the drain voltage. In the saturation region, several physical mechanisms affect the output resistance: channel length modulation (CLM), drain-induced barrier lowering (DIBL), and the substrate current induced body effect (SCBE). These mechanisms all affect the output resistance in the saturation range, but each of them dominates in a specific region. The channel current equation for both linear and saturation regions is:

(21-43)

$$I_{ds} = \frac{I_{ds0}NF}{1 + \frac{R_{ds}I_{ds0}}{V_{dseff}}} \left[1 + \frac{1}{C_{clm}} \ln \left(\frac{V_A}{V_{Asat}} \right) \right] \left(1 + \frac{V_{ds} - V_{dseff}}{V_{ADIBL}} \right) \left(1 + \frac{V_{ds} - V_{dseff}}{V_{ASCBE}} \right) \left(1 + \frac{V_{ds} - V_{dseff}}{V_{ADITS}} \right)$$

where NF is the number of device fingers, and Early voltage.

(21-44)

$$V_A = V_{Asat} + V_{ACLM}$$

The Early voltage at $V_{ds} = V_{dsat}$ is

(21-45)

$$V_{Asat} = \frac{E_{sat}L_{eff} + V_{dsat} + 2R_{ds}vsatC_{oxe}W_{eff}V_{gsteff}}{R_{ds}vsatC_{oxe}W_{eff}A_{bulk} - 1 + \frac{2}{\lambda}} \left[1 - \frac{A_{bulk}V_{dsat}}{2(V_{gsteff} + 2v_t)} \right]$$

The Early voltage due to CLM effect is

(21-46)

$$V_{ACLM} = C_{clm}(V_{ds} - V_{dsat})$$

where

(21-47)

The Early voltage due to DIBL effect is

$$C_{clm} = \frac{F}{PCLM} \left(1 + PVAG \frac{V_{gsteff}}{E_{sat} L_{eff}} \right) \left(1 + \frac{R_{ds} I_{ds0}}{V_{dseff}} \right) \left(L_{eff} + \frac{V_{sat}}{E_{sat}} \right) \frac{1}{litl}$$

(21-48)

$$V_{ADIBL} = \frac{V_{gsteff} + 2v_t}{\theta_{rout} (1 + PDIBLCB \cdot V_{bseff})} \left(1 - \frac{A_{bulk} V_{dsat}}{A_{bulk} V_{sat} + V_{gsteff} + 2v_t} \right) \left(1 + PVAG \frac{V_{gsteff}}{E_{sat} L_{eff}} \right)$$

The Early voltage due to SCBE effect is

(21-49)

$$V_{ASCBE} = \frac{L_{eff}}{PSCBE2} \exp\left(\frac{PSCBE1 \cdot litl}{V_{ds} - V_{dsat}}\right)$$

The Early voltage due to Drain-Induced Threshold Shift (DITS) by pocket implant is

(21-50)

$$V_{ADITS} = \frac{F}{PDITS} [1 + (1 + PDITSL \cdot L_{eff}) \exp(PDITSD \cdot V_{ds})]$$

Velocity Overshoot and Source End Velocity Limit Model

In the deep-submicron region, the velocity overshoot and source end velocity limit model should be used. The unified current expression with velocity saturation, velocity overshoot and source velocity limit is:

(21-51)

$$I_{DS} = \frac{I_{DS,HD}}{[1 + (v_{sHD}/v_{sBT})^{2MM}]^{1/(2MM)}}$$

where the current including the velocity overshoot effect is:

(21-52)

$$I_{DS,HD} = \frac{I_{DS} \left(1 + \frac{V_{dseff}}{L_{eff} E_{sat}} \right)}{1 + \frac{V_{dseff}}{L_{eff} E_{sat}} \overset{OV}{}}$$

Body Current Model

I_{sub} Model

When the electrical field near the drain is very large ($> 0.1\text{MV/cm}$), some electrons coming from the source (in the case of NMOSFETs) will be energetic (hot) enough to cause impact ionization. This will generate electron-hole pairs when these energetic electrons collide with silicon atoms. The substrate current I_{sub} thus created during impact ionization will increase exponentially with the drain voltage. A well known I_{sub} model is:

(21-53)

$$I_{sub} = \frac{A_i}{B_i} I_{ds} (V_{ds} - V_{dsat}) \exp\left(-\frac{B_i \cdot litl}{V_{ds} - V_{dsat}}\right)$$

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In addition to the junction diode current and gate-to-body tunneling current, the substrate terminal current consists of the substrate current due to impact ionization (I_{ii}), and gate-induced drain leakage and source leakage currents (I_{GIDL} and I_{GISL}).

I_{ii} Model

(21-54)

$$I_{ii} = \frac{ALPHA0 + ALPHA1 \cdot L_{eff}}{L_{eff}} (V_{ds} - V_{dseff}) \exp\left(\frac{BETA0}{V_{ds} - V_{dseff}}\right) \cdot \frac{I_{ds}}{1 + \frac{V_{ds} - V_{dseff}}{V_{ASCBE}}}$$

I_{GIDL} and I_{GISL} Model

mtrmod=0

(21-55)

$$I_{GIDL} = AGIDL \cdot W_{effCJ} \cdot NF \cdot \frac{V_{ds} - V_{gse} - EGIDL}{3T_{oxe}} \exp\left(-\frac{3T_{oxe} \cdot BGIDL}{V_{ds} - V_{gse} - EGIDL}\right) \cdot \frac{V_{db}^3}{CGIDL + V_{db}^3}$$

(21-56)

$$I_{GISL} = AGISL \cdot W_{effCJ} \cdot NF \cdot \frac{-V_{ds} - V_{gde} - EGISL}{3T_{oxe}} \cdot \exp\left(-\frac{3T_{oxe} \cdot BGISL}{-V_{ds} - V_{gde} - EGISL}\right) \cdot \frac{V_{sb}^3}{CGISL + V_{sb}^3}$$

(21-57)

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

mtrmod=1

$$I_{GIDL} = AGIDL \cdot W_{effCJ} \cdot NF \cdot \frac{V_{ds} - V_{gse} - EGIDL + V_{fbsd}}{EOT \cdot \frac{EPSRSUB}{3.9}} \cdot \exp\left(-\frac{EOT \cdot \frac{EPSRSUB}{3.9} \cdot BGIDL}{V_{ds} - V_{gse} - EGIDL + V_{fbsd}}\right) \cdot \frac{V_{db}^3}{CGIDL + V_{db}^3}$$

(21-58)

$$I_{GISL} = AGISL \cdot W_{effCJ} \cdot NF \cdot \frac{-V_{ds} - V_{gde} - EGISL + V_{fbsd}}{EOT \cdot \frac{EPSRSUB}{3.9}} \cdot \exp\left(-\frac{EOT \cdot \frac{EPSRSUB}{3.9} \cdot BGISL}{-V_{ds} - V_{gde} - EGISL + V_{fbsd}}\right) \cdot \frac{V_{sb}^3}{CGISL + V_{sb}^3}$$

(21-59)

where

$$V_{fbsd} = PHIG - \left(EASUB + \frac{Eg0}{2} - BSIM4type \cdot \text{MIN}\left(\frac{Eg0}{2}, v_t \ln\left(\frac{NSD}{n_i}\right)\right)\right)$$

Capacitance Model

The following table displays the BSIM4 capacitance model options:

BSIM4 Capacitance Models

capMod = 0 (simple and piecewise model)

capMod = 1 (single equation model)

capMod = 2 (default; single-equation and charge-thickness model)

Matched capmod in BSIM3v3.2.2

Intrinsic capMod = 0 + overlap/fringing
capMod=0

Intrinsic capMod = 2 + overlap/fringing
capMod = 2

Intrinsic capMod = 3 + overlap/fringing
capMod = 2

Intrinsic Capacitance Modeling

The relationship of terminal charges (Q_g , Q_b , Q_s , and Q_d) and the channel charge Q_{inv} , accumulation charge Q_{acc} and substrate depletion charge Q_{sub} are:

(21-60)

$$Q_g = -(Q_{sub} + Q_{inv} + Q_{acc})$$

(21-61)

$$Q_b = Q_{acc} + Q_{sub}$$

(21-62)

$$Q_{inv} = Q_s + Q_d$$

All capacitances are derived from the charges to ensure charge conservation. Since there are four terminals, there are a total of 16 components. For each component:

(21-63)

$$C_{ij} = \frac{\partial Q_i}{\partial V_j}$$

where i and j denote the transistor terminals. C_{ij} satisfies

(21-64)

$$\sum_i C_{ij} = \sum_j C_{ij} = 0$$

A new threshold voltage definition is introduced to improve the fitting in subthreshold region. Setting `cvchargemod = 1` activates the new V_{gsteff} , CV calculation which is similar to the V_{gsteff} formulation in the I-V model. Setting `cvchargemod = 0` is corresponding to long-channel charge model which assumes a constant mobility with no velocity saturation.

Intrinsic capacitance model equations

For capmod=0

Accumulation region

(21-65)

$$Q_g = W_{active} L_{active} C_{oxe} (V_{gs} - V_{bs} - VFBCV)$$

(21-66)

$$Q_{sub} = -Q_g$$

(21-67)

$$Q_{inv} = 0$$

Subthreshold region

(21-68)

$$Q_{sub0} = -W_{active} L_{active} C_{oxe} \frac{K_{1ox}^2}{2} \left(-1 + \sqrt{1 + \frac{4(V_{gs} - VFBCV - V_{bs})}{K_{1ox}^2}} \right)$$

(21-69)

$$Q_g = -Q_{sub0}$$

(21-70)

$$Q_{inv} = 0$$

Strong inversion

(21-71)

$$V_{dsat, cv} = \frac{V_{gs} - V_{th}}{A_{bulk}}$$

(21-72)

$$A_{bulk}' = A_{bulk} \left(1 + \left(\frac{CLC}{L_{eff}} \right)^{CLE} \right)$$

(21-73)

$$V_{TH} = VFBCV + \Phi_s + K_{1ox} \sqrt{\Phi_s - V_{bseff}}$$

Linear Region

(21-74)

$$Q_g = C_{oxe} W_{active} L_{active} \left[V_{gs} - VFBCV - \Phi_s - \frac{V_{ds}}{2} + \frac{A_{bulk}' \times V_{ds}^2}{12 \left(V_{gs} - V_{th} - \frac{A_{bulk}' V_{ds}}{2} \right)} \right]$$

(21-75)

$$Q_b = C_{oxe} W_{active} L_{active} \left[VFBCV - V_{th} - \Phi_s + \frac{(1 - A_{bulk}') V_{ds}}{2} - \frac{(1 - A_{bulk}') A_{bulk}' V_{ds}^2}{12 \left(V_{gs} - V_{th} - \frac{A_{bulk}' V_{ds}}{2} \right)} \right]$$

50/50 Charge Partition

(21-76)

$$Q_{inv} = -C_{oxe} W_{active} L_{active} \left(V_{gs} - V_{th} - \Phi_s - \frac{A_{bulk}' V_{ds}}{2} + \frac{A_{bulk}'^2 V_{ds}^2}{12 \left(V_{gs} - V_{th} - \frac{A_{bulk}' V_{ds}}{2} \right)} \right)$$

(21-77)

$$Q_s = Q_d = 0.5 Q_{inv}$$

Virtuoso Simulator Components and Device Models Reference
BSIM4 Level-14 Model (bsim4)

40/60 Channel-Charge Partition

(21-78)

$$Q_d = -C_{oxe} W_{active} L_{active}$$

$$\left(\frac{V_{gs} - V_{th}}{2} - \frac{A_{bulk}' V_{ds}}{2} + \frac{A_{bulk}' V_{ds} \left[\frac{(V_{gs} - V_{th})^2}{6} - \frac{A_{bulk}' V_{ds} (V_{gs} - V_{th})}{8} + \frac{(A_{bulk}' V_{ds})^2}{40} \right]}{12 \left(V_{gs} - V_{th} - \frac{A_{bulk}' V_{ds}}{2} \right)^2} \right)$$

(21-79)

$$Q_s = -(Q_g + Q_b + Q_d)$$

0/100 Partitioning

(21-80)

$$Q_d = -C_{oxe} W_{active} L_{active} \left(\frac{V_{gs} - V_{th}}{2} + \frac{A_{bulk}' V_{ds}}{4} - \frac{(A_{bulk}' V_{ds})^2}{24} \right)$$

(21-81)

$$Q_s = -(Q_g + Q_b + Q_d)$$

Saturation Region

(21-82)

$$Q_g = C_{oxe} W_{active} L_{active} \left(V_{gs} - VFBCV - \Phi_s - \frac{V_{dsat}}{3} \right)$$

(21-83)

$$Q_b = -C_{oxe} W_{active} L_{active} \left(VFBCV + \Phi_s - V_{th} + \frac{(1 - A_{bulk}') V_{dsat}}{3} \right)$$

50/50 Partitioning

(21-84)

$$Q_s = Q_d = -\frac{1}{3} C_{oxe} W_{active} L_{active} (V_{gs} - V_{th})$$

40/60 Partitioning

(21-85)

$$Q_d = -\frac{4}{15} C_{oxe} W_{active} L_{active} (V_{gs} - V_{th})$$

(21-86)

$$Q_s = -(Q_g + Q_b + Q_d)$$

0/100 Channel-Charge Partition

(21-87)

$$Q_d = 0$$

(21-88)

$$Q_s = -(Q_g + Q_b)$$

For capmod=1

(21-89)

$$Q_g = -(Q_{inv} + Q_{acc} + Q_{sub0} + \delta Q_{sub})$$

(21-90)

$$Q_b = -(Q_{acc} + Q_{sub0} + \delta Q_{sub})$$

(21-91)

$$Q_{inv} = Q_s + Q_d$$

(21-92)

$$Q_{acc} = -W_{active} L_{active} C_{oxe} \cdot (V_{FBeff} - V_{fbzb})$$

(21-93)

$$Q_{sub0} = -W_{active} L_{active} C_{oxe} \cdot \frac{K_{1ox}^2}{2} \cdot \left[-1 + \sqrt{1 + \frac{4(V_{gse} - V_{FBeff} - V_{gsteff} - V_{bseff})^2}{K_{1ox}^2}} \right]$$

(21-94)

$$V_{dsat, cv} = \frac{V_{gsteffcv}}{A_{bulk}'}$$

(21-95)

$$Q_{inv} = -W_{active} L_{active} C_{oxe} \cdot \left[V_{gsteff, cv} - \frac{1}{2} A_{bulk}' V_{cveff} + \frac{A_{bulk}'^2 V_{cveff}^2}{12 \cdot \left(V_{gsteff, cv} - \frac{A_{bulk}' V_{cveff}}{2} \right)} \right]$$

(21-96)

$$\delta Q_{sub} = W_{active} L_{active} C_{oxe} \cdot \left[\frac{1 - A_{bulk}'}{2} V_{cveff} - \frac{(1 - A_{bulk}') \cdot A_{bulk}' V_{cveff}^2}{12 \cdot \left(V_{gsteff, cv} - \frac{A_{bulk}' V_{cveff}}{2} \right)} \right]$$

Virtuoso Simulator Components and Device Models Reference
BSIM4 Level-14 Model (bsim4)

50/50 Charge Partition

(21-97)

$$Q_S = Q_D = -\frac{W_{active}L_{active}C_{oxe}}{2} \left[V_{gsteff,cv} - \frac{1}{2}A_{bulk}'V_{cveff} + \frac{A_{bulk}'^2V_{cveff}^2}{12 \cdot \left(V_{gsteff,cv} - \frac{A_{bulk}'V_{cveff}}{2} \right)} \right]$$

40/60 Channel-Charge Partition

(21-98)

$$Q_S = -\frac{W_{active}L_{active}C_{oxe}}{2 \left(V_{gsteff,cv} - \frac{A_{bulk}'V_{cveff}}{2} \right)^2} \left[V_{gsteff,cv}^3 - \frac{4}{3}V_{gsteff,cv}^2A_{bulk}'V_{cveff} + \frac{2}{3}V_{gsteff,cv}(A_{bulk}'V_{cveff})^2 - \frac{2}{15}(A_{bulk}'V_{cveff})^3 \right]$$

(21-99)

$$Q_D = -\frac{W_{active}L_{active}C_{oxe}}{2 \left(V_{gsteff,cv} - \frac{A_{bulk}'V_{cveff}}{2} \right)^2} \left[V_{gsteff,cv}^3 - \frac{5}{3}V_{gsteff,cv}^2A_{bulk}'V_{cveff} + V_{gsteff,cv}(A_{bulk}'V_{cveff})^2 - \frac{1}{5}(A_{bulk}'V_{cveff})^3 \right]$$

0/100 Charge Partition

(21-100)

$$Q_S = -\frac{W_{active}L_{active}C_{oxe}}{2} \cdot \left(V_{gsteff,cv} + \frac{1}{2}A_{bulk}'V_{cveff} - \frac{A_{bulk}'^2V_{cveff}^2}{12 \cdot \left(V_{gsteff,cv} - \frac{A_{bulk}'V_{cveff}}{2} \right)} \right)$$

(21-101)

$$Q_D = -\frac{W_{active}L_{active}C_{oxe}}{2} \cdot \left[V_{gsteff, cv} - \frac{3}{2}A_{bulk}'V_{cveff} + \frac{A_{bulk}'^2V_{cveff}^2}{4 \cdot \left(V_{gsteff, cv} - \frac{A_{bulk}'V_{cveff}}{2} \right)} \right]$$

For capmod = 2

(21-102)

$$Q_{acc} = W_{active}L_{active}C_{oxeff} \cdot V_{gbacc}$$

(21-103)

$$V_{gbacc} = \frac{1}{2} \cdot \left[V_0 + \sqrt{V_0^2 + 0.08V_{fbzb}} \right]$$

(21-104)

$$V_0 = V_{fbzb} + V_{bseff} - V_{gs} - 0.02$$

(21-105)

$$V_{cveff} = V_{dsat} - \frac{1}{2} \cdot \left(V_1 + \sqrt{V_1^2 + 0.08V_{dsat}} \right)$$

(21-106)

$$V_1 = V_{dsat} - V_{ds} - 0.02$$

(21-107)

$$V_{dsat} = \frac{\langle V_{gsteff, cv} - \Psi_{\delta} \rangle_{eff}}{A_{bulk}'}$$

When updatelevel=1, a smooth function is applied when calculating $(V_{gsteff, cv} - \Psi_{\delta})_{eff}$ to improve convergence behavior of the model.

(21-108)

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(21-109)

$$\varphi_{\delta} = \Phi_s - 2\Phi_B = v_t \ln \left(\frac{V_{gsteffCV} \cdot (V_{gsteffCV} + 2K_{1ox} \sqrt{2\Phi_B})}{MOIN \cdot K_{1ox}^2 v_t} \right)$$

(21-110)

$$Q_{sub0} = -W_{active} L_{active} C_{oxeff} \cdot \frac{K_{1ox}^2}{2} \left[-1 + \sqrt{1 + \frac{4(V_{gse} - V_{FBeff} - V_{bseffs} - V_{gsteff, cv})}{K_{1ox}^2}} \right]$$

(21-111)

$$Q_{inv} = -W_{active} L_{active} C_{oxeff} \cdot \left[\langle V_{gsteff, cv} - \varphi_{\delta} \rangle_{eff} - \frac{1}{2} A_{bulk}' V_{cveff} + \frac{A_{bulk}'^2 V_{cveff}^2}{12 \cdot \left(\langle V_{gsteff, cv} - \varphi_{\delta} \rangle_{eff} - \frac{A_{bulk}' V_{cveff}}{2} \right)} \right]$$

(21-112)

$$\delta Q_{sub} = -W_{active} L_{active} C_{oxeff} \cdot \left[\frac{1 - A_{bulk}'}{2} V_{cveff} - \frac{(1 - A_{bulk}') \cdot A_{bulk}' V_{cveff}^2}{12 \cdot \left(\langle V_{gsteff, cv} - \varphi_{\delta} \rangle_{eff} - \frac{A_{bulk}' V_{cveff}}{2} \right)} \right]$$

Virtuoso Simulator Components and Device Models Reference
BSIM4 Level-14 Model (bsim4)

50/50 Partitioning

(21-113)

$$Q_S = Q_D = -\frac{W_{active}L_{active}C_{oxeff}}{2}$$

$$\left[\langle V_{gsteff, cv - \phi_{\delta}} \rangle_{eff} - \frac{1}{2}A_{bulk}'V_{cveff} + \frac{A_{bulk}'^2V_{cveff}^2}{12 \cdot \left(\langle V_{gsteff, cv - \phi_{\delta}} \rangle_{eff} - \frac{A_{bulk}'V_{cveff}}{2} \right)} \right]$$

40/60 Partitioning

(21-114)

$$Q_S = -\frac{W_{active}L_{active}C_{oxeff}}{2 \left(\langle V_{gsteff, cv - \phi_{\delta}} \rangle_{eff} - \frac{A_{bulk}'V_{cveff}}{2} \right)^2}$$

$$\left[\langle V_{gsteff, cv - \phi_{\delta}} \rangle_{eff}^3 - \frac{4}{3} \langle V_{gsteff, cv - \phi_{\delta}} \rangle_{eff}^2 A_{bulk}'V_{cveff} + \frac{2}{3} \langle V_{gsteff, cv - \phi_{\delta}} \rangle_{eff} (A_{bulk}'V_{cveff})^2 - \frac{2}{15} (A_{bulk}'V_{cveff})^3 \right]$$

(21-115)

$$Q_D = -\frac{W_{active}L_{active}C_{oxeff}}{2 \left(\langle V_{gsteff, cv - \phi_{\delta}} \rangle_{eff} - \frac{A_{bulk}'V_{cveff}}{2} \right)^2}$$

$$\left[\langle V_{gsteff, cv - \phi_{\delta}} \rangle_{eff}^3 - \frac{5}{3} \langle V_{gsteff, cv - \phi_{\delta}} \rangle_{eff}^2 A_{bulk}'V_{cveff} + \langle V_{gsteff, cv - \phi_{\delta}} \rangle_{eff} (A_{bulk}'V_{cveff})^2 - \frac{1}{5} (A_{bulk}'V_{cveff})^3 \right]$$

Virtuoso Simulator Components and Device Models Reference
BSIM4 Level-14 Model (bsim4)

0/100 Partitioning

(21-116)

$$Q_S = -\frac{W_{active}L_{active}C_{oxeff}}{2} \cdot \left[(V_{gsteff, cv} - \varphi_{\delta})_{eff} + \frac{1}{2}A_{bulk}'V_{cveff} - \frac{A_{bulk}'^2V_{cveff}^2}{12 \cdot \left((V_{gsteff, cv} - \varphi_{\delta})_{eff} - \frac{A_{bulk}'V_{cveff}}{2} \right)} \right]$$

(21-117)

$$Q_D = -\frac{W_{active}L_{active}C_{oxeff}}{2} \cdot \left[(V_{gsteff, cv} - \varphi_{\delta})_{eff} - \frac{3}{2}A_{bulk}'V_{cveff} - \frac{A_{bulk}'^2V_{cveff}^2}{4 \cdot \left((V_{gsteff, cv} - \varphi_{\delta})_{eff} - \frac{A_{bulk}'V_{cveff}}{2} \right)} \right]$$

When updatelevel=0,

(21-118)

$$\langle V_{gsteff, cv} - \varphi_{\delta} \rangle_{eff} = V_{gsteff, cv} - \varphi_{\delta}$$

When updatelevel=1, or version=4.5,

(21-119)

$$\langle V_{gsteff, cv} - \varphi_{\delta} \rangle_{eff} = 0.5 \cdot \left[(V_{gsteff, cv} - \varphi_{\delta} - 0.0001) + \sqrt{(V_{gsteff, cv} - \varphi_{\delta} - 0.0001)^2 + V_{gsteff, cv} \cdot 0.0004} \right]$$

Intrinsic Capacitances (with Body Bias and DIBL)

(21-120)

$$C_{(s,d,g,b),g} = \frac{\partial Q_{s,d,g,b}}{\partial V_{gsteffcv}} \frac{\partial V_{gsteffcv}}{\partial V_{gt}}$$

(21-121)

$$C_{(s,d,g,b),s} = -\frac{\partial Q_{s,d,g,b}}{\partial V_{ds}} + \frac{\partial Q_{s,d,g,b}}{\partial V_{gsteffcv}} \frac{\partial V_{gsteffcv}}{\partial V_{gt}} \left(\frac{\partial V_{th}}{\partial V_{ds}} + \frac{\partial V_{th}}{\partial V_{bs}} \right)$$

(21-122)

$$C_{(s,d,g,b),d} = \frac{\partial Q_{s,d,g,b}}{\partial V_{ds}} - \frac{\partial Q_{s,d,g,b}}{\partial (V_{gsteffcv})} \frac{\partial V_{gsteffcv}}{\partial V_{gt}} \frac{\partial V_{th}}{\partial V_{ds}}$$

(21-123)

$$C_{(s,d,g,b),b} = \frac{\partial Q_{s,d,g,b}}{\partial V_{bs}} - \frac{\partial Q_{s,d,g,b}}{\partial V_{gsteffcv}} \frac{\partial V_{gsteffcv}}{\partial V_{gt}} \frac{\partial V_{th}}{\partial V_{bs}}$$

Overlap Capacitance Models

capmod=0, Bias-independent overlap capacitance model

(21-124)

$$Q_{overlap,s} = W_{active} \cdot CGSO \cdot V_{gs}$$

(21-125)

$$Q_{overlap,d} = W_{active} \cdot CGDO \cdot V_{gd}$$

(21-126)

$$Q_{overlap,b} = L_{active} \cdot CGBO \cdot V_{gb}$$

capmod 1 and 2, Bias dependent overlap capacitance model

(21-127)

$$\frac{Q_{overlap,s}}{W_{active}} = CGSO \cdot V_{gs} + CGSL \left(V_{gs} - V_{gs,overlap} - \frac{CKAPPAS}{2} \left(-1 + \sqrt{1 - \frac{4V_{gs,overlap}}{CKAPPAS}} \right) \right)$$

(21-128)

$$\frac{Q_{overlap,d}}{W_{active}} = CGDO \cdot V_{gd} + CGDL \left(V_{gd} - V_{gd,overlap} - \frac{CKAPPAD}{2} \left(-1 + \sqrt{1 - \frac{4V_{gd,overlap}}{CKAPPAD}} \right) \right)$$

(21-129)

$$Q_{overlap,g} = -(Q_{overlap,d} + Q_{overlap,s} + CGBO \cdot L_{active} \cdot V_{gb})$$

(21-130)

$$V_{gs,overlap} = \frac{V_{gs} + \delta_1 - \sqrt{(V_{gs} + \delta_1)^2 + 4\delta_1}}{2}$$

(21-131)

$$V_{gd,overlap} = \frac{V_{gd} + \delta_1 - \sqrt{(V_{gd} + \delta_1)^2 + 4\delta_1}}{2}, \delta_1 = 0.02V$$

High Speed/RF Models

Charge-deficit Nonquasi-static (NQS) Model

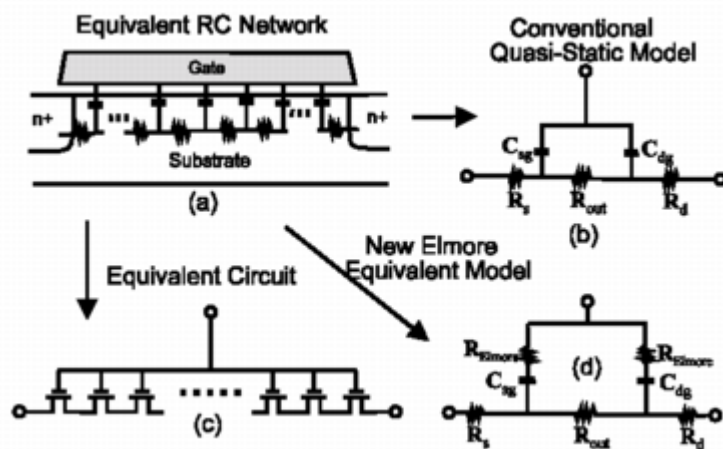
BSIM4 uses two separate model selectors to turn on or off the charge-deficit NQS model in transient simulation (using *trnqsmMod*) and AC simulation (using *acnqsmMod*). The AC NQS model does not require the internal NQS charge node that is needed for the transient NQS model. The transient and AC NQS models are developed from the same fundamental physics: the channel/gate charge response to the external signal are relaxation-time (τ)

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

dependent and the transcapacitances and transconductances (such as G_m) for AC analysis can therefore be expressed as functions for $j\omega\tau$.

MOSGFET channel region is analogous to a bias-dependent RC distributed transmission line as shown section "a" of the figure below. In the Quasi-Static (QS) approach, the gate capacitor node is lumped with the external source and drain nodes as shown in section "b" of the figure below. This ignores the finite time for the channel charge to build-up. One way to capture the NQS effect is to represent the channel with n transistors in series as shown in section "c" of the figure below, but it comes at the expense of simulation time. The BSIM4 charge-deficit NQS model uses Elmore equivalent circuit to model channel charge build-up as shown in section "d" of the figure below.



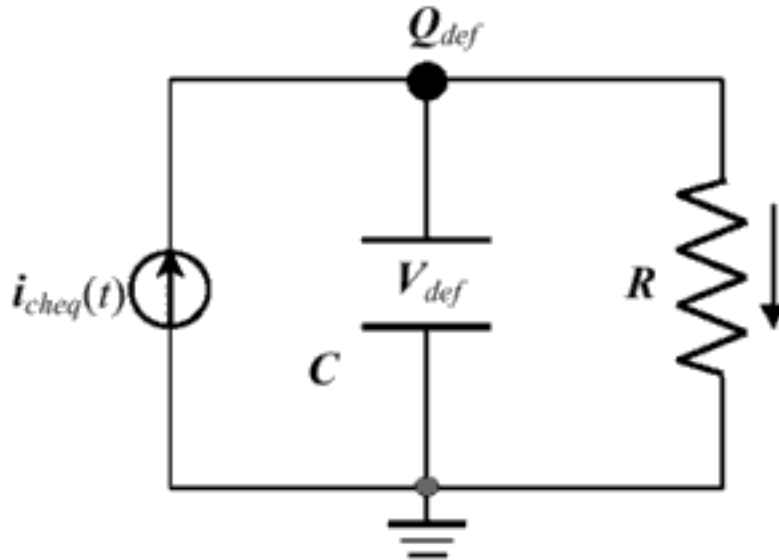
The Transient Model

The transient charge-deficit NQS model can be turned on by setting ***trnqsmMod*** = 1 and off by setting ***trnqsmMod*** = 0.

The figure below shows the RC subcircuit of charge deficit NQS model for transient simulation. An internal node, $Q_{def}(t)$, is created to keep track of the amount of deficit/surplus channel charge necessary to reach equilibrium. The resistance R is determined from the RC time constant (τ). The current source $i_{cheq}(t)$ represents the equilibrium channel charging effect. The capacitor C is the value of C_{fact} (with a typical value of 1×10^{-9} Farad) to improve simulation accuracy. Q_{def} now becomes:

(21-132)

$$Q_{def}(t) = V_{def} \times C_{fact}$$



Considering both the transport and charging component, the total current related to the terminals D, G, and S can be written as:

(21-133)

$$i_{D,G,S}(t) = I_{D,G,S}(DC) + \frac{\partial Q_{d,g,s}(t)}{\partial t}$$

Based on the relaxation time approach, the terminal charge and corresponding charging current are modeled by

(21-134)

$$Q_{def}(t) = Q_{cheq}(t) - Q_{ch}(t)$$

and

(21-135)

$$\frac{\partial Q_{def}(t)}{\partial t} = \frac{\partial Q_{cheq}(t)}{\partial t} - \frac{Q_{def}(t)}{\tau}$$

(21-136)

$$\frac{\partial Q_{d,g,s}(t)}{\partial t} = D, G, S_{xpart} \frac{Q_{def}(t)}{\tau}$$

where D, G, S_{xpart} are charge deficit NQS channel charge partitioning numbers for terminals D, G, and S; $D_{xpart} + S_{xpart} = 1$ and $G_{xpart} = -1$.

The transit time τ is equal to the product of R_{ij} and $W_{eff}L_{eff}C_{oxe}$, where R_{ij} is the intrinsic input resistance given by

(21-137)

$$\frac{1}{R_{ii}} = XRCRG1 \cdot \left(\frac{I_{ds}}{V_{dseff}} + XRCRG2 \cdot \frac{W_{eff}L_{eff}C_{oxeff}k_B T}{qL_{eff}} \right)$$

where C_{oxeff} is the effective gate dielectric capacitance calculated from the DC model.

Note: R_{ij} considers both the drift and diffusion components of the channel conduction, each of which dominates in inversion and subthreshold regions.

The AC Mode

The small-signal AC charge-deficit NQS model can be turned on by setting ***acnqsMod*** = 1 and off by setting ***acnqsMod*** = 0.

For small signals in the frequency domain, $Q_{ch}(t)$ can be transformed into:

(21-138)

$$\Delta Q_{ch}(t) = \frac{\Delta Q_{cheq}(t)}{1 + j\omega\tau}$$

where ω is the angular frequency. It can be shown that the transcapacitances C_{gj} , C_{sj} , and C_{di} (i stands for any of the G, D, S, and B terminals of the device) and the channel transconductances G_m , G_{ds} , and G_{mbs} all become complex quantities. For example, now G_m has the form of:

(21-139)

$$G_m = \frac{G_{m0}}{1 + \omega^2 \tau^2} + j \left(-\frac{G_{m0} \cdot \omega \tau}{1 + \omega^2 \tau^2} \right)$$

and

(21-140)

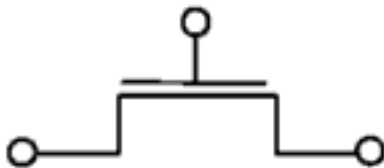
$$C_{dg} = \frac{C_{dg0}}{1 + \omega^2 \tau^2} + j \left(-\frac{C_{dg0} \cdot \omega \tau}{1 + \omega^2 \tau^2} \right)$$

The quantities above with sub "0" are known from OP (Operating Point) analysis.

Gate Electrode and Intrinsic-Input Resistance (IIR) Model

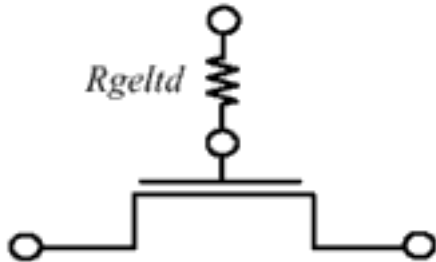
BSIM4 provides four options for modeling gate electrode resistance (bias-independent) and intrinsic-input resistance (IIR, bias-dependent). The IIR model considers the relaxation-time effect due to the distributive RC nature of the channel region, and therefore describes the first-order non-quasi-static effect. Thus, the IIR model should not be used together with the charge-deficit NQS model. The model selector ***rgateMod*** is used to choose different options.

rgateMod = 0 (zero-resistance)



In this case, no gate resistance is generated.

rgateMod = 1 (constant-resistance)

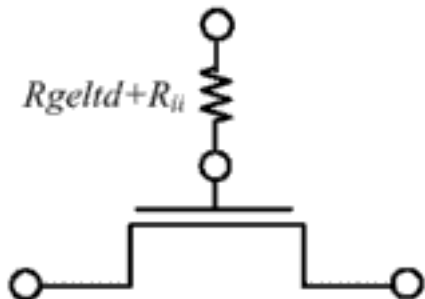


In this case, only the electrode gate resistance (bias-dependent) is generated by adding an internal gate node. R_{geltd} is given by

(21-141)

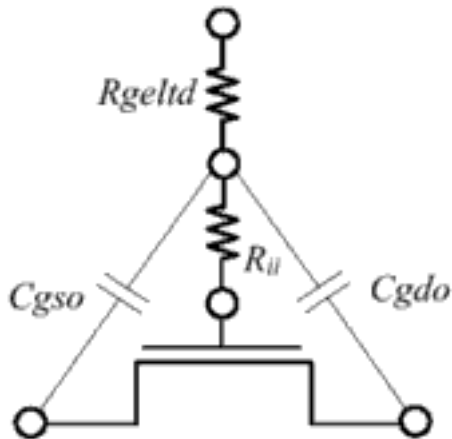
$$R_{geltd} = \frac{RSHG \cdot \left(XGW + \frac{W_{effj}}{3 \cdot NGCON} \right)}{NGCON \cdot (L_{drawn} - XGL) \cdot NF}$$

rgateMod = 2 (IIR model with variable resistance)



In this case, the gate resistance is the sum of the electrode gate resistance and the intrinsic-input resistance R_{ij} . An internal gate node will be generated. ***trnqsMod = 0*** (default) and ***acnqsMod = 0*** (default) should be selected for this case.

rgateMod = 3 (IIR model with two nodes)



In this case, the gate electrode resistance given is in series with the intrinsic-input resistance R_{ii} through two internal gate nodes, so that the overlap capacitance current will not pass through the intrinsic-input resistance. ***trnqsMod = 0*** (default) and ***acnqsMod = 0*** (default) should be selected for this case.

Substrate Resistance Network

For CMOS RF circuit simulation, it is essential to consider the high frequency coupling through the substrate. BSIM4 offers a flexible built-in substrate resistance network. This network is constructed so that little simulation efficiency penalty will result.

Model Selector and Topology

The model selector ***rbodyMod*** can be used to turn on or turn off the resistance network.

rbody = 0 (Off)

No substrate resistance network is generated at all.

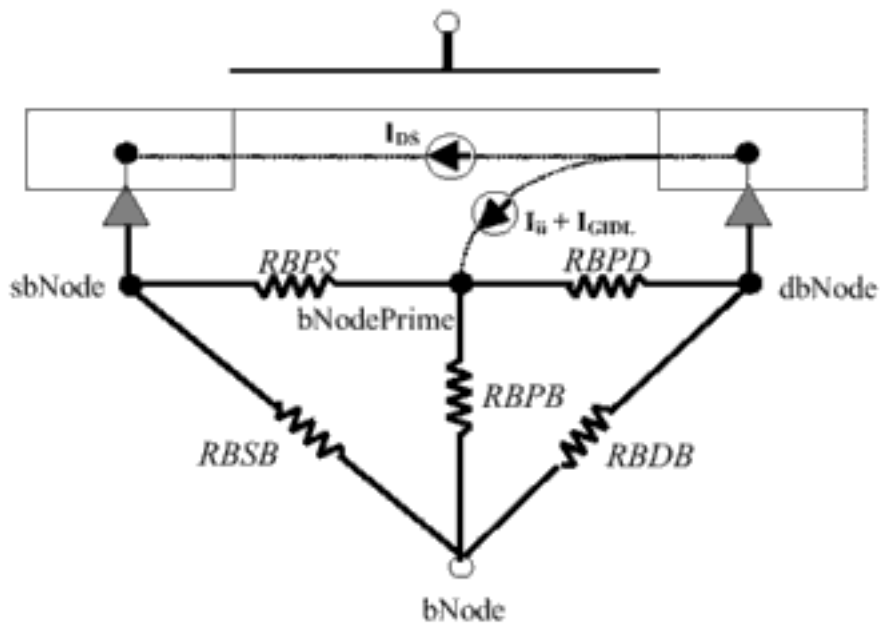
rbody = 1 (On)

All five resistances in the substrate network as shown schematically below are present simultaneously.

A minimum conductance, $GBMIN$, is introduced in parallel with each resistance to prevent infinite resistance values which would otherwise cause poor convergence. In the following

figure, $GBMIN$ is merged into each resistance to simplify the representation of the model topology.

Note: The intrinsic model substrate reference point in this case is the internal body node **bNodePrime**, into which the impact ionization current I_{ii} and the GIDL current I_{GIDL} flow.



Noise Models

The following noise sources in MOSFETs are modeled in BSIM4 for noise analysis: flicker noise (also known as $1/f$ noise), channel thermal noise and induced gate noise and their correlation, thermal noise due to physical resistances such as the source/ drain, gate electrode, and substrate resistances, and shot noise due to the gate dielectric tunneling current.

Flicker Noise Models

BSIM4 provides two flicker noise models: simple model and unified physical model (default model). They can be selected by *fnoiMod*. Both modes come from BSIM3v3, but there are many improvements in unified physical model.

fnoiMod = 0 (simple model)

The noise density is:

(21-142)

$$S_{id}(f) = \frac{KF \cdot I_{ds}^{AF}}{C_{oxe} L_{eff}^2 f^{EF}}$$

$fnoimod = 1$ (unified model)

The total flicker noise density is:

(21-143)

$$S_{id}(f) = \frac{S_{id,inv}(f) \cdot S_{id,subvt}(f)}{S_{id,inv}(f) + S_{id,subvt}(f)}$$

The noise density in the inversion region is:

(21-144)

$$S_{id,inv}(f) = \frac{k_B T q^2 \mu_{eff} I_{ds}}{C_{ox} (L_{eff} - 2 \cdot LINTNOI)^2 A_{bulk} f^{EF} \cdot 10^{10}} \cdot \left(NOIA \cdot \log \left(\frac{N_0 + N^*}{N_l + N^*} \right) + NOIB \cdot (N_0 - N_l) + \frac{NOIC}{2} (N_0^2 - N_l^2) \right) + \frac{k_B T I_{ds}^2 \Delta L_{clm}}{W_{eff} \cdot (L_{eff} - 2 \cdot LINTNOI)^2 f^{EF} \cdot 10^{10}} \cdot \frac{NOIA + NOIB \cdot N_l + NOIC \cdot N_l^2}{(N_l + N^*)^2}$$

$lintmoi$ is an offset to the length reduction parameter ($lint$) for flicker noise, which is introduced by BSIM4.4.

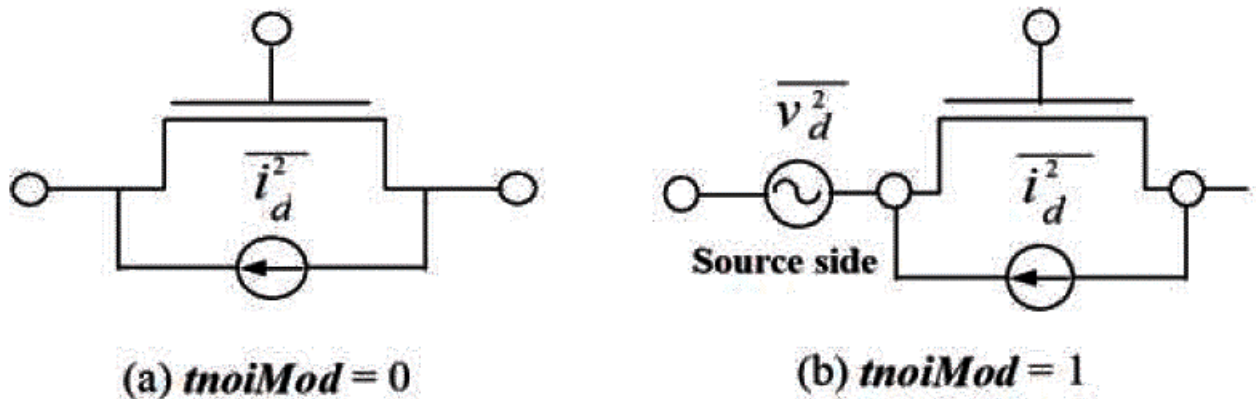
The noise density in the subthreshold region is:

(21-145)

$$S_{id,subVt}(f) = \frac{NOIA \cdot k_B T \cdot I_{ds}^2}{W_{eff} L_{eff} f^{EF} N^{*2} \cdot 10^{10}}$$

Channel Thermal Noise

BSIM4 provides two channel thermal noise models: charge-based model (default model) and the holistic model. They can be selected by *tnomod*. The schematic for BSIM4 channel thermal noise modeling is shown as following:



***tnoiMod* = 0 (charge-based)**

Charge-based model is similar to that used in BSIM3v3.2. The noise current is given by:

(21-146)

$$\overline{i_D^2} = \frac{4k_B T \Delta f}{R_{ds}(V) + \frac{L_{eff}^2}{\mu_{eff} |Q_{inv}|}} \cdot NTNOI$$

where

(21-147)

$$Q_{inv} = W_{active} L_{active} C_{oxeff} \cdot NF \cdot \left[V_{gsteff} - \frac{A_{bulk} V_{dseff}}{2} + \frac{A_{bulk}^2 V_{dseff}^2}{12 \cdot \left(V_{gsteff} - \frac{A_{bulk} V_{dseff}}{2} \right)} \right]$$

tnoiMod = 1 (holistic)

In this thermal noise model, all the short-channel effects and velocity saturation effect incorporated in the IV model are automatically included, hence the name “holistic thermal noise model”. In addition, the amplification of the channel thermal noise through G_m and G_{mbs} as well as the induced-gate noise with partial correlation to the channel thermal noise are all captured in the new “noise partition” model.

The noise voltage source partitioned to the source side is given by

(21-148)

$$\overline{v_d^2} = 4k_B T \cdot \theta_{tnoi}^2 \cdot \frac{V_{dseff} \Delta f}{I_{ds}}$$

The noise current source put in the channel region with gate and body amplification is given by:

(21-149)

$$\overline{i_d^2} = 4k_B T \frac{V_{dseff} \Delta f}{I_{ds}} [G_{ds} + \beta_{tnoi} \cdot (G_m + G_{mbs})]^2 - \overline{v_d^2} \cdot (G_m + G_{ds} + G_{mbs})^2 \quad \text{if } V_{ds} \geq V_{dsat}$$

where

(21-150)

$$\theta_{toi} = RNOIB \cdot \left[1 + TNOIB \cdot L_{eff} \cdot \left(\frac{V_{gsteff}}{E_{sat} L_{eff}} \right)^2 \right]$$

$$\beta_{toi} = RNOLA \cdot \left[1 + TNOLA \cdot L_{eff} \cdot \left(\frac{V_{gsteff}}{E_{sat} L_{eff}} \right)^2 \right]$$

Asymmetric MOS Junction Diode Models

Junction Diode IV Model

In BSIM4, there are three junction diode IV models. When the IV model selector **dioMod** is set to 0 ("resistance free"), the diode IV is modeled as resistance-free with or without breakdown depending on the parameter values of **XJBVS** or **XJBVD**. When **dioMod** is set to 1 ("breakdown-free"), the diode is modeled exactly the same way as in BSIM3v3 with current-limiting feature in the forward-bias region through the limiting current parameters **IJTHSFWD** or **IJTHDFWD**; diode breakdown is not modeled for **dioMod** = 1 and **XJBVS**, **XJBVD**, **BVS**, and **BVD** parameters all have no effect. When **dioMod** is set to 2 ("resistance-and-breakdown"), BSIM4 models the diode breakdown with current limiting in both forward and reverse operations. In general, setting **dioMod** to 1 produces fast convergence.

Source/Body Junction Diode

dioMod - 0 (resistance-free)

(21-151)

$$I_{bs} = I_{sbs} \left[\exp \left(\frac{qV_{bs}}{NJS \cdot k_B T_{NOM}} \right) - 1 \right] \cdot f_{breakdown} + V_{bs} \cdot G_{min}$$

where I_{sbs} is the total saturation current consisting of the components through the gate-edge (J_{sswgs}) and isolation-edge sidewalls (J_{ssws}) and the bottom junction (J_{ss}).

(21-152)

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

$$I_{sbs} = A_{seff} J_{ss}(T) + R_{seff} J_{ssws}(T) + W_{effcj} \cdot NF \cdot J_{sswgs}(T)$$

where

(21-153)

$$f_{breakdown} = 1 + XJBVS \cdot \exp\left(\frac{q \cdot (BVS + V_{bs})}{NJS \cdot k_B TNOM}\right)$$

In the above equation, if $XJBVS = 0$, no breakdown will be modeled. If $XJBVS < 0.0$, it is reset to 1.0.

dioMod = 1 (breakdown-free)

The exponential IV term is linearized at the limiting current $I_{JTHSFWD}$ in the forward-bias model only.

(21-154)

$$I_{bs} = I_{sbs} \left[\exp\left(\frac{qV_{bs}}{NJS \cdot k_B TNOM}\right) - 1 \right] + V_{bs} \cdot G_{min}$$

dioMod = 2 (resistance-and-breakdown)

Diode breakdown is always modeled. The exponential term is linearized at both the limiting current $I_{JTHSFWD}$ in the forward-bias mode and the limiting current $I_{JTHSREV}$ in the reverse-bias mode.

(21-155)

$$I_{bs} = I_{sbs} \left[\exp\left(\frac{qV_{bs}}{NJS \cdot k_B TNOM}\right) - 1 \right] \cdot f_{breakdown} + V_{bs} \cdot G_{min}$$

for **dioMod = 2**, if $XJBVS \leq 0.0$, it is reset to 1.0.

Drain/Body Junction Diode

The drain-side diode has the same system of equations as those for the source-side diode, but with a separate set of model parameters.

dioMod = 0 (resistance-free)

(21-156)

$$I_{bd} = I_{sbd} \left[\exp \left(\frac{qV_{bd}}{NJD \cdot k_B TNOM} \right) - 1 \right] \cdot f_{breakdown} + V_{bd} \cdot G_{min}$$

where I_{sbd} is the total saturation current consisting of the components through the gate-edge (J_{sswgd}) and isolation-edge sidewalls (J_{sswd}) and the bottom junction (J_{sd}),

(21-157)

$$I_{sbd} = A_{deff} J_{sd}(T) + P_{deff} J_{sswd}(T) + W_{effcj} \cdot NF \cdot J_{sswgd}(T)$$

where

(21-158)

$$f_{breakdown} = 1 + XJBVD \cdot \exp \left(- \frac{q \cdot (BVD + V_{bd})}{NJD \cdot k_B TNOM} \right)$$

In the above equation, when $XJBVD = 0$, no breakdown is modeled. If $XJBVD < 0.0$, it is reset to 1.0.

dioMod = 1 (breakdown-free)

No breakdown is modeled. The exponential IV term is linearized at the limiting current $I_{JTHSFWD}$ in the forward-bias model only.

(21-159)

$$I_{bd} = I_{sbd} \left[\exp \left(\frac{qV_{bd}}{NJD \cdot k_B TNOM} \right) - 1 \right] + V_{bd} \cdot G_{min}$$

dioMod = 2 (resistance-and-breakdown)

Diode breakdown is always modeled. The exponential term is linearized at both the limiting current $I_{JTHSFWD}$ in the forward-bias mode and the limiting current $I_{JTHSFWD}$ in the reverse-bias mode.

(21-160)

$$I_{bd} = I_{sbd} \left[\exp \left(\frac{qV_{bd}}{NJD \cdot k_B TNOM} \right) - 1 \right] \cdot f_{breakdown} + V_{bd} \cdot G_{min}$$

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

For ***diMod*** = 2, if $XJBVD \leq 0.0$, it is reset to 1.0.

Total Junction Source/Drain Diode Including Tunneling

Total diode current including the carrier recombination and trap-assisted tunneling current in the space-charge region is modeled by:

(21-161)

$$\begin{aligned}
 I_{bs_total} &= I_{bs} \\
 &-W_{effcj} \cdot NF \cdot J_{tsswgs}(T) \cdot \left[\exp\left(\frac{-V_{bs}}{NJTSSWG(T) \cdot Vtm0} \cdot \frac{VTSSWGS}{VTSSWGS - V_{bs}}\right) - 1 \right] \\
 &-P_{s, deff} J_{tssws}(T) \left[\exp\left(\frac{-V_{bs}}{NJTSSW(T) \cdot Vtm0} \cdot \frac{VTSSWS}{VTSSWS - V_{bs}}\right) - 1 \right] \\
 &-A_{s, deff} J_{tss}(T) \left[\exp\left(\frac{-V_{bs}}{NJTS(T) \cdot Vtm0} \cdot \frac{VTSS}{VTSS - V_{bs}}\right) - 1 \right] + g_{min} \cdot V_{bs}
 \end{aligned}$$

(21-162)

$$\begin{aligned}
 I_{bd_total} &= I_{bd} \\
 &-W_{effcj} \cdot NF \cdot J_{tsswgd}(T) \cdot \left[\exp\left(\frac{-V_{bd}}{NJTSSWGD(T) \cdot Vtm0} \cdot \frac{VTSSWGD}{VTSSWGD - V_{bd}}\right) - 1 \right] \\
 &-P_{s, deff} J_{tsswd}(T) \left[\exp\left(\frac{-V_{bd}}{NJTSSWD(T) \cdot Vtm0} \cdot \frac{VTSSWD}{VTSSWD - V_{bd}}\right) - 1 \right] \\
 &-A_{d, deff} J_{tsd}(T) \left[\exp\left(\frac{-V_{bd}}{NJTSD(T) \cdot Vtm0} \cdot \frac{VTSD}{VTSD - V_{bd}}\right) - 1 \right] + g_{min} \cdot V_{bd}
 \end{aligned}$$

Junction Diode CV Model

Source and drain junction capacitances consist of three components: the bottom junction capacitance, sidewall junction capacitance along the isolation edge, and sidewall junction capacitance along the gate edge. An analogous set of equations are used for both sides but each side has a separate set of model parameters.

Source/Body Junction Diode

(21-163)

$$C_{bs} = A_{seff}C_{jbs} + P_{seff}C_{jbsws} + W_{effcj} \cdot NF \cdot C_{jbswgs}$$

where C_{jbs} is the unit-area bottom S/B junction capacitance, C_{jbsws} is the unit-length S/B junction sidewall capacitance along the isolation edge, and C_{jbswgs} is the unit-length S/B junction sidewall capacitance along the gate edge.

$$C_{jbs}$$

if $V_{bs} < 0$

(21-164)

$$C_{jbs} = CJS(T) \cdot \left(1 - \frac{V_{bs}}{PBS(T)}\right)^{-MJS}$$

otherwise

(21-165)

$$C_{jbs} = CJS(T) \cdot \left(1 + MJS \cdot \frac{V_{bs}}{PBS(T)}\right)$$

Virtuoso Simulator Components and Device Models Reference
BSIM4 Level-14 Model (bsim4)

C_{jbsws}

if $V_{bs} < 0$

(21-166)

$$C_{jbsws} = CJSWS(T) \cdot \left(1 - \frac{V_{bs}}{PBSWS(T)}\right)^{-MJSWS}$$

otherwise

(21-167)

$$C_{jbsws} = CJSWS(T) \cdot \left(1 + MJSWS \cdot \frac{V_{bs}}{PBSWS(T)}\right)$$

C_{jbswgs}

if $V_{bs} < 0$

(21-168)

$$C_{jbswgs} = CJSWGS(T) \cdot \left(1 - \frac{V_{bs}}{PBSWGS(T)}\right)^{-MJSWGS}$$

otherwise

(21-169)

$$C_{jbswgs} = CJSWGS(T) \cdot \left(1 + MJSWGS \cdot \frac{V_{bs}}{PBSWGS(T)}\right)$$

Drain/Body Junction Diode

(21-170)

$$C_{bd} = A_{deff} C_{jbd} + P_{deff} C_{jbswd} + W_{effcj} \cdot NF \cdot C_{jbswgd}$$

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

where C_{jbd} is the unit-area bottom D/B junction capacitance, C_{jbswd} is the unit-length D/B junction sidewall capacitance along the isolation edge, and C_{jbswgd} is the unit-length D/B junction sidewall capacitance along the gate edge.

C_{jbd}

if $V_{bd} < 0$

(21-171)

$$C_{jbd} = CJD(T) \cdot \left(1 - \frac{V_{bd}}{PBD(T)}\right)^{-MJD}$$

otherwise

(21-172)

$$C_{jbd} = CJD(T) \cdot \left(1 + MJD \cdot \frac{V_{bd}}{PBD(T)}\right)$$

C_{jbswd}

f $V_{bd} < 0$

(21-173)

$$C_{jbswd} = CJSWD(T) \cdot \left(1 - \frac{V_{bd}}{PBSWD(T)}\right)^{-MJSWD}$$

otherwise

(21-174)

$$C_{jbswd} = CJSWD(T) \cdot \left(1 + MJSWD \cdot \frac{V_{bd}}{PBSWD(T)}\right)$$

C_{jbdswg}

f $V_{bd} < 0$

(21-175)

$$C_{jbdswgd} = CJSWGD(T) \cdot \left(1 - \frac{V_{bd}}{PBSWGD(T)}\right)^{-MJSWD}$$

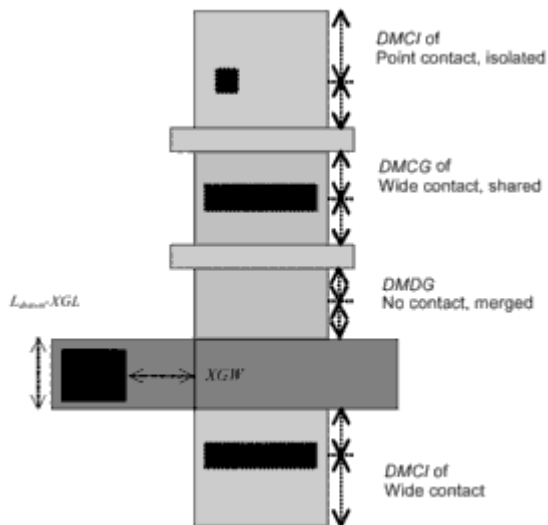
otherwise

(21-176)

$$C_{jbdswgd} = CJSWGD(T) \cdot \left(1 + MJSWGD \cdot \frac{V_{bd}}{PBSWGD(T)}\right)$$

Layout Dependent Parasitics Models

The following figure shows the geometry definition for various source/drain connections and source/drain/gate contacts. The layout parameters shown in this figure will be used to calculate resistances and source/drain perimeters and areas.



Effective Junction Perimeter and Area

The source-side case is illustrated below. The same approach is used for the drain side. The effective junction perimeter is calculated by:

If (*PS* is given)

if (***perMod*** = 0)

$$P_{seff} = PS$$

else

(21-177)

$$P_{seff} = PS - W_{effcj} \cdot NF$$

Else

P_{seff} computed from *NF*, *DWJ*, ***geoMod***, *DMCG*, *DMCI*, *DMDG*, *DMCGT*, and *MIN*.

The effective junction area is calculated by:

If (*AS* is given)

$$A_{seff} = AS$$

Else

A_{seff} computed from *NF*, *DWJ*, ***geoMod***, *DMCG*, *DMCI*, *DMDG*, *DMCGT*, and *MIN*.

In the above, P_{seff} and A_{seff} will be used to calculate junction diode IV and CV. P_{seff} does not include the gate-edge perimeter.

<i>geoMod</i>	End source	End drain	Note
0	isolated	isolated	<i>NF=Odd</i>
1	isolated	shared	<i>NF=Odd, Even</i>
2	shared	isolated	<i>NF=Odd, Even</i>
3	shared	shared	<i>NF=Odd, Even</i>
4	isolated	merged	<i>NF=Odd</i>
5	shared	merged	<i>NF=Odd, Even</i>

Virtuoso Simulator Components and Device Models Reference
BSIM4 Level-14 Model (bsim4)

<i>geoMod</i>	End source	End drain	Note
6	merged	isolated	<i>NF=Odd</i>
7	merged	shared	<i>NF=Odd, Even</i>
8	merged	merged	<i>NF=Odd</i>
9	sha/iso	shared	<i>NF=Even</i>
10	shared	sha/iso	<i>NF=Even</i>

Temperature Effects Models

Accurate modeling of the temperature effects on MOSFET characteristics is important to predict circuit behavior over a range of operating temperatures (T). The operating temperature might be different from the nominal temperature ($TNOM$) at which the BSIM4 model parameters are extracted.

Temperature Dependence of Threshold Voltage

The temperature dependence of V_{th} is modeled by:

(21-178)

$$V_{th}(T) = V_{th}(TNOM) + \left(KT1 + \frac{KT1L}{L_{eff}} + KT2 \cdot V_{bseff} \right) \cdot \left(\frac{T}{TNOM} - 1 \right)$$

(21-179)

$$V_{fb}(T) = V_{fb}(TNOM) - KT1 \cdot \left(\frac{T}{TNOM} - 1 \right)$$

(21-180)

$$VOFF(T) = VOFF(TNOM) \cdot [1 + TVOFF \cdot (T - TNOM)]$$

(21-181)

$$VFBSDOFF(T) = VFBSDOFF(TNOM) \cdot [1 + TVFBSDOFF \cdot (T - TNOM)]$$

Temperature Dependence of Mobility

(21-182)

$$U_0(T) = U_0(TNOM) \cdot (T/TNOM)^{UTE}$$

(21-183)

$$U_A(T) = U_A(TNOM) + UA1 \cdot (T/TNOM - 1)$$

(21-184)

$$U_B(T) = U_B(TNOM) + UB1 \cdot (T/TNOM - 1)$$

(21-185)

$$U_C(T) = U_C(TNOM) + UC1 \cdot (T/TNOM - 1)$$

Temperature Dependence of Saturation Velocity

(21-186)

$$v_{sat}(T) = VSAT(TNOM) - AT \cdot (T/TNOM - 1)$$

Temperature Dependence of LDD Resistance

rdsMod = 0 (internal source/drain LDD resistance)

(21-187)

$$RDSW(T) = RDSW(TNOM) + PRT \cdot \left(\frac{T}{TNOM} - 1 \right)$$

(21-188)

$$RDSWMIN(T) = RDSWMIN(TNOM) + PRT \cdot \left(\frac{T}{TNOM} - 1 \right)$$

rdsMod = 1 (external source/drain LDD resistance)

(21-189)

$$RDW(T) = RDW(TNOM) + PRT \cdot \left(\frac{T}{TNOM} - 1 \right)$$

(21-190)

$$RDWMIN(T) = RDWMIN(TNOM) + PRT \cdot \left(\frac{T}{TNOM} - 1 \right)$$

(21-191)

$$RSW(T) = RSW(TNOM) + PRT \cdot \left(\frac{T}{TNOM} - 1 \right)$$

(21-192)

$$RSWMIN(T) = RSWMIN(TNOM) + PRT \cdot \left(\frac{T}{TNOM} - 1 \right)$$

Temperature Dependence of Junction Diode IV

Side Source Diode 0

(21-193)

$$I_{sbs} = A_{seff} J_{ss}(T) + P_{seff} J_{ssws}(T) + W_{effcj} \cdot NF \cdot J_{sswgs}(T)$$

where

(21-194)

$$J_{ss}(T) = JSS(TNOM) \cdot \exp \left(\frac{\frac{E_g(TNOM)}{v_t(TNOM)} - \frac{E_g(T)}{v_t(T)} + XTIS \cdot \ln \left(\frac{T}{TNOM} \right)}{NJS} \right)$$

Virtuoso Simulator Components and Device Models Reference
BSIM4 Level-14 Model (bsim4)

(21-195)

$$J_{ssws}(T) = JSSWS(TNOM) \cdot \exp\left(\frac{\frac{E_g(TNOM)}{v_t(TNOM)} - \frac{E_g(T)}{v_t(T)} + XTIS \cdot \ln\left(\frac{T}{TNOM}\right)}{NJS}\right)$$

(21-196)

$$J_{sswgs}(T) = JSSWGS(TNOM) \times \left(\sqrt{\frac{JTWEFF}{W_{effi}}} + 1.0\right) \exp\left(\frac{\frac{E_g(Tnom)}{V_t(Tnom)} - \frac{E_g(T)}{V_t(T)} + XTIS \cdot \ln\left(\frac{T}{Tnom}\right)}{NJS}\right)$$

where

(21-197)

$$E_g(TNOM) = 1.16 - \frac{7.02 \times 10^{-4} TNOM^2}{TNOM + 1108}$$

(21-198)

$$E_g(T) = 1.16 - \frac{7.02 \times 10^{-4} T^2}{T + 1108}$$

(21-199)

$$n_i = 1.45e10 \cdot \frac{TNOM}{300.15} \cdot \sqrt{\frac{TNOM}{300.15}} \cdot \exp\left[21.5565981 - \frac{qE_g(TNOM)}{2 \cdot k_B T}\right]$$

Temperature Dependence of Junction Diode CV

Source-Side Diode

The temperature dependences of zero-bias unit-length/area junction capacitances on the source side are modeled by

(21-200)

$$CJS(T) = CJS(TNOM) \cdot [1 + TCJ \cdot (T - TNOM)]$$

(21-201)

$$CJSWS(T) = CJSWS(TNOM) + TCJSW \cdot (T - TNOM)$$

(21-202)

$$CJSWGS(T) = CJSWGS(TNOM) \cdot [1 + TCJSWG \cdot (T - TNOM)]$$

The temperature dependences of the built-in potentials on the source side are modeled by

(21-203)

$$PBS(T) = PBS(TNOM) - TPB \cdot (T - TNOM)$$

(21-204)

$$PBSWS(T) = PBSWS(TNOM) - TPBSW \cdot (T - TNOM)$$

(21-205)

$$PBSWGS(T) = PBSWGS(TNOM) - TPBSWG \cdot (T - TNOM)$$

Temperature Dependence of Junction Diode IV

(21-206)

$$J_{tswgs,d}(T) = J_{tswgs,d}(TNOM) \cdot \exp\left[\frac{-Eg(TNOM)}{k_B T} \cdot X_{tswgs,d} \cdot \left(1 - \frac{T}{TNOM}\right)\right]$$

Virtuoso Simulator Components and Device Models Reference
BSIM4 Level-14 Model (bsim4)

(21-207)

$$J_{tssws,d}(T) = J_{tssws,d}(TNOM) \cdot \exp\left[\frac{-E_g(TNOM)}{k_B T} \cdot X_{tssws,d} \cdot \left(1 - \frac{T}{TNOM}\right)\right]$$

(21-208)

$$J_{tss,d}(T) = J_{tss,d}(TNOM) \cdot \exp\left[\frac{-E_g(TNOM)}{k_B T} \cdot X_{tss,d} \cdot \left(1 - \frac{T}{TNOM}\right)\right]$$

(21-209)

$$NJTSSWG(T) = NJTSSWG(TNOM) \cdot \left[1 + TNJTSSWG\left(\frac{T}{TNOM} - 1\right)\right]$$

(21-210)

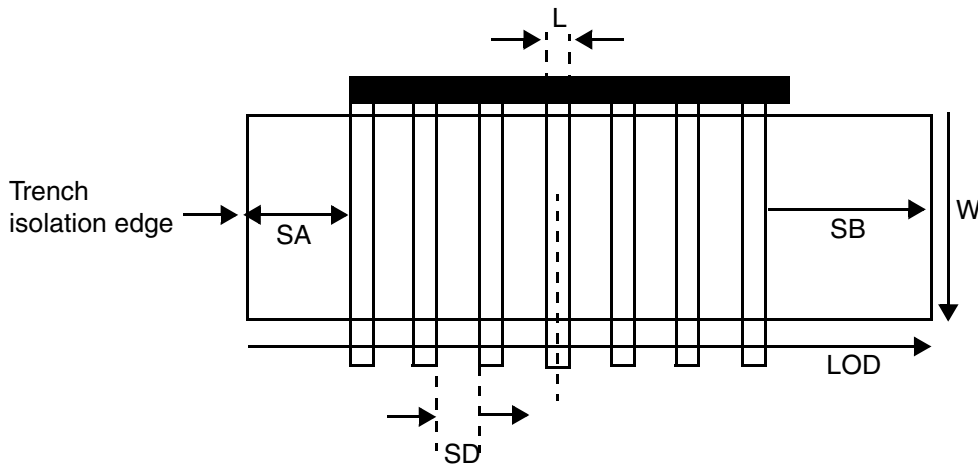
$$NJTSSW(T) = NJTSSW(TNOM) \cdot \left[1 + TNJTSSW\left(\frac{T}{TNOM} - 1\right)\right]$$

(21-211)

$$NJTS(T) = NJTS(TNOM) \cdot \left[1 + TNTJS\left(\frac{T}{TNOM} - 1\right)\right]$$

Stress Effects Models

BSIM4 considers the influence of stress on mobility, velocity saturation, threshold voltage, body effect, and DIBL effect. The following diagram displays the LOD instance geometry parameters SA and SB.



(21-212)

$$\mu_{eff} = \frac{1 + \rho_{\mu_{eff}}(SA, SB)}{1 + \rho_{\mu_{eff}}(SA_{ref}, SB_{ref})} \mu_{eff0}$$

(21-213)

$$v_{sattemp} = \frac{1 + KVSAT \cdot \rho_{\mu_{eff}}(SA, SB)}{1 + KVSAT \cdot \rho_{\mu_{eff}}(SA_{ref}, SB_{ref})} v_{sattemp0}$$

(21-214)

$$VTH0 = VTH0_{original} + \frac{KVTH0}{Kstress_vth0} \cdot (Inv_sa + Inv_sb - Inv_sa_{ref} - Inv_sb_{ref})$$

(21-215)

$$K2 = K2_{original} + \frac{STK2}{Kstress_vth0^{LODK2}} \cdot (Inv_sa + Inv_sb - Inv_sa_{ref} - Inv_sb_{ref})$$

(21-216)

$$ETA0 = ETA0_{original} + \frac{STETA0}{K_{stress_vth0}^{LODETA0}} \cdot (Inv_sa + Inv_sb - Inv_sa_{ref} - Inv_sb_{ref})$$

where

(21-217)

$$\rho_{\mu eff} = \frac{KU_0}{K_{stress_mu0}} \cdot (Inv_sa + Inv_sb)$$

(21-218)

$$K_{stress_mu0} = \left(1 + \frac{LKU0}{(L_{drawn} + XL)^{LLODKU0}} + \frac{WKU0}{(W_{drawn} + XW + WLOD)^{WLODKU0}} \right) + \frac{PKU0}{(L_{drawn} + XL)^{LLODKU0} \cdot (W_{drawn} + XW + WLOD)^{WLODKU0}} \cdot \left(1 + TKU0 \cdot \left(\frac{Temperature}{TNOM} - 1 \right) \right)$$

(21-219)

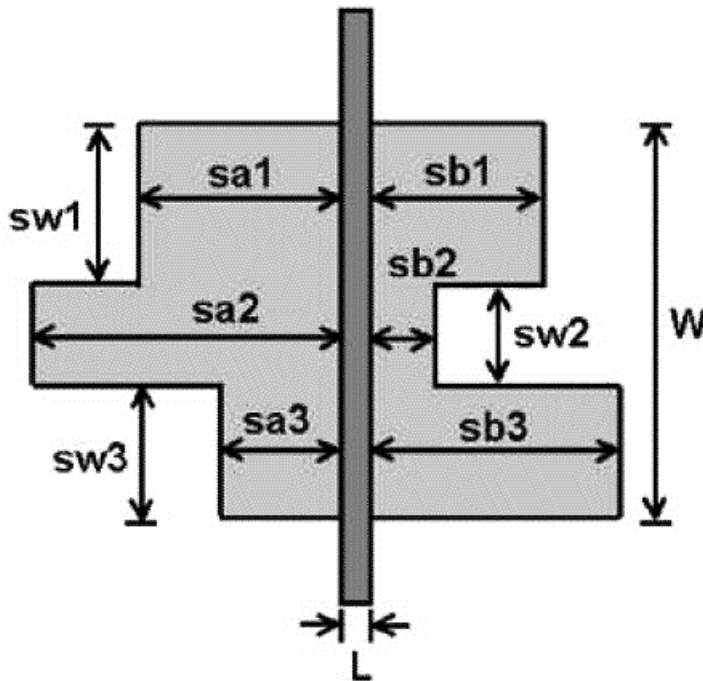
$$K_{stress_vth0} = \left(1 + \frac{LKVTH0}{(L_{drawn} + XL)^{LLODKVTH}} + \frac{WKVTH0}{(W_{drawn} + XW + WLOD)^{WLODKVTH}} \right) + \frac{PKVTH0}{(L_{drawn} + XL)^{LLODKVTH} \cdot (W_{drawn} + XW + WLOD)^{WLODKVTH}} \cdot \left(1 + TKU0 \cdot \left(\frac{Temperature}{TNOM} - 1 \right) \right)$$

(21-220)

$$Inv_sa = \frac{1}{NF} \sum_{i=0}^{NF-1} \frac{1}{SA + 0.5 \cdot L_{drawn} + i \cdot (SD + L_{drawn})}$$

(21-221)

$$Inv_sb = \frac{1}{NF} \sum_{i=0}^{NF-1} \frac{1}{SB + 0.5 \cdot L_{drawn} + i \cdot (SD + L_{drawn})}$$



For irregular LOD device like above figure, more instance parameters (sw_i , sa_i and sb_i) are needed. Then,

(21-222)

$$Inv_sa = \sum_{i=1}^n \frac{sw_i}{W_{drawn}} \cdot \frac{1}{sa_i + 0.5 \cdot L_{drawn}}$$

(21-223)

$$Inv_sb = \sum_{i=1}^n \frac{sw_i}{W_{drawn}} \cdot \frac{1}{sb_i + 0.5 \cdot L_{drawn}}$$

Well Proximity Effect Model

Deep buried layers can affect devices located near the mask edge. Some of the ions scattered out of the edge of the photoresist are implanted in the silicon surface near the mask edge, altering the threshold voltage of those devices. BSIM4 considers the influence of well proximity effect on threshold voltage, mobility, and body effect as following:

(21-224)

$$V_{th0} = V_{th0_{org}} + KV_{TH0WE} \cdot (SCA + WEB \cdot SCB + WEC \cdot SCC)$$

(21-225)

$$\mu_{eff} = \mu_{eff,org} \cdot (1 + KU_{0WE} \cdot (SCA + WEB \cdot SCB + WEC \cdot SCC))$$

(21-226)

$$K2 = K2_{org} + K2_{WE} \cdot (SCA + WEB \cdot SCB + WEC \cdot SCC)$$

TMIBSIM4 Model (tmibsim4)

The TSMC Model Interface (TMI) implements a modified version of the BSIM4 model, known as TMIBSIM4. You can activate the `tmibsim4` model by specifying the `tmiflag` and `tmipath` parameters as follows:

```
.options tmiflag = 1
.option tmipath = TMI_shared-library_path
```

Models and Equations in Version Updates

This section briefly lists equations and information for various BSIM4 model versions. For more details, please refer to UC Berkeley's BSIM4.64 Users' Manual

http://www-device.eecs.berkeley.edu/~bsim3/BSIM4/BSIM464/BSIM464_Manual.pdf

BSIM4 Version 4

BSIM4.4 has the following updates.

Trap-Assisted-Tunneling Current

(21-227)

$$\begin{aligned}
 I_{bs,d} = & I_{sbs,d} \left[\exp\left(\frac{qV_{bs,d}}{NJS,D \cdot k_B T}\right) - 1 \right] \cdot f_{breakdown} \\
 & - W_{effcj} \cdot NF \cdot J_{tsswgs,d}(T) \cdot \left[\exp\left(\frac{-V_{bs,d}}{NJTSSWG(T) \cdot V_{tm0}} \cdot \frac{VTSSWGS,D}{VTSSWGS,D - V_{bs,d}}\right) - 1 \right] \\
 & - P_{s,deff} J_{tssws,d}(T) \left[\exp\left(\frac{-V_{bs,d}}{NJTSSW(T) \cdot V_{tm0}} \cdot \frac{VTSSWS,D}{VTSSWS,D - V_{bs,d}}\right) - 1 \right] \\
 & - A_{s,deff} J_{tss,d}(T) \left[\exp\left(\frac{-V_{bs,d}}{NJTS(T) \cdot V_{tm0}} \cdot \frac{VTSS,D}{VTSS,D - V_{bs,d}}\right) - 1 \right] \\
 & + V_{bs,d} \cdot G_{min}
 \end{aligned}$$

Flatband Voltage Offset Parameter

VFBSDOFF is an offset voltage added to the original source/drain flatband voltage which allows independent setting of V_{fbsd} to accurately model gate overlap tunneling current.

(21-228)

$$V_{fbsd} = k_B T / q \log(NGATE/NSD) + VFBSDOFF$$

Length Reduction Parameter Offset

BSIM4.4 has a new parameter LINTNOI which is an offset to the length reduction parameter (Lint) for flicker noise.

For fnoiMod=1 (unified model), the noise density in the inversion region is:

(21-229)

$$S_{id,inv}(f) = \frac{k_B T q^2 \mu_{eff} J_{ds}}{C_{oxe}(L_{eff} + LINTNOI)^2 A_{bulk} f^{eff}} \left(NOIA \cdot \log\left(\frac{N_0 + N^*}{N_l + N^*}\right) + NOIB \cdot (N_o - N_l) \right) + \frac{NOIC}{2} (N_0^2 - N_l^2) + \frac{k_B (T I_{ds}^2 \Delta L_{clm})}{W_{eff} \cdot (L_{eff} + LINTNOI)^2 f^{eff} \cdot 10^{10}} \cdot \frac{NOIA + NOIB \cdot N_l + NOIC \cdot N_l^2}{(N_l + N^*)^2}$$

New Temperature Model

(21-230)

$$J_{tsswgs,d}(T) = J_{tsswgs,d}(TNOM) \cdot \exp\left[\frac{-E_g(TNOM)}{k_B T} \cdot X_{tsswgs,d} \cdot \left(1 - \frac{T}{TNOM}\right)\right]$$

(21-231)

$$J_{tssws,d}(T) = J_{tssws,d}(TNOM) \cdot \exp\left[\frac{-E_g(TNOM)}{k_B T} \cdot X_{tssws,d} \cdot \left(1 - \frac{T}{TNOM}\right)\right]$$

(21-232)

$$J_{tss,d}(T) = J_{tss,d}(TNOM) \cdot \exp\left[\frac{-E_g(TNOM)}{k_B T} \cdot X_{tss,d} \cdot \left(1 - \frac{T}{TNOM}\right)\right]$$

(21-233)

$$NJTSSWG(T) = NJTSSWG(TNOM) \cdot \left[1 + TNJTSSWG\left(\frac{T}{TNOM} - 1\right)\right]$$

(21-234)

$$NJTSSW(T) = NJTSSW(TNOM) \cdot \left[1 + TNJTSSW\left(\frac{T}{TNOM} - 1\right)\right]$$

(21-235)

$$NJTS(T) = NJTS(TNOM) \cdot \left[1 + TNTJS\left(\frac{T}{TNOM} - 1\right)\right]$$

BSIM4 Version 5

BSIM4.5.0 has the following new features:

- A mobility model which accounts for Coulomb scattering effect as well as the channel length dependence of mobility due to heavy halo-doping
- A scalable substrate resistance model (rbodyMod = 2) that is scalable with channel length, channel width, and number of fingers
- Gate resistance parameters XGW, NGCON that can now be specified as instance parameters (XGL is still a model parameter)
- Additional temperature dependence of model parameters VOFF and VFBSDOFF
- Enhanced tempMod = 2, where Vth(DITS) and gate tunneling models are functions of nominal temperature and the temperature dependence of zero-bias flat-band voltage is added
- A new instance parameter DELVTO that may be used to represent threshold voltage variation
- A new well-proximity effect model developed by CMC companies
- Igc Vbs dependence improvement with the full BSIM4 Vth model implemented

Mobility Model

Mobility Coulomb Scattering Model and Leff dependence

(21-236)

mobMod=0

$$\mu_{eff} = \frac{U0 \cdot f(L_{eff})}{1 + (UA + UC V_{bseff}) \left(\frac{V_{gsteff} + 2V_{th}}{TOXE} \right) + UB \left(\frac{V_{gsteff} + 2V_{th}}{TOXE} \right)^2 + UD \left(\frac{V_{th} \cdot TOXE}{V_{gsteff} + 2\sqrt{V_{th} + 0.0001}} \right)^2}$$

(21-237)

mobMod=1

Virtuoso Simulator Components and Device Models Reference
BSIM4 Level-14 Model (bsim4)

$$\mu_{eff} = \frac{U0 \cdot f(L_{eff})}{1 + \left[UA \left(\frac{V_{gsteff} + 2V_{th}}{TOXE} \right) + UB \left(\frac{V_{gsteff} + 2V_{th}}{TOXE} \right)^2 \right] (1 + UC \cdot V_{bseff}) + UD \left(\frac{V_{th} \cdot TOXE}{V_{gsteff} + 2\sqrt{V_{th} + 0.0001}} \right)^2}$$

(21-238)

mobMod=2

$$\mu_{eff} = U0 / 1 + (UA + UC \cdot V_{bseff}) \left[\frac{V_{gsteff} + C_0 \cdot (V_{THO} - V_{FB} - \Phi_s)}{TOXE} \right]^{EU} + UD \left(\frac{V_{th} \cdot TOXE}{V_{gsteff} + 2\sqrt{V_{th}^2 + 0.0001}} \right)^2$$

where the constant C0 = 2 for NMOS and 2.5 for PMOS.

(21-239)

$$f(L_{eff}) = 1 - UP \cdot e^{-L_{eff}/(LP)}$$

Scalable Substrate Resistance Model

(21-240)

$$R_X = R_{X_HORT} \parallel R_{X_VERT} \quad \text{where } R_{X_H(V)} = R_0 L^a W^\beta NF$$

Temperature Dependence for VOFF, VFBSDOFF

(21-241)

$$VOFF(T) = VOFF(TNOM) \cdot [1 + TVOFF \cdot (T - TNOM)]$$

(21-242)

$$VFBSDOFF(T) = VFBSDOFF(TNOM) \cdot [1 + TVFBSDOFF \cdot (T - TNOM)]$$

New Temperature Mode (TempMod = 2)

Share the same temperature equations as for TempMod=1 with the following modifications:

From

(21-243)

$$\Delta V_{th}(DITS) = -n v_t \cdot \ln \left(\frac{L_{eff}}{L_{eff} + DVTP0 \cdot (1 + e^{-DVPT1 \cdot V_{ds}})} \right)$$

To

(21-244)

$$\Delta V_{th}(DITS) = -n v_{tnom} \cdot \ln \left(\frac{L_{eff}}{L_{eff} + DVTP0 \cdot (1 + e^{-DVPT1 \cdot V_{ds}})} \right)$$

Vfbzb(T)

(21-245)

$$V_{fbzb}(T) = V_{fbzb}(TNOM) - KT1 \cdot \left(\frac{T}{TNOM} - 1 \right)$$

Igate(T)

T is replaced by TNOM

DELVTO: An Instance Parameter

if v_{th0} is given:

(21-246)

$$V_{th0} = V_{th0} + DELVTO$$

if v_{th0} is not given,

(21-247)

$$V_{fb} = V_{fb} + DELVTO$$

(21-248)

$$V_{th0} = V_{fb} + \Phi + k1 \times \sqrt{k1}$$

Well-Proximity Effect Modeling

Instance parameters: SCA, SCB, SCC, SC

Model parameters: WEB, WEC, KVTH0WE, K2WE, KU0WE, SCREF, WPEMOD

Model equations:

(21-249)

$$V_{th0} = V_{th0}_{org} + KVTH0WE \cdot (SCA + WEB \cdot SCB + WEC \cdot SCC)$$

(21-250)

$$K2 = K2_{ORG} + K2WE \cdot (SCA + WEB \cdot SCB + WEC \cdot SCC)$$

(21-251)

$$\mu_{eff} = \mu_{eff,org} \cdot (1 + KU0WE \cdot (SCA + WEB \cdot SCB + WEC \cdot SCC))$$

Gate Current Vbs Dependence

(21-252)

$$I_{gc0} = W_{eff} L_{eff} \cdot A \cdot T_{oxRatio} \cdot V_{gse} \cdot V_{aux} \cdot \exp[-B \cdot TOXE(AIGC - BIGC \cdot V_{OXDEPINV}) \cdot (1 + CIGC \cdot v_{oxdepinv})]$$

For IGCMOD=1

(21-253)

$$V_{aux} = NIGC \cdot v_t \cdot \log\left(1 + \exp\left(\frac{V_{gse} - V_{TH0}}{NIGC \cdot v_t}\right)\right)$$

For IGCMOD=2

(21-254)

$$V_{aux} = NIGC \cdot v_t \cdot \log\left(1 + \exp\left(\frac{V_{gse} - V_{TH_bsim4}}{NIGC \cdot v_t}\right)\right)$$

Implementing full BSIM4 Vth model into Igc enables the accurate prediction of Igc Vbs dependence.

BSIM4 Version 6

GISL and GIDL Leakage Module

Four new parameters have been added.

Junction Diode I-V

In BSIM4.5.0, the junction diode current due to the trap-assisted tunneling current in space-charge region has same set of parameters for both source and drain junctions.

Gate Tunneling Current

In BSIM4.5.0, the gate tunneling current in the overlapping S/D diffusion regions (IGS / IGD) share the same set of parameters for both source and drain (DLCIG, AIGSD, BIGSD, CIGSD).

In BSIM4.6.0, the parameters for IGS and IGD are separate.

- I_{GS} : DLCIG, AIGS, BIGS, CIGS
- I_{GD} : DLCIGD, AIGD, BIGD, CIGD

Mobility Model

The coulomb scattering term has been modified in BSIM4.6.0 release to avoid the possibility of non-monotonic drain current trend with respect to gate voltage.

mobMod=0

(21-255)

$$\mu_{eff} = \frac{U0 \cdot f(L_{eff})}{1 + (UA + UCV_{bseff}) \left(\frac{V_{gsteff} + 2V_{th}}{TOXE} \right) + UB \left(\frac{V_{gsteff} + 2V_{th}}{TOXE} \right)^2 + UD \left(\frac{V_{th} \cdot TOXE}{V_{gsteff} + 2\sqrt{V_{th}^2 + 0.00001}} \right)^2}$$

mobMod=1

(21-256)

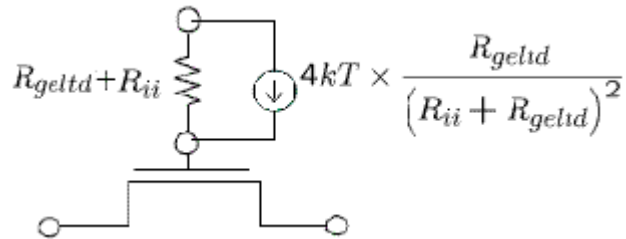
$$\mu_{eff} = \frac{U0 \cdot f(L_{eff})}{1 + \left[UA \left(\frac{V_{gsteff} + 2V_{th}}{TOXE} \right) + UB \left(\frac{V_{gsteff} + 2V_{th}}{TOXE} \right)^2 \right] (1 + UC \cdot V_{bseff}) + UD \left(\frac{V_{th} \cdot TOXE}{V_{gsteff} + 2\sqrt{V_{th}^2 + 0.00001}} \right)^2}$$

mobMod=2

(21-257)

$$\mu_{eff} = \frac{U0}{1 + (UA + UC \cdot V_{bseff}) \left[\frac{V_{gsteff} + C_0 \cdot (V_{THO} - V_{FB} - \Phi_s)}{TOXE} \right]^{EU} + UD \left(\frac{V_{th} \cdot TOXE}{V_{gsteff} + 2\sqrt{V_{th}^2 + 0.00001}} \right)^2}$$

Improvement to NOIMOD = 2



BSIM4 Version 6.1

C-V Model

A new $V_{gstffCV}$ definition is introduced in the C-V model to improve threshold fitting. Six new parameters have been added: $CVCHARGEMOD$, $MINV_{CV}$, $L_{MINV_{CV}}$, $W_{MINV_{CV}}$, $WMINV_{CV}$, $PMINV_{CV}$, and $VOFF_{CVL}$.

New Material Model

A new materials model (activated by setting $MTRLMOD=1$) has been introduced with the following features:

- Predictive modeling of
 - Non-SiO₂ insulator
 - Non-poly-Si gate
 - New parameters
 - Non-silicon channel
- Improved predictive models for GIDL/GISL leakage current, mobility degradation, and short channel effects
- A model selector ($MTRLMOD$) is used to turn on/off all the new materials parameters and equations for backward compatibility.

New Materials Model Parameters

Model selector:

MTRLMOD : =1 activates the new-materials option and =0 (default) deactivates

For non-poly-silicon gate:

- PHIG : Gate work function
- EPSRGATE : Dielectric constant of gate relative to vacuum (= 0 deactivates poly depletion)

For non-SiO2 gate-dielectric:

- EOT : Equivalent SiO2 thickness
- VDDEOT : Gate voltage at which EOT is measured

For non-silicon channel material:

- EASUB : Electron affinity of substrate
- EPSRSUB : Dielectric constant of substrate relative to vacuum
- NI0SUB : Intrinsic carrier concentration at T=300.15K
- BG0SUB : Band-gap of substrate at T=0K
- TBGASUB : First parameter of band-gap change due to temperature
- TBGBSUB : Second parameter of band-gap change due to temperature
- ADOS : Density of states parameter to control charge centroid
- BDOS : Density of states parameter to control charge centroid

Non-Silicon Channel Material

Defines the temperature-dependent intrinsic carrier concentrations and the band gap with the new non-silicon parameters for MTRLMOD = 1.

(21-258)

$$E_{g0} = BG0SUB - \frac{TBGASUB \times Tnom^2}{Tnom + TBGBSUB}$$

(21-259)

$$E_{g(300.15)} = BG0SUB - \frac{TBGASUB \times 300.15^2}{300.15 + TBGBSUB}$$

(21-260)

$$n_i = NIOSUB \times \left(\frac{Tnom}{300.15} \right)^{3/2} \cdot e^{-\frac{E_{g(300.15K)} - E_{g0}}{2V_t}}$$

(21-261)

$$E_g = BG0SUB - \frac{TBGASUB \times Temp^2}{Temp + TBGBSUB}$$

Introduces two new parameters for charge centroid for non-silicon channel materials in both I-V and C-V models.

(21-262)

$$X_{dc} = \frac{ADOS \times 1.9 \times 10^{-9}}{1 + \left(\frac{Vgsteff + (VTH0 - VFB - \phi_s)}{2tox} \right)^{0.7 \times BDOS}}$$

Non-SiO2 Dielectric Material

For MTRLMOD = 1, use EOT (defined as the electrical oxide thickness at $V_{gs} = VDDEOT$) to calculate oxide thickness at flatband voltage.

(21-263)

$$T_{oxp} = EOT - \frac{3.9}{EPSRSUB} \cdot X_{dc} |_{V_{gs} = VDDEOT, V_{ds} = V_{bs} = 0}$$

Non-poly-Si gate Material

Poly depletion is calculated using the following equation:

(21-264)

$$V_{gse} = VFB + \Phi_s + \frac{q\varepsilon_{gate}^{NGATE}}{c_{oxe}^2} \left(\sqrt{1 + \frac{2c_{oxe}^2(V_{gs} - VFB - \Phi_s)}{q\varepsilon_{gate}^{NGATE}}} - 1 \right)$$

where

(21-265)

$$\begin{aligned} \varepsilon_{gate} &= EPSRGATE \cdot EPS0 && \text{for MTRLMOD}=1 \\ \varepsilon_{gate} &= EPSSI && \text{for MTRLMOD}=0 \end{aligned}$$

Setting EPSRGATE = 0 turns the poly depletion model off.

Improved Mobility Model

The new equations for the improved mobility model are given in the coming sections.

Improved GIDL/GISL Model

For MTRLMOD=1, the flat band voltage at source/drain is given in the coming sections. New equations for the GIDL and GISL model are also given.

BSIM4 Version 6.2

Width Dependent TAT Model

New Model Parameter

A new model parameter J_{TWEFF} is added to describe the TAT current width dependence.

Change in Equation for Temperature Dependence of Junction Diode IV

Side Source Diode 0

(21-266)

$$I_{sbs} = A_{seff} J_{ss}(T) + P_{seff} J_{ssws}(T) + W_{effcj} \cdot NF \cdot J_{sswgs}(T)$$

where

(21-267)

$$J_{ss}(T) = JSS(TNOM) \cdot \exp \left(\frac{\frac{E_g(TNOM)}{v_t(TNOM)} - \frac{E_g(T)}{v_t(T)} + XTIS \cdot \ln \left(\frac{T}{TNOM} \right)}{NJS} \right)$$

(21-268)

$$J_{ssws}(T) = JSSWS(TNOM) \cdot \exp \left(\frac{\frac{E_g(TNOM)}{v_t(TNOM)} - \frac{E_g(T)}{v_t(T)} + XTIS \cdot \ln \left(\frac{T}{TNOM} \right)}{NJS} \right)$$

(21-269)

$$J_{sswgs}(T) = JSSWGS(TNOM) \times \left(\sqrt{\frac{JTWEFF}{W_{effi}}} + 1.0 \right) \exp \left(\frac{\frac{E_g(Tnom) - E_g(T)}{V_t(Tnom) - V_t(T)} + XTIS \cdot \ln\left(\frac{T}{Tnom}\right)}{NJS} \right)$$

where

(21-270)

$$E_g(TNOM) = 1.16 - \frac{7.02 \times 10^{-4} TNOM^2}{TNOM + 1108}$$

(21-271)

$$E_g(T) = 1.16 - \frac{7.02 \times 10^{-4} T^2}{T + 1108}$$

(21-272)

$$n_i = 1.45e10 \cdot \frac{TNOM}{300.15} \cdot \sqrt{\frac{TNOM}{300.15}} \cdot \exp \left[21.5565981 - \frac{qE_g(TNOM)}{2 \cdot k_B T} \right]$$

High K Mobility

New Model Parameters

The following new model parameters are added:

- LUCS
- LUCSTE
- PUCS
- PUCSTE
- UCS

- UCSTE
- WUCS
- WUCSTE

The UCS parameter is temperature dependent as given below:

(21-273)

$$UCS(T) = UCS(TNOM) \cdot \left(\frac{T}{TNOM}\right)^{UCSTE}$$

New Mobility Model for High K Material

A new mobility model `mobMod=3` is added to enhance the modeling of coulomb scattering in high-k and metal gate transistors.

New Temperature Mode (tempMod = 3) for Mobility

`tempMod=3` only affects the mobility. Other parameters, such as `Rs` and `Rd` are the same as in `tempMod=2`.

Note the following:

- For `tempMod=1`, `tempMod=2` and `tempMod=3`:

(21-274)

$$U0(T) = U0(TNOM) \cdot \left(\frac{T}{TNOM}\right)^{UTE}$$

and

(21-275)

$$UCS(T) = UCS(TNOM) \cdot \left(\frac{T}{TNOM}\right)^{UCSTE}$$

- However, when `tempMod=3`:

(21-276)

$$UA(T) = UA(TNOM) \cdot \left(\frac{T}{TNOM}\right)^{UA1}$$

(21-277)

$$UB(T) = UB(TNOM) \cdot \left(\frac{T}{TNOM}\right)^{UB1}$$

(21-278)

$$UC(T) = UC(TNOM) \cdot \left(\frac{T}{TNOM}\right)^{UC1}$$

(21-279)

$$UD(T) = UD(TNOM) \cdot \left(\frac{T}{TNOM}\right)^{UD1}$$

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GIDL/GISL Model

A new model selector GIDL_{MOD}=1 is introduced to decouple V_d from V_g through new parameters RGIDL, KGIDL and FGIDL (same for GISL).

(21-280)

$$I_{GIDL} = AGIDL \cdot W_{diod} \cdot Nf \cdot \frac{V_{ds} - RGIDL \cdot V_{gse} - EGIDL + V_{fbsd}}{3 \cdot T_{oxe}} \cdot \exp\left(-\frac{3 \cdot T_{oxe} \cdot BGIDL}{V_{ds} - V_{gse} - EGIDL}\right) \cdot \exp\left(\frac{KGIDL}{V_{ds} - FGIDL}\right)$$

DIBL/Rout Model

A new function tanh() is introduced to capture the V_{ds} effect in long channel devices.

(21-281)

$$\begin{aligned}
 V_{th} = & V_{TH0} + (K_{10x} \cdot \sqrt{\Phi_s - V_{bseff}} - K1 \cdot \sqrt{\Phi_s}) \sqrt{1 + \frac{LPEB}{L_{eff}}} - K_{2ox} V_{bseff} \\
 & + K_{1ox} \left(\sqrt{1 + \frac{LPE0}{L_{eff}}} - 1 \right) \sqrt{\Phi_s} + (K3 + K3B \cdot V_{bseff}) \frac{TOXE}{W_{eff}' + W0} \Phi_s \\
 & - 0.5 \cdot \left[\frac{DVT0W}{\cosh\left(DVT1W \frac{L_{eff} W_{eff}}{l_{tw}}\right) - 1} + \frac{DVT0}{\cosh\left(DVT1 \frac{L_{eff}}{l_t}\right) - 1} \right] (V_{bi} - \Phi_s) \\
 & - \frac{0.5}{\cosh\left(DSUB \frac{L_{eff}}{l_{t0}}\right) - 1} (ETA0 + ETAB \cdot V_{bseff}) \cdot V_{ds} \\
 & - n v_t \cdot \ln \left(\frac{L_{eff}}{L_{eff} + DVTP0 \cdot \left(1 + e^{-DVTP1 \cdot V_{DS}}\right)} \right) \\
 & - \left(DVTP5 + \frac{DVTP2}{DVTP3} \right) \cdot \tanh(DVTP4 \cdot V_{ds})
 \end{aligned}$$

where DVTP2, DVTP3, DVTP4, and DVTP5 are new model parameters.

Temperature Dependence of Subthreshold Leakage Current

The new temperature dependence of subthreshold leakage current is modeled by:

(21-282)

$$Nfactor(T) = nfactor(Tnom) + tnfactor\left(\frac{T}{Tnom} - 1\right)$$

$$ETA0(T) = ETA0(Tnom) + TETA0 * \left(\frac{T}{Tnom} - 1\right)$$

$$voffCV(T) = voffCV * (1.0 + tvoffCV * (T - Tnom))$$

where tnfactor, TETA0, and tvoffCV are the new model parameters.

New Model Selector for MTRLMOD=0 and MTRLMOD=1 Compatibility

A new model selector MTRLCOMPATMOD=1 is introduced to make MTRLMOD=0 and MTRLMOD=1 consistent.

Physical Oxide Thickness

When MTRLMOD=1 and MTRLCOMPATMOD=1

(21-283)

$$T_{oxp} = EOT * \frac{EPSROX}{3.9} - DTOX$$

Effective Field for Mobility Calculation

(21-284)

$$E_{eff}(V_{gsteff} + 2V_{th} - 2(V_{fb} + \phi_{st})) \quad \text{for mtrlMod} = 1$$
$$E_{eff}(V_{gsteff} + 2V_{th}) \quad \text{for mtrlMod} = 0$$

With MTRLCOMPATMOD=1 and MTRLMOD=1

(21-285)

$$E_{eff}(V_{gsteff} + 2V_{th})$$

Enhanced Thermal Noise Model

A new thermal noise model tnoimod=2 has been implemented in SPICE3. Following new expressions have been added for drain noise (S_{id}), induced gate noise (S_{ig}) and correlation coefficient (c):

Drain Noise

(21-286)

$$S_{id} = 4kT \cdot \gamma \cdot g_{d0} \cdot (3 \cdot \beta_{noi}^2)$$

Induced Gate Noise

(21-287)

$$S_{ig0} = 4kT \cdot C_0^2 \cdot \omega^2 \cdot \frac{\delta}{g_{d0}} \cdot \left(\frac{15 \cdot \theta_{noi}}{4} \right)^2$$

Correlation Coefficient

(21-288)

$$c = -j \sqrt{\frac{\varepsilon}{\gamma \cdot \delta}} \cdot \left(\frac{c_{tnoi}}{0.395} \right)$$

Where

(21-289)

$$\beta_{noi} = RNOIA \cdot \left[1 + TNOIA \cdot L_{eff} \cdot \left(\frac{V_{gsteff}}{E_{sat} L_{eff}} \right)^2 \right] \quad RNOIA = 0.577(\text{default})$$

$$\theta_{noi} = RNOIB \cdot \left[1 + TNOIB \cdot L_{eff} \cdot \left(\frac{V_{gsteff}}{E_{sat} L_{eff}} \right)^2 \right] \quad RNOIB = 0.5164(\text{default})$$

$$C_{tnoi} = RNOIC \cdot \left[1 + TNOIC \cdot L_{eff} \cdot \left(\frac{V_{gsteff}}{E_{sat} L_{eff}} \right)^2 \right] \quad RNOIC = 0.395(\text{default})$$

$$g_{d0} = NF \times \frac{\mu_{eff} C_{oxeff} \frac{W_{eff}}{L_{eff}} V_{gsteff}}{1 + g_{che} \cdot R_{ds}}$$

$$C_0 = NF \times C_{oxeff} W_{eff,CV} L_{eff,CV}$$

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Mobility Models

BSIM4.80 introduces three new mobility models `mobmod=4`, `mobmod=5`, and `mobmod=6`. See equations [21-31](#), [21-32](#), and [21-33](#) for details.

Component Statements

This device is supported within altergroups.

Instance Definition

Name `d g s b` ModelName parameter=value ...

Instance Parameters

1	<code>w</code> (m)	Channel width.
2	<code>l</code> (m)	Channel length.
3	<code>as</code> (m ²)	Area of source diffusion.
4	<code>ad</code> (m ²)	Area of drain diffusion.
5	<code>ps</code> (m)	Perimeter of source diffusion.
6	<code>pd</code> (m)	Perimeter of drain diffusion.
7	<code>nrd</code>	Number of squares of drain diffusion.
8	<code>nrs</code>	Number of squares of source diffusion.
9	<code>rdc=0.0</code> Ω	Drain contact resistance.
10	<code>rsc=0.0</code> Ω	Source contact resistance.
11	<code>sa=0.0</code> m	Distance between OD edge to poly from one side.
12	<code>sb=0.0</code> m	Distance between OD edge to poly from the other side.
13	<code>sd=0.0</code> m	Distance between neighbor fingers.
14	<code>sa1=0.0</code> m	Distance between OD edge to poly from one side 1.

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

15	sa2=0.0 m	Distance between OD edge to poly from one side 2.
16	sa3=0.0 m	Distance between OD edge to poly from one side 3.
17	sa4=0.0 m	Distance between OD edge to poly from one side 4.
18	sa5=0.0 m	Distance between OD edge to poly from one side 5.
19	sa6=0.0 m	Distance between OD edge to poly from one side 6.
20	sa7=0.0 m	Distance between OD edge to poly from one side 7.
21	sa8=0.0 m	Distance between OD edge to poly from one side 8.
22	sa9=0.0 m	Distance between OD edge to poly from one side 9.
23	sa10=0.0 m	Distance between OD edge to poly from one side 10.
24	sb1=0.0 m	Distance between OD edge to poly from other side 1.
25	sb2=0.0 m	Distance between OD edge to poly from other side 2.
26	sb3=0.0 m	Distance between OD edge to poly from other side 3.
27	sb4=0.0 m	Distance between OD edge to poly from other side 4.
28	sb5=0.0 m	Distance between OD edge to poly from other side 5.
29	sb6=0.0 m	Distance between OD edge to poly from other side 6.
30	sb7=0.0 m	Distance between OD edge to poly from other side 7.
31	sb8=0.0 m	Distance between OD edge to poly from other side 8.
32	sb9=0.0 m	Distance between OD edge to poly from other side 9.
33	sb10=0.0 m	Distance between OD edge to poly from other side 10.
34	sw1=0.0 m	Width of SA1/SB1.
35	sw2=0.0 m	Width of SA2/SB2.
36	sw3=0.0 m	Width of SA3/SB3.

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

37	<code>sw4=0.0 m</code>	Width of SA4/SB4.
38	<code>sw5=0.0 m</code>	Width of SA5/SB5.
39	<code>sw6=0.0 m</code>	Width of SA6/SB6.
40	<code>sw7=0.0 m</code>	Width of SA7/SB7.
41	<code>sw8=0.0 m</code>	Width of SA8/SB8.
42	<code>sw9=0.0 m</code>	Width of SA9/SB9.
43	<code>sw10=0.0 m</code>	Width of SA10/SB10.
44	<code>isnoisy=yes</code>	Should device generate noise. Possible values are <code>no</code> and <code>yes</code> .
45	<code>m=1</code>	Multiplicity factor (number of MOSFETs in parallel).
46	<code>region=triode</code>	Estimated operating region. %Z outputs the number (0-4) in a rawfile. Possible values are <code>off</code> , <code>triode</code> , <code>sat</code> , <code>subth</code> , and <code>breakdown</code> .
47	<code>trnqsmo</code>	Transient NQS model selector.
48	<code>acnqsmo</code>	AC small-signal NQS model selector.
49	<code>trise (C)</code>	Temperature rise from ambient.
50	<code>dtemp (C)</code>	Alias for <code>trise</code> .
51	<code>deltox=0 m</code>	Shift in gate electrical/physical equivalent oxide thickness (for both TOXE and TOXP).
52	<code>rgatemo</code>	Gate resistance model selector.
53	<code>rbodymo</code>	Substrate resistance network model selector.
54	<code>geomod</code>	Geometry dependent parasitics model selector.
55	<code>stimod</code>	LOD stress effect model selector.

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

56	<code>rgeomod</code>	Diffusion resistance and contact model selector.
57	<code>rbpb</code> (Ω)	Resistance connected between bNode' and bNode.
58	<code>rbpd</code> (Ω)	Resistance connected between bNode' and dbNode.
59	<code>rbps</code> (Ω)	Resistance connected between bNode' and sbNode.
60	<code>rbdb</code> (Ω)	Resistance connected between dbNode and bNode.
61	<code>rsbs</code> (Ω)	Resistance connected between sbNode and bNode.
62	<code>nf</code>	Number of device fingers.
63	<code>min</code>	Whether to minimize the number of drain or source diffusions for evennumber fingered device. Set to 0 to minimize.
64	<code>delvto=0.0</code> V	Shift in zero-bias threshold voltage <code>vth0</code> .
65	<code>mulmu0=1.0</code>	Mobility multiplier, alias of <code>mulu0</code> .
66	<code>mulvsat=1.0</code>	<code>Vsat</code> multiplier.
67	<code>mulu0=1.0</code>	Mobility multiplier.
68	<code>mulid0=1.0</code>	<code>Ids</code> multiplier.
69	<code>delk1=0.0</code> v	Shift in body bias coefficient <code>k1</code> .
70	<code>delnfct=0.0</code>	Shift in subthreshold swing factor <code>nfactor</code> .
71	<code>deleta0=0.0</code>	Shift in DIBL coefficient subthreshold region.
72	<code>sca=0.0</code>	Integral of the first distribution function for scattered well dopant.
73	<code>scb=0.0</code>	Integral of the second distribution function for scattered well dopant.
74	<code>scc=0.0</code>	Integral of the third distribution function for scattered well dopant.
75	<code>sc=0.0</code> m	Distance to a single well edge.
76	<code>xgw=0.0</code> m	Distance from the gate contact to the channel edge.

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

77 `ngcon=1.0` Number of gate contacts.

Model Definition

model modelName bsim4 parameter=value ...

Model Parameters

Device type parameters

1 `type=n` Transistor type.
Possible values are `n` and `p`.

Model Selectors & Controller

- 2 `level=14` Model level selector for spice compatibility.
- 3 `version=4.21` Model parameter "version" only accepts real number value, like 4.21 for version=4.2.1. The available versions are 4.21(4.2.1), 4.30(4.3.0), 4.40(4.4.0), 4.50(4.5.0), 4.60(4.6.0), 4.61(4.6.1), 4.62(4.6.2), 4.63(4.6.3), 4.64(4.6.4), 4.65(4.6.5), 4.70(4.7.0), and 4.80(4.8.0).
- 4 `binunit=1` Bin parameter unit selector. 1 for microns and 2 for meters.
- 5 `paramchk=1` Switch for parameter value check. Set to 1 to turn on.
- 6 `mobmod=0` Mobility model selector.
- 7 `cvchargemod=0.0` Capacitance Charge model selector.
- 8 `mtrlmod=0.0` parameter for non-silicon substrate or metal gate selector.
- 9 `mtrlcompatmod=0` New material mod backward compatibility selector.
- 10 `rdsmode=0` Bias-dependent source/drain resistance model selector.
- 11 `igcmode=0` Gate-to-channel tunneling model selector.
- 12 `igbmode=0` Gate-to-substrate tunneling model selector.

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

13	capmod=2	Capacitance model selector.
14	rgatmod=0	Gate resistance model selector.
15	rbodymod=0	Substrate resistance network model selector.
16	trnqsmode=0	Transient Non-quasi static model selector. Set to 1 to turn on nqs.
17	acnqsmode=0	Ac Non-quasi static model selector. Set to 1 to turn on nqs.
18	fnoimod=1	Flicker noise model selector.
19	tnoimod=0	Thermal noise model selector.
20	diomod=1	Source/Drain junction diode IV model selector.
21	tempmod=0	Temperature model selector. 0 for original model and 1 for new format.
22	permod=1	Perimeter model selector.
23	geomod=0	Geometry dependent parasitics model selector.
24	stimod=0	LOD stress effect model selector. 0 for Berkeley LOD, 1 & 2 for TSMC LOD.
25	wpemod=0	Flag for WPE model (WPEMOD=1 to activate this model).
26	rgeomod=0	Diffusion resistance and contact model selector. It served as the default value of instance rgeomod.
27	flkmod=0	Flicker Noise Model.
28	fullreinit=0	Model parameter full reinit selector.
29	updatelevel=0	Model update selector. Available versions are 0, 1 and 2.
30	eglev=0	DC temperature selector.
31	minr=0.001 Ω	Minimum source/drain resistance.

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

Process parameters

32	<code>epsrox=3.9</code>	Gate dielectric constant.
33	<code>epsrgate=11.7</code>	Dielectric constant of gate relative to vacuum.
34	<code>epsrsub=11.7</code>	Dielectric constant of substrate relative to vacuum.
35	<code>eot=1.5e-9 m</code>	Equivalent gate oxide thickness in meters.
36	<code>toxe=3.0e-9 m</code>	Electrical gate equivalent oxide thickness.
37	<code>toxpr=`toxem'</code>	Physical gate equivalent oxide thickness.
38	<code>toxm=`toxem'</code>	Toxe at which parameters were extracted.
39	<code>dtox=0.0 m</code>	Difference between electrical and physical gate oxide thickness.
40	<code>xj=0.15e-6 m</code>	Source/drain junction depth.
41	<code>gamma1 (V)</code>	Body-effect coefficient near the surface.
42	<code>gamma2 (V)</code>	Body-effect coefficient in the bulk.
43	<code>ndep=1.7e17 cm⁻³</code>	Channel doping concentration at depletion edge for zero body bias.
44	<code>nsub=6.0e16 cm⁻³</code>	Substrate doping concentration.
45	<code>ngate=0.0 cm⁻³</code>	Poly Si gate doping concentration.
46	<code>nsd=1.0e20 cm⁻³</code>	Source-drain doping concentration.
47	<code>vbx (V)</code>	Vbs at which the depletion region width equals XT.
48	<code>xt=1.55e-7 m</code>	Doping depth.
49	<code>rsh=0.0 Ω/sqr</code>	Source/drain sheet resistance.
50	<code>rshg=0.1 Ω/sqr</code>	Gate electrode sheet resistance.
51	<code>lint=0.0 m</code>	Lateral diffusion for one side.

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

52	<code>wint=0.0 m</code>	Width reduction for one side.
53	<code>wl=0.0 m^{wln}</code>	Length dependence of delta W.
54	<code>wln=1.0</code>	Length exponent of delta W.
55	<code>ww=0.0 m^{wwn}</code>	Width dependence of delta W.
56	<code>wwn=1.0</code>	Width exponent of delta W.
57	<code>wwl=0.0 m^(wwn+wln)</code>	Area dependence of delta W.
58	<code>ll=0.0 m^{lln}</code>	Length dependence of delta L.
59	<code>lln=1.0</code>	Length exponent of delta L.
60	<code>lw=0.0 m^{lwn}</code>	Width dependence of delta L.
61	<code>lwn=1.0</code>	Width exponent of delta L.
62	<code>lwl=0.0 m^(lln+lwn)</code>	Area dependence of delta L.
63	<code>dwg=0.0 m/V</code>	Gate-bias dependence of channel width.
64	<code>dwb=0.0 m/ V</code>	Body-bias dependence of channel width.
65	<code>lmlt=1.0</code>	Length shrink reduction factor.
66	<code>wmlt=1.0</code>	Width shrink reduction factor.

Threshold voltage parameters

67	<code>vtho=0.7 (nmos) / -0.7 (pmos) V</code>	Threshold voltage at V _{bs} =0 for long-channel devices. Alias of vth0.
68	<code>vfb=-1.0 V</code>	Flat-band voltage.
69	<code>vddeot=1.5 (nmos) / -1.5 (pmos) V</code>	Voltage for extraction of Equivalent gate oxide thickness.

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

70	$\text{phin}=0.0 \text{ V}$	Non-uniform vertical doping effect on surface potential.
71	$k1=0.53 \text{ V}$	First-order body bias coefficient.
72	$k2=-0.0186$	Second-order body bias coefficient.
73	$k3=80.0$	Narrow width coefficient.
74	$k3b=0.0 \text{ 1/V}$	Body effect coefficient of K3.
75	$w0=2.5e-6 \text{ m}$	Narrow width coefficient.
76	$lpe0=1.74e-7 \text{ m}$	Lateral non-uniform doping at $V_{bs}=0$.
77	$lpeb=0.0 \text{ m}$	Lateral non-uniform doping effect on K1.
78	$v_{bm}=-3.0 \text{ V}$	Maximum applied body voltage in V_{th0} calculation.
79	$dvt0=2.2$	First coefficient of short-channel effects.
80	$dvt1=0.53$	Second coefficient of short-channel effects.
81	$dvt2=-0.032 \text{ 1/V}$	Body-bias coefficient of short-channel effects.
82	$dvt_{p0}=0.0 \text{ m}$	First coefficient of drain-induced V_{th} shift for long-channel pocket devices.
83	$dvt_{p1}=0.0 \text{ 1/V}$	Second coefficient of drain-induced V_{th} shift for long-channel pocket devices.
84	$dvt_{p2}=0.0$	3rd parameter for V_{th} shift due to pocket.
85	$dvt_{p3}=0.0$	4th parameter for V_{th} shift due to pocket.
86	$dvt_{p4}=0.0$	5th parameter for V_{th} shift due to pocket.
87	$dvt_{p5}=0.0$	6th parameter for V_{th} shift due to pocket.
88	$dvt0w=0.0$	First coefficient of narrow-width effects.
89	$dvt1w=5.3e6 \text{ 1/m}$	Second coefficient of narrow-width effects.
90	$dvt2w=-0.032 \text{ 1/V}$	Body-bias coefficient of narrow-width effects.

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BSIM4 Level-14 Model (bsim4)

91	$a_0=1.0$	Nonuniform depletion width effect coefficient.
92	$ags=0.0$ 1/V	Gate-bias dependence of A_{bulk} .
93	$b_0=0.0$ m	Bulk charge coefficient due to narrow width effect.
94	$b_1=0.0$ m	Bulk charge coefficient due to narrow width effect.
95	$keta=-0.047$ 1/V	Body-bias coefficient for non-uniform depletion width effect.
96	$a_1=0.0$ 1/V	First non-saturation effect parameter.
97	$a_2=1.0$	Second non-saturation factor.
98	$\phi_{ig}=4.05$ eV	The gate work function.
99	$ni_{0sub}=1.45e10$ cm ⁻³	Intrinsic carrier concentration at T=300.15K.
100	$bg_{0sub}=1.16$ eV	Band-gap of substrate at T=0K.
101	$tbg_{asub}=7.02e-4$ V/K	First parameter of band-gap change due to temperature.
102	$tbg_{bsub}=1108.0$ K	Second parameter of bandgap change due to temperature.
103	$ados=1.0$	Charge centroid parameter.
104	$bdos=1.0$	Charge centroid parameter.
105	$tempeot=300.15$ C	Temperature for extraction of EOT.
106	$leffeot=1$ m	Effective length for extraction of EOT.
107	$weffeot=10$ m	Effective width for extraction of EOT.
108	$vthmod$	Vth output selector. 'std' outputs model equation Vth. 'vthcc' outputs constant current Vth, and may impact simulation performance. The default value is taken from the options parameter 'vthmod'. Possible values are <code>std</code> and <code>vthcc</code> .

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BSIM4 Level-14 Model (bsim4)

109	<code>ivth</code> (A)	Vth current parameter. The default value is taken from the options parameter 'ivthn' or 'ivthp', depending on the type of the model.
110	<code>ivthw</code> (m)	Width offset for constant current Vth. The default value is taken from the options parameter 'ivthw'.
111	<code>ivthl</code> (m)	Length offset for constant current Vth. The default value is taken from the options parameter 'ivthl'.
112	<code>ivth_vdsmin</code> (V)	Minimum Vds in constant current Vth calculating. The default value is taken from the options parameter 'ivth_vdsmin'.
113	<code>acm=12</code>	area calculation method selector.
114	<code>hdif=0</code> m	Length of heavily doped diffusion.
115	<code>ldif=0</code> m	Lateral diffusion beyond the gate.
116	<code>rs=12.5</code> Ω	Source resistance.
117	<code>rd=12.5</code> Ω	Drain resistance.
118	<code>ld</code> (m)	Lateral diffusion into the channel from the source and drain diffusion.
119	<code>trd=0</code> 1/C	Temperature parameter for drain resistance.
120	<code>trs=0</code> 1/C	Temperature parameter for source resistance.

Mobility parameters

121	<code>u0=670</code> (nmos) / <code>250</code> (pmos)	Low-field surface mobility at <code>tnom</code> .
122	<code>ua=1.0e-9</code> (mobmod=0,1) / <code>1.0e-15</code> (mobmod=2) m/V	First-order mobility reduction coefficient.
123	<code>ub=1.0e-19</code> m^2/V^2	Second-order mobility reduction coefficient.
124	<code>uc=-0.0465</code> 1/V (mobmod=1) / <code>-0.0465e-9</code> m/V^2 (mobmod=0,2)	Body-bias dependence of mobility.

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125	$ud=1.0e14 \text{ /m}^2$	Coulomb scattering factor of mobility.
126	$up=0.0$	Channel length linear factor of mobility.
127	$lp=1.0e-8 \text{ m}$	Channel length exponential factor of mobility.
128	$eu=1.67 \text{ (nmos)} / 1.0 \text{ (pms)}$	Exponent for mobility degradation of mobmod=2.
129	$vsat=8.0e4 \text{ m/s}$	Carrier saturation velocity at tnom.
130	$lambda=0.0$	Velocity overshoot coefficient.
131	$vtl=2.0e5 \text{ m/s}$	Thermal velocity.
132	$lc=5.0e-9 \text{ m}$	Velocity back scattering coefficient.
133	$xn=3.0$	Velocity back scattering coefficient.
134	$easub=4.05 \text{ eV}$	Electron affinity of substrate.
135	$ucs=1.67 \text{ (nmos)} / 1.0 \text{ (pms)}$	Coulomb scattering exponent.
136	$ucste=-4.775e-3$	Temperature coefficient of colombic mobility.

Subthreshold parameters

137	$voff=-0.08 \text{ V}$	Threshold voltage offset.
138	$tvoff=0.0 \text{ V}$	Temperature parameter for voff.
139	$ltvoff=0.0 \text{ V}$	Length dependence of tvoff.
140	$wtvoff=0.0 \text{ V}$	Width dependence of tvoff.
141	$ptvoff=0.0 \text{ V}$	Cross-term dependence of tvoff.
142	$voffl=0.0 \text{ mV}$	Channel-length dependence of Voff.
143	$minv=0.0$	Vgsteff fitting parameter for moderate inversion condition.
144	$nfactor=1.0$	Subthreshold swing coefficient.

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BSIM4 Level-14 Model (bsim4)

145	$\text{eta0}=0.08$	DIBL coefficient subthreshold region.
146	$\text{etab}=-0.07 \text{ 1/V}$	Body-bias dependence of et0 .
147	$\text{dsub}=\text{'drout'}$	DIBL effect in subthreshold region.
148	$\text{cit}=0.0 \text{ F/m}^2$	Interface trap parameter for subthreshold swing.
149	$\text{cdsc}=2.4\text{e-}4 \text{ F/m}^2$	Source/drain and channel coupling capacitance.
150	$\text{cdscb}=0.0 \text{ F/m}^2 \text{ V}$	Body-bias dependence of cdsc .
151	$\text{cdscd}=0.0 \text{ F/m}^2 \text{ V}$	Drain-bias dependence of cdsc .

Output resistance parameters

152	$\text{pclm}=1.3$	Channel length modulation coefficient.
153	$\text{pdiblc1}=0.39$	First coefficient of drain-induced barrier lowering.
154	$\text{pdiblc2}=8.6\text{e-}3$	Second coefficient of drain-induced barrier lowering.
155	$\text{pdiblcb}=0.0 \text{ 1/V}$	Body-effect coefficient for DIBL.
156	$\text{drout}=0.56$	DIBL effect on output resistance coefficient.
157	$\text{pscbe1}=4.24\text{e}8 \text{ V/m}$	First coefficient of substrate current body effect.
158	$\text{pscbe2}=1\text{e-}5 \text{ m/V}$	Second coefficient of substrate current body effect.
159	$\text{fprout}=0.0 \text{ V/}\mu\text{m}$	Effect of pocket implant on R_{out} degradation.
160	$\text{pvag}=0.0$	Gate dependence of Early voltage.
161	$\text{delta}=0.01 \text{ V}$	Effective drain voltage smoothing parameter.
162	$\text{pdits}=0.0 \text{ 1/V}$	Effect of pocket implant on R_{out} degradation.
163	$\text{pditsl}=0.0 \text{ 1/m}$	Channel-length dependence of drain-induced V_{th} shift on R_{out} .
164	$\text{pditsd}=0.0 \text{ 1/V}$	V_{ds} dependence of drain-induced V_{th} shift on R_{out} .

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BSIM4 Level-14 Model (bsim4)

Bias-dependent Rds parameters

- 165 $r_{dsw}=200.0 \ \Omega \ \mu\text{m}^{wr}$ Zero bias LDD resistance per unit width for RDSMOD=0.
- 166 $r_{dswmin}=0.0 \ \Omega \ \mu\text{m}^{wr}$ LDD resistance per unit width at high Vgs and zero Vbs for RDSMOD=0.
- 167 $r_{dw}=100.0 \ \Omega \ \mu\text{m}^{wr}$ Zero bias LDD resistance per unit width for RDSMOD=1.
- 168 $r_{dwmin}=0.0 \ \Omega \ \mu\text{m}^{wr}$ LDD resistance per unit width at high Vgs and zero Vbs for RDSMOD=1.
- 169 $r_{sw}=100.0 \ \Omega \ \mu\text{m}^{wr}$ Zero bias LDD resistance per unit width for RDSMOD=1.
- 170 $r_{swmin}=0.0 \ \Omega \ \mu\text{m}^{wr}$ LDD resistance per unit width at high Vgs and zero Vbs for RDSMOD=1.
- 171 $prwg=1 \ 1/V$ Gate-effect coefficient for Rds.
- 172 $prwb=0.0 \ 1/V$ Body-effect coefficient for Rds.
- 173 $wr=1.0$ Width offset for parasitic resistance.

Substrate current parameters

- 174 $\alpha_0=0.0 \ \text{A} \ \mu\text{m}/V$ Substrate current impact ionization coefficient.
- 175 $\alpha_1=0.0 \ \text{A}/V$ Substrate current impact ionization coefficient.
- 176 $\beta_0=30.0 \ 1/V$ Substrate current impact ionization exponent.

Gate-Induced drain leakage parameters

- 177 $gidlmod=0$ Parameter for GIDL selector.

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BSIM4 Level-14 Model (bsim4)

178	$agidl=0.0$	$1/\Omega$	Pre-exponential coefficient for GIDL.
179	$bgidl=2.3e9$	V/m	Exponential coefficient for GIDL.
180	$cgidl=0.5$	V^3	Parameter for body-bias effect on GIDL.
181	$egidl=0.8$	V	Fitting parameter for band bending for GIDL.
182	$fgidl=0.0$	V	GIDL vb parameter.
183	$kgidl=0.0$	V	GIDL vb parameter.
184	$rgidl=1.0$		GIDL vg parameter.
185	$agisl=agidl$	$1/\Omega$	Pre-exponential coefficient for GISL (bsim4.6).
186	$bgisl=bgidl$	V/m	Exponential coefficient for GISL (bsim4.6).
187	$cgisl=cgidl$	V^3	Parameter for body-bias effect on GISL (bsim4.6).
188	$egisl=egidl$	V	Fitting parameter for band bending for GISL (bsim4.6).
189	$fgisl=fgidl$	V	GISL vb parameter.
190	$kgisl=kgidl$	V	GISL vb parameter.
191	$rgisl=rgidl$		GISL vg parameter.

Gate Tunneling parameters

192	$aigbacc=0.43$	$ F/g$	s/m	Parameter for I_{gb} in accumulation.
193	$bigbacc=0.054$	$ F/g$	$s/(m V)$	Parameter for I_{gb} in accumulation.
194	$cigbacc=0.075$	$1/V$		Parameter for I_{gb} in accumulation.
195	$nigbacc=1.0$			Parameter for I_{gb} in accumulation.
196	$aigbinv=0.35$	$ F/g$	s/m	Parameter for I_{gb} in inversion.

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BSIM4 Level-14 Model (bsim4)

- 197 $\text{bigbinv}=0.03 \text{ F/g s/(m V)}$
Parameter for I_{gb} in inversion.
- 198 $\text{cigbinv}=0.006 \text{ 1/V}$ Parameter for I_{gb} in inversion.
- 199 $\text{eigbinv}=1.1 \text{ V}$ Parameter for I_{gb} in inversion.
- 200 $\text{nigbinv}=3.0$ Parameter for I_{gb} in inversion.
- 201 $\text{aigc}=0.43 \text{ (nmos) / } 0.31 \text{ (pmos) F/g s/m}$
Parameter for I_{gcs} and I_{gcd} .
- 202 $\text{bigc}=0.054 \text{ (nmos) / } 0.024 \text{ (pmos) F/g s/(m V)}$
Parameter for I_{gcs} and I_{gcd} .
- 203 $\text{cigc}=0.075 \text{ (nmos) / } 0.03 \text{ (pmos) 1/V}$
Parameter for I_{gcs} and I_{gcd} .
- 204 $\text{aigsd}=0.43 \text{ (nmos) / } 0.31 \text{ (pmos) F/g s/m}$
Parameter for I_{gs} and I_{gd} .
- 205 $\text{bigsd}=0.054 \text{ (nmos) / } 0.024 \text{ (pmos) F/g s/(m V)}$
Parameter for I_{gs} and I_{gd} .
- 206 $\text{cigsd}=0.075 \text{ (nmos) / } 0.03 \text{ (pmos) 1/V}$
Parameter for I_{gs} and I_{gd} .
- 207 $\text{aigs}=1.36\text{e-}2 \text{ (nmos) / } 9.80\text{e-}3 \text{ (pmos) F/g s/m}$
Parameter for I_{gs} (bsim4.6).
- 208 $\text{big}=1.71\text{e-}3 \text{ (nmos) / } 7.59\text{e-}4 \text{ (pmos) F/g s/(m V)}$
Parameter for I_{gs} (bsim4.6).
- 209 $\text{cigs}=0.075 \text{ (nmos) / } 0.03 \text{ (pmos) 1/V}$
Parameter for I_{gs} (bsim4.6).
- 210 $\text{aigd}=1.36\text{e-}2 \text{ (nmos) / } 9.80\text{e-}3 \text{ (pmos) F/g s/m}$
Parameter for I_{gd} (bsim4.6).
- 211 $\text{bigd}=1.71\text{e-}3 \text{ (nmos) / } 7.59\text{e-}4 \text{ (pmos) F/g s/(m V)}$
Parameter for I_{gd} (bsim4.6).

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BSIM4 Level-14 Model (bsim4)

212	$cigd=0.075$ (nmos) / 0.03 (pmos) $1/V$	Parameter for I_{gd} (bsim4.6).
213	$dlcig=\text{'Lintm'}$	Source overlap length for I_{gs} .
214	$dlcigd=dlcig$ m	drain overlap length for I_{gd} (bsim4.6).
215	$nigc=1.0$	Parameter for I_{gcs} , I_{gcd} , I_{gs} and I_{gd} .
216	$poxedge=1.0$	Factor for the gate oxide thickness in source/drain overlap regions.
217	$pigcd=1.0$	V_{ds} dependence of I_{gcs} and I_{gcd} .
218	$ntox=1.0$	Exponent for the gate oxide ratio.
219	$toxref=3.0e-9$ m	Nominal gate oxide thickness for gate dielectric tunneling current model only.
220	$vfbsdoff=0.0$ V	S/D flatband voltage offset.
221	$tvfbsdoff=0.0$ V	Temperature parameter for $vfbsdoff$.
222	$ltvfbsdoff=0.0$ V	Length dependence of $tvfbsdoff$.
223	$wtvfbsdoff=0.0$ V	Width dependence of $tvfbsdoff$.
224	$ptvfbsdoff=0.0$ V	Cross-term dependence of $tvfbsdoff$.

Overlap capacitance parameters

225	$cgso$ (F/m)	Non LDD region source-gate overlap capacitance per unit channel width.
226	$cgdo$ (F/m)	Non LDD region drain-gate overlap capacitance per unit channel width.
227	$cgbo=2$ Dwc $Coxe$ F/m	Non LDD region drain-gate overlap capacitance per unit channel width.
228	$meto=0.0$ m	Metal overlap in fringing field.

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BSIM4 Level-14 Model (bsim4)

229	<code>cgsl=0.0 F/m</code>	Overlap capacitance between gate and lightly-doped source region.
230	<code>cgdl=0.0 F/m</code>	Overlap capacitance between gate and lightly-doped drain region.
231	<code>ckappas=0.6 V</code>	Coefficient of bias-dependent overlap capacitance for the source side.
232	<code>ckappad=`ckappasV'</code>	Coefficient of bias-dependent overlap capacitance for the source side.

Charge model selection parameters

233	<code>xpart=0.0</code>	Charge partition number. Use 0.0 for 40/60, 0.5 for 50/50, and 1.0 for 0/100.
234	<code>cf (F/m)</code>	Fringing field capacitance (alias= <code>lx91</code>).
235	<code>clc=1e-7 m</code>	Constant term for the short channel model.
236	<code>cle=0.6</code>	Exponential term for the short channel model.
237	<code>dlc=`lintm'</code>	Delta L for capacitance model.
238	<code>dwc=`wintm'</code>	Delta W for capacitance model.
239	<code>vfbcv=-1.0</code>	Flat-band voltage for <code>capmod=0</code> .
240	<code>noff=1.0</code>	Transition parameter.
241	<code>voffcv=0.0 V</code>	CV parameter in <code>VgsteffCV</code> for weak to strong inversion.
242	<code>minvcv=0.0</code>	Fitting parameter for moderate inversion condition.
243	<code>voffcvl=0.0 V m</code>	Length dependence parameter for <code>Vth</code> offset in CV.
244	<code>acde=1.0 m/V</code>	Exponential coefficient for charge thickness in <code>CAPMOD=2</code> for accumulation and depletion regions.
245	<code>moin=15.0</code>	Exponential coefficient for charge thickness for accumulation and depletion regions.

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246 $llc = llm^{lln}$ Length dependence of delta L for CV.

247 $lwc = lwm^{lwn}$ Width dependence of delta L for CV.

248 $lwlc = lwlm^{(lln+lwn)}$ Area dependence of delta L for CV.

249 $wlc = wlm^{wln}$ Length dependence of delta W for CV.

250 $wwc = wwm^{wwn}$ Width dependence of delta W for CV.

251 $wwlc = wwlm^{(wwn+wln)}$ Area dependence of delta W for CV.

Parasitic resistance parameters

252 $dmcg = 0.0$ m Distance from S/D contact center to the gate edge.

253 $dmci = dmcm$ Distance from S/D contact center to the isolation edge in the channel-length direction.

254 $dm dg = 0.0$ m Distance from S/D contact center to the gate edge.

255 $dmcgt = 0.0$ m DMCG of test structures.

256 $d w j = dwcm$ Offset of the S/D junction width.

257 $xgw = 0.0$ m Distance from the gate contact to the channel edge.

258 $xgl = 0.0$ m Offset of gate length due to variations in patterning.

259 $xl = 0.0$ m Length variation due to masking and etching.

260 $xw = 0.0$ m Width variation due to masking and etching.

261 $ngcon = 1.0$ Number of gate contacts.

262 $nf = 1$ Number of device fingers. It served as the default value of instance nf.

263 $min = 0$ Whether to minimize the number of drain or source diffusions for evennumber fingered device. Set to 0 to minimize. It served as the default value of instance min.

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BSIM4 Level-14 Model (bsim4)

Junction diode model parameters

264	$ijthsrev=0.1$ A	Source diode limiting current in reverse bias region.
265	$ijthdrev=\text{'ijthsrevA'}$	Drain diode limiting current in reverse bias region.
266	$ijthsfwd=0.1$ A	Source diode limiting current in forward bias region.
267	$ijthdfwd=\text{'ijthsfwdA'}$	Drain diode limiting current in forward bias region.
268	$xjbvs=1.0$	Fitting parameter for bulk-source diode breakdown.
269	$xjbvd=\text{'xjbvs'}$	Fitting parameter for bulk-drain diode breakdown.
270	$bv=10.0$ V	Diode breakdown voltage. Alias of bvs.
271	$bvs=10.0$ V	Source diode breakdown voltage.
272	$bvd=\text{'bvsV'}$	Drain diode breakdown voltage.
273	$is=1.0e-14$ A	Bulk junction reverse saturation current.
274	$js=1.0e-4$ A/m ²	Bottom junction reverse saturation current density. Alias of jss.
275	$jss=1.0e-4$ A/m ²	Source bottom junction reverse saturation current density.
276	$jds=\text{'jssA/m'}$ ²	Drain bottom junction reverse saturation current density.
277	$jsws=0.0$ A/m	Isolation-edge sidewall source junction reverse saturation current density.
278	$jswd=\text{'jswsA/m'}$	Isolation-edge sidewall drain junction reverse saturation current density.
279	$jswgs=0.0$ A/m	Gate-edge sidewall source junction reverse saturation current density.
280	$jswgd=\text{'jswgsA/m'}$	Gate-edge sidewall drain junction reverse saturation current density.
281	$jtss=0.0$ A/m ²	Source bottom trap-assisted saturation current density.

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BSIM4 Level-14 Model (bsim4)

282	$jtssd = \text{jtssA}/m^2$	Drain bottom trap-assisted saturation current density.
283	$jtssws = 0.0 \text{ A}/m$	Source isolation-edge sidewall trap-assisted saturation current density.
284	$jtsswd = \text{jtsswsA}/m'$	Drain isolation-edge sidewall trap-assisted saturation current density.
285	$jtsswgs = 0.0 \text{ A}/m$	Source Gate-edge isolation-edge sidewall trap-assisted saturation current density.
286	$jtsswgd = \text{jtsswgsA}/m'$	Drain isolation-edge sidewall trap-assisted saturation current density.
287	$njts = 20.0$	Non-ideality factor for jtss. For TSMC diode model, default=60.0.
288	$njtssw = 20.0$	Non-ideality factor for jtssws. For TSMC diode model, default=60.0.
289	$njtsswg = 20$	Non-ideality factor for jtsswgs. For TSMC diode model, default=60.0.
290	$njtssd = njts$	Non-ideality factor for jtssd (bsim4.6).
291	$njtsswd = njtssw$	Non-ideality factor for jtsswd (bsim4.6).
292	$njtsswgd = njtsswg$	Non-ideality factor for jtsswgd (bsim4.6).
293	$xtss = 0.02$	Power dependence of jtss on temperature.
294	$xtssd = \text{xtss}'$	Power dependence of jtssd on temperature.
295	$xtssws = 0.02$	Power dependence of jtssws on temperature.
296	$xtsswd = \text{xtssws}'$	Power dependence of jtsswd on temperature.
297	$xtsswgs = 0.02$	Power dependence of jtsswgs on temperature.
298	$xtsswgd = \text{xtsswgs}'$	Power dependence of jtsswgd on temperature.

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299	<code>vtss=10.0 V</code>	Source bottom trap-assisted voltage dependent parameter.
300	<code>vtssd=`vtssV'</code>	Drain bottom trap-assisted voltage dependent parameter.
301	<code>vtssws=10.0 V</code>	Source STI sidewall trap-assisted voltage dependent parameter.
302	<code>vtsswd=`vtsswsV'</code>	Drain STI sidewall trap-assisted voltage dependent parameter.
303	<code>vtsswgs=10.0 V</code>	Source gate-edge sidewall trap-assisted voltage dependent parameter.
304	<code>vtsswgd=`vtsswgsV'</code>	Drain gate-edge sidewall trap-assisted voltage dependent parameter.
305	<code>tnjts=0.0</code>	Temperature coefficient for <code>njts</code> .
306	<code>tnjtssw=0.0</code>	Temperature coefficient for <code>njtssw</code> .
307	<code>tnjtsswg=0.0</code>	Temperature coefficient for <code>njtsswg</code> .
308	<code>tnjtssd=tnjts</code>	Temperature coefficient for <code>njtssd</code> (bsim4.6).
309	<code>tnjtsswd=tnjtssw</code>	Temperature coefficient for <code>njtsswd</code> (bsim4.6).
310	<code>tnjtsswgd=tnjtsswg</code>	Temperature coefficient for <code>njtsswgd</code> (bsim4.6).
311	<code>dskip=yes</code>	Use simple piece-wise linear model for diode currents below $0.1 \cdot i_{abstol}$. Possible values are <code>no</code> and <code>yes</code> .
312	<code>imelt=`imaxA'</code>	Explosion current.
313	<code>jmelt=`jmaxA/m'²</code>	Explosion current density.
314	<code>jtweff=0.0 m</code>	TAT current width dependence.

TSMC junction diode model parameters

315	<code>mnr=21.0</code>	Fitting parameter for resistance induced non-ideality factor.
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BSIM4 Level-14 Model (bsim4)

316	$b_{nr}=0.0$	Fitting parameter for resistance induced non-ideality factor.
317	$c_{nr}=0.0 \text{ 1/V m}$	Fitting parameter for resistance induced non-ideality factor.
318	$d_{nr}=0.0 \text{ 1/V}$	Fitting parameter for resistance induced non-ideality factor.
319	$t_{mnr}=0.0$	Temperature coefficient for m_{nr} .
320	$t_{c_{nr}}=0.0$	Temperature coefficient for c_{nr} .
321	$t_{d_{nr}}=0.0$	Temperature coefficient for d_{nr} .
322	$n_{rfd}=1.0 \text{ A/m}^2$	Source bottom trap-assisted saturation current density.
323	$j_{sswg}=0.0$	Sidewall-gate junction reverse saturation current density.

Junction capacitance model parameters

324	$c_j=5e-4 \text{ F/m}^2$	Zero bias bottom junction capacitance per unit area. Alias of c_{js} .
325	$c_{js}=5.0e-4 \text{ F/m}^2$	Zero bias source bottom junction capacitance per unit area.
326	$c_{jd}=\text{'c}_{js}\text{F/m}^2$	Zero bias drain bottom junction capacitance per unit area.
327	$m_j=1/2$	Bottom junction capacitance grading coefficient. Alias of m_{js} .
328	$m_{js}=1/2$	Source bottom junction capacitance grading coefficient.
329	$m_{jd}=\text{'m}_{js}$	Drain bottom junction capacitance grading coefficient.
330	$p_b=1.0 \text{ V}$	Bottom junction built-in potential. Alias of p_{bs} .
331	$p_{bs}=1.0 \text{ V}$	Source bottom junction built-in potential.
332	$p_{bd}=\text{'p}_{bs}\text{V}$	Drain bottom junction built-in potential.
333	$f_c=0.5$	Forward-bias depletion capacitance threshold.
334	$c_{jsw}=5e-10 \text{ F/m}$	Sidewall junction capacitance per unit periphery. Alias of c_{jsws} .
335	$c_{jsws}=5.0e-10 \text{ F/m}$	Source sidewall junction capacitance per unit periphery.
336	$c_{jswd}=\text{'c}_{jsws}\text{F/m}$	Drain sidewall junction capacitance per unit periphery.

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337	$mj_{sw}=0.33$	Isolation-edge sidewall junction capacitance grading coefficient. Alias of mjsws.
338	$mj_{sws}=0.33$	Isolation-edge sidewall source junction capacitance grading coefficient.
339	$mj_{swd}=\text{'mjsws'}$	Isolation-edge sidewall drain junction capacitance grading coefficient.
340	$pbsw=1.0\text{ V}$	Isolation-edge sidewall junction built-in potential. Alias of pbsws.
341	$pbsws=1.0\text{ V}$	Isolation-edge sidewall source junction built-in potential.
342	$pbswd=\text{'pbswsV'}$	Isolation-edge sidewall drain junction built-in potential.
343	$cj_{swg}=\text{'cjswF/m'}$	Gate-side junction capacitance per unit width. Alias of cjswgs.
344	$cj_{swgs}=\text{'cjswsF/m'}$	Gate-side source junction capacitance per unit width.
345	$cj_{swgd}=\text{'cjswgsF/m'}$	Gate-side source junction capacitance per unit width.
346	$mj_{swg}=\text{'mjsw'}$	Gate-edge sidewall junction grading coefficient. Alias of mjswgs.
347	$mj_{swgs}=\text{'mjsws'}$	Gate-edge sidewall source junction grading coefficient.
348	$mj_{swgd}=\text{'mjswgs'}$	Gate-edge sidewall junction grading coefficient.
349	$pbswg=\text{'pbswV'}$	Gate-edge sidewall junction built-in potential. Alias of pbswgs.
350	$pbswgs=\text{'pbswsV'}$	Gate-edge sidewall source junction built-in potential.
351	$pbswgd=\text{'pbswgsV'}$	Gate-edge sidewall drain junction built-in potential.
352	$f_{csw}=0.5$	Side-wall forward-bias depletion capacitance threshold.

Temperature effects parameters

353	t_{nom} (C)	Parameters measurement temperature. Default set by options.
354	$t_{rise}=0.0\text{ C}$	Temperature rise from ambient, alias of dtemp. It served as the default value of instance trise.

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BSIM4 Level-14 Model (bsim4)

355	<code>ute=-1.5</code>	Mobility temperature exponent.
356	<code>kt1=-0.11 V</code>	Temperature coefficient for threshold voltage.
357	<code>kt1l=0.0 V m</code>	Channel length dependence of the temperature coefficient for threshold voltage.
358	<code>kt2=0.022</code>	Body-bias coefficient of Vth temperature effect.
359	<code>ua1=1.0e-9 m/V</code>	Temperature coefficient for ua. When tempmod=1, units should be 1/C.
360	<code>ub1=-1.0e-18 m²/V²</code>	Temperature coefficient for ub. When tempmod=1, units should be 1/C.
361	<code>uc1=-0.056 1/V (mobmod=1) / -5.6e-11 m/V² (modmod=0,2)</code>	Temperature coefficient for uc. When tempmod=1, units should be 1/C.
362	<code>ud1=0.0 /m²</code>	Temperature coefficient of ud.
363	<code>at=3.3e4 m/s</code>	Temperature coefficient for vsat. When tempmod=1, units should be 1/C.
364	<code>pvt=0.0 Ω m</code>	Temperature coefficient for Rds. If tempmod=1, units of the parameter equals 1/C.
365	<code>tlev=0</code>	DC temperature selector.
366	<code>tlevc=0</code>	AC temperature selector.
367	<code>eg=1.124519231 V</code>	Energy band gap.
368	<code>gap1=7.02e-4 V/C</code>	Band gap temperature coefficient.
369	<code>gap2=1108 C</code>	Band gap temperature offset.
370	<code>n=1.0</code>	junction emission coefficient. Alias of njs.
371	<code>njs=1.0</code>	Bulk-Source junction emission coefficient.
372	<code>njd=`njs`</code>	Bulk-Drain junction emission coefficient.

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373	<code>xti=3</code>	Saturation current temperature exponent. Alias of <code>xtis</code> .
374	<code>xtis=3.0</code>	Bulk-Source junction saturation current temperature exponent.
375	<code>xtid=`xtis`</code>	Bulk-Drain junction saturation current temperature exponent.
376	<code>pta=0.0 V/C</code>	Temperature coefficient for <code>pb</code> . Alias of <code>tpb</code> .
377	<code>tpb=0.0 V/C</code>	Temperature coefficient for <code>pb</code> .
378	<code>ptp=0.0 V/C</code>	Temperature coefficient for <code>pbsw</code> . Alias of <code>tpbsw</code> .
379	<code>tpbsw=0.0 V/C</code>	Temperature coefficient for <code>pbsw</code> .
380	<code>tpbswg=0.0 V/C</code>	Temperature coefficient for <code>pbswg</code> .
381	<code>cta=0.0 1/C</code>	Temperature coefficient for <code>cj</code> . Alias of <code>tcj</code> .
382	<code>tcj=0.0 1/C</code>	Temperature coefficient for <code>cj</code> .
383	<code>ctp=0.0 1/C</code>	Temperature coefficient for <code>cjsw</code> . Alias of <code>tcjsw</code> .
384	<code>tcjsw=0.0 1/C</code>	Temperature coefficient for <code>cjsw</code> .
385	<code>tcjswg=0.0 1/C</code>	Temperature coefficient for <code>cjswg</code> .
386	<code>tnfactor=0.0</code>	Temperature parameter for <code>nfactor</code> .
387	<code>teta0=0.0</code>	Temperature parameter for <code>eta0</code> .
388	<code>tvoffcv=0.0 1/C</code>	Temperature parameter for <code>tvoffcv</code> .

LOD model parameters

389	<code>saref=1.0e-6 m</code>	Reference distance between <code>od</code> edge to poly of one side.
390	<code>sbref=1.0e-6 m</code>	Reference distance between <code>od</code> edge to poly of the other side.
391	<code>sl=2.0e-6 m</code>	Character length along length for stress effect.
392	<code>lsl=0.0</code>	Length dependence of <code>sl</code> .
393	<code>wsl=0.0</code>	Width dependence of <code>sl</code> .

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BSIM4 Level-14 Model (bsim4)

394	$psl=0.0$	Cross-term dependence of sl .
395	$sw=2.0e-6$ m	Character length along width for stress effect.
396	$lsw=0.0$	Length dependence of sw .
397	$ws w=0.0$	Width dependence of sw .
398	$psw=0.0$	Cross-term dependence of sw .
399	$sk0=0.0$	First coefficient of stress effect.
400	$lsk0=0.0$	Length dependence of $sk0$.
401	$wsk0=0.0$	Width dependence of $sk0$.
402	$psk0=0.0$	Cross-term dependence of $sk0$.
403	$sk1=0.0$ m	Length coefficient of stress effect.
404	$lsk1=0.0$	Length dependence of $sk1$.
405	$wsk1=0.0$	Width dependence of $sk1$.
406	$psk1=0.0$	Cross-term dependence of $sk1$.
407	$sk2=0.0$ m	Width coefficient of stress effect.
408	$lsk2=0.0$	Length dependence of $sk2$.
409	$wsk2=0.0$	Width dependence of $sk2$.
410	$psk2=0.0$	Cross-term dependence of $sk2$.
411	$k=0.0$	Ratio of velocity/mobility changes for stress.
412	$lk=0.0$	Length dependence of k .
413	$wk=0.0$	Width dependence of k .
414	$pk=0.0$	Cross-term dependence of k .
415	$wlod=0.0$ m	Length parameter for stress effect.

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BSIM4 Level-14 Model (bsim4)

416	$ku0=0.0$ m	Mobility degradation/enhancement coefficient for stress effect.
417	$kvsat=0.0$ m	Saturation velocity degradation/enhancement parameter for stress effect.
418	$tku0=0.0$	Temperature coefficient of $ku0$.
419	$llodku0=0.0$	Length parameter for $u0$ stress effect.
420	$wlodku0=0.0$	Width parameter for $u0$ stress effect.
421	$kvth0=0.0$ V m	Threshold shift parameter for stress effect.
422	$llodvth=0.0$	Length parameter for vth stress effect.
423	$wlodvth=0.0$	Width parameter for vth stress effect.
424	$stk2=0.0$ m	$k2$ shift factor related to $vth0$ change.
425	$lodk2=1.0$	$k2$ shift modification factor for stress effect.
426	$steta0=0.0$ m	$eta0$ shift factor related to $vth0$ change.
427	$lodeta0=1.0$	$eta0$ shift modification factor for stress effect.

WPE model parameters

428	$web=0.0$	Coefficient for SCB.
429	$wec=0.0$	Coefficient for SCC.
430	$kvth0we=0.0$ V	Threshold shift factor for well proximity effect.
431	$k2we=0.0$	$K2$ shift factor for well proximity effect.
432	$ku0we=0.0$	Mobility degradation factor for well proximity effect.
433	$scref=1.0e-6$ m	Reference distance to calculate SCA, SCB and SCC.

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BSIM4 Level-14 Model (bsim4)

Noise model parameters

- 434 $\text{noia}=6.25\text{e}41$ (nmos) / $6.188\text{e}40$ (pmos) $\text{s}^{(1-\text{EF})} / (\text{eV m}^2)$
Flicker noise parameter A.
- 435 $\text{noib}=3.125\text{e}26$ (nmos) / $1.5\text{e}25$ (pmos) $\text{s}^{(1-\text{EF})} / \text{eV}$
Flicker noise parameter C.
- 436 $\text{noic}=8.75\text{e}9$ $\text{s}^{(1-\text{EF})} \text{m}^2 / \text{eV}$
Flicker noise parameter C.
- 437 $\text{em}=4.1\text{e}7$ V/m Saturation field.
- 438 $\text{af}=1.0$ Flicker noise exponent.
- 439 $\text{ef}=1.0$ Flicker noise frequency exponent.
- 440 $\text{kf}=0.0$ $\text{A}^{(2-\text{EF})} \text{s}^{(1-\text{EF})} \text{F}$
Flicker noise coefficient.
- 441 $\text{lintnoi}=0.0$ m Lint offset for noise calculation.
- 442 $\text{wnoi}=1.0\text{e}-5$ m Channel width at which noise parameters were extracted.
- 443 $\text{ntnoi}=1.0$ Noise factor for short-channel devices for TNOIMOD=0 only.
- 444 $\text{tnoia}=1.5$ Coefficient of channel-length dependence of total channel thermal noise.
- 445 $\text{tnoib}=3.5$ Coefficient of channel-length dependence of total channel thermal noise.
- 446 $\text{tnoic}=0.0$ Thermal noise parameter.
- 447 $\text{rnoia}=0.577$ Thermal noise coefficient.
- 448 $\text{rnoib}=0.5164$ Thermal noise coefficient.
- 449 $\text{rnoic}=0.395$ Thermal noise coefficient.

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BSIM4 Level-14 Model (bsim4)

Substrate Network parameters

450	<code>xrcrg1=12.0</code>	Parameter for distributed channel-resistance effect for both intrinsic-input resistance and charge-deficit NQS models.
451	<code>xrcrg2=1.0</code>	Parameter to account for the excess channel diffusion resistance for both intrinsic-input resistance and charge-deficit NQS models.
452	<code>rbpb=50.0 Ω</code>	Resistance connected between bNode' and bNode.
453	<code>rbpbx0=100.0 Ω</code>	Body resistance RBPBX scaling.
454	<code>rbpbx1=0.0</code>	Body resistance RBPBX L scaling.
455	<code>rbpbxw=0.0</code>	Body resistance RBPBX W scaling.
456	<code>rbpbxnf=0.0</code>	Body resistance RBPBX NF scaling.
457	<code>rbpby0=100.0 Ω</code>	Body resistance RBPBY scaling.
458	<code>rbpby1=0.0</code>	Body resistance RBPBY L scaling.
459	<code>rbpbyw=0.0</code>	Body resistance RBPBY W scaling.
460	<code>rbpbynf=0.0</code>	Body resistance RBPBY NF scaling.
461	<code>rbpd=50.0 Ω</code>	Resistance connected between bNode' and dbNode.
462	<code>rbpd0=50.0 Ω</code>	Body resistance RBPD scaling.
463	<code>rbpd1=0.0</code>	Body resistance RBPD L scaling.
464	<code>rbpdw=0.0</code>	Body resistance RBPD W scaling.
465	<code>rbpdnf=0.0</code>	Body resistance RBPD NF scaling.
466	<code>rbps=50.0 Ω</code>	Resistance connected between bNode' and sbNode.
467	<code>rbps0=50.0 Ω</code>	Body resistance RBPS scaling.
468	<code>rbps1=0.0</code>	Body resistance RBPS L scaling.

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BSIM4 Level-14 Model (bsim4)

469	$rbpsw=0.0$	Body resistance RBPS W scaling.
470	$rbpsnf=0.0$	Body resistance RBPS NF scaling.
471	$rbdb=50.0 \Omega$	Resistance connected between dbNode and bNode.
472	$rbsb=50.0 \Omega$	Resistance connected between sbNode and bNode.
473	$rbsbx0=100.0 \Omega$	Body resistance RBSBX scaling.
474	$rbsby0=100.0 \Omega$	Body resistance RSBY scaling.
475	$rbdbx0=100.0 \Omega$	Body resistance RBDBX scaling.
476	$rbdbby0=100.0 \Omega$	Body resistance RBDBY scaling.
477	$rbsdbxl=0.0$	Body resistance RBSDBX L scaling.
478	$rbsdbxw=0.0$	Body resistance RBSDBX W scaling.
479	$rbsdbxnf=0.0$	Body resistance RBSDBX NF scaling.
480	$rbsdbyl=0.0$	Body resistance RBSDBY L scaling.
481	$rbsdbyw=0.0$	Body resistance RBSDBY W scaling.
482	$rbsdbynf=0.0$	Body resistance RBSDBY NF scaling.
483	$gbmin=1.0e-12 \text{ } 1/\Omega$	Conductance in parallel with each of the five substrate resistances to avoid potential numerical instability due to an unreasonably large substrate resistance.

Default for instance parameters

484	$w=5e-6 \text{ m}$	Default channel width.
485	$l=5e-6 \text{ m}$	Default channel length.
486	$as \text{ (m}^2\text{)}$	Default area of source diffusion.
487	$ad \text{ (m}^2\text{)}$	Default area of drain diffusion.

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BSIM4 Level-14 Model (bsim4)

488	<code>ps</code> (m)	Default perimeter of source diffusion.
489	<code>pd</code> (m)	Default perimeter of drain diffusion.
490	<code>nrd</code>	Default number of squares of drain diffusion.
491	<code>nrs</code>	Default number of squares of source diffusion.
492	<code>rdc=0.0</code> Ω	Default drain contact resistance.
493	<code>rsc=0.0</code> Ω	Default source contact resistance.

Auto Model Selector parameters

494	<code>wmax=1.0</code> m	Maximum channel width for which the model is valid.
495	<code>wmin=0.0</code> m	Minimum channel width for which the model is valid.
496	<code>lmax=1.0</code> m	Maximum channel length for which the model is valid.
497	<code>lmin=0.0</code> m	Minimum channel length for which the model is valid.

Operating region warning control parameters

498	<code>alarm=none</code>	Forbidden operating region. Possible values are <code>none</code> , <code>off</code> , <code>triode</code> , <code>sat</code> , <code>subth</code> , and <code>rev</code> .
499	<code>imax=1.0</code> A	Maximum allowable junction current.
500	<code>jmax=1.0e8</code> A/m ²	Maximum allowable junction current density.
501	<code>bvj=infinity</code> V	Voltage at which junction breakdown warning is issued.
502	<code>vbox=3e9</code> <code>toxe</code> V	Oxide breakdown voltage.
503	<code>warn=on</code>	Parameter to turn warnings on and off. Possible values are <code>off</code> and <code>on</code> .

Safe Operating Areas Parameters

- 504 `vds_max=infinity` V
Maximum allowed voltage cross source and drain.
- 505 `vgd_max=infinity` V
Maximum allowed voltage cross drain and gate.
- 506 `vgs_max=infinity` V
Maximum allowed voltage cross source/bulk and gate.
- 507 `vbd_max=infinity` V
Maximum allowed voltage cross drain/source and bulk.
- 508 `vbs_max=vbd_max` V
Maximum allowed voltage cross source and bulk.
- 509 `vgb_max=infinity` V
Maximum allowed voltage cross gate and bulk.
- 510 `vgdr_max=vgd_max` V
Maximum allowed reverse voltage cross gate and drain.
- 511 `vgsr_max=vgs_max` V
Maximum allowed reverse voltage cross gate and source.
- 512 `vgbr_max=vgb_max` V
Maximum allowed reverse voltage cross gate and bulk.
- 513 `vbsr_max=vbs_max` V
Maximum allowed reverse voltage cross bulk and source.
- 514 `vbdr_max=vbd_max` V
Maximum allowed reverse voltage cross bulk and drain.

Length dependent parameters

- 515 `lvtho=0.0` V
Length dependence of `vtho`.
- 516 `lvth0`
Length dependence of `vth0`.
- 517 `lvfb=0.0`
Length dependence of `vfb`.
- 518 `lk1=0.0` |V
Length dependence of `k1`.

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519	$lk2=0.0$	Length dependence of $k2$.
520	$lk3=0.0$	Length dependence of $k3$.
521	$lk3b=0.0$ 1/V	Length dependence of $k3b$.
522	$lw0=0.0$ m	Length dependence of $w0$.
523	$lgamma1=0.0$ V	Length dependence of $gamma1$.
524	$lgamma2=0.0$ V	Length dependence of $gamma2$.
525	$lvbx=0.0$ V	Length dependence of vb_x .
526	$lvbm=0.0$ V	Length dependence of v_{bm} .
527	$ldvt0=0.0$	Length dependence of $dvt0$.
528	$ldvt1=0.0$	Length dependence of $dvt1$.
529	$ldvt2=0.0$ 1/V	Length dependence of $dvt2$.
530	$ldvt0w=0.0$	Length dependence of $dvt0w$.
531	$ldvt1w=0.0$	Length dependence of $dvt1w$.
532	$ldvt2w=0.0$	Length dependence of $dvt2w$.
533	$la0=0.0$	Length dependence of $a0$.
534	$lb0=0.0$ m	Length dependence of $b0$.
535	$lb1=0.0$ m	Length dependence of $b1$.
536	$la1=0.0$	Length dependence of $a1$.
537	$la2=0.0$	Length dependence of $a2$.
538	$lags=0.0$ F/m ² V	Length dependence of ags .
539	$lketa=0.0$ 1/V	Length dependence of $keta$.

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BSIM4 Level-14 Model (bsim4)

540	$l_{nsub}=0.0 \text{ cm}^{-3}$	Length dependence of nsub.
541	$l_{ngate}=0.0 \text{ cm}^{-3}$	Length dependence of ngate.
542	$l_{xj}=0.0 \text{ m}$	Length dependence of xj.
543	$l_{dwg}=0.0 \text{ m/V}$	Length dependence of dwg.
544	$l_{dwb}=0.0 \text{ m}/ V$	Length dependence of dwb.
545	$l_{xt}=0.0 \text{ m}$	Length dependence of xt.
546	$l_{rdsw}=0.0 \text{ } \Omega \text{ } \mu\text{m}$	Length dependence of rdsw.
547	$l_{prwb}=0.0 \text{ } 1/ V$	Length dependence of prwb.
548	$l_{prwg}=0.0 \text{ } 1/V$	Length dependence of prwg.
549	$l_{wr}=0.0$	Length dependence of wr.
550	$l_{u0}=0.0$	Length dependence of u0.
551	$l_{vsat}=0.0 \text{ m/s}$	Length dependence of vsat.
552	$l_{ua}=0.0 \text{ m/V}$	Length dependence of ua.
553	$l_{ub}=0.0 \text{ m}^2/V^2$	Length dependence of ub.
554	$l_{uc}=0.0 \text{ m}/V^2$	Length dependence of uc.
555	$l_{ud}=0.0 \text{ } /\text{m}^2$	Length dependence of ud.
556	$l_{up}=0.0$	Length dependence of up.
557	$l_{lp}=0.0 \text{ m}$	Length dependence of lp.
558	$l_{drout}=0.0$	Length dependence of drout.
559	$l_{pclm}=0.0$	Length dependence of pclm.
560	$l_{pdiblc1}=0.0$	Length dependence of pdiblc1.

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BSIM4 Level-14 Model (bsim4)

561	lpdiblc2=0.0		Length dependence of pdiblc2.
562	lpdiblcb=0.0	1/V	Length dependence of pdiblcd.
563	lpscbe1=0.0	V/m	Length dependence of pscbe1.
564	lpscbe2=0.0	m/V	Length dependence of pscbe2.
565	lpvag=0.0		Length dependence of pvag.
566	ldelta=0.0	V	Length dependence of delta.
567	lcdsc=0.0	F/m ²	Length dependence of cdsc.
568	lcdscb=0.0	F/m ² V	Length dependence of cdsb.
569	lcdscd=0.0	F/m ² V	Length dependence of cdsd.
570	lnfactor=0.0		Length dependence of nfactor.
571	ltnfactor=0.0		Length dependence of tnfactor.
572	lcit=0.0	F	Length dependence of cit.
573	lvoff=0.0	V	Length dependence of voff.
574	ldsub=0.0		Length dependence of dsub.
575	leta0=0.0		Length dependence of eta0.
576	lteta0=0.0		Length dependence of teta0.
577	letab=0.0	1/V	Length dependence of etab.
578	lalpha0=0.0	m/V	Length dependence of alpha0.
579	lalpha1=0.0	m/V	Length dependence of alpha1.
580	lbeta0=0.0	1/V	Length dependence of beta0.
581	lcgsl=0.0	F/m	Length dependence of cgsl.

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BSIM4 Level-14 Model (bsim4)

582	$l_{cgdl}=0.0$	F/m	Length dependence of $cgdl$.
583	$l_{clc}=0.0$	m	Length dependence of clc .
584	$l_{cle}=0.0$		Length dependence of cle .
585	$l_{cf}=0.0$	F/m	Length dependence of cf .
586	$l_{vfbcv}=0.0$		Length dependence of $vfbcv$.
587	$l_{acde}=0.0$		Length dependence of $acde$.
588	$l_{moin}=0.0$		Length dependence of $moin$.
589	$l_{noff}=0.0$		Length dependence of $noff$.
590	$l_{voffcv}=0.0$		Length dependence of $voffcv$.
591	$l_{tvoffcv}=0.0$		Length dependence of $tvoffcv$.
592	$l_{minvcv}=0.0$		Length dependence of $minvcv$.
593	$l_{kt1}=0.0$	V	Length dependence of $kt1$.
594	$l_{kt1l}=0$	V m	Length dependence of $kt1l$.
595	$l_{kt2}=0.0$		Length dependence of $kt2$.
596	$l_{at}=0.0$	m/s	Length dependence of at .
597	$l_{ua1}=0.0$	m/V	Length dependence of $ua1$.
598	$l_{ub1}=0.0$	m^2/V^2	Length dependence of $ub1$.
599	$l_{uc1}=0.0$	m/V^2	Length dependence of $uc1$.
600	$l_{ud1}=0.0$	$/m^2$	Length dependence of $ud1$.
601	$l_{prt}=0.0$	Ω	Length dependence of prt .
602	$l_{ute}=0.0$		Length dependence of ute .
603	$l_{ndep}=0.0$		Length dependence of $ndep$.

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

604	lnsd=0.0	Length dependence of nsd.
605	lphin=0.0	Length dependence of phin.
606	llpe0=0.0	Length dependence of lpe0.
607	llpeb=0.0	Length dependence of lpeb.
608	ldvtp0=0.0	Length dependence of dvtp0.
609	ldvtp1=0.0	Length dependence of dvtp1.
610	ldvtp2=0.0	Length dependence of dvtp2.
611	ldvtp3=0.0	Length dependence of dvtp3.
612	ldvtp4=0.0	Length dependence of dvtp4.
613	ldvtp5=0.0	Length dependence of dvtp5.
614	leu=0.0	Length dependence of eu.
615	lminv=0.0	Length dependence of minv.
616	lfprout=0.0	Length dependence of fprout.
617	lpdits=0.0	Length dependence of pdits.
618	lpditsd=0.0	Length dependence of pditsd.
619	lrsw=0.0	Length dependence of rdw.
620	lrsd=0.0	Length dependence of rsw.
621	lagidl=0.0	Length dependence of agidl.
622	lbgidl=0.0	Length dependence of bgidl.
623	lcgidl=0.0	Length dependence of cgidl.
624	legidl=0.0	Length dependence of egidl.
625	lfgidl=0.0	Length dependence of fgidl.

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

626	lkgidl=0.0	Length dependence of kgidl.
627	lrgidl=0.0	Length dependence of rgidl.
628	lfgisl=lfgidl	Length dependence of fgisl.
629	lkgisl=lkgidl	Length dependence of kgisl.
630	lrgisl=lrgidl	Length dependence of rgisl.
631	laigbacc=0.0	Length dependence of aigbacc.
632	lbigbacc=0.0	Length dependence of bigbacc.
633	lcigbacc=0.0	Length dependence of cigbacc.
634	lnigbacc=0.0	Length dependence of nigbacc.
635	laigbinv=0.0	Length dependence of aigbinv.
636	lbigbinv=0.0	Length dependence of bigbinv.
637	lcigbinv=0.0	Length dependence of cigbinv.
638	leigbinv=0.0	Length dependence of eigbinv.
639	lnigbinv=0.0	Length dependence of nigbinv.
640	laigc=0.0	Length dependence of aigc.
641	lbigc=0.0	Length dependence of bigc.
642	lcigc=0.0	Length dependence of cigc.
643	laigsd=0.0	Length dependence of aigsd.
644	lbigsd=0.0	Length dependence of bigsd.
645	lcigsd=0.0	Length dependence of cigsd.
646	lnigc=0.0	Length dependence of nigc.
647	lpoxedge=0.0	Length dependence of poxedge.

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

648	lpigcd=0.0	Length dependence of pigcd.
649	lntox=0.0	Length dependence of ntox.
650	lckappas=0.0	Length dependence of ckappas.
651	lckappad=0.0	Length dependence of ckappad.
652	lxrcrg1=0.0	Length dependence of xrcrg1.
653	lxrcrg2=0.0	Length dependence of xrcrg2.
654	lvfbsdoff=0.0	Length dependence of vfbsdoff.
655	llambda=0.0	Length dependence of lambda.
656	lvtl=0.0	Length dependence of vtl.
657	lxn=0.0	Length dependence of xn.
658	lkvth0we=0.0 V	Length dependence of kvth0we.
659	lk2we=0.0	Length dependence of k2we.
660	lku0we=0.0	Length dependence of ku0we.
661	lku0=0.0 m ¹¹ odku0	Length dependence of ku0.
662	lkvth0=0.0 V m ¹¹ odku0	Length dependence of kvth0.
663	lucs=0.0	Length dependence of ucs.
664	lucste=0.0	Length dependence of ucste.

Width dependent parameters

665	wvtho=0.0 V	Width dependence of vtho.
666	wvth0	Width dependence of vth0.
667	wvfb=0.0	Width dependence of vfb.

Virtuoso Simulator Components and Device Models Reference
BSIM4 Level-14 Model (bsim4)

668	$wk1=0.0$	$ V$	Width dependence of $k1$.
669	$wk2=0.0$		Width dependence of $k2$.
670	$wk3=0.0$		Width dependence of $k3$.
671	$wk3b=0.0$	$1/V$	Width dependence of $k3b$.
672	$ww0=0.0$	m	Width dependence of $w0$.
673	$wgamma1=0.0$	$ V$	Width dependence of $gamma1$.
674	$wgamma2=0.0$	$ V$	Width dependence of $gamma2$.
675	$wvbx=0.0$	V	Width dependence of vbx .
676	$wvbm=0.0$	V	Width dependence of vbm .
677	$wdvt0=0.0$		Width dependence of $dvt0$.
678	$wdvt1=0.0$		Width dependence of $dvt1$.
679	$wdvt2=0.0$	$1/V$	Width dependence of $dvt2$.
680	$wdvt0w=0.0$		Width dependence of $dvt0w$.
681	$wdvt1w=0.0$		Width dependence of $dvt1w$.
682	$wdvt2w=0.0$		Width dependence of $dvt2w$.
683	$wa0=0.0$		Width dependence of $a0$.
684	$wb0=0.0$	m	Width dependence of $b0$.
685	$wb1=0.0$	m	Width dependence of $b1$.
686	$wa1=0.0$		Width dependence of $a1$.
687	$wa2=0.0$		Width dependence of $a2$.
688	$wags=0.0$	$F/m^2 V$	Width dependence of ags .

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

689	$wketa=0.0 \text{ 1/V}$	Width dependence of keta.
690	$wnsub=0.0 \text{ cm}^{-3}$	Width dependence of nsub.
691	$wngate=0.0 \text{ cm}^{-3}$	Width dependence of ngate.
692	$wxj=0.0 \text{ m}$	Width dependence of xj.
693	$wdwg=0.0 \text{ m/V}$	Width dependence of dwg.
694	$wdwb=0.0 \text{ m/ V}$	Width dependence of dwb.
695	$wxt=0.0 \text{ m}$	Width dependence of xt.
696	$wrdsw=0.0 \text{ } \Omega \text{ } \mu\text{m}$	Width dependence of rdsw.
697	$wprwb=0.0 \text{ 1/ V}$	Width dependence of prwb.
698	$wprwg=0.0 \text{ 1/V}$	Width dependence of prwg.
699	$wwr=0.0$	Width dependence of wr.
700	$wu0=0.0$	Width dependence of u0.
701	$wvsat=0.0 \text{ m/s}$	Width dependence of vsat.
702	$wua=0.0 \text{ m/V}$	Width dependence of ua.
703	$wub=0.0 \text{ m}^2/\text{V}^2$	Width dependence of ub.
704	$wuc=0.0 \text{ m/V}^2$	Width dependence of uc.
705	$wud=0.0 \text{ /m}^2$	Width dependence of ud.
706	$wup=0.0$	Width dependence of up.
707	$wlp=0.0 \text{ m}$	Width dependence of lp.
708	$wdrout=0.0$	Width dependence of drout.
709	$wpclm=0.0$	Width dependence of pclm.

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

710	<code>wpdiblc1=0.0</code>	Width dependence of <code>pdiblc1</code> .
711	<code>wpdiblc2=0.0</code>	Width dependence of <code>pdiblc2</code> .
712	<code>wpdiblcb=0.0</code> 1/V	Width dependence of <code>pdiblcb</code> .
713	<code>wpscbe1=0.0</code> V/m	Width dependence of <code>pscbe1</code> .
714	<code>wpscbe2=0.0</code> m/V	Width dependence of <code>pscbe2</code> .
715	<code>wpvag=0.0</code>	Width dependence of <code>pvag</code> .
716	<code>wdelta=0.0</code> V	Width dependence of <code>delta</code> .
717	<code>wcdsc=0.0</code> F/m ²	Width dependence of <code>cdsc</code> .
718	<code>wcdscb=0.0</code> F/m ² V	Width dependence of <code>cdscb</code> .
719	<code>wcdscd=0.0</code> F/m ² V	Width dependence of <code>cdscd</code> .
720	<code>wnfactor=0.0</code>	Width dependence of <code>nfactor</code> .
721	<code>wtnfactor=0.0</code>	Width dependence of <code>tnfactor</code> .
722	<code>wcit=0.0</code> F	Width dependence of <code>cit</code> .
723	<code>wvoff=0.0</code> V	Width dependence of <code>voff</code> .
724	<code>wdsub=0.0</code>	Width dependence of <code>dsub</code> .
725	<code>weta0=0.0</code>	Width dependence of <code>eta0</code> .
726	<code>wteta0=0.0</code>	Width dependence of <code>teta0</code> .
727	<code>wetab=0.0</code> 1/V	Width dependence of <code>etab</code> .
728	<code>walpha0=0.0</code> m/V	Width dependence of <code>alpha0</code> .
729	<code>walpha1=0.0</code> m/V	Width dependence of <code>alpha1</code> .
730	<code>wbeta0=0.0</code> 1/V	Width dependence of <code>beta0</code> .

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

731	wcgs1=0.0 F/m	Width dependence of cgsl.
732	wcgdl=0.0 F/m	Width dependence of cgdl.
733	wclc=0.0 m	Width dependence of clc.
734	wcle=0.0	Width dependence of cle.
735	wcf=0.0 F/m	Width dependence of cf.
736	wvfbcv=0.0	Width dependence of vfbcv.
737	wacde=0.0	Width dependence of acde.
738	wmoin=0.0	Width dependence of moin.
739	wnoff=0.0	Width dependence of noff.
740	wvoffcv=0.0	Width dependence of voffcv.
741	wtvoffcv=0.0	Width dependence of tvoffcv.
742	wminvcv=0.0	Width dependence of minvcv.
743	wkt1=0.0 V	Width dependence of kt1.
744	wkt1l=0 V m	Width dependence of kt1l.
745	wkt2=0.0	Width dependence of kt2.
746	wat=0.0 m/s	Width dependence of at.
747	wua1=0.0 m/V	Width dependence of ua1.
748	wub1=0.0 m ² /V ²	Width dependence of ub1.
749	wuc1=0.0 m/V ²	Width dependence of uc1.
750	wud1=0.0 /m ²	Width dependence of ud1.
751	wprt=0.0 Ω	Width dependence of prt.
752	wute=0.0	Width dependence of ute.

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

753	wndep=0.0	Width dependence of ndep.
754	wnsd=0.0	Width dependence of nsd.
755	wphin=0.0	Width dependence of phin.
756	wlpe0=0.0	Width dependence of lpe0.
757	wlpeb=0.0	Width dependence of lpeb.
758	wdvtp0=0.0	Width dependence of dvtp0.
759	wdvtp1=0.0	Width dependence of dvtp1.
760	wdvtp2=0.0	Width dependence of dvtp2.
761	wdvtp3=0.0	Width dependence of dvtp3.
762	wdvtp4=0.0	Width dependence of dvtp4.
763	wdvtp5=0.0	Width dependence of dvtp5.
764	weu=0.0	Width dependence of eu.
765	wminv=0.0	Width dependence of minv.
766	wfprout=0.0	Width dependence of fprout.
767	wpdits=0.0	Width dependence of pdits.
768	wpditsd=0.0	Width dependence of pditsd.
769	wrdw=0.0	Width dependence of rdw.
770	wrsd=0.0	Width dependence of rsd.
771	wagidl=0.0	Width dependence of agidl.
772	wbgidl=0.0	Width dependence of bgidl.
773	wcgidl=0.0	Width dependence of cgidl.
774	wegidl=0.0	Width dependence of egidl.

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

775	wfgidl=0.0	Width dependence of fgidl.
776	wkgidl=0.0	Width dependence of kgidl.
777	wrgidl=0.0	Width dependence of rgidl.
778	wfgisl=wfgidl	Width dependence of fgisl.
779	wkgisl=wkgidl	Width dependence of kgisl.
780	wrgisl=wrgidl	Width dependence of rgisl.
781	waigbacc=0.0	Width dependence of aigbacc.
782	wbigbacc=0.0	Width dependence of bigbacc.
783	wcigbacc=0.0	Width dependence of cigbacc.
784	wnigbacc=0.0	Width dependence of nigbacc.
785	waigbinv=0.0	Width dependence of aigbinv.
786	wbigbinv=0.0	Width dependence of bigbinv.
787	wcigbinv=0.0	Width dependence of cigbinv.
788	weigbinv=0.0	Width dependence of eigbinv.
789	wnigbinv=0.0	Width dependence of nigbinv.
790	waigc=0.0	Width dependence of aigc.
791	wbigc=0.0	Width dependence of bigc.
792	wcigc=0.0	Width dependence of cigc.
793	waigsd=0.0	Width dependence of aigsd.
794	wbigsd=0.0	Width dependence of bigsd.
795	wcigsd=0.0	Width dependence of cigsd.
796	wnigc=0.0	Width dependence of nigc.

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

797	wpoxedge=0.0	Width dependence of poxedge.
798	wpigcd=0.0	Width dependence of pigcd.
799	wntox=0.0	Width dependence of ntox.
800	wckappas=0.0	Width dependence of ckappas.
801	wckappad=0.0	Width dependence of ckappad.
802	wxrcrg1=0.0	Width dependence of xrcrg1.
803	wxrcrg2=0.0	Width dependence of xrcrg2.
804	wvbsdoff=0.0	Width dependence of vbsdoff.
805	wlambda=0.0	Width dependence of lambda.
806	wvtl=0.0	Width dependence of vtl.
807	wxn=0.0	Width dependence of xn.
808	wkvth0we=0.0 V	Width dependence of kvth0we.
809	wk2we=0.0	Width dependence of k2we.
810	wku0we=0.0	Width dependence of ku0we.
811	wku0=0.0 $m^{w lod ku0}$	Width dependence of ku0.
812	wkvth0=0.0 V $m^{w lod ku0}$	Width dependence of kvth0.
813	wucs=0.0	Width dependence of ucs.
814	wucste=0.0	Width dependence of ucste.

Cross-term dependent parameters

815	pvtho=0.0 V	Cross-term dependence of vtho.
816	pvth0	Cross-term dependence of vth0.

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

817	$p_{vfb}=0.0$	Cross-term dependence of v_{fb} .
818	$p_{k1}=0.0$ $ v$	Cross-term dependence of $k1$.
819	$p_{k2}=0.0$	Cross-term dependence of $k2$.
820	$p_{k3}=0.0$	Cross-term dependence of $k3$.
821	$p_{k3b}=0.0$ $1/V$	Cross-term dependence of $k3b$.
822	$p_{w0}=0.0$ m	Cross-term dependence of $w0$.
823	$p_{\gamma1}=0.0$ $ v$	Cross-term dependence of $\gamma1$.
824	$p_{\gamma2}=0.0$ $ v$	Cross-term dependence of $\gamma2$.
825	$p_{vbx}=0.0$ V	Cross-term dependence of v_{bx} .
826	$p_{vbm}=0.0$ V	Cross-term dependence of v_{bm} .
827	$p_{dvt0}=0.0$	Cross-term dependence of $dvt0$.
828	$p_{dvt1}=0.0$	Cross-term dependence of $dvt1$.
829	$p_{dvt2}=0.0$ $1/V$	Cross-term dependence of $dvt2$.
830	$p_{dvt0w}=0.0$	Cross-term dependence of $dvt0w$.
831	$p_{dvt1w}=0.0$	Cross-term dependence of $dvt1w$.
832	$p_{dvt2w}=0.0$	Cross-term dependence of $dvt2w$.
833	$p_{a0}=0.0$	Cross-term dependence of $a0$.
834	$p_{b0}=0.0$ m	Cross-term dependence of $b0$.
835	$p_{b1}=0.0$ m	Cross-term dependence of $b1$.
836	$p_{a1}=0.0$	Cross-term dependence of $a1$.
837	$p_{a2}=0.0$	Cross-term dependence of $a2$.

Virtuoso Simulator Components and Device Models Reference
BSIM4 Level-14 Model (bsim4)

838	$p_{ags}=0.0 \text{ F/m}^2 \text{ V}$	Cross-term dependence of ags.
839	$p_{keta}=0.0 \text{ 1/V}$	Cross-term dependence of keta.
840	$p_{nsub}=0.0 \text{ cm}^{-3}$	Cross-term dependence of nsub.
841	$p_{ngate}=0.0 \text{ cm}^{-3}$	Cross-term dependence of ngate.
842	$p_{xj}=0.0 \text{ m}$	Cross-term dependence of xj.
843	$p_{dwg}=0.0 \text{ m/V}$	Cross-term dependence of dwg.
844	$p_{dwb}=0.0 \text{ m/ V}$	Cross-term dependence of dwb.
845	$p_{xt}=0.0 \text{ m}$	Cross-term dependence of xt.
846	$p_{rdsw}=0.0 \text{ } \Omega \text{ } \mu\text{m}$	Cross-term dependence of rdsw.
847	$p_{prwb}=0.0 \text{ 1/ V}$	Cross-term dependence of prwb.
848	$p_{prwg}=0.0 \text{ 1/V}$	Cross-term dependence of prwg.
849	$p_{wr}=0.0$	Cross-term dependence of wr.
850	$p_{u0}=0.0$	Cross-term dependence of u0.
851	$p_{vsat}=0.0 \text{ m/s}$	Cross-term dependence of vsat.
852	$p_{ua}=0.0 \text{ m/V}$	Cross-term dependence of ua.
853	$p_{ub}=0.0 \text{ m}^2/\text{V}^2$	Cross-term dependence of ub.
854	$p_{uc}=0.0 \text{ m/V}^2$	Cross-term dependence of uc.
855	$p_{ud}=0.0 \text{ /m}^2$	Cross-term dependence of ud.
856	$p_{up}=0.0$	Cross-term dependence of up.
857	$p_{lp}=0.0 \text{ m}$	Cross-term dependence of lp.
858	$p_{drout}=0.0$	Cross-term dependence of drout.

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

859	ppclm=0.0	Cross-term dependence of pclm.
860	ppdiblc1=0.0	Cross-term dependence of pdiblc1.
861	ppdiblc2=0.0	Cross-term dependence of pdiblc2.
862	ppdiblcb=0.0 1/V	Cross-term dependence of pdiblcd.
863	ppscbe1=0.0 V/m	Cross-term dependence of pscbe1.
864	ppscbe2=0.0 m/V	Cross-term dependence of pscbe2.
865	ppvag=0.0	Cross-term dependence of pvag.
866	pdelta=0.0 V	Cross-term dependence of delta.
867	pcdsc=0.0 F/m ²	Cross-term dependence of cdsc.
868	pcdscb=0.0 F/m ² V	Cross-term dependence of cdsb.
869	pcdscd=0.0 F/m ² V	Cross-term dependence of cdsd.
870	pnfactor=0.0	Cross-term dependence of nfactor.
871	ptnfactor=0.0	Cross-term dependence of tnfactor.
872	pcit=0.0 F	Cross-term dependence of cit.
873	pvoff=0.0 V	Cross-term dependence of voff.
874	pdsb=0.0	Cross-term dependence of dsb.
875	peta0=0.0	Cross-term dependence of eta0.
876	pteta0=0.0	Cross-term dependence of teta0.
877	petab=0.0 1/V	Cross-term dependence of etab.
878	palpha0=0.0 m/V	Cross-term dependence of alpha0.
879	palpha1=0.0 m/V	Cross-term dependence of alpha1.

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

880	$p\beta_0=0.0$	1/V	Cross-term dependence of β_0 .
881	$p\text{cgsl}=0.0$	F/m	Cross-term dependence of cgsl .
882	$p\text{cgdl}=0.0$	F/m	Cross-term dependence of cgdl .
883	$p\text{clc}=0.0$	m	Cross-term dependence of clc .
884	$p\text{cle}=0.0$		Cross-term dependence of cle .
885	$p\text{cf}=0.0$	F/m	Cross-term dependence of cf .
886	$p\text{vfbcv}=0.0$		Cross-term dependence of vfbcv .
887	$p\text{acde}=0.0$		Cross-term dependence of acde .
888	$p\text{moin}=0.0$		Cross-term dependence of moin .
889	$p\text{noff}=0.0$		Cross-term dependence of noff .
890	$p\text{voffcv}=0.0$		Cross-term dependence of voffcv .
891	$p\text{tvoffcv}=0.0$		Cross-term dependence of tvoffcv .
892	$p\text{minvcv}=0.0$		Cross-term dependence of minvcv .
893	$p\text{kt1}=0.0$	V	Cross-term dependence of kt1 .
894	$p\text{kt1l}=0$	V m	Cross-term dependence of kt1l .
895	$p\text{kt2}=0.0$		Cross-term dependence of kt2 .
896	$p\text{at}=0.0$	m/s	Cross-term dependence of at .
897	$p\text{ua1}=0.0$	m/V	Cross-term dependence of ua1 .
898	$p\text{ub1}=0.0$	m^2/V^2	Cross-term dependence of ub1 .
899	$p\text{uc1}=0.0$	m/V^2	Cross-term dependence of uc1 .
900	$p\text{ud1}=0.0$	$/\text{m}^2$	Cross-term dependence of ud1 .
901	$p\text{prt}=0.0$	Ω	Cross-term dependence of prt .

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

902	pute=0.0	Cross-term dependence of ute.
903	pndep=0.0	Cross-term dependence of ndep.
904	pnsd=0.0	Cross-term dependence of nsd.
905	pphin=0.0	Cross-term dependence of phin.
906	plpe0=0.0	Cross-term dependence of lpe0.
907	plpeb=0.0	Cross-term dependence of lpeb.
908	pdvtp0=0.0	Cross-term dependence of dvtp0.
909	pdvtp1=0.0	Cross-term dependence of dvtp1.
910	pdvtp2=0.0	Cross-term dependence of dvtp2.
911	pdvtp3=0.0	Cross-term dependence of dvtp3.
912	pdvtp4=0.0	Cross-term dependence of dvtp4.
913	pdvtp5=0.0	Cross-term dependence of dvtp5.
914	peu=0.0	Cross-term dependence of eu.
915	pminv=0.0	Cross-term dependence of minv.
916	pfprout=0.0	Cross-term dependence of fprout.
917	ppdits=0.0	Cross-term dependence of pdits.
918	ppditsd=0.0	Cross-term dependence of pditsd.
919	prdw=0.0	Cross-term dependence of rdw.
920	prsw=0.0	Cross-term dependence of rsw.
921	pagidl=0.0	Cross-term dependence of agidl.
922	pbgidl=0.0	Cross-term dependence of bgidl.
923	pcgidl=0.0	Cross-term dependence of cgidl.

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

924	<code>pegidl=0.0</code>	Cross-term dependence of <code>egidl</code> .
925	<code>pfgidl=0.0</code>	Cross-term dependence of <code>fgidl</code> .
926	<code>pkgidl=0.0</code>	Cross-term dependence of <code>kgidl</code> .
927	<code>prgidl=0.0</code>	Cross-term dependence of <code>rgidl</code> .
928	<code>pfgisl=pfgidl</code>	Cross-term dependence of <code>fgisl</code> .
929	<code>pkgisl=pkgidl</code>	Cross-term dependence of <code>kgisl</code> .
930	<code>prgisl=prgidl</code>	Cross-term dependence of <code>rgisl</code> .
931	<code>paigbacc=0.0</code>	Cross-term dependence of <code>aigbacc</code> .
932	<code>pbigbacc=0.0</code>	Cross-term dependence of <code>bigbacc</code> .
933	<code>pcigbacc=0.0</code>	Cross-term dependence of <code>cigbacc</code> .
934	<code>pnigbacc=0.0</code>	Cross-term dependence of <code>nigbacc</code> .
935	<code>paigbinv=0.0</code>	Cross-term dependence of <code>aigbinv</code> .
936	<code>pbigbinv=0.0</code>	Cross-term dependence of <code>bigbinv</code> .
937	<code>pcigbinv=0.0</code>	Cross-term dependence of <code>cigbinv</code> .
938	<code>peigbinv=0.0</code>	Cross-term dependence of <code>eigbinv</code> .
939	<code>pnigbinv=0.0</code>	Cross-term dependence of <code>nigbinv</code> .
940	<code>paigc=0.0</code>	Cross-term dependence of <code>aigc</code> .
941	<code>pbigc=0.0</code>	Cross-term dependence of <code>bigc</code> .
942	<code>pcigc=0.0</code>	Cross-term dependence of <code>cigc</code> .
943	<code>paigsd=0.0</code>	Cross-term dependence of <code>aigsd</code> .
944	<code>pbigsd=0.0</code>	Cross-term dependence of <code>bigsd</code> .
945	<code>pcigsd=0.0</code>	Cross-term dependence of <code>cigsd</code> .

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946	<code>pnigc=0.0</code>	Cross-term dependence of <code>nigc</code> .
947	<code>ppoxedge=0.0</code>	Cross-term dependence of <code>poxedge</code> .
948	<code>ppigcd=0.0</code>	Cross-term dependence of <code>pigcd</code> .
949	<code>pntox=0.0</code>	Cross-term dependence of <code>ntox</code> .
950	<code>pckappas=0.0</code>	Cross-term dependence of <code>ckappas</code> .
951	<code>pckappad=0.0</code>	Cross-term dependence of <code>ckappad</code> .
952	<code>pxrcrg1=0.0</code>	Cross-term dependence of <code>xrcrg1</code> .
953	<code>pxrcrg2=0.0</code>	Cross-term dependence of <code>xrcrg2</code> .
954	<code>pvfbsdoff=0.0</code>	Cross-term dependence of <code>Vfbsdoff</code> .
955	<code>plambda=0.0</code>	Cross-term dependence of <code>lambda</code> .
956	<code>pvtl=0.0</code>	Cross-term dependence of <code>vtl</code> .
957	<code>pxn=0.0</code>	Cross-term dependence of <code>xn</code> .
958	<code>pkvth0we=0.0 V</code>	Cross-term dependence of <code>kvth0we</code> .
959	<code>pk2we=0.0</code>	Cross-term dependence of <code>k2we</code> .
960	<code>pku0we=0.0</code>	Cross-term dependence of <code>ku0we</code> .
961	<code>pku0=0.0 m^(llodku0+wlodku0)</code>	Cross-term dependence of <code>ku0</code> .
962	<code>pkvth0=0.0 V m^(llodku0+wlodku0)</code>	Cross-term dependence of <code>kvth0</code> .
963	<code>pucs=0.0</code>	Cross-term dependence of <code>ucs</code> .
964	<code>pucste=0.0</code>	Cross-term dependence of <code>ucste</code> .

DC-mismatch dependent parameters

965	<code>mvtwl=0.0 V m</code>	Threshold mismatch area dependence.
-----	----------------------------	-------------------------------------

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- 966 `mvtwl2=0.0 V m^1.5` Threshold mismatch area square dependence.
- 967 `mvt0=0.0 V` Threshold mismatch intercept.
- 968 `mbewl=0.0 m` Beta mismatch area dependence.
- 969 `mbe0=0.0` Beta mismatch intercept.
- 970 `mismatchmod=0` Select Mismatch mode.
- 971 `mismatchdist=0 m` Mismatch Distance.

Compatibility model parameters

- 972 `compatible=spectre` Encourage device equations to be compatible with a foreign simulator. This option does not affect input syntax. Possible values are `spectre`, `spice2`, `spice3`, `cdsspice`, `hspice`, `spiceplus`, `eldo`, `sspice`, `mica`, `tispice`, and `pspice`.

Shrink Parameters

- 973 `shrink=0` Linear shrink parameter.
- 974 `shrink2=0` Area shrink parameter.

Imax and Imelt

The `imax` parameter aids convergence and prevents numerical overflow. The junction characteristics of the device are accurately modeled for current up to `imax`. If `imax` is exceeded during iterations, the linear model is substituted until the current drops below `imax` or until convergence is achieved. If convergence is achieved with the current exceeding `imax`, the results are inaccurate, and a warning is printed out.

A separate model parameter, `imelt`, is used as a limit warning for the junction current. This parameter can be set to the maximum current rating of the device. When any component of the junction current exceeds `imelt`, note that base and collector currents are composed of many exponential terms, a warning will be issued and the results become inaccurate. The

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junction current is linearized above the value of `imelt` to prevent arithmetic exception, with the exponential term replaced by a linear equation at `imelt`.

Both of these parameters have current density counterparts, `jmax` and `jmelt`, that you can specify if you want the absolute current values to depend on the device area.

In BSIM4, `imax` (`jmax`) will take effect only when `diomod=3` (Spectre common diode model). Berkeley uses other model parameters, such as `ijthsfwd`, `ijthdfwd` to do limitation. For more information, see the Berkeley BSIM4 manual.

Auto Model Selection

Many models need to be characterized for different geometries in order to obtain accurate results for model development. The model selector program automatically searches for a model with the length and width range specified in the instance statement and uses this model in the simulations.

For the auto model selector program to find a specific model, the models to be searched should be grouped together within braces. Such a group is called a model group. An opening brace is required at the end of the line defining each model group. Every model in the group is given a name followed by a colon and the list of parameters. Also, the four geometric parameters `lmax`, `lmin`, `wmax`, and `wmin` should be given. The selection criteria to choose a model is as follows:

```
lmin <= inst_length < lmax and wmin <= inst_width < wmax
```

Example:

```
model ModelName ModelType {
    1: <model parameters> lmin=2 lmax=4 wmin=1 wmax=2
    2: <model parameters> lmin=1 lmax=2 wmin=2 wmax=4
    3: <model parameters> lmin=2 lmax=4 wmin=4 wmax=6
}
```

Then for a given instance

```
M1 1 2 3 4 ModelName w=3 l=1.5
```

the program would search all the models in the model group with the name `ModelName` and then pick the first model whose geometric range satisfies the selection criteria. In the preceding example, the auto model selector program would choose `ModelName.2`.

You must specify both length (`l`) and width (`w`) on the device instance line to enable automatic model selection.

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Inst Default to Model

In BSIM4, for customer convenience, some model parameters are added to serve as default values for the corresponding instance parameters (they are not Berkeley model parameters. These include: `l`, `w`, `as`, `ad`, `ps`, `pd`, `nrs`, `nrd`, `rdc`, `rsc`, `rgeomod`, `nf`, `min`, and `trise`.

Output Parameters

1	<code>tempeff</code> (C)	Effective temperature for a single device.
2	<code>m_{eff}</code>	Effective multiplicity factor (m-factor).
3	<code>w_{eff}</code> (m)	Effective channel width (alias= <code>lx62</code>).
4	<code>l_{eff}</code> (m)	Effective channel length (alias= <code>lx63</code>).
5	<code>w_{effcv}</code> (m)	Effective channel width for CV (alias= <code>lx64</code>).
6	<code>l_{effcv}</code> (m)	Effective channel length for CV (alias= <code>lx65</code>).
7	<code>vfbsd</code> (V)	Flat band Voltage between the gate and Drain/source diffusions (alias= <code>lx75</code>).
8	<code>rgbi</code> (Ω)	Gate bias-independent resistance.
9	<code>ad_{eff}</code> (m ²)	Effective drain area.
10	<code>as_{eff}</code> (m ²)	Effective source area.
11	<code>pd_{eff}</code> (m)	Effective drain perimeter.
12	<code>ps_{eff}</code> (m)	Effective source perimeter.

Operating-Point Parameters

1	<code>region=triode</code>	Estimated operating region. %Z outputs the number (0-4) in a rawfile. Possible values are <code>off</code> , <code>triode</code> , <code>sat</code> , <code>subth</code> , and <code>breakdown</code> .
2	<code>reversed</code>	Reverse mode indicator. Possible values are <code>no</code> and <code>yes</code> .

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3	i_{ds} (A)	Resistive drain-to-source current.
4	v_{gs} (V)	Gate-source voltage.
5	v_{ds} (V)	Drain-source voltage.
6	v_{bs} (V)	Bulk-source voltage.
7	v_{gd} (V)	Gate-drain voltage.
8	v_{db} (V)	Drain-bulk voltage.
9	v_{gb} (V)	Gate-bulk voltage.
10	v_{th} (V)	Threshold voltage (alias=lv9).
11	v_{dsat} (V)	Drain-source saturation voltage (alias=lv10).
12	g_m (S)	Common-source transconductance (alias=lx7).
13	g_{ds} (S)	Common-source output conductance (alias=lx8).
14	g_{mbs} (S)	Body-transconductance (alias=lx9).
15	β_{eff} (A/V ²)	Effective beta (alias LV21).
16	c_{jd} (F)	Drain-bulk junction capacitance (alias=lx29).
17	c_{js} (F)	Source-bulk junction capacitance (alias=lx28).
18	c_{gg} (F)	Total gate capacitance, including intrinsic, overlap and fringing components (alias=lx82).
19	c_{gd} (F)	Total gate-to-drain capacitance, including intrinsic, overlap, and fringing components (alias=lx83).
20	c_{gs} (F)	Total gate-to-source capacitance, including intrinsic, overlap, and fringing components (alias=lx84).
21	c_{gb} (F)	Total gate-to-bulk capacitance, including intrinsic and overlap components.

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22	c_{dg} (F)	Total drain-to-gate capacitance, including intrinsic, overlap, and fringing components (alias=lx87).
23	c_{dd} (F)	Drain capacitance, including intrinsic, overlap, and fringing components.
24	c_{ds} (F)	Total drain-to-source capacitance (alias=lx86).
25	c_{db} (F)	Intrinsic drain-to-bulk capacitance.
26	c_{sg} (F)	Total source-to-gate capacitance, including intrinsic, overlap, and fringing components.
27	c_{sd} (F)	Total source-to-drain capacitance.
28	c_{ss} (F)	Source capacitance, including intrinsic, overlap, and fringing components.
29	c_{sb} (F)	Intrinsic source-to-bulk capacitance.
30	c_{bg} (F)	Total bulk-to-gate capacitance, including intrinsic and overlap components (alias=lx88).
31	c_{bd} (F)	Intrinsic bulk-to-drain capacitance.
32	c_{bs} (F)	Intrinsic bulk-to-source capacitance.
33	c_{bb} (F)	Bulk capacitance, including intrinsic and overlap components.
34	c_{ovlgs} (F/m)	Gate-source overlap and fringing capacitances (alias=lv36).
35	c_{ovlgd} (F/m)	Gate-drain overlap and fringing capacitances (alias=lv37).
36	c_{ovlgb} (F/m)	Gate-bulk overlap capacitances (alias=lv38).
37	c_{ggbo} (F)	CGGBO = dQ_g/dV_g intrinsic gate capacitance (alias=lx18).
38	c_{gdbo} (F)	CGDBO = $-dQ_g/dV_d$ intrinsic gate-to-drain capacitance (alias=lx19).
39	c_{gsbo} (F)	CGSBO = $-dQ_g/dV_s$ intrinsic gate-to-source capacitance (alias=lx20).

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40	cbgbo (F)	CBGBO = $-dQ_b/dV_g$ intrinsic bulk-to-gate capacitance (alias=lx21).
41	cbdbo (F)	CBDBO = $-dQ_b/dV_d$ intrinsic bulk-to-drain capacitance (alias=lx22).
42	cbsbo (F)	CBSBO = $-dQ_b/dV_s$ intrinsic bulk-to-source capacitance (alias=lx23).
43	cdgbo (F)	CDGBO = $-dQ_d/dV_g$ intrinsic drain-to-gate capacitance (alias=lx32).
44	cddbbo (F)	CDDBO = dQ_d/dV_d intrinsic drain capacitance (alias=lx33).
45	cdsbo (F)	CDSBO = $-dQ_d/dV_s$ intrinsic drain-to-source capacitance (alias=lx34).
46	ron (Ω)	On-resistance.
47	id (A)	Resistive drain current.
48	ibulk (A)	Resistive bulk current.
49	pwr (W)	Power at op point.
50	gmoverid (1/V)	Gm/Ids.
51	ueff	ueff.
52	rdeff (Ω)	Effective drain resistance.
53	rseff (Ω)	Effective source resistance.
54	rgbd (Ω)	Gate bias-dependent resistance.
55	igidl (A)	Gate-induced drain leakage current (alias=lx70).
56	igisl (A)	Gate-induced source leakage current.
57	igdt (A)	Gate Dielectric tunneling current (alias=lx71).
58	igd (A)	Gate-to-drain tunneling current (alias=lx39).

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59	<code>igs</code> (A)	Gate-to-source tunneling current (alias= <code>lx38</code>).
60	<code>igb</code> (A)	Gate-to-bulk tunneling current (alias= <code>lx66</code>).
61	<code>igbacc</code> (A)	Gate-to-bulk tunneling current determined by ECB (alias= <code>lx73</code>).
62	<code>igbinv</code> (A)	Gate-to-bulk tunneling current determined by EVB (alias= <code>lx74</code>).
63	<code>igcs</code> (A)	Gate-to-channel (source side) tunneling current (alias= <code>lx67</code>).
64	<code>igcd</code> (A)	Gate-to-channel (drain side) tunneling current (alias= <code>lx68</code>).
65	<code>isub</code> (A)	Substrate current (alias to LX69).
66	<code>gbs</code> (S)	Bulk-source diode conductance (alias= <code>lx11</code>).
67	<code>gbd</code> (S)	Bulk-drain diode conductance (alias= <code>lx10</code>).
68	<code>qg</code> (Coul)	Total gate charge, including intrinsic, overlap and fringing components.
69	<code>qd</code> (Coul)	Total drain charge, including intrinsic, overlap and fringing components.
70	<code>qs</code> (Coul)	Total source charge, including intrinsic, overlap and fringing components.
71	<code>qb</code> (Coul)	Total bulk charge, including intrinsic and overlap components.
72	<code>qjd</code> (Coul)	Drain-bulk junction charge.
73	<code>qjs</code> (Coul)	Source-bulk junction charge.
74	<code>qgdovl</code> (Coul)	Gate-drain overlap and fringing charge.
75	<code>qgsovl</code> (Coul)	Gate-source overlap and fringing charge.
76	<code>qgi</code> (Coul)	Intrinsic gate charge.
77	<code>qdi</code> (Coul)	Intrinsic drain charge.
78	<code>qsi</code> (Coul)	Intrinsic source charge.

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79	qbi (Coul)	Intrinsic bulk charge.
80	ide (A)	Total DC drain current.
81	ige (A)	Total DC gate current.
82	ise (A)	Total DC source current.
83	ibe (A)	Total DC bulk current.
84	idb (A)	DC drain-bulk current.
85	isb (A)	DC source-bulk current.
86	vsb (V)	Source-bulk DC voltage.
87	gmb (S)	DC bulk transconductance.
88	vgt (V)	Wffective gate drive voltage including back bias and drain bias effects.
89	vdss (V)	Drain saturation voltage at actual bias.
90	vsat_marg (V)	Vds margin.
91	self_gain	Transistor self gain.
92	rout (Ω)	AC output resistor.
93	b _{eff} (A/V ²)	Gain factor in saturation.
94	fug (Hz)	Unity current gain frequency at actual bias.
95	rgate (Ω)	MOS gate resistance.
96	vearly (V)	Equivalent early voltage.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the

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BSIM4 Level-14 Model (bsim4)

description for that parameter. For example, a reference of M-35 means the 35th model parameter.

a0	M-91	lcgdl	M-582	pdvt2w	M-832	tnoic	M-446
a1	M-96	lcgidl	M-623	pdvtp0	M-908	tnoimod	M-19
a2	M-97	lcgsl	M-581	pdvtp1	M-909	tnom	M-353
acde	M-244	lcigbacc	M-633	pdvtp2	M-910	toxe	M-36
acm	M-113	lcigbinv	M-637	pdvtp3	M-911	toxm	M-38
acnqsmod	I-48	lcigc	M-642	pdvtp4	M-912	toxp	M-37
acnqsmod	M-17	lcigsd	M-645	pdvtp5	M-913	toxref	M-219
ad	I-4	lcit	M-572	pdwb	M-844	tpb	M-377
ad	M-487	lckappad	M-651	pdwg	M-843	tpbsw	M-379
adef	O-9	lckappas	M-650	pegidl	M-924	tpbswg	M-380
ados	M-103	lclc	M-583	peigbinv	M-938	trd	M-119
af	M-438	lcle	M-584	permod	M-22	trise	I-49
agidl	M-178	ld	M-118	peta0	M-875	trise	M-354
agisl	M-185	ldelta	M-566	petab	M-877	trnqsmod	I-47
ags	M-92	ldif	M-115	peu	M-914	trnqsmod	M-16
aigbacc	M-192	ldrout	M-558	pfgidl	M-925	trs	M-120
aigbinv	M-196	ldsub	M-574	pfgisl	M-928	tvfbsdoff	M-221
aigc	M-201	ldvt0	M-527	pfprout	M-916	tvoff	M-138
aigd	M-210	ldvt0w	M-530	pgamma1	M-823	tvoffcv	M-388
aigs	M-207	ldvt1	M-528	pgamma2	M-824	type	M-1

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aigsd M-204	ldvt1w M-531	phig M-98	u0 M-121
alarm M-498	ldvt2 M-529	phin M-70	ua M-122
alpha0 M-174	ldvt2w M-532	pigcd M-217	ua1 M-359
alpha1 M-175	ldvtp0 M-608	pk M-414	ub M-123
as I-3	ldvtp1 M-609	pk1 M-818	ub1 M-360
as M-486	ldvtp2 M-610	pk2 M-819	uc M-124
aseff O-10	ldvtp3 M-611	pk2we M-959	uc1 M-361
at M-363	ldvtp4 M-612	pk3 M-820	ucs M-135
b0 M-93	ldvtp5 M-613	pk3b M-821	ucste M-136
b1 M-94	ldwb M-544	pketa M-839	ud M-125
bdos M-104	ldwg M-543	pkgidl M-926	ud1 M-362
beff OP-93	leff O-4	pkgisl M-929	ueff OP-51
beta0 M-176	leffcv O-6	pkt1 M-893	up M-126
betaeff OP-15	leffeot M-106	pkt1l M-894	updatelevel M-29
bg0sub M-100	legidl M-624	pkt2 M-895	ute M-355
bgidl M-179	leigbinv M-638	pku0 M-961	vbd_max M-507
bgisl M-186	leta0 M-575	pku0we M-960	vhdr_max M-514
bigbacc M-193	letab M-577	pkvth0 M-962	vbm M-78
bigbinv M-197	leu M-614	pkvth0we M-958	vbox M-502
bigc M-202	level M-2	plambda M-955	vbs OP-6
bigd M-211	lfgidl M-625	plp M-857	vbs_max M-508

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big5	M-208	lfgisl	M-628	plpe0	M-906	vbsr_max	M-513
bigsd	M-205	lfprout	M-616	plpeb	M-907	vbx	M-47
binunit	M-4	lgamma1	M-523	pminv	M-915	vdb	OP-8
bnr	M-316	lgamma2	M-524	pminvcv	M-892	vddeot	M-69
bv	M-270	lint	M-51	pmoin	M-888	vds	OP-5
bvd	M-272	lintnoi	M-441	pndep	M-903	vds_max	M-504
bvj	M-501	lk	M-412	pnfactor	M-870	vdsat	OP-11
bvs	M-271	lk1	M-518	pngate	M-841	vdss	OP-89
capmod	M-13	lk2	M-519	pnigbacc	M-934	vearly	OP-96
cbb	OP-33	lk2we	M-659	pnigbinv	M-939	version	M-3
cbd	OP-31	lk3	M-520	pnigc	M-946	vfb	M-68
cbdbo	OP-41	lk3b	M-521	pnoff	M-889	vfbcv	M-239
cbg	OP-30	lketa	M-539	pnsd	M-904	vfbsd	O-7
cbgbo	OP-40	lkgidl	M-626	pnsb	M-840	vfbsdoff	M-220
cbs	OP-32	lkgisl	M-629	pntox	M-949	vgb	OP-9
cbsbo	OP-42	lkt1	M-593	poxedge	M-216	vgb_max	M-509
cdb	OP-25	lkt11	M-594	ppclm	M-859	vgbr_max	M-512
cdd	OP-23	lkt2	M-595	ppdiblc1	M-860	vgd	OP-7
cddbo	OP-44	lku0	M-661	ppdiblc2	M-861	vgd_max	M-505
cdg	OP-22	lku0we	M-660	ppdiblc3	M-862	vgdr_max	M-510
cdgbo	OP-43	lkvth0	M-662	ppdits	M-917	vgs	OP-4

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cds	OP-24	lkvth0we	M-658	ppditsd	M-918	vgs_max	M-506
cdsbo	OP-45	ll	M-58	pphin	M-905	vgssr_max	M-511
cdsc	M-149	llambda	M-655	ppigcd	M-948	vgt	OP-88
cdscb	M-150	llc	M-246	ppoxedge	M-947	voff	M-137
cdscd	M-151	lln	M-59	pprt	M-901	voffcv	M-241
cf	M-234	llodku0	M-419	pprwb	M-847	voffcvl	M-243
cgb	OP-21	llodvth	M-422	pprwg	M-848	voffl	M-142
cgbo	M-227	llp	M-557	ppscbe1	M-863	vsat	M-129
cgd	OP-19	llpe0	M-606	ppscbe2	M-864	vsat_marg	OP-90
cgdbo	OP-38	llpeb	M-607	ppvag	M-865	vsb	OP-86
cgdl	M-230	lmax	M-496	prds	M-846	vth	OP-10
cgdo	M-226	lmin	M-497	prdw	M-919	vthmod	M-108
cgg	OP-18	lminv	M-615	prgidl	M-927	vtho	M-67
cggbo	OP-37	lminvcv	M-592	prgisl	M-930	vtl	M-131
cgidl	M-180	lmlt	M-65	prsw	M-920	vtss	M-300
cgisl	M-187	lmoin	M-588	prt	M-364	vtss	M-299
cgs	OP-20	lndep	M-603	prwb	M-172	vtsswd	M-302
cgsbo	OP-39	lnfactor	M-570	prwg	M-171	vtsswgd	M-304
cgs1	M-229	lngate	M-541	ps	I-5	vtsswgs	M-303
cgs0	M-225	lnigbacc	M-634	ps	M-488	vtssws	M-301
cigbacc	M-194	lnigbinv	M-639	pscbel	M-157	w	I-1

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cigbinv M-198	lnigc M-646	psche2 M-158	w M-484
cigc M-203	lnoff M-589	pseff O-12	w0 M-75
cigd M-212	lnsd M-604	psk0 M-402	wa0 M-683
cigs M-209	lnsub M-540	psk1 M-406	wa1 M-686
cigsd M-206	lntox M-649	psk2 M-410	wa2 M-687
cit M-148	lodeta0 M-427	psl M-394	wacde M-737
cj M-324	lodk2 M-425	psw M-398	wagidl M-771
cjd M-326	lp M-127	pta M-376	wags M-688
cjd OP-16	lpclm M-559	pteta0 M-876	waigbacc M-781
cjs M-325	lpdiblc1 M-560	ptnfactor M-871	waigbinv M-785
cjs OP-17	lpdiblc2 M-561	ptp M-378	waigc M-790
cjsw M-334	lpdiblc3 M-562	ptvfbsdoff M-224	waigsd M-793
cjswd M-336	lpdits M-617	ptvoff M-141	walpha0 M-728
cjswg M-343	lpditsd M-618	ptvoffcv M-891	walpha1 M-729
cjswgd M-345	lpe0 M-76	pu0 M-850	warn M-503
cjswgs M-344	lpeb M-77	pua M-852	wat M-746
cjsws M-335	lphin M-605	pua1 M-897	wb0 M-684
ckappad M-232	lpigcd M-648	pub M-853	wb1 M-685
ckappas M-231	lpoxedge M-647	pub1 M-898	wbeta0 M-730
clc M-235	lprt M-601	puc M-854	wbgidl M-772
cle M-236	lprwb M-547	puc1 M-899	wbigbacc M-782

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

cnr M-317	lprwg M-548	pucs M-963	wbigbinv M-786
compatible M-972	lpscbe1 M-563	pucste M-964	wbigc M-791
covlgb OP-36	lpscbe2 M-564	pud M-855	wbigsd M-794
covlgd OP-35	lpvag M-565	pud1 M-900	wcdsc M-717
covlgs OP-34	lrdsb M-546	pup M-856	wcdscb M-718
csb OP-29	lrdw M-619	pute M-902	wcdscd M-719
csd OP-27	lrgidl M-627	pvag M-160	wcf M-735
csg OP-26	lrgisl M-630	pvbh M-826	wcgdl M-732
css OP-28	lrsw M-620	pvbh M-825	wcgidl M-773
cta M-381	lsk0 M-400	pvcf M-817	wcgs1 M-731
ctp M-383	lsk1 M-404	pvcfcv M-886	wcigbacc M-783
cvchargemod M-7	lsk2 M-408	pvcfsdoff M-954	wcigbinv M-787
deleta0 I-71	lsl M-392	pvcff M-873	wcigc M-792
delk1 I-69	lsw M-396	pvcffc M-890	wcigsd M-795
delnfct I-70	lteta0 M-576	pvsat M-851	wcit M-722
delta M-161	ltnfactor M-571	pvth0 M-816	wckappad M-801
deltox I-51	ltvfbsdoff M-222	pvtho M-815	wckappas M-800
delvto I-64	ltvoff M-139	pvt1 M-956	wclc M-733
diomod M-20	ltvoffcv M-591	pw0 M-822	wcle M-734
dlc M-237	lu0 M-550	pwr M-849	wdelta M-716
dlcig M-213	lua M-552	pwr OP-49	wdrout M-708

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

dlcigd	M-214	lua1	M-597	pxj	M-842	wdsub	M-724
dmcg	M-252	lub	M-553	pxn	M-957	wdvt0	M-677
dmcgt	M-255	lub1	M-598	pxrcrg1	M-952	wdvt0w	M-680
dmci	M-253	luc	M-554	pxrcrg2	M-953	wdvt1	M-678
dmdg	M-254	luc1	M-599	pxt	M-845	wdvt1w	M-681
dnr	M-318	lucs	M-663	qjb	OP-71	wdvt2	M-679
drout	M-156	lucste	M-664	qbi	OP-79	wdvt2w	M-682
dskip	M-311	lud	M-555	qjd	OP-69	wdvtp0	M-758
dsub	M-147	lud1	M-600	qdi	OP-77	wdvtp1	M-759
dtemp	I-50	lup	M-556	qg	OP-68	wdvtp2	M-760
dtox	M-39	lute	M-602	qgdov1	OP-74	wdvtp3	M-761
dvt0	M-79	lvbm	M-526	qgi	OP-76	wdvtp4	M-762
dvt0w	M-88	lvbx	M-525	qgsov1	OP-75	wdvtp5	M-763
dvt1	M-80	lvfb	M-517	qjd	OP-72	wdwb	M-694
dvt1w	M-89	lvfbcv	M-586	qjs	OP-73	wdwg	M-693
dvt2	M-81	lvfbsdoff	M-654	qs	OP-70	web	M-428
dvt2w	M-90	lvoff	M-573	qsi	OP-78	wec	M-429
dvtp0	M-82	lvoffcv	M-590	rbdb	I-60	weff	O-3
dvtp1	M-83	lvsat	M-551	rbdb	M-471	weffcv	O-5
dvtp2	M-84	lvth0	M-516	rdbbx0	M-475	weffeot	M-107
dvtp3	M-85	lvtho	M-515	rdbby0	M-476	wegidl	M-774

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

dvtp4	M-86	lvt1	M-656	rbodymod	I-53	weigbinv	M-788
dvtp5	M-87	lw	M-60	rbodymod	M-15	weta0	M-725
dwb	M-64	lw0	M-522	rbpb	I-57	wetab	M-727
dwc	M-238	lwc	M-247	rbpb	M-452	weu	M-764
dwg	M-63	lw1	M-62	rbpbx0	M-453	wfgidl	M-775
dwj	M-256	lwlc	M-248	rbpbx1	M-454	wfgisl	M-778
easub	M-134	lwn	M-61	rbpbxnf	M-456	wfprout	M-766
ef	M-439	lwr	M-549	rbpbxw	M-455	wgamma1	M-673
eg	M-367	lxj	M-542	rbpby0	M-457	wgamma2	M-674
egidl	M-181	lxn	M-657	rbpby1	M-458	wint	M-52
egisl	M-188	lxrcrg1	M-652	rbpbynf	M-460	wk	M-413
eglev	M-30	lxrcrg2	M-653	rbpbyw	M-459	wk1	M-668
eigbinv	M-199	lxt	M-545	rbpd	I-58	wk2	M-669
em	M-437	m	I-45	rbpd	M-461	wk2we	M-809
eot	M-35	mbe0	M-969	rbpd0	M-462	wk3	M-670
epsrgate	M-33	mbew1	M-968	rbpd1	M-463	wk3b	M-671
epsrox	M-32	meff	O-2	rbpdf	M-465	wketa	M-689
epsrsub	M-34	meto	M-228	rbpdw	M-464	wkgidl	M-776
eta0	M-145	min	I-63	rbps	I-59	wkgisl	M-779
etab	M-146	min	M-263	rbps	M-466	wkt1	M-743
eu	M-128	minr	M-31	rbps0	M-467	wkt11	M-744

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

fc	M-333	minv	M-143	rbpsl	M-468	wkt2	M-745
fcsw	M-352	minvcv	M-242	rbpsnf	M-470	wku0	M-811
fgidl	M-182	mismatchdist	M-971	rbpsw	M-469	wku0we	M-810
fgisl	M-189	mismatchmod	M-970	rbsb	I-61	wkvth0	M-812
flkmod	M-27	mj	M-327	rbsb	M-472	wkvth0we	M-808
fnoimod	M-18	mjd	M-329	rbsbx0	M-473	wl	M-53
fprout	M-159	mjs	M-328	rbsby0	M-474	wlambda	M-805
fug	OP-94	mjsw	M-337	rbsdbxl	M-477	wlc	M-249
fullreinit	M-28	mjswd	M-339	rbsdbxnf	M-479	wln	M-54
gamma1	M-41	mjswg	M-346	rbsdbxw	M-478	wlod	M-415
gamma2	M-42	mjswgd	M-348	rbsdbyl	M-480	wlodku0	M-420
gap1	M-368	mjswgs	M-347	rbsdbynf	M-482	wlodvth	M-423
gap2	M-369	mjsws	M-338	rbsdbyw	M-481	wlp	M-707
gbd	OP-67	mnr	M-315	rd	M-117	wlpe0	M-756
gbmin	M-483	mobmod	M-6	rdc	I-9	wlpeb	M-757
gbs	OP-66	moin	M-245	rdc	M-492	wmax	M-494
gds	OP-13	mtrlcompatmod	M-9	rdeff	OP-52	wmin	M-495
geomod	I-54	mtrlmod	M-8	rdsmod	M-10	wminv	M-765
geomod	M-23	mulid0	I-68	rds	M-165	wminvcv	M-742
gidlmod	M-177	mulmu0	I-65	rdsmin	M-166	wmlt	M-66

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

gm	OP-12	mulu0	I-67	rdw	M-167	wmoin	M-738
gmb	OP-87	mulvsat	I-66	rdwmin	M-168	wndep	M-753
gmbs	OP-14	mvt0	M-967	region	I-46	wnfactor	M-720
gmoverid	OP-50	mvtwl	M-965	region	OP-1	wngate	M-691
hdif	M-114	mvtwl2	M-966	reversed	OP-2	wnigbacc	M-784
ibe	OP-83	n	M-370	rgate	OP-95	wnigbinv	M-789
ibulk	OP-48	ndep	M-43	rgatemod	I-52	wnigc	M-796
id	OP-47	nf	I-62	rgatemod	M-14	wnoff	M-739
idb	OP-84	nf	M-262	rgbd	OP-54	wnoi	M-442
ide	OP-80	nfactor	M-144	rgbi	O-8	wnsd	M-754
ids	OP-3	ngate	M-45	rgeomod	I-56	wnsub	M-690
igb	OP-60	ngcon	I-77	rgeomod	M-26	wntox	M-799
igbacc	OP-61	ngcon	M-261	rgidl	M-184	wpclm	M-709
igbinv	OP-62	ni0sub	M-99	rgisl	M-191	wpdiblc1	M-710
igbmod	M-12	nigbacc	M-195	rnoia	M-447	wpdiblc2	M-711
igcd	OP-64	nigbinv	M-200	rnoib	M-448	wpdiblc3	M-712
igcmmod	M-11	nigc	M-215	rnoic	M-449	wpdits	M-767
igcs	OP-63	njd	M-372	ron	OP-46	wpditsd	M-768
igd	OP-58	njs	M-371	rout	OP-92	wpemod	M-25
igdt	OP-57	njts	M-287	rs	M-116	wphin	M-755
ige	OP-81	njtscd	M-290	rsc	I-10	wpigcd	M-798

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

igidl	OP-55	njtssw	M-288	rsc	M-493	wpoxedge	M-797
igisl	OP-56	njtsswd	M-291	rseff	OP-53	wprt	M-751
igs	OP-59	njtsswg	M-289	rsh	M-49	wprwb	M-697
ijthdfwd	M-267	njtsswgd	M-292	rshg	M-50	wprwg	M-698
ijthdrev	M-265	noff	M-240	rsw	M-169	wpscbe1	M-713
ijthsfwd	M-266	noia	M-434	rswmin	M-170	wpscbe2	M-714
ijthsrev	M-264	noib	M-435	sa	I-11	wpvag	M-715
imax	M-499	noic	M-436	sa1	I-14	wr	M-173
imelt	M-312	nrd	I-7	sa10	I-23	wrdsw	M-696
is	M-273	nrd	M-490	sa2	I-15	wrdw	M-769
isb	OP-85	nrfwd	M-322	sa3	I-16	wrgidl	M-777
ise	OP-82	nrs	I-8	sa4	I-17	wrgisl	M-780
isnoisy	I-44	nrs	M-491	sa5	I-18	wrsw	M-770
isub	OP-65	nsd	M-46	sa6	I-19	wsk0	M-401
ivth	M-109	nsub	M-44	sa7	I-20	wsk1	M-405
ivth_vdsmin	M-112	ntnoi	M-443	sa8	I-21	wsk2	M-409
ivthl	M-111	ntox	M-218	sa9	I-22	ws1	M-393
ivthw	M-110	pa0	M-833	saref	M-389	wsw	M-397
jmax	M-500	pa1	M-836	sb	I-12	wteta0	M-726
jme1t	M-313	pa2	M-837	sb1	I-24	wtnfactor	M-721
js	M-274	pacde	M-887	sb10	I-33	wtvfbsdoff	M-223

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

j _{sd}	M-276	pagidl	M-921	sb2	I-25	wtvoff	M-140
j _{ss}	M-275	pags	M-838	sb3	I-26	wtvoffcv	M-741
j _{sswg}	M-323	paigbacc	M-931	sb4	I-27	wu0	M-700
j _{swd}	M-278	paigbinv	M-935	sb5	I-28	wua	M-702
j _{swgd}	M-280	paigc	M-940	sb6	I-29	wua1	M-747
j _{swgs}	M-279	paigsd	M-943	sb7	I-30	wub	M-703
j _{sws}	M-277	palpha0	M-878	sb8	I-31	wub1	M-748
j _{tsd}	M-282	palpha1	M-879	sb9	I-32	wuc	M-704
j _{tss}	M-281	paramchk	M-5	sbref	M-390	wuc1	M-749
j _{tsswd}	M-284	pat	M-896	sc	I-75	wucs	M-813
j _{tsswg}	M-286	pb	M-330	sca	I-72	wucste	M-814
j _{tsswgs}	M-285	pb0	M-834	scb	I-73	wud	M-705
j _{tssws}	M-283	pb1	M-835	scc	I-74	wud1	M-750
j _{tweff}	M-314	pbd	M-332	scref	M-433	wup	M-706
k	M-411	pbeta0	M-880	sd	I-13	wute	M-752
k ₁	M-71	pbgidl	M-922	self_gain	OP-91	wvbm	M-676
k ₂	M-72	pbigbacc	M-932	shrink	M-973	wvbx	M-675
k _{2we}	M-431	pbigbinv	M-936	shrink2	M-974	wvfb	M-667
k ₃	M-73	pbigc	M-941	sk0	M-399	wvfbcv	M-736
k _{3b}	M-74	pbigsd	M-944	sk1	M-403	wvfbsdoff	M-804
k _{eta}	M-95	pbs	M-331	sk2	M-407	wvoff	M-723

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

kf	M-440	pbsw	M-340	sl	M-391	wvoffcv	M-740
kgidl	M-183	pbswd	M-342	steta0	M-426	wvsat	M-701
kgisl	M-190	pbswg	M-349	stimod	I-55	wvth0	M-666
kt1	M-356	pbswgd	M-351	stimod	M-24	wvtho	M-665
kt1l	M-357	pbswgs	M-350	stk2	M-424	wvtl	M-806
kt2	M-358	pbsws	M-341	sw	M-395	ww	M-55
ku0	M-416	pcdsc	M-867	sw1	I-34	ww0	M-672
ku0we	M-432	pcdscb	M-868	sw10	I-43	wwc	M-250
kvsat	M-417	pcdsd	M-869	sw2	I-35	wwl	M-57
kvth0	M-421	pcf	M-885	sw3	I-36	wwlc	M-251
kvth0we	M-430	pcgdl	M-882	sw4	I-37	wwn	M-56
l	I-2	pcgidl	M-923	sw5	I-38	wwr	M-699
l	M-485	pcgsl	M-881	sw6	I-39	wxj	M-692
la0	M-533	pcigbacc	M-933	sw7	I-40	wxn	M-807
la1	M-536	pcigbinv	M-937	sw8	I-41	wxrcrg1	M-802
la2	M-537	pcigc	M-942	sw9	I-42	wxrcrg2	M-803
lacde	M-587	pcigsd	M-945	tbgasub	M-101	wxt	M-695
lagidl	M-621	pcit	M-872	tbgbsub	M-102	xgl	M-258
lags	M-538	pckappad	M-951	tcj	M-382	xgw	I-76
laigbacc	M-631	pckappas	M-950	tcjsw	M-384	xgw	M-257
laigbinv	M-635	pclc	M-883	tcjswg	M-385	xj	M-40

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

laigc M-640	pcle M-884	tcnr M-320	xjbvd M-269
laigsd M-643	pclm M-152	tdnr M-321	xjbvs M-268
lalpha0 M-578	pd I-6	tempeff O-1	x1 M-259
lalpha1 M-579	pd M-489	tempeot M-105	xn M-133
lambda M-130	pdeff O-11	tempmod M-21	xpart M-233
lat M-596	pdelta M-866	teta0 M-387	xrcrg1 M-450
lb0 M-534	pdiblc1 M-153	tku0 M-418	xrcrg2 M-451
lb1 M-535	pdiblc2 M-154	tlev M-365	xt M-48
lbeta0 M-580	pdiblcb M-155	tlevc M-366	xti M-373
lbgid1 M-622	pdits M-162	tmnr M-319	xtid M-375
lbigbacc M-632	pditsd M-164	tnfactor M-386	xtis M-374
lbigbinv M-636	pditsl M-163	tnjts M-305	xtsd M-294
lbigc M-641	pdrout M-858	tnjtsd M-308	xtss M-293
lbigsd M-644	pdsb M-874	tnjtssw M-306	xtsswd M-296
lc M-132	pdvt0 M-827	tnjtsswd M-309	xtsswgd M-298
lcdsc M-567	pdvt0w M-830	tnjtsswg M-307	xtsswgs M-297
lcdscb M-568	pdvt1 M-828	tnjtsswgd M-310	xtssws M-295
lcdscd M-569	pdvt1w M-831	tnoia M-444	xw M-260
lcf M-585	pdvt2 M-829	tnoib M-445	

BSIM6 Model (bsim6)

BSIM6 is the new Bulk MOSFET model from the BSIM Group. The model provides excellent accuracy compared to measured data in all regions of operation. It features model symmetry valued for analog and RF applications while maintaining the strong support and performance of the BSIM model valued for all applications. The available version is 6.0.0.

This chapter contains the following information about the BSIM6 model:

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 - [Model syntax](#) on page 1435
- [Model Equations](#) on page 1435
 - [Effective Channel Length and Width](#) on page 1435
 - [Binning Calculations](#) on page 1436
 - [Global Geometrical Scaling](#) on page 1436
 - [Terminal Voltages](#) on page 1437
 - [Pinch-Off Potential and Normalized Charge Calculation](#) on page 1438
 - [Short Channel Effects](#) on page 1439
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Virtuoso Simulator Components and Device Models Reference

BSIM6 Model (bsim6)

- ❑ [Drain Current Model](#) on page 1443
- ❑ [Impact Ionization Model](#) on page 1444
- ❑ [GIDL/GISL Current Model](#) on page 1444
- ❑ [Gate Tunneling Current Model](#) on page 1444
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- [Component Statements](#) on page 1462

Instance

Instance syntax

BSIM6 instance have 4 terminals. To specify BSIM6 instance element, the ModelName has to be associated with a BSIM6 model card.

```
InstanceName (d g s b) ModelName <parameter=value> ...
```

Sample Instance Statement

```
m1 (0 2 1 1) pchmod w=2u l=0.8u as=250p ad=250p pd=168p ps=168p m=1
```

Note: For detailed list of Instance Parameters, see section [Component Statements](#) on page 1462.

Model

Model syntax

The following syntax specifies BSIM6 model:

```
model ModelName bsim6 <parameter=value> ...
```

The third parameter, “bsim6”, is the master to indicate this model card is a BSIM6 model card.

Sample Model Statement

```
model pchmod bsim6 type=p version=6.00
```

Note: For detailed list of Model Parameters, see section [Component Statements](#) on page 1462.

Model Equations

Effective Channel Length and Width

(22-1)

$$\Delta L = LINT$$

(22-2)

$$\Delta W = WINT$$

(22-3)

$$\Delta L_{CV} = DLC$$

(22-4)

$$\Delta W_{CV} = DWC$$

(22-5)

$$L_{eff} = L + XL - 2\Delta L$$

(22-6)

$$W_{eff} = W + XW - 2\Delta W$$

(22-7)

$$L_{eff, CV} = L + XL - 2\Delta L_{CV}$$

(22-8)

$$W_{eff, CV} = W + XW - 2\Delta W_{CV}$$

Binning Calculations

For given L and W, each model parameter $PARAM_i$ is calculated as a function of PARAM, a length dependent term, LPARAM, width dependent term, WPARAM, and area dependent term PPARAM:

(22-9)

$$PARAM_i = PARAM + \frac{LPARAM}{L_{eff}} + \frac{WPARAM}{W_{eff}} + \frac{PPARAM}{L_{eff} \cdot W_{eff}}$$

For the list of binnable parameters, refer to the Components Statements section.

Global Geometrical Scaling

Following scaling formulation is used in global scaling:

(22-10)

$$\begin{aligned}
 PARAM[L] = & PARAM \cdot \left[1 + PARAML \cdot \left(\frac{1}{L_{eff}^{PARAMLEXP}} - \frac{1}{LLONG^{PARAMLEXP}} \right) \right. \\
 & + PARAMW \cdot \left(\frac{1}{W_{eff}^{PARAMWEXP}} - \frac{1}{WWIDE^{PARAMWEXP}} \right) \\
 & \left. + PARAMWL \cdot \left(\frac{1}{(L_{eff} \cdot W_{eff})^{PARAMWLEXP}} \right) \right]
 \end{aligned}$$

Terminal Voltages

(22-11)

$$V_t = \frac{K \cdot T}{q}$$

(22-12)

$$V_g = V_g - V_b$$

(22-13)

$$V_d = V_d - V_b$$

(22-14)

$$V_s = V_s - V_b$$

(22-15)

$$V_{gs} = V_g - V_s$$

(22-16)

$$V_{gd} = V_g - V_d$$

(22-17)

$$V_{gb} = V_g - V_b$$

(22-18)

$$V_{ds} = V_d - V_s$$

(22-19)

$$V_{dsx} = \sqrt{V_{ds}^2 + 0.01} - 0.1$$

(22-20)

$$V_{bsx} = -\left[V_s + \frac{1}{2}(V_{ds} - V_{dsx})\right]$$

Pinch-Off Potential and Normalized Charge Calculation

Pinch-Off Potential with Poly Depletion

(22-21)

$$\psi_p = \begin{cases} 1 + \left[\sqrt{v_g + v_{fb} - 1 + \left(\frac{\gamma}{2}\right)^2} - \frac{\gamma}{2} \right]^2 & \text{if } v_g - v_{fb} > \phi_b + \gamma\sqrt{\phi_b} \\ 1 + e^{-\psi_{p0}} \left[\sqrt{v_g - v_{fb} - 1 + e^{-\psi_{p0}} + \left(\frac{\gamma}{2}\right)^2} - \frac{\gamma}{2} \right]^2 & \text{if } \phi_b + \gamma\sqrt{\phi_b} \geq v_g - v_{fb} \geq 0 \\ -\ln \left[1 - \psi_{p0} + \left(\frac{v_g - v_{fb} - \psi_{p0}}{\gamma} \right)^2 \right] & \text{if } v_g - v_{fb} < 0 \end{cases}$$

Note: Derivatives of ψ_p are continuous in all regions.

Normalized Charge Density

Inversion charge: Normalized inversion charge density at source/drain is newly derived for BSIM6, and can be obtained as follows:

(22-22)

$$\ln(q_i) = \ln\left(\frac{4nq}{\gamma_0} \cdot \sqrt{\psi_p}\right) + 2q_i = \psi_p - 2\phi_f - v_{ch}$$

Short Channel Effects

Vt roll-off, DIBL, and Subthreshold Slope Degradation

(22-23)

$$\Delta V_{th,VDNUD} = -K2 \cdot V_{bsx}$$

(22-24)

$$\Delta V_{th,DIBL} = -(ETA0 + ETAB \cdot V_{bsx}) \cdot V_{dsx}$$

(22-25)

$$\Delta V_{th,DITS} = -n \frac{KT}{q} \cdot \ln \left(\frac{L_{eff}}{L_{eff} + DVTP0 \cdot (1 + \exp(-DVTP1 \cdot V_{ds}))} \right) \\ - \left(DVTP5 + \frac{DVTP2}{L_{eff}} \right) \cdot \tanh(DVTP4 \cdot V_{dsx})$$

(22-26)

$$\Delta V_{th,all} = \Delta V_{th,VDNUD} + \Delta V_{th,DIBL} + \Delta V_{th,DITS}$$

(22-27)

$$V_{gfb} = V_g - V_{fb} - \Delta V_{th,all}$$

Note: Short channel effect and reverse short channel effect are modeled using NDEPL1, NDELEXP1, NDEPL2, and NDEPLEXP2 parameters. Width scaling of Vth is modeled using NDEPW and NDEPWEXP parameters.

Drain Saturation Voltage

The drain saturation voltage model is calculated after the source-side charge (q_s) has been calculated. V_{dseff} is subsequently used to compute the drain-side charge (q_d).

Electric Field Calculations

(22-28)

$$E_{effs} = 10^{-8} \cdot \left(\frac{qbs + \eta \cdot qis}{\epsilon_{ratio} \cdot Tox} \right)$$

Drain Saturation Voltage (V_{dsat}) Calculations

(22-29)

$$D_{mobs} = 1 + (UA + UC \cdot V_{bsx}) \cdot (E_{effs})^{EU} + \frac{UD}{\left[\frac{1}{2} \cdot \left(1 + \frac{q_{is}}{q_{bs'}} \right) \right]^{UCS}}$$

(22-30)

$$T_0 = \begin{cases} \frac{1}{1 + PSATB \cdot V_{bsx}} & V_{bs} \geq 0 \\ 1 - PSATB \cdot V_{bsx} & V_{bs} < 0 \end{cases}$$

(22-31)

$$\lambda_C = \frac{2 \cdot U0 \cdot nV_t}{(D_{mobs})^{PSAT} \cdot VSAT \cdot L_{eff}} \cdot \left[1 + PTWG \cdot \frac{10 \cdot PSATX \cdot q_s \cdot T0}{10 \cdot PSATX + q_s \cdot T0} \right]$$

(22-32)

$$q_{dsat} = \frac{\lambda_C}{2} \cdot \frac{q_s^2 + q_s}{1 + \frac{\lambda_C}{2} \cdot (1 + q_s)}$$

(22-33)

$$v_{dsat} = \psi_p - \frac{2\phi_b}{n} - 2q_{dsat} - \ln \left[\frac{2q_{dsat} \cdot n_q}{gam} \cdot \left(\frac{2q_{dsat} \cdot n_q}{gam} + \frac{gam}{n_q - 1} \right) \right]$$

(22-34)

$$V_{dsat} = v_{dsat} \cdot nV_t$$

(22-35)

$$V_{dssat} = v_{dsat} - V_s$$

Mobility Degradation with Vertical Field

(22-36)

$$D_{mob} = 1 + (UA + UC \cdot V_{bsx}) \cdot (E_{effm})^{EU} + \frac{UD}{\left[\frac{1}{2} \cdot \left(1 + \frac{q_{ia}}{q_{ba'}} \right) \right]^{UCS}}$$

Parasitic Series Resistance

Bias-Dependent Internal Series Resistance ($R_{ds}(V)$)

The internal source-drain resistance ($R_{ds}(V)$) option can be invoked by setting the model selector $RDSMOD=0$ (internal). Following are the expressions for source/drain series resistance calculation:

(22-37)

$$T_0 = 1 + PRWG \cdot q_{ia}$$

(22-38)

$$T_1 = PRWB \cdot (\sqrt{\phi_s - V_{bs}} - \sqrt{\phi_s})$$

(22-39)

$$T_2 = \frac{1}{T_0} + T_1$$

(22-40)

$$\frac{1}{2} \left[T_2 + \sqrt{T_2^2 + 0.01} \right]$$

(22-41)

$$R_{ds}(V) = NF \cdot (R_{s,geo} + R_{d,geo} + W_{eff}^{WR} [RDSWMIN + RDSW \cdot T3])$$

Bias-Dependent External Series Resistance ($R_s(V)$ & $R_d(V)$)

The bias-dependent external series resistance model is adopted from BSIM4 and can be invoked by setting the model selector $RDSMOD=1$

(22-42)

$$R_{source} = \frac{1}{W_{eff} \cdot WR \cdot NF} \cdot \left(RSWMIN + RSW \cdot \left[-PRWB \cdot V_{bs} + \frac{1}{1 + PRWG_i \cdot V_{gs,eff}} \right] \right) + R_{s,geo}$$

(22-43)

$$R_{drain} = \frac{1}{W_{eff} \cdot WR \cdot NF} \cdot \left(RDWMIN + RDW \cdot \left[-PRWB \cdot V_{bd} + \frac{1}{1 + PRWG_i \cdot V_{gd,eff}} \right] \right) + R_{d,geo}$$

Sheet Resistance Model

(22-44)

$$R_{s,geo} = NRS \cdot RSHS$$

$$R_{d,geo} = NRD \cdot RSHD$$

Output Conductance

Channel Length Modulation (CLM)

(22-45)

$$M_{CLM} = 1 + C_{clm} \ln \left[1 + \frac{V_{ds} - V_{dseff}}{V_{asat}} \cdot \frac{1}{C_{clm}} \right]$$

Drain Induced Barrier Lowering (DIBL)

(22-46)

$$M_{DIBL} = \left(1 + \frac{V_{ds} - V_{dseff}}{VAIDBL} \right)$$

Drain Induced Threshold Shift (DITS)

(22-47)

$$M_{DITS} = \left(1 + \frac{V_{ds} - V_{dseff}}{VADITS} \right)$$

Substrate Current Induced Body Effect (SCBE)

(22-48)

$$M_{OC} = M_{DIBL} + M_{CLM} + M_{DITS} + M_{SCBE}$$

Velocity Saturation

Current Degradation Due to Velocity Saturation

(22-49)

$$D_{tot} = D_{mob} \cdot D_{vsat} \cdot D_r$$

Effective Mobility

(22-50)

$$\mu_{eff} = \frac{U_0}{D_{tot}}$$

Drain Current Model

Without Velocity Saturation

(22-51)

$$I_{DS} = 2 \cdot n_q \cdot \mu_{eff} \cdot \frac{W_{eff}}{L_{eff}} \cdot C_{ox} \cdot nV_t^2 \cdot [(q_s - q_{deff})(q_s + q_{deff} + 1)]$$

Including Velocity Saturation

(22-52)

$$I_{DS} = 2 \cdot n_q \cdot \mu_{eff} \cdot \frac{W_{eff}}{L_{eff}} \cdot C_{ox} \cdot nV_t^2 \cdot [(q_s - q_{deff})(q_s + q_{deff} + 1)] \cdot M_{OC}$$

Impact Ionization Model

(22-53)

$$I_{ii} = ALPHA0 \cdot (V_{ds} - V_{dseff}) \cdot \exp\left(-\frac{BETA0}{V_{ds} - V_{dseff}}\right) \cdot \frac{I_{ds}}{M_{SCBE}}$$

GIDL/GISL Current Model

(22-54)

$$I_{GIDL} = AGIDL \cdot W_{eff} \cdot NF \cdot \frac{V_{ds} - V_{gse} - EGIDL}{3 \cdot Toxe} \cdot \exp\left(\frac{-3 \cdot Toxe \cdot BGIDL}{V_{ds} - V_{gse} - EGIDL}\right) \cdot \frac{V_{db}^3}{CGIDL + V_{db}^3}$$

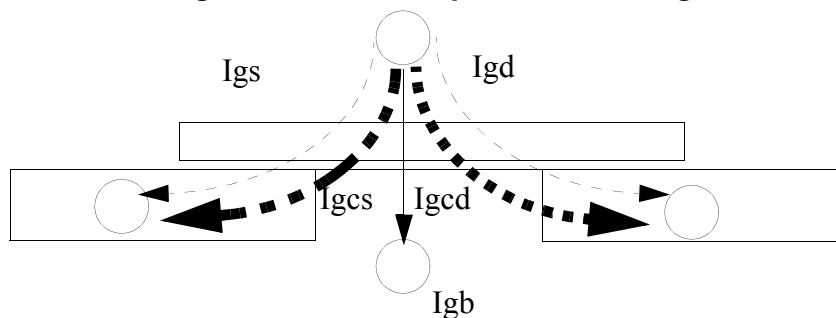
(22-55)

$$I_{GISL} = AGISL \cdot W_{eff} \cdot NF \cdot \frac{V_{ds} - V_{gde} - EGISL}{3 \cdot Toxe} \cdot \exp\left(\frac{-3 \cdot Toxe \cdot BGISL}{V_{ds} - V_{gde} - EGISL}\right) \cdot \frac{V_{sb}^3}{CGISL + V_{sb}^3}$$

I_{GIDL}/I_{GISL} can be switched off by setting GIDLMOD=0

Gate Tunneling Current Model

Figure 22-1 Schematic gate current components flowing between MOSFET terminals



Model Selectors

Two global selectors are provided to turn on or off the tunneling components. $IGCMOD=1$ turns on I_{gc} , I_{gs} , and I_{gd} ; $IGBMOD=1$ turns on I_{gb} . When the selectors are set to 0, no gate tunneling currents are modeled.

Equations for Tunneling Currents

Gate-to-Substrate Current

(22-56)

$$I_{gbacc} = NF \cdot W_{eff} L_{eff} \cdot A \cdot T_{oxRatio} \cdot V_{gb} \cdot V_{aux} \cdot i_{gtemp} \cdot \exp[-B \cdot TOXE(AIGBACC - BIGBACC \cdot V_{oxacc}) \cdot (1 + CIGBAC \cdot V_{oxacc})]$$

(22-57)

$$I_{gbinv} = NF \cdot W_{eff} L_{eff} \cdot A \cdot T_{oxRatio} \cdot V_{gb} \cdot V_{aux} \cdot i_{gtemp} \cdot \exp[-B \cdot TOXE(AIGBINV - BIGBINV \cdot V_{oxdepinv}) \cdot (1 + CIGBINVV \cdot V_{oxdepinv})]$$

Gate-to-Channel Current (I_{gc0}) and Gate-to-S/D (I_{gs} and I_{gd})

(22-58)

$$I_{gc0} = NF \cdot W_{eff} L_{eff} \cdot A \cdot T_{oxRatio} \cdot V_{gse} \cdot V_{aux} \cdot i_{gtemp} \cdot \exp[-B \cdot TOXE(AIGC - BIGC \cdot V_{oxdepinv}) \cdot (1 + CIGCV_{oxdepinv})]$$

Partition of I_{gc} : $I_{gc} = I_{gcs} + I_{gcd}$

(22-59)

$$I_{gcs} = I_{gc0} \cdot \frac{PIGCD \cdot V_{dseffx} + \exp(-PIGCD \cdot V_{dseffx}) - 1 + 10^{-4}}{PIGCD \cdot V_{dseffx}^2 + 2 \cdot 10^{-4}}$$

(22-60)

$$I_{gcd} = I_{gc0} \cdot \frac{1 - (PIGCD \cdot V_{dseffx} + 1) \cdot \exp(-PIGCD \cdot V_{dseffx}) + 10^{-4}}{PIGCD \cdot V_{dseffx}^2 + 2 \cdot 10^{-4}}$$

I_{gs}* and *I_{gd}

(22-61)

$$I_{gs} = \frac{NF \cdot W_{eff} \cdot DLCIG \cdot A \cdot T_{oxRatioEdge} \cdot V_{gs} \cdot V_{gs}' \cdot i_{gtemp}}{\exp[-B \cdot TOXE \cdot POXEDGE \cdot (AIGS - BIGS \cdot V_{gs}') \cdot (1 + CIGSV_{gs}')]}$$

(22-62)

$$I_{gd} = \frac{NF \cdot W_{eff} \cdot DLCIGD \cdot A \cdot T_{oxRatioEdge} \cdot V_{gd} \cdot V_{gd}' \cdot i_{gtemp}}{\exp[-B \cdot TOXE \cdot POXEDGE \cdot (AIGD - BIGD \cdot V_{gd}') \cdot (1 + CIGSV_{gd}')]}$$

V_{fbsd} is the flat-band voltage between gate and source/drain diffusions calculated as:

If NGATE>0

(22-63)

$$V_{fbsd} = \frac{k_B T}{q} \log\left(\frac{NGATE}{NSD}\right) + VFBSDOFF$$

Else V_{fbsd}=0.0.

Gate Resistance and Body Resistance Model

Gate Electrode and Intrinsic -Input Resistance (IIR) Model

BSIM6 provides four options for modeling gate electrode resistance (bias-dependent) and intrinsic-input resistance (IIR, bias-dependent). The IIR model considers relaxation-time effect due to distributive RC nature of the channel region, and therefore describes the first-order non-quasi static effect. Thus, the IIR model should not be used together with the charge-deficit NQS model at the same time. The model selector RGATEMOD is used to choose different options.

Model Option and Schematic

RGATEMOD=0 (zero resistance). In this case, no gate resistance is generated.

RGATEMOD=1 (constant resistance). Rg_{eltd} is given by the following equation:

(22-64)

$$R_{geltd} = \frac{RSHG \cdot \left(XGW + \frac{W_{effci}}{3 \cdot NGCON} \right)}{NGCON \cdot (L_{drawn} - XGL) \cdot NF}$$

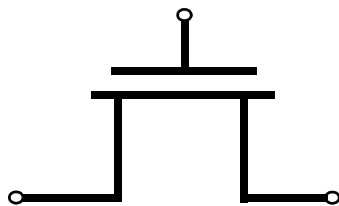
RGATEMOD=2 (IIR model with variable resistance):

(22-65)

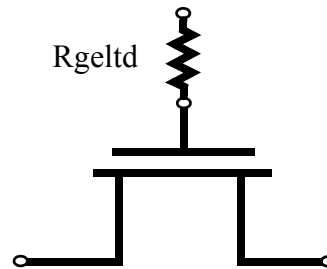
$$\frac{1}{R_{ii}} \approx XRCRG1 \cdot NF \cdot \left(\mu_{eff} \left(\frac{W_{eff}}{L_{eff}} \right) C_{ox} \cdot q_{ia} + XRCRG2 \cdot \frac{W_{eff} \mu_{eff} C_{ox} V_t}{L_{eff}} \right)$$

RGATEMOD=3 (IIR model with two nodes):

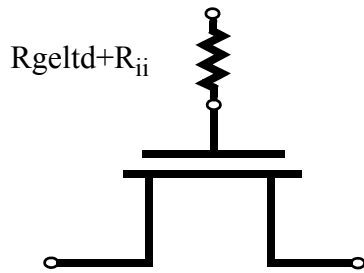
Figure 22-2 Gate resistance network for (a) RGATEMOD=0 (b) RGATEMOD=1 (c) RGATEMOD=2 and (d) RGATEMOD=3



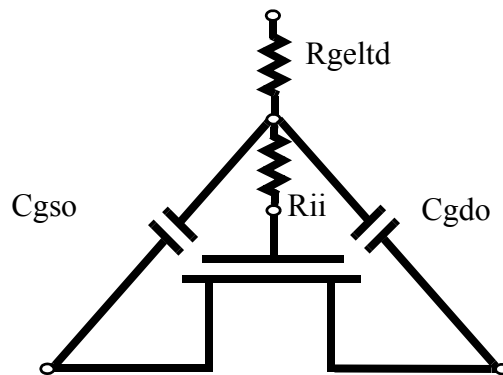
(a)



(b)



(c)



(d)

Substrate Resistance Network

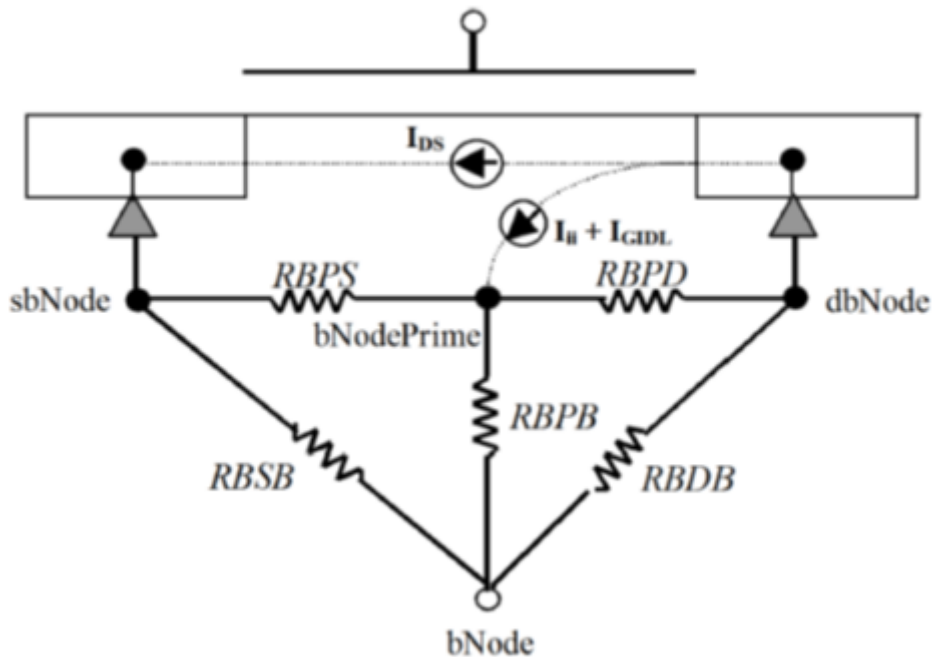
Model Selector and Topology

RBODYMOD=0 (Off)

RBODYMOD=1 (On)

RBODYMOD=2 (On: Scalable Substrate Network)

Figure 22-3 Topology with the substrate resistance network turned on



Noise Modeling

Noise Models in BSIM 6.0.0	Origin
Flicker noise model	BSIM4 Unified model (FNOIMOD=1)
Thermal noise (TNOIMOD=0)	BSIM4 (TNOIMOD=0)
Thermal noise (TNOIMOD=1)	BSIM4 (TNOIMOD=2)
Gate current shot noise	BSIM4 gate current noise

Noise Models in BSIM 6.0.0	Origin
Noise associated with parasitic resistance	BSIM4 parasitic resistance noise

Flicker Noise Models

The flicker noise model in BSIM6 is the same as FNOIMOD=1 in BSIM4. The unified physical flicker noise model is smooth over all bias regions.

(22-66)

$$S_{id,inv}(f) = \frac{kTq^2\mu_{eff}I_{ds}}{C_{oxe}L_{eff}^2NOI f^{EF} \cdot 10^{10}} \left(NOIA \cdot \log \left(\frac{N_0 + N^*}{N_t + N^*} \right) \right. \\ \left. NOIB \cdot (N_0 - N_t) + \frac{NOIC}{2} (N_0^2 - N_t^2) \right) \\ \frac{kTI_{ds}^2\Delta L_{clm}}{W_{eff}L_{eff}^2NOI f^{EF} \cdot 10^{10}} \left(\frac{NOIA + NOIB \cdot N_t + NOIC \cdot N_t^2}{(N_t + N^*)^2} \right)$$

(22-67)

$$S_{id,subVt}(f) = \frac{NOIA \cdot k \cdot T \cdot I_{ds}^2}{W_{eff}L_{eff}^2 f^{EF} N^{*2} \cdot 10^{10}}$$

(22-68)

$$S_{id}(f) = \frac{S_{id,inv} \cdot S_{id,subVt}}{S_{id,inv} + S_{id,subVt}}$$

Channel Thermal Noise

There are two channel thermal noise models in BSIM6. One is a charge-based model (default model) similar to that used in BSIM3v3.2 and BSIM4.7.0 (TNOIMOD=0). The other is the holistic model similar to BSIM4.7.0 (TNOIMOD=2). These two models can be selected through the model selector TNOIMOD.

TNOIDMOD=0 (Charge based model): The noise current is given by:

(22-69)

$$Q_{inv} = |Q_{s,intrinsic} + Q_{s,intrinsic}| \times NFIN_{total}$$

(22-70)

$$\bar{i}_d^2 = \begin{cases} NTNOI \cdot \frac{4kT\Delta f}{R_{ds} + \frac{L_{eff}}{\mu_{eff}Q_{inv}}} & \text{if RDSMOD=0} \\ NTNOI \cdot \frac{4kT\Delta f}{L_{eff}} \cdot \mu_{eff}Q_{inv} & \text{if RDSMOD=1} \end{cases}$$

TNOIMOD=1 (Holistic Model)

(22-71)

$$\beta_{tnoi} = RNOIA \cdot \left[1.0 + TNOIA \cdot L_{eff} \cdot \left(\frac{q_{ia}}{E_{sat,noi}L_{eff}} \right)^2 \right]$$

(22-72)

$$\theta_{tnoi} = RNOIB \cdot \left[1.0 + TNOIB \cdot L_{eff} \cdot \left(\frac{q_{ia}}{E_{sat,noi}L_{eff}} \right)^2 \right]$$

(22-73)

$$c_{tnoi} = RNOIC \cdot \left[1.0 + TNOIC \cdot L_{eff} \cdot \left(\frac{q_{ia}}{E_{sat,noi}L_{eff}} \right)^2 \right]$$

(22-74)

$$S_{id} = 4KT \cdot \mu C_{ox} \frac{W_{eff}}{L_{vsat}} V_t D_{ptwg} M_{oc} \left[\frac{q_s + q_{defl}}{2} + \frac{(q_s - q_{defl})^2}{12 \left(\frac{1+q_s+q_{defl}}{2} \right)} \right] \cdot (3 \cdot \beta_{tnoi}^2)$$

(22-75)

$$S_{ig} = 4KT \cdot \frac{1}{12 \cdot NF \cdot W_{eff} \mu_{eff} \cdot D_{ptwg} M_{oc} C_{ox} \cdot V_t} \frac{L_{vsat}^3}{L_{eff}^2} \cdot \left[\frac{\frac{q_s+q_{defl}}{2}}{\left(\frac{1+q_s+q_{defl}}{2} \right)^2} - \frac{6 \left(\frac{1+q_s+q_{defl}}{2} \right) (q_s - q_{defl})^2}{60 \left(\frac{1+q_s+q_{defl}}{2} \right)^4} + \frac{(q_s - q_{defl})^4}{144 \left(\frac{1+q_s+q_{defl}}{2} \right)^5} \right] \cdot \left(\frac{15}{4} \cdot \theta_{tnoi}^2 \right)$$

(22-76)

$$S_{ig,id} = -j\omega \cdot 4KT \cdot \mu C_{ox} D_{ptwg} M_{oc} V_t \left(\frac{L_{vsat}}{L_{eff}} \right) \cdot \left[\frac{(q_s - q_{def})}{12 \left(\frac{1+q_s+q_{def}}{2} \right)} - \frac{(q_s - q_{def})^3}{144 \left(\frac{1+q_s+q_{def}}{2} \right)^3} \right] \cdot \frac{C_{tnoi}}{0.395}$$

(22-77)

$$c = \frac{S_{ig,id}}{\sqrt{S_{ig}} \cdot \sqrt{S_{id}}}$$

IGate Current Shot Noise

(22-78)

$$\overline{i_{gs}^2} = 2q(I_{gcs} + I_{gs})$$

(22-79)

$$\overline{i_{gd}^2} = 2q(I_{gcd} + I_{gd})$$

(22-80)

$$\overline{i_{gb}^2} = 2qI_{gbinv}$$

Resistor Noise

If RDSMOD=,1 then

(22-81)

$$\frac{\overline{i_{RS}^2}}{\Delta f} = 4kT \cdot \frac{1}{R_{source}}$$

Figure 22-4

$$\frac{\overline{i_{RD}^2}}{\Delta f} = 4kT \cdot \frac{1}{R_{drain}}$$

If RGATGEMOD=1, then

(22-82)

$$\frac{i_{RG}^2}{\Delta f} = 4kT \cdot \frac{1}{R_{g\text{eltd}}}$$

Asymmetric MOS Junction Diode Models

Junction Diode IV Model

(22-83)

$$I_{bs} = I_{sbs} \left[\exp\left(\frac{V_{bs}}{NJS \cdot V_T}\right) - 1 \right] \cdot f_{breakdown} + V_{bs} \cdot G_{min}$$

(22-84)

$$I_{bd} = I_{sbd} \left[\exp\left(\frac{V_{bd}}{NJD \cdot V_T}\right) - 1 \right] \cdot f_{breakdown} + V_{bd} \cdot G_{min}$$

(22-85)

$$\begin{aligned} I_{bs_totle} = & I_{bs} \\ & - W_{effcj} \cdot NF \cdot J_{tsswgs}(T) \cdot \left[\exp\left(\frac{-V_{bs}}{NJTSSWG(T) \cdot V_{tm0}} \cdot \frac{VTSSWGS}{VTSSWGS - V_{bs}}\right) \right] \\ & - P_{s,deff} J_{tssws}(T) \left[\exp\left(\frac{-V_{bs}}{NJTSSW(T) \cdot V_{tm0}} \cdot \frac{VTSSWS}{VTSSWS - V_{bs}}\right) - 1 \right] \\ & - A_{s,deff} J_{tss}(T) \left[\exp\left(\frac{-V_{bs}}{NJTS(T) \cdot V_{tm0}} \cdot \frac{VTSS}{VTSS - V_{bs}}\right) - 1 \right] + g_{min} \cdot V_{bs} \end{aligned}$$

(22-86)

$$\begin{aligned} I_{bd_totle} = & I_{bd} \\ & - W_{effcj} \cdot NF \cdot J_{tsswgd}(T) \cdot \left[\exp\left(\frac{-V_{bd}}{NJTSSWGD(T) \cdot V_{tm0}} \cdot \frac{VTSSWGD}{VTSSWGD - V_{bd}}\right) \right] \\ & - P_{d,deff} J_{tsswd}(T) \left[\exp\left(\frac{-V_{bd}}{NJTSSWD(T) \cdot V_{tm0}} \cdot \frac{VTSSWD}{VTSSWD - V_{bd}}\right) - 1 \right] \\ & - A_{d,deff} J_{tstd}(T) \left[\exp\left(\frac{-V_{bd}}{NJTD(T) \cdot V_{tm0}} \cdot \frac{VTSD}{VTSD - V_{bd}}\right) - 1 \right] + g_{min} \cdot V_{bd} \end{aligned}$$

Junction Diode CV Model

(22-87)

$$C_{bs} = A_{seff}C_{jbs} + P_{seff}C_{jbssw} + W_{effcj} \cdot NF \cdot C_{jbsswg}$$

(22-88)

$$C_{jbs} = \begin{cases} CJS(T) \cdot \left(1 - \frac{V_{bs}}{PBS(T)}\right)^{-MJS} & \text{if } \frac{V_{bs}}{PBS(T)} \leq x_0 \\ CJS(T) \cdot \frac{1}{(1-x_0)^{MJS}} \cdot \left[1 + MJS \left(1 + \frac{\frac{V_{bs}}{PBS} - 1}{1-x_0}\right)\right] & \text{otherwise} \end{cases}$$

(22-89)

$$C_{jbssw} = \begin{cases} CJSWS(T) \cdot \left(1 - \frac{V_{bs}}{PBSWS(T)}\right)^{-MJSWS} & \text{if } \frac{V_{bs}}{PBSWS(T)} \leq x_0 \\ CJSWS(T) \cdot \frac{1}{(1-x_0)^{MJSWS}} \cdot \left[1 + MJSWS \left(1 + \frac{\frac{V_{bs}}{PBSWS(T)} - 1}{1-x_0}\right)\right] & \text{otherwise} \end{cases}$$

(22-90)

$$C_{jbsswg} = \begin{cases} CJSWGS(T) \cdot \left(1 - \frac{V_{bs}}{PBSWGS(T)}\right)^{-MJSWGS} & \text{if } \frac{V_{bs}}{PBSWGS(T)} \leq x_0 \\ CJSWGS(T) \cdot \frac{1}{(1-x_0)^{MJSWGS}} \cdot \left[1 + MJSWGS \left(1 + \frac{\frac{V_{bs}}{PBSWGS(T)} - 1}{1-x_0}\right)\right] & \text{otherwise} \end{cases}$$

where the value of x_0 is taken as 0.9.

(22-91)

$$C_{bd} = A_{deff}C_{jbd} + P_{deff}C_{jbdsw} + W_{effcj} \cdot NF \cdot C_{jbdswg}$$

(22-92)

$$C_{jbd} = \begin{cases} CJD(T) \cdot \left(1 - \frac{V_{bs}}{PBD(T)}\right)^{-MJD} & \text{if } \frac{V_{bs}}{PBD(T)} \leq x_0 \\ CJD(T) \cdot \frac{1}{(1-x_0)^{MJD}} \cdot \left[1 + MJD \left(1 + \frac{\frac{V_{bs}}{PBD} - 1}{1-x_0}\right)\right] & \text{otherwise} \end{cases}$$

(22-93)

$$C_{jbdsw} = \begin{cases} CJSWD(T) \cdot \left(1 - \frac{V_{bs}}{PBSWD(T)}\right)^{-MJSWS} & \text{if } \frac{V_{bs}}{PBSWD(T)} \leq x_0 \\ CJSWD(T) \cdot \frac{1}{(1-x_0)^{MJSWD}} \cdot \left[1 + MJSWD \left(1 + \frac{\frac{V_{bs}}{PBSWD(T)} - 1}{1-x_0}\right)\right] & \text{otherwise} \end{cases}$$

(22-94)

$$C_{jbdswg} = \begin{cases} CJSWGD(T) \cdot \left(1 - \frac{V_{bs}}{PBSWGD(T)}\right)^{-MJSWGD} & \text{if } \frac{V_{bs}}{PBSWGD(T)} \leq x_0 \\ CJSWGD(T) \cdot \frac{1}{(1-x_0)^{MJSWGD}} \cdot \left[1 + MJSWGD \left(1 + \frac{\frac{V_{bs}}{PBSWGD(T)} - 1}{1-x_0}\right)\right] & \text{otherwise} \end{cases}$$

where the value of x_0 is taken as 0.9.

Layout Dependent Parasitic Models

Effective Junction Perimeter and Area

If (PS is given)

if (**perMod**=0)

$$P_{seff} = PS$$

Else

P_{seff} computed from NF, DWJ, geoMod, DMCG, DMCI, DMDG, DMC GT, RSH, and MIN.

The effective junction area on the source side is calculated by:

If (AS is given)

$$A_{seff} = AS$$

Else

A_{seff} computed from NF, DWJ, geoMod, DMCG, DMCI, DMDG, DMC GT, RSH, and MIN.

Source/Drain Diffusion Resistance

If (number of sources NRS is given)

ELSE if (rgeoMod=0)

Source diffusion resistance Rsdiff is not generated.

Else

Rsdiff computed from NF, DWJ, geoMod, DMCG, DMCI, DMDG, DMC GT, RSH, and MIN.

where the number of source squares NRS is an instance parameter.

Similarly, the drain diffusion resistance is calculated by:

If (number of sources NRD is given)

ELSE if (rgeoMod=0)

Drain diffusion resistance Rddiff is not generated.

Else

Rddiff computed from NF, DWJ, geoMod, DMCG, DMCI, DMDG, DMC GT, RSH, and MIN.

Gate Electrode Resistance

(22-95)

$$R_{g\text{eltd}} = \frac{RSHG \cdot \left(XGW + \frac{W_{\text{effci}}}{3NGCON} \right)}{NGCON \cdot (L_{\text{drawn}} - XGL) \cdot NF}$$

Options for Source/Drain Connections

Table 1: geoMod Options

geomod	End Source	End Drain	Note
0	isolated	isolated	NF=Odd
1	isolated	shared	NF=Odd, Even

Virtuoso Simulator Components and Device Models Reference

BSIM6 Model (bsim6)

2	shared	shared	NF=Odd, Even
3	shared	isolated	NF=Odd, Even
4	isolated	merged	NF=Odd
5	shared	merged	NF=Odd, Even
6	merged	isolated	NF=Odd
7	merged	shared	NF=Odd, Even
8	merged	merged	NF=Odd
9	sha/iso	shared	NF=Even
10	shared	sha/iso	NF=Even

Options for Source Drain Contacts

Table 2: rgeoMod Options

rgeomod	End Source contact	End Drain Contact
0	No R_{sdiff}	No R_{ddiff}
1	wide	wide
2	wide	point
3	point	wide
4	point	point
5	wide	merged
6	point	merged
7	merged	wide
8	merged	point

Temperature Dependence Models

Temperature Dependence Model

Temperature Dependence of Threshold Voltage

The temperature dependence of V_{th} is modeled by:

(22-96)

$$V_{th}(T) = V_{th}(TNOM) + \left(KT1 + \frac{KT1L}{L_{eff}} + KT2 \cdot V_{br\text{eff}} \right) \cdot \left(\left(\frac{T}{TNOM} \right)^{KT1EXP} - 1 \right)$$

$$V_{fb}(T) = V_{fb}(TNOM) - KT1 \cdot \left(\frac{T}{TNOM} - 1 \right)$$

(22-97)

$$VFBSDOFF(T) = VFBSDOFF(TNOM) \cdot [1 + TVFBSDOFF \cdot (T - TNOM)]$$

$$NFACTOR(T) = NFACTOR(TNOM) + TFACTOR \cdot \left(\frac{T}{TNOM} - 1 \right)$$

(22-98)

$$ETA0(T) = ETA0(TNOM) + TETA0 \left(\frac{T}{TNOM} - 1 \right)$$

Temperature Dependence of Mobility

(22-99)

$$U0(T) = U0(TNOM) \cdot (T/TNOM)^{UTE}$$

(22-100)

$$UA(T) = UA(TNOM)[1 + UA1 \cdot (T - TNOM)]$$

(22-101)

$$UC(T) = UC(TNOM)[1 + UC1 \cdot (T - TNOM)]$$

(22-102)

$$UD(T) = UD(TNOM) \cdot (T/TNOM)^{UD1}$$

(22-103)

$$UCS(T) = UCS(TNOM) \cdot (T/TNOM)^{UCSTE}$$

Temperature Dependence of Junction Diode IV

(22-104)

$$I_{sbs} = A_{seff} J_{ss}(T) + P_{seff} J_{ssws}(T) + W_{effcj} \cdot NF \cdot J_{sswgs}(T)$$

(22-105)

$$I_{sbd} = A_{deff} J_{sd}(T) + P_{deff} J_{sswd}(T) + W_{effcj} \cdot NF \cdot J_{sswgd}(T)$$

Temperature Dependence of Junction Diode CV

(22-106)

$$PBS(T) = PBS(TNOM) - TPB \cdot (T - TNOM)$$

(22-107)

$$PBSWS(T) = PBSWS(TNOM) - TPBSW \cdot (T - TNOM)$$

(22-108)

$$PBSWGS(T) = PBSWGS(TNOM) - TPBSWG \cdot (T - TNOM)$$

(22-109)

$$PBD(T) = PBD(TNOM) - TPB \cdot (T - TNOM)$$

(22-110)

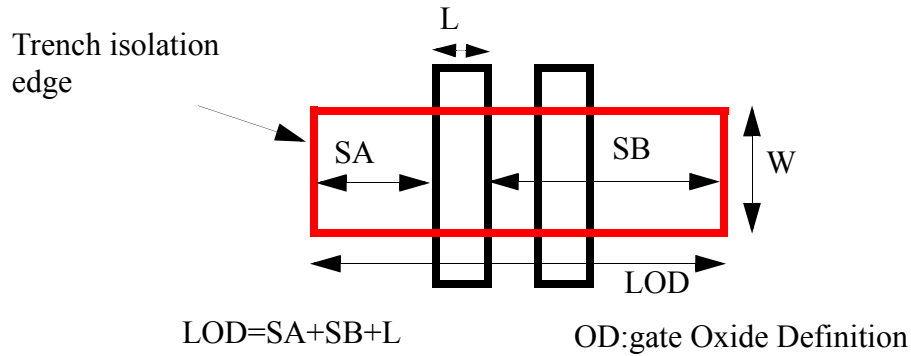
$$PBSWD(T) = PBSWD(TNOM) - TPBSW \cdot (T - TNOM)$$

(22-111)

$$PBSWGD(T) = PBSWGD(TNOM) - TPBSWG \cdot (T - TNOM)$$

Stress Effect Model Development

Figure 22-5 Typical Layout of a MOSFET



(22-112)

$$VTH0 = VTH0_{original} + \frac{KVTH0}{K_{stress_vth0}} \cdot (Inv_sa + Inv_sb - Inv_sa_{ref} - Inv_sb_{ref})$$

$$K2 = K2_{original} + \frac{STK2}{K_{stress_vth0}^{LODK2}} \cdot (Inv_sa + Inv_sb - Inv_sa_{ref} - Inv_sb_{ref})$$

$$ETA0 = ETA0_{original} + \frac{STETA0}{K_{stress_vth0}^{LODETA0}} \cdot (Inv_sa + Inv_sb - Inv_sa_{ref} - Inv_sb_{ref})$$

Figure 22-6 Layout of multiple finger MOSFET

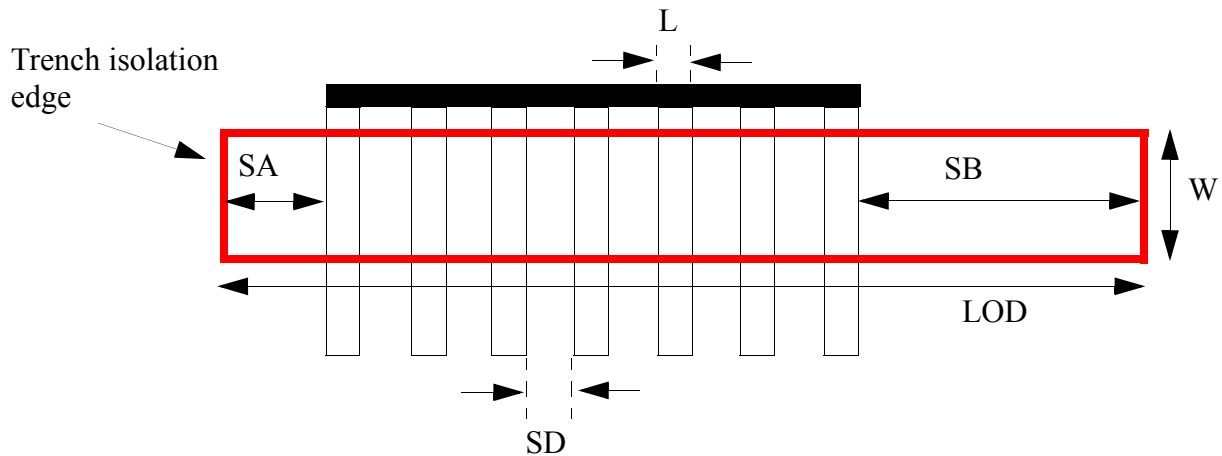
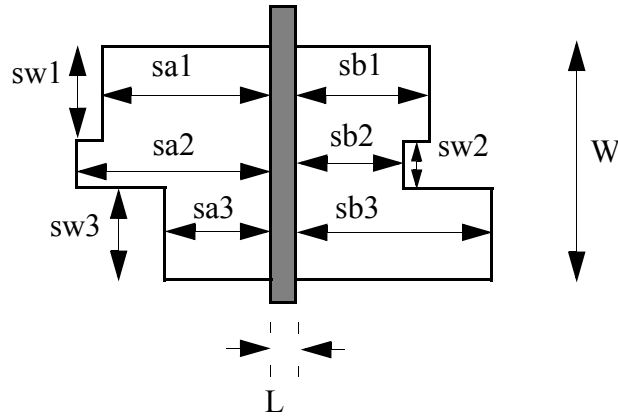


Figure 22-7 Typical layout of MOS devices with more instance parameters (swi, sai, and sbi) in addition to traditional L and W



Well Proximity Effect Model

(22-113)

$$V_{th0} = V_{th0_{org}} + KV_{TH0WE} \cdot (SCA + WEB \cdot SCB + WEC \cdot SCC)$$

$$K2 = K2_{org} + K2WE \cdot (SCA + WEB \cdot SCB + WEC \cdot SCC)$$

$$\mu_{eff} = \mu_{eff,org} \cdot (1 + KU_{0WE} \cdot (SCA + WEB \cdot SCB + WEC \cdot SCC))$$

C-V Model

Inversion Charge

(22-114)

$$q_I = n_q \cdot \left[q_s + q_d + \frac{1}{3} \cdot \frac{(q_s - q_d)^2}{1 + q_s + q_d} \right]$$

Bulk Charge

(22-115)

$$q_B = A + B + \frac{1}{3} \cdot \frac{\Delta q^2}{C^3} \cdot \left[\frac{4}{8} \cdot (C^2 + P \cdot Q) \cdot \frac{1}{1 + q_s + q_d} + \frac{2}{\gamma_g^2} \right] - n_q \cdot \left[q_s + q_d + \frac{1}{3} \cdot \frac{(q_s - q_d)^2}{1 + q_s + q_d} \right]$$

where

(22-116)

$$P = \sqrt{\frac{1}{4} + \frac{v_g - v_{fb} - \psi_p + 2.q_s}{\gamma_g^2}}$$

$$Q = \sqrt{\frac{1}{4} + \frac{v_g - v_{fb} - \psi_p + 2.q_d}{\gamma_g^2}}$$

$$A = \frac{v_g - v_{fb} - \psi_p + 2.q_s}{1 + 2 \cdot \sqrt{\frac{1}{4} + \frac{v_g - v_{fb} - \psi_p + 2.q_s}{\gamma_g^2}}}$$

$$B = \frac{v_g - v_{fb} - \psi_p + 2.q_d}{1 + 2 \cdot \sqrt{\frac{1}{4} + \frac{v_g - v_{fb} - \psi_p + 2.q_d}{\gamma_g^2}}}$$

$$C = \sqrt{\frac{1}{4} + \frac{v_g - v_{fb} - \psi_p + 2.q_s}{\gamma_g^2}} + \sqrt{\frac{1}{4} + \frac{v_g - v_{fb} - \psi_p + 2.q_d}{\gamma_g^2}}$$

Source and Drain Charges

(22-117)

$$Q_s = \frac{n_q}{3} \left[2 \cdot q_s + q_{def} + \frac{1}{2} \cdot \left(1 + \frac{4}{5} \cdot q_s + \frac{6}{5} \cdot q_{def} \right) \left(\frac{q_s - q_{def}}{1 + q_s + q_{def}} \right)^2 \right]$$

$$Q_d = \frac{n_q}{3} \left[q_s + 2 \cdot q_{def} + \frac{1}{2} \cdot \left(1 + \frac{6}{5} \cdot q_s + \frac{4}{5} \cdot q_{def} \right) \left(\frac{q_s - q_{def}}{1 + q_s + q_{def}} \right)^2 \right]$$

Bias Dependent Overlap Capacitance Model

(22-118)

$$\frac{Q_{gs,ov}}{NF \cdot W_{effCV}} = CGSO \cdot V_{gs} +$$

$$CGSL \cdot \left[V_{gs} - V_{fbsd} - V_{gs,overlap} - \frac{CKAPPAS}{2} \left(\sqrt{1 - \frac{4V_{gs,overlap}}{CKAPPAS}} - 1 \right) \right]$$

(22-119)

$$\frac{Q_{gd,ov}}{NF \cdot W_{effCV}} = CGDO \cdot V_{gd} +$$

$$CGDL \cdot \left[V_{gd} - V_{fbsd} - V_{gd,overlap} - \frac{CKAPPAD}{2} \left(\sqrt{1 - \frac{4V_{gd,overlap}}{CKAPPAD}} - 1 \right) \right]$$

Outer Fringing Capacitance

(22-120)

$$C_F = \frac{2 \cdot EPSROX \cdot \epsilon_0}{\pi} \cdot \ln[CFRCOEFF \cdot (1 + \frac{0.4e - 6}{TOX})]$$

Component Statements

This device is supported within altergroups.

Instance Parameters

1	m=1.0	Multiplicity factor (number of MOSFETs in parallel).
2	geomod	Geo dependent parasitics model.
3	rgeomod	Geometry-dependent source/drain resistance. 0: RSH-based, 1: Holistic.
4	rgatemod	Gate resistance model selector.
5	rbodymod	Distributed body R model.
6	l (m)	Channel length.
7	w (m)	Total width including fingers.
8	nf	Number of fingers.
9	as=0.0 m ²	Source to substrate junction area.
10	ad=0.0 m ²	Drain to substrate junction area.
11	ps=0.0 m	Source to substrate junction perimeter.
12	pd=0.0 m	Drain to substrate junction perimeter.
13	vfbsdoff	S/D flatband voltage offset.
14	nrs=1.0	Number of squares in source.

Virtuoso Simulator Components and Device Models Reference

BSIM6 Model (bsim6)

15	<code>nrd=1.0</code>	Number of squares in drain.
16	<code>minz=0</code>	Minimize either D or S.
17	<code>xgw=0.0 m</code>	Dist from gate contact center to dev edge.
18	<code>ngcon</code>	Number of gate contacts.
19	<code>rbpb (Ω)</code>	Resistance between bNodePrime and bNode.
20	<code>rbdb (Ω)</code>	Resistance between bNode and dbNode.
21	<code>rbsb (Ω)</code>	Resistance between bNode and sbNode.
22	<code>rbps (Ω)</code>	Resistance between bNodePrime and sbNode.
23	<code>rbpd (Ω)</code>	Resistance between bNodePrime and bNode.
24	<code>dtemp=0.0 C</code>	Offset of device temperature.
25	<code>trise=0.0 C</code>	Alias of dtemp.
26	<code>sa=0.0 m</code>	Distance between OD edge from Poly from one side.
27	<code>sb=0.0 m</code>	Distance between OD edge from Poly from other side.
28	<code>sd=0.0 m</code>	Distance between neighboring fingers.
29	<code>sca=0.0</code>	Integration of first distribution function for scattered well dopant.
30	<code>scb=0.0</code>	Integration of second distribution function for scattered well dopant.
31	<code>scc=0.0</code>	Integration of second distribution function for scattered well dopant.
32	<code>sc=0.0 m</code>	Distance to a single well edge.
33	<code>isnoisy=1</code>	Should device generate noise.

Model Definition

```
model modelName bsim6 parameter=value ...
```

Virtuoso Simulator Components and Device Models Reference

BSIM6 Model (bsim6)

Model Parameters

1	<code>type=n</code>	Transistor type. Possible values are p and n.
2	<code>version=6.00</code>	Model parameter "version" only accepts real number value, like 6.00 for version=6.0.0. The available version is 6.00 (6.0.0).
3	<code>cvmod=0</code>	0: Consistent IV-CV, 1: Different IV-CV.
4	<code>covmod=0</code>	0: Use Bias-independent Overlap Capacitances, 1: Use Bias-dependent Overlap Capacitances.
5	<code>rdsmode=0</code>	0: Internal bias dependent and external bias independent s/d resistance model, 1: External s/d resistance model, 2: Internal s/d resistance model.
6	<code>gidlmod=0</code>	0: Turn off GIDL Current, 1: Turn on GIDL Current.
7	<code>igcmode=0</code>	0: Turn off Igc, Igs and Igd, 1: Turn on Igc, Igs and Igd.
8	<code>igbmode=0</code>	0: Turn off Igb, 1: Turn on Igb.
9	<code>tnoimode=0</code>	Thermal noise model selector.
10	<code>shmode=0</code>	Self heating model selector, 1 : Turn on self heating model.
11	<code>llong=(10 1.0e-6) m</code>	L of extracted Long channel device.
12	<code>lmlt=1.0</code>	Length Shrinking Parameter.
13	<code>wmlt=1.0</code>	Width Shrinking Parameter.
14	<code>xl=0.0 m</code>	L offset for channel length due to mask/etch effect.
15	<code>wwide=(10 1.0e-6) m</code>	W of extracted Wide channel device.
16	<code>xw=0.0 m</code>	W offset for channel width due to mask/etch effect.
17	<code>lint=0.0 m</code>	delta L for IV.

Virtuoso Simulator Components and Device Models Reference

BSIM6 Model (bsim6)

18	$ll=0.0 \text{ m}^{lln}$	Length dependence of delta L.
19	$lw=0.0 \text{ m}^{lwn}$	Width dependence of delta L.
20	$lwl=0.0 \text{ m}^{(lln+lwn)}$	Area dependence of delta L.
21	$lln=1.0$	Length exponent of delta L.
22	$lwn=1.0$	Width exponent of delta L.
23	$wint=0.0 \text{ m}$	delta W for IV.
24	$wl=0.0 \text{ m}^{wln}$	Length dependence of delta W.
25	$ww=0.0 \text{ m}^{wwn}$	Width dependence of delta W.
26	$wwl=0.0 \text{ m}^{(wwn+wln)}$	Area dependence of delta W.
27	$wln=1.0$	Length exponent of delta W.
28	$wwn=1.0$	Width exponent of delta W.
29	$dlc=0.0 \text{ m}$	delta L for CV.
30	$llc=0.0 \text{ m}^{lln}$	Length dependence of delta L for CV.
31	$lwc=0.0 \text{ m}^{lwn}$	Width dependence of delta L for CV.
32	$lwlc=0.0 \text{ m}^{(lln+lwn)}$	Area dependence of delta L for CV.
33	$dwc=0.0 \text{ m}$	delta W for CV.
34	$wlc=0.0 \text{ m}^{wln}$	Length dependence of delta W for CV.
35	$wwc=0.0 \text{ m}^{wwn}$	Width dependence of delta W for CV.
36	$wwlc=0.0 \text{ m}^{(wwn+wln)}$	Area dependence of delta W for CV.
37	$tox_e=3.0e-9 \text{ m}$	Effective gate dielectric thickness relative to SiO ₂ .

Virtuoso Simulator Components and Device Models Reference

BSIM6 Model (bsim6)

38	$t_{oxp}=3.0e-9$ m	Physical gate dielectric thickness. If not given, t_{oxp} is calculated from t_{oxe} and d_{tox} .
39	$d_{tox}=0.0$ m	Difference between effective dielectric thickness and physical thickness.
40	$n_{dep}=1e24$ m ⁻³	Channel Doping Concentration for IV.
41	$n_{dep11}=0.0$	Length dependence coefficient of n_{dep} .
42	$n_{dep1exp1}=1.0$	Length dependence exponent coefficient of n_{dep} .
43	$n_{dep12}=0.0$	Length dependence of n_{dep} - for short channel devices.
44	$n_{dep1exp2}=2.0$	Length dependence exponent coefficient of n_{dep} .
45	$n_{depw}=0.0$	Width dependence coefficient of n_{dep} .
46	$n_{depwexp}=1.0$	Width dependence exponent coefficient of n_{dep} .
47	$n_{depw1}=0.0$	Width-Length dependence coefficient of n_{dep} .
48	$n_{depw1exp}=1.0$	Width-Length dependence exponent coefficient of n_{dep} .
49	$l_{ndep}=0.0$	Length dependence of n_{dep} .
50	$w_{ndep}=0.0$	Width dependence of n_{dep} .
51	$p_{ndep}=0.0$	Cross-term dependence of n_{dep} .
52	$n_{depCV}=1e24$ m ⁻³	Channel Doping Concentration for CV.
53	$n_{depCV11}=0.0$	Length dependence coefficient of n_{depCV} .
54	$n_{depCV1exp1}=1.0$	Length dependence exponent coefficient of n_{depCV} .
55	$n_{depCV12}=0.0$	Length dependence coefficient of n_{depCV} - for short channel devices.
56	$n_{depCV1exp2}=2.0$	Length dependence exponent coefficient of n_{depCV} .
57	$n_{depCVw}=0.0$	Width dependence coefficient of n_{depCV} .

Virtuoso Simulator Components and Device Models Reference

BSIM6 Model (bsim6)

58	<code>ndepcvwexp=1.0</code>	Width dependence exponent coefficient of <code>ndepcv</code> .
59	<code>ndepcvwl=0.0</code>	Width-Length dependence coefficient of <code>ndepcv</code> .
60	<code>ndepcvwlexp=1.0</code>	Width-Length dependence exponent coefficient of <code>ndepcv</code> .
61	<code>lndepcv=0.0</code>	Length dependence of <code>ndepcv</code> .
62	<code>wndepcv=0.0</code>	Width dependence of <code>ndepcv</code> .
63	<code>pndepcv=0.0</code>	Cross-term dependence of <code>ndepcv</code> .
64	<code>ngate=5e25 m⁻³</code>	Gate Doping Concentration.
65	<code>lngate=0.0</code>	Length dependence of <code>ngate</code> .
66	<code>wngate=0.0</code>	Width dependence of <code>ngate</code> .
67	<code>pngate=0.0</code>	Cross-term dependence of <code>ngate</code> .
68	<code>easub=4.05 eV</code>	Electron affinity of substrate.
69	<code>ni0sub=1.1e16 m⁻³</code>	Intrinsic carrier concentration of the substrate at 300.15K.
70	<code>bg0sub=1.17 eV</code>	Band gap of substrate at 300.15K.
71	<code>epsrsub=11.9</code>	Relative dielectric constant of the channel material.
72	<code>epsrox=3.9</code>	Relative dielectric constant of the gate dielectric.
73	<code>xj=1.5e-7 m</code>	S/D junction depth.
74	<code>lxj=0.0</code>	Length dependence of <code>xj</code> .
75	<code>wxj=0.0</code>	Width dependence of <code>xj</code> .
76	<code>pxj=0.0</code>	Cross-term dependence of <code>xj</code> .
77	<code>vfb=(-1.0) V</code>	Flat band voltage for IV.
78	<code>lvfb=0.0</code>	Length dependence of <code>vfb</code> .

Virtuoso Simulator Components and Device Models Reference

BSIM6 Model (bsim6)

79	wvfb=0.0	Width dependence of vfb.
80	pvfb=0.0	Cross-term dependence vfb.
81	vfbcv=(-1.0) V	Flat band voltage for CV.
82	lvfbcv=0.0	Length dependence of vfbcv.
83	wvfbcv=0.0	Width dependence of vfbcv.
84	pvfbcv=0.0	Cross-term dependence vfbcv.
85	vfbcvl=0.0	Length dependence coefficient of vfbcv.
86	vfbcvlexp=1.0	Length dependence exponent coefficient of vfbcv.
87	vfbcvw=0.0	Width dependence coefficient of vfbcv.
88	vfbcvwexp=1.0	Width dependence exponent coefficient of vfbcv.
89	vfbcvwl=0.0	Width-Length dependence coefficient of vfbcv.
90	vfbcvwlexp=1.0	Width-Length dependence coefficient of vfbcv.
91	permod=1	Whether ps/pd (when given) include gate-edge perimeter.
92	dwj=0.0	delta W for S/D junctions.
93	nsd=1e26 m ⁻³	S/D doping concentration.
94	lnsd=0.0	Length dependence of nsd.
95	wnsd=0.0	Width dependence of nsd.
96	pnsd=0.0	Cross-term dependence of nsd.
97	dvtp0=0.0	First coefficient of drain-induced vth shift for long-channel pocket devices.
98	ldvtp0=0	Length dependence of dvtp0.
99	wdvtp0=0	Width dependence of dvtp0.

Virtuoso Simulator Components and Device Models Reference

BSIM6 Model (bsim6)

100	$pdvtp0=0$	Cross-term dependence of $dvtp0$.
101	$dvtp1=0.0$	Second coefficient of drain-induced V_{th} shift for long-channel pocket devices.
102	$ldvtp1=0$	Length dependence of $dvtp1$.
103	$wdvtp1=0$	Width dependence of $dvtp1$.
104	$pdvtp1=0$	Cross-term dependence of $dvtp1$.
105	$dvtp2=0.0$	3rd parameter for v_{th} shift due to pocket.
106	$ldvtp2=0$	Length dependence of $dvtp2$.
107	$wdvtp2=0$	Width dependence of $dvtp2$.
108	$pdvtp2=0$	Cross-term dependence of $dvtp2$.
109	$dvtp3=0.0$	4th parameter for v_{th} shift due to pocket.
110	$ldvtp3=0$	Length dependence of $dvtp3$.
111	$wdvtp3=0$	Width dependence of $dvtp3$.
112	$pdvtp3=0$	Cross-term dependence of $dvtp3$.
113	$dvtp4=0.0$	5th parameter for v_{th} shift due to pocket.
114	$ldvtp4=0$	Length dependence of $dvtp4$.
115	$wdvtp4=0$	Width dependence of $dvtp4$.
116	$pdvtp4=0$	Cross-term dependence of $dvtp4$.
117	$dvtp5=0.0$	6th parameter for v_{th} shift due to pocket.
118	$ldvtp5=0$	Length dependence of $dvtp5$.
119	$wdvtp5=0$	Width dependence of $dvtp5$.
120	$pdvtp5=0$	Cross-term dependence of $dvtp5$.

Virtuoso Simulator Components and Device Models Reference

BSIM6 Model (bsim6)

121	$\text{phin}=0.045$ V	Nonuniform vertical doping effect on surface potential.
122	$\text{lphin}=0.0$	Length dependence of phin .
123	$\text{wphin}=0.0$	Width dependence of phin .
124	$\text{pphin}=0.0$	Cross-term dependence of phin .
125	$\text{eta0}=0.08$	DIBL coefficient.
126	$\text{l eta0}=0.0$	Length dependence of eta0 .
127	$\text{w eta0}=0.0$	Width dependence of eta0 .
128	$\text{p eta0}=0.0$	Cross-term dependence of eta0 .
129	$\text{dsub}=1.0$	Length scaling exponent for DIBL.
130	$\text{etab}=(-0.07)$	Body bias coefficient for subthreshold DIBL effect.
131	$\text{etabexp}=1.0$	Exponent coefficient of etab .
132	$\text{l etab}=0.0$	Length dependence of etab .
133	$\text{w etab}=0.0$	Width dependence of etab .
134	$\text{p etab}=0.0$	Cross-term dependence of etab .
135	$\text{k2}=0.0$	V_{th} shift due to vertical non-uniform doping.
136	$\text{k2l}=0.0$	Length dependence coefficient of k2 .
137	$\text{k2l exp}=1.0$	Length dependence exponent coefficient of k2 .
138	$\text{k2w}=0.0$	Width dependence coefficient of k2 .
139	$\text{k2w exp}=1.0$	Width dependence exponent coefficient of k2 .
140	$\text{k2wl}=0.0$	Width-Length dependence coefficient of k2 .
141	$\text{k2wl exp}=1.0$	Width-Length dependence exponent coefficient of k2 .
142	$\text{lk2}=0.0$	Length dependence of k2 .

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BSIM6 Model (bsim6)

143	$wk2=0.0$	Width dependence of $k2$.
144	$pk2=0.0$	Cross-term dependence of $k2$.
145	$ados=0.0$	Quantum mechanical effect prefactor cum switch in inversion.
146	$bdos=1.0$	Charge centroid parameter - slope of CV curve under QME in inversion.
147	$qm0=1.0e-3$	Charge centroid parameter - starting point for QME in inversion.
148	$etaqm=0.54$	Bulk charge coefficient for charge centroid in inversion.
149	$cit=0.0 \text{ F/m}^2$	parameter for interface trap.
150	$lcit=0.0$	Length dependence of cit .
151	$wcit=0.0$	Width dependence of cit .
152	$pcit=0.0$	Cross-term dependence of cit .
153	$nfactor=0.0$	Sub-threshold slope factor.
154	$nfactorl=0.0$	Length dependence coefficient of $nfactor$.
155	$nfactorlexp=1.0$	Length dependence exponent coefficient of $nfactor$.
156	$nfactorw=0.0$	Width dependence coefficient of $nfactor$.
157	$nfactorwexp=1.0$	Width dependence exponent coefficient of $nfactor$.
158	$nfactorwl=0.0$	Width-Length dependence coefficient of $nfactor$.
159	$nfactorwlexp=1.0$	Width-Length dependence exponent coefficient of $nfactor$.
160	$lnfactor=0.0$	Length dependence of $nfactor$.
161	$wnfactor=0.0$	Width dependence of $nfactor$.
162	$pnfactor=0.0$	Cross-term dependence of $nfactor$.
163	$cdscd=1e-9 \text{ F/m}^2 \text{ V}$	drain-bias sensitivity of sub-threshold slope.

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BSIM6 Model (bsim6)

164	$cdscd1=0.0$	Length dependence coefficient of $cdscd$.
165	$cdscd1exp=1.0$	Length dependence exponent coefficient of $cdscd$.
166	$lcdscd=0.0$	Length dependence of $cdscd$.
167	$wcdscd=0.0$	Width dependence of $cdscd$.
168	$pcdscd=0.0$	Cross-term dependence of $cdscd$.
169	$cdscb=0.0$	F/m^2 V body-bias sensitivity of sub-threshold slope.
170	$cdscb1=0.0$	Length dependence coefficient of $cdscb$.
171	$cdscb1exp=1.0$	Length dependence exponent coefficient of $cdscb$.
172	$lcdscb=0.0$	Length dependence of $cdscb$.
173	$wcdscb=0.0$	Width dependence of $cdscb$.
174	$pcdscb=0.0$	Cross-term dependence of $cdscb$.
175	$vsat=1e5$	m/s Saturation velocity.
176	$lvsat=0.0$	Length dependence of $vsat$.
177	$wvsat=0.0$	Width dependence of $vsat$.
178	$pvsat=0.0$	Cross-term dependence of $vsat$.
179	$vsatl=0.0$	Length dependence coefficient of $vsat$.
180	$vsatl1exp=1.0$	Length dependence exponent coefficient of $vsat$.
181	$vsatw=0.0$	Width dependence coefficient of $vsat$.
182	$vsatw1exp=1.0$	Width dependence exponent coefficient of $vsat$.
183	$vsatwl=0.0$	Width-Length dependence coefficient of $vsat$.
184	$vsatwl1exp=1.0$	Width-Length dependence exponent coefficient of $vsat$.
185	$delta=0.125$	V Smoothing function factor for $Vdsat$.

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BSIM6 Model (bsim6)

186	<code>ldelta=0.0</code>	Length dependence of delta.
187	<code>wdelta=0.0</code>	Width dependence of delta.
188	<code>pdelta=0.0</code>	Cross-term dependence of delta.
189	<code>deltal=0.0</code>	Length dependence coefficient of delta.
190	<code>deltalexp=1.0</code>	Length dependence exponent coefficient of delta.
191	<code>vsatcv=1e5 m/s</code>	vsat parameter for CV.
192	<code>lvsatcv=0.0</code>	Length dependence of vsatcv.
193	<code>wvsatcv=0.0</code>	Width dependence of vsatcv.
194	<code>pvsatcv=0.0</code>	Cross-term dependence of vsatcv.
195	<code>vsatcvl=0.0</code>	Length dependence coefficient of of vsatcv.
196	<code>vsatcvlexp=1.0</code>	Length dependence exponent coefficient of vsatcv.
197	<code>vsatcvw=0.0</code>	Width dependence coefficient of of vsatcv.
198	<code>vsatcvwexp=1.0</code>	Length dependence exponent coefficient of vsatcv.
199	<code>vsatcvwl=0.0</code>	Width-Length dependence coefficient of of vsatcv.
200	<code>vsatcvwlexp=1.0</code>	Width-Length dependence exponent coefficient of of vsatcv.
201	<code>u0=67.0e-3 m²/Vs</code>	Low-field surface mobility at tnom.
202	<code>u0l=0.0</code>	Length dependence coefficient of u0.
203	<code>u0lexp=1.0</code>	Length dependence exponent coefficient of u0.
204	<code>lu0=0.0</code>	Length dependence of u0.
205	<code>wu0=0.0</code>	Width dependence of u0.
206	<code>pu0=0.0</code>	Cross-term dependence of u0.
207	<code>etamob=1.0</code>	Effective field parameter (should be kept close to 1).

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BSIM6 Model (bsim6)

208	$ua=0.001 \text{ m/V}$	Mobility reduction coefficient.
209	$ual=0.0$	Length dependence coefficient of ua .
210	$ualexp=1.0$	Length dependence exponent coefficient of ua .
211	$uaw=0.0$	Width dependence coefficient of ua .
212	$uawexp=1.0$	Width dependence exponent coefficient of ua .
213	$uawl=0.0$	Width-Length dependence coefficient of ua .
214	$uawlexp=1.0$	Width-Length dependence coefficient of ua .
215	$lua=0.0$	Length dependence of ua .
216	$wua=0.0$	Width dependence of ua .
217	$pua=0.0$	Cross-term dependence of ua .
218	$eu=1.5$	Mobility reduction exponent.
219	$leu=0.0$	Length dependence of eu .
220	$weu=0.0$	Width dependence of eu .
221	$peu=0.0$	Cross-term dependence of eu .
222	$eul=0.0$	Length dependence coefficient of eu .
223	$eulexp=1.0$	Length dependence exponent coefficient of eu .
224	$euw=0.0$	Width dependence coefficient of eu .
225	$euwexp=1.0$	Width dependence exponent coefficient of eu .
226	$euwl=0.0$	Width-Length dependence coefficient of eu .
227	$euwlexp=1.0$	Width-Length dependence coefficient of eu .
228	$ud=0.001 \text{ 1/m}^2$	Coulombic scattering parameter.
229	$udl=0.0$	Length dependence coefficient of ud .

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BSIM6 Model (bsim6)

230	<code>udl_{exp}=1.0</code>	Length dependence exponent coefficient of <code>ud</code> .
231	<code>l_{ud}=0.0</code>	Length dependence of <code>ud</code> .
232	<code>w_{ud}=0.0</code>	Width dependence of <code>ud</code> .
233	<code>p_{ud}=0.0</code>	Cross-term dependence of <code>ud</code> .
234	<code>uc_s=2.0</code>	Coulombic scattering parameter.
235	<code>l_{uc_s}=0.0</code>	Length dependence of <code>uc_s</code> .
236	<code>w_{uc_s}=0.0</code>	Width dependence of <code>uc_s</code> .
237	<code>p_{uc_s}=0.0</code>	Cross-term dependence of <code>uc_s</code> .
238	<code>uc=0.0</code>	Mobility reduction with body bias.
239	<code>uc_l=0.0</code>	Length dependence coefficient of <code>uc</code> .
240	<code>uc_{l_{exp}}=1.0</code>	Length dependence exponent coefficient of <code>uc</code> .
241	<code>uc_w=0.0</code>	Width dependence coefficient of <code>uc</code> .
242	<code>uc_{w_{exp}}=1.0</code>	Width dependence exponent coefficient of <code>uc</code> .
243	<code>uc_{w_l}=0.0</code>	Width-Length dependence coefficient of <code>uc</code> .
244	<code>uc_{w_{l_{exp}}}=1.0</code>	Width-Length dependence exponent coefficient.
245	<code>l_{uc}=0.0</code>	Length dependence of <code>uc</code> .
246	<code>w_{uc}=0.0</code>	Width dependence of <code>uc</code> .
247	<code>p_{uc}=0.0</code>	Cross-term dependence of <code>uc</code> .
248	<code>p_{clm}=0.0</code>	<code>clm</code> prefactor.
249	<code>p_{clm_l}=0.0</code>	Length dependence coefficient of <code>p_{clm}</code> .
250	<code>p_{clm_{l_{exp}}}=1.0</code>	Length dependence exponent coefficient of <code>p_{clm}</code> .
251	<code>l_{p_{clm}}=0.0</code>	Length dependence of <code>p_{clm}</code> .

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BSIM6 Model (bsim6)

252	$w_{pclm}=0.0$	Width dependence of p_{clm} .
253	$pp_{pclm}=0.0$	Cross-term dependence of p_{clm} .
254	$p_{clmg}=0.0$	clm prefactor gate voltage dependence.
255	$p_{clm_{cv}}=0.0$	clm parameter for CV.
256	$p_{clm_{cv1}}=0.0$	Length dependence coefficient of $p_{clm_{cv}}$.
257	$p_{clm_{cv1exp}}=1.0$	Length dependence exponent coefficient of $p_{clm_{cv}}$.
258	$lp_{clm_{cv}}=0.0$	Length dependence of $p_{clm_{cv}}$.
259	$w_{p_{clm_{cv}}}=0.0$	Width dependence of $p_{clm_{cv}}$.
260	$pp_{p_{clm_{cv}}}=0.0$	Cross-term dependence of $p_{clm_{cv}}$.
261	$pscbe1=4.24e8$ V/m	Substrate current body-effect coeff.
262	$lp_{pscbe1}=0.0$	Length dependence of $pscbe1$.
263	$w_{pscbe1}=0.0$	Width dependence of $pscbe1$.
264	$pp_{pscbe1}=0.0$	Cross-term dependence of $pscbe1$.
265	$pscbe2=1.0e-8$ V/m	Substrate current body-effect coeff.
266	$lp_{pscbe2}=0.0$	Length dependence of $pscbe2$.
267	$w_{pscbe2}=0.0$	Width dependence of $pscbe2$.
268	$pp_{pscbe2}=0.0$	Cross-term dependence of $pscbe2$.
269	$pdits=0.0$ 1/V	Coefficient for drain-induced v_{th} shifts.
270	$lp_{pdits}=0.0$	Length dependence of $pdits$.
271	$w_{pdits}=0.0$	Width dependence of $pdits$.
272	$pp_{pdits}=0.0$	Cross-term dependence of $pdits$.
273	$pditsl=0.0$ 1/m	L dep of drain-induced v_{th} shifts.

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BSIM6 Model (bsim6)

274	<code>pditsd=0.0</code>	$1/V$	Vds dep of drain-induced vth shifts.
275	<code>lpditsd=0.0</code>		Length dependence of pditsl.
276	<code>wpditsd=0.0</code>		Width dependence of pditsl.
277	<code>ppditsd=0.0</code>		Cross-term dependence of pditsl.
278	<code>rsh=0.0</code>	Ω	Source-drain sheet resistance.
279	<code>prwg=1.0</code>	$1/V$	gate bias dependence of S/D extension resistance.
280	<code>lprwg=0.0</code>		Length dependence of prwg.
281	<code>wprwg=0.0</code>		Width dependence of prwg.
282	<code>pprgw=0.0</code>		Cross-term dependence of prwg.
283	<code>prwb=0.0</code>	$1/ V$	Body bias dependence of resistance.
284	<code>lprwb=0.0</code>		Length dependence of prwb.
285	<code>wprwb=0.0</code>		Width dependence of prwb.
286	<code>pprwb=0.0</code>		Cross-term dependence of prwb.
287	<code>prwbl=0.0</code>		Length dependence coefficient of pprwb.
288	<code>prwblexp=1.0</code>		Length dependence exponent coefficient of pprwb.
289	<code>wr=1.0</code>		W dependence parameter of S/D extension resistance.
290	<code>lwr=0.0</code>		Length dependence of wr.
291	<code>wwr=0.0</code>		Width dependence of wr.
292	<code>pwr=0.0</code>		Cross-term dependence of wr.
293	<code>rswmin=0.0</code>	$\Omega \mu m^{wr}$	Source Resistance per unit width at high Vgs (rdsmod=1).
294	<code>lrswmin=0.0</code>		Length dependence of rswmin.

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BSIM6 Model (bsim6)

295	<code>wrswmin=0.0</code>	Width dependence of <code>rswmin</code> .
296	<code>prswmin=0.0</code>	Cross-term dependence of <code>rswmin</code> .
297	<code>rsw=10.0</code> Ω μm^{wr}	zero bias Source Resistance (<code>rdsmod=1</code>).
298	<code>lrsw=0.0</code>	Length dependence of <code>rsw</code> .
299	<code>wrsw=0.0</code>	Width dependence of <code>rsw</code> .
300	<code>prsw=0.0</code>	Cross-term dependence of <code>rsw</code> .
301	<code>rswl=0.0</code>	Geometrical scaling of <code>rsw</code> (<code>rdsmod=1</code>).
302	<code>rswlexp=1.0</code>	Geometrical scaling of <code>rsw</code> (<code>rdsmod=1</code>).
303	<code>rdwmin=rswmin</code> Ω μm^{wr}	Drain Resistance per unit width at high <code>Vgs</code> (<code>rdsmod=1</code>).
304	<code>lrdwmin=lrswmin</code>	Length dependence of <code>rdwmin</code> .
305	<code>wrdwmin=wrswmin</code>	Width dependence of <code>rdwmin</code> .
306	<code>prdwmin=prswmin</code>	Cross-term dependence of <code>rdwmin</code> .
307	<code>rdw=rsw</code> Ω μm^{wr}	zero bias Drain Resistance (<code>rdsmod=1</code>).
308	<code>lrdw=lrsw</code>	Length dependence of <code>rdw</code> .
309	<code>wrdw=wrsw</code>	Width dependence of <code>rdw</code> .
310	<code>prdw=prsw</code>	Cross-term dependence of <code>rdw</code> .
311	<code>rdwl=rswl</code>	Geometrical scaling of <code>rdw</code> (<code>rdsmod=1</code>).
312	<code>rdwlexp=rswlexp</code>	Geometrical scaling of <code>rdw</code> (<code>rdsmod=1</code>).
313	<code>rdswmin=0.0</code> Ω μm^{wr}	S/D Resistance per unit width at high <code>Vgs</code> (<code>rdsmod=0</code> and <code>rdsmod=2</code>).
314	<code>lrdswmin=0.0</code>	Length dependence of <code>rdswmin</code> .

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BSIM6 Model (bsim6)

315	<code>wrdswmin=0.0</code>	Width dependence of <code>rdswwmin</code> .
316	<code>prdswwmin=0.0</code>	Cross-term dependence of <code>rdswwmin</code> .
317	<code>rdsww=20.0</code>	$\Omega \mu\text{m}^{\text{wr}}$ zero bias Resistance (<code>rdsmod=0</code> and <code>rdsmod=2</code>).
318	<code>rdswwl=0.0</code>	Geometrical scaling of <code>rdsww</code> (<code>rdsmod=0</code> and <code>rdsmod=2</code>).
319	<code>rdswwlexp=1.0</code>	Geometrical scaling of <code>rdsww</code> (<code>rdsmod=0</code> and <code>rdsmod=2</code>).
320	<code>lrdsww=0.0</code>	Length dependence of <code>rdsww</code> .
321	<code>wrdsww=0.0</code>	Width dependence of <code>rdsww</code> .
322	<code>prdsww=0.0</code>	Cross-term dependence of <code>rdsww</code> .
323	<code>psat=1.0</code>	Gmsat variation with gate bias.
324	<code>lpsat=0.0</code>	Length dependence of <code>psat</code> .
325	<code>wpsat=0.0</code>	Width dependence of <code>psat</code> .
326	<code>ppsat=0.0</code>	Cross-term dependence of <code>psat</code> .
327	<code>psatl=0.0</code>	Geometrical scaling of <code>psat</code> .
328	<code>psatlexp=1.0</code>	Geometrical scaling of <code>psat</code> .
329	<code>psatb=0.0</code>	Body bias effect on <code>Idsat</code> .
330	<code>lpsatb=0.0</code>	Length dependence of <code>psatb</code> .
331	<code>wpsatb=0.0</code>	Width dependence of <code>psatb</code> .
332	<code>ppsatb=0.0</code>	Cross-term dependence of <code>psatb</code> .
333	<code>psatx=1.0</code>	Parameter for <code>Idsat</code> .
334	<code>ptwg=0.0</code>	<code>Idsat</code> variation with gate bias.
335	<code>lptwg=0.0</code>	Length dependence of <code>ptwg</code> .

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BSIM6 Model (bsim6)

336	wptwg=0.0	Width dependence of ptwg.
337	pptwg=0.0	Cross-term dependence of ptwg.
338	ptwgl=0.0	Length dependence coefficient of ptwg.
339	ptwglexp=1.0	Length dependence exponent coefficient of ptwg.
340	pdiblc=0.0	parameter for DIBL effect on rout.
341	pdiblc1=0.0	Length dependence coefficient of pdiblc.
342	pdiblc1exp=1.0	Length dependence exponent coefficient of pdiblc.
343	lpdiblc=0.0	Length dependence of pdiblc.
344	wpdiblc=0.0	Width dependence of pdiblc.
345	ppdiblc=0.0	Cross-term dependence of pdiblc.
346	pdiblc1cb=0.0	parameter for DIBL effect on rout.
347	lpdiblc1cb=0.0	Length dependence of pdiblc1cb.
348	wpdiblc1cb=0.0	Width dependence of pdiblc1cb.
349	ppdiblc1cb=0.0	Cross-term dependence of pdiblc1cb.
350	pvag=1.0	Vg dependence of early voltage.
351	lpvag=0.0	Length dependence of pvag.
352	wpvag=0.0	Width dependence of pvag.
353	ppvag=0.0	Cross-term dependence of pvag.
354	fprout=0.0	$V / \mu\text{m}$ Effect of pocket implant on rout degradation.
355	fprout1=0.0	Length dependence coefficient of fprout.
356	fprout1exp=1.0	Length dependence exponent coefficient of fprout.

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BSIM6 Model (bsim6)

357	<code>lfprout=0.0</code>	Length dependence of <code>fprout</code> .
358	<code>wfprout=0.0</code>	Width dependence of <code>fprout</code> .
359	<code>pfprout=0.0</code>	Cross-term dependence of <code>fprout</code> .
360	<code>alpha0=0.0</code> m/V	first parameter of <code>lii</code> .
361	<code>alpha0l=0.0</code>	Length dependence coefficient of <code>alpha0</code> .
362	<code>alpha0lexp=1.0</code>	Length dependence exponent coefficient of <code>alpha0</code> .
363	<code>lalpha0=0.0</code>	Length dependence of <code>alpha0</code> .
364	<code>walpha0=0.0</code>	Width dependence of <code>alpha0</code> .
365	<code>palpha0=0.0</code>	Cross-term dependence of <code>alpha0</code> .
366	<code>beta0=0.0</code> 1/V	Vds dependent parameter of <code>lii</code> .
367	<code>lbeta0=0.0</code>	Length dependence of <code>beta0</code> .
368	<code>wbeta0=0.0</code>	Width dependence of <code>beta0</code> .
369	<code>pbeta0=0.0</code>	Cross-term dependence of <code>beta0</code> .
370	<code>aigbacc=1.36e-2</code>	$\left \frac{F}{g} \right \text{ s/m}$ Parameter for <code>Igb</code> in accumulation.
371	<code>bigbacc=1.71e-3</code>	$\left \frac{F}{g} \right \text{ s/(m V)}$ Parameter for <code>Igb</code> in accumulation.
372	<code>cigbacc=0.075</code>	1/V Parameter for <code>Igb</code> in accumulation.
373	<code>nigbacc=1.0</code>	Parameter for <code>Igbacc</code> slope.
374	<code>aigbinv=1.11e-2</code>	$\left \frac{F}{g} \right \text{ s/m}$ Parameter for <code>Igb</code> in inversion.
375	<code>bigbinv=9.49e-4</code>	$\left \frac{F}{g} \right \text{ s/(m V)}$ Parameter for <code>Igb</code> in inversion.
376	<code>cigbinv=0.006</code>	1/V Parameter for <code>Igb</code> in inversion.

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BSIM6 Model (bsim6)

377	eigbinv=1.1 V	Parm for the Si bandgap for Igbinv.
378	nigbinv=3.0	Parameter for Igbinv slope.
379	aigc=1.36e-2 F/g s/m	Parameter for Igc.
380	bigc=1.71e-3 F/g s/(m V)	Parameter for Igc.
381	cigc=0.075 1/V	Parameter for Igc.
382	aigs=1.36e-2 F/g s/m	Parameter for Igs.
383	bigd=1.71e-3 F/g s/(m V)	Parameter for Igs.
384	cigs=0.075 1/V	Parameter for Igs.
385	aigd=1.36e-2 F/g s/m	Parameter for Igd.
386	bigd=1.71e-3 F/g s/(m V)	Parameter for Igd.
387	cigd=0.075 1/V	Parameter for Igd.
388	dlcig=0.0 m	Delta L for Ig model.
389	dlcigd=0.0 m	Delta L for Ig model.
390	poxedge=1.0	Factor for the gate edge tox.
391	ntox=1.0	Exponent for tox ratio.
392	toxref=3.0e-9 m	Target tox value.
393	pigcd=1.0	Igc, S/D partition parameter.
394	aigcl=0.0	Length dependence coefficient of aigc.
395	aigcw=0.0	Width dependence coefficient of aigc.

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BSIM6 Model (bsim6)

396	aigsl=0.0	Length dependence coefficient of aigs.
397	aigsw=0.0	Width dependence coefficient of aigs.
398	aigd1=0.0	Length dependence coefficient of aigd.
399	aigdw=0.0	Width dependence coefficient of aigd.
400	pigcd1=0.0	Length dependence coefficient of pigcd.
401	laigbinv=0.0	Length dependence of aigbinv.
402	waigbinv=0.0	Width dependence of aigbinv.
403	paigbinv=0.0	Cross-term dependence of aigbinv.
404	lbigbinv=0.0	Length dependence of bigbinv.
405	wbigbinv=0.0	Width dependence of bigbinv.
406	pbigbinv=0.0	Cross-term dependence of bigbinv.
407	lcigbinv=0.0	Length dependence of cigbinv.
408	wcigbinv=0.0	Width dependence of cigbinv.
409	pcigbinv=0.0	Cross-term dependence of cigbinv.
410	leigbinv=0.0	Length dependence of eigbinv.
411	weigbinv=0.0	Width dependence of eigbinv.
412	peigbinv=0.0	Cross-term dependence of eigbinv.
413	lnigbinv=0.0	Length dependence of nigbinv.
414	wnigbinv=0.0	Width dependence of nigbinv.
415	pnigbinv=0.0	Cross-term dependence of nigbinv.
416	laigbacc=0.0	Length dependence of aigbacc.
417	waigbacc=0.0	Width dependence of aigbacc.

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BSIM6 Model (bsim6)

418	paigbacc=0.0	Cross-term dependence of aigbacc.
419	lbigbacc=0.0	Length dependence of bigbacc.
420	wbigbacc=0.0	Width dependence of bigbacc.
421	pbigbacc=0.0	Cross-term dependence of bigbacc.
422	lcigbacc=0.0	Length dependence of cigbacc.
423	wcigbacc=0.0	Width dependence of cigbacc.
424	pcigbacc=0.0	Cross-term dependence of cigbacc.
425	lnigbacc=0.0	Length dependence of nigbacc.
426	wnigbacc=0.0	Width dependence of nigbacc.
427	pnigbacc=0.0	Cross-term dependence of nigbacc.
428	laigc=0.0	Length dependence of aigc.
429	waigc=0.0	Width dependence of aigc.
430	paigc=0.0	Cross-term dependence of aigc.
431	lbigc=0.0	Length dependence of bigc.
432	wbigc=0.0	Width dependence of bigc.
433	pbigc=0.0	Cross-term dependence of bigc.
434	lcigc=0.0	Length dependence of cigc.
435	wcigc=0.0	Width dependence of cigc.
436	pcigc=0.0	Cross-term dependence of cigc.
437	laigs=0.0	Length dependence of aigs.
438	waigs=0.0	Width dependence of aigs.
439	paigs=0.0	Cross-term dependence of aigs.

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BSIM6 Model (bsim6)

440	lbig _s =0.0	Length dependence of big _s .
441	wbig _s =0.0	Width dependence of big _s .
442	pbig _s =0.0	Cross-term dependence of big _s .
443	lcig _s =0.0	Length dependence of cig _s .
444	wcig _s =0.0	Width dependence of cig _s .
445	pcig _s =0.0	Cross-term dependence of cig _s .
446	laig _d =0.0	Length dependence of aig _d .
447	waig _d =0.0	Width dependence of aig _d .
448	paig _d =0.0	Cross-term dependence of aig _d .
449	lbig _d =0.0	Length dependence of big _d .
450	wbig _d =0.0	Width dependence of big _d .
451	pbig _d =0.0	Cross-term dependence of big _d .
452	lcig _d =0.0	Length dependence of cig _d .
453	wcig _d =0.0	Width dependence of cig _d .
454	pcig _d =0.0	Cross-term dependence of cig _d .
455	lpoxedge=0.0	Length dependence of poxedge.
456	wpoxedge=0.0	Width dependence of poxedge.
457	ppoxedge=0.0	Cross-term dependence of poxedge.
458	ldlcig=0.0	Length dependence of dlcig.
459	wdlcig=0.0	Width dependence of dlcig.
460	pdlcig=0.0	Cross-term dependence of dlcig.
461	ldlcig _d =0.0	Length dependence of dlcig _d .

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462	<code>wdlcigd=0.0</code>	Width dependence of <code>dlcigd</code> .
463	<code>pdlcigd=0.0</code>	Cross-term dependence of <code>dlcigd</code> .
464	<code>lntox=0.0</code>	Length dependence of <code>ntox</code> .
465	<code>wntox=0.0</code>	Width dependence of <code>ntox</code> .
466	<code>pntox=0.0</code>	Cross-term dependence of <code>ntox</code> .
467	<code>agidl=0.0</code> $1/\Omega$	Pre-exponential coefficient for GIDL.
468	<code>agidl1=0.0</code>	Length dependence coefficient of <code>agidl</code> .
469	<code>agidlw=0.0</code>	Width dependence coefficient of <code>agidl</code> .
470	<code>lagidl=0.0</code>	Length dependence of <code>agidl</code> .
471	<code>wagidl=0.0</code>	Width dependence of <code>agidl</code> .
472	<code>pagidl=0.0</code>	Cross-term dependence of <code>agidl</code> .
473	<code>bgidl=2.3e9</code> V/m	Exponential coefficient for GIDL.
474	<code>lbgidl=0.0</code>	Length dependence of <code>bgidl</code> .
475	<code>wbgidl=0.0</code>	Width dependence of <code>bgidl</code> .
476	<code>pbgidl=0.0</code>	Cross-term dependence of <code>bgidl</code> .
477	<code>cgidl=0.5</code> V^3	Parameter for body-bias effect on GIDL.
478	<code>lcgidl=0.0</code>	Length dependence of <code>cgidl</code> .
479	<code>wcgidl=0.0</code>	Width dependence of <code>cgidl</code> .
480	<code>pcgidl=0.0</code>	Cross-term dependence of <code>cgidl</code> .
481	<code>egidl=0.8</code> V	Fitting parameter for band bending for GIDL.
482	<code>legidl=0.0</code>	Length dependence of <code>egidl</code> .
483	<code>wegidl=0.0</code>	Width dependence of <code>egidl</code> .

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BSIM6 Model (bsim6)

484	<code>pegidl=0.0</code>	Cross-term dependence of <code>egidl</code> .
485	<code>agisl=0.0</code> $1/\Omega$	Pre-exponential coefficient for GISL.
486	<code>agisl1=0.0</code>	Length dependence coefficient of <code>agisl</code> .
487	<code>agislw=0.0</code>	Width dependence coefficient of <code>agisl</code> .
488	<code>lagisl=0.0</code>	Length dependence of <code>agisl</code> .
489	<code>wagisl=0.0</code>	Width dependence of <code>agisl</code> .
490	<code>pagisl=0.0</code>	Cross-term dependence of <code>agisl</code> .
491	<code>bgisl=2.3e9</code> V/m	Exponential coefficient for GISL.
492	<code>lbgisl=0.0</code>	Length dependence of <code>bgisl</code> .
493	<code>wbgisl=0.0</code>	Width dependence of <code>bgisl</code> .
494	<code>pbgisl=0.0</code>	Cross-term dependence of <code>bgisl</code> .
495	<code>cgisl=0.5</code> V^3	Parameter for body-bias effect on GISL.
496	<code>lcgisl=0.0</code>	Length dependence of <code>cgisl</code> .
497	<code>wcgisl=0.0</code>	Width dependence of <code>cgisl</code> .
498	<code>pcgisl=0.0</code>	Cross-term dependence of <code>cgisl</code> .
499	<code>egisl=0.8</code> V	Fitting parameter for band bending for GISL.
500	<code>legisl=0.0</code>	Length dependence of <code>egisl</code> .
501	<code>wegisl=0.0</code>	Width dependence of <code>egisl</code> .
502	<code>pegisl=0.0</code>	Cross-term dependence of <code>egisl</code> .
503	<code>cf=0.0</code> F	Outer fringe cap.
504	<code>lcf=0.0</code>	Length dependence of <code>cf</code> .
505	<code>wcf=0.0</code>	Width dependence of <code>cf</code> .

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506	$pcf=0.0$	Cross-term dependence of cf .
507	$cfrcoeff=1.0$ F	coefficient for outer fringe cap.
508	$cgs0=0.0$ F/m	Gate - source overlap capacitance.
509	$cgdo=0.0$ F/m	Gate - drain overlap capacitance.
510	$cgbo=0.0$ F/m	Gate - body overlap capacitance.
511	$cgs1=0.0$ F/m	Overlap capacitance between gate and lightly-doped source region.
512	$lcgs1=0.0$	Length dependence of $cgs1$.
513	$wcgs1=0.0$	Width dependence of $cgs1$.
514	$pcgs1=0.0$	Cross-term dependence of $cgs1$.
515	$cgdl=0.0$ F/m	Overlap capacitance between gate and lightly-doped drain region.
516	$lcgdl=0.0$	Length dependence of $cgdl$.
517	$wcgdl=0.0$	Width dependence of $cgdl$.
518	$pcgdl=0.0$	Cross-term dependence of $cgdl$.
519	$ckappas=0.6$ V	Coefficient of bias-dependent overlap capacitance for the source side.
520	$lckappas=0.0$	Length dependence of $ckappas$.
521	$wckappas=0.0$	Width dependence of $ckappas$.
522	$pckappas=0.0$	Cross-term dependence of $ckappas$.
523	$ckappad=0.6$ V	Coefficient of bias-dependent overlap capacitance for the source side.
524	$lckappad=0.0$	Length dependence of $ckappad$.
525	$wckappad=0.0$	Width dependence of $ckappad$.

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BSIM6 Model (bsim6)

526	$pckappad=0.0$	Cross-term dependence of $ckappad$.
527	$dmcg=0.0$ m	Distance of mid-contact to gate edge.
528	$dmci=0.0$ m	Distance of mid-contact to isolation.
529	$dmdg=0.0$ m	Distance of mid-diffusion to gate edge.
530	$dmcgt=0.0$ m	Dist of mid-contact to gate edge in test.
531	$xgl=0.0$ m	Variation in $Ldrawn$.
532	$rshg=0.1$ Ω	Gate sheet resistance.
533	$cjs=5.0e-4$ F/m ²	Unit area source-side junction capacitance at zero bias.
534	$cjd=5.0e-4$ F/m ²	Unit area drain-side junction capacitance at zero bias.
535	$cjsws=5.0e-10$ F/m	Unit length source-side sidewall junction capacitance at zero bias.
536	$cjswd=5.0e-10$ F/m	Unit length drain-side sidewall junction capacitance at zero bias.
537	$cjswgs=0.0$ F/m	Unit length source-side gate sidewall junction capacitance at zero bias.
538	$cjswgd=0.0$ F/m	Unit length drain-side gate sidewall junction capacitance at zero bias.
539	$pbs=1.0$ V	Source-side bulk junction built-in potential.
540	$pbd=1.0$ V	Drain-side bulk junction built-in potential.
541	$pbsws=1.0$ V	Built-in potential for Source-side sidewall junction capacitance.
542	$pbswd=1.0$ V	Built-in potential for Drain-side sidewall junction capacitance.
543	$pbswgs=1.0$ V	Built-in potential for Source-side gate sidewall junction capacitance.
544	$pbswgd=1.0$ V	Built-in potential for Drain-side gate sidewall junction capacitance.

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545	$mjs=0.5$	Source bottom junction capacitance grading coefficient.
546	$mjd=0.5$	Drain bottom junction capacitance grading coefficient.
547	$mjsws=0.33$	Source sidewall junction capacitance grading coefficient.
548	$mjswd=0.33$	Drain sidewall junction capacitance grading coefficient.
549	$mjswgs=0.33$	Source-side gate sidewall junction capacitance grading coefficient.
550	$mjswgd=0.33$	Drain-side gate sidewall junction capacitance grading coefficient.
551	$jss=1.0e-4 \text{ A/m}^2$	Bottom source junction reverse saturation current density.
552	$jds=1.0e-4 \text{ A/m}^2$	Bottom drain junction reverse saturation current density.
553	$jsws=0.0 \text{ A/m}$	Unit length reverse saturation current for sidewall source junction.
554	$jswd=0.0 \text{ A/m}$	Unit length reverse saturation current for sidewall drain junction.
555	$jswgs=0.0 \text{ A/m}$	Unit length reverse saturation current for gate-edge sidewall source junction.
556	$jswgd=0.0 \text{ A/m}$	Unit length reverse saturation current for gate-edge sidewall drain junction.
557	$njs=1.0$	Source junction emission coefficient.
558	$njd=1.0$	Drain junction emission coefficient.
559	$ijthsfwd=0.1 \text{ A}$	Forward source diode breakdown limiting current.
560	$ijthdfwd=0.1 \text{ A}$	Forward drain diode breakdown limiting current.
561	$ijthsrev=0.1 \text{ A}$	Reverse source diode breakdown limiting current.
562	$ijthdrev=0.1 \text{ A}$	Reverse drain diode breakdown limiting current.
563	$bvs=10.0 \text{ V}$	Source diode breakdown voltage.
564	$bvd=10.0 \text{ V}$	Drain diode breakdown voltage.

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565	$xj_{bvs}=1.0$	Fitting parameter for source diode breakdown current.
566	$xj_{bvd}=1.0$	Fitting parameter for drain diode breakdown current.
567	$jt_{ss}=0.0 \text{ A/m}^2$	Bottom source junction trap-assisted saturation current density.
568	$jt_{sd}=0.0 \text{ A/m}^2$	Bottom drain junction trap-assisted saturation current density.
569	$jt_{ssws}=0.0 \text{ A/m}$	Unit length trap-assisted saturation current for sidewall source junction.
570	$jt_{sswd}=0.0 \text{ A/m}$	Unit length trap-assisted saturation current for sidewall drain junction.
571	$jt_{sswgs}=0.0 \text{ A/m}$	Unit length trap-assisted saturation current for gate-edge sidewall source junction.
572	$jt_{sswgd}=0.0 \text{ A/m}$	Unit length trap-assisted saturation current for gate-edge sidewall drain junction.
573	$jt_{weff}=0.0 \text{ m}$	Trap assisted tunneling current width dependence.
574	$nj_{ts}=20.0$	Non-ideality factor for jt_{ss} .
575	$nj_{tsd}=20.0$	Non-ideality factor for jt_{sd} .
576	$nj_{tssw}=20.0$	Non-ideality factor for jt_{ssws} .
577	$nj_{tsswd}=20.0$	Non-ideality factor for jt_{sswd} .
578	$nj_{tsswg}=20.0$	Non-ideality factor for jt_{sswgs} .
579	$nj_{tsswgd}=20.0$	Non-ideality factor for jt_{sswgd} .
580	$vt_{ss}=10.0 \text{ V}$	Bottom source junction trap-assisted current voltage dependent parameter.
581	$vt_{sd}=10.0 \text{ V}$	Bottom drain junction trap-assisted current voltage dependent parameter.
582	$vt_{ssws}=10.0 \text{ V}$	Unit length trap-assisted current voltage dependent parameter for sidewall source junction.

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583	<code>vtsswd=10.0 V</code>	Unit length trap-assisted current voltage dependent parameter for sidewall drain junction.
584	<code>vtsswgs=10.0 V</code>	Unit length trap-assisted current voltage dependent parameter for gate-edge sidewall source junction.
585	<code>vtsswgd=10.0 V</code>	Unit length trap-assisted current voltage dependent parameter for gate-edge sidewall drain junction.
586	<code>xrcrg1=12.0</code>	1st fitting parameter for the bias-dependent r_g .
587	<code>xrcrg2=1.0</code>	2nd fitting parameter for the bias-dependent r_g .
588	<code>gbmin=1.0e-12 1/Ω</code>	Minimum body conductance.
589	<code>rbps0=50.0 Ohms</code>	Scaling prefactor for r_{bps} .
590	<code>rbpsl=0.0</code>	Length scaling parameter for r_{bps} .
591	<code>rbpsw=0.0</code>	Width scaling parameter for r_{bps} .
592	<code>rbpsnf=0.0</code>	Number of fingers scaling parameter for r_{bps} .
593	<code>rbpd0=50.0 Ohms</code>	Scaling prefactor for r_{bpd} .
594	<code>rbpdl=0.0</code>	Length scaling parameter for r_{bpd} .
595	<code>rbpdw=0.0</code>	Width scaling parameter for r_{bpd} .
596	<code>rbpdnf=0.0</code>	Number of fingers scaling parameter for r_{bpd} .
597	<code>rbpbx0=100.0 Ohms</code>	Scaling prefactor for r_{pbx} .
598	<code>rbpbxl=0.0</code>	Length scaling parameter for r_{pbx} .
599	<code>rbpbxw=0.0</code>	Width scaling parameter for r_{pbx} .
600	<code>rbpbxnf=0.0</code>	Number of fingers scaling parameter for r_{pbx} .
601	<code>rbpby0=100.0 Ohms</code>	Scaling prefactor for r_{pby} .
602	<code>rbpbyl=0.0</code>	Length scaling parameter for r_{pby} .

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603	<code>rbpbyw=0.0</code>	Width scaling parameter for rbpby.
604	<code>rbpbynf=0.0</code>	Number of fingers scaling parameter for rbpby.
605	<code>rbsbx0=100.0</code>	Ohms Scaling prefactor for rbsbx.
606	<code>rbsby0=100.0</code>	Ohms Scaling prefactor for rbsby.
607	<code>rbdbx0=100.0</code>	Ohms Scaling prefactor for rdbbx.
608	<code>rbdby0=100.0</code>	Ohms Scaling prefactor for rbdby.
609	<code>rbsdbxl=0.0</code>	Length scaling parameter for rbsbx and rdbbx.
610	<code>rbsdbxw=0.0</code>	Width scaling parameter for rbsbx and rdbbx.
611	<code>rbsdbxnf=0.0</code>	Number of fingers Scaling parameter for rbsbx and rdbbx.
612	<code>rbsdbyl=0.0</code>	Length scaling parameter for rbsby and rbdby.
613	<code>rbsdbyw=0.0</code>	Width scaling parameter for rbsby and rbdby.
614	<code>rbsdbynf=0.0</code>	Number of fingers scaling parameter for rbsby and rbdby.
615	<code>ef=1.0</code>	Flicker Noise frequency exponent.
616	<code>em=4.1e7</code>	V/m Saturation field.
617	<code>noia=6.250e+40</code>	$s^{(1-ef)} / (eV \text{ m}^2)$ Flicker noise parameter A.
618	<code>noib=3.125e+25</code>	$s^{(1-EF)} / eV$ Flicker noise parameter B.
619	<code>noic=8.750e+8</code>	$s^{(1-EF)} \text{ m}^2 / eV$ Flicker noise parameter C.
620	<code>lintnoi=0.0</code>	m Lint offset for noise calculation.
621	<code>ntnoi=1.0</code>	Noise factor for short-channel devices for tnoimod=0 only.
622	<code>rnoia=0.577</code>	Thermal noise coefficient for tnoimod=1.

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623	<code>rnoib=0.5164</code>	Thermal noise coefficient for <code>tnomod=1</code> .
624	<code>rnoic=0.395</code>	Thermal noise coefficient for <code>tnomod=1</code> .
625	<code>tnoia=0.0</code>	Coefficient of channel-length dependence of total channel thermal noise for <code>tnomod=1</code> .
626	<code>tnoib=0.0</code>	Coefficient of channel-length dependence of total channel thermal noise for <code>tnomod=1</code> .
627	<code>tnoic=0.0</code>	Correlation coefficient.
628	<code>binunit=1</code>	Bin parameter unit selector. 1 for microns and 0 for meters.
629	<code>dlbin=0.0</code>	Binning parameters.
630	<code>dwbin=0.0</code>	Binning parameters.
631	<code>tnom=27.0 C</code>	Temperature at which the model was extracted.
632	<code>tbgasub=4.73e-4 eV/C</code>	Bandgap Temperature Coefficient.
633	<code>tbgbsub=636.0 C</code>	Bandgap Temperature Coefficient.
634	<code>tnfactor=0.0</code>	Temperature exponent for <code>nfactor</code> .
635	<code>ute=(-1.5)</code>	Mobility temperature exponent.
636	<code>lute=0.0</code>	Length dependence of <code>ute</code> .
637	<code>wute=0.0</code>	Width dependence of <code>ute</code> .
638	<code>pute=0.0</code>	Cross-term dependence of <code>ute</code> .
639	<code>utel=0.0</code>	Length Scaling parameter for <code>ute</code> .
640	<code>ua1=1.0e-3</code>	Temperature coefficient for <code>ua</code> .
641	<code>lua1=0.0</code>	Length dependence of <code>ua1</code> .
642	<code>wua1=0.0</code>	Width dependence of <code>ua1</code> .

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643	$pua1=0.0$	Cross-term dependence of $ua1$.
644	$ua1l=0.0$	Length Scaling parameter for $ua1$.
645	$uc1=0.056e-9$	Temperature coefficient for uc .
646	$luc1=0.0$	Length dependence of $uc1$.
647	$wuc1=0.0$	Width dependence of $uc1$.
648	$puc1=0.0$	Cross-term dependence of $uc1$.
649	$ud1=0.0$	Temperature coefficient for ud .
650	$lud1=0.0$	Length dependence of $ud1$.
651	$wud1=0.0$	Width dependence of $ud1$.
652	$pud1=0.0$	Cross-term dependence of $ud1$.
653	$ud1l=0.0$	Length Scaling parameter for $ud1$.
654	$ucste=(-4.775e-3)$	Temperature coefficient for ucs .
655	$lucste=0.0$	Length dependence of $ucste$.
656	$wucste=0.0$	Width dependence of $ucste$.
657	$pucste=0.0$	Cross-term dependence of $ucste$.
658	$teta0=0.0$	Temperature coefficient for $eta0$.
659	$prt=0.0 \Omega \cdot m$	Temperature coefficient for resistance.
660	$lprt=0.0$	Length dependence of prt .
661	$wprt=0.0$	Width dependence of prt .
662	$pprt=0.0$	Cross-term dependence of prt .
663	$at=(-1.56e-3)$	Temperature coefficient for saturation velocity.

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664	lat=0.0	Length dependence of at.
665	wat=0.0	Width dependence of at.
666	pat=0.0	Cross-term dependence of at.
667	atl=0.0	Length Scaling parameter for at.
668	tdelta=0.0	Temperature coefficient for delta.
669	ptwgt=0.0	Temperature coefficient for ptwgt.
670	lptwgt=0.0	Length dependence of ptwgt.
671	wptwgt=0.0	Width dependence of ptwgt.
672	pptwgt=0.0	Cross-term dependence of ptwgt.
673	ptwgtl=0.0	Length Scaling parameter for ptwgt.
674	kt1=(-0.11) V	Temperature coefficient for vth.
675	kt1exp=1.0	Temperature coefficient for vth.
676	kt1l=0.0	Temperature coefficient for vth.
677	lkt1=0.0	Length dependence of kt1.
678	wkt1=0.0	Width dependence of kt1.
679	pkt1=0.0	Cross-term dependence of kt1.
680	kt2=0.022	Temperature coefficient for vth.
681	lkt2=0.0	Length dependence of kt2.
682	wkt2=0.0	Width dependence of kt2.
683	pkt2=0.0	Cross-term dependence of kt2.
684	iit=0.0	Temperature coefficient for beta0.
685	liit=0.0	Length dependence of iit.

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686	wiit=0.0	Width dependence of iit.
687	piit=0.0	Cross-term dependence of iit.
688	igt=2.5	Gate current temperature dependence.
689	ligt=0.0	Length dependence of igt.
690	wigt=0.0	Width dependence of igt.
691	pigt=0.0	Cross-term dependence of igt.
692	tgidl=0.0	Temperature coefficient for GIDL/GISL.
693	ltgidl=0.0	Length dependence of tgidl.
694	wtgidl=0.0	Width dependence of tgidl.
695	ptgidl=0.0	Cross-term dependence of tgidl.
696	tcj=0.0	Temperature coefficient for cjs/cjd.
697	tcjsw=0.0	Temperature coefficient for cjsws/cjswd.
698	tcjswg=0.0	Temperature coefficient for cjswgs/cjswgd.
699	tpb=0.0	Temperature coefficient for pbs/pbd.
700	tpbsw=0.0	Temperature coefficient for pbsws/pbswd.
701	tpbswg=0.0	Temperature coefficient for pbswgs/pbswgd.
702	xtis=3.0	Source junction current temperature exponent.
703	xtid=3.0	Drain junction current temperature exponent.
704	xtss=0.02	Power dependence of jtss on temperature.
705	xtsd=0.02	Power dependence of jtssd on temperature.
706	xtssws=0.02	Power dependence of jtssws on temperature.
707	xtsswd=0.02	Power dependence of jtsswd on temperature.

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708	$xtsswgs=0.02$	Power dependence of $jtsswgs$ on temperature.
709	$xtsswgd=0.02$	Power dependence of $jtsswgd$ on temperature.
710	$tnjts=0.0$	Temperature coefficient for $njts$.
711	$tnjt\bar{s}d=0.0$	Temperature coefficient for $njt\bar{s}d$.
712	$tnjtssw=0.0$	Temperature coefficient for $njtssw$.
713	$tnjtssw\bar{d}=0.0$	Temperature coefficient for $njtssw\bar{d}$.
714	$tnjtsswg=0.0$	Temperature coefficient for $njtsswg$.
715	$tnjtsswgd=0.0$	Temperature coefficient for $njtsswgd$.
716	$rth0=0.0$	Thermal resistance.
717	$cth0=1.0e-05$	Thermal capacitance.
718	$wth0=0.0$	Width dependence coefficient for Rth and Cth .
719	$saref=1.0e-6$ m	Reference distance between OD edge from Poly from one side.
720	$sbref=1.0e-6$ m	Reference distance between OD edge from Poly from other side.
721	$wlod=0.0$ m	Width Parameter for Stress Effect.
722	$ku0=0.0$ m	Mobility degradation/enhancement parameter for stress effect.
723	$kvsat=0.0$ m	Saturation velocity degradation/enhancement parameter for stress effect.
724	$tku0=0.0$	Temperature coefficient for $ku0$.
725	$lku0=0.0$ m ¹¹ $lodku0$	Length dependence of $ku0$.
726	$wku0=0.0$ m ^w $wlodku0$	Width dependence of $ku0$.
727	$pku0=0.0$ m ⁽¹¹ $lodku0+w$ $wlodku0)$	Cross term dependence of $ku0$.

Virtuoso Simulator Components and Device Models Reference

BSIM6 Model (bsim6)

728	$l_{lodku0}=0.0$	Length Parameter for u_0 stress effect.
729	$w_{lodku0}=0.0$	Width Parameter for u_0 stress effect.
730	$kv_{th0}=0.0$ V m	Threshold shift parameter for stress effect.
731	$l_{kv_{th0}}=0.0$	Length dependence of kv_{th0} .
732	$w_{kv_{th0}}=0.0$	Width dependence of kv_{th0} .
733	$p_{kv_{th0}}=0.0$	Cross-term dependence of kv_{th0} .
734	$l_{lodv_{th}}=0.0$	Length parameter for v_{th} stress effect.
735	$w_{lodv_{th}}=0.0$	Width parameter for v_{th} stress effect.
736	$stk_2=0.0$ m	K2 shift factor related to v_{th} change.
737	$lodk_2=0.0$	K2 shift modification factor for stress effect.
738	$steta_0=0.0$ m	eta_0 shift related to v_{th0} change.
739	$lodeta_0=0.0$	eta_0 modification foator for stress effect.
740	$w_{eb}=0.0$	Coefficient for sc_b .
741	$w_{ec}=0.0$	Coefficient for sc_c .
742	$kv_{th0we}=0.0$ V	V_{th} shift for well proximity effect.
743	$l_{kv_{th0we}}=0.0$	Length dependence of kv_{th0we} .
744	$w_{kv_{th0we}}=0.0$	Width dependence of kv_{th0we} .
745	$p_{kv_{th0we}}=0.0$	Cross term dependence of kv_{th0we} .
746	$k_{2we}=0.0$	K2 shift for well proximity effect.
747	$l_{k_{2we}}=0.0$	Length dependence of k_{2we} .
748	$w_{k_{2we}}=0.0$	Width dependence of k_{2we} .
749	$p_{k_{2we}}=0.0$	Cross term dependence of k_{2we} .

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750	<code>ku0we=0.0</code>	Mobility degradation factor for well proximity effect.
751	<code>lku0we=0.0</code>	Length dependence of <code>ku0we</code> .
752	<code>wku0we=0.0</code>	Width dependence of <code>ku0we</code> .
753	<code>pku0we=0.0</code>	Cross term dependence of <code>ku0we</code> .
754	<code>scref=1.0e-6 m</code>	Reference distance to calculate <code>sca</code> , <code>scb</code> and <code>scc</code> .
755	<code>noisemethod=1</code>	1:Verilog-A method; 0:Simkit method.
756	<code>geomod=0</code>	Geo dependent parasitics model.
757	<code>rgeomod=0</code>	Geometry-dependent source/drain resistance. 0: RSH-based, 1: Holistic.
758	<code>rgatmod=0</code>	Gate resistance model selector.
759	<code>rbodymod=0</code>	Distributed body R model.
760	<code>l=1.0e-5 m</code>	Default channel length.
761	<code>w=1.0e-5 m</code>	Default total width including fingers.
762	<code>nf=1</code>	Number of fingers. It served as the default value of instance <code>nf</code> .
763	<code>lmin=0.0 m</code>	Minimum channel length for which the model is valid.
764	<code>lmax=1.0 m</code>	Maximum channel length for which the model is valid.
765	<code>wmin=0.0 m</code>	Minimum channel width for which the model is valid.
766	<code>wmax=1.0 m</code>	Maximum channel width for which the model is valid.
767	<code>vds_max=infinity V</code>	Maximum allowed voltage cross source and drain.
768	<code>vgd_max=infinity V</code>	Maximum allowed voltage cross drain and gate.
769	<code>vgs_max=infinity V</code>	Maximum allowed voltage cross source/bulk and gate.

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BSIM6 Model (bsim6)

770	<code>vbd_max=infinity</code>	V	Maximum allowed voltage cross drain/source and bulk.
771	<code>vbs_max=vbd_max</code>	V	Maximum allowed voltage cross source and bulk.
772	<code>vgb_max=infinity</code>	V	Maximum allowed voltage cross gate and bulk.
773	<code>vgdr_max=vgd_max</code>	V	Maximum allowed reverse voltage cross gate and drain.
774	<code>vgdr_max=vgd_max</code>	V	Maximum allowed reverse voltage cross gate and source.
775	<code>vgbr_max=vgb_max</code>	V	Maximum allowed reverse voltage cross gate and bulk.
776	<code>vbsr_max=vbs_max</code>	V	Maximum allowed reverse voltage cross bulk and source.
777	<code>vbdr_max=vbd_max</code>	V	Maximum allowed reverse voltage cross bulk and drain.
778	<code>vfbsdoff=0.0</code>		S/D flatband voltage offset.
779	<code>rbpb=50.0</code>	Ω	Resistance between bNodePrime and bNode.
780	<code>rbdb=50.0</code>	Ω	Resistance between bNode and dbNode.
781	<code>rbsb=50.0</code>	Ω	Resistance between bNode and sbNode.
782	<code>rbps=50.0</code>	Ω	Resistance between bNodePrime and sbNode.
783	<code>rbpd=50.0</code>	Ω	Resistance between bNodePrime and bNode.
784	<code>ngcon=1</code>		Number of gate contacts.

Output Parameters

1	<code>tempeff</code>	(C)	Effective temperature for a single device.
2	<code>meff</code>		Effective multiplicity factor (m-factor).

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BSIM6 Model (bsim6)

Operating-Point Parameters

1	qbi (Coul)	Intrinsic bulk charge.
2	qsi (Coul)	Intrinsic source charge.
3	qdi (Coul)	Intrinsic drain charge.
4	qgi (Coul)	Intrinsic gate charge.
5	cggi (F)	Intrinsic gate capacitance.
6	cgbi (F)	Intrinsic gate-to-bulk capacitance.
7	cgsi (F)	Intrinsic gate-to-source capacitance.
8	cgdi (F)	Intrinsic gate-to-drain capacitance.
9	csg_i (F)	Intrinsic source-to-gate capacitance.
10	csbi (F)	Intrinsic source-to-bulk capacitance.
11	cssi (F)	Intrinsic source capacitance.
12	csdi (F)	Intrinsic source-to-drain capacitance.
13	cdgi (F)	Intrinsic drain-to-gate capacitance.
14	cdbi (F)	Intrinsic drain-to-body capacitance.
15	cdsi (F)	Intrinsic drain-to-source capacitance.
16	cddi (F)	Intrinsic drain capacitance.
17	cbgi (F)	Intrinsic body-to-gate capacitance.
18	cbbi (F)	Intrinsic body capacitance.
19	cbsi (F)	Intrinsic body-to-source capacitance.
20	cbdi (F)	Intrinsic body-to-drain capacitance.
21	qb (Coul)	Total bulk charge.

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BSIM6 Model (bsim6)

22	qs (Coul)	Total source charge.
23	qd (Coul)	Total drain charge.
24	qg (Coul)	Total gate charge.
25	cgg (F)	Total gate capacitance.
26	cgb (F)	Total gate-to-bulk capacitance.
27	cgs (F)	Total gate-to-source capacitance.
28	cgd (F)	Total gate-to-drain capacitance.
29	csG (F)	Total source-to-gate capacitance.
30	csb (F)	Total source-to-bulk capacitance.
31	css (F)	Total source capacitance.
32	csd (F)	Total source-to-drain capacitance.
33	cdg (F)	Total drain-to-gate capacitance.
34	cdb (F)	Total drain-to-bulk capacitance.
35	cds (F)	Total drain-to-source capacitance.
36	added (F)	Total drain capacitance.
37	cbg (F)	Total bulk-to-gate capacitance.
38	cbb (F)	Total bulk capacitance.
39	cbs (F)	Total bulk-to-source capacitance.
40	added (F)	Total bulk-to-drain capacitance.
41	iii (A)	Alias of isub.
42	isub (A)	Impact ionization current.
43	igidl (A)	Gate-induced drain leakage current.

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BSIM6 Model (bsim6)

44	<code>igisl</code> (A)	Gate-induced source leakage current.
45	<code>igs</code> (A)	Gate-to-source tunneling current.
46	<code>igd</code> (A)	Gate-to-drain tunneling current.
47	<code>igcs</code> (A)	Gate-to-channel (source side) tunneling current.
48	<code>igcd</code> (A)	Gate-to-channel (drain side) tunneling current.
49	<code>igb</code> (A)	Gate-to-bulk tunneling current.
50	<code>cgsext</code> (F)	Gate-source overlap capacitance.
51	<code>cgdext</code> (F)	Gate-drain overlap capacitance.
52	<code>cgbov</code> (F)	Gate-bulk overlap capacitance.
53	<code>cjst</code> (F)	Alias of <code>capbs</code> .
54	<code>capbs</code> (F)	Source-bulk junction capacitance.
55	<code>cjdt</code> (F)	Alias of <code>capbd</code> .
56	<code>capbd</code> (F)	Drain-bulk junction capacitance.
57	<code>weff</code> (m)	Effective channel width.
58	<code>leff</code> (m)	Effective channel length.
59	<code>weffcv</code> (m)	Effective channel width for CV.
60	<code>leffcv</code> (m)	Effective channel length for CV.
61	<code>ids</code> (A)	Resistive drain-to-source current.
62	<code>ideff</code> (A)	Resistive drain current.
63	<code>iseff</code> (A)	Resistive source current.
64	<code>igeff</code> (A)	Resistive gate current.
65	<code>ijsb</code> (A)	Alias of <code>ibs</code> .

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BSIM6 Model (bsim6)

66	i_{bs} (A)	Source-bulk junction current.
67	i_{jdb} (A)	Alias of i_{bd} .
68	i_{bd} (A)	Drain-bulk junction current.
69	v_{ds} (V)	Internal drain-source voltage.
70	v_{gs} (V)	Internal gate-source voltage.
71	v_{sb} (V)	- v_{bs} .
72	v_{bs} (V)	Internal bulk-source voltage.
73	v_{dst} (V)	External drain-source voltage.
74	v_{gst} (V)	External gate-source voltage.
75	v_{sbt} (V)	External source-bulk voltage.
76	v_{dssat} (V)	Alias of v_{dsat} .
77	v_{dsat} (V)	Drain-source saturation voltage.
78	g_m (S)	Common-source transconductance.
79	g_{mbs} (S)	Body-transconductance.
80	g_{ds} (S)	Common-source output conductance.
81	pwr (W)	Power at op point.
82	τ_k (K)	TK.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the

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BSIM6 Model (bsim6)

description for that parameter. For example, a reference of M-35 means the 35th model parameter.

ad	I-10	laigs	M-437	pdelta	M-188	ua11	M-644
ados	M-145	lalpha0	M-363	pdiblc	M-340	ua1	M-209
agidl	M-467	lat	M-664	pdiblcb	M-346	ualexp	M-210
agidl1	M-468	lbeta0	M-367	pdiblcl	M-341	uaw	M-211
agidlw	M-469	lbgidl	M-474	pdiblclexp	M-342	uawexp	M-212
agisl	M-485	lbgisl	M-492	pdits	M-269	uawl	M-213
agisl1	M-486	lbigbacc	M-419	pditsd	M-274	uawlexp	M-214
agislw	M-487	lbigbinv	M-404	pditsl	M-273	uc	M-238
aigbacc	M-370	lbigc	M-431	pdlcig	M-460	uc1	M-645
aigbinv	M-374	lbigd	M-449	pdlcigd	M-463	uc1	M-239
aigc	M-379	lbiggs	M-440	pdvtp0	M-100	uclexp	M-240
aigcl	M-394	lcdscb	M-172	pdvtp1	M-104	ucs	M-234
aigcw	M-395	lcdscd	M-166	pdvtp2	M-108	ucste	M-654
aigd	M-385	lcf	M-504	pdvtp3	M-112	ucw	M-241
aigdl	M-398	lcgdl	M-516	pdvtp4	M-116	ucwexp	M-242
aigdw	M-399	lcgidl	M-478	pdvtp5	M-120	ucw1	M-243
aigs	M-382	lcgisl	M-496	pegidl	M-484	ucwlexp	M-244
aigsl	M-396	lcgsl	M-512	pegisl	M-502	ud	M-228
aigsw	M-397	lcigbacc	M-422	peigbinv	M-412	ud1	M-649

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alpha0	M-360	lcigbinv	M-407	permod	M-91	ud11	M-653
alpha01	M-361	lcigc	M-434	peta0	M-128	ud1	M-229
alpha0lexp	M-362	lcigd	M-452	petab	M-134	udlexp	M-230
as	I-9	lcigs	M-443	peu	M-221	ute	M-635
at	M-663	lcit	M-150	pfprout	M-359	utel	M-639
atl	M-667	lckappad	M-524	phin	M-121	vbd_max	M-770
bdos	M-146	lckappas	M-520	pigcd	M-393	vbdr_max	M-777
beta0	M-366	ldelta	M-186	pigcdl	M-400	vbs	OP-72
bg0sub	M-70	ldlcig	M-458	pigtl	M-691	vbs_max	M-771
bgidl	M-473	ldlcigd	M-461	piit	M-687	vbsr_max	M-776
bgisl	M-491	ldvtp0	M-98	pk2	M-144	vds	OP-69
bigbacc	M-371	ldvtp1	M-102	pk2we	M-749	vds_max	M-767
bigbinv	M-375	ldvtp2	M-106	pkt1	M-679	vdsat	OP-77
bigc	M-380	ldvtp3	M-110	pkt2	M-683	vdssat	OP-76
bigd	M-386	ldvtp4	M-114	pku0	M-727	vdst	OP-73
biggs	M-383	ldvtp5	M-118	pku0we	M-753	version	M-2
binunit	M-628	leff	OP-58	pkvth0	M-733	vfb	M-77
bvd	M-564	leffcv	OP-60	pkvth0we	M-745	vfbcv	M-81
bvs	M-563	legidl	M-482	pndep	M-51	vfbcvl	M-85
capbd	OP-56	legisl	M-500	pndepcv	M-63	vfbcvlexp	M-86
capbs	OP-54	leigbinv	M-410	pnfactor	M-162	vfbcvw	M-87

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cbb	OP-38	leta0	M-126	pngate	M-67	vfbcvwexp	M-88
cbbi	OP-18	letab	M-132	pnigbacc	M-427	vfbcvwl	M-89
cbd	OP-40	leu	M-219	pnigbinv	M-415	vfbcvwlexp	M-90
cbdi	OP-20	lfprout	M-357	pnsd	M-96	vfbsdoff	I-13
cbg	OP-37	ligt	M-689	pntox	M-466	vfbsdoff	M-778
cbgi	OP-17	liit	M-685	poxedge	M-390	vgb_max	M-772
cbs	OP-39	lint	M-17	ppclm	M-253	vgbr_max	M-775
cbsi	OP-19	lintnoi	M-620	ppclmcv	M-260	vgd_max	M-768
cdb	OP-34	lk2	M-142	ppdiblc	M-345	vgdr_max	M-773
cbdi	OP-14	lk2we	M-747	ppdiblcb	M-349	vgs	OP-70
cdd	OP-36	lkt1	M-677	ppdits	M-272	vgs_max	M-769
cddi	OP-16	lkt2	M-681	ppditsd	M-277	vgsr_max	M-774
cdg	OP-33	lku0	M-725	pphin	M-124	vgst	OP-74
cdgi	OP-13	lku0we	M-751	ppoxedge	M-457	vsat	M-175
cds	OP-35	lkvth0	M-731	pprt	M-662	vsatcv	M-191
cdscb	M-169	lkvth0we	M-743	pprwb	M-286	vsatcvl	M-195
cdscbl	M-170	ll	M-18	pprwg	M-282	vsatcvlexp	M-196
cdschlexp	M-171	llc	M-30	ppsats	M-326	vsatcvw	M-197
cdscd	M-163	lln	M-21	ppsatsb	M-332	vsatcvwexp	M-198
cdscdl	M-164	llodku0	M-728	ppscbel	M-264	vsatcvwl	M-199

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cdscdlexp M-165	llodvth M-734	ppscbe2 M-268	vsatcvwlexp M-200
cdsi OP-15	llong M-11	pptwg M-337	vsatl M-179
cf M-503	lmax M-764	pptwgt M-672	vsatlexp M-180
cfrcoeff M-507	lmin M-763	ppvag M-353	vsatw M-181
cgb OP-26	lmlt M-12	prds w M-322	vsatwexp M-182
cgbi OP-6	lndep M-49	prds wmin M-316	vsatwl M-183
cgbo M-510	lndepcv M-61	prdw M-310	vsatwlexp M-184
cgbov OP-52	lnfactor M-160	prdwmin M-306	vsb OP-71
cgd OP-28	lngate M-65	prsw M-300	vsbt OP-75
cgdext OP-51	lnigbacc M-425	prswmin M-296	vt sd M-581
cgdi OP-8	lnigbinv M-413	prt M-659	vtss M-580
cgdl M-515	lnsd M-94	prwb M-283	vtsswd M-583
cgdo M-509	lntox M-464	prwbl M-287	vtsswgd M-585
cgg OP-25	lodeta0 M-739	prwblexp M-288	vtsswgs M-584
cggi OP-5	lodk2 M-737	prwg M-279	vtssws M-582
cgidl M-477	lpclm M-251	ps I-11	w I-7
cgisl M-495	lpclmcv M-258	psat M-323	w M-761
cgs OP-27	lpdiblc M-343	psatb M-329	wagidl M-471
cgsext OP-50	lpdiblcb M-347	psatl M-327	wagisl M-489
cgsi OP-7	lpdits M-270	psatlexp M-328	waigbacc M-417

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cgs1 M-511	lpditsd M-275	psatx M-333	waigbinv M-402
cgso M-508	lphin M-122	pscbe1 M-261	waigc M-429
cigbacc M-372	lpoxedge M-455	pscbe2 M-265	waigd M-447
cigbinv M-376	lprt M-660	ptgidl M-695	waigs M-438
cigc M-381	lprwb M-284	ptwg M-334	walpha0 M-364
cigd M-387	lprwg M-280	ptwgl M-338	wat M-665
cigs M-384	lpsat M-324	ptwglexp M-339	wbeta0 M-368
cit M-149	lpsatb M-330	ptwgt M-669	wbgidl M-475
cjd M-534	lpscbe1 M-262	ptwgtl M-673	wbgisl M-493
cjdt OP-55	lpscbe2 M-266	pu0 M-206	wbigbacc M-420
cjs M-533	lptwg M-335	pua M-217	wbigbinv M-405
cjst OP-53	lptwgt M-670	pua1 M-643	wbigc M-432
cjswd M-536	lpvag M-351	puc M-247	wbigd M-450
cjswgd M-538	lrdsw M-320	puc1 M-648	wbiggs M-441
cjswgs M-537	lrdswmin M-314	pucs M-237	wcdscb M-173
cjsws M-535	lrdw M-308	pucste M-657	wcdscd M-167
ckappad M-523	lrdwmin M-304	pud M-233	wcf M-505
ckappas M-519	lrsw M-298	pud1 M-652	wcgdl M-517
covmod M-4	lrswmin M-294	pute M-638	wcgidl M-479
csb OP-30	ltgidl M-693	pvag M-350	wcgisl M-497
csbi OP-10	lu0 M-204	pvfb M-80	wcgs1 M-513

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csd	OP-32	lua	M-215	pvfbcv	M-84	wcigbacc	M-423
csdi	OP-12	lua1	M-641	pvsat	M-178	wcigbinv	M-408
csq	OP-29	luc	M-245	pvsatcv	M-194	wcigc	M-435
csqi	OP-9	luc1	M-646	pwr	M-292	wcigd	M-453
css	OP-31	lucs	M-235	pwr	OP-81	wcigs	M-444
cssi	OP-11	lucste	M-655	pxj	M-76	wcit	M-151
cth0	M-717	lud	M-231	qj	OP-21	wckappad	M-525
cvmod	M-3	lud1	M-650	qbi	OP-1	wckappas	M-521
delta	M-185	lute	M-636	qd	OP-23	wdelta	M-187
deltal	M-189	lvfb	M-78	qdi	OP-3	wdlcig	M-459
deltalex	M-190	lvfbcv	M-82	qg	OP-24	wdlcigd	M-462
dlbin	M-629	lvsat	M-176	qgi	OP-4	wdvtp0	M-99
dlc	M-29	lvsatcv	M-192	qm0	M-147	wdvtp1	M-103
dlcig	M-388	lw	M-19	qs	OP-22	wdvtp2	M-107
dlcigd	M-389	lwc	M-31	qsi	OP-2	wdvtp3	M-111
dmcg	M-527	lwl	M-20	rdbb	I-20	wdvtp4	M-115
dmcgt	M-530	lwlc	M-32	rdbb	M-780	wdvtp5	M-119
dmci	M-528	lwn	M-22	rdbbx0	M-607	web	M-740
dmdg	M-529	lwr	M-290	rdbby0	M-608	wec	M-741
dsub	M-129	lxj	M-74	rbodymod	I-5	weff	OP-57
dtemp	I-24	m	I-1	rbodymod	M-759	weffcv	OP-59

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dtox	M-39	meff	O-2	rbpb	I-19	wegidl	M-483
dvtp0	M-97	minz	I-16	rbpb	M-779	wegis1	M-501
dvtp1	M-101	mjd	M-546	rbpbx0	M-597	weigbinv	M-411
dvtp2	M-105	mjs	M-545	rbpbx1	M-598	weta0	M-127
dvtp3	M-109	mjswd	M-548	rbpbxnf	M-600	wetab	M-133
dvtp4	M-113	mjswgd	M-550	rbpbxw	M-599	weu	M-220
dvtp5	M-117	mjswgs	M-549	rbpby0	M-601	wfprout	M-358
dwbin	M-630	mjsws	M-547	rbpby1	M-602	wigt	M-690
dwc	M-33	ndep	M-40	rbpbynf	M-604	wiit	M-686
dwj	M-92	ndepcv	M-52	rbpbyw	M-603	wint	M-23
easub	M-68	ndepcvl1	M-53	rbpd	I-23	wk2	M-143
ef	M-615	ndepcvl2	M-55	rbpd	M-783	wk2we	M-748
egidl	M-481	ndepcvlexp1	M-54	rbpd0	M-593	wkt1	M-678
egis1	M-499	ndepcvlexp2	M-56	rbpd1	M-594	wkt2	M-682
eigbinv	M-377	ndepcvw	M-57	rbpdf	M-596	wku0	M-726
em	M-616	ndepcvwexp	M-58	rbpdw	M-595	wku0we	M-752
epsrox	M-72	ndepcvw1	M-59	rbps	I-22	wkvth0	M-732
epsrsub	M-71	ndepcvwlexp	M-60	rbps	M-782	wkvth0we	M-744
eta0	M-125	ndep11	M-41	rbps0	M-589	w1	M-24
etab	M-130	ndep12	M-43	rbps1	M-590	w1c	M-34
etabexp	M-131	ndep1exp1	M-42	rbpsnf	M-592	w1n	M-27

Virtuoso Simulator Components and Device Models Reference

BSIM6 Model (bsim6)

etamob	M-207	ndeplexp2	M-44	rbspw	M-591	wlod	M-721
etaqm	M-148	ndepw	M-45	rbsb	I-21	wlodku0	M-729
eu	M-218	ndepwexp	M-46	rbsb	M-781	wlodvth	M-735
eul	M-222	ndepwl	M-47	rbsbx0	M-605	wmax	M-766
eulexp	M-223	ndepwlexp	M-48	rbsby0	M-606	wmin	M-765
euw	M-224	nf	I-8	rbsdbxl	M-609	wmlt	M-13
euwexp	M-225	nf	M-762	rbsdbxnf	M-611	wndep	M-50
euwl	M-226	nfactor	M-153	rbsdbxw	M-610	wndepcv	M-62
euwlexp	M-227	nfactorl	M-154	rbsdbyl	M-612	wnfactor	M-161
fprout	M-354	nfactorlexp	M-155	rbsdbynf	M-614	wngate	M-66
fproutl	M-355	nfactorw	M-156	rbsdbyw	M-613	wnigbacc	M-426
fproutlexp	M-356	nfactorwexp	M-157	rdsmod	M-5	wnigbinv	M-414
gbmin	M-588	nfactorwl	M-158	rds	M-317	wnsd	M-95
gds	OP-80	nfactorwlexp	M-159	rdswl	M-318	wntox	M-465
geomod	I-2	ngate	M-64	rdswwlexp	M-319	wpclm	M-252
geomod	M-756	ngcon	I-18	rdswwmin	M-313	wpclmcb	M-259
gidlmod	M-6	ngcon	M-784	rdw	M-307	wpdiblc	M-344
gm	OP-78	ni0sub	M-69	rdwl	M-311	wpdiblcb	M-348
gmbs	OP-79	nigbacc	M-373	rdwwlexp	M-312	wpdits	M-271
ibd	OP-68	nigbinv	M-378	rdwwmin	M-303	wpditsd	M-276

Virtuoso Simulator Components and Device Models Reference

BSIM6 Model (bsim6)

ibs	OP-66	njd	M-558	rgatemod	I-4	wphin	M-123
ideff	OP-62	njs	M-557	rgatemod	M-758	wpoxedge	M-456
ids	OP-61	njts	M-574	rgeomod	I-3	wprt	M-661
igb	OP-49	njttd	M-575	rgeomod	M-757	wprwb	M-285
igbmod	M-8	njtssw	M-576	rnoia	M-622	wprwg	M-281
igcd	OP-48	njtsswd	M-577	rnoib	M-623	wpsat	M-325
igcmmod	M-7	njtsswg	M-578	rnoic	M-624	wpsatb	M-331
igcs	OP-47	njtsswg	M-579	rsh	M-278	wpscbe1	M-263
igd	OP-46	noia	M-617	rshg	M-532	wpscbe2	M-267
igeff	OP-64	noib	M-618	rsw	M-297	wptwg	M-336
igidl	OP-43	noic	M-619	rswl	M-301	wptwgt	M-671
igisl	OP-44	noisemethod	M-755	rswlexp	M-302	wpvag	M-352
igs	OP-45	nrd	I-15	rswmin	M-293	wr	M-289
igt	M-688	nrs	I-14	rth0	M-716	wrdsw	M-321
iii	OP-41	nsd	M-93	sa	I-26	wrdswmin	M-315
iit	M-684	ntnoi	M-621	saref	M-719	wrdw	M-309
ijdb	OP-67	ntox	M-391	sb	I-27	wrdwmin	M-305
ijsb	OP-65	pagidl	M-472	sbref	M-720	wrs	M-299
ijthdfwd	M-560	pagisl	M-490	sc	I-32	wrsmin	M-295
ijthdrev	M-562	paigbacc	M-418	sca	I-29	wtgidl	M-694

Virtuoso Simulator Components and Device Models Reference

BSIM6 Model (bsim6)

ijthsfwd	M-559	paigbinv	M-403	scb	I-30	wth0	M-718
ijthsrev	M-561	paigc	M-430	scc	I-31	wu0	M-205
iseff	OP-63	paigd	M-448	scref	M-754	wua	M-216
isnoisy	I-33	paigs	M-439	sd	I-28	wua1	M-642
isub	OP-42	palpha0	M-365	shmod	M-10	wuc	M-246
jsd	M-552	pat	M-666	steta0	M-738	wuc1	M-647
jss	M-551	pbd	M-540	stk2	M-736	wucs	M-236
jswd	M-554	pbeta0	M-369	tbgasub	M-632	wucste	M-656
jswgd	M-556	pbgidl	M-476	tbgbsub	M-633	wud	M-232
jswgs	M-555	pbgisl	M-494	tcj	M-696	wud1	M-651
jsws	M-553	pbigbacc	M-421	tcjsw	M-697	wute	M-637
jttd	M-568	pbigbinv	M-406	tcjswg	M-698	wvfb	M-79
jtss	M-567	pbigc	M-433	tdelta	M-668	wvfbcv	M-83
jtsswd	M-570	pbigd	M-451	tempeff	O-1	wvsat	M-177
jtsswgd	M-572	pbiggs	M-442	teta0	M-658	wvsatcv	M-193
jtsswgs	M-571	pbs	M-539	tgidl	M-692	ww	M-25
jtssws	M-569	pbswd	M-542	tk	OP-82	wwc	M-35
jtweff	M-573	pbswgd	M-544	tku0	M-724	wwide	M-15
k2	M-135	pbswgs	M-543	tnfactor	M-634	wwl	M-26
k21	M-136	pbsws	M-541	tnjts	M-710	wwlc	M-36
k2lexp	M-137	pcdscb	M-174	tnjttd	M-711	wnn	M-28

Virtuoso Simulator Components and Device Models Reference

BSIM6 Model (bsim6)

k2w	M-138	pcdscd	M-168	tnjtssw	M-712	wwr	M-291
k2we	M-746	pcf	M-506	tnjtsswd	M-713	wxj	M-75
k2wexp	M-139	pcgdl	M-518	tnjtsswg	M-714	xgl	M-531
k2wl	M-140	pcgidl	M-480	tnjtsswgd	M-715	xgw	I-17
k2wlexp	M-141	pcgisl	M-498	tnoia	M-625	xj	M-73
kt1	M-674	pcgsl	M-514	tnoib	M-626	xjbvd	M-566
ktlexp	M-675	pcigbacc	M-424	tnoic	M-627	xjbvs	M-565
kt1l	M-676	pcigbinv	M-409	tnoimod	M-9	xl	M-14
kt2	M-680	pcigc	M-436	tnom	M-631	xrcrg1	M-586
ku0	M-722	pcigd	M-454	toxe	M-37	xrcrg2	M-587
ku0we	M-750	pcigs	M-445	toxp	M-38	xtid	M-703
kvsat	M-723	pcit	M-152	toxref	M-392	xtis	M-702
kvth0	M-730	pckappad	M-526	tpb	M-699	xtsd	M-705
kvth0we	M-742	pckappas	M-522	tpbsw	M-700	xtss	M-704
l	I-6	pclm	M-248	tpbswg	M-701	xtsswd	M-707
l	M-760	pclmcv	M-255	trise	I-25	xtsswgd	M-709
lagidl	M-470	pclmcvl	M-256	type	M-1	xtsswgs	M-708
lagisl	M-488	pclmcvlexp	M-257	u0	M-201	xtssws	M-706
laigbacc	M-416	pclmg	M-254	u0l	M-202	xw	M-16
laigbinv	M-401	pclml	M-249	u0lexp	M-203		
laigc	M-428	pclmlexp	M-250	ua	M-208		

Virtuoso Simulator Components and Device Models Reference

BSIM6 Model (bsim6)

laigd M-446

pd I-12

ua1 M-640

Virtuoso Simulator Components and Device Models Reference

BSIM6 Model (bsim6)

PSP102 Model

PSP102 is a compact MOSFET model intended for digital, analog and RF designs. It is jointly developed by NXP Semiconductors Research and Arizona State University, and is a surface-potential based MOS model containing all relevant physical effects (mobility reduction, velocity saturation, DIBL, gate current, lateral doping gradient effects, STI stress, and so forth), to model present-day and upcoming deep-submicron bulk CMOS technologies. The JUNCAP2 source/drain junction model is an integrated part of PSP102.

PSP102 not only gives an accurate description of currents, charges, and their first order derivatives (i.e. transconductance, conductance and capacitances), but also of the higher order derivatives, resulting in an accurate description of electrical distortion behavior. The latter is especially important for analog and RF circuit design. The model, furthermore, gives an accurate description of the noise behavior of MOSFETs.

For a full description of the PSP102 model, see <http://pspmodel.asu.edu>.

This chapter contains the following information about the PSP model:

- Model Usage on page 1520
 - Instance syntax on page 1520
 - Model syntax on page 1520
- Model History and Development on page 1521
- Reference on page 1525
 - Structure of PSP102 on page 1525
 - Geometrical Scaling and Stress Model for Intrinsic MOSFET on page 1527
 - PSP 102 Model Equations on page 1543
 - Non-Quasi-Static (NQS) RF Model on page 1563
- Component Statements on page 1572

Model Usage

Instance syntax

PSP102 instance has 4 terminals. The ModelName has to be associated with a PSP102 model card.

```
InstanceName (d g s b) PSP102ModelName <parameter=value>
```

Sample Instance Statement

```
q1 (v1 v2 v3 v4) psp102_mod w=1e-6 l=0.5e-6
```

Model syntax

The following syntax specifies PSP102 model:

```
model ModelName psp102 parameter=value ...
```

The third parameter, "psp102", is the master to indicate this model card is a PSP102 model card.

Version and Master name

1. Versions 102.2, 102.2.1, 102.3, 102.3.2, 102.3.3, 102.3.4, and 102.4 are supported.
2. There are 7 master names - psp102, psp1020, psp1021, psp102e, pspnqs1020, pspnqs1021 and pspnqs102e
3. psp1020 is global model without NQS effect. psp1021 is bin model without NQS effect. psp102e is local model without NQS effect. pspnqs1020 is global model with NQS effect. pspnqs1021 is bin model with NQS effect. pspnqs102e is local model with NQS effect.
4. Master name "psp102" is a general name for PSP102, and it covers 6 psp102 masternames mentioned above. The relation between psp102 and other six masters is listed in the following table:

psp1020	psp102(binmod=0 geomod=1 swnqs=0)
psp1021	psp102(binmod=1 geomod=0/1 swnqs=0)
psp102e	psp102(binmod=0 geomod=0 swnqs=0)
pspnqs1020	psp102(binmod=0 geomod=1 swnqs=0)


```
pspnqs1021      psp102(binmod=1 geomod=0/1 swnqs=0)
pspnqs102e      psp102(binmod=0 geomod=0 swnqs=0)
```

Sample Model Statement

Example: PSP102.2

```
model psp102_mod psp102 type=n version=102.2
+tr = 25 swigate = 0
+binmod=0 geomod=1 swnqs=9 swgidl = 1 swjuncap = 3
```

Example: PSP102.3

```
model psp102_mod psp102 type=n version=102.3
+tr = 25 swigate = 0
+binmod=0 geomod=1 swnqs=9 swgidl = 1 swjuncap = 3
```

Model History and Development

PSP100

1. PSP100 is released by NXP in April 2005
2. PSP100 is supported in MMSIM 6.0.2 in Dec 2005

PSP101 (SiMKit2.3)

1. PSP101 is supported in MMISIM 6.1 in June 2006
2. PSP101 is not backward compatible with PSP100

Changes

- A complete set of binning scaling rules has been added as a phenomenological alternative to the physics-based geometrical scaling rules.
- BSIM-like instance parameters AS, AD, PS, and PD were added for the junction model.
- To avoid confusion between zeros and “O”s, zeros no longer occur in parameter names. They have all been replaced by “O”s.

Virtuoso Simulator Components and Device Models Reference

PSP102 Model

- Some global parameter names have an additional “O” in their names in order to avoid duplicate names in the global and local model.

PSP102.0 (SiMKit2.3.2)

PSP102.0 is supported in MMSIM6.1.1 in Dec 2006

Changes

- The value for LG when SWJUNCAP = 2 was corrected.
- The clipping/limiting behavior of NP has been made more transparent.
- A minor numerical issue has been resolved.
- The scaling rule for DPHIB is now correctly implemented.
- A coding bug in JUNCAP has been corrected.
- A coding bug in the stress model (involving parameter PKVTHO) has been corrected.
- The parameters LVARW and WVARL have been removed from the binning model in order to ensure continuity of parameters across bin boundaries.

PSP102.1 (SiMKit2.4)

PSP102.1 is supported in MMSIM6.2 in June 2007

Changes

- Added clipping boundaries for SWNQS
- Several minor changes and improvements in model implementation
- Solved bug in stress model
- Solved bug in JUNCAP2
- Included preliminary implementation of PSP-NQS in SiMKit.

PSP102.1.1 (SiMKit 2.5)

PSP102.1.1 is released in MMSIM6.2.1 in Dec 2007

PSP102.2

VerilogA code for PSP102.2 is released in Oct 2007

Changes

- Add parameters EPSROX (electrical or local), EPSROXO (geometrical or global), POEPSROX (binning) representing relative dielectric constant of gate oxide.
- Added a "Well Proximity Effect" model
- Added instance parameters DELVTO (threshold voltage shift parameter) and FACTUO (zero-field mobility pre-factor) to the electrical (or local), geometrical (or global) and binning model.
- Added NF (number of fingers) support to geometrical (or global) and binning model.
- Extended the stress model to support NF.
- Added substrate resistance network and external gate resistance.
- Added geometry scaling for gate resistance in global and binning model.
- Integration of JUNCAP express into PSP. PSP is equipped with a switch-parameter SWJUNEXP.

PSP102.2.1 (SiMKit4.0.1)

Implemented in MMSIM7.0.1 in June 2008

Changes:

- Minor implementation change in juncap initInstance
- Fix issue in calculation of v_{fmin} (juncap initInstance).
- Add clipping for fbbt-variables to nonnegative values (juncap initModel)
- Fix noise calculation for parasitic resistances
- Solved issue with G_{min} for V_{ds}<0
- Corrected error in expression for OP-variable cjssti

PSP102.3 (SiMKit3.1.2)

Implemented in MMSIM7.1.0 in Dec 2008

Changes

- Addition of asymmetric junction model. The new parameter SWJUNASYM is a flag.
- Addition of flicker noise frequency exponent parameter EF (local model), EFO (global model) and POEF (binning model).
- Addition of parameters LINTNOI and ALPNOI to the global model, to increase the flexibility of the length scaling of the flicker noise.
- Some minor bug-fixes and implementation changes.

PSP102.3.2 (SiMKit3.2)

Implemented in MMSIM7.1.1 in June 2009

Changes

- Fixed bug in JUNCAP2-model, involving FJUNQ-based selection-criterion in JUNCAPexpress charge model.
- Some minor implementation changes.

PSP102.3.3 (SiMKit3.3)

Implemented in MMSIM7.2 in Dec 2009. Since MMSIM7.2, version control and master name “psp102” are supported.

Changes

- Added value of gate resistance to OP-output
- Minor bug fix in conditional for SP-calculation of overlap areas.

PSP102.3.4 (SiMKit3.4)

Implemented in MMSIM10.1 in June 2010.

Changes

- Modified implementation of the asymmetrical junction model to improve simulation speed of the verilog-A code
- Modified scaling of the MULT-scaling factor
- Minor bug fix for the output of `sfl`, `sqrtsw`, and `fknee`

PSP102.4 (SiMKit4.01)

Implemented in MMSIM13.1 in September 2013.

Changes

The implementation of the thermal noise model has been improved in version 102.4. As a result, better convergence for some noise analysis could be expected in this version.

- A bug in the sign of the correlation coefficient for negative V_{ds} has been resolved
- Gummel symmetry of `sid` at very high frequency has been improved
- The number of `white_noise` sources has been reduced and the noise voltage values in the noise subcircuit have been scaled to more physical values

Reference

Structure of PSP102

The PSP model has a hierarchical structure, similar to that of MOS Model 11 and SP. This means that there is a strict separation of the geometry scaling in the global model and the model equations in the local model.

As a consequence, PSP can be used at either one of two levels.

- Global level One uses a global parameter set, which describes a whole geometry range. Combined with instance parameters (such as L and W), a local parameter set is internally generated and further processed at the local level in exactly the same way as a custom-made local parameter set.
- Local level One uses a custom-made local parameter set to simulate a transistor with a specific geometry. Temperature scaling is included at this level.

Virtuoso Simulator Components and Device Models Reference

PSP102 Model

The set of parameters which occur in the equations for the various electrical quantities is called the local parameter set. In PSP, temperature scaling parameters are included in the local parameter set. Each of these parameters can be determined by purely electrical measurements. As a consequence, a local parameter set gives a complete description of the electrical properties of a device of one particular geometry.

Since most of these parameters scale with geometry, all transistors of a particular process can be described by a (larger) set of parameters, called the global parameter set. This set contains all local parameters for a long/wide device plus a number of sensitivity coefficients. From the global parameter set, you can obtain a local parameter set for a specific device by applying a set of scaling rules. For more information, see [“Calculation of Transistor Geometry”](#) on page 1528. The geometric properties of that specific device (such as its length and width) enter these scaling rules as instance parameters.

PSP is preferably used at the global level when designing a circuit in a specific technology for which a global parameter set is available. On the other hand, using PSP at local level can be helpful during parameter extraction.

As an option, it is possible to deal with the modification of transistor properties due to stress. In PSP, this is implemented by an additional set of transformation rules, which are optionally applied to the intermediate local parameter set generated at the global level. The parameters associated with the stress model are consequently part of the global parameter set.

The model structure described above is schematically depicted in the following figure.

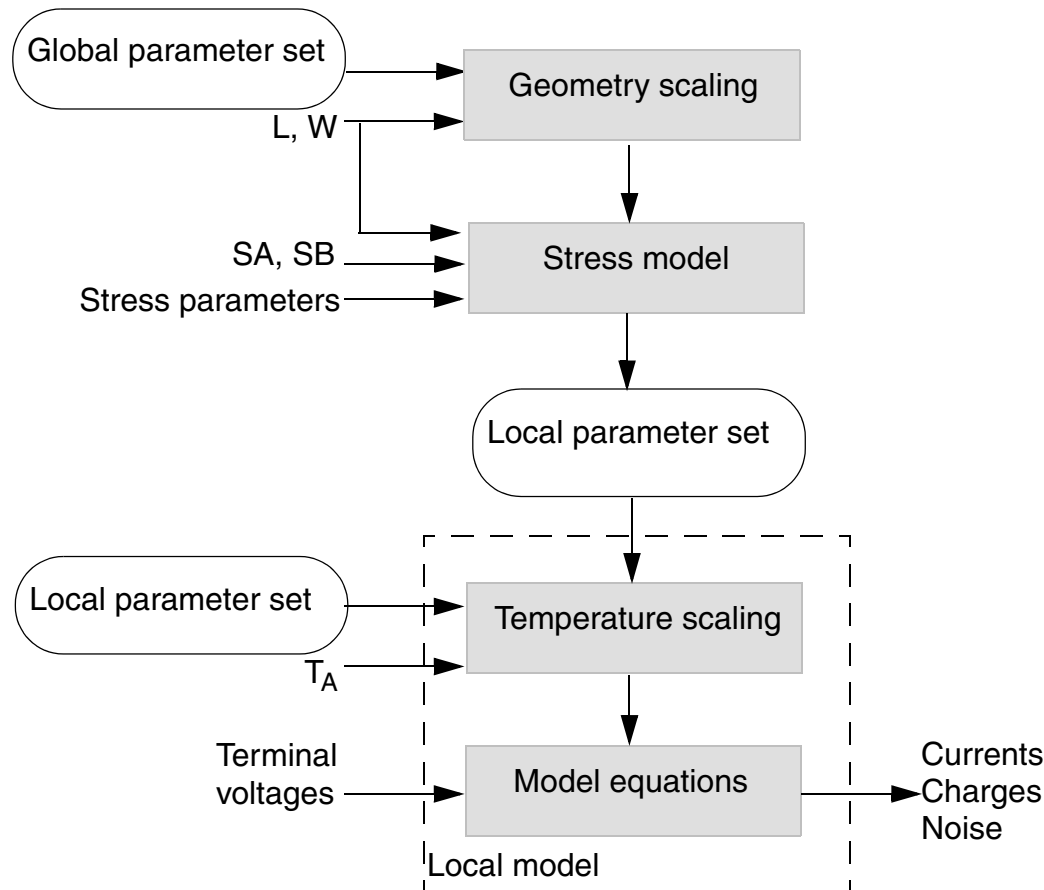


Figure 23-1 Schematic Overview of the PSP Model Structure

The JUNCAP2 model is implemented in such a way that the same set of JUNCAP2 parameters can be used at both the global and the local level.

Geometrical Scaling and Stress Model for Intrinsic MOSFET

The physical geometry scaling rules of PSP have been developed to give a good description over the whole geometry range of CMOS technologies. The parameters for which no scaling rules are specified, appear in both the list for the physical geometrical scaling rules and the list for the electrical model and can simply be copied. When the stress model is used, only the parameters for which shifts or multiplication factors are defined in “Parameter Modification due to Stress Effects” on page 1534 are affected.

Geometrical Scaling Rules

Calculation of Transistor Geometry

$$L_{EN} = 10^{-6}$$

$$W_{EN} = 10^{-6}$$

$$\Delta L_{PS} = LVAR0 \cdot \left(1 + LVARL \cdot \frac{L_{EN}}{L}\right) \cdot \left(1 + LVARW \cdot \frac{W_{EN}}{W}\right)$$

$$\Delta W_{OD} = WVAR0 \cdot \left(1 + WVARL \cdot \frac{L_{EN}}{L}\right) \cdot \left(1 + WVARW \cdot \frac{W_{EN}}{W}\right)$$

$$L_E = L - \Delta L = L + \Delta L_{PS} - 2 \cdot LAP$$

$$W_E = W - \Delta W = W + \Delta W_{OD} - 2 \cdot WOT$$

Note: L_E and W_E cannot be smaller than 10^{-9} after calculation.

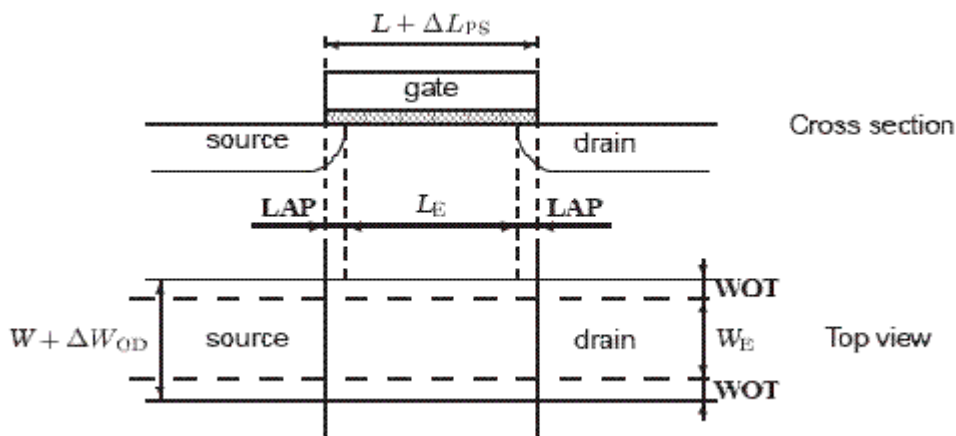


Figure 23-2 Dimensions of a MOS Transistor

Calculation of geometry-dependent parameters using physical scaling rules

Calculation of Process Parameters

$$VFB = VFB0 \cdot \left(1 + VFBL \cdot \frac{L_{EN}}{L_E}\right) \cdot \left(1 + VFBW \cdot \frac{W_{EN}}{W_E}\right) \cdot \left(1 + VFBWLW \cdot \frac{W_{EN} \cdot L_{EN}}{W_E \cdot L_E}\right)$$

$$STVFB = STVFB0 \cdot \left(1 + STVFBL \cdot \frac{L_{EN}}{L_E}\right) \cdot \left(1 + STVFBW \cdot \frac{W_{EN}}{W_E}\right) \cdot \left(1 + STVFBLW \cdot \frac{W_{EN} \cdot L_{EN}}{W_E \cdot L_E}\right)$$

$$NSUB0e = NSUB0 \cdot MAX\left(\left[1 + NSUB0W \cdot \frac{W_{EN}}{W_E} \cdot \ln\left(1 + \frac{W_E}{WSEG}\right)\right], 10^{-3}\right)$$

$$NPCKe = NPCK \cdot MAX\left(\left[1 + NPCK \cdot \frac{W_{EN}}{W_E} \cdot \ln\left(1 + \frac{W_E}{WSEGP}\right)\right], 10^{-3}\right)$$

$$LPCKe = LPCK \cdot MAX\left(\left[1 + LPCKW \cdot \frac{W_{EN}}{W_E} \cdot \ln\left(1 + \frac{W_E}{WSEGP}\right)\right], 10^{-3}\right)$$

$$a = 7.5 \cdot 10^{10}$$

$$b = \sqrt{NSUB0e + 0.5 \cdot NPVCKe} - \sqrt{NSUB0e}$$

$$NP = NP0 \cdot \left(1 + NPL \cdot \frac{L_{EN}}{L_E}\right)$$

$$NSUB = \begin{cases} NSUB0e + NPCKe \cdot \left[2 - \frac{L_E}{LPCKe}\right] & \text{for } L_E < LPCKe \\ NSUB0e + NPCKe \cdot \frac{LPCKe}{L_E} & \text{for } LPCKe < L_E < LPCKe \\ \left[\sqrt{NSUB0e} + a \cdot \ln\left(1 + 2 \cdot \frac{LPCKe}{L_E} \cdot \left[\exp\left(\frac{b}{a}\right) - 1\right]\right)\right]^2 & \text{for } L_E > 2 \cdot LPCKe \end{cases}$$

$$CT = \left(CT0 + CTL \cdot \left[\frac{L_{EN}}{L_E}\right]^{CTLEXP}\right) \cdot \left(1 + CTW \cdot \frac{W_{EN}}{W_E}\right)$$

Calculation of Lateral Gradient Factor Parameters

$$F0 = 1 - F0L1 \cdot \frac{L_{EN}}{L_E} - F0L2 \cdot \left[\frac{L_{EN}}{L_E}\right]^2$$

$$AF = \left(AF0 + AFL \cdot \left[\frac{L_{EN}}{L_E}\right]^{AFLEXP}\right) \cdot \left(1 + AFW \cdot \frac{W_{EN}}{W_E}\right)$$

$$BF = BFL \cdot \left[\frac{L_{EN}}{L_E}\right]^2$$

Calculation of Mobility Parameters

$$FBETle = FBET1 \cdot \left(1 + FBET1W \cdot \frac{W_{EN}}{W_E} \right)$$

$$LPle = LP1 \cdot \text{MAX} \left(\left[1 + LP1W \cdot \frac{W_{EN}}{W_E} \right], 10^{-3} \right)$$

$$G_{P,E} = 1 + FBETle \cdot \frac{LPle}{L_E} \cdot \left[1 - \exp\left(-\frac{L_E}{LPle}\right) \right] + FBET2 \cdot \frac{LP2}{L_E} \cdot \left[1 - \exp\left(-\frac{L_E}{LP2}\right) \right]$$

$$G_{W,E} = 1 + BETW1 \cdot \frac{W_{EN}}{W_E} + BETW2 \cdot \frac{W_{EN}}{W_E} \cdot \ln\left(1 + \frac{W_E}{WBET} \right)$$

$$BETN = \frac{U0}{G_{P,E}} \cdot \frac{W_E}{L_E} \cdot G_{W,E}$$

$$STBET = STBET0 \cdot \left(1 + STBETL \cdot \frac{L_{EN}}{L_E} \right) \cdot \left(1 + STBETW \cdot \frac{W_{EN}}{W_E} \right) \\ \cdot \left(1 + STBETLW \cdot \frac{W_{EN} \cdot L_{EN}}{W_E \cdot L_E} \right)$$

$$MUE = MUE0 \cdot \left[1 + MUEW \cdot \frac{W_{EN}}{W_E} \right]$$

$$XCOR = XCOR0 \cdot \left(1 + XCORL \cdot \frac{L_{EN}}{L_E} \right) \cdot \left(1 + XCORW \cdot \frac{W_{EN}}{LW_E} \right) \\ \cdot \left(1 + XCORLW \cdot \frac{W_{EN} \cdot L_{EN}}{W_E \cdot L_E} \right)$$

$$CS = CS0 \cdot \left[1 + CSW \cdot \frac{W_{EN}}{W_E} \right]$$

Calculation of Series Resistance Parameters

$$RS = RSW1 \cdot \frac{W_{EN}}{W_E} \cdot \left[1 + RSW2 \cdot \frac{W_{EN}}{W_E} \right]$$

Calculation of Velocity Saturation Parameters

$$THESAT = \left(THESAT0 + THESATL \cdot \frac{G_{W,E}}{G_{P,E}} \cdot \left[\frac{L_{EN}}{L_E} \right]^{THESATLEXP} \right) \cdot \left(1 + THESATW \cdot \frac{W_{EN}}{W_E} \right)$$

$$STTHESAT = STTHESAT0 \cdot \left(1 + STTHESATL \cdot \frac{L_{EN}}{L_E} \right) \cdot \left(1 + STTHESATW \cdot \frac{W_{EN}}{W_E} \right) \cdot \left(1 + STTHESATLW \cdot \frac{W_{EN} \cdot L_{EN}}{W_E \cdot L_E} \right)$$

Calculation of Saturation Voltage Parameters

$$AX = \frac{AX0}{1 + AXL \cdot \frac{L_{EN}}{L_E}}$$

Calculation of Channel Length Modulation (CLM) Parameters

$$ALP = ALPL \cdot \left[\frac{L_{EN}}{L_E} \right]^{ALPLEXP} \cdot \left(1 + ALPW \cdot \frac{W_{EN}}{W_E} \right)$$

$$ALP1 = \frac{ALP1L1 \cdot \left[\frac{L_{EN}}{L_E} \right]^{-ALP1LEXP}}{1 + ALP1L2 \cdot \left[\frac{L_{EN}}{L_E} \right]^{ALP1LEXP + 1}} \cdot \left(1 + ALP1W \cdot \frac{W_{EN}}{W_E} \right)$$

$$ALP2 = ALP20 \cdot \frac{1 + ALP2W \cdot \frac{W_{EN}}{W_E}}{1 + ALPL \cdot \frac{L_{EN}}{L_E}}$$

Calculation of Impact Ionization (II) Parameters

$$A1 = A10 \cdot \left(1 + A1L \cdot \frac{L_{EN}}{L_E}\right) \cdot \left(1 + A1W \cdot \frac{W_{EN}}{W_E}\right)$$

$$A3 = A30 \cdot \left(1 + A3L \cdot \frac{L_{EN}}{L_E}\right) \cdot \left(1 + A3W \cdot \frac{W_{EN}}{W_E}\right)$$

$$A4 = A40 \cdot \left(1 + A4W \cdot \frac{W_{EN}}{W_E}\right)$$

Calculation of Gate Current Parameters

$$IGINV = IGINVLW \cdot \frac{W_E \cdot L_E}{W_{EN} \cdot L_{EN}}$$

$$IGOV = IGOVW \cdot \frac{W_E \cdot LOV}{W_{EN} \cdot L_{EN}}$$

Calculation of Gate-Induced Drain Leakage (GIDL) Parameters

$$AGIDL = AGIDLLW \cdot \frac{W_E \cdot LOV}{W_{EN} \cdot L_{EN}}$$

Calculation of Charge Model Parameters

$$COX = \epsilon_{OX} \cdot \frac{W_E \cdot L_E}{TOX}$$

$$CGOV = \epsilon_{OX} \cdot \frac{W_E \cdot LOV}{TOXOV}$$

$$CGBOV = CGBOVL \cdot \frac{L + \Delta L_{PS}}{L_{EN}}$$

$$IFK = IFKW \cdot \frac{W_E}{W_{EN}}$$

$$CFR = CFRW \cdot \frac{W + \Delta W_{OD}}{W_{EN}}$$

Calculation of Noise Model Parameters

$$NFA = NFALW \cdot \frac{W_{EN} \cdot L_{EN}}{W_E \cdot L_E}$$

$$NFB = NFBLW \cdot \frac{W_{EN} \cdot L_{EN}}{W_E \cdot L_E}$$

$$NFC = NFCLW \cdot \frac{W_{EN} \cdot L_{EN}}{W_E \cdot L_E}$$

Parameter Modification due to Stress Effects

The stress model of BSIM4.4.0 has been adopted in PSP without any modifications. The PSP parameters affected are BETN, THESAT, VFB, AF, and CF.

Layout Effects for Regular Shapes

$$Inv_sa = \frac{1}{SA + 0.5 \cdot L}$$

$$Inv_sb = \frac{1}{SB + 0.5 \cdot L}$$

$$Inv_sa_{ref} = \frac{1}{SA_{REF} + 0.5 \cdot L}$$

$$Inv_sb_{ref} = \frac{1}{SB_{REF} + 0.5 \cdot L}$$

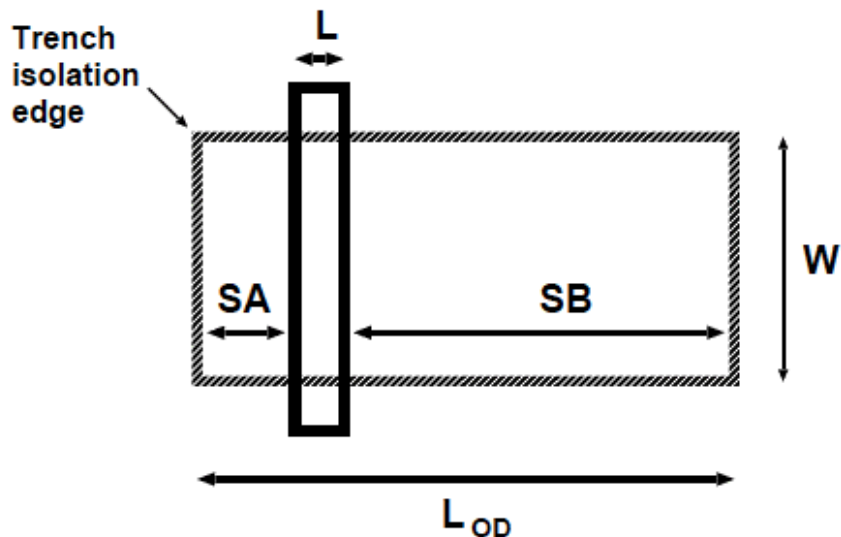


Figure 23-3 Typical layout of a MOSFET. Note that $L_{OD} = SA + SB + L$, where OD is gate oxide definition

Layout effects for irregular shapes

For irregular shapes, the following effective values for **SA** and **SB** are to be used. You have to provide these values manually or by a layout extraction tool.

$$\frac{1}{SA_{EFF} + 0.5 \cdot L} = \sum_{i=1}^n \frac{SW_i}{W} \cdot \frac{1}{SA_i + 0.5 \cdot L}$$

$$\frac{1}{SB_{EFF} + 0.5 \cdot L} = \sum_{i=1}^n \frac{SW_i}{W} \cdot \frac{1}{SB_i + 0.5 \cdot L}$$

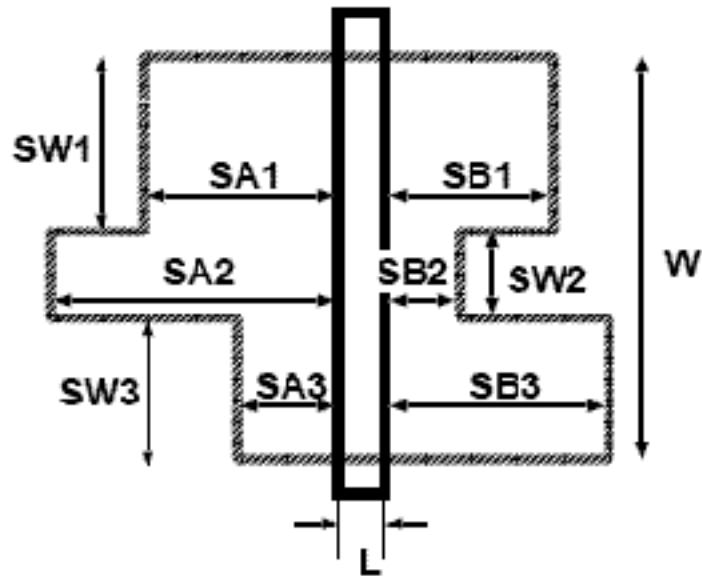


Figure 23-4 A typical layout of MOS devices with more instance parameters (SW_i , SA_i and SB_i) in addition to the traditional L and W)

Calculation of Parameter Modifications

Mobility-Related Equations

$$K_{stress_u0} = \left(1 + \frac{L_{KU0}}{(L + \Delta L_{PS})^{LLODKU0}} + \frac{W_{KU0}}{(W + \Delta W_{OD} + WLOD)^{WLODKU0}} + \frac{P_{KU0}}{(L + \Delta L_{PS})^{LLODKU0} \cdot (W + \Delta W_{OD} + WLOD)^{WLODKU0}} \right) \cdot \left(1 + TKU0 \cdot \left(\frac{T_{KD}}{T_{KR}} - 1 \right) \right)$$

$$\rho\beta = \frac{KU0}{K_{stress_u0}} \cdot (Inv_sa + Inv_sb)$$

$$\rho\beta, ref = \frac{KU0}{K_{stress_u0}} \cdot (Inv_sa_{ref} + Inv_sb_{ref})$$

$$BETN = \frac{1 + \rho\beta}{1 + \rho\beta, ref} \cdot BETN_{ref}$$

$$THESAT = \frac{1 + \rho\beta}{1 + \rho\beta, ref} + \frac{1 + KVSAT \cdot \rho\beta, ref}{1 + KVSAT \cdot \rho\beta} \cdot THESAT_{ref}$$

Threshold-Voltage-Related Equations

$$K_{stress_vth0} = 1 + \frac{LKVTH0}{(L + \Delta L_{PS})^{LLODKVTH}} + \frac{WKVTH0}{(W + \Delta W_{OD} + WLOD)^{WLODKVTH}} + \frac{PKU0}{(L + \Delta L_{PS})^{LLODVTH} \cdot (W + \Delta W_{OD} + WLOD)^{WLODVTH}}$$

$$\Delta Inv_s = Inv_sa + Inv_sb - Inv_sa_{ref} - Inv_sb_{ref}$$

$$VFB = VFB_{ref} + KVTH0 \cdot \frac{\Delta Inv_s}{K_{stress_vth0}}$$

$$AF = AF_{ref} + STK2 \cdot \frac{\Delta Inv_s}{K_{stress_vth0}^{LODK2}}$$

$$CF = CF_{ref} + STETA0 \cdot \frac{\Delta Inv_s}{K_{stress_vth0}^{LODETA0}}$$

PSP102 Model Equations

Calculation of Internal Parameters (including Temperature Scaling)

Calculation of Transistor Temperature

$$T_{KR} = T_0 + TR$$

$$T_{KD} = T_0 + T_A + DTA$$

$$\Delta T = T_{KD} - T_{KR}$$

$$\phi_T = \frac{k_B \cdot T_{KD}}{q}$$

Calculation of Local Process Parameters:

$$\phi^*_T = \phi_T \cdot \left(1 + CT \cdot \frac{T_{KR}}{T_{KD}} \right)$$

$$V_{FB} = V_{FB} + STV_{FB} \cdot \Delta T$$

$$E_g/q = 1.179 - 9.025 \cdot 10^{-5} \cdot T_{KD} - 3.05 \cdot 10^{-7} \cdot T_{KD}^2$$

$$r_T = (1.045 + 4.5 \cdot 10^{-4} \cdot T_{KD}) \cdot (0.523 + 1.4 \cdot 10^{-3} \cdot T_{KD} - 1.48 \cdot 10^{-6} \cdot T_{KD}^2)$$

$$n_i = 2.5 \cdot 10^{25} \cdot r_T^{3/4} \cdot (T_{KD}/300)^{3/2} \cdot \exp\left(\frac{E_g/q}{2 \cdot \phi_T}\right)$$

$$\phi_B^{cl} = \text{MAX}(2 \cdot \phi_T \cdot \ln[(NSUB)/n_i], 0.05)$$

$$C_{ox} = \epsilon_{ox}/(TOX)$$

$$\gamma_0 = \sqrt{2 \cdot q \cdot \epsilon_{Si} \cdot NSUB / C_{ox}}$$

$$G_0^{cl} = \gamma_0 / (\sqrt{\phi_T})$$

Calculation of Polysilicon Depletion Parameter

$$kp = \begin{cases} \text{if } NP \leq 1 \text{ or } NP \geq 10^{28} & \{kp = 0 \\ \text{if } 1 < NP < 10^{28} & \begin{cases} NP_1 = \text{MAX}(NP, 8 \cdot 10^7 / TOX^2) \\ NP_2 = \text{MAX}(NP_1, 3 \cdot 10^2) \\ kp = (2 \cdot \phi_T \cdot C_{ox}^2) / (q \cdot \epsilon_{Si} \cdot NP^2) \end{cases} \end{cases}$$

Calculation of Quantum-Mechanical Correction Parameters

$$q_{lim} = 10 \cdot \phi_T$$

$$q_q = \begin{cases} 0.4 \cdot QMC \cdot QM_N \cdot C_{ox}^{2/3} & \text{for NMOS} \\ 0.4 \cdot QMC \cdot QM_p \cdot C_{ox}^{2/3} & \text{for PMOS} \end{cases}$$

$$q_{b0} = \gamma_0 \cdot \sqrt{\phi_B^{cl}}$$

$$\phi_B = \phi_B^{cl} + 0.75 \cdot q_q \cdot q_{b0}^{2/3}$$

$$G_0 = G_0^{cl} \cdot (1 + q_q \cdot q_{b0}^{-2/3})$$

$$\phi_X = 0.95 \cdot \phi_B$$

$$a_\phi = 2.5 \cdot 10^{-5} \cdot \phi_b^2$$

$$\phi_X^* = \text{MAXA}(\phi_X, 0, a_\phi) = 0.95000658 \cdot |\phi_B|$$

Calculation of Local Process Parameters in Gate Overlap Regions

$$\gamma_{ov} = \sqrt{2 \cdot q \cdot \epsilon_{Si} \cdot NOV} \cdot (TOXOV) / \epsilon_{ox}$$

$$G_{ov} = \gamma_{ov} / (\sqrt{\phi_T})$$

$$\xi_{ov} = 1 + G_{ov} / (\sqrt{2})$$

$$x_{mrgov} = 10^{-5} \cdot \xi_{ov}$$

Calculation of Lateral Gradient Factor Parameters

$$B_f = \text{MIN}\left(BF, \frac{1-F0}{F0+0.01}\right)$$

Calculation of Mobility Parameters

$$\beta = BETN \cdot C_{ox} \cdot (T_{KR}/T_{KD})^{STBET}$$

$$\theta_{\mu} = THEMU \cdot (T_{KR}/T_{KD})^{STHEMU}$$

$$\mu_E = MUE \cdot (T_{KR}/T_{KD})^{STMUE}$$

$$X_{cor} = XCOR \cdot (T_{KR}/T_{KD})^{STXCOR}$$

$$C_S = CS \cdot (T_{KR}/T_{KD})^{STCS}$$

$$E_{eff0} = 10^{-8} \cdot C_{ox} / \epsilon_{Si}$$

$$\eta_{\mu} = \begin{cases} 1/2 & \text{for NMOS} \\ 1/3 & \text{for PMOS} \end{cases}$$

Calculation of Series Resistance Parameters

$$R_s = RS \cdot (T_{KR}/T_{KD})^{STRS}$$

$$\theta_R = 2 \cdot \beta \cdot R_s$$

Calculation of Velocity Saturation Parameter

$$\theta_{sat} = A2 \cdot (T_{KR}/T_{KD})^{STTHESAT}$$

Calculation of Impact-Ionization Parameter

$$\alpha_2 = A2 \cdot (T_{KD}/T_{KR})^{STA2}$$

Calculation of Gate Current Parameters

$$I_{GINV} = I_{GINV} \cdot (T_{KD}/T_{KR})^{STIG}$$

$$I_{GOV} = A2IGOV \cdot (T_{KD}/T_{KR})^{STIG}$$

$$B = \frac{4}{3} \cdot \frac{TOX}{h} \cdot \sqrt{2 \cdot q \cdot m_0 \cdot CHIB} = 6.830909 \cdot 10^9 \cdot TOX \cdot \sqrt{CHIB}$$

$$B_{ov} = B \cdot (TOXOV)/(TOX)$$

$$GC_q = \begin{cases} -0.99 \cdot \frac{GC2}{2 \cdot GC3} & \text{if } GC3 < 0 \\ 0 & \text{if } GC3 \geq 0 \end{cases}$$

$$\alpha_b = \frac{E_g/q + \phi_B}{2}$$

$$D_{ch} = GC0 \cdot \phi^*_T$$

$$D_{ov} = GC0 \cdot \phi_T$$

Calculation of Gate-Induced Drain Leakage Parameters

$$A_{GIDL} = AGIDL \cdot \left(\frac{2 \cdot 10^{-9}}{TOXOV} \right)^2$$

$$B_{GIDL} = BGIDL \cdot \text{MAX}([1 + STBGIDL \cdot \Delta T], 0) \cdot \left(\frac{TOXOV}{2 \cdot 10^{-9}} \right)$$

Calculation of Noise Parameter

$$N_T = FNT \cdot 4 \cdot k_B \cdot T_{KD}$$

Calculation of Additional Internal Parameters

$$x_1 = 1.25$$

$$x_{g1} = \chi_1 + G_{ov} \cdot \sqrt{\exp(-\chi_1) + \chi_1 - 1}$$

PSP 102 Model Equations

Conditioning of Terminal Voltages

$$V^*_{GB} = V_{GS} + V_{SB} - V_{FB}$$

$$x_g = V^*_{GB} / \phi^*_T$$

$$V^*_{SB} = \text{MAXA}(V_{SB} + \phi_X, 0, a_\phi) - \phi^*_X$$

$$V^*_{DB} = V_{DS} + V^*_{SB}$$

Bias-Dependent Body Factor

$$D_{nsub} = DNSUB \cdot \text{MAXA}(0, V_{GS} + V_{SB} - VNSUB, NSLP)$$

$$G = G_0 \cdot \sqrt{1 + D_{nsub}}$$

Lateral Gradient Factor

$$V_{dsx} = \sqrt{V_{DS}^2 + 0.010.01}$$

$$V_{sbx} = V_{SB}^* + \frac{V_{DS} - V_{dsx}}{2}$$

$$V_{sbx1} = \text{MAXA}(V_{sbx}, 0, 10^{-4})$$

$$F_{DIBL} = CF \cdot V_{dsx} \cdot (1 + CF \cdot V_{dsx}) \cdot (1 + CFB \cdot V_{sbx})$$

$$f_0 = \frac{F_0}{1 + AF \cdot V_{sbx} + B_f \cdot V_{sbx1} + F_{DIBL}} + 0.01$$

$$B_t = (f_0 - 0.01) \cdot B_f \cdot \phi^*_X$$

$$\tilde{x}_0 = \frac{\phi_B + V_{sbx}}{\phi^*_T}$$

$$x_{gc} = \text{MAXA}(\chi_g, 0, 50)$$

$$x_{subf} = \frac{\chi_{gc}^2}{\chi_{gc} + \frac{G^2 \times f_0}{2} + G \cdot \sqrt{B_t \cdot \chi_{gc}^2 + f_0 \cdot \chi_{gc} + \left(\frac{G \cdot f_0}{2}\right)^2}}$$

$$\eta_f = \text{MINA}(\chi_{subf}, \tilde{x}_0 + 3, 5)$$

$$a_f = (\chi_{gc} - \eta_f)^2 - G^2 \cdot \eta_f \cdot (f_0 + B_t \cdot \eta_f)$$

$$c_f = 2 \cdot (\chi_{gc} - \eta_f) + G^2 \cdot (f_0 + 2 \cdot B_t \cdot \eta_f)$$

$$\tau = \tilde{x}_0 - \eta_f + \ln(a_f / G^2)$$

$$x_f = \sigma\left(\frac{a_f}{1 - B_t \cdot G^2}, \frac{c_f}{1 - B_t \cdot G^2}, \tau, \eta_f\right)$$

$$f = f_0 + B_t \cdot \chi_f$$

Surface Potential at Source Side and Related Variables

$$G_f = G \cdot \sqrt{f}$$

$$\xi = 1 + G_f / (\sqrt{2})$$

$$x_{ns} = \frac{\phi_B + V^*_{SB}}{\phi^*_T}$$

$$\Delta_{ns} = \exp(-\chi_{ns}) / f$$

$$x_{mrg} = 10^{-5} \cdot \xi$$

$$\begin{cases}
 y_g = -x_g \\
 z = 1.25 \cdot y_g / \xi \\
 \eta = \left[z + 10 - \sqrt{(z-6)^2 + 64} \right] / 2 \\
 a = (y_g - \eta)^2 + G_f^2 \cdot (\eta + 1) \\
 c = 2 \cdot (y_g - \eta) - G_f^2 \\
 \tau = -\eta + \ln(a / G_f^2) \\
 y_0 = \sigma_1(a, c, \tau, \eta) \\
 \Delta_0 = EXP(y_0) \\
 p = 2 \cdot (y_g - y_0) + G_f^2 \cdot [\Delta_0 - 1 + \Delta_{ns} \cdot (1 - \chi'(y_0) - 1/\Delta_0)] \\
 q = (y_g - y_0)^2 + G_f^2 \cdot [y_0 - \Delta_0 + 1 + \Delta_{ns} \cdot (1 + \chi(y_0) - 1/\Delta_0 - 2 \cdot y_0)] \\
 x_s = -y_0 - \frac{2 \cdot q}{p + \sqrt{p^2 - 2 \cdot q \cdot \left\{ 2 - G_f^2 \cdot [\Delta_0 + \Delta_{ns} \cdot (1/\Delta_0 - x^n(y_0))] \right\}}}
 \end{cases}$$

$$\text{if } |x_g| \leq x_{mrg} \quad \left\{ x_s = \frac{x_g}{\xi}, \left[1 + G_f \cdot x_g \cdot \frac{1 - \Delta_{ns}}{\xi^2 \cdot 6 \cdot \sqrt{2}} \right] \right.$$

$$\text{if } x_g > x_{mrg} = \left\{ \begin{array}{l}
 \hat{x}_{g1} = x_1 + G_f \cdot \sqrt{\exp(-x_1) + x_1 - 1} \\
 \bar{x} = \frac{x_g}{\xi} \cdot [1 + x_g \cdot (\xi \cdot x_1 - \hat{x}_{g1}) / x_{g1}^2] \\
 x_0 = x_g + G_f^2 / 2 - G_f \cdot \sqrt{x_g + G_f^2 / 4 - 1 + \exp(-\bar{x})} \\
 b_x = x_{ns} + 0.5 + 2.5 \cdot f \\
 \eta = \text{MINA}(x_0, b_x, 5) - (b_x - \sqrt{b_x^2 + 5}) / 2 \\
 a = (x_g - \eta)^2 - G_f^2 \cdot [\exp(-\eta) + \eta - 1 - \Delta_{ns} - (\eta + 1 + \chi(\eta))] \\
 b = 1 - G_f^2 \cdot [\exp(-\eta) - \Delta_{ns} \cdot x^n(\eta)] \\
 c = 2 \cdot (x_g - \eta) + G_f^2 \cdot [1 - \exp(-\eta) - \Delta_{ns} \cdot (1 + x'(\eta))] \\
 \tau = x_{ns} - \eta + \ln(a / G^2) \\
 y_0 = a_2(a, b, c, \tau, \eta) \\
 \Delta_0 = \exp(y_0) \\
 p = 2 \cdot (x_g - y_0) + G_f^2 \cdot [1 - 1 / \Delta_0 + \Delta_{ns} \cdot (\Delta_0 - 1 - (y_0))] \\
 x_s = \frac{2 \cdot q}{p + \sqrt{p^2 - 2 \cdot q \cdot \left\{ 2 - G_f^2 \cdot [1 / \Delta_0 + \Delta_{ns} \cdot (\Delta_0 - x^n(y_0))] \right\}}}
 \end{array} \right.$$

The values of E_s , D_s , and P_s are calculated only for $x_g > 0$.

$$E_s = \exp(-x_s)$$

$$D_s = [1/E_s - x_s - 1 - x(x_s)] \cdot \Delta_{ns}$$

$$P_s = x_s - 1 + E_s$$

$$x_{gs} = \begin{cases} x_g - x_s & \text{for } x_g \leq 0 \\ G_f \cdot \sqrt{D_s + P_s} & \text{for } x_g > 0 \end{cases}$$

$$\Psi_{ss} = \phi^*_T \cdot x_s$$

Drain Saturation Voltage

All the equations in this sections have been calculated for $x_g > 0$.

$$q_{is} = \frac{G_f^2 \cdot \phi^*_T \cdot D_s}{x_{gs} + G_f \cdot \sqrt{P_s}}$$

$$\alpha_s = 1 + \frac{G_f \cdot (1 - E_s)}{2 \cdot \sqrt{P_s}}$$

$$q_{bs} = \phi^*_T \cdot G_f \cdot \sqrt{P_s}$$

$$\rho_s = \theta_R \cdot \frac{1 + RSB \cdot V_{sbx}}{1 + RSG \cdot q_{is}} \cdot q_{is}$$

$$\mu_x = \frac{1 + X_{cor} \cdot V_{sbx}}{1 + 0.2 \cdot X_{cor} \cdot V_{sbx}}$$

$$E_{effs,s} = E_{eff0} \cdot (q_{bs} + \eta_\mu \cdot q_{is})$$

$$G_{mob,s} = \frac{1 + (\mu_E \cdot E_{eff,s})^{\theta_\mu} + C_S \cdot \left(\frac{q_{bs}}{q_{is} + q_{bs}} \right)^2 + \rho_s}{\mu_x}$$

$$w_{sat,s} = \frac{100 \cdot q_{is} \cdot (1 + THESATB \cdot V_{sbx})}{100 + q_{is} \cdot (1 + THESATB \cdot V_{sbx})}$$

$$\theta^*_{sat,s} = \frac{\theta_{sat,s}}{G_{mob,s}} \cdot (1 + THESATG \cdot w_{sat,s})$$

$$\phi_\infty = q_{is} / \alpha_s + \phi^*_T$$

$$y_{sat} = \begin{cases} \theta^*_{sat,s} \cdot \phi_{\infty} / (\sqrt{2}) & \text{for NMOS} \\ \frac{\theta^*_{sat,s} \cdot \phi_{\infty} / (\sqrt{2})}{\sqrt{1 + \theta^*_{sat,s} \cdot \phi_{\infty} / (\sqrt{2})}} & \text{for PMOS} \end{cases}$$

$$\phi_2 = \frac{\phi^*_T \cdot G_f^2 \cdot D_s \cdot SO}{a_{sat} + \sqrt{a_{sat}^2 - G_f^2 \cdot D_s \cdot SO}}$$

$$\phi_{sat} = \frac{2 \cdot \phi_0 \cdot \phi_2}{\phi_0 + \phi_2 + \sqrt{(\phi_0 + \phi_2)^2 - 3.96 \cdot \phi_0 \cdot \phi_2}}$$

$$V_{dsat} = \phi_{sat} - \phi^*_T \cdot \ln \left[1 + \frac{\phi_{sat} \cdot (\phi_{sat} - 2 \cdot a_{sat} \cdot \phi^*_T)}{G_f^2 \cdot D_s \cdot \phi_T^{*2}} \right]$$

$$V_{dse} = \frac{V_{DS}}{[1 + (V_{DS}/V_{dsat})^{AX}]^{1/(AX)}}$$

Surface Potential at Drain Side and Related Variables

$$x_{nd} = \frac{\phi_B + V_{SB} + V_{dse}}{\phi^*_T}$$

$$k_{ds} = \exp(-V_{dse}/\phi^*_T)$$

$$\text{if } x_g \leq x_{mrg} \quad \left\{ x_d = \frac{x_g}{\xi} \cdot \left[1 + G_f \cdot x_g \cdot \frac{1 - \Delta_{nd}}{\xi^2 \cdot 6 \cdot \sqrt{2}} \right] \right.$$

$$\text{if } x_g > x_{mrg} \left\{ \begin{array}{l}
 b_x = x_{nd} + 0.5 + 2.5 \cdot f \\
 \eta = \text{MINA}(x_0, b_x, 5) - (b_x - \sqrt{b_x^2 + 5})/2 \\
 a = (x_g - \eta)^2 - G_f^2 \cdot [\exp(-\eta) + \eta - 1 - \Delta_{nd} \cdot (\eta + 1 + x(\eta))] \\
 b = 1 - G_f^2/2 \cdot [\exp(-\eta) - \Delta_{nd} \cdot x^n(\eta)] \\
 c = 2 \cdot (x_g - \eta) + G_f^2 \cdot [1 - \exp(-\eta) - \Delta_{nd} \cdot (1 + x'(\eta))] \\
 \tau = x_{nd} - \eta + \ln(a/G^2) \\
 y_0 = \sigma_2(a, b, c, \tau, \eta) \\
 \Delta_0 = \exp(y_0) \\
 p = 2 \cdot (x_g - y_0) + G_f^2 \cdot [1 - 1/\Delta_0 + \Delta_{nd} \cdot (\Delta_0 - 1 - x'(y_0))] \\
 q = (x_g - y_0)^2 - G_f^2 \cdot [y_0 + 1/\Delta_0 - 1 + \Delta_{nd} \cdot (\Delta_0 - y_0 - 1 - x'(y_0))] \\
 x_d = y_0 + \frac{2 \cdot q}{p + \sqrt{p^2 - 2 \cdot q \cdot \left\{ 2 - G_f^2 \cdot [1/\Delta_0 + \Delta_{nd} \cdot (\Delta_0 - x^n(y_0))] \right\}}}
 \end{array} \right.$$

$$x_{ds} = x_d - x_s$$

$$\text{if } x_{ds} < 10^{-10} \left\{ \begin{array}{l}
 p = 2 \cdot x_{gs} + G_f^2 \cdot [1 - E_s + \Delta_{nd} \cdot (1/E_s - 1 - x'(x_s))] \\
 q = G_f^2 \cdot (1 - k_{ds}) \cdot D_s \\
 \xi = 1 - G_f^2 \cdot [E_s + \Delta_{nd} (1/E_s - x^n(x_s))] \\
 x_{ds} = \frac{2 \cdot q}{p + \sqrt{p^2 - 4 \cdot \xi \cdot q}} \\
 x_d = x_s + x_{ds}
 \end{array} \right.$$

$$E_d = \exp(-x_d)$$

$$D_d = (1/E_d - x_d - 1 - (x_d)) \cdot \Delta_{nd}$$

$$\Delta\Psi = \phi_T^* \cdot x_{ds}$$

$$\Psi_{sd} = \phi_T^* \cdot x_d$$

Mid-Point Surface Potential and Related Variables

$$\text{if } x_g > 0 \quad \left\{ \begin{array}{l} x_m = (x_s + x_d)/2 \\ E_m = \sqrt{E_s \cdot E_d + 10^{-40}} \\ \bar{D} = (D_s + D_d)/2 \\ D_m = \bar{D} + x_{ds}^2 / 8 \cdot (E_m - 2/G_f^2) \\ P_m = x_m - 1 + E_m \\ x_{gm} = G_f \cdot \sqrt{D_m + P_m} \end{array} \right.$$

$$\text{if } x_g \leq 0 \quad \left\{ \begin{array}{l} x_m = x_s \\ x_{gm} = x_g - x_s \end{array} \right.$$

Polysilicon Depletion

The equations in this section are only calculated for $k_p > 0$ and $x_g > 0$ (otherwise $\eta_p = 1$).

$$x_m^{(0)} = x_m, \quad D_m^{(0)} = D_m, \quad E_m^{(0)} = E_m, \quad \Delta\psi^{(0)} = \Delta\psi$$

$$d_0 = 1 - E_m^{(0)} + 2 \cdot x_{gm} / G_f^2$$

$$\eta_p = 1 / (\sqrt{1 + k_p \cdot x_{gm}})$$

$$x_{pm} = k_p \cdot \left[\frac{\eta_p \cdot x_{gm}}{1 + \eta_p} \right] \cdot \frac{D_m^{(0)}}{D_m^{(0)} + P_m}$$

$$p = 2 \cdot (x_{gm} - x_{pm}) + G_f^2 \cdot (1 - E_m^{(0)} + D_m^{(0)})$$

$$q = x_{pm} \cdot (x_{pm} - 2 \cdot x_{gm})$$

$$\xi_p = 1 - G_f^2 / 2 \cdot (E_m^{(0)} + D_m^{(0)})$$

$$u_p = \frac{p \cdot q}{p^2 - \xi_p \cdot q}$$

$$x_m = x_m^{(0)} + u_p$$

$$E_m = E_m^{(0)} \cdot \exp(-u_p)$$

$$D_m = D_m^{(0)} \cdot \exp(-u_p)$$

$$P_m = x_m - 1 + E_m$$

$$x_{gm} = G_f \cdot \sqrt{D_m + P_m}$$

$$\Delta\Psi = \Delta\Psi^{(0)} \cdot \frac{\exp(u_p) \cdot [\bar{D} + d_0]}{1 - E_m + 2 \cdot x_{gm} \cdot \eta_p / G_f^2 + \exp(u_p) \cdot \bar{D}}$$

Potential Mid-Point Inversion Charge and Related Variables

The equations in this section are only calculated for $x_g > 0$.

$$q_{im} = \frac{G_f^2 \cdot \phi_T^* \cdot D_m}{x_{gm} + G_f \cdot \sqrt{P_m}}$$

$$\alpha_m = \eta_p + \frac{G_f \cdot (1 - E_m)}{2 \cdot \sqrt{P_m}}$$

$$q_{im}^* = q_{im} + \phi_T^* \cdot \alpha_m$$

$$q_{bm} = \phi_T^* \cdot G_f \cdot \sqrt{P_m}$$

Series Resistance

$$\rho = \theta_R \cdot \frac{1 + RSB \cdot V_{sbx}}{1 + RSG \cdot q_{im}} \cdot q_{im}$$

Mobility Reduction

$$E_{eff} = E_{eff0} \cdot (q_{bm} + \eta_{\mu} \cdot q_{im})$$

$$G_{mob} = \frac{1 + (\mu_E \cdot E_{eff})^{\theta_{\mu}} + C_S \cdot \left(\frac{q_{bm}}{q_{im} + q_{bm}} \right) + \rho}{\mu_x}$$

Drain-Source Channel Current

Channel Length Modulation

$$R_1 = q_{im} / q_{im}^*$$

$$R_2 = \phi_T^* \cdot \alpha_m / q_{im}^*$$

$$\Delta L / L = ALP \cdot \frac{V_{DS}}{V_{DS} + \phi_T^*} \cdot \ln \left(1 + \frac{V_{DS} - \Delta \Psi}{VP} \right)$$

$$G_{\Delta L} = \frac{1}{1 + \Delta L / L + (\Delta L / L)^2}$$

$$\Delta L_1 / L = \left[ALP + \frac{ALP1}{q_m^*} \cdot R_1 + ALP2 \cdot q_{bm} \cdot R_2 \right] \cdot \frac{V_{DS}}{V_{DS} + \phi_T^*} \cdot \ln \left(1 + \frac{V_{DS} - \Delta \Psi}{VP} \right)$$

$$F_{\Delta L} = 1 + \Delta L_1 / L + (\Delta L_1 / L)^2$$

Velocity Saturation

$$w_{sat} = \frac{100 \cdot q_{im} \cdot (1 + THESATB \cdot V_{sbx})}{100 + q_{im} \cdot (1 + THESATB \cdot V_{sbx})}$$

$$\theta^*_{sat} = \frac{\theta_{sat}}{G_{mob} \cdot G_{\Delta L}} \cdot (1 + THESATG \cdot w_{sat})$$

$$z_{sat} = \begin{cases} (\theta^*_{sat} \cdot \Delta\Psi)^2 & \text{for NMOS} \\ \frac{(\theta^*_{sat} \cdot \Delta\Psi)^2}{1 + \theta^*_{sat} \cdot \Delta\Psi} & \text{for PMOS} \end{cases}$$

$$G_{vsat} = \frac{G_{mob} \cdot G_{\Delta L}}{2} \cdot (1 + \sqrt{1 + 2 \cdot z_{sat}})$$

Drain-Source Channel Current

$$I_{DS} = \begin{cases} 0 & \text{for } x_g \leq 0 \\ \beta \cdot F_{\Delta L} \cdot \frac{q^*_{im}}{G_{vsat}} \cdot \Delta\Psi & \text{for } x_g > 0 \end{cases}$$

Variables for Calculation of Intrinsic Charges and Gate Current

The equations in this section are only calculated for $x_g > 0$.

$$V_{oxm} = \theta^*_T \cdot x_{gm}$$

$$\alpha'_m = \alpha_m \cdot \left[1 + \frac{z_{sat}}{2} \cdot \left(\frac{G_{mob} \cdot G_{\Delta L}}{G_{vsat}} \right)^2 \right]$$

$$H = \frac{G_{mob} \cdot G_{\Delta L}}{G_{vsat}} \cdot \frac{q^*_{im}}{\alpha'_m}$$

Impact Ionization or Weak-Avalanche

The equations in this Section are calculated when SWIMPACT = 1 and only for $x_g > 0$.

$$a^*_2 = a_2 \cdot [1 + A4 \cdot (\sqrt{V^*_{SB} + \phi_B} - \sqrt{\phi_B})]$$

$$\Delta V_{sat} = V_{DS} - A3 \cdot \Delta\psi$$

$$M_{avl} = \begin{cases} 0 & \text{for } \Delta V_{sat} \leq 0 \\ A1 \cdot \Delta V_{sat} \cdot \exp(\Delta\psi) & \text{for } \Delta V_{sat} > 0 \end{cases}$$

$$I_{avl} = M_{avl} \cdot I_{DS}$$

Surface Potential in Gate Overlap Regions

$$x_{ov}(x_g) = \begin{cases} \text{if } x_g < -x_{mrgov} & \left\{ \begin{array}{l} y_g = -x_g \\ z = x_1 \cdot y_g / \xi_{ov} \\ \eta = [z + 10 - \sqrt{(z-6)^2 + 64}] / 2 \\ a = (y_g - \eta)^2 + G_{ov}^2 \cdot (\eta + 1) \\ c = 2 \cdot (y_g - \eta) - G_{ov}^2 \\ \tau = -\eta + \ln(a / G_{ov}^2) \\ y_0 = \sigma_1(a, c, \tau, \eta) \\ \Delta_0 = \exp(y_0) \\ p = 2 \cdot (y_g - y_0) + G_{ov}^2 \cdot (\Delta_0 - 1) \\ q = (y_g - y_0)^2 + G_{ov}^2 \cdot (y_0 - \Delta_0 + 1) \\ x_{ov} = \frac{2 \cdot q}{p + \sqrt{p^2 - 2 \cdot q \cdot (2 - G_{ov}^2 \cdot \Delta_0)}} \end{array} \right. \\ \text{if } |x_g| < x_{mrgov} & \{ x_{ov} = x_g / \xi_{ov} \end{cases}$$

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$$x_{ov}(x_g) = \begin{cases} \left. \begin{array}{l} \text{if } x_g < -x_{mrgov} \\ \\ \\ \\ \\ \\ \\ \\ \\ \end{array} \right\} \begin{array}{l} y_g = -x_g \\ z = x_1 \cdot y_g / \xi_{ov} \\ \eta = [z + 10 - \sqrt{(z-6)^2 + 64}] / 2 \\ a = (y_g - \eta)^2 + G_{ov}^2 \cdot (\eta + 1) \\ c = 2 \cdot (y_g - \eta) - G_{ov}^2 \\ \tau = -\eta + \ln(a / G_{ov}^2) \\ y_0 = \sigma_1(a, c, \tau, \eta) \\ \Delta_0 = \exp(y_0) \\ p = 2 \cdot (y_g - y_0) + G_{ov}^2 \cdot (\Delta_0 - 1) \\ q = (y_g - y_0)^2 + G_{ov}^2 \cdot (y_0 - \Delta_0 + 1) \\ x_{ov} = \frac{2 \cdot q}{p + \sqrt{p^2 - 2 \cdot q \cdot (2 - G_{ov}^2 \cdot \Delta_0)}} \end{array} \\ \\ \left. \begin{array}{l} \text{if } |x_g| < x_{mrgov} \\ \\ \\ \\ \\ \\ \\ \\ \\ \end{array} \right\} \begin{array}{l} \{x_{ov} = x_g / \xi_{ov} \\ \\ \\ \\ \\ \\ \\ \\ \\ \end{array} \\ \\ \left. \begin{array}{l} \text{if } x_g > x_{mrgov} \\ \\ \\ \\ \\ \\ \\ \\ \\ \end{array} \right\} \begin{array}{l} \bar{x} = x_g / \xi_{ov} \cdot [1 + x_g \cdot (\xi_{ov} \cdot x_1 - x_{g1}) / x_{g1}^2] \\ w = 1 - \exp(-\bar{x}) \\ x_0 = x_g + G_{ov}^2 / 2 - G_{ov} \cdot \sqrt{x_g + G_{ov}^2 / 4 - w} \\ p = 2 \cdot (x_g - x_0) + G_{ov}^2 \cdot (1 + \Delta_0) \\ q = (x_g - x_0)^2 - G_{ov}^2 \cdot (x_0 + \Delta_0 - 1) \\ x_{ov} = x_0 + \frac{2 \cdot q}{p + \sqrt{p^2 - 2 \cdot q \cdot (2 - G_{ov}^2 \cdot \Delta_0)}} \end{array} \end{cases}$$

$$\Psi_{sov} = -\phi_T \cdot x_{ov} \left(-\frac{V_{GS}}{\phi_T} \right)$$

$$\Psi_{dov} = -\phi_T \cdot x_{ov} \left(\frac{V_{GS} - V_{DS}}{\phi_T} \right)$$

$$V_{ov0} = V_{GS} - \Psi_{sov}$$

$$V_{ovL} = V_{GS} - V_{DS} - \Psi_{dov}$$

Gate Current

The equations in this section are calculated when SWIGATE = 1.

Source/Drain Gate Overlap Current

The gate tunnelling currents in both gate/source and gate/drain overlap are given by:

$$I_{GOV}(V_{GX}, \Psi_{ov}, V_{ov}) = \begin{cases} V_{ov}^* = \sqrt{V_{ov}^2 + 10^{-6}} \\ \Psi_{tov} = \text{MINA}(0, V_{ov} + D_{ov}, 0.01) \\ z_g = \begin{cases} \text{MINA}\left(\frac{V_{ov}^*}{CHIB}, GC_Q, 10^{-6}\right) & \text{for } GC3 < 0 \\ \frac{V_{ov}^*}{CHIB} & \text{for } GC3 \geq 0 \end{cases} \\ \Delta_{Siov} = \exp\left(\frac{3.0 \cdot \phi_T + \Psi_{ov} + \Psi_{tov}}{\phi_T}\right) \\ F_{Sov} = \ln\left[\frac{1 + \Delta_{Siov}}{1 + \Delta_{Siov} \cdot \exp(-V_{GX}/\phi_T)}\right] \\ I_{GOV} = I_{GOV} \cdot F_{Sov} \cdot \exp\left(B_{ov} \cdot \left[-\frac{3}{2} + z_g \cdot (GC2 + GC3 \cdot z_g)\right]\right) \end{cases}$$

$$I_{GSov} = I_{GOV}(V_{GS}, \Psi_{sov}, V_{ov0})$$

$$I_{GDov} = I_{GOV}(V_{GS} - V_{DS}, \Psi_{dov}, V_{ovL})$$

Gate-Channel Current

$$V_m = V_{SB}^* + \phi_T^* \cdot \left[x_m - x_s - \ln\left(\frac{1 + \exp(V_{dse}/\phi_T^*)}{2}\right) \right]$$

$$\psi_T = \text{MINA}(0, V_{oxm} + D_{ch}, 0.01)$$

$$V_{oxm}^* = \sqrt{V_{oxm}^2 + 10^{-6}}$$

$$z_g = \begin{cases} \text{MINA}\left(\frac{V_{oxm}^*}{CHIB}, GC_Q, 10^{-6}\right) & \text{for } GC3 < 0 \\ \frac{V_{oxm}^*}{CHIB} & \text{for } GC3 \geq 0 \end{cases}$$

$$\Delta_{Si} = \exp\left(x_m - \frac{\alpha_b + V_m - \psi_T}{\phi_T^*}\right)$$

$$F_S = \ln \left[\frac{1 + \Delta_{Si}}{1 + \Delta_{Si} \cdot \exp\left(-\frac{V_{HS} + V_{SB} - V_m}{\phi_T^*}\right)} \right]$$

$$I_{GCO} = I_{GINV} \cdot F_S \cdot \exp\left(B \cdot \left[-\frac{3}{2} + z_g \cdot (GC2 + GC3 \cdot z_g)\right]\right)$$

$$\text{if } x_g > 0 \left\{ \begin{array}{l} u_0 = CHIB / [B \cdot (GC2 + 2 \cdot GC3 \cdot z_g)] \\ x = \Delta\psi / (2 \cdot u_0) \\ b = u_0 / H \\ B_b = b \cdot (1 - b) / 2 \\ A_g = 1/2 - 3 \cdot B_g \\ p_{gc} = (1 - b) \cdot \frac{\sinh(x)}{x} + b \cdot \cosh(x) \\ p_{gd} = \frac{p_{gc}}{2} - B_g \cdot \sinh(x) - A_g \cdot \frac{\sinh(x)}{x} \cdot \left[\coth(x) - \frac{1}{x} \right] \end{array} \right.$$

$$\text{if } x_g \leq 0 \quad \begin{cases} p_{gc} = 1 \\ p_{gd} = 1/2 \end{cases}$$

$$M S_g = \frac{1}{2} \cdot \left(1 + \frac{x_g}{\sqrt{x_g^2 + 10^{-6}}} \right)$$

$$I_{GC} = I_{GCO} \cdot p_{gc} \cdot S_g$$

$$I_{GCD} = I_{GCO} \cdot p_{gd} \cdot S_g$$

$$I_{GSD} = I_{GC} - I_{GCD}$$

$$I_{GB} = I_{GCO} \cdot p_{gc} \cdot (1 - S_g)$$

Gate-Induced Drain/Source Leakage Current

The equations in this section are calculated when SWGIDL = 1.

$$I_{gixl}(V_{ov}, V) = \begin{cases} \begin{cases} V_{tov} = \sqrt{V_{ov}^2 + CGIDL^2 \cdot V^2 + 10^{-6}} \\ t = V \cdot V_{tov} \cdot V_{ov} \end{cases} \\ I_{gixl} = \begin{cases} -A_{GIDL} \cdot t \cdot \exp\left(-\frac{B_{GIDL}}{V_{tov}}\right) & \text{for } V_{ov} > 0 \\ 0 & \text{for } V_{ov} \geq 0 \end{cases} \end{cases}$$

$$I_{gisl} = I_{gixl}(V_{ov0}, V_{SB})$$

$$I_{gidl} = I_{gixl}(V_{ovl}, V_{DS} + V_{SB})$$

Total Terminal Currents

$$I_D = I_{DS} + I_{avl} - I_{GDOV} - I_{GCD} + I_{gidl}$$

$$I_S = -I_{DS} - I_{GSov} - I_{GCS} + I_{gisl}$$

$$I_G = I_{GC} + I_{GB} + I_{GDov} + I_{GSov}$$

$$I_B = -I_{avl} - I_{GB} - I_{gidl} - I_{gisl}$$

Quantum-Mechanical Corrections

$$q_{eff} = \begin{cases} V_{oxm} & \text{for } x_g \leq 0 \\ q_{bm} + \eta_{\mu} \cdot q_m & \text{for } x_g > 0 \end{cases}$$

$$C_{OX}^{qm} = \begin{cases} COX & \text{for } q_q = \\ \frac{COX}{1 + q_q / (q_{eff}^2 + q_{lim}^2)^{1/6}} & \text{for } q_q > 0 \end{cases}$$

Intrinsic Charge Model

$$\text{if } x_g > 0 \quad \left\{ \begin{array}{l} F_1 = \Delta\psi / (2 \cdot H) \\ q\Delta L = (1 - G_{\Delta L}) \cdot (q_{im} - \alpha_{am} \cdot \Delta\psi / 2) \\ q^*_{\Delta L} = q\Delta L \cdot (1 + G_{\Delta L}) \\ Q_G^{(i)} = C_{OX}^{qm} \cdot \left[V_{oxm} + \frac{\eta_p \cdot \Delta\psi}{2} \cdot \left(\frac{G_{\Delta L}}{3} \cdot F_j + G_{\Delta L} - 1 \right) \right] \\ Q_I^{(i)} = -C_{OX}^{qm} \cdot \left[G_{\Delta L} \cdot \left(q_{im} + \frac{\alpha \cdot \Delta\psi}{6} \cdot F_j \right) + q\Delta L \right] \\ Q_D^{(i)} = \frac{C_{OX}^{qm}}{2} \cdot \left[G_{\Delta L}^2 \cdot \left(q_{im} + \frac{\alpha \cdot \Delta\psi}{6} \cdot \left[\frac{F_j^2}{5} + F_j - 1 \right] \right) + q^*_{\Delta L} \right] \end{array} \right.$$

$$\text{if } x_g \leq 0 \quad \left\{ \begin{array}{l} Q_G^{(i)} = C_{OX}^{qm} \cdot V_{oxm} \\ Q_I^{(i)} = 0 \\ Q_D^{(i)} = 0 \end{array} \right.$$

$$Q_S^{(i)} = Q_I^{(i)} - Q_D^{(i)}$$

$$Q_B^{(i)} = Q_I^{(i)} - Q_G^{(i)}$$

Extrinsic Charge Model

The charges of the source and drain overlap regions

$$Q_{sov} = CGOV \cdot (V_{GS} - \Psi_{sov})$$

$$Q_{dov} = CGOV \cdot (V_{GS} - V_{DS} - \Psi_{dov})$$

The charge of the bulk overlap region

$$Q_{bov} = CGBOV \cdot (V_{GS} - V_{SB})$$

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Inner fringe charge correction

$$\Delta Q_S = IFK \cdot (1 + IFC \cdot V^*_{SB}) \cdot \sqrt{\text{MAXA}(IFVBI + V^*_{SB} - \psi_{ss}, 0, 10^{-3})}$$

$$\Delta Q_D = IFK \cdot (1 + IFC \cdot V^*_{DB}) \cdot \sqrt{\text{MAXA}(IFVBI + V^*_{DB} - \psi_{sd}, 0, 10^{-3})}$$

$$\Delta Q_G = -\Delta Q_S - \Delta Q_D$$

Outer fringe charge

$$Q_{ofs} = CFR \cdot V_{GS}$$

$$Q_{ofd} = CFR \cdot (V_{GS} - V_{DS})$$

Total Terminal Charges

$$Q_G = Q_G^{(i)} + Q_{sov} + Q_{dov} + \Delta Q_G + Q_{ofs} + Q_{ofd} + Q_{bov}$$

$$Q_S = Q_S^{(i)} - Q_{sov} + \Delta Q_S - Q_{ofs}$$

$$Q_D = Q_D^{(i)} - Q_{dov} + \Delta Q_D - Q_{ofd}$$

$$Q_B = Q_B^{(i)} - Q_{bov}$$

Noise Model

The equations in this section are only calculated for $x_{g_j} > 0$. In these equations f_{op} represents the operation frequency of the transistor and $j = -1^{1/2}$.

$$N^* = \frac{C_{ox}}{q} \cdot \alpha_m \cdot \phi_T$$

$$N_m^* = \frac{C_{ox}}{q} \cdot q_m^*$$

$$\Delta N = \frac{C_{ox}}{q} \cdot \alpha_m \cdot \Delta \Psi$$

$$S_{fl} = \frac{q \cdot \phi_T^2 \cdot \beta \cdot I_{DS}}{f_{op} \cdot C_{ox} \cdot G_{vsat} \cdot N^*} \cdot \left[(NFA - NFB \cdot N^* + NFC \cdot N^{*2}) \cdot \ln \left(\frac{N_m^* + \Delta N/2}{N_m^* - \Delta N/2} \right) + (NFB + NFC \cdot N_m^* - 2 \cdot N^*) \cdot \Delta N \right]$$

$$H_0 = \frac{q_{im}^*}{\alpha_m}$$

$$t_1 = \frac{q_{im}}{q_{im}^*}$$

$$t_2 = \left(\frac{\Delta \Psi}{2 \cdot H_0} \right)^2$$

$$R = \frac{H_0}{H} - 1$$

$$l_c = 1 - 12 \cdot t_2 \cdot R$$

$$g_{ideal} = \frac{\beta \cdot q_{im}^*}{G_{vsat}} \cdot F_{\Delta L}$$

$$C_{Geff} = \left(\frac{G_{vsat}}{G_{mob} \cdot G_{\Delta L}} \right)^2 \cdot COX \cdot \eta_p$$

$$m_{id} = \frac{g_{ideal}}{l_c^2} \cdot [t_1 + 12 \cdot t_2 - 24 \cdot (1 + t_1) \cdot t_2 \cdot R]$$

$$S_{th} = N_T \cdot m_{id}$$

$$m_{ig} = \frac{1}{l_c^2 \cdot g_{ideal}} \cdot \left[\frac{t_1}{12} - t_2 \cdot \left(t_1 + \frac{1}{5} - 12 \cdot t_2 \right) - \frac{8}{5} \cdot t_2 \cdot (t_1 + 1 - 12 \cdot t_2) \cdot R \right]$$

$$S_{ig} = N_T \cdot \frac{(2 \cdot \pi \cdot f_{op} \cdot C_{Geff})^2 \cdot m_{ig}}{1 + (2 \cdot \pi \cdot f_{op} \cdot C_{Geff} \cdot m_{ig})^2}$$

$$m_{igid} = \frac{\sqrt{t_2}}{I_c^2} \cdot \left[1 - 12 \cdot t_2 - \left(t_1 + \frac{96}{5} \cdot t_2 - 12 \cdot t_1 \cdot t_2 \right) \cdot R \right]$$

$$S_{igth} = N_T \cdot \frac{2 \cdot \pi \cdot j \cdot f_{op} \cdot C_{Geff} \cdot m_{igid}}{1 + 2 \cdot \pi \cdot j \cdot f_{op} \cdot C_{Geff} \cdot m_{ig}}$$

Gate Current Shot Noise

$$S_{hotgs} = 2 \cdot q \cdot I_{js}$$

$$S_{hotgd} = 2 \cdot q \cdot (I_{GCD} + I_{GDov})$$

Avalanche Current Shot Noise

$$S_{jnoise} = 2 \cdot q \cdot (1 + M_{avl}) \cdot I_{avl}$$

$$D_{jnoise} = 2 \cdot q \cdot (1 + M_{avl}) \cdot I_{avl} + I_{jd}$$

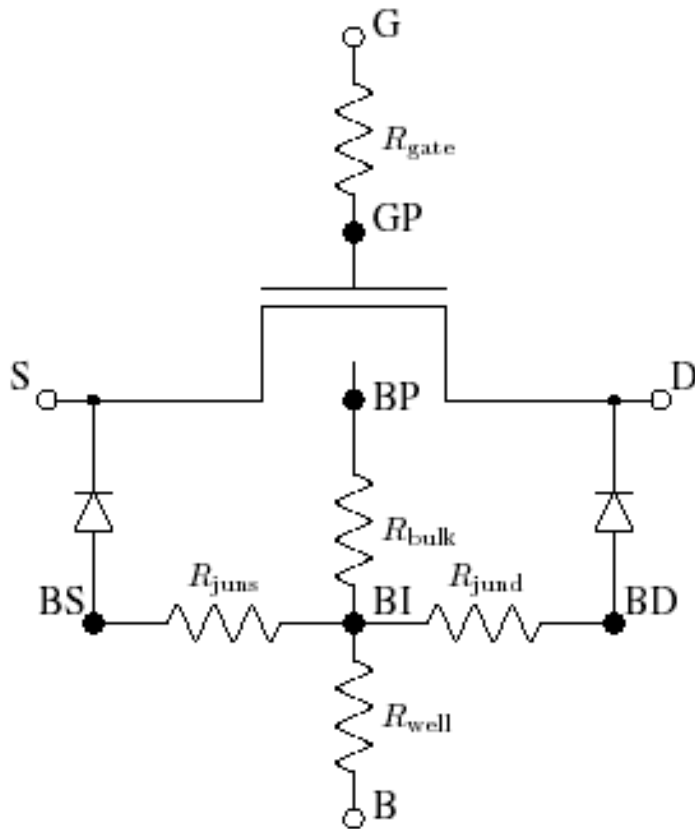
Non-Quasi-Static (NQS) RF Model

For high-frequency modeling and fast transient simulations, a special version of the PSP model is available, which enables the simulation of non-quasi-static (NQS) effects, and includes several parasitic resistances.

$$\begin{cases} \frac{dQ_1}{dt} = f_1(Q_1, \dots, Q_N) \\ \frac{dQ_N}{dt} = f_N(Q_1, \dots, Q_N) \end{cases}$$

Q_i is the charge density at the i -th collocation point and f_i are functions, which contain the complete PSP-charge model.

Parasitics Circuit



$$S_{R_G} = 4 \cdot k_B \cdot T_{KD} \cdot R_{gate}$$

$$S_{R_{BULK}} = 4 \cdot k_B \cdot T_{KD} \cdot R_{bulk}$$

$$S_{R_{WELL}} = 4 \cdot k_B \cdot T_{KD} \cdot R_{well}$$

$$S_{R_{JUNS}} = 4 \cdot k_B \cdot T_{KD} \cdot R_{juns}$$

$$S_{R_{JUND}} = 4 \cdot k_B \cdot T_{KD} \cdot R_{jund}$$

Additional NQS and RF Parameters

The PSP-NQS model has a few additional parameters, which are described in the tables below. The allowed values for the parameter SWNQS are 0, 1, 2, 3, 5, and 9. If SWNQS = 0, then NQS effects are switched off, i.e. the intrinsic MOS model is identical to the standard PSP-model (however, the parasitics-circuit is still in place). If SWNQS is nonzero, it indicates the number of collocation points to be used in the NQS-calculations. A higher value increases the accuracy, but leads to an increased computational burden.

Additional Parameters for Global NQS Model

Name	Unit	Default	Min	Max	Description
SWNQS	–	0	0	9	Switch for NQS effects / number of collocation points
MUNQSO	–	1	–	–	Relative mobility for NQS modeling
RGO	–	10 ⁻³	–	–	Gate resistance R _{gate}
RBULKO	–	10 ⁻³	–	–	Bulk resistance R _{bulk}
RWELLO	–	10 ⁻³	–	–	Well resistance R _{well}
RJUNSO	–	10 ⁻³	–	–	Source-side bulk resistance R _{juns}
RJUNDO	–	10 ⁻³	–	–	Drain-side bulk resistance R _{jund}

Geometrical Scaling Rules

Although the parasitic resistances are (in general) dependent on geometry, the actual form of this dependency is be strongly influenced by the device layout. For this reason, L and W dependence of these resistances is currently not included in PSP; the correct values must be supplied manually for each geometry.

The following (trivial) scaling-rules are included for the NQS-model.

$$MUNQS = MUNQSO$$

$$RG = RGO$$

$$RBULK = RBULKO$$

$$RWELL = RWELLO$$

$RJUNS = RJUNSO$

$RJUND = RJUNDO$

Equations

In this section, y denotes the (normalized) position along the channel ($y = 0$ is source side, $y = 1$ is drain side), while x denotes the surface potential (normalized to ϕ^*T) at a certain position.

In PSP 101.0 and before, only $SWNQS=0,1,2,3,5,9$ are allowed.

$$n = SWNQS + 1$$

$$h = 1/n$$

Initial Values

$$A_{i,j} = 0 \quad \text{for } 0 \leq i, j \leq n$$

$$v_i = 0 \quad \text{for } 0 \leq i \leq n$$

First Loop

$$\left. \begin{aligned} p &= 2 + v_{i-1}/2 \\ v_i &= -1/(2 \cdot p) \\ A_{i,i-1} &= 1/h \\ A_{i,i} &= -2/h \\ A_{i,i+1} &= 1/h \\ A_{i,j} &= \frac{1}{p} \cdot (3 \cdot A_{i,j}/h - A_{i-1,j}/2) \end{aligned} \right\} \begin{array}{l} \text{for } i = 1 \dots (n-1) \\ \text{for } j = 0 \dots n \end{array}$$

Second Loop (Back Substitution)

$$A_{i,j} = v_i \cdot A_{i+1,j} + A_{i,j} \quad \text{for } j = 0 \dots n \quad \text{for } i = (n-1) \dots 0$$

Position Independent Quantities

$$\text{If } x_g > 0 \left\{ \begin{array}{l} y_m = \frac{1}{2} \cdot \left(1 + \frac{\Delta\Psi}{4 \cdot H} \right) \\ p_d = \frac{x_{gm}}{x_g - x_m} \\ G_p = G/p_d \end{array} \right.$$

$$\text{If } x_g \leq 0 \left\{ \begin{array}{l} y_m = \frac{1}{2} \\ p_d = 1 \\ G_p = G/p_d \end{array} \right.$$

$$a_p = 1 + G_p / \sqrt{2}$$

$$p_{mrg} = 10^{-5} \cdot a_p$$

Position Dependent Surface Potential and Charge

Interpolated (quasi-static) surface potential along the channel:

$$\Psi(y) = x_m + \frac{H}{\phi_T} \cdot \left(1 - \sqrt{1 - \frac{2 \cdot \Delta\Psi}{H} \cdot (y - y_m)} \right)$$

Normalized bulk-charge and its first two derivatives as functions of surface potential:

$$q_b(x) = -\text{sgn}(x) \cdot G_p \cdot \sqrt{\exp(-x) + x - 1}$$

$$q'_b(x) = \frac{G_p^2 \cdot [1 - \exp(-x)]}{2 \cdot q_b(x)}$$

$$q''_b(x) = q'_b(x) - \frac{q'_b(x)^2 - G_p^2/2}{q_b(x)}$$

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$$II(x_g) = \begin{cases}
 \begin{aligned}
 & \text{if } x_g < -p_{mrg} \\
 & \left\{ \begin{aligned}
 & y_g = -x_g \\
 & z = 1.25 \cdot y_g / a_p \\
 & \eta = [z + 10 - \sqrt{(z-6)^2 + 64}] / 2 \\
 & a = (y_g - \eta)^2 + G_p^2 \cdot (\eta + 1) \\
 & c = 2 \cdot (y_g - \eta) - G_p^2 \\
 & r = -\eta + \ln(a / G_p^2) \\
 & y_0 = \sigma_1(a, c, r, \eta) \\
 & \Delta_0 = \exp(y_0) \\
 & \xi = 1 - G_p^2 \cdot \Delta_0 / 2 \\
 & p = 2 \cdot (y_g - y_0) + G_p^2 \cdot (\Delta_0 - 1) \\
 & q = (y_g - y_0)^2 + G_p^2 \cdot (y_0 - \Delta_0 + 1) \\
 & II = -y_0 - \frac{2 \cdot q}{p + \sqrt{p^2 - 4 \cdot q \cdot \xi}}
 \end{aligned}
 \right. \\
 \\
 & \text{if } |x_g| \leq -p_{mrg} \\
 & \left\{ II = \frac{x_g}{a_p} \right. \\
 \\
 & \text{if } x_g > x_{mrg} \\
 & \left\{ \begin{aligned}
 & \hat{x}_{g1} = x_1 + G \cdot \sqrt{\exp(-x_1) + x_1 - 1} \\
 & \bar{x} = \frac{x_g}{a_p} \cdot [1 + x_g \cdot (x_g + a_p / \hat{x}_{g1} - 1) / \hat{x}_{g1}] \\
 & x_0 = x_g + G_p^2 / 2 - G_p \cdot \sqrt{x_g + G_p^2 / 4 - 1 + \exp(-\bar{x})} \\
 & \Delta_0 = \exp(-x_0) \\
 & \xi = 1 - G_p^2 \cdot \Delta_0 / 2 \\
 & p = 2 \cdot (x_g - x_0) + G_p^2 \cdot (1 - \Delta_0) \\
 & q = (x_g - x_0)^2 - G_p^2 \cdot (x_0 + \Delta_0 - 1) \\
 & II = x_0 + \frac{2 \cdot q}{p + \sqrt{p^2 - 4 \cdot q \cdot \xi}}
 \end{aligned}
 \right.
 \end{aligned}
 \end{cases}$$

$$X(x_g, q_{inv}) = II(x_g + q_{inv} / p_d)$$

Auxiliary Functions

$$q(x) = -p_d \cdot (x_g - x) - q_b(x)$$

$$\psi(q, q_{x1}) = \frac{q}{q_{x1}} - 1$$

$$\phi(q, q_{x1}, q_{x2}) = \left(1 - \frac{q \cdot q_{x2}}{q_{x1}^2}\right) / q_{x1}$$

Normalized right-hand-side of continuity equation

$$f(x_g, q, q', q'') = \left\{ \begin{array}{l} x_z = X(x_g, q) \\ q_{x1} = \frac{\partial q}{\partial x}(x_z) = p_d - q'_b(x_z) \\ q_{x2} = \frac{\partial^2 q}{\partial x^2}(x_z) = q''_b(x_z) \\ f_0 = \psi(q, q_{z1}) \cdot q'' + \phi(q, q_{z1}, q_{z2}) \cdot q'^2 \\ x_{y1} = \frac{\partial x_z}{\partial y} = (q') / q_{x1} \\ z_{sat} = \frac{(\theta_{sat}^* \cdot \phi_T^* \cdot x_{y1})^2}{1 + \theta_{sat}^* \cdot \Delta\psi} \\ \zeta = \sqrt{1 + 2 \cdot z_{sat}} \\ F_{vsat} = 2 / (1 + \zeta) \\ f = F_{vsat} \cdot \left[f_0 - F_{vsat} \cdot \frac{z_{sat}}{\zeta} \cdot \psi(q, q_{x1}) \cdot (q'' + x_{y1}^2 \cdot q''_b(x_z)) \right] \end{array} \right.$$

$$T_{norm} = \frac{MUNQS \cdot \phi_T^* \cdot \beta}{C_{OX}^{gm} \cdot G_{mob} \cdot G_{\Delta L}}$$

Cubic Spline Interpolation

$$q''_0 = 0$$

$$q''_n = 0$$

$$q''_i = \sum_{j=0}^n A_{i,j} \cdot q_j \quad \text{for } 1 \leq i \leq n-1$$

$$q'_i = \frac{q_{i+1} - q_i}{h} - \frac{h}{6} \cdot (2 \cdot q''_i + q''_{i+1}) \quad \text{for } 1 \leq i \leq n-1$$

Continuity Equation

$$x_{i,0} = \psi(i \cdot h)$$

$$q_{i,0} = q(x_{i,0})$$

Note that $x_{0,0} = x_s$ and $x_{n,0} = x_d$. Also, these values coincide with those in the quasi-static part of PSP.

The core of the NQS-model is the solution of $q(y, t)$ from the charge continuity equation along the channel. By approximating the y -dependence by a cubic spline through a number of collocation points, the problem is reduced to solving the $q_i(t)$ from the following set of coupled differential equations.

$$\begin{cases} \frac{\partial q_i}{\partial t}(t) + T_{norm} \cdot f\left(x_g, q_i(t), \frac{\partial q_i}{\partial y}(t), \frac{\partial^2 q_i}{\partial y^2}(t)\right) = 0 \\ q_i(0) = q_{i,0} \end{cases} \quad \text{for } 1 \leq i \leq n$$

Note that the boundary points $q_0(t) = q(x_s) = q_{is}$ and $q_n(t) = q(x_d) = q_{id}$ remain fixed to their quasi-static values; they are not solved from the equation above.

Non-Quasi-State Terminal Charges

$$S_0 = \sum_{i=1}^{n-1} q_i$$

$$S_2 = \sum_{i=1}^{n-1} q''_i$$

$$q_I^{NQS} = \int_0^1 q(y) dy = h \cdot S_0 + \frac{h}{2} \cdot (u_0 + u_n) - \frac{h^3}{12} \cdot S_2$$

$$U_0 = \sum_{i=1}^{n-1} i \cdot q_i$$

$$U_2 = \sum_{i=1}^{n-1} i \cdot q''_i$$

$$q_D^{NQS} = \int_0^1 q(y) dy = h^2 \cdot U_0 + \frac{h^2}{6} \cdot [q_0 + (3n-1)u_n] - \frac{h^4}{12} \cdot U_2$$

$$q_S^{NQS} = q_I^{NQS} - q_D^{NQS}$$

Currently, only SWNQS = 0; 1; 2; 3; 5; 9 are allowed. For odd values of SWNQS, the gate charge is integrated along the channel using Simpson's rule. If SWNQS = 2, Simpson's 3=8-rule is used.

- If SWNQS is odd (that is, n is even),

$$q_G^{NQS} = pd \cdot \left[x_g - \frac{h}{3} \cdot \left(X(x_g, q_0) + 4 \cdot \sum_{i=1}^{n/2} X(x_g, q_{2i-1}) + 2 \cdot \sum_{i=1}^{n/2-1} X(x_g, q_{2i}) + X(x_g, q_n) \right) \right]$$

- If SWNQS =2 (that is, n=3),

$$q_G^{NQS} = pd \cdot \left[x_g - \frac{3 \cdot h}{8} \cdot (X(x_g, q_0) + 3 \cdot X(x_g, q_1) + 3 \cdot X(x_g, q_2) + X(x_g, q_3)) \right]$$

Converting back to conventional units:

$$Q_S^{NQS} = C_{OX}^{qm} \cdot \phi_T^* \cdot q_S^{NQS}$$

$$Q_D^{NQS} = C_{OX}^{qm} \cdot \phi_T^* \cdot q_D^{NQS}$$

$$Q_G^{NQS} = C_{OX}^{qm} \cdot \phi_T^* \cdot q_G^{NQS}$$

$$Q_B^{NQS} = -(Q_S^{NQS} + Q_D^{NQS} + Q_G^{NQS})$$

Component Statements

PSP MOSFET Model (psp102)

This is SiMKit 3.1.2

This device is supported within altergroups.

This device is dynamically loaded from the shared object /vobs/spectre_dev/tools.lnx86/cmi/lib/5.0/libphilips_sh.so

Instance Definition

```
InstanceName (d g s b) PSP102ModelName <parameter=value> ...
```

Instance Parameters

- | | | |
|---|------------------------|--|
| 1 | <code>l=10e-6 m</code> | Design length. |
| 2 | <code>w=10e-6 m</code> | Design width. |
| 3 | <code>sa=0.0 m</code> | Distance between OD-edge and poly from one side. |
| 4 | <code>sb=0.0 m</code> | Distance between OD-edge and poly from other side. |
| 5 | <code>sd=0.0 m</code> | Distance between neighboring fingers. |

Virtuoso Simulator Components and Device Models Reference

PSP102 Model

6	<code>sca=0.0</code>	Integral of the first distribution function for scattered well dopants.
7	<code>scb=0.0</code>	Integral of the second distribution function for scattered well dopants.
8	<code>scc=0.0</code>	Integral of the third distribution function for scattered well dopants.
9	<code>sc=0.0 m</code>	Distance between OD-edge and nearest well edge.
10	<code>delvto=0.0 V</code>	Threshold voltage shift parameter.
11	<code>factuo=1.0</code>	Zero-field mobility pre-factor.
12	<code>absource=1E-12 m²</code>	Bottom area of source junction.
13	<code>lssource=1E-6 m</code>	STI-edge length of source junction.
14	<code>lgsource=1E-6 m</code>	Gate-edge length of source junction.
15	<code>abdRAIN=1E-12 m²</code>	Bottom area of drain junction.
16	<code>lsdRAIN=1E-6 m</code>	STI-edge length of drain junction.
17	<code>lgdRAIN=1E-6 m</code>	Gate-edge length of drain junction.
18	<code>as=1E-12 m²</code>	Bottom area of source junction.
19	<code>ps=1E-6 m</code>	Perimeter of source junction.
20	<code>ad=1E-12 m²</code>	Bottom area of drain junction.
21	<code>pd=1E-6 m</code>	Perimeter of drain junction.
22	<code>mulid0=1</code>	Ids multiplier.
23	<code>jw=1E-6 m</code>	Gate-edge length of source/drain junction.
24	<code>mult=1.0</code>	Number of devices in parallel.
25	<code>nf=1.0</code>	Number of fingers.

Virtuoso Simulator Components and Device Models Reference

PSP102 Model

26	<code>ngcon=1.0</code>	Number of gate contacts.
27	<code>xgw=1.0E-7 m</code>	Distance from the gate contact to the channel edge.
28	<code>region=triode</code>	Estimated operating region. %Z outputs the number (0-4) in a rawfile. Possible values are <code>off</code> , <code>triode</code> , <code>sat</code> , <code>subth</code> , and <code>breakdown</code> .
29	<code>trise=0.0 K</code>	Temperature rise from ambient.
30	<code>m=1.0</code>	Multiplicity factor.
31	<code>isnoisy=yes</code>	Should device generate noise. Possible values are <code>no</code> and <code>yes</code> .

Model Definition

model modelName psp102 parameter=value ...

Model Parameters

1	<code>level=102</code>	Model level.
2	<code>type=n</code>	Channel type parameter, n,NMOS p,PMOS. Possible values are <code>n</code> and <code>p</code> .
3	<code>tr=value of tnom C</code>	nominal (reference) temperature.
4	<code>swnqs=0</code>	Flag for NQS, 0,off, 1, 2, 3, 5, or 9,number of collocation points.
5	<code>swigate=0</code>	Flag for gate current, 0,turn off IG.
6	<code>swimpact=0</code>	Flag for impact ionization current, 0,turn off II.
7	<code>swgidl=0</code>	Flag for GIDL current, 0,turn off IGIDL.
8	<code>swjuncap=0</code>	Flag for juncap, 0,turn off juncap.
9	<code>swjunasym=0</code>	Flag for asymmetric junctions; 0,symmetric, 1,asymmetric.
10	<code>qmc=1.0</code>	Quantum-mechanical correction factor.

Virtuoso Simulator Components and Device Models Reference

PSP102 Model

11	<code>version=102.32</code>	The available versions are 102.2, 102.21, 102.3, 102.32, 102.33, 102.34 and 102.40.
12	<code>geomod=1</code>	1 for geometrical model and 0 for electrical model.
13	<code>binmod=0</code>	1 for bin model and 0 for non-bin model.
14	<code>scalelev=102</code>	102 for local, 1020 for global model and 1021 for bin model.
15	<code>compatible=spectre</code>	for compatible. Possible values are <code>spectre</code> , <code>spice2</code> , <code>spice3</code> , <code>cdsspice</code> , <code>hspice</code> , <code>spiceplus</code> , <code>eldo</code> , <code>sspice</code> , and <code>mica</code> .
16	<code>vfb=(-1.0) V</code>	Flatband voltage at TR.
17	<code>stvfb=5.0e-4 V/K</code>	Temperature dependence of VFB.
18	<code>tox=2.0e-09 m</code>	Gate oxide thickness.
19	<code>epsrox=3.9</code>	Relative permittivity of gate dielectric.
20	<code>neff=5.0e+23 m⁻³</code>	Effective substrate doping.
21	<code>vnsb=0.0 V</code>	Effective doping bias-dependence parameter.
22	<code>nslp=0.05 V</code>	Effective doping bias-dependence parameter.
23	<code>dnsub=0.0 V⁻¹</code>	Effective doping bias-dependence parameter.
24	<code>dphib=0.0 V</code>	Offset parameter for PHIB.
25	<code>np=1.0e+26 m⁻³</code>	Gate poly-silicon doping.
26	<code>ct=0.0</code>	Interface states factor.
27	<code>toxov=2.0e-09 m</code>	Overlap oxide thickness.
28	<code>toxovd=2.0e-09 m</code>	Overlap oxide thickness for drain side.
29	<code>nov=5.0e+25 m⁻³</code>	Effective doping of overlap region.
30	<code>novd=5.0e+25 m⁻³</code>	Effective doping of overlap region for drain side.

Virtuoso Simulator Components and Device Models Reference

PSP102 Model

31	$cf=0.0$	DIBL-parameter.
32	$cfb=0.0 \text{ V}^{-1}$	Back bias dependence of CF.
33	$betn=7e-2 \text{ m}^2/\text{V}/\text{s}$	Channel aspect ratio times zero-field mobility.
34	$stbet=1.0$	Temperature dependence of BETN.
35	$mue=0.5 \text{ m}/\text{V}$	Mobility reduction coefficient at TR.
36	$stmue=0.0$	Temperature dependence of MUE.
37	$themu=1.5$	Mobility reduction exponent at TR.
38	$stthemu=1.5$	Temperature dependence of THEMU.
39	$cs=0.0$	Coulomb scattering parameter at TR.
40	$stcs=0.0$	Temperature dependence of CS.
41	$xcor=0.0 \text{ V}^{-1}$	Non-universality factor.
42	$stxcor=0.0$	Temperature dependence of XCOR.
43	$feta=1.0$	Effective field parameter.
44	$rs=30 \text{ } \Omega$	Series resistance at TR.
45	$strs=1.0$	Temperature dependence of RS.
46	$rsb=0.0 \text{ V}^{-1}$	Back-bias dependence of series resistance.
47	$rsg=0.0 \text{ V}^{-1}$	Gate-bias dependence of series resistance.
48	$thesat=1.0 \text{ V}^{-1}$	Velocity saturation parameter at TR.
49	$stthesat=1.0$	Temperature dependence of THESAT.
50	$thesatb=0.0 \text{ V}^{-1}$	Back-bias dependence of velocity saturation.
51	$thesatg=0.0 \text{ V}^{-1}$	Gate-bias dependence of velocity saturation.
52	$ax=3.0$	Linear/saturation transition factor.

Virtuoso Simulator Components and Device Models Reference

PSP102 Model

53	<code>alp=0.01</code>	CLM pre-factor.
54	<code>alp1=0.00 V</code>	CLM enhancement factor above threshold.
55	<code>alp2=0.00 V⁻¹</code>	CLM enhancement factor below threshold.
56	<code>vp=0.05 V</code>	CLM logarithm dependence factor.
57	<code>a1=1.0</code>	Impact-ionization pre-factor.
58	<code>a2=10.0 V</code>	Impact-ionization exponent at TR.
59	<code>sta2=0.0 V</code>	Temperature dependence of A2.
60	<code>a3=1.0</code>	Saturation-voltage dependence of impact-ionization.
61	<code>a4=0.0 V^{-0.5}</code>	Back-bias dependence of impact-ionization.
62	<code>gco=0.0</code>	Gate tunnelling energy adjustment.
63	<code>iginv=0.0 A</code>	Gate channel current pre-factor.
64	<code>igov=0.0 A</code>	Gate overlap current pre-factor.
65	<code>igovd=0.0 A</code>	Gate overlap current pre-factor for drain side.
66	<code>stig=2.0</code>	Temperature dependence of IGINV and IGOV.
67	<code>gc2=0.375</code>	Gate current slope factor.
68	<code>gc3=0.063</code>	Gate current curvature factor.
69	<code>chib=3.1 V</code>	Tunnelling barrier height.
70	<code>agidl=0.0 A/V³</code>	GIDL pre-factor.
71	<code>agidld=0.0 A/V³</code>	GIDL pre-factor for drain side.
72	<code>bgidl=41.0 V</code>	GIDL probability factor at TR.
73	<code>bgidld=41.0 V</code>	GIDL probability factor at TR for drain side.
74	<code>stbgidl=0.0 V/K</code>	Temperature dependence of BGIDL.

Virtuoso Simulator Components and Device Models Reference

PSP102 Model

75	<code>stbgidl=0.0</code>	V/K	Temperature dependence of BGIDL for drain side.
76	<code>cgidl=0.0</code>		Back-bias dependence of GIDL.
77	<code>cgidld=0.0</code>		Back-bias dependence of GIDL for drain side.
78	<code>cox=1.0e-14</code>	F	Oxide capacitance for intrinsic channel.
79	<code>cgov=1.0e-15</code>	F	Oxide capacitance for gate-drain/source overlap.
80	<code>cgovd=1.0e-15</code>	F	Oxide capacitance for gate-drain overlap.
81	<code>cgbov=0.0</code>	F	Oxide capacitance for gate-bulk overlap.
82	<code>cfr=0.0</code>	F	Outer fringe capacitance.
83	<code>cfrd=0.0</code>	F	Outer fringe capacitance for drain side.
84	<code>fnt=1.0</code>		Thermal noise coefficient.
85	<code>nfa=8.0e+22</code>	V^{-1}/m^4	First coefficient of flicker noise.
86	<code>nfb=3.0e+07</code>	V^{-1}/m^2	Second coefficient of flicker noise.
87	<code>nfc=0.0</code>	V^{-1}	Third coefficient of flicker noise.
88	<code>ef=1.0</code>		Flicker noise frequency exponent.
89	<code>munqs=1.0</code>		Relative mobility for NQS modeling.
90	<code>rg=0.0</code>	Ω	Gate resistance.
91	<code>rbulk=0.0</code>	Ω	Bulk resistance between node BP and BI.
92	<code>rwell=0.0</code>	Ω	Well resistance between node BI and B.
93	<code>rjuns=0.0</code>	Ω	Source-side bulk resistance between node BI and BS.
94	<code>rjund=0.0</code>	Ω	Drain-side bulk resistance between node BI and BD.

Virtuoso Simulator Components and Device Models Reference

PSP102 Model

95	$lvaro=0.0$ m	Geom. independent difference between actual and programmed gate length.
96	$lvarl=0.0$	Length dependence of LVAR.
97	$lvarw=0.0$	Width dependence of LVAR.
98	$lap=0.0$ m	Effective channel length reduction per side.
99	$wvaro=0.0$ m	Geom. independent difference between actual and programmed field-oxide opening.
100	$wvarl=0.0$	Length dependence of WVAR.
101	$wvarw=0.0$	Width dependence of WVAR.
102	$wot=0.0$ m	Effective channel width reduction per side.
103	$dlq=0.0$ m	Effective channel length reduction for CV.
104	$dwq=0.0$ m	Effective channel width reduction for CV.
105	$vfbo=(-1.0)$ V	Geometry-independent flat-band voltage at TR.
106	$vfbl=0.0$	Length dependence of flat-band voltage.
107	$vfbw=0.0$	Width dependence of flat-band voltage.
108	$vfblw=0.0$	Area dependence of flat-band voltage.
109	$stvfbo=5e-4$ V/K	Geometry-independent temperature dependence of VFB.
110	$stvfbl=0.0$	Length dependence of temperature dependence of VFB.
111	$stvfbw=0.0$	Width dependence of temperature dependence of VFB.
112	$stvfblw=0.0$	Area dependence of temperature dependence of VFB.
113	$tox=2e-9$ m	Gate oxide thickness.
114	$epsrox=3.9$	Relative permittivity of gate dielectric.
115	$nsub=3e23$ m ⁻³	Geometry independent substrate doping.

Virtuoso Simulator Components and Device Models Reference

PSP102 Model

116	$n_{subw}=0.0$	Width dependence of background doping NSUBO due to segregation.
117	$w_{seg}=1e-8$ m	Char. length of segregation of background doping NSUBO.
118	$n_{pck}=1e24$ m ⁻³	Pocket doping level.
119	$n_{pckw}=0.0$	Width dependence of pocket doping NPCK due to segregation.
120	$w_{segp}=1e-8$ m	Char. length of segregation of pocket doping NPCK.
121	$l_{pck}=1e-8$ m	Char. length of lateral doping profile.
122	$l_{pckw}=0.0$	Width dependence of char. length of lateral doping profile.
123	$f_{o11}=0.0$	First length dependence coefficient for short channel body effect.
124	$f_{o12}=0.0$	Second length dependence coefficient for short channel body effect.
125	$v_{nsubo}=0.0$ V	Effective doping bias-dependence parameter.
126	$n_{slpo}=0.05$ V	Effective doping bias-dependence parameter.
127	$d_{nsubo}=0.0$ V ⁻¹	Effective doping bias-dependence parameter.
128	$d_{phibo}=0.0$ V	Geometry independent offset of PHIB.
129	$d_{phibl}=0.0$ V	Length dependence offset of PHIB.
130	$d_{phiblexp}=1.0$	Exponent for length dependence of offset of PHIB.
131	$d_{phibw}=0.0$	Width dependence of offset of PHIB.
132	$d_{phibl w}=0.0$	Area dependence of offset of PHIB.
133	$n_{po}=1e26$ m ⁻³	Geometry-independent gate poly-silicon doping.
134	$n_{pl}=0.0$	Length dependence of gate poly-silicon doping.
135	$cto=0.0$	Geometry-independent interface states factor.
136	$ctl=0.0$	Length dependence of interface states factor.

Virtuoso Simulator Components and Device Models Reference

PSP102 Model

137	$ctlexp=1.0$	Exponent for length dependence of interface states factor.
138	$ctw=0.0$	Width dependence of interface states factor.
139	$ctlw=0.0$	Area dependence of interface states factor.
140	$toxovo=2e-9$ m	Overlap oxide thickness.
141	$toxovdo=2e-9$ m	Overlap oxide thickness for drain side.
142	$lov=0$ m	Overlap length for gate/drain and gate/source overlap capacitance.
143	$lovd=0$ m	Overlap length for gate/drain overlap capacitance.
144	$novo=5e25$ m ⁻³	Effective doping of overlap region.
145	$novdo=5e25$ m ⁻³	Effective doping of overlap region for drain side.
146	$cfl=0.0$	Length dependence of DIBL-parameter.
147	$cfl exp=2.0$	Exponent for length dependence of CF.
148	$cfw=0.0$	Width dependence of CF.
149	$cfbo=0.0$ V ⁻¹	Back-bias dependence of CF.
150	$uo=5e-2$ m ² /V/s	Zero-field mobility at TR.
151	$fbet1=0.0$	Relative mobility decrease due to first lateral profile.
152	$fbet1w=0.0$	Width dependence of relative mobility decrease due to first lateral profile.
153	$lp1=1e-8$ m	Mobility-related characteristic length of first lateral profile.
154	$lp1w=0.0$	Width dependence of mobility-related characteristic length of first lateral profile.
155	$fbet2=0.0$	Relative mobility decrease due to second lateral profile.
156	$lp2=1e-8$ m	Mobility-related characteristic length of second lateral profile.

Virtuoso Simulator Components and Device Models Reference

PSP102 Model

157	<code>betw1=0.0</code>	First higher-order width scaling coefficient of BETN.
158	<code>betw2=0.0</code>	Second higher-order width scaling coefficient of BETN.
159	<code>wbet=1e-9 m</code>	Characteristic width for width scaling of BETN.
160	<code>stbeto=1.0</code>	Geometry independent temperature dependence of BETN.
161	<code>stbetl=0.0</code>	Length dependence of temperature dependence of BETN.
162	<code>stbetw=0.0</code>	Width dependence of temperature dependence of BETN.
163	<code>stbetlw=0.0</code>	Area dependence of temperature dependence of BETN.
164	<code>mueo=0.5 m/V</code>	Geometry independent mobility reduction coefficient at TR.
165	<code>muew=0.0</code>	Width dependence of mobility reduction coefficient at TR.
166	<code>stmueo=0.0</code>	Temperature dependence of MUE.
167	<code>themuo=1.5</code>	Mobility reduction exponent at TR.
168	<code>stthemuo=1.5</code>	Temperature dependence of THEMU.
169	<code>cso=0.0</code>	Geometry independent coulomb scattering parameter at TR.
170	<code>cs1=0.0</code>	Length dependence of CS.
171	<code>cs1exp=0.0</code>	Exponent for length dependence of CS.
172	<code>csw=0.0</code>	Width dependence of CS.
173	<code>cslw=0.0</code>	Area dependence of CS.
174	<code>stcso=0.0</code>	Temperature dependence of CS.
175	<code>xcoro=0.0 V⁻¹</code>	Geometry independent non-universality parameter.
176	<code>xcorl=0.0</code>	Length dependence of non-universality parameter.
177	<code>xcorw=0.0</code>	Width dependence of non-universality parameter.
178	<code>xcorlw=0.0</code>	Area dependence of non-universality parameter.

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179	$stxcoro=0.0$	Temperature dependence of XCOR.
180	$fetao=1.0$	Effective field parameter.
181	$rsw1=2.5e3 \Omega$	Source/drain series resistance for 1 um wide channel at TR.
182	$rsw2=0.0$	Higher-order width scaling of RS.
183	$strso=1.0$	Temperature dependence of RS.
184	$rsbo=0.0 V^{-1}$	Back-bias dependence of series resistance.
185	$rsgo=0.0 V^{-1}$	Gate-bias dependence of series resistance.
186	$thesato=0.0 V^{-1}$	Geometry independent velocity saturation parameter at TR.
187	$thesatl=0.05 V^{-1}$	Length dependence of THESAT.
188	$thesatlexp=1.0$	Exponent for length dependence of THESAT.
189	$thesatw=0.0$	Width dependence of velocity saturation parameter.
190	$thesatlw=0.0$	Area dependence of velocity saturation parameter.
191	$stthesato=1.0$	Geometry independent temperature dependence of THESAT.
192	$stthesatl=0.0$	Length dependence of temperature dependence of THESAT.
193	$stthesatw=0.0$	Width dependence of temperature dependence of THESAT.
194	$stthesatlw=0.0$	Area dependence of temperature dependence of THESAT.
195	$thesatbo=0.0 V^{-1}$	Back-bias dependence of velocity saturation.
196	$thesatgo=0.0 V^{-1}$	Gate-bias dependence of velocity saturation.
197	$axo=18$	Geometry independent linear/saturation transition factor.
198	$axl=0.4$	Length dependence of AX.
199	$alpl=5e-4$	Length dependence of ALP.
200	$alplexp=1.0$	Exponent for length dependence of ALP.

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201	alp _w =0.0	Width dependence of ALP.
202	alp _{1l1} =0.0 V	Length dependence of CLM enhancement factor above threshold.
203	alp _{1l} exp=0.5	Exponent for length dependence of ALP1.
204	alp _{1l2} =0.0	Second_order length dependence of ALP1.
205	alp _{1w} =0.0	Width dependence of ALP1.
206	alp _{2l1} =0.0 V ⁻¹	Length dependence of CLM enhancement factor below threshold.
207	alp _{2l} exp=0.5	Exponent for length dependence of ALP2.
208	alp _{2l2} =0.0	Second_order length dependence of ALP2.
209	alp _{2w} =0.0	Width dependence of ALP2.
210	v _{po} =0.05 V	CLM logarithmic dependence parameter.
211	a _{1o} =1.0	Geometry independent impact-ionization pre-factor.
212	a _{1l} =0.0	Length dependence of A1.
213	a _{1w} =0.0	Width dependence of A1.
214	a _{2o} =10 V	Impact-ionization exponent at TR.
215	sta _{2o} =0.0 V	Temperature dependence of A2.
216	a _{3o} =1.0	Geometry independent saturation-voltage dependence of I1.
217	a _{3l} =0.0	Length dependence of A3.
218	a _{3w} =0.0	Width dependence of A3.
219	a _{4o} =0.0 V ^{-0.5}	Geometry independent back-bias dependence of I1.
220	a _{4l} =0.0	Length dependence of A4.
221	a _{4w} =0.0	Width dependence of A4.

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222	gcoo=0.0	Gate tunnelling energy adjustment.
223	iginvlw=0.0 A	Gate channel current pre-factor for 1 μm^2 channel area.
224	igovw=0.0 A	Gate overlap current pre-factor for 1 μm wide channel.
225	igovdw=0.0 A	Gate overlap current pre-factor for 1 μm wide channel for drain side.
226	stigo=2.0	Temperature dependence of IGINV and IGOV.
227	gc2o=0.375	Gate current slope factor.
228	gc3o=0.063	Gate current curvature factor.
229	chibo=3.1 V	Tunnelling barrier height.
230	agidlw=0.0 A/V ³	Width dependence of GIDL pre-factor.
231	agidldw=0.0 A/V ³	Width dependence of GIDL pre-factor for drain side.
232	bgidlo=41 V	GIDL probability factor at TR.
233	bgidldo=41 V	GIDL probability factor at TR for drain side.
234	stbgidlo=0.0 V/K	Temperature dependence of BGIDL.
235	stbgidldo=0.0 V/K	Temperature dependence of BGIDL for drain side.
236	cgidlo=0.0	Back-bias dependence of GIDL.
237	cgidldo=0.0	Back-bias dependence of GIDL for drain side.
238	cgbovl=0.0 F	Oxide capacitance for gate-bulk overlap for 1 μm long channel.
239	cfrw=0.0 F	Outer fringe capacitance for 1 μm wide channel.
240	cfrdw=0.0 F	Outer fringe capacitance for 1 μm wide channel for drain side.
241	fnto=1.0	Thermal noise coefficient.
242	nfalw=8e22 V ⁻¹ /m ⁴	First coefficient of flicker noise for 1 μm^2 channel area.

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243	$nfb1w=3e7 \text{ V}^{-1}/\text{m}^2$	Second coefficient of flicker noise for 1 μm^2 channel area.
244	$nfclw=0.0 \text{ V}^{-1}$	Third coefficient of flicker noise for 1 μm^2 channel area.
245	$efo=1.0$	Flicker noise frequency exponent.
246	$lintnoi=0.0 \text{ m}$	Length offset for flicker noise.
247	$alpnoi=2.0$	Exponent for length offset for flicker noise.
248	$dta=0 \text{ K}$	Temperature offset w.r.t. ambient circuit temperature.
249	$kvthoweo=0$	Geometrical independent threshold shift parameter.
250	$kvthowel=0$	Length dependent threshold shift parameter.
251	$kvthowew=0$	Width dependent threshold shift parameter.
252	$kvthowelw=0$	Area dependent threshold shift parameter.
253	$kuoweo=0$	Geometrical independent mobility degradation factor.
254	$kuowel=0$	Length dependent mobility degradation factor.
255	$kuowew=0$	Width dependent mobility degradation factor.
256	$kuowelw=0$	Area dependent mobility degradation factor.
257	$vds_max=\infty \text{ V}$	Maximum allowed voltage cross source and drain.
258	$vgd_max=\infty \text{ V}$	Maximum allowed voltage cross gate and drain.
259	$vgs_max=\infty \text{ V}$	Maximum allowed voltage cross gate and source/bulk.
260	$vbd_max=\infty \text{ V}$	Maximum allowed voltage cross source/drain and bulk.
261	$vbs_max=\infty \text{ V}$	Maximum allowed voltage cross source and bulk.

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262	$v_{gb_max} = \infty$ V	Maximum allowed voltage cross gate and bulk.
263	$v_{gdr_max} = \infty$ V	Maximum allowed reverse voltage cross gate and drain.
264	$v_{gsr_max} = \infty$ V	Maximum allowed reverse voltage cross gate and source.
265	$v_{gbr_max} = \infty$ V	Maximum allowed reverse voltage cross gate and bulk.
266	$\mu_{nqso} = 1.0$	Relative mobility for NQS modeling.
267	$r_{go} = 0.0$ Ω	Gate resistance.
268	$r_{bulko} = 0.0$ Ω	Bulk resistance between node BP and BI.
269	$r_{wello} = 0.0$ Ω	Well resistance between node BI and B.
270	$r_{junso} = 0.0$ Ω	Source-side bulk resistance between node BI and BS.
271	$r_{jundo} = 0.0$ Ω	Drain-side bulk resistance between node BI and BD.
272	$r_{int} = 0.0$ Ω/Sqr	Contact resistance between silicide and poly.
273	$r_{vpoly} = 0.0$ Ω/Sqr	Vertical poly resistance.
274	$r_{shg} = 0.0$ Ω/Sqr	Gate electrode diffusion sheet resistance.
275	$d_{lsil} = 0.0$ m	Silicide extension over the physical gate length.
276	$s_{aref} = 1.0e-6$ m	Reference distance between OD-edge and poly from one side.
277	$s_{bref} = 1.0e-6$ m	Reference distance between OD-edge and poly from other side.
278	$w_{lod} = 0$ m	Width parameter.
279	$k_{uo} = 0$ m	Mobility degradation/enhancement coefficient.
280	$k_{vsat} = 0$ m	Saturation velocity degradation/enhancement coefficient.

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281	$t_{kuo}=0$	Temperature dependence of KUO.
282	$l_{kuo}=0$ $m^{LLODKUO}$	Length dependence of KUO.
283	$w_{kuo}=0$ $m^{WLODKUO}$	Width dependence of KUO.
284	$p_{kuo}=0$ $m^{(LLODKUO+WLODKUO)}$	Cross-term dependence of KUO.
285	$l_{lodkuo}=0$	Length parameter for UO stress effect.
286	$w_{lodkuo}=0$	Width parameter for UO stress effect.
287	$k_{vtho}=0$ V_m	Threshold shift parameter.
288	$l_{kvtho}=0$ $m^{LLODVTH}$	Length dependence of KVTHO.
289	$w_{kvtho}=0$ $m^{WLODVTH}$	Width dependence of KVTHO.
290	$p_{kvtho}=0$ $m^{(LLODVTH+WLODVTH)}$	Cross-term dependence of KVTHO.
291	$l_{lodvth}=0$	Length parameter for VTH-stress effect.
292	$w_{lodvth}=0$	Width parameter for VTH-stress effect.
293	$s_{etao}=0$ m	η_0 shift factor related to VTHO change.
294	$l_{odetao}=1.0$	η_0 shift modification factor for stress effect.
295	$s_{cref}=10e-6$ m	Distance between OD-edge and well edge of a reference device.
296	$w_{eb}=0$	Coefficient for SCB.
297	$w_{ec}=0$	Coefficient for SCC.
298	$i_{max}=1000$ A	Maximum current up to which forward current behaves exponentially.
299	$t_{rj}=21$ C	reference temperature.

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PSP102 Model

- 300 $c_{jorbot}=1E-3 \text{ Fm}^{-2}$ Zero-bias capacitance per unit-of-area of bottom component for source-bulk junction.
- 301 $c_{jorsti}=1E-9 \text{ Fm}^{-1}$ Zero-bias capacitance per unit-of-length of STI-edge component for source-bulk junction.
- 302 $c_{jorgat}=1E-9 \text{ Fm}^{-1}$ Zero-bias capacitance per unit-of-length of gate-edge component for source-bulk junction.
- 303 $v_{birbot}=1 \text{ V}$ Built-in voltage at the reference temperature of bottom component for source-bulk junction.
- 304 $v_{birsti}=1 \text{ V}$ Built-in voltage at the reference temperature of STI-edge component for source-bulk junction.
- 305 $v_{birgat}=1 \text{ V}$ Built-in voltage at the reference temperature of gate-edge component for source-bulk junction.
- 306 $p_{bot}=0.5$ Grading coefficient of bottom component for source-bulk junction.
- 307 $p_{sti}=0.5$ Grading coefficient of STI-edge component for source-bulk junction.
- 308 $p_{gat}=0.5$ Grading coefficient of gate-edge component for source-bulk junction.
- 309 $\phi_{igbot}=1.16 \text{ V}$ Zero-temperature bandgap voltage of bottom component for source-bulk junction.
- 310 $\phi_{igsti}=1.16 \text{ V}$ Zero-temperature bandgap voltage of STI-edge component for source-bulk junction.
- 311 $\phi_{iggat}=1.16 \text{ V}$ Zero-temperature bandgap voltage of gate-edge component for source-bulk junction.
- 312 $i_{dsatrbot}=1E-12 \text{ Am}^{-2}$ Saturation current density at the reference temperature of bottom component for source-bulk junction.

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PSP102 Model

- 313 `idsatrsti=1E-18` Am^{-1} Saturation current density at the reference temperature of STI-edge component for source-bulk junction.
- 314 `idsatrgat=1E-18` Am^{-1} Saturation current density at the reference temperature of gate-edge component for source-bulk junction.
- 315 `csrbot=1E2` Am^{-3} Shockley-Read-Hall prefactor of bottom component for source-bulk junction.
- 316 `csrhisti=1E-4` Am^{-2} Shockley-Read-Hall prefactor of STI-edge component for source-bulk junction.
- 317 `csrhgat=1E-4` Am^{-2} Shockley-Read-Hall prefactor of gate-edge component for source-bulk junction.
- 318 `xjunsti=100E-9` m Junction depth of STI-edge component for source-bulk junction.
- 319 `xjungat=100E-9` m Junction depth of gate-edge component for source-bulk junction.
- 320 `ctatbot=1E2` Am^{-3} Trap-assisted tunneling prefactor of bottom component for source-bulk junction.
- 321 `ctatsti=1E-4` Am^{-2} Trap-assisted tunneling prefactor of STI-edge component for source-bulk junction.
- 322 `ctatgat=1E-4` Am^{-2} Trap-assisted tunneling prefactor of gate-edge component for source-bulk junction.
- 323 `mefftatbot=0.25` Effective mass (in units of m_0) for trap-assisted tunneling of bottom component for source-bulk junction.
- 324 `mefftatsti=0.25` Effective mass (in units of m_0) for trap-assisted tunneling of STI-edge component for source-bulk junction.
- 325 `mefftatgat=0.25` Effective mass (in units of m_0) for trap-assisted tunneling of gate-edge component for source-bulk junction.

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PSP102 Model

- 326 $cbbtbot=1E-12$ AV^{-3}
Band-to-band tunneling prefactor of bottom component for source-bulk junction.
- 327 $cbbtsti=1E-18$ AV_m^3
Band-to-band tunneling prefactor of STI-edge component for source-bulk junction.
- 328 $cbbtgat=1E-18$ AV_m^3
Band-to-band tunneling prefactor of gate-edge component for source-bulk junction.
- 329 $fbbtbot=1E9$ Vm^{-1}
Normalization field at the reference temperature for band-to-band tunneling of bottom component for source-bulk junction.
- 330 $fbbtsti=1E9$ Vm^{-1}
Normalization field at the reference temperature for band-to-band tunneling of STI-edge component for source-bulk junction.
- 331 $fbbtgat=1E9$ Vm^{-1}
Normalization field at the reference temperature for band-to-band tunneling of gate-edge component for source-bulk junction.
- 332 $stfbbtbot=(-1E-3)$ K^{-1}
Temperature scaling parameter for band-to-band tunneling of bottom component for source-bulk junction.
- 333 $stfbbtsti=(-1E-3)$ K^{-1}
Temperature scaling parameter for band-to-band tunneling of STI-edge component for source-bulk junction.
- 334 $stfbbtgat=(-1E-3)$ K^{-1}
Temperature scaling parameter for band-to-band tunneling of gate-edge component for source-bulk junction.
- 335 $vbrbot=10$ V
Breakdown voltage of bottom component for source-bulk junction.
- 336 $vbrsti=10$ V
Breakdown voltage of STI-edge component for source-bulk junction.

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337	<code>vbrgat=10</code>	V	Breakdown voltage of gate-edge component for source-bulk junction.
338	<code>pbrbot=4</code>	V	Breakdown onset tuning parameter of bottom component for source-bulk junction.
339	<code>pbrsti=4</code>	V	Breakdown onset tuning parameter of STI-edge component for source-bulk junction.
340	<code>pbrgat=4</code>	V	Breakdown onset tuning parameter of gate-edge component for source-bulk junction.
341	<code>cjorbotd=1E-3</code>	Fm^{-2}	Zero-bias capacitance per unit-of-area of bottom component for drain-bulk junction.
342	<code>cjorstid=1E-9</code>	Fm^{-1}	Zero-bias capacitance per unit-of-length of STI-edge component for drain-bulk junction.
343	<code>cjorgatd=1E-9</code>	Fm^{-1}	Zero-bias capacitance per unit-of-length of gate-edge component for drain-bulk junction.
344	<code>vbirbotd=1</code>	V	Built-in voltage at the reference temperature of bottom component for drain-bulk junction.
345	<code>vbirstid=1</code>	V	Built-in voltage at the reference temperature of STI-edge component for drain-bulk junction.
346	<code>vbirgatd=1</code>	V	Built-in voltage at the reference temperature of gate-edge component for drain-bulk junction.
347	<code>pbotd=0.5</code>		Grading coefficient of bottom component for drain-bulk junction.
348	<code>pstid=0.5</code>		Grading coefficient of STI-edge component for drain-bulk junction.
349	<code>pgatd=0.5</code>		Grading coefficient of gate-edge component for drain-bulk junction.
350	<code>phigbotd=1.16</code>	V	Zero-temperature bandgap voltage of bottom component for drain-bulk junction.

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- 351 `phigstid=1.16` V Zero-temperature bandgap voltage of STI-edge component for drain-bulk junction.
- 352 `phiggatd=1.16` V Zero-temperature bandgap voltage of gate-edge component for drain-bulk junction.
- 353 `idsatrbotd=1E-12` Am^{-2} Saturation current density at the reference temperature of bottom component for drain-bulk junction.
- 354 `idsatrstid=1E-18` Am^{-1} Saturation current density at the reference temperature of STI-edge component for drain-bulk junction.
- 355 `idsatrgatd=1E-18` Am^{-1} Saturation current density at the reference temperature of gate-edge component for drain-bulk junction.
- 356 `csrbotd=1E2` Am^{-3} Shockley-Read-Hall prefactor of bottom component for drain-bulk junction.
- 357 `csrhistid=1E-4` Am^{-2} Shockley-Read-Hall prefactor of STI-edge component for drain-bulk junction.
- 358 `csrhgatd=1E-4` Am^{-2} Shockley-Read-Hall prefactor of gate-edge component for drain-bulk junction.
- 359 `xjunstid=100E-9` m Junction depth of STI-edge component for drain-bulk junction.
- 360 `xjungatd=100E-9` m Junction depth of gate-edge component for drain-bulk junction.
- 361 `ctatbotd=1E2` Am^{-3} Trap-assisted tunneling prefactor of bottom component for drain-bulk junction.
- 362 `ctatstid=1E-4` Am^{-2} Trap-assisted tunneling prefactor of STI-edge component for drain-bulk junction.

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- 363 $ctatgatd=1E-4 \text{ Am}^{-2}$ Trap-assisted tunneling prefactor of gate-edge component for drain-bulk junction.
- 364 $mefftatbotd=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of bottom component for drain-bulk junction.
- 365 $mefftatstid=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of STI-edge component for drain-bulk junction.
- 366 $mefftatgatd=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of gate-edge component for drain-bulk junction.
- 367 $cbbtbotd=1E-12 \text{ AV}^3$ Band-to-band tunneling prefactor of bottom component for drain-bulk junction.
- 368 $cbbtstid=1E-18 \text{ AV}^3_m$ Band-to-band tunneling prefactor of STI-edge component for drain-bulk junction.
- 369 $cbbtgatd=1E-18 \text{ AV}^3_m$ Band-to-band tunneling prefactor of gate-edge component for drain-bulk junction.
- 370 $fbbtrbotd=1E9 \text{ Vm}^{-1}$ Normalization field at the reference temperature for band-to-band tunneling of bottom component for drain-bulk junction.
- 371 $fbbtrstid=1E9 \text{ Vm}^{-1}$ Normalization field at the reference temperature for band-to-band tunneling of STI-edge component for drain-bulk junction.
- 372 $fbbtrgatd=1E9 \text{ Vm}^{-1}$ Normalization field at the reference temperature for band-to-band tunneling of gate-edge component for drain-bulk junction.
- 373 $stfbbtbotd=(-1E-3) \text{ K}^{-1}$ Temperature scaling parameter for band-to-band tunneling of bottom component for drain-bulk junction.

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374	$stfbbtstid = (-1E-3) K^{-1}$	Temperature scaling parameter for band-to-band tunneling of STI-edge component for drain-bulk junction.
375	$stfbbtgatd = (-1E-3) K^{-1}$	Temperature scaling parameter for band-to-band tunneling of gate-edge component for drain-bulk junction.
376	$vbrbotd = 10 V$	Breakdown voltage of bottom component for drain-bulk junction.
377	$vbrstid = 10 V$	Breakdown voltage of STI-edge component for drain-bulk junction.
378	$vbrgatd = 10 V$	Breakdown voltage of gate-edge component for drain-bulk junction.
379	$pbrbotd = 4 V$	Breakdown onset tuning parameter of bottom component for drain-bulk junction.
380	$pbrstid = 4 V$	Breakdown onset tuning parameter of STI-edge component for drain-bulk junction.
381	$pbrgatd = 4 V$	Breakdown onset tuning parameter of gate-edge component for drain-bulk junction.
382	$swjunexp = 0.0$	Flag for JUNCAP-express; 0,full model, 1,express model.
383	$vjunref = 2.5$	Typical maximum source-bulk junction voltage; usually about $2 \cdot VSUP$.
384	$fjunq = 0.03$	Fraction below which source-bulk junction capacitance components are considered negligible.
385	$vjunrefd = 2.5$	Typical maximum drain-bulk junction voltage; usually about $2 \cdot VSUP$.
386	$fjunqd = 0.03$	Fraction below which drain-bulk junction capacitance components are considered negligible.
387	$povfb = (-1) V$	Coefficient for the geometry independent part of VFB.
388	$plvfb = 0.0 V$	Coefficient for the length dependence of VFB.

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389	$p_{wvfb}=0.0$	V	Coefficient for the width dependence of VFB.
390	$p_{lwvfb}=0.0$	V	Coefficient for the length times width dependence of VFB.
391	$p_{ostvfb}=0.0005$	V/K	Coefficient for the geometry independent part of STVFB.
392	$p_{lstvfb}=0.0$	V/K	Coefficient for the length dependence of STVFB.
393	$p_{wstvfb}=0.0$	V/K	Coefficient for the width dependence of STVFB.
394	$p_{lwstvfb}=0.0$	V/K	Coefficient for the length times width dependence of STVFB.
395	$p_{otox}=2E-09$	m	Coefficient for the geometry independent part of TOX.
396	$p_{oepsrox}=3.9$		Coefficient for the geometry independent part of EPSOX.
397	$p_{oneff}=5E+23$	m^{-3}	Coefficient for the geometry independent part of NEFF.
398	$p_{lneff}=0.0$	m^{-3}	Coefficient for the length dependence of NEFF.
399	$p_{wneff}=0.0$	m^{-3}	Coefficient for the width dependence of NEFF.
400	$p_{lwneff}=0.0$	m^{-3}	Coefficient for the length times width dependence of NEFF.
401	$p_{ovnsb}=0$	V	Coefficient for the geometry independent part of VNSUB.
402	$p_{onslp}=0.05$	V	Coefficient for the geometry independent part of NSLP.
403	$p_{odnsub}=0$	V^{-1}	Coefficient for the geometry independent part of DNSUB.
404	$p_{odphib}=0$	V	Coefficient for the geometry independent part of DPHIB.
405	$p_{ldphib}=0.0$	V	Coefficient for the length dependence of DPHIB.
406	$p_{wdphib}=0.0$	V	Coefficient for the width dependence of DPHIB.
407	$p_{lwdphib}=0.0$	V	Coefficient for the length times width dependence of DPHIB.
408	$p_{onp}=1E+26$	m^{-3}	Coefficient for the geometry independent part of NP.
409	$p_{lnp}=0.0$	m^{-3}	Coefficient for the length dependence of NP.

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410	$pwnp=0.0 \text{ m}^{-3}$	Coefficient for the width dependence of NP.
411	$plwnp=0.0 \text{ m}^{-3}$	Coefficient for the length times width dependence of NP.
412	$pocct=0$	Coefficient for the geometry independent part of CT.
413	$plcct=0.0$	Coefficient for the length dependence of CT.
414	$pwct=0.0$	Coefficient for the width dependence of CT.
415	$plwct=0.0$	Coefficient for the length times width dependence of CT.
416	$potoxov=2E-09 \text{ m}$	Coefficient for the geometry independent part of TOXOV.
417	$potoxovd=2E-09 \text{ m}$	Coefficient for the geometry independent part of TOXOV for drain side.
418	$ponov=5E+25 \text{ m}^{-3}$	Coefficient for the geometry independent part of NOV.
419	$plnov=0.0 \text{ m}^{-3}$	Coefficient for the length dependence of NOV.
420	$pwnov=0.0 \text{ m}^{-3}$	Coefficient for the width dependence of NOV.
421	$plwnov=0.0 \text{ m}^{-3}$	Coefficient for the length times width dependence of NOV.
422	$ponovd=5E+25 \text{ m}^{-3}$	Coefficient for the geometry independent part of NOV for drain side.
423	$plnovd=0.0 \text{ m}^{-3}$	Coefficient for the length dependence of NOV for drain side.
424	$pwnovd=0.0 \text{ m}^{-3}$	Coefficient for the width dependence of NOV for drain side.
425	$plwnovd=0.0 \text{ m}^{-3}$	Coefficient for the length times width dependence of NOV for drain side.
426	$pocf=0$	Coefficient for the geometry independent part of CF.
427	$plcf=0.0$	Coefficient for the length dependence of CF.
428	$pwcf=0.0$	Coefficient for the width dependence of CF.
429	$plwcf=0.0$	Coefficient for the length times width dependence of CF.

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430	$pocfb=0 \ V^{-1}$	Coefficient for the geometry independent part of CFB.
431	$pobetn=0.07 \ m^2/V/s$	Coefficient for the geometry independent part of BETN.
432	$plbetn=0.0 \ m^2/V/s$	Coefficient for the length dependence of BETN.
433	$pwbetn=0.0 \ m^2/V/s$	Coefficient for the width dependence of BETN.
434	$plwbetn=0.0 \ m^2/V/s$	Coefficient for the length times width dependence of BETN.
435	$postbet=1$	Coefficient for the geometry independent part of STBET.
436	$plstbet=0.0$	Coefficient for the length dependence of STBET.
437	$pwstbet=0.0$	Coefficient for the width dependence of STBET.
438	$plwstbet=0.0$	Coefficient for the length times width dependence of STBET.
439	$pomue=0.5 \ m/V$	Coefficient for the geometry independent part of MUE.
440	$plmue=0.0 \ m/V$	Coefficient for the length dependence of MUE.
441	$pwmue=0.0 \ m/V$	Coefficient for the width dependence of MUE.
442	$plwmue=0.0 \ m/V$	Coefficient for the length times width dependence of MUE.
443	$postmue=0$	Coefficient for the geometry independent part of STMUE.
444	$pothemu=1.5$	Coefficient for the geometry independent part of THEMU.
445	$postthemu=1.5$	Coefficient for the geometry independent part of STTHEMU.
446	$pocs=0$	Coefficient for the geometry independent part of CS.
447	$plcs=0.0$	Coefficient for the length dependence of CS.
448	$pwcs=0.0$	Coefficient for the width dependence of CS.
449	$plwcs=0.0$	Coefficient for the length times width dependence of CS.

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450	<code>postcs=0</code>	Coefficient for the geometry independent part of STCS.
451	<code>poxcor=0 V⁻¹</code>	Coefficient for the geometry independent part of XCOR.
452	<code>plxcor=0.0 V⁻¹</code>	Coefficient for the length dependence of XCOR.
453	<code>pwxcor=0.0 V⁻¹</code>	Coefficient for the width dependence of XCOR.
454	<code>plwxcor=0.0 V⁻¹</code>	Coefficient for the length times width dependence of XCOR.
455	<code>postxcor=0</code>	Coefficient for the geometry independent part of STXCOR.
456	<code>pofeta=1</code>	Coefficient for the geometry independent part of FETA.
457	<code>pors=30 Ω</code>	Coefficient for the geometry independent part of RS.
458	<code>plrs=0.0 Ω</code>	Coefficient for the length dependence of RS.
459	<code>pwr=0.0 Ω</code>	Coefficient for the width dependence of RS.
460	<code>plwrs=0.0 Ω</code>	Coefficient for the length times width dependence of RS.
461	<code>postrs=1</code>	Coefficient for the geometry independent part of STRS.
462	<code>porsb=0 V⁻¹</code>	Coefficient for the geometry independent part of RSB.
463	<code>porsg=0 V⁻¹</code>	Coefficient for the geometry independent part of RSG.
464	<code>pothesat=1 V⁻¹</code>	Coefficient for the geometry independent part of THESAT.
465	<code>plthesat=0.0 V⁻¹</code>	Coefficient for the length dependence of THESAT.
466	<code>pwthesat=0.0 V⁻¹</code>	Coefficient for the width dependence of THESAT.
467	<code>plwthesat=0.0 V⁻¹</code>	Coefficient for the length times width dependence of THESAT.
468	<code>postthesat=1</code>	Coefficient for the geometry independent part of STTHESAT.
469	<code>plstthesat=0.0</code>	Coefficient for the length dependence of STTHESAT.
470	<code>pwstthesat=0.0</code>	Coefficient for the width dependence of STTHESAT.

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- 471 $plwstthesat=0.0$ Coefficient for the length times width dependence of STTHESAT.
- 472 $pothesatb=0 V^{-1}$ Coefficient for the geometry independent part of THESATB.
- 473 $plthesatb=0.0 V^{-1}$
Coefficient for the length dependence of THESATB.
- 474 $pwthesatb=0.0 V^{-1}$
Coefficient for the width dependence of THESATB.
- 475 $plwthesatb=0.0 V^{-1}$
Coefficient for the length times width dependence of THESATB.
- 476 $pothesatg=0 V^{-1}$ Coefficient for the geometry independent part of THESATG.
- 477 $plthesatg=0.0 V^{-1}$
Coefficient for the length dependence of THESATG.
- 478 $pwthesatg=0.0 V^{-1}$
Coefficient for the width dependence of THESATG.
- 479 $plwthesatg=0.0 V^{-1}$
Coefficient for the length times width dependence of THESATG.
- 480 $poax=3$ Coefficient for the geometry independent part of AX.
- 481 $plax=0.0$ Coefficient for the length dependence of AX.
- 482 $pwax=0.0$ Coefficient for the width dependence of AX.
- 483 $plwax=0.0$ Coefficient for the length times width dependence of AX.
- 484 $poalp=0.01$ Coefficient for the geometry independent part of ALP.
- 485 $plalp=0.0$ Coefficient for the length dependence of ALP.
- 486 $pwalp=0.0$ Coefficient for the width dependence of ALP.
- 487 $plwalp=0.0$ Coefficient for the length times width dependence of ALP.
- 488 $poalp1=0 V$ Coefficient for the geometry independent part of ALP1.
- 489 $plalp1=0.0 V$ Coefficient for the length dependence of ALP1.

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490	$p_{walp1}=0.0 \ V$	Coefficient for the width dependence of ALP1.
491	$p_{lwalp1}=0.0 \ V$	Coefficient for the length times width dependence of ALP1.
492	$p_{oalp2}=0 \ V^{-1}$	Coefficient for the geometry independent part of ALP2.
493	$p_{lalp2}=0.0 \ V^{-1}$	Coefficient for the length dependence of ALP2.
494	$p_{walp2}=0.0 \ V^{-1}$	Coefficient for the width dependence of ALP2.
495	$p_{lwalp2}=0.0 \ V^{-1}$	Coefficient for the length times width dependence of ALP2.
496	$p_{ovp}=0.05 \ V$	Coefficient for the geometry independent part of VP.
497	$p_{oa1}=1$	Coefficient for the geometry independent part of A1.
498	$p_{la1}=0.0$	Coefficient for the length dependence of A1.
499	$p_{wa1}=0.0$	Coefficient for the width dependence of A1.
500	$p_{lwa1}=0.0$	Coefficient for the length times width dependence of A1.
501	$p_{oa2}=10 \ V$	Coefficient for the geometry independent part of A2.
502	$p_{osta2}=0 \ V$	Coefficient for the geometry independent part of STA2.
503	$p_{oa3}=1$	Coefficient for the geometry independent part of A3.
504	$p_{la3}=0.0$	Coefficient for the length dependence of A3.
505	$p_{wa3}=0.0$	Coefficient for the width dependence of A3.
506	$p_{lwa3}=0.0$	Coefficient for the length times width dependence of A3.
507	$p_{oa4}=0 \ V^{-0.5}$	Coefficient for the geometry independent part of A4.
508	$p_{la4}=0.0 \ V^{-0.5}$	Coefficient for the length dependence of A4.
509	$p_{wa4}=0.0 \ V^{-0.5}$	Coefficient for the width dependence of A4.
510	$p_{lwa4}=0.0 \ V^{-0.5}$	Coefficient for the length times width dependence of A4.
511	$p_{ogco}=0$	Coefficient for the geometry independent part of GCO.

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512	$poiginv=0$	A	Coefficient for the geometry independent part of IGINV.
513	$pliginv=0.0$	A	Coefficient for the length dependence of IGINV.
514	$pwiginv=0.0$	A	Coefficient for the width dependence of IGINV.
515	$plwiginv=0.0$	A	Coefficient for the length times width dependence of IGINV.
516	$poigov=0$	A	Coefficient for the geometry independent part of IGOV.
517	$pligov=0.0$	A	Coefficient for the length dependence of IGOV.
518	$pwigov=0.0$	A	Coefficient for the width dependence of IGOV.
519	$plwigov=0.0$	A	Coefficient for the length times width dependence of IGOV.
520	$poigovd=0$	A	Coefficient for the geometry independent part of IGOV for drain side.
521	$pligovd=0.0$	A	Coefficient for the length dependence of IGOV for drain side.
522	$pwigovd=0.0$	A	Coefficient for the width dependence of IGOV for drain side.
523	$plwigovd=0.0$	A	Coefficient for the length times width dependence of IGOV for drain side.
524	$postig=2$		Coefficient for the geometry independent part of STIG.
525	$pogc2=0.375$		Coefficient for the geometry independent part of GC2.
526	$pogc3=0.063$		Coefficient for the geometry independent part of GC3.
527	$pochib=3.1$	V	Coefficient for the geometry independent part of CHIB.
528	$poagidl=0$	A/V^3	Coefficient for the geometry independent part of AGIDL.
529	$plagidl=0.0$	A/V^3	Coefficient for the length dependence of AGIDL.
530	$pwagidl=0.0$	A/V^3	Coefficient for the width dependence of AGIDL.
531	$plwagidl=0.0$	A/V^3	Coefficient for the length times width dependence of AGIDL.

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532	<code>poagidld=0</code>	A/V^3	Coefficient for the geometry independent part of AGIDL for drain side.
533	<code>plagidld=0.0</code>	A/V^3	Coefficient for the length dependence of AGIDL for drain side.
534	<code>pwagidld=0.0</code>	A/V^3	Coefficient for the width dependence of AGIDL for drain side.
535	<code>plwagidld=0.0</code>	A/V^3	Coefficient for the length times width dependence of AGIDL for drain side.
536	<code>pobgidl=41</code>	V	Coefficient for the geometry independent part of BGIDL.
537	<code>pobgidld=41</code>	V	Coefficient for the geometry independent part of BGIDL for drain side.
538	<code>postbgidl=0</code>	V/K	Coefficient for the geometry independent part of STBGIDL.
539	<code>postbgidld=0</code>	V/K	Coefficient for the geometry independent part of STBGIDL for drain side.
540	<code>pocgidl=0</code>		Coefficient for the geometry independent part of CGIDL.
541	<code>pocgidld=0</code>		Coefficient for the geometry independent part of CGIDL for drain side.
542	<code>poccox=1E-14</code>	F	Coefficient for the geometry independent part of COX.
543	<code>plcox=0.0</code>	F	Coefficient for the length dependence of COX.
544	<code>pwcox=0.0</code>	F	Coefficient for the width dependence of COX.
545	<code>plwcox=0.0</code>	F	Coefficient for the length times width dependence of COX.
546	<code>pocgov=1E-15</code>	F	Coefficient for the geometry independent part of CGOV.
547	<code>plcgov=0.0</code>	F	Coefficient for the length dependence of CGOV.
548	<code>pwcgov=0.0</code>	F	Coefficient for the width dependence of CGOV.
549	<code>plwcgov=0.0</code>	F	Coefficient for the length times width dependence of CGOV.

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550	$pocgovd=1E-15$	F	Coefficient for the geometry independent part of CGOV for drain side.
551	$plcgovd=0.0$	F	Coefficient for the length dependence of CGOV for drain side.
552	$pwcgovd=0.0$	F	Coefficient for the width dependence of CGOV for drain side.
553	$plwcgovd=0.0$	F	Coefficient for the length times width dependence of CGOV for drain side.
554	$pocgbov=0$	F	Coefficient for the geometry independent part of CGBOV.
555	$plcgbov=0.0$	F	Coefficient for the length dependence of CGBOV.
556	$pwcgbov=0.0$	F	Coefficient for the width dependence of CGBOV.
557	$plwcgbov=0.0$	F	Coefficient for the length times width dependence of CGBOV.
558	$pocfr=0$	F	Coefficient for the geometry independent part of CFR.
559	$plcfr=0.0$	F	Coefficient for the length dependence of CFR.
560	$pwcfr=0.0$	F	Coefficient for the width dependence of CFR.
561	$plwcf=0.0$	F	Coefficient for the length times width dependence of CFR.
562	$pocfrd=0$	F	Coefficient for the geometry independent part of CFR for drain side.
563	$plcfrd=0.0$	F	Coefficient for the length dependence of CFR for drain side.
564	$pwcfrd=0.0$	F	Coefficient for the width dependence of CFR for drain side.
565	$plwcfrd=0.0$	F	Coefficient for the length times width dependence of CFR for drain side.
566	$pofnt=1$		Coefficient for the geometry independent part of FNT.
567	$ponfa=8E+22$	V^{-1}/m^4	Coefficient for the geometry independent part of NFA.
568	$plnfa=0.0$	V^{-1}/m^4	Coefficient for the length dependence of NFA.

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569	$pwnfa=0.0 \ V^{-1}/m^4$	Coefficient for the width dependence of NFA.
570	$plwnfa=0.0 \ V^{-1}/m^4$	Coefficient for the length times width dependence of NFA.
571	$ponfb=3E+07 \ V^{-1}/m^2$	Coefficient for the geometry independent part of NFB.
572	$plnfb=0.0 \ V^{-1}/m^2$	Coefficient for the length dependence of NFB.
573	$pwnfb=0.0 \ V^{-1}/m^2$	Coefficient for the width dependence of NFB.
574	$plwnfb=0.0 \ V^{-1}/m^2$	Coefficient for the length times width dependence of NFB.
575	$ponfc=0 \ V^{-1}$	Coefficient for the geometry independent part of NFC.
576	$plnfc=0.0 \ V^{-1}$	Coefficient for the length dependence of NFC.
577	$pwnfc=0.0 \ V^{-1}$	Coefficient for the width dependence of NFC.
578	$plwnfc=0.0 \ V^{-1}$	Coefficient for the length times width dependence of NFC.
579	$poef=1.0$	Coefficient for the flicker noise frequency exponent.
580	$pokvthowe=0$	Coefficient for the geometry independent part of KVTHOWE.
581	$plkvthowe=0$	Coefficient for the length dependence part of KVTHOWE.
582	$pwkvthowe=0$	Coefficient for the width dependence part of KVTHOWE.
583	$plwkvthowe=0$	Coefficient for the length times width dependence part of KVTHOWE.
584	$pokuowe=0$	Coefficient for the geometry independent part of KUOWE.
585	$plkuowe=0$	Coefficient for the length dependence part of KUOWE.
586	$pwkuowe=0$	Coefficient for the width dependence part of KUOWE.

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587	<code>plwkuowe=0</code>	Coefficient for the length times width dependence part of KUOWE.
588	<code>lmin=0 m</code>	Dummy parameter to label binning set.
589	<code>lmax=1.0 m</code>	Dummy parameter to label binning set.
590	<code>wmin=0 m</code>	Dummy parameter to label binning set.
591	<code>wmax=1.0 m</code>	Dummy parameter to label binning set.
592	<code>w=10e-6 m</code>	Default width.
593	<code>l=10e-6 m</code>	Default length.
594	<code>nf=1</code>	Number of fingers, It served as the default value of instance nf.
595	<code>mvt=0.0</code>	DCmatch parameter.
596	<code>mvto=0.0</code>	DCmatch parameter.
597	<code>mbe=0.0</code>	DCmatch parameter.
598	<code>mbeo=0.0</code>	DCmatch parameter.
599	<code>vthmod</code>	Vth output selector. 'std' outputs model equation Vth. 'vthcc' outputs constant current Vth, and may impact simulation performance. The default value is taken from the options parameter 'vthmod'. Possible values are <code>std</code> and <code>vthcc</code> .
600	<code>ivth (A)</code>	Vth current parameter. The default value is taken from the options parameter 'ivthn' or 'ivthp', depending on the type of the model.
601	<code>ivthw (m)</code>	Width offset for constant current Vth. The default value is taken from the options parameter 'ivthw'.
602	<code>ivthl (m)</code>	Length offset for constant current Vth. The default value is taken from the options parameter 'ivthl'.
603	<code>ivth_vdsmin (V)</code>	Minimum Vds in constant current Vth calculating. The default value is taken from the options parameter 'ivth_vdsmin'.

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PSP102 Model

604 noisemethod=oldcmi

Induced gate noise implementation .
Possible values are oldcmi, subckt, and newcmi.

Output Parameters

1 weff (m)	Effective channel width for geometrical models.
2 leff (m)	Effective channel length for geometrical models.
3 lp_vfb (V)	Local parameter VFB after T-scaling and clipping.
4 lp_stvfb (V/K)	Local parameter STVFB after clipping.
5 lp_tox (m)	Local parameter TOX after clipping.
6 lp_epsrox	Local parameter EPSROX after clipping.
7 lp_neff (m ⁻³)	Local parameter NEFF after clipping.
8 lp_vnsub (V)	Local parameter VNSUB after clipping.
9 lp_nslp (V)	Local parameter NSLP after clipping.
10 lp_dnsb (V ⁻¹)	Local parameter DNSUB after clipping.
11 lp_dphib (V)	Local parameter DPHIB after clipping.
12 lp_np (m ⁻³)	Local parameter NP after clipping.
13 lp_ct	Local parameter CT after clipping.
14 lp_toxov (m)	Local parameter TOXOV after clipping.
15 lp_toxovd (m)	Local parameter TOXOVD after clipping.
16 lp_nov (m ⁻³)	Local parameter NOV after clipping.
17 lp_novd (m ⁻³)	Local parameter NOVD after clipping.
18 lp_cf	Local parameter CF after clipping.

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19	lp_cfb (V^{-1})	Local parameter CFB after clipping.
20	lp_betn ($m^2/(V \cdot s)$)	Local parameter BETN after T-scaling and clipping.
21	lp_stbet	Local parameter STBET after clipping.
22	lp_mue (m/V)	Local parameter MUE after T-scaling and clipping.
23	lp_stmue	Local parameter STMUE after clipping.
24	lp_themu	Local parameter THEMU after T-scaling and clipping.
25	lp_stthemu	Local parameter STTHEMU after clipping.
26	lp_cs	Local parameter CS after T-scaling and clipping.
27	lp_stcs	Local parameter STCS after clipping.
28	lp_xcor (V^{-1})	Local parameter XCOR after T-scaling and clipping.
29	lp_stxcor	Local parameter STXCOR after clipping.
30	lp_feta	Local parameter FETA after clipping.
31	lp_rs (Ω)	Local parameter RS after T-scaling and clipping.
32	lp_strs	Local parameter STRS after clipping.
33	lp_rsb (V^{-1})	Local parameter RSB after clipping.
34	lp_rsg (V^{-1})	Local parameter RSG after clipping.
35	lp_thesat (V^{-1})	Local parameter THESAT after T-scaling and clipping.
36	lp_stthesat	Local parameter STTHESAT after clipping.
37	lp_thesatb (V^{-1})	Local parameter THESATB after clipping.
38	lp_thesatg (V^{-1})	Local parameter THESATG after clipping.

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39	lp_ax	Local parameter AX after clipping.
40	lp_alp	Local parameter ALP after clipping.
41	lp_alp1 (V)	Local parameter ALP1 after clipping.
42	lp_alp2 (V ⁻¹)	Local parameter ALP2 after clipping.
43	lp_vp (V)	Local parameter VP after clipping.
44	lp_a1	Local parameter A1 after clipping.
45	lp_a2 (V)	Local parameter A2 after T-scaling and clipping.
46	lp_sta2	Local parameter STA2 after clipping.
47	lp_a3	Local parameter A3 after clipping.
48	lp_a4 (1/ V)	Local parameter A4 after clipping.
49	lp_gco	Local parameter GCO after clipping.
50	lp_iginv (A)	Local parameter IGINV after T-scaling and clipping.
51	lp_igov (A)	Local parameter IGOV after T-scaling and clipping.
52	lp_igovd (A)	Local parameter IGOVD after T-scaling and clipping.
53	lp_stig	Local parameter STIG after clipping.
54	lp_gc2	Local parameter GC2 after clipping.
55	lp_gc3	Local parameter GC3 after clipping.
56	lp_chib (V)	Local parameter CHIB after clipping.
57	lp_agidl (A/V ³)	Local parameter AGIDL after clipping.
58	lp_agidld (A/V ³)	Local parameter AGIDLD after clipping.

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PSP102 Model

59	lp_bgidl (V)	Local parameter BGIDL after T-scaling and clipping.
60	lp_bgidld (V)	Local parameter BGIDLD after T-scaling and clipping.
61	lp_stbgidl (V/K)	Local parameter STBGIDL after clipping.
62	lp_stbgidld (V/K)	Local parameter STBGIDLD after clipping.
63	lp_cgidl	Local parameter CGIDL after clipping.
64	lp_cgidld	Local parameter CGIDLD after clipping.
65	lp_cox (F)	Local parameter COX after clipping.
66	lp_cgov (F)	Local parameter CGOV after clipping.
67	lp_cgovd (F)	Local parameter CGOVD after clipping.
68	lp_cgbov (F)	Local parameter CGBOV after clipping.
69	lp_cfr (F)	Local parameter CFR after clipping.
70	lp_cfrd (F)	Local parameter CFRD after clipping.
71	lp_fnt	Local parameter FNT after clipping.
72	lp_nfa (1/(V m ⁴))	Local parameter NFA after clipping.
73	lp_nfb (1/(V m ²))	Local parameter NFB after clipping.
74	lp_nfc (V ⁻¹)	Local parameter NFC after clipping.
75	lp_ef	Local parameter EF after clipping.
76	lp_rg (Ω)	Local parameter RG after clipping.
77	lp_rbulk (Ω)	Local parameter RBULK after clipping.
78	lp_rwell (Ω)	Local parameter RWELL after clipping.

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PSP102 Model

79	lp_rjuns (Ω)	Local parameter RJUNS after clipping.
80	lp_rjund (Ω)	Local parameter RJUND after clipping.
81	tk (K)	Device Temperature.
82	lp_munqs	Local parameter MUNQS after clipping.
83	cjosbot (F)	Bottom component of total zero-bias source junction capacitance at device temperature.
84	cjossti (F)	STI-edge component of total zero-bias source junction capacitance at device temperature.
85	cjosgat (F)	Gate-edge component of total zero-bias source junction capacitance at device temperature.
86	vbisbot (V)	Built-in voltage of source-side bottom junction at device temperature.
87	vbissti (V)	Built-in voltage of source-side STI-edge junction at device temperature.
88	vbisgat (V)	Built-in voltage of source-side gate-edge junction at device temperature.
89	idsatsbot (A)	Total source-side bottom junction saturation current.
90	idsatssti (A)	Total source-side STI-edge junction saturation current.
91	idsatsgat (A)	Total source-side gate-edge junction saturation current.
92	cjosbotd (F)	Bottom component of total zero-bias drain junction capacitance at device temperature.
93	cjosstid (F)	STI-edge component of total zero-bias drain junction capacitance at device temperature.
94	cjosgatd (F)	Gate-edge component of total zero-bias drain junction capacitance at device temperature.
95	vbisbotd (V)	Built-in voltage of drain-side bottom junction at device temperature.

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96	<code>vbisstid</code> (V)	Built-in voltage of drain-side STI-edge junction at device temperature.
97	<code>vbisgatd</code> (V)	Built-in voltage of drain-side gate-edge junction at device temperature.
98	<code>idsatsbotd</code> (A)	Total drain-side bottom junction saturation current.
99	<code>idsatsstid</code> (A)	Total drain-side STI-edge junction saturation current.
100	<code>idsatsgatd</code> (A)	Total drain-side gate-edge junction saturation current.
101	<code>lv1</code> (m)	alias of <code>l</code> .
102	<code>lv2</code> (m)	alias of <code>w</code> .
103	<code>lv3</code> (m ²)	alias of <code>ad</code> .
104	<code>lv4</code> (m ²)	alias of <code>as</code> .
105	<code>lv11</code> (m)	alias of <code>pd</code> .
106	<code>lv12</code> (m)	alias of <code>ps</code> .
107	<code>tempeff</code> (C)	Effective temperature for a single device.

Operating-Point Parameters

1	<code>region=triode</code>	Estimated operating region. %Z outputs the number (0-4) in a rawfile. Possible values are <code>off</code> , <code>triode</code> , <code>sat</code> , <code>subth</code> , and <code>breakdown</code> .
2	<code>ctype</code>	Flag for channel type.
3	<code>sdint</code>	Flag for source-drain interchange.
4	<code>ise</code> (A)	Total source current.
5	<code>ige</code> (A)	Total gate current.
6	<code>ide</code> (A)	Total drain current.

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7	<code>ibe</code> (A)	Total bulk current.
8	<code>ids</code> (A)	Drain current, excl. avalanche, tunnel, GISL, GIDL, and junction currents.
9	<code>idb</code> (A)	Drain to bulk current.
10	<code>isb</code> (A)	Source to bulk current.
11	<code>igs</code> (A)	Gate-source tunneling current.
12	<code>igd</code> (A)	Gate-drain tunneling current.
13	<code>igb</code> (A)	Gate-bulk tunneling current.
14	<code>igcs</code> (A)	Gate-channel tunneling current (source component).
15	<code>igcd</code> (A)	Gate-channel tunneling current (drain component).
16	<code>iavl</code> (A)	Substrate current due to weak avalanche.
17	<code>igisl</code> (A)	Gate-induced source leakage current.
18	<code>igidl</code> (A)	Gate-induced drain leakage current.
19	<code>ijs</code> (A)	Total source junction current.
20	<code>ijsbot</code> (A)	Source junction current (bottom component).
21	<code>ijsgat</code> (A)	Source junction current (gate-edge component).
22	<code>ijssti</code> (A)	Source junction current (STI-edge component).
23	<code>ijd</code> (A)	Total drain junction current.
24	<code>ijdbot</code> (A)	Drain junction current (bottom component).
25	<code>ijdgat</code> (A)	Drain junction current (gate-edge component).
26	<code>ijdsti</code> (A)	Drain junction current (STI-edge component).
27	<code>qg</code> (Coul)	Intrinsic gate charge.

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28	q_d (Coul)	Intrinsic drain charge.
29	q_b (Coul)	Intrinsic bulk charge.
30	q_s (Coul)	Intrinsic source charge.
31	q_{gs_ov} (Coul)	Overlap charge for gate-source.
32	q_{gd_ov} (Coul)	Overlap charge for gate-drain.
33	q_{fgs} (Coul)	Total outerFringe + overlap for gate-source.
34	q_{fgd} (Coul)	Total outerFringe + overlap for gate-drain.
35	q_{gb_ov} (Coul)	Gate-bulk overlap charge.
36	q_{jun_s} (Coul)	Junction charge on source side.
37	q_{jun_d} (Coul)	Junction charge on drain side.
38	v_{ds} (V)	Drain-source voltage.
39	v_{gs} (V)	Gate-source voltage.
40	v_{sb} (V)	Source-bulk voltage.
41	v_{to} (V)	Zero-bias threshold voltage.
42	v_{ts} (V)	Threshold voltage including back bias effects.
43	v_{th} (V)	Threshold voltage including back bias and drain bias effects.
44	v_{gt} (V)	Effective gate drive voltage including back bias and drain bias effects.
45	v_{dss} (V)	Drain saturation voltage at actual bias.
46	v_{sat} (V)	Saturation limit.
47	pwr (W)	Power at op point.
48	g_m ($1/\Omega$)	Transconductance.

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49	g_{mb} ($1/\Omega$)	Substrate transconductance.
50	g_{ds} ($1/\Omega$)	Output conductance.
51	g_{js} ($1/\Omega$)	Source junction conductance.
52	g_{jd} ($1/\Omega$)	Drain junction conductance.
53	c_{dd} (F)	Drain capacitance.
54	c_{dg} (F)	Drain-gate capacitance.
55	c_{ds} (F)	Drain-source capacitance.
56	c_{db} (F)	Drain-bulk capacitance.
57	c_{gd} (F)	Gate-drain capacitance.
58	c_{gg} (F)	Gate capacitance.
59	c_{gs} (F)	Gate-source capacitance.
60	c_{gb} (F)	Gate-bulk capacitance.
61	c_{sd} (F)	Source-drain capacitance.
62	c_{sg} (F)	Source-gate capacitance.
63	c_{ss} (F)	Source capacitance.
64	c_{sb} (F)	Source-bulk capacitance.
65	c_{bd} (F)	Bulk-drain capacitance.
66	c_{bg} (F)	Bulk-gate capacitance.
67	c_{bs} (F)	Bulk-source capacitance.
68	c_{bb} (F)	Bulk capacitance.
69	c_{gsol} (F)	Total gate-source overlap capacitance.
70	c_{gdol} (F)	Total gate-drain overlap capacitance.

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71	<code>cgbol</code> (F)	Total gate-bulk overlap capacitance.
72	<code>cjs</code> (F)	Total source junction capacitance.
73	<code>cjsbot</code> (F)	Source junction capacitance (bottom component).
74	<code>cjsgat</code> (F)	Source junction capacitance (gate-edge component).
75	<code>cjssti</code> (F)	Source junction capacitance (STI-edge component).
76	<code>cjd</code> (F)	Total drain junction capacitance.
77	<code>cjdbot</code> (F)	Drain junction capacitance (bottom component).
78	<code>cjdgat</code> (F)	Drain junction capacitance (gate-edge component).
79	<code>cjdsti</code> (F)	Drain junction capacitance (STI-edge component).
80	<code>lpoly</code> (m)	
81	<code>u</code>	Transistor gain.
82	<code>rout</code> (Ω)	Small-signal output resistance.
83	<code>vearly</code> (V)	Equivalent Early voltage.
84	<code>beff</code> (A/V^2)	Gain factor.
85	<code>fug</code> (Hz)	Unity gain frequency at actual bias.
86	<code>rg</code> (Ω)	Gate resistance.
87	<code>sfl</code> (A^2/Hz)	Flicker noise current spectral density at 1 Hz.
88	<code>sqrtsff</code> (V/ \sqrt{Hz})	Input-referred RMS white noise voltage spectral density at 1 kHz.
89	<code>sqrtsfw</code> (V/ \sqrt{Hz})	Input-referred RMS white noise voltage spectral density.
90	<code>sid</code> (A^2/Hz)	White noise current spectral density.
91	<code>sig</code> (A^2/Hz)	Induced gate noise current spectral density at 1 Hz.

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92	<code>cigid</code>	Imaginary part of correlation coefficient between Sig and Sid.
93	<code>fknee</code> (Hz)	Cross-over frequency above which white noise is dominant.
94	<code>sigs</code> (A^2/Hz)	Gate-source current noise spectral density.
95	<code>sigd</code> (A^2/Hz)	Gate-drain current noise spectral density.
96	<code>siavl</code> (A^2/Hz)	Impact ionization current noise spectral density.
97	<code>ssi</code> (A^2/Hz)	Total source junction current noise spectral density.
98	<code>sdi</code> (A^2/Hz)	Total drain junction current noise spectral density.
99	<code>vbs</code> (V)	Bulk-source voltage.
100	<code>lv9</code> (V)	alias of <code>vth</code> .
101	<code>lv10</code> (V)	alias of <code>vdss</code> .
102	<code>lv36</code> (F)	alias of <code>cgsol</code> .
103	<code>lv37</code> (F)	alias of <code>cgdol</code> .
104	<code>lv38</code> (F)	alias of <code>cgbol</code> .
105	<code>lv51</code> (m)	alias of <code>tox</code> .
106	<code>lx4</code> (A)	alias of <code>ids</code> .
107	<code>lx3</code> (V)	alias of <code>vds</code> .
108	<code>lx2</code> (V)	alias of <code>vgs</code> .
109	<code>lx7</code> ($1/\Omega$)	alias of <code>gm</code> .
110	<code>lx8</code> ($1/\Omega$)	alias of <code>gds</code> .
111	<code>lx9</code> ($1/\Omega$)	alias of <code>gmb</code> .
112	<code>lx33</code> (F)	alias of <code>cdd</code> .
113	<code>lx32</code> (F)	alias of <code>cdg</code> .

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114	1x34 (F)	alias of cds.
115	1x19 (F)	alias of cgd.
116	1x18 (F)	alias of cgg.
117	1x20 (F)	alias of cgs.
118	1x22 (F)	alias of cbd.
119	1x21 (F)	alias of cbg.
120	1x23 (F)	alias of cbs.
121	1x5 (A)	alias of ijs.
122	1x6 (A)	alias of ijd.
123	1x28 (F)	alias of cjs.
124	1x29 (F)	alias of cjd.
125	1x38 (A)	alias of igs.
126	1x39 (A)	alias of igd.
127	1x66 (A)	alias of igb.
128	1x67 (A)	alias of igcs.
129	1x68 (A)	alias of igcd.
130	1x110 (A)	alias of igisl.
131	1x47 (A)	alias of igidl.
132	1x60 (F)	alias of csd.
133	1x59 (F)	alias of csg.
134	1x58 (F)	alias of css.
135	1x12 (Coul)	alias of Qb including overlap charge.

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136	1x14 (Coul)	alias of Qg including overlap charge.
137	1x16 (Coul)	alias of Qd including overlap charge.
138	1x83 (F)	alias of cgd including overlap cap.
139	1x84 (F)	alias of cgs including overlap cap.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

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a1l	M-212	ijd	OP-23	nsubo	M-115	pwthesat	M-466
a1o	M-211	ijdbot	OP-24	nsubw	M-116	pwthesatb	M-474
a1w	M-213	ijdgat	OP-25	pbot	M-306	pwthesatg	M-478
a2	M-58	ijdsti	OP-26	pbotd	M-347	pwvfb	M-389
a2o	M-214	ijs	OP-19	pbrbot	M-338	pwxcor	M-453
a3	M-60	ijsbot	OP-20	pbrbotd	M-379	qb	OP-29
a3l	M-217	ijsgat	OP-21	pbrgat	M-340	qd	OP-28
a3o	M-216	ijssti	OP-22	pbrgatd	M-381	qfgd	OP-34
a3w	M-218	imax	M-298	pbrsti	M-339	qfgs	OP-33
a4	M-61	isb	OP-10	pbrstid	M-380	qg	OP-27
a4l	M-220	ise	OP-4	pd	I-21	qgb_ov	OP-35
a4o	M-219	isnoisy	I-31	pgat	M-308	qgd_ov	OP-32

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absorce I-12	ivthl M-602	phigbotd M-350	qjun_s OP-36
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cdb	OP-56	lp_betn	O-20	plthesat	M-465	sigd	OP-95
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cfr	M-82	lp_cgidld	O-64	plwalp	M-487	stbetlw	M-163
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cfrdw	M-240	lp_cgovd	O-67	plwalp2	M-495	stbetw	M-162
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cgg	OP-58	lp_feta	O-30	plwcox	M-545	stfbbtbotd	M-373
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cjorgat	M-302	lp_rbulk	O-77	plwstbet	M-438	stvfb	M-17
cjorgatd	M-343	lp_rg	O-76	plwstthesat	M-471	stvfb1	M-110
cjorsti	M-301	lp_rjund	O-80	plwstvfb	M-394	stvfb1w	M-112
cjorstid	M-342	lp_rjuns	O-79	plwthesat	M-467	stvfb0	M-109
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dta	M-248	lx19	OP-115	ponp	M-408	vbrgat	M-337
dwq	M-104	lx2	OP-108	ponslp	M-402	vbrgatd	M-378
ef	M-88	lx20	OP-117	pors	M-457	vbrsti	M-336
efo	M-245	lx21	OP-119	porsb	M-462	vbrstid	M-377
epsrox	M-19	lx22	OP-118	porsg	M-463	vbs	OP-99

Virtuoso Simulator Components and Device Models Reference

PSP102 Model

epsroxo	M-114	1x23	OP-120	posta2	M-502	vbs_max	M-261
factuo	I-11	1x28	OP-123	postbet	M-435	vds	OP-38
fbtrbot	M-329	1x29	OP-124	postbgidl	M-538	vds_max	M-257
fbtrbotd	M-370	1x3	OP-107	postbgidld	M-539	vdss	OP-45
fbtrgat	M-331	1x32	OP-113	postcs	M-450	vearly	OP-83
fbtrgatd	M-372	1x33	OP-112	postig	M-524	version	M-11
fbtrsti	M-330	1x34	OP-114	postmue	M-443	vfb	M-16
fbtrstid	M-371	1x38	OP-125	postrs	M-461	vfb1	M-106
fbet1	M-151	1x39	OP-126	postthemu	M-445	vfb1w	M-108
fbet1w	M-152	1x4	OP-106	postthesat	M-468	vfb0	M-105
fbet2	M-155	1x47	OP-131	postvfb	M-391	vfbw	M-107
feta	M-43	1x5	OP-121	postxcor	M-455	vgb_max	M-262
fetao	M-180	1x58	OP-134	pothemu	M-444	vgbr_max	M-265
fjunq	M-384	1x59	OP-133	pothesat	M-464	vgd_max	M-258
fjunqd	M-386	1x6	OP-122	pothesatb	M-472	vgdr_max	M-263
fknee	OP-93	1x60	OP-132	pothesatg	M-476	vgs	OP-39
fnt	M-84	1x66	OP-127	potox	M-395	vgs_max	M-259
fnto	M-241	1x67	OP-128	potoxov	M-416	vgsr_max	M-264
fol1	M-123	1x68	OP-129	potoxovd	M-417	vgt	OP-44
fol2	M-124	1x7	OP-109	povfb	M-387	vjunref	M-383
fug	OP-85	1x8	OP-110	povnsub	M-401	vjunrefd	M-385

Virtuoso Simulator Components and Device Models Reference

PSP102 Model

gc2	M-67	lx83	OP-138	povp	M-496	vnsb	M-21
gc2o	M-227	lx84	OP-139	poxcor	M-451	vnsbo	M-125
gc3	M-68	lx9	OP-111	ps	I-19	vp	M-56
gc3o	M-228	m	I-30	psti	M-307	vpo	M-210
gco	M-62	mbe	M-597	pstid	M-348	vsat	OP-46
gcoo	M-222	mbeo	M-598	pwal	M-499	vsb	OP-40
gds	OP-50	mefftatbot	M-323	pwa3	M-505	vth	OP-43
geomod	M-12	mefftatbotd	M-364	pwa4	M-509	vthmod	M-599
gjd	OP-52	mefftatgat	M-325	pwagidl	M-530	vto	OP-41
gjs	OP-51	mefftatgatd	M-366	pwagidld	M-534	vts	OP-42
gm	OP-48	mefftatsti	M-324	pwalp	M-486	w	I-2
gmb	OP-49	mefftatstid	M-365	pwalp1	M-490	w	M-592
iavl	OP-16	mue	M-35	pwalp2	M-494	wbet	M-159
ibe	OP-7	mueo	M-164	pwax	M-482	web	M-296
idb	OP-9	muew	M-165	pwbetn	M-433	wec	M-297
ide	OP-6	mulid0	I-22	pwcf	M-428	weff	O-1
ids	OP-8	mult	I-24	pwcfrr	M-560	wkuo	M-283
idsatrbot	M-312	munqs	M-89	pwcfrrd	M-564	wkvtho	M-289
idsatrbotd	M-353	munqso	M-266	pwcgbov	M-556	wlod	M-278
idsatrgat	M-314	mvt	M-595	pwcgov	M-548	wlodkuo	M-286

Virtuoso Simulator Components and Device Models Reference

PSP102 Model

idsatrgatd M-355 mvto M-596 pwcgovd M-552 wlodvth M-292
idsatrsti M-313 neff M-20 pwcox M-544 wmax M-591

PSP MOSFET Model (psp1020)

This is SiMKit 4.0.1.

This device is supported withing altergroups.

This device is dynamically loaded from the shared object /vobs/spectre_dev/tools.lnx86/cmi/lib/5.0.doc/libphilips_sh.so.

Instance Definition

Name d g s b ModelName parameter=value ...

Instance Parameters

- | | | |
|----|----------------|--|
| 1 | $l=10e-6$ m | Design length. |
| 2 | $w=10e-6$ m | Design width. |
| 3 | $sa=0.0$ m | Distance between OD-edge and poly from one side. |
| 4 | $sb=0.0$ m | Distance between OD-edge and poly from other side. |
| 5 | $sd=0.0$ m | Distance between neighboring fingers. |
| 6 | $sca=0.0$ | Integral of the first distribution function for scattered well dopants. |
| 7 | $scb=0.0$ | Integral of the second distribution function for scattered well dopants. |
| 8 | $scc=0.0$ | Integral of the third distribution function for scattered well dopants. |
| 9 | $sc=0.0$ m | Distance between OD-edge and nearest well edge. |
| 10 | $delvto=0.0$ V | Threshold voltage shift parameter. |

Virtuoso Simulator Components and Device Models Reference

PSP102 Model

11	<code>factuo=1.0</code>	Zero-field mobility pre-factor.
12	<code>absource=1E-12 m²</code>	Bottom area of source junction.
13	<code>lssource=1E-6 m</code>	STI-edge length of source junction.
14	<code>lgsource=1E-6 m</code>	Gate-edge length of source junction.
15	<code>abdRAIN=1E-12 m²</code>	Bottom area of drain junction.
16	<code>lsdRAIN=1E-6 m</code>	STI-edge length of drain junction.
17	<code>lgdRAIN=1E-6 m</code>	Gate-edge length of drain junction.
18	<code>as=1E-12 m²</code>	Bottom area of source junction.
19	<code>ps=1E-6 m</code>	Perimeter of source junction.
20	<code>ad=1E-12 m²</code>	Bottom area of drain junction.
21	<code>pd=1E-6 m</code>	Perimeter of drain junction.
22	<code>mulid0=1</code>	Ids multiplier.
23	<code>mult=1.0</code>	Number of devices in parallel.
24	<code>nf=1.0</code>	Number of fingers.
25	<code>ngcon=1.0</code>	Number of gate contacts.
26	<code>xgw=1.0E-7 m</code>	Distance from the gate contact to the channel edge.
27	<code>trise=0.0 K</code>	Temperature rise from ambient.
28	<code>m=1.0</code>	Multiplicity factor.
29	<code>isnoisy=yes</code>	Should device generate noise. Possible values are <code>no</code> and <code>yes</code> .

Model Definition

model modelName psp1020 parameter=value ...

Virtuoso Simulator Components and Device Models Reference

PSP102 Model

Model Parameters

1	<code>level=102</code>	Model level.
2	<code>type=n</code>	Channel type parameter, n,NMOS p,PMOS. Possible values are n and p.
3	<code>tr=value of tnom C</code>	nominal (reference) temperature.
4	<code>swnqs=0</code>	Flag for NQS, 0,off, 1, 2, 3, 5, or 9,number of collocation points.
5	<code>swigate=0</code>	Flag for gate current, 0,turn off IG.
6	<code>swimpact=0</code>	Flag for impact ionization current, 0,turn off II.
7	<code>swgidl=0</code>	Flag for GIDL current, 0,turn off IGIDL.
8	<code>swjuncap=0</code>	Flag for juncap, 0,turn off juncap.
9	<code>swjunasym=0</code>	Flag for asymmetric junctions; 0,symmetric, 1,asymmetric.
10	<code>qmc=1.0</code>	Quantum-mechanical correction factor.
11	<code>version=102.32</code>	The available versions are 102.2, 102.21, 102.3, 102.32, 102.33, 102.34 and 102.40.
12	<code>geomod=1</code>	1 for geometrical model and 0 for electrical model.
13	<code>binmod=0</code>	1 for bin model and 0 for non-bin model.
14	<code>scalelev=102</code>	102 for local, 1020 for global model and 1021 for bin model.
15	<code>compatible=spectre</code>	for compatible. Possible values are spectre, spice2, spice3, cdsspice, hspice, spiceplus, eldo, sspice, and mica.
16	<code>lvaro=0.0 m</code>	Geom. independent difference between actual and programmed gate length.
17	<code>lvarl=0.0</code>	Length dependence of LVAR.

Virtuoso Simulator Components and Device Models Reference

PSP102 Model

18	$lvarw=0.0$	Width dependence of LVAR.
19	$lap=0.0$ m	Effective channel length reduction per side.
20	$wvaro=0.0$ m	Geom. independent difference between actual and programmed field-oxide opening.
21	$wvarl=0.0$	Length dependence of WVAR.
22	$wvarw=0.0$	Width dependence of WVAR.
23	$wot=0.0$ m	Effective channel width reduction per side.
24	$dlq=0.0$ m	Effective channel length reduction for CV.
25	$dwq=0.0$ m	Effective channel width reduction for CV.
26	$vfbo=(-1.0)$ V	Geometry-independent flat-band voltage at TR.
27	$vfbl=0.0$	Length dependence of flat-band voltage.
28	$vfbw=0.0$	Width dependence of flat-band voltage.
29	$vfblw=0.0$	Area dependence of flat-band voltage.
30	$stvfbo=5e-4$ V/K	Geometry-independent temperature dependence of VFB.
31	$stvfbl=0.0$	Length dependence of temperature dependence of VFB.
32	$stvfbw=0.0$	Width dependence of temperature dependence of VFB.
33	$stvfblw=0.0$	Area dependence of temperature dependence of VFB.
34	$tox=2e-9$ m	Gate oxide thickness.
35	$epsrox=3.9$	Relative permittivity of gate dielectric.
36	$nsub=3e23$ m ⁻³	Geometry independent substrate doping.
37	$nsubw=0.0$	Width dependence of background doping NSUBO due to segregation.
38	$wseg=1e-8$ m	Char. length of segregation of background doping NSUBO.

Virtuoso Simulator Components and Device Models Reference

PSP102 Model

39	$npck=1e24 \text{ m}^{-3}$	Pocket doping level.
40	$npckw=0.0$	Width dependence of pocket doping NPCK due to segregation.
41	$wsegp=1e-8 \text{ m}$	Char. length of segregation of pocket doping NPCK.
42	$lpck=1e-8 \text{ m}$	Char. length of lateral doping profile.
43	$lpckw=0.0$	Width dependence of char. length of lateral doping profile.
44	$f_{ol1}=0.0$	First length dependence coefficient for short channel body effect.
45	$f_{ol2}=0.0$	Second length dependence coefficient for short channel body effect.
46	$vnsubo=0.0 \text{ V}$	Effective doping bias-dependence parameter.
47	$nslpo=0.05 \text{ V}$	Effective doping bias-dependence parameter.
48	$dnsubo=0.0 \text{ V}^{-1}$	Effective doping bias-dependence parameter.
49	$dphibo=0.0 \text{ V}$	Geometry independent offset of PHIB.
50	$dphibl=0.0 \text{ V}$	Length dependence offset of PHIB.
51	$dphiblexp=1.0$	Exponent for length dependence of offset of PHIB.
52	$dphibw=0.0$	Width dependence of offset of PHIB.
53	$dphiblw=0.0$	Area dependence of offset of PHIB.
54	$np0=1e26 \text{ m}^{-3}$	Geometry-independent gate poly-silicon doping.
55	$np1=0.0$	Length dependence of gate poly-silicon doping.
56	$cto=0.0$	Geometry-independent interface states factor.
57	$ctl=0.0$	Length dependence of interface states factor.
58	$ctlexp=1.0$	Exponent for length dependence of interface states factor.
59	$ctw=0.0$	Width dependence of interface states factor.

Virtuoso Simulator Components and Device Models Reference

PSP102 Model

60	$ctlw=0.0$	Area dependence of interface states factor.
61	$toxovo=2e-9$ m	Overlap oxide thickness.
62	$toxovdo=2e-9$ m	Overlap oxide thickness for drain side.
63	$lov=0$ m	Overlap length for gate/drain and gate/source overlap capacitance.
64	$lovd=0$ m	Overlap length for gate/drain overlap capacitance.
65	$novo=5e25$ m ⁻³	Effective doping of overlap region.
66	$novdo=5e25$ m ⁻³	Effective doping of overlap region for drain side.
67	$cfl=0.0$	Length dependence of DIBL-parameter.
68	$cfl_{exp}=2.0$	Exponent for length dependence of CF.
69	$cfw=0.0$	Width dependence of CF.
70	$cfbo=0.0$ V ⁻¹	Back-bias dependence of CF.
71	$uo=5e-2$ m ² /V/s	Zero-field mobility at TR.
72	$fbet1=0.0$	Relative mobility decrease due to first lateral profile.
73	$fbet1w=0.0$	Width dependence of relative mobility decrease due to first lateral profile.
74	$lp1=1e-8$ m	Mobility-related characteristic length of first lateral profile.
75	$lp1w=0.0$	Width dependence of mobility-related characteristic length of first lateral profile.
76	$fbet2=0.0$	Relative mobility decrease due to second lateral profile.
77	$lp2=1e-8$ m	Mobility-related characteristic length of second lateral profile.
78	$betw1=0.0$	First higher-order width scaling coefficient of BETN.
79	$betw2=0.0$	Second higher-order width scaling coefficient of BETN.

Virtuoso Simulator Components and Device Models Reference

PSP102 Model

80	<code>wbet=1e-9 m</code>	Characteristic width for width scaling of BETN.
81	<code>stbeto=1.0</code>	Geometry independent temperature dependence of BETN.
82	<code>stbetl=0.0</code>	Length dependence of temperature dependence of BETN.
83	<code>stbetw=0.0</code>	Width dependence of temperature dependence of BETN.
84	<code>stbetlw=0.0</code>	Area dependence of temperature dependence of BETN.
85	<code>mueo=0.5 m/V</code>	Geometry independent mobility reduction coefficient at TR.
86	<code>muew=0.0</code>	Width dependence of mobility reduction coefficient at TR.
87	<code>stmueo=0.0</code>	Temperature dependence of MUE.
88	<code>themuo=1.5</code>	Mobility reduction exponent at TR.
89	<code>stthemuo=1.5</code>	Temperature dependence of THEMU.
90	<code>cso=0.0</code>	Geometry independent coulomb scattering parameter at TR.
91	<code>csl=0.0</code>	Length dependence of CS.
92	<code>cslexp=0.0</code>	Exponent for length dependence of CS.
93	<code>csw=0.0</code>	Width dependence of CS.
94	<code>cslw=0.0</code>	Area dependence of CS.
95	<code>stcso=0.0</code>	Temperature dependence of CS.
96	<code>xcoro=0.0 V⁻¹</code>	Geometry independent non-universality parameter.
97	<code>xcorl=0.0</code>	Length dependence of non-universality parameter.
98	<code>xcorw=0.0</code>	Width dependence of non-universality parameter.
99	<code>xcorlw=0.0</code>	Area dependence of non-universality parameter.
100	<code>stxcoro=0.0</code>	Temperature dependence of XCOR.
101	<code>fetao=1.0</code>	Effective field parameter.

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PSP102 Model

102	$rsw1=2.5e3 \ \Omega$	Source/drain series resistance for 1 um wide channel at TR.
103	$rsw2=0.0$	Higher-order width scaling of RS.
104	$strso=1.0$	Temperature dependence of RS.
105	$rsbo=0.0 \ V^{-1}$	Back-bias dependence of series resistance.
106	$rsgo=0.0 \ V^{-1}$	Gate-bias dependence of series resistance.
107	$thesato=0.0 \ V^{-1}$	Geometry independent velocity saturation parameter at TR.
108	$thesatl=0.05 \ V^{-1}$	Length dependence of THESAT.
109	$thesatlexp=1.0$	Exponent for length dependence of THESAT.
110	$thesatw=0.0$	Width dependence of velocity saturation parameter.
111	$thesatlw=0.0$	Area dependence of velocity saturation parameter.
112	$stthesato=1.0$	Geometry independent temperature dependence of THESAT.
113	$stthesatl=0.0$	Length dependence of temperature dependence of THESAT.
114	$stthesatw=0.0$	Width dependence of temperature dependence of THESAT.
115	$stthesatlw=0.0$	Area dependence of temperature dependence of THESAT.
116	$thesatbo=0.0 \ V^{-1}$	Back-bias dependence of velocity saturation.
117	$thesatgo=0.0 \ V^{-1}$	Gate-bias dependence of velocity saturation.
118	$axo=18$	Geometry independent linear/saturation transition factor.
119	$axl=0.4$	Length dependence of AX.
120	$alp1=5e-4$	Length dependence of ALP.
121	$alplexp=1.0$	Exponent for length dependence of ALP.
122	$alpw=0.0$	Width dependence of ALP.

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PSP102 Model

123	$\text{alp1l1}=0.0 \text{ V}$	Length dependence of CLM enhancement factor above threshold.
124	$\text{alp1lexp}=0.5$	Exponent for length dependence of ALP1.
125	$\text{alp1l2}=0.0$	Second_order length dependence of ALP1.
126	$\text{alp1w}=0.0$	Width dependence of ALP1.
127	$\text{alp2l1}=0.0 \text{ V}^{-1}$	Length dependence of CLM enhancement factor below threshold.
128	$\text{alp2lexp}=0.5$	Exponent for length dependence of ALP2.
129	$\text{alp2l2}=0.0$	Second_order length dependence of ALP2.
130	$\text{alp2w}=0.0$	Width dependence of ALP2.
131	$\text{vpo}=0.05 \text{ V}$	CLM logarithmic dependence parameter.
132	$\text{a1o}=1.0$	Geometry independent impact-ionization pre-factor.
133	$\text{a1l}=0.0$	Length dependence of A1.
134	$\text{a1w}=0.0$	Width dependence of A1.
135	$\text{a2o}=10 \text{ V}$	Impact-ionization exponent at TR.
136	$\text{sta2o}=0.0 \text{ V}$	Temperature dependence of A2.
137	$\text{a3o}=1.0$	Geometry independent saturation-voltage dependence of II.
138	$\text{a3l}=0.0$	Length dependence of A3.
139	$\text{a3w}=0.0$	Width dependence of A3.
140	$\text{a4o}=0.0 \text{ V}^{-0.5}$	Geometry independent back-bias dependence of II.
141	$\text{a4l}=0.0$	Length dependence of A4.
142	$\text{a4w}=0.0$	Width dependence of A4.
143	$\text{gcoo}=0.0$	Gate tunnelling energy adjustment.

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144	<code>iginv1w=0.0 A</code>	Gate channel current pre-factor for 1 μm^2 channel area.
145	<code>igovw=0.0 A</code>	Gate overlap current pre-factor for 1 μm wide channel.
146	<code>igovdw=0.0 A</code>	Gate overlap current pre-factor for 1 μm wide channel for drain side.
147	<code>stigo=2.0</code>	Temperature dependence of IGINV and IGOV.
148	<code>gc2o=0.375</code>	Gate current slope factor.
149	<code>gc3o=0.063</code>	Gate current curvature factor.
150	<code>chibo=3.1 V</code>	Tunnelling barrier height.
151	<code>agidlw=0.0 A/V³</code>	Width dependence of GIDL pre-factor.
152	<code>agidldw=0.0 A/V³</code>	Width dependence of GIDL pre-factor for drain side.
153	<code>bgidlo=41 V</code>	GIDL probability factor at TR.
154	<code>bgidldo=41 V</code>	GIDL probability factor at TR for drain side.
155	<code>stbgidlo=0.0 V/K</code>	Temperature dependence of BGIDL.
156	<code>stbgidldo=0.0 V/K</code>	Temperature dependence of BGIDL for drain side.
157	<code>cgidlo=0.0</code>	Back-bias dependence of GIDL.
158	<code>cgidldo=0.0</code>	Back-bias dependence of GIDL for drain side.
159	<code>cgbovl=0.0 F</code>	Oxide capacitance for gate-bulk overlap for 1 μm long channel.
160	<code>cfrw=0.0 F</code>	Outer fringe capacitance for 1 μm wide channel.
161	<code>cfrdw=0.0 F</code>	Outer fringe capacitance for 1 μm wide channel for drain side.
162	<code>fnto=1.0</code>	Thermal noise coefficient.
163	<code>nfalw=8e22 V⁻¹/m⁴</code>	First coefficient of flicker noise for 1 μm^2 channel area.

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164	$nfb1w=3e7 \text{ V}^{-1}/\text{m}^2$	Second coefficient of flicker noise for 1 μm^2 channel area.
165	$nfclw=0.0 \text{ V}^{-1}$	Third coefficient of flicker noise for 1 μm^2 channel area.
166	$efo=1.0$	Flicker noise frequency exponent.
167	$lintnoi=0.0 \text{ m}$	Length offset for flicker noise.
168	$alpnoi=2.0$	Exponent for length offset for flicker noise.
169	$dta=0 \text{ K}$	Temperature offset w.r.t. ambient circuit temperature.
170	$kvthoweo=0$	Geometrical independent threshold shift parameter.
171	$kvthowel=0$	Length dependent threshold shift parameter.
172	$kvthowew=0$	Width dependent threshold shift parameter.
173	$kvthowelw=0$	Area dependent threshold shift parameter.
174	$kuoweo=0$	Geometrical independent mobility degradation factor.
175	$kuowel=0$	Length dependent mobility degradation factor.
176	$kuowew=0$	Width dependent mobility degradation factor.
177	$kuowelw=0$	Area dependent mobility degradation factor.
178	$vds_max=\infty \text{ V}$	Maximum allowed voltage cross source and drain.
179	$vgd_max=\infty \text{ V}$	Maximum allowed voltage cross gate and drain.
180	$vgs_max=\infty \text{ V}$	Maximum allowed voltage cross gate and source/bulk.
181	$vbd_max=\infty \text{ V}$	Maximum allowed voltage cross source/drain and bulk.
182	$vbs_max=\infty \text{ V}$	Maximum allowed voltage cross source and bulk.

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183	$v_{gb_max}=\infty$ V	Maximum allowed voltage cross gate and bulk.
184	$v_{gdr_max}=\infty$ V	Maximum allowed reverse voltage cross gate and drain.
185	$v_{gsr_max}=\infty$ V	Maximum allowed reverse voltage cross gate and source.
186	$v_{gbr_max}=\infty$ V	Maximum allowed reverse voltage cross gate and bulk.
187	$\mu_{nqso}=1.0$	Relative mobility for NQS modeling.
188	$r_{go}=0.0$ Ω	Gate resistance.
189	$r_{bulko}=0.0$ Ω	Bulk resistance between node BP and BI.
190	$r_{wello}=0.0$ Ω	Well resistance between node BI and B.
191	$r_{junso}=0.0$ Ω	Source-side bulk resistance between node BI and BS.
192	$r_{jundo}=0.0$ Ω	Drain-side bulk resistance between node BI and BD.
193	$r_{int}=0.0$ Ω/Sqr	Contact resistance between silicide and poly.
194	$r_{vpoly}=0.0$ Ω/Sqr	Vertical poly resistance.
195	$r_{shg}=0.0$ Ω/Sqr	Gate electrode diffusion sheet resistance.
196	$d_{lsil}=0.0$ m	Silicide extension over the physical gate length.
197	$s_{aref}=1.0e-6$ m	Reference distance between OD-edge and poly from one side.
198	$s_{bref}=1.0e-6$ m	Reference distance between OD-edge and poly from other side.
199	$w_{lod}=0$ m	Width parameter.
200	$k_{uo}=0$ m	Mobility degradation/enhancement coefficient.
201	$k_{vsat}=0$ m	Saturation velocity degradation/enhancement coefficient.

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202	$t_{kuo}=0$	Temperature dependence of KUO.
203	$l_{kuo}=0$ $m^{LLODKUO}$	Length dependence of KUO.
204	$w_{kuo}=0$ $m^{WLODKUO}$	Width dependence of KUO.
205	$p_{kuo}=0$ $m^{(LLODKUO+WLODKUO)}$	Cross-term dependence of KUO.
206	$l_{lodkuo}=0$	Length parameter for UO stress effect.
207	$w_{lodkuo}=0$	Width parameter for UO stress effect.
208	$k_{vtho}=0$ V_m	Threshold shift parameter.
209	$l_{kvtho}=0$ $m^{LLODVTH}$	Length dependence of KVTHO.
210	$w_{kvtho}=0$ $m^{WLODVTH}$	Width dependence of KVTHO.
211	$p_{kvtho}=0$ $m^{(LLODVTH+WLODVTH)}$	Cross-term dependence of KVTHO.
212	$l_{lodvth}=0$	Length parameter for VTH-stress effect.
213	$w_{lodvth}=0$	Width parameter for VTH-stress effect.
214	$s_{\eta_0}=0$ m	η_0 shift factor related to VTHO change.
215	$l_{od\eta_0}=1.0$	η_0 shift modification factor for stress effect.
216	$s_{cref}=10e-6$ m	Distance between OD-edge and well edge of a reference device.
217	$w_{eb}=0$	Coefficient for SCB.
218	$w_{ec}=0$	Coefficient for SCC.
219	$i_{max}=1000$ A	Maximum current up to which forward current behaves exponentially.
220	$t_{rj}=21$ C	reference temperature.

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- 221 $c_{jorbot}=1E-3 \text{ Fm}^{-2}$ Zero-bias capacitance per unit-of-area of bottom component for source-bulk junction.
- 222 $c_{jorsti}=1E-9 \text{ Fm}^{-1}$ Zero-bias capacitance per unit-of-length of STI-edge component for source-bulk junction.
- 223 $c_{jorgat}=1E-9 \text{ Fm}^{-1}$ Zero-bias capacitance per unit-of-length of gate-edge component for source-bulk junction.
- 224 $v_{birbot}=1 \text{ V}$ Built-in voltage at the reference temperature of bottom component for source-bulk junction.
- 225 $v_{birsti}=1 \text{ V}$ Built-in voltage at the reference temperature of STI-edge component for source-bulk junction.
- 226 $v_{birgat}=1 \text{ V}$ Built-in voltage at the reference temperature of gate-edge component for source-bulk junction.
- 227 $p_{bot}=0.5$ Grading coefficient of bottom component for source-bulk junction.
- 228 $p_{sti}=0.5$ Grading coefficient of STI-edge component for source-bulk junction.
- 229 $p_{gat}=0.5$ Grading coefficient of gate-edge component for source-bulk junction.
- 230 $\phi_{igbot}=1.16 \text{ V}$ Zero-temperature bandgap voltage of bottom component for source-bulk junction.
- 231 $\phi_{igsti}=1.16 \text{ V}$ Zero-temperature bandgap voltage of STI-edge component for source-bulk junction.
- 232 $\phi_{iggat}=1.16 \text{ V}$ Zero-temperature bandgap voltage of gate-edge component for source-bulk junction.
- 233 $i_{dsatrbot}=1E-12 \text{ Am}^{-2}$ Saturation current density at the reference temperature of bottom component for source-bulk junction.

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- 234 `idsatrsti=1E-18` Am^{-1} Saturation current density at the reference temperature of STI-edge component for source-bulk junction.
- 235 `idsatrgat=1E-18` Am^{-1} Saturation current density at the reference temperature of gate-edge component for source-bulk junction.
- 236 `csrbot=1E2` Am^{-3} Shockley-Read-Hall prefactor of bottom component for source-bulk junction.
- 237 `csrhisti=1E-4` Am^{-2} Shockley-Read-Hall prefactor of STI-edge component for source-bulk junction.
- 238 `csrhgat=1E-4` Am^{-2} Shockley-Read-Hall prefactor of gate-edge component for source-bulk junction.
- 239 `xjunsti=100E-9` m Junction depth of STI-edge component for source-bulk junction.
- 240 `xjungat=100E-9` m Junction depth of gate-edge component for source-bulk junction.
- 241 `ctatbot=1E2` Am^{-3} Trap-assisted tunneling prefactor of bottom component for source-bulk junction.
- 242 `ctatsti=1E-4` Am^{-2} Trap-assisted tunneling prefactor of STI-edge component for source-bulk junction.
- 243 `ctatgat=1E-4` Am^{-2} Trap-assisted tunneling prefactor of gate-edge component for source-bulk junction.
- 244 `mefftatbot=0.25` Effective mass (in units of m_0) for trap-assisted tunneling of bottom component for source-bulk junction.
- 245 `mefftatsti=0.25` Effective mass (in units of m_0) for trap-assisted tunneling of STI-edge component for source-bulk junction.
- 246 `mefftatgat=0.25` Effective mass (in units of m_0) for trap-assisted tunneling of gate-edge component for source-bulk junction.

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- 247 `cbbtbot=1E-12` AV^{-3}
Band-to-band tunneling prefactor of bottom component for source-bulk junction.
- 248 `cbbtsti=1E-18` AV_m^3
Band-to-band tunneling prefactor of STI-edge component for source-bulk junction.
- 249 `cbbtgat=1E-18` AV_m^3
Band-to-band tunneling prefactor of gate-edge component for source-bulk junction.
- 250 `fbbtbot=1E9` Vm^{-1}
Normalization field at the reference temperature for band-to-band tunneling of bottom component for source-bulk junction.
- 251 `fbbtsti=1E9` Vm^{-1}
Normalization field at the reference temperature for band-to-band tunneling of STI-edge component for source-bulk junction.
- 252 `fbbtgat=1E9` Vm^{-1}
Normalization field at the reference temperature for band-to-band tunneling of gate-edge component for source-bulk junction.
- 253 `stfbbtbot=(-1E-3)` K^{-1}
Temperature scaling parameter for band-to-band tunneling of bottom component for source-bulk junction.
- 254 `stfbbtsti=(-1E-3)` K^{-1}
Temperature scaling parameter for band-to-band tunneling of STI-edge component for source-bulk junction.
- 255 `stfbbtgat=(-1E-3)` K^{-1}
Temperature scaling parameter for band-to-band tunneling of gate-edge component for source-bulk junction.
- 256 `vbrbot=10` V
Breakdown voltage of bottom component for source-bulk junction.
- 257 `vbrsti=10` V
Breakdown voltage of STI-edge component for source-bulk junction.

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258	<code>vbrgat=10</code>	V	Breakdown voltage of gate-edge component for source-bulk junction.
259	<code>pbrbot=4</code>	V	Breakdown onset tuning parameter of bottom component for source-bulk junction.
260	<code>pbrsti=4</code>	V	Breakdown onset tuning parameter of STI-edge component for source-bulk junction.
261	<code>pbrgat=4</code>	V	Breakdown onset tuning parameter of gate-edge component for source-bulk junction.
262	<code>cjorbotd=1E-3</code>	Fm^{-2}	Zero-bias capacitance per unit-of-area of bottom component for drain-bulk junction.
263	<code>cjorstid=1E-9</code>	Fm^{-1}	Zero-bias capacitance per unit-of-length of STI-edge component for drain-bulk junction.
264	<code>cjorgatd=1E-9</code>	Fm^{-1}	Zero-bias capacitance per unit-of-length of gate-edge component for drain-bulk junction.
265	<code>vbirbotd=1</code>	V	Built-in voltage at the reference temperature of bottom component for drain-bulk junction.
266	<code>vbirstd=1</code>	V	Built-in voltage at the reference temperature of STI-edge component for drain-bulk junction.
267	<code>vbirgatd=1</code>	V	Built-in voltage at the reference temperature of gate-edge component for drain-bulk junction.
268	<code>pbotd=0.5</code>		Grading coefficient of bottom component for drain-bulk junction.
269	<code>pstid=0.5</code>		Grading coefficient of STI-edge component for drain-bulk junction.
270	<code>pgatd=0.5</code>		Grading coefficient of gate-edge component for drain-bulk junction.
271	<code>phigbotd=1.16</code>	V	Zero-temperature bandgap voltage of bottom component for drain-bulk junction.

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- 272 `phigstid=1.16` V Zero-temperature bandgap voltage of STI-edge component for drain-bulk junction.
- 273 `phiggatd=1.16` V Zero-temperature bandgap voltage of gate-edge component for drain-bulk junction.
- 274 `idsatrbotd=1E-12` Am^{-2} Saturation current density at the reference temperature of bottom component for drain-bulk junction.
- 275 `idsatrstid=1E-18` Am^{-1} Saturation current density at the reference temperature of STI-edge component for drain-bulk junction.
- 276 `idsatrgatd=1E-18` Am^{-1} Saturation current density at the reference temperature of gate-edge component for drain-bulk junction.
- 277 `csrbotd=1E2` Am^{-3} Shockley-Read-Hall prefactor of bottom component for drain-bulk junction.
- 278 `csrhostid=1E-4` Am^{-2} Shockley-Read-Hall prefactor of STI-edge component for drain-bulk junction.
- 279 `csrhgatd=1E-4` Am^{-2} Shockley-Read-Hall prefactor of gate-edge component for drain-bulk junction.
- 280 `xjunstid=100E-9` m Junction depth of STI-edge component for drain-bulk junction.
- 281 `xjungatd=100E-9` m Junction depth of gate-edge component for drain-bulk junction.
- 282 `ctatbotd=1E2` Am^{-3} Trap-assisted tunneling prefactor of bottom component for drain-bulk junction.
- 283 `ctatstid=1E-4` Am^{-2} Trap-assisted tunneling prefactor of STI-edge component for drain-bulk junction.

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- 284 $ctatgatd=1E-4 \text{ Am}^{-2}$ Trap-assisted tunneling prefactor of gate-edge component for drain-bulk junction.
- 285 $mefftatbotd=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of bottom component for drain-bulk junction.
- 286 $mefftatstid=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of STI-edge component for drain-bulk junction.
- 287 $mefftatgatd=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of gate-edge component for drain-bulk junction.
- 288 $cbbtbotd=1E-12 \text{ AV}^3$ Band-to-band tunneling prefactor of bottom component for drain-bulk junction.
- 289 $cbbtstid=1E-18 \text{ AV}^3_m$ Band-to-band tunneling prefactor of STI-edge component for drain-bulk junction.
- 290 $cbbtgatd=1E-18 \text{ AV}^3_m$ Band-to-band tunneling prefactor of gate-edge component for drain-bulk junction.
- 291 $fbbtrbotd=1E9 \text{ Vm}^{-1}$ Normalization field at the reference temperature for band-to-band tunneling of bottom component for drain-bulk junction.
- 292 $fbbtrstid=1E9 \text{ Vm}^{-1}$ Normalization field at the reference temperature for band-to-band tunneling of STI-edge component for drain-bulk junction.
- 293 $fbbtrgatd=1E9 \text{ Vm}^{-1}$ Normalization field at the reference temperature for band-to-band tunneling of gate-edge component for drain-bulk junction.
- 294 $stfbbtbotd=(-1E-3) \text{ K}^{-1}$ Temperature scaling parameter for band-to-band tunneling of bottom component for drain-bulk junction.

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295	$stfbbtstid=(-1E-3) K^{-1}$	Temperature scaling parameter for band-to-band tunneling of STI-edge component for drain-bulk junction.
296	$stfbbtgatd=(-1E-3) K^{-1}$	Temperature scaling parameter for band-to-band tunneling of gate-edge component for drain-bulk junction.
297	$vbrbotd=10 V$	Breakdown voltage of bottom component for drain-bulk junction.
298	$vbrstid=10 V$	Breakdown voltage of STI-edge component for drain-bulk junction.
299	$vbrgatd=10 V$	Breakdown voltage of gate-edge component for drain-bulk junction.
300	$pbrbotd=4 V$	Breakdown onset tuning parameter of bottom component for drain-bulk junction.
301	$pbrstid=4 V$	Breakdown onset tuning parameter of STI-edge component for drain-bulk junction.
302	$pbrgatd=4 V$	Breakdown onset tuning parameter of gate-edge component for drain-bulk junction.
303	$swjunexp=0.0$	Flag for JUNCAP-express; 0,full model, 1,express model.
304	$vjunref=2.5$	Typical maximum source-bulk junction voltage; usually about $2*VSUP$.
305	$fjunq=0.03$	Fraction below which source-bulk junction capacitance components are considered negligible.
306	$vjunrefd=2.5$	Typical maximum drain-bulk junction voltage; usually about $2*VSUP$.
307	$fjunqd=0.03$	Fraction below which drain-bulk junction capacitance components are considered negligible.
308	$mvto=0.0$	DCmatch parameter.
309	$mbeo=0.0$	DCmatch parameter.

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310	<code>vthmod</code>	Vth output selector. 'std' outputs model equation Vth. 'vthcc' outputs constant current Vth, and may impact simulation performance. The default value is taken from the options parameter 'vthmod'. Possible values are <code>std</code> and <code>vthcc</code> .
311	<code>ivth</code> (A)	Vth current parameter. The default value is taken from the options parameter 'ivthn' or 'ivthp', depending on the type of the model.
312	<code>ivthw</code> (m)	Width offset for constant current Vth. The default value is taken from the options parameter 'ivthw'.
313	<code>ivthl</code> (m)	Length offset for constant current Vth. The default value is taken from the options parameter 'ivthl'.
314	<code>ivth_vdsmin</code> (V)	Minimum Vds in constant current Vth calculating. The default value is taken from the options parameter 'ivth_vdsmin'.
315	<code>noisemethod=oldcmi</code>	Induced gate noise implementation . Possible values are <code>oldcmi</code> , <code>subckt</code> , and <code>newcmi</code> .

Output Parameters

1	<code>w_{eff}</code> (m)	Effective channel width for geometrical models.
2	<code>l_{eff}</code> (m)	Effective channel length for geometrical models.
3	<code>lv1</code> (m)	alias of l.
4	<code>lv2</code> (m)	alias of w.
5	<code>lv3</code> (m ²)	alias of ad.
6	<code>lv4</code> (m ²)	alias of as.
7	<code>lv11</code> (m)	alias of pd.
8	<code>lv12</code> (m)	alias of ps.

Operating-Point Parameters

1	<code>ctype</code>	Flag for channel type.
2	<code>sdint</code>	Flag for source-drain interchange.
3	<code>ise (A)</code>	Total source current.
4	<code>ige (A)</code>	Total gate current.
5	<code>ide (A)</code>	Total drain current.
6	<code>ibe (A)</code>	Total bulk current.
7	<code>ids (A)</code>	Drain current, excl. avalanche, tunnel, GISL, GIDL, and junction currents.
8	<code>idb (A)</code>	Drain to bulk current.
9	<code>isb (A)</code>	Source to bulk current.
10	<code>igs (A)</code>	Gate-source tunneling current.
11	<code>igd (A)</code>	Gate-drain tunneling current.
12	<code>igb (A)</code>	Gate-bulk tunneling current.
13	<code>igcs (A)</code>	Gate-channel tunneling current (source component).
14	<code>igcd (A)</code>	Gate-channel tunneling current (drain component).
15	<code>iavl (A)</code>	Substrate current due to weak avalanche.
16	<code>igisl (A)</code>	Gate-induced source leakage current.
17	<code>igidl (A)</code>	Gate-induced drain leakage current.
18	<code>ijs (A)</code>	Total source junction current.
19	<code>ijsbot (A)</code>	Source junction current (bottom component).
20	<code>ijsgat (A)</code>	Source junction current (gate-edge component).

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21	<code>ijssti</code> (A)	Source junction current (STI-edge component).
22	<code>ijd</code> (A)	Total drain junction current.
23	<code>ijdbot</code> (A)	Drain junction current (bottom component).
24	<code>ijdgat</code> (A)	Drain junction current (gate-edge component).
25	<code>ijdsti</code> (A)	Drain junction current (STI-edge component).
26	<code>qg</code> (Coul)	Intrinsic gate charge.
27	<code>qd</code> (Coul)	Intrinsic drain charge.
28	<code>qb</code> (Coul)	Intrinsic bulk charge.
29	<code>qs</code> (Coul)	Intrinsic source charge.
30	<code>qgs_ov</code> (Coul)	Overlap charge for gate-source.
31	<code>qgd_ov</code> (Coul)	Overlap charge for gate-drain.
32	<code>qfgs</code> (Coul)	Total outerFringe + overlap for gate-source.
33	<code>qfgd</code> (Coul)	Total outerFringe + overlap for gate-drain.
34	<code>qgb_ov</code> (Coul)	Gate-bulk overlap charge.
35	<code>qjun_s</code> (Coul)	Junction charge on source side.
36	<code>qjun_d</code> (Coul)	Junction charge on drain side.
37	<code>vds</code> (V)	Drain-source voltage.
38	<code>vgs</code> (V)	Gate-source voltage.
39	<code>vsb</code> (V)	Source-bulk voltage.
40	<code>vto</code> (V)	Zero-bias threshold voltage.
41	<code>vts</code> (V)	Threshold voltage including back bias effects.
42	<code>vth</code> (V)	Threshold voltage including back bias and drain bias effects.

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43	v_{gt} (V)	Effective gate drive voltage including back bias and drain bias effects.
44	v_{dss} (V)	Drain saturation voltage at actual bias.
45	v_{sat} (V)	Saturation limit.
46	p_{wr} (W)	Power at op point.
47	g_m ($1/\Omega$)	Transconductance.
48	g_{mb} ($1/\Omega$)	Substrate transconductance.
49	g_{ds} ($1/\Omega$)	Output conductance.
50	g_{js} ($1/\Omega$)	Source junction conductance.
51	g_{jd} ($1/\Omega$)	Drain junction conductance.
52	c_{dd} (F)	Drain capacitance.
53	c_{dg} (F)	Drain-gate capacitance.
54	c_{ds} (F)	Drain-source capacitance.
55	c_{db} (F)	Drain-bulk capacitance.
56	c_{gd} (F)	Gate-drain capacitance.
57	c_{gg} (F)	Gate capacitance.
58	c_{gs} (F)	Gate-source capacitance.
59	c_{gb} (F)	Gate-bulk capacitance.
60	c_{sd} (F)	Source-drain capacitance.
61	c_{sg} (F)	Source-gate capacitance.
62	c_{ss} (F)	Source capacitance.
63	c_{sb} (F)	Source-bulk capacitance.

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64	cbd (F)	Bulk-drain capacitance.
65	cbg (F)	Bulk-gate capacitance.
66	cbs (F)	Bulk-source capacitance.
67	cbb (F)	Bulk capacitance.
68	cgsol (F)	Total gate-source overlap capacitance.
69	cgdol (F)	Total gate-drain overlap capacitance.
70	cgbol (F)	Total gate-bulk overlap capacitance.
71	cjs (F)	Total source junction capacitance.
72	cjsbot (F)	Source junction capacitance (bottom component).
73	cjsgat (F)	Source junction capacitance (gate-edge component).
74	cjssti (F)	Source junction capacitance (STI-edge component).
75	cjd (F)	Total drain junction capacitance.
76	cjdbot (F)	Drain junction capacitance (bottom component).
77	cjdgat (F)	Drain junction capacitance (gate-edge component).
78	cjdsti (F)	Drain junction capacitance (STI-edge component).
79	lpoly (m)	
80	u	Transistor gain.
81	rout (Ω)	Small-signal output resistance.
82	vearly (V)	Equivalent Early voltage.
83	beff (A/V^2)	Gain factor.
84	fug (Hz)	Unity gain frequency at actual bias.
85	rg (Ω)	Gate resistance.

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86	sfl (A^2/Hz)	Flicker noise current spectral density at 1 Hz.
87	$sqrtsff$ (V/\sqrt{Hz})	Input-referred RMS white noise voltage spectral density at 1 kHz.
88	$sqrtsfw$ (V/\sqrt{Hz})	Input-referred RMS white noise voltage spectral density.
89	sid (A^2/Hz)	White noise current spectral density.
90	sig (A^2/Hz)	Induced gate noise current spectral density at 1 Hz.
91	$cigid$	Imaginary part of correlation coefficient between Sig and Sid.
92	$fknee$ (Hz)	Cross-over frequency above which white noise is dominant.
93	$sigs$ (A^2/Hz)	Gate-source current noise spectral density.
94	$sigd$ (A^2/Hz)	Gate-drain current noise spectral density.
95	$siavl$ (A^2/Hz)	Impact ionization current noise spectral density.
96	ssi (A^2/Hz)	Total source junction current noise spectral density.
97	sdi (A^2/Hz)	Total drain junction current noise spectral density.
98	vbs (V)	Bulk-source voltage.
99	$lv9$ (V)	alias of vth .
100	$lv10$ (V)	alias of $vdss$.
101	$lv36$ (F)	alias of $cgsol$.
102	$lv37$ (F)	alias of $cgdol$.
103	$lv38$ (F)	alias of $cgbol$.
104	$lv51$ (m)	alias of tox .
105	$lx4$ (A)	alias of ids .
106	$lx3$ (V)	alias of vds .

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107	1x2 (V)	alias of vgs.
108	1x7 ($1/\Omega$)	alias of gm.
109	1x8 ($1/\Omega$)	alias of gds.
110	1x9 ($1/\Omega$)	alias of gmb.
111	1x33 (F)	alias of cdd.
112	1x32 (F)	alias of cdg.
113	1x34 (F)	alias of cds.
114	1x19 (F)	alias of cgd.
115	1x18 (F)	alias of cgg.
116	1x20 (F)	alias of cgs.
117	1x22 (F)	alias of cbd.
118	1x21 (F)	alias of cbg.
119	1x23 (F)	alias of cbs.
120	1x5 (A)	alias of ijs.
121	1x6 (A)	alias of ijd.
122	1x28 (F)	alias of cjs.
123	1x29 (F)	alias of cjd.
124	1x38 (A)	alias of igs.
125	1x39 (A)	alias of igd.
126	1x66 (A)	alias of igb.
127	1x67 (A)	alias of igcs.
128	1x68 (A)	alias of igcd.

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129	1x110 (A)	alias of igisl.
130	1x47 (A)	alias of igidl.
131	1x60 (F)	alias of csd.
132	1x59 (F)	alias of csg.
133	1x58 (F)	alias of css.
134	1x12 (Coul)	alias of Qb including overlap charge.
135	1x14 (Coul)	alias of Qg including overlap charge.
136	1x16 (Coul)	alias of Qd including overlap charge.
137	1x83 (F)	alias of cgd including overlap cap.
138	1x84 (F)	alias of cgs including overlap cap.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

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beff OP-83	ide OP-5	mefftatsti M-245	swigate M-5
betw1 M-78	ids OP-7	mefftatstid M-286	swimpact M-6
betw2 M-79	idsatrbot M-233	mueo M-85	swjunasym M-9
bgidldo M-154	idsatrbotd M-274	muew M-86	swjuncap M-8
bgidlo M-153	idsatrgat M-235	mulid0 I-22	swjunexp M-303
binmod M-13	idsatrgatd M-276	mult I-23	swnqs M-4
cbb OP-67	idsatrsti M-234	munqso M-187	themuo M-88
cbbtbot M-247	idsatrstid M-275	mvto M-308	thesatbo M-116
cbbtbotd M-288	igb OP-12	nf I-24	thesatgo M-117
cbbtgat M-249	igcd OP-14	nfalw M-163	thesatl M-108
cbbtgatd M-290	igcs OP-13	nfblw M-164	thesatlexp M-109
cbbtsti M-248	igd OP-11	nfclw M-165	thesatlw M-111
cbbtstid M-289	ige OP-4	ngcon I-25	thesato M-107
cbd OP-64	igidl OP-17	noisemethod M-315	thesatw M-110
cbg OP-65	iginvlw M-144	novdo M-66	tkuo M-202
cbs OP-66	igisl OP-16	novo M-65	toxoxo M-34
cdb OP-55	igovdw M-146	npck M-39	toxovdo M-62
cdd OP-52	igovw M-145	npckw M-40	toxovo M-61

Virtuoso Simulator Components and Device Models Reference

PSP102 Model

cdg OP-53	igs OP-10	npl M-55	tr M-3
cds OP-54	ijd OP-22	npo M-54	trise I-27
cfbo M-70	ijdbot OP-23	nsipo M-47	trj M-220
cfl M-67	ijdgat OP-24	nsubo M-36	type M-2
cflexp M-68	ijdsti OP-25	nsubw M-37	u OP-80
cfrdw M-161	ijs OP-18	pbot M-227	uo M-71
cfrw M-160	ijsbot OP-19	pbotd M-268	vbd_max M-181
cfw M-69	ijsgat OP-20	pbrbot M-259	vbirbot M-224
cgb OP-59	ijssti OP-21	pbrbotd M-300	vbirbotd M-265
cgbol OP-70	imax M-219	pbrgat M-261	vbirgat M-226
cgbovl M-159	isb OP-9	pbrgatd M-302	vbirgatd M-267
cgd OP-56	ise OP-3	pbrsti M-260	vbirsti M-225
cgdol OP-69	isnoisy I-29	pbrstid M-301	vbirstid M-266
cgg OP-57	ivth M-311	pd I-21	vbrbot M-256
cgidldo M-158	ivth_vdsmin M-314	pgat M-229	vbrbotd M-297
cgidlo M-157	ivthl M-313	pgatd M-270	vbrgat M-258
cgs OP-58	ivthw M-312	phigbot M-230	vbrgatd M-299
cgsol OP-68	kuo M-200	phigbotd M-271	vbrsti M-257
chibo M-150	kuowel M-175	phiggat M-232	vbrstid M-298
cigid OP-91	kuowelw M-177	phiggatd M-273	vbs OP-98
cjd OP-75	kuoweo M-174	phigsti M-231	vbs_max M-182

Virtuoso Simulator Components and Device Models Reference

PSP102 Model

cjdbot	OP-76	kuowew	M-176	phigstid	M-272	vds	OP-37
cjdgat	OP-77	kvsat	M-201	pkuo	M-205	vds_max	M-178
cjdsti	OP-78	kvtho	M-208	pkvtho	M-211	vdss	OP-44
cjorbot	M-221	kvthowel	M-171	ps	I-19	vearly	OP-82
cjorbotd	M-262	kvthowelw	M-173	psti	M-228	version	M-11
cjorgat	M-223	kvthoweo	M-170	pstid	M-269	vfb1	M-27
cjorgatd	M-264	kvthowew	M-172	pwr	OP-46	vfb1w	M-29
cjorsti	M-222	l	I-1	qb	OP-28	vfbo	M-26
cjorstid	M-263	lap	M-19	qd	OP-27	vfbw	M-28
cjs	OP-71	leff	O-2	qfgd	OP-33	vgb_max	M-183
cjsbot	OP-72	level	M-1	qfgs	OP-32	vgbr_max	M-186
cjsgat	OP-73	lgdrain	I-17	qg	OP-26	vgd_max	M-179
cjssti	OP-74	lgsource	I-14	qgb_ov	OP-34	vgdr_max	M-184
compatible	M-15	lintnoi	M-167	qgd_ov	OP-31	vgs	OP-38
csb	OP-63	lkuo	M-203	qgs_ov	OP-30	vgs_max	M-180
csd	OP-60	lkvtho	M-209	qjun_d	OP-36	vgsr_max	M-185
csg	OP-61	llodkuo	M-206	qjun_s	OP-35	vgt	OP-43
cs1	M-91	llodvth	M-212	qmc	M-10	vjunref	M-304
cslexp	M-92	lodetao	M-215	qs	OP-29	vjunrefd	M-306
cs1w	M-94	lov	M-63	rbulko	M-189	vnsubo	M-46
cso	M-90	lovd	M-64	rg	OP-85	vpo	M-131

Virtuoso Simulator Components and Device Models Reference

PSP102 Model

csrbot	M-236	lp1	M-74	rgo	M-188	vsat	OP-45
csrbotd	M-277	lp1w	M-75	rint	M-193	vsb	OP-39
csrhat	M-238	lp2	M-77	rjundo	M-192	vth	OP-42
csrhatd	M-279	lpck	M-42	rjunso	M-191	vthmod	M-310
csrhti	M-237	lpckw	M-43	rout	OP-81	vto	OP-40
csrhtid	M-278	lpoly	OP-79	rsbo	M-105	vts	OP-41
css	OP-62	lsdrain	I-16	rsgo	M-106	w	I-2
csw	M-93	lssource	I-13	rshg	M-195	wbet	M-80
ctatbot	M-241	lv1	O-3	rsw1	M-102	web	M-217
ctatbotd	M-282	lv10	OP-100	rsw2	M-103	wec	M-218
ctatgat	M-243	lv11	O-7	rvpoly	M-194	weff	O-1
ctatgatd	M-284	lv12	O-8	rwello	M-190	wkuo	M-204
ctatsti	M-242	lv2	O-4	sa	I-3	wkvtho	M-210
ctatstid	M-283	lv3	O-5	saref	M-197	wlod	M-199
ctl	M-57	lv36	OP-101	sb	I-4	wlodkuo	M-207
ctlexp	M-58	lv37	OP-102	sbref	M-198	wlodvth	M-213
ctlw	M-60	lv38	OP-103	sc	I-9	wot	M-23
cto	M-56	lv4	O-6	sca	I-6	wseg	M-38
ctw	M-59	lv51	OP-104	scalelev	M-14	wsegp	M-41
ctype	OP-1	lv9	OP-99	scb	I-7	wvarl	M-21
delvto	I-10	lvarl	M-17	scc	I-8	wvaro	M-20

Virtuoso Simulator Components and Device Models Reference

PSP102 Model

dlq	M-24	lvaro	M-16	scref	M-216	wvarw	M-22
dlsil	M-196	lvarw	M-18	sd	I-5	xcorl	M-97
dnsubo	M-48	lx110	OP-129	sdi	OP-97	xcorlw	M-99
dphibl	M-50	lx12	OP-134	sdint	OP-2	xcoro	M-96
dphiblexp	M-51	lx14	OP-135	sfl	OP-86	xcorw	M-98
dphiblw	M-53	lx16	OP-136	siavl	OP-95	xgw	I-26
dphibo	M-49	lx18	OP-115	sid	OP-89	xjungat	M-240
dphibw	M-52	lx19	OP-114	sig	OP-90	xjungatd	M-281
dta	M-169	lx2	OP-107	sigd	OP-94	xjunsti	M-239
dwq	M-25	lx20	OP-116	sigs	OP-93	xjunstid	M-280
efo	M-166	lx21	OP-118	sqrtsff	OP-87		
epsroxo	M-35	lx22	OP-117	sqrtsfw	OP-88		

PSP MOSFET Model (psp1021)

This is SiMKit 4.0.1.

This device is supported within altergroups.

This device is dynamically loaded from the shared object /vobs/spectre_dev/tools.lnx86/cmi/lib/5.0.doc/libphilips_sh.so

Instance Definition

Name d g s b ModelName parameter=value ...

Instance Parameters

1 l=10e-6 m Design length.

Virtuoso Simulator Components and Device Models Reference

PSP102 Model

2	$w=10e-6$ m	Design width.
3	$sa=0.0$ m	Distance between OD-edge and poly from one side.
4	$sb=0.0$ m	Distance between OD-edge and poly from other side.
5	$sd=0.0$ m	Distance between neighboring fingers.
6	$sca=0.0$	Integral of the first distribution function for scattered well dopants.
7	$scb=0.0$	Integral of the second distribution function for scattered well dopants.
8	$scc=0.0$	Integral of the third distribution function for scattered well dopants.
9	$sc=0.0$ m	Distance between OD-edge and nearest well edge.
10	$delvto=0.0$ V	Threshold voltage shift parameter.
11	$factuo=1.0$	Zero-field mobility pre-factor.
12	$absource=1E-12$ m ²	Bottom area of source junction.
13	$lssource=1E-6$ m	STI-edge length of source junction.
14	$lgsource=1E-6$ m	Gate-edge length of source junction.
15	$abdRAIN=1E-12$ m ²	Bottom area of drain junction.
16	$lsdRAIN=1E-6$ m	STI-edge length of drain junction.
17	$lgdRAIN=1E-6$ m	Gate-edge length of drain junction.
18	$as=1E-12$ m ²	Bottom area of source junction.
19	$ps=1E-6$ m	Perimeter of source junction.
20	$ad=1E-12$ m ²	Bottom area of drain junction.
21	$pd=1E-6$ m	Perimeter of drain junction.

Virtuoso Simulator Components and Device Models Reference

PSP102 Model

22	<code>mulid0=1</code>	Ids multiplier.
23	<code>mult=1.0</code>	Number of devices in parallel.
24	<code>nf=1.0</code>	Number of fingers.
25	<code>ngcon=1.0</code>	Number of gate contacts.
26	<code>xgw=1.0E-7 m</code>	Distance from the gate contact to the channel edge.
27	<code>trise=0.0 K</code>	Temperature rise from ambient.
28	<code>m=1.0</code>	Multiplicity factor.
29	<code>isnoisy=yes</code>	Should device generate noise. Possible values are <code>no</code> and <code>yes</code> .

Model Definition

model modelName psp1021 parameter=value ...

Model Parameters

1	<code>level=102</code>	Model level.
2	<code>type=n</code>	Channel type parameter, n,NMOS p,PMOS. Possible values are <code>n</code> and <code>p</code> .
3	<code>tr=value of tnom C</code>	nominal (reference) temperature.
4	<code>swnqs=0</code>	Flag for NQS, 0,off, 1, 2, 3, 5, or 9,number of collocation points.
5	<code>swigate=0</code>	Flag for gate current, 0,turn off IG.
6	<code>swimpact=0</code>	Flag for impact ionization current, 0,turn off II.
7	<code>swgidl=0</code>	Flag for GIDL current, 0,turn off IGIDL.
8	<code>swjuncap=0</code>	Flag for juncap, 0,turn off juncap.
9	<code>swjunasym=0</code>	Flag for asymmetric junctions; 0,symmetric, 1,asymmetric.

Virtuoso Simulator Components and Device Models Reference

PSP102 Model

10	<code>qmc=1.0</code>	Quantum-mechanical correction factor.
11	<code>version=102.32</code>	The available versions are 102.2, 102.21, 102.3, 102.32, 102.33, 102.34 and 102.40.
12	<code>geomod=1</code>	1 for geometrical model and 0 for electrical model.
13	<code>binmod=0</code>	1 for bin model and 0 for non-bin model.
14	<code>scalelev=102</code>	102 for local, 1020 for global model and 1021 for bin model.
15	<code>compatible=spectre</code>	for compatible. Possible values are <code>spectre</code> , <code>spice2</code> , <code>spice3</code> , <code>cdsspice</code> , <code>hspice</code> , <code>spiceplus</code> , <code>eldo</code> , <code>sspice</code> , and <code>mica</code> .
16	<code>lvaro=0.0 m</code>	Geom. independent difference between actual and programmed gate length.
17	<code>lvarl=0.0</code>	Length dependence of LVAR.
18	<code>lap=0.0 m</code>	Effective channel length reduction per side.
19	<code>wvaro=0.0 m</code>	Geom. independent difference between actual and programmed field-oxide opening.
20	<code>wvarw=0.0</code>	Width dependence of WVAR.
21	<code>wot=0.0 m</code>	Effective channel width reduction per side.
22	<code>dlq=0.0 m</code>	Effective channel length reduction for CV.
23	<code>dwq=0.0 m</code>	Effective channel width reduction for CV.
24	<code>povfb=(-1) V</code>	Coefficient for the geometry independent part of VFB.
25	<code>plvfb=0.0 V</code>	Coefficient for the length dependence of VFB.
26	<code>pwvfb=0.0 V</code>	Coefficient for the width dependence of VFB.
27	<code>plwvfb=0.0 V</code>	Coefficient for the length times width dependence of VFB.

Virtuoso Simulator Components and Device Models Reference

PSP102 Model

28	<code>postvfb=0.0005 V/K</code>	Coefficient for the geometry independent part of STVFB.
29	<code>plstvfb=0.0 V/K</code>	Coefficient for the length dependence of STVFB.
30	<code>pwstvfb=0.0 V/K</code>	Coefficient for the width dependence of STVFB.
31	<code>plwstvfb=0.0 V/K</code>	Coefficient for the length times width dependence of STVFB.
32	<code>potox=2E-09 m</code>	Coefficient for the geometry independent part of TOX.
33	<code>poepsrox=3.9</code>	Coefficient for the geometry independent part of EPSOX.
34	<code>poneff=5E+23 m⁻³</code>	Coefficient for the geometry independent part of NEFF.
35	<code>plneff=0.0 m⁻³</code>	Coefficient for the length dependence of NEFF.
36	<code>pwneff=0.0 m⁻³</code>	Coefficient for the width dependence of NEFF.
37	<code>plwneff=0.0 m⁻³</code>	Coefficient for the length times width dependence of NEFF.
38	<code>povnsb=0 V</code>	Coefficient for the geometry independent part of VNSUB.
39	<code>ponslp=0.05 V</code>	Coefficient for the geometry independent part of NSLP.
40	<code>podnsb=0 V⁻¹</code>	Coefficient for the geometry independent part of DNSUB.
41	<code>podphib=0 V</code>	Coefficient for the geometry independent part of DPHIB.
42	<code>pldphib=0.0 V</code>	Coefficient for the length dependence of DPHIB.
43	<code>pwdphib=0.0 V</code>	Coefficient for the width dependence of DPHIB.
44	<code>plwdphib=0.0 V</code>	Coefficient for the length times width dependence of DPHIB.
45	<code>ponp=1E+26 m⁻³</code>	Coefficient for the geometry independent part of NP.
46	<code>plnp=0.0 m⁻³</code>	Coefficient for the length dependence of NP.
47	<code>pwnp=0.0 m⁻³</code>	Coefficient for the width dependence of NP.
48	<code>plwnp=0.0 m⁻³</code>	Coefficient for the length times width dependence of NP.

Virtuoso Simulator Components and Device Models Reference

PSP102 Model

49	$p_{oct}=0$	Coefficient for the geometry independent part of CT.
50	$p_{lct}=0.0$	Coefficient for the length dependence of CT.
51	$p_{wct}=0.0$	Coefficient for the width dependence of CT.
52	$p_{lwct}=0.0$	Coefficient for the length times width dependence of CT.
53	$p_{toxov}=2E-09 \text{ m}$	Coefficient for the geometry independent part of TOXOV.
54	$p_{toxovd}=2E-09 \text{ m}$	Coefficient for the geometry independent part of TOXOV for drain side.
55	$p_{onov}=5E+25 \text{ m}^{-3}$	Coefficient for the geometry independent part of NOV.
56	$p_{lnov}=0.0 \text{ m}^{-3}$	Coefficient for the length dependence of NOV.
57	$p_{wnov}=0.0 \text{ m}^{-3}$	Coefficient for the width dependence of NOV.
58	$p_{lwnov}=0.0 \text{ m}^{-3}$	Coefficient for the length times width dependence of NOV.
59	$p_{onovd}=5E+25 \text{ m}^{-3}$	Coefficient for the geometry independent part of NOV for drain side.
60	$p_{lnovd}=0.0 \text{ m}^{-3}$	Coefficient for the length dependence of NOV for drain side.
61	$p_{wnovd}=0.0 \text{ m}^{-3}$	Coefficient for the width dependence of NOV for drain side.
62	$p_{lwnovd}=0.0 \text{ m}^{-3}$	Coefficient for the length times width dependence of NOV for drain side.
63	$p_{ocf}=0$	Coefficient for the geometry independent part of CF.
64	$p_{lcf}=0.0$	Coefficient for the length dependence of CF.
65	$p_{wcf}=0.0$	Coefficient for the width dependence of CF.
66	$p_{lwcf}=0.0$	Coefficient for the length times width dependence of CF.
67	$p_{ocfb}=0 \text{ V}^{-1}$	Coefficient for the geometry independent part of CFB.
68	$p_{obetn}=0.07 \text{ m}^2/\text{V}/\text{s}$	Coefficient for the geometry independent part of BETN.

Virtuoso Simulator Components and Device Models Reference

PSP102 Model

69	$plbetn=0.0 \text{ m}^2/V/s$	Coefficient for the length dependence of BETN.
70	$pwbetn=0.0 \text{ m}^2/V/s$	Coefficient for the width dependence of BETN.
71	$plwbetn=0.0 \text{ m}^2/V/s$	Coefficient for the length times width dependence of BETN.
72	$postbet=1$	Coefficient for the geometry independent part of STBET.
73	$plstbet=0.0$	Coefficient for the length dependence of STBET.
74	$pwstbet=0.0$	Coefficient for the width dependence of STBET.
75	$plwstbet=0.0$	Coefficient for the length times width dependence of STBET.
76	$pomue=0.5 \text{ m}/V$	Coefficient for the geometry independent part of MUE.
77	$plmue=0.0 \text{ m}/V$	Coefficient for the length dependence of MUE.
78	$pwmue=0.0 \text{ m}/V$	Coefficient for the width dependence of MUE.
79	$plwmue=0.0 \text{ m}/V$	Coefficient for the length times width dependence of MUE.
80	$postmue=0$	Coefficient for the geometry independent part of STMUE.
81	$pothemu=1.5$	Coefficient for the geometry independent part of THEMU.
82	$postthemu=1.5$	Coefficient for the geometry independent part of STTHEMU.
83	$pocs=0$	Coefficient for the geometry independent part of CS.
84	$plcs=0.0$	Coefficient for the length dependence of CS.
85	$pwcs=0.0$	Coefficient for the width dependence of CS.
86	$plwcs=0.0$	Coefficient for the length times width dependence of CS.
87	$postcs=0$	Coefficient for the geometry independent part of STCS.
88	$poxcor=0 \text{ V}^{-1}$	Coefficient for the geometry independent part of XCOR.

Virtuoso Simulator Components and Device Models Reference

PSP102 Model

89	$plxcor=0.0 V^{-1}$	Coefficient for the length dependence of XCOR.
90	$pwxcor=0.0 V^{-1}$	Coefficient for the width dependence of XCOR.
91	$plwxcor=0.0 V^{-1}$	Coefficient for the length times width dependence of XCOR.
92	$postxcor=0$	Coefficient for the geometry independent part of STXCOR.
93	$pofeta=1$	Coefficient for the geometry independent part of FETA.
94	$pors=30 \Omega$	Coefficient for the geometry independent part of RS.
95	$plrs=0.0 \Omega$	Coefficient for the length dependence of RS.
96	$pwrS=0.0 \Omega$	Coefficient for the width dependence of RS.
97	$plwrs=0.0 \Omega$	Coefficient for the length times width dependence of RS.
98	$postrs=1$	Coefficient for the geometry independent part of STRS.
99	$porsb=0 V^{-1}$	Coefficient for the geometry independent part of RSB.
100	$porsg=0 V^{-1}$	Coefficient for the geometry independent part of RSG.
101	$pothesat=1 V^{-1}$	Coefficient for the geometry independent part of THESAT.
102	$plthesat=0.0 V^{-1}$	Coefficient for the length dependence of THESAT.
103	$pwthesat=0.0 V^{-1}$	Coefficient for the width dependence of THESAT.
104	$plwthesat=0.0 V^{-1}$	Coefficient for the length times width dependence of THESAT.
105	$postthesat=1$	Coefficient for the geometry independent part of STTHESAT.
106	$plstthesat=0.0$	Coefficient for the length dependence of STTHESAT.
107	$pwstthesat=0.0$	Coefficient for the width dependence of STTHESAT.
108	$plwstthesat=0.0$	Coefficient for the length times width dependence of STTHESAT.
109	$pothesatb=0 V^{-1}$	Coefficient for the geometry independent part of THESATB.

Virtuoso Simulator Components and Device Models Reference

PSP102 Model

- 110 $plthesatb=0.0 V^{-1}$ Coefficient for the length dependence of THESATB.
- 111 $pwthesatb=0.0 V^{-1}$ Coefficient for the width dependence of THESATB.
- 112 $plwthesatb=0.0 V^{-1}$ Coefficient for the length times width dependence of THESATB.
- 113 $pothesatg=0 V^{-1}$ Coefficient for the geometry independent part of THESATG.
- 114 $plthesatg=0.0 V^{-1}$ Coefficient for the length dependence of THESATG.
- 115 $pwthesatg=0.0 V^{-1}$ Coefficient for the width dependence of THESATG.
- 116 $plwthesatg=0.0 V^{-1}$ Coefficient for the length times width dependence of THESATG.
- 117 $poax=3$ Coefficient for the geometry independent part of AX.
- 118 $plax=0.0$ Coefficient for the length dependence of AX.
- 119 $pwax=0.0$ Coefficient for the width dependence of AX.
- 120 $plwax=0.0$ Coefficient for the length times width dependence of AX.
- 121 $poalp=0.01$ Coefficient for the geometry independent part of ALP.
- 122 $plalp=0.0$ Coefficient for the length dependence of ALP.
- 123 $pwalp=0.0$ Coefficient for the width dependence of ALP.
- 124 $plwalp=0.0$ Coefficient for the length times width dependence of ALP.
- 125 $poalp1=0 V$ Coefficient for the geometry independent part of ALP1.
- 126 $plalp1=0.0 V$ Coefficient for the length dependence of ALP1.
- 127 $pwalp1=0.0 V$ Coefficient for the width dependence of ALP1.
- 128 $plwalp1=0.0 V$ Coefficient for the length times width dependence of ALP1.

Virtuoso Simulator Components and Device Models Reference

PSP102 Model

129	$p_{oa1p2}=0 \ V^{-1}$	Coefficient for the geometry independent part of ALP2.
130	$p_{la1p2}=0.0 \ V^{-1}$	Coefficient for the length dependence of ALP2.
131	$p_{wa1p2}=0.0 \ V^{-1}$	Coefficient for the width dependence of ALP2.
132	$p_{lwa1p2}=0.0 \ V^{-1}$	Coefficient for the length times width dependence of ALP2.
133	$p_{ovp}=0.05 \ V$	Coefficient for the geometry independent part of VP.
134	$p_{oa1}=1$	Coefficient for the geometry independent part of A1.
135	$p_{la1}=0.0$	Coefficient for the length dependence of A1.
136	$p_{wa1}=0.0$	Coefficient for the width dependence of A1.
137	$p_{lwa1}=0.0$	Coefficient for the length times width dependence of A1.
138	$p_{oa2}=10 \ V$	Coefficient for the geometry independent part of A2.
139	$p_{osta2}=0 \ V$	Coefficient for the geometry independent part of STA2.
140	$p_{oa3}=1$	Coefficient for the geometry independent part of A3.
141	$p_{la3}=0.0$	Coefficient for the length dependence of A3.
142	$p_{wa3}=0.0$	Coefficient for the width dependence of A3.
143	$p_{lwa3}=0.0$	Coefficient for the length times width dependence of A3.
144	$p_{oa4}=0 \ V^{-0.5}$	Coefficient for the geometry independent part of A4.
145	$p_{la4}=0.0 \ V^{-0.5}$	Coefficient for the length dependence of A4.
146	$p_{wa4}=0.0 \ V^{-0.5}$	Coefficient for the width dependence of A4.
147	$p_{lwa4}=0.0 \ V^{-0.5}$	Coefficient for the length times width dependence of A4.
148	$p_{ogco}=0$	Coefficient for the geometry independent part of GCO.
149	$p_{oiginv}=0 \ A$	Coefficient for the geometry independent part of IGINV.
150	$p_{liginv}=0.0 \ A$	Coefficient for the length dependence of IGINV.

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151	$pwiginv=0.0$	A	Coefficient for the width dependence of IGINV.
152	$plwiginv=0.0$	A	Coefficient for the length times width dependence of IGINV.
153	$poigov=0$	A	Coefficient for the geometry independent part of IGOV.
154	$pligov=0.0$	A	Coefficient for the length dependence of IGOV.
155	$pwigov=0.0$	A	Coefficient for the width dependence of IGOV.
156	$plwigov=0.0$	A	Coefficient for the length times width dependence of IGOV.
157	$poigovd=0$	A	Coefficient for the geometry independent part of IGOV for drain side.
158	$pligovd=0.0$	A	Coefficient for the length dependence of IGOV for drain side.
159	$pwigovd=0.0$	A	Coefficient for the width dependence of IGOV for drain side.
160	$plwigovd=0.0$	A	Coefficient for the length times width dependence of IGOV for drain side.
161	$postig=2$		Coefficient for the geometry independent part of STIG.
162	$pogc2=0.375$		Coefficient for the geometry independent part of GC2.
163	$pogc3=0.063$		Coefficient for the geometry independent part of GC3.
164	$pochib=3.1$	V	Coefficient for the geometry independent part of CHIB.
165	$poagidl=0$	A/V^3	Coefficient for the geometry independent part of AGIDL.
166	$plagidl=0.0$	A/V^3	Coefficient for the length dependence of AGIDL.
167	$pwagidl=0.0$	A/V^3	Coefficient for the width dependence of AGIDL.
168	$plwagidl=0.0$	A/V^3	Coefficient for the length times width dependence of AGIDL.
169	$poagidd=0$	A/V^3	Coefficient for the geometry independent part of AGIDL for drain side.

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170	$p_{lagidld}=0.0$	A/V^3	Coefficient for the length dependence of AGIDL for drain side.
171	$p_{wagidld}=0.0$	A/V^3	Coefficient for the width dependence of AGIDL for drain side.
172	$p_{lwagidld}=0.0$	A/V^3	Coefficient for the length times width dependence of AGIDL for drain side.
173	$p_{obgidl}=41$	V	Coefficient for the geometry independent part of BGIDL.
174	$p_{obgidld}=41$	V	Coefficient for the geometry independent part of BGIDL for drain side.
175	$p_{ostbgidl}=0$	V/K	Coefficient for the geometry independent part of STBGIDL.
176	$p_{ostbgidld}=0$	V/K	Coefficient for the geometry independent part of STBGIDL for drain side.
177	$p_{ocgidl}=0$		Coefficient for the geometry independent part of CGIDL.
178	$p_{ocgidld}=0$		Coefficient for the geometry independent part of CGIDL for drain side.
179	$p_{ocox}=1E-14$	F	Coefficient for the geometry independent part of COX.
180	$p_{lcox}=0.0$	F	Coefficient for the length dependence of COX.
181	$p_{wcox}=0.0$	F	Coefficient for the width dependence of COX.
182	$p_{lwcox}=0.0$	F	Coefficient for the length times width dependence of COX.
183	$p_{ocgov}=1E-15$	F	Coefficient for the geometry independent part of CGOV.
184	$p_{lcgov}=0.0$	F	Coefficient for the length dependence of CGOV.
185	$p_{wcgov}=0.0$	F	Coefficient for the width dependence of CGOV.
186	$p_{lwcgov}=0.0$	F	Coefficient for the length times width dependence of CGOV.
187	$p_{ocgovd}=1E-15$	F	Coefficient for the geometry independent part of CGOV for drain side.

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188	$plcgovd=0.0$	F	Coefficient for the length dependence of CGOV for drain side.
189	$pwcgovd=0.0$	F	Coefficient for the width dependence of CGOV for drain side.
190	$plwcgovd=0.0$	F	Coefficient for the length times width dependence of CGOV for drain side.
191	$pocgbov=0$	F	Coefficient for the geometry independent part of CGBOV.
192	$plcgbov=0.0$	F	Coefficient for the length dependence of CGBOV.
193	$pwcgbov=0.0$	F	Coefficient for the width dependence of CGBOV.
194	$plwcgbov=0.0$	F	Coefficient for the length times width dependence of CGBOV.
195	$pocfr=0$	F	Coefficient for the geometry independent part of CFR.
196	$plcfr=0.0$	F	Coefficient for the length dependence of CFR.
197	$pwcfrr=0.0$	F	Coefficient for the width dependence of CFR.
198	$plwcfrr=0.0$	F	Coefficient for the length times width dependence of CFR.
199	$pocfrd=0$	F	Coefficient for the geometry independent part of CFR for drain side.
200	$plcfrd=0.0$	F	Coefficient for the length dependence of CFR for drain side.
201	$pwcfrrd=0.0$	F	Coefficient for the width dependence of CFR for drain side.
202	$plwcfrrd=0.0$	F	Coefficient for the length times width dependence of CFR for drain side.
203	$pofnt=1$		Coefficient for the geometry independent part of FNT.
204	$ponfa=8E+22$	V^{-1}/m^4	Coefficient for the geometry independent part of NFA.
205	$plnfa=0.0$	V^{-1}/m^4	Coefficient for the length dependence of NFA.
206	$pwnfa=0.0$	V^{-1}/m^4	Coefficient for the width dependence of NFA.

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207	$p_{lwnfa}=0.0 \text{ V}^{-1}/\text{m}^4$	Coefficient for the length times width dependence of NFA.
208	$p_{onfb}=3\text{E}+07 \text{ V}^{-1}/\text{m}^2$	Coefficient for the geometry independent part of NFB.
209	$p_{lnfb}=0.0 \text{ V}^{-1}/\text{m}^2$	Coefficient for the length dependence of NFB.
210	$p_{wnfb}=0.0 \text{ V}^{-1}/\text{m}^2$	Coefficient for the width dependence of NFB.
211	$p_{lwnfb}=0.0 \text{ V}^{-1}/\text{m}^2$	Coefficient for the length times width dependence of NFB.
212	$p_{onfc}=0 \text{ V}^{-1}$	Coefficient for the geometry independent part of NFC.
213	$p_{lnfc}=0.0 \text{ V}^{-1}$	Coefficient for the length dependence of NFC.
214	$p_{wnfc}=0.0 \text{ V}^{-1}$	Coefficient for the width dependence of NFC.
215	$p_{lwnfc}=0.0 \text{ V}^{-1}$	Coefficient for the length times width dependence of NFC.
216	$p_{oef}=1.0$	Coefficient for the flicker noise frequency exponent.
217	$d_{ta}=0 \text{ K}$	Temperature offset w.r.t. ambient circuit temperature.
218	$p_{okvthowe}=0$	Coefficient for the geometry independent part of KVTHOWE.
219	$p_{lkvthowe}=0$	Coefficient for the length dependence part of KVTHOWE.
220	$p_{wkvthowe}=0$	Coefficient for the width dependence part of KVTHOWE.
221	$p_{lwkvthowe}=0$	Coefficient for the length times width dependence part of KVTHOWE.
222	$p_{okuowe}=0$	Coefficient for the geometry independent part of KUOWE.
223	$p_{lkuowe}=0$	Coefficient for the length dependence part of KUOWE.
224	$p_{wkuowe}=0$	Coefficient for the width dependence part of KUOWE.

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225	<code>plwkuowe=0</code>	Coefficient for the length times width dependence part of KUOWE.
226	<code>lmin=0 m</code>	Dummy parameter to label binning set.
227	<code>lmax=1.0 m</code>	Dummy parameter to label binning set.
228	<code>wmin=0 m</code>	Dummy parameter to label binning set.
229	<code>wmax=1.0 m</code>	Dummy parameter to label binning set.
230	<code>vds_max=∞ V</code>	Maximum allowed voltage cross source and drain.
231	<code>vgd_max=∞ V</code>	Maximum allowed voltage cross gate and drain.
232	<code>vgs_max=∞ V</code>	Maximum allowed voltage cross gate and source/bulk.
233	<code>vbd_max=∞ V</code>	Maximum allowed voltage cross source/drain and bulk.
234	<code>vbs_max=∞ V</code>	Maximum allowed voltage cross source and bulk.
235	<code>vgb_max=∞ V</code>	Maximum allowed voltage cross gate and bulk.
236	<code>vgdr_max=∞ V</code>	Maximum allowed reverse voltage cross gate and drain.
237	<code>vgdr_max=∞ V</code>	Maximum allowed reverse voltage cross gate and source.
238	<code>vgbr_max=∞ V</code>	Maximum allowed reverse voltage cross gate and bulk.
239	<code>munqso=1.0</code>	Relative mobility for NQS modeling.
240	<code>rgo=0.0 Ω</code>	Gate resistance.
241	<code>rbulko=0.0 Ω</code>	Bulk resistance between node BP and BI.

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242	$r_{wello}=0.0 \ \Omega$	Well resistance between node BI and B.
243	$r_{junso}=0.0 \ \Omega$	Source-side bulk resistance between node BI and BS.
244	$r_{jundo}=0.0 \ \Omega$	Drain-side bulk resistance between node BI and BD.
245	$r_{int}=0.0 \ \Omega/Sqr$	Contact resistance between silicide and ploy.
246	$r_{vpoly}=0.0 \ \Omega/Sqr$	Vertical poly resistance.
247	$r_{shg}=0.0 \ \Omega/Sqr$	Gate electrode diffusion sheet resistance.
248	$d_{lsil}=0.0 \ m$	Silicide extension over the physical gate length.
249	$s_{aref}=1.0e-6 \ m$	Reference distance between OD-edge and poly from one side.
250	$s_{bref}=1.0e-6 \ m$	Reference distance between OD-edge and poly from other side.
251	$w_{lod}=0 \ m$	Width parameter.
252	$k_{uo}=0 \ m$	Mobility degradation/enhancement coefficient.
253	$k_{vsat}=0 \ m$	Saturation velocity degradation/enhancement coefficient.
254	$t_{kuo}=0$	Temperature dependence of KUO.
255	$l_{kuo}=0 \ m^{LLODKUO}$	Length dependence of KUO.
256	$w_{kuo}=0 \ m^{WLODKUO}$	Width dependence of KUO.
257	$p_{kuo}=0 \ m^{(LLODKUO+WLODKUO)}$	Cross-term dependence of KUO.
258	$l_{lodkuo}=0$	Length parameter for UO stress effect.
259	$w_{lodkuo}=0$	Width parameter for UO stress effect.
260	$k_{vtho}=0 \ Vm$	Threshold shift parameter.
261	$l_{kvtho}=0 \ m^{LLODVTH}$	Length dependence of KVTHO.

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262	$wkvtho=0 \text{ m}^{WLODVTH}$	Width dependence of KVTHO.
263	$pkvtho=0 \text{ m}^{(LLODVTH+WLODVTH)}$	Cross-term dependence of KVTHO.
264	$llodvth=0$	Length parameter for VTH-stress effect.
265	$wlodvth=0$	Width parameter for VTH-stress effect.
266	$stetao=0 \text{ m}$	eta0 shift factor related to VTHO change.
267	$lodetao=1.0$	eta0 shift modification factor for stress effect.
268	$scref=10e-6 \text{ m}$	Distance between OD-edge and well edge of a reference device.
269	$web=0$	Coefficient for SCB.
270	$wec=0$	Coefficient for SCC.
271	$imax=1000 \text{ A}$	Maximum current up to which forward current behaves exponentially.
272	$trj=21 \text{ C}$	reference temperature.
273	$cjorbot=1E-3 \text{ Fm}^{-2}$	Zero-bias capacitance per unit-of-area of bottom component for source-bulk junction.
274	$cjorsti=1E-9 \text{ Fm}^{-1}$	Zero-bias capacitance per unit-of-length of STI-edge component for source-bulk junction.
275	$cjorgat=1E-9 \text{ Fm}^{-1}$	Zero-bias capacitance per unit-of-length of gate-edge component for source-bulk junction.
276	$vbirbot=1 \text{ V}$	Built-in voltage at the reference temperature of bottom component for source-bulk junction.
277	$vbirsti=1 \text{ V}$	Built-in voltage at the reference temperature of STI-edge component for source-bulk junction.

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278	<code>vbirgat=1</code>	V	Built-in voltage at the reference temperature of gate-edge component for source-bulk junction.
279	<code>pbot=0.5</code>		Grading coefficient of bottom component for source-bulk junction.
280	<code>psti=0.5</code>		Grading coefficient of STI-edge component for source-bulk junction.
281	<code>pgat=0.5</code>		Grading coefficient of gate-edge component for source-bulk junction.
282	<code>phigbot=1.16</code>	V	Zero-temperature bandgap voltage of bottom component for source-bulk junction.
283	<code>phigsti=1.16</code>	V	Zero-temperature bandgap voltage of STI-edge component for source-bulk junction.
284	<code>phiggat=1.16</code>	V	Zero-temperature bandgap voltage of gate-edge component for source-bulk junction.
285	<code>idsatrbot=1E-12</code>	Am^{-2}	Saturation current density at the reference temperature of bottom component for source-bulk junction.
286	<code>idsatrsti=1E-18</code>	Am^{-1}	Saturation current density at the reference temperature of STI-edge component for source-bulk junction.
287	<code>idsatrgat=1E-18</code>	Am^{-1}	Saturation current density at the reference temperature of gate-edge component for source-bulk junction.
288	<code>csrbot=1E2</code>	Am^{-3}	Shockley-Read-Hall prefactor of bottom component for source-bulk junction.
289	<code>csrhisti=1E-4</code>	Am^{-2}	Shockley-Read-Hall prefactor of STI-edge component for source-bulk junction.
290	<code>csrhgat=1E-4</code>	Am^{-2}	Shockley-Read-Hall prefactor of gate-edge component for source-bulk junction.

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- 291 $x_{junsti}=100E-9$ m Junction depth of STI-edge component for source-bulk junction.
- 292 $x_{jungat}=100E-9$ m Junction depth of gate-edge component for source-bulk junction.
- 293 $ctatbot=1E2$ Am^{-3} Trap-assisted tunneling prefactor of bottom component for source-bulk junction.
- 294 $ctatsti=1E-4$ Am^{-2} Trap-assisted tunneling prefactor of STI-edge component for source-bulk junction.
- 295 $ctatgat=1E-4$ Am^{-2} Trap-assisted tunneling prefactor of gate-edge component for source-bulk junction.
- 296 $mefftatbot=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of bottom component for source-bulk junction.
- 297 $mefftatsti=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of STI-edge component for source-bulk junction.
- 298 $mefftatgat=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of gate-edge component for source-bulk junction.
- 299 $cbbtbot=1E-12$ AV^{-3} Band-to-band tunneling prefactor of bottom component for source-bulk junction.
- 300 $cbbtsti=1E-18$ $AV^{-3}m$ Band-to-band tunneling prefactor of STI-edge component for source-bulk junction.
- 301 $cbbtgat=1E-18$ $AV^{-3}m$ Band-to-band tunneling prefactor of gate-edge component for source-bulk junction.
- 302 $fbbtrbot=1E9$ Vm^{-1} Normalization field at the reference temperature for band-to-band tunneling of bottom component for source-bulk junction.
- 303 $fbbtrsti=1E9$ Vm^{-1} Normalization field at the reference temperature for band-to-band tunneling of STI-edge component for source-bulk junction.

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- 304 $fbttrgat=1E9 \text{ Vm}^{-1}$
Normalization field at the reference temperature for band-to-band tunneling of gate-edge component for source-bulk junction.
- 305 $stfbbtbot=(-1E-3) \text{ K}^{-1}$
Temperature scaling parameter for band-to-band tunneling of bottom component for source-bulk junction.
- 306 $stfbbtsti=(-1E-3) \text{ K}^{-1}$
Temperature scaling parameter for band-to-band tunneling of STI-edge component for source-bulk junction.
- 307 $stfbbtgat=(-1E-3) \text{ K}^{-1}$
Temperature scaling parameter for band-to-band tunneling of gate-edge component for source-bulk junction.
- 308 $vbrbot=10 \text{ V}$
Breakdown voltage of bottom component for source-bulk junction.
- 309 $vbrsti=10 \text{ V}$
Breakdown voltage of STI-edge component for source-bulk junction.
- 310 $vbrgat=10 \text{ V}$
Breakdown voltage of gate-edge component for source-bulk junction.
- 311 $pbrbot=4 \text{ V}$
Breakdown onset tuning parameter of bottom component for source-bulk junction.
- 312 $pbrsti=4 \text{ V}$
Breakdown onset tuning parameter of STI-edge component for source-bulk junction.
- 313 $pbrgat=4 \text{ V}$
Breakdown onset tuning parameter of gate-edge component for source-bulk junction.
- 314 $cjorbotd=1E-3 \text{ Fm}^{-2}$
Zero-bias capacitance per unit-of-area of bottom component for drain-bulk junction.
- 315 $cjorstid=1E-9 \text{ Fm}^{-1}$
Zero-bias capacitance per unit-of-length of STI-edge component for drain-bulk junction.

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- 316 $cjorgatd=1E-9$ Fm^{-1} Zero-bias capacitance per unit-of-length of gate-edge component for drain-bulk junction.
- 317 $vbirbotd=1$ V Built-in voltage at the reference temperature of bottom component for drain-bulk junction.
- 318 $vbirstid=1$ V Built-in voltage at the reference temperature of STI-edge component for drain-bulk junction.
- 319 $vbirgatd=1$ V Built-in voltage at the reference temperature of gate-edge component for drain-bulk junction.
- 320 $pbotd=0.5$ Grading coefficient of bottom component for drain-bulk junction.
- 321 $pstid=0.5$ Grading coefficient of STI-edge component for drain-bulk junction.
- 322 $pgatd=0.5$ Grading coefficient of gate-edge component for drain-bulk junction.
- 323 $phigbotd=1.16$ V Zero-temperature bandgap voltage of bottom component for drain-bulk junction.
- 324 $phigstid=1.16$ V Zero-temperature bandgap voltage of STI-edge component for drain-bulk junction.
- 325 $phiggatd=1.16$ V Zero-temperature bandgap voltage of gate-edge component for drain-bulk junction.
- 326 $idsatrbotd=1E-12$ Am^{-2} Saturation current density at the reference temperature of bottom component for drain-bulk junction.
- 327 $idsatrstid=1E-18$ Am^{-1} Saturation current density at the reference temperature of STI-edge component for drain-bulk junction.
- 328 $idsatrgatd=1E-18$ Am^{-1} Saturation current density at the reference temperature of gate-edge component for drain-bulk junction.

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- 329 $\text{csrbotd}=1\text{E}2 \text{ Am}^{-3}$ Shockley-Read-Hall prefactor of bottom component for drain-bulk junction.
- 330 $\text{csrstid}=1\text{E}-4 \text{ Am}^{-2}$ Shockley-Read-Hall prefactor of STI-edge component for drain-bulk junction.
- 331 $\text{crgatd}=1\text{E}-4 \text{ Am}^{-2}$ Shockley-Read-Hall prefactor of gate-edge component for drain-bulk junction.
- 332 $\text{xjunstid}=100\text{E}-9 \text{ m}$ Junction depth of STI-edge component for drain-bulk junction.
- 333 $\text{xjngatd}=100\text{E}-9 \text{ m}$ Junction depth of gate-edge component for drain-bulk junction.
- 334 $\text{ctatbotd}=1\text{E}2 \text{ Am}^{-3}$ Trap-assisted tunneling prefactor of bottom component for drain-bulk junction.
- 335 $\text{ctatstid}=1\text{E}-4 \text{ Am}^{-2}$ Trap-assisted tunneling prefactor of STI-edge component for drain-bulk junction.
- 336 $\text{ctatgatd}=1\text{E}-4 \text{ Am}^{-2}$ Trap-assisted tunneling prefactor of gate-edge component for drain-bulk junction.
- 337 $\text{mefftatbotd}=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of bottom component for drain-bulk junction.
- 338 $\text{mefftatstid}=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of STI-edge component for drain-bulk junction.
- 339 $\text{mefftatgatd}=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of gate-edge component for drain-bulk junction.
- 340 $\text{cbbtbotd}=1\text{E}-12 \text{ AV}^{-3}$ Band-to-band tunneling prefactor of bottom component for drain-bulk junction.

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- 341 `cbbtstid=1E-18` AV^3_{m}
Band-to-band tunneling prefactor of STI-edge component for drain-bulk junction.
- 342 `cbbtgatd=1E-18` AV^3_{m}
Band-to-band tunneling prefactor of gate-edge component for drain-bulk junction.
- 343 `fbbtbotd=1E9` Vm^{-1}
Normalization field at the reference temperature for band-to-band tunneling of bottom component for drain-bulk junction.
- 344 `fbbtrstid=1E9` Vm^{-1}
Normalization field at the reference temperature for band-to-band tunneling of STI-edge component for drain-bulk junction.
- 345 `fbbtgatd=1E9` Vm^{-1}
Normalization field at the reference temperature for band-to-band tunneling of gate-edge component for drain-bulk junction.
- 346 `stfbbtbotd=(-1E-3)` K^{-1}
Temperature scaling parameter for band-to-band tunneling of bottom component for drain-bulk junction.
- 347 `stfbbtstid=(-1E-3)` K^{-1}
Temperature scaling parameter for band-to-band tunneling of STI-edge component for drain-bulk junction.
- 348 `stfbbtgatd=(-1E-3)` K^{-1}
Temperature scaling parameter for band-to-band tunneling of gate-edge component for drain-bulk junction.
- 349 `vbrbotd=10` V
Breakdown voltage of bottom component for drain-bulk junction.
- 350 `vbrstid=10` V
Breakdown voltage of STI-edge component for drain-bulk junction.
- 351 `vbrgatd=10` V
Breakdown voltage of gate-edge component for drain-bulk junction.
- 352 `pbrbotd=4` V
Breakdown onset tuning parameter of bottom component for drain-bulk junction.

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353	<code>pbrstid=4</code> V	Breakdown onset tuning parameter of STI-edge component for drain-bulk junction.
354	<code>pbrgatd=4</code> V	Breakdown onset tuning parameter of gate-edge component for drain-bulk junction.
355	<code>swjunexp=0.0</code>	Flag for JUNCAP-express; 0,full model, 1,express model.
356	<code>vjunref=2.5</code>	Typical maximum source-bulk junction voltage; usually about 2*VSUP.
357	<code>fjunq=0.03</code>	Fraction below which source-bulk junction capacitance components are considered negligible.
358	<code>vjunrefd=2.5</code>	Typical maximum drain-bulk junction voltage; usually about 2*VSUP.
359	<code>fjunqd=0.03</code>	Fraction below which drain-bulk junction capacitance components are considered negligible.
360	<code>mvto=0.0</code>	DCmatch parameter.
361	<code>mbeo=0.0</code>	DCmatch parameter.
362	<code>vthmod</code>	Vth output selector. 'std' outputs model equation Vth. 'vthcc' outputs constant current Vth, and may impact simulation performance. The default value is taken from the options parameter 'vthmod'. Possible values are <code>std</code> and <code>vthcc</code> .
363	<code>ivth</code> (A)	Vth current parameter. The default value is taken from the options parameter 'ivthn' or 'ivthp', depending on the type of the model.
364	<code>ivthw</code> (m)	Width offset for constant current Vth. The default value is taken from the options parameter 'ivthw'.
365	<code>ivthl</code> (m)	Length offset for constant current Vth. The default value is taken from the options parameter 'ivthl'.
366	<code>ivth_vdsmin</code> (V)	Minimum Vds in constant current Vth calculating. The default value is taken from the options parameter 'ivth_vdsmin'.

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367 `noisemethod=oldcmi`

Induced gate noise implementation .

Possible values are `oldcmi`, `subckt`, and `newcmi`.

Output Parameters

1	<code>weff</code> (m)	Effective channel width for geometrical models.
2	<code>leff</code> (m)	Effective channel length for geometrical models.
3	<code>lv1</code> (m)	alias of <code>l</code> .
4	<code>lv2</code> (m)	alias of <code>w</code> .
5	<code>lv3</code> (m ²)	alias of <code>ad</code> .
6	<code>lv4</code> (m ²)	alias of <code>as</code> .
7	<code>lv11</code> (m)	alias of <code>pd</code> .
8	<code>lv12</code> (m)	alias of <code>ps</code> .

Operating-Point Parameters

1	<code>ctype</code>	Flag for channel type.
2	<code>sdint</code>	Flag for source-drain interchange.
3	<code>ise</code> (A)	Total source current.
4	<code>ige</code> (A)	Total gate current.
5	<code>ide</code> (A)	Total drain current.
6	<code>ibe</code> (A)	Total bulk current.
7	<code>ids</code> (A)	Drain current, excl. avalanche, tunnel, GISL, GIDL, and junction currents.
8	<code>idb</code> (A)	Drain to bulk current.
9	<code>isb</code> (A)	Source to bulk current.

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PSP102 Model

10	i_{gs} (A)	Gate-source tunneling current.
11	i_{gd} (A)	Gate-drain tunneling current.
12	i_{gb} (A)	Gate-bulk tunneling current.
13	i_{gcs} (A)	Gate-channel tunneling current (source component).
14	i_{gcd} (A)	Gate-channel tunneling current (drain component).
15	i_{avl} (A)	Substrate current due to weak avalanche.
16	i_{gisl} (A)	Gate-induced source leakage current.
17	i_{gidl} (A)	Gate-induced drain leakage current.
18	i_{js} (A)	Total source junction current.
19	i_{jsbot} (A)	Source junction current (bottom component).
20	i_{jsgat} (A)	Source junction current (gate-edge component).
21	i_{jssti} (A)	Source junction current (STI-edge component).
22	i_{jd} (A)	Total drain junction current.
23	i_{jdbot} (A)	Drain junction current (bottom component).
24	i_{jdgat} (A)	Drain junction current (gate-edge component).
25	i_{jdsti} (A)	Drain junction current (STI-edge component).
26	q_g (Coul)	Intrinsic gate charge.
27	q_d (Coul)	Intrinsic drain charge.
28	q_b (Coul)	Intrinsic bulk charge.
29	q_s (Coul)	Intrinsic source charge.
30	q_{gs_ov} (Coul)	Overlap charge for gate-source.
31	q_{gd_ov} (Coul)	Overlap charge for gate-drain.

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32	q_{fgs} (Coul)	Total outerFringe + overlap for gate-source.
33	q_{fgd} (Coul)	Total outerFringe + overlap for gate-drain.
34	q_{gb_ov} (Coul)	Gate-bulk overlap charge.
35	q_{jun_s} (Coul)	Junction charge on source side.
36	q_{jun_d} (Coul)	Junction charge on drain side.
37	v_{ds} (V)	Drain-source voltage.
38	v_{gs} (V)	Gate-source voltage.
39	v_{sb} (V)	Source-bulk voltage.
40	v_{to} (V)	Zero-bias threshold voltage.
41	v_{ts} (V)	Threshold voltage including back bias effects.
42	v_{th} (V)	Threshold voltage including back bias and drain bias effects.
43	v_{gt} (V)	Effective gate drive voltage including back bias and drain bias effects.
44	v_{dss} (V)	Drain saturation voltage at actual bias.
45	v_{sat} (V)	Saturation limit.
46	pwr (W)	Power at op point.
47	g_m ($1/\Omega$)	Transconductance.
48	g_{mb} ($1/\Omega$)	Substrate transconductance.
49	g_{ds} ($1/\Omega$)	Output conductance.
50	g_{js} ($1/\Omega$)	Source junction conductance.
51	g_{jd} ($1/\Omega$)	Drain junction conductance.
52	c_{dd} (F)	Drain capacitance.

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53	<code>cdg</code> (F)	Drain-gate capacitance.
54	<code>cds</code> (F)	Drain-source capacitance.
55	<code>cdb</code> (F)	Drain-bulk capacitance.
56	<code>cgd</code> (F)	Gate-drain capacitance.
57	<code>cgg</code> (F)	Gate capacitance.
58	<code>cgs</code> (F)	Gate-source capacitance.
59	<code>cgb</code> (F)	Gate-bulk capacitance.
60	<code>csd</code> (F)	Source-drain capacitance.
61	<code>csg</code> (F)	Source-gate capacitance.
62	<code>css</code> (F)	Source capacitance.
63	<code>csb</code> (F)	Source-bulk capacitance.
64	<code>cbd</code> (F)	Bulk-drain capacitance.
65	<code>cbg</code> (F)	Bulk-gate capacitance.
66	<code>cbs</code> (F)	Bulk-source capacitance.
67	<code>cbb</code> (F)	Bulk capacitance.
68	<code>cgso1</code> (F)	Total gate-source overlap capacitance.
69	<code>cgdo1</code> (F)	Total gate-drain overlap capacitance.
70	<code>cgbo1</code> (F)	Total gate-bulk overlap capacitance.
71	<code>cjs</code> (F)	Total source junction capacitance.
72	<code>cjsbot</code> (F)	Source junction capacitance (bottom component).
73	<code>cjsgat</code> (F)	Source junction capacitance (gate-edge component).
74	<code>cjssti</code> (F)	Source junction capacitance (STI-edge component).

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75	$cj\bar{d}$ (F)	Total drain junction capacitance.
76	$cj\bar{d}bot$ (F)	Drain junction capacitance (bottom component).
77	$cj\bar{d}gat$ (F)	Drain junction capacitance (gate-edge component).
78	$cj\bar{d}sti$ (F)	Drain junction capacitance (STI-edge component).
79	$lpoly$ (m)	
80	u	Transistor gain.
81	$rout$ (Ω)	Small-signal output resistance.
82	$vearly$ (V)	Equivalent Early voltage.
83	b_{eff} (A/V^2)	Gain factor.
84	fug (Hz)	Unity gain frequency at actual bias.
85	rg (Ω)	Gate resistance.
86	sfl (A^2/Hz)	Flicker noise current spectral density at 1 Hz.
87	$sqrtsff$ (V/ \sqrt{Hz})	Input-referred RMS white noise voltage spectral density at 1 kHz.
88	$sqrtsfw$ (V/ \sqrt{Hz})	Input-referred RMS white noise voltage spectral density.
89	sid (A^2/Hz)	White noise current spectral density.
90	sig (A^2/Hz)	Induced gate noise current spectral density at 1 Hz.
91	$cigid$	Imaginary part of correlation coefficient between Sig and Sid.
92	$fknee$ (Hz)	Cross-over frequency above which white noise is dominant.
93	$sigs$ (A^2/Hz)	Gate-source current noise spectral density.
94	$sigd$ (A^2/Hz)	Gate-drain current noise spectral density.
95	$siavl$ (A^2/Hz)	Impact ionization current noise spectral density.

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96	ssi (A^2/Hz)	Total source junction current noise spectral density.
97	sdi (A^2/Hz)	Total drain junction current noise spectral density.
98	vbs (V)	Bulk-source voltage.
99	$lv9$ (V)	alias of vth .
100	$lv10$ (V)	alias of $vdss$.
101	$lv36$ (F)	alias of $cgsol$.
102	$lv37$ (F)	alias of $cgdol$.
103	$lv38$ (F)	alias of $cgbol$.
104	$lv51$ (m)	alias of tox .
105	$lx4$ (A)	alias of ids .
106	$lx3$ (V)	alias of vds .
107	$lx2$ (V)	alias of vgs .
108	$lx7$ ($1/\Omega$)	alias of gm .
109	$lx8$ ($1/\Omega$)	alias of gds .
110	$lx9$ ($1/\Omega$)	alias of gmb .
111	$lx33$ (F)	alias of cdd .
112	$lx32$ (F)	alias of cdg .
113	$lx34$ (F)	alias of cds .
114	$lx19$ (F)	alias of cgd .
115	$lx18$ (F)	alias of cgg .
116	$lx20$ (F)	alias of cgs .
117	$lx22$ (F)	alias of cbd .

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118	1x21	(F)	alias of cbg.
119	1x23	(F)	alias of cbs.
120	1x5	(A)	alias of ijs.
121	1x6	(A)	alias of ijd.
122	1x28	(F)	alias of cjs.
123	1x29	(F)	alias of cjd.
124	1x38	(A)	alias of igs.
125	1x39	(A)	alias of igd.
126	1x66	(A)	alias of igb.
127	1x67	(A)	alias of igcs.
128	1x68	(A)	alias of igcd.
129	1x110	(A)	alias of igisl.
130	1x47	(A)	alias of igidl.
131	1x60	(F)	alias of csd.
132	1x59	(F)	alias of csg.
133	1x58	(F)	alias of css.
134	1x12	(Coul)	alias of Qb including overlap charge.
135	1x14	(Coul)	alias of Qg including overlap charge.
136	1x16	(Coul)	alias of Qd including overlap charge.
137	1x83	(F)	alias of cgd including overlap cap.
138	1x84	(F)	alias of cgs including overlap cap.

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PSP102 Model

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

abdrain	I-15	lv1	O-3	plwcgbov	M-194	pwnfb	M-210
absorce	I-12	lv10	OP-100	plwcgov	M-186	pwnfc	M-214
ad	I-20	lv11	O-7	plwcgovd	M-190	pwnov	M-57
as	I-18	lv12	O-8	plwcox	M-182	pwnovd	M-61
beff	OP-83	lv2	O-4	plwcs	M-86	pwnp	M-47
binmod	M-13	lv3	O-5	plwct	M-52	pwr	OP-46
cbb	OP-67	lv36	OP-101	plwdphib	M-44	pws	M-96
cbbtbot	M-299	lv37	OP-102	plwiginv	M-152	pwstbet	M-74
cbbtbotd	M-340	lv38	OP-103	plwigov	M-156	pwstthesat	M-107
cbbtgat	M-301	lv4	O-6	plwigovd	M-160	pwstvfb	M-30
cbbtgatd	M-342	lv51	OP-104	plwkuowe	M-225	pwthesat	M-103
cbbtsti	M-300	lv9	OP-99	plwkvthowe	M-221	pwthesatb	M-111
cbbtstid	M-341	lvar1	M-17	plwmue	M-79	pwthesatg	M-115
cbd	OP-64	lvaro	M-16	plwneff	M-37	pwvfb	M-26
cbg	OP-65	lx110	OP-129	plwnfa	M-207	pwxcor	M-90
cbs	OP-66	lx12	OP-134	plwnfb	M-211	qb	OP-28

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PSP102 Model

cdb	OP-55	lx14	OP-135	plwnfc	M-215	qgd	OP-27
cdd	OP-52	lx16	OP-136	plwnov	M-58	qfgd	OP-33
cdg	OP-53	lx18	OP-115	plwnovd	M-62	qfgs	OP-32
cds	OP-54	lx19	OP-114	plwnp	M-48	qg	OP-26
cgb	OP-59	lx2	OP-107	plwrs	M-97	qgb_ov	OP-34
cgbol	OP-70	lx20	OP-116	plwstbet	M-75	qgd_ov	OP-31
cgd	OP-56	lx21	OP-118	plwstthesat	M-108	qgs_ov	OP-30
cgdol	OP-69	lx22	OP-117	plwstvfb	M-31	qjun_d	OP-36
cgg	OP-57	lx23	OP-119	plwthesat	M-104	qjun_s	OP-35
cgs	OP-58	lx28	OP-122	plwthesatb	M-112	qmc	M-10
cgsol	OP-68	lx29	OP-123	plwthesatg	M-116	qs	OP-29
cigid	OP-91	lx3	OP-106	plwvfb	M-27	rbulko	M-241
cjd	OP-75	lx32	OP-112	plwxcor	M-91	rg	OP-85
cjdbot	OP-76	lx33	OP-111	plxcor	M-89	rgo	M-240
cjdgat	OP-77	lx34	OP-113	poa1	M-134	rint	M-245
cjdsti	OP-78	lx38	OP-124	poa2	M-138	rjundo	M-244
cjorbot	M-273	lx39	OP-125	poa3	M-140	rjunso	M-243
cjorbotd	M-314	lx4	OP-105	poa4	M-144	rout	OP-81
cjorgat	M-275	lx47	OP-130	poagidl	M-165	rshg	M-247
cjorgatd	M-316	lx5	OP-120	poagidld	M-169	rvpoly	M-246

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cjorsti	M-274	lx58	OP-133	poalp	M-121	rwello	M-242
cjorstid	M-315	lx59	OP-132	poalp1	M-125	sa	I-3
cjs	OP-71	lx6	OP-121	poalp2	M-129	saref	M-249
cjsbot	OP-72	lx60	OP-131	poax	M-117	sb	I-4
cjsgat	OP-73	lx66	OP-126	pobetn	M-68	sbref	M-250
cjssti	OP-74	lx67	OP-127	pobgidl	M-173	sc	I-9
compatible	M-15	lx68	OP-128	pobgidld	M-174	sca	I-6
csb	OP-63	lx7	OP-108	pocf	M-63	scalelev	M-14
csd	OP-60	lx8	OP-109	pocfb	M-67	scb	I-7
csg	OP-61	lx83	OP-137	pocfr	M-195	scc	I-8
csrbot	M-288	lx84	OP-138	pocfrd	M-199	scref	M-268
csrbotd	M-329	lx9	OP-110	pocgbov	M-191	sd	I-5
csrhgat	M-290	m	I-28	pocgidl	M-177	sdi	OP-97
csrhgatd	M-331	mbeo	M-361	pocgidld	M-178	sdint	OP-2
csrhisti	M-289	mefftatbot	M-296	pocgov	M-183	sfl	OP-86
csrhistid	M-330	mefftatbotd	M-337	pocgovd	M-187	siavl	OP-95
css	OP-62	mefftatgat	M-298	pochib	M-164	sid	OP-89
ctatbot	M-293	mefftatgatd	M-339	pocox	M-179	sig	OP-90
ctatbotd	M-334	mefftatsti	M-297	pocs	M-83	sigd	OP-94
ctatgat	M-295	mefftatstid	M-338	poct	M-49	sigs	OP-93

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ctatgatd M-336	mulid0 I-22	podnsub M-40	sqrtsff OP-87
ctatsti M-294	mult I-23	podphib M-41	sqrtsfw OP-88
ctatstid M-335	munqso M-239	poef M-216	ssi OP-96
ctype OP-1	mvto M-360	poepsrox M-33	stetao M-266
delvto I-10	nf I-24	pofeta M-93	stfbbtbot M-305
dlq M-22	ngcon I-25	pofnt M-203	stfbbtbotd M-346
dlsil M-248	noisemethod M-367	pogc2 M-162	stfbbtgat M-307
dta M-217	pbot M-279	pogc3 M-163	stfbbtgatd M-348
dwq M-23	pbotd M-320	pogco M-148	stfbbtsti M-306
factuo I-11	pbrbot M-311	poiginv M-149	stfbbtstid M-347
fbbtrbot M-302	pbrbotd M-352	poigov M-153	swgidl M-7
fbbtrbotd M-343	pbrgat M-313	poigovd M-157	swigate M-5
fbbtrgat M-304	pbrgatd M-354	pokuowe M-222	swimpact M-6
fbbtrgatd M-345	pbrsti M-312	pokvthowe M-218	swjunasym M-9
fbbtrsti M-303	pbrstid M-353	pomue M-76	swjuncap M-8
fbbtrstid M-344	pd I-21	poneff M-34	swjunexp M-355
fjunq M-357	pgat M-281	ponfa M-204	swnqs M-4
fjunqd M-359	pgatd M-322	ponfb M-208	tkuo M-254
fknee OP-92	phigbot M-282	ponfc M-212	tr M-3
fug OP-84	phigbotd M-323	ponov M-55	trise I-27

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gds	OP-49	phiggat	M-284	ponovd	M-59	trj	M-272
geomod	M-12	phiggatd	M-325	ponp	M-45	type	M-2
gjd	OP-51	phigsti	M-283	ponslp	M-39	u	OP-80
gjs	OP-50	phigstid	M-324	pors	M-94	vbd_max	M-233
gm	OP-47	pkuo	M-257	porsb	M-99	vbirbot	M-276
gmb	OP-48	pkvtho	M-263	porsg	M-100	vbirbotd	M-317
iavl	OP-15	pla1	M-135	posta2	M-139	vbirgat	M-278
ibe	OP-6	pla3	M-141	postbet	M-72	vbirgatd	M-319
idb	OP-8	pla4	M-145	postbgidl	M-175	vbursti	M-277
ide	OP-5	plagidl	M-166	postbgidld	M-176	vburstid	M-318
ids	OP-7	plagidld	M-170	postcs	M-87	vrbot	M-308
idsatrbot	M-285	plalp	M-122	postig	M-161	vrbotd	M-349
idsatrbotd	M-326	plalp1	M-126	postmue	M-80	vbrgat	M-310
idsatrgat	M-287	plalp2	M-130	postrs	M-98	vbrgatd	M-351
idsatrgatd	M-328	plax	M-118	postthemu	M-82	vbrsti	M-309
idsatrsti	M-286	plbetn	M-69	postthesat	M-105	vbrstid	M-350
idsatrstid	M-327	plcf	M-64	postvfb	M-28	vbs	OP-98
igb	OP-12	plcfr	M-196	postxcor	M-92	vbs_max	M-234
igcd	OP-14	plcfrd	M-200	pothemu	M-81	vds	OP-37
igcs	OP-13	plcgbov	M-192	pothesat	M-101	vds_max	M-230
igd	OP-11	plcgov	M-184	pothesatb	M-109	vdss	OP-44

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ige OP-4	plcgovd M-188	pothesatg M-113	vearly OP-82
igidl OP-17	plcox M-180	potox M-32	version M-11
igisl OP-16	plcs M-84	potoxov M-53	vgb_max M-235
igs OP-10	plct M-50	potoxovd M-54	vgbr_max M-238
ijd OP-22	pldphib M-42	povfb M-24	vgd_max M-231
ijdbot OP-23	pliginv M-150	povnsub M-38	vgdr_max M-236
ijdgat OP-24	pligov M-154	povp M-133	vgs OP-38
ijdsti OP-25	pligovd M-158	poxcor M-88	vgs_max M-232
ijs OP-18	plkuowe M-223	ps I-19	vgsr_max M-237
ijsbot OP-19	plkvthowe M-219	psti M-280	vgt OP-43
ijsgat OP-20	plmue M-77	pstid M-321	vjunref M-356
ijssti OP-21	plneff M-35	pwal M-136	vjunrefd M-358
imax M-271	plnfa M-205	pwa3 M-142	vsat OP-45
isb OP-9	plnfb M-209	pwa4 M-146	vsb OP-39
ise OP-3	plnfc M-213	pwagidl M-167	vth OP-42
isnoisy I-29	plnov M-56	pwagidld M-171	vthmod M-362
ivth M-363	plnovd M-60	pwalp M-123	vto OP-40
ivth_vdsmin M-366	plnp M-46	pwalp1 M-127	vts OP-41
ivthl M-365	plrs M-95	pwalp2 M-131	w I-2
ivthw M-364	plstbet M-73	pwax M-119	web M-269

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PSP102 Model

kuo M-252	plstthesat M-106	pwbetn M-70	wec M-270
kvsat M-253	plstvfb M-29	pwcf M-65	weff O-1
kvtho M-260	plthesat M-102	pwcfr M-197	wkuo M-256
l I-1	plthesatb M-110	pwcfrd M-201	wkvtho M-262
lap M-18	plthesatg M-114	pwcgbov M-193	wlod M-251
leff O-2	plvfb M-25	pwcgov M-185	wlodkuo M-259
level M-1	plwa1 M-137	pwcgovd M-189	wlodvth M-265
lgdrain I-17	plwa3 M-143	pwcox M-181	wmax M-229
lgsource I-14	plwa4 M-147	pwcs M-85	wmin M-228
lkuo M-255	plwagidl M-168	pwct M-51	wot M-21
lkvtho M-261	plwagidld M-172	pwdphib M-43	wvaro M-19
llodkuo M-258	plwalp M-124	pwiginv M-151	wvarw M-20
llodvth M-264	plwalp1 M-128	pwigov M-155	xgw I-26
lmax M-227	plwalp2 M-132	pwigovd M-159	xjungat M-292
lmin M-226	plwax M-120	pwkuowe M-224	xjungatd M-333
lodetao M-267	plwbetn M-71	pwkvthowe M-220	xjunsti M-291
lpoly OP-79	plwcf M-66	pwmue M-78	xjunstid M-332
lsdrain I-16	plwcfr M-198	pwneff M-36	
lssource I-13	plwcfrd M-202	pwnfa M-206	
abdrain I-15	lv1 O-3	plwcgbov M-194	pwnfb M-210
absource I-12	lv10 OP-100	plwcgov M-186	pwnfc M-214

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PSP102 Model

ad	I-20	lv11	O-7	plwcvovd	M-190	pwnov	M-57
as	I-18	lv12	O-8	plwcox	M-182	pwnovd	M-61
beff	OP-83	lv2	O-4	plwcs	M-86	pwnp	M-47

PSP local MOSFET Model (psp102e)

This is SiMKit 4.0.1.

This device is supported within altergroups.

This device is dynamically loaded from the shared object /vobs/spectre_dev/tools.lnx86/cmi/lib/5.0.doc/libphilips_sh.so

Instance Definition

Name d g s b ModelName parameter=value ...

Instance Parameters

- 1 delvto=0.0 V Threshold voltage shift parameter.
- 2 factuo=1.0 Zero-field mobility pre-factor.
- 3 absourc=1E-12 m² Bottom area of source junction.
- 4 lssourc=1E-6 m STI-edge length of source junction.
- 5 lgsourc=1E-6 m Gate-edge length of source junction.
- 6 abdrain=1E-12 m² Bottom area of drain junction.
- 7 lsdrain=1E-6 m STI-edge length of drain junction.
- 8 lgdrain=1E-6 m Gate-edge length of drain junction.
- 9 as=1E-12 m² Bottom area of source junction.

Virtuoso Simulator Components and Device Models Reference

PSP102 Model

10	<code>ps=1E-6 m</code>	Perimeter of source junction.
11	<code>ad=1E-12 m²</code>	Bottom area of drain junction.
12	<code>pd=1E-6 m</code>	Perimeter of drain junction.
13	<code>mulid0=1</code>	Ids multiplier.
14	<code>jw=1E-6 m</code>	Gate-edge length of source/drain junction.
15	<code>mult=1.0</code>	Number of devices in parallel.
16	<code>trise=0.0 K</code>	Temperature rise from ambient.
17	<code>m=1.0</code>	Multiplicity factor.
18	<code>isnoisy=yes</code>	Should device generate noise. Possible values are <code>no</code> and <code>yes</code> .

Model Definition

model modelName psp102e parameter=value ...

Model Parameters

1	<code>level=102</code>	Model level.
2	<code>type=n</code>	Channel type parameter, <code>n</code> ,NMOS <code>p</code> ,PMOS. Possible values are <code>n</code> and <code>p</code> .
3	<code>tr=value of tnom C</code>	nominal (reference) temperature.
4	<code>swnqs=0</code>	Flag for NQS, 0,off, 1, 2, 3, 5, or 9,number of collocation points.
5	<code>swigate=0</code>	Flag for gate current, 0,turn off IG.
6	<code>swimpact=0</code>	Flag for impact ionization current, 0,turn off II.
7	<code>swgidl=0</code>	Flag for GIDL current, 0,turn off IGIDL.
8	<code>swjuncap=0</code>	Flag for juncap, 0,turn off juncap.

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9	<code>swjunasym=0</code>	Flag for asymmetric junctions; 0,symmetric, 1,asymmetric.
10	<code>qmc=1.0</code>	Quantum-mechanical correction factor.
11	<code>version=102.32</code>	The available versions are 102.2, 102.21, 102.3, 102.32, 102.33, 102.34 and 102.40.
12	<code>geomod=1</code>	1 for geometrical model and 0 for electrical model.
13	<code>binmod=0</code>	1 for bin model and 0 for non-bin model.
14	<code>scalelev=102</code>	102 for local, 1020 for global model and 1021 for bin model.
15	<code>compatible=spectre</code>	for compatible. Possible values are <code>spectre</code> , <code>spice2</code> , <code>spice3</code> , <code>cdsspice</code> , <code>hspice</code> , <code>spiceplus</code> , <code>eldo</code> , <code>sspice</code> , and <code>mica</code> .
16	<code>vfb=(-1.0) V</code>	Flatband voltage at TR.
17	<code>stvfb=5.0e-4 V/K</code>	Temperature dependence of VFB.
18	<code>tox=2.0e-09 m</code>	Gate oxide thickness.
19	<code>epsrox=3.9</code>	Relative permittivity of gate dielectric.
20	<code>neff=5.0e+23 m⁻³</code>	Effective substrate doping.
21	<code>vnsb=0.0 V</code>	Effective doping bias-dependence parameter.
22	<code>ns1p=0.05 V</code>	Effective doping bias-dependence parameter.
23	<code>dnsb=0.0 V⁻¹</code>	Effective doping bias-dependence parameter.
24	<code>dphib=0.0 V</code>	Offset parameter for PHIB.
25	<code>np=1.0e+26 m⁻³</code>	Gate poly-silicon doping.
26	<code>ct=0.0</code>	Interface states factor.
27	<code>toxov=2.0e-09 m</code>	Overlap oxide thickness.
28	<code>toxovd=2.0e-09 m</code>	Overlap oxide thickness for drain side.

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29	$nov=5.0e+25 \text{ m}^{-3}$	Effective doping of overlap region.
30	$novd=5.0e+25 \text{ m}^{-3}$	Effective doping of overlap region for drain side.
31	$cf=0.0$	DIBL-parameter.
32	$cfb=0.0 \text{ V}^{-1}$	Back bias dependence of CF.
33	$betn=7e-2 \text{ m}^2/\text{V}/\text{s}$	Channel aspect ratio times zero-field mobility.
34	$stbet=1.0$	Temperature dependence of BETN.
35	$mue=0.5 \text{ m}/\text{V}$	Mobility reduction coefficient at TR.
36	$stmue=0.0$	Temperature dependence of MUE.
37	$themu=1.5$	Mobility reduction exponent at TR.
38	$stthemu=1.5$	Temperature dependence of THEMU.
39	$cs=0.0$	Coulomb scattering parameter at TR.
40	$stcs=0.0$	Temperature dependence of CS.
41	$xcor=0.0 \text{ V}^{-1}$	Non-universality factor.
42	$stxcor=0.0$	Temperature dependence of XCOR.
43	$feta=1.0$	Effective field parameter.
44	$rs=30 \text{ } \Omega$	Series resistance at TR.
45	$strs=1.0$	Temperature dependence of RS.
46	$rsb=0.0 \text{ V}^{-1}$	Back-bias dependence of series resistance.
47	$rsg=0.0 \text{ V}^{-1}$	Gate-bias dependence of series resistance.
48	$thesat=1.0 \text{ V}^{-1}$	Velocity saturation parameter at TR.
49	$stthesat=1.0$	Temperature dependence of THESAT.
50	$thesatb=0.0 \text{ V}^{-1}$	Back-bias dependence of velocity saturation.

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51	thesatg=0.0 V ⁻¹	Gate-bias dependence of velocity saturation.
52	ax=3.0	Linear/saturation transition factor.
53	alp=0.01	CLM pre-factor.
54	alp1=0.00 V	CLM enhancement factor above threshold.
55	alp2=0.00 V ⁻¹	CLM enhancement factor below threshold.
56	vp=0.05 V	CLM logarithm dependence factor.
57	a1=1.0	Impact-ionization pre-factor.
58	a2=10.0 V	Impact-ionization exponent at TR.
59	sta2=0.0 V	Temperature dependence of A2.
60	a3=1.0	Saturation-voltage dependence of impact-ionization.
61	a4=0.0 V ^{-0.5}	Back-bias dependence of impact-ionization.
62	gco=0.0	Gate tunnelling energy adjustment.
63	iginv=0.0 A	Gate channel current pre-factor.
64	igov=0.0 A	Gate overlap current pre-factor.
65	igovd=0.0 A	Gate overlap current pre-factor for drain side.
66	stig=2.0	Temperature dependence of IGINV and IGOV.
67	gc2=0.375	Gate current slope factor.
68	gc3=0.063	Gate current curvature factor.
69	chib=3.1 V	Tunnelling barrier height.
70	agidl=0.0 A/V ³	GIDL pre-factor.
71	agidld=0.0 A/V ³	GIDL pre-factor for drain side.
72	bgidl=41.0 V	GIDL probability factor at TR.

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73	$\text{bgidl}d=41.0 \text{ V}$	GIDL probability factor at TR for drain side.
74	$\text{stbgidl}=0.0 \text{ V/K}$	Temperature dependence of BGIDL.
75	$\text{stbgidl}d=0.0 \text{ V/K}$	Temperature dependence of BGIDL for drain side.
76	$\text{cgidl}=0.0$	Back-bias dependence of GIDL.
77	$\text{cgidl}d=0.0$	Back-bias dependence of GIDL for drain side.
78	$\text{cox}=1.0e-14 \text{ F}$	Oxide capacitance for intrinsic channel.
79	$\text{cgov}=1.0e-15 \text{ F}$	Oxide capacitance for gate-drain/source overlap.
80	$\text{cgov}d=1.0e-15 \text{ F}$	Oxide capacitance for gate-drain overlap.
81	$\text{cgbov}=0.0 \text{ F}$	Oxide capacitance for gate-bulk overlap.
82	$\text{cfr}=0.0 \text{ F}$	Outer fringe capacitance.
83	$\text{cfr}d=0.0 \text{ F}$	Outer fringe capacitance for drain side.
84	$\text{fnt}=1.0$	Thermal noise coefficient.
85	$\text{nfa}=8.0e+22 \text{ V}^{-1}/\text{m}^4$	First coefficient of flicker noise.
86	$\text{nfb}=3.0e+07 \text{ V}^{-1}/\text{m}^2$	Second coefficient of flicker noise.
87	$\text{nfc}=0.0 \text{ V}^{-1}$	Third coefficient of flicker noise.
88	$\text{ef}=1.0$	Flicker noise frequency exponent.
89	$\text{munqs}=1.0$	Relative mobility for NQS modeling.
90	$\text{rg}=0.0 \text{ } \Omega$	Gate resistance.
91	$\text{rbulk}=0.0 \text{ } \Omega$	Bulk resistance between node BP and BI.
92	$\text{rwell}=0.0 \text{ } \Omega$	Well resistance between node BI and B.
93	$\text{rjuns}=0.0 \text{ } \Omega$	Source-side bulk resistance between node BI and BS.

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94	$r_{jund}=0.0 \ \Omega$	Drain-side bulk resistance between node BI and BD.
95	$i_{max}=1000 \ A$	Maximum current up to which forward current behaves exponentially.
96	$trj=21 \ C$	reference temperature.
97	$c_{jorbot}=1E-3 \ Fm^{-2}$	Zero-bias capacitance per unit-of-area of bottom component for source-bulk junction.
98	$c_{jorsti}=1E-9 \ Fm^{-1}$	Zero-bias capacitance per unit-of-length of STI-edge component for source-bulk junction.
99	$c_{jorgat}=1E-9 \ Fm^{-1}$	Zero-bias capacitance per unit-of-length of gate-edge component for source-bulk junction.
100	$v_{birbot}=1 \ V$	Built-in voltage at the reference temperature of bottom component for source-bulk junction.
101	$v_{birsti}=1 \ V$	Built-in voltage at the reference temperature of STI-edge component for source-bulk junction.
102	$v_{birgat}=1 \ V$	Built-in voltage at the reference temperature of gate-edge component for source-bulk junction.
103	$p_{bot}=0.5$	Grading coefficient of bottom component for source-bulk junction.
104	$p_{sti}=0.5$	Grading coefficient of STI-edge component for source-bulk junction.
105	$p_{gat}=0.5$	Grading coefficient of gate-edge component for source-bulk junction.
106	$\phi_{higbot}=1.16 \ V$	Zero-temperature bandgap voltage of bottom component for source-bulk junction.
107	$\phi_{higsti}=1.16 \ V$	Zero-temperature bandgap voltage of STI-edge component for source-bulk junction.

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- 108 `phiggat=1.16` V Zero-temperature bandgap voltage of gate-edge component for source-bulk junction.
- 109 `idsatrbot=1E-12` Am^{-2} Saturation current density at the reference temperature of bottom component for source-bulk junction.
- 110 `idsatrsti=1E-18` Am^{-1} Saturation current density at the reference temperature of STI-edge component for source-bulk junction.
- 111 `idsatrgat=1E-18` Am^{-1} Saturation current density at the reference temperature of gate-edge component for source-bulk junction.
- 112 `csrbot=1E2` Am^{-3} Shockley-Read-Hall prefactor of bottom component for source-bulk junction.
- 113 `csrhisti=1E-4` Am^{-2} Shockley-Read-Hall prefactor of STI-edge component for source-bulk junction.
- 114 `csrhgat=1E-4` Am^{-2} Shockley-Read-Hall prefactor of gate-edge component for source-bulk junction.
- 115 `xjunsti=100E-9` m Junction depth of STI-edge component for source-bulk junction.
- 116 `xjungat=100E-9` m Junction depth of gate-edge component for source-bulk junction.
- 117 `ctatbot=1E2` Am^{-3} Trap-assisted tunneling prefactor of bottom component for source-bulk junction.
- 118 `ctatsti=1E-4` Am^{-2} Trap-assisted tunneling prefactor of STI-edge component for source-bulk junction.
- 119 `ctatgat=1E-4` Am^{-2} Trap-assisted tunneling prefactor of gate-edge component for source-bulk junction.
- 120 `mefftatbot=0.25` Effective mass (in units of m_0) for trap-assisted tunneling of bottom component for source-bulk junction.

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- 121 `mefftatsti=0.25` Effective mass (in units of m_0) for trap-assisted tunneling of STI-edge component for source-bulk junction.
- 122 `mefftatgat=0.25` Effective mass (in units of m_0) for trap-assisted tunneling of gate-edge component for source-bulk junction.
- 123 `cbbtbot=1E-12` AV^{-3}
Band-to-band tunneling prefactor of bottom component for source-bulk junction.
- 124 `cbbtsti=1E-18` AV^3m
Band-to-band tunneling prefactor of STI-edge component for source-bulk junction.
- 125 `cbbtgat=1E-18` AV^3m
Band-to-band tunneling prefactor of gate-edge component for source-bulk junction.
- 126 `fbbtrbot=1E9` Vm^{-1}
Normalization field at the reference temperature for band-to-band tunneling of bottom component for source-bulk junction.
- 127 `fbbtrsti=1E9` Vm^{-1}
Normalization field at the reference temperature for band-to-band tunneling of STI-edge component for source-bulk junction.
- 128 `fbbtrgat=1E9` Vm^{-1}
Normalization field at the reference temperature for band-to-band tunneling of gate-edge component for source-bulk junction.
- 129 `stfbbtbot=(-1E-3)` K^{-1}
Temperature scaling parameter for band-to-band tunneling of bottom component for source-bulk junction.
- 130 `stfbbtsti=(-1E-3)` K^{-1}
Temperature scaling parameter for band-to-band tunneling of STI-edge component for source-bulk junction.
- 131 `stfbbtgat=(-1E-3)` K^{-1}
Temperature scaling parameter for band-to-band tunneling of gate-edge component for source-bulk junction.

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132	<code>vbrbot=10</code>	V	Breakdown voltage of bottom component for source-bulk junction.
133	<code>vbrsti=10</code>	V	Breakdown voltage of STI-edge component for source-bulk junction.
134	<code>vbrgat=10</code>	V	Breakdown voltage of gate-edge component for source-bulk junction.
135	<code>pbrbot=4</code>	V	Breakdown onset tuning parameter of bottom component for source-bulk junction.
136	<code>pbrsti=4</code>	V	Breakdown onset tuning parameter of STI-edge component for source-bulk junction.
137	<code>pbrgat=4</code>	V	Breakdown onset tuning parameter of gate-edge component for source-bulk junction.
138	<code>cjorbotd=1E-3</code>	Fm^{-2}	Zero-bias capacitance per unit-of-area of bottom component for drain-bulk junction.
139	<code>cjorstid=1E-9</code>	Fm^{-1}	Zero-bias capacitance per unit-of-length of STI-edge component for drain-bulk junction.
140	<code>cjorgatd=1E-9</code>	Fm^{-1}	Zero-bias capacitance per unit-of-length of gate-edge component for drain-bulk junction.
141	<code>vbirbotd=1</code>	V	Built-in voltage at the reference temperature of bottom component for drain-bulk junction.
142	<code>vbirstid=1</code>	V	Built-in voltage at the reference temperature of STI-edge component for drain-bulk junction.
143	<code>vbirgatd=1</code>	V	Built-in voltage at the reference temperature of gate-edge component for drain-bulk junction.
144	<code>pbotd=0.5</code>		Grading coefficient of bottom component for drain-bulk junction.
145	<code>pstid=0.5</code>		Grading coefficient of STI-edge component for drain-bulk junction.

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- 146 `pgatd=0.5` Grading coefficient of gate-edge component for drain-bulk junction.
- 147 `phigbotd=1.16 V` Zero-temperature bandgap voltage of bottom component for drain-bulk junction.
- 148 `phigstid=1.16 V` Zero-temperature bandgap voltage of STI-edge component for drain-bulk junction.
- 149 `phiggatd=1.16 V` Zero-temperature bandgap voltage of gate-edge component for drain-bulk junction.
- 150 `idsatrbotd=1E-12 A_m^{-2}` Saturation current density at the reference temperature of bottom component for drain-bulk junction.
- 151 `idsatrstid=1E-18 A_m^{-1}` Saturation current density at the reference temperature of STI-edge component for drain-bulk junction.
- 152 `idsatrgatd=1E-18 A_m^{-1}` Saturation current density at the reference temperature of gate-edge component for drain-bulk junction.
- 153 `csrbotd=1E2 A_m^{-3}` Shockley-Read-Hall prefactor of bottom component for drain-bulk junction.
- 154 `csrhostid=1E-4 A_m^{-2}` Shockley-Read-Hall prefactor of STI-edge component for drain-bulk junction.
- 155 `csrhgatd=1E-4 A_m^{-2}` Shockley-Read-Hall prefactor of gate-edge component for drain-bulk junction.
- 156 `xjunstid=100E-9 m` Junction depth of STI-edge component for drain-bulk junction.
- 157 `xjungatd=100E-9 m` Junction depth of gate-edge component for drain-bulk junction.
- 158 `ctatbotd=1E2 A_m^{-3}` Trap-assisted tunneling prefactor of bottom component for drain-bulk junction.

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- 159 $c_{\text{statstid}}=1\text{E-}4 \text{ Am}^{-2}$ Trap-assisted tunneling prefactor of STI-edge component for drain-bulk junction.
- 160 $c_{\text{statgatd}}=1\text{E-}4 \text{ Am}^{-2}$ Trap-assisted tunneling prefactor of gate-edge component for drain-bulk junction.
- 161 $m_{\text{efftatbotd}}=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of bottom component for drain-bulk junction.
- 162 $m_{\text{efftatstid}}=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of STI-edge component for drain-bulk junction.
- 163 $m_{\text{efftatgatd}}=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of gate-edge component for drain-bulk junction.
- 164 $c_{\text{bbtbotd}}=1\text{E-}12 \text{ AV}^3$ Band-to-band tunneling prefactor of bottom component for drain-bulk junction.
- 165 $c_{\text{bbtstid}}=1\text{E-}18 \text{ AV}^3_m$ Band-to-band tunneling prefactor of STI-edge component for drain-bulk junction.
- 166 $c_{\text{bbtgatd}}=1\text{E-}18 \text{ AV}^3_m$ Band-to-band tunneling prefactor of gate-edge component for drain-bulk junction.
- 167 $f_{\text{bbtrbotd}}=1\text{E}9 \text{ Vm}^{-1}$ Normalization field at the reference temperature for band-to-band tunneling of bottom component for drain-bulk junction.
- 168 $f_{\text{bbtrstid}}=1\text{E}9 \text{ Vm}^{-1}$ Normalization field at the reference temperature for band-to-band tunneling of STI-edge component for drain-bulk junction.
- 169 $f_{\text{bbtrgatd}}=1\text{E}9 \text{ Vm}^{-1}$ Normalization field at the reference temperature for band-to-band tunneling of gate-edge component for drain-bulk junction.

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- 170 $stfbbtbotd = (-1E-3) K^{-1}$ Temperature scaling parameter for band-to-band tunneling of bottom component for drain-bulk junction.
- 171 $stfbbtstid = (-1E-3) K^{-1}$ Temperature scaling parameter for band-to-band tunneling of STI-edge component for drain-bulk junction.
- 172 $stfbbtgatd = (-1E-3) K^{-1}$ Temperature scaling parameter for band-to-band tunneling of gate-edge component for drain-bulk junction.
- 173 $vbrbotd = 10 V$ Breakdown voltage of bottom component for drain-bulk junction.
- 174 $vbrstid = 10 V$ Breakdown voltage of STI-edge component for drain-bulk junction.
- 175 $vbrgatd = 10 V$ Breakdown voltage of gate-edge component for drain-bulk junction.
- 176 $pbrbotd = 4 V$ Breakdown onset tuning parameter of bottom component for drain-bulk junction.
- 177 $pbrstid = 4 V$ Breakdown onset tuning parameter of STI-edge component for drain-bulk junction.
- 178 $pbrgatd = 4 V$ Breakdown onset tuning parameter of gate-edge component for drain-bulk junction.
- 179 $swjunexp = 0.0$ Flag for JUNCAP-express; 0,full model, 1,express model.
- 180 $vjunref = 2.5$ Typical maximum source-bulk junction voltage; usually about $2 \cdot VSUP$.
- 181 $fjunq = 0.03$ Fraction below which source-bulk junction capacitance components are considered negligible.
- 182 $vjunrefd = 2.5$ Typical maximum drain-bulk junction voltage; usually about $2 \cdot VSUP$.
- 183 $fjunqd = 0.03$ Fraction below which drain-bulk junction capacitance components are considered negligible.

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184	$\text{dta}=0$ K	Temperature offset w.r.t. ambient circuit temperature.
185	$\text{mvt}=0.0$	DCmatch parameter.
186	$\text{mbe}=0.0$	DCmatch parameter.
187	$\text{vds_max}=\infty$ V	Maximum allowed voltage cross source and drain.
188	$\text{vgd_max}=\infty$ V	Maximum allowed voltage cross gate and drain.
189	$\text{vgs_max}=\infty$ V	Maximum allowed voltage cross gate and source/bulk.
190	$\text{vbd_max}=\infty$ V	Maximum allowed voltage cross source/drain and bulk.
191	$\text{vbs_max}=\infty$ V	Maximum allowed voltage cross source and bulk.
192	$\text{vgb_max}=\infty$ V	Maximum allowed voltage cross gate and bulk.
193	$\text{vgdr_max}=\infty$ V	Maximum allowed reverse voltage cross gate and drain.
194	$\text{vgsr_max}=\infty$ V	Maximum allowed reverse voltage cross gate and source.
195	$\text{vgbr_max}=\infty$ V	Maximum allowed reverse voltage cross gate and bulk.
196	vthmod	Vth output selector. 'std' outputs model equation Vth. 'vthcc' outputs constant current Vth, and may impact simulation performance. The default value is taken from the options parameter 'vthmod'. Possible values are <code>std</code> and <code>vthcc</code> .
197	ivth (A)	Vth current parameter. The default value is taken from the options parameter 'ivthn' or 'ivthp', depending on the type of the model.

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198	<code>ivthw</code> (m)	Width offset for constant current V_{th} . The default value is taken from the options parameter 'ivthw'.
199	<code>ivthl</code> (m)	Length offset for constant current V_{th} . The default value is taken from the options parameter 'ivthl'.
200	<code>ivth_vdsmin</code> (V)	Minimum V_{ds} in constant current V_{th} calculating. The default value is taken from the options parameter 'ivth_vdsmin'.
201	<code>noisemethod=oldcmi</code>	Induced gate noise implementation . Possible values are <code>oldcmi</code> , <code>subckt</code> , and <code>newcmi</code> .

Output Parameters

1	<code>w_{eff}</code> (m)	Effective channel width for geometrical models.
2	<code>l_{eff}</code> (m)	Effective channel length for geometrical models.
3	<code>lv1</code> (m)	alias of l.
4	<code>lv2</code> (m)	alias of w.
5	<code>lv3</code> (m ²)	alias of ad.
6	<code>lv4</code> (m ²)	alias of as.
7	<code>lv11</code> (m)	alias of pd.
8	<code>lv12</code> (m)	alias of ps.

Operating-Point Parameters

1	<code>ctype</code>	Flag for channel type.
2	<code>sdint</code>	Flag for source-drain interchange.
3	<code>ise</code> (A)	Total source current.
4	<code>ige</code> (A)	Total gate current.
5	<code>ide</code> (A)	Total drain current.

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6	<code>ibe</code> (A)	Total bulk current.
7	<code>ids</code> (A)	Drain current, excl. avalanche, tunnel, GISL, GIDL, and junction currents.
8	<code>idb</code> (A)	Drain to bulk current.
9	<code>isb</code> (A)	Source to bulk current.
10	<code>igs</code> (A)	Gate-source tunneling current.
11	<code>igd</code> (A)	Gate-drain tunneling current.
12	<code>igb</code> (A)	Gate-bulk tunneling current.
13	<code>igcs</code> (A)	Gate-channel tunneling current (source component).
14	<code>igcd</code> (A)	Gate-channel tunneling current (drain component).
15	<code>iavl</code> (A)	Substrate current due to weak avalanche.
16	<code>igisl</code> (A)	Gate-induced source leakage current.
17	<code>igidl</code> (A)	Gate-induced drain leakage current.
18	<code>ijs</code> (A)	Total source junction current.
19	<code>ijsbot</code> (A)	Source junction current (bottom component).
20	<code>ijsgat</code> (A)	Source junction current (gate-edge component).
21	<code>ijssti</code> (A)	Source junction current (STI-edge component).
22	<code>ijd</code> (A)	Total drain junction current.
23	<code>ijdbot</code> (A)	Drain junction current (bottom component).
24	<code>ijdgat</code> (A)	Drain junction current (gate-edge component).
25	<code>ijdsti</code> (A)	Drain junction current (STI-edge component).
26	<code>qg</code> (Coul)	Intrinsic gate charge.

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27	q_d (Coul)	Intrinsic drain charge.
28	q_b (Coul)	Intrinsic bulk charge.
29	q_s (Coul)	Intrinsic source charge.
30	q_{gs_ov} (Coul)	Overlap charge for gate-source.
31	q_{gd_ov} (Coul)	Overlap charge for gate-drain.
32	q_{fgs} (Coul)	Total outerFringe + overlap for gate-source.
33	q_{fgd} (Coul)	Total outerFringe + overlap for gate-drain.
34	q_{gb_ov} (Coul)	Gate-bulk overlap charge.
35	q_{jun_s} (Coul)	Junction charge on source side.
36	q_{jun_d} (Coul)	Junction charge on drain side.
37	v_{ds} (V)	Drain-source voltage.
38	v_{gs} (V)	Gate-source voltage.
39	v_{sb} (V)	Source-bulk voltage.
40	v_{to} (V)	Zero-bias threshold voltage.
41	v_{ts} (V)	Threshold voltage including back bias effects.
42	v_{th} (V)	Threshold voltage including back bias and drain bias effects.
43	v_{gt} (V)	Effective gate drive voltage including back bias and drain bias effects.
44	v_{dss} (V)	Drain saturation voltage at actual bias.
45	v_{sat} (V)	Saturation limit.
46	pwr (W)	Power at op point.
47	g_m ($1/\Omega$)	Transconductance.

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48	g_{mb} ($1/\Omega$)	Substrate transconductance.
49	g_{ds} ($1/\Omega$)	Output conductance.
50	g_{js} ($1/\Omega$)	Source junction conductance.
51	g_{jd} ($1/\Omega$)	Drain junction conductance.
52	c_{dd} (F)	Drain capacitance.
53	c_{dg} (F)	Drain-gate capacitance.
54	c_{ds} (F)	Drain-source capacitance.
55	c_{db} (F)	Drain-bulk capacitance.
56	c_{gd} (F)	Gate-drain capacitance.
57	c_{gg} (F)	Gate capacitance.
58	c_{gs} (F)	Gate-source capacitance.
59	c_{gb} (F)	Gate-bulk capacitance.
60	c_{sd} (F)	Source-drain capacitance.
61	c_{sg} (F)	Source-gate capacitance.
62	c_{ss} (F)	Source capacitance.
63	c_{sb} (F)	Source-bulk capacitance.
64	c_{bd} (F)	Bulk-drain capacitance.
65	c_{bg} (F)	Bulk-gate capacitance.
66	c_{bs} (F)	Bulk-source capacitance.
67	c_{bb} (F)	Bulk capacitance.
68	c_{gsol} (F)	Total gate-source overlap capacitance.
69	c_{gdol} (F)	Total gate-drain overlap capacitance.

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70	<code>cgbo1</code> (F)	Total gate-bulk overlap capacitance.
71	<code>cjs</code> (F)	Total source junction capacitance.
72	<code>cjsbot</code> (F)	Source junction capacitance (bottom component).
73	<code>cjsgat</code> (F)	Source junction capacitance (gate-edge component).
74	<code>cjssti</code> (F)	Source junction capacitance (STI-edge component).
75	<code>cjd</code> (F)	Total drain junction capacitance.
76	<code>cjdbot</code> (F)	Drain junction capacitance (bottom component).
77	<code>cjdgat</code> (F)	Drain junction capacitance (gate-edge component).
78	<code>cjdsti</code> (F)	Drain junction capacitance (STI-edge component).
79	<code>lpoly</code> (m)	
80	<code>u</code>	Transistor gain.
81	<code>rout</code> (Ω)	Small-signal output resistance.
82	<code>vearly</code> (V)	Equivalent Early voltage.
83	<code>bef</code> (A/V^2)	Gain factor.
84	<code>fug</code> (Hz)	Unity gain frequency at actual bias.
85	<code>rg</code> (Ω)	Gate resistance.
86	<code>sfl</code> (A^2/Hz)	Flicker noise current spectral density at 1 Hz.
87	<code>sqrtsff</code> (V/ \sqrt{Hz})	Input-referred RMS white noise voltage spectral density at 1 kHz.
88	<code>sqrtsfw</code> (V/ \sqrt{Hz})	Input-referred RMS white noise voltage spectral density.
89	<code>sid</code> (A^2/Hz)	White noise current spectral density.
90	<code>sig</code> (A^2/Hz)	Induced gate noise current spectral density at 1 Hz.

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91	<code>cigid</code>	Imaginary part of correlation coefficient between Sig and Sid.
92	<code>fknee</code> (Hz)	Cross-over frequency above which white noise is dominant.
93	<code>sigs</code> (A^2/Hz)	Gate-source current noise spectral density.
94	<code>sigd</code> (A^2/Hz)	Gate-drain current noise spectral density.
95	<code>siavl</code> (A^2/Hz)	Impact ionization current noise spectral density.
96	<code>ssi</code> (A^2/Hz)	Total source junction current noise spectral density.
97	<code>sdi</code> (A^2/Hz)	Total drain junction current noise spectral density.
98	<code>vbs</code> (V)	Bulk-source voltage.
99	<code>lv9</code> (V)	alias of <code>vth</code> .
100	<code>lv10</code> (V)	alias of <code>vdss</code> .
101	<code>lv36</code> (F)	alias of <code>cgsol</code> .
102	<code>lv37</code> (F)	alias of <code>cgdol</code> .
103	<code>lv38</code> (F)	alias of <code>cgbol</code> .
104	<code>lv51</code> (m)	alias of <code>tox</code> .
105	<code>lx4</code> (A)	alias of <code>ids</code> .
106	<code>lx3</code> (V)	alias of <code>vds</code> .
107	<code>lx2</code> (V)	alias of <code>vgs</code> .
108	<code>lx7</code> ($1/\Omega$)	alias of <code>gm</code> .
109	<code>lx8</code> ($1/\Omega$)	alias of <code>gds</code> .
110	<code>lx9</code> ($1/\Omega$)	alias of <code>gmb</code> .
111	<code>lx33</code> (F)	alias of <code>cdd</code> .
112	<code>lx32</code> (F)	alias of <code>cdg</code> .

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113	1x34	(F)	alias of cds.
114	1x19	(F)	alias of cgd.
115	1x18	(F)	alias of cgg.
116	1x20	(F)	alias of cgs.
117	1x22	(F)	alias of cbd.
118	1x21	(F)	alias of cbg.
119	1x23	(F)	alias of cbs.
120	1x5	(A)	alias of ijs.
121	1x6	(A)	alias of ijd.
122	1x28	(F)	alias of cjs.
123	1x29	(F)	alias of cjd.
124	1x38	(A)	alias of igs.
125	1x39	(A)	alias of igd.
126	1x66	(A)	alias of igb.
127	1x67	(A)	alias of igcs.
128	1x68	(A)	alias of igcd.
129	1x110	(A)	alias of igisl.
130	1x47	(A)	alias of igidl.
131	1x60	(F)	alias of csd.
132	1x59	(F)	alias of csg.
133	1x58	(F)	alias of css.
134	1x12	(Coul)	alias of Qb including overlap charge.

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135	1x14 (Coul)	alias of Qg including overlap charge.
136	1x16 (Coul)	alias of Qd including overlap charge.
137	1x83 (F)	alias of cgd including overlap cap.
138	1x84 (F)	alias of cgs including overlap cap.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

a1	M-57	factuo	I-2	1x29	OP-123	sid	OP-89
a2	M-58	fbtrbot	M-126	1x3	OP-106	sig	OP-90
a3	M-60	fbtrbotd	M-167	1x32	OP-112	sigd	OP-94
a4	M-61	fbtrgat	M-128	1x33	OP-111	sigs	OP-93
abdrain	I-6	fbtrgatd	M-169	1x34	OP-113	sqrtsff	OP-87
absorce	I-3	fbtrsti	M-127	1x38	OP-124	sqrtsfw	OP-88
ad	I-11	fbtrstid	M-168	1x39	OP-125	ssi	OP-96
agidl	M-70	feta	M-43	1x4	OP-105	sta2	M-59
agidld	M-71	fjunq	M-181	1x47	OP-130	stbet	M-34
alp	M-53	fjunqd	M-183	1x5	OP-120	stbgidl	M-74
alp1	M-54	fknee	OP-92	1x58	OP-133	stbgidld	M-75
alp2	M-55	fnt	M-84	1x59	OP-132	stcs	M-40

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as	I-9	fug	OP-84	lx6	OP-121	stfbbtbot	M-129
ax	M-52	gc2	M-67	lx60	OP-131	stfbbtbotd	M-170
beff	OP-83	gc3	M-68	lx66	OP-126	stfbbtgat	M-131
betn	M-33	gco	M-62	lx67	OP-127	stfbbtgatd	M-172
bgidl	M-72	gds	OP-49	lx68	OP-128	stfbbtsti	M-130
bgidld	M-73	geomod	M-12	lx7	OP-108	stfbbtstid	M-171
binmod	M-13	gjd	OP-51	lx8	OP-109	stig	M-66
cbb	OP-67	gjs	OP-50	lx83	OP-137	stmue	M-36
cbbtbot	M-123	gm	OP-47	lx84	OP-138	strs	M-45
cbbtbotd	M-164	gmb	OP-48	lx9	OP-110	stthemu	M-38
cbbtgat	M-125	iavl	OP-15	m	I-17	stthesat	M-49
cbbtgatd	M-166	ibe	OP-6	mbe	M-186	stvfb	M-17
cbbtsti	M-124	idb	OP-8	mefftatbot	M-120	stxcor	M-42
cbbtstid	M-165	ide	OP-5	mefftatbotd	M-161	swgidl	M-7
cbd	OP-64	ids	OP-7	mefftatgat	M-122	swigate	M-5
cbg	OP-65	idsatrbot	M-109	mefftatgatd	M-163	swimpact	M-6
cbs	OP-66	idsatrbotd	M-150	mefftatsti	M-121	swjunasym	M-9
cdb	OP-55	idsatrgat	M-111	mefftatstid	M-162	swjuncap	M-8
cdd	OP-52	idsatrgatd	M-152	mue	M-35	swjunexp	M-179
cdg	OP-53	idsatrsti	M-110	mulid0	I-13	swnqs	M-4

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cds	OP-54	idsatrstid	M-151	mult	I-15	themu	M-37
cf	M-31	igb	OP-12	munqs	M-89	thesat	M-48
cfb	M-32	igcd	OP-14	mvt	M-185	thesatb	M-50
cfr	M-82	igcs	OP-13	neff	M-20	thesatg	M-51
cfrd	M-83	igd	OP-11	nfa	M-85	tox	M-18
cgb	OP-59	ige	OP-4	nfb	M-86	toxov	M-27
cgbol	OP-70	igidl	OP-17	nfc	M-87	toxovd	M-28
cgbov	M-81	iginv	M-63	noisemethod	M-201	tr	M-3
cgd	OP-56	igisl	OP-16	nov	M-29	trise	I-16
cgdol	OP-69	igov	M-64	novd	M-30	trj	M-96
cgg	OP-57	igovd	M-65	np	M-25	type	M-2
cgidl	M-76	igs	OP-10	nslp	M-22	u	OP-80
cgidld	M-77	ijd	OP-22	pbot	M-103	vbd_max	M-190
cgov	M-79	ijdbot	OP-23	pbotd	M-144	vbirbot	M-100
cgovd	M-80	ijdgat	OP-24	pbrbot	M-135	vbirbotd	M-141
cgs	OP-58	ijdsti	OP-25	pbrbotd	M-176	vbirgat	M-102
cgsol	OP-68	ijs	OP-18	pbrgat	M-137	vbirgatd	M-143
chib	M-69	ijsbot	OP-19	pbrgatd	M-178	vbirsti	M-101
cigid	OP-91	ijsgat	OP-20	pbrsti	M-136	vbirstid	M-142
cjd	OP-75	ijssti	OP-21	pbrstid	M-177	vbrbot	M-132

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cjdbot	OP-76	imax	M-95	pd	I-12	vrbotd	M-173
cjdgat	OP-77	isb	OP-9	pgat	M-105	vbrgat	M-134
cjdsti	OP-78	ise	OP-3	pgatd	M-146	vbrgatd	M-175
cjorbot	M-97	isnoisy	I-18	phigbot	M-106	vbrsti	M-133
cjorbotd	M-138	ivth	M-197	phigbotd	M-147	vbrstid	M-174
cjorgat	M-99	ivth_vdsmin	M-200	phiggat	M-108	vbs	OP-98
cjorgatd	M-140	ivth1	M-199	phiggatd	M-149	vbs_max	M-191
cjorsti	M-98	ivthw	M-198	phigsti	M-107	vds	OP-37
cjorstid	M-139	jw	I-14	phigstid	M-148	vds_max	M-187
cjs	OP-71	leff	O-2	ps	I-10	vdss	OP-44
cjsbot	OP-72	level	M-1	psti	M-104	vearly	OP-82
cjsgat	OP-73	lgdrain	I-8	pstid	M-145	version	M-11
cjssti	OP-74	lgsource	I-5	pwr	OP-46	vfb	M-16
compatible	M-15	lpoly	OP-79	qb	OP-28	vgb_max	M-192
cox	M-78	lsdrain	I-7	qd	OP-27	vgbr_max	M-195
cs	M-39	lssource	I-4	qfgd	OP-33	vgd_max	M-188
csb	OP-63	lv1	O-3	qfgs	OP-32	vgdr_max	M-193
csd	OP-60	lv10	OP-100	qg	OP-26	vgs	OP-38
csg	OP-61	lv11	O-7	qgb_ov	OP-34	vgs_max	M-189
csrbot	M-112	lv12	O-8	qgd_ov	OP-31	vgsr_max	M-194

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csrbotd	M-153	lv2	O-4	qgs_ov	OP-30	vgt	OP-43
csrhat	M-114	lv3	O-5	qjun_d	OP-36	vjunref	M-180
csrhatd	M-155	lv36	OP-101	qjun_s	OP-35	vjunrefd	M-182
csrhisti	M-113	lv37	OP-102	qmc	M-10	vnsb	M-21
csrhistid	M-154	lv38	OP-103	qs	OP-29	vp	M-56
css	OP-62	lv4	O-6	rbulk	M-91	vsat	OP-45
ct	M-26	lv51	OP-104	rg	M-90	vsb	OP-39
ctatbot	M-117	lv9	OP-99	rg	OP-85	vth	OP-42
ctatbotd	M-158	lx110	OP-129	rjund	M-94	vthmod	M-196
ctatgat	M-119	lx12	OP-134	rjuns	M-93	vto	OP-40
ctatgatd	M-160	lx14	OP-135	rout	OP-81	vts	OP-41
ctatsti	M-118	lx16	OP-136	rs	M-44	weff	O-1
ctatstid	M-159	lx18	OP-115	rsb	M-46	xcor	M-41
ctype	OP-1	lx19	OP-114	rsg	M-47	xjungat	M-116
delvto	I-1	lx2	OP-107	rwell	M-92	xjungatd	M-157
dnsub	M-23	lx20	OP-116	scalelev	M-14	xjunsti	M-115
dphib	M-24	lx21	OP-118	sdi	OP-97	xjunstid	M-156
dta	M-184	lx22	OP-117	sdint	OP-2		
ef	M-88	lx23	OP-119	sfl	OP-86		
epsrox	M-19	lx28	OP-122	siavl	OP-95		
al	M-57	factuo	I-2	lx29	OP-123	sid	OP-89

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a2	M-58	fbttrbot	M-126	1x3	OP-106	sig	OP-90
a3	M-60	fbttrbotd	M-167	1x32	OP-112	sigd	OP-94
a4	M-61	fbttrgat	M-128	1x33	OP-111	sig	OP-93
abdrain	I-6	fbttrgatd	M-169	1x34	OP-113	sqrtsff	OP-87

PSP NQS MOSFET Model (pspnqs1020)

This is SiMKit 4.0.1.

This device is supported within altergroups.

This device is dynamically loaded from the shared object /vobs/spectre_dev/tools.lnx86/cmi/lib/5.0.doc/libphilips_sh.so

Instance Definition

```
Name d g s b ModelName parameter=value ...
```

Instance Parameters

1	l=10e-6 m	Design length.
2	w=10e-6 m	Design width.
3	sa=0.0 m	Distance between OD-edge and poly from one side.
4	sb=0.0 m	Distance between OD-edge and poly from other side.
5	sd=0.0 m	Distance between neighboring fingers.
6	sca=0.0	Integral of the first distribution function for scattered well dopants.
7	scb=0.0	Integral of the second distribution function for scattered well dopants.

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8	<code>scc=0.0</code>	Integral of the third distribution function for scattered well dopants.
9	<code>sc=0.0 m</code>	Distance between OD-edge and nearest well edge.
10	<code>delvto=0.0 V</code>	Threshold voltage shift parameter.
11	<code>factuo=1.0</code>	Zero-field mobility pre-factor.
12	<code>absource=1E-12 m²</code>	Bottom area of source junction.
13	<code>lssource=1E-6 m</code>	STI-edge length of source junction.
14	<code>lgsource=1E-6 m</code>	Gate-edge length of source junction.
15	<code>abdRAIN=1E-12 m²</code>	Bottom area of drain junction.
16	<code>lsdRAIN=1E-6 m</code>	STI-edge length of drain junction.
17	<code>lgdRAIN=1E-6 m</code>	Gate-edge length of drain junction.
18	<code>as=1E-12 m²</code>	Bottom area of source junction.
19	<code>ps=1E-6 m</code>	Perimeter of source junction.
20	<code>ad=1E-12 m²</code>	Bottom area of drain junction.
21	<code>pd=1E-6 m</code>	Perimeter of drain junction.
22	<code>mulid0=1</code>	I _{ds} multiplier.
23	<code>mult=1.0</code>	Number of devices in parallel.
24	<code>nf=1.0</code>	Number of fingers.
25	<code>ngcon=1.0</code>	Number of gate contacts.
26	<code>xgw=1.0E-7 m</code>	Distance from the gate contact to the channel edge.
27	<code>trise=0.0 K</code>	Temperature rise from ambient.
28	<code>m=1.0</code>	Multiplicity factor.

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PSP102 Model

29 `isnoisy=yes` Should device generate noise.
Possible values are `no` and `yes`.

Model Definition

`model modelName pspnqs1020 parameter=value ...`

Model Parameters

1 `level=102` Model level.

2 `type=n` Channel type parameter, `n`,NMOS `p`,PMOS.
Possible values are `n` and `p`.

3 `tr=value of tnom C` nominal (reference) temperature.

4 `swnqs=0` Flag for NQS, 0,off, 1, 2, 3, 5, or 9,number of collocation points.

5 `swigate=0` Flag for gate current, 0,turn off IG.

6 `swimpact=0` Flag for impact ionization current, 0,turn off II.

7 `swgidl=0` Flag for GIDL current, 0,turn off IGIDL.

8 `swjuncap=0` Flag for juncap, 0,turn off juncap.

9 `swjunasym=0` Flag for asymmetric junctions; 0,symmetric, 1,asymmetric.

10 `qmc=1.0` Quantum-mechanical correction factor.

11 `version=102.32` The available versions are 102.2, 102.21, 102.3, 102.32, 102.33, 102.34 and 102.40.

12 `geomod=1` 1 for geometrical model and 0 for electrical model.

13 `binmod=0` 1 for bin model and 0 for non-bin model.

14 `scalelev=102` 102 for local, 1020 for global model and 1021 for bin model.

15 `compatible=spectre`
for compatible.

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	Possible values are <code>spectre</code> , <code>spice2</code> , <code>spice3</code> , <code>cdsspice</code> , <code>hspice</code> , <code>spiceplus</code> , <code>eldo</code> , <code>sspice</code> , and <code>mica</code> .
16 <code>lvaro=0.0 m</code>	Geom. independent difference between actual and programmed gate length.
17 <code>lvarl=0.0</code>	Length dependence of LVAR.
18 <code>lvarw=0.0</code>	Width dependence of LVAR.
19 <code>lap=0.0 m</code>	Effective channel length reduction per side.
20 <code>wvaro=0.0 m</code>	Geom. independent difference between actual and programmed field-oxide opening.
21 <code>wvarl=0.0</code>	Length dependence of WVAR.
22 <code>wvarw=0.0</code>	Width dependence of WVAR.
23 <code>wot=0.0 m</code>	Effective channel width reduction per side.
24 <code>dlq=0.0 m</code>	Effective channel length reduction for CV.
25 <code>dwq=0.0 m</code>	Effective channel width reduction for CV.
26 <code>vfbo=(-1.0) V</code>	Geometry-independent flat-band voltage at TR.
27 <code>vfbl=0.0</code>	Length dependence of flat-band voltage.
28 <code>vfbw=0.0</code>	Width dependence of flat-band voltage.
29 <code>vfblw=0.0</code>	Area dependence of flat-band voltage.
30 <code>stvfbo=5e-4 V/K</code>	Geometry-independent temperature dependence of VFB.
31 <code>stvfbl=0.0</code>	Length dependence of temperature dependence of VFB.
32 <code>stvfbw=0.0</code>	Width dependence of temperature dependence of VFB.
33 <code>stvfblw=0.0</code>	Area dependence of temperature dependence of VFB.
34 <code>toxox=2e-9 m</code>	Gate oxide thickness.

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35	$\text{epsroxo}=3.9$	Relative permittivity of gate dielectric.
36	$\text{nsubo}=3e23 \text{ m}^{-3}$	Geometry independent substrate doping.
37	$\text{nsubw}=0.0$	Width dependence of background doping NSUBO due to segregation.
38	$\text{wseg}=1e-8 \text{ m}$	Char. length of segregation of background doping NSUBO.
39	$\text{npck}=1e24 \text{ m}^{-3}$	Pocket doping level.
40	$\text{npckw}=0.0$	Width dependence of pocket doping NPCK due to segregation.
41	$\text{wsegp}=1e-8 \text{ m}$	Char. length of segregation of pocket doping NPCK.
42	$\text{lpck}=1e-8 \text{ m}$	Char. length of lateral doping profile.
43	$\text{lpckw}=0.0$	Width dependence of char. length of lateral doping profile.
44	$\text{fol1}=0.0$	First length dependence coefficient for short channel body effect.
45	$\text{fol2}=0.0$	Second length dependence coefficient for short channel body effect.
46	$\text{vnsubo}=0.0 \text{ V}$	Effective doping bias-dependence parameter.
47	$\text{nslpo}=0.05 \text{ V}$	Effective doping bias-dependence parameter.
48	$\text{dnsubo}=0.0 \text{ V}^{-1}$	Effective doping bias-dependence parameter.
49	$\text{dphibo}=0.0 \text{ V}$	Geometry independent offset of PHIB.
50	$\text{dphibl}=0.0 \text{ V}$	Length dependence offset of PHIB.
51	$\text{dphiblexp}=1.0$	Exponent for length dependence of offset of PHIB.
52	$\text{dphibw}=0.0$	Width dependence of offset of PHIB.
53	$\text{dphiblw}=0.0$	Area dependence of offset of PHIB.
54	$\text{npo}=1e26 \text{ m}^{-3}$	Geometry-independent gate poly-silicon doping.
55	$\text{np1}=0.0$	Length dependence of gate poly-silicon doping.

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56	$cto=0.0$	Geometry-independent interface states factor.
57	$ctl=0.0$	Length dependence of interface states factor.
58	$ctlexp=1.0$	Exponent for length dependence of interface states factor.
59	$ctw=0.0$	Width dependence of interface states factor.
60	$ctlw=0.0$	Area dependence of interface states factor.
61	$toxovo=2e-9$ m	Overlap oxide thickness.
62	$toxovdo=2e-9$ m	Overlap oxide thickness for drain side.
63	$lov=0$ m	Overlap length for gate/drain and gate/source overlap capacitance.
64	$lovd=0$ m	Overlap length for gate/drain overlap capacitance.
65	$novo=5e25$ m ⁻³	Effective doping of overlap region.
66	$novdo=5e25$ m ⁻³	Effective doping of overlap region for drain side.
67	$cf1=0.0$	Length dependence of DIBL-parameter.
68	$cf1exp=2.0$	Exponent for length dependence of CF.
69	$cfw=0.0$	Width dependence of CF.
70	$cfbo=0.0$ V ⁻¹	Back-bias dependence of CF.
71	$uo=5e-2$ m ² /V/s	Zero-field mobility at TR.
72	$fbet1=0.0$	Relative mobility decrease due to first lateral profile.
73	$fbet1w=0.0$	Width dependence of relative mobility decrease due to first lateral profile.
74	$lp1=1e-8$ m	Mobility-related characteristic length of first lateral profile.
75	$lp1w=0.0$	Width dependence of mobility-related characteristic length of first lateral profile.

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76	<code>fbet2=0.0</code>	Relative mobility decrease due to second lateral profile.
77	<code>lp2=1e-8 m</code>	Mobility-related characteristic length of second lateral profile.
78	<code>betw1=0.0</code>	First higher-order width scaling coefficient of BETN.
79	<code>betw2=0.0</code>	Second higher-order width scaling coefficient of BETN.
80	<code>wbet=1e-9 m</code>	Characteristic width for width scaling of BETN.
81	<code>stbeto=1.0</code>	Geometry independent temperature dependence of BETN.
82	<code>stbetl=0.0</code>	Length dependence of temperature dependence of BETN.
83	<code>stbetw=0.0</code>	Width dependence of temperature dependence of BETN.
84	<code>stbetlw=0.0</code>	Area dependence of temperature dependence of BETN.
85	<code>mueo=0.5 m/V</code>	Geometry independent mobility reduction coefficient at TR.
86	<code>muew=0.0</code>	Width dependence of mobility reduction coefficient at TR.
87	<code>stmueo=0.0</code>	Temperature dependence of MUE.
88	<code>themuo=1.5</code>	Mobility reduction exponent at TR.
89	<code>stthemuo=1.5</code>	Temperature dependence of THEMU.
90	<code>cso=0.0</code>	Geometry independent coulomb scattering parameter at TR.
91	<code>cs1=0.0</code>	Length dependence of CS.
92	<code>cs1exp=0.0</code>	Exponent for length dependence of CS.
93	<code>csw=0.0</code>	Width dependence of CS.
94	<code>cslw=0.0</code>	Area dependence of CS.
95	<code>stcso=0.0</code>	Temperature dependence of CS.
96	<code>xcoro=0.0 V⁻¹</code>	Geometry independent non-universality parameter.
97	<code>xcorl=0.0</code>	Length dependence of non-universality parameter.

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98	<code>xcorw=0.0</code>	Width dependence of non-universality parameter.
99	<code>xcorlw=0.0</code>	Area dependence of non-universality parameter.
100	<code>stxcoro=0.0</code>	Temperature dependence of XCOR.
101	<code>fetao=1.0</code>	Effective field parameter.
102	<code>rsw1=2.5e3 Ω</code>	Source/drain series resistance for 1 um wide channel at TR.
103	<code>rsw2=0.0</code>	Higher-order width scaling of RS.
104	<code>strso=1.0</code>	Temperature dependence of RS.
105	<code>rsbo=0.0 V^{-1}</code>	Back-bias dependence of series resistance.
106	<code>rsgo=0.0 V^{-1}</code>	Gate-bias dependence of series resistance.
107	<code>thesato=0.0 V^{-1}</code>	Geometry independent velocity saturation parameter at TR.
108	<code>thesatl=0.05 V^{-1}</code>	Length dependence of THESAT.
109	<code>thesatlexp=1.0</code>	Exponent for length dependence of THESAT.
110	<code>thesatw=0.0</code>	Width dependence of velocity saturation parameter.
111	<code>thesatlw=0.0</code>	Area dependence of velocity saturation parameter.
112	<code>stthesato=1.0</code>	Geometry independent temperature dependence of THESAT.
113	<code>stthesatl=0.0</code>	Length dependence of temperature dependence of THESAT.
114	<code>stthesatw=0.0</code>	Width dependence of temperature dependence of THESAT.
115	<code>stthesatlw=0.0</code>	Area dependence of temperature dependence of THESAT.
116	<code>thesatbo=0.0 V^{-1}</code>	Back-bias dependence of velocity saturation.
117	<code>thesatgo=0.0 V^{-1}</code>	Gate-bias dependence of velocity saturation.
118	<code>axo=18</code>	Geometry independent linear/saturation transition factor.
119	<code>axl=0.4</code>	Length dependence of AX.

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120	<code>alp1=5e-4</code>	Length dependence of ALP.
121	<code>alp1exp=1.0</code>	Exponent for length dependence of ALP.
122	<code>alp1w=0.0</code>	Width dependence of ALP.
123	<code>alp1l1=0.0 V</code>	Length dependence of CLM enhancement factor above threshold.
124	<code>alp1l1exp=0.5</code>	Exponent for length dependence of ALP1.
125	<code>alp1l2=0.0</code>	Second_order length dependence of ALP1.
126	<code>alp1w=0.0</code>	Width dependence of ALP1.
127	<code>alp2l1=0.0 V^-1</code>	Length dependence of CLM enhancement factor below threshold.
128	<code>alp2l1exp=0.5</code>	Exponent for length dependence of ALP2.
129	<code>alp2l2=0.0</code>	Second_order length dependence of ALP2.
130	<code>alp2w=0.0</code>	Width dependence of ALP2.
131	<code>vpo=0.05 V</code>	CLM logarithmic dependence parameter.
132	<code>a1o=1.0</code>	Geometry independent impact-ionization pre-factor.
133	<code>a1l=0.0</code>	Length dependence of A1.
134	<code>a1w=0.0</code>	Width dependence of A1.
135	<code>a2o=10 V</code>	Impact-ionization exponent at TR.
136	<code>sta2o=0.0 V</code>	Temperature dependence of A2.
137	<code>a3o=1.0</code>	Geometry independent saturation-voltage dependence of II.
138	<code>a3l=0.0</code>	Length dependence of A3.
139	<code>a3w=0.0</code>	Width dependence of A3.
140	<code>a4o=0.0 V^-0.5</code>	Geometry independent back-bias dependence of II.

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141	$a4l=0.0$	Length dependence of A4.
142	$a4w=0.0$	Width dependence of A4.
143	$gcoo=0.0$	Gate tunnelling energy adjustment.
144	$iginv1w=0.0$ A	Gate channel current pre-factor for 1 μm^2 channel area.
145	$igovw=0.0$ A	Gate overlap current pre-factor for 1 μm wide channel.
146	$igovdw=0.0$ A	Gate overlap current pre-factor for 1 μm wide channel for drain side.
147	$stigo=2.0$	Temperature dependence of IGINV and IGOV.
148	$gc2o=0.375$	Gate current slope factor.
149	$gc3o=0.063$	Gate current curvature factor.
150	$chibo=3.1$ V	Tunnelling barrier height.
151	$agidlw=0.0$ A/V ³	Width dependence of GIDL pre-factor.
152	$agidldw=0.0$ A/V ³	Width dependence of GIDL pre-factor for drain side.
153	$bgidlo=41$ V	GIDL probability factor at TR.
154	$bgidldo=41$ V	GIDL probability factor at TR for drain side.
155	$stbgidlo=0.0$ V/K	Temperature dependence of BGIDL.
156	$stbgidldo=0.0$ V/K	Temperature dependence of BGIDL for drain side.
157	$cgidlo=0.0$	Back-bias dependence of GIDL.
158	$cgidldo=0.0$	Back-bias dependence of GIDL for drain side.
159	$cgbovl=0.0$ F	Oxide capacitance for gate-bulk overlap for 1 μm long channel.
160	$cfrw=0.0$ F	Outer fringe capacitance for 1 μm wide channel.
161	$cfrdw=0.0$ F	Outer fringe capacitance for 1 μm wide channel for drain side.

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162	$fnto=1.0$	Thermal noise coefficient.
163	$nfalw=8e22 \text{ V}^{-1}/\text{m}^4$	First coefficient of flicker noise for 1 um^2 channel area.
164	$nfblw=3e7 \text{ V}^{-1}/\text{m}^2$	Second coefficient of flicker noise for 1 um^2 channel area.
165	$nfclw=0.0 \text{ V}^{-1}$	Third coefficient of flicker noise for 1 um^2 channel area.
166	$efo=1.0$	Flicker noise frequency exponent.
167	$lintnoi=0.0 \text{ m}$	Length offset for flicker noise.
168	$alpnoi=2.0$	Exponent for length offset for flicker noise.
169	$dta=0 \text{ K}$	Temperature offset w.r.t. ambient circuit temperature.
170	$kvthoweo=0$	Geometrical independent threshold shift parameter.
171	$kvthowel=0$	Length dependent threshold shift parameter.
172	$kvthowew=0$	Width dependent threshold shift parameter.
173	$kvthowelw=0$	Area dependent threshold shift parameter.
174	$kuoweo=0$	Geometrical independent mobility degradation factor.
175	$kuowel=0$	Length dependent mobility degradation factor.
176	$kuowew=0$	Width dependent mobility degradation factor.
177	$kuowelw=0$	Area dependent mobility degradation factor.
178	$vds_max=\infty \text{ V}$	Maximum allowed voltage cross source and drain.
179	$vgd_max=\infty \text{ V}$	Maximum allowed voltage cross gate and drain.
180	$vgs_max=\infty \text{ V}$	Maximum allowed voltage cross gate and source/bulk.

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181	$vbd_max=\infty$ V	Maximum allowed voltage cross source/drain and bulk.
182	$vbs_max=\infty$ V	Maximum allowed voltage cross source and bulk.
183	$vgb_max=\infty$ V	Maximum allowed voltage cross gate and bulk.
184	$vgdr_max=\infty$ V	Maximum allowed reverse voltage cross gate and drain.
185	$vg sr_max=\infty$ V	Maximum allowed reverse voltage cross gate and source.
186	$vgbr_max=\infty$ V	Maximum allowed reverse voltage cross gate and bulk.
187	$munqso=1.0$	Relative mobility for NQS modeling.
188	$rgo=0.0$ Ω	Gate resistance.
189	$rbulko=0.0$ Ω	Bulk resistance between node BP and BI.
190	$rwello=0.0$ Ω	Well resistance between node BI and B.
191	$rjunso=0.0$ Ω	Source-side bulk resistance between node BI and BS.
192	$rjundo=0.0$ Ω	Drain-side bulk resistance between node BI and BD.
193	$rint=0.0$ Ω/Sqr	Contact resistance between silicide and poly.
194	$rvpoly=0.0$ Ω/Sqr	Vertical poly resistance.
195	$rshg=0.0$ Ω/Sqr	Gate electrode diffusion sheet resistance.
196	$dlsil=0.0$ m	Silicide extension over the physical gate length.
197	$saref=1.0e-6$ m	Reference distance between OD-edge and poly from one side.
198	$sbref=1.0e-6$ m	Reference distance between OD-edge and poly from other side.

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199	$w_{lod}=0$ m	Width parameter.
200	$k_{uo}=0$ m	Mobility degradation/enhancement coefficient.
201	$k_{vsat}=0$ m	Saturation velocity degradation/enhancement coefficient.
202	$t_{kuo}=0$	Temperature dependence of KUO.
203	$l_{kuo}=0$ m ^{LLODKUO}	Length dependence of KUO.
204	$w_{kuo}=0$ m ^{WLODKUO}	Width dependence of KUO.
205	$p_{kuo}=0$ m ^(LLODKUO+WLODKUO)	Cross-term dependence of KUO.
206	$l_{lodkuo}=0$	Length parameter for UO stress effect.
207	$w_{lodkuo}=0$	Width parameter for UO stress effect.
208	$k_{vtho}=0$ Vm	Threshold shift parameter.
209	$l_{kvtho}=0$ m ^{LLODVTH}	Length dependence of KVTHO.
210	$w_{kvtho}=0$ m ^{WLODVTH}	Width dependence of KVTHO.
211	$p_{kvtho}=0$ m ^(LLODVTH+WLODVTH)	Cross-term dependence of KVTHO.
212	$l_{lodvth}=0$	Length parameter for VTH-stress effect.
213	$w_{lodvth}=0$	Width parameter for VTH-stress effect.
214	$s_{tetao}=0$ m	eta0 shift factor related to VTHO change.
215	$l_{odetao}=1.0$	eta0 shift modification factor for stress effect.
216	$s_{cref}=10e-6$ m	Distance between OD-edge and well edge of a reference device.
217	$w_{eb}=0$	Coeffecient for SCB.
218	$w_{ec}=0$	Coeffecient for SCC.

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219	$i_{max}=1000$ A	Maximum current up to which forward current behaves exponentially.
220	$trj=21$ C	reference temperature.
221	$c_{jorbot}=1E-3$ Fm ⁻²	Zero-bias capacitance per unit-of-area of bottom component for source-bulk junction.
222	$c_{jorsti}=1E-9$ Fm ⁻¹	Zero-bias capacitance per unit-of-length of STI-edge component for source-bulk junction.
223	$c_{jorgat}=1E-9$ Fm ⁻¹	Zero-bias capacitance per unit-of-length of gate-edge component for source-bulk junction.
224	$v_{birbot}=1$ V	Built-in voltage at the reference temperature of bottom component for source-bulk junction.
225	$v_{birsti}=1$ V	Built-in voltage at the reference temperature of STI-edge component for source-bulk junction.
226	$v_{birgat}=1$ V	Built-in voltage at the reference temperature of gate-edge component for source-bulk junction.
227	$p_{bot}=0.5$	Grading coefficient of bottom component for source-bulk junction.
228	$p_{sti}=0.5$	Grading coefficient of STI-edge component for source-bulk junction.
229	$p_{gat}=0.5$	Grading coefficient of gate-edge component for source-bulk junction.
230	$\phi_{igbot}=1.16$ V	Zero-temperature bandgap voltage of bottom component for source-bulk junction.
231	$\phi_{igsti}=1.16$ V	Zero-temperature bandgap voltage of STI-edge component for source-bulk junction.
232	$\phi_{iggat}=1.16$ V	Zero-temperature bandgap voltage of gate-edge component for source-bulk junction.

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- 233 `idsatrbot=1E-12` Am^{-2} Saturation current density at the reference temperature of bottom component for source-bulk junction.
- 234 `idsatrsti=1E-18` Am^{-1} Saturation current density at the reference temperature of STI-edge component for source-bulk junction.
- 235 `idsatrgat=1E-18` Am^{-1} Saturation current density at the reference temperature of gate-edge component for source-bulk junction.
- 236 `csrbot=1E2` Am^{-3} Shockley-Read-Hall prefactor of bottom component for source-bulk junction.
- 237 `csrhisti=1E-4` Am^{-2} Shockley-Read-Hall prefactor of STI-edge component for source-bulk junction.
- 238 `csrhgat=1E-4` Am^{-2} Shockley-Read-Hall prefactor of gate-edge component for source-bulk junction.
- 239 `xjunsti=100E-9` m Junction depth of STI-edge component for source-bulk junction.
- 240 `xjungat=100E-9` m Junction depth of gate-edge component for source-bulk junction.
- 241 `ctatbot=1E2` Am^{-3} Trap-assisted tunneling prefactor of bottom component for source-bulk junction.
- 242 `ctatsti=1E-4` Am^{-2} Trap-assisted tunneling prefactor of STI-edge component for source-bulk junction.
- 243 `ctatgat=1E-4` Am^{-2} Trap-assisted tunneling prefactor of gate-edge component for source-bulk junction.
- 244 `mefftatbot=0.25` Effective mass (in units of m_0) for trap-assisted tunneling of bottom component for source-bulk junction.
- 245 `mefftatsti=0.25` Effective mass (in units of m_0) for trap-assisted tunneling of STI-edge component for source-bulk junction.

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- 246 $m_{eff\,at\,gat}=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of gate-edge component for source-bulk junction.
- 247 $c_{bbt\,bot}=1E-12$ AV^{-3} Band-to-band tunneling prefactor of bottom component for source-bulk junction.
- 248 $c_{bbt\,sti}=1E-18$ AV^3m Band-to-band tunneling prefactor of STI-edge component for source-bulk junction.
- 249 $c_{bbt\,gat}=1E-18$ AV^3m Band-to-band tunneling prefactor of gate-edge component for source-bulk junction.
- 250 $f_{bbtr\,bot}=1E9$ Vm^{-1} Normalization field at the reference temperature for band-to-band tunneling of bottom component for source-bulk junction.
- 251 $f_{bbtr\,sti}=1E9$ Vm^{-1} Normalization field at the reference temperature for band-to-band tunneling of STI-edge component for source-bulk junction.
- 252 $f_{bbtr\,gat}=1E9$ Vm^{-1} Normalization field at the reference temperature for band-to-band tunneling of gate-edge component for source-bulk junction.
- 253 $stf_{bbt\,bot}=(-1E-3)$ K^{-1} Temperature scaling parameter for band-to-band tunneling of bottom component for source-bulk junction.
- 254 $stf_{bbt\,sti}=(-1E-3)$ K^{-1} Temperature scaling parameter for band-to-band tunneling of STI-edge component for source-bulk junction.
- 255 $stf_{bbt\,gat}=(-1E-3)$ K^{-1} Temperature scaling parameter for band-to-band tunneling of gate-edge component for source-bulk junction.
- 256 $v_{br\,bot}=10$ V Breakdown voltage of bottom component for source-bulk junction.

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257	<code>vbrsti=10</code>	V	Breakdown voltage of STI-edge component for source-bulk junction.
258	<code>vbrgat=10</code>	V	Breakdown voltage of gate-edge component for source-bulk junction.
259	<code>pbrbot=4</code>	V	Breakdown onset tuning parameter of bottom component for source-bulk junction.
260	<code>pbrsti=4</code>	V	Breakdown onset tuning parameter of STI-edge component for source-bulk junction.
261	<code>pbrgat=4</code>	V	Breakdown onset tuning parameter of gate-edge component for source-bulk junction.
262	<code>cjorbotd=1E-3</code>	Fm^{-2}	Zero-bias capacitance per unit-of-area of bottom component for drain-bulk junction.
263	<code>cjorstid=1E-9</code>	Fm^{-1}	Zero-bias capacitance per unit-of-length of STI-edge component for drain-bulk junction.
264	<code>cjorgatd=1E-9</code>	Fm^{-1}	Zero-bias capacitance per unit-of-length of gate-edge component for drain-bulk junction.
265	<code>vbirbotd=1</code>	V	Built-in voltage at the reference temperature of bottom component for drain-bulk junction.
266	<code>vbirstid=1</code>	V	Built-in voltage at the reference temperature of STI-edge component for drain-bulk junction.
267	<code>vbirgatd=1</code>	V	Built-in voltage at the reference temperature of gate-edge component for drain-bulk junction.
268	<code>pbotd=0.5</code>		Grading coefficient of bottom component for drain-bulk junction.
269	<code>pstid=0.5</code>		Grading coefficient of STI-edge component for drain-bulk junction.
270	<code>pgatd=0.5</code>		Grading coefficient of gate-edge component for drain-bulk junction.

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- 271 `phigbotd=1.16` V Zero-temperature bandgap voltage of bottom component for drain-bulk junction.
- 272 `phigstid=1.16` V Zero-temperature bandgap voltage of STI-edge component for drain-bulk junction.
- 273 `phiggatd=1.16` V Zero-temperature bandgap voltage of gate-edge component for drain-bulk junction.
- 274 `idsatrbotd=1E-12` Am^{-2} Saturation current density at the reference temperature of bottom component for drain-bulk junction.
- 275 `idsatrstid=1E-18` Am^{-1} Saturation current density at the reference temperature of STI-edge component for drain-bulk junction.
- 276 `idsatrgatd=1E-18` Am^{-1} Saturation current density at the reference temperature of gate-edge component for drain-bulk junction.
- 277 `csrbotd=1E2` Am^{-3} Shockley-Read-Hall prefactor of bottom component for drain-bulk junction.
- 278 `csrhostid=1E-4` Am^{-2} Shockley-Read-Hall prefactor of STI-edge component for drain-bulk junction.
- 279 `csrhgatd=1E-4` Am^{-2} Shockley-Read-Hall prefactor of gate-edge component for drain-bulk junction.
- 280 `xjunstid=100E-9` m Junction depth of STI-edge component for drain-bulk junction.
- 281 `xjungatd=100E-9` m Junction depth of gate-edge component for drain-bulk junction.
- 282 `ctatbotd=1E2` Am^{-3} Trap-assisted tunneling prefactor of bottom component for drain-bulk junction.

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- 283 $c_{statstid}=1E-4 \text{ Am}^{-2}$
Trap-assisted tunneling prefactor of STI-edge component for drain-bulk junction.
- 284 $c_{statgatd}=1E-4 \text{ Am}^{-2}$
Trap-assisted tunneling prefactor of gate-edge component for drain-bulk junction.
- 285 $m_{efftatbotd}=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of bottom component for drain-bulk junction.
- 286 $m_{efftatstid}=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of STI-edge component for drain-bulk junction.
- 287 $m_{efftatgatd}=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of gate-edge component for drain-bulk junction.
- 288 $c_{bbtbotd}=1E-12 \text{ AV}^3$
Band-to-band tunneling prefactor of bottom component for drain-bulk junction.
- 289 $c_{bbtstid}=1E-18 \text{ AV}^3m$
Band-to-band tunneling prefactor of STI-edge component for drain-bulk junction.
- 290 $c_{bbtgatd}=1E-18 \text{ AV}^3m$
Band-to-band tunneling prefactor of gate-edge component for drain-bulk junction.
- 291 $f_{bbtrbotd}=1E9 \text{ Vm}^{-1}$
Normalization field at the reference temperature for band-to-band tunneling of bottom component for drain-bulk junction.
- 292 $f_{bbtrstid}=1E9 \text{ Vm}^{-1}$
Normalization field at the reference temperature for band-to-band tunneling of STI-edge component for drain-bulk junction.
- 293 $f_{bbtrgatd}=1E9 \text{ Vm}^{-1}$
Normalization field at the reference temperature for band-to-band tunneling of gate-edge component for drain-bulk junction.

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- 294 `stfbbtbotd=(-1E-3) K^-1`
Temperature scaling parameter for band-to-band tunneling of bottom component for drain-bulk junction.
- 295 `stfbbtstid=(-1E-3) K^-1`
Temperature scaling parameter for band-to-band tunneling of STI-edge component for drain-bulk junction.
- 296 `stfbbtgatd=(-1E-3) K^-1`
Temperature scaling parameter for band-to-band tunneling of gate-edge component for drain-bulk junction.
- 297 `vbrbotd=10 V`
Breakdown voltage of bottom component for drain-bulk junction.
- 298 `vbrstid=10 V`
Breakdown voltage of STI-edge component for drain-bulk junction.
- 299 `vbrgatd=10 V`
Breakdown voltage of gate-edge component for drain-bulk junction.
- 300 `pbrbotd=4 V`
Breakdown onset tuning parameter of bottom component for drain-bulk junction.
- 301 `pbrstid=4 V`
Breakdown onset tuning parameter of STI-edge component for drain-bulk junction.
- 302 `pbrgatd=4 V`
Breakdown onset tuning parameter of gate-edge component for drain-bulk junction.
- 303 `swjunexp=0.0`
Flag for JUNCAP-express; 0,full model, 1,express model.
- 304 `vjunref=2.5`
Typical maximum source-bulk junction voltage; usually about 2*VSUP.
- 305 `fjung=0.03`
Fraction below which source-bulk junction capacitance components are considered negligible.
- 306 `vjunrefd=2.5`
Typical maximum drain-bulk junction voltage; usually about 2*VSUP.
- 307 `fjungd=0.03`
Fraction below which drain-bulk junction capacitance components are considered negligible.

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308	<code>mvto=0.0</code>	DCmatch parameter.
309	<code>mbeo=0.0</code>	DCmatch parameter.
310	<code>vthmod</code>	Vth output selector. 'std' outputs model equation Vth. 'vthcc' outputs constant current Vth, and may impact simulation performance. The default value is taken from the options parameter 'vthmod'. Possible values are <code>std</code> and <code>vthcc</code> .
311	<code>ivth (A)</code>	Vth current parameter. The default value is taken from the options parameter 'ivthn' or 'ivthp', depending on the type of the model.
312	<code>ivthw (m)</code>	Width offset for constant current Vth. The default value is taken from the options parameter 'ivthw'.
313	<code>ivthl (m)</code>	Length offset for constant current Vth. The default value is taken from the options parameter 'ivthl'.
314	<code>ivth_vdsmin (V)</code>	Minimum Vds in constant current Vth calculating. The default value is taken from the options parameter 'ivth_vdsmin'.
315	<code>noisemethod=oldcmi</code>	Induced gate noise implementation . Possible values are <code>oldcmi</code> , <code>subckt</code> , and <code>newcmi</code> .

Output Parameters

1	<code>w_{eff} (m)</code>	Effective channel width for geometrical models.
2	<code>l_{eff} (m)</code>	Effective channel length for geometrical models.
3	<code>lv1 (m)</code>	alias of l.
4	<code>lv2 (m)</code>	alias of w.
5	<code>lv3 (m²)</code>	alias of ad.
6	<code>lv4 (m²)</code>	alias of as.
7	<code>lv11 (m)</code>	alias of pd.

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8 lv12 (m) alias of ps.

Operating-Point Parameters

1	ctype	Flag for channel type.
2	sdint	Flag for source-drain interchange.
3	ise (A)	Total source current.
4	ige (A)	Total gate current.
5	ide (A)	Total drain current.
6	ibe (A)	Total bulk current.
7	ids (A)	Drain current, excl. avalanche, tunnel, GISL, GIDL, and junction currents.
8	idb (A)	Drain to bulk current.
9	isb (A)	Source to bulk current.
10	igs (A)	Gate-source tunneling current.
11	igd (A)	Gate-drain tunneling current.
12	igb (A)	Gate-bulk tunneling current.
13	igcs (A)	Gate-channel tunneling current (source component).
14	igcd (A)	Gate-channel tunneling current (drain component).
15	iavl (A)	Substrate current due to weak avalanche.
16	igisl (A)	Gate-induced source leakage current.
17	igidl (A)	Gate-induced drain leakage current.
18	ijs (A)	Total source junction current.
19	ijsbot (A)	Source junction current (bottom component).

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20	<code>ijsgat</code> (A)	Source junction current (gate-edge component).
21	<code>ijssti</code> (A)	Source junction current (STI-edge component).
22	<code>ijd</code> (A)	Total drain junction current.
23	<code>ijdbot</code> (A)	Drain junction current (bottom component).
24	<code>ijdgat</code> (A)	Drain junction current (gate-edge component).
25	<code>ijdsti</code> (A)	Drain junction current (STI-edge component).
26	<code>qg</code> (Coul)	Intrinsic gate charge.
27	<code>qd</code> (Coul)	Intrinsic drain charge.
28	<code>qb</code> (Coul)	Intrinsic bulk charge.
29	<code>qs</code> (Coul)	Intrinsic source charge.
30	<code>qgs_ov</code> (Coul)	Overlap charge for gate-source.
31	<code>qgd_ov</code> (Coul)	Overlap charge for gate-drain.
32	<code>qfgs</code> (Coul)	Total outerFringe + overlap for gate-source.
33	<code>qfgd</code> (Coul)	Total outerFringe + overlap for gate-drain.
34	<code>qgb_ov</code> (Coul)	Gate-bulk overlap charge.
35	<code>qjun_s</code> (Coul)	Junction charge on source side.
36	<code>qjun_d</code> (Coul)	Junction charge on drain side.
37	<code>vds</code> (V)	Drain-source voltage.
38	<code>vgs</code> (V)	Gate-source voltage.
39	<code>vsb</code> (V)	Source-bulk voltage.
40	<code>vto</code> (V)	Zero-bias threshold voltage.
41	<code>vts</code> (V)	Threshold voltage including back bias effects.

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42	v_{th} (V)	Threshold voltage including back bias and drain bias effects.
43	v_{gt} (V)	Effective gate drive voltage including back bias and drain bias effects.
44	v_{dss} (V)	Drain saturation voltage at actual bias.
45	v_{sat} (V)	Saturation limit.
46	pwr (W)	Power at op point.
47	g_m ($1/\Omega$)	Transconductance.
48	g_{mb} ($1/\Omega$)	Substrate transconductance.
49	g_{ds} ($1/\Omega$)	Output conductance.
50	g_{js} ($1/\Omega$)	Source junction conductance.
51	g_{jd} ($1/\Omega$)	Drain junction conductance.
52	c_{dd} (F)	Drain capacitance.
53	c_{dg} (F)	Drain-gate capacitance.
54	c_{ds} (F)	Drain-source capacitance.
55	c_{db} (F)	Drain-bulk capacitance.
56	c_{gd} (F)	Gate-drain capacitance.
57	c_{gg} (F)	Gate capacitance.
58	c_{gs} (F)	Gate-source capacitance.
59	c_{gb} (F)	Gate-bulk capacitance.
60	c_{sd} (F)	Source-drain capacitance.
61	c_{sg} (F)	Source-gate capacitance.
62	c_{ss} (F)	Source capacitance.

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63	csb (F)	Source-bulk capacitance.
64	cbd (F)	Bulk-drain capacitance.
65	cbg (F)	Bulk-gate capacitance.
66	cbs (F)	Bulk-source capacitance.
67	cbb (F)	Bulk capacitance.
68	cgso1 (F)	Total gate-source overlap capacitance.
69	cgdo1 (F)	Total gate-drain overlap capacitance.
70	cgbo1 (F)	Total gate-bulk overlap capacitance.
71	cjs (F)	Total source junction capacitance.
72	cjsbot (F)	Source junction capacitance (bottom component).
73	cjsgat (F)	Source junction capacitance (gate-edge component).
74	cjssti (F)	Source junction capacitance (STI-edge component).
75	cjd (F)	Total drain junction capacitance.
76	cjdbot (F)	Drain junction capacitance (bottom component).
77	cjdgat (F)	Drain junction capacitance (gate-edge component).
78	cjdsti (F)	Drain junction capacitance (STI-edge component).
79	lpoly (m)	
80	u	Transistor gain.
81	rout (Ω)	Small-signal output resistance.
82	vearly (V)	Equivalent Early voltage.
83	bef _f (A/V^2)	Gain factor.
84	fug (Hz)	Unity gain frequency at actual bias.

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85	r_g (Ω)	Gate resistance.
86	s_{fl} (A^2/Hz)	Flicker noise current spectral density at 1 Hz.
87	s_{qrtsff} (V/\sqrt{Hz})	Input-referred RMS white noise voltage spectral density at 1 kHz.
88	s_{qrtsfw} (V/\sqrt{Hz})	Input-referred RMS white noise voltage spectral density.
89	s_{id} (A^2/Hz)	White noise current spectral density.
90	s_{ig} (A^2/Hz)	Induced gate noise current spectral density at 1 Hz.
91	c_{igid}	Imaginary part of correlation coefficient between Sig and Sid.
92	f_{knee} (Hz)	Cross-over frequency above which white noise is dominant.
93	s_{igs} (A^2/Hz)	Gate-source current noise spectral density.
94	s_{igd} (A^2/Hz)	Gate-drain current noise spectral density.
95	s_{iavl} (A^2/Hz)	Impact ionization current noise spectral density.
96	s_{si} (A^2/Hz)	Total source junction current noise spectral density.
97	s_{di} (A^2/Hz)	Total drain junction current noise spectral density.
98	v_{bs} (V)	Bulk-source voltage.
99	$lv9$ (V)	alias of v_{th} .
100	$lv10$ (V)	alias of v_{dss} .
101	$lv36$ (F)	alias of c_{gsol} .
102	$lv37$ (F)	alias of c_{gdol} .
103	$lv38$ (F)	alias of c_{gbol} .
104	$lv51$ (m)	alias of t_{ox} .
105	$lx4$ (A)	alias of i_{ds} .

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106	1x3 (V)	alias of vds.
107	1x2 (V)	alias of vgs.
108	1x7 ($1/\Omega$)	alias of gm.
109	1x8 ($1/\Omega$)	alias of gds.
110	1x9 ($1/\Omega$)	alias of gmb.
111	1x33 (F)	alias of cdd.
112	1x32 (F)	alias of cdg.
113	1x34 (F)	alias of cds.
114	1x19 (F)	alias of cgd.
115	1x18 (F)	alias of cgg.
116	1x20 (F)	alias of cgs.
117	1x22 (F)	alias of cbd.
118	1x21 (F)	alias of cbg.
119	1x23 (F)	alias of cbs.
120	1x5 (A)	alias of ijs.
121	1x6 (A)	alias of ijd.
122	1x28 (F)	alias of cjs.
123	1x29 (F)	alias of cjd.
124	1x38 (A)	alias of igs.
125	1x39 (A)	alias of igd.
126	1x66 (A)	alias of igb.
127	1x67 (A)	alias of igcs.

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128	1x68 (A)	alias of igcd.
129	1x110 (A)	alias of igisl.
130	1x47 (A)	alias of igidl.
131	1x60 (F)	alias of csd.
132	1x59 (F)	alias of csg.
133	1x58 (F)	alias of css.
134	1x12 (Coul)	alias of Qb including overlap charge.
135	1x14 (Coul)	alias of Qg including overlap charge.
136	1x16 (Coul)	alias of Qd including overlap charge.
137	1x83 (F)	alias of cgd including overlap cap.
138	1x84 (F)	alias of cgs including overlap cap.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

a1l	M-133	factuo	I-11	1x23	OP-119	ssi	OP-96
a1o	M-132	fbbotrbot	M-250	1x28	OP-122	sta2o	M-136
a1w	M-134	fbbotrbotd	M-291	1x29	OP-123	stbetl	M-82
a2o	M-135	fbbotrgat	M-252	1x3	OP-106	stbetlw	M-84
a3l	M-138	fbbotrgatd	M-293	1x32	OP-112	stbeto	M-81

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a3o	M-137	fbtrsti	M-251	lx33	OP-111	stbetw	M-83
a3w	M-139	fbtrstid	M-292	lx34	OP-113	stbgidldo	M-156
a4l	M-141	fbet1	M-72	lx38	OP-124	stbgidlo	M-155
a4o	M-140	fbet1w	M-73	lx39	OP-125	stcso	M-95
a4w	M-142	fbet2	M-76	lx4	OP-105	stetao	M-214
abdrain	I-15	fetao	M-101	lx47	OP-130	stfbbtbot	M-253
absorce	I-12	fjunq	M-305	lx5	OP-120	stfbbtbotd	M-294
ad	I-20	fjunqd	M-307	lx58	OP-133	stfbbtgat	M-255
agidldw	M-152	fknee	OP-92	lx59	OP-132	stfbbtgatd	M-296
agidlw	M-151	fnto	M-162	lx6	OP-121	stfbbtsti	M-254
alp1l1	M-123	fol1	M-44	lx60	OP-131	stfbbtstid	M-295
alp1l2	M-125	fol2	M-45	lx66	OP-126	stigo	M-147
alp1lexp	M-124	fug	OP-84	lx67	OP-127	stmueo	M-87
alp1w	M-126	gc2o	M-148	lx68	OP-128	strso	M-104
alp2l1	M-127	gc3o	M-149	lx7	OP-108	stthemuo	M-89
alp2l2	M-129	gcoo	M-143	lx8	OP-109	stthesatl	M-113
alp2lexp	M-128	gds	OP-49	lx83	OP-137	stthesatlw	M-115
alp2w	M-130	geomod	M-12	lx84	OP-138	stthesato	M-112
alpl	M-120	gjd	OP-51	lx9	OP-110	stthesatw	M-114
alplexp	M-121	gjs	OP-50	m	I-28	stvfbl	M-31
alpnoi	M-168	gm	OP-47	mbeo	M-309	stvfblw	M-33

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alpw M-122	gmb OP-48	mefftatbot M-244	stvfbo M-30
as I-18	iavl OP-15	mefftatbotd M-285	stvfbo M-32
axl M-119	ibe OP-6	mefftatgat M-246	stxcoro M-100
axo M-118	idb OP-8	mefftatgatd M-287	swgidl M-7
beff OP-83	ide OP-5	mefftatsti M-245	swigate M-5
betw1 M-78	ids OP-7	mefftatstid M-286	swimpact M-6
betw2 M-79	idsatrbot M-233	mueo M-85	swjunasym M-9
bgidldo M-154	idsatrbotd M-274	muew M-86	swjuncap M-8
bgidlo M-153	idsatrgat M-235	mulid0 I-22	swjunexp M-303
binmod M-13	idsatrgatd M-276	mult I-23	swnqs M-4
cbb OP-67	idsatrsti M-234	munqso M-187	themuo M-88
cbbtbot M-247	idsatrstid M-275	mvto M-308	thesatbo M-116
cbbtbotd M-288	igb OP-12	nf I-24	thesatgo M-117
cbbtgat M-249	igcd OP-14	nfalw M-163	thesatl M-108
cbbtgatd M-290	igcs OP-13	nfblw M-164	thesatlexp M-109
cbbtsti M-248	igd OP-11	nfclw M-165	thesatlw M-111
cbbtstid M-289	ige OP-4	ngcon I-25	thesato M-107
cbd OP-64	igidl OP-17	noisemethod M-315	thesatw M-110
cbg OP-65	iginvlw M-144	novdo M-66	tkuo M-202

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cbs	OP-66	igisl	OP-16	novo	M-65	toxoxo	M-34
cdb	OP-55	igovdw	M-146	npck	M-39	toxovdo	M-62
cdd	OP-52	igovw	M-145	npckw	M-40	toxovo	M-61
cdg	OP-53	igs	OP-10	npl	M-55	tr	M-3
cds	OP-54	ijd	OP-22	npo	M-54	trise	I-27
cfbo	M-70	ijdbot	OP-23	nslpo	M-47	trj	M-220
cfl	M-67	ijdgat	OP-24	nsubo	M-36	type	M-2
cflexp	M-68	ijdsti	OP-25	nsubw	M-37	u	OP-80
cfrdw	M-161	ijs	OP-18	pbot	M-227	uo	M-71
cfrw	M-160	ijsbot	OP-19	pbotd	M-268	vbd_max	M-181
cfw	M-69	ijsgat	OP-20	pbrbot	M-259	vbirbot	M-224
cgb	OP-59	ijssti	OP-21	pbrbotd	M-300	vbirbotd	M-265
cgbol	OP-70	imax	M-219	pbrgat	M-261	vbirgat	M-226
cgbovl	M-159	isb	OP-9	pbrgatd	M-302	vbirgatd	M-267
cgd	OP-56	ise	OP-3	pbrsti	M-260	vbirsti	M-225
cgdol	OP-69	isnoisy	I-29	pbrstid	M-301	vbirstid	M-266
cgg	OP-57	ivth	M-311	pd	I-21	vbrbot	M-256
cgidldo	M-158	ivth_vdsmin	M-314	pgat	M-229	vbrbotd	M-297
cgidlo	M-157	ivthl	M-313	pgatd	M-270	vbrgat	M-258
cgs	OP-58	ivthw	M-312	phigbot	M-230	vbrgatd	M-299

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cgsol	OP-68	kuo	M-200	phigbotd	M-271	vbrsti	M-257
chibo	M-150	kuowel	M-175	phiggat	M-232	vbrstid	M-298
cigid	OP-91	kuowelw	M-177	phiggatd	M-273	vbs	OP-98
cjd	OP-75	kuoweo	M-174	phigsti	M-231	vbs_max	M-182
cjdbot	OP-76	kuowew	M-176	phigstid	M-272	vds	OP-37
cjdgat	OP-77	kvsat	M-201	pkuo	M-205	vds_max	M-178
cjdsti	OP-78	kvtho	M-208	pkvtho	M-211	vdss	OP-44
cjorbot	M-221	kvthowel	M-171	ps	I-19	vearly	OP-82
cjorbotd	M-262	kvthowelw	M-173	psti	M-228	version	M-11
cjorgat	M-223	kvthoweo	M-170	pstid	M-269	vfb1	M-27
cjorgatd	M-264	kvthowew	M-172	pwr	OP-46	vfb1w	M-29
cjorsti	M-222	l	I-1	qbr	OP-28	vfbo	M-26
cjorstid	M-263	lap	M-19	qdr	OP-27	vfbw	M-28
cjs	OP-71	leff	O-2	qfgd	OP-33	vgb_max	M-183
cjsbot	OP-72	level	M-1	qfgs	OP-32	vgbr_max	M-186
cjsgat	OP-73	lgdrain	I-17	qg	OP-26	vgd_max	M-179
cjssti	OP-74	lgsource	I-14	qgb_ov	OP-34	vgdr_max	M-184
compatible	M-15	lintnoi	M-167	qgd_ov	OP-31	vgs	OP-38
csb	OP-63	lkuo	M-203	qgs_ov	OP-30	vgs_max	M-180
csd	OP-60	lkvtho	M-209	qjun_d	OP-36	vgsr_max	M-185
csg	OP-61	llodkuo	M-206	qjun_s	OP-35	vgt	OP-43

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cs1 M-91	llodvth M-212	qmc M-10	vjunref M-304
cslexp M-92	lodetao M-215	qs OP-29	vjunrefd M-306
cslw M-94	lov M-63	rbulko M-189	vnsubo M-46
cso M-90	lovd M-64	rg OP-85	vpo M-131
csrhibot M-236	lp1 M-74	rgo M-188	vsat OP-45
csrhibotd M-277	lp1w M-75	rint M-193	vsb OP-39
csrhgat M-238	lp2 M-77	rjundo M-192	vth OP-42
csrhgatd M-279	lpck M-42	rjunso M-191	vthmod M-310
csrhisti M-237	lpckw M-43	rout OP-81	vto OP-40
csrhistid M-278	lpoly OP-79	rsbo M-105	vts OP-41
css OP-62	lsdrain I-16	rsgo M-106	w I-2
csw M-93	lssource I-13	rshg M-195	wbet M-80
ctatbot M-241	lv1 O-3	rsw1 M-102	web M-217
ctatbotd M-282	lv10 OP-100	rsw2 M-103	wec M-218
ctatgat M-243	lv11 O-7	rvpoly M-194	weff O-1
ctatgatd M-284	lv12 O-8	rwello M-190	wkuo M-204
ctatsti M-242	lv2 O-4	sa I-3	wkvtho M-210
ctatstid M-283	lv3 O-5	saref M-197	wlod M-199
ctl M-57	lv36 OP-101	sb I-4	wlodkuo M-207
ctlexp M-58	lv37 OP-102	sbref M-198	wlodvth M-213
ctlw M-60	lv38 OP-103	sc I-9	wot M-23

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cto	M-56	lv4	O-6	sca	I-6	wseg	M-38
ctw	M-59	lv51	OP-104	scalelev	M-14	wsegp	M-41
ctype	OP-1	lv9	OP-99	scb	I-7	wvarl	M-21
delvto	I-10	lvarl	M-17	scc	I-8	wvaro	M-20
dlq	M-24	lvaro	M-16	scref	M-216	wvarw	M-22
dlsil	M-196	lvarw	M-18	sd	I-5	xcorl	M-97
dnsubo	M-48	lx110	OP-129	sdi	OP-97	xcorlw	M-99
dphibl	M-50	lx12	OP-134	sdint	OP-2	xcoro	M-96
dphiblexp	M-51	lx14	OP-135	sfl	OP-86	xcorw	M-98
dphiblw	M-53	lx16	OP-136	siavl	OP-95	xgw	I-26
dphibo	M-49	lx18	OP-115	sid	OP-89	xjungat	M-240
dphibw	M-52	lx19	OP-114	sig	OP-90	xjungatd	M-281
dta	M-169	lx2	OP-107	sigd	OP-94	xjunsti	M-239
dwq	M-25	lx20	OP-116	sigs	OP-93	xjunstid	M-280
efo	M-166	lx21	OP-118	sqrtsff	OP-87		
epsroxo	M-35	lx22	OP-117	sqrtsfw	OP-88		
a1l	M-133	factuo	I-11	lx23	OP-119	ssi	OP-96
a1o	M-132	fbbtrbot	M-250	lx28	OP-122	sta2o	M-136
a1w	M-134	fbbtrbotd	M-291	lx29	OP-123	stbetl	M-82
a2o	M-135	fbbtrgat	M-252	lx3	OP-106	stbetlw	M-84
a3l	M-138	fbbtrgatd	M-293	lx32	OP-112	stbeto	M-81

PSP NQS MOSFET Model (pspnqs1021)

This is SiMKit 4.0.1.

This device is supported within altergroups.

This device is dynamically loaded from the shared object /vobs/spectre_dev/tools.lnx86/cmi/lib/5.0.doc/libphilips_sh.so

Instance Definition

```
Name d g s b ModelName parameter=value ...
```

Instance Parameters

1	<code>l=10e-6 m</code>	Design length.
2	<code>w=10e-6 m</code>	Design width.
3	<code>sa=0.0 m</code>	Distance between OD-edge and poly from one side.
4	<code>sb=0.0 m</code>	Distance between OD-edge and poly from other side.
5	<code>sd=0.0 m</code>	Distance between neighboring fingers.
6	<code>sca=0.0</code>	Integral of the first distribution function for scattered well dopants.
7	<code>scb=0.0</code>	Integral of the second distribution function for scattered well dopants.
8	<code>scc=0.0</code>	Integral of the third distribution function for scattered well dopants.
9	<code>sc=0.0 m</code>	Distance between OD-edge and nearest well edge.
10	<code>delvto=0.0 V</code>	Threshold voltage shift parameter.
11	<code>factuo=1.0</code>	Zero-field mobility pre-factor.
12	<code>absource=1E-12 m²</code>	Bottom area of source junction.
13	<code>lssource=1E-6 m</code>	STI-edge length of source junction.

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14	<code>lgsource=1E-6 m</code>	Gate-edge length of source junction.
15	<code>abdrain=1E-12 m²</code>	Bottom area of drain junction.
16	<code>lsdrain=1E-6 m</code>	STI-edge length of drain junction.
17	<code>lgdrain=1E-6 m</code>	Gate-edge length of drain junction.
18	<code>as=1E-12 m²</code>	Bottom area of source junction.
19	<code>ps=1E-6 m</code>	Perimeter of source junction.
20	<code>ad=1E-12 m²</code>	Bottom area of drain junction.
21	<code>pd=1E-6 m</code>	Perimeter of drain junction.
22	<code>mulid0=1</code>	Ids multiplier.
23	<code>mult=1.0</code>	Number of devices in parallel.
24	<code>nf=1.0</code>	Number of fingers.
25	<code>ngcon=1.0</code>	Number of gate contacts.
26	<code>xgw=1.0E-7 m</code>	Distance from the gate contact to the channel edge.
27	<code>trise=0.0 K</code>	Temperature rise from ambient.
28	<code>m=1.0</code>	Multiplicity factor.
29	<code>isnoisy=yes</code>	Should device generate noise. Possible values are <code>no</code> and <code>yes</code> .

Model Definition

`model modelName pspnqs1021 parameter=value ...`

Model Parameters

1	<code>level=102</code>	Model level.
2	<code>type=n</code>	Channel type parameter, n,NMOS p,PMOS. Possible values are <code>n</code> and <code>p</code> .

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3	<code>tr=value of tnom C</code>	nominal (reference) temperature.
4	<code>swnqs=0</code>	Flag for NQS, 0,off, 1, 2, 3, 5, or 9,number of collocation points.
5	<code>swigate=0</code>	Flag for gate current, 0,turn off IG.
6	<code>swimpact=0</code>	Flag for impact ionization current, 0,turn off II.
7	<code>swgidl=0</code>	Flag for GIDL current, 0,turn off IGIDL.
8	<code>swjuncap=0</code>	Flag for juncap, 0,turn off juncap.
9	<code>swjunasym=0</code>	Flag for asymmetric junctions; 0,symmetric, 1,asymmetric.
10	<code>qmc=1.0</code>	Quantum-mechanical correction factor.
11	<code>version=102.32</code>	The available versions are 102.2, 102.21, 102.3, 102.32, 102.33, 102.34 and 102.40.
12	<code>geomod=1</code>	1 for geometrical model and 0 for electrical model.
13	<code>binmod=0</code>	1 for bin model and 0 for non-bin model.
14	<code>scalelev=102</code>	102 for local, 1020 for global model and 1021 for bin model.
15	<code>compatible=spectre</code>	for compatible. Possible values are <code>spectre</code> , <code>spice2</code> , <code>spice3</code> , <code>cdsspice</code> , <code>hspice</code> , <code>spiceplus</code> , <code>eldo</code> , <code>sspice</code> , and <code>mica</code> .
16	<code>lvaro=0.0 m</code>	Geom. independent difference between actual and programmed gate length.
17	<code>lvarl=0.0</code>	Length dependence of LVAR.
18	<code>lap=0.0 m</code>	Effective channel length reduction per side.
19	<code>wvaro=0.0 m</code>	Geom. independent difference between actual and programmed field-oxide opening.
20	<code>wvarw=0.0</code>	Width dependence of WVAR.

Virtuoso Simulator Components and Device Models Reference

PSP102 Model

21	wot=0.0 m	Effective channel width reduction per side.
22	dlq=0.0 m	Effective channel length reduction for CV.
23	dwq=0.0 m	Effective channel width reduction for CV.
24	povfb=(-1) V	Coefficient for the geometry independent part of VFB.
25	plvfb=0.0 V	Coefficient for the length dependence of VFB.
26	pwvfb=0.0 V	Coefficient for the width dependence of VFB.
27	plwvfb=0.0 V	Coefficient for the length times width dependence of VFB.
28	postvfb=0.0005 V/K	Coefficient for the geometry independent part of STVFB.
29	plstvfb=0.0 V/K	Coefficient for the length dependence of STVFB.
30	pwstvfb=0.0 V/K	Coefficient for the width dependence of STVFB.
31	plwstvfb=0.0 V/K	Coefficient for the length times width dependence of STVFB.
32	potox=2E-09 m	Coefficient for the geometry independent part of TOX.
33	poepsrox=3.9	Coefficient for the geometry independent part of EPSOX.
34	poneff=5E+23 m ⁻³	Coefficient for the geometry independent part of NEFF.
35	plneff=0.0 m ⁻³	Coefficient for the length dependence of NEFF.
36	pwneff=0.0 m ⁻³	Coefficient for the width dependence of NEFF.
37	plwneff=0.0 m ⁻³	Coefficient for the length times width dependence of NEFF.
38	povnsb=0 V	Coefficient for the geometry independent part of VNSUB.
39	ponslp=0.05 V	Coefficient for the geometry independent part of NSLP.
40	podnsb=0 V ⁻¹	Coefficient for the geometry independent part of DNSUB.
41	podphib=0 V	Coefficient for the geometry independent part of DPHIB.

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PSP102 Model

42	<code>pldphib=0.0 V</code>	Coefficient for the length dependence of DPHIB.
43	<code>pwdphib=0.0 V</code>	Coefficient for the width dependence of DPHIB.
44	<code>plwdphib=0.0 V</code>	Coefficient for the length times width dependence of DPHIB.
45	<code>ponp=1E+26 m⁻³</code>	Coefficient for the geometry independent part of NP.
46	<code>plnp=0.0 m⁻³</code>	Coefficient for the length dependence of NP.
47	<code>pwnp=0.0 m⁻³</code>	Coefficient for the width dependence of NP.
48	<code>plwnp=0.0 m⁻³</code>	Coefficient for the length times width dependence of NP.
49	<code>poct=0</code>	Coefficient for the geometry independent part of CT.
50	<code>plct=0.0</code>	Coefficient for the length dependence of CT.
51	<code>pwct=0.0</code>	Coefficient for the width dependence of CT.
52	<code>plwct=0.0</code>	Coefficient for the length times width dependence of CT.
53	<code>potoxov=2E-09 m</code>	Coefficient for the geometry independent part of TOXOV.
54	<code>potoxovd=2E-09 m</code>	Coefficient for the geometry independent part of TOXOV for drain side.
55	<code>ponov=5E+25 m⁻³</code>	Coefficient for the geometry independent part of NOV.
56	<code>plnov=0.0 m⁻³</code>	Coefficient for the length dependence of NOV.
57	<code>pwnov=0.0 m⁻³</code>	Coefficient for the width dependence of NOV.
58	<code>plwnov=0.0 m⁻³</code>	Coefficient for the length times width dependence of NOV.
59	<code>ponovd=5E+25 m⁻³</code>	Coefficient for the geometry independent part of NOV for drain side.
60	<code>plnovd=0.0 m⁻³</code>	Coefficient for the length dependence of NOV for drain side.
61	<code>pwnovd=0.0 m⁻³</code>	Coefficient for the width dependence of NOV for drain side.

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62	$plwnovd=0.0 \text{ m}^{-3}$	Coefficient for the length times width dependence of NOV for drain side.
63	$pocf=0$	Coefficient for the geometry independent part of CF.
64	$plcf=0.0$	Coefficient for the length dependence of CF.
65	$pwcf=0.0$	Coefficient for the width dependence of CF.
66	$plwcf=0.0$	Coefficient for the length times width dependence of CF.
67	$pocfb=0 \text{ V}^{-1}$	Coefficient for the geometry independent part of CFB.
68	$pobetn=0.07 \text{ m}^2/\text{V}/\text{s}$	Coefficient for the geometry independent part of BETN.
69	$plbetn=0.0 \text{ m}^2/\text{V}/\text{s}$	Coefficient for the length dependence of BETN.
70	$pwbetn=0.0 \text{ m}^2/\text{V}/\text{s}$	Coefficient for the width dependence of BETN.
71	$plwbetn=0.0 \text{ m}^2/\text{V}/\text{s}$	Coefficient for the length times width dependence of BETN.
72	$postbet=1$	Coefficient for the geometry independent part of STBET.
73	$plstbet=0.0$	Coefficient for the length dependence of STBET.
74	$pwstbet=0.0$	Coefficient for the width dependence of STBET.
75	$plwstbet=0.0$	Coefficient for the length times width dependence of STBET.
76	$pomue=0.5 \text{ m}/\text{V}$	Coefficient for the geometry independent part of MUE.
77	$plmue=0.0 \text{ m}/\text{V}$	Coefficient for the length dependence of MUE.
78	$pwmue=0.0 \text{ m}/\text{V}$	Coefficient for the width dependence of MUE.
79	$plwmue=0.0 \text{ m}/\text{V}$	Coefficient for the length times width dependence of MUE.
80	$postmue=0$	Coefficient for the geometry independent part of STMUE.

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PSP102 Model

81	<code>pothemu=1.5</code>	Coefficient for the geometry independent part of THEMU.
82	<code>postthemu=1.5</code>	Coefficient for the geometry independent part of STTHEMU.
83	<code>pocs=0</code>	Coefficient for the geometry independent part of CS.
84	<code>plcs=0.0</code>	Coefficient for the length dependence of CS.
85	<code>pwcs=0.0</code>	Coefficient for the width dependence of CS.
86	<code>plwcs=0.0</code>	Coefficient for the length times width dependence of CS.
87	<code>postcs=0</code>	Coefficient for the geometry independent part of STCS.
88	<code>poxcor=0 V⁻¹</code>	Coefficient for the geometry independent part of XCOR.
89	<code>plxcor=0.0 V⁻¹</code>	Coefficient for the length dependence of XCOR.
90	<code>pwxcor=0.0 V⁻¹</code>	Coefficient for the width dependence of XCOR.
91	<code>plwxcor=0.0 V⁻¹</code>	Coefficient for the length times width dependence of XCOR.
92	<code>postxcor=0</code>	Coefficient for the geometry independent part of STXCOR.
93	<code>pofeta=1</code>	Coefficient for the geometry independent part of FETA.
94	<code>pors=30 Ω</code>	Coefficient for the geometry independent part of RS.
95	<code>plrs=0.0 Ω</code>	Coefficient for the length dependence of RS.
96	<code>pwrs=0.0 Ω</code>	Coefficient for the width dependence of RS.
97	<code>plwrs=0.0 Ω</code>	Coefficient for the length times width dependence of RS.
98	<code>postrs=1</code>	Coefficient for the geometry independent part of STRS.
99	<code>porsb=0 V⁻¹</code>	Coefficient for the geometry independent part of RSB.
100	<code>porsg=0 V⁻¹</code>	Coefficient for the geometry independent part of RSG.
101	<code>pothesat=1 V⁻¹</code>	Coefficient for the geometry independent part of THESAT.
102	<code>plthesat=0.0 V⁻¹</code>	Coefficient for the length dependence of THESAT.

Virtuoso Simulator Components and Device Models Reference

PSP102 Model

- 103 $pwthesat=0.0 V^{-1}$ Coefficient for the width dependence of THESAT.
- 104 $plwthesat=0.0 V^{-1}$
Coefficient for the length times width dependence of THESAT.
- 105 $postthesat=1$ Coefficient for the geometry independent part of STTHESAT.
- 106 $plstthesat=0.0$ Coefficient for the length dependence of STTHESAT.
- 107 $pwstthesat=0.0$ Coefficient for the width dependence of STTHESAT.
- 108 $plwstthesat=0.0$ Coefficient for the length times width dependence of STTHESAT.
- 109 $pothesatb=0 V^{-1}$ Coefficient for the geometry independent part of THESATB.
- 110 $plthesatb=0.0 V^{-1}$
Coefficient for the length dependence of THESATB.
- 111 $pwthesatb=0.0 V^{-1}$
Coefficient for the width dependence of THESATB.
- 112 $plwthesatb=0.0 V^{-1}$
Coefficient for the length times width dependence of THESATB.
- 113 $pothesatg=0 V^{-1}$ Coefficient for the geometry independent part of THESATG.
- 114 $plthesatg=0.0 V^{-1}$
Coefficient for the length dependence of THESATG.
- 115 $pwthesatg=0.0 V^{-1}$
Coefficient for the width dependence of THESATG.
- 116 $plwthesatg=0.0 V^{-1}$
Coefficient for the length times width dependence of THESATG.
- 117 $poax=3$ Coefficient for the geometry independent part of AX.
- 118 $plax=0.0$ Coefficient for the length dependence of AX.
- 119 $pwax=0.0$ Coefficient for the width dependence of AX.
- 120 $plwax=0.0$ Coefficient for the length times width dependence of AX.

Virtuoso Simulator Components and Device Models Reference

PSP102 Model

121	$poalp=0.01$	Coefficient for the geometry independent part of ALP.
122	$plalp=0.0$	Coefficient for the length dependence of ALP.
123	$pwalp=0.0$	Coefficient for the width dependence of ALP.
124	$plwalp=0.0$	Coefficient for the length times width dependence of ALP.
125	$poalp1=0 \ V$	Coefficient for the geometry independent part of ALP1.
126	$plalp1=0.0 \ V$	Coefficient for the length dependence of ALP1.
127	$pwalp1=0.0 \ V$	Coefficient for the width dependence of ALP1.
128	$plwalp1=0.0 \ V$	Coefficient for the length times width dependence of ALP1.
129	$poalp2=0 \ V^{-1}$	Coefficient for the geometry independent part of ALP2.
130	$plalp2=0.0 \ V^{-1}$	Coefficient for the length dependence of ALP2.
131	$pwalp2=0.0 \ V^{-1}$	Coefficient for the width dependence of ALP2.
132	$plwalp2=0.0 \ V^{-1}$	Coefficient for the length times width dependence of ALP2.
133	$povp=0.05 \ V$	Coefficient for the geometry independent part of VP.
134	$poa1=1$	Coefficient for the geometry independent part of A1.
135	$pla1=0.0$	Coefficient for the length dependence of A1.
136	$pwa1=0.0$	Coefficient for the width dependence of A1.
137	$plwa1=0.0$	Coefficient for the length times width dependence of A1.
138	$poa2=10 \ V$	Coefficient for the geometry independent part of A2.
139	$posta2=0 \ V$	Coefficient for the geometry independent part of STA2.
140	$poa3=1$	Coefficient for the geometry independent part of A3.
141	$pla3=0.0$	Coefficient for the length dependence of A3.
142	$pwa3=0.0$	Coefficient for the width dependence of A3.

Virtuoso Simulator Components and Device Models Reference

PSP102 Model

143	$p_{lwa3}=0.0$	Coefficient for the length times width dependence of A3.
144	$p_{oa4}=0 \ V^{-0.5}$	Coefficient for the geometry independent part of A4.
145	$p_{la4}=0.0 \ V^{-0.5}$	Coefficient for the length dependence of A4.
146	$p_{wa4}=0.0 \ V^{-0.5}$	Coefficient for the width dependence of A4.
147	$p_{lwa4}=0.0 \ V^{-0.5}$	Coefficient for the length times width dependence of A4.
148	$p_{ogco}=0$	Coefficient for the geometry independent part of GCO.
149	$p_{oiginv}=0 \ A$	Coefficient for the geometry independent part of IGINV.
150	$p_{liginv}=0.0 \ A$	Coefficient for the length dependence of IGINV.
151	$p_{wiginv}=0.0 \ A$	Coefficient for the width dependence of IGINV.
152	$p_{lwiginv}=0.0 \ A$	Coefficient for the length times width dependence of IGINV.
153	$p_{oigov}=0 \ A$	Coefficient for the geometry independent part of IGOV.
154	$p_{ligov}=0.0 \ A$	Coefficient for the length dependence of IGOV.
155	$p_{wigov}=0.0 \ A$	Coefficient for the width dependence of IGOV.
156	$p_{lwigov}=0.0 \ A$	Coefficient for the length times width dependence of IGOV.
157	$p_{oigovd}=0 \ A$	Coefficient for the geometry independent part of IGOV for drain side.
158	$p_{ligovd}=0.0 \ A$	Coefficient for the length dependence of IGOV for drain side.
159	$p_{wigovd}=0.0 \ A$	Coefficient for the width dependence of IGOV for drain side.
160	$p_{lwigovd}=0.0 \ A$	Coefficient for the length times width dependence of IGOV for drain side.
161	$p_{ostig}=2$	Coefficient for the geometry independent part of STIG.
162	$p_{ogc2}=0.375$	Coefficient for the geometry independent part of GC2.
163	$p_{ogc3}=0.063$	Coefficient for the geometry independent part of GC3.

Virtuoso Simulator Components and Device Models Reference

PSP102 Model

164	<code>pochib=3.1</code>	V	Coefficient for the geometry independent part of CHIB.
165	<code>poagidl=0</code>	A/V ³	Coefficient for the geometry independent part of AGIDL.
166	<code>plagidl=0.0</code>	A/V ³	Coefficient for the length dependence of AGIDL.
167	<code>pwagidl=0.0</code>	A/V ³	Coefficient for the width dependence of AGIDL.
168	<code>plwagidl=0.0</code>	A/V ³	Coefficient for the length times width dependence of AGIDL.
169	<code>poagidld=0</code>	A/V ³	Coefficient for the geometry independent part of AGIDL for drain side.
170	<code>plagidld=0.0</code>	A/V ³	Coefficient for the length dependence of AGIDL for drain side.
171	<code>pwagidld=0.0</code>	A/V ³	Coefficient for the width dependence of AGIDL for drain side.
172	<code>plwagidld=0.0</code>	A/V ³	Coefficient for the length times width dependence of AGIDL for drain side.
173	<code>pobgidl=41</code>	V	Coefficient for the geometry independent part of BGIDL.
174	<code>pobgidld=41</code>	V	Coefficient for the geometry independent part of BGIDL for drain side.
175	<code>postbgidl=0</code>	V/K	Coefficient for the geometry independent part of STBGIDL.
176	<code>postbgidld=0</code>	V/K	Coefficient for the geometry independent part of STBGIDL for drain side.
177	<code>pocgidl=0</code>		Coefficient for the geometry independent part of CGIDL.
178	<code>pocgidld=0</code>		Coefficient for the geometry independent part of CGIDL for drain side.
179	<code>pocox=1E-14</code>	F	Coefficient for the geometry independent part of COX.
180	<code>plcox=0.0</code>	F	Coefficient for the length dependence of COX.

Virtuoso Simulator Components and Device Models Reference

PSP102 Model

181	<code>pwc_{cox}=0.0</code>	F	Coefficient for the width dependence of COX.
182	<code>plw_{cox}=0.0</code>	F	Coefficient for the length times width dependence of COX.
183	<code>poc_{gov}=1E-15</code>	F	Coefficient for the geometry independent part of CGOV.
184	<code>plc_{gov}=0.0</code>	F	Coefficient for the length dependence of CGOV.
185	<code>pwc_{gov}=0.0</code>	F	Coefficient for the width dependence of CGOV.
186	<code>plw_{gov}=0.0</code>	F	Coefficient for the length times width dependence of CGOV.
187	<code>poc_{govd}=1E-15</code>	F	Coefficient for the geometry independent part of CGOV for drain side.
188	<code>plc_{govd}=0.0</code>	F	Coefficient for the length dependence of CGOV for drain side.
189	<code>pwc_{govd}=0.0</code>	F	Coefficient for the width dependence of CGOV for drain side.
190	<code>plw_{govd}=0.0</code>	F	Coefficient for the length times width dependence of CGOV for drain side.
191	<code>poc_{gbov}=0</code>	F	Coefficient for the geometry independent part of CGBOV.
192	<code>plc_{gbov}=0.0</code>	F	Coefficient for the length dependence of CGBOV.
193	<code>pwc_{gbov}=0.0</code>	F	Coefficient for the width dependence of CGBOV.
194	<code>plw_{gbov}=0.0</code>	F	Coefficient for the length times width dependence of CGBOV.
195	<code>poc_{fr}=0</code>	F	Coefficient for the geometry independent part of CFR.
196	<code>plc_{fr}=0.0</code>	F	Coefficient for the length dependence of CFR.
197	<code>pwc_{fr}=0.0</code>	F	Coefficient for the width dependence of CFR.
198	<code>plw_{fr}=0.0</code>	F	Coefficient for the length times width dependence of CFR.
199	<code>poc_{frd}=0</code>	F	Coefficient for the geometry independent part of CFR for drain side.
200	<code>plc_{frd}=0.0</code>	F	Coefficient for the length dependence of CFR for drain side.

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PSP102 Model

201	$pwcfrd=0.0$	F	Coefficient for the width dependence of CFR for drain side.
202	$plwcfrd=0.0$	F	Coefficient for the length times width dependence of CFR for drain side.
203	$pofnt=1$		Coefficient for the geometry independent part of FNT.
204	$ponfa=8E+22$	V^{-1}/m^4	Coefficient for the geometry independent part of NFA.
205	$plnfa=0.0$	V^{-1}/m^4	Coefficient for the length dependence of NFA.
206	$pwnfa=0.0$	V^{-1}/m^4	Coefficient for the width dependence of NFA.
207	$plwnfa=0.0$	V^{-1}/m^4	Coefficient for the length times width dependence of NFA.
208	$ponfb=3E+07$	V^{-1}/m^2	Coefficient for the geometry independent part of NFB.
209	$plnfb=0.0$	V^{-1}/m^2	Coefficient for the length dependence of NFB.
210	$pwnfb=0.0$	V^{-1}/m^2	Coefficient for the width dependence of NFB.
211	$plwnfb=0.0$	V^{-1}/m^2	Coefficient for the length times width dependence of NFB.
212	$ponfc=0$	V^{-1}	Coefficient for the geometry independent part of NFC.
213	$plnfc=0.0$	V^{-1}	Coefficient for the length dependence of NFC.
214	$pwnfc=0.0$	V^{-1}	Coefficient for the width dependence of NFC.
215	$plwnfc=0.0$	V^{-1}	Coefficient for the length times width dependence of NFC.
216	$poef=1.0$		Coefficient for the flicker noise frequency exponent.
217	$dta=0$	K	Temperature offset w.r.t. ambient circuit temperature.

Virtuoso Simulator Components and Device Models Reference

PSP102 Model

218	<code>pokvthowe=0</code>	Coefficient for the geometry independent part of KVTHOWE.
219	<code>plkvthowe=0</code>	Coefficient for the length dependence part of KVTHOWE.
220	<code>pwkvthowe=0</code>	Coefficient for the width dependence part of KVTHOWE.
221	<code>plwkvthowe=0</code>	Coefficient for the length times width dependence part of KVTHOWE.
222	<code>pokuowe=0</code>	Coefficient for the geometry independent part of KUOWE.
223	<code>plkuowe=0</code>	Coefficient for the length dependence part of KUOWE.
224	<code>pwkuowe=0</code>	Coefficient for the width dependence part of KUOWE.
225	<code>plwkuowe=0</code>	Coefficient for the length times width dependence part of KUOWE.
226	<code>lmin=0 m</code>	Dummy parameter to label binning set.
227	<code>lmax=1.0 m</code>	Dummy parameter to label binning set.
228	<code>wmin=0 m</code>	Dummy parameter to label binning set.
229	<code>wmax=1.0 m</code>	Dummy parameter to label binning set.
230	<code>vds_max=∞ V</code>	Maximum allowed voltage cross source and drain.
231	<code>vgd_max=∞ V</code>	Maximum allowed voltage cross gate and drain.
232	<code>vgs_max=∞ V</code>	Maximum allowed voltage cross gate and source/bulk.
233	<code>vbd_max=∞ V</code>	Maximum allowed voltage cross source/drain and bulk.
234	<code>vbs_max=∞ V</code>	Maximum allowed voltage cross source and bulk.
235	<code>vgb_max=∞ V</code>	Maximum allowed voltage cross gate and bulk.

Virtuoso Simulator Components and Device Models Reference

PSP102 Model

236	$vgdr_max=\infty$ V	Maximum allowed reverse voltage cross gate and drain.
237	$vgdr_max=\infty$ V	Maximum allowed reverse voltage cross gate and source.
238	$vgbr_max=\infty$ V	Maximum allowed reverse voltage cross gate and bulk.
239	$munqso=1.0$	Relative mobility for NQS modeling.
240	$rgo=0.0$ Ω	Gate resistance.
241	$rbulko=0.0$ Ω	Bulk resistance between node BP and BI.
242	$rwello=0.0$ Ω	Well resistance between node BI and B.
243	$rjunso=0.0$ Ω	Source-side bulk resistance between node BI and BS.
244	$rjundo=0.0$ Ω	Drain-side bulk resistance between node BI and BD.
245	$rint=0.0$ Ω/Sqr	Contact resistance between silicide and poly.
246	$rvpoly=0.0$ Ω/Sqr	Vertical poly resistance.
247	$rshg=0.0$ Ω/Sqr	Gate electrode diffusion sheet resistance.
248	$dlsil=0.0$ m	Silicide extension over the physical gate length.
249	$saref=1.0e-6$ m	Reference distance between OD-edge and poly from one side.
250	$sbref=1.0e-6$ m	Reference distance between OD-edge and poly from other side.
251	$wlod=0$ m	Width parameter.
252	$kuo=0$ m	Mobility degradation/enhancement coefficient.
253	$kvsat=0$ m	Saturation velocity degradation/enhancement coefficient.
254	$tkuo=0$	Temperature dependence of KUO.
255	$lkuo=0$ $m^{LLODKUO}$	Length dependence of KUO.

Virtuoso Simulator Components and Device Models Reference

PSP102 Model

- 256 $w_{kuo}=0$ $m^{WLODKUO}$ Width dependence of KUO.
- 257 $p_{kuo}=0$ $m^{(LLODKUO+WLODKUO)}$
Cross-term dependence of KUO.
- 258 $l_{lodkuo}=0$ Length parameter for UO stress effect.
- 259 $w_{lodkuo}=0$ Width parameter for UO stress effect.
- 260 $k_{vtho}=0$ V_m Threshold shift parameter.
- 261 $l_{kvtho}=0$ $m^{LLODVTH}$
Length dependence of KVTHO.
- 262 $w_{kvtho}=0$ $m^{WLODVTH}$
Width dependence of KVTHO.
- 263 $p_{kvtho}=0$ $m^{(LLODVTH+WLODVTH)}$
Cross-term dependence of KVTHO.
- 264 $l_{lodvth}=0$ Length parameter for VTH-stress effect.
- 265 $w_{lodvth}=0$ Width parameter for VTH-stress effect.
- 266 $s_{etao}=0$ m η_0 shift factor related to VTHO change.
- 267 $l_{odetao}=1.0$ η_0 shift modification factor for stress effect.
- 268 $s_{cref}=10e-6$ m Distance between OD-edge and well edge of a reference device.
- 269 $w_{eb}=0$ Coefficient for SCB.
- 270 $w_{ec}=0$ Coefficient for SCC.
- 271 $i_{max}=1000$ A Maximum current up to which forward current behaves exponentially.
- 272 $t_{rj}=21$ C reference temperature.
- 273 $c_{jorbot}=1E-3$ Fm^{-2}
Zero-bias capacitance per unit-of-area of bottom component for source-bulk junction.

Virtuoso Simulator Components and Device Models Reference

PSP102 Model

- 274 `cjorsti=1E-9` Fm^{-1}
Zero-bias capacitance per unit-of-length of STI-edge component for source-bulk junction.
- 275 `cjorgat=1E-9` Fm^{-1}
Zero-bias capacitance per unit-of-length of gate-edge component for source-bulk junction.
- 276 `vbirbot=1` V
Built-in voltage at the reference temperature of bottom component for source-bulk junction.
- 277 `vbirsti=1` V
Built-in voltage at the reference temperature of STI-edge component for source-bulk junction.
- 278 `vbirgat=1` V
Built-in voltage at the reference temperature of gate-edge component for source-bulk junction.
- 279 `pbot=0.5`
Grading coefficient of bottom component for source-bulk junction.
- 280 `psti=0.5`
Grading coefficient of STI-edge component for source-bulk junction.
- 281 `pgat=0.5`
Grading coefficient of gate-edge component for source-bulk junction.
- 282 `phigbot=1.16` V
Zero-temperature bandgap voltage of bottom component for source-bulk junction.
- 283 `phigsti=1.16` V
Zero-temperature bandgap voltage of STI-edge component for source-bulk junction.
- 284 `phiggat=1.16` V
Zero-temperature bandgap voltage of gate-edge component for source-bulk junction.
- 285 `idsatrbot=1E-12` Am^{-2}
Saturation current density at the reference temperature of bottom component for source-bulk junction.
- 286 `idsatrsti=1E-18` Am^{-1}
Saturation current density at the reference temperature of STI-edge component for source-bulk junction.

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- 287 $idsatrgat=1E-18 \text{ Am}^{-1}$ Saturation current density at the reference temperature of gate-edge component for source-bulk junction.
- 288 $csrbot=1E2 \text{ Am}^{-3}$ Shockley-Read-Hall prefactor of bottom component for source-bulk junction.
- 289 $csrhisti=1E-4 \text{ Am}^{-2}$ Shockley-Read-Hall prefactor of STI-edge component for source-bulk junction.
- 290 $csrhat=1E-4 \text{ Am}^{-2}$ Shockley-Read-Hall prefactor of gate-edge component for source-bulk junction.
- 291 $xjunsti=100E-9 \text{ m}$ Junction depth of STI-edge component for source-bulk junction.
- 292 $xjngat=100E-9 \text{ m}$ Junction depth of gate-edge component for source-bulk junction.
- 293 $ctatbot=1E2 \text{ Am}^{-3}$ Trap-assisted tunneling prefactor of bottom component for source-bulk junction.
- 294 $ctatsti=1E-4 \text{ Am}^{-2}$ Trap-assisted tunneling prefactor of STI-edge component for source-bulk junction.
- 295 $ctatgat=1E-4 \text{ Am}^{-2}$ Trap-assisted tunneling prefactor of gate-edge component for source-bulk junction.
- 296 $mefftatbot=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of bottom component for source-bulk junction.
- 297 $mefftatsti=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of STI-edge component for source-bulk junction.
- 298 $mefftatgat=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of gate-edge component for source-bulk junction.
- 299 $cbbtbot=1E-12 \text{ AV}^{-3}$ Band-to-band tunneling prefactor of bottom component for source-bulk junction.

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- 300 `cbbtsti=1E-18` AV^3_{m}
Band-to-band tunneling prefactor of STI-edge component for source-bulk junction.
- 301 `cbbtgat=1E-18` AV^3_{m}
Band-to-band tunneling prefactor of gate-edge component for source-bulk junction.
- 302 `fbbtbot=1E9` Vm^{-1}
Normalization field at the reference temperature for band-to-band tunneling of bottom component for source-bulk junction.
- 303 `fbbtsti=1E9` Vm^{-1}
Normalization field at the reference temperature for band-to-band tunneling of STI-edge component for source-bulk junction.
- 304 `fbbtgat=1E9` Vm^{-1}
Normalization field at the reference temperature for band-to-band tunneling of gate-edge component for source-bulk junction.
- 305 `stfbbtbot=(-1E-3)` K^{-1}
Temperature scaling parameter for band-to-band tunneling of bottom component for source-bulk junction.
- 306 `stfbbtsti=(-1E-3)` K^{-1}
Temperature scaling parameter for band-to-band tunneling of STI-edge component for source-bulk junction.
- 307 `stfbbtgat=(-1E-3)` K^{-1}
Temperature scaling parameter for band-to-band tunneling of gate-edge component for source-bulk junction.
- 308 `vbrbot=10` V
Breakdown voltage of bottom component for source-bulk junction.
- 309 `vbrsti=10` V
Breakdown voltage of STI-edge component for source-bulk junction.
- 310 `vbrgat=10` V
Breakdown voltage of gate-edge component for source-bulk junction.
- 311 `pbrbot=4` V
Breakdown onset tuning parameter of bottom component for source-bulk junction.

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312	<code>pbrsti=4</code>	V	Breakdown onset tuning parameter of STI-edge component for source-bulk junction.
313	<code>pbrgat=4</code>	V	Breakdown onset tuning parameter of gate-edge component for source-bulk junction.
314	<code>cjorbotd=1E-3</code>	Fm^{-2}	Zero-bias capacitance per unit-of-area of bottom component for drain-bulk junction.
315	<code>cjorstid=1E-9</code>	Fm^{-1}	Zero-bias capacitance per unit-of-length of STI-edge component for drain-bulk junction.
316	<code>cjorgatd=1E-9</code>	Fm^{-1}	Zero-bias capacitance per unit-of-length of gate-edge component for drain-bulk junction.
317	<code>vbirbotd=1</code>	V	Built-in voltage at the reference temperature of bottom component for drain-bulk junction.
318	<code>vbirstid=1</code>	V	Built-in voltage at the reference temperature of STI-edge component for drain-bulk junction.
319	<code>vbirgatd=1</code>	V	Built-in voltage at the reference temperature of gate-edge component for drain-bulk junction.
320	<code>pbotd=0.5</code>		Grading coefficient of bottom component for drain-bulk junction.
321	<code>pstid=0.5</code>		Grading coefficient of STI-edge component for drain-bulk junction.
322	<code>pgatd=0.5</code>		Grading coefficient of gate-edge component for drain-bulk junction.
323	<code>phigbotd=1.16</code>	V	Zero-temperature bandgap voltage of bottom component for drain-bulk junction.
324	<code>phigstid=1.16</code>	V	Zero-temperature bandgap voltage of STI-edge component for drain-bulk junction.
325	<code>phiggatd=1.16</code>	V	Zero-temperature bandgap voltage of gate-edge component for drain-bulk junction.

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- 326 `idsatrbotd=1E-12` Am^{-2}
Saturation current density at the reference temperature of bottom component for drain-bulk junction.
- 327 `idsatrstid=1E-18` Am^{-1}
Saturation current density at the reference temperature of STI-edge component for drain-bulk junction.
- 328 `idsatrgatd=1E-18` Am^{-1}
Saturation current density at the reference temperature of gate-edge component for drain-bulk junction.
- 329 `csrbotd=1E2` Am^{-3}
Shockley-Read-Hall prefactor of bottom component for drain-bulk junction.
- 330 `csrhostid=1E-4` Am^{-2}
Shockley-Read-Hall prefactor of STI-edge component for drain-bulk junction.
- 331 `csrhgatd=1E-4` Am^{-2}
Shockley-Read-Hall prefactor of gate-edge component for drain-bulk junction.
- 332 `xjunstid=100E-9` m Junction depth of STI-edge component for drain-bulk junction.
- 333 `xjungatd=100E-9` m Junction depth of gate-edge component for drain-bulk junction.
- 334 `ctatbotd=1E2` Am^{-3}
Trap-assisted tunneling prefactor of bottom component for drain-bulk junction.
- 335 `ctatstid=1E-4` Am^{-2}
Trap-assisted tunneling prefactor of STI-edge component for drain-bulk junction.
- 336 `ctatgatd=1E-4` Am^{-2}
Trap-assisted tunneling prefactor of gate-edge component for drain-bulk junction.
- 337 `mefftatbotd=0.25` Effective mass (in units of m_0) for trap-assisted tunneling of bottom component for drain-bulk junction.

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- 338 `mefftatstid=0.25` Effective mass (in units of m_0) for trap-assisted tunneling of STI-edge component for drain-bulk junction.
- 339 `mefftatgatd=0.25` Effective mass (in units of m_0) for trap-assisted tunneling of gate-edge component for drain-bulk junction.
- 340 `cbbtbotd=1E-12` AV^{-3}
Band-to-band tunneling prefactor of bottom component for drain-bulk junction.
- 341 `cbbtstid=1E-18` AV^3m
Band-to-band tunneling prefactor of STI-edge component for drain-bulk junction.
- 342 `cbbtgatd=1E-18` AV^3m
Band-to-band tunneling prefactor of gate-edge component for drain-bulk junction.
- 343 `fbbtrbotd=1E9` Vm^{-1}
Normalization field at the reference temperature for band-to-band tunneling of bottom component for drain-bulk junction.
- 344 `fbbtrstid=1E9` Vm^{-1}
Normalization field at the reference temperature for band-to-band tunneling of STI-edge component for drain-bulk junction.
- 345 `fbbtrgatd=1E9` Vm^{-1}
Normalization field at the reference temperature for band-to-band tunneling of gate-edge component for drain-bulk junction.
- 346 `stfbbtbotd=(-1E-3)` K^{-1}
Temperature scaling parameter for band-to-band tunneling of bottom component for drain-bulk junction.
- 347 `stfbbtstid=(-1E-3)` K^{-1}
Temperature scaling parameter for band-to-band tunneling of STI-edge component for drain-bulk junction.
- 348 `stfbbtgatd=(-1E-3)` K^{-1}
Temperature scaling parameter for band-to-band tunneling of gate-edge component for drain-bulk junction.
- 349 `vbrbotd=10` V Breakdown voltage of bottom component for drain-bulk junction.

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350	<code>vbrstid=10 V</code>	Breakdown voltage of STI-edge component for drain-bulk junction.
351	<code>vbrgatd=10 V</code>	Breakdown voltage of gate-edge component for drain-bulk junction.
352	<code>pbrbotd=4 V</code>	Breakdown onset tuning parameter of bottom component for drain-bulk junction.
353	<code>pbrstid=4 V</code>	Breakdown onset tuning parameter of STI-edge component for drain-bulk junction.
354	<code>pbrgatd=4 V</code>	Breakdown onset tuning parameter of gate-edge component for drain-bulk junction.
355	<code>swjunexp=0.0</code>	Flag for JUNCAP-express; 0,full model, 1,express model.
356	<code>vjunref=2.5</code>	Typical maximum source-bulk junction voltage; usually about 2*VSUP.
357	<code>fjunq=0.03</code>	Fraction below which source-bulk junction capacitance components are considered negligible.
358	<code>vjunrefd=2.5</code>	Typical maximum drain-bulk junction voltage; usually about 2*VSUP.
359	<code>fjunqd=0.03</code>	Fraction below which drain-bulk junction capacitance components are considered negligible.
360	<code>mvto=0.0</code>	DCmatch parameter.
361	<code>mbeo=0.0</code>	DCmatch parameter.
362	<code>vthmod</code>	Vth output selector. 'std' outputs model equation Vth. 'vthcc' outputs constant current Vth, and may impact simulation performance. The default value is taken from the options parameter 'vthmod'. Possible values are <code>std</code> and <code>vthcc</code> .
363	<code>ivth (A)</code>	Vth current parameter. The default value is taken from the options parameter 'ivthn' or 'ivthp', depending on the type of the model.

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364	<code>ivthw</code> (m)	Width offset for constant current V_{th} . The default value is taken from the options parameter 'ivthw'.
365	<code>ivthl</code> (m)	Length offset for constant current V_{th} . The default value is taken from the options parameter 'ivthl'.
366	<code>ivth_vdsmin</code> (V)	Minimum V_{ds} in constant current V_{th} calculating. The default value is taken from the options parameter 'ivth_vdsmin'.
367	<code>noisemethod=oldcmi</code>	Induced gate noise implementation . Possible values are <code>oldcmi</code> , <code>subckt</code> , and <code>newcmi</code> .

Output Parameters

1	<code>w_{eff}</code> (m)	Effective channel width for geometrical models.
2	<code>l_{eff}</code> (m)	Effective channel length for geometrical models.
3	<code>lv1</code> (m)	alias of l.
4	<code>lv2</code> (m)	alias of w.
5	<code>lv3</code> (m ²)	alias of ad.
6	<code>lv4</code> (m ²)	alias of as.
7	<code>lv11</code> (m)	alias of pd.
8	<code>lv12</code> (m)	alias of ps.

Operating-Point Parameters

1	<code>ctype</code>	Flag for channel type.
2	<code>sdint</code>	Flag for source-drain interchange.
3	<code>ise</code> (A)	Total source current.
4	<code>ige</code> (A)	Total gate current.
5	<code>ide</code> (A)	Total drain current.

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6	<code>ibe</code> (A)	Total bulk current.
7	<code>ids</code> (A)	Drain current, excl. avalanche, tunnel, GISL, GIDL, and junction currents.
8	<code>idb</code> (A)	Drain to bulk current.
9	<code>isb</code> (A)	Source to bulk current.
10	<code>igs</code> (A)	Gate-source tunneling current.
11	<code>igd</code> (A)	Gate-drain tunneling current.
12	<code>igb</code> (A)	Gate-bulk tunneling current.
13	<code>igcs</code> (A)	Gate-channel tunneling current (source component).
14	<code>igcd</code> (A)	Gate-channel tunneling current (drain component).
15	<code>iavl</code> (A)	Substrate current due to weak avalanche.
16	<code>igisl</code> (A)	Gate-induced source leakage current.
17	<code>igidl</code> (A)	Gate-induced drain leakage current.
18	<code>ijs</code> (A)	Total source junction current.
19	<code>ijsbot</code> (A)	Source junction current (bottom component).
20	<code>ijsgat</code> (A)	Source junction current (gate-edge component).
21	<code>ijssti</code> (A)	Source junction current (STI-edge component).
22	<code>ijd</code> (A)	Total drain junction current.
23	<code>ijdbot</code> (A)	Drain junction current (bottom component).
24	<code>ijdgat</code> (A)	Drain junction current (gate-edge component).
25	<code>ijdsti</code> (A)	Drain junction current (STI-edge component).
26	<code>qg</code> (Coul)	Intrinsic gate charge.

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27	q_d (Coul)	Intrinsic drain charge.
28	q_b (Coul)	Intrinsic bulk charge.
29	q_s (Coul)	Intrinsic source charge.
30	q_{gs_ov} (Coul)	Overlap charge for gate-source.
31	q_{gd_ov} (Coul)	Overlap charge for gate-drain.
32	q_{fgs} (Coul)	Total outerFringe + overlap for gate-source.
33	q_{fgd} (Coul)	Total outerFringe + overlap for gate-drain.
34	q_{gb_ov} (Coul)	Gate-bulk overlap charge.
35	q_{jun_s} (Coul)	Junction charge on source side.
36	q_{jun_d} (Coul)	Junction charge on drain side.
37	v_{ds} (V)	Drain-source voltage.
38	v_{gs} (V)	Gate-source voltage.
39	v_{sb} (V)	Source-bulk voltage.
40	v_{to} (V)	Zero-bias threshold voltage.
41	v_{ts} (V)	Threshold voltage including back bias effects.
42	v_{th} (V)	Threshold voltage including back bias and drain bias effects.
43	v_{gt} (V)	Effective gate drive voltage including back bias and drain bias effects.
44	v_{dss} (V)	Drain saturation voltage at actual bias.
45	v_{sat} (V)	Saturation limit.
46	pwr (W)	Power at op point.
47	g_m ($1/\Omega$)	Transconductance.

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48	g_{mb} ($1/\Omega$)	Substrate transconductance.
49	g_{ds} ($1/\Omega$)	Output conductance.
50	g_{js} ($1/\Omega$)	Source junction conductance.
51	g_{jd} ($1/\Omega$)	Drain junction conductance.
52	c_{dd} (F)	Drain capacitance.
53	c_{dg} (F)	Drain-gate capacitance.
54	c_{ds} (F)	Drain-source capacitance.
55	c_{db} (F)	Drain-bulk capacitance.
56	c_{gd} (F)	Gate-drain capacitance.
57	c_{gg} (F)	Gate capacitance.
58	c_{gs} (F)	Gate-source capacitance.
59	c_{gb} (F)	Gate-bulk capacitance.
60	c_{sd} (F)	Source-drain capacitance.
61	c_{sg} (F)	Source-gate capacitance.
62	c_{ss} (F)	Source capacitance.
63	c_{sb} (F)	Source-bulk capacitance.
64	c_{bd} (F)	Bulk-drain capacitance.
65	c_{bg} (F)	Bulk-gate capacitance.
66	c_{bs} (F)	Bulk-source capacitance.
67	c_{bb} (F)	Bulk capacitance.
68	c_{gsol} (F)	Total gate-source overlap capacitance.
69	c_{gdol} (F)	Total gate-drain overlap capacitance.

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70	<code>cgbol</code> (F)	Total gate-bulk overlap capacitance.
71	<code>cjs</code> (F)	Total source junction capacitance.
72	<code>cjsbot</code> (F)	Source junction capacitance (bottom component).
73	<code>cjsgat</code> (F)	Source junction capacitance (gate-edge component).
74	<code>cjssti</code> (F)	Source junction capacitance (STI-edge component).
75	<code>cjd</code> (F)	Total drain junction capacitance.
76	<code>cjdbot</code> (F)	Drain junction capacitance (bottom component).
77	<code>cjdgat</code> (F)	Drain junction capacitance (gate-edge component).
78	<code>cjdsti</code> (F)	Drain junction capacitance (STI-edge component).
79	<code>lpoly</code> (m)	
80	<code>u</code>	Transistor gain.
81	<code>rout</code> (Ω)	Small-signal output resistance.
82	<code>vearly</code> (V)	Equivalent Early voltage.
83	<code>beff</code> (A/V^2)	Gain factor.
84	<code>fug</code> (Hz)	Unity gain frequency at actual bias.
85	<code>rg</code> (Ω)	Gate resistance.
86	<code>sfl</code> (A^2/Hz)	Flicker noise current spectral density at 1 Hz.
87	<code>sqrtsff</code> (V/ \sqrt{Hz})	Input-referred RMS white noise voltage spectral density at 1 kHz.
88	<code>sqrtsfw</code> (V/ \sqrt{Hz})	Input-referred RMS white noise voltage spectral density.
89	<code>sid</code> (A^2/Hz)	White noise current spectral density.
90	<code>sig</code> (A^2/Hz)	Induced gate noise current spectral density at 1 Hz.

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91	<code>cigid</code>	Imaginary part of correlation coefficient between Sig and Sid.
92	<code>fknee</code> (Hz)	Cross-over frequency above which white noise is dominant.
93	<code>sigs</code> (A^2/Hz)	Gate-source current noise spectral density.
94	<code>sigd</code> (A^2/Hz)	Gate-drain current noise spectral density.
95	<code>siavl</code> (A^2/Hz)	Impact ionization current noise spectral density.
96	<code>ssi</code> (A^2/Hz)	Total source junction current noise spectral density.
97	<code>sdi</code> (A^2/Hz)	Total drain junction current noise spectral density.
98	<code>vbs</code> (V)	Bulk-source voltage.
99	<code>lv9</code> (V)	alias of <code>vth</code> .
100	<code>lv10</code> (V)	alias of <code>vdss</code> .
101	<code>lv36</code> (F)	alias of <code>cgsol</code> .
102	<code>lv37</code> (F)	alias of <code>cgdol</code> .
103	<code>lv38</code> (F)	alias of <code>cgbol</code> .
104	<code>lv51</code> (m)	alias of <code>tox</code> .
105	<code>lx4</code> (A)	alias of <code>ids</code> .
106	<code>lx3</code> (V)	alias of <code>vds</code> .
107	<code>lx2</code> (V)	alias of <code>vgs</code> .
108	<code>lx7</code> ($1/\Omega$)	alias of <code>gm</code> .
109	<code>lx8</code> ($1/\Omega$)	alias of <code>gds</code> .
110	<code>lx9</code> ($1/\Omega$)	alias of <code>gmb</code> .
111	<code>lx33</code> (F)	alias of <code>cdd</code> .
112	<code>lx32</code> (F)	alias of <code>cdg</code> .

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113	1x34	(F)	alias of cds.
114	1x19	(F)	alias of cgd.
115	1x18	(F)	alias of cgg.
116	1x20	(F)	alias of cgs.
117	1x22	(F)	alias of cbd.
118	1x21	(F)	alias of cbg.
119	1x23	(F)	alias of cbs.
120	1x5	(A)	alias of ijs.
121	1x6	(A)	alias of ijd.
122	1x28	(F)	alias of cjs.
123	1x29	(F)	alias of cjd.
124	1x38	(A)	alias of igs.
125	1x39	(A)	alias of igd.
126	1x66	(A)	alias of igb.
127	1x67	(A)	alias of igcs.
128	1x68	(A)	alias of igcd.
129	1x110	(A)	alias of igisl.
130	1x47	(A)	alias of igidl.
131	1x60	(F)	alias of csd.
132	1x59	(F)	alias of csg.
133	1x58	(F)	alias of css.
134	1x12	(Coul)	alias of Qb including overlap charge.

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135	lx14 (Coul)	alias of Qg including overlap charge.
136	lx16 (Coul)	alias of Qd including overlap charge.
137	lx83 (F)	alias of cgd including overlap cap.
138	lx84 (F)	alias of cgs including overlap cap.

Parameter Index

In the following index, I refers to instance parameters, M refers to the model parameters section, O refers to the output parameters section, and OP refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of M-35 means the 35th model parameter.

abdrain	I-15	lv1	O-3	plwcbgov	M-194	pwnfb	M-210
absorce	I-12	lv10	OP-100	plwcbgov	M-186	pwnfc	M-214
ad	I-20	lv11	O-7	plwcbgovd	M-190	pwnov	M-57
as	I-18	lv12	O-8	plwcox	M-182	pwnovd	M-61
beff	OP-83	lv2	O-4	plwcs	M-86	pwnp	M-47
binmod	M-13	lv3	O-5	plwct	M-52	pwr	OP-46
cbb	OP-67	lv36	OP-101	plwdphib	M-44	pwr	M-96
cbbtbot	M-299	lv37	OP-102	plwiginv	M-152	pwtbet	M-74
cbbtbotd	M-340	lv38	OP-103	plwigov	M-156	pwtthesat	M-107
cbbtgat	M-301	lv4	O-6	plwigovd	M-160	pwtvfb	M-30
cbbtgatd	M-342	lv51	OP-104	plwkuowe	M-225	pwtthesat	M-103
cbbtsti	M-300	lv9	OP-99	plwkvthowe	M-221	pwtthesatb	M-111

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cbbtstid	M-341	lvar1	M-17	plwmue	M-79	pwthesatg	M-115
cbd	OP-64	lvaro	M-16	plwneff	M-37	pwvfb	M-26
cbg	OP-65	lx110	OP-129	plwnfa	M-207	pwxcor	M-90
cbs	OP-66	lx12	OP-134	plwnfb	M-211	qb	OP-28
cdb	OP-55	lx14	OP-135	plwnfc	M-215	qd	OP-27
cdd	OP-52	lx16	OP-136	plwnov	M-58	qfgd	OP-33
cdg	OP-53	lx18	OP-115	plwnovd	M-62	qfgs	OP-32
cds	OP-54	lx19	OP-114	plwnp	M-48	qg	OP-26
cgb	OP-59	lx2	OP-107	plwrs	M-97	qgb_ov	OP-34
cgbol	OP-70	lx20	OP-116	plwstbet	M-75	qgd_ov	OP-31
cgd	OP-56	lx21	OP-118	plwstthesat	M-108	qgs_ov	OP-30
cgdol	OP-69	lx22	OP-117	plwstvfb	M-31	qjun_d	OP-36
cgg	OP-57	lx23	OP-119	plwthesat	M-104	qjun_s	OP-35
cgs	OP-58	lx28	OP-122	plwthesatb	M-112	qmc	M-10
cgsol	OP-68	lx29	OP-123	plwthesatg	M-116	qs	OP-29
cigid	OP-91	lx3	OP-106	plwvfb	M-27	rbulko	M-241
cjd	OP-75	lx32	OP-112	plwxcor	M-91	rg	OP-85
cjdbot	OP-76	lx33	OP-111	plxcor	M-89	rgo	M-240
cjdgat	OP-77	lx34	OP-113	poa1	M-134	rint	M-245
cjdsti	OP-78	lx38	OP-124	poa2	M-138	rjundo	M-244

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cjorbot	M-273	lx39	OP-125	poa3	M-140	rjunso	M-243
cjorbotd	M-314	lx4	OP-105	poa4	M-144	rout	OP-81
cjorgat	M-275	lx47	OP-130	poagidl	M-165	rshg	M-247
cjorgatd	M-316	lx5	OP-120	poagidld	M-169	rvpoly	M-246
cjorsti	M-274	lx58	OP-133	poalp	M-121	rwello	M-242
cjorstid	M-315	lx59	OP-132	poalpl	M-125	sa	I-3
cjs	OP-71	lx6	OP-121	poalpl2	M-129	saref	M-249
cjsbot	OP-72	lx60	OP-131	poax	M-117	sb	I-4
cjsgat	OP-73	lx66	OP-126	pobetn	M-68	sbref	M-250
cjssti	OP-74	lx67	OP-127	pobgidl	M-173	sc	I-9
compatible	M-15	lx68	OP-128	pobgidld	M-174	sca	I-6
csb	OP-63	lx7	OP-108	pocf	M-63	scalelev	M-14
csd	OP-60	lx8	OP-109	pocfb	M-67	scb	I-7
csg	OP-61	lx83	OP-137	pocfr	M-195	scc	I-8
csrbot	M-288	lx84	OP-138	pocfrd	M-199	scref	M-268
csrbotd	M-329	lx9	OP-110	pocgbov	M-191	sd	I-5
csrhgat	M-290	m	I-28	pocgidl	M-177	sdi	OP-97
csrhgatd	M-331	mbeo	M-361	pocgidld	M-178	sdint	OP-2
csrhsti	M-289	mefftatbot	M-296	pocgov	M-183	sfl	OP-86
csrhistid	M-330	mefftatbotd	M-337	pocgovd	M-187	siavl	OP-95

Virtuoso Simulator Components and Device Models Reference

PSP102 Model

css OP-62	mefftatgat M-298	pochib M-164	sid OP-89
ctatbot M-293	mefftatgatd M-339	pocox M-179	sig OP-90
ctatbotd M-334	mefftatsti M-297	pocs M-83	sigd OP-94
ctatgat M-295	mefftatstid M-338	poct M-49	sigs OP-93
ctatgatd M-336	mulid0 I-22	podnsub M-40	sqrtsff OP-87
ctatsti M-294	mult I-23	podphib M-41	sqrtsfw OP-88
ctatstid M-335	munqso M-239	poef M-216	ssi OP-96
ctype OP-1	mvto M-360	poepsrox M-33	stetao M-266
delvto I-10	nf I-24	pofeta M-93	stfbbtbot M-305
dlq M-22	ngcon I-25	pofnt M-203	stfbbtbotd M-346
dlsil M-248	noisemethod M-367	pogc2 M-162	stfbbtgat M-307
dta M-217	pbot M-279	pogc3 M-163	stfbbtgatd M-348
dwq M-23	pbotd M-320	pogco M-148	stfbbtsti M-306
factuo I-11	pbrbot M-311	poiginv M-149	stfbbtstid M-347
fbbrbot M-302	pbrbotd M-352	poigov M-153	swgidl M-7
fbbrbotd M-343	pbrgat M-313	poigovd M-157	swigate M-5
fbbrgat M-304	pbrgatd M-354	pokuowe M-222	swimpact M-6
fbbrgatd M-345	pbrsti M-312	pokvthowe M-218	swjunasym M-9
fbbrsti M-303	pbrstid M-353	pomue M-76	swjuncap M-8
fbbrstid M-344	pd I-21	poneff M-34	swjunexp M-355

Virtuoso Simulator Components and Device Models Reference

PSP102 Model

fjunq M-357	pgat M-281	ponfa M-204	swnqs M-4
fjunqd M-359	pgatd M-322	ponfb M-208	tkuo M-254
fknee OP-92	phigbot M-282	ponfc M-212	tr M-3
fug OP-84	phigbotd M-323	ponov M-55	trise I-27
gds OP-49	phiggat M-284	ponovd M-59	trj M-272
geomod M-12	phiggatd M-325	ponp M-45	type M-2
gjd OP-51	phigsti M-283	ponslp M-39	u OP-80
gjs OP-50	phigstid M-324	pors M-94	vbd_max M-233
gm OP-47	pkuo M-257	porsb M-99	vbirbot M-276
gmb OP-48	pkvtho M-263	porsg M-100	vbirbotd M-317
iavl OP-15	pla1 M-135	posta2 M-139	vbirgat M-278
ibe OP-6	pla3 M-141	postbet M-72	vbirgatd M-319
idb OP-8	pla4 M-145	postbgidl M-175	vbirsti M-277
ide OP-5	plagidl M-166	postbgidld M-176	vbirstid M-318
ids OP-7	plagidld M-170	postcs M-87	vbrbot M-308
idsatrbot M-285	plalp M-122	postig M-161	vbrbotd M-349
idsatrbotd M-326	plalp1 M-126	postmue M-80	vbrgat M-310
idsatrgat M-287	plalp2 M-130	postrs M-98	vbrgatd M-351
idsatrgatd M-328	plax M-118	postthemu M-82	vbrsti M-309
idsatrsti M-286	plbetn M-69	postthesat M-105	vbrstid M-350
idsatrstid M-327	plcf M-64	postvfb M-28	vbs OP-98

Virtuoso Simulator Components and Device Models Reference

PSP102 Model

igb	OP-12	plcfr	M-196	postxcor	M-92	vbs_max	M-234
igcd	OP-14	plcfrd	M-200	pothemu	M-81	vds	OP-37
igcs	OP-13	plcgbov	M-192	pothesat	M-101	vds_max	M-230
igd	OP-11	plcgov	M-184	pothesatb	M-109	vdss	OP-44
ige	OP-4	plcgovd	M-188	pothesatg	M-113	vearly	OP-82
igidl	OP-17	plcox	M-180	potox	M-32	version	M-11
igisl	OP-16	plcs	M-84	potoxov	M-53	vgb_max	M-235
igs	OP-10	plct	M-50	potoxovd	M-54	vgbr_max	M-238
ijd	OP-22	pldphib	M-42	povfb	M-24	vgd_max	M-231
ijdbot	OP-23	pliginv	M-150	povsub	M-38	vgdr_max	M-236
ijdgat	OP-24	pligov	M-154	povp	M-133	vgs	OP-38
ijdsti	OP-25	pligovd	M-158	poxcor	M-88	vgs_max	M-232
ijs	OP-18	plkuowe	M-223	ps	I-19	vgsr_max	M-237
ijsbot	OP-19	plkvthowe	M-219	psti	M-280	vgt	OP-43
ijsgat	OP-20	plmue	M-77	pstid	M-321	vjunref	M-356
ijssti	OP-21	plneff	M-35	pwal	M-136	vjunrefd	M-358
imax	M-271	plnfa	M-205	pwa3	M-142	vsat	OP-45
isb	OP-9	plnfb	M-209	pwa4	M-146	vsb	OP-39
ise	OP-3	plnfc	M-213	pwagidl	M-167	vth	OP-42
isnoisy	I-29	plnov	M-56	pwagidld	M-171	vthmod	M-362
ivth	M-363	plnovd	M-60	pwalp	M-123	vto	OP-40

Virtuoso Simulator Components and Device Models Reference

PSP102 Model

ivth_vdsmin M-366	plnp M-46	pwalp1 M-127	vts OP-41
ivth1 M-365	plrs M-95	pwalp2 M-131	w I-2
ivthw M-364	plstbet M-73	pwax M-119	web M-269
kuo M-252	plstthesat M-106	pwbetn M-70	wec M-270
kvsat M-253	plstvfb M-29	pwcf M-65	weff O-1
kvtho M-260	plthesat M-102	pwcfr M-197	wkuo M-256
l I-1	plthesatb M-110	pwcfrd M-201	wkvtho M-262
lap M-18	plthesatg M-114	pwcgbov M-193	wlod M-251
leff O-2	plvfb M-25	pwcgov M-185	wlodkuo M-259
level M-1	plwa1 M-137	pwcgovd M-189	wlodvth M-265
lgdrain I-17	plwa3 M-143	pwcox M-181	wmax M-229
lgsource I-14	plwa4 M-147	pwcs M-85	wmin M-228
lkuo M-255	plwagidl M-168	pwct M-51	wot M-21
lkvtho M-261	plwagidld M-172	pwdphib M-43	wvaro M-19
llodkuo M-258	plwalp M-124	pwiginv M-151	wvarw M-20
llodvth M-264	plwalp1 M-128	pwigov M-155	xgw I-26
lmax M-227	plwalp2 M-132	pwigovd M-159	xjungat M-292
lmin M-226	plwax M-120	pwkuowe M-224	xjungatd M-333
lodetao M-267	plwbetn M-71	pwkvthowe M-220	xjunsti M-291
lpoly OP-79	plwcf M-66	pwmue M-78	xjunstid M-332

Virtuoso Simulator Components and Device Models Reference

PSP102 Model

lsdrain	I-16	plwcfrr	M-198	pwneff	M-36		
lssource	I-13	plwcfrrd	M-202	pwnfa	M-206		
abdrain	I-15	lv1	O-3	plwcbgov	M-194	pwnfb	M-210
absource	I-12	lv10	OP-100	plwcbgov	M-186	pwnfc	M-214
ad	I-20	lv11	O-7	plwcbgovd	M-190	pwnov	M-57
as	I-18	lv12	O-8	plwcox	M-182	pwnovd	M-61
beff	OP-83	lv2	O-4	plwcs	M-86	pwnp	M-47

PSP NQS local MOSFET Model (pspnqs102e)

This is SiMKit 4.0.1.

This device is supported within altergroups.

This device is dynamically loaded from the shared object /vobs/spectre_dev/tools.lnx86/cmi/lib/5.0.doc/libphilips_sh.so

Instance Definition

Name d g s b ModelName parameter=value ...

Instance Parameters

Instance Definition

Name d g s b ModelName parameter=value ...

Instance Parameters

1 delvto=0.0 V Threshold voltage shift parameter.

2 factuo=1.0 Zero-field mobility pre-factor.

Virtuoso Simulator Components and Device Models Reference

PSP102 Model

3	<code>absource=1E-12 m²</code>	Bottom area of source junction.
4	<code>lssource=1E-6 m</code>	STI-edge length of source junction.
5	<code>lgsource=1E-6 m</code>	Gate-edge length of source junction.
6	<code>abdrain=1E-12 m²</code>	Bottom area of drain junction.
7	<code>lsdrain=1E-6 m</code>	STI-edge length of drain junction.
8	<code>lgdrain=1E-6 m</code>	Gate-edge length of drain junction.
9	<code>as=1E-12 m²</code>	Bottom area of source junction.
10	<code>ps=1E-6 m</code>	Perimeter of source junction.
11	<code>ad=1E-12 m²</code>	Bottom area of drain junction.
12	<code>pd=1E-6 m</code>	Perimeter of drain junction.
13	<code>mulid0=1</code>	Ids multiplier.
14	<code>jw=1E-6 m</code>	Gate-edge length of source/drain junction.
15	<code>mult=1.0</code>	Number of devices in parallel.
16	<code>trise=0.0 K</code>	Temperature rise from ambient.
17	<code>m=1.0</code>	Multiplicity factor.
18	<code>isnoisy=yes</code>	Should device generate noise. Possible values are <code>no</code> and <code>yes</code> .

Model Definition

`model modelName pspnqs102e parameter=value ...`

Model Parameters

1	<code>level=102</code>	Model level.
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Virtuoso Simulator Components and Device Models Reference

PSP102 Model

2	<code>type=n</code>	Channel type parameter, n,NMOS p,PMOS. Possible values are n and p.
3	<code>tr=value of tnom C</code>	nominal (reference) temperature.
4	<code>swnqs=0</code>	Flag for NQS, 0,off, 1, 2, 3, 5, or 9,number of collocation points.
5	<code>swigate=0</code>	Flag for gate current, 0,turn off IG.
6	<code>swimpact=0</code>	Flag for impact ionization current, 0,turn off II.
7	<code>swgidl=0</code>	Flag for GIDL current, 0,turn off IGIDL.
8	<code>swjuncap=0</code>	Flag for juncap, 0,turn off juncap.
9	<code>swjunasym=0</code>	Flag for asymmetric junctions; 0,symmetric, 1,asymmetric.
10	<code>qmc=1.0</code>	Quantum-mechanical correction factor.
11	<code>version=102.32</code>	The available versions are 102.2, 102.21, 102.3, 102.32, 102.33, 102.34 and 102.40.
12	<code>geomod=1</code>	1 for geometrical model and 0 for electrical model.
13	<code>binmod=0</code>	1 for bin model and 0 for non-bin model.
14	<code>scalelev=102</code>	102 for local, 1020 for global model and 1021 for bin model.
15	<code>compatible=spectre</code>	for compatible. Possible values are spectre, spice2, spice3, cdsspice, hspice, spiceplus, eldo, sspice, and mica.
16	<code>vfb=(-1.0) V</code>	Flatband voltage at TR.
17	<code>stvfb=5.0e-4 V/K</code>	Temperature dependence of VFB.
18	<code>tox=2.0e-09 m</code>	Gate oxide thickness.
19	<code>epsrox=3.9</code>	Relative permittivity of gate dielectric.
20	<code>neff=5.0e+23 m⁻³</code>	Effective substrate doping.

Virtuoso Simulator Components and Device Models Reference

PSP102 Model

21	$v_{nsub}=0.0$ V	Effective doping bias-dependence parameter.
22	$n_{slp}=0.05$ V	Effective doping bias-dependence parameter.
23	$d_{nsub}=0.0$ V ⁻¹	Effective doping bias-dependence parameter.
24	$d_{phib}=0.0$ V	Offset parameter for PHIB.
25	$n_p=1.0e+26$ m ⁻³	Gate poly-silicon doping.
26	$c_t=0.0$	Interface states factor.
27	$t_{oxov}=2.0e-09$ m	Overlap oxide thickness.
28	$t_{oxovd}=2.0e-09$ m	Overlap oxide thickness for drain side.
29	$n_{ov}=5.0e+25$ m ⁻³	Effective doping of overlap region.
30	$n_{ovd}=5.0e+25$ m ⁻³	Effective doping of overlap region for drain side.
31	$c_f=0.0$	DIBL-parameter.
32	$c_{fb}=0.0$ V ⁻¹	Back bias dependence of CF.
33	$\beta_{etn}=7e-2$ m ² /V/s	Channel aspect ratio times zero-field mobility.
34	$st_{bet}=1.0$	Temperature dependence of BETN.
35	$\mu_e=0.5$ m/V	Mobility reduction coefficient at TR.
36	$st_{\mu_e}=0.0$	Temperature dependence of MUE.
37	$th_{\mu_e}=1.5$	Mobility reduction exponent at TR.
38	$st_{th_{\mu_e}}=1.5$	Temperature dependence of THEMU.
39	$c_s=0.0$	Coulomb scattering parameter at TR.
40	$st_{c_s}=0.0$	Temperature dependence of CS.
41	$x_{cor}=0.0$ V ⁻¹	Non-universality factor.
42	$st_{x_{cor}}=0.0$	Temperature dependence of XCOR.

Virtuoso Simulator Components and Device Models Reference

PSP102 Model

43	feta=1.0	Effective field parameter.
44	rs=30 Ω	Series resistance at TR.
45	strs=1.0	Temperature dependence of RS.
46	rsb=0.0 V^{-1}	Back-bias dependence of series resistance.
47	rsg=0.0 V^{-1}	Gate-bias dependence of series resistance.
48	thesat=1.0 V^{-1}	Velocity saturation parameter at TR.
49	stthesat=1.0	Temperature dependence of THESAT.
50	thesatb=0.0 V^{-1}	Back-bias dependence of velocity saturation.
51	thesatg=0.0 V^{-1}	Gate-bias dependence of velocity saturation.
52	ax=3.0	Linear/saturation transition factor.
53	alp=0.01	CLM pre-factor.
54	alp1=0.00 V	CLM enhancement factor above threshold.
55	alp2=0.00 V^{-1}	CLM enhancement factor below threshold.
56	vp=0.05 V	CLM logarithm dependence factor.
57	a1=1.0	Impact-ionization pre-factor.
58	a2=10.0 V	Impact-ionization exponent at TR.
59	sta2=0.0 V	Temperature dependence of A2.
60	a3=1.0	Saturation-voltage dependence of impact-ionization.
61	a4=0.0 $V^{-0.5}$	Back-bias dependence of impact-ionization.
62	gco=0.0	Gate tunnelling energy adjustment.
63	iginv=0.0 A	Gate channel current pre-factor.
64	igov=0.0 A	Gate overlap current pre-factor.

Virtuoso Simulator Components and Device Models Reference

PSP102 Model

65	$igovd=0.0$ A	Gate overlap current pre-factor for drain side.
66	$stig=2.0$	Temperature dependence of IGINV and IGOV.
67	$gc2=0.375$	Gate current slope factor.
68	$gc3=0.063$	Gate current curvature factor.
69	$chib=3.1$ V	Tunnelling barrier height.
70	$agidl=0.0$ A/V ³	GIDL pre-factor.
71	$agidld=0.0$ A/V ³	GIDL pre-factor for drain side.
72	$bgidl=41.0$ V	GIDL probability factor at TR.
73	$bgidld=41.0$ V	GIDL probability factor at TR for drain side.
74	$stbgidl=0.0$ V/K	Temperature dependence of BGIDL.
75	$stbgidld=0.0$ V/K	Temperature dependence of BGIDL for drain side.
76	$cgidl=0.0$	Back-bias dependence of GIDL.
77	$cgidld=0.0$	Back-bias dependence of GIDL for drain side.
78	$cox=1.0e-14$ F	Oxide capacitance for intrinsic channel.
79	$cgov=1.0e-15$ F	Oxide capacitance for gate-drain/source overlap.
80	$cgovd=1.0e-15$ F	Oxide capacitance for gate-drain overlap.
81	$cgbov=0.0$ F	Oxide capacitance for gate-bulk overlap.
82	$cfr=0.0$ F	Outer fringe capacitance.
83	$cfrd=0.0$ F	Outer fringe capacitance for drain side.
84	$fnt=1.0$	Thermal noise coefficient.
85	$nfa=8.0e+22$ V ⁻¹ /m ⁴	First coefficient of flicker noise.

Virtuoso Simulator Components and Device Models Reference

PSP102 Model

86	$nfb=3.0e+07 \text{ V}^{-1}/\text{m}^2$	Second coefficient of flicker noise.
87	$nfc=0.0 \text{ V}^{-1}$	Third coefficient of flicker noise.
88	$ef=1.0$	Flicker noise frequency exponent.
89	$munqs=1.0$	Relative mobility for NQS modeling.
90	$rg=0.0 \text{ } \Omega$	Gate resistance.
91	$rbulk=0.0 \text{ } \Omega$	Bulk resistance between node BP and BI.
92	$rwell=0.0 \text{ } \Omega$	Well resistance between node BI and B.
93	$rjuns=0.0 \text{ } \Omega$	Source-side bulk resistance between node BI and BS.
94	$rjund=0.0 \text{ } \Omega$	Drain-side bulk resistance between node BI and BD.
95	$imax=1000 \text{ A}$	Maximum current up to which forward current behaves exponentially.
96	$trj=21 \text{ C}$	reference temperature.
97	$cjorbot=1E-3 \text{ Fm}^{-2}$	Zero-bias capacitance per unit-of-area of bottom component for source-bulk junction.
98	$cjorsti=1E-9 \text{ Fm}^{-1}$	Zero-bias capacitance per unit-of-length of STI-edge component for source-bulk junction.
99	$cjorgat=1E-9 \text{ Fm}^{-1}$	Zero-bias capacitance per unit-of-length of gate-edge component for source-bulk junction.
100	$vbirbot=1 \text{ V}$	Built-in voltage at the reference temperature of bottom component for source-bulk junction.
101	$vbirsti=1 \text{ V}$	Built-in voltage at the reference temperature of STI-edge component for source-bulk junction.

Virtuoso Simulator Components and Device Models Reference

PSP102 Model

102	<code>vbirgat=1 V</code>	Built-in voltage at the reference temperature of gate-edge component for source-bulk junction.
103	<code>pbot=0.5</code>	Grading coefficient of bottom component for source-bulk junction.
104	<code>psti=0.5</code>	Grading coefficient of STI-edge component for source-bulk junction.
105	<code>pgat=0.5</code>	Grading coefficient of gate-edge component for source-bulk junction.
106	<code>phigbot=1.16 V</code>	Zero-temperature bandgap voltage of bottom component for source-bulk junction.
107	<code>phigsti=1.16 V</code>	Zero-temperature bandgap voltage of STI-edge component for source-bulk junction.
108	<code>phiggat=1.16 V</code>	Zero-temperature bandgap voltage of gate-edge component for source-bulk junction.
109	<code>idsatrbot=1E-12 Am⁻²</code>	Saturation current density at the reference temperature of bottom component for source-bulk junction.
110	<code>idsatrsti=1E-18 Am⁻¹</code>	Saturation current density at the reference temperature of STI-edge component for source-bulk junction.
111	<code>idsatrgat=1E-18 Am⁻¹</code>	Saturation current density at the reference temperature of gate-edge component for source-bulk junction.
112	<code>csrhhbot=1E2 Am⁻³</code>	Shockley-Read-Hall prefactor of bottom component for source-bulk junction.
113	<code>csrhisti=1E-4 Am⁻²</code>	Shockley-Read-Hall prefactor of STI-edge component for source-bulk junction.
114	<code>csrhhgat=1E-4 Am⁻²</code>	Shockley-Read-Hall prefactor of gate-edge component for source-bulk junction.

Virtuoso Simulator Components and Device Models Reference

PSP102 Model

- 115 $x_{junsti}=100E-9$ m Junction depth of STI-edge component for source-bulk junction.
- 116 $x_{jungat}=100E-9$ m Junction depth of gate-edge component for source-bulk junction.
- 117 $ctatbot=1E2$ Am^{-3} Trap-assisted tunneling prefactor of bottom component for source-bulk junction.
- 118 $ctatsti=1E-4$ Am^{-2} Trap-assisted tunneling prefactor of STI-edge component for source-bulk junction.
- 119 $ctatgat=1E-4$ Am^{-2} Trap-assisted tunneling prefactor of gate-edge component for source-bulk junction.
- 120 $mefftatbot=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of bottom component for source-bulk junction.
- 121 $mefftatsti=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of STI-edge component for source-bulk junction.
- 122 $mefftatgat=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of gate-edge component for source-bulk junction.
- 123 $cbbtbot=1E-12$ AV^{-3} Band-to-band tunneling prefactor of bottom component for source-bulk junction.
- 124 $cbbtsti=1E-18$ AV^3m Band-to-band tunneling prefactor of STI-edge component for source-bulk junction.
- 125 $cbbtgat=1E-18$ AV^3m Band-to-band tunneling prefactor of gate-edge component for source-bulk junction.
- 126 $fbbtrbot=1E9$ Vm^{-1} Normalization field at the reference temperature for band-to-band tunneling of bottom component for source-bulk junction.
- 127 $fbbtrsti=1E9$ Vm^{-1} Normalization field at the reference temperature for band-to-band tunneling of STI-edge component for source-bulk junction.

Virtuoso Simulator Components and Device Models Reference

PSP102 Model

- 128 $fbttrgat=1E9 \text{ Vm}^{-1}$
Normalization field at the reference temperature for band-to-band tunneling of gate-edge component for source-bulk junction.
- 129 $stfbbtbot=(-1E-3) \text{ K}^{-1}$
Temperature scaling parameter for band-to-band tunneling of bottom component for source-bulk junction.
- 130 $stfbbtsti=(-1E-3) \text{ K}^{-1}$
Temperature scaling parameter for band-to-band tunneling of STI-edge component for source-bulk junction.
- 131 $stfbbtgat=(-1E-3) \text{ K}^{-1}$
Temperature scaling parameter for band-to-band tunneling of gate-edge component for source-bulk junction.
- 132 $vbrbot=10 \text{ V}$
Breakdown voltage of bottom component for source-bulk junction.
- 133 $vbrsti=10 \text{ V}$
Breakdown voltage of STI-edge component for source-bulk junction.
- 134 $vbrgat=10 \text{ V}$
Breakdown voltage of gate-edge component for source-bulk junction.
- 135 $pbrbot=4 \text{ V}$
Breakdown onset tuning parameter of bottom component for source-bulk junction.
- 136 $pbrsti=4 \text{ V}$
Breakdown onset tuning parameter of STI-edge component for source-bulk junction.
- 137 $pbrgat=4 \text{ V}$
Breakdown onset tuning parameter of gate-edge component for source-bulk junction.
- 138 $cjorbotd=1E-3 \text{ Fm}^{-2}$
Zero-bias capacitance per unit-of-area of bottom component for drain-bulk junction.
- 139 $cjorstid=1E-9 \text{ Fm}^{-1}$
Zero-bias capacitance per unit-of-length of STI-edge component for drain-bulk junction.

Virtuoso Simulator Components and Device Models Reference

PSP102 Model

- 140 $cjorgatd=1E-9$ Fm^{-1} Zero-bias capacitance per unit-of-length of gate-edge component for drain-bulk junction.
- 141 $vbirbotd=1$ V Built-in voltage at the reference temperature of bottom component for drain-bulk junction.
- 142 $vbirstd=1$ V Built-in voltage at the reference temperature of STI-edge component for drain-bulk junction.
- 143 $vbirgatd=1$ V Built-in voltage at the reference temperature of gate-edge component for drain-bulk junction.
- 144 $pbotd=0.5$ Grading coefficient of bottom component for drain-bulk junction.
- 145 $pstd=0.5$ Grading coefficient of STI-edge component for drain-bulk junction.
- 146 $pgatd=0.5$ Grading coefficient of gate-edge component for drain-bulk junction.
- 147 $phigbotd=1.16$ V Zero-temperature bandgap voltage of bottom component for drain-bulk junction.
- 148 $phigstd=1.16$ V Zero-temperature bandgap voltage of STI-edge component for drain-bulk junction.
- 149 $phiggatd=1.16$ V Zero-temperature bandgap voltage of gate-edge component for drain-bulk junction.
- 150 $idsatrbotd=1E-12$ Am^{-2} Saturation current density at the reference temperature of bottom component for drain-bulk junction.
- 151 $idsatrstd=1E-18$ Am^{-1} Saturation current density at the reference temperature of STI-edge component for drain-bulk junction.
- 152 $idsatrgatd=1E-18$ Am^{-1} Saturation current density at the reference temperature of gate-edge component for drain-bulk junction.

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- 153 $\text{csrbotd}=1\text{E}2 \text{ Am}^{-3}$ Shockley-Read-Hall prefactor of bottom component for drain-bulk junction.
- 154 $\text{csrstid}=1\text{E}-4 \text{ Am}^{-2}$ Shockley-Read-Hall prefactor of STI-edge component for drain-bulk junction.
- 155 $\text{crgatd}=1\text{E}-4 \text{ Am}^{-2}$ Shockley-Read-Hall prefactor of gate-edge component for drain-bulk junction.
- 156 $\text{xjunstid}=100\text{E}-9 \text{ m}$ Junction depth of STI-edge component for drain-bulk junction.
- 157 $\text{xjngatd}=100\text{E}-9 \text{ m}$ Junction depth of gate-edge component for drain-bulk junction.
- 158 $\text{ctatbotd}=1\text{E}2 \text{ Am}^{-3}$ Trap-assisted tunneling prefactor of bottom component for drain-bulk junction.
- 159 $\text{ctatstid}=1\text{E}-4 \text{ Am}^{-2}$ Trap-assisted tunneling prefactor of STI-edge component for drain-bulk junction.
- 160 $\text{ctatgatd}=1\text{E}-4 \text{ Am}^{-2}$ Trap-assisted tunneling prefactor of gate-edge component for drain-bulk junction.
- 161 $\text{mefftatbotd}=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of bottom component for drain-bulk junction.
- 162 $\text{mefftatstid}=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of STI-edge component for drain-bulk junction.
- 163 $\text{mefftatgatd}=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of gate-edge component for drain-bulk junction.
- 164 $\text{cbbtbotd}=1\text{E}-12 \text{ AV}^{-3}$ Band-to-band tunneling prefactor of bottom component for drain-bulk junction.

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- 165 `cbbtstid=1E-18` AV^3_{m}
Band-to-band tunneling prefactor of STI-edge component for drain-bulk junction.
- 166 `cbbtgatd=1E-18` AV^3_{m}
Band-to-band tunneling prefactor of gate-edge component for drain-bulk junction.
- 167 `fbbtbotd=1E9` Vm^{-1}
Normalization field at the reference temperature for band-to-band tunneling of bottom component for drain-bulk junction.
- 168 `fbbtrstid=1E9` Vm^{-1}
Normalization field at the reference temperature for band-to-band tunneling of STI-edge component for drain-bulk junction.
- 169 `fbbtgatd=1E9` Vm^{-1}
Normalization field at the reference temperature for band-to-band tunneling of gate-edge component for drain-bulk junction.
- 170 `stfbbtbotd=(-1E-3)` K^{-1}
Temperature scaling parameter for band-to-band tunneling of bottom component for drain-bulk junction.
- 171 `stfbbtstid=(-1E-3)` K^{-1}
Temperature scaling parameter for band-to-band tunneling of STI-edge component for drain-bulk junction.
- 172 `stfbbtgatd=(-1E-3)` K^{-1}
Temperature scaling parameter for band-to-band tunneling of gate-edge component for drain-bulk junction.
- 173 `vbrbotd=10` V
Breakdown voltage of bottom component for drain-bulk junction.
- 174 `vbrstid=10` V
Breakdown voltage of STI-edge component for drain-bulk junction.
- 175 `vbrgatd=10` V
Breakdown voltage of gate-edge component for drain-bulk junction.
- 176 `pbrbotd=4` V
Breakdown onset tuning parameter of bottom component for drain-bulk junction.

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177	<code>pbrstid=4 V</code>	Breakdown onset tuning parameter of STI-edge component for drain-bulk junction.
178	<code>pbrgatd=4 V</code>	Breakdown onset tuning parameter of gate-edge component for drain-bulk junction.
179	<code>swjunexp=0.0</code>	Flag for JUNCAP-express; 0,full model, 1,express model.
180	<code>vjunref=2.5</code>	Typical maximum source-bulk junction voltage; usually about 2*VSUP.
181	<code>fjunq=0.03</code>	Fraction below which source-bulk junction capacitance components are considered negligible.
182	<code>vjunrefd=2.5</code>	Typical maximum drain-bulk junction voltage; usually about 2*VSUP.
183	<code>fjunqd=0.03</code>	Fraction below which drain-bulk junction capacitance components are considered negligible.
184	<code>dta=0 K</code>	Temperature offset w.r.t. ambient circuit temperature.
185	<code>mvt=0.0</code>	DCmatch parameter.
186	<code>mbe=0.0</code>	DCmatch parameter.
187	<code>vds_max=∞ V</code>	Maximum allowed voltage cross source and drain.
188	<code>vgd_max=∞ V</code>	Maximum allowed voltage cross gate and drain.
189	<code>vgs_max=∞ V</code>	Maximum allowed voltage cross gate and source/bulk.
190	<code>vbd_max=∞ V</code>	Maximum allowed voltage cross source/drain and bulk.
191	<code>vbs_max=∞ V</code>	Maximum allowed voltage cross source and bulk.
192	<code>vgb_max=∞ V</code>	Maximum allowed voltage cross gate and bulk.

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193	<code>vgdr_max=∞ V</code>	Maximum allowed reverse voltage cross gate and drain.
194	<code>vgsr_max=∞ V</code>	Maximum allowed reverse voltage cross gate and source.
195	<code>vgbr_max=∞ V</code>	Maximum allowed reverse voltage cross gate and bulk.
196	<code>vthmod</code>	Vth output selector. 'std' outputs model equation Vth. 'vthcc' outputs constant current Vth, and may impact simulation performance. The default value is taken from the options parameter 'vthmod'. Possible values are <code>std</code> and <code>vthcc</code> .
197	<code>ivth (A)</code>	Vth current parameter. The default value is taken from the options parameter 'ivthn' or 'ivthp', depending on the type of the model.
198	<code>ivthw (m)</code>	Width offset for constant current Vth. The default value is taken from the options parameter 'ivthw'.
199	<code>ivthl (m)</code>	Length offset for constant current Vth. The default value is taken from the options parameter 'ivthl'.
200	<code>ivth_vdsmin (V)</code>	Minimum Vds in constant current Vth calculating. The default value is taken from the options parameter 'ivth_vdsmin'.
201	<code>noisemethod=oldcmi</code>	Induced gate noise implementation . Possible values are <code>oldcmi</code> , <code>subckt</code> , and <code>newcmi</code> .

Output Parameters

1	<code>weff (m)</code>	Effective channel width for geometrical models.
2	<code>leff (m)</code>	Effective channel length for geometrical models.
3	<code>lv1 (m)</code>	alias of l.
4	<code>lv2 (m)</code>	alias of w.
5	<code>lv3 (m²)</code>	alias of ad.

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6	lv4 (m ²)	alias of as.
7	lv11 (m)	alias of pd.
8	lv12 (m)	alias of ps.

Operating-Point Parameters

1	ctype	Flag for channel type.
2	sdint	Flag for source-drain interchange.
3	ise (A)	Total source current.
4	ige (A)	Total gate current.
5	ide (A)	Total drain current.
6	ibe (A)	Total bulk current.
7	ids (A)	Drain current, excl. avalanche, tunnel, GISL, GIDL, and junction currents.
8	idb (A)	Drain to bulk current.
9	isb (A)	Source to bulk current.
10	igs (A)	Gate-source tunneling current.
11	igd (A)	Gate-drain tunneling current.
12	igb (A)	Gate-bulk tunneling current.
13	igcs (A)	Gate-channel tunneling current (source component).
14	igcd (A)	Gate-channel tunneling current (drain component).
15	iavl (A)	Substrate current due to weak avalanche.
16	igisl (A)	Gate-induced source leakage current.
17	igidl (A)	Gate-induced drain leakage current.

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18	i_{js} (A)	Total source junction current.
19	i_{jsbot} (A)	Source junction current (bottom component).
20	i_{jsgat} (A)	Source junction current (gate-edge component).
21	i_{jsssti} (A)	Source junction current (STI-edge component).
22	i_{jd} (A)	Total drain junction current.
23	i_{jdbot} (A)	Drain junction current (bottom component).
24	i_{jdgat} (A)	Drain junction current (gate-edge component).
25	i_{jdsti} (A)	Drain junction current (STI-edge component).
26	q_g (Coul)	Intrinsic gate charge.
27	q_d (Coul)	Intrinsic drain charge.
28	q_b (Coul)	Intrinsic bulk charge.
29	q_s (Coul)	Intrinsic source charge.
30	q_{gs_ov} (Coul)	Overlap charge for gate-source.
31	q_{gd_ov} (Coul)	Overlap charge for gate-drain.
32	q_{fgs} (Coul)	Total outerFringe + overlap for gate-source.
33	q_{fgd} (Coul)	Total outerFringe + overlap for gate-drain.
34	q_{gb_ov} (Coul)	Gate-bulk overlap charge.
35	q_{jun_s} (Coul)	Junction charge on source side.
36	q_{jun_d} (Coul)	Junction charge on drain side.
37	v_{ds} (V)	Drain-source voltage.
38	v_{gs} (V)	Gate-source voltage.
39	v_{sb} (V)	Source-bulk voltage.

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40	v_{to} (V)	Zero-bias threshold voltage.
41	v_{ts} (V)	Threshold voltage including back bias effects.
42	v_{th} (V)	Threshold voltage including back bias and drain bias effects.
43	v_{gt} (V)	Effective gate drive voltage including back bias and drain bias effects.
44	v_{dss} (V)	Drain saturation voltage at actual bias.
45	v_{sat} (V)	Saturation limit.
46	p_{wr} (W)	Power at op point.
47	g_m ($1/\Omega$)	Transconductance.
48	g_{mb} ($1/\Omega$)	Substrate transconductance.
49	g_{ds} ($1/\Omega$)	Output conductance.
50	g_{js} ($1/\Omega$)	Source junction conductance.
51	g_{jd} ($1/\Omega$)	Drain junction conductance.
52	c_{dd} (F)	Drain capacitance.
53	c_{dg} (F)	Drain-gate capacitance.
54	c_{ds} (F)	Drain-source capacitance.
55	c_{db} (F)	Drain-bulk capacitance.
56	c_{gd} (F)	Gate-drain capacitance.
57	c_{gg} (F)	Gate capacitance.
58	c_{gs} (F)	Gate-source capacitance.
59	c_{gb} (F)	Gate-bulk capacitance.
60	c_{sd} (F)	Source-drain capacitance.

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61	<code>csg</code> (F)	Source-gate capacitance.
62	<code>css</code> (F)	Source capacitance.
63	<code>csb</code> (F)	Source-bulk capacitance.
64	<code>cbd</code> (F)	Bulk-drain capacitance.
65	<code>cbg</code> (F)	Bulk-gate capacitance.
66	<code>cbs</code> (F)	Bulk-source capacitance.
67	<code>cbb</code> (F)	Bulk capacitance.
68	<code>cgsol</code> (F)	Total gate-source overlap capacitance.
69	<code>cgdol</code> (F)	Total gate-drain overlap capacitance.
70	<code>cgbol</code> (F)	Total gate-bulk overlap capacitance.
71	<code>cjs</code> (F)	Total source junction capacitance.
72	<code>cjsbot</code> (F)	Source junction capacitance (bottom component).
73	<code>cjsgat</code> (F)	Source junction capacitance (gate-edge component).
74	<code>cjssti</code> (F)	Source junction capacitance (STI-edge component).
75	<code>cjd</code> (F)	Total drain junction capacitance.
76	<code>cjdbot</code> (F)	Drain junction capacitance (bottom component).
77	<code>cjdgat</code> (F)	Drain junction capacitance (gate-edge component).
78	<code>cjdsti</code> (F)	Drain junction capacitance (STI-edge component).
79	<code>lpoly</code> (m)	
80	<code>u</code>	Transistor gain.
81	<code>rout</code> (Ω)	Small-signal output resistance.
82	<code>vearly</code> (V)	Equivalent Early voltage.

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83	$beff$ (A/V ²)	Gain factor.
84	fug (Hz)	Unity gain frequency at actual bias.
85	rg (Ω)	Gate resistance.
86	sfl (A ² /Hz)	Flicker noise current spectral density at 1 Hz.
87	$sqrtsff$ (V/ $\sqrt{\text{Hz}}$)	Input-referred RMS white noise voltage spectral density at 1 kHz.
88	$sqrtsfw$ (V/ $\sqrt{\text{Hz}}$)	Input-referred RMS white noise voltage spectral density.
89	sid (A ² /Hz)	White noise current spectral density.
90	sig (A ² /Hz)	Induced gate noise current spectral density at 1 Hz.
91	$cigid$	Imaginary part of correlation coefficient between Sig and Sid.
92	$fknee$ (Hz)	Cross-over frequency above which white noise is dominant.
93	$sigs$ (A ² /Hz)	Gate-source current noise spectral density.
94	$sigd$ (A ² /Hz)	Gate-drain current noise spectral density.
95	$siavl$ (A ² /Hz)	Impact ionization current noise spectral density.
96	ssi (A ² /Hz)	Total source junction current noise spectral density.
97	sdi (A ² /Hz)	Total drain junction current noise spectral density.
98	vbs (V)	Bulk-source voltage.
99	$lv9$ (V)	alias of vth .
100	$lv10$ (V)	alias of $vdss$.
101	$lv36$ (F)	alias of $cgsol$.
102	$lv37$ (F)	alias of $cgdol$.
103	$lv38$ (F)	alias of $cgbol$.

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104	1v51 (m)	alias of tox.
105	1x4 (A)	alias of ids.
106	1x3 (V)	alias of vds.
107	1x2 (V)	alias of vgs.
108	1x7 ($1/\Omega$)	alias of gm.
109	1x8 ($1/\Omega$)	alias of gds.
110	1x9 ($1/\Omega$)	alias of gmb.
111	1x33 (F)	alias of cdd.
112	1x32 (F)	alias of cdg.
113	1x34 (F)	alias of cds.
114	1x19 (F)	alias of cgd.
115	1x18 (F)	alias of cgg.
116	1x20 (F)	alias of cgs.
117	1x22 (F)	alias of cbd.
118	1x21 (F)	alias of cbg.
119	1x23 (F)	alias of cbs.
120	1x5 (A)	alias of ijs.
121	1x6 (A)	alias of ijd.
122	1x28 (F)	alias of cjs.
123	1x29 (F)	alias of cjd.
124	1x38 (A)	alias of igs.
125	1x39 (A)	alias of igd.

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126	1x66	(A)	alias of igb.
127	1x67	(A)	alias of igcs.
128	1x68	(A)	alias of igcd.
129	1x110	(A)	alias of igisl.
130	1x47	(A)	alias of igidl.
131	1x60	(F)	alias of csd.
132	1x59	(F)	alias of csg.
133	1x58	(F)	alias of css.
134	1x12	(Coul)	alias of Qb including overlap charge.
135	1x14	(Coul)	alias of Qg including overlap charge.
136	1x16	(Coul)	alias of Qd including overlap charge.
137	1x83	(F)	alias of cgd including overlap cap.
138	1x84	(F)	alias of cgs including overlap cap.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

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ctatstid	M-159	lx18	OP-115	rsb	M-46	xcor	M-41
ctype	OP-1	lx19	OP-114	rsg	M-47	xjungat	M-116
delvto	I-1	lx2	OP-107	rwell	M-92	xjungatd	M-157
dnsub	M-23	lx20	OP-116	scalelev	M-14	xjunsti	M-115
dphib	M-24	lx21	OP-118	sdi	OP-97	xjunstid	M-156
dta	M-184	lx22	OP-117	sdint	OP-2		
ef	M-88	lx23	OP-119	sfl	OP-86		
epsrox	M-19	lx28	OP-122	siavl	OP-95		
a1	M-57	factuo	I-2	lx29	OP-123	sid	OP-89
a2	M-58	fbtrbot	M-126	lx3	OP-106	sig	OP-90
a3	M-60	fbtrbotd	M-167	lx32	OP-112	sigd	OP-94
a4	M-61	fbtrgat	M-128	lx33	OP-111	sigs	OP-93
abdrain	I-6	fbtrgatd	M-169	lx34	OP-113	sqrtsff	OP-87

Virtuoso Simulator Components and Device Models Reference
PSP102 Model

PSP103 Model

PSP103 is a compact MOSFET model intended for digital, analog and RF designs. It is jointly developed by NXP Semiconductors Research and Arizona State University, and is a surface-potential based MOS model containing all relevant physical effects (mobility reduction, velocity saturation, DIBL, gate current, lateral doping gradient effects, STI stress, and so forth), to model present-day and upcoming deep-submicron bulk CMOS technologies. The JUNCAP2 source/drain junction model is an integrated part of PSP103.

PSP103 not only gives an accurate description of currents, charges, and their first order derivatives (i.e. transconductance, conductance and capacitances), but also of the higher order derivatives, resulting in an accurate description of electrical distortion behavior. The latter is especially important for analog and RF circuit design. The model, furthermore, gives an accurate description of the noise behavior of MOSFETs.

For a full description of the PSP102 model, see <http://pspmodel.asu.edu>.

This chapter contains the following information:

- Model Usage on page 1827
 - Instance Syntax on page 1827
 - Model Syntax on page 1827
- Model History and Development on page 1828
- Reference on page 1829
 - Model Description on page 1829
 - Geometry Scaling and Stress Model for Intrinsic MOSFET on page 1829
 - PSP 103 Model Equations on page 1859
 - Non-quasi-static RF model on page 1893
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Virtuoso Simulator Components and Device Models Reference

PSP103 Model

- [Operating-Point Parameters](#) on page 1940
- [Parameter Index](#) on page 2011

Model Usage

Instance Syntax

PSP103 instance has 4 terminals. The ModelName has to be associated with a PSP103 model card.

```
InstanceName (d g s b) PSP103ModelName <parameter=value>
```

Sample Instance Statement

```
q1(v1 v2 v3 v4) psp103_mod w=1e-6 l=0.5e-6
```

Model Syntax

The following syntax specifies PSP103 model:

```
model ModelName psp103 parameter=value ...
```

The third parameter, "psp103", is the master to indicate this model card is a PSP103 model card.

Version and Master Name

1. Versions 103.0, 103.1, and 103.1.1 are supported
2. There are two master names - psp103 and pspnqs103

Sample Model Statement

Example PSP103.0

```
model psp103_mod psp103 type=n version=103.0  
+tr = 25 swigate = 0  
  
+binmod=0 geomod=1 swnqs=9 swgidl = 1 swjuncap = 3
```

Example PSP103.1

```
model psp103_mod psp103 type=n version=103.1  
+tr = 25 swigate = 0  
  
+binmod=0 geomod=1 swnqs=9 swgidl = 1 swjuncap = 3
```

Model History and Development

PSP103.0 (SiMKit3.2)

- Implemented in MMSIM7.1.1 in June 2009

PSP103.1 (SiMKit3.3)

- Implemented in MMSIM7.2 in December 2010

Changes

- Added external sheet resistance RSHD for drain diffusion (used when SWJUNASYM=1)
- Extended NUD model to allow retrograde profiles (GFACNUD>1)
- Added value of gate resistance to OP-output
- Bug fix and minor implementation change in NUD-model
- Minor bug fix in conditional for SP-calculation of overlap areas

PSP103.1.1 (SiMKit3.4)

- Implemented in MMSIM10.1 in June 2010

Changes

- Modified implementation of the asymmetrical junction model to improve simulation speed of the verilog-A code.
- Modified implementation of the MULT-scaling factor.
- Modified implementation of the NUD model.
- Modified implementation of the stand-alone JUNCAP2 model.
- Minor bug fix for the output of sfl, sqrtsw, and fknee

PSP103.2.0 (SiMKit4.0.1)

- Implemented in MMSIM12.1.1 in May 2013

Changes

- Introduction of self heating. The self heating version has an additional temperature terminal \dot{t} , thermal resistance R_{TH} , and thermal capacitance C_{TH} . Geometry scaling rules for R_{TH} and C_{TH} , as well as temperature dependence of R_{TH} are also provided.
- Implementation of the thermal noise model has been improved:
 - A bug in the sign of the correlation coefficient for negative v_{ds} has been fixed
 - Gummel symmetry of S_{id} at very high frequencies has been improved
 - Number of `white_noise` sources has been reduced and the noise voltage values in the noise-subcircuit have been scaled to more physical values (simulation results are not affected).
- The calculation of the surface potential in the gate-diffusion overlap region has been simplified to improve simulation speed of verilog-A code.
- The expression for q_{lim2} in QM correction has been modified to avoid unphysical behavior when oxide thickness is large. This modification is relevant for high-k dielectrics.
- Minor bugs in the calculation of OP-output variables have been fixed.
- Minor implementation changes have been made.
- Few OP-output variables have been added.

Reference

Model Description

Geometry Scaling and Stress Model for Intrinsic MOSFET

The physical geometry scaling rules of PSP have been developed to give a good description over the whole geometry range of CMOS technologies. As an alternative, the binning-rules can be used to allow for a more phenomenological geometry dependency. (Note that the user

has to choose between the two options; the geometrical scaling rules and the binning scaling rules cannot be used at the same time.) In both cases, the result is a local parameter set (for a transistor of the specified L and W), which is fed into the local model.

Stress and well proximity effects are included in PSP. Use of the stress model and/or well proximity effect model leads to modification of some of the local parameters calculated from the geometrical or binning scaling rules.

Geometrical scaling rules

The physical scaling rules to calculate the local parameters from a global parameter set are given in this section.

Note:

- After calculation of the local parameters (and possible application of the stress equations), clipping is applied according to Section “Intrinsic Parameters” for the model.
- The geometrical scaling equations are only calculated when SWGEO = 1.

Effective length and width

$$W_t = \frac{W}{NF}$$

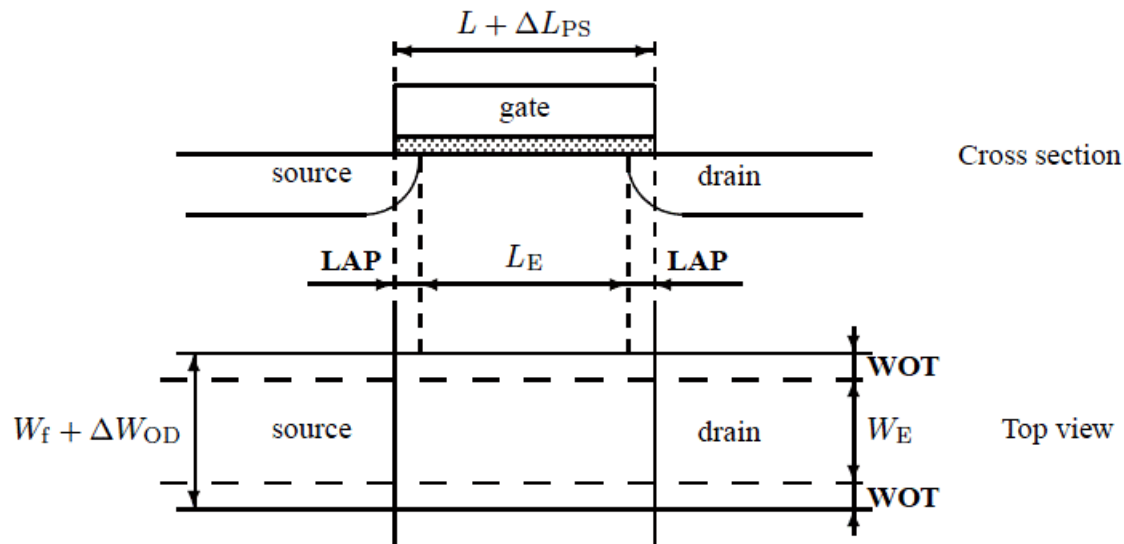
$$L_{EN} = 10^{-6}$$

$$W_{EN} = 10^{-6}$$

$$\Delta L_{PS} = LVARO \cdot \left(1 + LVARL \cdot \frac{L_{EN}}{L} \right) \cdot \left(1 + LVARW \cdot \frac{W_{EN}}{W_t} \right)$$

$$\Delta W_{OD} = WVARO \cdot \left(1 + WVARL \cdot \frac{L_{EN}}{L} \right) \cdot \left(1 + WVARW \cdot \frac{W_{EN}}{W_t} \right)$$

Figure 24-1 Specification of the dimensions of a MOS transistor



$$L_E = L - \Delta L = L + \Delta L_{PS} - 2 \cdot LAP$$

$$W_E = W_f - \Delta W = W_f + \Delta W_{OD} - 2 \cdot WOT$$

$$L_{E,CV} = L + \Delta L_{PS} - 2 \cdot LAP + DLQ$$

$$W_{E,CV} = W_f + \Delta W_{OD} - 2 \cdot WOT + DWQ$$

$$L_{G,CV} = L + \Delta L_{PS} + DLQ$$

$$W_{G,CV} = W_f + \Delta W_{OD} + DWQ$$

Note: If the calculated L_E , W_E , $L_{E,CV}$, $W_{E,CV}$, $L_{G,CV}$, or $W_{G,CV}$ is smaller than 1 nm (10⁻⁹ m), the value is clipped to this lower bound of 1 nm.

Process Parameters

$$VFB = VFBO + VFBL \cdot \frac{L_{EN}}{L_E} + VFBW \cdot \frac{W_{EN}}{W_E} + VFBLW \cdot \frac{W_{EN} \cdot L_{EN}}{W_E \cdot L_E}$$

$$STVFB = STVFB0 + STVFB1 \cdot \frac{L_{EN}}{L_E} + STVFBW \cdot \frac{W_{EN}}{W_E} + STVFB1W \cdot \frac{W_{EN} \cdot L_{EN}}{W_E \cdot L_E}$$

$$TOX = TOX0$$

$$EPSROX = EPSROX0$$

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PSP103 Model

$$N_{sub0,off} = NSUBO \cdot \text{MAX} \left(\left[1 + NSUBW \cdot \frac{W_{EN}}{W_E} \cdot \ln \left(1 + \frac{W_E}{WSEC} \right) \right], 10^{-9} \right)$$

$$N_{pk,off} = NPCK \cdot \text{MAX} \left(\left[1 + NPCKW \cdot \frac{W_{EN}}{W_E} \cdot \ln \left(1 + \frac{W_E}{WSEGF} \right) \right], 10^{-9} \right)$$

$$L_{pk,off} = LPCK \cdot \text{MAX} \left(\left[1 + LPCKW \cdot \frac{W_{EN}}{W_E} \cdot \ln \left(1 + \frac{W_E}{WSEGF} \right) \right], 10^{-9} \right)$$

$$a = 7.5 \cdot 10^{10}$$

$$b = \sqrt{N_{sub0,off} + 0.5 \cdot N_{pk,off}} - \sqrt{N_{sub0,off}}$$

$$N_{sub} = \begin{cases} N_{sub0,off} + N_{pk,off} \cdot \left[2 - \frac{L_E}{L_{pk,off}} \right] & \text{for } L_E < L_{pk,off} \\ N_{sub0,off} + N_{pk,off} \cdot \frac{L_{pk,off}}{L_E} & \text{for } L_{pk,off} \leq L_E \leq 2 \cdot L_{pk,off} \\ \left[\sqrt{N_{sub0,off}} + a \cdot \ln \left(1 + 2 \cdot \frac{L_{pk,off}}{L_E} \cdot \left[\exp \left(\frac{b}{a} \right) - 1 \right] \right) \right]^2 & \text{for } L_E > 2 \cdot L_{pk,off} \end{cases}$$

$$NEFF = N_{sub} \cdot \left(1 - FOL1 \cdot \frac{L_{EN}}{L_E} - FOL2 \cdot \left[\frac{L_{EN}}{L_E} \right]^2 \right)$$

$$\begin{aligned} FACNEFFAC &= FACNEFFACO + FACNEFFACL \cdot \frac{L_{EN}}{L_E} \\ &+ FACNEFFACW \cdot \frac{W_{EN}}{W_E} + FACNEFFACLW \cdot \frac{L_{EN} \cdot W_{EN}}{L_E \cdot W_E} \end{aligned}$$

$$\begin{aligned} GFACNUD &= GFACNUDO + GFACNUDL \cdot \left[\frac{L_{EN}}{L_E} \right]^{GFACNUDEXP} \\ &+ GFACNUDW \cdot \frac{W_{EN}}{W_E} + GFACNUDLW \cdot \frac{L_{EN} \cdot W_{EN}}{L_E \cdot W_E} \end{aligned}$$

$$VSBNUD = VSBNUDO$$

$$DVSBNUD = DVSBNUDO$$

$$VNSUB = VNSUBO$$

$$NSLP = NSLPO$$

$$DNSUB = DNSUBO$$

Virtuoso Simulator Components and Device Models Reference

PSP103 Model

$$\begin{aligned}
 \text{DPHIB} &= \text{DPHIBO} + \text{DPHIBL} \cdot \left[\frac{L_{\text{EN}}}{L_{\text{E}}} \right]^{\text{DPHIBEXP}} \\
 &\quad + \text{DPHIBW} \cdot \frac{W_{\text{EN}}}{W_{\text{E}}} + \text{DPHIBLW} \cdot \frac{W_{\text{EN}} \cdot L_{\text{EN}}}{W_{\text{E}} \cdot L_{\text{E}}} \\
 \text{DELVTAC} &= \text{DELVTACO} + \text{DELVTACL} \cdot \left[\frac{L_{\text{EN}}}{L_{\text{E}}} \right]^{\text{DELVTACLEXP}} \\
 &\quad + \text{DELVTACW} \cdot \frac{W_{\text{EN}}}{W_{\text{E}}} + \text{DELVTACLW} \cdot \frac{W_{\text{EN}} \cdot L_{\text{EN}}}{W_{\text{E}} \cdot L_{\text{E}}} \\
 \text{NP} &= \text{NPO} \cdot \text{MAX} \left(10^{-6}, 1 + \text{NPL} \cdot \frac{L_{\text{EN}}}{L_{\text{E}}} \right) \\
 \text{CT} &= \left(\text{CTO} + \text{CTL} \cdot \left[\frac{L_{\text{EN}}}{L_{\text{E}}} \right]^{\text{CTLEXP}} \right) \cdot \left(1 + \text{CTW} \cdot \frac{W_{\text{EN}}}{W_{\text{E}}} \right) \\
 &\quad \cdot \left(1 + \text{CTLW} \cdot \frac{W_{\text{EN}} \cdot L_{\text{EN}}}{W_{\text{E}} \cdot L_{\text{E}}} \right) \\
 \text{TOXOV} &= \text{TOXOVO} \\
 \text{TOXOVD} &= \text{TOXOVO} \\
 \text{NOV} &= \text{NOVO} \\
 \text{NOVD} &= \text{NOVO}
 \end{aligned}$$

DIBL Parameters

$$\begin{aligned}
 \text{CF} &= \text{CFL} \cdot \left[\frac{L_{\text{EN}}}{L_{\text{E}}} \right]^{\text{CFLEXP}} \cdot \left(1 + \text{CFW} \cdot \frac{W_{\text{EN}}}{W_{\text{E}}} \right) \\
 \text{CFB} &= \text{CFBO} \\
 F_{\beta 1, \text{eff}} &= \text{FBET1} \cdot \left(1 + \text{FBET1W} \cdot \frac{W_{\text{EN}}}{W_{\text{E}}} \right) \\
 L_{P1, \text{eff}} &= \text{LP1} \cdot \text{MAX} \left(\left[1 + \text{LP1W} \cdot \frac{W_{\text{EN}}}{W_{\text{E}}} \right], 10^{-3} \right) \\
 G_{P, E} &= 1 + F_{\beta 1, \text{eff}} \cdot \frac{L_{P1, \text{eff}}}{L_{\text{E}}} \cdot \left[1 - \exp \left(-\frac{L_{\text{E}}}{L_{P1, \text{eff}}} \right) \right] \\
 &\quad + \text{FBET2} \cdot \frac{\text{LP2}}{L_{\text{E}}} \cdot \left[1 - \exp \left(-\frac{L_{\text{E}}}{\text{LP2}} \right) \right] \\
 G_{W, E} &= 1 + \text{BETW1} \cdot \frac{W_{\text{EN}}}{W_{\text{E}}} + \text{BETW2} \cdot \frac{W_{\text{EN}}}{W_{\text{E}}} \cdot \ln \left(1 + \frac{W_{\text{E}}}{\text{WBET}} \right)
 \end{aligned}$$

$$\mathbf{BETN} = \frac{\mathbf{UO}}{G_{P,E}} \cdot \frac{W_E}{L_E} \cdot G_{W,E}$$

$$\mathbf{STBET} = \mathbf{STBETO} + \mathbf{STBETL} \cdot \frac{L_{EN}}{L_E} + \mathbf{STBETW} \cdot \frac{W_{EN}}{W_E} + \mathbf{STBETLW} \cdot \frac{W_{EN} \cdot L_{EN}}{W_E \cdot L_E}$$

$$\mathbf{MUE} = \mathbf{MUEO} \cdot \left[1 + \mathbf{MUEW} \cdot \frac{W_{EN}}{W_E} \right]$$

$$\mathbf{STMUE} = \mathbf{STMUEO}$$

$$\mathbf{THEMU} = \mathbf{THEMUO}$$

$$\mathbf{STTHEMU} = \mathbf{STTHEMUO}$$

$$\mathbf{CS} = \left(\mathbf{CSO} + \mathbf{CSL} \cdot \left[\frac{L_{EN}}{L_E} \right]^{\mathbf{CSLEXP}} \right) \cdot \left(1 + \mathbf{CSW} \cdot \frac{W_{EN}}{W_E} \right) \cdot \left(1 + \mathbf{CSLW} \cdot \frac{W_{EN} \cdot L_{EN}}{W_E \cdot L_E} \right)$$

$$\mathbf{STCS} = \mathbf{STCSO}$$

$$\mathbf{XCOR} = \mathbf{XCORO} \cdot \left(1 + \mathbf{XCORL} \cdot \frac{L_{EN}}{L_E} \right) \cdot \left(1 + \mathbf{XCORW} \cdot \frac{W_{EN}}{W_E} \right) \cdot \left(1 + \mathbf{XCORLW} \cdot \frac{W_{EN} \cdot L_{EN}}{W_E \cdot L_E} \right)$$

$$\mathbf{STXCOR} = \mathbf{STXCORO}$$

$$\mathbf{FETA} = \mathbf{FETAO}$$

Series Resistance Parameters

$$\mathbf{RS} = \mathbf{RSW1} \cdot \frac{W_{EN}}{W_E} \cdot \left[1 + \mathbf{RSW2} \cdot \frac{W_{EN}}{W_E} \right]$$

$$\mathbf{STRS} = \mathbf{STRSO}$$

$$\mathbf{RSB} = \mathbf{RSBO}$$

$$\mathbf{RSG} = \mathbf{RSGO}$$

Velocity Saturation Parameters

$$\text{THESAT} = \left(\text{THESATO} + \text{THESATL} \cdot \frac{G_{W,E}}{G_{P,E}} \cdot \left[\frac{L_{EN}}{L_E} \right]^{\text{THESATLEXP}} \right) \cdot \left(1 + \text{THESATW} \cdot \frac{W_{EN}}{W_E} \right) \cdot \left(1 + \text{THESATLW} \cdot \frac{W_{EN} \cdot L_{EN}}{W_E \cdot L_E} \right)$$

$$\text{STTHESAT} = \text{STTHESATO} + \text{STTHESATL} \cdot \frac{L_{EN}}{L_E} + \text{STTHESATW} \cdot \frac{W_{EN}}{W_E} + \text{STTHESATLW} \cdot \frac{W_{EN} \cdot L_{EN}}{W_E \cdot L_E}$$

$$\text{THESATB} = \text{THESATBO}$$

$$\text{THESATG} = \text{THESATGO}$$

Saturation Voltage Parameter

$$\text{AX} = \frac{\text{AXO}}{1 + \text{AXL} \cdot \frac{L_{EN}}{L_E}}$$

Channel Length Modulation (CLM) Parameters

$$\text{ALP} = \text{ALPL} \cdot \left[\frac{L_{EN}}{L_E} \right]^{\text{ALPLEXP}} \cdot \left(1 + \text{ALPW} \cdot \frac{W_{EN}}{W_E} \right)$$

$$\text{ALP1} = \frac{\text{ALP1L1} \cdot \left[\frac{L_{EN}}{L_E} \right]^{\text{ALP1LEXP}}}{1 + \text{ALP1L2} \cdot \left[\frac{L_{EN}}{L_E} \right]^{\text{ALP1LEXP}+1}} \cdot \left(1 + \text{ALP1W} \cdot \frac{W_{EN}}{W_E} \right)$$

$$\text{ALP2} = \frac{\text{ALP2L1} \cdot \left[\frac{L_{EN}}{L_E} \right]^{\text{ALP2LEXP}}}{1 + \text{ALP2L2} \cdot \left[\frac{L_{EN}}{L_E} \right]^{\text{ALP2LEXP}+1}} \cdot \left(1 + \text{ALP2W} \cdot \frac{W_{EN}}{W_E} \right)$$

$$\text{VP} = \text{VPO}$$

Impact Ionization (II) Parameters

$$A1 = A1O \cdot \left(1 + A1L \cdot \frac{L_{EN}}{L_E}\right) \cdot \left(1 + A1W \cdot \frac{W_{EN}}{W_E}\right)$$

$$A2 = A2O$$

$$STA2 = STA2O$$

$$A3 = A3O \cdot \left(1 + A3L \cdot \frac{L_{EN}}{L_E}\right) \cdot \left(1 + A3W \cdot \frac{W_{EN}}{W_E}\right)$$

$$A4 = A4O \cdot \left(1 + A4L \cdot \frac{L_{EN}}{L_E}\right) \cdot \left(1 + A4W \cdot \frac{W_{EN}}{W_E}\right)$$

Gate Current Parameters

$$GCO = GCOO$$

$$IGINV = IGINVLW \cdot \frac{W_E \cdot L_E}{W_{EN} \cdot L_{EN}}$$

$$IGOV = IGOVW \cdot \frac{W_E \cdot LOV}{W_{EN} \cdot L_{EN}}$$

$$IGOVD = IGOVDW \cdot \frac{W_E \cdot LOVD}{W_{EN} \cdot L_{EN}}$$

$$STIG = STIGO$$

$$GC2 = GC2O$$

$$GC3 = GC3O$$

$$CHIB = CHIBO$$

Gate-Induced Drain Leakage (GIDL) Parameters

$$AGIDL = AGIDLW \cdot \frac{W_E \cdot LOV}{W_{EN} \cdot L_{EN}}$$

$$AGIDL D = AGIDL DW \cdot \frac{W_E \cdot LOVD}{W_{EN} \cdot L_{EN}}$$

$$BGIDL = BGIDLO$$

$$BGIDL D = BGIDL DO$$

$$STBGIDL = STBGIDLO$$

$$STBGIDL D = STBGIDL DO$$

$$CGIDL = CGIDLO$$

$$CGIDL D = CGIDL DO$$

Charge Model Parameters

$$COX = \epsilon_{ox} \cdot \frac{W_{E,CV} \cdot L_{E,CV}}{TOX}$$

$$CGOV = \epsilon_{ox} \cdot \frac{W_{E,CV} \cdot LOV}{TOXOV}$$

$$CGOVD = \epsilon_{ox} \cdot \frac{W_{E,CV} \cdot LOVD}{TOXOVD}$$

$$CGBOV = CGBOVL \cdot \frac{L_{G,CV}}{L_{EN}}$$

$$CFR = CFRW \cdot \frac{W_{G,CV}}{W_{EN}}$$

$$CFRD = CFRDW \cdot \frac{W_{G,CV}}{W_{EN}}$$

Noise Model Parameters

$$L_{\text{not}} = \text{MAX} \left(1 - \frac{2 \cdot \text{LINTNOI}}{L_E}, 10^{-3} \right)$$

$$L_{\text{red}} = \frac{1}{L_{\text{not}}^{\text{ALPNOI}}}$$

$$\text{NFA} = L_{\text{red}} \cdot \text{NFALW} \cdot \frac{W_{\text{EN}} \cdot L_{\text{EN}}}{W_E \cdot L_E}$$

$$\text{NFB} = L_{\text{red}} \cdot \text{NFBLW} \cdot \frac{W_{\text{EN}} \cdot L_{\text{EN}}}{W_E \cdot L_E}$$

$$\text{NFC} = L_{\text{red}} \cdot \text{NFCLW} \cdot \frac{W_{\text{EN}} \cdot L_{\text{EN}}}{W_E \cdot L_E}$$

$$\text{EF} = \text{EFO}$$

WPE Parameters

$$K_{\text{vthowe}} = \text{KVTHOWEO} + \text{KVTHOWEL} \cdot \frac{L_{\text{EN}}}{L_E} + \text{KVTHOWEW} \cdot \frac{W_{\text{EN}}}{W_E} \\ + \text{KVTHOWELW} \cdot \frac{L_{\text{EN}} \cdot W_{\text{EN}}}{L_E \cdot W_E}$$

$$K_{\text{uowe}} = \text{KUOWEO} + \text{KUOWEL} \cdot \frac{L_{\text{EN}}}{L_E} + \text{KUOWEW} \cdot \frac{W_{\text{EN}}}{W_E} \\ + \text{KUOWELW} \cdot \frac{L_{\text{EN}} \cdot W_{\text{EN}}}{L_E \cdot W_E}$$

Note: The parameter equations described in the above section are for Global Model. The equations for the Binning Model are described in the next section with similar headings and names.

Binning Equations

The binning equations are provided as a (phenomenological) alternative to the physical scaling equations for computing local parameters. The physical geometrical scaling rules have been developed to give a good de-scription over the whole geometry range of CMOS technologies. For processes under development, however, it is sometimes useful to have more flexible scaling relation s. In that case on could opt for a binning strategy, where the accuracy with geometry is mostly determined by the number of bins used. The physical scaling rules of Section 3.2 are generally not suitable for binning strategies, since they may result in discontinuities in local parameter values at the bin boundaries. Consequently, special

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PSP103 Model

binning geometrical scaling relations have been developed, which guarantee continuity of the resulting local model parameters at the bin boundaries.

Note: The binning equations are only calculated when $SWGEO = 2$.

Only four different types of binning scaling rules are used, which are based on first order developments of the geometrical scaling rules in terms of LE , $1/LE$, WE , and $1/WE$ (examples below are for a fictitious parameter YYY):

1. Type I

$$YYY = POYYY + PLYYY \cdot \frac{L_{EN}}{L_E} + PWYYY \cdot \frac{W_{EN}}{W_E} + PLWYYY \cdot \frac{L_{EN} \cdot W_{EN}}{L_E \cdot W_E}$$

2. Type II

$$YYY = POYYY + PLYYY \cdot \frac{L_E}{L_{EN}} + PWYYY \cdot \frac{W_E}{W_{EN}} + PLWYYY \cdot \frac{L_E \cdot W_E}{L_{EN} \cdot W_{EN}}$$

3. Type III

$$YYY = POYYY + PLYYY \cdot \frac{L_{EN}}{L_E} + PWYYY \cdot \frac{W_E}{W_{EN}} + PLWYYY \cdot \frac{W_E \cdot L_{EN}}{W_{EN} \cdot L_E}$$

4. Type IV (no binning)

$$YYY = POYYY$$

In Table 23.1 a survey of the binning type used for each local parameter is given. In some cases where the geometrical scaling rule is constant, the binning rule is chosen to be more flexible.

When using the binning rules above, the binning parameters for one bin can be directly calculated from the local parameter sets of the four corner devices of the bin. This results in a separate parameter set for each bin. The binning scheme ensures that the local parameters are exactly reproduced at the bin corners and that no humps occur in the local parameter values across bin boundaries.

Note: After calculation of the local parameters from the binning rules (and possible applications of the stress equations and well proximity equations), clipping is applied according to Intrinsic Parameters for the model.

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PSP103 Model

Table 24-1 Overview of local parameters and binnings type. the third column indicates whether there is a physical geometrical scaling rule for the local parameters.

#	parameter	physical scaling	binning	#	parameter	physical scaling	binning
0	VFB	yes	type I	40	THESATG	no	type I
1	STVFB	yes	type I	41	AX	yes	type I
2	TOX	no	no	42	ALP	yes	type I
3	EPSROX	no	no	43	ALP1	yes	type I
4	NEFF	yes	type I	44	ALP2	yes	type I
5	FACNEFFAC	yes	type I	45	VP	no	no
6	GFACNUD	yes	type I	46	A1	yes	type I
7	VSBNUD	no	no	47	A2	no	no
8	DVSBNUD	no	no	48	STA2	no	no
9	VNSUB	no	no	49	A3	yes	type I
10	NSLP	no	no	50	A4	yes	type I
11	DNSUB	no	no	51	GCO	no	no
12	DPHIB	yes	type I	52	IGINV	yes	type II
13	DELVTAC	yes	type I	53	IGOV	yes	type III
14	NP	yes	type I	54	IGOVD	yes	type III
15	CT	yes	type I	55	STIG	no	no
16	TOXOV	no	no	56	GC2	no	no
17	TOXOVD	no	no	57	GC3	no	no
18	NOV	no	type I	58	CHIB	no	no
19	NOVD	no	Type I	59	AGIDL	yes	type III
20	CF	yes	type I	60	AGIDLD	yes	type III
21	CFB	no	no	61	BGIDL	no	no
22	BETN	yes	type III	62	BGIDLD	no	no
23	STBET	yes	type I	63	STBGIDL	no	no
24	MUE	yes	type I	64	STBGIDLD	no	no
25	STMUE	no	no	65	CGIDL	no	no
26	THEMU	no	no	66	CGIDLD	no	no
27	STTHEMU	no	no	67	COX	yes	type II
28	CS	yes	type I	68	CGOV	yes	type III
29	STCS	no	no	69	CGOVD	yes	type III
30	XCOR	yes	type I	70	CGBOV	yes	type II
31	STXCOR	no	no	71	CFR	yes	type III
32	FETA	no	no	72	CFRD	yes	type III
33	RS	yes	type I	73	FNT	no	no
34	STRS	no	no	74	NFA	yes	type I
35	RSB	no	no	75	NFB	yes	type I
36	RSG	no	no	76	NFC	yes	type I
37	THESAT	yes	type I	77	EF	no	no
38	STTHESAT	yes	type I	78	DTA	no	no
39	THESATB	no	type I				

Effective length and width

$$L_{EN} = 10^{-6}$$

$$W_{EN} = 10^{-6}$$

$$\Delta L_{PS} = LVARO \cdot \left(1 + LVARL \cdot \frac{L_{EN}}{L} \right)$$

$$\Delta W_{OD} = WVARO \cdot \left(1 + WVARW \cdot \frac{W_{EN}}{W_I} \right)$$

$$L_E = L - \Delta L = L + \Delta L_{PS} - 2 \cdot LAP$$

$$W_E = W_I - \Delta W = W_I + \Delta W_{OD} - 2 \cdot WOT$$

$$L_{E,CV} = L + \Delta L_{PS} - 2 \cdot LAP + DLQ$$

$$W_{E,CV} = W_I + \Delta W_{OD} - 2 \cdot WOT + DWQ$$

$$L_{G,CV} = L + \Delta L_{PS} + DLQ$$

$$W_{G,CV} = W_I + \Delta W_{OD} + DWQ$$

Note: If the calculated L_E , W_E , $L_{E,CV}$, $W_{E,CV}$, $L_{G,CV}$, or $W_{G,CV}$ is smaller than 1 nm (10^{-9} m), the value is clipped to this lower bound of 1 nm.

Process Parameters

$$\mathbf{VFB} = \mathbf{POVFB} + \mathbf{PLVFB} \cdot \frac{L_{EN}}{L_E} + \mathbf{PWVFB} \cdot \frac{W_{EN}}{W_E} + \mathbf{PLWVFB} \cdot \frac{L_{EN} \cdot W_{EN}}{L_E \cdot W_E}$$

$$\mathbf{STVFB} = \mathbf{POSTVFB} + \mathbf{PLSTVFB} \cdot \frac{L_{EN}}{L_E} \\ + \mathbf{PWSTVFB} \cdot \frac{W_{EN}}{W_E} + \mathbf{PLWSTVFB} \cdot \frac{L_{EN} \cdot W_{EN}}{L_E \cdot W_E}$$

$$\mathbf{TOX} = \mathbf{POTOX}$$

$$\mathbf{EPSROX} = \mathbf{POEPSROX}$$

$$\mathbf{NEFF} = \mathbf{PONEFF} + \mathbf{PLNEFF} \cdot \frac{L_{EN}}{L_E} + \mathbf{PWNEFF} \cdot \frac{W_{EN}}{W_E} + \mathbf{PLWNEFF} \cdot \frac{L_{EN} \cdot W_{EN}}{L_E \cdot W_E}$$

$$\mathbf{FACNEFFAC} = \mathbf{POFACNEFFAC} + \mathbf{PLFACNEFFAC} \cdot \frac{L_{EN}}{L_E} \\ + \mathbf{PWFACNEFFAC} \cdot \frac{W_{EN}}{W_E} + \mathbf{PLWFACNEFFAC} \cdot \frac{L_{EN} \cdot W_{EN}}{L_E \cdot W_E}$$

Virtuoso Simulator Components and Device Models Reference

PSP103 Model

$$\begin{aligned} \text{GFACNUD} &= \text{POGFACNUD} + \text{PLGFACNUD} \cdot \frac{L_{\text{EN}}}{L_{\text{E}}} \\ &\quad + \text{PWGFACNUD} \cdot \frac{W_{\text{EN}}}{W_{\text{E}}} + \text{PLWGFACNUD} \cdot \frac{L_{\text{EN}} \cdot W_{\text{EN}}}{L_{\text{E}} \cdot W_{\text{E}}} \end{aligned}$$

$$\text{VSBNUD} = \text{POVSBNUD}$$

$$\text{DVSBNUD} = \text{PODVSBNUD}$$

$$\text{VNSUB} = \text{POVNSUB}$$

$$\text{NSLP} = \text{PONS LP}$$

$$\text{DNSUB} = \text{PODNSUB}$$

$$\begin{aligned} \text{DPHIB} &= \text{PODPHIB} + \text{PLDPHIB} \cdot \frac{L_{\text{EN}}}{L_{\text{E}}} \\ &\quad + \text{PWDPHIB} \cdot \frac{W_{\text{EN}}}{W_{\text{E}}} + \text{PLWDPHIB} \cdot \frac{L_{\text{EN}} \cdot W_{\text{EN}}}{L_{\text{E}} \cdot W_{\text{E}}} \end{aligned}$$

$$\begin{aligned} \text{DELVTAC} &= \text{PODELVTAC} + \text{PLDELVTAC} \cdot \frac{L_{\text{EN}}}{L_{\text{E}}} \\ &\quad + \text{PWDELVTAC} \cdot \frac{W_{\text{EN}}}{W_{\text{E}}} + \text{PLWDELVTAC} \cdot \frac{L_{\text{EN}} \cdot W_{\text{EN}}}{L_{\text{E}} \cdot W_{\text{E}}} \end{aligned}$$

$$\text{NP} = \text{PONP} + \text{PLNP} \cdot \frac{L_{\text{EN}}}{L_{\text{E}}} + \text{PWNP} \cdot \frac{W_{\text{EN}}}{W_{\text{E}}} + \text{PLWNP} \cdot \frac{L_{\text{EN}} \cdot W_{\text{EN}}}{L_{\text{E}} \cdot W_{\text{E}}}$$

$$\text{CT} = \text{POCT} + \text{PLCT} \cdot \frac{L_{\text{EN}}}{L_{\text{E}}} + \text{PWCT} \cdot \frac{W_{\text{EN}}}{W_{\text{E}}} + \text{PLWCT} \cdot \frac{L_{\text{EN}} \cdot W_{\text{EN}}}{L_{\text{E}} \cdot W_{\text{E}}}$$

$$\text{TOXOV} = \text{POTOXOV}$$

$$\text{TOXOVD} = \text{POTOXOVD}$$

$$\text{NOV} = \text{PONOV} + \text{PLNOV} \cdot \frac{L_{\text{EN}}}{L_{\text{E}}} + \text{PWNOV} \cdot \frac{W_{\text{EN}}}{W_{\text{E}}} + \text{PLWNOV} \cdot \frac{L_{\text{EN}} \cdot W_{\text{EN}}}{L_{\text{E}} \cdot W_{\text{E}}}$$

$$\text{NOVD} = \text{PONOVD} + \text{PLNOVD} \cdot \frac{L_{\text{EN}}}{L_{\text{E}}} + \text{PWNOVD} \cdot \frac{W_{\text{EN}}}{W_{\text{E}}} + \text{PLWNOVD} \cdot \frac{L_{\text{EN}} \cdot W_{\text{EN}}}{L_{\text{E}} \cdot W_{\text{E}}}$$

DIBL Parameters

$$\text{CF} = \text{POCF} + \text{PLCF} \cdot \frac{L_{\text{EN}}}{L_{\text{E}}} + \text{PWCF} \cdot \frac{W_{\text{EN}}}{W_{\text{E}}} + \text{PLWCF} \cdot \frac{L_{\text{EN}} \cdot W_{\text{EN}}}{L_{\text{E}} \cdot W_{\text{E}}}$$

$$\text{CFB} = \text{POCFB}$$

Mobility Parameters

$$\text{BETN} = \frac{W_E}{L_E} \cdot \left(\text{POBETN} + \text{PLBETN} \cdot \frac{L_{EN}}{L_E} + \text{PWBETN} \cdot \frac{W_{EN}}{W_E} + \text{PLWBETN} \cdot \frac{L_{EN} \cdot W_{EN}}{L_E \cdot W_E} \right)$$

$$\text{STBET} = \text{POSTBET} + \text{PLSTBET} \cdot \frac{L_{EN}}{L_E} + \text{PWSTBET} \cdot \frac{W_{EN}}{W_E} + \text{PLWSTBET} \cdot \frac{L_{EN} \cdot W_{EN}}{L_E \cdot W_E}$$

$$\text{MUE} = \text{POMUE} + \text{PLMUE} \cdot \frac{L_{EN}}{L_E} + \text{PWMUE} \cdot \frac{W_{EN}}{W_E} + \text{PLWMUE} \cdot \frac{L_{EN} \cdot W_{EN}}{L_E \cdot W_E}$$

$$\text{STMUE} = \text{POSTMUE}$$

$$\text{THEMU} = \text{POTHEMU}$$

$$\text{STTHEMU} = \text{POSTTHEMU}$$

$$\text{CS} = \text{POCS} + \text{PLCS} \cdot \frac{L_{EN}}{L_E} + \text{PWCS} \cdot \frac{W_{EN}}{W_E} + \text{PLWCS} \cdot \frac{L_{EN} \cdot W_{EN}}{L_E \cdot W_E}$$

$$\text{STCS} = \text{POSTCS}$$

$$\text{XCOR} = \text{POXCOR} + \text{PLXCOR} \cdot \frac{L_{EN}}{L_E} + \text{PWXCOR} \cdot \frac{W_{EN}}{W_E} + \text{PLWXCOR} \cdot \frac{L_{EN} \cdot W_{EN}}{L_E \cdot W_E}$$

$$\text{STXCOR} = \text{POSTXCOR}$$

$$\text{FETA} = \text{POFETA}$$

Series Resistance Parameters

$$RS = PORS + PLRS \cdot \frac{L_{EN}}{L_E} + PWRS \cdot \frac{W_{EN}}{W_E} + PLWRS \cdot \frac{L_{EN} \cdot W_{EN}}{L_E \cdot W_E}$$

$$STRS = POSTRS$$

$$RSB = PORSB$$

$$RSG = PORSG$$

Velocity Saturation Parameters

$$\begin{aligned} \text{THESAT} = & \text{POTHESAT} + \text{PLTHESAT} \cdot \frac{L_{EN}}{L_E} \\ & + \text{PWTHESAT} \cdot \frac{W_{EN}}{W_E} + \text{PLWTHESAT} \cdot \frac{L_{EN} \cdot W_{EN}}{L_E \cdot W_E} \end{aligned}$$

$$\begin{aligned} \text{STTHESAT} = & \text{POSTTHESAT} + \text{PLSTTHESAT} \cdot \frac{L_{EN}}{L_E} \\ & + \text{PWSTRTHESAT} \cdot \frac{W_{EN}}{W_E} + \text{PLWSTRTHESAT} \cdot \frac{L_{EN} \cdot W_{EN}}{L_E \cdot W_E} \end{aligned}$$

$$\begin{aligned} \text{THESATB} = & \text{POTHESATB} + \text{PLTHESATB} \cdot \frac{L_{EN}}{L_E} \\ & + \text{PWTHESATB} \cdot \frac{W_{EN}}{W_E} + \text{PLWTHESATB} \cdot \frac{L_{EN} \cdot W_{EN}}{L_E \cdot W_E} \end{aligned}$$

$$\begin{aligned} \text{THESATG} = & \text{POTHESATG} + \text{PLTHESATG} \cdot \frac{L_{EN}}{L_E} \\ & + \text{PWTHESATG} \cdot \frac{W_{EN}}{W_E} + \text{PLWTHESATG} \cdot \frac{L_{EN} \cdot W_{EN}}{L_E \cdot W_E} \end{aligned}$$

Saturation Voltage Parameters

$$\mathbf{AX} = \mathbf{POAX} + \mathbf{PLAX} \cdot \frac{L_{EN}}{L_E} + \mathbf{PWAX} \cdot \frac{W_{EN}}{W_E} + \mathbf{PLWAX} \cdot \frac{L_{EN} \cdot W_{EN}}{L_E \cdot W_E}$$

Channel Length Modulation (CLM) Parameters

$$\mathbf{ALP} = \mathbf{POALP} + \mathbf{PLALP} \cdot \frac{L_{EN}}{L_E} + \mathbf{PWALP} \cdot \frac{W_{EN}}{W_E} + \mathbf{PLWALP} \cdot \frac{L_{EN} \cdot W_{EN}}{L_E \cdot W_E}$$

$$\mathbf{ALP1} = \mathbf{POALP1} + \mathbf{PLALP1} \cdot \frac{L_{EN}}{L_E} + \mathbf{PWALP1} \cdot \frac{W_{EN}}{W_E} + \mathbf{PLWALP1} \cdot \frac{L_{EN} \cdot W_{EN}}{L_E \cdot W_E}$$

$$\mathbf{ALP2} = \mathbf{POALP2} + \mathbf{PLALP2} \cdot \frac{L_{EN}}{L_E} + \mathbf{PWALP2} \cdot \frac{W_{EN}}{W_E} + \mathbf{PLWALP2} \cdot \frac{L_{EN} \cdot W_{EN}}{L_E \cdot W_E}$$

$$\mathbf{VP} = \mathbf{POVP}$$

Impact Ionization (II) Parameters

$$\mathbf{A1} = \mathbf{POA1} + \mathbf{PLA1} \cdot \frac{L_{EN}}{L_E} + \mathbf{PWA1} \cdot \frac{W_{EN}}{W_E} + \mathbf{PLWA1} \cdot \frac{L_{EN} \cdot W_{EN}}{L_E \cdot W_E}$$

$$\mathbf{A2} = \mathbf{POA2}$$

$$\mathbf{STA2} = \mathbf{POSTA2}$$

$$\mathbf{A3} = \mathbf{POA3} + \mathbf{PLA3} \cdot \frac{L_{EN}}{L_E} + \mathbf{PWA3} \cdot \frac{W_{EN}}{W_E} + \mathbf{PLWA3} \cdot \frac{L_{EN} \cdot W_{EN}}{L_E \cdot W_E}$$

$$\mathbf{A4} = \mathbf{POA4} + \mathbf{PLA4} \cdot \frac{L_{EN}}{L_E} + \mathbf{PWA4} \cdot \frac{W_{EN}}{W_E} + \mathbf{PLWA4} \cdot \frac{L_{EN} \cdot W_{EN}}{L_E \cdot W_E}$$

Gate Current Parameters

$$\mathbf{GCO = POGCO}$$

$$\mathbf{IGINV = POIGINV + PLIGINV \cdot \frac{L_E}{L_{EN}}}$$
$$\mathbf{\quad\quad\quad + PWIGINV \cdot \frac{W_E}{W_{EN}} + PLWIGINV \cdot \frac{L_E \cdot W_E}{L_{EN} \cdot W_{EN}}}$$

$$\mathbf{IGOV = POIGOV + PLIGOV \cdot \frac{L_{EN}}{L_E} + PWIGOV \cdot \frac{W_E}{W_{EN}} + PLWIGOV \cdot \frac{W_E \cdot L_{EN}}{W_{EN} \cdot L_E}}$$

$$\mathbf{IGOVD = POIGOVD + PLIGOVD \cdot \frac{L_{EN}}{L_E}}$$
$$\mathbf{\quad\quad\quad + PWIGOVD \cdot \frac{W_E}{W_{EN}} + PLWIGOVD \cdot \frac{W_E \cdot L_{EN}}{W_{EN} \cdot L_E}}$$

$$\mathbf{STIG = POSTIG}$$

$$\mathbf{GC2 = POGC2}$$

$$\mathbf{GC3 = POGC3}$$

$$\mathbf{CHIB = POCHIB}$$

Gate Induced Drain Leakage (GIDL) Parameters

$$\begin{aligned} \mathbf{AGIDL} = & \mathbf{POAGIDL} + \mathbf{PLAGIDL} \cdot \frac{L_{EN}}{L_E} \\ & + \mathbf{PWAGIDL} \cdot \frac{W_E}{W_{EN}} + \mathbf{PLWAGIDL} \cdot \frac{W_E \cdot L_{EN}}{W_{EN} \cdot L_E} \end{aligned}$$

$$\begin{aligned} \mathbf{AGIDLD} = & \mathbf{POAGIDLD} + \mathbf{PLAGIDLD} \cdot \frac{L_{EN}}{L_E} \\ & + \mathbf{PWAGIDLD} \cdot \frac{W_E}{W_{EN}} + \mathbf{PLWAGIDLD} \cdot \frac{W_E \cdot L_{EN}}{W_{EN} \cdot L_E} \end{aligned}$$

$$\mathbf{BGIDL} = \mathbf{POBGIDL}$$

$$\mathbf{BGIDLD} = \mathbf{POBGIDLD}$$

$$\mathbf{STBGIDL} = \mathbf{POSTBGIDL}$$

$$\mathbf{STBGIDLD} = \mathbf{POSTBGIDLD}$$

$$\mathbf{CGIDL} = \mathbf{POCGIDL}$$

$$\mathbf{CGIDLD} = \mathbf{POCGIDLD}$$

Charge Model Parameters

$$\mathbf{COX} = \mathbf{POCOX} + \mathbf{PLCOX} \cdot \frac{L_{E,CV}}{L_{EN}} + \mathbf{PWCOX} \cdot \frac{W_{E,CV}}{W_{EN}} + \mathbf{PLWCOX} \cdot \frac{L_{E,CV} \cdot W_{E,CV}}{L_{EN} \cdot W_{EN}}$$

$$\begin{aligned} \mathbf{CGOV} = \mathbf{POCGOV} + \mathbf{PLCGOV} \cdot \frac{L_{EN}}{L_{E,CV}} \\ + \mathbf{PWCGOV} \cdot \frac{W_{E,CV}}{W_{EN}} + \mathbf{PLWCGOV} \cdot \frac{W_{E,CV} \cdot L_{EN}}{W_{EN} \cdot L_{E,CV}} \end{aligned}$$

$$\begin{aligned} \mathbf{CGOVD} = \mathbf{POCGOVD} + \mathbf{PLCGOVD} \cdot \frac{L_{EN}}{L_{E,CV}} \\ + \mathbf{PWCGOVD} \cdot \frac{W_{E,CV}}{W_{EN}} + \mathbf{PLWCGOVD} \cdot \frac{W_{E,CV} \cdot L_{EN}}{W_{EN} \cdot L_{E,CV}} \end{aligned}$$

$$\begin{aligned} \mathbf{CGBOV} = \mathbf{POCGBOV} + \mathbf{PLCGBOV} \cdot \frac{L_{G,CV}}{L_{EN}} \\ + \mathbf{PWCGBOV} \cdot \frac{W_{G,CV}}{W_{EN}} + \mathbf{PLWCGBOV} \cdot \frac{L_{G,CV} \cdot W_{G,CV}}{L_{EN} \cdot W_{EN}} \end{aligned}$$

$$\mathbf{CFR} = \mathbf{POCFR} + \mathbf{PLCFR} \cdot \frac{L_{EN}}{L_{G,CV}} + \mathbf{PWCFR} \cdot \frac{W_{G,CV}}{W_{EN}} + \mathbf{PLWCFR} \cdot \frac{W_{G,CV} \cdot L_{EN}}{W_{EN} \cdot L_{G,CV}}$$

$$\mathbf{CFRD} = \mathbf{POCFRD} + \mathbf{PLCFRD} \cdot \frac{L_{EN}}{L_{G,CV}} + \mathbf{PWCFRD} \cdot \frac{W_{G,CV}}{W_{EN}} + \mathbf{PLWCFRD} \cdot \frac{W_{G,CV} \cdot L_{EN}}{W_{EN} \cdot L_{G,CV}}$$

Noise Model Parameters

$$\mathbf{FNT} = \mathbf{POFNT}$$

$$\mathbf{NFA} = \mathbf{PONFA} + \mathbf{PLNFA} \cdot \frac{L_{EN}}{L_E} + \mathbf{PWNFA} \cdot \frac{W_{EN}}{W_E} + \mathbf{PLWNFA} \cdot \frac{L_{EN} \cdot W_{EN}}{L_E \cdot W_E}$$

$$\mathbf{NFB} = \mathbf{PONFB} + \mathbf{PLNFB} \cdot \frac{L_{EN}}{L_E} + \mathbf{PWNFB} \cdot \frac{W_{EN}}{W_E} + \mathbf{PLWNFB} \cdot \frac{L_{EN} \cdot W_{EN}}{L_E \cdot W_E}$$

$$\mathbf{NFC} = \mathbf{PONFC} + \mathbf{PLNFC} \cdot \frac{L_{EN}}{L_E} + \mathbf{PWNFC} \cdot \frac{W_{EN}}{W_E} + \mathbf{PLWNFC} \cdot \frac{L_{EN} \cdot W_{EN}}{L_E \cdot W_E}$$

$$\mathbf{EF} = \mathbf{POEF}$$

WPE Parameters

$$\begin{aligned} K_{vthowe} = \mathbf{POKVTHOWE} + \mathbf{PLKVTHOWE} \cdot \frac{L_{EN}}{L_E} + \mathbf{PWKVTHOWE} \cdot \frac{W_{EN}}{W_E} \\ + \mathbf{PLWKVTHOWE} \cdot \frac{L_{EN} \cdot W_{EN}}{L_E \cdot W_E} \end{aligned}$$

$$\begin{aligned} K_{uowe} = \mathbf{POKUOWE} + \mathbf{PLKUOWE} \cdot \frac{L_{EN}}{L_E} + \mathbf{PWKUOWE} \cdot \frac{W_{EN}}{W_E} \\ + \mathbf{PLWKUOWE} \cdot \frac{L_{EN} \cdot W_{EN}}{L_E \cdot W_E} \end{aligned}$$

Parasitic resistances

PSP model contains a network of parasitic elements: a gate resistance, two diffusion resistances for source and drain, and four bulk resistances. Note that the junction diodes are no longer directly connected to the bulk terminal of the intrinsic MOS-transistor. The complete circuit is shown in Figure 24-2. At this moment, only the gate resistance is scaled with geometry (facilitating the implementation of multi-finger devices).

Virtuoso Simulator Components and Device Models Reference

PSP103 Model

Note: The resistance equations are calculated when **SWGEO** = 1 or 2.

$$L_f = L + \Delta L_{PS}$$

$$L_{sil,f} = L_f + \mathbf{DLSIL}$$

$$W_{E,f} = W_f + \Delta W_{OD}$$

$$X_{GWE} = \mathbf{XGW} - 0.5 \cdot \Delta W_{OD}$$

$$\mathbf{RG} = \mathbf{RGO} + \frac{1}{\mathbf{NF}} \cdot \left[\frac{\mathbf{RSHG} \cdot \left(\frac{W_{E,f}}{3 \cdot \mathbf{NGCON}} + X_{GWE} \right)}{\mathbf{NGCON} \cdot L_{sil,f}} + \frac{\mathbf{RINT} + \mathbf{RVPOLY}}{W_{E,f} \cdot L_f} \right]$$

$$\mathbf{RSE} = \mathbf{NRS} \cdot \mathbf{RSH}$$

$$\mathbf{RDE} = \mathbf{NRD} \cdot \mathbf{RSH}$$

$$\mathbf{RBULK} = \mathbf{RBULKO}$$

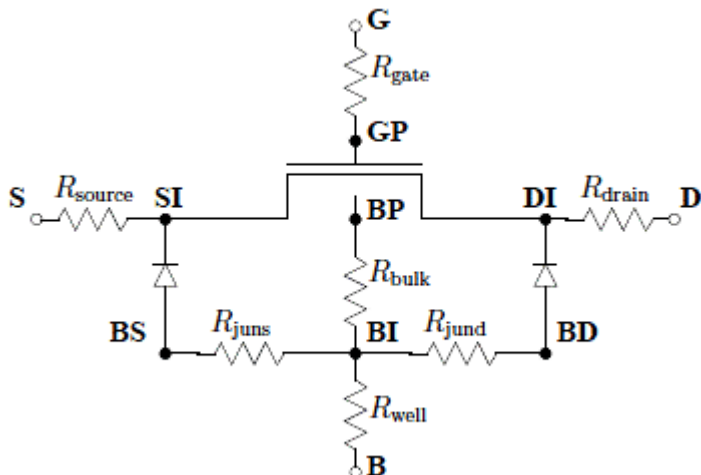
$$\mathbf{RWELL} = \mathbf{RWELLO}$$

$$\mathbf{RJUNS} = \mathbf{RJUNSO}$$

$$\mathbf{RJUND} = \mathbf{RJUNDO}$$

Note: The values of L_f , $L_{sil,f}$, $W_{E,f}$ and X_{GWE} are clipped to a minimum value of 1 nm. The calculated local parameters are subject to the boundaries specified in next section.

Figure 24-2 Parasitics Circuit



Stress effects

The stress model of BSIM4.4.0 has been adopted in PSP without any modifications, except for two changes:

1. In the original BSIM parameter names all zeros have been replaced by “O”s, in order to comply with PSP conventions.
2. The BSIM parameters STK2 and LODK2 are not available in PSP. Some trivial conversion of parameters BSIM-PSP is still necessary.

The local PSP parameters affected by the stress equations are **BETN**, **THESAT**, **VFB**, and **CF**. Calculation of **SA** and **SB** for irregular layouts is given separately.

Note:

- After modification of the local parameters by the stress equations, clipping is applied according to Section “Intrinsic Parameters for the model”.
- If both SA and SB are set to 0, the stress-equations are not computed.
- The stress equations are calculated when SWGEO = 1 or 2.

Layout effects for multi-finger devices

For multi-finger devices, effective values SA_{eff} and SB_{eff} for the instance parameters are calculated.

$$\frac{1}{SA_{\text{eff}} + 0.5 \cdot L} = \frac{1}{NF} \cdot \sum_{i=0}^{NF-1} \frac{1}{SA + 0.5 \cdot L + i \cdot (SD + L)}$$

$$\frac{1}{SB_{\text{eff}} + 0.5 \cdot L} = \frac{1}{NF} \cdot \sum_{i=0}^{NF-1} \frac{1}{SB + 0.5 \cdot L + i \cdot (SD + L)}$$

Layout effects for regular shapes

$$R_A = \frac{1}{SA_{\text{eff}} + 0.5 \cdot L}$$

$$R_B = \frac{1}{SB_{\text{eff}} + 0.5 \cdot L}$$

$$R_{A,\text{ref}} = \frac{1}{SAREF + 0.5 \cdot L}$$

$$R_{B,\text{ref}} = \frac{1}{SBREF + 0.5 \cdot L}$$

Figure 24-3 A typical layout of multi-finger devices with an a additional instance parameters SD.

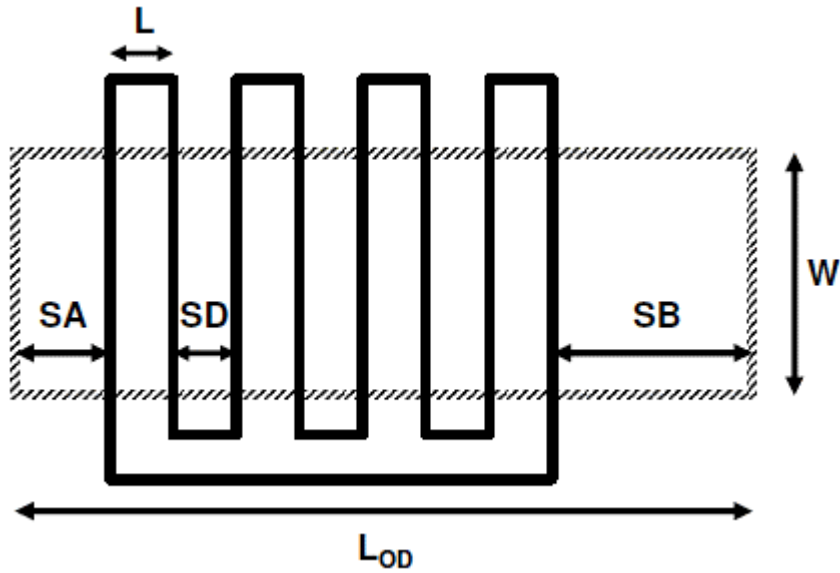
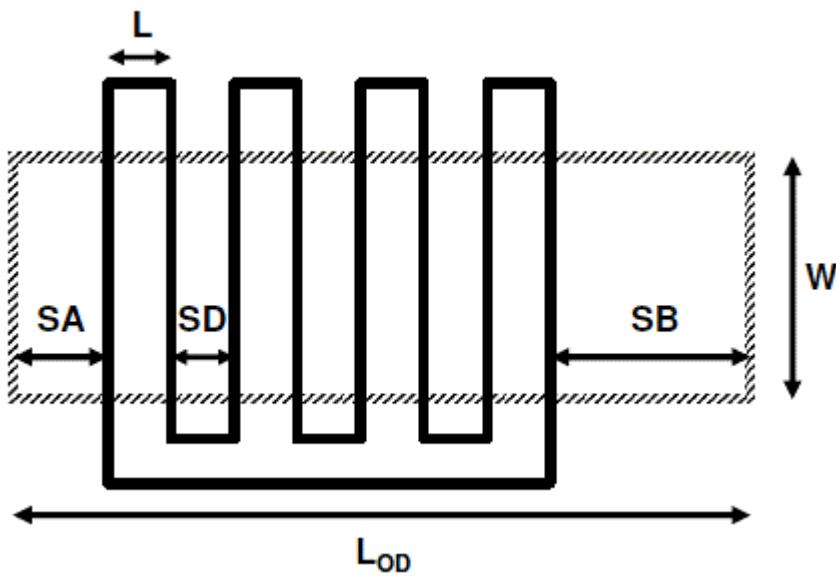


Figure 24-4 Typical layout of a MOSFET. Note that $L_{OD} = SA + SB + L$, where OD is the active region definition.



Parameter Modifications

Mobility related equations

$$K_{u0} = \left(1 + \frac{\mathbf{LKUO}}{(L + \Delta L_{PS})^{\mathbf{LLODKUO}}} + \frac{\mathbf{WKUO}}{(W_f + \Delta W_{OD} + \mathbf{WLOD})^{\mathbf{WLODKUO}}} + \frac{\mathbf{PKUO}}{(L + \Delta L_{PS})^{\mathbf{LLODKUO}} \cdot (W_f + \Delta W_{OD} + \mathbf{WLOD})^{\mathbf{WLODKUO}}} \right) \cdot \left[1 + \mathbf{TKUO} \cdot \left(\frac{T_{KD}}{T_{KR}} - 1 \right) \right]$$

$$\rho_{\beta} = \frac{\mathbf{KUO}}{K_{u0}} \cdot (R_A + R_B)$$

$$\rho_{\beta,ref} = \frac{\mathbf{KUO}}{K_{u0}} \cdot (R_{A,ref} + R_{B,ref})$$

$$\mathbf{BETN} = \frac{1 + \rho_{\beta}}{1 + \rho_{\beta,ref}} \cdot \mathbf{BETN}_{ref}$$

$$\mathbf{THESAT} = \frac{1 + \rho_{\beta}}{1 + \rho_{\beta,ref}} \cdot \frac{1 + \mathbf{KVSAT} \cdot \rho_{\beta,ref}}{1 + \mathbf{KVSAT} \cdot \rho_{\beta}} \cdot \mathbf{THESAT}_{ref}$$

Threshold Voltage related equations

$$K_{vth0} = 1 + \frac{LKVTHO}{(L + \Delta L_{PS})^{LLODVTH}} + \frac{WKVTHO}{(W_f + \Delta W_{OD} + WL_{OD})^{WLODVTH}} + \frac{PKVTHO}{(L + \Delta L_{PS})^{LLODVTH} \cdot (W_f + \Delta W_{OD} + WL_{OD})^{WLODVTH}}$$

$$\Delta R = R_A + R_B - R_{A,ref} - R_{B,ref}$$

$$VFB = VFB_{ref} + KVTHO \cdot \frac{\Delta R}{K_{vth0}}$$

$$CF = CF_{ref} + STETAO \cdot \frac{\Delta R}{K_{vth0}^{LODETAO}}$$

Well proximity effects

The well proximity effect (WPE) model from BSIM4.5.0 has been adopted in PSP with two changes relative to BSIM4.5.0: (1) in the original BSIM parameter names all zeros have been replaced by `O's in order to comply with PSP naming convention and (2) the BSIM parameter K2WE is not available in PSP. Except for some trivial conversion of parameters BSIM-PSP, WPE parameters from BSIM can be used directly in PSP.

The local PSP parameters affected by the WPE equations are VFB and BETN.

Note:

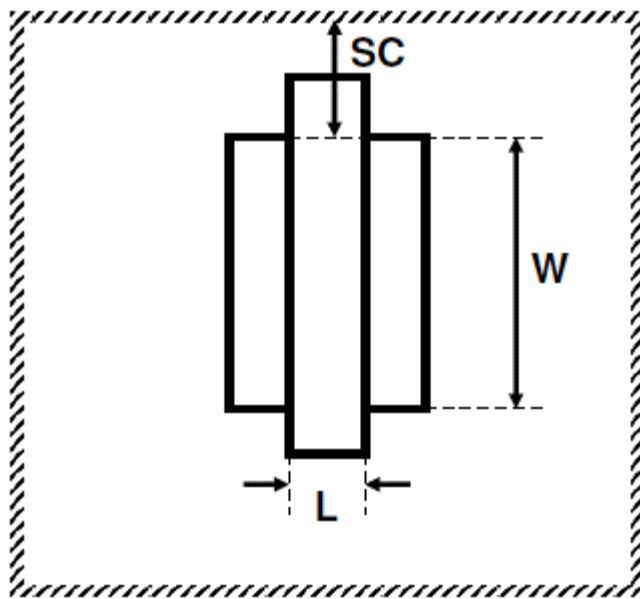
- After modification of the local parameters by the WPE equations, clipping is applied according to Section "Intrinsic Parameters for the model".
- If SCA, SCB, SCC and SC are all set to 0, the WPE equations are not computed.
- The WPE equations are calculated when SWGEO = 1 or 2.

Parameters for pre-layout simulation

If **SCA = SCB = SCC = 0** and **SC > 0**, **SCA**, **SCB**, and **SCC** will be computed from **SC** as shown below. Here, **SC** should be taken as the distance to the nearest well edge (see Figure below). If any of the parameters **SCA**, **SCB**, or **SCC** is positive, all three values as supplied will be used and **SC** will be ignored.

If $SCA = SCB = SCC = 0$ and $SC > 0$

Figure 24-5 A layout of MOS devices for pre-layout simulation using estimated value for SC.



$$SCB = \frac{1}{W_f \cdot SCREF} \cdot \left[\frac{SCREF}{10} \cdot SC \cdot \exp\left(-10 \cdot \frac{SC}{SCREF}\right) + \frac{SCREF^2}{100} \cdot \exp\left(-10 \cdot \frac{SC}{SCREF}\right) - \frac{SCREF}{10} \cdot (SC + W_f) \cdot \exp\left(-10 \cdot \frac{SC + W_f}{SCREF}\right) - \frac{SCREF}{10} \cdot (SC + W_f) \cdot \exp\left(-10 \cdot \frac{SC + W_f}{SCREF}\right) - \frac{SCREF^2}{100} \cdot \exp\left(-10 \cdot \frac{SC + W_f}{SCREF}\right) \right]$$

$$SCC = \frac{1}{W_f \cdot SCREF} \cdot \left[\frac{SCREF}{20} \cdot SC \cdot \exp\left(-20 \cdot \frac{SC}{SCREF}\right) + \frac{SCREF^2}{400} \cdot \exp\left(-20 \cdot \frac{SC}{SCREF}\right) - \frac{SCREF}{20} \cdot (SC + W_f) \cdot \exp\left(-20 \cdot \frac{SC + W_f}{SCREF}\right) \right]$$

Calculation of parameter modifications

The calculation of K_{vthowe} and K_{uowe} is given in Sections for Global Model or Binning Model.

$$\mathbf{VFB} = \mathbf{VFB}_{ref} + K_{vthowe} \cdot (\mathbf{SCA} + \mathbf{WEB} \cdot \mathbf{SCB} + \mathbf{WEC} \cdot \mathbf{SCC})$$

$$\mathbf{BETN} = \mathbf{BETN}_{ref} \cdot [1 + K_{uowe} \cdot (\mathbf{SCA} + \mathbf{WEB} \cdot \mathbf{SCB} + \mathbf{WEC} \cdot \mathbf{SCC})]$$

Asymmetric junctions

From PSP 102.3 onwards, asymmetric junction can be modeled in PSP. This includes asymmetric source-bulk and drain-bulk junctions, GIDL/GISL, overlap gate currents, overlap capacitances and outer fringe capacitances. The asymmetric junction model can be switched on by means of the parameter SWJUNASYM. Note that if SWJUNASYM = 1, the new parameters for the drain side are used all together. Those whose values are not explicitly specified in the model card are set to their default value, not to their counterparts for the source side. In other words, it is not possible to activate the parameters for the drain side on a one-by-one basis. The physical scaling and binning rules to calculate the related local parameters for the drain side are given separately in this chapter.

If **SWJUNASYM** = 0, the related parameters for the drain side are ignored. Effectively, the following assignments are applied before evaluation of the calculations described in the next section.

If **SWJUNASYM** = 0:

TOXOVD = **TOXOV**

NOVD = **NOV**

AGIDLD = **AGIDL**

BGIDLD = **BGIDL**

STBGIDLD = **STBGIDL**

CGIDLD = **CGIDL**

IGOVD = **IGOV**

CGOVD = **CGOV**

CFRD = **CFR**

RSHD = **RSH**

PSP 103 Model Equations

Internal Parameters (including Temperature Scaling)

In this section, bias-independent internal parameters are calculated, including temperature scaling. These parameters are computed from local parameters. Local parameters are (as usual) denoted by capital characters in bold font, whereas the internal parameters are denoted by symbols in bold font.

Transistor temperature

$$T_{KR} = T_0 + \mathbf{TR}$$

$$T_{KD} = T_0 + T_A + \mathbf{DTA}$$

$$\Delta T = T_{KD} - T_{KR}$$

$$\phi_T = \frac{k_B \cdot T_{KD}}{q}$$

Local process parameters

$$\phi_T^* = \phi_T \cdot \left(1 + \text{CT} \cdot \frac{T_{\text{KR}}}{T_{\text{KD}}}\right)$$

$$V_{\text{FB}} = \text{VFB} + \text{STVFB} \cdot \Delta T + \text{DELVTO}$$

$$E_g/q = 1.179 - 9.025 \cdot 10^{-5} \cdot T_{\text{KD}} - 3.05 \cdot 10^{-7} \cdot T_{\text{KD}}^2$$

$$r_T = (1.045 + 4.5 \cdot 10^{-4} \cdot T_{\text{KD}}) \cdot (0.523 + 1.4 \cdot 10^{-3} \cdot T_{\text{KD}} - 1.48 \cdot 10^{-6} \cdot T_{\text{KD}}^2)$$

$$n_i = 2.5 \cdot 10^{25} \cdot r_T^{3/4} \cdot (T_{\text{KD}}/300)^{3/2} \cdot \exp\left(-\frac{E_g/q}{2 \cdot \phi_T}\right)$$

$$\phi_{\text{B,dc}}^{\text{cl}} = \text{MAX}(\text{DPHIB} + 2 \cdot \phi_T \cdot \ln[\text{NEFF}/n_i], 0.05)$$

$$N_{\text{eff,ac}} = \text{MIN}[\text{MAX}(\text{FACNEFFAC} \cdot \text{NEFF}, 10^{20}), 10^{26}]$$

$$\phi_{\text{B,ac}}^{\text{cl}} = \text{MAX}(\text{DPHIB} + \text{DELVTAC} + 2 \cdot \phi_T \cdot \ln[N_{\text{eff,ac}}/n_i], 0.05)$$

$$\epsilon_{\text{ox}} = \text{EPSROX} \cdot \epsilon_0$$

$$C_{\text{ox}} = \epsilon_{\text{ox}} / \text{TOX}$$

$$\epsilon_{\text{Si}} = \epsilon_{\text{r,Si}} \cdot \epsilon_0$$

$$\gamma_{0,\text{dc}} = \sqrt{2 \cdot q \cdot \epsilon_{\text{Si}} \cdot \text{NEFF}} / C_{\text{ox}}$$

$$\gamma_{0,\text{ac}} = \sqrt{2 \cdot q \cdot \epsilon_{\text{Si}} \cdot N_{\text{eff,ac}}} / C_{\text{ox}}$$

$$G_{0,\text{dc}}^{\text{cl}} = \gamma_{0,\text{dc}} / \sqrt{\phi_T}$$

$$G_{0,\text{ac}}^{\text{cl}} = \gamma_{0,\text{ac}} / \sqrt{\phi_T}$$

Polysilicon depletion parameter

$$k_p = \begin{cases} \text{if } NP = 0 & \left\{ \begin{array}{l} k_p = 0 \end{array} \right. \\ \text{if } NP > 0 & \left\{ \begin{array}{l} NP_1 = \text{MAX}(NP, 8 \cdot 10^7 / \text{TOX}^2) \\ NP_2 = \text{MAX}(NP_1, 5 \cdot 10^{24}) \\ k_p = 2 \cdot \phi_T \cdot C_{\text{ox}}^2 / (q \cdot \epsilon_{\text{Si}} \cdot NP_2) \end{array} \right. \end{cases}$$

Quantum-mechanical correction parameters

$$q_{\text{lim}} = 10 \cdot \phi_T$$

$$q_q = \begin{cases} 0.4 \cdot \text{QMC} \cdot QM_N \cdot C_{\text{ox}}^{2/3} & \text{for NMOS} \\ 0.4 \cdot \text{QMC} \cdot QM_P \cdot C_{\text{ox}}^{2/3} & \text{for PMOS} \end{cases}$$

$$q_{\text{b0,dc}} = \gamma_{0,\text{dc}} \cdot \sqrt{\phi_{\text{B,dc}}^{\text{cl}}}$$

$$q_{\text{b0,ac}} = \gamma_{0,\text{ac}} \cdot \sqrt{\phi_{\text{B,ac}}^{\text{cl}}}$$

$$\phi_{\text{B,dc}} = \phi_{\text{B,dc}}^{\text{cl}} + 0.75 \cdot q_q \cdot q_{\text{b0,dc}}^{2/3}$$

$$\phi_{\text{B,ac}} = \phi_{\text{B,ac}}^{\text{cl}} + 0.75 \cdot q_q \cdot q_{\text{b0,ac}}^{2/3}$$

$$G_{0,\text{dc}} = G_{0,\text{dc}}^{\text{cl}} \cdot \left(1 + q_q \cdot q_{\text{b0,dc}}^{-1/3}\right)$$

$$G_{0,\text{ac}} = G_{0,\text{ac}}^{\text{cl}} \cdot \left(1 + q_q \cdot q_{\text{b0,ac}}^{-1/3}\right)$$

VSF-clipping parameters

$$\phi_{X,dc} = 0.95 \cdot \phi_{B,dc}$$

$$\phi_{X,ac} = 0.95 \cdot \phi_{B,ac}$$

$$a_{\phi,dc} = 2.5 \cdot 10^{-3} \cdot \phi_{B,dc}^2$$

$$a_{\phi,ac} = 2.5 \cdot 10^{-3} \cdot \phi_{B,ac}^2$$

$$b_{\phi,dc} = 2.5 \cdot 10^{-3} \cdot \phi_{B,dc}^2$$

$$b_{\phi,ac} = 2.5 \cdot 10^{-3} \cdot \phi_{B,ac}^2$$

$$\phi_{X,dc}^* = 0.5 \cdot \sqrt{b_{\phi,dc}}$$

$$\phi_{X,ac}^* = 0.5 \cdot \sqrt{b_{\phi,ac}}$$

$$\phi_{X,dc}^{\ddagger} = \text{MINA}(\phi_{X,dc} - \phi_{X,dc}^*, 0, a_{\phi,dc})$$

$$\phi_{X,ac}^{\ddagger} = \text{MINA}(\phi_{X,ac} - \phi_{X,ac}^*, 0, a_{\phi,ac})$$

NUD parameters

$$u_{s1} = \sqrt{\text{VSBNUD} + \phi_B} - \sqrt{\phi_B}$$

$$u_{s21} = \sqrt{\text{DVSBNUD} + \phi_B} - \sqrt{\phi_B} - u_{s1}$$

Local process parameters in gate overlap region

$$\gamma_{ov} = \sqrt{2 \cdot q \cdot \epsilon_{Si} \cdot NOV \cdot TOXOV} / \epsilon_{ox}$$

$$\gamma_{dov} = \sqrt{2 \cdot q \cdot \epsilon_{Si} \cdot NOVD \cdot TOXOVD} / \epsilon_{ox}$$

$$G_{ov} = \gamma_{ov} / \sqrt{\phi_T}$$

$$G_{dov} = \gamma_{dov} / \sqrt{\phi_T}$$

$$\xi_{ov} = 1 + G_{ov} / \sqrt{2}$$

$$\xi_{dov} = 1 + G_{dov} / \sqrt{2}$$

$$x_{mrgov} = 10^{-5} \cdot \xi_{ov}$$

$$x_{mrgdov} = 10^{-5} \cdot \xi_{dov}$$

Mobility parameters

$$\beta = \text{FACTUO} \cdot \text{BETN} \cdot C_{\text{ox}} \cdot (T_{\text{KR}}/T_{\text{KD}})^{\text{STBET}}$$

$$\theta_{\mu} = \text{THEMU} \cdot (T_{\text{KR}}/T_{\text{KD}})^{\text{STTHEMU}}$$

$$\mu_{\text{E}} = \text{MUE} \cdot (T_{\text{KR}}/T_{\text{KD}})^{\text{STMUE}}$$

$$X_{\text{cor}} = \text{XCOR} \cdot (T_{\text{KR}}/T_{\text{KD}})^{\text{STXCOR}}$$

$$C_{\text{S}} = \text{CS} \cdot (T_{\text{KR}}/T_{\text{KD}})^{\text{STCS}}$$

$$E_{\text{eff0}} = 10^{-8} \cdot C_{\text{ox}} / \epsilon_{\text{Si}}$$

$$\eta_{\mu} = \begin{cases} 1/2 \cdot \text{FETA} & \text{for NMOS} \\ 1/3 \cdot \text{FETA} & \text{for PMOS} \end{cases}$$

$$\eta_{\mu,\text{ac}} = \begin{cases} 1/2 & \text{for NMOS} \\ 1/3 & \text{for PMOS} \end{cases}$$

Series resistance parameter

$$R_{\text{s}} = \text{RS} \cdot (T_{\text{KR}}/T_{\text{KD}})^{\text{STRS}}$$

$$\theta_{\text{R}} = 2 \cdot \beta \cdot R_{\text{s}}$$

Velocity saturation parameter

$$\theta_{\text{sat}} = \text{THESAT} \cdot (T_{\text{KR}}/T_{\text{KD}})^{\text{STTHESAT}}$$

Impact-ionization parameter

$$a_2 = A2 \cdot (T_{KD}/T_{KR})^{STA2}$$

Gate current parameters

$$I_{GINV} = IGINV \cdot (T_{KD}/T_{KR})^{SIG}$$

$$I_{GOV} = IGOV \cdot (T_{KD}/T_{KR})^{SIG}$$

$$I_{GOVD} = IGOVD \cdot (T_{KD}/T_{KR})^{SIG}$$

$$B = \frac{4}{3} \cdot \frac{TOX}{h} \cdot \sqrt{2 \cdot q \cdot m_0 \cdot CHIB} = 6.830909 \cdot 10^9 \cdot TOX \cdot \sqrt{CHIB}$$

$$B_{ov} = B \cdot TOXOV/TOX$$

$$B_{ovd} = B \cdot TOXOVD/TOX$$

$$GC_Q = \begin{cases} -0.99 \cdot \frac{GC2}{2 \cdot GC3} & \text{for } GC3 < 0 \\ 0 & \text{for } GC3 \geq 0 \end{cases}$$

$$\alpha_b = \frac{E_g/q + \phi_B}{2}$$

$$D_{ch} = GCO \cdot \phi_T^*$$

$$D_{ov} = GCO \cdot \phi_T$$

Gate-induced drain leakage parameters

$$A_{\mathbf{GIDL}} = \mathbf{AGIDL} \cdot \left(\frac{2 \cdot 10^{-9}}{\mathbf{TOXOV}} \right)^2$$

$$A_{\mathbf{GIDL D}} = \mathbf{AGIDL D} \cdot \left(\frac{2 \cdot 10^{-9}}{\mathbf{TOXOVD}} \right)^2$$

$$B_{\mathbf{GIDL}} = \mathbf{BGIDL} \cdot \text{MAX}([1 + \mathbf{STBGIDL} \cdot \Delta T], 0) \cdot \left(\frac{\mathbf{TOXOV}}{2 \cdot 10^{-9}} \right)$$

$$B_{\mathbf{GIDL D}} = \mathbf{BGIDL D} \cdot \text{MAX}([1 + \mathbf{STBGIDL D} \cdot \Delta T], 0) \cdot \left(\frac{\mathbf{TOXOVD}}{2 \cdot 10^{-9}} \right)$$

Noise parameter

$$N_{\mathbf{T}} = \mathbf{FNT} \cdot 4 \cdot k_{\mathbf{B}} \cdot T_{\mathbf{KD}}$$

Additional internal parameters

$$x_1 = 1.25$$

$$x_{\mathbf{gl}} = x_1 + G_{\mathbf{ov}} \cdot \sqrt{\exp(-x_1) + x_1 - 1}$$

$$x_{\mathbf{dgl}} = x_1 + G_{\mathbf{dov}} \cdot \sqrt{\exp(-x_1) + x_1 - 1}$$

Current Model

In this section, the current model equations of the PSP-model are given. Use is made of the applied terminal bias values V_{GS} , V_{DS} and V_{SB} , the local parameters listed in Section 'Intrinsic Parameters for the model', and the internal parameters introduced in previous section. Local parameters are denoted by capital characters in bold font, whereas internal (bias-independent) parameters are denoted by symbols in bold font.

Depending on the value of the parameters SWNUD and SWDELVTAC, the surface potential (at source- and drain-side of the channel) and associated computations may be evaluated twice: once for the dc-characteristics and a second time for the ac-characteristics of the model. Details are given below.

Conditioning of Terminal Voltages

$$V_{dsx} = \sqrt{V_{DS}^2 + 0.01} - 0.1$$

$$\phi_{V,dc} = \text{MINA}(V_{SB}, V_{SB} + V_{DS}, \mathbf{b}_{\phi,dc}) + \phi_{X,dc}$$

$$\phi_{V,ac} = \text{MINA}(V_{SB}, V_{SB} + V_{DS}, \mathbf{b}_{\phi,ac}) + \phi_{X,ac}$$

$$V_{SB,dc}^* = V_{SB} - \text{MINA}(\phi_V, 0, \mathbf{a}_{\phi,dc}) + \phi_{X,dc}^*$$

$$V_{SB,ac}^* = V_{SB} - \text{MINA}(\phi_V, 0, \mathbf{a}_{\phi,ac}) + \phi_{X,ac}^*$$

Nonuniform doping effect. are only evaluated when

SWNUD \neq 0 and **GFACNUD** \neq 1:

$$V_{mB} = V_{SB}^* + 0.5 \cdot (V_{DS} - V_{dsx})$$

$$u_s = \sqrt{V_{mB} + \phi_B} - \sqrt{\phi_B}$$

$$p = 2 \cdot \frac{u_s - u_{s1}}{u_{s21}} - 1$$

$$u_{s,nud} = u_s - 0.25 \cdot (1 - \text{GFACNUD}) \cdot u_{s21} \cdot \left\{ p + \sqrt{p^2 + [\ln(2)]^2} \right\}$$

$$V_{mB,nud} = (u_{s,nud} + 2 \cdot \sqrt{\phi_B}) \cdot u_{s,nud}$$

$$V_{SB}^{nud} = V_{mB,nud} - 0.5 \cdot (V_{DS} - V_{dsx})$$

$$V_{SB,dc}^* = V_{SB}^{nud}$$

The surface potential (at source- and drain-side of the channel) and associated computations are evaluated using

$$V_{SB}^* = V_{SB,dc}^*, \phi_B = \phi_{B,dc}, \text{ and } G_0 = G_{0,dc}.$$

If SWNUD = 1 or SWDELVTAC = 1, calculations are done a second time using

$$V_{SB}^* = V_{SB,ac}^*, \quad \phi_B = \phi_{B,ac}, \quad \text{and} \quad G_0 = G_{0,ac}.$$

$$V_{DB}^* = V_{DS} + V_{SB}^*$$

$$V_{sbx} = V_{SB}^* + \frac{V_{DS} - V_{dsx}}{2}$$

Drain-induced barrier lowering:

$$\Delta V_G = \mathbf{CF} \cdot V_{dsx} \cdot (1 + \mathbf{CFB} \cdot V_{sbx})$$

$$V_{GB}^* = V_{GS} + V_{SB}^* + \Delta V_G - V_{FB}$$

$$x_g = V_{GB}^* / \phi_T^*$$

Bias-Dependent Body Factor

$$D_{nsub} = \mathbf{DNSUB} \cdot \text{MAXA}(0, V_{GS} + V_{SB} - \mathbf{VNSUB}, \mathbf{NSLP})$$

$$G = G_0 \cdot \sqrt{1 + D_{nsub}}$$

Surface Potential at Source Side and Related Variables

$$\xi = 1 + G/\sqrt{2}$$

$$x_{\text{ns}} = \frac{\phi_{\text{B}} + V_{\text{SB}}^*}{\phi_{\text{T}}^*}$$

$$\Delta_{\text{ns}} = \exp(-x_{\text{ns}})$$

$$x_{\text{mrg}} = 10^{-5} \cdot \xi$$

Virtuoso Simulator Components and Device Models Reference
PSP103 Model

$$\text{if } x_g < -x_{\text{mrg}} \left\{ \begin{array}{l} y_g = -x_g \\ z = 1.25 \cdot y_g / \xi \\ \eta = [z + 10 - \sqrt{(z-6)^2 + 64}] / 2 \\ a = (y_g - \eta)^2 + G^2 \cdot (\eta + 1) \\ c = 2 \cdot (y_g - \eta) - G^2 \\ \tau = -\eta + \ln(a/G^2) \\ y_0 = \sigma_1(a, c, \tau, \eta) \\ \Delta_0 = \exp(y_0) \\ p = 2 \cdot (y_g - y_0) + G^2 \cdot [\Delta_0 - 1 + \Delta_{\text{ns}} \cdot (1 - \chi'(y_0) - 1/\Delta_0)] \\ q = (y_g - y_0)^2 + G^2 \cdot [y_0 - \Delta_0 + 1 + \Delta_{\text{ns}} \cdot (1 + \chi(y_0) - 1/\Delta_0 - 2 \cdot y_0)] \\ x_s = -y_0 - \frac{2 \cdot q}{p + \sqrt{p^2 - 2 \cdot q \cdot \{2 - G^2 \cdot [\Delta_0 + \Delta_{\text{ns}} \cdot (1/\Delta_0 - \chi''(y_0))\]}}} \end{array} \right.$$

$$\text{if } |x_g| \leq x_{\text{mrg}} \left\{ x_s = \frac{x_g}{\xi} \cdot \left[1 + G \cdot x_g \cdot \frac{1 - \Delta_{\text{ns}}}{\xi^2 \cdot 6 \cdot \sqrt{2}} \right] \right.$$

$$\text{if } x_g > x_{\text{mrg}} \left\{ \begin{array}{l} \hat{x}_{g1} = x_1 + G \cdot \sqrt{\exp(-x_1) + x_1 - 1} \\ \bar{x} = \frac{x_g}{\xi} \cdot [1 + x_g \cdot (\xi \cdot x_1 - \hat{x}_{g1}) / \hat{x}_{g1}^2] \\ x_0 = x_g + G^2/2 - G \cdot \sqrt{x_g + G^2/4 - 1 + \exp(-\bar{x})} \\ b_x = x_{\text{ns}} + 3 \\ \eta = \text{MINA}(x_0, b_x, 5) - (b_x - \sqrt{b_x^2 + 5}) / 2 \\ a = (x_g - \eta)^2 - G^2 \cdot [\exp(-\eta) + \eta - 1 - \Delta_{\text{ns}} \cdot (\eta + 1 + \chi(\eta))] \\ b = 1 - G^2/2 \cdot [\exp(-\eta) - \Delta_{\text{ns}} \cdot \chi''(\eta)] \\ c = 2 \cdot (x_g - \eta) + G^2 \cdot [1 - \exp(-\eta) - \Delta_{\text{ns}} \cdot (1 + \chi'(\eta))] \\ \tau = x_{\text{ns}} - \eta + \ln(a/G^2) \\ y_0 = \sigma_2(a, b, c, \tau, \eta) \\ \Delta_0 = \exp(y_0) \\ p = 2 \cdot (x_g - y_0) + G^2 \cdot [1 - 1/\Delta_0 + \Delta_{\text{ns}} \cdot (\Delta_0 - 1 - \chi'(y_0))] \\ q = (x_g - y_0)^2 - G^2 \cdot [y_0 + 1/\Delta_0 - 1 + \Delta_{\text{ns}} \cdot (\Delta_0 - y_0 - 1 - \chi(y_0))] \\ x_s = y_0 + \frac{2 \cdot q}{p + \sqrt{p^2 - 2 \cdot q \cdot \{2 - G^2 \cdot [1/\Delta_0 + \Delta_{\text{ns}} \cdot (\Delta_0 - \chi''(y_0))\]}}} \end{array} \right.$$

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PSP103 Model

Calculations are only done for $x_g > 0$.

$$E_s = \exp(-x_s)$$

$$D_s = [1/E_s - x_s - 1 - \chi(x_s)] \cdot \Delta_{ns}$$

$$P_s = x_s - 1 + E_s$$

$$x_{gs} = \begin{cases} x_g - x_s & \text{for } x_g \leq 0 \\ G \cdot \sqrt{D_s + P_s} & \text{for } x_g > 0 \end{cases}$$

$$\psi_{ss} = \phi_{\Gamma}^* \cdot x_s$$

Drain Saturation Voltage

Calculations are only done for $x_g > 0$.

$$q_{is} = \frac{G^2 \cdot \phi_T^* \cdot D_s}{x_{gs} + G \cdot \sqrt{P_s}}$$

$$\alpha_s = 1 + \frac{G \cdot (1 - E_s)}{2 \cdot \sqrt{P_s}}$$

$$q_{bs} = \phi_T^* \cdot G \cdot \sqrt{P_s}$$

$$\rho_b = \begin{cases} 1 + \text{RSB} \cdot V_{sbx} & \text{for } \text{RSB} \geq 0 \\ \frac{1}{1 - \text{RSB} \cdot V_{sbx}} & \text{for } \text{RSB} < 0 \end{cases}$$

$$\rho_{g,s} = \begin{cases} \frac{1}{1 + \text{RSG} \cdot q_{is}} & \text{for } \text{RSG} \geq 0 \\ 1 - \text{RSG} \cdot q_{is} & \text{for } \text{RSG} < 0 \end{cases}$$

$$\rho_s = \theta_R \cdot \rho_b \cdot \rho_{g,s} \cdot q_{is}$$

$$\mu_x = \frac{1 + X_{cor} \cdot V_{sbx}}{1 + 0.2 \cdot X_{cor} \cdot V_{sbx}}$$

$$E_{eff,s} = E_{eff0} \cdot (q_{bs} + \eta_\mu \cdot q_{is})$$

$$G_{mob,s} = \frac{1 + (\mu_E \cdot E_{eff,s})^{\theta_\mu} + C_S \cdot \left(\frac{q_{bs}}{q_{is} + q_{bs}} \right)^2 + \rho_s}{\mu_x}$$

$$\xi_{tb} = \begin{cases} 1 + \text{THESATB} \cdot V_{sbx} & \text{for } \text{THESATB} \geq 0 \\ \frac{1}{1 - \text{THESATB} \cdot V_{sbx}} & \text{for } \text{THESATB} < 0 \end{cases}$$

$$w_{\text{sat},s} = \frac{100 \cdot q_{\text{is}} \cdot \xi_{\text{tb}}}{100 + q_{\text{is}} \cdot \xi_{\text{tb}}}$$

$$\theta_{\text{sat},s}^* = \begin{cases} \frac{\theta_{\text{sat}}}{G_{\text{mob},s}} \cdot (1 + \text{THESATG} \cdot w_{\text{sat},s}) & \text{for } \text{THESATG} \geq 0 \\ \frac{\theta_{\text{sat}}}{G_{\text{mob},s}} \cdot \frac{1}{1 - \text{THESATG} \cdot w_{\text{sat},s}} & \text{for } \text{THESATG} < 0 \end{cases}$$

$$\phi_{\infty} = q_{\text{is}}/\alpha_s + \phi_{\text{T}}^*$$

$$y_{\text{sat}} = \begin{cases} \theta_{\text{sat},s}^* \cdot \phi_{\infty} / \sqrt{2} & \text{for NMOS} \\ \frac{\theta_{\text{sat},s}^* \cdot \phi_{\infty} / \sqrt{2}}{\sqrt{1 + \theta_{\text{sat},s}^* \cdot \phi_{\infty} / \sqrt{2}}} & \text{for PMOS} \end{cases}$$

$$z_{\text{a}} = \frac{2}{1 + \sqrt{1 + 4 \cdot y_{\text{sat}}}}$$

$$\phi_0 = \phi_{\infty} \cdot z_{\text{a}} \cdot \left[1 + 0.86 \cdot z_{\text{a}} \cdot y_{\text{sat}} \cdot \frac{1 - z_{\text{a}}^2 \cdot y_{\text{sat}}}{1 + 4 \cdot z_{\text{a}}^3 \cdot y_{\text{sat}}^2} \right]$$

$$a_{\text{sat}} = x_{\text{gs}} + G^2/2$$

$$\phi_2 = \frac{\phi_{\text{T}}^* \cdot 0.98 \cdot G^2 \cdot D_s}{a_{\text{sat}} + \sqrt{a_{\text{sat}}^2 - 0.98 \cdot G^2 \cdot D_s}}$$

$$\phi_{\text{sat}} = \frac{2 \cdot \phi_0 \cdot \phi_2}{\phi_0 + \phi_2 + \sqrt{(\phi_0 + \phi_2)^2 - 3.96 \cdot \phi_0 \cdot \phi_2}}$$

$$V_{\text{dsat}} = \phi_{\text{sat}} - \phi_{\text{T}}^* \cdot \ln \left[1 + \frac{\phi_{\text{sat}} \cdot (\phi_{\text{sat}} - 2 \cdot a_{\text{sat}} \cdot \phi_{\text{T}}^*)}{G^2 \cdot D_s \cdot \phi_{\text{T}}^{*2}} \right]$$

$$V_{\text{dse}} = \frac{V_{\text{DS}}}{\left[1 + (V_{\text{DS}}/V_{\text{dsat}})^{\text{AX}} \right]^{1/\text{AX}}}$$

Surface Potential at Drain Side and Related Variables

Calculations are only done for $x_g > 0$.

$$x_{nd} = \frac{\phi_B + V_{SB}^* + V_{dse}}{\phi_T^*}$$

$$k_{ds} = \exp\left(-V_{dse}/\phi_T^*\right)$$

$$\Delta_{nd} = \Delta_{ns} \cdot k_{ds}$$

$$\text{if } x_g \leq x_{mrg} \left\{ \begin{array}{l} x_d = \frac{x_g}{\xi} \cdot \left[1 + G \cdot x_g \cdot \frac{1 - \Delta_{nd}}{\xi^2 \cdot 6 \cdot \sqrt{2}} \right] \\ \\ \left\{ \begin{array}{l} b_x = x_{nd} + 3.0 \\ \eta = \text{MINA}(x_0, b_x, 5) - (b_x - \sqrt{b_x^2 + 5}) / 2 \\ a = (x_g - \eta)^2 - G^2 \cdot [\exp(-\eta) + \eta - 1 - \Delta_{nd} \cdot (\eta + 1 + \chi(\eta))] \\ b = 1 - G^2 / 2 \cdot [\exp(-\eta) - \Delta_{nd} \cdot \chi''(\eta)] \\ c = 2 \cdot (x_g - \eta) + G^2 \cdot [1 - \exp(-\eta) - \Delta_{nd} \cdot (1 + \chi'(\eta))] \\ \tau = x_{nd} - \eta + \ln(a/G^2) \\ y_0 = \sigma_2(a, b, c, \tau, \eta) \\ \Delta_0 = \exp(y_0) \\ p = 2 \cdot (x_g - y_0) + G^2 \cdot [1 - 1/\Delta_0 + \Delta_{nd} \cdot (\Delta_0 - 1 - \chi'(y_0))] \\ q = (x_g - y_0)^2 - G^2 \cdot [y_0 + 1/\Delta_0 - 1 + \Delta_{nd} \cdot (\Delta_0 - y_0 - 1 - \chi(y_0))] \\ x_d = y_0 + \frac{2 \cdot q}{p + \sqrt{p^2 - 2 \cdot q \cdot \{2 - G^2 \cdot [1/\Delta_0 + \Delta_{nd} \cdot (\Delta_0 - \chi''(y_0))]\}}} \end{array} \right. \end{array} \right.$$

$$x_{ds} = x_d - x_s$$

$$\text{if } x_{ds} < 10^{-10} \left\{ \begin{array}{l} p = 2 \cdot x_{gs} + G^2 \cdot [1 - E_s + \Delta_{nd} \cdot (1/E_s - 1 - \chi'(x_s))] \\ q = G^2 \cdot (1 - k_{ds}) \cdot D_s \\ \xi = 1 - G^2 / 2 \cdot [E_s + \Delta_{nd} (1/E_s - \chi''(x_s))] \\ x_{ds} = \frac{2 \cdot q}{p + \sqrt{p^2 - 4 \cdot \xi \cdot q}} \\ x_d = x_s + x_{ds} \end{array} \right.$$

$$E_d = \exp(-x_d)$$

$$D_d = (1/E_d - x_d - 1 - \chi(x_d)) \cdot \Delta_{nd}$$

$$\Delta\psi = \phi_T^* \cdot x_{ds}$$

$$\psi_{sd} = \phi_T^* \cdot x_d$$

Mid-Point Surface Potential and Related Variables

$$\text{if } x_g > 0 \left\{ \begin{array}{l} x_m = (x_s + x_d) / 2 \\ E_m = \sqrt{E_s \cdot E_d} \\ \bar{D} = (D_s + D_d) / 2 \\ D_m = \bar{D} + x_{ds}^2 / 8 \cdot (E_m - 2 / G^2) \\ P_m = x_m - 1 + E_m \\ x_{gm} = G \cdot \sqrt{D_m + P_m} \end{array} \right.$$

$$\text{if } x_g \leq 0 \left\{ \begin{array}{l} x_m = x_s \\ x_{gm} = x_g - x_s \end{array} \right.$$

Polysilicon Depletion

Calculations are only done for $k_p > 0$ and $x_g > 0$ (otherwise $n_p = 1$):

$$x_m^{(0)} = x_m, \quad x_{ds}^{(0)} = x_{ds}, \quad D_m^{(0)} = D_m, \quad E_m^{(0)} = E_m,$$

$$d_0 = 1 - E_m^{(0)} + 2 \cdot x_{gm}/G^2$$

$$\eta_p = 1/\sqrt{1 + k_p \cdot x_{gm}}$$

$$x_{pm} = k_p \cdot \left[\frac{\eta_p \cdot x_{gm}}{1 + \eta_p} \right]^2 \cdot \frac{D_m^{(0)}}{D_m^{(0)} + P_m}$$

$$p = 2 \cdot (x_{gm} - x_{pm}) + G^2 \cdot (1 - E_m^{(0)} + D_m^{(0)})$$

$$q = x_{pm} \cdot (x_{pm} - 2 \cdot x_{gm})$$

$$\xi_p = 1 - G^2/2 \cdot (E_m^{(0)} + D_m^{(0)})$$

$$u_p = \frac{p \cdot q}{p^2 - \xi_p \cdot q}$$

$$x_m = x_m^{(0)} + u_p$$

$$E_m = E_m^{(0)} \cdot \exp(-u_p)$$

$$D_m = D_m^{(0)} \cdot \exp(u_p)$$

$$P_m = x_m - 1 + E_m$$

$$x_{gm} = G \cdot \sqrt{D_m + P_m}$$

$$x_{ds} = x_{ds}^{(0)} \cdot \frac{\exp(u_p) \cdot [\bar{D} + d_0]}{1 - E_m + 2 \cdot x_{gm} \cdot \eta_p / G^2 + \exp(u_p) \cdot D}$$

$$\Delta\psi = \phi_T^* \cdot x_{ds}$$

Potential Mid-Point Inversion Charge and Related Variables

Calculations are only done for $x_g > 0$.

$$q_{im} = \frac{G^2 \cdot \phi_T^* \cdot D_m}{x_{gm} + G \cdot \sqrt{P_m}}$$

$$\alpha_m = \eta_p + \frac{G \cdot (1 - E_m)}{2 \cdot \sqrt{P_m}}$$

$$q_{im}^* = q_{im} + \phi_T^* \cdot \alpha_m$$

$$q_{bm} = \phi_T^* \cdot G \cdot \sqrt{P_m}$$

Series resistance:

$$\rho_g = \begin{cases} \frac{1}{1 + \text{RSG} \cdot q_{im}} & \text{for } \text{RSG} \geq 0 \\ 1 - \text{RSG} \cdot q_{im} & \text{for } \text{RSG} < 0 \end{cases}$$

$$\rho_s = \theta_R \cdot \rho_b \cdot \rho_g \cdot q_{im}$$

Mobility reduction:

$$E_{\text{eff}} = E_{\text{eff0}} \cdot (q_{bm} + \eta_{\mu} \cdot q_{im})$$

$$q_{\text{eff1}} = q_{bm} + \eta_{\mu,ac} \cdot q_{im}$$

$$G_{\text{mob}} = \frac{1 + (\mu_E \cdot E_{\text{eff}})^{\theta_{\mu}} + C_S \cdot \left(\frac{q_{bm}}{q_{im} + q_{bm}} \right)^2 + \rho}{\mu_x}$$

Drain Source Channel Current

Calculations are only done for $x_g > 0$

Channel Length Modulation

$$R_1 = q_{im}/q_{im}^*$$

$$R_2 = \phi_T^* \cdot \alpha_m/q_{im}^*$$

$$T_1 = \ln \left(\frac{1 + \frac{V_{DS} - \Delta\psi}{VP}}{1 + \frac{V_{dse} - \Delta\psi}{VP}} \right)$$

$$T_2 = \ln \left(1 + \frac{V_{dsx}}{VP} \right)$$

$$\Delta L/L = \mathbf{ALP} \cdot T_1$$

$$G_{\Delta L} = \frac{1}{1 + \Delta L/L + (\Delta L/L)^2}$$

$$\Delta L_1/L = \left[\mathbf{ALP} + \frac{\mathbf{ALP1}}{q_{im}^*} \cdot R_1 \right] \cdot T_1 + \mathbf{ALP2} \cdot q_{bm} \cdot R_2^2 \cdot T_2$$

$$F_{\Delta L} = [1 + \Delta L_1/L + (\Delta L_1/L)^2] \cdot G_{\Delta L}$$

Velocity Saturation

$$w_{\text{sat}} = \frac{100 \cdot q_{\text{im}} \cdot \xi_{\text{tb}}}{100 + q_{\text{im}} \cdot \xi_{\text{tb}}}$$

$$\theta_{\text{sat}}^* = \begin{cases} \frac{\theta_{\text{sat}}}{G_{\text{mob},s} \cdot G_{\Delta L}} \cdot (1 + \text{THESATG} \cdot w_{\text{sat}}) & \text{for } \text{THESATG} \geq 0 \\ \frac{\theta_{\text{sat}}}{G_{\text{mob},s} \cdot G_{\Delta L}} \cdot \frac{1}{1 - \text{THESATG} \cdot w_{\text{sat}}} & \text{for } \text{THESATG} < 0 \end{cases}$$

$$z_{\text{sat}} = \begin{cases} (\theta_{\text{sat}}^* \cdot \Delta\psi)^2 & \text{for NMOS} \\ \frac{(\theta_{\text{sat}}^* \cdot \Delta\psi)^2}{1 + \theta_{\text{sat}}^* \cdot \Delta\psi} & \text{for PMOS} \end{cases}$$

$$G_{\text{vsat}} = \frac{G_{\text{mob}} \cdot G_{\Delta L}}{2} \cdot (1 + \sqrt{1 + 2 \cdot z_{\text{sat}}})$$

Auxiliary Variables for Calculation of Intrinsic Charges and Gate Current. are only calculated for $x_g > 0$.

$$V_{\text{oxm}} = \phi_{\text{T}}^* \cdot x_{\text{gm}}$$

$$\alpha_{\text{m}}' = \alpha_{\text{m}} \cdot \left[1 + \frac{z_{\text{sat}}}{2} \cdot \left(\frac{G_{\text{mob}} \cdot G_{\Delta L}}{G_{\text{vsat}}} \right)^2 \right]$$

$$H = \frac{G_{\text{mob}} \cdot G_{\Delta L}}{G_{\text{vsat}}} \cdot \frac{q_{\text{im}}^*}{\alpha_{\text{m}}'}$$

In the remainder of this section, some variables (e.g. x_g) are labeled 'dc' or 'ac' (e.g., $x_{g,\text{dc}}$ or $x_{g,\text{ac}}$). Variables labeled 'dc' result from the first evaluation some calculations. For variables labeled 'ac', there are two possibilities. If **SWNUD** = 1 or **SWDELVTAC** = 1, their values result from the second evaluation of the same equations. In any other case, their value is equal to their 'dc'-counterpart.

This applies to the following variables:

$$x_g, q_{\text{eff1}}, V_{\text{oxm}}, q_{\text{im}}, q_{\text{im}}^*, \alpha_m, \Delta\psi, G_{\Delta L}, F_{\Delta L}, H, \eta_p, G_{\text{vsat}}, V_{\text{dse}}, G_{\text{mob}}, x_m, G, x_{\text{gm}}, \theta_{\text{sat}}^*$$

Drain source channel current

$$I_{\text{DS}} = \begin{cases} 0 & \text{for } x_{g,\text{dc}} \leq 0 \\ \beta \cdot F_{\Delta L,\text{dc}} \cdot \frac{q_{\text{im},\text{dc}}^*}{G_{\text{vsat},\text{dc}}} \cdot \Delta\psi_{\text{dc}} & \text{for } x_{g,\text{dc}} > 0 \end{cases}$$

Impact Ionization or Weak-Avalanche

The equations in this section are only calculated when **SWIMPACT** = 1 and $x_g > 0$.

$$a_2^* = a_2 \cdot \left[1 + \mathbf{A4} \cdot \left(\sqrt{V_{\text{SB},\text{dc}}^* + \phi_{\text{B}}} - \sqrt{\phi_{\text{B}}} \right) \right]$$

$$\Delta V_{\text{sat}} = V_{\text{DS}} - \mathbf{A3} \cdot \Delta\psi_{\text{dc}}$$

$$M_{\text{avl}} = \begin{cases} 0 & \text{for } \Delta V_{\text{sat}} \leq 0 \\ \mathbf{A1} \cdot \Delta V_{\text{sat}} \cdot \exp\left(-\frac{a_2^*}{\Delta V_{\text{sat}}}\right) & \text{for } \Delta V_{\text{sat}} > 0 \end{cases}$$

$$I_{\text{avl}} = M_{\text{avl}} \cdot I_{\text{DS}}$$

Surface Potential in Gate Overlap Regions

$$x_{sov}(x_g) = \begin{cases} \text{if } x_g < -x_{mrgov} & \left\{ \begin{array}{l} y_g = -x_g \\ z = x_1 \cdot y_g / \xi_{ov} \\ \eta = \left[z + 10 - \sqrt{(z - 6)^2 + 64} \right] / 2 \\ a = (y_g - \eta)^2 + G_{ov}^2 \cdot (\eta + 1) \\ c = 2 \cdot (y_g - \eta) - G_{ov}^2 \\ \tau = -\eta + \ln(a / G_{ov}^2) \\ y_0 = \sigma_1(a, c, \tau, \eta) \\ \Delta_0 = \exp(y_0) \\ p = 2 \cdot (y_g - y_0) + G_{ov}^2 \cdot (\Delta_0 - 1) \\ q = (y_g - y_0)^2 + G_{ov}^2 \cdot (y_0 - \Delta_0 + 1) \\ x_{sov} = -y_0 - \frac{2 \cdot q}{p + \sqrt{p^2 - 2 \cdot q \cdot (2 - G_{ov}^2 \cdot \Delta_0)}} \end{array} \right. \\ \\ \text{if } |x_g| < x_{mrgov} & \left\{ x_{sov} = x_g / \xi_{ov} \right. \\ \\ \text{if } x_g > x_{mrgov} & \left\{ \begin{array}{l} \bar{x} = x_g / \xi_{ov} \cdot \left[1 + x_g \cdot (\xi_{ov} \cdot x_1 - x_{g1}) / x_{g1}^2 \right] \\ \omega = 1 - \exp(-\bar{x}) \\ x_0 = x_g + G_{ov}^2 / 2 - G_{ov} \cdot \sqrt{x_g + G_{ov}^2 / 4 - \omega} \\ \Delta_0 = \exp(-x_0) \\ p = 2 \cdot (x_g - x_0) + G_{ov}^2 \cdot (1 - \Delta_0) \\ q = (x_g - x_0)^2 - G_{ov}^2 \cdot (x_0 + \Delta_0 - 1) \\ x_{sov} = x_0 + \frac{2 \cdot q}{p + \sqrt{p^2 - 2 \cdot q \cdot (2 - G_{ov}^2 \cdot \Delta_0)}} \end{array} \right. \end{cases}$$

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$$x_{\text{dov}}(x_g) = \begin{cases} \text{if } x_g < -x_{\text{mrgdov}} \left\{ \begin{array}{l} y_g = -x_g \\ z = x_1 \cdot y_g / \xi_{\text{dov}} \\ \eta = \left[z + 10 - \sqrt{(z-6)^2 + 64} \right] / 2 \\ a = (y_g - \eta)^2 + G_{\text{dov}}^2 \cdot (\eta + 1) \\ c = 2 \cdot (y_g - \eta) - G_{\text{dov}}^2 \\ \tau = -\eta + \ln(a / G_{\text{dov}}^2) \\ y_0 = \sigma_1(a, c, \tau, \eta) \\ \Delta_0 = \exp(y_0) \\ p = 2 \cdot (y_g - y_0) + G_{\text{dov}}^2 \cdot (\Delta_0 - 1) \\ q = (y_g - y_0)^2 + G_{\text{dov}}^2 \cdot (y_0 - \Delta_0 + 1) \\ x_{\text{dov}} = -y_0 - \frac{2 \cdot q}{p + \sqrt{p^2 - 2 \cdot q \cdot (2 - G_{\text{dov}}^2 \cdot \Delta_0)}} \end{array} \right. \\ \\ \text{if } |x_g| < x_{\text{mrgdov}} \left\{ x_{\text{dov}} = x_g / \xi_{\text{dov}} \right. \\ \\ \text{if } x_g > x_{\text{mrgdov}} \left\{ \begin{array}{l} \bar{x} = x_g / \xi_{\text{dov}} \cdot \left[1 + x_g \cdot (\xi_{\text{dov}} \cdot x_1 - x_{\text{dgl}}) / x_{\text{dgl}}^2 \right] \\ \omega = 1 - \exp(-\bar{x}) \\ x_0 = x_g + G_{\text{dov}}^2 / 2 - G_{\text{dov}} \cdot \sqrt{x_g + G_{\text{dov}}^2 / 4 - \omega} \\ \Delta_0 = \exp(-x_0) \\ p = 2 \cdot (x_g - x_0) + G_{\text{dov}}^2 \cdot (1 - \Delta_0) \\ q = (x_g - x_0)^2 - G_{\text{dov}}^2 \cdot (x_0 + \Delta_0 - 1) \\ x_{\text{dov}} = x_0 + \frac{2 \cdot q}{p + \sqrt{p^2 - 2 \cdot q \cdot (2 - G_{\text{dov}}^2 \cdot \Delta_0)}} \end{array} \right. \end{cases}$$

$$\psi_{\text{sov}} = -\phi_{\text{T}} \cdot x_{\text{sov}} \left(-\frac{V_{\text{GS}}}{\phi_{\text{T}}} \right)$$

$$\psi_{\text{dov}} = -\phi_{\text{T}} \cdot x_{\text{dov}} \left(-\frac{V_{\text{GS}} - V_{\text{DS}}}{\phi_{\text{T}}} \right)$$

$$V_{\text{ov}_0} = V_{\text{GS}} - \psi_{\text{sov}}$$

$$V_{\text{ov}_L} = V_{\text{GS}} - V_{\text{DS}} - \psi_{\text{dov}}$$

Gate Current

The equations in this Section are only calculated when **SWIGATE** = 1.

Source/Drain gate overlap current

$$I_{GSov}(V_{GX}, \psi_{ov}, V_{ov}) = \left\{ \begin{array}{l} V_{ov}^* = \sqrt{V_{ov}^2 + 10^{-6}} \\ \psi_{tov} = \text{MINA}(0, V_{ov} + D_{ov}, 0.01) \\ z_g = \begin{cases} \text{MINA}\left(\frac{V_{ov}^*}{\text{CHIB}}, GC_Q, 10^{-6}\right) & \text{for } GC3 < 0 \\ \frac{V_{ov}^*}{\text{CHIB}} & \text{for } GC3 \geq 0 \end{cases} \\ \Delta_{Siov} = \exp\left(\frac{3.0 \cdot \phi_T + \psi_{ov} + \psi_{tov}}{\phi_T}\right) \\ F_{Sov} = \ln\left[\frac{1 + \Delta_{Siov}}{1 + \Delta_{Siov} \cdot \exp(-V_{GX}/\phi_T)}\right] \\ I_{Gov} = I_{GOV} \cdot F_{Sov} \cdot \exp\left(B_{ov} \cdot \left[-\frac{3}{2} + z_g \cdot (GC2 + GC3 \cdot z_g)\right]\right) \end{array} \right.$$

$$I_{GDov}(V_{GX}, \psi_{ov}, V_{ov}) = \left\{ \begin{array}{l} V_{ov}^* = \sqrt{V_{ov}^2 + 10^{-6}} \\ \psi_{tov} = \text{MINA}(0, V_{ov} + D_{ov}, 0.01) \\ z_g = \begin{cases} \text{MINA}\left(\frac{V_{ov}^*}{\text{CHIB}}, GC_Q, 10^{-6}\right) & \text{for } GC3 < 0 \\ \frac{V_{ov}^*}{\text{CHIB}} & \text{for } GC3 \geq 0 \end{cases} \\ \Delta_{Siov} = \exp\left(\frac{3.0 \cdot \phi_T + \psi_{ov} + \psi_{tov}}{\phi_T}\right) \\ F_{Sov} = \ln\left[\frac{1 + \Delta_{Siov}}{1 + \Delta_{Siov} \cdot \exp(-V_{GX}/\phi_T)}\right] \\ I_{Gov} = I_{GOVD} \cdot F_{Sov} \cdot \exp\left(B_{dov} \cdot \left[-\frac{3}{2} + z_g \cdot (GC2 + GC3 \cdot z_g)\right]\right) \end{array} \right.$$

$$I_{GSov} = I_{GSov}(V_{GS}, \psi_{sov}, V_{ov0})$$

$$I_{GDov} = I_{GDov}(V_{GS} - V_{DS}, \psi_{dov}, V_{ovL})$$

Gate-channel current:

$$V_m = V_{SB,dc}^* + \phi_T^* \cdot \left[\frac{x_{ds,dc}}{2} - \ln \left(\frac{1 + \exp(x_{ds,dc} - V_{dse,dc}/\phi_T^*)}{2} \right) \right]$$

$$\psi_t = \text{MINA}(0, V_{oxm,dc} + D_{ch}, 0.01)$$

$$V_{oxm}^* = \sqrt{V_{oxm,dc}^2 + 10^{-6}}$$

$$z_g = \begin{cases} \text{MINA} \left(\frac{V_{oxm}^*}{\text{CHIB}}, GC_Q, 10^{-6} \right) & \text{for } GC3 < 0 \\ \frac{V_{oxm}^*}{\text{CHIB}} & \text{for } GC3 \geq 0 \end{cases}$$

$$\Delta_{Si} = \exp \left(x_{m,dc} - \frac{\alpha_b + V_m - \psi_t}{\phi_T^*} \right)$$

$$F_S = \ln \left[\frac{1 + \Delta_{Si}}{1 + \Delta_{Si} \cdot \exp \left(-\frac{V_{GS} + V_{SB,dc}^* - V_m}{\phi_T^*} \right)} \right]$$

$$I_{GCO} = I_{GINV} \cdot F_S \cdot \exp(B \cdot [-3/2 + z_g \cdot (GC2 + GC3 \cdot z_g)])$$

$$\text{if } x_{g,dc} > 0 \left\{ \begin{array}{l} u_0 = \text{CHIB} / [B \cdot (GC2 + 2 \cdot GC3 \cdot z_g)] \\ x = \Delta\psi_{dc} / (2 \cdot u_0) \\ b = u_0 / H_{dc} \\ B_g = b \cdot (1 - b) / 2 \\ A_g = 1/2 - 3 \cdot B_g \\ p_{gc} = (1 - b) \cdot \frac{\sinh(x)}{x} + b \cdot \cosh(x) \\ p_{gd} = \frac{p_{gc}}{2} - B_g \cdot \sinh(x) - A_g \cdot \frac{\sinh(x)}{x} \cdot \left[\coth(x) - \frac{1}{x} \right] \end{array} \right.$$

$$\text{if } x_{g,\text{dc}} \leq 0 \begin{cases} p_{\text{gc}} = 1 \\ p_{\text{gd}} = 1/2 \end{cases}$$

$$S_g = \frac{1}{2} \cdot \left(1 + \frac{x_{g,\text{dc}}}{\sqrt{x_{g,\text{dc}}^2 + 10^{-6}}} \right)$$

$$I_{\text{GC}} = I_{\text{GCO}} \cdot p_{\text{gc}} \cdot S_g$$

$$I_{\text{GCD}} = I_{\text{GCO}} \cdot p_{\text{gd}} \cdot S_g$$

$$I_{\text{GCS}} = I_{\text{GC}} - I_{\text{GCD}}$$

$$I_{\text{GB}} = I_{\text{GCO}} \cdot p_{\text{gc}} \cdot (1 - S_g)$$

Gate-Induced Drain/Source Leakage Current

The equations in this section are only calculated when **SWGIDL** = 1.

$$I_{\text{gisl}}(V_{\text{ov}}, V) = \begin{cases} V_{\text{tov}} = \sqrt{V_{\text{ov}}^2 + \mathbf{CGIDL}^2 \cdot V^2 + 10^{-6}} \\ t = V \cdot V_{\text{tov}} \cdot V_{\text{ov}} \\ I_{\text{gisl}} = \begin{cases} -A_{\mathbf{GIDL}} \cdot t \cdot \exp\left(-\frac{B_{\mathbf{GIDL}}}{V_{\text{tov}}}\right) & \text{for } V_{\text{ov}} < 0 \\ 0 & \text{for } V_{\text{ov}} \geq 0 \end{cases} \end{cases}$$

$$I_{\text{gidl}}(V_{\text{ov}}, V) = \begin{cases} V_{\text{tov}} = \sqrt{V_{\text{ov}}^2 + \mathbf{CGIDL}^2 \cdot V^2 + 10^{-6}} \\ t = V \cdot V_{\text{tov}} \cdot V_{\text{ov}} \\ I_{\text{gidl}} = \begin{cases} -A_{\mathbf{GIDL}} \cdot t \cdot \exp\left(-\frac{B_{\mathbf{GIDL}}}{V_{\text{tov}}}\right) & \text{for } V_{\text{ov}} < 0 \\ 0 & \text{for } V_{\text{ov}} \geq 0 \end{cases} \end{cases}$$

$$I_{\text{gisl}} = I_{\text{gisl}}(V_{\text{ov0}}, V_{\text{SB}})$$

$$I_{\text{gidl}} = I_{\text{gidl}}(V_{\text{ovL}}, V_{\text{DS}} + V_{\text{SB}})$$

Total Terminal Currents

$$I_{\text{D}} = I_{\text{DS}} + I_{\text{avl}} - I_{\text{GDov}} - I_{\text{GCD}} + I_{\text{gidl}}$$

$$I_{\text{S}} = -I_{\text{DS}} - I_{\text{GSov}} - I_{\text{GCS}} + I_{\text{gisl}}$$

$$I_{\text{G}} = I_{\text{GC}} + I_{\text{GB}} + I_{\text{GDov}} + I_{\text{GSov}}$$

$$I_{\text{B}} = -I_{\text{avl}} - I_{\text{GB}} - I_{\text{gidl}} - I_{\text{gisl}}$$

Charge Model

In this section, the charge model equations of the PSP-model are given. Use is made of the applied terminal bias values V_{GS} , V_{DS} and V_{SB} , the local parameters listed in section “Intrinsic Parameters” and the internal parameters introduced in the Model Equations section. The parameters are denoted by capital characters in bold font, whereas internal (bias-independent) parameters are denoted by symbols in bold font.

Quantum-Mechanical Corrections

$$q_{\text{eff},ac} = \begin{cases} V_{\text{oxm},ac} & \text{for } x_{g,ac} \leq 0 \\ q_{\text{eff1},ac} & \text{for } x_{g,ac} > 0 \end{cases}$$

$$C_{\text{OX}}^{\text{qm}} = \begin{cases} \text{COX} & \text{for } q_q = 0 \\ \frac{\text{COX}}{1 + q_q / (q_{\text{eff},ac}^2 + q_{\text{lim}}^2)^{1/6}} & \text{for } q_q > 0 \end{cases}$$

Intrinsic Charge Model

$$\text{if } x_g > 0 \left\{ \begin{array}{l} F_j = \Delta\psi_{ac} / (2 \cdot H_{ac}) \\ q_{\Delta L} = (1 - G_{\Delta L,ac}) \cdot (q_{im,ac} - \alpha_{m,ac} \cdot \Delta\psi_{ac} / 2) \\ q_{\Delta L}^* = q_{\Delta L,ac} \cdot (1 + G_{\Delta L,ac}) \\ Q_G^{(i)} = C_{OX}^{qm} \cdot \left[V_{oxm,ac} + \frac{\eta_{p,ac} \cdot \Delta\psi_{ac}}{2} \cdot \left(\frac{G_{\Delta L,ac}}{3} \cdot F_j + G_{\Delta L,ac} - 1 \right) \right] \\ Q_I^{(i)} = -C_{OX}^{qm} \cdot \left[G_{\Delta L,ac} \cdot \left(q_{im,ac} + \frac{\alpha_{m,ac} \cdot \Delta\psi_{ac}}{6} \cdot F_j \right) + q_{\Delta L,ac} \right] \\ Q_D^{(i)} = -\frac{C_{OX}^{qm}}{2} \cdot \left[G_{\Delta L,ac}^2 \cdot \left(q_{im,ac} + \frac{\alpha_{m,ac} \cdot \Delta\psi_{ac}}{6} \cdot \left[\frac{F_j^2}{5} + F_j - 1 \right] \right) + q_{\Delta L}^* \right] \end{array} \right.$$

$$\text{if } x_g \leq 0 \left\{ \begin{array}{l} Q_G^{(i)} = C_{OX}^{qm} \cdot V_{oxm,ac} \\ Q_I^{(i)} = 0 \\ Q_D^{(i)} = 0 \end{array} \right.$$

$$Q_S^{(i)} = Q_I^{(i)} - Q_D^{(i)}$$

$$Q_B^{(i)} = -Q_I^{(i)} - Q_G^{(i)}$$

Extrinsic Charge Model

The charges of the source and drain overlap regions:

$$Q_{\text{sov}} = \mathbf{CGOV} \cdot (V_{\text{GS}} - \psi_{\text{sov}})$$

$$Q_{\text{dov}} = \mathbf{CGOVD} \cdot (V_{\text{GS}} - V_{\text{DS}} - \psi_{\text{dov}})$$

The charge of the bulk overlap region

$$Q_{\text{bov}} = \mathbf{CGBOV} \cdot (V_{\text{GS}} + V_{\text{SB}})$$

Outer fringe charge:

$$Q_{\text{ofs}} = \mathbf{CFR} \cdot V_{\text{GS}}$$

$$Q_{\text{ofd}} = \mathbf{CFRD} \cdot (V_{\text{GS}} - V_{\text{DS}})$$

Total Terminal Charges

$$Q_{\text{G}} = Q_{\text{G}}^{(i)} + Q_{\text{sov}} + Q_{\text{dov}} + Q_{\text{ofs}} + Q_{\text{ofd}} + Q_{\text{bov}}$$

$$Q_{\text{S}} = Q_{\text{S}}^{(i)} - Q_{\text{sov}} - Q_{\text{ofs}}$$

$$Q_{\text{D}} = Q_{\text{D}}^{(i)} - Q_{\text{dov}} - Q_{\text{ofd}}$$

$$Q_{\text{B}} = Q_{\text{B}}^{(i)} - Q_{\text{bov}}$$

Noise Model

Equations are only calculated for $x_g > 0$. In these equations f_{op} represents the operation frequency of the transistor and $j = \sqrt{-1}$

$$N^* = \frac{C_{ox}}{q} \cdot \alpha_{m,dc} \cdot \phi_T$$

$$N_m^* = \frac{C_{ox}}{q} \cdot q_{im,dc}^*$$

$$\Delta N = \frac{C_{ox}}{q} \cdot \alpha_{m,dc} \cdot \Delta\psi_{dc}$$

$$S_{fl} = \frac{q \cdot \phi_T^2 \cdot \beta \cdot I_{DS}}{(f_{op})^{EF} \cdot C_{ox} \cdot G_{vsat,dc} \cdot N^*} \cdot \left[(\mathbf{NFA} - \mathbf{NFB} \cdot N^* + \mathbf{NFC} \cdot N^{*2}) \cdot \ln \left(\frac{N_m^* + \Delta N/2}{N_m^* - \Delta N/2} \right) + (\mathbf{NFB} + \mathbf{NFC} \cdot [N_m^* - 2 \cdot N^*]) \cdot \Delta N \right]$$

$$H_0 = \frac{q_{im,dc}^*}{\alpha_{m,dc}}$$

$$t_1 = \frac{q_{im,dc}}{q_{im,dc}^*}$$

$$t_2 = \left(\frac{\Delta\psi_{dc}}{12 \cdot H_0} \right)^2$$

$$R = \frac{H_0}{H} - 1$$

$$l_c = 1 - 12 \cdot t_2 \cdot R$$

$$g_{ideal} = \frac{\beta \cdot q_{im,dc}^*}{G_{vsat,dc}} \cdot F_{\Delta L,dc}$$

$$C_{Geff} = \left(\frac{G_{vsat,ac}}{G_{mob,ac} \cdot G_{\Delta L,ac}} \right)^2 \cdot C_{OX}^{qm} \cdot \eta_{p,ac}$$

$$m_{id} = \frac{g_{ideal}}{l_c^2} \cdot [t_1 + 12 \cdot t_2 - 24 \cdot (1 + t_1) \cdot t_2 \cdot R]$$

$$S_{th} = N_T \cdot m_{id}$$

$$m_{ig} = \frac{1}{l_c^2 \cdot g_{ideal}} \cdot \left[\frac{t_1}{12} - t_2 \cdot \left(t_1 + \frac{1}{5} - 12 \cdot t_2 \right) - \frac{8}{5} \cdot t_2 \cdot (t_1 + 1 - 12 \cdot t_2) \cdot R \right]$$

$$S_{ig} = N_T \cdot \frac{(2 \cdot \pi \cdot f_{op} \cdot C_{Geff})^2 \cdot m_{ig}}{1 + (2 \cdot \pi \cdot f_{op} \cdot C_{Geff} \cdot m_{ig})^2}$$

$$m_{igid} = \frac{\sqrt{t_2}}{l_c^2} \cdot \left[1 - 12 \cdot t_2 - \left(t_1 + \frac{96}{5} \cdot t_2 - 12 \cdot t_1 \cdot t_2 \right) \cdot R \right]$$

$$S_{igth} = N_T \cdot \frac{2 \cdot \pi \cdot j \cdot f_{op} \cdot C_{Geff} \cdot m_{igid}}{1 + 2 \cdot \pi \cdot j \cdot f_{op} \cdot C_{Geff} \cdot m_{ig}}$$

Gate current shot noise

$$S_{hotgs} = 2 \cdot q \cdot (I_{GCS} + I_{GSov})$$

$$S_{hotgd} = 2 \cdot q \cdot (I_{GCD} + I_{GDov})$$

Avalanche current shot noise

$$S_{jnoise} = 2 \cdot q \cdot I_{js}$$

$$D_{jnoise} = 2 \cdot q \cdot ((1 + M_{avl}) \cdot I_{avl} + I_{jd})$$

Thermal noise for parasitic resistances

$$S_{RG} = 4 \cdot k_B \cdot T_{KD} / R_{gate}$$

$$S_{RBULK} = 4 \cdot k_B \cdot T_{KD} / R_{bulk}$$

$$S_{RWELL} = 4 \cdot k_B \cdot T_{KD} / R_{well}$$

$$S_{RJUNS} = 4 \cdot k_B \cdot T_{KD} / R_{juns}$$

$$S_{RJUND} = 4 \cdot k_B \cdot T_{KD} / R_{jund}$$

Non-quasi-static RF model

For high-frequency modeling and fast transient simulations, a special version of the PSP model is available, which enables the simulation of non-quasi-static (NQS) effects, and includes several parasitic resistances.

NQS-effects

In the PSP-NQS model, NQS-effects are introduced by applying the one-dimensional current continuity equation ($\partial_I/\partial_y \times \alpha - \partial_p/\partial_t$) to the channel. A full numerical solution of this equation is too inefficient for compact modeling, therefore an approximate technique is used. The channel is partitioned into $N + 1$ sections of equal length by assigning N equidistant collocation points. The charge density (per unit channel area) along the channel is then approximated by a cubic spline through these collocation points, assuring that both the charge and its first and second spatial derivatives are continuous along the channel. Within this approximation, the current continuity equation reduces to a system of N coupled first order ordinary differential equations, from which the channel charge at each collocation point can be found:

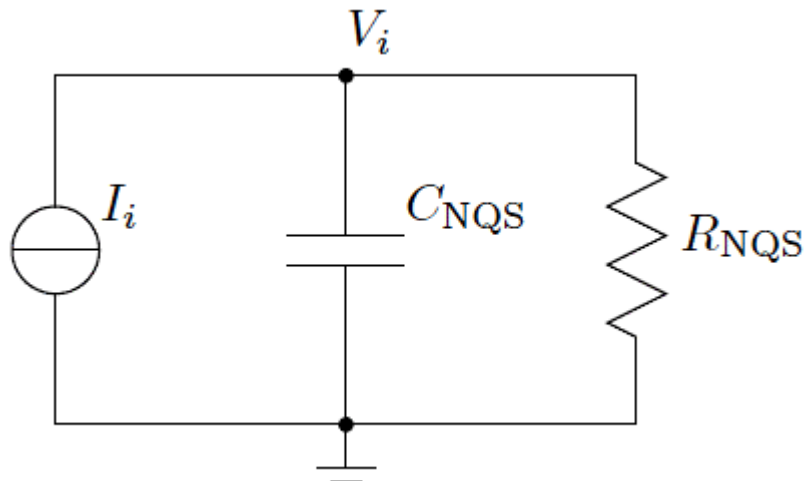
$$\begin{cases} \frac{dQ_1}{dt} = f_1(Q_1, \dots, Q_N) \\ \vdots \\ \frac{dQ_N}{dt} = f_N(Q_1, \dots, Q_N) \end{cases}$$

Here, Q_i is the charge density at the i -th collocation point and f_i are functions, which contain the complete PSP-charge model. These equations are implemented by the definition of appropriate subcircuits (see left part of figure below) and solved by the circuit simulator. Finally, the four terminal charges are calculated from the channel charges, using the Ward-Dutton partitioning scheme for the source and drain charges.

NQS Model Equations

In this section, several symbols and notations are used which were defined in Section 4. Moreover, y denotes the (normalized) position along the channel ($y = 0$ is source side, $y = 1$ is drain side), while x denotes the surface potential (normalized to ϕ^*T) at a certain position.

Figure 24-6 The subcircuit used to solve one of the differential equations



The current is set to $I_i = C_{NQS} \cdot f(V_1, \dots, V_N)$, where the voltage V_i represents the charge density Q_i at the i -th collocation point and is solved by the circuit simulator. N of these circuits are defined and they are coupled through the dependence of I_i on the voltages of the other circuits. The resistance R_{NQS} has a very large value and is present only for convergence purposes. Right: The full network of parasitic elements in the PSP-NQS model. The large full dots indicate the five additional internal nodes.

Internal constants

Equations in this section are independent of bias conditions and time. Consequently, they have to be computed only once.

Note: In PSP only **SWNQS** = 0, 1, 2, 3, 5, 9 are allowed.

$$n = \text{SWNQS} + 1$$

$$h = 1/n$$

The matrix A is a square $(n + 1) \times (n + 1)$ -matrix with elements $A_{i,j}$ ($0 \leq i, j \leq n$), which are used in equations. They are computed using the following algorithm:

Initial values

$$A_{i,j} = 0 \quad \text{for } 0 \leq i, j \leq n$$

$$v_i = 0 \quad \text{for } 0 \leq i \leq n$$

First loop

$$p = 2 + v_{i-1}/2$$

$$v_i = -1/(2 \cdot p)$$

$$A_{i,i-1} = 1/h$$

$$A_{i,i} = -2/h$$

$$A_{i,i+1} = 1/h$$

$$A_{i,j} = \frac{1}{p} \cdot (3 \cdot A_{i,j}/h - A_{i-1,j}/2) \quad \left. \vphantom{A_{i,j}} \right\} \text{for } j = 0 \dots n$$

} for $i = 1 \dots (n - 1)$

Second loop (back substitution)

$$A_{i,j} = v_i \cdot A_{i+1,j} + A_{i,j} \quad \text{for } j = 0 \dots n \quad \left. \vphantom{A_{i,j}} \right\} \text{for } i = (n - 1) \dots 0$$

Position independent quantities

The following quantities depend on the bias conditions, but are constant along the channel:

$$\text{if } x_{g,ac} > 0 \left\{ \begin{array}{l} y_m = \frac{1}{2} \cdot \left(1 + \frac{\Delta\psi_{ac}}{4 \cdot H_{ac}} \right) \\ p_d = \frac{x_{gm,ac}}{x_{g,ac} - x_{m,ac}} \\ G_p = G_{ac}/p_d \end{array} \right.$$

$$\text{if } x_{g,ac} \leq 0 \left\{ \begin{array}{l} y_m = 1/2 \\ p_d = 1 \\ G_p = G_{ac} \end{array} \right.$$

$$a_p = 1 + G_p/\sqrt{2}$$

$$p_{mrg} = 10^{-5} \cdot a_p$$

Position dependent surface potential and charge

Interpolated (quasi-static) surface potential along the channel:

$$\Psi(y) = x_{m,ac} + \frac{H_{ac}}{\phi_T^*} \cdot \left(1 - \sqrt{1 - \frac{2 \cdot \Delta\psi_{ac}}{H_{ac}} \cdot (y - y_m)} \right)$$

Normalized bulk-charge and its first two derivatives as functions of surface potential:

$$q_b(x) = -\text{sgn}(x) \cdot G_p \cdot \sqrt{\exp(-x) + x - 1}$$

$$q'_b(x) = \frac{G_p^2 \cdot [1 - \exp(-x)]}{2 \cdot q_b(x)}$$

$$q''_b(x) = -q'_b(x) - \frac{q'_b(x)^2 - G_p^2/2}{q_b(x)}$$

Surface potential as a function of normalized inversion charge

$$\Pi(x_g) = \begin{cases} \text{if } x_g < -p_{mrg} & \left\{ \begin{array}{l} y_g = -x_g \\ z = 1.25 \cdot y_g / a_p \\ \eta = \left[z + 10 - \sqrt{(z - 6)^2 + 64} \right] / 2 \\ a = (y_g - \eta)^2 + G_p^2 \cdot (\eta + 1) \\ c = 2 \cdot (y_g - \eta) - G_p^2 \\ \tau = -\eta + \ln(a / G_p^2) \\ y_0 = \sigma_1(a, c, \tau, \eta) \\ \Delta_0 = \exp(y_0) \\ \xi = 1 - G_p^2 \cdot \Delta_0 / 2 \\ p = 2 \cdot (y_g - y_0) + G_p^2 \cdot (\Delta_0 - 1) \\ q = (y_g - y_0)^2 + G_p^2 \cdot (y_0 - \Delta_0 + 1) \\ \Pi = -y_0 - \frac{2 \cdot q}{p + \sqrt{p^2 - 4 \cdot q \cdot \xi}} \end{array} \right. \\ \text{if } |x_g| \leq p_{mrg} & \left\{ \begin{array}{l} \Pi = \frac{x_g}{a_p} \end{array} \right. \\ \text{if } x_g > p_{mrg} & \left\{ \begin{array}{l} \hat{x}_{g1} = x_1 + G_p \cdot \sqrt{\exp(-x_1) + x_1 - 1} \\ \bar{x} = \frac{x_g}{a_p} \cdot [1 + x_g \cdot (x_1 \cdot a_p / \hat{x}_{g1} - 1) / \hat{x}_{g1}] \\ x_0 = x_g + G_p^2 / 2 - G_p \cdot \sqrt{x_g + G_p^2 / 4 - 1 + \exp(-\bar{x})} \\ \Delta_0 = \exp(-x_0) \\ \xi = 1 - G_p^2 \cdot \Delta_0 / 2 \\ p = 2 \cdot (x_g - x_0) + G_p^2 \cdot (1 - \Delta_0) \\ q = (x_g - x_0)^2 - G_p^2 \cdot (x_0 + \Delta_0 - 1) \\ \Pi = x_0 + \frac{2 \cdot q}{p + \sqrt{p^2 - 4 \cdot q \cdot \xi}} \end{array} \right. \end{cases}$$

$$X(x_g, q_{inv}) = \Pi(x_g + q_{inv} / p_d)$$

Auxiliary functions

$$q(x) = -p_d \cdot (x_g - x) - q_b(x)$$

$$\psi(q, q_{x1}) = \frac{q}{q_{x1}} - 1$$

$$\phi(q, q_{x1}, q_{x2}) = \left(1 - \frac{q \cdot q_{x2}}{q_{x1}^2}\right) / q_{x1}$$

Normalized right-hand side of continuity equation

$$f(x_g, q, q', q'') = \left\{ \begin{array}{l} x_z = X(x_g, q) \\ q_{x1} = \frac{\partial q}{\partial x}(x_z) = p_d - q'_b(x_z) \\ q_{x2} = \frac{\partial^2 q}{\partial x^2}(x_z) = q''_b(x_z) \\ f_0 = \psi(q, q_{x1}) \cdot q'' + \phi(q, q_{x1}, q_{x2}) \cdot q'^2 \\ x_{y1} = \frac{\partial x_z}{\partial y} = q' / q_{x1} \\ z_{\text{sat}} = \begin{cases} \left(\theta_{\text{sat,ac}}^* \cdot \phi_{\text{T}}^* \cdot x_{y1}\right)^2 & \text{for NMOS} \\ \frac{\left(\theta_{\text{sat,ac}}^* \cdot \phi_{\text{T}}^* \cdot x_{y1}\right)^2}{1 + \theta_{\text{sat,ac}}^* \cdot \Delta\psi_{\text{ac}}} & \text{for PMOS} \end{cases} \\ \zeta = \sqrt{1 + 2 \cdot z_{\text{sat}}} \\ F_{\text{vsat}} = 2 / (1 + \zeta) \\ f = F_{\text{vsat}} \cdot \left[f_0 - F_{\text{vsat}} \cdot \frac{z_{\text{sat}}}{\zeta} \cdot \psi(q, q_{x1}) \cdot (q'' + x_{y1}^2 \cdot q''_b(x_z)) \right] \end{array} \right.$$

Normalization constant:

$$T_{\text{norm}} = \frac{\text{MUNQS} \cdot \phi_{\text{T}}^* \cdot \beta}{C_{\text{OX}}^{\text{qm}}} \cdot G_{\text{mob,ac}} \cdot G_{\Delta L, \text{ac}}$$

Cubic spline interpolation

Using cubic spline interpolation, the spatial derivatives $\frac{\partial q_i}{\partial y} \cdot (t)$ and $\frac{\partial^2 q_i}{\partial y^2} \cdot (t)$ can be expressed as functions of $q_i(t)$.

$$q_0'' = 0$$

$$q_n'' = 0$$

$$q_i'' = \sum_{j=0}^n A_{i,j} \cdot q_j \quad \text{for } 1 \leq i \leq n - 1$$

$$q_i' = \frac{q_{i+1} - q_i}{h} - \frac{h}{6} \cdot (2 \cdot q_i'' + q_{i+1}'') \quad \text{for } 1 \leq i \leq n - 1$$

Continuity equation

Initial value for the q_i ($0 \leq i \leq n$). These values are used for the DC operating point.

$$x_{i,0} = \Psi(i \cdot h)$$

$$q_{i,0} = q(x_{i,0})$$

Note: $x_{0,0} = x_s$ and $x_{n,0} = x_d$. Moreover, these values coincide with those in the quasi-static part of PSP.

The core of the NQS-model is the solution of $q(y, t)$ from the charge continuity equation along the channel. By approximating the y -dependence by a cubic spline through a number of collocation points, the problem is reduced to solving the $q_i(t)$ from the following set of coupled differential equations.

$$\left\{ \begin{array}{l} \frac{\partial q_i}{\partial t}(t) + T_{\text{norm}} \cdot f \left(x_{g,\text{ac}}, q_i(t), \frac{\partial q_i}{\partial y}(t), \frac{\partial^2 q_i}{\partial y^2}(t) \right) = 0 \\ q_i(0) = q_{i,0} \end{array} \right. \quad \text{for } 1 \leq i \leq n - 1$$

Note that the boundary points $q_0(t) = q(x_s) = q_{is}$ and $q_n(t) = q(x_d) = q_{id}$ remain fixed to their quasi-static values; they are not solved from the equation above. The set of differential

equations defined above is solved by the circuit simulator via the subcircuits shown in the left part of Figure [24-6](#).

Non-quasi-static terminal charges

Once the q_i are known, the NQS terminal charges can be computed:

$$S_0 = \sum_{i=1}^{n-1} q_i$$

$$S_2 = \sum_{i=1}^{n-1} q_i''$$

$$q_I^{\text{NQS}} = \int_0^1 q(y) dy = h \cdot S_0 + \frac{h}{2} \cdot (u_0 + u_n) - \frac{h^3}{12} \cdot S_2$$

$$U_0 = \sum_{i=1}^{n-1} i \cdot q_i$$

$$U_2 = \sum_{i=1}^{n-1} i \cdot q_i''$$

$$q_D^{\text{NQS}} = \int_0^1 y \cdot q(y) dy = h^2 \cdot U_0 + \frac{h^2}{6} \cdot [q_0 + (3n - 1)u_n] - \frac{h^4}{12} \cdot U_2$$

$$q_S^{\text{NQS}} = q_I^{\text{NQS}} - q_D^{\text{NQS}}$$

Currently, only **SWNQS** = 0, 1, 2, 3, 5, 9 are allowed. For odd values of **SWNQS** the gate charge is integrated along the channel using Simpson's Rule. If **SWNQS** = 2, Simpson's 3/8-rule is used.

If **SWNQS** is odd (that is, n is even):

$$q_G^{NQS} = p_d \cdot \left[x_{g,ac} - \frac{h}{3} \cdot \left(X(x_{g,ac}, q_0) + 4 \cdot \sum_{i=1}^{n/2} X(x_{g,ac}, q_{2i-1}) + 2 \cdot \sum_{i=1}^{n/2-1} X(x_{g,ac}, q_{2i}) + X(x_{g,ac}, q_n) \right) \right]$$

If **SWNQS** = 2 (that is, n = 3):

$$q_G^{NQS} = p_d \cdot \left[x_{g,ac} - \frac{3 \cdot h}{8} \cdot (X(x_{g,ac}, q_0) + 3 \cdot X(x_{g,ac}, q_1) + 3 \cdot X(x_{g,ac}, q_2) + X(x_{g,ac}, q_3)) \right]$$

Converting back to conventional units:

$$Q_S^{NQS} = C_{OX}^{qm} \cdot \phi_T^* \cdot q_S^{NQS}$$

$$Q_D^{NQS} = C_{OX}^{qm} \cdot \phi_T^* \cdot q_D^{NQS}$$

$$Q_G^{NQS} = C_{OX}^{qm} \cdot \phi_T^* \cdot q_G^{NQS}$$

$$Q_B^{NQS} = -(Q_S^{NQS} + Q_D^{NQS} + Q_G^{NQS})$$

Instance Definition

Name d g s b ModelName parameter=value ...

Instance Parameters

- | | | |
|---|-----------|--|
| 1 | l=10e-6 m | Design length. |
| 2 | w=10e-6 m | Design width. |
| 3 | sa=0.0 m | Distance between OD-edge and poly from one side. |
| 4 | sb=0.0 m | Distance between OD-edge and poly from other side. |
| 5 | sd=0.0 m | Distance between neighboring fingers. |

Virtuoso Simulator Components and Device Models Reference

PSP103 Model

6	<code>sca=0.0</code>	Integral of the first distribution function for scattered well dopants.
7	<code>scb=0.0</code>	Integral of the second distribution function for scattered well dopants.
8	<code>scc=0.0</code>	Integral of the third distribution function for scattered well dopants.
9	<code>sc=0.0 m</code>	Distance between OD-edge and nearest well edge.
10	<code>nf=1</code>	Number of fingers.
11	<code>ngcon=1.0</code>	Number of gate contacts.
12	<code>xgw=1.0E-7 m</code>	Distance from the gate contact to the channel edge.
13	<code>nrs=0.0</code>	Number of squares of source diffusion.
14	<code>nrd=0.0</code>	Number of squares of drain diffusion.
15	<code>trise=0.0 k</code>	Temperature rise from ambient.
16	<code>jw=1E-6 m</code>	Gate-edge length of source/drain junction.
17	<code>delvto=0.0 V</code>	Threshold voltage shift parameter.
18	<code>factuo=1.0</code>	Zero-field mobility pre-factor.
19	<code>absource=1E-12 m²</code>	Bottom area of source junction.
20	<code>lssource=1E-6 m</code>	STI-edge length of source junction.
21	<code>lgsource=1E-6 m</code>	Gate-edge length of source junction.
22	<code>abdrain=1E-12 m²</code>	Bottom area of drain junction.
23	<code>lsdrain=1E-6 m</code>	STI-edge length of drain junction.
24	<code>lgdrain=1E-6 m</code>	Gate-edge length of drain junction.
25	<code>as=1E-12 m²</code>	Bottom area of source junction.

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PSP103 Model

26	<code>ps=1E-6 m</code>	Perimeter of source junction.
27	<code>ad=1E-12 m^2</code>	Bottom area of drain junction.
28	<code>pd=1E-6 m</code>	Perimeter of drain junction.
29	<code>mult=1.0</code>	Number of devices in parallel.
30	<code>mulid0=1</code>	Ids multiplier.
31	<code>m=1.0</code>	Multiplicity factor.
32	<code>isnoisy=yes</code>	Should device generate noise. Possible values are <code>no</code> or <code>yes</code> .

Model Definition

`model modelName psp103 parameter=value ...`

Model Parameters

1	<code>level=103</code>	Model level.
2	<code>type=n</code>	Channel type parameter, <code>n</code> ,NMOS <code>p</code> ,PMOS. Possible values are <code>n</code> or <code>p</code> .
3	<code>tr=value of tnom C</code>	nominal (reference) temperature.
4	<code>swnqs=0</code>	Flag for NQS, 0,off, 1, 2, 3, 5, or 9,number of collocation points.
5	<code>swgeo=1</code>	Flag for geometrical model, 0,local, 1,global, 2,binning.
6	<code>swigate=0</code>	Flag for gate current, 0,turn off IG.
7	<code>swimpact=0</code>	Flag for impact ionization current, 0,turn off II.
8	<code>swgidl=0</code>	Flag for GIDL current, 0,turn off IGIDL.
9	<code>swjuncap=0</code>	Flag for juncap, 0,turn off juncap.
10	<code>swjunasym=0</code>	Flag for asymmetric junctions; 0,symmetric, 1,asymmetric.

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PSP103 Model

11	<code>swnud=0</code>	Flag for NUD-effect; 0,off, 1,on, 2,on+CV-correction.
12	<code>swdelvtac=0</code>	Flag for separate capacitance calculation; 0,off, 1,on.
13	<code>qmc=1.0</code>	Quantum-mechanical correction factor.
14	<code>version=103.0</code>	Model version selector. The available versions are 103.0, 103.1 and 103.11.
15	<code>minr=0.0</code>	Minimum resistance, in order to be compatible with the original model, set its default to 0.0.
16	<code>mvt=0.0</code>	DCmatch parameter.
17	<code>mvto=0.0</code>	DCmatch parameter.
18	<code>mbe=0.0</code>	DCmatch parameter.
19	<code>mbeo=0.0</code>	DCmatch parameter.
20	<code>vfb=-1.0 V</code>	Flat band voltage at TR.
21	<code>stvfb=5.0E-4 V/K</code>	Temperature dependence of VFB.
22	<code>tox=2.0e-09 m</code>	Gate oxide thickness.
23	<code>epsrox=3.9</code>	Relative permittivity of gate dielectric.
24	<code>neff=5.0e+23 m⁻³</code>	Effective substrate doping.
25	<code>facneffac=1.0</code>	Pre-factor for effective substrate doping in separate charge calculation.
26	<code>gfacnud=1.0</code>	Bodyfactor change due to NUD-effect.
27	<code>vsbnud=0.0 V</code>	Lower Vsb value for NUD-effect.
28	<code>dvsbnud=1.0</code>	Vsb-range for NUD-effect.
29	<code>vnsb=0.0 V</code>	Effective doping bias-dependence parameter.
30	<code>nslp=0.05 V</code>	Effective doping bias-dependence parameter.

Virtuoso Simulator Components and Device Models Reference

PSP103 Model

31	$dn_{sub}=0.0 \text{ V}^{-1}$	Effective doping bias-dependence parameter.
32	$d_{phib}=0.0 \text{ V}$	Offset parameter for PHIB.
33	$delvtac=0.0 \text{ V}$	Offset parameter for PHIB in separate charge calculation.
34	$np=1.0E+26 \text{ m}^{-3}$	Gate poly-silicon doping.
35	$ct=0.0$	Interface states factor.
36	$toxov=2.0e-09 \text{ m}$	Overlap oxide thickness.
37	$toxovd=2.0e-09 \text{ m}$	Overlap oxide thickness for drain side.
38	$nov=5.0e+25 \text{ m}^{-3}$	Effective doping of overlap region.
39	$novd=5.0e+25 \text{ m}^{-3}$	Effective doping of overlap region for drain side.
40	$cf=0.0$	DIBL-parameter.
41	$cfb=0.0 \text{ V}^{-1}$	Back bias dependence of CF.
42	$betn=7e-2 \text{ m}^2/\text{V}/\text{s}$	Channel aspect ratio times zero-field mobility.
43	$stbet=1.0$	Temperature dependence of BETN.
44	$mue=0.5 \text{ m}/\text{V}$	Mobility reduction coefficient at TR.
45	$stmue=0.0$	Temperature dependence of MUE.
46	$themu=1.5$	Mobility reduction exponent at TR.
47	$stthemu=1.5$	Temperature dependence of THEMU.
48	$cs=0.0$	Coulomb scattering parameter at TR.
49	$stcs=0.0$	Temperature dependence of CS.
50	$xcor=0.0 \text{ V}^{-1}$	Non-universality factor.
51	$stxcor=0.0$	Temperature dependence of XCOR.
52	$feta=1.0$	Effective field parameter.

Virtuoso Simulator Components and Device Models Reference

PSP103 Model

53	<code>rs=30 Ohm</code>	Series resistance at TR.
54	<code>strs=1.0</code>	Temperature dependence of RS.
55	<code>rsb=0.0 V⁻¹</code>	Back-bias dependence of series resistance.
56	<code>rsg=0.0 V⁻¹</code>	Gate-bias dependence of series resistance.
57	<code>thesat=1.0 V⁻¹</code>	Velocity saturation parameter at TR.
58	<code>stthesat=1.0</code>	Temperature dependence of THESAT.
59	<code>thesatb=0.0 V⁻¹</code>	Back-bias dependence of velocity saturation.
60	<code>thesatg=0.0 V⁻¹</code>	Gate-bias dependence of velocity saturation.
61	<code>ax=3.0</code>	Linear/saturation transition factor.
62	<code>alp=0.01</code>	CLM pre-factor.
63	<code>alp1=0.00 V</code>	CLM enhancement factor above threshold.
64	<code>alp2=0.00 V⁻¹</code>	CLM enhancement factor below threshold.
65	<code>vp=0.05 V</code>	CLM logarithm dependence factor.
66	<code>a1=1.0</code>	Impact-ionization pre-factor.
67	<code>a2=10.0 V</code>	Impact-ionization exponent at TR.
68	<code>sta2=0.0 V</code>	Temperature dependence of A2.
69	<code>a3=1.0</code>	Saturation-voltage dependence of impact-ionization.
70	<code>a4=0.0 V^{-0.5}</code>	Back-bias dependence of impact-ionization.
71	<code>gco=0.0</code>	Gate tunneling energy adjustment.
72	<code>iginv=0.0 A</code>	Gate channel current pre-factor.
73	<code>igov=0.0 A</code>	Gate overlap current pre-factor.
74	<code>igovd=0.0 A</code>	Gate overlap current pre-factor for drain side.

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75	<code>stig=2.0</code>	Temperature dependence of IGINV and IGOV.
76	<code>gc2=0.375</code>	Gate current slope factor.
77	<code>gc3=0.063</code>	Gate current curvature factor.
78	<code>chib=3.1 V</code>	Tunneling barrier height.
79	<code>agidl=0.0 A/V³</code>	GIDL pre-factor.
80	<code>agidld=0.0 A/V³</code>	GIDL pre-factor for drain side.
81	<code>bgidl=41.0 V</code>	GIDL probability factor at TR.
82	<code>bgidld=41.0 V</code>	GIDL probability factor at TR for drain side.
83	<code>stbgidl=0.0 V/K</code>	Temperature dependence of BGIDL.
84	<code>stbgidld=0.0 V/K</code>	Temperature dependence of BGIDL for drain side.
85	<code>cgidl=0.0</code>	Back-bias dependence of GIDL.
86	<code>cgidld=0.0</code>	Back-bias dependence of GIDL for drain side.
87	<code>cox=1.0e-14 F</code>	Oxide capacitance for intrinsic channel.
88	<code>cgov=1.0e-15 F</code>	Oxide capacitance for gate-drain/source overlap.
89	<code>cgovd=1.0e-15 F</code>	Oxide capacitance for gate-drain overlap.
90	<code>cgbov=0.0 F</code>	Oxide capacitance for gate-bulk overlap.
91	<code>cfr=0.0 F</code>	Outer fringe capacitance.
92	<code>cfrd=0.0 F</code>	Outer fringe capacitance for drain side.
93	<code>fnt=1.0</code>	Thermal noise coefficient.
94	<code>nfa=8.0e+22 V⁻¹/m⁴</code>	First coefficient of flicker noise.
95	<code>nfb=3.0e+07 V⁻¹/m²</code>	Second coefficient of flicker noise.

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96	$nfc=0.0 \text{ V}^{-1}$	Third coefficient of flicker noise.
97	$ef=1.0$	Flicker noise frequency exponent.
98	$munqs=1.0$	Relative mobility for NQS modeling.
99	$rg=0.0 \text{ Ohm}$	Gate resistance.
100	$rse=0.0 \text{ Ohm}$	External source resistance.
101	$rde=0.0 \text{ Ohm}$	External drain resistance.
102	$rbulk=0.0 \text{ Ohm}$	Bulk resistance between node BP and BI.
103	$rwell=0.0 \text{ Ohm}$	Well resistance between node BI and B.
104	$rjuns=0.0 \text{ Ohm}$	Source-side bulk resistance between node BI and BS.
105	$rjund=0.0 \text{ Ohm}$	Drain-side bulk resistance between node BI and BD.
106	$povfb=-1 \text{ V}$	Coefficient for the geometry independent part of VFB.
107	$plvfb=0.0 \text{ V}$	Coefficient for the length dependence of VFB.
108	$pwvfb=0.0 \text{ V}$	Coefficient for the width dependence of VFB.
109	$plwvfb=0.0 \text{ V}$	Coefficient for the length times width dependence of VFB.
110	$postvfb=0.0005 \text{ V/K}$	Coefficient for the geometry independent part of STVFB.
111	$plstvfb=0.0 \text{ V/K}$	Coefficient for the length dependence of STVFB.
112	$pwstvfb=0.0 \text{ V/K}$	Coefficient for the width dependence of STVFB.
113	$plwstvfb=0.0 \text{ V/K}$	Coefficient for the length times width dependence of STVFB.
114	$potox=2E-09 \text{ m}$	Coefficient for the geometry independent part of TOX.
115	$poepsrox=3.9$	Coefficient for the geometry independent part of EPSOX.
116	$poneff=5E+23 \text{ m}^{-3}$	Coefficient for the geometry independent part of NEFF.

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117	$p_{lneff}=0.0 \text{ m}^{-3}$	Coefficient for the length dependence of NEFF.
118	$p_{wneff}=0.0 \text{ m}^{-3}$	Coefficient for the width dependence of NEFF.
119	$p_{lwneff}=0.0 \text{ m}^{-3}$	Coefficient for the length times width dependence of NEFF.
120	$p_{ofacneffac}=1.0$	Coefficient for the geometry independent part of FACNEFFAC.
121	$p_{lfacneffac}=0.0$	Coefficient for the length dependence of FACNEFFAC.
122	$p_{wfacneffac}=0.0$	Coefficient for the width dependence of FACNEFFAC.
123	$p_{lwfacneffac}=0.0$	Coefficient for the length times width dependence of FACNEFFAC.
124	$p_{ogfacnud}=1.0$	Coefficient for the geometry independent part of GFACNUD.
125	$p_{lgfacnud}=0.0$	Coefficient for the length dependence of GFACNUD.
126	$p_{wgfacnud}=0.0$	Coefficient for the width dependence of GFACNUD.
127	$p_{lwgfacnud}=0.0$	Coefficient for the length times width dependence of GFACNUD.
128	$p_{ovsbnud}=0.0 \text{ V}$	Coefficient for the geometry independent part of VSBNUD.
129	$p_{odvsbnud}=1.0 \text{ V}$	Coefficient for the geometry independent part of DVSBNUD.
130	$p_{ovnsusb}=0 \text{ V}$	Coefficient for the geometry independent part of VNSUB.
131	$p_{onslp}=0.05 \text{ V}$	Coefficient for the geometry independent part of NSLP.
132	$p_{odnsub}=0 \text{ V}^{-1}$	Coefficient for the geometry independent part of DNSUB.
133	$p_{odphib}=0 \text{ v}$	Coefficient for the geometry independent part of DPHIB.
134	$p_{ldphib}=0.0 \text{ V}$	Coefficient for the length dependence of DPHIB.
135	$p_{wdphib}=0.0 \text{ V}$	Coefficient for the width dependence of DPHIB.
136	$p_{lwdphib}=0.0 \text{ V}$	Coefficient for the length times width dependence of DPHIB.
137	$p_{odelvtac}=0 \text{ V}$	Coefficient for the geometry independent part of DELVTAC.

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138	$p_{ldelvtac}=0.0 \text{ V}$	Coefficient for the length dependence of DELVTAC.
139	$p_{wdelvtac}=0.0 \text{ V}$	Coefficient for the width dependence of DELVTAC.
140	$p_{lwdelvtac}=0.0 \text{ V}$	Coefficient for the length times width dependence of DELVTAC.
141	$p_{onp}=1E+26 \text{ m}^{-3}$	Coefficient for the geometry independent part of NP.
142	$p_{lnp}=0.0 \text{ m}^{-3}$	Coefficient for the length dependence of NP.
143	$p_{wnp}=-.0 \text{ m}^{-3}$	Coefficient for the width dependence of NP.
144	$p_{lwnp}=0.0 \text{ m}^{-3}$	Coefficient for the length times width dependence of NP.
145	$p_{oct}=0$	Coefficient for the geometry independent part of CT.
146	$p_{lct}=0.0$	Coefficient for the length dependence of CT.
147	$p_{wct}=0.0$	Coefficient for the width dependence of CT.
148	$p_{lwct}=0.0$	Coefficient for the length times width dependence of CT.
149	$p_{toxov}=2E-09 \text{ m}$	Coefficient for the geometry independent part of TOXOV.
150	$p_{toxovd}=2E-09 \text{ m}$	Coefficient for the geometry independent part of TOXOV for drain side.
151	$p_{onov}=5E+25 \text{ m}^{-3}$	Coefficient for the geometry independent part of NOV.
152	$p_{lnov}=0.0 \text{ m}^{-3}$	Coefficient for the length dependence of NOV.
153	$p_{wnov}=0.0 \text{ m}^{-3}$	Coefficient for the width dependence of NOV.
154	$p_{lwnov}=0.0 \text{ m}^{-3}$	Coefficient for the length times width dependence of NOV.
155	$p_{onovd}=5E+25 \text{ m}^{-3}$	Coefficient for the geometry independent part of NOV for drain side.
156	$p_{lnovd}=0.0 \text{ m}^{-3}$	Coefficient for the length dependence of NOV for drain side.
157	$p_{wnovd}=0.0 \text{ m}^{-3}$	Coefficient for the width dependence of NOV for drain side.

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PSP103 Model

158	$p_{lwnovd}=0.0 \text{ m}^{-3}$	Coefficient for the length times width dependence of NOV for drain side.
159	$p_{ocf}=0$	Coefficient for the geometry independent part of CF.
160	$p_{lcf}=0.0$	Coefficient for the length dependence of CF.
161	$p_{wcf}=0.0$	Coefficient for the width dependence of CF.
162	$p_{lwcf}=0.0$	Coefficient for the length times width dependence of CF.
163	$p_{ocfb}=0 \text{ V}^{-1}$	Coefficient for the geometry independent part of CFB.
164	$p_{obetn}=0.07 \text{ m}^2/\text{V}/\text{s}$	Coefficient for the geometry independent part of BETN.
165	$p_{lbetn}=0.0 \text{ m}^2/\text{V}/\text{s}$	Coefficient for the length dependence of BETN.
166	$p_{wbetn}=0.0 \text{ m}^2/\text{V}/\text{s}$	Coefficient for the width dependence of BETN.
167	$p_{lwbetn}=0.0 \text{ m}^2/\text{V}/\text{s}$	Coefficient for the length times width dependence of BETN.
168	$p_{ostbet}=1$	Coefficient for the geometry independent part of STBET.
169	$p_{lstbet}=0.0$	Coefficient for the length dependence of STBET.
170	$p_{wstbet}=0.0$	Coefficient for the width dependence of STBET.
171	$p_{lwstbet}=0.0$	Coefficient for the length times width dependence of STBET.
172	$p_{omue}=0.5 \text{ m}/\text{V}$	Coefficient for the geometry independent part of MUE.
173	$p_{lmue}=0.0 \text{ m}/\text{V}$	Coefficient for the length dependence of MUE.
174	$p_{wmue}=0.0 \text{ m}/\text{V}$	Coefficient for the width dependence of MUE.
175	$p_{lwmue}=0.0 \text{ m}/\text{V}$	Coefficient for the length times width dependence of MUE.
176	$p_{ostmue}=0$	Coefficient for the geometry independent part of STMUE.

Virtuoso Simulator Components and Device Models Reference

PSP103 Model

177	<code>pothemu=1.5</code>	Coefficient for the geometry independent part of THEMU.
178	<code>postthemu=1.5</code>	Coefficient for the geometry independent part of STTHEMU.
179	<code>pocs=0</code>	Coefficient for the geometry independent part of CS.
180	<code>plcs=0.0</code>	Coefficient for the length dependence of CS.
181	<code>pwcs=0.0</code>	Coefficient for the width dependence of CS.
182	<code>plwcs=0.0</code>	Coefficient for the length times width dependence of CS.
183	<code>postcs=0</code>	Coefficient for the geometry independent part of STCS.
184	<code>poxcor=0 V^-1</code>	Coefficient for the geometry independent part of XCOR.
185	<code>plxcor=0.0 V^-1</code>	Coefficient for the length dependence of XCOR.
186	<code>pwxcor=0.0 V^-1</code>	Coefficient for the width dependence of XCOR.
187	<code>plwxcor=0.0 V^-1</code>	Coefficient for the length times width dependence of XCOR.
188	<code>postxcor=0</code>	Coefficient for the geometry independent part of STXCOR.
189	<code>pofeta=1</code>	Coefficient for the geometry independent part of FETA.
190	<code>pors=30 Ohm</code>	Coefficient for the geometry independent part of RS.
191	<code>plrs=0.0 Ohm</code>	Coefficient for the length dependence of RS.
192	<code>pwr=0.0 Ohm</code>	Coefficient for the width dependence of RS.
193	<code>plwrs=0.0 Ohm</code>	Coefficient for the length times width dependence of RS.
194	<code>postrs=1</code>	Coefficient for the geometry independent part of STRS.
195	<code>porsb=0 V^-1</code>	Coefficient for the geometry independent part of RSB.
196	<code>porsg=0 V^-1</code>	Coefficient for the geometry independent part of RSG.
197	<code>pothesat=1 V^-1</code>	Coefficient for the geometry independent part of THESAT.
198	<code>plthesat=0.0 V^-1</code>	Coefficient for the length dependence of THESAT.

Virtuoso Simulator Components and Device Models Reference

PSP103 Model

- 199 $pwthesat=0.0 V^{-1}$ Coefficient for the width dependence of THESAT.
- 200 $plwthesat=0.0 V^{-1}$
Coefficient for the length times width dependence of THESAT.
- 201 $postthesat=1$ Coefficient for the geometry independent part of STTHESAT.
- 202 $plstthesat=0.0$ Coefficient for the length dependence of STTHESAT.
- 203 $pwstthesat=0.0$ Coefficient for the width dependence of STTHESAT.
- 204 $plwstthesat=0.0$ Coefficient for the length times width dependence of STTHESAT.
- 205 $pothesatb=0 V^{-1}$ Coefficient for the geometry independent part of THESATB.
- 206 $plthesatb=0.0 V^{-1}$
Coefficient for the length dependence of THESATB.
- 207 $pwthesatb=0.0 V^{-1}$
Coefficient for the width dependence of THESATB.
- 208 $plwthesatb=0.0 V^{-1}$
Coefficient for the length times width dependence of THESATB.
- 209 $pothesatg=0 V^{-1}$ Coefficient for the geometry independent part of THESATG.
- 210 $plthesatg=0.0 V^{-1}$
Coefficient for the length dependence of THESATG.
- 211 $pwthesatg=0.0 V^{-1}$
Coefficient for the width dependence of THESATG.
- 212 $plwthesatg=0.0 V^{-1}$
Coefficient for the length times width dependence of THESATG.
- 213 $poax=3$ Coefficient for the geometry independent part of AX.
- 214 $plax=0.0$ Coefficient for the length dependence of AX.
- 215 $pwax=0.0$ Coefficient for the width dependence of AX.
- 216 $plwax=0.0$ Coefficient for the length times width dependence of AX.

Virtuoso Simulator Components and Device Models Reference

PSP103 Model

217	$p_{oa1p}=0.01$	Coefficient for the geometry independent part of ALP.
218	$p_{la1p}=0.0$	Coefficient for the length dependence of ALP.
219	$p_{wa1p}=0.0$	Coefficient for the width dependence of ALP.
220	$p_{lwa1p}=0.0$	Coefficient for the length times width dependence of ALP.
221	$p_{oa1p1}=0 \text{ V}$	Coefficient for the geometry independent part of ALP1.
222	$p_{la1p1}=0.0 \text{ V}$	Coefficient for the length dependence of ALP1.
223	$p_{wa1p1}=0.0 \text{ V}$	Coefficient for the width dependence of ALP1.
224	$p_{lwa1p1}=0.0 \text{ V}$	Coefficient for the length times width dependence of ALP1.
225	$p_{oa1p2}=0 \text{ V}^{-1}$	Coefficient for the geometry independent part of ALP2.
226	$p_{la1p2}=0.0 \text{ V}^{-1}$	Coefficient for the length dependence of ALP2.
227	$p_{wa1p2}=0.0 \text{ V}^{-1}$	Coefficient for the width dependence of ALP2.
228	$p_{lwa1p2}=0.0 \text{ V}^{-1}$	Coefficient for the length times width dependence of ALP2.
229	$p_{ovp}=0.05 \text{ V}$	Coefficient for the geometry independent part of VP.
230	$p_{oa1}=1$	Coefficient for the geometry independent part of A1.
231	$p_{la1}=0.0$	Coefficient for the length dependence of A1.
232	$p_{wa1}=0.0$	Coefficient for the width dependence of A1.
233	$p_{lwa1}=0.0$	Coefficient for the length times width dependence of A1.
234	$p_{oa2}=10 \text{ V}$	Coefficient for the geometry independent part of A2.
235	$p_{osta2}=0 \text{ V}$	Coefficient for the geometry independent part of STA2.
236	$p_{oa3}=1$	Coefficient for the geometry independent part of A3.
237	$p_{la3}=0.0$	Coefficient for the length dependence of A3.
238	$p_{wa3}=0.0$	Coefficient for the width dependence of A3.

Virtuoso Simulator Components and Device Models Reference

PSP103 Model

239	$p_{lwa3}=0.0$	Coefficient for the length times width dependence of A3.
240	$p_{oa4}=0 \ V^{-0.5}$	Coefficient for the geometry independent part of A4.
241	$p_{la4}=0.0 \ V^{-0.5}$	Coefficient for the length dependence of A4.
242	$p_{wa4}=0.0 \ V^{-0.5}$	Coefficient for the width dependence of A4.
243	$p_{lwa4}=0.0 \ V^{-0.5}$	Coefficient for the length times width dependence of A4.
244	$p_{ogco}=0$	Coefficient for the geometry independent part of GCO.
245	$p_{oiginv}=0 \ A$	Coefficient for the geometry independent part of IGINV.
246	$p_{liginv}=0.0 \ A$	Coefficient for the length dependence of IGINV.
247	$p_{wiginv}=0.0 \ A$	Coefficient for the width dependence of IGINV.
248	$p_{lwiginv}=0.0 \ A$	Coefficient for the length times width dependence of IGINV.
249	$p_{oigov}=0 \ A$	Coefficient for the geometry independent part of IGOV.
250	$p_{ligov}=0.0 \ A$	Coefficient for the length dependence of IGOV.
251	$p_{wigo v}=0.0 \ A$	Coefficient for the width dependence of IGOV.
252	$p_{lwigo v}=0.0 \ A$	Coefficient for the length times width dependence of IGOV.
253	$p_{oigovd}=0 \ A$	Coefficient for the geometry independent part of IGOV for drain side.
254	$p_{ligovd}=0.0 \ A$	Coefficient for the length dependence of IGOV for drain side.
255	$p_{wigo vd}=0.0 \ A$	Coefficient for the width dependence of IGOV for drain side.
256	$p_{lwigo vd}=0.0 \ A$	Coefficient for the length times width dependence of IGOV for drain side.
257	$p_{ostig}=2$	Coefficient for the geometry independent part of STIG.
258	$p_{ogc2}=0.375$	Coefficient for the geometry independent part of GC2.
259	$p_{ogc3}=0.063$	Coefficient for the geometry independent part of GC3.

Virtuoso Simulator Components and Device Models Reference

PSP103 Model

- 260 `pochib=3.1 V` Coefficient for the geometry independent part of CHIB.
- 261 `poagidl=0 A/V^3` Coefficient for the geometry independent part of AGIDL.
- 262 `plagidl=0.0 A/V^3` Coefficient for the length dependence of AGIDL.
- 263 `pwagidl=0.0 A/V^3` Coefficient for the width dependence of AGIDL.
- 264 `plwagidl=0.0 A/V^3`
Coefficient for the length times width dependence of AGIDL.
- 265 `poagidld=0 A/V^3` Coefficient for the geometry independent part of AGIDL for drain side.
- 266 `plagidld=0.0 A/V^3`
Coefficient for the length dependence of AGIDL for drain side.
- 267 `pwagidld=0.0 A/V^3`
Coefficient for the width dependence of AGIDL for drain side.
- 268 `plwagidld=0.0 A/V^3`
Coefficient for the length times width dependence of AGIDL for drain side.
- 269 `pobgidl=41 V` Coefficient for the geometry independent part of BGIDL.
- 270 `pobgidld=41 V` Coefficient for the geometry independent part of BGIDL for drain side.
- 271 `postbgidl=0 V/K` Coefficient for the geometry independent part of STBGIDL.
- 272 `postbgidld=0 V/K` Coefficient for the geometry independent part of STBGIDL for drain side.
- 273 `pocgidl=0` Coefficient for the geometry independent part of CGIDL.
- 274 `pocgidld=0` Coefficient for the geometry independent part of CGIDL for drain side.
- 275 `pocox=1E-14 F` Coefficient for the geometry independent part of COX.
- 276 `plcox=0.0 F` Coefficient for the length dependence of COX.

Virtuoso Simulator Components and Device Models Reference

PSP103 Model

277	<code>pwc_{cox}=0.0</code>	F	Coefficient for the width dependence of COX.
278	<code>plw_{cox}=0.0</code>	F	Coefficient for the length times width dependence of COX.
279	<code>poc_{gov}=1E-15</code>	F	Coefficient for the geometry independent part of CGOV.
280	<code>plc_{gov}=0.0</code>	F	Coefficient for the length dependence of CGOV.
281	<code>pwc_{gov}=0.0</code>	F	Coefficient for the width dependence of CGOV.
282	<code>plw_{gov}=0.0</code>	F	Coefficient for the length times width dependence of CGOV.
283	<code>poc_{govd}=1E-15</code>	F	Coefficient for the geometry independent part of CGOV for drain side.
284	<code>plc_{govd}=0.0</code>	F	Coefficient for the length dependence of CGOV for drain side.
285	<code>pwc_{govd}=0.0</code>	F	Coefficient for the width dependence of CGOV for drain side.
286	<code>plw_{govd}=0.0</code>	F	Coefficient for the length times width dependence of CGOV for drain side.
287	<code>poc_{gbov}=0</code>	F	Coefficient for the geometry independent part of CGBOV.
288	<code>plc_{gbov}=0.0</code>	F	Coefficient for the length dependence of CGBOV.
289	<code>pwc_{gbov}=0.0</code>	F	Coefficient for the width dependence of CGBOV.
290	<code>plw_{gbov}=0.0</code>	F	Coefficient for the length times width dependence of CGBOV.
291	<code>poc_{fr}=0</code>	F	Coefficient for the geometry independent part of CFR.
292	<code>plc_{fr}=0.0</code>	F	Coefficient for the length dependence of CFR.
293	<code>pwc_{fr}=0.0</code>	F	Coefficient for the width dependence of CFR.
294	<code>plw_{fr}=0.0</code>	F	Coefficient for the length times width dependence of CFR.
295	<code>poc_{frd}=0</code>	F	Coefficient for the geometry independent part of CFR for drain side.
296	<code>plc_{frd}=0.0</code>	F	Coefficient for the length dependence of CFR for drain side.

Virtuoso Simulator Components and Device Models Reference

PSP103 Model

297	$pwcfrd=0.0$	F	Coefficient for the width dependence of CFR for drain side.
298	$plwcfrd=0.0$	F	Coefficient for the length times width dependence of CFR for drain side.
299	$pofnt=1$		Coefficient for the geometry independent part of FNT.
300	$ponfa=8E+22$	V^{-1}/m^4	Coefficient for the geometry independent part of NFA.
301	$plnfa=0.0$	V^{-1}/m^4	Coefficient for the length dependence of NFA.
302	$pwnfa=0.0$	V^{-1}/m^4	Coefficient for the width dependence of NFA.
303	$plwnfa=0.0$	V^{-1}/m^4	Coefficient for the length times width dependence of NFA.
304	$ponfb=0.0$	V^{-1}/m^2	Coefficient for the geometry independent part of NFB.
305	$plnfb=0.0$	V^{-1}/m^2	Coefficient for the length dependence of NFB.
306	$pwnfb=0.0$	V^{-1}/m^2	Coefficient for the width dependence of NFB.
307	$plwnfb=0.0$	V^{-1}/m^2	Coefficient for the length times width dependence of NFB.
308	$ponfc=0$	V^{-1}	Coefficient for the geometry independent part of NFC.
309	$plnfc=0.0$	V^{-1}	Coefficient for the length dependence of NFC.
310	$pwnfc=0.0$	V^{-1}	Coefficient for the width dependence of NFC.
311	$plwnfc=0.0$	V^{-1}	Coefficient for the length times width dependence of NFC.
312	$poef=1.0$		Coefficient for the flicker noise frequency exponent.
313	$pokvthowe=0$		Coefficient for the geometry independent part of KVTHOWE.

Virtuoso Simulator Components and Device Models Reference

PSP103 Model

314	<code>plkvthowe=0</code>	Coefficient for the length dependence part of KVTHOWE.
315	<code>pwkvthowe=0</code>	Coefficient for the width dependence part of KVTHOWE.
316	<code>plwkvthowe=0</code>	Coefficient for the length times width dependence part of KVTHOWE.
317	<code>pokuowe=0</code>	Coefficient for the geometry independent part of KUOWE.
318	<code>plkuowe=0</code>	Coefficient for the length dependence part of KUOWE.
319	<code>pwkuowe=0</code>	Coefficient for the width dependence part of KUOWE.
320	<code>plwkuowe=0</code>	Coefficient for the length times width dependence part of KUOWE.
321	<code>lmin=0 m</code>	Dummy parameter to label binning set.
322	<code>lmax=1.0 m</code>	Dummy parameter to label binning set.
323	<code>wmin=0 m</code>	Dummy parameter to label binning set.
324	<code>wmax=1.0 m</code>	Dummy parameter to label binning set.
325	<code>lvaro=0.0 m</code>	Geom. independent difference between actual and programmed gate length.
326	<code>lvarl=0.0</code>	Length dependence of LVAR.
327	<code>lvarw=0.0</code>	Width dependence of LVAR.
328	<code>lap=0.0 m</code>	Effective channel length reduction per side.
329	<code>wvaro=0.0 m</code>	Geom. independent difference between actual and programmed field-oxide opening.
330	<code>wvarl=0.0</code>	Length dependence of WVAR.
331	<code>wvarw=0.0</code>	Width dependence of WVAR.
332	<code>wot=0.0 m</code>	Effective channel width reduction per side.
333	<code>dlq=0.0 m</code>	Effective channel length reduction for CV.

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334	$\text{dwq}=0.0 \text{ m}$	Effective channel width reduction for CV.
335	$\text{vfbo}=-1.0 \text{ V}$	Geometry-independent flat-band voltage at TR.
336	$\text{vfb1}=0.0 \text{ V}$	Length dependence of flat-band voltage.
337	$\text{vfbw}=0.0 \text{ V}$	Width dependence of flat-band voltage.
338	$\text{vfb1w}=0.0 \text{ V}$	Area dependence of flat-band voltage.
339	$\text{stvfbo}=5\text{e-}4 \text{ V/K}$	Geometry-independent temperature dependence of VFB.
340	$\text{stvfbl}=0.0 \text{ V/K}$	Length dependence of temperature dependence of VFB.
341	$\text{stvfbw}=0.0 \text{ V/K}$	Width dependence of temperature dependence of VFB.
342	$\text{stvfb1w}=0.0 \text{ V/K}$	Area dependence of temperature dependence of VFB.
343	$\text{tox0}=2\text{e-}9 \text{ m}$	Gate oxide thickness.
344	$\text{epsrox0}=3.9$	Relative permittivity of gate dielectric.
345	$\text{nsub0}=3\text{e}23 \text{ m}^{-3}$	Geometry independent substrate doping.
346	$\text{nsubw}=0.0$	Width dependence of background doping NSUBO due to segregation.
347	$\text{wseg}=1\text{e-}8\text{m}$	Char. length of segregation of background doping NSUBO.
348	$\text{npck}=1\text{e}24 \text{ m}^{-3}$	Pocket doping level.
349	$\text{npckw}=0.0$	Width dependence of pocket doping NPCK due to segregation.
350	$\text{wsegp}=1\text{e-}8 \text{ m}$	Char. length of segregation of pocket doping NPCK.
351	$\text{lpck}=1\text{e-}8 \text{ m}$	Char. length of lateral doping profile.
352	$\text{lpckw}=0.0$	Width dependence of char. length of lateral doping profile.
353	$\text{f011}=0.0$	First length dependence coefficient for short channel body effect.
354	$\text{f012}=0.0$	Second length dependence coefficient for short channel body effect.

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355	<code>facneffaco=1.0</code>	Geom. independent pre-factor for effective substrate doping in separate charge calculation.
356	<code>facneffacl=0.0</code>	Length dependence of FACNEFFAC.
357	<code>facneffacw=0.0</code>	Width dependence of FACNEFFAC.
358	<code>facneffaclw=0.0</code>	Area dependence of FACNEFFAC.
359	<code>gfacnudo=1.0</code>	Geom. independent bodyfactor change due to NUD-effect.
360	<code>gfacnudl=0.0</code>	Length dependence of GFACNUD.
361	<code>gfacnudlexp=1.0</code>	Exponent for length dependence of GFACNUD.
362	<code>gfacnudw=0.0</code>	Width dependence of GFACNUD.
363	<code>gfacnudlw=0.0</code>	Area dependence of GFACNUD.
364	<code>vsbnudo=0.0 V</code>	Lower V_{sb} value for NUD-effect.
365	<code>dvsbnudo=1.0 V</code>	V_{sb} range for NUD-effect.
366	<code>vnsubo=0.0 V</code>	Effective doping bias-dependence parameter.
367	<code>nslpo=0.05 V</code>	Effective doping bias-dependence parameter.
368	<code>dnsubo=0.0 V⁻¹</code>	Effective doping bias-dependence parameter.
369	<code>dphibo=0.0 V</code>	Geometry independent offset of PHIB.
370	<code>dphibl=0.0 V</code>	Length dependence offset of PHIB.
371	<code>dphiblexp=1.0</code>	Exponent for length dependence of offset of PHIB.
372	<code>dphibw=0.0 V</code>	Width dependence of offset of PHIB.
373	<code>dphiblw=0.0 V</code>	Area dependence of offset of PHIB.
374	<code>delvtaco=0.0 V</code>	Geom. independent offset parameter for PHIB in separate charge calculation.
375	<code>delvtacl=0.0 V</code>	Length dependence of DELVTAC.

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376	<code>delvtaclexp=1.0</code>	Exponent for length dependence of offset of DELVTAC.
377	<code>delvtacw=0.0 V</code>	Width dependence of DELVTAC.
378	<code>delvtaclw=0.0 V</code>	Area dependence of DELVTAC.
379	<code>npo=1e26 m^-3</code>	Geometry-independent gate poly-silicon doping.
380	<code>npl=0.0</code>	Length dependence of gate poly-silicon doping.
381	<code>cto=0.0</code>	Geometry-independent interface states factor.
382	<code>ctl=0.0</code>	Length dependence of interface states factor.
383	<code>ctlexp=1.0</code>	Exponent for length dependence of interface states factor.
384	<code>ctw=0.0</code>	Width dependence of interface states factor.
385	<code>ctlw=0.0</code>	Area dependence of interface states factor.
386	<code>toxovo=2e-9 m</code>	Overlap oxide thickness.
387	<code>toxovdo=2e-9 m</code>	Overlap oxide thickness for drain side.
388	<code>lov=0 m</code>	Overlap length for gate/drain and gate/source overlap capacitance.
389	<code>lovd=0 m</code>	Overlap length for gate/drain overlap capacitance.
390	<code>novo=5e25 m^-3</code>	Effective doping of overlap region.
391	<code>novdo=5e25 m^-3</code>	Effective doping of overlap region for drain side.
392	<code>cfl=0.0</code>	Length dependence of DIBL-parameter.
393	<code>cflexp=2.0</code>	Exponent for length dependence of CF.
394	<code>cfw=0.0</code>	Width dependence of CF.
395	<code>cfbo=0.0 V^-1</code>	Back-bias dependence of CF.
396	<code>uo=5e-2 m^2/V/s</code>	Zero-field mobility at TR.

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397	$f_{bet1}=0.0$	Relative mobility decrease due to first lateral profile.
398	$f_{bet1w}=0.0$	Width dependence of relative mobility decrease due to first lateral profile.
399	$lp1=1e-8$ m	Mobility-related characteristic length of first lateral profile.
400	$lp1w=0.0$	Width dependence of mobility-related characteristic length of first lateral profile.
401	$f_{bet2}=0.0$	Relative mobility decrease due to second lateral profile.
402	$lp2=1e-8$ m	Mobility-related characteristic length of second lateral profile.
403	$betw1=0.0$	First higher-order width scaling coefficient of BETN.
404	$betw2=0.0$	Second higher-order width scaling coefficient of BETN.
405	$wbet=1e-9$ m	Characteristic width for width scaling of BETN.
406	$stbeto=1.0$	Geometry independent temperature dependence of BETN.
407	$stbetl=0.0$	Length dependence of temperature dependence of BETN.
408	$stbetw=0.0$	Width dependence of temperature dependence of BETN.
409	$stbetlw=0.0$	Area dependence of temperature dependence of BETN.
410	$mueo=0.5$ m/V	Geometry independent mobility reduction coefficient at TR.
411	$muew=0.0$	Width dependence of mobility reduction coefficient at TR.
412	$stmueo=0.0$	Temperature dependence of MUE.
413	$themuo=1.5$	Mobility reduction exponent at TR.
414	$stthemuo=1.5$	Temperature dependence of THEMU.
415	$cso=0.0$	Geometry independent coulomb scattering parameter at TR.
416	$cs1=0.0$	Length dependence of CS.
417	$cs1exp=1.0$	Exponent for length dependence of CS.

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418	<code>csw=0.0</code>	Width dependence of CS.
419	<code>cslw=0.0</code>	Area dependence of CS.
420	<code>stcso=0.0</code>	Temperature dependence of CS.
421	<code>xcoro=0.0 V⁻¹</code>	Geometry independent non-universality parameter.
422	<code>xcorl=0.0</code>	Length dependence of non-universality parameter.
423	<code>xcorw=0.0</code>	Width dependence of non-universality parameter.
424	<code>xcorlw=0.0</code>	Area dependence of non-universality parameter.
425	<code>stxcoro=0.0</code>	Temperature dependence of XCOR.
426	<code>fetao=1.0</code>	Effective field parameter.
427	<code>rsw1=50.0 Ohm</code>	Source/drain series resistance for 1 um wide channel at TR.
428	<code>rsw2=0.0</code>	Higher-order width scaling of RS.
429	<code>strso=1.0</code>	Temperature dependence of RS.
430	<code>rsbo=0.0 V⁻¹</code>	Back-bias dependence of series resistance.
431	<code>rsgo=0.0 V⁻¹</code>	Gate-bias dependence of series resistance.
432	<code>thesato=0.0 V⁻¹</code>	Geometry independent velocity saturation parameter at TR.
433	<code>thesatl=0.05 V⁻¹</code>	Length dependence of THESAT.
434	<code>thesatlexp=1.0</code>	Exponent for length dependence of THESAT.
435	<code>thesatw=0.0</code>	Width dependence of velocity saturation parameter.
436	<code>thesatlw=0.0</code>	Area dependence of velocity saturation parameter.
437	<code>stthesato=1.0</code>	Geometry independent temperature dependence of THESAT.
438	<code>stthesatl=0.0</code>	Length dependence of temperature dependence of THESAT.
439	<code>stthesatw=0.0</code>	Width dependence of temperature dependence of THESAT.

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440	<code>stthesatlw=0.0</code>	Area dependence of temperature dependence of THESAT.
441	<code>thesatbo=0.0</code>	V^{-1} Back-bias dependence of velocity saturation.
442	<code>thesatgo=0.0</code>	V^{-1} Gate-bias dependence of velocity saturation.
443	<code>axo=18</code>	Geometry independent linear/saturation transition factor.
444	<code>axl=0.4</code>	Length dependence of AX.
445	<code>alp1=5e-4</code>	Length dependence of ALP.
446	<code>alplexp=1.0</code>	Exponent for length dependence of ALP.
447	<code>alpw=0.0</code>	Width dependence of ALP.
448	<code>alp1l1=0.0</code>	V Length dependence of CLM enhancement factor above threshold.
449	<code>alp1lexp=0.5</code>	Exponent for length dependence of ALP1.
450	<code>alp1l2=0.0</code>	Second_order length dependence of ALP1.
451	<code>alp1w=0.0</code>	Width dependence of ALP1.
452	<code>alp2l1=0.5</code>	Length dependence of CLM enhancement factor below threshold.
453	<code>alp2lexp=0.0</code>	Exponent for length dependence of ALP2.
454	<code>alp2l2=0.0</code>	Second_order length dependence of ALP2.
455	<code>alp2w=0.0</code>	Width dependence of ALP2.
456	<code>vpo=0.05</code>	V CLM logarithmic dependence parameter.
457	<code>a1o=1.0</code>	Geometry independent impact-ionization pre-factor.
458	<code>a1l=0.0</code>	Length dependence of A1.
459	<code>a1w=0.0</code>	Width dependence of A1.
460	<code>a2o=10</code>	V Impact-ionization exponent at TR.

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461	$sta2o=0.0$	V	Temperature dependence of A2.
462	$a3o=1.0$		Geometry independent saturation-voltage dependence of II.
463	$a3l=0.0$		Length dependence of A3.
464	$a3w=0.0$		Width dependence of A3.
465	$a4o=0.0$	$V^{-0.5}$	Geometry independent back-bias dependence of II.
466	$a4l=0.0$		Length dependence of A4.
467	$a4w=0.0$		Width dependence of A4.
468	$gcoo=0.0$		Gate tunneling energy adjustment.
469	$iginv1w=0.0$	A	Gate channel current pre-factor for 1 μm^2 channel area.
470	$igovw=0.0$	A	Gate overlap current pre-factor for 1 μm wide channel.
471	$igovdw=0.0$	A	Gate overlap current pre-factor for 1 μm wide channel for drain side.
472	$stigo=2.0$		Temperature dependence of IGINV and IGOV.
473	$gc2o=0.375$		Gate current slope factor.
474	$gc3o=0.063$		Gate current curvature factor.
475	$chibo=3.1$	V	Tunneling barrier height.
476	$agidlw=0.0$	A/V^3	Width dependence of GIDL pre-factor.
477	$agidl\bar{d}w=0.0$	A/V^3	Width dependence of GIDL pre-factor for drain side.
478	$bgidlo=41$	V	GIDL probability factor at TR.
479	$bgidl\bar{d}o=41$	V	GIDL probability factor at TR for drain side.
480	$stbgidlo=0.0$	V/K	Temperature dependence of BGIDL.
481	$stbgidl\bar{d}o=0.0$	V/K	Temperature dependence of BGIDL for drain side.

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482	<code>cgidlo=0.0</code>	Back-bias dependence of GIDL.
483	<code>cgidldo=0.0</code>	Back-bias dependence of GIDL for drain side.
484	<code>cgbovl=0.0 F</code>	Oxide capacitance for gate-bulk overlap for 1 um long channel.
485	<code>cfrw=0.0 F</code>	Outer fringe capacitance for 1 um wide channel.
486	<code>cfrdw=0.0 F</code>	Outer fringe capacitance for 1 um wide channel for drain side.
487	<code>fnto=1.0</code>	Thermal noise coefficient.
488	<code>nfalw=8e22 V⁻¹/m⁴</code>	First coefficient of flicker noise for 1 um ² channel area.
489	<code>nfblw=3e7 V⁻¹/m²</code>	Second coefficient of flicker noise for 1 um ² channel area.
490	<code>nfclw=.0 V⁻¹</code>	Third coefficient of flicker noise for 1 um ² channel area.
491	<code>efo=1.0</code>	Flicker noise frequency exponent.
492	<code>lintnoi=0.0 m</code>	Length offset for flicker noise.
493	<code>alpnoi=2.0</code>	Exponent for length offset for flicker noise.
494	<code>kvthoweo=0</code>	Geometrical independent threshold shift parameter.
495	<code>kvthowel=0</code>	Length dependent threshold shift parameter.
496	<code>kvthowew=0</code>	Width dependent threshold shift parameter.
497	<code>kvthowelw=0</code>	Area dependent threshold shift parameter.
498	<code>kuoweo=0</code>	Geometrical independent mobility degradation factor.
499	<code>kuowel=0</code>	Length dependent mobility degradation factor.
500	<code>kuowew=0</code>	Width dependent mobility degradation factor.
501	<code>kuowelw=0</code>	Area dependent mobility degradation factor.
502	<code>munqso=1.0</code>	Relative mobility for NQS modeling.

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503	$r_{go}=0.0$ Ohm	Gate resistance.
504	$r_{int}=0.0$ Ohm m^2	Contact resistance between silicide and poly.
505	$r_{vpoly}=0.0$ Ohm m^2	Vertical poly resistance.
506	$r_{shg}=0.0$ Ohm/Sqr	Gate electrode diffusion sheet resistance.
507	$d_{lsil}=0.0$ m	Silicide extension over the physical gate length.
508	$r_{sh}=0.0$ Ohm/sq	Sheet resistance of source diffusion.
509	$r_{shd}=0.0$ Ohm/sq	Sheet resistance of drain diffusion.
510	$r_{bulko}=0.0$ Ohm	Bulk resistance between node BP and BI.
511	$r_{wello}=0.0$ Ohm	Well resistance between node BI and B.
512	$r_{junso}=0.0$ Ohm	Source-side bulk resistance between node BI and BS.
513	$r_{jundo}=0.0$ Ohm	Drain-side bulk resistance between node BI and BD.
514	$s_{aref}=1.0e-6$ m	Reference distance between OD-edge and poly from one side.
515	$s_{bref}=1.0e-6$ m	Reference distance between OD-edge and poly from other side.
516	$w_{lod}=0$ m	Width parameter.
517	$k_{uo}=0$ m	Mobility degradation/enhancement coefficient.
518	$k_{vsat}=0$ m	Saturation velocity degradation/enhancement coefficient.
519	$t_{kuo}=0$	Temperature dependence of KUO.
520	$l_{kuo}=0$ $m^{LLODKUO}$	Length dependence of KUO.
521	$w_{kuo}=0$ $m^{WLODKUO}$	Width dependence of KUO.
522	$p_{kuo}=0$ $m^{(LLODKUO+WLODKUO)}$	Cross-term dependence of KUO.
523	$l_{lodkuo}=0$	Length parameter for UO stress effect.

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524	$w_{lodkuo}=0$	Width parameter for UO stress effect.
525	$kv_{tho}=0$ Vm	Threshold shift parameter.
526	$lkv_{tho}=0$ m ^{LLODVTH}	Length dependence of KVTHO.
527	$wkv_{tho}=0$ m ^{WLODVTH}	Width dependence of KVTHO.
528	$pkv_{tho}=0$ m ^(LLODVTH+WLODVTH)	Cross-term dependence of KVTHO.
529	$llodvth=0$	Length parameter for VTH-stress effect.
530	$wlodvth=0$	Width parameter for VTH-stress effect.
531	$stetao=0$ m	eta0 shift factor related to VTHO change.
532	$lodetao=1.0$	eta0 shift modification factor for stress effect.
533	$scref=1.0e-6$ m	Distance between OD-edge and well edge of a reference device.
534	$web=0$	Coefficient for SCB.
535	$wec=0$	Coefficient for SCC.
536	$imax=1000$ A	Maximum current up to which forward current behaves exponentially.
537	$trj=21$ C	reference temperature.
538	$cjorbot=1E-3$ Fm ⁻²	Zero-bias capacitance per unit-of-area of bottom component for source-bulk junction.
539	$cjorsti=1E-9$ Fm ⁻¹	Zero-bias capacitance per unit-of-length of STI-edge component for source-bulk junction.
540	$cjorgat=1E-9$ Fm ⁻¹	Zero-bias capacitance per unit-of-length of gate-edge component for source-bulk junction.

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541	<code>vbirbot=1 V</code>	Built-in voltage at the reference temperature of bottom component for source-bulk junction.
542	<code>vbirsti=1 V</code>	Built-in voltage at the reference temperature of STI-edge component for source-bulk junction.
543	<code>vbirgat=1 V</code>	Built-in voltage at the reference temperature of gate-edge component for source-bulk junction.
544	<code>pbot=0.5</code>	Grading coefficient of bottom component for source-bulk junction.
545	<code>psti=0.5</code>	Grading coefficient of STI-edge component for source-bulk junction.
546	<code>pgat=0.5</code>	Grading coefficient of gate-edge component for source-bulk junction.
547	<code>phigbot=1.16 V</code>	Zero-temperature bandgap voltage of bottom component for source-bulk junction.
548	<code>phigsti=1.16 V</code>	Zero-temperature bandgap voltage of STI-edge component for source-bulk junction.
549	<code>phiggat=1.16 V</code>	Zero-temperature bandgap voltage of gate-edge component for source-bulk junction.
550	<code>idsatrbot=1E-12 Am⁻²</code>	Saturation current density at the reference temperature of bottom component for source-bulk junction.
551	<code>idsatrsti=1E-18 Am⁻¹</code>	Saturation current density at the reference temperature of STI-edge component for source-bulk junction.
552	<code>idsatrgat=1E-18 Am⁻¹</code>	Saturation current density at the reference temperature of gate-edge component for source-bulk junction.
553	<code>csrbot=1E2 Am⁻³</code>	Shockley-Read-Hall prefactor of bottom component for source-bulk junction.

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- 554 $csrhisti=1E-4 \text{ Am}^{-2}$ Shockley-Read-Hall prefactor of STI-edge component for source-bulk junction.
- 555 $csrhgat=1E-4 \text{ Am}^{-2}$ Shockley-Read-Hall prefactor of gate-edge component for source-bulk junction.
- 556 $xjunsti=100E-9 \text{ m}$ Junction depth of STI-edge component for source-bulk junction.
- 557 $xjungat=100E-9 \text{ m}$ Junction depth of gate-edge component for source-bulk junction.
- 558 $ctatbot=1E2 \text{ Am}^{-3}$ Trap-assisted tunneling prefactor of bottom component for source-bulk junction.
- 559 $ctatsti=1E-4 \text{ Am}^{-2}$ Trap-assisted tunneling prefactor of STI-edge component for source-bulk junction.
- 560 $ctatgat=1E-4 \text{ Am}^{-2}$ Trap-assisted tunneling prefactor of gate-edge component for source-bulk junction.
- 561 $mefftatbot=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of bottom component for source-bulk junction.
- 562 $mefftatsti=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of STI-edge component for source-bulk junction.
- 563 $mefftatgat=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of gate-edge component for source-bulk junction.
- 564 $cbbtbot=1E-12 \text{ AV}^{-3}$ Band-to-band tunneling prefactor of bottom component for source-bulk junction.
- 565 $cbbtsti=1E-18 \text{ AV}^{-3m}$ Band-to-band tunneling prefactor of STI-edge component for source-bulk junction.
- 566 $cbbtgat= 1E-18 \text{ AV}^{-3m}$ Band-to-band tunneling prefactor of gate-edge component for source-bulk junction.

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- 567 `fbbtrbot=1E9 Vm^-1`
Normalization field at the reference temperature for band-to-band tunneling of bottom component for source-bulk junction.
- 568 `fbbtrsti=1E9 Vm^-1`
Normalization field at the reference temperature for band-to-band tunneling of STI-edge component for source-bulk junction.
- 569 `fbbtrgat=1E9 Vm^-1`
Normalization field at the reference temperature for band-to-band tunneling of gate-edge component for source-bulk junction.
- 570 `stfbbtbot=-1E-3 K^-1`
Temperature scaling parameter for band-to-band tunneling of bottom component for source-bulk junction.
- 571 `stfbbtsti=-3 K^-1`
Temperature scaling parameter for band-to-band tunneling of STI-edge component for source-bulk junction.
- 572 `stfbbtgat=-1E-3 K^-1`
Temperature scaling parameter for band-to-band tunneling of gate-edge component for source-bulk junction.
- 573 `vbrbot=10 V`
Breakdown voltage of bottom component for source-bulk junction.
- 574 `vbrsti=10 V`
Breakdown voltage of STI-edge component for source-bulk junction.
- 575 `vbrgat=10 V`
Breakdown voltage of gate-edge component for source-bulk junction.
- 576 `pbrbot=4 V`
Breakdown onset tuning parameter of bottom component for source-bulk junction.
- 577 `pbrsti=4 V`
Breakdown onset tuning parameter of STI-edge component for source-bulk junction.
- 578 `pbrgat=4 V`
Breakdown onset tuning parameter of gate-edge component for source-bulk junction.

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- 579 `cjorbotd=1E-3` Fm^{-2}
Zero-bias capacitance per unit-of-area of bottom component for drain-bulk junction.
- 580 `cjorstid=1E-9` Fm^{-1}
Zero-bias capacitance per unit-of-length of STI-edge component for drain-bulk junction.
- 581 `cjorgatd=1E-9` Fm^{-1}
Zero-bias capacitance per unit-of-length of gate-edge component for drain-bulk junction.
- 582 `vbirbotd=1` V
Built-in voltage at the reference temperature of bottom component for drain-bulk junction.
- 583 `vbirstid=1` V
Built-in voltage at the reference temperature of STI-edge component for drain-bulk junction.
- 584 `vbirgatd=1` V
Built-in voltage at the reference temperature of gate-edge component for drain-bulk junction.
- 585 `pbotd=0.5`
Grading coefficient of bottom component for drain-bulk junction.
- 586 `pstid=0.5`
Grading coefficient of STI-edge component for drain-bulk junction.
- 587 `pgatd=0.5`
Grading coefficient of gate-edge component for drain-bulk junction.
- 588 `phigbotd=1.16` V
Zero-temperature bandgap voltage of bottom component for drain-bulk junction.
- 589 `phigstid=1.16` V
Zero-temperature bandgap voltage of STI-edge component for drain-bulk junction.
- 590 `phiggatd=1.16` V
Zero-temperature bandgap voltage of gate-edge component for drain-bulk junction.
- 591 `idsatrbotd=1E-12` Am^{-2}
Saturation current density at the reference temperature of bottom component for drain-bulk junction.

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- 592 $idsatrstid=1E-18$ $A m^{-1}$
Saturation current density at the reference temperature of STI-edge component for drain-bulk junction.
- 593 $idsatrgatd=1E-18$ $A m^{-1}$
Saturation current density at the reference temperature of gate-edge component for drain-bulk junction.
- 594 $csrbotd=1E2$ $A m^{-3}$
Shockley-Read-Hall prefactor of bottom component for drain-bulk junction.
- 595 $csrhostid=1E-4$ $A m^{-2}$
Shockley-Read-Hall prefactor of STI-edge component for drain-bulk junction.
- 596 $csrhatd=1E-4$ $A m^{-2}$
Shockley-Read-Hall prefactor of gate-edge component for drain-bulk junction.
- 597 $xjunstid=100E-9$ m Junction depth of STI-edge component for drain-bulk junction.
- 598 $xjungatd=100E-9$ m Junction depth of gate-edge component for drain-bulk junction.
- 599 $ctatbotd=1E2$ $A m^{-3}$
Trap-assisted tunneling prefactor of bottom component for drain-bulk junction.
- 600 $ctatstid=1E-4$ $A m^{-2}$
Trap-assisted tunneling prefactor of STI-edge component for drain-bulk junction.
- 601 $ctatgatd=1E-4$ $A m^{-2}$
Trap-assisted tunneling prefactor of gate-edge component for drain-bulk junction.
- 602 $mefftatbotd=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of bottom component for drain-bulk junction.
- 603 $mefftatstid=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of STI-edge component for drain-bulk junction.

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- 604 $m_{eff,tatgatd}=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of gate-edge component for drain-bulk junction.
- 605 $c_{bbtbotd}=1E-12$ AV^{-3}
Band-to-band tunneling prefactor of bottom component for drain-bulk junction.
- 606 $c_{bbtstid}=1E-18$ AV^{-3m}
Band-to-band tunneling prefactor of STI-edge component for drain-bulk junction.
- 607 $c_{bbtgatd}=1E-18$ AV^{-3m}
Band-to-band tunneling prefactor of gate-edge component for drain-bulk junction.
- 608 $f_{bbtrbotd}=1E9$ Vm^{-1}
Normalization field at the reference temperature for band-to-band tunneling of bottom component for drain-bulk junction.
- 609 $f_{bbtrstid}=1E9$ Vm^{-1}
Normalization field at the reference temperature for band-to-band tunneling of STI-edge component for drain-bulk junction.
- 610 $f_{bbtrgatd}=1E9$ Vm^{-1}
Normalization field at the reference temperature for band-to-band tunneling of gate-edge component for drain-bulk junction.
- 611 $stf_{bbtbotd}=-1E-3$ K^{-1}
Temperature scaling parameter for band-to-band tunneling of bottom component for drain-bulk junction.
- 612 $stf_{bbtstid}=-1E-3$ K^{-1}
Temperature scaling parameter for band-to-band tunneling of STI-edge component for drain-bulk junction.
- 613 $stf_{bbtgatd}=1E-3$ K^{-1}
Temperature scaling parameter for band-to-band tunneling of gate-edge component for drain-bulk junction.
- 614 $v_{brbotd}=10$ V Breakdown voltage of bottom component for drain-bulk junction.
- 615 $v_{brstid}=10$ V Breakdown voltage of STI-edge component for drain-bulk junction.

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616	<code>vbrgatd=10 V</code>	Breakdown voltage of gate-edge component for drain-bulk junction.
617	<code>pbrbotd=4 V</code>	Breakdown onset tuning parameter of bottom component for drain-bulk junction.
618	<code>pbrstid=4 V</code>	Breakdown onset tuning parameter of STI-edge component for drain-bulk junction.
619	<code>pbrgatd=4 V</code>	Breakdown onset tuning parameter of gate-edge component for drain-bulk junction.
620	<code>swjunexp=0</code>	Flag for JUNCAP-express; 0,full model, 1,express model.
621	<code>vjunref=2.5</code>	Typical maximum source-bulk junction voltage; usually about 2*VSUP.
622	<code>fjunq=0.03</code>	Fraction below which source-bulk junction capacitance components are considered negligible.
623	<code>vjunrefd=2.5</code>	Typical maximum drain-bulk junction voltage; usually about 2*VSUP.
624	<code>fjunqd=0.03</code>	Fraction below which drain-bulk junction capacitance components are considered negligible.
625	<code>dta=0.0 K</code>	Temperature offset w.r.t. ambient temperature.
626	<code>w=10e-6 m</code>	Default width.
627	<code>l=10e-6 m</code>	Default length.
628	<code>nf=1</code>	Number of fingers, It served as the default value of instance nf.
629	<code>vds_max=infinity V</code>	Maximum allowed voltage cross source and drain.
630	<code>vgd_max=infinity V</code>	Maximum allowed voltage cross gate and drain.
631	<code>vgs_max=infinity V</code>	Maximum allowed voltage cross gate and source/bulk.

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632	<code>vbd_max=infinity</code>	V	Maximum allowed voltage cross source/drain and bulk.
633	<code>vbs_max=infinity</code>	V	Maximum allowed voltage cross source and bulk.
634	<code>vgb_max=infinity</code>	V	Maximum allowed voltage cross gate and bulk.
635	<code>vthmod</code>		Vth output selector. std outputs model equation Vth. vthcc outputs constant current Vth, and may impact simulation performance. The default value is taken from the options parameter vthmod. Possible values are <code>std</code> or <code>vthcc</code> .
636	<code>ivth</code>	(A)	Vth current parameter. The default value is taken from the options parameter ivthn or ivthp, depending on the type of the model.
637	<code>ivthw</code>	(m)	Width offset for constant current Vth. The default value is taken from the options parameter ivthw.
638	<code>ivthl</code>	(m)	Length offset for constant current Vth. The default value is taken from the options parameter ivthl.
639	<code>ivth_vdsmin</code>	(V)	Minimum Vds in constant current Vth calculating. The default value is taken from the options parameter ivth_vdsmin.

Output Parameters

1	<code>lv2</code>	(m)	alias of w.
2	<code>lv1</code>	(m)	alias of l.
3	<code>lv3</code>	(m ²)	alias of ad.
4	<code>lv4</code>	(m ²)	alias of as.
5	<code>lv11</code>	(m)	alias of pd.
6	<code>lv12</code>	(m)	alias of ps.

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7 `table_pseff` (m) For table model.

8 `table_pdeff` (m) For table model.

Operating-Point Parameters

1 `l=10e-6` m Design length.

2 `w=10e-6` m Design width.

3 `sa=0.0` m Distance between OD-edge and poly from one side.

4 `sb=0.0` m Distance between OD-edge and poly from other side.

5 `sd=0.0` m Distance between neighboring fingers.

6 `sca=0.0` Integral of the first distribution function for scattered well dopants.

7 `scb=0.0` Integral of the second distribution function for scattered well dopants.

8 `scc=0.0` Integral of the third distribution function for scattered well dopants.

9 `sc=0.0` m Distance between OD-edge and nearest well edge.

10 `nf=1` Number of fingers.

11 `ngcon=1.0` Number of gate contacts.

12 `xgw= 1.0E-7` m Distance from the gate contact to the channel edge.

13 `nrs=0.0` Number of squares of source diffusion.

14 `nrd=0.0` Number of squares of drain diffusion.

15 `trise=0.0` K Temperature rise from ambient.

16 `jw=1E-6` m Gate-edge length of source/drain junction.

17 `delvto=0.0` V Threshold voltage shift parameter.

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18	<code>factuo=1.0</code>	Zero-field mobility pre-factor.
19	<code>absource=1E-12 m^2</code>	Bottom area of source junction.
20	<code>lssource=1E-6 m</code>	STI-edge length of source junction.
21	<code>lgsource=1E-6 m</code>	Gate-edge length of source junction.
22	<code>abdRAIN=1E-12 m^2</code>	Bottom area of drain junction.
23	<code>lsdRAIN=1E-6 m</code>	STI-edge length of drain junction.
24	<code>lgdRAIN=1E-6 m</code>	Gate-edge length of drain junction.
25	<code>as=1E-12 m^2</code>	Bottom area of source junction.
26	<code>ps=1E-6 m</code>	Perimeter of source junction.
27	<code>ad=1E-12 m^2</code>	Bottom area of drain junction.
28	<code>pd=1E-6 m</code>	Perimeter of drain junction.
29	<code>ctype</code>	Flag for channel type.
30	<code>sdint</code>	Flag for source-drain interchange.
31	<code>ise (A)</code>	Total source current.
32	<code>ige (A)</code>	Total gate current.
33	<code>ide (A)</code>	Total drain current.
34	<code>ibe (A)</code>	Total bulk current.
35	<code>ids (A)</code>	Drain current, excl. avalanche, tunnel, GISL, GIDL, and junction currents.
36	<code>idb (A)</code>	Drain to bulk current.
37	<code>isb (A)</code>	Source to bulk current.
38	<code>igs (A)</code>	Gate-source tunneling current.

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39	i_{gd} (A)	Gate-drain tunneling current.
40	i_{gb} (A)	Gate-bulk tunneling current.
41	i_{gcs} (A)	Gate-channel tunneling current (source component.
42	i_{gcd} (A)	Gate-channel tunneling current (drain component.
43	i_{avl} (A)	Substrate current due to weak avalanche.
44	i_{gisl} (A)	Gate-induced source leakage current.
45	i_{gidl} (A)	Gate-induced drain leakage current.
46	i_{js} (A)	Total source junction current.
47	i_{jsbot} (A)	Source junction current (bottom component.
48	i_{jsgat} (A)	Source junction current (gate-edge component.
49	i_{jssti} (A)	Source junction current (STI-edge component.
50	i_{jd} (A)	Total drain junction current.
51	i_{jdbot} (A)	Drain junction current (bottom component.
52	i_{jdgat} (A)	Drain junction current (gate-edge component.
53	i_{jdsti} (A)	Drain junction current (STI-edge component.
54	q_g (Coul)	Intrinsic gate charge.
55	q_d (Coul)	Intrinsic drain charge.
56	q_b (Coul)	Intrinsic bulk charge.
57	q_s (Coul)	Intrinsic source charge.
58	q_{gs_ov} (Coul)	Overlap charge for gate-source.
59	q_{gd_ov} (Coul)	Overlap charge for gate-drain.
60	q_{fgs} (Coul)	Total outerFringe + overlap for gate-source.

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61	qfgd (Coul)	Total outerFringe + overlap for gate-drain.
62	qgb_ov (Coul)	Gate-bulk overlap charge.
63	qjun_s (Coul)	Junction charge on source side.
64	qjun_d (Coul)	Junction charge on drain side.
65	vds (V)	Drain-source voltage.
66	vgs (V)	Gate-source voltage.
67	vsb (V)	Source-bulk voltage.
68	vto (V)	Zero-bias threshold voltage.
69	vtb (V)	Threshold voltage including back bias effects.
70	vth (V)	Threshold voltage including back bias and drain bias effects.
71	vgt (V)	Effective gate drive voltage including back bias and drain bias effects.
72	vdss (V)	Drain saturation voltage at actual bias.
73	vsat	Saturation limit.
74	gm (1/Ohm)	Transconductance.
75	gmb (1/Ohm)	Substrate transconductance.
76	gds (1/Ohm)	Output conductance.
77	gjs (1/Ohm)	Source junction conductance.
78	gjd (1/Ohm)	Drain junction conductance.
79	cd_d (F)	Drain capacitance.
80	cd_g (F)	Drain-gate capacitance.
81	cd_s (F)	Drain-source capacitance.

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82	<code>cdb</code> (F)	Drain-bulk capacitance.
83	<code>cgd</code> (F)	Gate-drain capacitance.
84	<code>cgg</code> (F)	Gate capacitance.
85	<code>cgs</code> (F)	Gate-source capacitance.
86	<code>cgb</code> (F)	Gate-bulk capacitance.
87	<code>csd</code> (F)	Source-drain capacitance.
88	<code>csg</code> (F)	Source-gate capacitance.
89	<code>css</code> (F)	Source capacitance.
90	<code>csb</code> (F)	Source-bulk capacitance.
91	<code>cbd</code> (F)	Bulk-drain capacitance.
92	<code>cbg</code> (F)	Bulk-gate capacitance.
93	<code>cbs</code> (F)	Bulk-source capacitance.
94	<code>ccb</code> (F)	Bulk capacitance.
95	<code>cgsol</code> (F)	Total gate-source overlap capacitance.
96	<code>cgdol</code> (F)	Total gate-drain overlap capacitance.
97	<code>cgbol</code> (F)	Total gate-bulk overlap capacitance.
98	<code>cjs</code> (F)	Total source junction capacitance.
99	<code>cjsbot</code> (F)	Source junction capacitance (bottom component.
100	<code>cjsgat</code> (F)	Source junction capacitance (gate-edge component.
101	<code>cjssti</code> (F)	Source junction capacitance (STI-edge component.
102	<code>cjd</code> (F)	Total drain junction capacitance.
103	<code>cjdbot</code> (F)	Drain junction capacitance (bottom component.

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104	<code>cjdgat</code> (F)	Drain junction capacitance (gate-edge component.
105	<code>cjdsti</code> (F)	Drain junction capacitance (STI-edge component.
106	<code>weff</code> (m)	Effective channel width for geometrical models.
107	<code>leff</code> (m)	Effective channel length for geometrical models.
108	<code>lpoly</code> (m)	
109	<code>u</code>	Transistor gain.
110	<code>rout</code> (Ohm)	Small-signal output resistance.
111	<code>vearly</code> (V)	Equivalent Early voltage.
112	<code>beff</code> (A/V ²)	Gain factor.
113	<code>fug</code> (Hz)	Unity gain frequency at actual bias.
114	<code>rg</code> (Ohm)	Gate resistance.
115	<code>sfl</code>	Flicker noise current density at 1 Hz.
116	<code>sqrtsff</code>	Input-referred RMS white noise voltage density at 1 kHz.
117	<code>sqrtsfw</code>	Input-referred RMS white noise voltage density.
118	<code>sid</code>	White noise current density.
119	<code>sig</code>	Induced gate noise current density at 1 Hz.
120	<code>cigid</code>	Imaginary part of correlation coefficient between Sig and Sid.
121	<code>fknee</code>	Cross-over frequency above which white noise is dominant.
122	<code>sig_s</code>	Gate-source current noise spectral density.
123	<code>sig_d</code>	Gate-drain current noise spectral density.
124	<code>siavl</code>	Impact ionization current noise spectral density.
125	<code>ssi</code>	Total source junction current noise spectral density.

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126	<code>sdi</code>	Total drain junction current noise spectral density.
127	<code>lp_vfb (V)</code>	Local parameter VFB after T-scaling and clipping.
128	<code>lp_stvfb (V/K)</code>	Local parameter STVFB after clipping.
129	<code>lp_tox (m)</code>	Local parameter TOX after clipping.
130	<code>lp_epsrox</code>	Local parameter EPSROX after clipping.
131	<code>lp_neff (m⁻³)</code>	Local parameter NEFF after clipping.
132	<code>lp_facneffac</code>	Local parameter FACNEFFAC after clipping.
133	<code>lp_gfacnud</code>	Local parameter GFACNUD after clipping.
134	<code>lp_vsbnud (V)</code>	Local parameter VSBNUD after clipping.
135	<code>lp_dvsbnud (V)</code>	Local parameter DVSBNUD after clipping.
136	<code>lp_vnsub (V)</code>	Local parameter VNSUB after clipping.
137	<code>lp_nslp (V)</code>	Local parameter NSLP after clipping.
138	<code>lp_dnsud (V⁻¹)</code>	Local parameter DNSUD after clipping.
139	<code>lp_dphib (V)</code>	Local parameter DPHIB after clipping.
140	<code>lp_delvtac (V)</code>	Local parameter DELVTAC after clipping.
141	<code>lp_np (m⁻³)</code>	Local parameter NP after clipping.
142	<code>lp_ct</code>	Local parameter CT after clipping.
143	<code>lp_toxov (m)</code>	Local parameter TOXOV after clipping.
144	<code>lp_toxovd (m)</code>	Local parameter TOXOVD after clipping.
145	<code>lp_nov (m⁻³)</code>	Local parameter NOV after clipping.
146	<code>lp_novd (m⁻³)</code>	Local parameter NOVD after clipping.

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147	lp_cf	Local parameter CF after clipping.
148	lp_cfb (V^{-1})	Local parameter CFB after clipping.
149	lp_betn ($m^2/V s$)	Local parameter BETN after T-scaling and clipping.
150	lp_stbet	Local parameter STBET after clipping.
151	lp_mue (m/V)	Local parameter MUE after T-scaling and clipping.
152	lp_stmue	Local parameter STMUE after clipping.
153	lp_themu	Local parameter THEMU after T-scaling and clipping.
154	lp_stthemu	Local parameter STTHEMU after clipping.
155	lp_cs	Local parameter CS after T-scaling and clipping.
156	lp_stcs	Local parameter STCS after clipping.
157	lp_xcor (V^{-1})	Local parameter XCOR after T-scaling and clipping.
158	lp_stxcor	Local parameter STXCOR after clipping.
159	lp_feta	Local parameter FETA after clipping.
160	lp_rs (Ohm)	Local parameter RS after T-scaling and clipping.
161	lp_strs	Local parameter STRS after clipping.
162	lp_rsb (V^{-1})	Local parameter RSB after clipping.
163	lp_rsg (V^{-1})	Local parameter RSG after clipping.
164	lp_thesat (V^{-1})	Local parameter THESAT after T-scaling and clipping.
165	lp_stthesat	Local parameter STTHESAT after clipping.
166	lp_thesatb (V^{-1})	Local parameter THESATB after clipping.

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167	$lp_thesatg$ (V^{-1})	Local parameter THESATG after clipping.
168	lp_ax	Local parameter AX after clipping.
169	lp_alp	Local parameter ALP after clipping.
170	lp_alp1 (V)	Local parameter ALP1 after clipping.
171	lp_alp2 (V^{-1})	Local parameter ALP2 after clipping.
172	lp_vp (V)	Local parameter VP after clipping.
173	lp_a1	Local parameter A1 after clipping.
174	lp_a2 (V)	Local parameter A2 after T-scaling and clipping.
175	lp_sta2	Local parameter STA2 after clipping.
176	lp_a3	Local parameter A3 after clipping.
177	lp_a4 ($1/\sqrt{V}$)	Local parameter A4 after clipping.
178	lp_gco	Local parameter GCO after clipping.
179	lp_iginv (A)	Local parameter IGINV after T-scaling and clipping.
180	lp_igov (A)	Local parameter IGOV after T-scaling and clipping.
181	lp_igovd (A)	Local parameter IGOVD after T-scaling and clipping.
182	lp_stig	Local parameter STIG after clipping.
183	lp_gc2	Local parameter GC2 after clipping.
184	lp_gc3	Local parameter GC3 after clipping.
185	lp_chib (V)	Local parameter CHIB after clipping.
186	lp_agidl (A/V^3)	Local parameter AGIDL after clipping.

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187	lp_agidld (A/V ³)	Local parameter AGIDLD after clipping.
188	lp_bgidl (V)	Local parameter BGIDL after T-scaling and clipping.
189	lp_bgidld (V)	Local parameter BGIDLD after T-scaling and clipping.
190	lp_stbgidl (V/K)	Local parameter STBGIDL after clipping.
191	lp_stbgidld (V/K)	Local parameter STBGIDLD after clipping.
192	lp_cgidl	Local parameter CGIDL after clipping.
193	lp_cgidld	Local parameter CGIDLD after clipping.
194	lp_cox (F)	Local parameter COX after clipping.
195	lp_cgov (F)	Local parameter CGOV after clipping.
196	lp_cgovd (F)	Local parameter CGOVD after clipping.
197	lp_cgbov (F)	Local parameter CGBOV after clipping.
198	lp_cfr (F)	Local parameter CFR after clipping.
199	lp_cfrd (F)	Local parameter CFRD after clipping.
200	lp_fnt	Local parameter FNT after clipping.
201	lp_nfa (1/(V m ⁴))	Local parameter NFA after clipping.
202	lp_nfb (1/(V m ²))	Local parameter NFB after clipping.
203	lp_nfc (V ⁻¹)	Local parameter NFC after clipping.
204	lp_ef	Local parameter EF after clipping.
205	lp_rg (Ohm)	Local parameter RG after clipping.

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206	lp_rse (Ohm)	Local parameter RSE after clipping.
207	lp_rde (Ohm)	Local parameter RDE after clipping.
208	lp_rbulk (Ohm)	Local parameter RBULK after clipping.
209	lp_rwell (Ohm)	Local parameter RWELL after clipping.
210	lp_rjuns (Ohm)	Local parameter RJUNS after clipping.
211	lp_rjund (Ohm)	Local parameter RJUND after clipping.
212	lp_munqs	Local parameter MUNQS after clipping.
213	lv13	alias of nrd.
214	lv14	alias of nrs.
215	lv36 (F)	alias of cgsol.
216	lv37 (F)	alias of cgdol.
217	lv38 (F)	alias of cgbol.
218	table_ids (A)	For table model.
219	table_vth (V)	For table model.
220	table_qg (coul)	For table model.
221	table_qd (coul)	For table model.
222	table_qb (Coul)	For table model.
223	table_id (A)	For table model.
224	table_isub (A)	For table model.
225	table_ibs (A)	For table model.

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226	table_ibd (A)	For table model.
227	table_igd (A)	For table model.
228	table_igb (A)	For table model.
229	table_igs (A)	For table model.
230	table_gds (1/Ohm)	For table model.
231	table_gm (1/Ohm)	For table model.
232	table_gmbs (1/Ohm)	For table model.
233	table_qbs (Coul)	For table model.
234	table_qbd (Coul)	For table model.
235	table_vdsat (V)	For table model.
236	table_leff (m)	For table model.
237	table_weff (m)	For table model.
238	table_aseff (m ²)	For table model.
239	table_adeff (m ²)	For table model.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

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a1	M-66	igovw	M-470	pla3	M-237	rbulk	M-102
a1l	M-458	igs	OP-38	pla4	M-241	rbulko	M-510
a1o	M-457	ijd	OP-50	plagidl	M-262	rde	M-101
a1w	M-459	ijdbot	OP-51	plagidld	M-266	rg	M-99
a2	M-67	ijdgat	OP-52	plalp	M-218	rg	OP-114
a2o	M-460	ijdsti	OP-53	plalpl	M-222	rgo	M-503
a3	M-69	ijs	OP-46	plalp2	M-226	rint	M-504
a3l	M-463	ijsbot	OP-47	plax	M-214	rjund	M-105
a3o	M-462	ijsgat	OP-48	plbetn	M-165	rjundo	M-513
a3w	M-464	ijssti	OP-49	plcf	M-160	rjuns	M-104
a4	M-70	imax	M-536	plcfr	M-292	rjunso	M-512
a4l	M-466	isb	OP-37	plcfrd	M-296	rout	OP-110
a4o	M-465	ise	OP-31	plcgbov	M-288	rs	M-53
a4w	M-467	isnoisy	I-32	plcgov	M-280	rsb	M-55
abdrain	I-22	ivth	M-636	plcgovd	M-284	rsbo	M-430
abdrain	OP-22	ivth_vdsmin	M-639	plcox	M-276	rse	M-100
absorce	I-19	ivthl	M-638	plcs	M-180	rsg	M-56
absorce	OP-19	ivthw	M-637	plct	M-146	rsgo	M-431
ad	I-27	jw	I-16	pldelvtac	M-138	rsh	M-508
ad	OP-27	jw	OP-16	pldphib	M-134	rshd	M-509

Virtuoso Simulator Components and Device Models Reference PSP103 Model

agidl M-79	kuo M-517	plfacneffac M-121	rshg M-506
agidd M-80	kuowel M-499	plgfacnud M-125	rsw1 M-427
agiddw M-477	kuowelw M-501	pliginv M-246	rsw2 M-428
agidlw M-476	kuoweo M-498	pligov M-250	rvpoly M-505
alp M-62	kuowew M-500	pligovd M-254	rwell M-103
alp1 M-63	kvsat M-518	plkuowe M-318	rwello M-511
alp111 M-448	kvtho M-525	plkvthowe M-314	sa I-3
alp112 M-450	kvthowel M-495	plmue M-173	sa OP-3
alp1lexp M-449	kvthowelw M-497	plneff M-117	saref M-514
alp1w M-451	kvthoweo M-494	plnfa M-301	sb I-4
alp2 M-64	kvthowew M-496	plnfb M-305	sb OP-4
alp211 M-452	l I-1	plnfc M-309	sbref M-515
alp212 M-454	l M-627	plnov M-152	sc I-9
alp2lexp M-453	l OP-1	plnovd M-156	sc OP-9
alp2w M-455	lap M-328	plnp M-142	sca I-6
alp1 M-445	leff OP-107	plrs M-191	sca OP-6
alplexp M-446	level M-1	plstbet M-169	scb I-7
alpnoi M-493	lgdrain I-24	plstthesat M-202	scb OP-7
alpww M-447	lgdrain OP-24	plstvfb M-111	scc I-8
as I-25	lgsource I-21	plthesat M-198	scc OP-8

Virtuoso Simulator Components and Device Models Reference

PSP103 Model

as	OP-25	lgsource	OP-21	plthesatb	M-206	scref	M-533
ax	M-61	lintnoi	M-492	plthesatg	M-210	sd	I-5
axl	M-444	lkuo	M-520	plvfb	M-107	sd	OP-5
axo	M-443	lkvtho	M-526	plwal	M-233	sdi	OP-126
beff	OP-112	llodkuo	M-523	plwa3	M-239	sdint	OP-30
betn	M-42	llodvth	M-529	plwa4	M-243	sfl	OP-115
betw1	M-403	lmax	M-322	plwagidl	M-264	siavl	OP-124
betw2	M-404	lmin	M-321	plwagidld	M-268	sid	OP-118
bgidl	M-81	lodetao	M-532	plwalp	M-220	sig	OP-119
bgidld	M-82	lov	M-388	plwalp1	M-224	sigd	OP-123
bgidldo	M-479	lovd	M-389	plwalp2	M-228	sigs	OP-122
bgidlo	M-478	lp1	M-399	plwax	M-216	sqrtsff	OP-116
cbb	OP-94	lp1w	M-400	plwbetn	M-167	sqrtsfw	OP-117
cbbtbot	M-564	lp2	M-402	plwcf	M-162	ssi	OP-125
cbbtbotd	M-605	lp_a1	OP-173	plwcfrr	M-294	sta2	M-68
cbbtgat	M-566	lp_a2	OP-174	plwcfrrd	M-298	sta2o	M-461
cbbtgatd	M-607	lp_a3	OP-176	plwcgbov	M-290	stbet	M-43
cbbtsti	M-565	lp_a4	OP-177	plwcgov	M-282	stbet1	M-407
cbbtstid	M-606	lp_agidl	OP-186	plwcgovd	M-286	stbetlw	M-409
cbd	OP-91	lp_agidld	OP-187	plwcox	M-278	stbeto	M-406
cbg	OP-92	lp_alp	OP-169	plwcs	M-182	stbetw	M-408

Virtuoso Simulator Components and Device Models Reference

PSP103 Model

cbs	OP-93	lp_alp1	OP-170	plwct	M-148	stbgidl	M-83
cdb	OP-82	lp_alp2	OP-171	plwdelvtac	M-140	stbgidld	M-84
cdd	OP-79	lp_ax	OP-168	plwdphib	M-136	stbgidldo	M-481
cdg	OP-80	lp_betn	OP-149	plwfacneffac	M-123	stbgidlo	M-480
cds	OP-81	lp_bgidl	OP-188	plwgfacnud	M-127	stcs	M-49
cf	M-40	lp_bgidld	OP-189	plwiginv	M-248	stcso	M-420
cfb	M-41	lp_cf	OP-147	plwigov	M-252	stetao	M-531
cfbo	M-395	lp_cfb	OP-148	plwigovd	M-256	stfbbtbot	M-570
cf1	M-392	lp_cfr	OP-198	plwkuowe	M-320	stfbbtbotd	M-611
cflexp	M-393	lp_cfrd	OP-199	plwkvthowe	M-316	stfbbtgat	M-572
cfr	M-91	lp_cgbov	OP-197	plwmue	M-175	stfbbtgatd	M-613
cfrd	M-92	lp_cgidl	OP-192	plwneff	M-119	stfbbtsti	M-571
cfrdw	M-486	lp_cgidld	OP-193	plwnfa	M-303	stfbbtstid	M-612
cfrw	M-485	lp_cgov	OP-195	plwnfb	M-307	stig	M-75
cfw	M-394	lp_cgovd	OP-196	plwnfc	M-311	stigo	M-472
cgb	OP-86	lp_chib	OP-185	plwnov	M-154	stmue	M-45
cgbol	OP-97	lp_cox	OP-194	plwnovd	M-158	stmueo	M-412
cgbov	M-90	lp_cs	OP-155	plwnp	M-144	strs	M-54
cgbovl	M-484	lp_ct	OP-142	plwrs	M-193	strso	M-429
cgd	OP-83	lp_delvtac	OP-140	plwstbet	M-171	stthemu	M-47

Virtuoso Simulator Components and Device Models Reference

PSP103 Model

cgdol	OP-96	lp_dnsb	OP-138	plwstthesat	M-204	stthemuo	M-414
cgg	OP-84	lp_dphib	OP-139	plwstvfb	M-113	stthesat	M-58
cgidl	M-85	lp_dvsbnud	OP-135	plwthesat	M-200	stthesatl	M-438
cgidld	M-86	lp_ef	OP-204	plwthesatb	M-208	stthesatlw	M-440
cgidldo	M-483	lp_epsrox	OP-130	plwthesatg	M-212	stthesato	M-437
cgidlo	M-482	lp_facneffac	OP-132	plwvfb	M-109	stthesatw	M-439
cgov	M-88	lp_feta	OP-159	plwxcor	M-187	stvfb	M-21
cgovd	M-89	lp_fnt	OP-200	plxcor	M-185	stvfb1	M-340
cgs	OP-85	lp_gc2	OP-183	poa1	M-230	stvfb1w	M-342
cgsol	OP-95	lp_gc3	OP-184	poa2	M-234	stvfb0	M-339
chib	M-78	lp_gco	OP-178	poa3	M-236	stvfbw	M-341
chibo	M-475	lp_gfacnud	OP-133	poa4	M-240	stxcor	M-51
cigid	OP-120	lp_iginv	OP-179	poagidl	M-261	stxcoro	M-425
cjd	OP-102	lp_igov	OP-180	poagidld	M-265	swdelvtac	M-12
cjdbot	OP-103	lp_igovd	OP-181	poalp	M-217	swgeo	M-5
cjdgat	OP-104	lp_mue	OP-151	poalp1	M-221	swgidl	M-8
cjdsti	OP-105	lp_munqs	OP-212	poalp2	M-225	swigate	M-6
cjorbot	M-538	lp_neff	OP-131	poax	M-213	swimpact	M-7
cjorbotd	M-579	lp_nfa	OP-201	pobetn	M-164	swjunasym	M-10

Virtuoso Simulator Components and Device Models Reference

PSP103 Model

cjorgat	M-540	lp_nfb	OP-202	pobgidl	M-269	swjuncap	M-9
cjorgatd	M-581	lp_nfc	OP-203	pobgidld	M-270	swjunexp	M-620
cjorsti	M-539	lp_nov	OP-145	pocf	M-159	swnqs	M-4
cjorstid	M-580	lp_novd	OP-146	pocfb	M-163	swnud	M-11
cjs	OP-98	lp_np	OP-141	pocfr	M-291	table_adeff	OP-239
cjsbot	OP-99	lp_nslp	OP-137	pocfrd	M-295	table_aseff	OP-238
cjsgat	OP-100	lp_rbulk	OP-208	pocgbov	M-287	table_gds	OP-230
cjssti	OP-101	lp_rde	OP-207	pocgidl	M-273	table_gm	OP-231
cox	M-87	lp_rg	OP-205	pocgidld	M-274	table_gmbs	OP-232
cs	M-48	lp_rjund	OP-211	pocgov	M-279	table_ibd	OP-226
csb	OP-90	lp_rjuns	OP-210	pocgovd	M-283	table_ibs	OP-225
csd	OP-87	lp_rs	OP-160	pochib	M-260	table_id	OP-223
csg	OP-88	lp_rsb	OP-162	pocox	M-275	table_ids	OP-218
csl	M-416	lp_rse	OP-206	pocs	M-179	table_igb	OP-228
cslexp	M-417	lp_rsg	OP-163	poct	M-145	table_igd	OP-227
cslw	M-419	lp_rwell	OP-209	podelvtac	M-137	table_igs	OP-229
cso	M-415	lp_sta2	OP-175	podnsub	M-132	table_isub	OP-224
csrbot	M-553	lp_stbet	OP-150	podphib	M-133	table_leff	OP-236
csrbotd	M-594	lp_stbgidl	OP-190	podvsbnud	M-129	table_pdeff	O-8

Virtuoso Simulator Components and Device Models Reference

PSP103 Model

csrhgat	M-555	lp_stbgidld	OP-191	poef	M-312	table_pseff	O-7
csrhgatd	M-596	lp_stcs	OP-156	poepsrox	M-115	table_qb	OP-222
csrhsti	M-554	lp_stig	OP-182	pofacneffac	M-120	table_qbd	OP-234
csrhstid	M-595	lp_stmue	OP-152	pofeta	M-189	table_qbs	OP-233
css	OP-89	lp_strs	OP-161	pofnt	M-299	table_qd	OP-221
csw	M-418	lp_stthemu	OP-154	pogc2	M-258	table_qg	OP-220
ct	M-35	lp_stthesat	OP-165	pogc3	M-259	table_vdsat	OP-235
ctatbot	M-558	lp_stvfb	OP-128	pogco	M-244	table_vth	OP-219
ctatbotd	M-599	lp_stxcor	OP-158	pogfacnud	M-124	table_weff	OP-237
ctatgat	M-560	lp_themu	OP-153	poiginv	M-245	themu	M-46
ctatgatd	M-601	lp_thesat	OP-164	poigov	M-249	themuo	M-413
ctatsti	M-559	lp_thesatb	OP-166	poigovd	M-253	thesat	M-57
ctatstid	M-600	lp_thesatg	OP-167	pokuowe	M-317	thesatb	M-59
ctl	M-382	lp_tox	OP-129	pokvthowe	M-313	thesatbo	M-441
ctlexp	M-383	lp_toxov	OP-143	pomue	M-172	thesatg	M-60
ctlw	M-385	lp_toxovd	OP-144	poneff	M-116	thesatgo	M-442
cto	M-381	lp_vfb	OP-127	ponfa	M-300	thesatl	M-433
ctw	M-384	lp_vnsub	OP-136	ponfb	M-304	thesatlexp	M-434

Virtuoso Simulator Components and Device Models Reference PSP103 Model

ctype	OP-29	lp_vp	OP-172	ponfc	M-308	thesatlw	M-436
delvtac	M-33	lp_vsbnud	OP-134	ponov	M-151	thesato	M-432
delvtac1	M-375	lp_xcor	OP-157	ponovd	M-155	thesatw	M-435
delvtaclexp	M-376	lpck	M-351	ponp	M-141	tkuo	M-519
delvtac1w	M-378	lpckw	M-352	ponslp	M-131	tox	M-22
delvtaco	M-374	lpoly	OP-108	pors	M-190	tox0	M-343
delvtacw	M-377	lsdrain	I-23	porsb	M-195	toxov	M-36
delvto	I-17	lsdrain	OP-23	porsg	M-196	toxovd	M-37
delvto	OP-17	lssource	I-20	posta2	M-235	toxovdo	M-387
dlq	M-333	lssource	OP-20	postbet	M-168	toxovo	M-386
dlsil	M-507	lv1	O-2	postbgidl	M-271	tr	M-3
dnsub	M-31	lv11	O-5	postbgidld	M-272	trise	I-15
dnsubo	M-368	lv12	O-6	postcs	M-183	trise	OP-15
dphib	M-32	lv13	OP-213	postig	M-257	trj	M-537
dphib1	M-370	lv14	OP-214	postmue	M-176	type	M-2
dphiblexp	M-371	lv2	O-1	postrs	M-194	u	OP-109
dphib1w	M-373	lv3	O-3	postthemu	M-178	uo	M-396
dphibo	M-369	lv36	OP-215	postthesat	M-201	vbd_max	M-632
dphibw	M-372	lv37	OP-216	postvfb	M-110	vbirbot	M-541
dta	M-625	lv38	OP-217	postxcor	M-188	vbirbotd	M-582

Virtuoso Simulator Components and Device Models Reference

PSP103 Model

dvsbnud M-28	lv4 O-4	pothemu M-177	vbirgat M-543
dvsbnudo M-365	lvarl M-326	pothesat M-197	vbirgatd M-584
dwq M-334	lvaro M-325	pothesatb M-205	vbirsti M-542
ef M-97	lvarw M-327	pothesatg M-209	vbirstid M-583
efo M-491	m I-31	potox M-114	vbrbot M-573
epsrox M-23	mbe M-18	potoxov M-149	vbrbotd M-614
epsroxo M-344	mbeo M-19	potoxovd M-150	vbrgat M-575
facneffac M-25	mefftatbot M-561	povfb M-106	vbrgatd M-616
facneffacl M-356	mefftatbotd M-602	povnsb M-130	vbrsti M-574
facneffaclw M-358	mefftatgat M-563	povp M-229	vbrstid M-615
facneffaco M-355	mefftatgatd M-604	povsbnud M-128	vbs_max M-633
facneffacw M-357	mefftatsti M-562	poxcor M-184	vds OP-65
factuo I-18	mefftatstid M-603	ps I-26	vds_max M-629
factuo OP-18	minr M-15	ps OP-26	vdss OP-72
fbtrbot M-567	mue M-44	psti M-545	vearly OP-111
fbtrbotd M-608	mueo M-410	pstid M-586	version M-14
fbtrgat M-569	muew M-411	pwal M-232	vfb M-20
fbtrgatd M-610	mulid0 I-30	pwa3 M-238	vfb1 M-336
fbtrsti M-568	mult I-29	pwa4 M-242	vfb1w M-338

Virtuoso Simulator Components and Device Models Reference

PSP103 Model

fbtrstid M-609	munqs M-98	pwagidl M-263	vfbo M-335
fbet1 M-397	munqso M-502	pwagidld M-267	vfbo M-337
fbet1w M-398	mvt M-16	pwalp M-219	vgb_max M-634
fbet2 M-401	mvto M-17	pwalpl M-223	vgd_max M-630
feta M-52	neff M-24	pwalp2 M-227	vgs OP-66
fetao M-426	nf I-10	pwax M-215	vgs_max M-631
fjunq M-622	nf M-628	pwbetn M-166	vgt OP-71
fjunqd M-624	nf OP-10	pwcf M-161	vjunref M-621
fknee OP-121	nfa M-94	pwcfr M-293	vjunrefd M-623
fnt M-93	nfalw M-488	pwcfrd M-297	vnsb M-29
fnto M-487	nfb M-95	pwcgbov M-289	vnsbo M-366
fol1 M-353	nfblw M-489	pwcgov M-281	vp M-65
fol2 M-354	nfc M-96	pwcgovd M-285	vpo M-456
fug OP-113	nfclw M-490	pwcox M-277	vsat OP-73
gc2 M-76	ngcon I-11	pwcs M-181	vsb OP-67
gc2o M-473	ngcon OP-11	pwct M-147	vsbnud M-27
gc3 M-77	nov M-38	pwdelvtac M-139	vsbnudo M-364
gc3o M-474	novd M-39	pwdphib M-135	vth OP-70
gco M-71	novdo M-391	pwfacneffac M-122	vthmod M-635
gcoo M-468	novo M-390	pwgfacnud M-126	vto OP-68

Virtuoso Simulator Components and Device Models Reference PSP103 Model

gds OP-76	np M-34	pwiginv M-247	vts OP-69
gfacnud M-26	npck M-348	pwigov M-251	w I-2
gfacnudl M-360	npckw M-349	pwigovd M-255	w M-626
gfacnudlexp M-361	npl M-380	pwkuowe M-319	w OP-2
gfacnudlw M-363	npo M-379	pwkvthowe M-315	wbet M-405
gfacnudo M-359	nrd I-14	pwmue M-174	web M-534
gfacnudw M-362	nrd OP-14	pwneff M-118	wec M-535
gjd OP-78	nrs I-13	pwnfa M-302	weff OP-106
gjs OP-77	nrs OP-13	pwnfb M-306	wkuo M-521
gm OP-74	nslp M-30	pwnfc M-310	wkvtho M-527
gmb OP-75	nslpo M-367	pwnov M-153	wlod M-516
iavl OP-43	nsubo M-345	pwnovd M-157	wlodkuo M-524
ibe OP-34	nsubw M-346	pwnp M-143	wlodvth M-530
idb OP-36	pbot M-544	pwrs M-192	wmax M-324
ide OP-33	pbotd M-585	pwstbet M-170	wmin M-323
ids OP-35	pbrbot M-576	pwstthesat M-203	wot M-332
idsatrbot M-550	pbrbotd M-617	pwstvfb M-112	wseg M-347
idsatrbotd M-591	pbrgat M-578	pwthesat M-199	wsegp M-350
idsatrgat M-552	pbrgatd M-619	pwthesatb M-207	wvarl M-330
idsatrgatd M-593	pbrsti M-577	pwthesatg M-211	wvaro M-329

Virtuoso Simulator Components and Device Models Reference

PSP103 Model

idsatrsti	M-551	pbrstid	M-618	pwvfb	M-108	wvarw	M-331
idsatrstid	M-592	pd	I-28	pwxcor	M-186	xcor	M-50
igb	OP-40	pd	OP-28	qj	OP-56	xcorl	M-422
igcd	OP-42	pgat	M-546	qd	OP-55	xcorlw	M-424
igcs	OP-41	pgatd	M-587	qfgd	OP-61	xcoro	M-421
igd	OP-39	phigbot	M-547	qfgs	OP-60	xcorw	M-423
ige	OP-32	phigbotd	M-588	qg	OP-54	xgw	I-12
igidl	OP-45	phiggat	M-549	qgb_ov	OP-62	xgw	OP-12
iginv	M-72	phiggatd	M-590	qgd_ov	OP-59	xjungat	M-557
iginvbw	M-469	phigsti	M-548	qgs_ov	OP-58	xjungatd	M-598
igisl	OP-44	phigstid	M-589	qjun_d	OP-64	xjunsti	M-556
igov	M-73	pkuo	M-522	qjun_s	OP-63	xjunstid	M-597
igovd	M-74	pkvtho	M-528	qmc	M-13		
igovdw	M-471	plal	M-231	qs	OP-57		

PSP NQS MOSFET Model (pspnqs103)

Instance Definition

Name d g s b ModelName parameter=value ...

Instance Parameters

- 1 l=10e-6 m Design length.
- 2 w=10e-6 m Design width.

Virtuoso Simulator Components and Device Models Reference

PSP103 Model

3	sa=0.0 m	Distance between OD-edge and poly from one side.
4	sb=0.0 m	Distance between OD-edge and poly from other side.
5	sd=0.0 m	Distance between neighboring fingers.
6	sca=0.0	Integral of the first distribution function for scattered well dopants.
7	scb=0.0	Integral of the second distribution function for scattered well dopants.
8	scc=0.0	Integral of the third distribution function for scattered well dopants.
9	sc=0.0 m	Distance between OD-edge and nearest well edge.
10	nf=1	Number of fingers.
11	ngcon=1.0	Number of gate contacts.
12	xgw=1.0E-7 m	Distance from the gate contact to the channel edge.
13	nrs=0.0	Number of squares of source diffusion.
14	nrd=0.0	Number of squares of drain diffusion.
15	trise=0.0 K	Temperature rise from ambient.
16	jw=1E-6 m	Gate-edge length of source/drain junction.
17	delvto=0.0 V	Threshold voltage shift parameter.
18	factuo=1.0	Zero-field mobility pre-factor.
19	absource=1E-12 m ²	Bottom area of source junction.
20	lssource=1E-6 m	STI-edge length of source junction.
21	lgsource=1E-6 m	Gate-edge length of source junction.
22	abdRAIN=1E-12 m ²	Bottom area of drain junction.

Virtuoso Simulator Components and Device Models Reference

PSP103 Model

23	<code>lsdrain=1E-6 m</code>	STI-edge length of drain junction.
24	<code>lgdrain=1E-6 m</code>	Gate-edge length of drain junction.
25	<code>as=1E-12 m^2</code>	Bottom area of source junction.
26	<code>ps=1E-6 m</code>	Perimeter of source junction.
27	<code>ad=1E-12 m^2</code>	Bottom area of drain junction.
28	<code>pd=1E-6 m</code>	Perimeter of drain junction.
29	<code>mult=1.0</code>	Number of devices in parallel.
30	<code>mlid0=1</code>	Ids multiplier.
31	<code>m=1.0</code>	Multiplicity factor.
32	<code>isnoisy=yes</code>	Should device generate noise. Possible values are <code>no</code> or <code>yes</code> .

Model Definition

```
model modelName pspnqs103 parameter=value ...
```

Model Parameters

1	<code>level=103</code>	Model level.
2	<code>type=n</code>	Channel type parameter, <code>n</code> ,NMOS <code>p</code> ,PMOS. Possible values are <code>n</code> or <code>p</code> .
3	<code>tr=value of tnom C</code>	nominal (reference) temperature.
4	<code>swnqs=0</code>	Flag for NQS, 0,off, 1, 2, 3, 5, or 9,number of collocation points.
5	<code>swgeo=0</code>	Flag for geometrical model, 0,local, 1,global, 2,binning.
6	<code>swigate=0</code>	Flag for gate current, 0,turn off IG.

Virtuoso Simulator Components and Device Models Reference

PSP103 Model

7	swimpact=0	Flag for impact ionization current, 0,turn off II.
8	swgidl=0	Flag for GIDL current, 0,turn off IGIDL.
9	swjuncap=0	Flag for juncap, 0,turn off juncap.
10	swjunasym=0	Flag for asymmetric junctions; 0,symmetric, 1,asymmetric.
11	swnud=0	Flag for NUD-effect; 0,off, 1,on, 2,on+CV-correction.
12	swdelvtac=0	Flag for separate capacitance calculation; 0,off, 1,on.
13	qmc=0	Quantum-mechanical correction factor.
14	version=103.0	Model version selector. The available versions are 103.0, 103.1 and 103.11.
15	minr=0.0	Minimum resistance, in order to be compatible with the original model, set its default to 0.0.
16	mvt=0.0	DCmatch parameter.
17	mvto=0.0	DCmatch parameter.
18	mbe=0.0	DCmatch parameter.
19	mbeo=0.0	DCmatch parameter.
20	vfb=1.0 V	Flat band voltage at TR.
21	stvfb=5.0e-4 V/K	Temperature dependence of VFB.
22	tox=2.0e-09 m	Gate oxide thickness.
23	epsrox=3.9	Relative permittivity of gate dielectric.
24	neff=5.0e+23 m ⁻³	Effective substrate doping.
25	facneffac=1.0	Pre-factor for effective substrate doping in separate charge calculation.
26	gfacnud=1.0	Bodyfactor change due to NUD-effect.

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27	$vsbnud=0.0\text{ V}$	Lower V_{sb} value for NUD-effect.
28	$dvvsbnud=1.0\text{ V}$	V_{sb} -range for NUD-effect.
29	$vnsb=0.0\text{ V}$	Effective doping bias-dependence parameter.
30	$ns1p=0.05\text{ V}$	Effective doping bias-dependence parameter.
31	$dnsb=0.0\text{ V}^{-1}$	Effective doping bias-dependence parameter.
32	$dphib=0.0\text{ V}$	Offset parameter for PHIB.
33	$delvtac=0.0\text{ V}$	Offset parameter for PHIB in separate charge calculation.
34	$np=1.0e+26\text{ m}^{-3}$	Gate poly-silicon doping.
35	$ct=0.0$	Interface states factor.
36	$toxov=2.0e-09\text{ m}$	Overlap oxide thickness.
37	$toxovd=2.0e-09\text{ m}$	Overlap oxide thickness for drain side.
38	$nov=5.0e+25\text{ m}^{-3}$	Effective doping of overlap region.
39	$novd=5.0e+25\text{ m}^{-3}$	Effective doping of overlap region for drain side.
40	$cf=0.0$	DIBL-parameter.
41	$cfb=0.0\text{ V}^{-1}$	Back bias dependence of CF.
42	$betn=7e-2\text{ m}^2/\text{V}/\text{s}$	Channel aspect ratio times zero-field mobility.
43	$stbet=1.0$	Temperature dependence of BETN.
44	$mue=0.5\text{ m}/\text{V}$	Mobility reduction coefficient at TR.
45	$stmue=0.0$	Temperature dependence of MUE.
46	$themu=1.5$	Mobility reduction exponent at TR.
47	$stthemu=1.5$	Temperature dependence of THEMU.
48	$cs=0.0$	Coulomb scattering parameter at TR.

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49	$stcs=0.0$	Temperature dependence of CS.
50	$xcor=0.0 V^{-1}$	Non-universality factor.
51	$stxcor=0.0$	Temperature dependence of XCOR.
52	$feta=1.0$	Effective field parameter.
53	$rs=30 \text{ Ohm}$	Series resistance at TR.
54	$strs=1.0$	Temperature dependence of RS.
55	$rsb=0.0 V^{-1}$	Back-bias dependence of series resistance.
56	$rsg=0.0 V^{-1}$	Gate-bias dependence of series resistance.
57	$thesat=1.0 V^{-1}$	Velocity saturation parameter at TR.
58	$stthesat=1.0$	Temperature dependence of THESAT.
59	$thesatb=0.0 V^{-1}$	Back-bias dependence of velocity saturation.
60	$thesatg=0.0 V^{-1}$	Gate-bias dependence of velocity saturation.
61	$ax=3.0$	Linear/saturation transition factor.
62	$alp=0.01$	CLM pre-factor.
63	$alp1=0.00 V$	CLM enhancement factor above threshold.
64	$alp2=0.00 V^{-1}$	CLM enhancement factor below threshold.
65	$vp=0.05 V$	CLM logarithm dependence factor.
66	$a1=0.05 V$	Impact-ionization pre-factor.
67	$a2=1.0$	Impact-ionization exponent at TR.
68	$sta2=0.0 V$	Temperature dependence of A2.
69	$a3=0$	Saturation-voltage dependence of impact-ionization.
70	$a4=0.0 V^{-0.5}$	Back-bias dependence of impact-ionization.

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71	<code>gco=0.0</code>	Gate tunneling energy adjustment.
72	<code>iginv=0.0 A</code>	Gate channel current pre-factor.
73	<code>igov=0.0 A</code>	Gate overlap current pre-factor.
74	<code>igovd=0.0 A</code>	Gate overlap current pre-factor for drain side.
75	<code>stig=2.0</code>	Temperature dependence of IGINV and IGOV.
76	<code>gc2=0.375</code>	Gate current slope factor.
77	<code>gc3=0.063</code>	Gate current curvature factor.
78	<code>chib=3.1 V</code>	Tunneling barrier height.
79	<code>agidl=0.0 A/V^3</code>	GIDL pre-factor.
80	<code>agidld=0.0 A/V^3</code>	GIDL pre-factor for drain side.
81	<code>bgidl=41.0 V</code>	GIDL probability factor at TR.
82	<code>bgidld=41.0 V</code>	GIDL probability factor at TR for drain side.
83	<code>stbgidl=0.0 V/K</code>	Temperature dependence of BGIDL.
84	<code>stbgidld=0.0 V/K</code>	Temperature dependence of BGIDL for drain side.
85	<code>cgidl=0.0</code>	Back-bias dependence of GIDL.
86	<code>cgidld=0.0</code>	Back-bias dependence of GIDL for drain side.
87	<code>cox=1.0e-14 F</code>	Oxide capacitance for intrinsic channel.
88	<code>cgov=1.0e-15 F</code>	Oxide capacitance for gate-drain/source overlap.
89	<code>cgovd=1.0e-15 F</code>	Oxide capacitance for gate-drain overlap.
90	<code>cgbov=0.0 F</code>	Oxide capacitance for gate-bulk overlap.
91	<code>cfr=0.0 F</code>	Outer fringe capacitance.
92	<code>cfrd=0.0 F</code>	Outer fringe capacitance for drain side.

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93	<code>fnt=1.0</code>	Thermal noise coefficient.
94	<code>nfa=8.0e+22 V⁻¹/m⁴</code>	First coefficient of flicker noise.
95	<code>nfb=3.0e+07 V⁻¹/m²</code>	Second coefficient of flicker noise.
96	<code>nfc=0.0 V⁻¹</code>	Third coefficient of flicker noise.
97	<code>ef=1.0</code>	Flicker noise frequency exponent.
98	<code>munqs=1.0</code>	Relative mobility for NQS modeling.
99	<code>rg=0.0 Ohm</code>	Gate resistance.
100	<code>rse=0.0 Ohm</code>	External source resistance.
101	<code>rde=0.0 Ohm</code>	External drain resistance.
102	<code>rbulk=0.0 Ohm</code>	Bulk resistance between node BP and BI.
103	<code>rwell=0.0 Ohm</code>	Well resistance between node BI and B.
104	<code>rjuns=0.0 Ohm</code>	Source-side bulk resistance between node BI and BS.
105	<code>rjund=0.0 Ohm</code>	Drain-side bulk resistance between node BI and BD.
106	<code>povfb=1 V</code>	Coefficient for the geometry independent part of VFB.
107	<code>plvfb=0.0 V</code>	Coefficient for the length dependence of VFB.
108	<code>pwvfb=0.0 V</code>	Coefficient for the width dependence of VFB.
109	<code>plwvfb=0.0 V</code>	Coefficient for the length times width dependence of VFB.
110	<code>postvfb=0.0005 V/K</code>	Coefficient for the geometry independent part of STVFB.
111	<code>plstvfb=0.0 V/K</code>	Coefficient for the length dependence of STVFB.
112	<code>pwstvfb=0.0 V/K</code>	Coefficient for the width dependence of STVFB.

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113	$plwstvfb=0.0$ V/K	Coefficient for the length times width dependence of STVFB.
114	$potox=2E-09$ m	Coefficient for the geometry independent part of TOX.
115	$poepsrox=3.9$	Coefficient for the geometry independent part of EPSOX.
116	$poneff=5E+23$ m ⁻³	Coefficient for the geometry independent part of NEFF.
117	$plneff=0.0$ m ⁻³	Coefficient for the length dependence of NEFF.
118	$pwneff=0.0$ m ⁻³	Coefficient for the width dependence of NEFF.
119	$plwneff=0.0$ m ⁻³	Coefficient for the length times width dependence of NEFF.
120	$pofacneffac=1.0$	Coefficient for the geometry independent part of FACNEFFAC.
121	$plfacneffac=0.0$	Coefficient for the length dependence of FACNEFFAC.
122	$pwfacneffac=0.0$	Coefficient for the width dependence of FACNEFFAC.
123	$plwfacneffac=0.0$	Coefficient for the length times width dependence of FACNEFFAC.
124	$pogfacnud=1.0$	Coefficient for the geometry independent part of GFACNUD.
125	$plgfacnud=0.0$	Coefficient for the length dependence of GFACNUD.
126	$pwgfacnud=0.0$	Coefficient for the width dependence of GFACNUD.
127	$plwgfacnud=0.0$	Coefficient for the length times width dependence of GFACNUD.
128	$povsbnud=0.0$ V	Coefficient for the geometry independent part of VSBNUD.
129	$podvsbnud=1.0$ V	Coefficient for the geometry independent part of DVSBNUD.
130	$povnsuub=0$ V	Coefficient for the geometry independent part of VNSUB.
131	$ponslp=0.05$ V	Coefficient for the geometry independent part of NSLP.
132	$podnsub=0$ V ⁻¹	Coefficient for the geometry independent part of DNSUB.
133	$podphib=0$ V	Coefficient for the geometry independent part of DPHIB.

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134	<code>pldphib=0.0 V</code>	Coefficient for the length dependence of DPHIB.
135	<code>pwdphib= 0.0 V</code>	Coefficient for the width dependence of DPHIB.
136	<code>plwdphib=0.0 V</code>	Coefficient for the length times width dependence of DPHIB.
137	<code>podelvtac=0 V</code>	Coefficient for the geometry independent part of DELVTAC.
138	<code>pldelvtac=0.0 V</code>	Coefficient for the length dependence of DELVTAC.
139	<code>pwdelvtac=0.0 V</code>	Coefficient for the width dependence of DELVTAC.
140	<code>plwdelvtac=0.0 V</code>	Coefficient for the length times width dependence of DELVTAC.
141	<code>ponp=1E+26 m⁻³</code>	Coefficient for the geometry independent part of NP.
142	<code>plnp=0.0 m⁻³</code>	Coefficient for the length dependence of NP.
143	<code>pwnp=0.0 m⁻³</code>	Coefficient for the width dependence of NP.
144	<code>plwnp=0.0 m⁻³</code>	Coefficient for the length times width dependence of NP.
145	<code>poct=0</code>	Coefficient for the geometry independent part of CT.
146	<code>plct=0.0</code>	Coefficient for the length dependence of CT.
147	<code>pwct=0.0</code>	Coefficient for the width dependence of CT.
148	<code>plwct=0.0</code>	Coefficient for the length times width dependence of CT.
149	<code>potoxov=2E-09 m</code>	Coefficient for the geometry independent part of TOXOV.
150	<code>potoxovd=2E-09 m</code>	Coefficient for the geometry independent part of TOXOV for drain side.
151	<code>ponov=5E+25 m⁻³</code>	Coefficient for the geometry independent part of NOV.
152	<code>plnov=0.0 m⁻³</code>	Coefficient for the length dependence of NOV.
153	<code>pwnov=0.0 m⁻³</code>	Coefficient for the width dependence of NOV.
154	<code>plwnov=0.0 m⁻³</code>	Coefficient for the length times width dependence of NOV.

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- 155 $p_{onovd}=5E+25 \text{ m}^{-3}$ Coefficient for the geometry independent part of NOV for drain side.
- 156 $p_{lnovd}=0.0 \text{ m}^{-3}$ Coefficient for the length dependence of NOV for drain side.
- 157 $p_{wnovd}=0.0 \text{ m}^{-3}$ Coefficient for the width dependence of NOV for drain side.
- 158 $p_{lwnovd}=0.0 \text{ m}^{-3}$ Coefficient for the length times width dependence of NOV for drain side.
- 159 $p_{ocf}=0$ Coefficient for the geometry independent part of CF.
- 160 $p_{lcf}=0.0$ Coefficient for the length dependence of CF.
- 161 $p_{wcf}=0.0$ Coefficient for the width dependence of CF.
- 162 $p_{lwcf}=0.0$ Coefficient for the length times width dependence of CF.
- 163 $p_{ocfb}=0 \text{ V}^{-1}$ Coefficient for the geometry independent part of CFB.
- 164 $p_{obetn}=0.07 \text{ m}^2/\text{V}/\text{s}$
Coefficient for the geometry independent part of BETN.
- 165 $p_{lbetn}=0.0 \text{ m}^2/\text{V}/\text{s}$
Coefficient for the length dependence of BETN.
- 166 $p_{wbetn}=0.0 \text{ m}^2/\text{V}/\text{s}$
Coefficient for the width dependence of BETN.
- 167 $p_{lwbetn}=0.0 \text{ m}^2/\text{V}/\text{s}$
Coefficient for the length times width dependence of BETN.
- 168 $p_{ostbet}=1$ Coefficient for the geometry independent part of STBET.
- 169 $p_{lstbet}=0.0$ Coefficient for the length dependence of STBET.
- 170 $p_{wstbet}=0.0$ Coefficient for the width dependence of STBET.
- 171 $p_{lwstbet}=0.0$ Coefficient for the length times width dependence of STBET.
- 172 $p_{omue}=0.5 \text{ m}/\text{V}$ Coefficient for the geometry independent part of MUE.
- 173 $p_{lmue}=0.0 \text{ m}/\text{V}$ Coefficient for the length dependence of MUE.

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PSP103 Model

174	<code>pwmue=0.0 m/V</code>	Coefficient for the width dependence of MUE.
175	<code>plwmue=0.0 m/V</code>	Coefficient for the length times width dependence of MUE.
176	<code>postmue=0</code>	Coefficient for the geometry independent part of STMUE.
177	<code>pothemu=1.5</code>	Coefficient for the geometry independent part of THEMU.
178	<code>postthemu=1.5</code>	Coefficient for the geometry independent part of STTHEMU.
179	<code>pocs=0</code>	Coefficient for the geometry independent part of CS.
180	<code>plcs=0.0</code>	Coefficient for the length dependence of CS.
181	<code>pwcs=0.0</code>	Coefficient for the width dependence of CS.
182	<code>plwcs=0.0</code>	Coefficient for the length times width dependence of CS.
183	<code>postcs=0</code>	Coefficient for the geometry independent part of STCS.
184	<code>poxcor=0 V⁻¹</code>	Coefficient for the geometry independent part of XCOR.
185	<code>plxcor=0 V⁻¹</code>	Coefficient for the length dependence of XCOR.
186	<code>pwxcor=0 V⁻¹</code>	Coefficient for the width dependence of XCOR.
187	<code>plwxcor=0 V⁻¹</code>	Coefficient for the length times width dependence of XCOR.
188	<code>postxcor=0</code>	Coefficient for the geometry independent part of STXCOR.
189	<code>pofeta=1</code>	Coefficient for the geometry independent part of FETA.
190	<code>pors=30 Ohm</code>	Coefficient for the geometry independent part of RS.
191	<code>plrs=0.0 Ohm</code>	Coefficient for the length dependence of RS.
192	<code>pwr=0.0 Ohm</code>	Coefficient for the width dependence of RS.
193	<code>plwrs=0.0 Ohm</code>	Coefficient for the length times width dependence of RS.
194	<code>postrs=1</code>	Coefficient for the geometry independent part of STRS.
195	<code>porsb=0 V⁻¹</code>	Coefficient for the geometry independent part of RSB.

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- 196 $porsg=0 V^{-1}$ Coefficient for the geometry independent part of RSG.
- 197 $pothesat=1 V^{-1}$ Coefficient for the geometry independent part of THESAT.
- 198 $plthesat=0.0 V^{-1}$ Coefficient for the length dependence of THESAT.
- 199 $pwthesat=0.0 V^{-1}$ Coefficient for the width dependence of THESAT.
- 200 $plwthesat=0.0 V^{-1}$
Coefficient for the length times width dependence of THESAT.
- 201 $postthesat=1$ Coefficient for the geometry independent part of STTHESAT.
- 202 $plstthesat=0.0$ Coefficient for the length dependence of STTHESAT.
- 203 $pwstthesat=0.0$ Coefficient for the width dependence of STTHESAT.
- 204 $plwstthesat=0.0$ Coefficient for the length times width dependence of STTHESAT.
- 205 $pothesatb=0 V^{-1}$ Coefficient for the geometry independent part of THESATB.
- 206 $plthesatb=0.0 V^{-1}$
Coefficient for the length dependence of THESATB.
- 207 $pwthesatb=0.0 V^{-1}$
Coefficient for the width dependence of THESATB.
- 208 $plwthesatb=0.0 V^{-1}$
Coefficient for the length times width dependence of THESATB.
- 209 $pothesatg=0 V^{-1}$ Coefficient for the geometry independent part of THESATG.
- 210 $plthesatg=0.0 V^{-1}$
Coefficient for the length dependence of THESATG.
- 211 $pwthesatg=0.0 V^{-1}$
Coefficient for the width dependence of THESATG.
- 212 $plwthesatg=0.0 V^{-1}$
Coefficient for the length times width dependence of THESATG.
- 213 $poax=3$ Coefficient for the geometry independent part of AX.

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214	$p_{lax}=0.0$	Coefficient for the length dependence of AX.
215	$p_{wax}=0.0$	Coefficient for the width dependence of AX.
216	$p_{lwax}=0.0$	Coefficient for the length times width dependence of AX.
217	$p_{oalp}=0.01$	Coefficient for the geometry independent part of ALP.
218	$p_{lalp}=0.0$	Coefficient for the length dependence of ALP.
219	$p_{walp}=0.0$	Coefficient for the width dependence of ALP.
220	$p_{lwalp}=0.0$	Coefficient for the length times width dependence of ALP.
221	$p_{oalp1}=0 \text{ V}$	Coefficient for the geometry independent part of ALP1.
222	$p_{lalp1}=0.0 \text{ V}$	Coefficient for the length dependence of ALP1.
223	$p_{walp1}=0.0 \text{ V}$	Coefficient for the width dependence of ALP1.
224	$p_{lwalp1}=0.0 \text{ V}$	Coefficient for the length times width dependence of ALP1.
225	$p_{oalp2}=0 \text{ V}^{-1}$	Coefficient for the geometry independent part of ALP2.
226	$p_{lalp2}=0.0 \text{ V}^{-1}$	Coefficient for the length dependence of ALP2.
227	$p_{walp2}=0.0 \text{ V}^{-1}$	Coefficient for the width dependence of ALP2.
228	$p_{lwalp2}=0.0 \text{ V}^{-1}$	Coefficient for the length times width dependence of ALP2.
229	$p_{ovp}=0.05 \text{ V}$	Coefficient for the geometry independent part of VP.
230	$p_{oa1}=1$	Coefficient for the geometry independent part of A1.
231	$p_{la1}=0.0$	Coefficient for the length dependence of A1.
232	$p_{wa1}=0.0$	Coefficient for the width dependence of A1.
233	$p_{lwa1}=0.0$	Coefficient for the length times width dependence of A1.
234	$p_{oa2}=10 \text{ V}$	Coefficient for the geometry independent part of A2.
235	$p_{osta2}=0 \text{ V}$	Coefficient for the geometry independent part of STA2.

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236	$poa3=1$	Coefficient for the geometry independent part of A3.
237	$pla3=0.0$	Coefficient for the length dependence of A3.
238	$pwa3=0.0$	Coefficient for the width dependence of A3.
239	$plwa3=0.0$	Coefficient for the length times width dependence of A3.
240	$poa4=0 \ V^{-0.5}$	Coefficient for the geometry independent part of A4.
241	$pla4=0.0 \ V^{-0.5}$	Coefficient for the length dependence of A4.
242	$pwa4=0.0 \ V^{-0.5}$	Coefficient for the width dependence of A4.
243	$plwa4=0.0 \ V^{-0.5}$	Coefficient for the length times width dependence of A4.
244	$pogco=0$	Coefficient for the geometry independent part of GCO.
245	$poiginv=0 \ A$	Coefficient for the geometry independent part of IGINV.
246	$pliginv=0.0 \ A$	Coefficient for the length dependence of IGINV.
247	$pwiginv=0.0 \ A$	Coefficient for the width dependence of IGINV.
248	$plwiginv=0.0 \ A$	Coefficient for the length times width dependence of IGINV.
249	$poigov=0 \ A$	Coefficient for the geometry independent part of IGOV.
250	$pligov=0.0 \ A$	Coefficient for the length dependence of IGOV.
251	$pwigov=0.0 \ A$	Coefficient for the width dependence of IGOV.
252	$plwigov=0.0 \ A$	Coefficient for the length times width dependence of IGOV.
253	$poigovd=0 \ A$	Coefficient for the geometry independent part of IGOV for drain side.
254	$pligovd=0.0 \ A$	Coefficient for the length dependence of IGOV for drain side.
255	$pwigovd=0.0 \ A$	Coefficient for the width dependence of IGOV for drain side.
256	$plwigovd=0.0 \ A$	Coefficient for the length times width dependence of IGOV for drain side.

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257	<code>postig=2</code>	Coefficient for the geometry independent part of STIG.
258	<code>pogc2=0.375</code>	Coefficient for the geometry independent part of GC2.
259	<code>pogc3=0.063</code>	Coefficient for the geometry independent part of GC3.
260	<code>pochib=3.1 V</code>	Coefficient for the geometry independent part of CHIB.
261	<code>poagidl=0 A/V^3</code>	Coefficient for the geometry independent part of AGIDL.
262	<code>plagidl=0.0 A/V^3</code>	Coefficient for the length dependence of AGIDL.
263	<code>pwagidl=0.0 A/V^3</code>	Coefficient for the width dependence of AGIDL.
264	<code>plwagidl=0.0 A/V^3</code>	Coefficient for the length times width dependence of AGIDL.
265	<code>poagidld=0 A/V^3</code>	Coefficient for the geometry independent part of AGIDL for drain side.
266	<code>plagidld=0.0 A/V^3</code>	Coefficient for the length dependence of AGIDL for drain side.
267	<code>pwagidld=0.0 A/V^3</code>	Coefficient for the width dependence of AGIDL for drain side.
268	<code>plwagidld=0.0 A/V^3</code>	Coefficient for the length times width dependence of AGIDL for drain side.
269	<code>pobgidl=41 V</code>	Coefficient for the geometry independent part of BGIDL.
270	<code>pobgidld=41 V</code>	Coefficient for the geometry independent part of BGIDL for drain side.
271	<code>postbgidl=0 V/K</code>	Coefficient for the geometry independent part of STBGIDL.
272	<code>postbgidld=0 V/K</code>	Coefficient for the geometry independent part of STBGIDL for drain side.
273	<code>pocgidl=0</code>	Coefficient for the geometry independent part of CGIDL.

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274	pocgidld=0	Coefficient for the geometry independent part of CGIDL for drain side.
275	pocox=1E-14 F	Coefficient for the geometry independent part of COX.
276	plcox=0.0 F	Coefficient for the length dependence of COX.
277	pwcox=0.0 F	Coefficient for the width dependence of COX.
278	plwcox=0.0 F	Coefficient for the length times width dependence of COX.
279	pocgov=1E-15 F	Coefficient for the geometry independent part of CGOV.
280	plcgov=0.0 F	Coefficient for the length dependence of CGOV.
281	pwcgov=0.0 F	Coefficient for the width dependence of CGOV.
282	plwcgov=0.0 F	Coefficient for the length times width dependence of CGOV.
283	pocgovd=1E-15 F	Coefficient for the geometry independent part of CGOV for drain side.
284	plcgovd=0.0 F	Coefficient for the length dependence of CGOV for drain side.
285	pwcgovd=0.0 F	Coefficient for the width dependence of CGOV for drain side.
286	plwcgovd=0.0 F	Coefficient for the length times width dependence of CGOV for drain side.
287	pocgbov=0 F	Coefficient for the geometry independent part of CGBOV.
288	plcgbov=0.0 F	Coefficient for the length dependence of CGBOV.
289	pwcgbov=0.0 F	Coefficient for the width dependence of CGBOV.
290	plwcgbov=0.0 F	Coefficient for the length times width dependence of CGBOV.
291	pocfr=0 F	Coefficient for the geometry independent part of CFR.
292	plcfr=0.0 F	Coefficient for the length dependence of CFR.
293	pwcfr=0.0 F	Coefficient for the width dependence of CFR.

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294	$plwcf_{rd}=0.0$	F	Coefficient for the length times width dependence of CFR.
295	$pocf_{rd}=0$	F	Coefficient for the geometry independent part of CFR for drain side.
296	$plcf_{rd}=0.0$	F	Coefficient for the length dependence of CFR for drain side.
297	$pwcf_{rd}=0.0$	F	Coefficient for the width dependence of CFR for drain side.
298	$plwcf_{rd}=0.0$	F	Coefficient for the length times width dependence of CFR for drain side.
299	$pof_{nt}=1$		Coefficient for the geometry independent part of FNT.
300	$ponf_{a}=8E+22$	V^{-1}/m^4	Coefficient for the geometry independent part of NFA.
301	$plnf_{a}=0.0$	V^{-1}/m^4	Coefficient for the length dependence of NFA.
302	$pwnf_{a}=0.0$	V^{-1}/m^4	Coefficient for the width dependence of NFA.
303	$plwnf_{a}=0.0$	V^{-1}/m^4	Coefficient for the length times width dependence of NFA.
304	$ponf_{b}=3E+07$	V^{-1}/m^2	Coefficient for the geometry independent part of NFB.
305	$plnf_{b}=0.0$	V^{-1}/m^2	Coefficient for the length dependence of NFB.
306	$pwnf_{b}=0.0$	V^{-1}/m^2	Coefficient for the width dependence of NFB.
307	$plwnf_{b}=0.0$	V^{-1}/m^2	Coefficient for the length times width dependence of NFB.
308	$ponf_{c}=0$	V^{-1}	Coefficient for the geometry independent part of NFC.
309	$plnf_{c}=0.0$	V^{-1}	Coefficient for the length dependence of NFC.
310	$pwnf_{c}=0.0$	V^{-1}	Coefficient for the width dependence of NFC.

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311	$plwnfc=0.0 \ V^{-1}$	Coefficient for the length times width dependence of NFC.
312	$poef=1.0$	Coefficient for the flicker noise frequency exponent.
313	$pokvthowe=0$	Coefficient for the geometry independent part of KVTHOWE.
314	$plkvthowe=0$	Coefficient for the length dependence part of KVTHOWE.
315	$pwkvthowe=0$	Coefficient for the width dependence part of KVTHOWE.
316	$plwkvthowe=0$	Coefficient for the length times width dependence part of KVTHOWE.
317	$pokuowe=0$	Coefficient for the geometry independent part of KUOWE.
318	$plkuowe=0$	Coefficient for the length dependence part of KUOWE.
319	$pwkuowe=0$	Coefficient for the width dependence part of KUOWE.
320	$plwkuowe=0$	Coefficient for the length times width dependence part of KUOWE.
321	$lmin=0 \ m$	Dummy parameter to label binning set.
322	$lmax=1.0 \ m$	Dummy parameter to label binning set.
323	$wmin=0 \ m$	Dummy parameter to label binning set.
324	$wmax=1.0 \ m$	Dummy parameter to label binning set.
325	$lvaro=0.0 \ m$	Geom. independent difference between actual and programmed gate length.
326	$lvarl=0.0$	Length dependence of LVAR.
327	$lvarw=0.0$	Width dependence of LVAR.
328	$lap=0.0 \ m$	Effective channel length reduction per side.
329	$wvaro=0.0 \ m$	Geom. independent difference between actual and programmed field-oxide opening.
330	$wvarl=0.0$	Length dependence of WVAR.

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331	$wvarw=0.0$	Width dependence of WVAR.
332	$wot=0.0$ m	Effective channel width reduction per side.
333	$dlq=0.0$ m	Effective channel length reduction for CV.
334	$dwq=0.0$ m	Effective channel width reduction for CV.
335	$vfb0=1.0$ V	Geometry-independent flat-band voltage at TR.
336	$vfb1=0.0$ V	Length dependence of flat-band voltage.
337	$vfbw=0.0$ V	Width dependence of flat-band voltage.
338	$vfb1w=0.0$ V	Area dependence of flat-band voltage.
339	$stvfb0=5e-4$ V/K	Geometry-independent temperature dependence of VFB.
340	$stvfb1=0.0$ V/K	Length dependence of temperature dependence of VFB.
341	$stvfbw=0.0$ V/K	Width dependence of temperature dependence of VFB.
342	$stvfb1w=0.0$ V/K	Area dependence of temperature dependence of VFB.
343	$tox0=2e-9$ m	Gate oxide thickness.
344	$epsrox0=3.9$	Relative permittivity of gate dielectric.
345	$nsub0=3e23$ m ⁻³	Geometry independent substrate doping.
346	$nsubw=0.0$	Width dependence of background doping NSUBO due to segregation.
347	$wseg=1e-8$ m	Char. length of segregation of background doping NSUBO.
348	$npck=1e24$ m ⁻³	Pocket doping level.
349	$npckw=0.0$	Width dependence of pocket doping NPCK due to segregation.
350	$wsegp=1e-8$ m	Char. length of segregation of pocket doping NPCK.
351	$lpck=1e-8$ m	Char. length of lateral doping profile.

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352	<code>lpckw=0.0</code>	Width dependence of char. length of lateral doping profile.
353	<code>foll1=0.0</code>	First length dependence coefficient for short channel body effect.
354	<code>foll2=0.0</code>	Second length dependence coefficient for short channel body effect.
355	<code>facneffaco=1.0</code>	Geom. independent pre-factor for effective substrate doping in separate charge calculation.
356	<code>facneffacl=0.0</code>	Length dependence of FACNEFFAC.
357	<code>facneffacw=0.0</code>	Width dependence of FACNEFFAC.
358	<code>facneffaclw=0.0</code>	Area dependence of FACNEFFAC.
359	<code>gfacnudo=1.0</code>	Geom. independent bodyfactor change due to NUD-effect.
360	<code>gfacnudl=0.0</code>	Length dependence of GFACNUD.
361	<code>gfacnudlexp=1.0</code>	Exponent for length dependence of GFACNUD.
362	<code>gfacnudw=0.0</code>	Width dependence of GFACNUD.
363	<code>gfacnudlw=0.0</code>	Area dependence of GFACNUD.
364	<code>vsbnudo=0.0 V</code>	Lower Vsb value for NUD-effect.
365	<code>dvvsbnudo=1.0 V</code>	Vsb range for NUD-effect.
366	<code>vnsubo=0.0 V</code>	Effective doping bias-dependence parameter.
367	<code>nslpo=0.05 V</code>	Effective doping bias-dependence parameter.
368	<code>dnsubo=0.0 V⁻¹</code>	Effective doping bias-dependence parameter.
369	<code>dphibo=0.0 V</code>	Geometry independent offset of PHIB.
370	<code>dphibl=0.0 V</code>	Length dependence offset of PHIB.
371	<code>dphiblexp=1.0</code>	Exponent for length dependence of offset of PHIB.
372	<code>dphibw=0.0 V</code>	Width dependence of offset of PHIB.

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373	$d_{\text{phiblw}}=0.0$ V	Area dependence of offset of PHIB.
374	$delvtaco=0.0$ V	Geom. independent offset parameter for PHIB in separate charge calculation.
375	$delvtacl=0.0$ V	Length dependence of DELVTAC.
376	$delvtaclexp=1.0$	Exponent for length dependence of offset of DELVTAC.
377	$delvtacw=0.0$ V	Width dependence of DELVTAC.
378	$delvtaclw=0.0$ V	Area dependence of DELVTAC.
379	$n_{\text{po}}=1e26$ m ⁻³	Geometry-independent gate poly-silicon doping.
380	$n_{\text{pl}}=0.0$	Length dependence of gate poly-silicon doping.
381	$cto=0.0$	Geometry-independent interface states factor.
382	$ctl=0.0$	Length dependence of interface states factor.
383	$ctlexp=1.0$	Exponent for length dependence of interface states factor.
384	$ctw=0.0$	Width dependence of interface states factor.
385	$ctlw=0.0$	Area dependence of interface states factor.
386	$toxovo=2e-9$ m	Overlap oxide thickness.
387	$toxovdo=2e-9$ m	Overlap oxide thickness for drain side.
388	$lov=0$ m	Overlap length for gate/drain and gate/source overlap capacitance.
389	$lovd=0$ m	Overlap length for gate/drain overlap capacitance.
390	$novo=5e25$ m ⁻³	Effective doping of overlap region.
391	$novdo=5e25$ m ⁻³	Effective doping of overlap region for drain side.
392	$cfl=0.0$	Length dependence of DIBL-parameter.
393	$cflexp=2.0$	Exponent for length dependence of CF.

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394	$cfw=0.0$	Width dependence of CF.
395	$cfbo=0.0 \ V^{-1}$	Back-bias dependence of CF.
396	$u_0=5e-2 \ m^2/V/s$	Zero-field mobility at TR.
397	$fbet1=0.0$	Relative mobility decrease due to first lateral profile.
398	$fbet1w=0.0$	Width dependence of relative mobility decrease due to first lateral profile.
399	$lp1=1e-8 \ m$	Mobility-related characteristic length of first lateral profile.
400	$lp1w=0.0$	Width dependence of mobility-related characteristic length of first lateral profile.
401	$fbet2=0.0$	Relative mobility decrease due to second lateral profile.
402	$lp2=1e-8 \ m$	Mobility-related characteristic length of second lateral profile.
403	$betw1=0.0$	First higher-order width scaling coefficient of BETN.
404	$betw2=0.0$	Second higher-order width scaling coefficient of BETN.
405	$wbet=1e-9 \ m$	Characteristic width for width scaling of BETN.
406	$stbeto=1.0$	Geometry independent temperature dependence of BETN.
407	$stbetl=0.0$	Length dependence of temperature dependence of BETN.
408	$stbetw=0.0$	Width dependence of temperature dependence of BETN.
409	$stbetlw=0.0$	Area dependence of temperature dependence of BETN.
410	$mueo=0.5 \ m/V$	Geometry independent mobility reduction coefficient at TR.
411	$muew=0.0$	Width dependence of mobility reduction coefficient at TR.
412	$stmueo=0.0$	Temperature dependence of MUE.
413	$themuo=1.5$	Mobility reduction exponent at TR.
414	$stthemuo=1.5$	Temperature dependence of THEMU.

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415	<code>cso=0.0</code>	Geometry independent coulomb scattering parameter at TR.
416	<code>csl=0.0</code>	Length dependence of CS.
417	<code>cslexp=1.0</code>	Exponent for length dependence of CS.
418	<code>csw=0.0</code>	Width dependence of CS.
419	<code>cslw=0.0</code>	Area dependence of CS.
420	<code>stcso=0.0</code>	Temperature dependence of CS.
421	<code>xcoro=0.0 V⁻¹</code>	Geometry independent non-universality parameter.
422	<code>xcorl=0.0</code>	Length dependence of non-universality parameter.
423	<code>xcorw=0.0</code>	Width dependence of non-universality parameter.
424	<code>xcorlw=0.0</code>	Area dependence of non-universality parameter.
425	<code>stxcoro=0.0</code>	Temperature dependence of XCOR.
426	<code>fetao=1.0</code>	Effective field parameter.
427	<code>rsw1=50.0 Ohm</code>	Source/drain series resistance for 1 um wide channel at TR.
428	<code>rsw2=0.0</code>	Higher-order width scaling of RS.
429	<code>strso=1.0</code>	Temperature dependence of RS.
430	<code>rsbo=0.0 V⁻¹</code>	Back-bias dependence of series resistance.
431	<code>rsgo=0.0 V⁻¹</code>	Gate-bias dependence of series resistance.
432	<code>thesato=0.0 V⁻¹</code>	Geometry independent velocity saturation parameter at TR.
433	<code>thesatl=0.05 V⁻¹</code>	Length dependence of THESAT.
434	<code>thesatlexp=1.0</code>	Exponent for length dependence of THESAT.
435	<code>thesatw=0.0</code>	Width dependence of velocity saturation parameter.
436	<code>thesatlw=0.0</code>	Area dependence of velocity saturation parameter.

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437	<code>stthesato=1.0</code>	Geometry independent temperature dependence of THESAT.
438	<code>stthesatl=0.0</code>	Length dependence of temperature dependence of THESAT.
439	<code>stthesatw=0.0</code>	Width dependence of temperature dependence of THESAT.
440	<code>stthesatlw=0.0</code>	Area dependence of temperature dependence of THESAT.
441	<code>thesatbo=0.0</code> V^{-1}	Back-bias dependence of velocity saturation.
442	<code>thesatgo=0.0</code> V^{-1}	Gate-bias dependence of velocity saturation.
443	<code>axo=18</code>	Geometry independent linear/saturation transition factor.
444	<code>axl=0.4</code>	Length dependence of AX.
445	<code>alp1=5e-4</code>	Length dependence of ALP.
446	<code>alp1exp=1.0</code>	Exponent for length dependence of ALP.
447	<code>alp1w=0.0</code>	Width dependence of ALP.
448	<code>alp1l1=0.0</code> V	Length dependence of CLM enhancement factor above threshold.
449	<code>alp1l1exp=0.5</code>	Exponent for length dependence of ALP1.
450	<code>alp1l2=0.0</code>	Second_order length dependence of ALP1.
451	<code>alp1w=0.0</code>	Width dependence of ALP1.
452	<code>alp2l1=0.0</code> V^{-1}	Length dependence of CLM enhancement factor below threshold.
453	<code>alp2l1exp=0.5</code>	Exponent for length dependence of ALP2.
454	<code>alp2l2=0.0</code>	Second_order length dependence of ALP2.
455	<code>alp2w=0.0</code>	Width dependence of ALP2.
456	<code>vpo=0.05</code> V	CLM logarithmic dependence parameter.
457	<code>alo=1.0</code>	Geometry independent impact-ionization pre-factor.

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458	$a_{1l}=0.0$	Length dependence of A1.
459	$a_{1w}=0.0$	Width dependence of A1.
460	$a_{2o}=10$ V	Impact-ionization exponent at TR.
461	$sta_{2o}=0.0$ V	Temperature dependence of A2.
462	$a_{3o}=1.0$	Geometry independent saturation-voltage dependence of II.
463	$a_{3l}=0.0$	Length dependence of A3.
464	$a_{3w}=0.0$	Width dependence of A3.
465	$a_{4o}=0.0$ V ^{-0.5}	Geometry independent back-bias dependence of II.
466	$a_{4l}=0.0$	Length dependence of A4.
467	$a_{4w}=0.0$	Width dependence of A4.
468	$g_{coo}=0.0$	Gate tunneling energy adjustment.
469	$ig_{invlw}=0.0$ A	Gate channel current pre-factor for 1 μm^2 channel area.
470	$ig_{ovw}=0.0$ A	Gate overlap current pre-factor for 1 μm wide channel.
471	$ig_{ovdw}=0.0$ A	Gate overlap current pre-factor for 1 μm wide channel for drain side.
472	$st_{igo}=2.0$	Temperature dependence of IGINV and IGOV.
473	$gc_{2o}=0.375$	Gate current slope factor.
474	$gc_{3o}=0.063$	Gate current curvature factor.
475	$ch_{ibo}=3.1$ V	Tunneling barrier height.
476	$ag_{idlw}=0.0$ A/V ³	Width dependence of GIDL pre-factor.
477	$ag_{idldw}=0.0$ A/V ³	Width dependence of GIDL pre-factor for drain side.
478	$bg_{idlo}=41$ V	GIDL probability factor at TR.

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479	<code>bgidldo=41</code>	V	GIDL probability factor at TR for drain side.
480	<code>stbgidlo=0.0</code>	V/K	Temperature dependence of BGIDL.
481	<code>stbgidldo=0.0</code>	V/K	Temperature dependence of BGIDL for drain side.
482	<code>cgidlo=0.0</code>		Back-bias dependence of GIDL.
483	<code>cgidldo=0.0</code>		Back-bias dependence of GIDL for drain side.
484	<code>cgbovl=0.0</code>	F	Oxide capacitance for gate-bulk overlap for 1 um long channel.
485	<code>cfrw=0.0</code>	F	Outer fringe capacitance for 1 um wide channel.
486	<code>cfrdw=0.0</code>	F	Outer fringe capacitance for 1 um wide channel for drain side.
487	<code>fnto=1.0</code>		Thermal noise coefficient.
488	<code>nfalw=8e22</code>	V^{-1}/m^4	First coefficient of flicker noise for 1 um ² channel area.
489	<code>nfblw=3e7</code>	V^{-1}/m^2	Second coefficient of flicker noise for 1 um ² channel area.
490	<code>nfclw=0.0</code>	V^{-1}	Third coefficient of flicker noise for 1 um ² channel area.
491	<code>efo=1.0</code>		Flicker noise frequency exponent.
492	<code>lintnoi=0.0</code>	m	Length offset for flicker noise.
493	<code>alpnoi=2.0</code>		Exponent for length offset for flicker noise.
494	<code>kvthoweo=0</code>		Geometrical independent threshold shift parameter.
495	<code>kvthowel=0</code>		Length dependent threshold shift parameter.
496	<code>kvthowew=0</code>		Width dependent threshold shift parameter.
497	<code>kvthowelw=0</code>		Area dependent threshold shift parameter.
498	<code>kuoweo=0</code>		Geometrical independent mobility degradation factor.
499	<code>kuowel=0</code>		Length dependent mobility degradation factor.

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500	<code>kuowew=0</code>	Width dependent mobility degradation factor.
501	<code>kuowelw=0</code>	Area dependent mobility degradation factor.
502	<code>munqso=1.0</code>	Relative mobility for NQS modeling.
503	<code>rgo=0.0 Ohm</code>	Gate resistance.
504	<code>rint=0.0 Ohm m^2</code>	Contact resistance between silicide and poly.
505	<code>rvpoly=0.0 Ohm m^2</code>	Vertical poly resistance.
506	<code>rshg=0.0 Ohm/Sqr</code>	Gate electrode diffusion sheet resistance.
507	<code>dlsil=0.0 m</code>	Silicide extension over the physical gate length.
508	<code>rsh=0.0 Ohm/sq</code>	Sheet resistance of source diffusion.
509	<code>rshd=0.0 Ohm/sq</code>	Sheet resistance of drain diffusion.
510	<code>rbulko=0.0 Ohm</code>	Bulk resistance between node BP and BI.
511	<code>rwello=0.0 Ohm</code>	Well resistance between node BI and B.
512	<code>rjunso=0.0 Ohm</code>	Source-side bulk resistance between node BI and BS.
513	<code>rjundo=0.0 Ohm</code>	Drain-side bulk resistance between node BI and BD.
514	<code>saref=1.0e-6 m</code>	Reference distance between OD-edge and poly from one side.
515	<code>sbref=1.0e-6 m</code>	Reference distance between OD-edge and poly from other side.
516	<code>wlod=0 m</code>	Width parameter.
517	<code>kuo=0 m</code>	Mobility degradation/enhancement coefficient.
518	<code>kvsat=0 m</code>	Saturation velocity degradation/enhancement coefficient.
519	<code>tkuo=0</code>	Temperature dependence of KUO.
520	<code>lkuo=0 m^LLODKUO</code>	Length dependence of KUO.

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- 521 $w_{kuo}=0$ $m^{WLODKUO}$ Width dependence of KUO.
- 522 $p_{kuo}=0$ $m^{(LLODKUO+WLODKUO)}$
Cross-term dependence of KUO.
- 523 $l_{lodkuo}=0$ Length parameter for UO stress effect.
- 524 $w_{lodkuo}=0$ Width parameter for UO stress effect.
- 525 $k_{vtho}=0$ V_m Threshold shift parameter.
- 526 $l_{kvtho}=0$ $m^{LLODVTH}$
Length dependence of KVTHO.
- 527 $w_{kvtho}=0$ $m^{WLODVTH}$
Width dependence of KVTHO.
- 528 $p_{kvtho}=0$ $m^{(LLODVTH+WLODVTH)}$
Cross-term dependence of KVTHO.
- 529 $l_{lodvth}=0$ Length parameter for VTH-stress effect.
- 530 $w_{lodvth}=0$ Width parameter for VTH-stress effect.
- 531 $s_{etao}=0$ m η_0 shift factor related to VTHO change.
- 532 $l_{odetao}=1.0$ η_0 shift modification factor for stress effect.
- 533 $s_{cref}=1.0e-6$ m Distance between OD-edge and well edge of a reference device.
- 534 $w_{eb}=0$ Coefficient for SCB.
- 535 $w_{ec}=0$ Coefficient for SCC.
- 536 $i_{max}=1000$ A Maximum current up to which forward current behaves exponentially.
- 537 $t_{rj}=21$ C reference temperature.
- 538 $c_{jorbot}=1E-3$ Fm^{-2}
Zero-bias capacitance per unit-of-area of bottom component for source-bulk junction.

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- 539 `cjorsti=1E-9 Fm-1` Zero-bias capacitance per unit-of-length of STI-edge component for source-bulk junction.
- 540 `cjorgat=1E-9 Fm-1` Zero-bias capacitance per unit-of-length of gate-edge component for source-bulk junction.
- 541 `vbirbot=1 V` Built-in voltage at the reference temperature of bottom component for source-bulk junction.
- 542 `vbirsti=1 V` Built-in voltage at the reference temperature of STI-edge component for source-bulk junction.
- 543 `vbirgat=1 V` Built-in voltage at the reference temperature of gate-edge component for source-bulk junction.
- 544 `pbot=0.5` Grading coefficient of bottom component for source-bulk junction.
- 545 `psti=0.5` Grading coefficient of STI-edge component for source-bulk junction.
- 546 `pgat=0.5` Grading coefficient of gate-edge component for source-bulk junction.
- 547 `phigbot=1.16 V` Zero-temperature bandgap voltage of bottom component for source-bulk junction.
- 548 `phigsti=1.16 V` Zero-temperature bandgap voltage of STI-edge component for source-bulk junction.
- 549 `phiggat= 1.16 V` Zero-temperature bandgap voltage of gate-edge component for source-bulk junction.
- 550 `idsatrbot=1E-12 Am-2` Saturation current density at the reference temperature of bottom component for source-bulk junction.
- 551 `idsatrsti=1E-18 Am-1` Saturation current density at the reference temperature of STI-edge component for source-bulk junction.

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- 552 $idsatrgat=1E-18 \text{ Am}^{-1}$ Saturation current density at the reference temperature of gate-edge component for source-bulk junction.
- 553 $csrbot=1E2 \text{ Am}^{-3}$ Shockley-Read-Hall prefactor of bottom component for source-bulk junction.
- 554 $csrhisti=1E-4 \text{ Am}^{-2}$ Shockley-Read-Hall prefactor of STI-edge component for source-bulk junction.
- 555 $csrgat=1E-4 \text{ Am}^{-2}$ Shockley-Read-Hall prefactor of gate-edge component for source-bulk junction.
- 556 $xjunsti=100E-9 \text{ m}$ Junction depth of STI-edge component for source-bulk junction.
- 557 $xjngat=100E-9 \text{ m}$ Junction depth of gate-edge component for source-bulk junction.
- 558 $ctatbot=1E2 \text{ Am}^{-3}$ Trap-assisted tunneling prefactor of bottom component for source-bulk junction.
- 559 $ctatsti=1E-4 \text{ Am}^{-2}$ Trap-assisted tunneling prefactor of STI-edge component for source-bulk junction.
- 560 $ctatgat=1E-4 \text{ Am}^{-2}$ Trap-assisted tunneling prefactor of gate-edge component for source-bulk junction.
- 561 $mefftatbot=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of bottom component for source-bulk junction.
- 562 $mefftatsti=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of STI-edge component for source-bulk junction.
- 563 $mefftatgat=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of gate-edge component for source-bulk junction.
- 564 $cbbtbot=1E-12 \text{ AV}^{-3}$ Band-to-band tunneling prefactor of bottom component for source-bulk junction.

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- 565 `cbbtsti=1E-18` AV^{-3m}
Band-to-band tunneling prefactor of STI-edge component for source-bulk junction.
- 566 `cbbtgat=1E-18` AV^{-3m}
Band-to-band tunneling prefactor of gate-edge component for source-bulk junction.
- 567 `fbbtbot=1E9` Vm^{-1}
Normalization field at the reference temperature for band-to-band tunneling of bottom component for source-bulk junction.
- 568 `fbbtsti=1E9` Vm^{-1}
Normalization field at the reference temperature for band-to-band tunneling of STI-edge component for source-bulk junction.
- 569 `fbbtgat=1E9` Vm^{-1}
Normalization field at the reference temperature for band-to-band tunneling of gate-edge component for source-bulk junction.
- 570 `stfbbtbot=1E-3` K^{-1}
Temperature scaling parameter for band-to-band tunneling of bottom component for source-bulk junction.
- 571 `stfbbtsti=1E-3` K^{-1}
Temperature scaling parameter for band-to-band tunneling of STI-edge component for source-bulk junction.
- 572 `stfbbtgat=1E-3` K^{-1}
Temperature scaling parameter for band-to-band tunneling of gate-edge component for source-bulk junction.
- 573 `vbrbot=10` V
Breakdown voltage of bottom component for source-bulk junction.
- 574 `vbrsti=10` V
Breakdown voltage of STI-edge component for source-bulk junction.
- 575 `vbrgat=10` V
Breakdown voltage of gate-edge component for source-bulk junction.
- 576 `pbrbot=4` V
Breakdown onset tuning parameter of bottom component for source-bulk junction.

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577	<code>pbrsti=4 V</code>	Breakdown onset tuning parameter of STI-edge component for source-bulk junction.
578	<code>pbrgat=4 V</code>	Breakdown onset tuning parameter of gate-edge component for source-bulk junction.
579	<code>cjorbotd=1E-3 Fm⁻²</code>	Zero-bias capacitance per unit-of-area of bottom component for drain-bulk junction.
580	<code>cjorstid=1E-9 Fm⁻¹</code>	Zero-bias capacitance per unit-of-length of STI-edge component for drain-bulk junction.
581	<code>cjorgatd=1E-9 Fm⁻¹</code>	Zero-bias capacitance per unit-of-length of gate-edge component for drain-bulk junction.
582	<code>vbirbotd=1 V</code>	Built-in voltage at the reference temperature of bottom component for drain-bulk junction.
583	<code>vbirstid=1 V</code>	Built-in voltage at the reference temperature of STI-edge component for drain-bulk junction.
584	<code>vbirgatd=1 V</code>	Built-in voltage at the reference temperature of gate-edge component for drain-bulk junction.
585	<code>pbotd=0.5</code>	Grading coefficient of bottom component for drain-bulk junction.
586	<code>pstid=0.5</code>	Grading coefficient of STI-edge component for drain-bulk junction.
587	<code>pgatd=0.5</code>	Grading coefficient of gate-edge component for drain-bulk junction.
588	<code>phigbotd=1.16 V</code>	Zero-temperature bandgap voltage of bottom component for drain-bulk junction.
589	<code>phigstid=1.16 V</code>	Zero-temperature bandgap voltage of STI-edge component for drain-bulk junction.
590	<code>phiggatd=1.16 V</code>	Zero-temperature bandgap voltage of gate-edge component for drain-bulk junction.

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- 591 `idsatrbotd=1E-12` Am^{-2}
Saturation current density at the reference temperature of bottom component for drain-bulk junction.
- 592 `idsatrstid=1E-18` Am^{-1}
Saturation current density at the reference temperature of STI-edge component for drain-bulk junction.
- 593 `idsatrgatd=1E-18` Am^{-1}
Saturation current density at the reference temperature of gate-edge component for drain-bulk junction.
- 594 `csrbotd=1E2` Am^{-3}
Shockley-Read-Hall prefactor of bottom component for drain-bulk junction.
- 595 `csrhostid=1E-4` Am^{-2}
Shockley-Read-Hall prefactor of STI-edge component for drain-bulk junction.
- 596 `csrhgatd=1E-4` Am^{-2}
Shockley-Read-Hall prefactor of gate-edge component for drain-bulk junction.
- 597 `xjunstid=100E-9` m Junction depth of STI-edge component for drain-bulk junction.
- 598 `xjungatd=100E-9` m Junction depth of gate-edge component for drain-bulk junction.
- 599 `ctatbotd=1E2` Am^{-3}
Trap-assisted tunneling prefactor of bottom component for drain-bulk junction.
- 600 `ctatstid=1E-4` Am^{-2}
Trap-assisted tunneling prefactor of STI-edge component for drain-bulk junction.
- 601 `ctatgatd=1E-4` Am^{-2}
Trap-assisted tunneling prefactor of gate-edge component for drain-bulk junction.
- 602 `mefftatbotd=0.25` Effective mass (in units of m_0) for trap-assisted tunneling of bottom component for drain-bulk junction.

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- 603 $m_{\text{eff}t\text{at}stid}=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of STI-edge component for drain-bulk junction.
- 604 $m_{\text{eff}t\text{at}gatd}=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of gate-edge component for drain-bulk junction.
- 605 $c_{\text{bb}t\text{bot}d}=1E-12$ AV^{-3}
Band-to-band tunneling prefactor of bottom component for drain-bulk junction.
- 606 $c_{\text{bb}t\text{stid}}=1E-18$ AV^{-3m}
Band-to-band tunneling prefactor of STI-edge component for drain-bulk junction.
- 607 $c_{\text{bb}t\text{gatd}}=1E-18$ AV^{-3m}
Band-to-band tunneling prefactor of gate-edge component for drain-bulk junction.
- 608 $f_{\text{bb}t\text{rbot}d}=1E9$ Vm^{-1}
Normalization field at the reference temperature for band-to-band tunneling of bottom component for drain-bulk junction.
- 609 $f_{\text{bb}t\text{rstid}}=1E9$ Vm^{-1}
Normalization field at the reference temperature for band-to-band tunneling of STI-edge component for drain-bulk junction.
- 610 $f_{\text{bb}t\text{rgatd}}=1E9$ Vm^{-1}
Normalization field at the reference temperature for band-to-band tunneling of gate-edge component for drain-bulk junction.
- 611 $stf_{\text{bb}t\text{bot}d}=-1E-3$ K^{-1}
Temperature scaling parameter for band-to-band tunneling of bottom component for drain-bulk junction.
- 612 $stf_{\text{bb}t\text{stid}}=-1E-3$ K^{-1}
Temperature scaling parameter for band-to-band tunneling of STI-edge component for drain-bulk junction.
- 613 $stf_{\text{bb}t\text{gatd}}=-1E-3$ K^{-1}
Temperature scaling parameter for band-to-band tunneling of gate-edge component for drain-bulk junction.
- 614 $v_{\text{brbot}d}=10$ V Breakdown voltage of bottom component for drain-bulk junction.

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615	<code>vbrstid=10 V</code>	Breakdown voltage of STI-edge component for drain-bulk junction.
616	<code>vbrgatd=10 V</code>	Breakdown voltage of gate-edge component for drain-bulk junction.
617	<code>pbrbotd=4 V</code>	Breakdown onset tuning parameter of bottom component for drain-bulk junction.
618	<code>pbrstid=4 V</code>	Breakdown onset tuning parameter of STI-edge component for drain-bulk junction.
619	<code>pbrgatd=4 V</code>	Breakdown onset tuning parameter of gate-edge component for drain-bulk junction.
620	<code>swjunexp=0</code>	Flag for JUNCAP-express; 0,full model, 1,express model.
621	<code>vjunref=2.5</code>	Typical maximum source-bulk junction voltage; usually about 2*VSUP.
622	<code>fjunq=0.03</code>	Fraction below which source-bulk junction capacitance components are considered negligible.
623	<code>vjunrefd=2.5</code>	Typical maximum drain-bulk junction voltage; usually about 2*VSUP.
624	<code>fjunqd=0.03</code>	Fraction below which drain-bulk junction capacitance components are considered negligible.
625	<code>dta=0.0 K</code>	Temperature offset w.r.t. ambient temperature.
626	<code>w=10e-6 m</code>	Default width.
627	<code>l=10e-6 m</code>	Default length.
628	<code>nf=1</code>	Number of fingers, It served as the default value of instance nf.
629	<code>vds_max=infinity V</code>	Maximum allowed voltage cross source and drain.
630	<code>vgd_max=infinity V</code>	Maximum allowed voltage cross gate and drain.

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631	<code>vgs_max=infinity</code>	V	Maximum allowed voltage cross gate and source/bulk.
632	<code>vbd_max=infinity</code>	V	Maximum allowed voltage cross source/drain and bulk.
633	<code>vbs_max=infinity</code>	V	Maximum allowed voltage cross source and bulk.
634	<code>vgb_max=infinity</code>	V	Maximum allowed voltage cross gate and bulk.
635	<code>vthmod</code>		Vth output selector. <code>std</code> outputs model equation Vth. <code>vthcc</code> outputs constant current Vth, and may impact simulation performance. The default value is taken from the options parameter <code>vthmod</code> . Possible values are <code>std</code> or <code>vthcc</code> .
636	<code>ivth</code>	(m)	Vth current parameter. The default value is taken from the options parameter <code>ivthn</code> or <code>ivthp</code> , depending on the type of the model.
637	<code>ivthw</code>	(m)	Width offset for constant current Vth. The default value is taken from the options parameter <code>ivthw</code> .
638	<code>ivthl</code>	(V)	Length offset for constant current Vth. The default value is taken from the options parameter <code>ivthl</code> .
639	<code>ivth_vdsmin</code>	(V)	Minimum Vds in constant current Vth calculating. The default value is taken from the options parameter <code>ivth_vdsmin</code> .

Output Parameters

1	<code>lv2</code>	(m)	alias of <code>w</code> .
2	<code>lv1</code>	(m)	alias of <code>l</code> .
3	<code>lv3</code>	(m ²)	alias of <code>ad</code> .
4	<code>lv4</code>	(m ²)	alias of <code>as</code> .
5	<code>lv11</code>	(m)	alias of <code>pd</code> .

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6	<code>lv12</code> (m)	alias of <code>ps</code> .
7	<code>table_pseff</code> (m)	For table model.
8	<code>table_pdeff</code> (m)	For table model.

Operating-Point Parameters

1	<code>l=10e-6</code> m	Design length.
2	<code>w=10e-6</code> m	Design width.
3	<code>sa=0.0</code> m	Distance between OD-edge and poly from one side.
4	<code>sb=0.0</code> m	Distance between OD-edge and poly from other side.
5	<code>sd=0.0</code> m	Distance between neighboring fingers.
6	<code>sca=0.0</code>	Integral of the first distribution function for scattered well dopants.
7	<code>scb=0.0</code>	Integral of the second distribution function for scattered well dopants.
8	<code>scc=0.0</code>	Integral of the third distribution function for scattered well dopants.
9	<code>sc=0.0</code> m	Distance between OD-edge and nearest well edge.
10	<code>nf=1</code>	Number of fingers.
11	<code>ngcon=1.0</code>	Number of gate contacts.
12	<code>xgw=1.0E-7</code> m	Distance from the gate contact to the channel edge.
13	<code>nrs=0.0</code>	Number of squares of source diffusion.
14	<code>nrd=0.0</code>	Number of squares of drain diffusion.
15	<code>trise=0.0</code> K	Temperature rise from ambient.
16	<code>jw=1E-6</code> m	Gate-edge length of source/drain junction.

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17	<code>delvto=0.0 V</code>	Threshold voltage shift parameter.
18	<code>factuo=1.0</code>	Zero-field mobility pre-factor.
19	<code>absource=1E-12 m^2</code>	Bottom area of source junction.
20	<code>lssource=1E-6 m</code>	STI-edge length of source junction.
21	<code>lgsource=1E-6 m</code>	Gate-edge length of source junction.
22	<code>abdrain=1E-12 m^2</code>	Bottom area of drain junction.
23	<code>lsdrain=1E-6 m</code>	STI-edge length of drain junction.
24	<code>lgdrain=1E-6 m</code>	Gate-edge length of drain junction.
25	<code>as=1E-12 m^2</code>	Bottom area of source junction.
26	<code>ps=1E-6 m</code>	Perimeter of source junction.
27	<code>ad=1E-12 m^2</code>	Bottom area of drain junction.
28	<code>pd=1E-6 m</code>	Perimeter of drain junction.
29	<code>ctype</code>	Flag for channel type.
30	<code>sdint</code>	Flag for source-drain interchange.
31	<code>ise (A)</code>	Total source current.
32	<code>ige (A)</code>	Total gate current.
33	<code>ide (A)</code>	Total drain current.
34	<code>ibe (A)</code>	Total bulk current.
35	<code>ids (A)</code>	Drain current, excl. avalanche, tunnel, GISL, GIDL, and junction currents.
36	<code>idb (A)</code>	Drain to bulk current.
37	<code>isb (A)</code>	Source to bulk current.

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38	i_{gs} (A)	Gate-source tunneling current.
39	i_{gd} (A)	Gate-drain tunneling current.
40	i_{gb} (A)	Gate-bulk tunneling current.
41	i_{gcs} (A)	Gate-channel tunneling current (source component.
42	i_{gcd} (A)	Gate-channel tunneling current (drain component.
43	i_{avl} (A)	Substrate current due to weak avalanche.
44	i_{gisl} (A)	Gate-induced source leakage current.
45	i_{gidl} (A)	Gate-induced drain leakage current.
46	i_{js} (A)	Total source junction current.
47	i_{jsbot} (A)	Source junction current (bottom component.
48	i_{jsgat} (A)	Source junction current (gate-edge component.
49	i_{jssti} (A)	Source junction current (STI-edge component.
50	i_{jd} (A)	Total drain junction current.
51	i_{jdbot} (A)	Drain junction current (bottom component.
52	i_{jdgat} (A)	Drain junction current (gate-edge component.
53	i_{jdsti} (A)	Drain junction current (STI-edge component.
54	q_g (Coul)	Intrinsic gate charge.
55	q_d (Coul)	Intrinsic drain charge.
56	q_b (Coul)	Intrinsic bulk charge.
57	q_s (Coul)	Intrinsic source charge.
58	q_{gs_ov} (Coul)	Overlap charge for gate-source.
59	q_{gd_ov} (Coul)	Overlap charge for gate-drain.

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60	qf _{gs} (Coul)	Total outerFringe + overlap for gate-source.
61	qf _{gd} (Coul)	Total outerFringe + overlap for gate-drain.
62	qgb _{ov} (Coul)	Gate-bulk overlap charge.
63	qjun _s (Coul)	Junction charge on source side.
64	qjun _d (Coul)	Junction charge on drain side.
65	v _{ds} (V)	Drain-source voltage.
66	v _{gs} (V)	Gate-source voltage.
67	v _{sb} (V)	Source-bulk voltage.
68	v _{to} (V)	Zero-bias threshold voltage.
69	v _{ts} (V)	Threshold voltage including back bias effects.
70	v _{th} (V)	Threshold voltage including back bias and drain bias effects.
71	v _{gt} (V)	Effective gate drive voltage including back bias and drain bias effects.
72	v _{dss} (V)	Drain saturation voltage at actual bias.
73	v _{sat}	Saturation limit.
74	g _m (1/Ohm)	Transconductance.
75	g _{mb} (1/Ohm)	Substrate transconductance.
76	g _{ds} (1/Ohm)	Output conductance.
77	g _{js} (1/Ohm)	Source junction conductance.
78	g _{jd} (1/Ohm)	Drain junction conductance.
79	c _{dd} (F)	Drain capacitance.
80	c _{dg} (F)	Drain-gate capacitance.

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81	<code>c_{ds}</code> (F)	Drain-source capacitance.
82	<code>c_{db}</code> (F)	Drain-bulk capacitance.
83	<code>c_{gd}</code> (F)	Gate-drain capacitance.
84	<code>c_{gg}</code> (F)	Gate capacitance.
85	<code>c_{gs}</code> (F)	Gate-source capacitance.
86	<code>c_{gb}</code> (F)	Gate-bulk capacitance.
87	<code>c_{sd}</code> (F)	Source-drain capacitance.
88	<code>c_{sg}</code> (F)	Source-gate capacitance.
89	<code>c_{ss}</code> (F)	Source capacitance.
90	<code>c_{sb}</code> (F)	Source-bulk capacitance.
91	<code>c_{bd}</code> (F)	Bulk-drain capacitance.
92	<code>c_{bg}</code> (F)	Bulk-gate capacitance.
93	<code>c_{bs}</code> (F)	Bulk-source capacitance.
94	<code>c_{bb}</code> (F)	Bulk capacitance.
95	<code>c_{gsol}</code> (F)	Total gate-source overlap capacitance.
96	<code>c_{gdol}</code> (F)	Total gate-drain overlap capacitance.
97	<code>c_{gbol}</code> (F)	Total gate-bulk overlap capacitance.
98	<code>c_{js}</code> (F)	Total source junction capacitance.
99	<code>c_{jsbot}</code> (F)	Source junction capacitance (bottom component).
100	<code>c_{jsgat}</code> (F)	Source junction capacitance (gate-edge component).
101	<code>c_{jssti}</code> (F)	Source junction capacitance (STI-edge component).
102	<code>c_{jd}</code> (F)	Total drain junction capacitance.

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103	<code>cjdbot</code> (F)	Drain junction capacitance (bottom component.
104	<code>cjdgat</code> (F)	Drain junction capacitance (gate-edge component.
105	<code>cjdsti</code> (F)	Drain junction capacitance (STI-edge component.
106	<code>weff</code> (m)	Effective channel width for geometrical models.
107	<code>leff</code> (m)	Effective channel length for geometrical models.
108	<code>lpoly</code> (m)	
109	<code>u</code>	Transistor gain.
110	<code>rout</code> (Ohm)	Small-signal output resistance.
111	<code>vearly</code> (V)	Equivalent Early voltage.
112	<code>beff</code> (V)	Gain factor.
113	<code>fug</code> (Hz)	Unity gain frequency at actual bias.
114	<code>rg</code> (Ohm)	Gate resistance.
115	<code>sfl</code>	Flicker noise current density at 1 Hz.
116	<code>sqrtsff</code>	Input-referred RMS white noise voltage density at 1 kHz.
117	<code>sqrtsfw</code>	Input-referred RMS white noise voltage density.
118	<code>sid</code>	White noise current density.
119	<code>sig</code>	Induced gate noise current density at 1 Hz.
120	<code>cigid</code>	Imaginary part of correlation coefficient between Sig and Sid.
121	<code>fknee</code>	Cross-over frequency above which white noise is dominant.
122	<code>sig_s</code>	Gate-source current noise spectral density.
123	<code>sig_d</code>	Gate-drain current noise spectral density.
124	<code>siavl</code>	Impact ionization current noise spectral density.

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125	<code>ssi</code>	Total source junction current noise spectral density.
126	<code>sdi</code>	Total drain junction current noise spectral density.
127	<code>lp_vfb</code> (V)	Local parameter VFB after T-scaling and clipping.
128	<code>lp_stvfb</code> (V/K)	Local parameter STVFB after clipping.
129	<code>lp_tox</code> (m)	Local parameter TOX after clipping.
130	<code>lp_epsrox</code>	Local parameter EPSROX after clipping.
131	<code>lp_neff</code> (m ⁻³)	Local parameter NEFF after clipping.
132	<code>lp_facneffac</code>	Local parameter FACNEFFAC after clipping.
133	<code>lp_gfacnud</code>	Local parameter GFACNUD after clipping.
134	<code>lp_vsbnud</code> (V)	Local parameter VSBNUD after clipping.
135	<code>lp_dvsbnud</code> (V)	Local parameter DVSBNUD after clipping.
136	<code>lp_vnsub</code> (V)	Local parameter VNSUB after clipping.
137	<code>lp_nslp</code> (V)	Local parameter NSLP after clipping.
138	<code>lp_dnsud</code> (V ⁻¹)	Local parameter DNSUD after clipping.
139	<code>lp_dphib</code> (V)	Local parameter DPHIB after clipping.
140	<code>lp_delvtac</code> (V)	Local parameter DELVTAC after clipping.
141	<code>lp_np</code> (m ⁻³)	Local parameter NP after clipping.
142	<code>lp_ct</code>	Local parameter CT after clipping.
143	<code>lp_toxov</code> (m)	Local parameter TOXOV after clipping.
144	<code>lp_toxovd</code> (m)	Local parameter TOXOVD after clipping.
145	<code>lp_nov</code> (m ⁻³)	Local parameter NOV after clipping.

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146	lp_novd (m^{-3})	Local parameter NOVD after clipping.
147	lp_cf	Local parameter CF after clipping.
148	lp_cfb (V^{-1})	Local parameter CFB after clipping.
149	lp_betn ($m^2/(V \cdot s)$)	Local parameter BETN after T-scaling and clipping.
150	lp_stbet	Local parameter STBET after clipping.
151	lp_mue (m/V)	Local parameter MUE after T-scaling and clipping.
152	lp_stmue	Local parameter STMUE after clipping.
153	lp_themu	Local parameter THEMU after T-scaling and clipping.
154	$lp_stthemu$	Local parameter STTHEMU after clipping.
155	lp_cs	Local parameter CS after T-scaling and clipping.
156	lp_stcs	Local parameter STCS after clipping.
157	lp_xcor (V^{-1})	Local parameter XCOR after T-scaling and clipping.
158	lp_stxcor	Local parameter STXCOR after clipping.
159	lp_feta	Local parameter FETA after clipping.
160	lp_rs (Ohm)	Local parameter RS after T-scaling and clipping.
161	lp_strs	Local parameter STRS after clipping.
162	lp_rsb (V^{-1})	Local parameter RSB after clipping.
163	lp_rsg (V^{-1})	Local parameter RSG after clipping.
164	lp_thesat (V^{-1})	Local parameter THESAT after T-scaling and clipping.
165	$lp_stthesat$	Local parameter STTHESAT after clipping.

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166	$lp_thesatb$ (V^{-1})	Local parameter THESATB after clipping.
167	$lp_thesatg$ (V^{-1})	Local parameter THESATG after clipping.
168	lp_ax	Local parameter AX after clipping.
169	lp_alp	Local parameter ALP after clipping.
170	lp_alp1 (V)	Local parameter ALP1 after clipping.
171	lp_alp2 (V^{-1})	Local parameter ALP2 after clipping.
172	lp_vp (V)	Local parameter VP after clipping.
173	lp_a1	Local parameter A1 after clipping.
174	lp_a2 (V)	Local parameter A2 after T-scaling and clipping.
175	lp_sta2	Local parameter STA2 after clipping.
176	lp_a3	Local parameter A3 after clipping.
177	lp_a4 ($1/\sqrt{V}$)	Local parameter A4 after clipping.
178	lp_gco	Local parameter GCO after clipping.
179	lp_iginv (A)	Local parameter IGINV after T-scaling and clipping.
180	lp_igov (A)	Local parameter IGOV after T-scaling and clipping.
181	lp_igovd (A)	Local parameter IGOVD after T-scaling and clipping.
182	lp_stig	Local parameter STIG after clipping.
183	lp_gc2	Local parameter GC2 after clipping.
184	lp_gc3	Local parameter GC3 after clipping.
185	lp_chib (V)	Local parameter CHIB after clipping.

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186	lp_agidl (A/V ³)	Local parameter AGIDL after clipping.
187	lp_agidld (A/V ³)	Local parameter AGIDLD after clipping.
188	lp_bgidl (V)	Local parameter BGIDL after T-scaling and clipping.
189	lp_bgidld (V)	Local parameter BGIDLD after T-scaling and clipping.
190	$lp_stbgidl$ (V/K)	Local parameter STBGIDL after clipping.
191	$lp_stbgidld$ (V/K)	Local parameter STBGIDLD after clipping.
192	lp_cgidl	Local parameter CGIDL after clipping.
193	lp_cgidld	Local parameter CGIDLD after clipping.
194	lp_cox (F)	Local parameter COX after clipping.
195	lp_cgov (F)	Local parameter CGOV after clipping.
196	lp_cgovd (F)	Local parameter CGOVD after clipping.
197	lp_cgbov (F)	Local parameter CGBOV after clipping.
198	lp_cfr (F)	Local parameter CFR after clipping.
199	lp_cfrd (F)	Local parameter CFRD after clipping.
200	lp_fnt	Local parameter FNT after clipping.
201	lp_nfa (1/(V m ⁴))	Local parameter NFA after clipping.
202	lp_nfb (1/(V m ²))	Local parameter NFB after clipping.
203	lp_nfc (V ⁻¹)	Local parameter NFC after clipping.
204	lp_ef	Local parameter EF after clipping.

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205	lp_rg (Ohm)	Local parameter RG after clipping.
206	lp_rse (Ohm)	Local parameter RSE after clipping.
207	lp_rde (Ohm)	Local parameter RDE after clipping.
208	lp_rbulk (Ohm)	Local parameter RBULK after clipping.
209	lp_rwell (Ohm)	Local parameter RWELL after clipping.
210	lp_rjuns (Ohm)	Local parameter RJUNS after clipping.
211	lp_rjund (Ohm)	Local parameter RJUND after clipping.
212	lp_munqs	Local parameter MUNQS after clipping.
213	lv13	alias of nrd.
214	lv14	alias of nrs.
215	lv36 (F)	alias of cgsol.
216	lv37 (F)	alias of cgdol.
217	lv38 (F)	alias of cgbol.
218	table_ids (A)	For table model.
219	table_vth (V)	For table model.
220	table_qg (Coul)	For table model.
221	table_qd (Coul)	For table model.
222	table_qb (Coul)	For table model.
223	table_id (A)	For table model.
224	table_isub (A)	For table model.

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225	table_ibs (A)	For table model.
226	table_ibd (A)	For table model.
227	table_igd (A)	For table model.
228	table_igb (A)	For table model.
229	table_igs (A)	For table model.
230	table_gds (1/Ohm)	For table model.
231	table_gm (1/Ohm)	For table model.
232	table_gmbs (1/Ohm)	For table model.
233	table_qbs (Coul)	For table model.
234	table_qbd (Coul)	For table model.
235	table_vdsat (V)	For table model.
236	table_leff (m)	For table model.
237	table_weff (m)	For table model.
238	table_aseff (m ²)	For table model.
239	table_adeff (m ²)	For table model.

Parameter Index

In the following index, I refers to instance parameters, M refers to the model parameters section, O refers to the output parameters section, and OP refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the

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description for that parameter. For example, a reference of M-35 means the 35th model parameter.

a1	M-62	iginv	M-68	plalp	M-214	qs	OP-58
a1l	M-454	iginvlw	M-465	plalp1	M-218	rbulk	M-98
a1o	M-453	igisl	OP-45	plalp2	M-222	rbulko	M-506
a1w	M-455	igov	M-69	plax	M-210	rde	M-97
a2	M-63	igovd	M-70	plbetn	M-161	rg	M-95
a2o	M-456	igovdw	M-467	plcf	M-156	rg	OP-113
a3	M-65	igovw	M-466	plcfr	M-288	rgo	M-499
a3l	M-459	igs	OP-39	plcfrd	M-292	rint	M-500
a3o	M-458	ijd	OP-51	plcgbov	M-284	rjund	M-101
a3w	M-460	ijdbot	OP-52	plcgov	M-276	rjundo	M-509
a4	M-66	ijdgat	OP-53	plcgovd	M-280	rjuns	M-100
a4l	M-462	ijdsti	OP-54	plcox	M-272	rjunso	M-508
a4o	M-461	ijs	OP-47	plcs	M-176	rout	OP-109
a4w	M-463	ijsbot	OP-48	plct	M-142	rs	M-49
abdrain	I-22	ijsgat	OP-49	pldelvtac	M-134	rsb	M-51
abdrain	OP-22	ijssti	OP-50	pldphib	M-130	rsbo	M-426
absource	I-19	imax	M-532	plfacneffac	M-117	rse	M-96
absource	OP-19	isb	OP-38	plgfacnud	M-121	rsg	M-52

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ad	I-27	ise	OP-32	pliginv	M-242	rsgo	M-427
ad	OP-27	isnoisy	I-30	pligov	M-246	rsh	M-504
agidl	M-75	jw	I-16	pligovd	M-250	rshd	M-505
agidld	M-76	jw	OP-16	plkuowe	M-314	rshg	M-502
agidldw	M-473	kuo	M-513	plkvthowe	M-310	rsw1	M-423
agidlw	M-472	kuowel	M-495	plmue	M-169	rsw2	M-424
alp	M-58	kuowelw	M-497	plneff	M-113	rvpoly	M-501
alp1	M-59	kuoweo	M-494	plnfa	M-297	rwell	M-99
alp111	M-444	kuowew	M-496	plnfb	M-301	rwello	M-507
alp112	M-446	kvsat	M-514	plnfc	M-305	sa	I-3
alp1lexp	M-445	kvtho	M-521	plnov	M-148	sa	OP-3
alp1w	M-447	kvthowel	M-491	plnovd	M-152	saref	M-510
alp2	M-60	kvthowelw	M-493	plnp	M-138	sb	I-4
alp211	M-448	kvthoweo	M-490	plrs	M-187	sb	OP-4
alp212	M-450	kvthowew	M-492	plstbet	M-165	sbref	M-511
alp2lexp	M-449	l	I-1	plstthesat	M-198	sc	I-9
alp2w	M-451	l	M-623	plstvfb	M-107	sc	OP-9
alp1	M-441	l	OP-1	plthesat	M-194	sca	I-6
alplexp	M-442	lap	M-324	plthesatb	M-202	sca	OP-6
alpnoi	M-489	leff	OP-107	plthesatg	M-206	scb	I-7
alpw	M-443	level	M-1	plvfb	M-103	scb	OP-7

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as	I-25	lgdrain	I-24	plwa1	M-229	scc	I-8
as	OP-25	lgdrain	OP-24	plwa3	M-235	scc	OP-8
ax	M-57	lgsource	I-21	plwa4	M-239	scref	M-529
ax1	M-440	lgsource	OP-21	plwagidl	M-260	sd	I-5
axo	M-439	lintnoi	M-488	plwagidld	M-264	sd	OP-5
beff	OP-111	lkuo	M-516	plwalp	M-216	sdi	OP-125
betn	M-38	lkvtho	M-522	plwalp1	M-220	sdint	OP-31
betn_mismatch	M-630	llodkuo	M-519	plwalp2	M-224	sfl	OP-114
betw1	M-399	llodvth	M-525	plwax	M-212	siavl	OP-123
betw2	M-400	lmax	M-318	plwbetn	M-163	sid	OP-117
bgidl	M-77	lmin	M-317	plwcf	M-158	sig	OP-118
bgidld	M-78	lodetao	M-528	plwcfr	M-290	sigd	OP-122
bgidldo	M-475	lov	M-384	plwcfrd	M-294	sigs	OP-121
bgidlo	M-474	lovd	M-385	plwcgbov	M-286	sqrtsf	OP-115
cbb	OP-95	lp1	M-395	plwcgov	M-278	sqrtsfw	OP-116
cbbtbot	M-560	lp1w	M-396	plwcgovd	M-282	ssi	OP-124
cbbtbotd	M-601	lp2	M-398	plwcox	M-274	sta2	M-64
cbbtgat	M-562	lp_a1	OP-172	plwcs	M-178	sta2o	M-457
cbbtgatd	M-603	lp_a2	OP-173	plwct	M-144	stbet	M-39
cbbtsti	M-561	lp_a3	OP-175	plwdelvtac	M-136	stbet1	M-403

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cbbtstid	M-602	lp_a4	OP-176	plwdphib	M-132	stbetlw	M-405
cbd	OP-92	lp_agidl	OP-185	plwfacneffac	M-119	stbeto	M-402
cbg	OP-93	lp_agidd	OP-186	plwgfacnud	M-123	stbetw	M-404
cbs	OP-94	lp_alp	OP-168	plwiginv	M-244	stbgidl	M-79
cdb	OP-83	lp_alp1	OP-169	plwigov	M-248	stbgidd	M-80
cdd	OP-80	lp_alp2	OP-170	plwigovd	M-252	stbgidldo	M-477
cdg	OP-81	lp_ax	OP-167	plwkuowe	M-316	stbgidlo	M-476
cds	OP-82	lp_betn	OP-148	plwkvthowe	M-312	stcs	M-45
cf	M-36	lp_bgidl	OP-187	plwmue	M-171	stcso	M-416
cfb	M-37	lp_bgidld	OP-188	plwneff	M-115	stetao	M-527
cfbo	M-391	lp_cf	OP-146	plwnfa	M-299	stfbbtbot	M-566
cf1	M-388	lp_cfb	OP-147	plwnfb	M-303	stfbbtbotd	M-607
cflexp	M-389	lp_cfr	OP-197	plwnfc	M-307	stfbbtgat	M-568
cfr	M-87	lp_cfrd	OP-198	plwnov	M-150	stfbbtgatd	M-609
cfrd	M-88	lp_cgbov	OP-196	plwnovd	M-154	stfbbtsti	M-567
cfrdw	M-482	lp_cgidl	OP-191	plwnp	M-140	stfbbtstid	M-608
cfrw	M-481	lp_cgidld	OP-192	plwrs	M-189	stig	M-71
cfw	M-390	lp_cgov	OP-194	plwstbet	M-167	stigo	M-468
cgb	OP-87	lp_cgovd	OP-195	plwstthesat	M-200	stmue	M-41
cgbov	M-86	lp_chib	OP-184	plwstvfb	M-109	stmueo	M-408

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cgbovl M-480	lp_cox OP-193	plwthesat M-196	strs M-50
cgd OP-84	lp_cs OP-154	plwthesatb M-204	strso M-425
cgdol OP-97	lp_ct OP-141	plwthesatg M-208	stthemu M-43
cgg OP-85	lp_delvtac OP-139	plwvfb M-105	stthemuo M-410
cgidl M-81	lp_dnsb OP-137	plwxcor M-183	stthesat M-54
cgidld M-82	lp_dphib OP-138	plxcor M-181	stthesatl M-434
cgidldo M-479	lp_dvsbnud OP-134	poa1 M-226	stthesatlw M-436
cgidlo M-478	lp_ef OP-203	poa2 M-230	stthesato M-433
cgov M-84	lp_epsrox OP-129	poa3 M-232	stthesatw M-435
cgovd M-85	lp_facneffac OP-131	poa4 M-236	stvfb M-17
cgs OP-86	lp_feta OP-158	poagidl M-257	stvfb1 M-336
cgsol OP-96	lp_fnt OP-199	poagidld M-261	stvfb1w M-338
chib M-74	lp_gc2 OP-182	poalp M-213	stvfb0 M-335
chibo M-471	lp_gc3 OP-183	poalp1 M-217	stvfbw M-337
cigid OP-119	lp_gco OP-177	poalp2 M-221	stxcor M-47
cjd OP-102	lp_gfacnud OP-132	poax M-209	stxcoro M-421
cjdbot OP-103	lp_iginv OP-178	pobetn M-160	swdelvtac M-12
cjdgat OP-104	lp_igov OP-179	pobgidl M-265	swgeo M-5
cjdsti OP-105	lp_igovd OP-180	pobgidld M-266	swgidl M-8

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cjorbot	M-534	lp_mue	OP-150	pocf	M-155	swigate	M-6
cjorbotd	M-575	lp_munqs	OP-211	pocfb	M-159	swimpact	M-7
cjorgat	M-536	lp_neff	OP-130	pocfr	M-287	swjunasym	M-10
cjorgatd	M-577	lp_nfa	OP-200	pocfrd	M-291	swjuncap	M-9
cjorsti	M-535	lp_nfb	OP-201	pocgbov	M-283	swjunexp	M-616
cjorstid	M-576	lp_nfc	OP-202	pocgidl	M-269	swnqs	M-4
cjs	OP-98	lp_nov	OP-144	pocgidld	M-270	swnud	M-11
cjsbot	OP-99	lp_novd	OP-145	pocgov	M-275	table_adeff	OP-234
cjsgat	OP-100	lp_np	OP-140	pocgovd	M-279	table_aseff	OP-233
cjssti	OP-101	lp_nslp	OP-136	pochib	M-256	table_gds	OP-225
cox	M-83	lp_rbulk	OP-207	pocox	M-271	table_gm	OP-226
cs	M-44	lp_rde	OP-206	pocs	M-175	table_gmbs	OP-227
csb	OP-91	lp_rg	OP-204	poct	M-141	table_ibd	OP-221
csd	OP-88	lp_rjund	OP-210	podelvtac	M-133	table_ibs	OP-220
csg	OP-89	lp_rjuns	OP-209	podnsub	M-128	table_id	OP-218
csl	M-412	lp_rs	OP-159	podphib	M-129	table_ids	OP-213
cslexp	M-413	lp_rsb	OP-161	podvsbnud	M-125	table_igb	OP-223
cslw	M-415	lp_rse	OP-205	poef	M-308	table_igd	OP-222
cso	M-411	lp_rsg	OP-162	poepsrox	M-111	table_igs	OP-224

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csrbot	M-549	lp_rwell	OP-208	pofacneffac	M-116	table_isub	OP-219
csrbotd	M-590	lp_sta2	OP-174	pofeta	M-185	table_leff	OP-231
csrhat	M-551	lp_stbet	OP-149	pofnt	M-295	table_pdeff	OP-236
csrhatd	M-592	lp_stbgidl	OP-189	pogc2	M-254	table_pseff	OP-235
csrhti	M-550	lp_stbgidd	OP-190	pogc3	M-255	table_qb	OP-217
csrhtid	M-591	lp_stcs	OP-155	pogco	M-240	table_qbd	OP-229
css	OP-90	lp_stig	OP-181	pogfacnud	M-120	table_qbs	OP-228
csw	M-414	lp_stmue	OP-151	poiginv	M-241	table_qd	OP-216
ct	M-31	lp_strs	OP-160	poigov	M-245	table_qg	OP-215
ctatbot	M-554	lp_stthemu	OP-153	poigovd	M-249	table_vdsat	OP-230
ctatbotd	M-595	lp_stthesat	OP-164	pokuowe	M-313	table_vth	OP-214
ctatgat	M-556	lp_stvfb	OP-127	pokvthowe	M-309	table_weff	OP-232
ctatgatd	M-597	lp_stxcor	OP-157	pomue	M-168	themu	M-42
ctatsti	M-555	lp_themu	OP-152	poneff	M-112	themuo	M-409
ctatstid	M-596	lp_thesat	OP-163	ponfa	M-296	thesat	M-53
ctl	M-378	lp_thesatb	OP-165	ponfb	M-300	thesatb	M-55
ctlexp	M-379	lp_thesatg	OP-166	ponfc	M-304	thesatbo	M-437

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ctlw M-381	lp_tox OP-128	ponov M-147	thesatg M-56
cto M-377	lp_toxov OP-142	ponovd M-151	thesatgo M-438
ctw M-380	lp_toxovd OP-143	ponp M-137	thesatl M-429
ctype OP-30	lp_vfb OP-126	ponslp M-127	thesatlexp M-430
dcmbbetn M-629	lp_vnsub OP-135	pors M-186	thesatlw M-432
delvtac M-29	lp_vp OP-171	porsb M-191	thesato M-428
delvtac1 M-371	lp_vsbnud OP-133	porsg M-192	thesatw M-431
delvtaclexp M-372	lp_xcor OP-156	posta2 M-231	tkuo M-515
delvtac1w M-374	lpck M-347	postbet M-164	tox M-18
delvtaco M-370	lpckw M-348	postbgidl M-267	toxoxo M-339
delvtacw M-373	lsdrain I-23	postbgidld M-268	toxov M-32
delvto I-17	lsdrain OP-23	postcs M-179	toxovd M-33
delvto OP-17	lssource I-20	postig M-253	toxovdo M-383
dlq M-329	lssource OP-20	postmue M-172	toxovo M-382
dlsil M-503	lvar1 M-322	postrs M-190	tr M-3
dnsub M-27	lvaro M-321	postthemu M-174	trise I-15
dnsubo M-364	lvarw M-323	postthesat M-197	trise OP-15
dphib M-28	m I-31	postvfb M-106	trj M-533
dphib1 M-366	m OP-212	postxcor M-184	type M-2
dphiblexp M-367	mbe M-627	pothemu M-173	u OP-108

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dphiblw M-369	mbeo M-628	pothesat M-193	uo M-392
dphibo M-365	mefftatbot M-557	pothesatb M-201	vbirbot M-537
dphibw M-368	mefftatbotd M-598	pothesatg M-205	vbirbotd M-578
dta M-621	mefftatgat M-559	potox M-110	vbirgat M-539
dvsbnud M-24	mefftatgatd M-600	potoxov M-145	vbirgatd M-580
dvsbnudo M-361	mefftatsti M-558	potoxovd M-146	vbirsti M-538
dwq M-330	mefftatstid M-599	povfb M-102	vbirstid M-579
ef M-93	minr M-15	povnsub M-126	vrbot M-569
efo M-487	mue M-40	povp M-225	vrbotd M-610
epsrox M-19	mueo M-406	povsbnud M-124	vbrgat M-571
epsroxo M-340	muew M-407	poxcor M-180	vbrgatd M-612
facneffac M-21	mult I-29	ps I-26	vbrsti M-570
facneffacl M-352	mult OP-29	ps OP-26	vbrstid M-611
facneffaclw M-354	munqs M-94	psti M-541	vds OP-66
facneffaco M-351	munqso M-498	pstid M-582	vdss OP-73
facneffacw M-353	mvt M-625	pwa1 M-228	vearly OP-110
factuo I-18	mvto M-626	pwa3 M-234	version M-14
factuo OP-18	neff M-20	pwa4 M-238	vfb M-16
fbtrbot M-563	nf I-10	pwagidl M-259	vfb1 M-332

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fbtrbotd M-604	nf M-624	pwagidld M-263	vfbw M-334
fbtrgat M-565	nf OP-10	pwalp M-215	vfbo M-331
fbtrgatd M-606	nfa M-90	pwalp1 M-219	vfbw M-333
fbtrsti M-564	nfalw M-484	pwalp2 M-223	vgs OP-67
fbtrstid M-605	nfb M-91	pwax M-211	vgt OP-72
fbet1 M-393	nfbw M-485	pwbetn M-162	vjunref M-617
fbetlw M-394	nfc M-92	pwcf M-157	vjunrefd M-619
fbet2 M-397	nfclw M-486	pwcfr M-289	vnsb M-25
feta M-48	ngcon I-11	pwcfrd M-293	vnsbo M-362
fetao M-422	ngcon OP-11	pwcgbov M-285	vp M-61
fjunq M-618	nov M-34	pwcgov M-277	vpo M-452
fjunqd M-620	novd M-35	pwcgovd M-281	vsat OP-74
fknee OP-120	novdo M-387	pwcox M-273	vsb OP-68
fnt M-89	novo M-386	pwcs M-177	vsbnud M-23
fnto M-483	np M-30	pwct M-143	vsbnudo M-360
fol1 M-349	npck M-344	pwdelvtac M-135	vth OP-71
fol2 M-350	npckw M-345	pwdphib M-131	vto OP-69
fug OP-112	npl M-376	pwfacneffac M-118	vts OP-70
gc2 M-72	npo M-375	pwgfacnud M-122	w I-2
gc2o M-469	nrd I-14	pwiginv M-243	w M-622

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gc3	M-73	nrd	OP-14	pwigov	M-247	w	OP-2
gc3o	M-470	nrs	I-13	pwigovd	M-251	wbet	M-401
gco	M-67	nrs	OP-13	pwkuowe	M-315	web	M-530
gcoo	M-464	nslp	M-26	pwkvthowe	M-311	wec	M-531
gds	OP-77	nslpo	M-363	pwmue	M-170	weff	OP-106
gfacnud	M-22	nsubo	M-341	pwneff	M-114	wkuo	M-517
gfacnudl	M-356	nsubw	M-342	pwnfa	M-298	wkvtho	M-523
gfacnudlexp	M-357	pbot	M-540	pwnfb	M-302	wlod	M-512
gfacnudlw	M-359	pbotd	M-581	pwnfc	M-306	wlodkuo	M-520
gfacnudo	M-355	pbrbot	M-572	pwnov	M-149	wlodvth	M-526
gfacnudw	M-358	pbrbotd	M-613	pwnovd	M-153	wmax	M-320
gjd	OP-79	pbrgat	M-574	pwnp	M-139	wmin	M-319
gjs	OP-78	pbrgatd	M-615	pwr	M-188	wot	M-328
gm	OP-75	pbrsti	M-573	pwstbet	M-166	wseg	M-343
gmb	OP-76	pbrstid	M-614	pwstthesat	M-199	wsegp	M-346
iavl	OP-44	pd	I-28	pwstvfb	M-108	wvarl	M-326
ibe	OP-35	pd	OP-28	pwthesat	M-195	wvaro	M-325
idb	OP-37	pgat	M-542	pwthesatb	M-203	wvarw	M-327
ide	OP-34	pgatd	M-583	pwthesatg	M-207	xcor	M-46
ids	OP-36	phigbot	M-543	pwvfb	M-104	xcorl	M-418

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idsatrbot	M-546	phigbotd	M-584	pwxcor	M-182	xcorlw	M-420
idsatrbotd	M-587	phiggat	M-545	qib	OP-57	xcoro	M-417
idsatrgat	M-548	phiggatd	M-586	qd	OP-56	xcorw	M-419
idsatrgatd	M-589	phigsti	M-544	qfgd	OP-62	xgw	I-12
idsatrsti	M-547	phigstid	M-585	qfgs	OP-61	xgw	OP-12
idsatrstid	M-588	pkuo	M-518	qg	OP-55	xjungat	M-553
igb	OP-41	pkvtho	M-524	qgb_ov	OP-63	xjungatd	M-594
igcd	OP-43	pla1	M-227	qgd_ov	OP-60	xjunsti	M-552
igcs	OP-42	pla3	M-233	qgs_ov	OP-59	xjunstid	M-593
igd	OP-40	pla4	M-237	qjun_d	OP-65		
ige	OP-33	plagidl	M-258	qjun_s	OP-64		
igidl	OP-46	plagidld	M-262	qmc	M-13		

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PSP-Based MOS Varactor Model (mosvar)

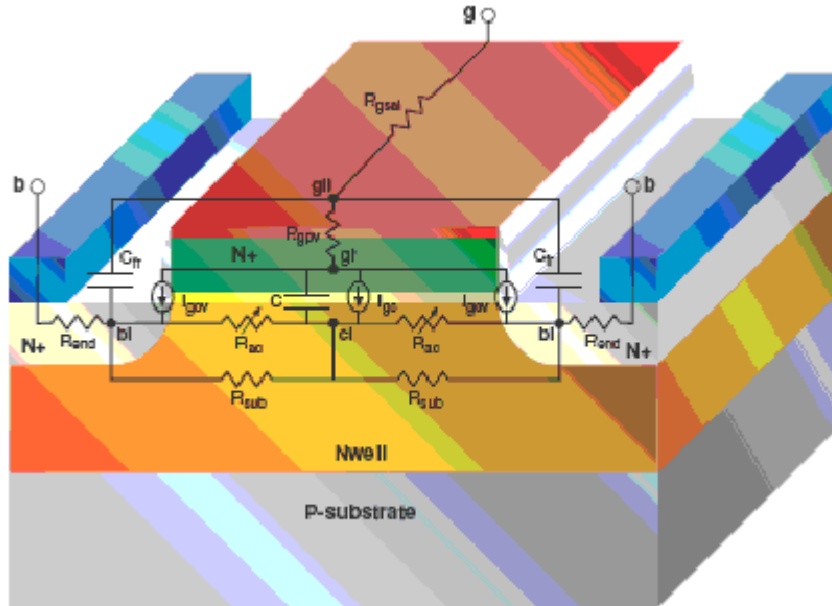
The PSP-based varactor model is intended for analog and radio-frequency circuit design. It includes dynamic inversion, finite poly doping, quantum mechanics, gate tunneling for different polarity combinations, and parasitics to model advanced MOS technologies.

This chapter contains the following information about the PSP model:

- [Device Structure](#) on page 2026
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Device Structure

The following figure shows a cross section of the standard MOS varactor offered in the current MOS technologies with its equivalent circuit model overlapped on it. g , bi and b are the external terminals while gii , gi and ci are the internal nodes.



The following table explains the meanings of the symbols in the above figure.

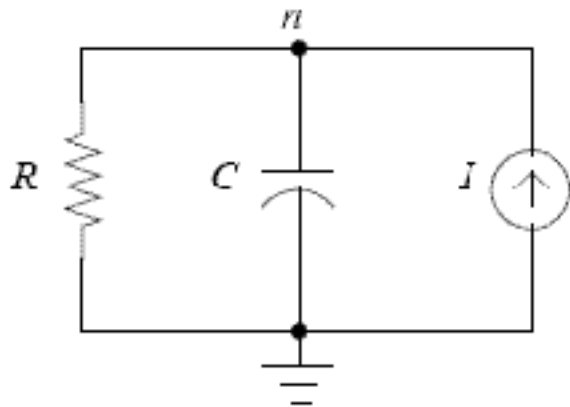
No.	Name	Description
1	C	Gate-channel capacitance
2	C_{fr}	Fringe and overlap capacitance
3	I_{gc}	Gate-channel current
4	I_{gov}	Gate-overlap current
5	R_{gsal}	Metal resistance
6	R_{gpv}	Poly gate resistance
7	R_{ac}	Accumulation resistance
8	R_{sub}	Substrate (in well region) resistance
9	R_{end}	End resistance

Model Version Updates

Version 1.2.0

- Parameter `EPSROXO` has been added for relative dielectric permittivity
- Gate current computations has been revised to avoid numerical problems and to use `GC3HVO` for HVB current
- Parameter `RACNOISE` has been added to select noise equations for `Rac`.
- Noise names have been made more descriptive.
- Shot noise for gate currents has been added.

RC Circuit Model for Inversion Charge



$$q_i = q_i^0 - TAU \cdot \frac{dq}{dt}$$

Parameter Initializing

Capacitance of Oxide and Body Factors

$$C_{ox} = \varepsilon_{ox} / TOXO$$

$$\Upsilon_s = \sqrt{2 \cdot q \cdot \varepsilon_{si} \cdot NSUBO / C_{ox}}$$

$$\Upsilon_p = \sqrt{2 \cdot q \cdot \varepsilon_{si} \cdot NPO / C_{ox}}$$

$$\Upsilon_{ov,s} = \sqrt{2 \cdot q \cdot \varepsilon_{si} \cdot NOVO / C_{ox}}$$

If QMC>0,

$$q_q = \begin{cases} 0.4 \cdot QMN \cdot QMC \cdot (C_{ox})^{2/3} & \text{if TYPE} > 0 \\ 0.4 \cdot QMP \cdot QMC \cdot (C_{ox})^{2/3} & \text{otherwise} \end{cases}$$

else

$\alpha_q = 0$.

$$\eta_\mu = \begin{cases} 0.5 \cdot FETA & \text{if TYPE} > 0 \\ \frac{1}{3} \cdot FETA & \text{otherwise} \end{cases}$$

$$norm_{tox} = TOXO / 10^{-9}$$

Initializing Parameters

Temperature-Related Parameters

$$TR1 = \begin{cases} TR, & \text{if } TR \geq -273 \\ -273, & \text{if } TR < -273 \end{cases}$$

$$T_{KR} = 273.15 + TR1$$

$$T_{KD} = T_A + DTA$$

$$\Delta T = T_{KD} - T_{KR}$$

$$\phi_T = k_B \cdot T_{KD} / q$$

$$q_{lim2} = 100 \cdot \phi_T^2$$

$$V_{fb, T} = VFBO + \Delta T \cdot STVFB$$

$$R_{shg, T} = RSHG \cdot \left(\frac{T_{KR}}{T_{KD}} \right)^{STRSHG}$$

$$R_{pv, T} = RPV \cdot \left(\frac{T_{KR}}{T_{KD}} \right)^{STRPV}$$

$$R_{end, T} = REND \cdot \left(\frac{T_{KR}}{T_{KD}} \right)^{STREND}$$

$$R_{shs, T} = RSHS \cdot \left(\frac{T_{KR}}{T_{KD}} \right)^{STRSHS}$$

$$U_{ac, T} = UAC \cdot \left(\frac{T_{KD}}{T_{KR}} \right)^{STUAC}$$

Virtuoso Simulator Components and Device Models Reference

PSP-Based MOS Varactor Model (mosvar)

General Parameters

$$nt0 = 4 \cdot \text{'KBOL} \cdot T_{\text{KD}}$$

$$L_{\text{eff}} = L + \text{DLQ}$$

$$W_{\text{eff}} = W + \text{DWQ}$$

$$M_{\text{eff}} = M_{\text{SEG}} \cdot \text{'MFACTOR_USE}$$

$$\text{INV}_{\text{Meff}} = 1.0 / M_{\text{eff}}$$

$$E_{\text{g}} = 1.179 - T_{\text{KD}} \cdot (9.025 \cdot 10^{-5} + 3.05 \cdot 10^{-7} \cdot T_{\text{KD}})$$

$$r_{\text{T}} = (1.045 + 4.5 \cdot 10^{-4} \cdot T_{\text{KD}}) \cdot (0.523 + 1.4 \cdot 10^{-3} \cdot T_{\text{KD}} - 1.48 \cdot 10^{-6} \cdot T_{\text{KD}}^2) \cdot \frac{T_{\text{KD}}^2}{90000}$$

$$\text{INV}_{\text{ni}} = 4 \cdot 10^{-26} \cdot r_{\text{T}}^{-0.75}$$

$$\phi_{\text{b}} = E_{\text{g}} + 2 \cdot \phi_{\text{T}} \cdot \ln(\text{NSUBO} \cdot \text{INV}_{\text{ni}})$$

$$k_{\text{se1}} = 230.26$$

$$k_{\text{se2}} = 460.52$$

Parameters Related to Polysilicon and Overlap Regions

$$G_p = \gamma_p / \sqrt{\phi_T}$$

$$\xi_p = 1 + G_p / \sqrt{2}$$

$$\varpi_{mrgp} = 10^{-5} \cdot \xi_p$$

$$\phi_p = E_g + 2 \cdot \phi_T \cdot \ln(\text{NPO} \cdot \text{INV}_{ni})$$

$$\varpi_{np} = \phi_p / \phi_T$$

$$\Delta_{np} = \begin{cases} \exp(-\varpi_{np}), & \text{if } \varpi_{np} < k_{se2} \\ \frac{10^{-200}}{\text{P3}(\varpi_{np} - k_{se2})}, & \text{otherwise} \end{cases}$$

$$G_{ov, s} = \gamma_{ov, s} / \sqrt{\phi_T}$$

$$\xi_{ov, s} = 1 + G_{ov, s} / \sqrt{2}$$

$$\varpi_{mrgov, s} = 10^{-5} \cdot \xi_{ov, s}$$

$$\phi_{b, ov} = E_g + 6 \cdot \phi_T$$

$$\varpi_1 = 1.25$$

$$\varpi_{g1, ov} = \varpi_1 + G_{ov, s} \cdot \sqrt{\exp(-\varpi_1) + \varpi_1 - 1}$$

Resistances

$$\text{If SWRES} = \text{true} \left\{ \begin{array}{l} R_{\text{gsal}} = \frac{R_{\text{shg}, T} \cdot W}{L \cdot [3 + 9 \cdot (\text{NGCON} - 1)]} \\ R_{\text{gpv}} = \frac{R_{\text{pv}, T}}{W \cdot L} \\ R_{\text{end}} = \frac{R_{\text{end}, T}}{2 \cdot (W + \text{DWR})} \\ R_{\text{sub}} = \frac{R_{\text{shs}, T} \cdot L}{12 \cdot (W + \text{DWR})} \\ R_{\text{gsal}} = \text{'CLIP_BOTH}(R_{\text{gsal}}, 1.0e - 03, 1e01) \\ R_{\text{gpv}} = \text{'CLIP_BOTH}(R_{\text{gpv}}, 1.0e - 03, 1e02) \\ R_{\text{end}} = \text{'CLIP_BOTH}(R_{\text{end}}, 1.0e - 03, 1e01) \\ R_{\text{sub}} = \text{'CLIP_BOTH}(R_{\text{sub}}, 1.0e - 03, 1e03) \\ U_{\text{ac}, T} = \text{'CLIP_BOTH}(U_{\text{ac}, T}, 1.0e - 03, 2e01) \\ G_{\text{gsal}} = 1/R_{\text{gsal}} \\ G_{\text{gpv}} = 1/R_{\text{gpv}} \\ G_{\text{end}} = 1/R_{\text{end}} \\ G_{\text{sub}} = 1/R_{\text{sub}} \\ G_{\text{ac0}} = 12 \cdot U_{\text{ac}, T} \cdot W/L \end{array} \right.$$

$$\text{If SWRES} = \text{false} \left\{ \begin{array}{l} G_{\text{gsal}} = 0.0 \\ G_{\text{gpv}} = 0.0 \\ G_{\text{end}} = 0.0 \\ G_{\text{sub}} = 0.0 \\ G_{\text{ac0}} = 0.0 \end{array} \right.$$

Gate Tunneling Parameters

If SWIGATE = true	{	$I_{ginv} = IGINVLW \cdot W_{eff} \cdot L_{eff} \cdot 10^{12} \cdot \left(\frac{T_{KD}}{T_{KR}} \right)^{STIG}$ $I_{gov} = 2 \cdot IGOVW \cdot LOV \cdot W_{eff} \cdot 10^{12} \cdot \left(\frac{T_{KD}}{T_{KR}} \right)^{STIG}$ $I_{gcHVB} = IGCHVLW \cdot W_{eff} \cdot L_{eff} \cdot 10^{12} \cdot \left(\frac{T_{KD}}{T_{KR}} \right)^{STIG}$ $I_{govHVB} = 2 \cdot IGOVHVW \cdot LOV \cdot W_{eff} \cdot 10^{12} \cdot \left(\frac{T_{KD}}{T_{KR}} \right)^{STIG}$ $INV_{CHIB} = 1/CHIBO$ $INV_{CHIB,HVB} = 1/CHIBPO$ $B_{CH} = (4/3) \cdot TOXO \cdot \sqrt{2 \cdot q \cdot m_0 \cdot CHIBO} / \hbar$ $B_{OV} = B_{CH}$ $B_{CH,HVB} = (4/3) \cdot TOXO \cdot \sqrt{2 \cdot q \cdot m_0 \cdot CHIBPO} / \hbar$ $B_{OV,HVB} = B_{CH,HVB}$ <p>If GC30 < 0, $Q_{CQ} = -0.495 \cdot GC20/GC30$, else $Q_{CQ} = 0.0$, endif</p> $\alpha_{b,s} = 0.5 \cdot (E_g + TYPE \cdot \phi_b)$ $\alpha_{b,ov} = 0.5 \cdot (E_g + TYPE \cdot \phi_{b,ov})$ $D_{ch} = GCOO \cdot \phi_T$ $D_{ch,HVB} = GCOO \cdot \phi_T$
If SWIGATE = false	{	$I_{ginv} = 0$ $I_{gov} = 0$ $I_{gcHVB} = 0$ $I_{govHVB} = 0$ $INV_{CHIB} = 0.1$ $INV_{CHIB,HVB} = 0.1$ $B_{CH} = 0$ $B_{OV} = 0$ $B_{CH,HVB} = 0$ $B_{OV,HVB} = 0$ $Q_{CQ} = 0$ $\alpha_{b,s} = 0$ $\alpha_{b,ov} = 0$ $D_{ch} = 0$ $D_{ch,HVB} = 0$

Parameter Extraction

Capacitance-Related Model Parameter Extraction

$$C(V) = C_o(V) \cdot L \cdot W \cdot m + C_{fr} \cdot m$$

where C_o is the bias-dependent capacitance of an intrinsic device,

$$L = L_g + DLQ, W = W_g + DWQ$$

and m is the multiplicity factor. Parameters DWQ and DLQ describe the deviations of the effective channel length (L) and Width (W) from their drawn values L_g and W_g .

The total fringe capacitance is given by

$$C_{fr} = 2 \cdot (CFRW \cdot W + CFRL \cdot L)$$

Auxiliary Equations

$$\text{MINA}(x, y, a) = \frac{1}{2} \cdot \left[x + y - \sqrt{(x - y)^2 + a} \right]$$

$$\text{MAXA}(x, y, a) = \frac{1}{2} \cdot \left[x + y + \sqrt{(x - y)^2 + a} \right]$$

$$\nu = a + c$$

$$\mu_1 = \frac{\nu^2}{\tau} + \frac{c^2}{2} - a$$

$$\sigma_1(a, c, \tau, \eta) = \frac{a \cdot \nu}{\mu_1 + (c^2/3 - a) \cdot c \cdot \nu / \mu_1} + \eta$$

$$\mu_2 = \frac{\nu^2}{\tau} + \frac{c^2}{2} - a \cdot b$$

$$\sigma_2(a, b, c, \tau, \eta) = \frac{a \cdot \nu}{\mu_2 + (c^2/3 - a \cdot b) \cdot c \cdot \nu / \mu_2} + \eta$$

$$\text{P3}(u) = 1 + u \cdot [1 + 0.5 \cdot u \cdot (1 + u/3)]$$

$$\text{expl}(x) = \begin{cases} \exp(x), & \text{if } |x| < k_{\text{sel}} \\ \frac{10^{-100}}{\text{P3}(-k_{\text{sel}} - x)}, & \text{if } x < -k_{\text{sel}} \\ 10^{100} \cdot \text{P3}(x - k_{\text{sel}}), & \text{otherwise} \end{cases}$$

$$\text{expl}_{\text{low}}(x) = \begin{cases} \exp(x), & \text{if } x > -k_{\text{sel}} \\ \frac{10^{-100}}{\text{P3}(-k_{\text{sel}} - x)}, & \text{otherwise} \end{cases}$$

$$\text{expl}_{\text{high}}(x) = \begin{cases} \exp(x), & \text{if } x < k_{\text{sel}} \\ 10^{100} \cdot \text{P3}(x - k_{\text{sel}}), & \text{otherwise} \end{cases}$$

Component Statements

This device is supported within altergroups.

Instance Definition

```
Name g bi b ModelName <parameter=value> ...
```

Instance Parameters

- | | | |
|---|--------------|-------------------------------------|
| 1 | m=1.0 | Multiplicity factor. |
| 2 | w=1.0e-06 m | Design width of varactor. |
| 3 | l=1.0e-06 m | Design length of varactor. |
| 4 | ngcon=1 | Number of gate contacts. |
| 5 | dta=0.0 degC | Local temperature delta to ambient. |

Model Definition

```
model modelName mosvar parameter=value ...
```

Model Parameters

- | | | |
|---|--------------------|--|
| 1 | version=1.1 | The available versions are 1.1 and 1.2. |
| 2 | subversion=0.0 | Model subversion. |
| 3 | revision=0.0 | Model revision. |
| 4 | level=1000 | Model level. |
| 5 | tmin=(-100.0) degC | Minimum reference/ambient temperature. |
| 6 | tmax=500.0 degC | Maximum reference/ambient temperature. |
| 7 | vmax=10000.0 V | Maximum voltage applied between nodes g and b. |

Virtuoso Simulator Components and Device Models Reference

PSP-Based MOS Varactor Model (mosvar)

8	<code>tr=21.0 degC</code>	Nominal (reference) temperature.
9	<code>lmin=1.0e-08 m</code>	Minimum allowed drawn length.
10	<code>lmax=9.9e+09 m</code>	Maximum allowed drawn length.
11	<code>wmin=1.0e-08 m</code>	Minimum allowed drawn width.
12	<code>wmax=9.9e+09 m</code>	Maximum allowed drawn width.
13	<code>swres=1</code>	Switch to control series resistance: 0=exclude and 1=include.
14	<code>type=(-1)</code>	Substrate doping TYPE: -1=n-TYPE and +1=p-TYPE.
15	<code>typep=(-1)</code>	Polysilicon doping TYPE: -1=n-TYPE and +1=p-TYPE.
16	<code>toxoxo=20.0e-10 m</code>	Oxide thickness.
17	<code>epsroxoxo=3.9</code>	Relative permittivity.
18	<code>tau=0.1 s</code>	Time constant for inversion charge recombination/generation.
19	<code>vfbo=0.0 V</code>	Flatband voltage (for p-TYPE substrate).
20	<code>nsubo=3.0e+23 /m³</code>	Substrate doping level.
21	<code>mnsubo=1.0</code>	Maximum change in absolute doping, limited to 1 order of mag up.
22	<code>dnsubo=0.0</code>	Doping profile slope parameter.
23	<code>vnsubo=0.0</code>	Doping profile corner voltage parameter.
24	<code>nslpo=0.1</code>	Doping profile smoothing parameter.
25	<code>npoxo=1.0e+27 /m³</code>	Polysilicon doping level.
26	<code>qmc=1.0</code>	Quantum mechanical correction factor.
27	<code>d1q=0.0 m</code>	Length delta for capacitor size.
28	<code>dwq=0.0 m</code>	Width delta for capacitor size.

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PSP-Based MOS Varactor Model (mosvar)

29	dwr=0.0 m	Width delta for substrate resistance calculation.
30	cfrl=0.0 F/m	Fringing capacitance in length direction.
31	cfrw=0.0 F/m	Fringing capacitance in width direction.
32	rshg=1.0 Ω /sq	Gate sheet resistance.
33	rpv=0.0 Ω m ²	Vertical resistance down through gate in units of ohm*m ² .
34	rend=1.0e-04 Ω m	End resistance (extrinsic well res. plus vertical contact res. to well) per width.
35	rshs=1000.0 Ω /sq	Substrate sheet resistance.
36	uac=5.0e-02 m ² /V/s	Accumulation layer zero bias mobility.
37	uacred=0.0 /V	Accumulation layer mobility degradation factor.
38	stvfb=0.0 V/K	Temperature dependence of VFB.
39	strshg=0.0	Temperature dependence of RSHG.
40	strpv=0.0	Temperature dependence of RPV.
41	strend=0.0	Temperature dependence of REND.
42	strshs=0.0	Temperature dependence of RSHS.
43	stuac=0.0	Temperature dependence of UAC.
44	feta=1.0	Effective field parameter.
45	swigate=0	Flag for gate current: 0=turn off and 1=turn on.
46	chibo=3.1 V	Tunneling barrier height for electrons.
47	chibpo=4.5 V	Tunneling barrier height for holes.

Virtuoso Simulator Components and Device Models Reference

PSP-Based MOS Varactor Model (mosvar)

48	<code>stig=2.0</code>	Common temperature coefficient for gate currents (ECB, HVB and HVB).
49	<code>lov=0.0 m</code>	Overlap length.
50	<code>nov=5.0e+25 /m³</code>	Effective doping level of overlap regions.
51	<code>iginvlw=0.0 A</code>	ECB gate channel current pre-factor for 1 um ² channel area.
52	<code>igovw=0.0 A</code>	ECB gate overlap current pre-factor for 1 um wide gate overlap region.
53	<code>gcoo=0.0</code>	ECB gate tunneling energy adjustment.
54	<code>gc2o=0.375</code>	ECB gate current slope factor.
55	<code>gc3o=0.063</code>	ECB gate current curvature factor.
56	<code>igchvlw=0.0 A</code>	HVB gate channel current pre-factor for 1 um ² channel area.
57	<code>igovhvw=0.0 A</code>	HVB gate overlap current pre-factor for 1 um wide gate overlap region.
58	<code>gcohvo=0.0</code>	HVB gate tunneling energy adjustment.
59	<code>gc2hvo=0.375</code>	HVB gate current slope factor.
60	<code>gc3hvo=0.063</code>	HVB gate current curvature factor.
61	<code>minr=0.001</code>	Minimum resistor between bi and b.
62	<code>igmax=1.0e-05 A</code>	Maximum gate tunneling current.
63	<code>compatible=spectre</code>	Compatible parameters. Possible values are <code>spectre</code> , <code>spice2</code> , <code>spice3</code> , <code>cdsspice</code> , <code>hspice</code> , <code>spiceplus</code> , <code>eldo</code> , <code>sspice</code> , and <code>mica</code> .
64	<code>racnoise=1</code>	Rac noise selector.

Output Parameters

1	<code>tempeff (C)</code>	Effective temperature for a single device.
---	--------------------------	--

Virtuoso Simulator Components and Device Models Reference

PSP-Based MOS Varactor Model (mosvar)

2 `meff` Effective multiplicity factor (m-factor).

Operating-Point Parameters

1 `v` voltage across capacitor.

2 `i` Current through capacitor.

3 `cap` LOw frequency capacitance.

4 `qg` Intrinsic charge.

5 `igc` Gate tunneling current.

6 `igover` Gate overlap tunneling current.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

<code>cap</code> OP-3	<code>igc</code> OP-5	<code>nsubo</code> M-20	<code>tempeff</code> O-1
<code>cfrl</code> M-30	<code>igchvlw</code> M-56	<code>qg</code> OP-4	<code>tmax</code> M-6
<code>cfrw</code> M-31	<code>iginvlw</code> M-51	<code>qmc</code> M-26	<code>tmin</code> M-5
<code>chibo</code> M-46	<code>igmax</code> M-62	<code>racnoise</code> M-64	<code>tox0</code> M-16
<code>chibpo</code> M-47	<code>igover</code> OP-6	<code>rend</code> M-34	<code>tr</code> M-8
<code>compatible</code> M-63	<code>igovhvw</code> M-57	<code>revision</code> M-3	<code>type</code> M-14
<code>dlq</code> M-27	<code>igovw</code> M-52	<code>rpv</code> M-33	<code>typep</code> M-15
<code>dnsubo</code> M-22	<code>l</code> I-3	<code>rshg</code> M-32	<code>uac</code> M-36

Virtuoso Simulator Components and Device Models Reference

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dta	I-5	level	M-4	rshs	M-35	uacred	M-37
dwq	M-28	lmax	M-10	stig	M-48	v	OP-1
dwr	M-29	lmin	M-9	strend	M-41	version	M-1
epsroxo	M-17	lov	M-49	strpv	M-40	vfbo	M-19
feta	M-44	m	I-1	strshg	M-39	vmax	M-7
gc2hvo	M-59	meff	O-2	strshs	M-42	vnsubo	M-23
gc2o	M-54	minr	M-61	stuac	M-43	w	I-2
gc3hvo	M-60	mnsubo	M-21	stvfb	M-38	wmax	M-12
gc3o	M-55	ngcon	I-4	subversion	M-2	wmin	M-11
gcohvo	M-58	novo	M-50	swigate	M-45		
gcoo	M-53	npo	M-25	swres	M-13		
i	OP-2	nslpo	M-24	tau	M-18		

Virtuoso Simulator Components and Device Models Reference
PSP-Based MOS Varactor Model (mosvar)

EKV MOSFET Model (ekv)

The EPFL-EKV MOSFET model was developed by the Electronics Laboratories, Swiss Federal Institute of Technology (EPFL), Switzerland. This chapter contains the following information for the EKV MOSFET model:

- [Coherence of Static and Dynamic Models](#) on page 2044
- [Bulk Reference and Symmetry](#) on page 2044
- [Equivalent Circuit](#) on page 2045
- [Static Intrinsic Model](#) on page 2046
- [Quasi-static Model](#) on page 2054
- [Nonquasi-static \(NQS\) Model](#) on page 2057
- [Intrinsic Noise Model](#) on page 2058
- [Scaling Effects](#) on page 2059
- [Component Statements](#) on page 2059

Virtuoso Simulator Components and Device Models Reference

EKV MOSFET Model (ekv)

This section provides a description of the equations used for the EPFL-EKV MOSFET model. The description concentrates on the intrinsic part of the MOSFET. The extrinsic part of the MOSFET is handled as it is commonly made for other MOSFET models.

The EPFL-EKV MOSFET model is formulated as a *single expression*, which preserves the continuity of first- and higher-order derivatives with respect to any terminal voltage, in the entire range of validity of the model.

The EPFL-EKV MOSFET model version 2.6 includes modeling of the following physical effects:

- Basic geometrical and process-related aspects, such as oxide thickness, junction depth, and effective channel length and width
- Effects of doping profile and substrate effects
- Modeling of weak, moderate, and strong inversion behavior
- Modeling of mobility effects due to vertical and lateral fields and velocity saturation
- Short-channel effects, such as channel-length modulation (CLM), source and drain charge-sharing (including for narrow channel widths), and reverse short-channel effect (RSCE)
- Quasi-static charge-based dynamic model
- Thermal and flicker noise modeling
- First-order nonquasi-static model for the transadmittances

Coherence of Static and Dynamic Models

All aspects regarding the static, the quasi-static, and nonquasi-static dynamic and noise models are all derived in a coherent way from a single characteristic, the normalized transconductance-to-current ratio. Symmetric normalized forward and reverse currents are used throughout these expressions. The Virtuoso[®] Spectre[®] circuit simulator supports only one dynamic model, a charge-based model for the node charges and transcapacitances. The dynamic model, including the time constant for the nonquasi-static model, is described in symmetrical terms of the forward and reverse normalized currents. The charge formulation is further used to express the effective mobility dependence of the local field.

Bulk Reference and Symmetry

Voltages are all referred to the local substrate:

Virtuoso Simulator Components and Device Models Reference

EKV MOSFET Model (ekv)

$V_G = V_{GB}$ Intrinsic gate-to-bulk voltage

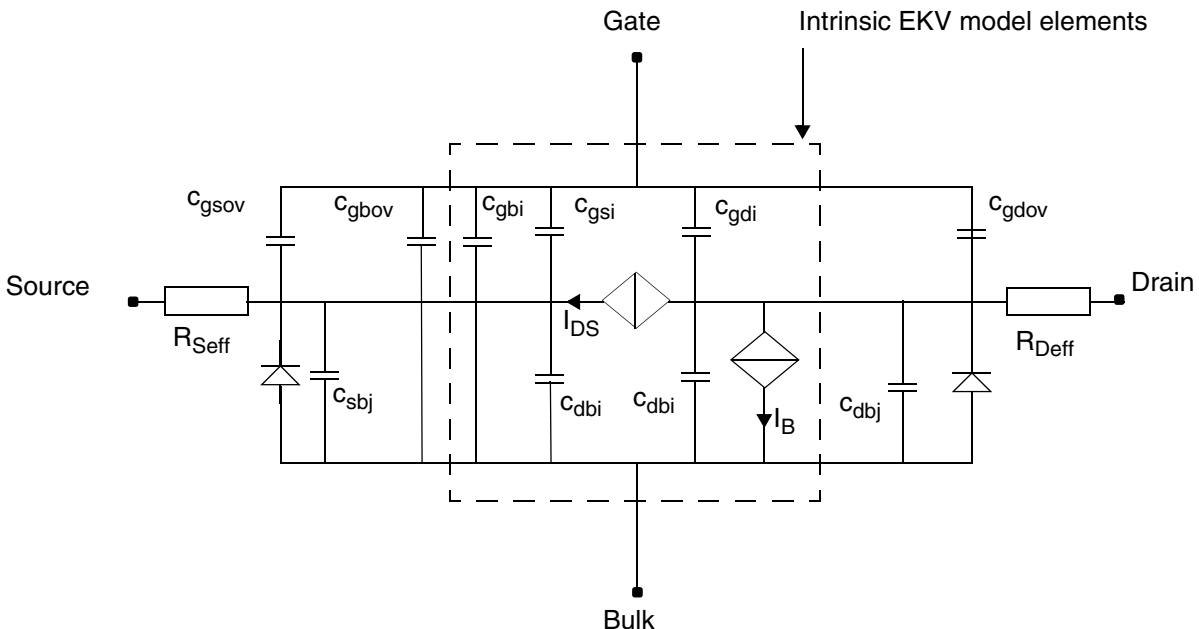
$V_S = V_{SB}$ Intrinsic source-to-bulk voltage

$V_D = V_{DB}$ Intrinsic drain-to-bulk voltage

V_S and V_D are the intrinsic voltages, which means that the voltage drop over extrinsic resistive elements is supposed to already be accounted for externally. V_D is the electrical drain voltage such that $V_D \geq V_S$. Bulk reference allows the model to be handled symmetrically with respect to source and drain, a symmetry that is inherent in common MOS technologies (excluding asymmetric source-drain layouts).

Note: Intrinsic model equations are present for an N-channel MOSFET. P-channel MOSFETs are dealt with as pseudo-N-channels; that is, the polarity of the voltages (V_G , V_S , V_D , as well as V_{TO}) is inverted before computing the current for PMOS, which is given a negative sign. No other distinctions are made between NMOS and PMOS, with the exception of the η factor for effective mobility calculation.

Equivalent Circuit



This figure represents the intrinsic and extrinsic elements of the MOS transistor. For quasi-static dynamic operation, only the intrinsic capacitances from the simpler capacitances model

are shown in the figure. However, a charge-based transcapacitances model is also available for computer simulation.

Static Intrinsic Model

Basic Relations

$$\varepsilon_0 \varepsilon_{si} = SCALE \cdot 104.5 \times 10^{-12} [F/m]$$

Thermal voltage

$$V_t = \frac{k \cdot T}{q}$$

Energy Gap

$$E_g(T) = 1.16 - 0.000702 \cdot \frac{T^2}{T + 1108}$$

Intrinsic Parameters Initialization

The basic intrinsic model parameters *COX*, *GAMMA*, *PHI*, *VTO*, *KP*, and *UCRIT* are related to the fundamental process parameters *TOX*, *NSUB*, *VFB*, *UO*, *VMAX*, respectively, similarly as in early SPICE models. For more information, see [Chapter 12, “Common MOSFET Equations”](#).

If *UCRIT* is not specified, it is initialized as

$$UCRIT = \begin{cases} VMAX / (UO \cdot 10^{-4}) & \text{for } VMAX > 0, UO > 0 \\ \text{default} & \text{otherwise} \end{cases}$$

If *E0* is not specified, a simplified mobility model is used with the parameter *THETA*:

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$$E0 = \begin{cases} 0 & \text{if } THETA \text{ specified} \\ \text{default} & \text{otherwise} \end{cases}$$

Note: The value zero is given to $E0$ here, indicating that the simplified mobility model is used in conjunction with $THETA$ instead of the standard mobility model.

Intrinsic Parameters Temperature Dependence

$$VTO(T) = VTO - TCV \cdot (T - Tnom)$$

$$KP(T) = KP \cdot \left(\frac{T}{Tnom}\right)^{BEX}$$

$$UCRIT(T) = UCRIT \cdot \left(\frac{T}{Tnom}\right)^{UCEX}$$

$$PHI(T) = PHI \cdot \frac{T}{Tnom} - 3 \cdot V_t \cdot \ln\left(\frac{T}{Tnom}\right) - E_g Tnom \cdot \frac{T}{Tnom} + E_g(T)$$

$$IBB(T) = IBB \cdot [1.0 + IBBT \cdot (T - Tnom)]$$

Effective Channel Length and Width

$$W_{eff} = W + DW$$

$$L_{eff} = L + DL$$

Note: Contrary to the convention adopted in other MOSFET models, DL and DW usually have a negative value because of the preceding definition.

Short Distance Matching

Random mismatch between two transistors with identical layout and close to each other is in most cases suitably described by a law following the inverse of the square root of the transistors' area. The following relationships have been adopted:

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$$VTO_a = VTO + \frac{AVTO}{\sqrt{NP \cdot W_{eff} \cdot NS \cdot L_{eff}}}$$

$$KP_a = KP \cdot \left(1 + \frac{AKP}{\sqrt{NP \cdot W_{eff} \cdot NS \cdot L_{eff}}} \right)$$

$$GAMMA_a = GAMMA + \frac{AGAMMA}{\sqrt{NP \cdot W_{eff} \cdot NS \cdot L_{eff}}}$$

Note: Because negative values for both KP_a and $GAMMA_a$ are not physically meaningful, these are clipped at zero.

Reverse Short-Channel Effect (RSCE)

$$C_\xi = 4 \cdot (22 \times 10^{-3})^2$$

$$C_A = 0.028$$

$$\xi = C_A \cdot \left(10 \cdot \frac{L_{eff}}{LK} - 1 \right)$$

$$\Delta V_{RSCE} = \frac{2 \cdot Q0}{COX} \cdot \frac{1}{\left[1 + \frac{1}{2} \cdot \left(\xi + \sqrt{\xi^2 + C_\xi} \right) \right]^2}$$

Effective Gate Voltage Including RSCE

$$V_G' = V_G - VTO_a - \Delta V_{RSCE} + PHI + GAMMA_a \sqrt{PHI}$$

Effective Substrate Factor Including Charge-Sharing for Short and Narrow Channels

Pinchoff Voltage for Narrow-Channel Effect

$$V_{P0} = \begin{cases} V_{G'} - PHI - GAMMA_a \left(\sqrt{V_{G'} + \left(\frac{GAMMA_a}{2} \right)^2} - \frac{GAMMA_a}{2} \right) & \text{for } V_{G'} > 0 \\ -PHI & \text{for } V_{G'} \leq 0 \end{cases}$$

Effective Substrate Factor Accounting for Charge Sharing

$$V_{S(D)} = \frac{1}{2} \cdot \left[V_{S(D)} + PHI + \sqrt{(V_{S(D)} + PHI)^2 + (4V_t)^2} \right]$$

Note: The preceding equation prevents the argument of the square roots in the subsequent code from becoming negative.

$$\gamma^o = GAMMA_a - \frac{\epsilon_0 \cdot \epsilon_{Si}}{COX} \cdot \left[\frac{LETA}{L_{eff}} \cdot (\sqrt{V_S} + \sqrt{V_D}) - \frac{3 \cdot WETA}{W_{eff}} (\sqrt{V_{P0} + PHI + 0.1 \cdot V_t}) \right]$$

$$\gamma' = \frac{1}{2} \cdot \left(\gamma^o + \sqrt{\gamma^{o2} + 0.1 \cdot V_t} \right)$$

Note: The purpose of the preceding equation is to prevent the effective substrate factor from becoming negative.

Pinchoff Voltage Including Short- and Narrow-Channel Effects

$$V_P = \begin{cases} V_{G'} - PHI - \gamma' \left(\sqrt{V_{G'} + \left(\frac{\gamma'}{2} \right)^2} - \frac{\gamma'}{2} \right) & \text{for } V_{G'} > 0 \\ -PHI & \text{for } V_{G'} \leq 0 \end{cases}$$

Slope Factor

$$n = 1 + \frac{GAMMA_a}{2 \cdot \sqrt{V_P + PHI + 4V_t}}$$

Large-Signal Interpolation Function

$F(v)$ is the large-scale interpolation function relating the normalized currents to the normalized voltages. A simple and accurate expression for the transconductance interpolation allows a consistent formulation of the static large-signal interpolation function, the dynamic model for the intrinsic charges (and capacitances), and the intrinsic time constant and the thermal noise model.

$$gms \cdot V_t / I_D = \frac{\sqrt{0.25 + i} - 0.5}{i}$$

Large-signal interpolation function:

$$y = \sqrt{0.25 + i} - 0.5$$

$$v = 2y + \ln(y)$$

Unfortunately, the preceding equation cannot be inverted analytically. However, it can be inverted using a Newton-Raphson iterative scheme. Currently, a simplification of this algorithm that avoids iteration is used, leading to a continuous expression for the large-signal interpolation function.

Large-Signal Interpolation Function for Hand Calculation

For hand calculations, an analytically simple interpolation function, presenting the same asymptotic behavior with slightly reduced accuracy in moderate inversion, can be used:

$$F(v) = [\ln(1 + \exp(v/2))]^2$$

Forward Normalized Current

$$i_f = F \left[\frac{V_P - V_S}{V_t} \right]$$

Velocity Saturation Voltage

$$V_C = UCRIT \cdot L_{eff}$$

$$V_{DSS} = V_C \cdot \left[\sqrt{\frac{1}{4} + \frac{V_t}{V_C} \cdot \sqrt{i_f} - \frac{1}{2}} \right]$$

Note: The variable V_{DSS} in this formulation for computer simulation is half the value of the actual saturation voltage.

Drain-to-Source Saturation Voltage for Reverse Normalized Current

$$V_{DSS} = V_C \cdot \left[\sqrt{\frac{1}{4} + \frac{V_t}{V_C} \cdot \left(\sqrt{i_f} - \frac{3}{4} \cdot \ln(i_f) \right) - \frac{1}{2}} \right] + V_t \cdot \left[\ln \left(\frac{V_C}{2V_t} \right) - 0.6 \right]$$

Channel-Length Modulation

$$\Delta V = 4 \cdot V_t \cdot \sqrt{LAMBDA \cdot \left(\sqrt{i_f} - \frac{V_{DSS}}{V_t} \right) + \frac{1}{64}}$$

$$\Delta L = LAMBDA \cdot L_C \cdot \ln \left(1 + \frac{V_{ds} - V_{ip}}{L_C \cdot UCRIT} \right)$$

$$V_{ds} = \frac{V_D - V_S}{2}$$

$$L_C = \sqrt{\frac{\varepsilon_0 \varepsilon_{si}}{COX}} \cdot XJ$$

$$V_{ip} = \sqrt{V_{DSS}^2 + \Delta V^2} - \sqrt{(V_{ds} - V_{DSS})^2 + \Delta V^2}$$

Equivalent Channel Length Including Channel-Length Modulation and Velocity Saturation

$$L' = L_{eff} - \Delta L + \frac{V_{ds} + V_{ip}}{UCRIT}$$

$$L_{min} = L_{eff} / 10$$

$$L_{eq} = \frac{1}{2} \cdot \left(L' + \sqrt{L'^2 + L_{min}^2} \right)$$

Note: The preceding equation prevents the equivalent channel length from becoming zero or negative.

Reverse Normalized Current

Reverse Normalized Current

$$i_r' = F \left[\frac{V_P - V_{ds} - V_S - \sqrt{V_{DSS}^2 + \Delta V^2} + \sqrt{(V_{ds} - V_{DSS})^2 + \Delta V^2}}{V_t} \right]$$

Reverse Normalized Current for Mobility Model, Intrinsic Charges/Capacitances, and NQS Time Constant

$$i_r = F \left[\frac{V_P - V_D}{V_t} \right]$$

Transconductance Factor and Mobility Reduction Due to Vertical Field

$$\beta_0 = KP_a \cdot \frac{NP \cdot W_{eff}}{NS \cdot L_{eq}}$$

Note: The use of the device parameter NP (or M) gives accurate results for the simulation of parallel devices, whereas the use of NS for series devices is only approximate.

$$\eta = \begin{cases} 1/2 & \text{for NMOS} \\ 1/3 & \text{for PMOS} \end{cases}$$

$$q_{B0} = GAMMA_a \cdot \sqrt{PHI}$$

$$\beta_0' = \beta_0 \cdot \left(1 + \frac{COX}{E0 \cdot \epsilon_0 \epsilon_{si}} \cdot q_{B0} \right)$$

$$\beta = \frac{\beta_0'}{1 + \frac{COX}{E0 \cdot \epsilon_0 \epsilon_{si}} \cdot V_t \cdot |q_B + \eta \cdot q_I|}$$

For the definition of the normalized bulk and inversion charges q_B and q_I , refer to [“Normalized Intrinsic Node Charges”](#) on page 2055.

Note: This formulation arises from the exact integration of the local effective field as a function of depletion and inversion charge densities along the channel. The bias dependence, in particular with the substrate bias, is accounted for due to the dependency on the channel charges.

Mobility Reduction Model Used in Former EKV Model Versions

For reasons of compatibility with EKV model versions before 2.6, a simpler mobility reduction model that uses the parameter $THETA$ can be used. The choice among model versions is made using the model version selector $UPDATE$. Check with the documentation in your simulator. If a model version $UPDATE < 2.6$ is specified, the former mobility reduction model is chosen:

$$V_P' = \frac{1}{2} \cdot \left(V_P + \sqrt{V_P^2 + 2V_t} \right)^2$$

$$\beta = \frac{\beta_0}{1 + THETA \cdot V_P}$$

Specific Current

$$I_S = 2 \cdot n \cdot \beta \cdot V_t^2$$

Drain-to-Source Current

$$I_{DS} = I_S \cdot (i_f - i_r)$$

Note: This drain current expression is a single equation, valid in all operating regions: weak, moderate, and strong inversion; conduction; and saturation. It is therefore not only continuous among all these regions, it is also continuously derivable.

Impact Ionization Current

$$V_{ib} = V_D - V_S - IBN \cdot 2 \cdot V_{DSS}$$

$$I_B = \begin{cases} I_{DS} \cdot \frac{IBA}{IBB} \cdot V_{ib} \cdot \exp\left(\frac{-IBB \cdot L_C}{V_{ib}}\right) & \text{for } V_{ib} > 0 \\ 0 & \text{for } V_{ib} \leq 0 \end{cases}$$

Note: The factor 2 in the expression for V_{ib} accounts for the fact that the numerical value of V_{DSS} is half the actual saturation voltage. The substrate current is intended to be treated as a component of the total extrinsic drain current, flowing from the drain to the bulk. It therefore also affects the total extrinsic conductances, in particular the drain conductance.

Quasi-static Model

Both a charge-based model for transcapacitances, allowing charge conservation during transient analysis, and a simpler capacitances-based model are available.

Note: The charges model is in principle formulated in symmetric terms of the forward and reverse normalized currents, that is, symmetrical for both drain and source sides. Further,

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short-channel effects, such as charge sharing and reverse short-channel effects, are included in the dynamic model through the pinchoff voltage.

Dynamic Model for the Intrinsic Node Charges

$$n_q = 1 + \frac{GAMMA_a}{2 \cdot \sqrt{V_P + PHI + 10^{-6}}}$$

Normalized Intrinsic Node Charges

$$x_f = \sqrt{\frac{1}{4} + i_f}$$

$$x_r = \sqrt{\frac{1}{4} + i_r}$$

$$q_{Qd} = -n_q \cdot \left(\frac{4}{15} \cdot \frac{3x_r^3 + 6x_r^2 x_f + 4x_r x_f^2 + 2x_f^3}{(x_f + x_r)^2} - \frac{1}{2} \right)$$

$$q_S = -n_q \cdot \left(\frac{4}{15} \cdot \frac{3x_f^3 + 6x_f^2 x_r + 4x_f x_r^2 + 2x_r^3}{(x_f + x_r)^2} - \frac{1}{2} \right)$$

$$q_I = q_S + q_D = -n_q \cdot \left(\frac{4}{3} \cdot \frac{x_f^2 + x_f x_r + x_r^2}{x_f + x_r} - 1 \right)$$

$$q_B = \begin{cases} \left(-GAMMA_a \cdot \sqrt{V_P + PHI + 10^{-6}} \right) \cdot \frac{1}{V_t} - \left(\frac{n_q - 1}{n_q} \right) \cdot q_I & \text{for } V_G > 0 \\ -V_G \cdot \frac{1}{V_t} & \text{for } V_G \leq 0 \end{cases}$$

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$$q_G = -q_I - q_{OX} - q_B$$

q_{OX} is a fixed-oxide charge assumed to be zero. The preceding equation expresses the charge conservation among the four nodes of the transistor.

Total Node Charges

$$C_{OX} = COX \cdot NP \cdot W_{eff} \cdot NS \cdot L_{eff}$$

$$Q_{(I,B,D,S,G)} = C_{ox} \cdot V_t \cdot q_{(I,B,D,S,G)}$$

Intrinsic Capacitances

Transcapacitances

The intrinsic capacitances are obtained through derivation of the node charges with respect to the terminal voltages. This results in simple analytical functions for all the transcapacitances in terms of x_f , x_r , the pinchoff voltage, the slope factor, and derivatives thereof.

Normalized Intrinsic Capacitances

A simpler model using the five intrinsic capacitances corresponding to the equivalent circuit shown in [“Equivalent Circuit”](#) on page 2045 can be obtained when neglecting the slight dependence on the slope factor n , resulting in the following simple functions:

$$c_{gs} = \frac{2}{3} \cdot \left(1 - \frac{x_r^2 - x_r + \frac{1}{2}x_f}{(x_f + x_r)^2} \right)$$

$$c_{gd} = \frac{2}{3} \cdot \left(1 - \frac{x_f^2 - x_f + \frac{1}{2}x_r}{(x_f + x_r)^2} \right)$$

$$c_{gb} = \left(\frac{n_q - 1}{n_q} \right) \cdot (1 - c_{gs} - c_{gd})$$

$$c_{sb} = (n_q - 1) \cdot c_{gs}$$

$$c_{db} = (n_q - 1) \cdot c_{gd}$$

Total Intrinsic Capacitances

$$C_{(gs,gd,gb,sb,db)} = C_{ox} \cdot c_{(gs,gd,gb,sb,db)}$$

Nonquasi-static (NQS) Model

The EKV model includes a first-order NQS model for small-signal (.AC) simulations. The expression of the NQS drain current is obtained from the quasi-static value of the drain current, which is then first-order low-pass filtered. *NQS* is a flag (model parameter) allowing you to disable the NQS model, and τ is the bias-dependent characteristic time constant.

Intrinsic Time Constant

τ_0 is the intrinsic time constant defined as

$$\tau_0 = \frac{COX}{2 \cdot \beta \cdot V_t} = \frac{(NS \cdot L_{eff})^2}{2 \cdot \mu_{eff} \cdot V_t}$$

$$\tau = \tau_0 \cdot \frac{4}{15} \cdot \frac{(x_f^2 + 3x_f x_r + x_r^2)}{(x_f + x_r)^3}$$

$$I_{DS}(s) = \frac{I_{DSq}(s)}{1 + NQS \cdot s \cdot \tau}$$

The corresponding small-signal (.AC) transadmittances are then given by

$$Y_m(s) = \frac{g_m}{1 + NQS \cdot s \cdot \tau}$$

$$Y_{ms}(s) = \frac{g_{ms}}{1 + NQS \cdot s \cdot \tau}$$

$$Y_{ds}(s) = \frac{g_{ds}}{1 + NQS \cdot s \cdot \tau}$$

$$Y_{mbs}(s) = Y_{ms}(s) - Y_m(s) - Y_{ds}(s)$$

where g_m , g_{ms} , and g_{ds} are the transconductances and output conductance evaluated at the operating point.

Intrinsic Noise Model

The noise is modeled by a current source I_{NDS} between intrinsic source and drain. It is composed of a thermal noise component and a flicker noise component and has the following power spectral density (PSD):

$$S_{INDS} = S_{thermal} + S_{flicker}$$

Thermal Noise

If model parameter `nlevel=1`,

$$S_{thermal} = \frac{8 \times kT \times |gm|}{3}$$

else

$$S_{thermal} = 4kT \cdot \frac{\mu_{eff}}{(NS \cdot L_{eff})^2} \cdot |Q_I| = 4kT \cdot \beta \cdot |q_I|$$

Note: The thermal noise expression is *valid in all regions of operation*, including for small V_{DS} .

Flicker Noise

When model parameter `noisemod=1`,

$$S_{flicker} = \frac{KF \times |Ids|^{AF}}{NP \cdot W_{eff} \cdot NS \cdot L_{eff} \cdot COX \cdot f^{EF}}$$

When model parameter `noisemod=2`,

$$S_{flicker} = \frac{KF \cdot |Ids|^{AF}}{NP \cdot L_{eff} \cdot NS \cdot L_{eff} \cdot COX \cdot f^{EF}}$$

When model parameter `noisemod=3`,

$$S_{flicker} = \frac{KF \cdot gm^2}{NP \cdot W_{eff} \cdot NS \cdot L_{eff} \cdot COX \cdot f^{AF}}$$

Scaling Effects

For scaling effects, see [Scaling Factors \(scale and scalem\)](#) on page 242.

Component Statements

This device is supported within altergroups.

Sample Instance Statement

```
mn1 (dn gn sn 0) ekvnmos w=1.5u l=1u ad=2.6p as=2.6p pd=6.6p ps=6.6p nrd=1.54  
nrs=1.54
```

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EKV MOSFET Model (ekv)

Sample Model Statement

```
model ekvnmos ekv type=n update=2.6 xqc=0.4 cox=3.4e-3 xj=0.145e-6 vto=0.6
gamma=0.71 phi=0.967 kp=155e-6 e0=88e6 iba=200e6 ibb=350e6 tnom=25 tcv=1.55e-3
bex=-1.45 kf=1e-27 af=1 hdif=0.94e-6 rsh=512 jsw=1.5e-10
```

Instance Definition

```
Name d g s b ModelName parameter=value ...
```

Instance Parameters

1	w (m)	Channel width.
2	l (m)	Channel length.
3	as (m ²)	Area of source diffusion.
4	ad (m ²)	Area of drain diffusion.
5	ps (m)	Perimeter of source diffusion.
6	pd (m)	Perimeter of drain diffusion.
7	nrd (m/m)	Number of squares of drain diffusion.
8	nrs (m/m)	Number of squares of source diffusion.
9	rdc (Ohm)	Drain contact resistance.
10	rsc (Ohm)	Source contact resistance.
11	m=1	Multiplicity factor (number of MOSFETs in parallel).
12	ns=1	Series Multiplicity factor (number of MOSFETs in series).
13	region=triode	Estimated operating region. Spectre outputs number (0-3) in a rawfile. Possible values are off, triode, sat, or subth.
14	trise	Temperature rise from ambient.
15	isnoisy=yes	Should device generate noise. Possible values are no or yes.

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EKV MOSFET Model (ekv)

Model Definition

```
model modelName ekv parameter=value ...
```

Model Parameters

Device type parameters:

- | | | |
|---|--------------------|--|
| 1 | type=n | Transistor type. Possible values are n or p. |
| 2 | vnds=-1.0 m | Reverse diode current transition point. |
| 3 | nds=1.0 m | Reverse bias slope coefficient. |
| 4 | compatible=spectre | |

Encourage device equations to be compatible with a foreign simulator. This option does not affect input syntax. Possible values are spectre, spice2, spice3, cdsspice, hspice, spiceplus, eldo, or spsice.

Process parameters:

- | | | |
|----|-------------------------------|--|
| 5 | tox=2e-8 m | Gate oxide thickness. |
| 6 | cox=7e-4 F/m ² | Gate oxide capacitance. (Overrides Tox). |
| 7 | xj=1.0e-7 m | Metallurgical junction depth. |
| 8 | dw=0 m | Channel Width Correction. |
| 9 | dl=0 m | Channel Length Correction. |
| 10 | nfs=0 cm ⁻² | Fast surface state density. |
| 11 | nsub=1.13e16 cm ⁻³ | |

Channel doping concentration.

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EKV MOSFET Model (ekv)

Drain current model parameters:

12	$v_{to}=0.5\text{ V}$	Threshold voltage at zero body bias.
13	$\gamma=1.0\text{ sqrt(V)}$	Body-effect parameter.
14	$\phi=0.7\text{ V}$	Surface potential at strong inversion.
15	$k_p=5.0e-5\text{ A/V}^2$	Transconductance parameter.
16	$e_0=1.0e12\text{ V/m}$	Vertical Critical Field.
17	$u_{crit}=2.0e6\text{ V/cm}$	Longitudinal Critical field for mobility degradation.
18	$\theta=0.0\text{ 1/V}$	Mobility reduction coefficient.
19	$u_0=710\text{ cm}^2/\text{V}\cdot\text{s}$	Carrier surface mobility.
20	$v_{max}\text{ (m/s)}$	Carrier saturation velocity.
21	$v_{fb}\text{ (V)}$	Flat-band voltage.
22	$\lambda=0.5$	Channel length modulation parameter.
23	$\eta=0.25$	Narrow Channel Effect Coefficient.
24	$\iota=0.1$	Short Channel Effect Coefficient.
25	$x_w=0\text{ m}$	Width variation due to masking and etching.
26	$x_l=0\text{ m}$	Length variation due to masking and etching.
27	$m_{eto}=0\text{ m}$	Metal overlap in fringing field.

Impact ionization parameters:

28	$i_{ba}=0\text{ 1/m}$	First Impact Ionization Coefficient.
29	$i_{bb}=3.0e8\text{ V/m}$	Second Impact Ionization Coefficient.
30	$i_{bc}=0$	Third Impact Ionization Coefficient.

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EKV MOSFET Model (ekv)

31 `ibn=1.0` Saturation velocity factor for impact ionization.

Reverse Short Channel parameters:

32 `q0=0 A*s/m^2` Reverse short channel peak charge density.

33 `lk=2.9e-7 m` Reverse short channel characteristic length.

Charge model selection parameters:

34 `xqc=0.0` Drain/source channel charge partition in saturation for charge models, e.g. use 0.4 for 40/60, 0.5 for 50/50, 0 for 0/100.

Junction diode model parameters:

35 `is=1e-14 A` Bulk junction reverse saturation current.

36 `js (A/m^2)` Bulk junction reverse saturation current density.

37 `jsw=0 A/m` Bulk junction reverse saturation sidewall current density.

38 `n=1` Junction emission coefficient.

39 `dskip=yes` Use simple piece-wise linear model for diode currents below $0.1 \cdot |i_{abstol}|$. Possible values are no or yes.

40 `imelt='imax' A` Explosion current, diode is linearized beyond this current to aid convergence.

Junction capacitance model parameters:

41 `cbd=0 F` Bulk-drain zero-bias p-n capacitance.

42 `cbs=0 F` Bulk-source zero-bias p-n capacitance.

43 `cj=0 F/m^2` Zero-bias junction bottom capacitance density.

44 `cjsw=0 F/m` Zero-bias junction sidewall capacitance density.

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EKV MOSFET Model (ekv)

45	$mj=0.5$	Bulk junction bottom grading coefficient.
46	$mjsw=0.33$	Bulk junction sidewall grading coefficient.
47	$cjswg=0$ F/m	Gate-side zero-bias junction sidewall capacitance density.
48	$mjswg=0.33$	Gate-side bulk junction sidewall grading coefficient.
49	$pbswg=0.8$ V	Gate-side junction built-in potential.
50	$fc=0.5$	Forward-bias capacitance coefficient.
51	$pb=0.8$ V	Bulk p-n bottom contact potential.
52	$pbsw=0.8$ V	Side-wall contact potential.
53	$tt=0.0$ V	Bulk p-n transit time.
54	$fcs=0.5$	Side-wall forward-bias depletion capacitance threshold.

Overlap capacitance parameters:

55	$cgso=0$ F/m	Gate-source overlap capacitance.
56	$cgdo=0$ F/m	Gate-drain overlap capacitance.
57	$cgbo=0$ F/m	Gate-bulk overlap capacitance.

Parasitic resistance parameters:

58	$rs=0$ Ohm	Source resistance.
59	$rd=0$ Ohm	Drain resistance.
60	$rsh=0$ Ohm/sqr	Source/drain diffusion sheet resistance.
61	$rss=0$ Ohm*m	Scalable source resistance.
62	$rdd=0$ Ohm*m	Scalable drain resistance.
63	$rsc=0$ Ohm	Source contact resistance.

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64	rdc=0 Ohm	Drain contact resistance.
65	minr=0.1 Ohm	Minimum source/drain resistance.
66	ldif=0 m	Lateral diffusion beyond the gate.
67	hdif=0 m	Length of heavily doped diffusion.

Short distance matching parameters:

68	avto=0 V*m	Area related threshold voltage mismatch parameter.
69	akp=0 m	Area related gain mismatch parameter.
70	agamma=0 sqrt(V)*m	Area related body effect mismatch parameter.

Operating region warning control parameters:

71	alarm=none	Forbidden operating region. Possible values are none, off, triode, sat, subth, or rev.
72	imax=1 A	Maximum current, currents above this limit generate a warning.
73	jmax=1e8 A/m ²	Maximum current density, currents above this limit generate a warning.
74	vbox=1e9*tox V	Oxide breakdown voltage.
75	bvj=infinity V	Junction reverse breakdown voltage.

Temperature effects parameters:

76	tnom (C)	Parameters measurement temperature. Default set by `options`.
77	trise=0 C	Temperature rise from ambient.
78	tcv=1.0e-3 V/C	Threshold voltage temperature coefficient.
79	bex=-1.5	Mobility temperature exponent.

Virtuoso Simulator Components and Device Models Reference

EKV MOSFET Model (ekv)

80	ucex=0.8	Longitudinal critical field temp. exponent.
81	ibbt=9.0e-4 1/C	Temperature coefficient for IBB.
82	x _{ti} =3	Saturation current temperature exponent.
83	tlev=0	DC temperature selector.
84	tlevc=0	C temperature selector.
85	phitmod=0	hi(T) selector for sanyo.
86	eg=1.12452 V	Energy band gap.
87	gap1=7.02e-4 V/C	Band gap temperature coefficient.
88	gap2=1108 C	Band gap temperature offset.
89	tr1=0.6	First source-drain resistance temperature coefficient.
90	tr2=0.6	Second source-drain resistance temperature coefficient.
91	ptc=0 V/C	Surface potential temperature coefficient.
92	pta=0 V/C	Junction potential temperature coefficient.
93	ptp=0 V/C	Sidewall junction potential temperature coefficient.
94	cta=0 1/C	Junction capacitance temperature coefficient.
95	ctp=0 1/C	Sidewall junction capacitance temperature coefficient.

Default instance parameters:

96	w=3e-6 m	Default channel width.
97	l=3e-6 m	Default channel length.
98	as=0 m ²	Default area of source diffusion.
99	ad=0 m ²	Default area of drain diffusion.
100	ps=0 m	Default perimeter of source diffusion.

Virtuoso Simulator Components and Device Models Reference

EKV MOSFET Model (ekv)

101	pd=0 m	Default perimeter of drain diffusion.
102	nrd=0 m/m	Default number of squares of drain diffusion.
103	nrs=0 m/m	Default number of squares of source diffusion.

Noise model parameters:

104	noisemod=1	Noise model selector.
105	kf=0	Flicker (1/f) noise coefficient.
106	af=1	Flicker (1/f) noise exponent.
107	ef=1	Flicker (1/f) noise frequency exponent.
108	nlevel=1	Noise level selector just for spice3 compatible.

Model selection parameters:

109	nqs=0	Nonquasi-static flag.
110	satlim=exp(4)	Ratio defining saturation limit.
111	ekvint=0.0	Interpolation function selector.
112	scalem=1.0	Model scaling factor.
113	update=2.6	Model version selector.

Auto Model Selector parameters:

114	wmax=1.0 m	Maximum channel width for which the model is valid.
115	wmin=0.0 m	Minimum channel width for which the model is valid.
116	lmax=1.0 m	Maximum channel length for which the model is valid.
117	lmin=0.0 m	Minimum channel length for which the model is valid.

Virtuoso Simulator Components and Device Models Reference

EKV MOSFET Model (ekv)

118 msgskip=off Skip some warning message customer requested. Possible values are off or on.

DC-mismatch model parameters:

119 mvtwl=0.0 V*m Threshold mismatch area dependence.

120 mvtwl2=0.0 v*m^{1.5}
Threshold mismatch area square dependence.

121 mvt0=0.0 V Threshold mismatch intercept.

122 mbe0=0.0 Beta mismatch intercept.

123 mbewl=0.0 m Beta mismatch area dependence.

Imax and Imelt

The `imax` parameter aids convergence and prevents numerical overflow. The junction characteristics of the device are accurately modeled for current up to `imax`. If `imax` is exceeded during iterations, the linear model is substituted until the current drops below `imax` or until convergence is achieved. If convergence is achieved with the current exceeding `imax`, the results are inaccurate, and a warning is printed out.

A separate model parameter, `imelt`, is used as a limit warning for the junction current. This parameter can be set to the maximum current rating of the device. When any component of the junction current exceeds `imelt`, note that base and collector currents are composed of many exponential terms, a warning will be issued and the results become inaccurate. The junction current is linearized above the value of `imelt` to prevent arithmetic exception, with the exponential term replaced by a linear equation at `imelt`.

Both of these parameters have current density counterparts, `jmax` and `jmelt`, that you can specify if you want the absolute current values to depend on the device area.

Auto Model Selection

Many models need to be characterized for different geometries in order to obtain accurate results for model development. The model selector program automatically searches for a model with the length and width range specified in the instance statement and uses this model in the simulations.

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EKV MOSFET Model (ekv)

For the auto model selector program to find a specific model, the models to be searched should be grouped together within braces. Such a group is called a model group. An opening brace is required at the end of the line defining each model group. Every model in the group is given a name followed by a colon and the list of parameters. Also, the four geometric parameters `lmax`, `lmin`, `wmax`, and `wmin` should be given. The selection criteria to choose a model is as follows:

$$lmin \leq inst_length < lmax \quad \text{and} \quad wmin \leq inst_width < wmax$$

Example:

```
model ModelName ModelType {  
    1: <model parameters> lmin=2 lmax=4 wmin=1 wmax=2  
    2: <model parameters> lmin=1 lmax=2 wmin=2 wmax=4  
    3: <model parameters> lmin=2 lmax=4 wmin=4 wmax=6  
}
```

Then for a given instance

```
M1 1 2 3 4 ModelName w=3 l=1.5
```

the program would search all the models in the model group with the name `ModelName` and then pick the first model whose geometric range satisfies the selection criteria. In the preceding example, the auto model selector program would choose `ModelName.2`.

You must specify both length (l) and width (w) on the device instance line to enable automatic model selection.

Output Parameters

1	w _{eff} (m)	Effective channel width(alias lv2).
2	l _{eff} (m)	Effective channel length(alias lv1).
3	r _{seff} (Ohm)	Effective source resistance(alias lv16).
4	r _{deff} (Ohm)	Effective drain resistance(alias lv17).
5	a _{seff} (m ²)	Effective source area (alias=lv4).

Virtuoso Simulator Components and Device Models Reference

EKV MOSFET Model (ekv)

6	adeff (m ²)	Effective drain area (alias=lv3).
7	pseff (m)	Effective source perimeter (alias=lv12).
8	pdeff (m)	Effective drain perimeter (alias=lv11).

Operating-Point Parameters

1	type=n	Transistor type. Possible values are n or p.
2	region=triode	Estimated operating region. Spectre outputs number (0-3) in a rawfile. Possible values are off, triode, sat, or subth.
3	reversed	Reverse mode indicator. Possible values are no or yes.
4	ids (A)	Resistive drain-to-source current.
5	vgs (V)	Gate-source voltage(alias lx2).
6	vds (V)	Drain-source voltage(alias lx3).
7	vbs (V)	Bulk-source voltage(alias lx1).
8	vp (V)	Pinchoff voltage.
9	vth (V)	Threshold voltage.
10	vdss (V)	Drain-source saturation voltage.
11	gm (S)	Common-source transconductance(alias lx7).
12	gds (S)	Common-source output conductance(alias lx8).
13	gmbs (S)	Body-transconductance(alias lx9).
14	nfac	Slope factor.
15	if (A)	Forward current.
16	ir (A)	Reverse current.
17	irprime (A)	Reverse current.

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EKV MOSFET Model (ekv)

18	isub (A)	Substrate Current.
19	ibd (A)	Bulk-drain junction current.
20	ibs (A)	Bulk-source junction current.
21	pwr (W)	Power at op point.
22	gmoverid (1/V)	$\frac{G_m}{I_{ds}}$.
23	gamma (sqrt(V))	Body-effect parameter.
24	cjd (F)	Drain-bulk junction capacitance(alias lx29).
25	cjs (F)	Source-bulk junction capacitance(alias lx28).
26	cgg (F)	Gate-gate capacitance.
27	cgd (F)	Gate-drain capacitance(alias lx19).
28	cgs (F)	Gate-source capacitance(alias lx20).
29	cgb (F)	Gate-bulk capacitance.
30	cdg (F)	Drain-gate capacitance(alias lx32).
31	cdd (F)	Drain-drain capacitance(alias lx33).
32	cds (F)	Drain-source capacitance(alias lx34).
33	cdb (F)	Drain-bulk capacitance.
34	csg (F)	Source-gate capacitance.
35	csd (F)	Source-drain capacitance.
36	css (F)	Source-source capacitance.
37	csb (F)	Source-bulk capacitance.
38	cbg (F)	Bulk-gate capacitance(alias lx21).
39	cbd (F)	Bulk-drain capacitance(alias lx22).

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EKV MOSFET Model (ekv)

40	cbs (F)	Bulk-source capacitance(alias lx23).
41	cbb (F)	Bulk-bulk capacitance.
42	vm (V)	Early voltage.
43	vovrdr (V)	Overdrive voltage.
44	tau (s)	NQS time constant.
45	tau0 (s)	Intrinsic time constant.
46	ron (Ohm)	On-resistance.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

ad	I-4	eg	M-86	mj	M-45	rseff	O-3
ad	M-99	ekvint	M-111	mjsw	M-46	rsh	M-60
adefeff	O-6	fc	M-50	mjswg	M-48	rss	M-61
af	M-106	fcs	M-54	msgskip	M-118	satlim	M-110
agamma	M-70	gamma	M-13	mvt0	M-121	scalem	M-112
akp	M-69	gamma	OP-23	mvtw1	M-119	tau	OP-44
alarm	M-71	gap1	M-87	mvtw12	M-120	tau0	OP-45
as	I-3	gap2	M-88	n	M-38	tcv	M-78
as	M-98	gds	OP-12	nds	M-3	theta	M-18

Virtuoso Simulator Components and Device Models Reference

EKV MOSFET Model (ekv)

aseff	O-5	gm	OP-11	nfac	OP-14	tlev	M-83
avto	M-68	gmbs	OP-13	nfs	M-10	tlevc	M-84
bex	M-79	gmoverid	OP-22	nlevel	M-108	tnom	M-76
bvj	M-75	hdif	M-67	noisemod	M-104	tox	M-5
cbb	OP-41	iba	M-28	nqs	M-109	tr1	M-89
cbd	M-41	ibb	M-29	nrd	I-7	tr2	M-90
cbd	OP-39	ibbt	M-81	nrd	M-102	trise	I-14
cbg	OP-38	ibc	M-30	nrs	I-8	trise	M-77
cbs	M-42	ibd	OP-19	nrs	M-103	tt	M-53
cbs	OP-40	ibn	M-31	ns	I-12	type	M-1
cdb	OP-33	ibs	OP-20	nsub	M-11	type	OP-1
cdd	OP-31	ids	OP-4	pb	M-51	ucex	M-80
cdg	OP-30	if	OP-15	pbsw	M-52	ucrit	M-17
cds	OP-32	imax	M-72	pbswg	M-49	uo	M-19
cgb	OP-29	imelt	M-40	pd	I-6	update	M-113
cgbo	M-57	ir	OP-16	pd	M-101	vbox	M-74
cgd	OP-27	irprime	OP-17	pdeff	O-8	vbs	OP-7
cgdo	M-56	is	M-35	phi	M-14	vds	OP-6
cgg	OP-26	isnoisy	I-15	phitmod	M-85	vdss	OP-10
cgs	OP-28	isub	OP-18	ps	I-5	vfb	M-21
cgso	M-55	jmax	M-73	ps	M-100	vgs	OP-5

Virtuoso Simulator Components and Device Models Reference

EKV MOSFET Model (ekv)

cj	M-43	js	M-36	pseff	O-7	vm	OP-42
cjd	OP-24	jsw	M-37	pta	M-92	vmax	M-20
cjs	OP-25	kf	M-105	ptc	M-91	vnds	M-2
cjsw	M-44	kp	M-15	ptp	M-93	vovrdr	OP-43
cjswg	M-47	l	I-2	pwr	OP-21	vp	OP-8
compatible	M-4	l	M-97	q0	M-32	vth	OP-9
cox	M-6	lambda	M-22	rd	M-59	vto	M-12
csb	OP-37	ldif	M-66	rdc	I-9	w	I-1
csd	OP-35	leff	O-2	rdc	M-64	w	M-96
csg	OP-34	leta	M-24	rdd	M-62	weff	O-1
css	OP-36	lk	M-33	rdeff	O-4	weta	M-23
cta	M-94	lmax	M-116	region	I-13	wmax	M-114
ctp	M-95	lmin	M-117	region	OP-2	wmin	M-115
dl	M-9	m	I-11	reversed	OP-3	xj	M-7
dskip	M-39	mbe0	M-122	ron	OP-46	xl	M-26
dw	M-8	mbewl	M-123	rs	M-58	xqc	M-34
e0	M-16	meto	M-27	rsc	I-10	xti	M-82
ef	M-107	minr	M-65	rsc	M-63	xw	M-25

EKV3 MOSFET Model (ekv3)

This chapter contains the following information for the EKV3 MOSFET model:

- [Modes](#) on page 2076
- [General Equations](#) on page 2078
- [Instance Level](#) on page 2078
- [Edge Conductance](#) on page 2090
- [Overlap Capacitances](#) on page 2092
- [Fringing Capacitance](#) on page 2095
- [Bias-Independent Overlap Capacitances](#) on page 2095
- [Gate Induced Drain and Source Current](#) on page 2095
- [Gate Current](#) on page 2096
- [Impact Ionization Current](#) on page 2099
- [Noise](#) on page 2099
- [Diodes](#) on page 2102
- [External Resistors \(Gate, Series, Bulk\)](#) on page 2105
- [Component Statements](#) on page 2107

Modes

The low-frequency macro model of the EKV3 model is shown in Figure 26.1. The EKV3 model supports five versions of internal circuitry. Each version covers the needs of certain areas. These versions are listed in table 26.1. Also, some simple schematics that correspond to each mode, are provided in Figure 26.2.

Figure 27-1 EKV3 low-frequency macro model

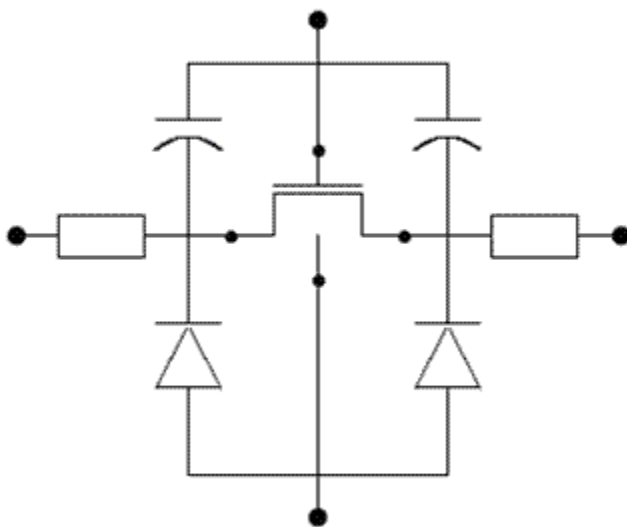
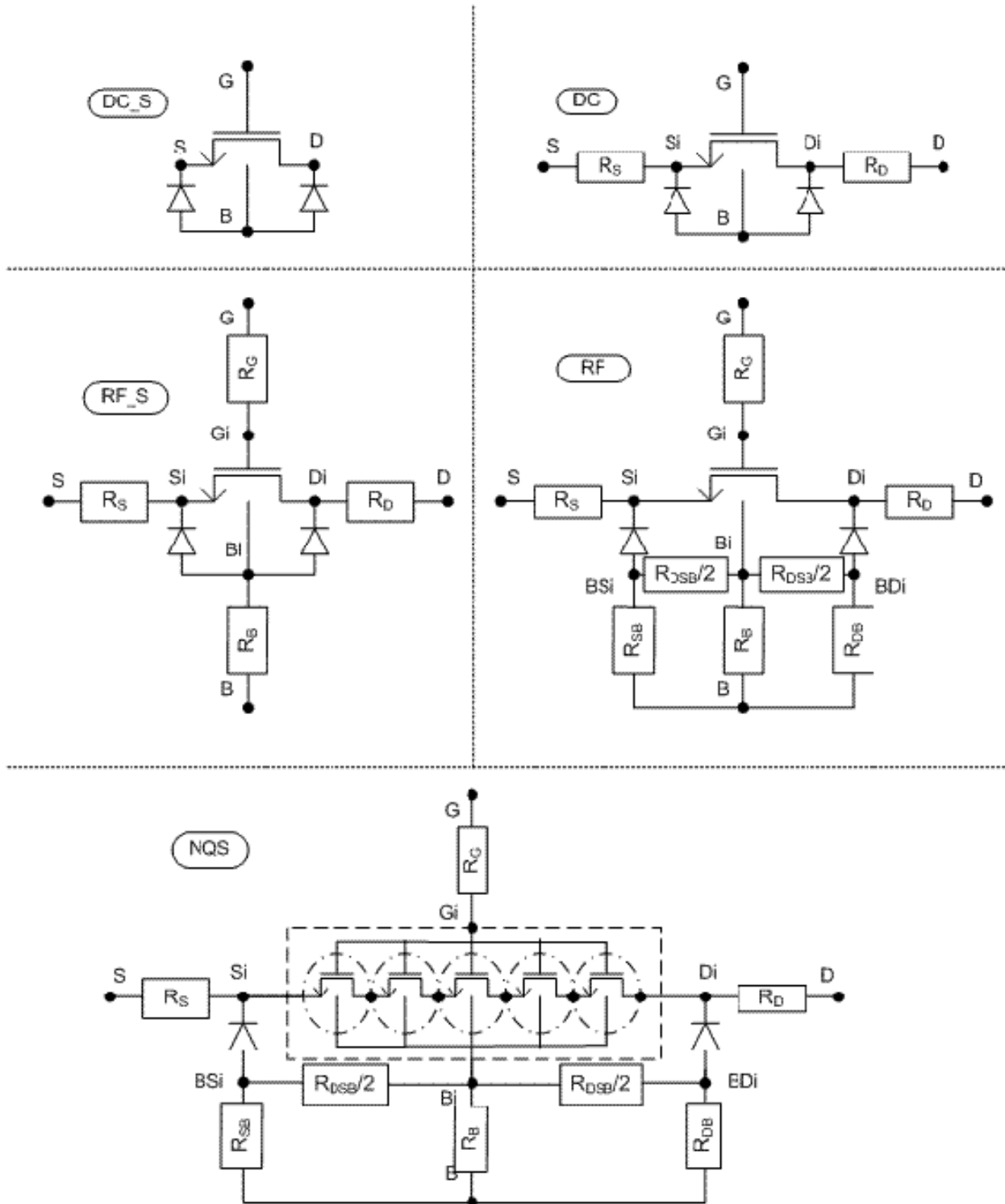


Table 27-1 Modes of the EKV3 model

Mode Name	Description	Internal Nodes
DC_S	No external resistors	0
DC	External series resistors	2
RF_S	External series resistors, gate resistor and 4 single substrate resistor	4
RF	External series resistors, gate resistor and 6 full substrate resistor network	6
NQS	External series resistors, gate resistor and 10 full substrate resistor network; minimal channel segmentation	10

Virtuoso Simulator Components and Device Models Reference
EKV3 MOSFET Model (ekv3)

Figure 27-2 Schematic representing the EKV3 Modes



General Equations

$$t_{si} = \frac{\epsilon_{si}}{COX}$$

$$t_{ox} = \frac{\epsilon_{ox}}{COX}$$

$$LC = \sqrt{t_{si} \cdot XJ}$$

Instance Level

Effective Geometry

$$L_{scaled} = L \cdot SCALE + XL$$

$$W_{scaled} = W \cdot SCALE + WL$$

$$L_{eff} = L_{scaled} + DL + \frac{WDL}{W_{scaled}} + \frac{LL}{L_{scaled}}$$

$$W_{eff} = W_{scaled} + DW + \frac{LDW}{L_{scaled}}$$

$$L_{eff,C} = L_{eff} + DLC$$

$$W_{eff,C} = W_{eff} + DWC$$

Matching

$$VTO_a = VTO + \frac{AVTO \cdot 10^6}{\sqrt{W_{eff} \cdot L_{eff}}}$$

$$GAMMA_a = GAMMA + \frac{AGAMMA \cdot 10^6}{\sqrt{W_{eff} \cdot L_{eff}}}$$

$$KP_a = KP \left(1 + \frac{AKP \cdot 10^6}{\sqrt{W_{eff} \cdot L_{eff}}} \right)$$

Long and wide channel correction of VTO and GAMMA

$$\Delta V_{T_L} = -AVT \cdot MX_S(\ln \frac{L_{eff}}{LVT}, 0, 10^{-2})$$

$$\Delta V_{T_W} = -AVT \cdot MX_S(\ln \frac{W_{eff}}{WVT}, 0, 10^{-2})$$

$$\Delta GAMMA_L = -AGAM \cdot MX_S(\ln \frac{L_{eff}}{LGAM}, 0, 10^{-2})$$

$$\Delta GAMMA_W = -AGAM \cdot MX_S(\ln \frac{W_{eff}}{WGAM}, 0, 10^{-2})$$

Parameter width and length scaling

$$LR_g = LR + \frac{WLR}{W_{eff}}$$

$$QLR_g = QLR \cdot \left(1 + \frac{WQLR}{W_{eff}}\right)$$

$$NLR_g = NLR \cdot \left(1 + \frac{WNLR}{W_{eff}}\right)$$

$$EU_g = EU \cdot \left(1 + \frac{WE0}{W_{eff}}\right)$$

$$EI_g = EI \cdot \left(1 + \frac{WE1}{W_{eff}}\right)$$

$$UCRIT_g = UCRIT \cdot \left(1 + \frac{WUCRIT}{W_{eff}}\right)$$

$$LAMBDA_g = LAMBDA \cdot \left(1 + \frac{WLAMBDA}{W_{eff}}\right)$$

$$ETAD_g = ETAD \cdot \left(1 + \frac{WETAD}{W_{eff}}\right)$$

$$UCEX_g = UCEX \cdot \left(1 + \frac{WUCEX}{W_{eff}}\right)$$

$$WR_g = WR + \frac{LWR}{L_{eff}}$$

$$QWR_g = QWR \cdot \left(1 + \frac{LQWR}{L_{eff}}\right)$$

$$NWR_g = NWR \cdot \left(1 + \frac{LNWR}{L_{eff}}\right)$$

$$TCV_g = TCV + \frac{TCVL}{L_{eff}} + \frac{TCVW}{W_{eff}} + \frac{TCVWL}{W_{eff} \cdot L_{eff}}$$

Reverse short channel effect (RSCE)

$$\Delta V_{T_{RSCE}} = \frac{2 \cdot Q_{LR_g} \cdot \left(1 - \exp\left(\left(\frac{L_{off}}{LR_g}\right)^2\right)\right)}{COX \cdot \frac{L_{off}}{LR_g}}$$

$$GAMMA_{RSCE} = \sqrt{1.0 + \frac{2 \cdot NLR_g \cdot \left(1 - \exp\left(\left(\frac{L_{off}}{LR_g}\right)^2\right)\right)}{COX \cdot \frac{L_{off}}{LR_g}}}$$

$$\Delta \bar{\varphi}_{f,RSCE} = U_T \cdot FLR \cdot \ln \left(1 + \frac{2 \cdot NLR_g \cdot \left(1 - \exp\left(\left(\frac{L_{off}}{LR_g}\right)^2\right)\right)}{COX \cdot \frac{L_{off}}{LR_g}}\right)$$

Inverse narrow width effect (INWE)

$$\Delta V_{T_{INWE}} = - \frac{2 \cdot Q_{WR_g} \cdot \left(1 - \exp\left(\left(\frac{W_{off}}{WR_g}\right)^2\right)\right)}{COX \cdot \frac{W_{off}}{WR_g}}$$

$$GAMMA_{INWE} = \frac{1}{\sqrt{1.0 + \frac{2 \cdot NWR_g \cdot \left(1 - \exp\left(\left(\frac{W_{off}}{WR_g}\right)^2\right)\right)}{COX \cdot \frac{W_{off}}{WR_g}}}}$$

Mobility Scaling

$$KP_1 = \frac{1}{\left(1 + \frac{KA \cdot LA}{L_{off}}\right) \cdot \left(1 - \exp\left(-\frac{L_{off}}{LA}\right)\right) + \left(1 + \frac{KB \cdot LB}{L_{off}}\right) \cdot \left(1 - \exp\left(-\frac{L_{off}}{LB}\right)\right)}$$

$$KP_w = 1 + WKP2 \cdot \exp\left(-\left(\frac{\ln\left(\frac{W_{off}}{WKP1}\right)}{WKP3}\right)^2\right)$$

Instance level parameters

$$VTO_g = VTO_a + \Delta VT_L + \Delta VT_W + \Delta VT_{RSCF} + \Delta VT_{INWE}$$

$$GAMMA_g = (GAMMA_a + \Delta GAMMA_L + \Delta GAMMA_W) \cdot \frac{GAMMA_{RSCF} \cdot GAMMA_{INWE}}{GAMMA_{RSCF} \cdot GAMMA_{INWE}}$$

$$\Phi_{fg} = PHIF + \Delta \Phi_{f,RSCF}$$

$$KP_g = KP \cdot KP_L \cdot KP_W$$

Temperature scaling

$$\Delta T = T - TNOM$$

$$rT = \frac{T}{TNOM}$$

$$VTO_{gt} = VTO_g - TCV_g \cdot \Delta T$$

$$KP_{gt} = KP_g \cdot rT^{BKEK}$$

$$ETA_t = ETA - TETA \cdot \Delta T$$

$$EO_{gt} = EO_g \cdot rT^{TEDEK}$$

$$EI_{gt} = EI_g \cdot rT^{TEIEK}$$

$$\Phi_{f,gt} = \Phi_{f,g} \cdot rT - \frac{E_g(T) - E_g(TNOM) \cdot rT - 3 \cdot U_T \cdot \ln rT}{2}$$

Normalizing

$$\phi_f = \frac{\Phi_{f,gt}}{U_T}$$

$$vto = \frac{VTO_{gt}}{U_T}$$

$$\gamma = \frac{GAMMA_g}{\sqrt{U_T}}$$

$$\gamma_g = \frac{GAMMAG}{\sqrt{U_T}}$$

$$\gamma_w = \frac{GAMMAOV}{\sqrt{U_T}}$$

$$vfb_{ov} = \frac{VFBOV}{U_T}$$

$$ucrit = \frac{UCRIT}{U_T}$$

$$xb = \frac{XB}{U_T}$$

$$ub = \frac{EB \cdot t_{ox}}{XB}$$

Slope factor nQ0

$$n_{Q0} = \begin{cases} 1 + \frac{\gamma}{2 \cdot \sqrt{2 \cdot \phi_f}}, & \text{if TG} = 0 \text{ or } 1 \\ \frac{1}{\gamma} + \frac{\gamma}{2 \cdot \sqrt{2 \cdot \phi_f}} + \frac{\gamma}{2 \cdot \sqrt{2 \cdot \phi_f}}, & \text{if TG} = -1 \end{cases}$$

Quantum mechanic effect

$$\alpha_{qma} = A_{QMA} \cdot \frac{COX^{2/3}}{U_T^{1/3}} \cdot ETA_{QM}^{2/3}$$

$$\delta_{qmi} = \frac{1}{3} \cdot A_{QMI} \cdot \frac{\gamma \cdot COX}{2 \cdot \phi_f \cdot \sqrt{U_T}} \left(\frac{2 \cdot ETA_{QM} \cdot n_{C0} \cdot \sqrt{2 \cdot \phi_f}}{\gamma} - 1 \right)$$

$$\Delta\psi_0 = A_{QMI} \cdot \frac{2}{3} \cdot \left(\gamma \cdot COX \cdot \sqrt{2 \cdot \phi_f} \right)^{2/3}$$

$$\Delta\psi_n = \frac{\Delta\psi_c}{U_T}$$

$$\phi = 2 \cdot \phi_f + \ln \left(4 \cdot n_{C0} \cdot \frac{\sqrt{2 \cdot \phi_f}}{\gamma} \right) + \Delta\psi_0$$

Normalization factor for charges

$$Q_0 = -W_{eff,C} \cdot NF \cdot L_{eff,C} \cdot U_T \cdot \frac{COX \cdot W_{eff} - WEDGE}{1 + \delta_{qmi} \cdot W_{eff}}$$

$$Q_{0OV} = -W_{eff} \cdot NF \cdot L_{OV} \cdot U_T \cdot \frac{COX}{1 + \delta_{qmi}}$$

Normalization of potentials

$$v_g = \frac{V_{GB}}{U_T}$$

$$v_d = \begin{cases} \frac{V_{DB}}{U_T}, & \text{if } V_D \geq V_S \\ \frac{V_{SB}}{U_T}, & \text{if } V_D < V_S \end{cases}$$

$$v_s = \begin{cases} \frac{V_{SB}}{U_T}, & \text{if } V_D \geq V_S \\ \frac{V_{DB}}{U_T}, & \text{if } V_D < V_S \end{cases}$$

Charge sharing effect

$$\text{CHSH}_L = \text{LETA0} + \frac{\text{LETA}}{L_{\text{eff}}} + \frac{\text{LETA}^2}{L_{\text{eff}}^2}$$

$$\text{CHSH}_W = \frac{\text{WETA}}{W_{\text{eff}}}$$

$$\text{NUV} = \text{N0} + 3 \cdot \text{NCS} \cdot t_{\text{ox}} \cdot \text{CHSH}_L$$

$$A_1 = 1 + \frac{\text{CHSH}_L \cdot t_{\text{si}}}{\gamma} \left(\sqrt{\text{MX}_G(v_{\text{bi}} + v_{\text{s}}, 0, U_{\text{D}}^2)} + \sqrt{\text{MX}_G(v_{\text{bi}} + v_{\text{d}}, 0, U_{\text{D}}^2)} \right)$$

$$A_2 = 2 \cdot A_1 - 1 + 2 \cdot \text{CHSH}_W \cdot \frac{\sqrt{\phi}}{\gamma}$$

$$A_3 = 1 + \text{CHSH}_W \cdot t_{\text{si}} \cdot \frac{\gamma}{\gamma_g} \cdot A_2$$

$$\gamma_{\text{chsh}} = \gamma \cdot \frac{A_1}{1 + \text{CHSH}_W}$$

$$\gamma_{\text{eff}} = \gamma \cdot \frac{A_1}{A_3}$$

$$A_{1,0} = 1 - 2 \cdot \frac{\text{CHSH}_L \cdot t_{\text{si}}}{\gamma} \cdot \sqrt{v_{\text{bi}}}$$

$$A_{2,0} = 2 \cdot A_{1,0} - 1 + 2 \cdot \text{CHSH}_W \cdot \frac{\sqrt{\phi}}{\gamma}$$

$$A_{3,0} = 1 + \text{CHSH}_W \cdot t_{\text{si}} \cdot \frac{\gamma^2}{\gamma_g^2} \cdot A_{2,0}$$

$$\gamma_{\text{chsh},0} = \gamma \cdot \frac{A_{1,0}}{1 + \text{CHSH}_W}$$

Flat-band voltage

$$v_{\text{fb}} - v_{\text{to}} - \phi \cdot \left(1 + \text{CHSH}_W \cdot t_{\text{si}} + \frac{\gamma^2}{\gamma_g^2} \cdot \left(1 - 2 \cdot \text{CHSH}_L \cdot t_{\text{si}} \cdot \frac{\sqrt{v_{\text{bi}}}}{\gamma} \right)^2 \right) - \\ - \gamma \cdot \left(1 - 2 \cdot \text{CHSH}_L \cdot \frac{\sqrt{v_{\text{bi}}}}{\gamma} \cdot \sqrt{\phi} \right)$$

Effective gate-voltage

$$v'_g = v_g - v_{Rb}$$

$$v'_{g, chsh} = \frac{v'_g}{1 + CESH_{W} \cdot t_{si}}$$

$$v'_{g, chsh, pd} = \frac{v'_g}{A_g}$$

$$v'_{g, chsh, pd, 0} = \frac{v'_g}{A_{3,0}}$$

Pinch-off surface potential

Approximation around zero

$$\psi_{po} = \text{MXS} \left(v'_{g, chsh} - \beta \cdot \left(1 + \frac{\gamma_{chsh}}{\sqrt{2}} \right), 0, \beta \cdot v'_{g, chsh} \right)$$

$$\psi_{po, 0} = \text{MXS} \left(v'_{g, chsh} - \beta \cdot \left(1 + \frac{\gamma_{chsh, 0}}{\sqrt{2}} \right), 0, \beta \cdot v'_{g, chsh} \right)$$

Exact solution

$$\psi_p = \begin{cases} -\ln \left(1 - \psi_{po} + \left(\frac{\psi_{po} - v'_{g, chsh}}{\gamma_{chsh}} \right)^2 \right), & \text{if } v'_g < 0 \\ \left(\sqrt{v_{g, chsh, pd} - 1 + \exp(-\psi_{po}) + \frac{\gamma_{eff}^2}{4} - \frac{\gamma_{eff}}{2}} \right)^2 + 1 - \exp(-\psi_{po}), & \text{if } v'_g \geq 0 \end{cases} \quad (2.90)$$

$$\psi_{p, 0} = \begin{cases} -\ln \left(1 - \psi_{po, 0} + \left(\frac{\psi_{po, 0} - v'_{g, chsh}}{\gamma_{chsh, 0}} \right)^2 \right), & \text{if } v'_g < 0 \\ \left(\sqrt{v_{g, chsh, pd, 0} - 1 + \exp(-\psi_{po, 0}) + \frac{\gamma_{chsh, 0}^2}{4} - \frac{\gamma_{chsh, 0}}{2}} \right)^2 + 1 - \exp(-\psi_{po, 0}), & \text{if } v'_g \geq 0 \end{cases}$$

Pinch-off voltage

$$v_p = \psi_p - \phi$$

Velocity saturation

$$e_{clm} = \frac{2}{u_{crit} \cdot L_{eff}}$$

$$q_{sat} = \frac{2 \cdot e_{clm} \cdot I_f}{e_{clm} + 2 + 2 \cdot e_{clm} \cdot q_s + \sqrt{(e_{clm} + 2)^2 + 8 \cdot e_{clm} \cdot q_s}}$$

$$v_{d,sat} = v_p - \frac{(2 \cdot q_{sat} + \ln q_{sat})(1 + e_{clm} \cdot (q_s - q_{sat}))}{\sqrt{1 + \frac{2 \cdot (e_{clm} \cdot (2 - \text{DELTA}) \cdot (q_s - q_{sat}))^2}{0.1 + e_{clm} \cdot (2 - \text{DELTA}) \cdot (q_s - q_{sat})}} + e_{clm} \cdot (q_s - q_{sat})}}$$

$$v_{ds,sat} = \text{MX}_S(v_{d,sat} - v_s, 3, 4)$$

$$dv = \frac{\text{ACLM}}{\text{DELTA}} \cdot \frac{4 \cdot q_{sat} + \text{DELTA}}{q_s + 1}$$

$$v'_d = \frac{1}{2} \cdot \sqrt{\left((v_d - v_s) \cdot \sqrt{1 + \frac{4 \cdot dv}{v_{ds,sat}}} + v_{ds,sat} \right)^2 + 4 \cdot dv \cdot v_{ds,sat}} - \frac{1}{2} \cdot \sqrt{\left((v_d - v_s) \cdot \sqrt{1 + \frac{4 \cdot dv}{v_{ds,sat}}} - v_{ds,sat} \right)^2 + 4 \cdot dv \cdot v_{ds,sat} + v_s}$$

Channel length modulation

$$u_{clm} = \frac{e_{clm} \cdot L_{eff}}{L_C \cdot (v_d - v'_d)}$$

$$\alpha_{clm} = \frac{L_C}{L_{eff} - 2 \cdot L_C}$$

$$\delta L = \text{LAMBDA}_{g,t} \cdot L_C \cdot \ln \frac{\alpha_{clm} + u_{clm} + \sqrt{u_{clm}^2 + 2 \cdot \alpha_{clm} \cdot u_{clm} + 1}}{\alpha_{clm} + 1}$$

Normalized drain inversion charge

$$q_d = q(v_p + \delta\psi_s - v'_d)$$

Normalized forward current

$$i_r = q_d + q_d^2$$

Slope factor n_v

$$n_v = A_3 + \gamma \cdot \frac{A_1}{2 \cdot \sqrt{\psi_p}}$$

Drain induced barrier lowering effect

$$l_0 = ETA_g \cdot \tau_{si} \cdot \sqrt{\frac{2 \cdot \sqrt{\phi}}{\gamma}}$$

$$v_c = 4 + 40 \cdot \frac{l_0}{L_{eff}}$$

$$dv = \text{MNS}(v_p, \text{MNS}(v_s, v_d, v_o^2), v_o^2)$$

$$\delta\psi_s = \exp\left(-\frac{L_{eff}}{2 \cdot l_0}\right) \cdot \left(2 + \text{SIGMAD} \cdot \frac{L_{eff}}{2 \cdot l_0} \cdot \frac{dv}{2 \cdot \phi}\right) \cdot \sqrt{(mul - v_s - dv) \cdot (mul + v_d - dv)} \quad (2.97)$$

Normalized source inversion charge

$$q(v) = \begin{cases} \text{if } \frac{v}{NUV} < -0.5 \\ z_1 = \frac{1}{4} \cdot \left(\frac{v}{NUV} - 1.4 + \sqrt{\frac{v}{NUV} \cdot \left(\frac{v}{NUV} - 0.384936\right) + 9.662671}\right) \\ z_2 = \frac{NUV - (2 \cdot z_1 + \ln z_1)}{2 \cdot z_1 + 1} \\ z_1(1 + z_2 \cdot (1 + 0.07 \cdot z_2)) \cdot NUV \\ \text{if } \frac{v}{NUV} \geq -0.5 \\ z_{1,h} = 0.5 \cdot \left(\frac{v}{NUV} - 0.201491 - \sqrt{\frac{v}{NUV} \cdot \left(\frac{v}{NUV} - 0.402982\right) + 2.446562}\right) \\ z_1 = \frac{1}{4} \cdot \left(\frac{v}{NUV} - 1.4 + \sqrt{\frac{v}{NUV} \cdot \left(\frac{v}{NUV} - 0.384936\right) + 9.662671}\right) \\ z_2 = \frac{NUV - (2 \cdot \exp(z_{1,h}) + z_{1,h})}{2z_1 + 1} \\ z_1(1 + z_2 \cdot (1 + 0.483 \cdot z_2)) \cdot NUV \end{cases}$$

$$q_s = q(v_p - \delta\psi_s - v_s)$$

Normalized forward current

$$i_f = q_s + q_d^2$$

Slope factor n_Q

$$\psi_{sa} = \psi_p \cdot q_s \cdot q_d \tag{2.112}$$

$$n_Q = \begin{cases} \text{if } TG < 0 & \frac{1 + \frac{\gamma^2}{\gamma_g^2} + \frac{GAMMA}{\sqrt{U_T}(\sqrt{\psi_p} + \sqrt{\psi_{sa}})}}{\frac{1}{2} + \frac{\gamma^2 \sqrt{U_T} \sqrt{\psi_{sa}}}{\gamma_g^2 GAMMA} + \sqrt{\left(\frac{1}{2} + \frac{\gamma^2 \sqrt{U_T} \sqrt{\psi_{sa}}}{\gamma_g^2 GAMMA}\right)^2 + \left(1 + \frac{\gamma^2}{\gamma_g^2} + \frac{GAMMA}{\sqrt{U_T}(\sqrt{\psi_p} + \sqrt{\psi_{sa}})}\right) \frac{q_s + q_d}{\gamma_g^2}}} \\ \text{if } TG \geq 0 & \frac{GAMMA}{1 + \frac{GAMMA}{\sqrt{U_T} \cdot (\sqrt{\psi_p} + \sqrt{\psi_{sa}})}} \end{cases}$$

Charge model

$$v_o = v'_{g, chsh} - \psi_{p,0}$$

Quantum mechanic effect

$$q_{bo} = v'_{g, chsh} - \psi_p, \quad \text{if } v'_g < 0$$

$$q_{bo} = \frac{v'_{g, chsh}}{1 + \frac{\gamma^2}{\gamma_g^2}} - \psi_{p,0}, \quad \text{if } v'_g < 0$$

$$\delta\psi_v = \alpha_{qma} \cdot \left(\left(\sqrt{\frac{q_{bo}^2}{4} + 4 \cdot \alpha_{qma} \cdot \gamma_{chsh}^2} - \frac{q_{bo}}{2} \right)^{2/3} - \left(\sqrt{\frac{9 \cdot \gamma_{chsh}^2}{2} + 4 \cdot \alpha_{qma} \cdot \gamma_{chsh}^2} - \frac{3 \cdot \gamma_{chsh}}{\sqrt{2}} \right)^{2/3} \right)$$

$$v_{o,qm} = v_o + \delta\psi_v$$

Q_S, Q_D, Q_G, Q_B

$$q_S = \frac{n_Q}{3 \cdot (1 + \delta_{qmi})} \cdot \left(2 \cdot q_S + q_D + \frac{(1 + \frac{4}{5} \cdot q_S + \frac{6}{5} \cdot q_D) \cdot (q_S - q_D)^2}{2 \cdot (q_S + q_D + 1)^2} \right)$$

$$q_D = \frac{n_Q}{3 \cdot (1 + \delta_{qmi})} \cdot \left(q_S - 2 \cdot q_D + \frac{(1 + \frac{6}{5} \cdot q_S + \frac{4}{5} \cdot q_D) \cdot (q_S - q_D)^2}{2 \cdot (q_S + q_D + 1)^2} \right)$$

$$q_G = \begin{cases} \text{if } TG < 0 \\ \frac{v_{o,qm} + \frac{2 \cdot q_S}{1 + \delta_{qmi}}}{1 + 2 \cdot \sqrt{\frac{1}{4} + \frac{v_{o,qm} + \frac{2 \cdot q_S}{1 + \delta_{qmi}}}{\gamma_g^2}}} + \frac{v_{o,qm} + \frac{2 \cdot q_D}{1 + \delta_{qmi}}}{1 + 2 \cdot \sqrt{\frac{1}{4} + \frac{v_{o,qm} - \frac{2 \cdot q_D}{1 + \delta_{qmi}}}{\gamma_g^2}}} + \\ - \frac{1}{3 \cdot (1 + \delta_{qmi})} \cdot \frac{(q_S - q_D)^2}{\left(\sqrt{\frac{1}{4} + \frac{v_{o,qm} + \frac{2 \cdot q_S}{1 + \delta_{qmi}}}{\gamma_g^2}} + \sqrt{\frac{1}{4} + \frac{v_{o,qm} + \frac{2 \cdot q_D}{1 + \delta_{qmi}}}{\gamma_g^2}} \right)^2} \\ \frac{4}{5} \cdot \left(\sqrt{\frac{1}{4} + \frac{v_{o,qm} + \frac{2 \cdot q_S}{1 + \delta_{qmi}}}{\gamma_g^2}} + \sqrt{\frac{1}{4} + \frac{v_{o,qm} + \frac{2 \cdot q_D}{1 + \delta_{qmi}}}{\gamma_g^2}} \right)^2 + \\ - \frac{4}{5} \cdot \sqrt{\frac{1}{4} + \frac{v_{o,qm} + \frac{2 \cdot q_S}{1 + \delta_{qmi}}}{\gamma_g^2}} \cdot \sqrt{\frac{1}{4} + \frac{v_{o,qm} + \frac{2 \cdot q_D}{1 + \delta_{qmi}}}{\gamma_g^2}} + \frac{2}{\gamma_g^2} \\ \text{if } TG \geq 0 \\ v_{o,qm} + q_S + q_D + \frac{1}{3 \cdot (1 + \delta_{qmi})} \cdot \frac{(q_S - q_D)^2}{q_S + q_D + 1} \end{cases}$$

$$q_I = q_S + q_D$$

$$q_B = q_G - q_S - q_D$$

Mobility effects

Coulomb scattering

$$\beta_{coul} = \frac{THC}{(1 + n_v \cdot ZC \cdot q_S) \cdot (1 + n_v \cdot ZC \cdot q_D)}$$

Vertical field effect

$$e_{q0} = q_B + ETA_t \cdot n_v \cdot q_I$$

$$e_{q1} = \left(\gamma_{\text{eff}} \cdot \sqrt{\psi_p} + n_v \cdot (1 - EFA_t) - 1 \right)^2 + (n_v \cdot (1 - ETA_t) - 1)^2 \cdot (1 + 2 \cdot i_f + 2 \cdot i_r) - \frac{8}{3} \cdot (n_v \cdot (1 - ETA_t) - 1) \cdot (\gamma_{\text{eff}} \cdot \sqrt{\psi_p} + n_v \cdot (1 - ETA_t) - 1) \cdot \frac{i_f + i_r + 0.5 + \sqrt{(i_f + 0.25) \cdot (i_r + 0.25)}}{\sqrt{i_f + 0.25} + \sqrt{i_r + 0.25}}$$

$$\beta_{\text{rvf,coal}} = \frac{1 + \frac{U_T}{E0_{g,t} \cdot t_{si}} \cdot \gamma_{\text{eff}} \cdot \sqrt{\phi} + \left(\frac{U_T}{E1_{g,t} \cdot t_{si}} \cdot \gamma_{\text{eff}} \cdot \sqrt{\phi} \right)^2}{1 + \frac{U_T}{E0_{g,t} \cdot t_{si}} \cdot e_{q0} + \left(\frac{U_T}{E1_{g,t} \cdot t_{si}} \right)^2 \cdot e_{q1} + \beta_{\text{coal}}}$$

Channel length modulation

$$\beta_{\text{clm}} = \left(\sqrt{1 + \frac{2 \cdot (e_{\text{clm}} \cdot (2 - DELTA) \cdot (q_s - q_d))^2}{0.1 + e_{\text{clm}} \cdot (2 - DELTA) \cdot (q_s - q_d)} + (e_{\text{clm}} \cdot (q_s - q_d))^2} \right)^{-1}$$

Overall effect

$$\beta = KP_{g,t} \cdot \beta_{\text{rvf,coal}} \cdot \beta_{\text{clm}}$$

Specific current

$$I_{\text{SPEC}} = \frac{2 \cdot n_Q \cdot U_T^2 \cdot \beta}{1 + \delta_{\text{qmi}}} \cdot \frac{(W_{\text{eff}} - WEDGE) \cdot NF}{L_{\text{eff}} - \delta L}$$

Drain induced threshold shift

$$v_{\text{dits}} = \frac{1}{1 + FPROUT \cdot \frac{V_{\text{eff}}}{qI + 2}} \cdot \frac{1}{PDITS} \cdot (1 + (1 + PDITSL \cdot L_{\text{off}}) \cdot \exp(PDITSD \cdot (v_d - v_s) \cdot U_T))$$

$$v_{\text{ds,dits}} = v_{\text{ds,sat}} - MXS(v_{\text{ds,sat}} - (v_d - v_s) - DDITS, 0, 4 \cdot DDITS \cdot v_{\text{ds,sat}})$$

$$f_{\text{dits}} = 1 + \frac{v_d - v_s - v_{\text{ds,dits}}}{v_{\text{dits}}}$$

Denormalizing

$$Q_S = q_S \cdot Q_0$$

$$Q_D = q_D \cdot Q_0$$

$$Q_G = -q_G \cdot Q_0$$

$$Q_B = q_B \cdot Q_0$$

$$I_{ds} = I_{SPEC} \cdot (i_f - i_r) \cdot I_{dits}$$

Edge Conductance

Normalization Factors (Edge Device)

$$I_{SPEC,edge} = \frac{2 \cdot n_Q \cdot U_T^2 \cdot \beta \cdot W_{eff} \cdot NF}{1 + \delta_{qmi}} \cdot \frac{W_{eff} - WEDGE}{L_{eff} - \ell L} \cdot \frac{W_{eff} - WEDGE}{W_{eff}}$$

$$Q_{0,edge} = -W_{eff,C} \cdot NF \cdot L_{eff,C} \cdot U_T \cdot \frac{COX}{1 + \delta_{qmi}} \cdot \frac{WEDGE}{W_{eff}}$$

Scaling - Normalizing

$$\delta\gamma_{edge} = \frac{DGAMMAEDGE}{\sqrt{U_T}} \cdot \left(1.0 + \frac{WLDGAMMAEDGE}{W_{eff} \cdot L_{eff}} \right)$$

$$\delta\phi_{edge} = \frac{DPHIEDGE}{U_T} \cdot \left(1.0 + \frac{LDPHIEDGE}{L_{eff}} \right) \cdot \left(1.0 + \frac{WDPHIEDGE}{W_{eff}} \right) \cdot \left(1.0 + \frac{WLDPHIEDGE}{W_{eff} \cdot L_{eff}} \right)$$

$$\delta v_{\gamma,edge} = -\delta\gamma_{edge} \cdot \frac{\psi_p}{\sqrt{\psi_p + \frac{\gamma}{2}}} - \delta\phi_{edge}$$

Normalized Inversion Charges (Edge Device)

$$q_{s,edge} = q(v_p + \delta v_{p,edge} + \delta\psi_s - v_s)$$

$$q_{d,edge} = q(v_p + \delta v_{p,edge} + \delta\psi_s - v'_d)$$

Normalized Currents (Edge Device)

$$i_{f,edge} = q_{f,edge}^2 + q_{s,edge}$$
$$i_{r,edge} = q_{d,edge}^2 + q_{d,edge}$$

Drain Current (Edge Device)

$$I_{DS,edge} = I_{SPEC,edge} \cdot (i_{f,edge} - i_{r,edge}) \cdot f_{dits}$$

Edge Device: Charge Model

$$\psi_{p,edge} = \psi_p - \delta\gamma_{edge} \cdot \frac{\psi_p}{\sqrt{\psi_p} + \frac{\gamma}{2}}$$

$$\gamma_{edge} = \gamma + \delta\gamma_{edge}$$

$$n_{q,edge}$$

$$Q_{S,edge}, Q_{D,edge}, Q_{G,edge}, Q_{B,edge}$$

Overlap Capacitances

$$v'_{gs,ov} = v_g - VOV \cdot \tau_s - v_{fb,ov}$$

if $TG < 0$

$$\gamma_{dep,sov} = \begin{cases} \gamma_{g,ov} & \text{if } v'_{gs,ov} \geq 0 \\ \gamma_{ov} & \text{if } v'_{gs,ov} < 0 \end{cases}$$

$$\gamma_{acc,sov} = \begin{cases} \gamma_{ot} & \text{if } v'_{gs,ov} \geq 0 \\ \gamma_{g,ov} & \text{if } v'_{gs,ov} < 0 \end{cases}$$

$$v_{0,sov} = \begin{cases} v'_{gs,ov} & \text{if } v'_{gs,ov} \geq 0 \\ -v'_{gs,ov} & \text{if } v'_{gs,ov} < 0 \end{cases}$$

$$a_{0,sov} = 1.0 + \frac{\gamma_{acc,sov}}{\sqrt{2}}$$

$$a_{1,sov} = \frac{\gamma_{dep,sov}}{\gamma_{acc,sov}}$$

$$a_{2,sov} = \frac{a_{0,sov}}{a_{0,sov} + a_{1,sov}}$$

$$a_{3,sov} = 1 + \frac{\gamma_{dep,sov}}{\sqrt{2}} + a_{1,sov}$$

$$v_{1,sov} = \frac{v_{0,sov}}{2} - 3 \cdot a_{2,sov} \cdot a_{3,sov}$$

$$\delta\psi_{gs0} = v_{1,sov} + \sqrt{v_{1,sov}^2 + 6 \cdot a_{2,sov} \cdot a_{3,sov}}$$

$$\gamma_{dep2,sov} = \gamma_{dep,sov} \cdot \left(\frac{1}{2} + \frac{3}{3 \cdot \sqrt{2} \cdot \gamma_{acc,sov} + v_{0,sov} - \delta\psi_{gs0}} \right)$$

$$a_{4,sov} = 1 - \exp(-\delta\psi_{gs0})$$

$$v_{2,sov} = v_{0,sov} - a_{4,sov}$$

Virtuoso Simulator Components and Device Models Reference
EKV3 MOSFET Model (ekv3)

$$\delta\psi_{gs} = \left(\frac{V_{2,sov}}{\gamma_{dep2,sov} + \sqrt{\gamma_{dep2,sov}^2 + V_{2,sov}}} \right)^2 - a_{4,sov}$$

$$V_{2b,sov} = V_{0,sov} - \delta\psi_{gs}$$

$$V_{3,sov} = \frac{V_{2b,sov}}{2}$$

$$\delta\psi_{ox,s} = \begin{cases} v_{3,sov} - 3 \cdot a_{0,sov} + \sqrt{\left(\frac{v_{3,sov}}{3 \cdot a_{0,sov}}\right)^2 - 6 \cdot v_{2b,sov}} & \text{if } v'_{gs,sov} > 0 \\ \left(v_{3,sov} - 3 \cdot a_{0,sov} + \sqrt{\left(\frac{v_{3,sov}}{3 \cdot a_{0,sov}}\right)^2 - 6 \cdot v_{2b,sov}} \right) & \text{if } v'_{gs,sov} < 0 \end{cases}$$

if $TG \geq 0$

$$\text{if } v'_{gs,sov} \geq 0$$

$$\gamma_{acc,sov} = \gamma_{ov}$$

$$V_{0,sov} = V_{gs,sov}$$

$$a_{0,sov} = 1 + \frac{\gamma_{acc,sov}}{\sqrt{2}}$$

$$V_{1,sov} = \frac{V_{0,sov}}{2} - 3 \cdot a_{0,sov}^2$$

$$\delta\psi_{gs0} = V_{1,sov} + \sqrt{V_{1,sov}^2}$$

$$\delta\psi_{gs} = 1 - \exp(-\delta\psi_{gs0})$$

$$V_{2b,sov} = V_{0,sov} - \delta\psi_{gs}$$

$$V_{3,sov} = \frac{V_{2b,sov}}{2}$$

$$\delta\psi_{ox,s} = V_{3,sov} - 2 \cdot a_{0,sov} + \sqrt{(V_{3,sov} + 3 \cdot a_{0,sov})^2 - 6 \cdot V_{2b,sov}}$$

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

$$\text{if } v'_{gs,ov} < 0$$

$$\gamma_{dep,sov} = \gamma_{ov}$$

$$V_{0,sov} = -V_{gs,ov}$$

$$a_{3,sov} = 1 + \frac{\gamma_{dep,sov}}{\sqrt{2}}$$

$$V_{1,sov} = \frac{V_{0,sov}}{2} - 3 \cdot a_{3,sov}^2$$

$$\delta\psi_{gs0} = V_{1,sov} + \sqrt{V_{1,sov}^2 + 6 \cdot V_{0,sov}}$$

$$\gamma_{dep2,sov} = \gamma_{dep,sov}^2$$

$$a_{4,sov} = 1 - \exp(-\delta\psi_{gs0})$$

$$V_{2,sov} = V_{0,sov} - a_{4,sov}$$

$$\delta\psi_{gs} = \left(\frac{V_{2,sov}}{\gamma_{dep2,sov} + \sqrt{\gamma_{dep2,sov}^2 + V_{2,sov}}} \right)^2 + a_{4,sov}$$

$$V_{2b,sov} = V_{0,sov} - \delta\psi_{gs}$$

$$\delta\psi_{ox,s} = -V_{2b,sov}$$

Denormalizing (Overlap)

$$Q_{G,OV} = -Q_{0,OV} \cdot \delta\psi_{ox,s}$$

$$Q_{D,OV} = -Q_{0,OV} \cdot \delta\psi_{ox,d}$$

Fringing Capacitance

$$Q_{S,FR} = W_{eff,c} \cdot NF \cdot KJF (1 + CJF \cdot U_T \cdot v_s) \cdot \sqrt{MXS \left(v_{bi} + \frac{VFR}{U_T} + v_s - (\psi_p - 2 \cdot q_s), 0, DFR \right)} \quad (2.192)$$

$$Q_{D,FR} = W_{eff,c} \cdot NF \cdot KJF (1 + CJF \cdot U_T \cdot v'_d) \cdot \sqrt{MXS \left(v_{bi} + \frac{VFR}{U_T} + v'_d - (\psi_p - 2 \cdot q'_d), 0, DFR \right)}$$

Bias-Independent Overlap Capacitances

$$C_{GSO} = CGSO \cdot W_{eff}$$

$$C_{GDO} = CGDO \cdot W_{eff}$$

$$C_{GBO} = CGBO \cdot 2 \cdot L_{eff}$$

Gate Induced Drain and Source Current

$$v_{gs,e} = v_{fb} + \psi_p - 2 \cdot q_s$$

$$I_{GIDL} = AGIDL \cdot W_{eff} \cdot NF \frac{(v'_d - v_s - v_{gs,e}) \cdot U_T - EGIDL}{3 \cdot T_{OX}} \cdot \exp \left(- \frac{3 \cdot T_{OX} \cdot BGIDL}{(v'_d - v_s - v_{gs,e}) \cdot U_T - EGIDL} \right) \cdot \frac{(v_d \cdot U_T)^3}{CGIDL + (v_d \cdot U_T)^3}$$

$$v_{gd,e} = v_{fb} + \psi_p - 2 \cdot q'_d$$

$$I_{GISL} = AGIDL \cdot W_{eff} \cdot NF \frac{(v_d - v'_d - v_{gd,e}) \cdot U_T - EGIDL}{3 \cdot T_{OX}} \cdot \exp \left(- \frac{3 \cdot T_{OX} \cdot BGIDL}{(v_s - v'_d - v_{gd,e}) \cdot U_T - EGIDL} \right) \cdot \frac{(v_s \cdot U_T)^3}{CGIDL + (v_s \cdot U_T)^3}$$

Gate Current

if $((\psi_p \geq 0) \text{ and } (\mathbf{TG} < 0))$ or $((\psi_p < 0) \text{ and } (\mathbf{TG} \geq 0))$

$$v_1 = \sqrt{\frac{1}{4} + \frac{v_o + 2 \cdot q_b}{\gamma_g^2}}$$

$$v_2 = v_1 + \frac{1}{2}$$

$$\psi_{ox} = \frac{v_o + 2 \cdot q_b}{v_2}$$

$$\delta\psi_{dq} = \frac{2}{v_2} \cdot \left(1 - \frac{v_o + 2 \cdot q_b}{2 \cdot v_1 \cdot v_2 \gamma_g^2}\right)$$

if $((\psi_p \leq 0) \text{ and } (\mathbf{TG} \leq 0))$ or $((\psi_p > 0) \text{ and } (\mathbf{TG} > 0))$

$$\psi_{ox} = \frac{v_o + 2 \cdot q_b}{v_2}$$

$$\delta\psi_{dq} = 2$$

$$\psi_x = \frac{\psi_{ox}}{x_b}$$

$$P_{tun} = \begin{cases} \exp\left(-\frac{w_b}{x_b} \left(\frac{1}{1 + \sqrt{1 - \psi_x}} + \sqrt{1 - \psi_x}\right)\right) & \text{if } \psi_x < 1 \\ \exp\left(-\frac{w_b}{\psi_x}\right) & \text{if } \psi_x > 1 \end{cases}$$

$$i_{go} = q_b \cdot \psi_{ox} \cdot P_{tun}$$

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

if ($v_s = v_d$) or ($\psi_{ox} = 0$)

$$n_{gc} = i_{gs} \cdot n_Q$$

$$n_{gs} = \frac{n_{igc}}{2}$$

$$n_{gd} = n_{igs}$$

if ($v_s \neq v_d$) and ($\psi_{ox} \neq 0$)

$$\delta q_{\delta\xi} = \frac{i'_r - i_f}{1 + 2 \cdot q_s}$$

$$a_{gc} = \delta q_{\delta\xi} \cdot \left(\frac{1}{q_s} + \frac{\delta\psi_{Aq}}{\psi_{ox}} \right)$$

if $\psi_x < 1$

$$b_{gc} = \begin{cases} \delta q_{\delta\xi} \cdot \delta\psi_{dq} \cdot \frac{u_b}{x_b} \cdot \frac{3 + \psi_x}{4 + 2\sqrt{1 - \psi_x} \cdot (2 + \psi_x)} & \text{if } \psi_{ox} > 0 \\ -\delta q_{\delta\xi} \cdot \delta\psi_{dq} \cdot \frac{u_b}{x_b} \cdot \frac{3 + \psi_x}{4 + 2\sqrt{1 - \psi_x} \cdot (2 + \psi_x)} & \text{if } \psi_{ox} < 0 \end{cases}$$

if $\psi_x \geq 1$

$$b_{gc} = \delta q_{\delta\xi} \cdot \delta\psi_{dq} \cdot \frac{u_b}{\psi_x + \psi_{ox}}$$

$$n_{gc} = i_{gs} \cdot n_Q \cdot \frac{2 + a_{gc}}{2 - b_{gc}}$$

$$n_{gs} = \frac{1}{2} \cdot i_{gs} \cdot n_Q \cdot \frac{3 + a_{gc}}{3 - b_{gc}}$$

$$n_{gd} = n_{igc} - n_{igs}$$

if $v_g \geq v_{fb}$

$$I_{GB} = 0$$

$$I_G = 2 \cdot \mathbf{KG} \cdot W_{\text{eff}} \cdot \mathbf{NF} \cdot L_{\text{eff}} \cdot U_T^2 \cdot n_{igv} \cdot P_{\text{tun}} \cdot T_{\text{OX}}^{-2}$$

$$I_{GD} = 2 \cdot \mathbf{KG} \cdot W_{\text{eff}} \cdot \mathbf{NF} \cdot L_{\text{eff}} \cdot U_T^2 \cdot n_{igd} \cdot P_{\text{tun}} \cdot T_{\text{OX}}^{-2}$$

$$I_{GS} = I_G - I_{GD}$$

if $v_g < v_{fb}$

$$I_{GB} = \mathbf{KG} \cdot W_{\text{eff}} \cdot \mathbf{NF} \cdot L_{\text{eff}} \cdot U_T^2 \cdot \psi_{\text{ox}} \cdot |\psi_{\text{ox}}| \cdot P_{\text{tun}} \cdot T_{\text{OX}}^{-2}$$

$$I_G = 0$$

$$I_{GD} = 0$$

$$I_{GS} = 0$$

Overlap Gate Current

Gate - Source (Overlap Current)

$$\psi_{\text{ocr,sov}} = \begin{cases} v_g - v_s - \left(\sqrt{v_g - v_s - v_{fb,ov}} + \frac{\gamma_g^2}{4} - \frac{\gamma_g}{2} \right)^2 & \text{if } v_g - v_s > v_{fb,ov} \\ v_g - v_s + \left(\sqrt{-v_g + v_s + v_{fb,ov}} + \frac{\gamma_{ov}^2}{4} - \frac{\gamma_{ov}}{2} \right)^2 & \text{if } v_g - v_s < v_{fb,ov} \end{cases}$$

$$\psi_{\text{xr,sov}} = \frac{|\psi_{\text{ocr,sov}}|}{\kappa_b}$$

$$P_{\text{tun,sov}} = \begin{cases} \exp\left(-\gamma_b \left(\frac{1}{1 + \sqrt{1 - \psi_{\text{xr,sov}}}} + \sqrt{1 - \psi_{\text{xr,sov}}} \right)\right) & \text{if } \psi_{\text{xr,sov}} < 1 \\ \exp\left(-\frac{\gamma_b}{\psi_{\text{xr,sov}}}\right) & \text{if } \psi_{\text{xr,sov}} > 1 \end{cases}$$

$$I_{\text{CSOV}} = \mathbf{KG} \cdot W_{\text{eff}} \cdot \mathbf{NF} \cdot \mathbf{LOVIG} \cdot \psi_{\text{ocr,sov}} \cdot |\psi_{\text{ocr,sov}}| \cdot U_T^2 \cdot P_{\text{tun}} \cdot T_{\text{OX}}^{-2}$$

Gate - Drain (Overlap Current)

Equations similar to Gate - Source (Overlap Current)

Impact Ionization Current

$$v_{ib} = v_d - v_s - 2 \cdot \text{IBN} \cdot v_{d\text{sat}}$$

$$I_{\text{DB}} = \begin{cases} I_{\text{DS}} \cdot v_{ib} \cdot U_T \cdot \exp\left(\frac{\text{IBB}_t \cdot L_C}{v_{ib} \cdot U_T}\right) \cdot \frac{\text{IBA}}{\text{IBB}_t} & \text{if } v_{ib} > 0 \\ 0 & \text{if } v_{ib} < 0 \end{cases}$$

Noise

Thermal Noise

$$g_n = \frac{2}{(1 + e_{\text{chn}} \cdot (q_s - q'_d))^2 \cdot (q_s + q'_d + 1)} \cdot \frac{1}{3} \cdot (q_s^2 + q_s + q'_d + q'_d{}^2) + e_{\text{chn}}^2 \cdot \frac{(i_f - i'_r)^2}{4} + \frac{(e_{\text{chn}} \cdot (i_f - i'_r) + 1) \cdot (q_s + q'_d)}{4} + \frac{e_{\text{chn}} \cdot (i_f - i'_r) - 1}{8} \cdot e_{\text{chn}}^2 \cdot (i_f - i'_r) \cdot (q_s + q'_d + 1) \cdot \ln \frac{q_s + \frac{1}{2} + \frac{e_{\text{chn}} \cdot (i_f - i'_r)}{2}}{q'_d + \frac{1}{2} + \frac{e_{\text{chn}} \cdot (i_f - i'_r)}{2}}$$

$$\text{thermal} = 4 \cdot K \cdot T \cdot \frac{I_{\text{SPEC}}}{U_T} \cdot z_n \cdot \text{TH_NOI}$$

Flicker Noise

$$g_{\text{avg}} = \frac{I_{\text{SPEC}}}{U_T} \cdot \frac{q_s - q'_d}{n_v}$$

$$\text{flicker} = \frac{\text{KF} \cdot g_{\text{avg}}^{\text{EF}} \cdot (\delta q_{\text{mi}} + 1)}{W_{\text{eff}} \cdot \text{NF} \cdot L_{\text{eff}} \cdot \text{COX}}$$

$$s_{\text{id,flicker}}(f) = \frac{\text{flicker}}{f_{\text{AF}}}$$

Induced Gate Noise

$$\omega_{spec} = \frac{\beta \cdot U_T}{COX \cdot L_{eff}^2}$$

$$x_f = q_s + \frac{1}{2}$$

$$x_r = q_d' + \frac{1}{2}$$

$$S_{n,idd} = \frac{4 \cdot x_f^2 - 3 \cdot x_f + 4 \cdot x_f \cdot x_r - 3 \cdot x_r + 4 \cdot x_r^2}{6 \cdot (x_f + x_r)}$$

$$S_{n,igig} = \frac{\omega^2 \cdot 16x_f^4 + 16x_r^4 + 80x_f x_r^3 + 80x_f^3 x_r + 168x_f^2 x_r^2 - 15x_f^3 - 15x_r^3 - 75x_f^2 x_r - 75x_r^2 x_f}{\omega_{spec}^2 \cdot 540n_{q0}^2 (x_f + x_r)^5}$$

$$S_{n,ibib} = \frac{S_{n,igig}}{(n_{q0} - 1)^2}$$

$$S_{n,igid} = \frac{J \cdot \frac{\omega}{\omega_{spec}}}{18 \cdot n_{q0}} \cdot \frac{(x_f - x_r) \cdot (x_f^2 + 4 \cdot x_f \cdot x_r + x_r^2)}{(x_f + x_r)^5}$$

$$C_{igid} = J \frac{S_{n,igid}}{\sqrt{S_{n,idd} \cdot S_{n,igig}}}$$

Shot and Flicker Gate Noise

$$S_{ig,shot} = 2 \cdot q_e \cdot I_G$$

$$S_{ig,flicker}(f) = \frac{KGFN \cdot I_G^2}{f}$$

Here is a table that lists the parameter names and their meaning in the Spectre Noise Summary table for the EKV3.0 model.

Parameter	Meaning
fn_id	Channel current flicker noise

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

Parameter	Meaning
fn_ig	Channel current gate noise
rs	Source parasitic resistor thermal noise
rd	Drain parasitic resistor thermal noise
rg	Gate parasitic resistor thermal noise
rsb	Thermal noise for the substrate resistor connected between BSi and B (see Figure 27-2 on page 2077).
rdb	Thermal noise for the substrate resistor connected between BDi and B (see Figure 27-2 on page 2077).
rbbs	Thermal noise for the substrate resistor connected between BSi and Bi (see Figure 27-2 on page 2077 where it is labeled $R_{DSB}/2$)
rbbd	Thermal noise for the substrate resistor connected between BDi and Bi (see Figure 27-2 on page 2077 where it is labeled $R_{DSB}/2$)
id	Thermal noise of the channel resistor
cor	Induced gate noise
shot_ig	Gate current shot noise

Diodes

Temperature Dependence

$$JS_t = JS \cdot \exp\left(\frac{U_{T,nom} - U_T + XTI \cdot T_{NOM}}{ND}\right)$$

$$JSW_t = JSW \cdot \exp\left(\frac{\frac{E_{g,nom}}{U_{T,nom}} - \frac{E_g}{U_T} + XTI \cdot \frac{T}{T_{NOM}}}{ND}\right)$$

$$JSWG_t = JSWG \cdot \exp\left(\frac{\frac{E_{g,nom}}{U_{T,nom}} - \frac{E_g}{U_T} + XTI \cdot \frac{T}{T_{NOM}}}{ND}\right)$$

$$PB_t = PB - TPB \cdot (T - T_{NOM})$$

$$PBSW_t = PBSW - TPBSW \cdot (T - T_{NOM})$$

$$PBSWG_t = PBSWG - TPBSWG \cdot (T - T_{NOM})$$

$$CJ_t = CJ \cdot (1 + TCJ \cdot (T - T_{NOM}))$$

$$CJSW_t = CJSW \cdot (1 + TCJSW \cdot (T - T_{NOM}))$$

$$CJSWG_t = CJSWG \cdot (1 + TCJSWG \cdot (T - T_{NOM}))$$

$$JTS_t = JTS \cdot \exp\left(\frac{E_{g,nom}}{U_T} \cdot XTS \cdot \left(1 - \frac{T}{T_{NOM}}\right)\right)$$

$$JT SW_t = JT SW \cdot \exp\left(\frac{E_{g,nom}}{U_T} \cdot XT SW \cdot \left(1 - \frac{T}{T_{NOM}}\right)\right)$$

$$JT SWG_t = JT SWG \cdot \exp\left(\frac{E_{g,nom}}{U_T} \cdot XT SWG \cdot \left(1 - \frac{T}{T_{NOM}}\right)\right)$$

$$NJTS_t = NJTS \cdot \left(1 + \left(\frac{T}{T_{NOM}} - 1\right) \cdot TNJTS\right)$$

$$NJTSSW_t = NJTSSW \cdot \left(1 + \left(\frac{T}{T_{NOM}} - 1\right) \cdot TNJTSSW\right)$$

$$NJTSSWG_t = NJTSSWG \cdot \left(1 + \left(\frac{T}{T_{NOM}} - 1\right) \cdot TNJTSSWG\right)$$

Area and Perimeter

$$AS = 2 \cdot HDIF \cdot W_{eff} \cdot NF$$

$$AD = 2 \cdot HDIF \cdot W_{eff} \cdot NF$$

$$PS = (4 \cdot HDIF + W_{eff}) \cdot NF$$

$$PD = (4 \cdot HDIF + W_{eff}) \cdot NF$$

Junction Current

$$I_{S,D} = JS_t \cdot AD + JSW_t \cdot PD + JSWG_t \cdot W_{eff} \cdot NF$$

$$f_{breakdown,d} = 1 + XJBV \cdot \exp\left(-\frac{-V(di,b) + BV}{U_T \cdot ND \cdot T_{NOM}}\right)$$

$$I_{DE,tun} = W_{eff} \cdot NF \cdot JT_{SWG_t} \cdot \left(\exp\left(\frac{V(di,b) \cdot T}{T_{NOM} \cdot U_T \cdot NJT_{SWG_t} \cdot VT_{SWG} + V(di,b)}\right) - 1\right) \\
+ PD \cdot JT_{SW_t} \cdot \left(\exp\left(\frac{V(di,b) \cdot T}{T_{NOM} \cdot U_T \cdot NJT_{SW_t} \cdot VT_{SW} + V(di,b)}\right) - 1\right) \\
+ AD \cdot JT_t \cdot \left(\exp\left(\frac{V(di,b) \cdot T}{T_{NOM} \cdot U_T \cdot NJT_t \cdot VTS + V(di,b)}\right) - 1\right)$$

$$I_{DBJ} = I_{S,D} \cdot \left(1 - \exp\left(-\frac{V(di,b) \cdot T}{T_{NOM} \cdot U_T \cdot ND}\right)\right) \cdot f_{breakdown,d} + V(di,b) \cdot GMIN$$

Junction Capacitance

if $V(di,b) \geq 0$

$$C_{DBJ} = CJ_t \cdot AD \cdot \exp\left(MJ \cdot \ln\left(1 + \frac{V(di,b)}{PR_t}\right)\right) + \\
+ CJSW_t \cdot PD \cdot \exp\left(MJSW \cdot \ln\left(1 + \frac{V(di,b)}{PBSW_t}\right)\right) + \\
+ CJSWG_t \cdot W_{eff} \cdot NF \cdot \exp\left(MJSWG \cdot \ln\left(1 - \frac{V(di,b)}{PBSWG_t}\right)\right)$$

if $V(di,b) < 0$

$$C_{DBJ} = CJ_t \cdot AD \cdot \left(1 - MJ \cdot \frac{V(di,b)}{PB_t}\right) + \\
+ CJSW_t \cdot PD \cdot \left(1 - MJSW \cdot \frac{V(di,b)}{PBSW_t}\right) + \\
+ CJSWG_t \cdot W_{eff} \cdot NF \cdot \left(1 - MJSWG \cdot \frac{V(di,b)}{PBSWG_t}\right)$$

External Resistors (Gate, Series, Bulk)

$$R_S = \frac{HDIF \cdot R_{SH} + \left(LDIF - \frac{DL}{2} \right) \cdot R_S}{W_{eff} \cdot NF}$$

$$R_D = \frac{HDIF \cdot R_{SH} + \left(LDIF - \frac{DL}{2} \right) \cdot R_D}{W_{eff} \cdot NF}$$

$$R_{S_g} = ES \cdot \left(1 + \frac{WRLX}{W_{eff}} \right)$$

$$R_{D_g} = RD \cdot \left(1 + \frac{WRLX}{W_{eff}} \right)$$

$$R_G = R_{GSH} \cdot \frac{W_{eff}}{3 \cdot GC^2 \cdot NF \cdot L_{eff}}$$

$$R_{DSB} = R_{DSBSH} \cdot \frac{L_{eff}}{L_{eff} \cdot NF}$$

Virtuoso Simulator Components and Device Models Reference
EKV3 MOSFET Model (ekv3)

if **RINGTYPE** = 1(HORSE - SHOE)

$$RB = \begin{cases} \frac{RBWSH}{2 \cdot W_{eff}} & \text{if } RBN = 0 \\ \frac{2 \cdot W_{eff}}{\frac{RBWSH}{1} + \frac{NF}{RBN}} & \text{if } RBN \neq 0 \end{cases}$$

if **NF** is even

$$RSB = \begin{cases} \frac{RSBWSH}{2 \cdot W_{eff}} & \text{if } RSBN = 0 \\ \frac{2 \cdot W_{eff}}{\frac{RSBWSH}{1} + \frac{NF}{RSBN}} & \text{if } RSBN \neq 0 \end{cases}$$

$$RDB = \begin{cases} \frac{RDBWSH}{2 \cdot W_{eff}} & \text{if } RDBN = 0 \\ \frac{2 \cdot W_{eff}}{\frac{RDBWSH}{1} + \frac{NF}{RDBN}} & \text{if } RDBN \neq 0 \end{cases}$$

if **NF** is odd

$$RSD = \begin{cases} \frac{RSBWSH}{W_{eff}} & \text{if } RSBN = 0 \\ \frac{W_{eff}}{\frac{RSBWSH}{1} + \frac{NF}{RSBN}} & \text{if } RSBN \neq 0 \end{cases}$$

$$RDB = RSB$$

if **RINGTYPE** = 2(SYMMETRIC)

$$RB = \frac{RBWSH}{2 \cdot W_{eff}}$$

if **NF** is even

$$RSB = \frac{RSBWSH}{2 \cdot W_{eff}}$$

$$RDB = \frac{RDBWSH}{2 \cdot W_{eff}}$$

if **NF** is odd

$$RSB = \frac{RSBWSH}{W_{eff}}$$

$$RDB = RSB$$

Temperature Dependence

$$RS_{gt} = RS_g \cdot (1 + TR \cdot (T - T_{NOM}) + TR2 \cdot (T - T_{NOM})^2)$$

$$RD_{gt} = RD_g \cdot (1 + TR \cdot (T - T_{NOM}) + TR2 \cdot (T - T_{NOM})^2)$$

$$RG_t = RG \cdot (1 + TR \cdot (T - T_{NOM}) + TR2 \cdot (T - T_{NOM})^2)$$

$$RB_t = RB \cdot (1 + TR \cdot (T - T_{NOM}) + TR2 \cdot (T - T_{NOM})^2)$$

$$RSR_t = RSR \cdot (1 + TR \cdot (T - T_{NOM}) + TR2 \cdot (T - T_{NOM})^2)$$

$$RDB_t = RDB \cdot (1 + TR \cdot (T - T_{NOM}) + TR2 \cdot (T - T_{NOM})^2)$$

$$RDSB_t = RDSB \cdot (1 + TR \cdot (T - T_{NOM}) + TR2 \cdot (T - T_{NOM})^2)$$

Component Statements

Instance Definition

Name d g s b ModelName parameter=value ...

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

Instance Parameters

1	<code>exp_cr=80.0</code>	This parameter is used by simulator
2	<code>cmi_limexp_method=1.0</code>	This parameter is used by simulator.
3	<code>cmi_compactable=1.0</code>	This parameter is used by simulator.
4	<code>l=10.0E-06</code>	GATES LENGTH.
5	<code>w=10.0E-06</code>	GATES WIDTH.
6	<code>nf=1</code>	NUMBER OF FINGERS.
7	<code>m=1</code>	NUMBER OF DEVICES IN PARALLEL.
8	<code>ad=0.0</code>	DRAINS AREA.
9	<code>as=0.0</code>	SOURCES AREA.
10	<code>pd=0.0</code>	DRAINS PERIMETER.
11	<code>ps=0.0</code>	SOURCES PERIMETER.
12	<code>sa=0.0</code>	STI PARAMETER; DISTANCE FROM STI.
13	<code>sb=0.0</code>	STI PARAMETER; DISTANCE FROM STI.
14	<code>sd=0.0</code>	STI PARAMETER; DISTANCE BETWEEN GATES.
15	<code>trise=0.0</code>	TEMPERATURE CHANGE FOR PARTICULAR TRANSISTOR.

Model Definition

```
model modelName ekv3 parameter=value ...
```

Model Parameters

1	<code>sign=1</code>	Sign = 1 for nmos; sign = -1 for pmos.
2	<code>tg=(-1)</code>	Type of gate: -1 enhancement type; 1 depletion type.

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

3	<code>tnom=27.0</code>	Nominal temperature (in celsius degrees).
4	<code>scale=1.0</code>	Scaling factor for gate length and with.
5	<code>qoff=0.0</code>	Charge partition flag.
6	<code>xl=0.0</code>	Optical offset for gate length.
7	<code>xw=0.0</code>	Optical offset for gate width.
8	<code>nqs_noi=1.0</code>	NQS noise flag (on/off), includes thermal noise with no short channel effects.
9	<code>th_noi=0.0</code>	Thermal noise flag (on/off), includes short channel effects but no gate induced noise.
10	<code>info_level=0.0</code>	Information level.
11	<code>avto=0.0</code>	Matching parameter for threshold voltage (VTO).
12	<code>agamma=0.0</code>	Matching parameter for body factor (GAMMA).
13	<code>akp=0.0</code>	Matching parameter for mobility (KP).
14	<code>cox=0.012</code>	Oxide capacitance per unit area.
15	<code>xj=20.0E-09</code>	Depth of active areas.
16	<code>vt0=0.3</code>	Threshold voltage.
17	<code>phif=0.45</code>	Fermi bulk potential.
18	<code>gamma=0.3</code>	Body effect coefficient.
19	<code>gammag=4.1</code>	Body effect coefficient for gate.
20	<code>n0=1.0</code>	Long channel slope factor fine tuning.
21	<code>vbi=0.0</code>	Built-in voltage drop.
22	<code>aqma=0.5</code>	Quantum effect coefficient for accumulation region.
23	<code>aqmi=0.4</code>	Quantum effect coefficient for inversion region.

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

24	$\text{etaqm}=0.75$	Quantum effect factor.
25	$\text{kp}=500.0\text{E}-06$	Mobility multiplied by cOX .
26	$\text{e0}=1.0\text{E}+10$	First order coefficient for mobility reduction due to vertical field.
27	$\text{e1}=3.1\text{E}+08$	Mobility reduction due to vertical field factor.
28	$\text{eta}=0.5$	Mobility reduction due to vertical field factor.
29	$\text{zc}=1.0\text{E}-6$	Coulomb scattering coefficient.
30	$\text{thc}=0.0$	Coulomb scattering coefficient.
31	$\text{la}=1.0$	First critical length for mobility length dependence.
32	$\text{lb}=1.0$	Second critical length for mobility length dependence.
33	$\text{ka}=0.0$	First factor for mobility length dependence.
34	$\text{kb}=0.0$	Second factor for mobility length dependence.
35	$\text{wkp1}=1.0\text{E}-6$	Width parameter for mobility profile vs. width.
36	$\text{wkp2}=0.0$	Amplitude parameter for mobility profile vs. width.
37	$\text{wkp3}=1.0$	Span parameter for mobility profile vs. width.
38	$\text{dl}=(-10.0\text{E}-9)$	Effective length parameter.
39	$\text{dlc}=0.0$	Effective length parameter for capacitance.
40	$\text{dw}=(-10.0\text{E}-9)$	Effective width parameter.
41	$\text{dwc}=0.0$	Effective width parameter for capacitance.
42	$\text{ldw}=0.0$	Length dependence of effective width.
43	$\text{wdl}=0.0$	Width dependence of effective length.
44	$\text{ll}=0.0$	Base for exponential dependence of effective length.
45	$\text{lln}=1.0$	Exponent for exponential dependence of effective length.

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

46	avt=0.0	Amplitude for long and wide channel threshold voltage correction.
47	lvt=1.0	Length for long channel threshold voltage correction.
48	wvt=1.0	Width for wide channel threshold voltage correction.
49	agam=0.0	Amplitude for long and wide channel body effect coefficient correction.
50	lgam=1.0	Length for long channel body effect coefficient correction.
51	wgam=1.0	Width for wide channel body effect coefficient correction.
52	nfvta=0.0	Number of fingers parameter for threshold voltage dependence on NF.
53	nfvtb=10000.0	Factor for threshold voltage dependence on NF.
54	ucrit=5.0E+06	Critical velocity of electrons.
55	lambda=0.5	Early effect factor.
56	delta=2.0	Order of velocity saturation model (variable order model 1,2).
57	aclm=0.83	Channel length modulation factor.
58	lr=50.0E-09	Length factor for RSCE.
59	qlr=0.5E-3	Threshold voltage factor of RSCE.
60	nlr=10.0E-3	Body effect coefficient factor of RSCE.
61	flr=0.0	Bulk fermi potential of RSCE.
62	leta0=0.0	Short channel charge sharing coefficient.
63	leta=500.0E-3	Long channel charge sharing coefficient.
64	leta2=0.0	Short channel dependence coefficient.
65	weta=200.0E-3	Narrow channel charge sharing coefficient.

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

66	<code>ncs=1.0</code>	Slope factor dependence from charge sharing.
67	<code>etad=1.0</code>	Primary DIBL coefficient.
68	<code>sigmad=1.0</code>	Secondary DIBL coefficient.
69	<code>wr=90.0E-09</code>	Width factor for INWE.
70	<code>qwr=0.3E-3</code>	Threshold voltage factor of INWE.
71	<code>nwr=5.0E-3</code>	Body effect coefficient factor of INWE.
72	<code>fprout=1.0E6</code>	Output resistance for DITS effect.
73	<code>pdits=0.0</code>	DITS parameter.
74	<code>pditsl=0.0</code>	DITS dependence on length.
75	<code>pditsd=1.0</code>	DITS dependence on drain bias.
76	<code>ddits=0.3</code>	Smooth factor of DITS effect.
77	<code>iba=000.0E+06</code>	Impact ionization current first parameter.
78	<code>ibb=300.0E+06</code>	Impact ionization current second parameter.
79	<code>ibn=1.0</code>	Impact ionization current coefficient
80	<code>xb=3.1</code>	Silicon to silicon oxide tunneling barrier height.
81	<code>eb=29.0E+09</code>	Characteristic electrical field.
82	<code>kg=00.0E-6</code>	Mobility for gate current.
83	<code>lovig=20.0E-9</code>	Overlap length for gate current.
84	<code>agidl=0.0</code>	First GIDL parameter.
85	<code>bgidl=2.3E+09</code>	Second GIDL parameter.
86	<code>cgidl=0.5</code>	Third GIDL parameter.
87	<code>egidl=0.8</code>	Fourth GIDL parameter.

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

88	<code>kf=0.0</code>	Flicker noise factor.
89	<code>af=1.0</code>	Frequency exponent for flicker noise.
90	<code>ef=2.0</code>	Transconductance exponent for flicker noise.
91	<code>kgfn=0.0</code>	Gate flicker noise factor.
92	<code>lqwr=0.0</code>	Length dependence of QWR.
93	<code>lnwr=0.0</code>	Length dependence of NWR.
94	<code>lwr=0.0</code>	Length dependence of WR.
95	<code>ldphiedge=0.0</code>	Length dependence of DPHIEDGE.
96	<code>wqlr=0.0</code>	Width dependence of QLR.
97	<code>wnlr=0.0</code>	Width dependence of NLR.
98	<code>wlr=0.0</code>	Width dependence of LR.
99	<code>wucrit=0.0</code>	Width dependence of UCRIT.
100	<code>wlambda=0.0</code>	Width dependence of LAMBDA.
101	<code>wetad=0.0</code>	Width dependence of ETAD.
102	<code>we0=0.0</code>	Width dependence of E0.
103	<code>we1=0.0</code>	Width dependence of E1.
104	<code>wrlx=0.0</code>	Width dependence of RLX.
105	<code>wucex=0.0</code>	Width dependence of UCEx.
106	<code>wdphiedge=0.0</code>	Width dependence of DPHIEDGE.
107	<code>wldphiedge=0.0</code>	Area dependence (fine tuning for short and narrow) of DPHIEDGE.
108	<code>wldgammaedge=0.0</code>	Area dependence (fine tuning for short and narrow) of DGAMMAEDGE.

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

109	wedge=0.0	Area dependence (fine tuning for short and narrow) of DGAMMAEDGE.
110	dgammaedge=0.0	Difference of body effect coefficient of edge conduction area with respect to the main part of the channel.
111	dphiedge=0.0	Difference of fermi potential of edge conduction area with respect to the main part of the channel.
112	saref=0.0	Reference distance from STI, for SA.
113	sbref=0.0	Reference distance from STI, for SB.
114	wlod=0.0	Width of common area between device and STI.
115	kkp=0.0	Mobility dependence on STI.
116	lkkp=0.0	Length dependence of mobility dependence on STI.
117	wkkp=0.0	Width dependence of mobility dependence on STI.
118	pkkp=0.0	Area dependence (fine tuning for short and narrow channel devices) of mobility dependence on STI.
119	tkkp=0.0	Temperature dependence of mobility dependence on STI.
120	llodkkp=1.0	Exponent of length dependence of mobility dependence on STI.
121	wlodkkp=1.0	Exponent of width dependence of mobility dependence on STI.
122	kvto=0.0	Threshold voltage dependence on STI.
123	lkvto=0.0	Length dependence of threshold voltage dependence on STI.
124	wkvto=0.0	Width dependence of threshold voltage dependence on STI.
125	pkvto=0.0	Area dependence (fine tuning for short and narrow channel devices) of threshold voltage dependence on STI.
126	llodkvto=1.0	Exponent of length dependence of threshold voltage dependence on STI.

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

127	wlodkvto=1.0	Exponent of width dependence of threshold voltage dependence on STI.
128	kgamma=0.0	Body effect dependence on STI.
129	lodkgamma=1.0	Exponential dependence of body effect on STI.
130	ketad=0.0	Primary DIBL dependence on STI.
131	lodketad=1.0	Exponential dependence of primary DIBL dependence on STI.
132	kucrit=0.0	Critical velocity of electrons dependence of STI.
133	teta=(-0.9E-3)	Temperature dependence of ETA.
134	tlambda=0.0	Temperature dependence of LAMBDA.
135	tcv=600.0E-6	Temperature dependence of VTO (threshold voltage).
136	bex=(-1.5)	Temperature dependence of KP (mobility).
137	ucex=1.5	Temperature dependence of UCRIT.
138	te0ex=0.5	Temperature dependence of E0.
139	te1ex=0.5	Temperature dependence of E1.
140	ibbt=800.0E-6	Temperature dependence of 1BB.
141	tcvl=0.0	Length dependence of TCV.
142	tcvw=0.0	Width dependence of TCV.
143	tcvwl=0.0	Area dependence of TCV.
144	gammaov=1.6	Length of the overlap area.
145	gammagov=10.0	Body effect coefficient of the gate of the overlap area.
146	vfbov=0.0	Flat-band voltage of the overlap area.
147	lov=20.0E-9	Length of the overlap area.

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EKV3 MOSFET Model (ekv3)

148	<code>vov=1.0</code>	Vs dependence of <code>vgsov</code> .
149	<code>cgso=0.0</code>	Bias-independent gate to source overlap capacitance.
150	<code>cgdo=0.0</code>	Bias-independent gate to drain overlap capacitance.
151	<code>cgbo=0.0</code>	Bias-independent gate to bulk overlap capacitance.
152	<code>kjf=0.0</code>	Fringing capacitance factor
153	<code>cjf=0.0</code>	Fringing capacitor bias factor.
154	<code>vfr=0.0</code>	Built-in correction for fringing capacitance.
155	<code>dfr=1.0E-3</code>	Smooth factor of fringing capacitance model.
156	<code>hdif=0.0e-6</code>	Half length of active area.
157	<code>rsh=0.0</code>	Square resistance of active area.
158	<code>ldif=0.0</code>	Distance between the middle of the active area and the start of the channel.
159	<code>rs=0.0</code>	LDD source series resistance.
160	<code>rd=0.0</code>	LDD drain series resistance.
161	<code>rlx=(-1.0)</code>	External series resistance.
162	<code>rsx=(-1.0)</code>	Source series resistance.
163	<code>rdx=(-1.0)</code>	Drain series resistance.
164	<code>tr=0.0</code>	First order temperature coefficient of resistors.
165	<code>tr2=0.0</code>	Second order temperature coefficient of resistors.
166	<code>gmin=0.0</code>	Minimum conductance of diode.
167	<code>njs=1.0</code>	Slope factor for parasitic diodes(S).
168	<code>xjbvs=0.0</code>	Breaddown effect coefficient.

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

169	bvs=10.0	Breakdown voltage(S).
170	jss=0.0E-09	Area component of diode current(S).
171	jssws=0.0E-12	Perimeter component of diode current(S).
172	jsswgs=0.0E-12	Gate side component of diode current(S).
173	jtss=0.0E-09	Area component of trap-assisted diode current(S).
174	jtssws=0.0E-12	Perimeter component of trap-assisted diode current(S).
175	jtsswgs=0.0E-12	Gate side component of trap-assisted diode current(S).
176	njtss=1.0	Area slope factor of trap-assisted diode current(S).
177	njtssws=1.0	Perimeter slope factor of trap-assisted diode current(S).
178	njtsswgs=1.0	Gate side slope factor of trap-assisted diode current(S).
179	vtss=0.0	Area voltage factor of trap-assisted diode current(S).
180	vtssws=0.0	Perimeter voltage factor of trap-assisted diode current(S).
181	vtsswgs=0.0	Gate side voltage factor of trap-assisted diode current(D).
182	cjs=0.0E-06	Area component of diode capacitance(S).
183	cjsws=0.0E-09	Perimeter component of diode capacitance(S).
184	cjswgs=0.0E-09	Gate side component of diode capacitance(S).
185	pbs=0.800	Area parameter of diode capacitance(S).
186	pbsws=0.600	Perimeter parameter of diode capacitance(S).
187	pbswgs=0.600	Gate side parameter of diode capacitance(S).
188	mjs=0.900	Area exponent of diode capacitance(S).
189	mjsws=0.700	Perimeter exponent of diode capacitance(S).
190	mjswgs=0.700	Gate side exponent of diode capacitance(S).

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191	$xtis=3.0$	Temperature dependence of diode(S).
192	$xtss=0.0$	Area component of temperature dependence of trap-assisted diode current(S).
193	$xtssws=0.0$	Perimeter component of temperature dependence of trap-assisted diode current(S).
194	$xtsswgs=0.0$	Gate side component of temperature dependence of trap-assisted diode current(S).
195	$tnjtss=0.0$	Temperature dependence of njtss.
196	$tnjtssws=0.0$	Temperature dependence of njtssws.
197	$tnjtsswgs=0.0$	Temperature dependence of njtsswgs.
198	$tcj=0.0$	Temperature dependence of CJ.
199	$tcjsw=0.0$	Temperature dependence of CJSW.
200	$tcjswg=0.0$	Temperature dependence of CJSWG.
201	$tpb=0.0$	Temperature dependence of PB.
202	$tpbsw=0.0$	Temperature dependence of PBSW.
203	$tpbswg=0.0$	Temperature dependence of PBSWG.
204	$njd=1.0$	Slope factor for parasitic diodes(D).
205	$xjbvd=0.0$	Breakdown effect coefficient(D).
206	$bvd=10.0$	Breakdown Voltage(D).
207	$jsd=0.0E-09$	Area component of diode current(D).
208	$jsd=0.0E-12$	Perimeter component of diode current(D).
209	$jsd=0.0E-12$	Gate side component of diode current(D).
210	$jtsd=0.0E-09$	Area component of trap-assisted diode current(D).

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211	$jtsswd=0.0E-12$	Perimeter component of trap-assisted diode current(D).
212	$jtsswg d=0.0E-12$	Gate side component of trap-assisted diode current(D).
213	$njt s d=1.0$	Area slope factor of trap-assisted diode current(D).
214	$njt s s w d=1.0$	Perimeter slope factor of trap-assisted diode current(D).
215	$njt s s w g d=1.0$	Gate side slope factor of trap-assisted diode current(D).
216	$vt s d=0.0$	Area voltage factor of trap-assisted diode current(D).
217	$vt s s w d=0.0$	Perimeter voltage factor of trap-assisted diode current(D).
218	$vt s s w g d=0.0$	Gate side voltage factor of trap-assisted diode current(D).
219	$cj d=0.0E-06$	Area component of diode capacitance(D).
220	$cj s w d=0.0E-09$	Perimeter component of diode capacitance(D).
221	$cj s w g d=0.0E-09$	Gate side component of diode capacitance(D).
222	$p b d=0.800$	Area parameter of diode capacitance(D).
223	$p b s w d=0.600$	Perimeter parameter of diode capacitance(D).
224	$p b s w g d=0.600$	Gate side parameter of diode capacitance(D).
225	$m j d=0.900$	Area exponent of diode capacitance(D).
226	$m j s w d=0.700$	Perimeter exponent of diode capacitance(D).
227	$m j s w g d=0.700$	Gate side exponent of diode capacitance(D).
228	$x t i d=3.0$	Temperature dependence of diode(D).
229	$x t s d=0.0$	Area component of temperature dependence of trap-assisted diode current(D).
230	$x t s s w d=0.0$	Perimeter component of temperature dependence of trap-assisted diode current(D).

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231	<code>xtsswg\bar{d}=0.0</code>	Gate side component of temperature dependence of trap-assisted diode current(D).
232	<code>tnjts\bar{d}=0.0</code>	Temperature dependence of njtsd.
233	<code>tnjtssw\bar{d}=0.0</code>	Temperature dependence of njtsswd.
234	<code>tnjtsswg\bar{d}=0.0</code>	Temperature dependence of njtsswg \bar{d} .
235	<code>rgsh=3.0</code>	Gate square resistance.
236	<code>gc=1</code>	Gate contacts (single sided = 1, double sided = 2).
237	<code>kr\bar{g}l1=0.0</code>	Length dependence of rg.
238	<code>rdsbsh=1.0E+3</code>	Drain to source substrate sheet resistance.
239	<code>rbwsh=3.0E-3</code>	Inner bulk to bulk sheet resistance.
240	<code>r\bar{b}n=0.0</code>	Inner bulk to bulk resistance per finger (for RINGTYPE=2).
241	<code>rsbwsh=1.0E-3</code>	Inner bulk-source side to bulk sheet resistance.
242	<code>r$\bar{s}$$\bar{b}$n=0.0</code>	Inner bulk-source side to bulk resistance per finger (for RINGTYPE=2).
243	<code>rdbwsh=1.0E-3</code>	Inner bulk-drain side to bulk sheet resistance.
244	<code>r$\bar{d}$$\bar{b}$n=0.0</code>	Inner bulk-drain side to bulk resistance per finger (for RINGTYPE=2).
245	<code>ringtype=1.0</code>	Type of guard ring (bulk contacts) (two sides/symmetric: 1, three sides/horse shoe: 2).

Output Parameters

1	<code>d</code>	node: Drain.
2	<code>g</code>	node: Gate.
3	<code>s</code>	node: Source.
4	<code>b</code>	node: Bulk.

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5	<code>di</code>	node: Internal drain.
6	<code>si</code>	node: Internal source.
7	<code>noi</code>	node: Noise.

Operating-Point Parameters

1	<code>exp_cr=(80.0)</code>	The parameter is used by simulator.
2	<code>cmi_limexp_method=(1.0)</code>	The parameter is used by simulator.
3	<code>cmi_compactable=1.0</code>	The parameter is used by simulator.
4	<code>qs (C)</code>	Source charge.
5	<code>qd (C)</code>	Drain charge.
6	<code>qg (C)</code>	Gate charge.
7	<code>qb (C)</code>	Bulk charge.
8	<code>ids (A)</code>	Resistive drain-to-source current.
9	<code>idb (A)</code>	Impact ionization current.
10	<code>qsedge (C)</code>	Edge charge.
11	<code>qdedge (C)</code>	Edge charge.
12	<code>qgedge (C)</code>	Edge charge.
13	<code>qbedge (C)</code>	Edge charge.
14	<code>qsov (C)</code>	Source side overlap charge.
15	<code>qdov (C)</code>	Drain side overlap charge.
16	<code>qsfr (C)</code>	Source side fringing charge.
17	<code>qdfrr (C)</code>	Drain side fringing charge.

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18	igidl (A)	Gate induced drain current.
19	igisl (A)	Gate induced source current.
20	igb (A)	Gate current(bulk).
21	igd (A)	Gate current(drain).
22	igs (A)	Gate current(source).
23	igdov (A)	Overlap gate current(drain).
24	igsov (A)	Overlap gate current(source).

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

ac1m M-53	igidov OP-18	njtsswgs M-174	th_noi M-9
ad I-7	igidl OP-22	njtssws M-173	thc M-26
ad OP-6	igisl OP-23	n1r M-56	tkkp M-115
af M-85	igs OP-21	noi O-7	tlambda M-130
agam M-45	igsov OP-17	nqs_noi M-8	tnjttd M-228
agamma I-15	jsd M-203	nwr M-67	tnjtss M-191
agamma OP-14	jss M-166	pbd M-218	tnjtsswd M-229
agidl M-80	jsswd M-204	pbs M-181	tnjtsswgd M-230
akp I-16	jsswgd M-205	pbswd M-219	tnjtsswgs M-193

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akp	OP-15	jsswgs	M-168	pbswgd	M-220	tnjtssws	M-192
aqma	M-18	jssws	M-167	pbswgs	M-183	tnom	M-3
aqmi	M-19	jtsd	M-206	pbsws	M-182	tpb	M-197
as	I-8	jtss	M-169	pd	I-9	tpbsw	M-198
as	OP-7	jtsswd	M-207	pd	OP-8	tpbswg	M-199
avt	M-42	jtsswgd	M-208	pdits	M-69	tr	M-160
avto	I-14	jtsswgs	M-171	pditsd	M-71	tr2	M-161
avto	OP-13	jtssws	M-170	pditsl	M-70	ucex	M-133
b	O-4	ka	M-29	phif	M-13	ucrit	M-50
bex	M-132	kb	M-30	pkkp	M-114	vbi	M-17
bgidl	M-81	ketad	M-126	pkvto	M-121	vdb	OP-38
bvd	M-202	kf	M-84	ps	I-10	vfbov	M-142
bvs	M-165	kg	M-78	ps	OP-9	vfr	M-150
cgbo	M-147	kgamma	M-124	qjb	OP-36	vgb	OP-39
cgdo	M-146	kgfn	M-87	qbedge	OP-32	vov	M-144
cgidl	M-82	kjf	M-148	qd	OP-34	vsb	OP-40
cgso	M-145	kkp	M-111	qdedge	OP-30	vto	M-12
cjd	M-215	kp	M-21	qdfrr	OP-25	vtssd	M-212
cjf	M-149	krgl1	M-233	qdov	OP-27	vtss	M-175
cjs	M-178	kucrit	M-128	qg	OP-35	vtsswd	M-213
cjswd	M-216	kvto	M-118	qgedge	OP-31	vtsswgd	M-214

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EKV3 MOSFET Model (ekv3)

cjswgd	M-217	l	I-4	qlr	M-55	vtsswgs	M-177
cjswgs	M-180	l	OP-3	qoff	M-5	vtssws	M-176
cjsws	M-179	la	M-27	qs	OP-33	w	I-5
cmi_limexp_method		lambda	M-51	qsedge	OP-29	w	OP-4
I-2							
cmi_limexp_method		lb	M-28	qsfr	OP-24	wdl	M-39
OP-2							
cox	M-10	ldif	M-154	qsov	OP-26	wdphiedge	M-102
d	O-1	ldphiedge	M-91	qwr	M-66	we0	M-98
ddits	M-72	ldw	M-38	rbn	M-236	we1	M-99
delta	M-52	leta	M-59	rbwsh	M-235	wedge	M-105
dfr	M-151	leta0	M-58	rd	M-156	weta	M-61
dgammaedge	M-106	leta2	M-60	rdbn	M-240	wetad	M-97
di	O-5	lgam	M-46	rdbwsh	M-239	wgam	M-47
dl	M-34	lkkp	M-112	rdsbsh	M-234	wkkp	M-113
dlc	M-35	lkvto	M-119	rdx	M-159	wkp1	M-31
dphiedge	M-107	ll	M-40	rgsh	M-231	wkp2	M-32
dw	M-36	lln	M-41	ringtype	M-241	wkp3	M-33
dwc	M-37	llodkkp	M-116	rlx	M-157	wkvto	M-120
e0	M-22	llodkvto	M-122	rs	M-155	wlambda	M-96
e1	M-23	lnwr	M-89	rsbn	M-238	wldgammaedge	M-104
eb	M-77	lodketad	M-127	rsbwsh	M-237	wldphiedge	M-103

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ef	M-86	lodkgamma	M-125	rsh	M-153	wlod	M-110
egidl	M-83	lov	M-143	rsx	M-158	wlodkkp	M-117
eta	M-24	lovig	M-79	s	O-3	wlodkvto	M-123
etad	M-63	lqwr	M-88	sa	I-11	wlr	M-94
etaqm	M-20	lr	M-54	sa	OP-10	wnlr	M-93
exp_cr	I-1	lvt	M-43	saref	M-108	wqlr	M-92
exp_cr	OP-1	lwr	M-90	sb	I-12	wr	M-65
flr	M-57	m	I-3	sb	OP-11	wrlx	M-100
fprout	M-68	mjd	M-221	sbref	M-109	wucex	M-101
g	O-2	mjs	M-184	scale	M-4	wucrit	M-95
gamma	M-14	mjswd	M-222	sd	I-13	wvt	M-44
gammag	M-15	mjswgd	M-223	sd	OP-12	xb	M-76
gammagov	M-141	mjswgs	M-186	si	O-6	xj	M-11
gammaov	M-140	mjsws	M-185	sigmad	M-64	xjbvd	M-201
gc	M-232	n0	M-16	sign	M-1	xjbvs	M-164
gmin	M-162	ncs	M-62	tcj	M-194	xl	M-6
hdif	M-152	nf	I-6	tcjsw	M-195	xtid	M-224
iba	M-73	nf	OP-5	tcjswg	M-196	xtis	M-187
ibb	M-74	nfvta	M-48	tcv	M-131	xtsd	M-225
ibbt	M-136	nfvtb	M-49	tcvl	M-137	xtss	M-188
ibn	M-75	njd	M-200	tcvw	M-138	xtsswd	M-226

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idb	OP-16	njs	M-163	tcvwl	M-139	xtsswgd	M-227
ids	OP-37	njtsd	M-209	te0ex	M-134	xtsswgs	M-190
idsedge	OP-28	njtss	M-172	telex	M-135	xtssws	M-189
igb	OP-19	njtsswd	M-210	teta	M-129	xw	M-7
igd	OP-20	njtsswgd	M-211	tg	M-2	zc	M-25

Device `ekv3_nqs` (`ekv3_nqs`)

This device is supported within altergroups.

Instance Definition

Name d g s b ModelName parameter=value ...

Instance Parameters

- 1 `exp_cr=(80.0)` The parameter is used by simulator.
- 2 `cmi_limexp_method=(1.0)` The parameter is used by simulator.
- 3 `m=(1.0)` Multiplicity factor (number of MOSFETs in parallel).
- 4 `l=(10.0E-06)` GATES LENGTH.
- 5 `w=(10.0E-06)` GATES WIDTH.
- 6 `nf=(1)` NUMBER OF FINGERS.
- 7 `ad=(0.0)` DRAINS AREA.
- 8 `as=(0.0)` SOURCES AREA.
- 9 `pd=(0.0)` DRAINS PERIMETER.

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

10	<code>ps=(0.0)</code>	SOURCES PERIMETER.
11	<code>sa=(0.0)</code>	STI PARAMETER; DISTANCE FROM STI.
12	<code>sb=(0.0)</code>	STI PARAMETER; DISTANCE FROM STI.
13	<code>sd=(0.0)</code>	STI PARAMETER; DISTANCE BETWEEN GATES.
14	<code>avto=(0.0)</code>	MATCHING PARAMETER FOR THRESHOLD VOLTAGE (VTO).
15	<code>agamma=(0.0)</code>	MATCHING PARAMETER FOR BODY FACTOR (GAMMA).
16	<code>akp=(0.0)</code>	MATCHING PARAMETER FOR MOBILITY (KP).

Model Definition

```
model modelName ekv3_nqs parameter=value ...
```

Model Parameters

1	<code>sign=(1)</code>	SIGN = 1 FOR NMOS; SIGN = -1 FOR PMOS.
2	<code>tg=((-1))</code>	TYPE OF GATE: -1 ENHANCEMENT TYPE; 1 DEPLETION TYPE.
3	<code>tnom=(27.0)</code>	Parameters measurement temperature.
4	<code>scale=(1.0)</code>	Scaling Factor for Gate Length and Width.
5	<code>qoff=(0.0)</code>	Charge partitioning flag.
6	<code>xl=(0.0)</code>	Optical offset for Gate Length.
7	<code>xw=(0.0)</code>	Optical offset for Gate Width.
8	<code>nqs_noi=(1.0)</code>	NQS noise flag(on/off). Includes thermal noise with no short channel effects.
9	<code>th_noi=(0.0)</code>	Thermal noise flag(on/off). Includes short channel effects but no gate induced noise.
10	<code>cox=(0.012)</code>	Oxide Capacitance per unit Area.

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

11	$xj=(20.0E-09)$	Depth of Active Areas.
12	$vto=(0.3)$	THRESHOLD VOLTAGE.
13	$phif=(0.45)$	FERMI BULK POTENTIAL.
14	$gamma=(0.3)$	Body Effect Coefficient.
15	$gammag=(4.1)$	Body Effect Coefficient for Gate.
16	$n0=(1.0)$	Long Channel Slope Factor Fine Tuning.
17	$vbi=(0.0)$	Built-in Voltage Drop.
18	$aqma=(0.5)$	Quantum Effect Coefficient for Accumulation Region.
19	$aqmi=(0.4)$	Quantum Effect Coefficient for Inversion Region.
20	$etaqm=(0.75)$	Quantum Effect Factor.
21	$kp=(500.0E-06)$	Mobility multiplied by COX.
22	$e0=(1.0E+10)$	First Order Coefficient for Mobility Reduction due to Vertical Field.
23	$e1=(3.1E+08)$	Second Order Coefficient for Mobility Reduction due to Vertical Field.
24	$eta=(0.5)$	Mobility Reduction due to Vertical Field Factor.
25	$zc=(1.0E-6)$	Coulomb Scattering coefficient.
26	$thc=(0.0)$	Coulomb Scattering coefficient.
27	$la=(1.0)$	First critical length for mobility length scaling.
28	$lb=(1.0)$	Second critical length for mobility length scaling.
29	$ka=(0.0)$	First factor for mobility length scaling.
30	$kb=(0.0)$	Second factor for mobility length scaling.
31	$wkp1=(1.0E-6)$	Width parameter for mobility profile vs. width.

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EKV3 MOSFET Model (ekv3)

32	<code>wkp2=(0.0)</code>	Amplitude parameter for mobility profile vs. width.
33	<code>wkp3=(1.0)</code>	Span parameter for mobility profile vs. width.
34	<code>d1=(-10.0E-9)</code>	Effective Length Parameter.
35	<code>d1c=(0.0)</code>	Effective Length Parameter for Capacitance.
36	<code>dW=(-10.0E-9)</code>	Effective Width Parameter.
37	<code>dWc=(0.0)</code>	Effective Width Parameter for Capacitance.
38	<code>ldw=(0.0)</code>	Length Dependence of Effective Width.
39	<code>wdl=(0.0)</code>	Width Dependence of Effective Length.
40	<code>ll=(0.0)</code>	Base for Exponential Dependence of Effective Length.
41	<code>lln=(1.0)</code>	Exponent for Exponential Dependence of Effective Length.
42	<code>avt=(0.0)</code>	Amplitude for long and wide channel threshold voltage correction.
43	<code>lvt=(1.0)</code>	Length for long channel threshold voltage correction.
44	<code>wvt=(1.0)</code>	Width for wide channel threshold voltage correction.
45	<code>agam=(0.0)</code>	Amplitude for long and wide channel body effect coefficient correction.
46	<code>lgam=(1.0)</code>	Length for long channel body effect coefficient correction.
47	<code>wgam=(1.0)</code>	Width for wide channel body effect coefficient correction.
48	<code>nfvta=(0.0)</code>	Number of fingers parameter for threshold voltage dependence on NF.
49	<code>nfvtb=(10000.0)</code>	Factor for threshold voltage dependence on NF.
50	<code>ucrit=(5.0E+06)</code>	Critical Velocity of Electrons.
51	<code>lambda=(0.5)</code>	Early effect factor.

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52	<code>delta=(2.0)</code>	Order of velocity saturation model (variable order model 1~2).
53	<code>aclm=(0.83)</code>	Channel Length Modulation Factor.
54	<code>l_r=(50.0E-09)</code>	Length Factor for RSCE.
55	<code>q_{l_r}=(0.5E-3)</code>	Threshold Voltage Factor of RSCE.
56	<code>n_{l_r}=(10.0E-3)</code>	Body Effect Coefficient Factor of RSCE.
57	<code>f_{l_r}=(0.0)</code>	Bulk Fermi Potential of RSCE.
58	<code>leta0=(0.0)</code>	Long Channel Charge Sharing Coefficient.
59	<code>leta=(500.0E-3)</code>	Short Channel Charge Sharing Coefficient.
60	<code>leta2=(0.0)</code>	Short Channel Scaling Coefficient.
61	<code>weta=(200.0E-3)</code>	Narrow Channel Charge Sharing Coefficient.
62	<code>ncs=(1.0)</code>	Slope Factor Dependence from Charge Sharing.
63	<code>etad=(1.0)</code>	Primary DIBL Coefficient.
64	<code>sigmad=(1.0)</code>	Secondary DIBL Coefficient.
65	<code>w_r=(90.0E-09)</code>	Width Factor for INWE.
66	<code>q_{w_r}=(0.3E-3)</code>	Threshold Voltage Factor of INWE.
67	<code>n_{w_r}=(5.0E-3)</code>	Body Effect Coefficient Factor of INWE.
68	<code>f_{prout}=(1.0E6)</code>	Output resistance for DITS effect.
69	<code>p_{dits}=(0.0)</code>	DITS parameter.
70	<code>p_{ditsl}=(0.0)</code>	DITS dependence on length.
71	<code>p_{ditsd}=(1.0)</code>	DITS dependence on drain bias.
72	<code>ddits=(0.3)</code>	Smooth factor of DITS effect.
73	<code>iba=(000.0E+06)</code>	Impact Ionization Current first parameter.

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74	<code>ibb=(300.0E+06)</code>	Impact Ionization Current second parameter.
75	<code>ibn=(1.0)</code>	Impact Ionization Current coefficient.
76	<code>xb=(3.1)</code>	Silicon to Silicon oxide tunneling barrier height.
77	<code>eb=(29.0E+09)</code>	Characteristic electrical field.
78	<code>kg=(00.0E-6)</code>	Mobility for Gate Current.
79	<code>lovig=(20.0E-9)</code>	Overlap Length for Gate current.
80	<code>agidl=(0.0)</code>	First GIDL parameter.
81	<code>bgidl=(2.3E+09)</code>	Second GIDL parameter.
82	<code>cgidl=(0.5)</code>	Third GIDL parameter.
83	<code>egidl=(0.8)</code>	Fourth GIDL parameter.
84	<code>kf=(0.0)</code>	Flicker noise factor.
85	<code>af=(1.0)</code>	Frequency exponent for flicker noise.
86	<code>ef=(2.0)</code>	Transconductance exponent for flicker noise.
87	<code>kgfn=(0.0)</code>	Gate flicker noise factor.
88	<code>lqwr=(0.0)</code>	Length scaling of QWR.
89	<code>lnwr=(0.0)</code>	Length scaling of NWR.
90	<code>lwr=(0.0)</code>	Length scaling of WR.
91	<code>ldphiedge=(0.0)</code>	Length scaling of DPHIEDGE.
92	<code>wqlr=(0.0)</code>	Width scaling of QLR.
93	<code>wnlr=(0.0)</code>	Width scaling of NLR.
94	<code>wlr=(0.0)</code>	Width scaling of LR.
95	<code>wucrit=(0.0)</code>	Width scaling of UCRIT.

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96	wlambda=(0.0)	Width scaling of LAMBDA.
97	wetad=(0.0)	Width scaling of ETAD.
98	we0=(0.0)	Width scaling of E0.
99	we1=(0.0)	Width scaling of E1.
100	wrlx=(0.0)	Width scaling of RLX.
101	wucex=(0.0)	Width scaling of UCEX.
102	wdphiedge=(0.0)	Width scaling of DPHIEDGE.
103	wldphiedge=(0.0)	Area scaling (fine tuning for short and narrow) of DPHIEDGE.
104	wldgammaedge=(0.0)	Area scaling (fine tuning for short and narrow) of DGAMMAEDGE.
105	wedge=(0.0)	Width of edge conduction area.
106	dgammaedge=(0.0)	Difference of body effect coefficient of edge conduction area with respect to the main part of the channel.
107	dphiedge=(0.0)	Difference of fermi potential of edge conduction area with respect to the main part of the channel.
108	saref=(0.0)	Reference distance from STI, for SA.
109	sbref=(0.0)	Reference distance from STI, for SB.
110	wlod=(0.0)	Width of common area between device and STI.
111	kkp=(0.0)	Mobility dependence on STI.
112	lkkp=(0.0)	Length scaling of mobility dependence on STI.
113	wkkp=(0.0)	Width scaling of mobility dependence on STI.
114	pkkp=(0.0)	Area scaling (fine tuning for short and narrow channel devices) of mobility dependence on STI.

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115	$t_{kcp} = (0.0)$	Temperature scaling of mobility dependence on STI.
116	$l_{lodkcp} = (1.0)$	Exponent of length scaling of mobility dependence on STI.
117	$w_{lodkcp} = (1.0)$	Exponent of width scaling of mobility dependence on STI.
118	$k_{vto} = (0.0)$	Threshold voltage dependence on STI.
119	$l_{k_{vto}} = (0.0)$	Length scaling of threshold voltage dependence on STI.
120	$w_{k_{vto}} = (0.0)$	Width scaling of threshold voltage dependence on STI.
121	$p_{k_{vto}} = (0.0)$	Area scaling (fine tuning for short and narrow channel devices) of threshold voltage dependence on STI.
122	$l_{lodk_{vto}} = (1.0)$	Exponent of length scaling of threshold voltage dependence on STI.
123	$w_{lodk_{vto}} = (1.0)$	Exponent of width scaling of threshold voltage dependence on STI.
124	$k_{gamma} = (0.0)$	Body effect dependence on STI.
125	$l_{odk_{gamma}} = (1.0)$	Exponential dependence of body effect on STI.
126	$k_{etad} = (0.0)$	Primary DIBL dependence on STI.
127	$l_{odk_{etad}} = (1.0)$	Exponential dependence of Primary DIBL dependence on STI.
128	$k_{ucrit} = (0.0)$	Critical Velocity of Electrons dependence of STI.
129	$t_{eta} = (-0.9E-3)$	Temperature dependence of ETA.
130	$t_{lambda} = (0.0)$	Temperature dependence of LAMBDA.
131	$t_{cv} = (600.0E-6)$	Temperature dependence of VTO (threshold voltage).
132	$b_{ex} = (-1.5)$	Temperature dependence of KP (mobility).
133	$u_{cex} = (1.5)$	Temperature dependence of UCRIT.
134	$t_{e0ex} = (0.5)$	Temperature dependence of E0.

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135	$t_{lex} = (0.5)$	Temperature dependence of E1.
136	$i_{bbt} = (800.0E-6)$	Temperature dependence of IBB.
137	$t_{cvl} = (0.0)$	Length dependence of TCV.
138	$t_{cvw} = (0.0)$	Width dependence of TCV.
139	$t_{cvwl} = (0.0)$	Area dependence of TCV.
140	$\gamma_{ov} = (1.6)$	Body effect coefficient of the overlap area.
141	$\gamma_{gov} = (10.0)$	Body effect coefficient of the gate of the overlap area.
142	$v_{fbov} = (0.0)$	Flat-band voltage of the overlap area.
143	$l_{ov} = (20.0E-9)$	Length of the overlap area.
144	$v_{ov} = (1.0)$	Vs dependence of Vgsov.
145	$c_{gso} = (0.0)$	Bias-independent gate to source overlap capacitance.
146	$c_{gdo} = (0.0)$	Bias-independent gate to drain overlap capacitance.
147	$c_{gbo} = (0.0)$	Bias-independent gate to bulk overlap capacitance.
148	$k_{jf} = (0.0)$	Fringing capacitance factor.
149	$c_{jf} = (0.0)$	Fringing capacitance bias factor.
150	$v_{fr} = (0.0)$	Built-in correction for fringing capacitance.
151	$d_{fr} = (1.0E-3)$	Smooth factor of fringing capacitance model.
152	$h_{dif} = (0.0e-6)$	Half length of active area.
153	$r_{sh} = (0.0)$	Square resistance of active area.
154	$l_{dif} = (0.0)$	Distance between the middle of the active area and the start of the channel.
155	$r_s = (0.0)$	Source series resistance.

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156	$r_{d}=(0.0)$	Drain series resistance.
157	$r_{lx}=(-1.0)$	Series resistance (symmetric model).
158	$r_{sx}=(-1.0)$	Source series resistance (asymmetric model).
159	$r_{dx}=(-1.0)$	Drain series resistance (asymmetric model).
160	$t_{r}=(0.0)$	First order temperature coefficient of resistors.
161	$t_{r2}=(0.0)$	Second order temperature coefficient of resistors.
162	$g_{min}=(0.0)$	Minimum conductance of diode.
163	$n_{js}=(1.0)$	Slope factor for parasitic diodes(S).
164	$x_{jbvs}=(0.0)$	Breakdown effect coefficient(S).
165	$b_{vs}=(10.0)$	Breakdown Voltage(S).
166	$j_{ss}=(0.0E-09)$	Area component of diode current(S).
167	$j_{ssws}=(0.0E-12)$	Perimeter component of diode current(S).
168	$j_{sswgs}=(0.0E-12)$	Gate side component of diode current(S).
169	$j_{tss}=(0.0E-09)$	Area component of trap-assisted diode current(S).
170	$j_{tssws}=(0.0E-12)$	Perimeter component of trap-assisted diode current(S).
171	$j_{tsswgs}=(0.0E-12)$	Gate side component of trap-assisted diode current(S).
172	$n_{jtss}=(1.0)$	Area slope factor of trap-assisted diode current(S).
173	$n_{jtssws}=(1.0)$	Perimeter slope factor of trap-assisted diode current(S).
174	$n_{jtsswgs}=(1.0)$	Gate side slope factor of trap-assisted diode current(S).
175	$v_{tss}=(0.0)$	Area voltage factor of trap-assisted diode current(S).
176	$v_{tssws}=(0.0)$	Perimeter voltage factor of trap-assisted diode current(S).

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177	$vtsswgs = (0.0)$	Gate side voltage factor of trap-assisted diode current(D).
178	$cjs = (0.0E-06)$	Area component of diode capacitance(S).
179	$cjsws = (0.0E-09)$	Perimeter component of diode capacitance(S).
180	$cjswgs = (0.0E-09)$	Gate side component of diode capacitance(S).
181	$pbs = (0.800)$	Area parameter of diode capacitance(S).
182	$pbsws = (0.600)$	Perimeter parameter of diode capacitance(S).
183	$pbswgs = (0.600)$	Gate side parameter of diode capacitance(S).
184	$mjs = (0.900)$	Area exponent of diode capacitance(S).
185	$mjsws = (0.700)$	Perimeter exponent of diode capacitance(S).
186	$mjswgs = (0.700)$	Gate side exponent of diode capacitance(S).
187	$xtis = (3.0)$	Temperature dependence of diode(S).
188	$xtss = (0.0)$	Area component of temperature dependence of trap-assisted diode current(S).
189	$xtssws = (0.0)$	Perimeter component of temperature dependence of trap-assisted diode current(S).
190	$xtsswgs = (0.0)$	Gate side component of temperature dependence of trap-assisted diode current(S).
191	$tnjtss = (0.0)$	Temperature dependence of njtss.
192	$tnjtssws = (0.0)$	Temperature dependence of njtssws.
193	$tnjtsswgs = (0.0)$	Temperature dependence of njtsswgs.
194	$tcj = (0.0)$	Temperature dependence of CJ.
195	$tcjsw = (0.0)$	Temperature dependence of CJSW.
196	$tcjswg = (0.0)$	Temperature dependence of CJSWG.

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197	$t_{pb}=(0.0)$	Temperature dependence of PB.
198	$t_{pbsw}=(0.0)$	Temperature dependence of PBSW.
199	$t_{pbswg}=(0.0)$	Temperature dependence of PBSWG.
200	$n_{jd}=(1.0)$	Slope factor for parasitic diodes(D).
201	$x_{jbvd}=(0.0)$	Breakdown effect coefficient(D).
202	$bvd=(10.0)$	Breakdown Voltage(D).
203	$j_{sd}=(0.0E-09)$	Area component of diode current(D).
204	$j_{sswd}=(0.0E-12)$	Perimeter component of diode current(D).
205	$j_{sswgd}=(0.0E-12)$	Gate side component of diode current(D).
206	$j_{tsd}=(0.0E-09)$	Area component of trap-assisted diode current(D).
207	$j_{tsswd}=(0.0E-12)$	Perimeter component of trap-assisted diode current(D).
208	$j_{tsswgd}=(0.0E-12)$	Gate side component of trap-assisted diode current(D).
209	$n_{jtsd}=(1.0)$	Area slope factor of trap-assisted diode current(D).
210	$n_{jtsswd}=(1.0)$	Perimeter slope factor of trap-assisted diode current(D).
211	$n_{jtsswgd}=(1.0)$	Gate side slope factor of trap-assisted diode current(D).
212	$v_{tsd}=(0.0)$	Area voltage factor of trap-assisted diode current(D).
213	$v_{tsswd}=(0.0)$	Perimeter voltage factor of trap-assisted diode current(D).
214	$v_{tsswgd}=(0.0)$	Gate side voltage factor of trap-assisted diode current(D).
215	$c_{jd}=(0.0E-06)$	Area component of diode capacitance(D).
216	$c_{jswd}=(0.0E-09)$	Perimeter component of diode capacitance(D).
217	$c_{jswgd}=(0.0E-09)$	Gate side component of diode capacitance(D).

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218	$pbd = (0.800)$	Area parameter of diode capacitance(D).
219	$pbswd = (0.600)$	Perimeter parameter of diode capacitance(D).
220	$pbswgd = (0.600)$	Gate side parameter of diode capacitance(D).
221	$mjd = (0.900)$	Area exponent of diode capacitance(D).
222	$mjswd = (0.700)$	Perimeter exponent of diode capacitance(D).
223	$mjswgd = (0.700)$	Gate side exponent of diode capacitance(D).
224	$xtid = (3.0)$	Temperature dependence of diode(D).
225	$xtsd = (0.0)$	Area component of temperature dependence of trap-assisted diode current(D).
226	$xtsswd = (0.0)$	Perimeter component of temperature dependence of trap-assisted diode current(D).
227	$xtsswgd = (0.0)$	Gate side component of temperature dependence of trap-assisted diode current(D).
228	$tnjtsd = (0.0)$	Temperature dependence of $njtsd$.
229	$tnjtsswd = (0.0)$	Temperature dependence of $njtsswd$.
230	$tnjtsswgd = (0.0)$	Temperature dependence of $njtsswgd$.
231	$rgsh = (3.0)$	Gate square resistance.
232	$gc = (1)$	Gate contacts (single sided = 1, double sided = 2).
233	$krgl1 = (0.0)$	Length dependence of rg .
234	$rdsbsh = (1.0E+3)$	Drain to source substrate sheet resistance.
235	$rbwsh = (3.0E-3)$	Inner bulk to bulk sheet resistance.
236	$rbn = (0.0)$	Inner bulk to bulk resistance per finger (for RINGTYPE=2).
237	$rsbwsh = (1.0E-3)$	Inner bulk-source side to bulk sheet resistance.

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238	<code>rsbn=(0.0)</code>	Inner bulk-source side to bulk resistance per finger (for RINGTYPE=2).
239	<code>rdbwsh=(1.0E-3)</code>	Inner bulk-drain side to bulk sheet resistance.
240	<code>rdbn=(0.0)</code>	Inner bulk-drain side to bulk resistance per finger (for RINGTYPE=2).
241	<code>ringtype=(1.0)</code>	Type of guard ring (bulk contacts) (two sides/symmetric: 1, three sides/horse shoe: 2).

Output Parameters

1	<code>d</code>	node: Drain.
2	<code>g</code>	node: Gate.
3	<code>s</code>	node: Source.
4	<code>b</code>	node: Bulk.
5	<code>di</code>	node: Internal drain.
6	<code>si</code>	node: Internal source.
7	<code>gi</code>	node: Internal gate.
8	<code>bi</code>	node: Internal bulk.
9	<code>bdi</code>	node: Internal bulk(D).
10	<code>bsi</code>	node: Internal bulk(S).
11	<code>m1</code>	node: NQS related node(1).
12	<code>m2</code>	node: NQS related node(2).
13	<code>m3</code>	node: NQS related node(3).
14	<code>m4</code>	node: NQS related node(4).
15	<code>noi</code>	node: Noise.

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Operating-Point Parameters

1	<code>exp_cr=(80.0)</code>	The parameter is used by simulator.
2	<code>cmi_limexp_method=(1.0)</code>	The parameter is used by simulator.
3	<code>l=(10.0E-06)</code>	GATES LENGTH.
4	<code>w=(10.0E-06)</code>	GATES WIDTH.
5	<code>nf=(1)</code>	NUMBER OF FINGERS.
6	<code>ad=(0.0)</code>	DRAINS AREA.
7	<code>as=(0.0)</code>	SOURCES AREA.
8	<code>pd=(0.0)</code>	DRAINS PERIMETER.
9	<code>ps=(0.0)</code>	SOURCES PERIMETER.
10	<code>sa=(0.0)</code>	STI PARAMETER; DISTANCE FROM STI.
11	<code>sb=(0.0)</code>	STI PARAMETER; DISTANCE FROM STI.
12	<code>sd=(0.0)</code>	STI PARAMETER; DISTANCE BETWEEN GATES.
13	<code>avto=(0.0)</code>	MATCHING PARAMETER FOR THRESHOLD VOLTAGE (VTO).
14	<code>agamma=(0.0)</code>	MATCHING PARAMETER FOR BODY FACTOR (GAMMA).
15	<code>akp=(0.0)</code>	MATCHING PARAMETER FOR MOBILITY (KP).
16	<code>idb</code>	Impact ionization current.
17	<code>igsov</code>	Overlap gate current(source).
18	<code>igdov</code>	Overlap gate current(drain).
19	<code>igb</code>	Gate current(bulk).
20	<code>igd</code>	Gate current(drain).

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21	igs	Gate current(source).
22	igidl	Gate induced drain current.
23	igisl	Gate induced source current.
24	qsfr	Fringing charge.
25	qdfcr	Fringing charge.
26	qsov	Overlap charge.
27	qdov	Overlap charge.
28	idsedge	Edge drain current.
29	qsedge	Edge charge.
30	qdedge	Edge charge.
31	qgedge	Edge charge.
32	qbedge	Edge charge.
33	qs	Source charge.
34	qd	Drain charge.
35	qg	Gate charge.
36	qb	Bulk charge.
37	ids	Resistive drain-to-source current.
38	vdb	Drain-bulk voltage.
39	vgb	Gate-bulk voltage.
40	vsb	Source-bulk voltage.

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Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

ac1m	M-53	igb	OP-19	njtsd	M-209	teta	M-129
ad	I-7	igd	OP-20	njtss	M-172	tg	M-2
ad	OP-6	igdov	OP-18	njtsswd	M-210	th_noi	M-9
af	M-85	igidl	OP-22	njtsswgd	M-211	thc	M-26
agam	M-45	igisl	OP-23	njtsswgs	M-174	tkkp	M-115
agamma	I-15	igs	OP-21	njtssws	M-173	tlambda	M-130
agamma	OP-14	igsov	OP-17	nlr	M-56	tnjtsd	M-228
agidl	M-80	jssd	M-203	noi	O-15	tnjtss	M-191
akp	I-16	jss	M-166	nqs_noi	M-8	tnjtsswd	M-229
akp	OP-15	jsswd	M-204	nwr	M-67	tnjtsswgd	M-230
aqma	M-18	jsswgd	M-205	pbd	M-218	tnjtsswgs	M-193
aqmi	M-19	jsswgs	M-168	pbs	M-181	tnjtssws	M-192
as	I-8	jssws	M-167	pbswd	M-219	tnom	M-3
as	OP-7	jtsd	M-206	pbswgd	M-220	tpb	M-197
avt	M-42	jtss	M-169	pbswgs	M-183	tpbsw	M-198
avto	I-14	jtsswd	M-207	pbsws	M-182	tpbswg	M-199

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avto OP-13	jtsswgd M-208	pd I-9	tr M-160
b O-4	jtsswgs M-171	pd OP-8	tr2 M-161
bdi O-9	jtssws M-170	pdits M-69	ucex M-133
bex M-132	ka M-29	pditsd M-71	ucrit M-50
bgidl M-81	kb M-30	pditsl M-70	vbi M-17
bi O-8	ketad M-126	phif M-13	vdb OP-38
bsi O-10	kf M-84	pkkp M-114	vfbov M-142
bvd M-202	kg M-78	pkvto M-121	vfr M-150
bvs M-165	kgamma M-124	ps I-10	vgb OP-39
cgbo M-147	kgfn M-87	ps OP-9	vov M-144
cgdo M-146	kjf M-148	qjb OP-36	vsb OP-40
cgidl M-82	kkp M-111	qbedge OP-32	vto M-12
cgso M-145	kp M-21	qd OP-34	vtsd M-212
cjd M-215	krgl1 M-233	qdedge OP-30	vtss M-175
cjf M-149	kucrit M-128	qdfr OP-25	vtsswd M-213
cjs M-178	kvto M-118	qdov OP-27	vtsswgd M-214
cjswd M-216	l I-4	qg OP-35	vtsswgs M-177
cjswgd M-217	l OP-3	qgedge OP-31	vtssws M-176
cjswgs M-180	la M-27	qlr M-55	w I-5
cjsws M-179	lambda M-51	qoff M-5	w OP-4

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cmi_limexp_method I-2	lb M-28	qs OP-33	wdl M-39
cmi_limexp_method OP-2	ldif M-154	qsedge OP-29	wdphiedge M-102
cox M-10	ldphiedge M-91	qsfr OP-24	we0 M-98
d O-1	ldw M-38	qsov OP-26	we1 M-99
ddits M-72	leta M-59	qwr M-66	wedge M-105
delta M-52	leta0 M-58	rbn M-236	weta M-61
dfr M-151	leta2 M-60	rbwsh M-235	wetad M-97
dgammaedge M-106	lgam M-46	rd M-156	wgam M-47
di O-5	lkkp M-112	rdbn M-240	wkkp M-113
dl M-34	lkvto M-119	rdbwsh M-239	wkp1 M-31
dlc M-35	ll M-40	rdsbsh M-234	wkp2 M-32
dphiedge M-107	lln M-41	rdx M-159	wkp3 M-33
dw M-36	llodkkp M-116	rgsh M-231	wkvto M-120
dwc M-37	llodkvto M-122	ringtype M-241	wlambda M-96
e0 M-22	lnwr M-89	rlx M-157	wldgammaedge M-104
e1 M-23	lodketad M-127	rs M-155	wldphiedge M-103
eb M-77	lodkgamma M-125	rsbn M-238	wlod M-110
ef M-86	lov M-143	rsbwsh M-237	wlodkkp M-117
egidl M-83	lovig M-79	rsh M-153	wlodkvto M-123
eta M-24	lqwr M-88	rsx M-158	wlr M-94

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

etad M-63	lr M-54	s O-3	wnlr M-93
etaqm M-20	lvt M-43	sa I-11	wqlr M-92
exp_cr I-1	lwr M-90	sa OP-10	wr M-65
exp_cr OP-1	m I-3	saref M-108	wrlx M-100
flr M-57	m1 O-11	sb I-12	wucex M-101
fprout M-68	m2 O-12	sb OP-11	wucrit M-95
g O-2	m3 O-13	sbref M-109	wvt M-44
gamma M-14	m4 O-14	scale M-4	xb M-76
gammag M-15	mjd M-221	sd I-13	xj M-11
gammagov M-141	mjs M-184	sd OP-12	xjbvd M-201
gammaov M-140	mjswd M-222	si O-6	xjbvs M-164
gc M-232	mjswgd M-223	sigmad M-64	xl M-6
gi O-7	mjswgs M-186	sign M-1	xtid M-224
gmin M-162	mjsws M-185	tcj M-194	xtis M-187
hdif M-152	n0 M-16	tcjsw M-195	xtsd M-225
iba M-73	ncs M-62	tcjswg M-196	xtss M-188
ibb M-74	nf I-6	tcv M-131	xtsswd M-226
ibbt M-136	nf OP-5	tcvl M-137	xtsswgd M-227
ibn M-75	nfvta M-48	tcvw M-138	xtsswgs M-190
idb OP-16	nfvtb M-49	tcvwl M-139	xtssws M-189
ids OP-37	njd M-200	te0ex M-134	xw M-7

idsedge OP-28

njs M-163

telex M-135

zc M-25

Device **ekv3_r4 (ekv3_r4)**

This device is supported within altergroups.

Instance Definition

Name d g s b ModelName parameter=value ...

Instance Parameters

- | | | |
|----|-------------------------|--|
| 1 | exp_cr=(80.0) | The parameter is used by simulator. |
| 2 | cmi_limexp_method=(1.0) | The parameter is used by simulator. |
| 3 | m=(1.0) | Multiplicity factor (number of MOSFETs in parallel). |
| 4 | l=(10.0E-06) | GATES LENGTH. |
| 5 | w=(10.0E-06) | GATES WIDTH. |
| 6 | nf=(1) | NUMBER OF FINGERS. |
| 7 | ad=(0.0) | DRAINS AREA. |
| 8 | as=(0.0) | SOURCES AREA. |
| 9 | pd=(0.0) | DRAINS PERIMETER. |
| 10 | ps=(0.0) | SOURCES PERIMETER. |
| 11 | sa=(0.0) | STI PARAMETER; DISTANCE FROM STI. |
| 12 | sb=(0.0) | STI PARAMETER; DISTANCE FROM STI. |
| 13 | sd=(0.0) | STI PARAMETER; DISTANCE BETWEEN GATES. |

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

- 14 `avto=(0.0)` MATCHING PARAMETER FOR THRESHOLD VOLTAGE (VTO).
- 15 `agamma=(0.0)` MATCHING PARAMETER FOR BODY FACTOR (GAMMA).
- 16 `akp=(0.0)` MATCHING PARAMETER FOR MOBILITY (KP).

Model Definition

```
model modelName ekv3_r4 parameter=value ...
```

Model Parameters

- 1 `sign=(1)` SIGN = 1 FOR NMOS; SIGN = -1 FOR PMOS.
- 2 `tg=((-1))` TYPE OF GATE: -1 ENHANCEMENT TYPE; 1 DEPLETION TYPE.
- 3 `tnom=(27.0)` Parameters measurement temperature.
- 4 `scale=(1.0)` Scaling Factor for Gate Length and Width.
- 5 `qoff=(0.0)` Charge partitioning flag.
- 6 `xl=(0.0)` Optical offset for Gate Length.
- 7 `xw=(0.0)` Optical offset for Gate Width.
- 8 `nqs_noi=(1.0)` NQS noise flag(on/off). Includes thermal noise with no short channel effects.
- 9 `th_noi=(0.0)` Thermal noise flag(on/off). Includes short channel effects but no gate induced noise.
- 10 `cox=(0.012)` Oxide Capacitance per unit Area.
- 11 `xj=(20.0E-09)` Depth of Active Areas.
- 12 `vto=(0.3)` THRESHOLD VOLTAGE.
- 13 `phif=(0.45)` FERMI BULK POTENTIAL.
- 14 `gamma=(0.3)` Body Effect Coefficient.

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

15	$\text{gammag}=(4.1)$	Body Effect Coefficient for Gate.
16	$\text{n0}=(1.0)$	Long Channel Slope Factor Fine Tuning.
17	$\text{vbi}=(0.0)$	Built-in Voltage Drop.
18	$\text{aqma}=(0.5)$	Quantum Effect Coefficient for Accumulation Region.
19	$\text{aqmi}=(0.4)$	Quantum Effect Coefficient for Inversion Region.
20	$\text{etaqm}=(0.75)$	Quantum Effect Factor.
21	$\text{kp}=(500.0\text{E}-06)$	Mobility multiplied by COX.
22	$\text{e0}=(1.0\text{E}+10)$	First Order Coefficient for Mobility Reduction due to Vertical Field.
23	$\text{e1}=(3.1\text{E}+08)$	Second Order Coefficient for Mobility Reduction due to Vertical Field.
24	$\text{eta}=(0.5)$	Mobility Reduction due to Vertical Field Factor.
25	$\text{zc}=(1.0\text{E}-6)$	Coulomb Scattering coefficient.
26	$\text{thc}=(0.0)$	Coulomb Scattering coefficient.
27	$\text{la}=(1.0)$	First critical length for mobility length scaling.
28	$\text{lb}=(1.0)$	Second critical length for mobility length scaling.
29	$\text{ka}=(0.0)$	First factor for mobility length scaling.
30	$\text{kb}=(0.0)$	Second factor for mobility length scaling.
31	$\text{wkp1}=(1.0\text{E}-6)$	Width parameter for mobility profile vs. width.
32	$\text{wkp2}=(0.0)$	Amplitude parameter for mobility profile vs. width.
33	$\text{wkp3}=(1.0)$	Span parameter for mobility profile vs. width.
34	$\text{dl}=((-10.0\text{E}-9))$	Effective Length Parameter.
35	$\text{dlc}=(0.0)$	Effective Length Parameter for Capacitance.

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

36	$d_w = (-10.0E-9)$	Effective Width Parameter.
37	$d_{wc} = (0.0)$	Effective Width Parameter for Capacitance.
38	$l_{dw} = (0.0)$	Length Dependence of Effective Width.
39	$w_{dl} = (0.0)$	Width Dependence of Effective Length.
40	$l_1 = (0.0)$	Base for Exponential Dependence of Effective Length.
41	$l_{1n} = (1.0)$	Exponent for Exponential Dependence of Effective Length.
42	$avt = (0.0)$	Amplitude for long and wide channel threshold voltage correction.
43	$lvt = (1.0)$	Length for long channel threshold voltage correction.
44	$wvt = (1.0)$	Width for wide channel threshold voltage correction.
45	$agam = (0.0)$	Amplitude for long and wide channel body effect coefficient correction.
46	$lgam = (1.0)$	Length for long channel body effect coefficient correction.
47	$wgam = (1.0)$	Width for wide channel body effect coefficient correction.
48	$nfvt_a = (0.0)$	Number of fingers parameter for threshold voltage dependence on NF.
49	$nfvt_b = (10000.0)$	Factor for threshold voltage dependence on NF.
50	$ucrit = (5.0E+06)$	Critical Velocity of Electrons.
51	$\lambda = (0.5)$	Early effect factor.
52	$\delta = (2.0)$	Order of velocity saturation model (variable order model 1~2).
53	$a_{clm} = (0.83)$	Channel Length Modulation Factor.
54	$l_r = (50.0E-09)$	Length Factor for RSCE.
55	$q_{lr} = (0.5E-3)$	Threshold Voltage Factor of RSCE.

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

56	$n1r=(10.0E-3)$	Body Effect Coefficient Factor of RSCE.
57	$flr=(0.0)$	Bulk Fermi Potential of RSCE.
58	$leta0=(0.0)$	Long Channel Charge Sharing Coefficient.
59	$leta=(500.0E-3)$	Short Channel Charge Sharing Coefficient.
60	$leta2=(0.0)$	Short Channel Scaling Coefficient.
61	$weta=(200.0E-3)$	Narrow Channel Charge Sharing Coefficient.
62	$ncs=(1.0)$	Slope Factor Dependence from Charge Sharing.
63	$etad=(1.0)$	Primary DIBL Coefficient.
64	$sigmad=(1.0)$	Secondary DIBL Coefficient.
65	$wr=(90.0E-09)$	Width Factor for INWE.
66	$qwr=(0.3E-3)$	Threshold Voltage Factor of INWE.
67	$nwr=(5.0E-3)$	Body Effect Coefficient Factor of INWE.
68	$fprout=(1.0E6)$	Output resistance for DITS effect.
69	$pdits=(0.0)$	DITS parameter.
70	$pditsl=(0.0)$	DITS dependence on length.
71	$pditsd=(1.0)$	DITS dependence on drain bias.
72	$ddits=(0.3)$	Smooth factor of DITS effect.
73	$iba=(000.0E+06)$	Impact Ionization Current first parameter.
74	$ibb=(300.0E+06)$	Impact Ionization Current second parameter.
75	$ibn=(1.0)$	Impact Ionization Current coefficient.
76	$xb=(3.1)$	Silicon to Silicon oxide tunneling barrier height.
77	$eb=(29.0E+09)$	Characteristic electrical field.

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

78	<code>kg=(00.0E-6)</code>	Mobility for Gate Current.
79	<code>lovig=(20.0E-9)</code>	Overlap Length for Gate current.
80	<code>agidl=(0.0)</code>	First GIDL parameter.
81	<code>bgidl=(2.3E+09)</code>	Second GIDL parameter.
82	<code>cgidl=(0.5)</code>	Third GIDL parameter.
83	<code>egidl=(0.8)</code>	Fourth GIDL parameter.
84	<code>kf=(0.0)</code>	Flicker noise factor.
85	<code>af=(1.0)</code>	Frequency exponent for flicker noise.
86	<code>ef=(2.0)</code>	Transconductance exponent for flicker noise.
87	<code>kgfn=(0.0)</code>	Gate flicker noise factor.
88	<code>lqwr=(0.0)</code>	Length scaling of QWR.
89	<code>lnwr=(0.0)</code>	Length scaling of NWR.
90	<code>lwr=(0.0)</code>	Length scaling of WR.
91	<code>ldphiedge=(0.0)</code>	Length scaling of DPHIEDGE.
92	<code>wqlr=(0.0)</code>	Width scaling of QLR.
93	<code>wnlr=(0.0)</code>	Width scaling of NLR.
94	<code>wlr=(0.0)</code>	Width scaling of LR.
95	<code>wucrit=(0.0)</code>	Width scaling of UCRIT.
96	<code>wlambda=(0.0)</code>	Width scaling of LAMBDA.
97	<code>wetad=(0.0)</code>	Width scaling of ETAD.
98	<code>we0=(0.0)</code>	Width scaling of E0.
99	<code>we1=(0.0)</code>	Width scaling of E1.

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

100	wrlx=(0.0)	Width scaling of RLX.
101	wucex=(0.0)	Width scaling of UCEX.
102	wdphiedge=(0.0)	Width scaling of DPHIEDGE.
103	wldphiedge=(0.0)	Area scaling (fine tuning for short and narrow) of DPHIEDGE.
104	wldgammaedge=(0.0)	Area scaling (fine tuning for short and narrow) of DGAMMAEDGE.
105	wedge=(0.0)	Width of edge conduction area.
106	dgammaedge=(0.0)	Difference of body effect coefficient of edge conduction area with respect to the main part of the channel.
107	dphiedge=(0.0)	Difference of fermi potential of edge conduction area with respect to the main part of the channel.
108	saref=(0.0)	Reference distance from STI, for SA.
109	sbref=(0.0)	Reference distance from STI, for SB.
110	wlod=(0.0)	Width of common area between device and STI.
111	kkp=(0.0)	Mobility dependence on STI.
112	lkkp=(0.0)	Length scaling of mobility dependence on STI.
113	wkkp=(0.0)	Width scaling of mobility dependence on STI.
114	pkkp=(0.0)	Area scaling (fine tuning for short and narrow channel devices) of mobility dependence on STI.
115	tkkp=(0.0)	Temperature scaling of mobility dependence on STI.
116	llodkkp=(1.0)	Exponent of length scaling of mobility dependence on STI.
117	wlodkkp=(1.0)	Exponent of width scaling of mobility dependence on STI.
118	kvt0=(0.0)	Threshold voltage dependence on STI.

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

119	$lkvto=(0.0)$	Length scaling of threshold voltage dependence on STI.
120	$wkvto=(0.0)$	Width scaling of threshold voltage dependence on STI.
121	$pkvto=(0.0)$	Area scaling (fine tuning for short and narrow channel devices) of threshold voltage dependence on STI.
122	$llodkvto=(1.0)$	Exponent of length scaling of threshold voltage dependence on STI.
123	$wlodkvto=(1.0)$	Exponent of width scaling of threshold voltage dependence on STI.
124	$kgamma=(0.0)$	Body effect dependence on STI.
125	$lodkgamma=(1.0)$	Exponential dependence of body effect on STI.
126	$ketad=(0.0)$	Primary DIBL dependence on STI.
127	$lodketad=(1.0)$	Exponential dependence of Primary DIBL dependence on STI.
128	$kucrit=(0.0)$	Critical Velocity of Electrons dependence of STI.
129	$teta=(-0.9E-3)$	Temperature dependence of ETA.
130	$tlambda=(0.0)$	Temperature dependence of LAMBDA.
131	$tcv=(600.0E-6)$	Temperature dependence of VTO (threshold voltage).
132	$bex=(-1.5)$	Temperature dependence of KP (mobility).
133	$ucex=(1.5)$	Temperature dependence of UCRIT.
134	$te0ex=(0.5)$	Temperature dependence of E0.
135	$te1ex=(0.5)$	Temperature dependence of E1.
136	$ibbt=(800.0E-6)$	Temperature dependence of IBB.
137	$tcvl=(0.0)$	Length dependence of TCV.
138	$tcvw=(0.0)$	Width dependence of TCV.

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

139	$t_{cvwl} = (0.0)$	Area dependence of TCV.
140	$\gamma_{aov} = (1.6)$	Body effect coefficient of the overlap area.
141	$\gamma_{giov} = (10.0)$	Body effect coefficient of the gate of the overlap area.
142	$v_{fbov} = (0.0)$	Flat-band voltage of the overlap area.
143	$l_{ov} = (20.0E-9)$	Length of the overlap area.
144	$v_{ov} = (1.0)$	V_s dependence of V_{gsov} .
145	$c_{gso} = (0.0)$	Bias-independent gate to source overlap capacitance.
146	$c_{gdo} = (0.0)$	Bias-independent gate to drain overlap capacitance.
147	$c_{gbo} = (0.0)$	Bias-independent gate to bulk overlap capacitance.
148	$k_{jf} = (0.0)$	Fringing capacitance factor.
149	$c_{jf} = (0.0)$	Fringing capacitance bias factor.
150	$v_{fr} = (0.0)$	Built-in correction for fringing capacitance.
151	$d_{fr} = (1.0E-3)$	Smooth factor of fringing capacitance model.
152	$h_{dif} = (0.0e-6)$	Half length of active area.
153	$r_{sh} = (0.0)$	Square resistance of active area.
154	$l_{dif} = (0.0)$	Distance between the middle of the active area and the start of the channel.
155	$r_s = (0.0)$	Source series resistance.
156	$r_d = (0.0)$	Drain series resistance.
157	$r_{lx} = ((-1.0))$	Series resistance (symmetric model).
158	$r_{sx} = ((-1.0))$	Source series resistance (asymmetric model).
159	$r_{dx} = ((-1.0))$	Drain series resistance (asymmetric model).

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

160	$tr=(0.0)$	First order temperature coefficient of resistors.
161	$tr2=(0.0)$	Second order temperature coefficient of resistors.
162	$gmin=(0.0)$	Minimum conductance of diode.
163	$njs=(1.0)$	Slope factor for parasitic diodes(S).
164	$xjbvs=(0.0)$	Breakdown effect coefficient(S).
165	$bvs=(10.0)$	Breakdown Voltage(S).
166	$jss=(0.0E-09)$	Area component of diode current(S).
167	$jssws=(0.0E-12)$	Perimeter component of diode current(S).
168	$jsswgs=(0.0E-12)$	Gate side component of diode current(S).
169	$jtss=(0.0E-09)$	Area component of trap-assisted diode current(S).
170	$jtssws=(0.0E-12)$	Perimeter component of trap-assisted diode current(S).
171	$jtsswgs=(0.0E-12)$	Gate side component of trap-assisted diode current(S).
172	$njtss=(1.0)$	Area slope factor of trap-assisted diode current(S).
173	$njtssws=(1.0)$	Perimeter slope factor of trap-assisted diode current(S).
174	$njtsswgs=(1.0)$	Gate side slope factor of trap-assisted diode current(S).
175	$vtss=(0.0)$	Area voltage factor of trap-assisted diode current(S).
176	$vtssws=(0.0)$	Perimeter voltage factor of trap-assisted diode current(S).
177	$vtsswgs=(0.0)$	Gate side voltage factor of trap-assisted diode current(D).
178	$cjs=(0.0E-06)$	Area component of diode capacitance(S).
179	$cjsws=(0.0E-09)$	Perimeter component of diode capacitance(S).
180	$cjswgs=(0.0E-09)$	Gate side component of diode capacitance(S).

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

181	$pbs=(0.800)$	Area parameter of diode capacitance(S).
182	$pbsws=(0.600)$	Perimeter parameter of diode capacitance(S).
183	$pbswgs=(0.600)$	Gate side parameter of diode capacitance(S).
184	$mjs=(0.900)$	Area exponent of diode capacitance(S).
185	$mjsws=(0.700)$	Perimeter exponent of diode capacitance(S).
186	$mjswgs=(0.700)$	Gate side exponent of diode capacitance(S).
187	$xtis=(3.0)$	Temperature dependence of diode(S).
188	$xtss=(0.0)$	Area component of temperature dependence of trap-assisted diode current(S).
189	$xtssws=(0.0)$	Perimeter component of temperature dependence of trap-assisted diode current(S).
190	$xtsswgs=(0.0)$	Gate side component of temperature dependence of trap-assisted diode current(S).
191	$tnjtss=(0.0)$	Temperature dependence of njtss.
192	$tnjtssws=(0.0)$	Temperature dependence of njtssws.
193	$tnjtsswgs=(0.0)$	Temperature dependence of njtsswgs.
194	$tcj=(0.0)$	Temperature dependence of CJ.
195	$tcjsw=(0.0)$	Temperature dependence of CJSW.
196	$tcjswg=(0.0)$	Temperature dependence of CJSWG.
197	$tpb=(0.0)$	Temperature dependence of PB.
198	$tpbsw=(0.0)$	Temperature dependence of PBSW.
199	$tpbswg=(0.0)$	Temperature dependence of PBSWG.
200	$njd=(1.0)$	Slope factor for parasitic diodes(D).

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

201	$xj_{bvd} = (0.0)$	Breakdown effect coefficient(D).
202	$bvd = (10.0)$	Breakdown Voltage(D).
203	$j_{sd} = (0.0E-09)$	Area component of diode current(D).
204	$j_{sswd} = (0.0E-12)$	Perimeter component of diode current(D).
205	$j_{sswg} = (0.0E-12)$	Gate side component of diode current(D).
206	$j_{tsd} = (0.0E-09)$	Area component of trap-assisted diode current(D).
207	$j_{tsswd} = (0.0E-12)$	Perimeter component of trap-assisted diode current(D).
208	$j_{tsswg} = (0.0E-12)$	Gate side component of trap-assisted diode current(D).
209	$n_{jtsd} = (1.0)$	Area slope factor of trap-assisted diode current(D).
210	$n_{jtsswd} = (1.0)$	Perimeter slope factor of trap-assisted diode current(D).
211	$n_{jtsswg} = (1.0)$	Gate side slope factor of trap-assisted diode current(D).
212	$vt_{sd} = (0.0)$	Area voltage factor of trap-assisted diode current(D).
213	$vt_{sswd} = (0.0)$	Perimeter voltage factor of trap-assisted diode current(D).
214	$vt_{sswg} = (0.0)$	Gate side voltage factor of trap-assisted diode current(D).
215	$c_{jd} = (0.0E-06)$	Area component of diode capacitance(D).
216	$c_{jswd} = (0.0E-09)$	Perimeter component of diode capacitance(D).
217	$c_{jswg} = (0.0E-09)$	Gate side component of diode capacitance(D).
218	$p_{bd} = (0.800)$	Area parameter of diode capacitance(D).
219	$p_{bswd} = (0.600)$	Perimeter parameter of diode capacitance(D).
220	$p_{bswg} = (0.600)$	Gate side parameter of diode capacitance(D).
221	$m_{jd} = (0.900)$	Area exponent of diode capacitance(D).

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

222	$mjswd = (0.700)$	Perimeter exponent of diode capacitance(D).
223	$mjswgd = (0.700)$	Gate side exponent of diode capacitance(D).
224	$xtid = (3.0)$	Temperature dependence of diode(D).
225	$xtsd = (0.0)$	Area component of temperature dependence of trap-assisted diode current(D).
226	$xtsswd = (0.0)$	Perimeter component of temperature dependence of trap-assisted diode current(D).
227	$xtsswgd = (0.0)$	Gate side component of temperature dependence of trap-assisted diode current(D).
228	$tnjtsd = (0.0)$	Temperature dependence of njtsd.
229	$tnjtsswd = (0.0)$	Temperature dependence of njtsswd.
230	$tnjtsswgd = (0.0)$	Temperature dependence of njtsswgd.
231	$rgsh = (3.0)$	Gate square resistance.
232	$gc = (1)$	Gate contacts (single sided = 1, double sided = 2).
233	$krgl1 = (0.0)$	Length dependence of rg.
234	$rdsbsh = (1.0E+3)$	Drain to source substrate sheet resistance.
235	$rbwsh = (3.0E-3)$	Inner bulk to bulk sheet resistance.
236	$rbn = (0.0)$	Inner bulk to bulk resistance per finger (for RINGTYPE=2).
237	$rsbwsh = (1.0E-3)$	Inner bulk-source side to bulk sheet resistance.
238	$rsbn = (0.0)$	Inner bulk-source side to bulk resistance per finger (for RINGTYPE=2).
239	$rdbwsh = (1.0E-3)$	Inner bulk-drain side to bulk sheet resistance.
240	$rdbn = (0.0)$	Inner bulk-drain side to bulk resistance per finger (for RINGTYPE=2).

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

241 ringtype=(1.0) Type of guard ring (bulk contacts) (two sides/symmetric: 1, three sides/horse shoe: 2).

Output Parameters

1 d node: Drain.
2 g node: Gate.
3 s node: Source.
4 b node: Bulk.
5 di node: Internal drain.
6 si node: Internal source.
7 gi node: Internal gate.
8 bi node: Internal bulk.
9 noi node: Noise.

Operating-Point Parameters

1 exp_cr=(80.0) The parameter is used by simulator.
2 cmi_limexp_method=(1.0) The parameter is used by simulator.
3 l=(10.0E-06) GATES LENGTH.
4 w=(10.0E-06) GATES WIDTH.
5 nf=(1) NUMBER OF FINGERS.
6 ad=(0.0) DRAINS AREA.
7 as=(0.0) SOURCES AREA.
8 pd=(0.0) DRAINS PERIMETER.

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

9	ps=(0.0)	SOURCES PERIMETER.
10	sa=(0.0)	STI PARAMETER; DISTANCE FROM STI.
11	sb=(0.0)	STI PARAMETER; DISTANCE FROM STI.
12	sd=(0.0)	STI PARAMETER; DISTANCE BETWEEN GATES.
13	avto=(0.0)	MATCHING PARAMETER FOR THRESHOLD VOLTAGE (VTO).
14	agamma=(0.0)	MATCHING PARAMETER FOR BODY FACTOR (GAMMA).
15	akp=(0.0)	MATCHING PARAMETER FOR MOBILITY (KP).
16	idb	Impact ionization current.
17	igsov	Overlap gate current(source).
18	igdov	Overlap gate current(drain).
19	igb	Gate current(bulk).
20	igd	Gate current(drain).
21	igs	Gate current(source).
22	igidl	Gate induced drain current.
23	igisl	Gate induced source current.
24	qsfr	Fringing charge.
25	qdfrr	Fringing charge.
26	qsov	Overlap charge.
27	qdov	Overlap charge.
28	idsedge	Edge drain current.
29	qsedge	Edge charge.
30	qdedge	Edge charge.

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

31	qgedge	Edge charge.
32	qbedge	Edge charge.
33	qs	Source charge.
34	qd	Drain charge.
35	qg	Gate charge.
36	qb	Bulk charge.
37	ids	Resistive drain-to-source current.
38	vdb	Drain-bulk voltage.
39	vgb	Gate-bulk voltage.
40	vsb	Source-bulk voltage.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

ac1m	M-53	igd	OP-20	njtsswgs	M-174	thc	M-26
ad	I-7	igdov	OP-18	njtssws	M-173	tkkp	M-115
ad	OP-6	igid1	OP-22	n1r	M-56	tlambda	M-130
af	M-85	igisl	OP-23	noi	O-9	tnjtsd	M-228
agam	M-45	igs	OP-21	nqs_noi	M-8	tnjtss	M-191
agamma	I-15	igsov	OP-17	nwr	M-67	tnjtsswd	M-229

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

agamma	OP-14	jtd	M-203	pbd	M-218	tnjtsswgd	M-230
agidl	M-80	jss	M-166	pbs	M-181	tnjtsswgs	M-193
akp	I-16	jsswd	M-204	pbswd	M-219	tnjtssws	M-192
akp	OP-15	jsswgd	M-205	pbswgd	M-220	tnom	M-3
aqma	M-18	jsswgs	M-168	pbswgs	M-183	tpb	M-197
aqmi	M-19	jssws	M-167	pbsws	M-182	tpbsw	M-198
as	I-8	jtsd	M-206	pd	I-9	tpbswg	M-199
as	OP-7	jtss	M-169	pd	OP-8	tr	M-160
avt	M-42	jtsswd	M-207	pdits	M-69	tr2	M-161
avto	I-14	jtsswgd	M-208	pditsd	M-71	ucex	M-133
avto	OP-13	jtsswgs	M-171	pditsl	M-70	ucrit	M-50
b	O-4	jtssws	M-170	phif	M-13	vbi	M-17
bex	M-132	ka	M-29	pkkp	M-114	vdb	OP-38
bgidl	M-81	kb	M-30	pkvto	M-121	vfbov	M-142
bi	O-8	ketad	M-126	ps	I-10	vfr	M-150
bvd	M-202	kf	M-84	ps	OP-9	vgb	OP-39
bvs	M-165	kg	M-78	qjb	OP-36	vov	M-144
cgbo	M-147	kgamma	M-124	qbedge	OP-32	vsb	OP-40
cgdo	M-146	kgfn	M-87	qd	OP-34	vto	M-12
cgidl	M-82	kjf	M-148	qdedge	OP-30	vtss	M-175
cgso	M-145	kkp	M-111	qdf	OP-25		

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

cjd	M-215	kp	M-21	qdov	OP-27	vtsswd	M-213
cjf	M-149	krgl1	M-233	qg	OP-35	vtsswgd	M-214
cjs	M-178	kucrit	M-128	qgedge	OP-31	vtsswgs	M-177
cjswd	M-216	kvto	M-118	qlr	M-55	vtssws	M-176
cjswgd	M-217	l	I-4	qoff	M-5	w	I-5
cjswgs	M-180	l	OP-3	qs	OP-33	w	OP-4
cjsws	M-179	la	M-27	qsedge	OP-29	wdl	M-39
cmi_limexp_method I-2		lambda	M-51	qsfr	OP-24	wdphiedge	M-102
cmi_limexp_method OP-2		lb	M-28	qsov	OP-26	we0	M-98
cox	M-10	ldif	M-154	qwr	M-66	we1	M-99
d	O-1	ldphiedge	M-91	rbn	M-236	wedge	M-105
ddits	M-72	ldw	M-38	rbwsh	M-235	weta	M-61
delta	M-52	leta	M-59	rd	M-156	wetad	M-97
dfr	M-151	leta0	M-58	rdbn	M-240	wgam	M-47
dgammaedge	M-106	leta2	M-60	rdbwsh	M-239	wkkp	M-113
di	O-5	lgam	M-46	rdsbsh	M-234	wkp1	M-31
dl	M-34	lkkp	M-112	rdx	M-159	wkp2	M-32
dlc	M-35	lkvto	M-119	rgsh	M-231	wkp3	M-33
dphiedge	M-107	ll	M-40	ringtype	M-241	wkvto	M-120
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Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

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e0 M-22	llodkvto M-122	rsbn M-238	wldphiedge M-103
e1 M-23	lnwr M-89	rsbwsh M-237	wlod M-110
eb M-77	lodketad M-127	rsh M-153	wlodkkp M-117
ef M-86	lodkgamma M-125	rsx M-158	wlodkvto M-123
egidl M-83	lov M-143	s O-3	wlr M-94
eta M-24	lovig M-79	sa I-11	wnlr M-93
etad M-63	lqwr M-88	sa OP-10	wqlr M-92
etaqm M-20	lr M-54	saref M-108	wr M-65
exp_cr I-1	lvt M-43	sb I-12	wrlx M-100
exp_cr OP-1	lwr M-90	sb OP-11	wucex M-101
flr M-57	m I-3	sbref M-109	wucrit M-95
fprout M-68	mjd M-221	scale M-4	wvt M-44
g O-2	mjs M-184	sd I-13	xb M-76
gamma M-14	mjswd M-222	sd OP-12	xj M-11
gammag M-15	mjswgd M-223	si O-6	xjbvd M-201
gammagov M-141	mjswgs M-186	sigmad M-64	xjbvs M-164
gammaov M-140	mjsws M-185	sign M-1	xl M-6
gc M-232	n0 M-16	tcj M-194	xtid M-224
gi O-7	ncs M-62	tcjsw M-195	xtis M-187

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<code>gmin</code>	M-162	<code>nf</code>	I-6	<code>tcjswg</code>	M-196	<code>xtsd</code>	M-225
<code>hdif</code>	M-152	<code>nf</code>	OP-5	<code>tcv</code>	M-131	<code>xtss</code>	M-188
<code>iba</code>	M-73	<code>nfvta</code>	M-48	<code>tcvl</code>	M-137	<code>xtsswd</code>	M-226
<code>ibb</code>	M-74	<code>nfvtb</code>	M-49	<code>tcvw</code>	M-138	<code>xtsswg</code>	M-227
<code>ibbt</code>	M-136	<code>njd</code>	M-200	<code>tcvwl</code>	M-139	<code>xtsswgs</code>	M-190
<code>ibn</code>	M-75	<code>njs</code>	M-163	<code>te0ex</code>	M-134	<code>xtssws</code>	M-189
<code>idb</code>	OP-16	<code>njt</code>	M-209	<code>telex</code>	M-135	<code>xw</code>	M-7
<code>ids</code>	OP-37	<code>njtss</code>	M-172	<code>teta</code>	M-129	<code>zc</code>	M-25
<code>idsedge</code>	OP-28	<code>njtsswd</code>	M-210	<code>tg</code>	M-2		
<code>igb</code>	OP-19	<code>njtsswg</code>	M-211	<code>th_noi</code>	M-9		

Device `ekv3_rf` (`ekv3_rf`)

Description

`ekv3_rf` model (compiled=Jun 2 2008 cmi=4.0 developer=admsXml-2.2.7, interface=spectre500 2.1.1, version=unknown)

This device is supported within altergroups.

Instance Definition

```
Name d g s b ModelName parameter=value ...
```

Instance Parameters

- `exp_cr=(80.0)` The parameter is used by simulator.
- `cmi_limexp_method=(1.0)` The parameter is used by simulator.

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

3	<code>m=(1.0)</code>	Multiplicity factor (number of MOSFETs in parallel).
4	<code>l=(10.0E-06)</code>	GATES LENGTH.
5	<code>w=(10.0E-06)</code>	GATES WIDTH.
6	<code>nf=(1)</code>	NUMBER OF FINGERS.
7	<code>ad=(0.0)</code>	DRAINS AREA.
8	<code>as=(0.0)</code>	SOURCES AREA.
9	<code>pd=(0.0)</code>	DRAINS PERIMETER.
10	<code>ps=(0.0)</code>	SOURCES PERIMETER.
11	<code>sa=(0.0)</code>	STI PARAMETER; DISTANCE FROM STI.
12	<code>sb=(0.0)</code>	STI PARAMETER; DISTANCE FROM STI.
13	<code>sd=(0.0)</code>	STI PARAMETER; DISTANCE BETWEEN GATES.
14	<code>avto=(0.0)</code>	MATCHING PARAMETER FOR THRESHOLD VOLTAGE (VTO).
15	<code>agamma=(0.0)</code>	MATCHING PARAMETER FOR BODY FACTOR (GAMMA).
16	<code>akp=(0.0)</code>	MATCHING PARAMETER FOR MOBILITY (KP).

Model Definition

model modelName ekv3_rf parameter=value ...

Model Parameters

1	<code>sign=(1)</code>	SIGN = 1 FOR NMOS; SIGN = -1 FOR PMOS.
2	<code>tg=((-1))</code>	TYPE OF GATE: -1 ENHANCEMENT TYPE; 1 DEPLETION TYPE.
3	<code>tnom=(27.0)</code>	Parameters measurement temperature.

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

4	<code>scale=(1.0)</code>	Scaling Factor for Gate Length and Width.
5	<code>qoff=(0.0)</code>	Charge partitioning flag.
6	<code>xl=(0.0)</code>	Optical offset for Gate Length.
7	<code>xw=(0.0)</code>	Optical offset for Gate Width.
8	<code>nqs_noi=(1.0)</code>	NQS noise flag(on/off). Includes thermal noise with no short channel effects.
9	<code>th_noi=(0.0)</code>	Thermal noise flag(on/off). Includes short channel effects but no gate induced noise.
10	<code>cox=(0.012)</code>	Oxide Capacitance per unit Area.
11	<code>xj=(20.0E-09)</code>	Depth of Active Areas.
12	<code>vt0=(0.3)</code>	THRESHOLD VOLTAGE.
13	<code>phif=(0.45)</code>	FERMI BULK POTENTIAL.
14	<code>gamma=(0.3)</code>	Body Effect Coefficient.
15	<code>gammag=(4.1)</code>	Body Effect Coefficient for Gate.
16	<code>n0=(1.0)</code>	Long Channel Slope Factor Fine Tuning.
17	<code>vbi=(0.0)</code>	Built-in Voltage Drop.
18	<code>aqma=(0.5)</code>	Quantum Effect Coefficient for Accumulation Region.
19	<code>aqmi=(0.4)</code>	Quantum Effect Coefficient for Inversion Region.
20	<code>etaqm=(0.75)</code>	Quantum Effect Factor.
21	<code>kp=(500.0E-06)</code>	Mobility multiplied by COX.
22	<code>e0=(1.0E+10)</code>	First Order Coefficient for Mobility Reduction due to Vertical Field.
23	<code>e1=(3.1E+08)</code>	Second Order Coefficient for Mobility Reduction due to Vertical Field.

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

24	$\text{eta}=(0.5)$	Mobility Reduction due to Vertical Field Factor.
25	$\text{zc}=(1.0\text{E}-6)$	Coulomb Scattering coefficient.
26	$\text{thc}=(0.0)$	Coulomb Scattering coefficient.
27	$\text{la}=(1.0)$	First critical length for mobility length scaling.
28	$\text{lb}=(1.0)$	Second critical length for mobility length scaling.
29	$\text{ka}=(0.0)$	First factor for mobility length scaling.
30	$\text{kb}=(0.0)$	Second factor for mobility length scaling.
31	$\text{wkp1}=(1.0\text{E}-6)$	Width parameter for mobility profile vs. width.
32	$\text{wkp2}=(0.0)$	Amplitude parameter for mobility profile vs. width.
33	$\text{wkp3}=(1.0)$	Span parameter for mobility profile vs. width.
34	$\text{dl}=((-10.0\text{E}-9))$	Effective Length Parameter.
35	$\text{dlc}=(0.0)$	Effective Length Parameter for Capacitance.
36	$\text{dw}=((-10.0\text{E}-9))$	Effective Width Parameter.
37	$\text{dwc}=(0.0)$	Effective Width Parameter for Capacitance.
38	$\text{ldw}=(0.0)$	Length Dependence of Effective Width.
39	$\text{wdl}=(0.0)$	Width Dependence of Effective Length.
40	$\text{ll}=(0.0)$	Base for Exponential Dependence of Effective Length.
41	$\text{lln}=(1.0)$	Exponent for Exponential Dependence of Effective Length.
42	$\text{avt}=(0.0)$	Amplitude for long and wide channel threshold voltage correction.
43	$\text{lvt}=(1.0)$	Length for long channel threshold voltage correction.
44	$\text{wvt}=(1.0)$	Width for wide channel threshold voltage correction.

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

45	agam=(0.0)	Amplitude for long and wide channel body effect coefficient correction.
46	lgam=(1.0)	Length for long channel body effect coefficient correction.
47	wgam=(1.0)	Width for wide channel body effect coefficient correction.
48	nfvtb=(0.0)	Number of fingers parameter for threshold voltage dependence on NF.
49	nfvtb=(10000.0)	Factor for threshold voltage dependence on NF.
50	ucrit=(5.0E+06)	Critical Velocity of Electrons.
51	lambda=(0.5)	Early effect factor.
52	delta=(2.0)	Order of velocity saturation model (variable order model 1~2).
53	ac1m=(0.83)	Channel Length Modulation Factor.
54	lr=(50.0E-09)	Length Factor for RSCE.
55	qlr=(0.5E-3)	Threshold Voltage Factor of RSCE.
56	n1r=(10.0E-3)	Body Effect Coefficient Factor of RSCE.
57	f1r=(0.0)	Bulk Fermi Potential of RSCE.
58	leta0=(0.0)	Long Channel Charge Sharing Coefficient.
59	leta=(500.0E-3)	Short Channel Charge Sharing Coefficient.
60	leta2=(0.0)	Short Channel Scaling Coefficient.
61	weta=(200.0E-3)	Narrow Channel Charge Sharing Coefficient.
62	ncs=(1.0)	Slope Factor Dependence from Charge Sharing.
63	etad=(1.0)	Primary DIBL Coefficient.
64	sigmad=(1.0)	Secondary DIBL Coefficient.
65	wr=(90.0E-09)	Width Factor for INWE.

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

66	$qwr=(0.3E-3)$	Threshold Voltage Factor of INWE.
67	$nwr=(5.0E-3)$	Body Effect Coefficient Factor of INWE.
68	$fprout=(1.0E6)$	Output resistance for DITS effect.
69	$pdits=(0.0)$	DITS parameter.
70	$pditsl=(0.0)$	DITS dependence on length.
71	$pditsd=(1.0)$	DITS dependence on drain bias.
72	$ddits=(0.3)$	Smooth factor of DITS effect.
73	$iba=(000.0E+06)$	Impact Ionization Current first parameter.
74	$ibb=(300.0E+06)$	Impact Ionization Current second parameter.
75	$ibn=(1.0)$	Impact Ionization Current coefficient.
76	$xb=(3.1)$	Silicon to Silicon oxide tunneling barrier height.
77	$eb=(29.0E+09)$	Characteristic electrical field.
78	$kg=(00.0E-6)$	Mobility for Gate Current.
79	$lovig=(20.0E-9)$	Overlap Length for Gate current.
80	$agidl=(0.0)$	First GIDL parameter.
81	$bgidl=(2.3E+09)$	Second GIDL parameter.
82	$cgidl=(0.5)$	Third GIDL parameter.
83	$egidl=(0.8)$	Fourth GIDL parameter.
84	$kf=(0.0)$	Flicker noise factor.
85	$af=(1.0)$	Frequency exponent for flicker noise.
86	$ef=(2.0)$	Transconductance exponent for flicker noise.
87	$kgfn=(0.0)$	Gate flicker noise factor.

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

88	lqwr=(0.0)	Length scaling of QWR.
89	lnwr=(0.0)	Length scaling of NWR.
90	lwr=(0.0)	Length scaling of WR.
91	ldphiedge=(0.0)	Length scaling of DPHIEDGE.
92	wqlr=(0.0)	Width scaling of QLR.
93	wnlr=(0.0)	Width scaling of NLR.
94	wlr=(0.0)	Width scaling of LR.
95	wucrit=(0.0)	Width scaling of UCRIT.
96	wlambda=(0.0)	Width scaling of LAMBDA.
97	wetad=(0.0)	Width scaling of ETAD.
98	we0=(0.0)	Width scaling of E0.
99	we1=(0.0)	Width scaling of E1.
100	wrlx=(0.0)	Width scaling of RLX.
101	wucex=(0.0)	Width scaling of UCEX.
102	wdphiedge=(0.0)	Width scaling of DPHIEDGE.
103	wldphiedge=(0.0)	Area scaling (fine tuning for short and narrow) of DPHIEDGE.
104	wldgammaedge=(0.0)	Area scaling (fine tuning for short and narrow) of DGAMMAEDGE.
105	wedge=(0.0)	Width of edge conduction area.
106	dgammaedge=(0.0)	Difference of body effect coefficient of edge conduction area with respect to the main part of the channel.
107	dphiedge=(0.0)	Difference of fermi potential of edge conduction area with respect to the main part of the channel.

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

108	saref=(0.0)	Reference distance from STI, for SA.
109	sbref=(0.0)	Reference distance from STI, for SB.
110	wlod=(0.0)	Width of common area between device and STI.
111	kkp=(0.0)	Mobility dependence on STI.
112	lkkp=(0.0)	Length scaling of mobility dependence on STI.
113	wkkp=(0.0)	Width scaling of mobility dependence on STI.
114	pkkp=(0.0)	Area scaling (fine tuning for short and narrow channel devices) of mobility dependence on STI.
115	tkkp=(0.0)	Temperature scaling of mobility dependence on STI.
116	llodkkp=(1.0)	Exponent of length scaling of mobility dependence on STI.
117	wlodkkp=(1.0)	Exponent of width scaling of mobility dependence on STI.
118	kvto=(0.0)	Threshold voltage dependence on STI.
119	lkvto=(0.0)	Length scaling of threshold voltage dependence on STI.
120	wkvto=(0.0)	Width scaling of threshold voltage dependence on STI.
121	pkvto=(0.0)	Area scaling (fine tuning for short and narrow channel devices) of threshold voltage dependence on STI.
122	llodkvto=(1.0)	Exponent of length scaling of threshold voltage dependence on STI.
123	wlodkvto=(1.0)	Exponent of width scaling of threshold voltage dependence on STI.
124	kgamma=(0.0)	Body effect dependence on STI.
125	lodkgamma=(1.0)	Exponential dependence of body effect on STI.
126	ketad=(0.0)	Primary DIBL dependence on STI.
127	lodketad=(1.0)	Exponential dependence of Primary DIBL dependence on STI.

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

128	$k_{ucrit}=(0.0)$	Critical Velocity of Electrons dependence of STI.
129	$t_{eta}=((-0.9E-3))$	Temperature dependence of ETA.
130	$t_{lambda}=(0.0)$	Temperature dependence of LAMBDA.
131	$t_{cv}=(600.0E-6)$	Temperature dependence of VTO (threshold voltage).
132	$b_{ex}=(-1.5)$	Temperature dependence of KP (mobility).
133	$u_{cex}=(1.5)$	Temperature dependence of UCRIT.
134	$t_{e0ex}=(0.5)$	Temperature dependence of E0.
135	$t_{e1ex}=(0.5)$	Temperature dependence of E1.
136	$i_{bbt}=(800.0E-6)$	Temperature dependence of IBB.
137	$t_{cvl}=(0.0)$	Length dependence of TCV.
138	$t_{cvw}=(0.0)$	Width dependence of TCV.
139	$t_{cvwl}=(0.0)$	Area dependence of TCV.
140	$\gamma_{ov}=(1.6)$	Body effect coefficient of the overlap area.
141	$\gamma_{gov}=(10.0)$	Body effect coefficient of the gate of the overlap area.
142	$v_{fbov}=(0.0)$	Flat-band voltage of the overlap area.
143	$l_{ov}=(20.0E-9)$	Length of the overlap area.
144	$v_{ov}=(1.0)$	V_s dependence of V_{gsov} .
145	$c_{gso}=(0.0)$	Bias-independent gate to source overlap capacitance.
146	$c_{gdo}=(0.0)$	Bias-independent gate to drain overlap capacitance.
147	$c_{gbo}=(0.0)$	Bias-independent gate to bulk overlap capacitance.
148	$k_{jf}=(0.0)$	Fringing capacitance factor.
149	$c_{jf}=(0.0)$	Fringing capacitance bias factor.

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

150	$vfr=(0.0)$	Built-in correction for fringing capacitance.
151	$dfr=(1.0E-3)$	Smooth factor of fringing capacitance model.
152	$hdif=(0.0e-6)$	Half length of active area.
153	$rsh=(0.0)$	Square resistance of active area.
154	$ldif=(0.0)$	Distance between the middle of the active area and the start of the channel.
155	$rs=(0.0)$	Source series resistance.
156	$rd=(0.0)$	Drain series resistance.
157	$rlx=(-1.0)$	Series resistance (symmetric model).
158	$rsx=(-1.0)$	Source series resistance (asymmetric model).
159	$rdx=(-1.0)$	Drain series resistance (asymmetric model).
160	$tr=(0.0)$	First order temperature coefficient of resistors.
161	$tr2=(0.0)$	Second order temperature coefficient of resistors.
162	$gmin=(0.0)$	Minimum conductance of diode.
163	$njs=(1.0)$	Slope factor for parasitic diodes(S).
164	$xjbvs=(0.0)$	Breakdown effect coefficient(S).
165	$bvs=(10.0)$	Breakdown Voltage(S).
166	$jss=(0.0E-09)$	Area component of diode current(S).
167	$jssws=(0.0E-12)$	Perimeter component of diode current(S).
168	$jsswgs=(0.0E-12)$	Gate side component of diode current(S).
169	$jtss=(0.0E-09)$	Area component of trap-assisted diode current(S).
170	$jtssws=(0.0E-12)$	Perimeter component of trap-assisted diode current(S).

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

171	$j_{tsswgs} = (0.0E-12)$	Gate side component of trap-assisted diode current(S).
172	$n_{jtss} = (1.0)$	Area slope factor of trap-assisted diode current(S).
173	$n_{jtssws} = (1.0)$	Perimeter slope factor of trap-assisted diode current(S).
174	$n_{jtsswgs} = (1.0)$	Gate side slope factor of trap-assisted diode current(S).
175	$v_{tss} = (0.0)$	Area voltage factor of trap-assisted diode current(S).
176	$v_{tssws} = (0.0)$	Perimeter voltage factor of trap-assisted diode current(S).
177	$v_{tsswgs} = (0.0)$	Gate side voltage factor of trap-assisted diode current(D).
178	$c_{js} = (0.0E-06)$	Area component of diode capacitance(S).
179	$c_{jsws} = (0.0E-09)$	Perimeter component of diode capacitance(S).
180	$c_{jswgs} = (0.0E-09)$	Gate side component of diode capacitance(S).
181	$p_{bs} = (0.800)$	Area parameter of diode capacitance(S).
182	$p_{bsws} = (0.600)$	Perimeter parameter of diode capacitance(S).
183	$p_{bswgs} = (0.600)$	Gate side parameter of diode capacitance(S).
184	$m_{js} = (0.900)$	Area exponent of diode capacitance(S).
185	$m_{jsws} = (0.700)$	Perimeter exponent of diode capacitance(S).
186	$m_{jswgs} = (0.700)$	Gate side exponent of diode capacitance(S).
187	$x_{tis} = (3.0)$	Temperature dependence of diode(S).
188	$x_{tss} = (0.0)$	Area component of temperature dependence of trap-assisted diode current(S).
189	$x_{tssws} = (0.0)$	Perimeter component of temperature dependence of trap-assisted diode current(S).
190	$x_{tsswgs} = (0.0)$	Gate side component of temperature dependence of trap-assisted diode current(S).

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

191	$t_{njtss}=(0.0)$	Temperature dependence of n_{jtss} .
192	$t_{njtssws}=(0.0)$	Temperature dependence of n_{jtssws} .
193	$t_{njtsswgs}=(0.0)$	Temperature dependence of $n_{jtsswgs}$.
194	$t_{cj}=(0.0)$	Temperature dependence of CJ.
195	$t_{cjsw}=(0.0)$	Temperature dependence of CJSW.
196	$t_{cjswg}=(0.0)$	Temperature dependence of CJSWG.
197	$t_{pb}=(0.0)$	Temperature dependence of PB.
198	$t_{pbsw}=(0.0)$	Temperature dependence of PBSW.
199	$t_{pbswg}=(0.0)$	Temperature dependence of PBSWG.
200	$n_{jd}=(1.0)$	Slope factor for parasitic diodes(D).
201	$x_{jbvd}=(0.0)$	Breakdown effect coefficient(D).
202	$bvd=(10.0)$	Breakdown Voltage(D).
203	$j_{sd}=(0.0E-09)$	Area component of diode current(D).
204	$j_{sswd}=(0.0E-12)$	Perimeter component of diode current(D).
205	$j_{sswgd}=(0.0E-12)$	Gate side component of diode current(D).
206	$j_{tsd}=(0.0E-09)$	Area component of trap-assisted diode current(D).
207	$j_{tsswd}=(0.0E-12)$	Perimeter component of trap-assisted diode current(D).
208	$j_{tsswgd}=(0.0E-12)$	Gate side component of trap-assisted diode current(D).
209	$n_{jtsd}=(1.0)$	Area slope factor of trap-assisted diode current(D).
210	$n_{jtsswd}=(1.0)$	Perimeter slope factor of trap-assisted diode current(D).
211	$n_{jtsswgd}=(1.0)$	Gate side slope factor of trap-assisted diode current(D).

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

212	$v_{tsd} = (0.0)$	Area voltage factor of trap-assisted diode current(D).
213	$v_{tsswd} = (0.0)$	Perimeter voltage factor of trap-assisted diode current(D).
214	$v_{tsswgd} = (0.0)$	Gate side voltage factor of trap-assisted diode current(D).
215	$c_{jd} = (0.0E-06)$	Area component of diode capacitance(D).
216	$c_{jswd} = (0.0E-09)$	Perimeter component of diode capacitance(D).
217	$c_{jswgd} = (0.0E-09)$	Gate side component of diode capacitance(D).
218	$p_{bd} = (0.800)$	Area parameter of diode capacitance(D).
219	$p_{bswd} = (0.600)$	Perimeter parameter of diode capacitance(D).
220	$p_{bswgd} = (0.600)$	Gate side parameter of diode capacitance(D).
221	$m_{jd} = (0.900)$	Area exponent of diode capacitance(D).
222	$m_{jswd} = (0.700)$	Perimeter exponent of diode capacitance(D).
223	$m_{jswgd} = (0.700)$	Gate side exponent of diode capacitance(D).
224	$x_{tid} = (3.0)$	Temperature dependence of diode(D).
225	$x_{tsd} = (0.0)$	Area component of temperature dependence of trap-assisted diode current(D).
226	$x_{tsswd} = (0.0)$	Perimeter component of temperature dependence of trap-assisted diode current(D).
227	$x_{tsswgd} = (0.0)$	Gate side component of temperature dependence of trap-assisted diode current(D).
228	$tnj_{tsd} = (0.0)$	Temperature dependence of nj_{tsd} .
229	$tnj_{tsswd} = (0.0)$	Temperature dependence of nj_{tsswd} .
230	$tnj_{tsswgd} = (0.0)$	Temperature dependence of nj_{tsswgd} .
231	$rg_{sh} = (3.0)$	Gate square resistance.

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232	<code>gc=(1)</code>	Gate contacts (single sided = 1, double sided = 2).
233	<code>krgl1=(0.0)</code>	Length dependence of <code>rg</code> .
234	<code>rdsbsh=(1.0E+3)</code>	Drain to source substrate sheet resistance.
235	<code>rbwsh=(3.0E-3)</code>	Inner bulk to bulk sheet resistance.
236	<code>rbn=(0.0)</code>	Inner bulk to bulk resistance per finger (for <code>RINGTYPE=2</code>).
237	<code>rsbwsh=(1.0E-3)</code>	Inner bulk-source side to bulk sheet resistance.
238	<code>rsbn=(0.0)</code>	Inner bulk-source side to bulk resistance per finger (for <code>RINGTYPE=2</code>).
239	<code>rdbwsh=(1.0E-3)</code>	Inner bulk-drain side to bulk sheet resistance.
240	<code>rdbn=(0.0)</code>	Inner bulk-drain side to bulk resistance per finger (for <code>RINGTYPE=2</code>).
241	<code>ringtype=(1.0)</code>	Type of guard ring (bulk contacts) (two sides/symmetric: 1, three sides/horse shoe: 2).

Output Parameters

1	<code>d</code>	node: Drain.
2	<code>g</code>	node: Gate.
3	<code>s</code>	node: Source.
4	<code>b</code>	node: Bulk.
5	<code>di</code>	node: Internal drain.
6	<code>si</code>	node: Internal source.
7	<code>gi</code>	node: Internal gate.
8	<code>bi</code>	node: Internal bulk.
9	<code>bdi</code>	node: Internal bulk(D).

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- 10 bsi node: Internal bulk(S).
- 11 noi node: Noise.

Operating-Point Parameters

- 1 exp_cr=(80.0) The parameter is used by simulator.
- 2 cmi_limexp_method=(1.0)
The parameter is used by simulator.
- 3 l=(10.0E-06) GATES LENGTH.
- 4 w=(10.0E-06) GATES WIDTH.
- 5 nf=(1) NUMBER OF FINGERS.
- 6 ad=(0.0) DRAINS AREA.
- 7 as=(0.0) SOURCES AREA.
- 8 pd=(0.0) DRAINS PERIMETER.
- 9 ps=(0.0) SOURCES PERIMETER.
- 10 sa=(0.0) STI PARAMETER; DISTANCE FROM STI.
- 11 sb=(0.0) STI PARAMETER; DISTANCE FROM STI.
- 12 sd=(0.0) STI PARAMETER; DISTANCE BETWEEN GATES.
- 13 avto=(0.0) MATCHING PARAMETER FOR THRESHOLD VOLTAGE (VTO).
- 14 agamma=(0.0) MATCHING PARAMETER FOR BODY FACTOR (GAMMA).
- 15 akp=(0.0) MATCHING PARAMETER FOR MOBILITY (KP).
- 16 idb Impact ionization current.
- 17 igsov Overlap gate current(source).
- 18 igdov Overlap gate current(drain).

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19	igb	Gate current(bulk).
20	igd	Gate current(drain).
21	igs	Gate current(source).
22	igidl	Gate induced drain current.
23	igisl	Gate induced source current.
24	qsfr	Fringing charge.
25	qdfrr	Fringing charge.
26	qsov	Overlap charge.
27	qdov	Overlap charge.
28	idsedge	Edge drain current.
29	qsedge	Edge charge.
30	qdedge	Edge charge.
31	qgedge	Edge charge.
32	qbedge	Edge charge.
33	qs	Source charge.
34	qd	Drain charge.
35	qg	Gate charge.
36	qb	Bulk charge.
37	ids	Resistive drain-to-source current.
38	vdb	Drain-bulk voltage.
39	vgb	Gate-bulk voltage.
40	vsb	Source-bulk voltage.

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Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

ac1m	M-53	idsedge	OP-28	njtsswd	M-210	tg	M-2
ad	I-7	igb	OP-19	njtsswgd	M-211	th_noi	M-9
ad	OP-6	igd	OP-20	njtsswgs	M-174	thc	M-26
af	M-85	igdov	OP-18	njtssws	M-173	tkkp	M-115
agam	M-45	igidl	OP-22	n1r	M-56	tlambda	M-130
agamma	I-15	igisl	OP-23	noi	O-11	tnjtsd	M-228
agamma	OP-14	igs	OP-21	nqs_noi	M-8	tnjtss	M-191
agidl	M-80	igsov	OP-17	nwr	M-67	tnjtsswd	M-229
akp	I-16	jsd	M-203	pbd	M-218	tnjtsswgd	M-230
akp	OP-15	jss	M-166	pbs	M-181	tnjtsswgs	M-193
aqma	M-18	jsswd	M-204	pbswd	M-219	tnjtssws	M-192
aqmi	M-19	jsswgd	M-205	pbswgd	M-220	tnom	M-3
as	I-8	jsswgs	M-168	pbswgs	M-183	tpb	M-197
as	OP-7	jssws	M-167	pbsws	M-182	tpbsw	M-198
avt	M-42	jtsd	M-206	pd	I-9	tpbswg	M-199
avto	I-14	jtss	M-169	pd	OP-8	tr	M-160

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avto	OP-13	jtsswd	M-207	pdits	M-69	tr2	M-161
b	O-4	jtsswgd	M-208	pditsd	M-71	ucex	M-133
bdi	O-9	jtsswgs	M-171	pditsl	M-70	ucrit	M-50
bex	M-132	jtssws	M-170	phif	M-13	vbi	M-17
bgidl	M-81	ka	M-29	pkkp	M-114	vdb	OP-38
bi	O-8	kb	M-30	pkvto	M-121	vfbov	M-142
bsi	O-10	ketad	M-126	ps	I-10	vfr	M-150
bvd	M-202	kf	M-84	ps	OP-9	vgb	OP-39
bvs	M-165	kg	M-78	qj	OP-36	vov	M-144
cgbo	M-147	kgamma	M-124	qjedge	OP-32	vsb	OP-40
cgdo	M-146	kgfn	M-87	qd	OP-34	vto	M-12
cgidl	M-82	kjf	M-148	qdedge	OP-30	vtsd	M-212
cgso	M-145	kkp	M-111	qdf	OP-25	vtss	M-175
cjd	M-215	kp	M-21	qdov	OP-27	vtsswd	M-213
cjf	M-149	krgl1	M-233	qg	OP-35	vtsswgd	M-214
cjs	M-178	kucrit	M-128	qgedge	OP-31	vtsswgs	M-177
cjswd	M-216	kvto	M-118	qlr	M-55	vtssws	M-176
cjswgd	M-217	l	I-4	qoff	M-5	w	I-5
cjswgs	M-180	l	OP-3	qs	OP-33	w	OP-4
cjsws	M-179	la	M-27	qsedge	OP-29	wl	M-39

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cmi_limexp_method I-2	lambda M-51	qsfr OP-24	wdphiedge M-102
cmi_limexp_method OP-2	lb M-28	qsov OP-26	we0 M-98
cox M-10	ldif M-154	qwr M-66	we1 M-99
d O-1	ldphiedge M-91	rbn M-236	wedge M-105
ddits M-72	ldw M-38	rbwsh M-235	weta M-61
delta M-52	leta M-59	rd M-156	wetad M-97
dfr M-151	leta0 M-58	rdbn M-240	wgam M-47
dgammaedge M-106	leta2 M-60	rdbwsh M-239	wkkp M-113
di O-5	lgam M-46	rdsbsh M-234	wkp1 M-31
dl M-34	lkkp M-112	rdx M-159	wkp2 M-32
dlc M-35	lkvto M-119	rgsh M-231	wkp3 M-33
dphiedge M-107	ll M-40	ringtype M-241	wkvto M-120
dw M-36	lln M-41	rlx M-157	wlambda M-96
dwc M-37	llodkkp M-116	rs M-155	wldgammaedge M-104
e0 M-22	llodkvto M-122	rsbn M-238	wldphiedge M-103
e1 M-23	lnwr M-89	rsbwsh M-237	wlod M-110
eb M-77	lodketad M-127	rsh M-153	wlodkkp M-117
ef M-86	lodkgamma M-125	rsx M-158	wlodkvto M-123
egidl M-83	lov M-143	s O-3	wlr M-94
eta M-24	lovig M-79	sa I-11	wnlr M-93

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etad M-63	lqwr M-88	sa OP-10	wqlr M-92
etaqm M-20	lr M-54	saref M-108	wr M-65
exp_cr I-1	lvt M-43	sb I-12	wrlx M-100
exp_cr OP-1	lwr M-90	sb OP-11	wucex M-101
flr M-57	m I-3	sbref M-109	wucrit M-95
fprout M-68	mjd M-221	scale M-4	wvt M-44
g O-2	mjs M-184	sd I-13	xb M-76
gamma M-14	mjswd M-222	sd OP-12	xj M-11
gammag M-15	mjswgd M-223	si O-6	xjbvd M-201
gammagov M-141	mjswgs M-186	sigmad M-64	xjbvs M-164
gammaov M-140	mjsws M-185	sign M-1	xl M-6
gc M-232	n0 M-16	tcj M-194	xtid M-224
gi O-7	ncs M-62	tcjsw M-195	xtis M-187
gmin M-162	nf I-6	tcjswg M-196	xtsd M-225
hdif M-152	nf OP-5	tcv M-131	xtss M-188
iba M-73	nfvta M-48	tcv1 M-137	xtsswd M-226
ibb M-74	nfvtb M-49	tcvw M-138	xtsswgd M-227
ibbt M-136	njd M-200	tcvwl M-139	xtsswgs M-190
ibn M-75	njs M-163	te0ex M-134	xtssws M-189
idb OP-16	njtsd M-209	telex M-135	xw M-7
ids OP-37	njtss M-172	teta M-129	zc M-25

Device `ekv3_s` (`ekv3_s`)

This device is supported within altergroups.

Instance Definition

Name `d g s b` ModelName parameter=value ...

Instance Parameters

- | | | |
|----|--------------------------------------|--|
| 1 | <code>exp_cr=(80.0)</code> | The parameter is used by simulator. |
| 2 | <code>cmi_limexp_method=(1.0)</code> | The parameter is used by simulator. |
| 3 | <code>m=(1.0)</code> | Multiplicity factor (number of MOSFETs in parallel). |
| 4 | <code>l=(10.0E-06)</code> | GATES LENGTH. |
| 5 | <code>w=(10.0E-06)</code> | GATES WIDTH. |
| 6 | <code>nf=(1)</code> | NUMBER OF FINGERS. |
| 7 | <code>ad=(0.0)</code> | DRAINS AREA. |
| 8 | <code>as=(0.0)</code> | SOURCES AREA. |
| 9 | <code>pd=(0.0)</code> | DRAINS PERIMETER. |
| 10 | <code>ps=(0.0)</code> | SOURCES PERIMETER. |
| 11 | <code>sa=(0.0)</code> | STI PARAMETER; DISTANCE FROM STI. |
| 12 | <code>sb=(0.0)</code> | STI PARAMETER; DISTANCE FROM STI. |
| 13 | <code>sd=(0.0)</code> | STI PARAMETER; DISTANCE BETWEEN GATES. |
| 14 | <code>avto=(0.0)</code> | MATCHING PARAMETER FOR THRESHOLD VOLTAGE (VTO). |
| 15 | <code>agamma=(0.0)</code> | MATCHING PARAMETER FOR BODY FACTOR (GAMMA). |
| 16 | <code>akp=(0.0)</code> | MATCHING PARAMETER FOR MOBILITY (KP). |

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

Model Definition

model modelName ekv3_s parameter=value ...

Model Parameters

1	<code>sign=(1)</code>	SIGN = 1 FOR NMOS; SIGN = -1 FOR PMOS.
2	<code>tg=((-1))</code>	TYPE OF GATE: -1 ENHANCEMENT TYPE; 1 DEPLETION TYPE.
3	<code>tnom=(27.0)</code>	Parameters measurement temperature.
4	<code>scale=(1.0)</code>	Scaling Factor for Gate Length and Width.
5	<code>qoff=(0.0)</code>	Charge partitioning flag.
6	<code>xl=(0.0)</code>	Optical offset for Gate Length.
7	<code>xw=(0.0)</code>	Optical offset for Gate Width.
8	<code>nqs_noi=(1.0)</code>	NQS noise flag(on/off). Includes thermal noise with no short channel effects.
9	<code>th_noi=(0.0)</code>	Thermal noise flag(on/off). Includes short channel effects but no gate induced noise.
10	<code>cox=(0.012)</code>	Oxide Capacitance per unit Area.
11	<code>xj=(20.0E-09)</code>	Depth of Active Areas.
12	<code>vto=(0.3)</code>	THRESHOLD VOLTAGE.
13	<code>phif=(0.45)</code>	FERMI BULK POTENTIAL.
14	<code>gamma=(0.3)</code>	Body Effect Coefficient.
15	<code>gammag=(4.1)</code>	Body Effect Coefficient for Gate.
16	<code>n0=(1.0)</code>	Long Channel Slope Factor Fine Tuning.
17	<code>vbi=(0.0)</code>	Built-in Voltage Drop.

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18	$a_{qma} = (0.5)$	Quantum Effect Coefficient for Accumulation Region.
19	$a_{qmi} = (0.4)$	Quantum Effect Coefficient for Inversion Region.
20	$e_{taqm} = (0.75)$	Quantum Effect Factor.
21	$k_p = (500.0E-06)$	Mobility multiplied by COX.
22	$e_0 = (1.0E+10)$	First Order Coefficient for Mobility Reduction due to Vertical Field.
23	$e_1 = (3.1E+08)$	Second Order Coefficient for Mobility Reduction due to Vertical Field.
24	$e_{ta} = (0.5)$	Mobility Reduction due to Vertical Field Factor.
25	$z_c = (1.0E-6)$	Coulomb Scattering coefficient.
26	$th_c = (0.0)$	Coulomb Scattering coefficient.
27	$l_a = (1.0)$	First critical length for mobility length scaling.
28	$l_b = (1.0)$	Second critical length for mobility length scaling.
29	$k_a = (0.0)$	First factor for mobility length scaling.
30	$k_b = (0.0)$	Second factor for mobility length scaling.
31	$w_{kp1} = (1.0E-6)$	Width parameter for mobility profile vs. width.
32	$w_{kp2} = (0.0)$	Amplitude parameter for mobility profile vs. width.
33	$w_{kp3} = (1.0)$	Span parameter for mobility profile vs. width.
34	$d_l = ((-10.0E-9))$	Effective Length Parameter.
35	$d_{lc} = (0.0)$	Effective Length Parameter for Capacitance.
36	$d_w = ((-10.0E-9))$	Effective Width Parameter.
37	$d_{wc} = (0.0)$	Effective Width Parameter for Capacitance.
38	$l_{dw} = (0.0)$	Length Dependence of Effective Width.

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39	<code>wdl=(0.0)</code>	Width Dependence of Effective Length.
40	<code>ll=(0.0)</code>	Base for Exponential Dependence of Effective Length.
41	<code>lln=(1.0)</code>	Exponent for Exponential Dependence of Effective Length.
42	<code>avt=(0.0)</code>	Amplitude for long and wide channel threshold voltage correction.
43	<code>lvt=(1.0)</code>	Length for long channel threshold voltage correction.
44	<code>wvt=(1.0)</code>	Width for wide channel threshold voltage correction.
45	<code>agam=(0.0)</code>	Amplitude for long and wide channel body effect coefficient correction.
46	<code>lgam=(1.0)</code>	Length for long channel body effect coefficient correction.
47	<code>wgam=(1.0)</code>	Width for wide channel body effect coefficient correction.
48	<code>nfvta=(0.0)</code>	Number of fingers parameter for threshold voltage dependence on NF.
49	<code>nfvtb=(10000.0)</code>	Factor for threshold voltage dependence on NF.
50	<code>ucrit=(5.0E+06)</code>	Critical Velocity of Electrons.
51	<code>lambda=(0.5)</code>	Early effect factor.
52	<code>delta=(2.0)</code>	Order of velocity saturation model (variable order model 1~2).
53	<code>aclm=(0.83)</code>	Channel Length Modulation Factor.
54	<code>l_r=(50.0E-09)</code>	Length Factor for RSCE.
55	<code>q_{l_r}=(0.5E-3)</code>	Threshold Voltage Factor of RSCE.
56	<code>n_{l_r}=(10.0E-3)</code>	Body Effect Coefficient Factor of RSCE.
57	<code>f_{l_r}=(0.0)</code>	Bulk Fermi Potential of RSCE.
58	<code>leta0=(0.0)</code>	Long Channel Charge Sharing Coefficient.

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59	<code>leta=(500.0E-3)</code>	Short Channel Charge Sharing Coefficient.
60	<code>leta2=(0.0)</code>	Short Channel Scaling Coefficient.
61	<code>weta=(200.0E-3)</code>	Narrow Channel Charge Sharing Coefficient.
62	<code>ncs=(1.0)</code>	Slope Factor Dependence from Charge Sharing.
63	<code>etad=(1.0)</code>	Primary DIBL Coefficient.
64	<code>sigmad=(1.0)</code>	Secondary DIBL Coefficient.
65	<code>wr=(90.0E-09)</code>	Width Factor for INWE.
66	<code>qwr=(0.3E-3)</code>	Threshold Voltage Factor of INWE.
67	<code>nwr=(5.0E-3)</code>	Body Effect Coefficient Factor of INWE.
68	<code>fprout=(1.0E6)</code>	Output resistance for DITS effect.
69	<code>pdits=(0.0)</code>	DITS parameter.
70	<code>pditsl=(0.0)</code>	DITS dependence on length.
71	<code>pditsd=(1.0)</code>	DITS dependence on drain bias.
72	<code>ddits=(0.3)</code>	Smooth factor of DITS effect.
73	<code>iba=(000.0E+06)</code>	Impact Ionization Current first parameter.
74	<code>ibb=(300.0E+06)</code>	Impact Ionization Current second parameter.
75	<code>ibn=(1.0)</code>	Impact Ionization Current coefficient.
76	<code>xb=(3.1)</code>	Silicon to Silicon oxide tunneling barrier height.
77	<code>eb=(29.0E+09)</code>	Characteristic electrical field.
78	<code>kg=(00.0E-6)</code>	Mobility for Gate Current.
79	<code>lovig=(20.0E-9)</code>	Overlap Length for Gate current.
80	<code>agidl=(0.0)</code>	First GIDL parameter.

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

81	<code>bgidl=(2.3E+09)</code>	Second GIDL parameter.
82	<code>cgidl=(0.5)</code>	Third GIDL parameter.
83	<code>egidl=(0.8)</code>	Fourth GIDL parameter.
84	<code>kf=(0.0)</code>	Flicker noise factor.
85	<code>af=(1.0)</code>	Frequency exponent for flicker noise.
86	<code>ef=(2.0)</code>	Transconductance exponent for flicker noise.
87	<code>kgfn=(0.0)</code>	Gate flicker noise factor.
88	<code>lqwr=(0.0)</code>	Length scaling of QWR.
89	<code>lnwr=(0.0)</code>	Length scaling of NWR.
90	<code>lwr=(0.0)</code>	Length scaling of WR.
91	<code>ldphiedge=(0.0)</code>	Length scaling of DPHIEDGE.
92	<code>wqlr=(0.0)</code>	Width scaling of QLR.
93	<code>wnlr=(0.0)</code>	Width scaling of NLR.
94	<code>wlr=(0.0)</code>	Width scaling of LR.
95	<code>wucrit=(0.0)</code>	Width scaling of UCRIT.
96	<code>wlambda=(0.0)</code>	Width scaling of LAMBDA.
97	<code>wetad=(0.0)</code>	Width scaling of ETAD.
98	<code>we0=(0.0)</code>	Width scaling of E0.
99	<code>we1=(0.0)</code>	Width scaling of E1.
100	<code>wrlx=(0.0)</code>	Width scaling of RLX.
101	<code>wucex=(0.0)</code>	Width scaling of UCEx.
102	<code>wdphiedge=(0.0)</code>	Width scaling of DPHIEDGE.

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EKV3 MOSFET Model (ekv3)

- 103 `wldphiedge=(0.0)` Area scaling (fine tuning for short and narrow) of DPHIEDGE.
- 104 `wldgammaedge=(0.0)` Area scaling (fine tuning for short and narrow) of DGAMMAEDGE.
- 105 `wedge=(0.0)` Width of edge conduction area.
- 106 `dgammaedge=(0.0)` Difference of body effect coefficient of edge conduction area with respect to the main part of the channel.
- 107 `dphiedge=(0.0)` Difference of fermi potential of edge conduction area with respect to the main part of the channel.
- 108 `saref=(0.0)` Reference distance from STI, for SA.
- 109 `sbref=(0.0)` Reference distance from STI, for SB.
- 110 `wlod=(0.0)` Width of common area between device and STI.
- 111 `kkp=(0.0)` Mobility dependence on STI.
- 112 `lkkp=(0.0)` Length scaling of mobility dependence on STI.
- 113 `wkkp=(0.0)` Width scaling of mobility dependence on STI.
- 114 `pkkp=(0.0)` Area scaling (fine tuning for short and narrow channel devices) of mobility dependence on STI.
- 115 `tkkp=(0.0)` Temperature scaling of mobility dependence on STI.
- 116 `llodkkp=(1.0)` Exponent of length scaling of mobility dependence on STI.
- 117 `wlodkkp=(1.0)` Exponent of width scaling of mobility dependence on STI.
- 118 `kvto=(0.0)` Threshold voltage dependence on STI.
- 119 `lkvto=(0.0)` Length scaling of threshold voltage dependence on STI.
- 120 `wkvto=(0.0)` Width scaling of threshold voltage dependence on STI.
- 121 `pkvto=(0.0)` Area scaling (fine tuning for short and narrow channel devices) of threshold voltage dependence on STI.

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

122	$l_{lodkvto}=(1.0)$	Exponent of length scaling of threshold voltage dependence on STI.
123	$w_{lodkvto}=(1.0)$	Exponent of width scaling of threshold voltage dependence on STI.
124	$kgamma=(0.0)$	Body effect dependence on STI.
125	$lodkgamma=(1.0)$	Exponential dependence of body effect on STI .
126	$ketad=(0.0)$	Primary DIBL dependence on STI.
127	$lodketad=(1.0)$	Exponential dependence of Primary DIBL dependence on STI.
128	$kucrit=(0.0)$	Critical Velocity of Electrons dependence of STI.
129	$teta=(-0.9E-3)$	Temperature dependence of ETA.
130	$tlambda=(0.0)$	Temperature dependence of LAMBDA.
131	$tcv=(600.0E-6)$	Temperature dependence of VTO (threshold voltage).
132	$bex=(-1.5)$	Temperature dependence of KP (mobility).
133	$ucex=(1.5)$	Temperature dependence of UCRIT.
134	$te0ex=(0.5)$	Temperature dependence of E0.
135	$te1ex=(0.5)$	Temperature dependence of E1.
136	$ibbt=(800.0E-6)$	Temperature dependence of IBB.
137	$tcvl=(0.0)$	Length dependence of TCV.
138	$tcvw=(0.0)$	Width dependence of TCV.
139	$tcvwl=(0.0)$	Area dependence of TCV.
140	$gammaov=(1.6)$	Body effect coefficient of the overlap area.
141	$gammagov=(10.0)$	Body effect coefficient of the gate of the overlap area.
142	$vfbov=(0.0)$	Flat-band voltage of the overlap area.

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

143	$l_{ov}=(20.0E-9)$	Length of the overlap area.
144	$v_{ov}=(1.0)$	V_s dependence of V_{gsov} .
145	$c_{gso}=(0.0)$	Bias-independent gate to source overlap capacitance.
146	$c_{gdo}=(0.0)$	Bias-independent gate to drain overlap capacitance.
147	$c_{gbo}=(0.0)$	Bias-independent gate to bulk overlap capacitance.
148	$k_{jf}=(0.0)$	Fringing capacitance factor.
149	$c_{jf}=(0.0)$	Fringing capacitance bias factor.
150	$v_{fr}=(0.0)$	Built-in correction for fringing capacitance.
151	$d_{fr}=(1.0E-3)$	Smooth factor of fringing capacitance model.
152	$h_{dif}=(0.0e-6)$	Half length of active area.
153	$r_{sh}=(0.0)$	Square resistance of active area.
154	$l_{dif}=(0.0)$	Distance between the middle of the active area and the start of the channel.
155	$r_s=(0.0)$	Source series resistance.
156	$r_d=(0.0)$	Drain series resistance.
157	$r_{lx}=((-1.0))$	Series resistance (symmetric model).
158	$r_{sx}=((-1.0))$	Source series resistance (asymmetric model).
159	$r_{dx}=((-1.0))$	Drain series resistance (asymmetric model).
160	$t_r=(0.0)$	First order temperature coefficient of resistors.
161	$t_{r2}=(0.0)$	Second order temperature coefficient of resistors.
162	$g_{min}=(0.0)$	Minimum conductance of diode.
163	$n_{js}=(1.0)$	Slope factor for parasitic diodes(S).

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

164	$x_{jbvs} = (0.0)$	Breakdown effect coefficient(S).
165	$bvs = (10.0)$	Breakdown Voltage(S).
166	$j_{ss} = (0.0E-09)$	Area component of diode current(S).
167	$j_{ssws} = (0.0E-12)$	Perimeter component of diode current(S).
168	$j_{sswgs} = (0.0E-12)$	Gate side component of diode current(S).
169	$j_{tss} = (0.0E-09)$	Area component of trap-assisted diode current(S).
170	$j_{tssws} = (0.0E-12)$	Perimeter component of trap-assisted diode current(S).
171	$j_{tsswgs} = (0.0E-12)$	Gate side component of trap-assisted diode current(S).
172	$n_{jtss} = (1.0)$	Area slope factor of trap-assisted diode current(S).
173	$n_{jtssws} = (1.0)$	Perimeter slope factor of trap-assisted diode current(S).
174	$n_{jtsswgs} = (1.0)$	Gate side slope factor of trap-assisted diode current(S).
175	$vtss = (0.0)$	Area voltage factor of trap-assisted diode current(S).
176	$vtssws = (0.0)$	Perimeter voltage factor of trap-assisted diode current(S).
177	$vtsswgs = (0.0)$	Gate side voltage factor of trap-assisted diode current(D).
178	$c_{js} = (0.0E-06)$	Area component of diode capacitance(S).
179	$c_{jsws} = (0.0E-09)$	Perimeter component of diode capacitance(S).
180	$c_{jswgs} = (0.0E-09)$	Gate side component of diode capacitance(S).
181	$p_{bs} = (0.800)$	Area parameter of diode capacitance(S).
182	$p_{bsws} = (0.600)$	Perimeter parameter of diode capacitance(S).
183	$p_{bswgs} = (0.600)$	Gate side parameter of diode capacitance(S).
184	$m_{js} = (0.900)$	Area exponent of diode capacitance(S).

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

185	$mjsws = (0.700)$	Perimeter exponent of diode capacitance(S).
186	$mjswgs = (0.700)$	Gate side exponent of diode capacitance(S).
187	$xtis = (3.0)$	Temperature dependence of diode(S).
188	$xtss = (0.0)$	Area component of temperature dependence of trap-assisted diode current(S).
189	$xtssws = (0.0)$	Perimeter component of temperature dependence of trap-assisted diode current(S).
190	$xtsswgs = (0.0)$	Gate side component of temperature dependence of trap-assisted diode current(S).
191	$tnjtss = (0.0)$	Temperature dependence of njtss.
192	$tnjtssws = (0.0)$	Temperature dependence of njtssws.
193	$tnjtsswgs = (0.0)$	Temperature dependence of njtsswgs.
194	$tcj = (0.0)$	Temperature dependence of CJ.
195	$tcjsw = (0.0)$	Temperature dependence of CJSW.
196	$tcjswg = (0.0)$	Temperature dependence of CJSWG.
197	$tpb = (0.0)$	Temperature dependence of PB.
198	$tpbsw = (0.0)$	Temperature dependence of PBSW.
199	$tpbswg = (0.0)$	Temperature dependence of PBSWG.
200	$njd = (1.0)$	Slope factor for parasitic diodes(D).
201	$xjbvd = (0.0)$	Breakdown effect coefficient(D).
202	$bvd = (10.0)$	Breakdown Voltage(D).
203	$jsd = (0.0E-09)$	Area component of diode current(D).
204	$jsswd = (0.0E-12)$	Perimeter component of diode current(D).

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

205	$j_{sswg\bar{d}} = (0.0E-12)$	Gate side component of diode current(D).
206	$j_{ts\bar{d}} = (0.0E-09)$	Area component of trap-assisted diode current(D).
207	$j_{tssw\bar{d}} = (0.0E-12)$	Perimeter component of trap-assisted diode current(D).
208	$j_{tsswg\bar{d}} = (0.0E-12)$	Gate side component of trap-assisted diode current(D).
209	$n_{jts\bar{d}} = (1.0)$	Area slope factor of trap-assisted diode current(D).
210	$n_{jtssw\bar{d}} = (1.0)$	Perimeter slope factor of trap-assisted diode current(D).
211	$n_{jtsswg\bar{d}} = (1.0)$	Gate side slope factor of trap-assisted diode current(D).
212	$v_{ts\bar{d}} = (0.0)$	Area voltage factor of trap-assisted diode current(D).
213	$v_{tssw\bar{d}} = (0.0)$	Perimeter voltage factor of trap-assisted diode current(D).
214	$v_{tsswg\bar{d}} = (0.0)$	Gate side voltage factor of trap-assisted diode current(D).
215	$c_{j\bar{d}} = (0.0E-06)$	Area component of diode capacitance(D).
216	$c_{jsw\bar{d}} = (0.0E-09)$	Perimeter component of diode capacitance(D).
217	$c_{jswg\bar{d}} = (0.0E-09)$	Gate side component of diode capacitance(D).
218	$p_{b\bar{d}} = (0.800)$	Area parameter of diode capacitance(D).
219	$p_{bsw\bar{d}} = (0.600)$	Perimeter parameter of diode capacitance(D).
220	$p_{bswg\bar{d}} = (0.600)$	Gate side parameter of diode capacitance(D).
221	$m_{j\bar{d}} = (0.900)$	Area exponent of diode capacitance(D).
222	$m_{jsw\bar{d}} = (0.700)$	Perimeter exponent of diode capacitance(D).
223	$m_{jswg\bar{d}} = (0.700)$	Gate side exponent of diode capacitance(D).
224	$x_{t\bar{d}} = (3.0)$	Temperature dependence of diode(D).
225	$x_{ts\bar{d}} = (0.0)$	Area component of temperature dependence of trap-assisted diode current(D).

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

226	$xtsswd=(0.0)$	Perimeter component of temperature dependence of trap-assisted diode current(D).
227	$xtsswg=(0.0)$	Gate side component of temperature dependence of trap-assisted diode current(D).
228	$tnjtsd=(0.0)$	Temperature dependence of njtsd.
229	$tnjtsswd=(0.0)$	Temperature dependence of njtsswd.
230	$tnjtsswg=(0.0)$	Temperature dependence of njtsswg.
231	$rgsh=(3.0)$	Gate square resistance.
232	$gc=(1)$	Gate contacts (single sided = 1, double sided = 2).
233	$krgl1=(0.0)$	Length dependence of rg.
234	$rdsbsh=(1.0E+3)$	Drain to source substrate sheet resistance.
235	$rbwsh=(3.0E-3)$	Inner bulk to bulk sheet resistance.
236	$rbn=(0.0)$	Inner bulk to bulk resistance per finger (for RINGTYPE=2).
237	$rsbwsh=(1.0E-3)$	Inner bulk-source side to bulk sheet resistance.
238	$rsbn=(0.0)$	Inner bulk-source side to bulk resistance per finger (for RINGTYPE=2).
239	$rdbwsh=(1.0E-3)$	Inner bulk-drain side to bulk sheet resistance.
240	$rdbn=(0.0)$	Inner bulk-drain side to bulk resistance per finger (for RINGTYPE=2).
241	$ringtype=(1.0)$	Type of guard ring (bulk contacts) (two sides/symmetric: 1, three sides/horse shoe: 2).

Output Parameters

1	d	node: Drain.
2	g	node: Gate.

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

3	s	node: Source.
4	b	node: Bulk.
5	noi	node: Noise.

Operating-Point Parameters

1	exp_cr=(80.0)	The parameter is used by simulator.
2	cmi_limexp_method=(1.0)	The parameter is used by simulator.
3	l=(10.0E-06)	GATES LENGTH.
4	w=(10.0E-06)	GATES WIDTH.
5	nf=(1)	NUMBER OF FINGERS.
6	ad=(0.0)	DRAINS AREA.
7	as=(0.0)	SOURCES AREA.
8	pd=(0.0)	DRAINS PERIMETER.
9	ps=(0.0)	SOURCES PERIMETER.
10	sa=(0.0)	STI PARAMETER; DISTANCE FROM STI.
11	sb=(0.0)	STI PARAMETER; DISTANCE FROM STI.
12	sd=(0.0)	STI PARAMETER; DISTANCE BETWEEN GATES.
13	avto=(0.0)	MATCHING PARAMETER FOR THRESHOLD VOLTAGE (VTO).
14	agamma=(0.0)	MATCHING PARAMETER FOR BODY FACTOR (GAMMA).
15	akp=(0.0)	MATCHING PARAMETER FOR MOBILITY (KP).
16	idb	Impact ionization current.
17	igsov	Overlap gate current(source).

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

18	igdov	Overlap gate current(drain).
19	igb	Gate current(bulk).
20	igd	Gate current(drain).
21	igs	Gate current(source).
22	igidl	Gate induced drain current.
23	igisl	Gate induced source current.
24	qsfr	Fringing charge.
25	qdfc	Fringing charge.
26	qsov	Overlap charge.
27	qdov	Overlap charge.
28	idsedge	Edge drain current.
29	qsedge	Edge charge.
30	qdedge	Edge charge.
31	qgedge	Edge charge.
32	qbedge	Edge charge.
33	qs	Source charge.
34	qd	Drain charge.
35	qg	Gate charge.
36	qb	Bulk charge.
37	ids	Resistive drain-to-source current.
38	vdb	Drain-bulk voltage.
39	vgb	Gate-bulk voltage.

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

40 vsb Source-bulk voltage.

Parameter Index

In the following index, I refers to instance parameters, M refers to the model parameters section, O refers to the output parameters section, and OP refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of M-35 means the 35th model parameter.

ac1m M-53	igid1 OP-22	njtssws M-173	tkkp M-115
ad I-7	igisl OP-23	n1r M-56	tlambda M-130
ad OP-6	igs OP-21	noi O-5	tnjtsd M-228
af M-85	igsov OP-17	nqs_noi M-8	tnjtss M-191
agam M-45	jssd M-203	nwr M-67	tnjtsswd M-229
agamma I-15	jss M-166	pbd M-218	tnjtsswgd M-230
agamma OP-14	jsswd M-204	pbs M-181	tnjtsswgs M-193
agidl M-80	jsswgd M-205	pbswd M-219	tnjtssws M-192
akp I-16	jsswgs M-168	pbswgd M-220	tnom M-3
akp OP-15	jssws M-167	pbswgs M-183	tpb M-197
aqma M-18	jtsd M-206	pbsws M-182	tpbsw M-198
aqmi M-19	jtss M-169	pd I-9	tpbswg M-199
as I-8	jtsswd M-207	pd OP-8	tr M-160
as OP-7	jtsswgd M-208	pdits M-69	tr2 M-161
avt M-42	jtsswgs M-171	pditsd M-71	ucex M-133

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

avto I-14	jtssws M-170	pditsl M-70	ucrit M-50
avto OP-13	ka M-29	phif M-13	vbi M-17
b O-4	kb M-30	pkkp M-114	vdb OP-38
bex M-132	ketad M-126	pkvto M-121	vfbov M-142
bgidl M-81	kf M-84	ps I-10	vfr M-150
bvd M-202	kg M-78	ps OP-9	vgb OP-39
bvs M-165	kgamma M-124	qb OP-36	vov M-144
cgbo M-147	kgfn M-87	qbedge OP-32	vsb OP-40
cgdo M-146	kjf M-148	qd OP-34	vto M-12
cgidl M-82	kkp M-111	qdedge OP-30	vtsd M-212
cgso M-145	kp M-21	qdftr OP-25	vtss M-175
cjd M-215	krgl1 M-233	qdov OP-27	vtsswd M-213
cjf M-149	kucrit M-128	qg OP-35	vtsswgd M-214
cjs M-178	kvto M-118	qgedge OP-31	vtsswgs M-177
cjswd M-216	l I-4	qlr M-55	vtssws M-176
cjswgd M-217	l OP-3	qoff M-5	w I-5
cjswgs M-180	la M-27	qs OP-33	w OP-4
cjsws M-179	lambda M-51	qsedge OP-29	wdl M-39
cmi_limexp_method I-2	lb M-28	qsfr OP-24	wdphiedge M-102
cmi_limexp_method OP-2	ldif M-154	qsov OP-26	we0 M-98

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

cox	M-10	ldphiedge	M-91	qwr	M-66	wel	M-99
d	O-1	ldw	M-38	rbn	M-236	wedge	M-105
ddits	M-72	leta	M-59	rbwsh	M-235	weta	M-61
delta	M-52	leta0	M-58	rd	M-156	wetad	M-97
dfr	M-151	leta2	M-60	rdbn	M-240	wgam	M-47
dgammaedge	M-106	lgam	M-46	rdbwsh	M-239	wkkp	M-113
dl	M-34	lkkp	M-112	rdsbsh	M-234	wkp1	M-31
dlc	M-35	lkvto	M-119	rdx	M-159	wkp2	M-32
dphiedge	M-107	ll	M-40	rgsh	M-231	wkp3	M-33
dw	M-36	lln	M-41	ringtype	M-241	wkvto	M-120
dwc	M-37	llodkkp	M-116	rlx	M-157	wlambda	M-96
e0	M-22	llodkvto	M-122	rs	M-155	wldgammaedge	M-104
e1	M-23	lnwr	M-89	rsbn	M-238	wldphiedge	M-103
eb	M-77	lodketad	M-127	rsbwsh	M-237	wlod	M-110
ef	M-86	lodkgamma	M-125	rsh	M-153	wlodkkp	M-117
egidl	M-83	lov	M-143	rsx	M-158	wlodkvto	M-123
eta	M-24	lovig	M-79	s	O-3	wlr	M-94
etad	M-63	lqwr	M-88	sa	I-11	wnlr	M-93
etaqm	M-20	lr	M-54	sa	OP-10	wqlr	M-92
exp_cr	I-1	lvt	M-43	saref	M-108	wr	M-65

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

exp_cr	OP-1	lwr	M-90	sb	I-12	wrlx	M-100
flr	M-57	m	I-3	sb	OP-11	wucex	M-101
fprout	M-68	mjd	M-221	sbref	M-109	wucrit	M-95
g	O-2	mjs	M-184	scale	M-4	wvt	M-44
gamma	M-14	mjswd	M-222	sd	I-13	xb	M-76
gammag	M-15	mjswgd	M-223	sd	OP-12	xj	M-11
gammagov	M-141	mjswgs	M-186	sigmad	M-64	xjbvd	M-201
gammaov	M-140	mjsws	M-185	sign	M-1	xjbvs	M-164
gc	M-232	n0	M-16	tcj	M-194	xl	M-6
gmin	M-162	ncs	M-62	tcjsw	M-195	xtid	M-224
hdif	M-152	nf	I-6	tcjswg	M-196	xtis	M-187
iba	M-73	nf	OP-5	tcv	M-131	xtsd	M-225
ibb	M-74	nfvtb	M-48	tcvl	M-137	xtss	M-188
ibbt	M-136	nfvtb	M-49	tcvw	M-138	xtsswd	M-226
ibn	M-75	njd	M-200	tcvwl	M-139	xtsswgd	M-227
idb	OP-16	njs	M-163	te0ex	M-134	xtsswgs	M-190
ids	OP-37	njtsd	M-209	telex	M-135	xtssws	M-189
idsedge	OP-28	njtss	M-172	teta	M-129	xw	M-7
igb	OP-19	njtsswd	M-210	tg	M-2	zc	M-25
igd	OP-20	njtsswgd	M-211	th_noi	M-9		
igdov	OP-18	njtsswgs	M-174	thc	M-26		

Virtuoso Simulator Components and Device Models Reference
EKV3 MOSFET Model (ekv3)

BSIMSOI MOSFET Model (bsimsoi)

The BSIMSOI model is a Silicon-on-Insulator (SOI) MOSFET model. It was developed by the BSIM/SOI modeling group at the University of California, Berkeley.

There are two modes in BSIMSOI depending on the value of *soiMod*:

- PD mode (*soiMod*=0), where the body potential is independent of ΔV_{bi} ($V_{BS} > \Delta V_{bi}$). Hence the calculation of ΔV_{bi} is skipped in this mode.
- DD (Unified) mode (*soiMod*=1), where both ΔV_{bi} and body current/charge are calculated to capture the floating-body behavior exhibited in FD devices.
- FD mode (*soiMod*=2), where the body potential is equal to ΔV_{bi} . Hence the calculation of body current/charge, which is essential to the PD model, is skipped.

This chapter contains the following information for the BSIMSOI model:

- [Instance](#) on page 2207
- [Model](#) on page 2207
- [Device Structure](#) on page 2208
- [Equivalent Circuit](#) on page 2209
- [Device Regions](#) on page 2209
- [Global Control Options](#) on page 2210
- [Model Version Update](#) on page 2211
 - [Version 3.2](#) on page 2211
 - [Version 4.0](#) on page 2211
 - [Version 4.1](#) on page 2212
 - [Version 4.2](#) on page 2212
 - [Version 4.3](#) on page 2212

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

- [Version 4.31](#) on page 2213
- [Version 4.4](#) on page 2213
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- [Special bug fixed](#) on page 2214
 - [Rth thermal resistance](#) on page 2214
 - [Cth thermal capacity](#) on page 2214
 - [ExpVgst bug handling](#) on page 2214
 - [Temperature node tolerance and quantity](#) on page 2215
 - [I_{jj} \(substrate current\)](#) on page 2215
 - [Bugfix control methodology](#) on page 2215
- [Model Equations](#) on page 2217
 - [DC current](#) on page 2217
 - [Body current](#) on page 2218
 - [Leakage current](#) on page 2221
 - [Charge and Capacitance](#) on page 2224
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 - [RF model](#) on page 2228
 - [Noise](#) on page 2230
- [Component Statements](#) on page 2234

Instance

BSIMSOI instance may have 4 to 7 terminals: drain (d), gate (g) source (s), back-gate (e), external-bulk (p), bulk (b), and temperature node (t). When more than 4 terminals are given, instance parameter “tnodeout” is specified, the last terminal is interpreted as temperature terminal. All the possible terminal connects are follows:

- InstanceName d g s e ModelName parameter=value
- InstanceName d g s e [p] ModelName parameter=value
- InstanceName d g s e [p b] ModelName parameter=value
- InstanceName d g s e [p b t] ModelName parameter=value
- InstanceName d g s e [t] ModelName **tnodeout** parameter=value
- InstanceName d g s e [p t] ModelName **tnodeout** parameter=value
- InstanceName d g s e [p b t] ModelName **tnodeout** parameter=value

To specify BSIMSOI instance element, the ModelName has to be associated with a BSIMSOI model card.

Simple Instance statement

```
MN1 (Vd Vg Vs Ve ) nmos_soil l=1e-6 w=5e-6
```

For detailed list of Instance parameters, see Section [Component Statements](#) on page 2234.

Model

The following syntax specified BSIMSOI model:

```
model ModelName bsimsoi parameter=value ...
```

The third parameter, `bsimsoi`, is the master to indicate this model is a BSIMSOI model card.

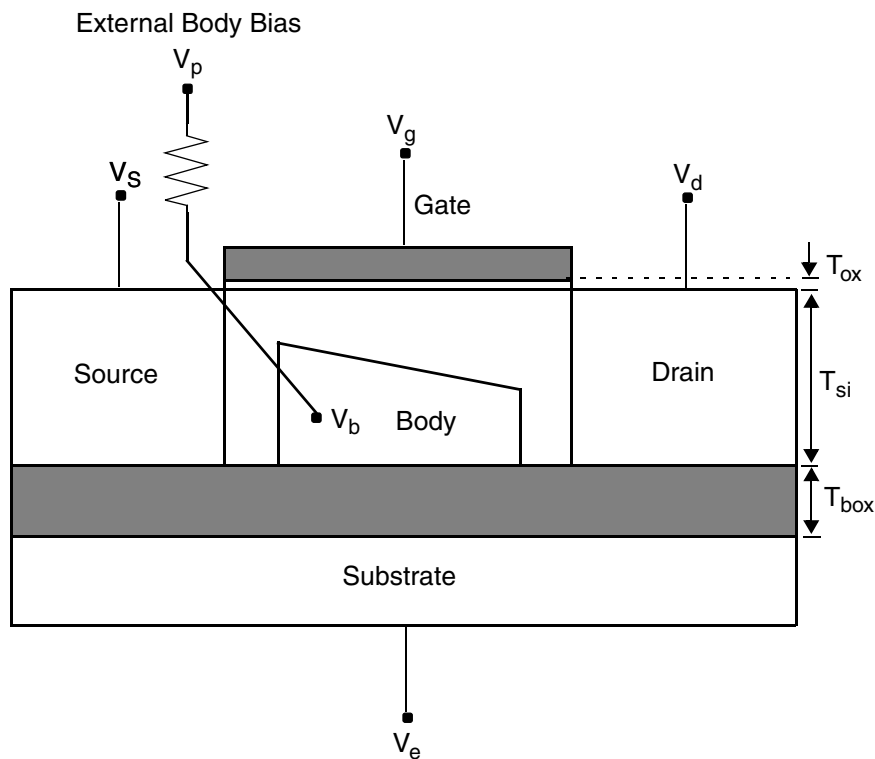
Simple Model statement

```
model bsimsoi_nmos1 bsimsoi type=n version=4.0 tnom=25 tox=3.0e-9 tsi=41e-9  
tbox=100e-9 toxm=3.0e-9 vth0=0.29 nch=4e17 nsub=1e16 rbody=0 rbsh=0
```

Note: For detailed list of model parameters, see Section [Component Statements](#) on page 2234.

Device Structure

BSIMSOI device's typical structure is shown in the following figure.



In the floating body configuration, there are four external biases: drain voltage (V_d), gate voltage (V_g), source voltage (V_s) and backgate voltage (V_e). The voltage of floating body is solved by iterating in circuit simulation. If body contact is applied, there is one mode external bias: bulk voltage (V_p).

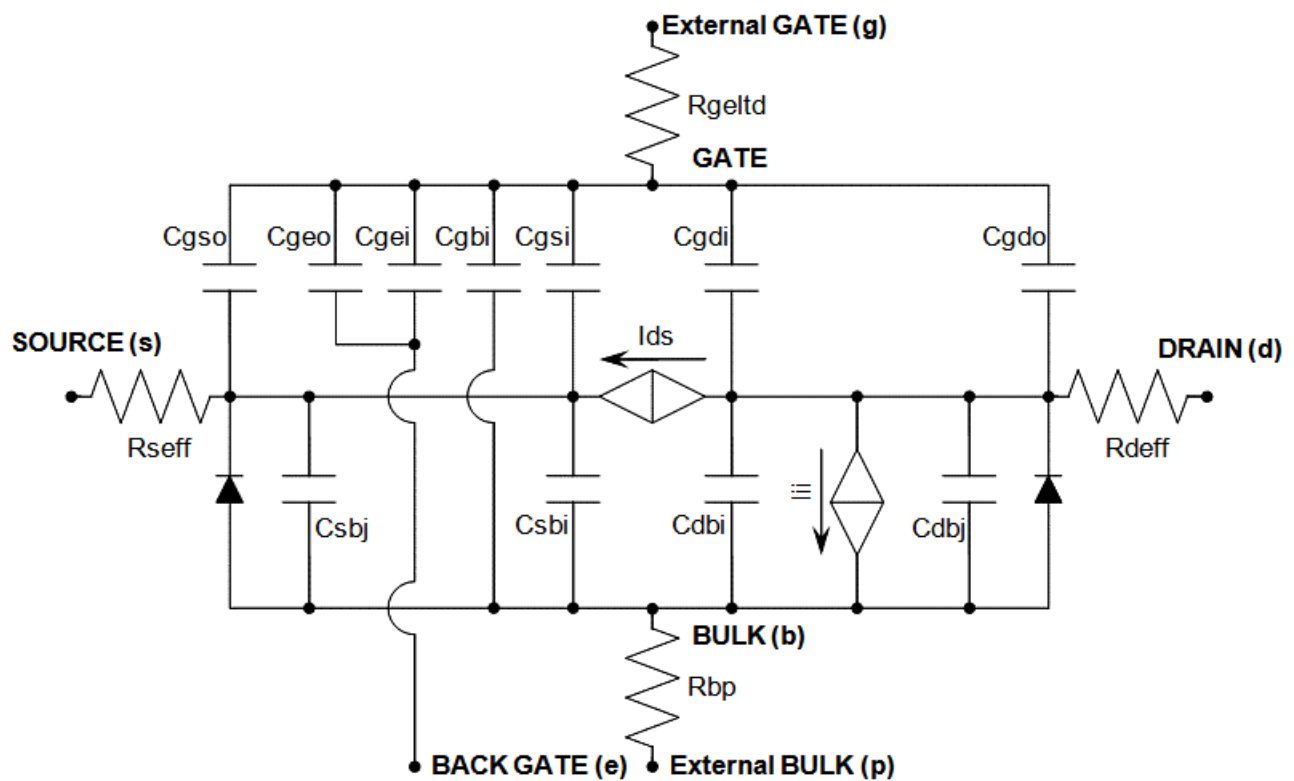
Since the backgate is decoupled by the isolated layer, there are three models to describe the behaviors of the floating body (selected by model parameter 'soimod'):

- PD mode (soimod=0): the body potential is independent for ψ_{bi} ;
- DD mode (soimod=1): both ψ_{bi} and body current/charge are concerned to capture the floating body behavior;
- FD mode (soimod=2): the body potential is equal to ψ_{bi}

Auto mode (soimod=3): determine the floating body model by with model parameters automatically.

Equivalent Circuit

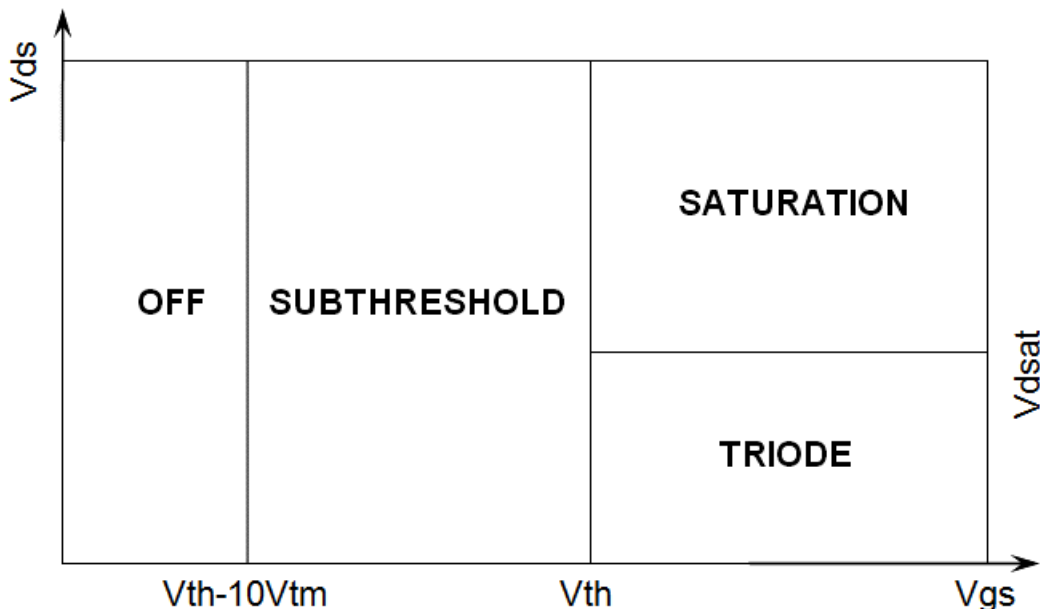
Since BSIMSOI model is developed based on BSIM3v3 model, it shares the similar basic equivalent circuit with BSIM3v3 model except the part of floating body. The followings show the equivalent circuits for BSIMSOI devices:



Device Regions

This section describes devices region for the BSIMSOI model. Device region is determined by both V_{ds} and V_{gs} . The following figure shows the region of N-type BSIMSOI device. For P-type device, all the voltage in figure is negative.

V_{tm} is the thermal voltage which is about 0.026V for 300°K temperature.



Global Control Options

The following global options affect BSIMSOI model.

1. **GMIN:** GMIN helps solver convergence. It places a conductance in parallel with both the channel and source junction. The default GMIN is 1.0e-12.
2. **MINR:** Source, drain and gate parasitic resistors inside devices less than minr will be removed. The order of checking inside devices is:
 - Check if resistors are smaller than local minr, if so then remove the parasitic resistors, give warning message.
 - Check global minr, parasitic resistors less than global minr will be removed and warning message will be issued.

In Spectre, both model parameter minr and global minr take effect at same time. So, for global minr to be activated, the value for minr has to be set both globally and locally.

Note: Local minr is specified by model parameter minr. The default value is 0.1

COMPATIBLE: Encourage device equations to be compatible with a foreign simulator. This option does not affect input syntax. Possible values are spectre, spice2, spice3, or hspice.

Model Version Update

Version 3.2

1. Add model selector “soimod”. “soimod” will determine the operation of BSIMSOI: If soimod=0 (default), the model equation is identical to the BSIMPD equation; if soimod=1 the model equation is an unified model for PD FD; if soimod=2, the model equation is identical to the BSIMFD equation
2. Implements a flicker noise and thermal noise model compatible with BSIM4 has been. In addition, the new noise model includes gate tunneling-induced shot noise and thermal noise due to gate electrode resistance.

Version 4.0

1. A scalable stress effect model for process induced stress effect, device performance becoming thus a function of the active area geometry and the location of the device in the active area;
2. Asymmetric current/capacitance model S/D diode and asymmetric S/D resistance;
3. Improved GIDL model with BSIM4 GIDL compatibility;
4. Noise model Improvements;
 - ❑ Improved width/length dependence on flicker noise
 - ❑ SPICE2 thermal noise model is introduced as TNOIMOD=2 with parameter NTNOI that adjusts the magnitude of the noise density
 - ❑ Body contact resistance induced thermal noise
 - ❑ Thermal noise induced by the body resistance network
 - ❑ Shot noises induced by Ibs and Ibd separated
5. A two resistance body resistance network introduced for RF simulation;
6. Threshold voltage model enhancement;
 - ❑ Long channel DIBL effect model added
 - ❑ Channel-length dependence of body effect improved
7. Drain induced threshold shift (DITS) model introduced in output conductance;
8. Improved model accuracy in moderate inversion region with BSIM4 compatible Vgsteff;

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

9. Multi-finger device with instance parameter NF;
10. A new instance parameter AGBCPD to improve gate current for body contact;
11. A new instance parameter DELVTO representing threshold voltage variation;
12. FRBODY is both instance/model parameters.

Version 4.1

1. New Material Model
2. New Mobility Model for High k Material
3. New GIDL/GISL Model
4. New Impact Ionization Current Model
5. New Body Contact Model
6. New DITS Model
7. Improved VgsteffCV model
8. Improved Built Improved Built-in Potential Lowering (?Vbi) Model

Version 4.2

1. No new features are added in this version.
2. Bug-fix for charge and capacitance
3. Bug-fix for gate to bulk tunneling current “lgb” calculation
4. Bug-fix for vgsteff derivative calculation.

Version 4.3

1. No new features are added in this version.
2. Bug-fix for temperature derivative calculation with selfheating.
3. Bug-fix for dc swapping issue.
4. Bug-fix for Abulk discontinuity issue.
5. Bug-fix for vgst, vfbeff, vfbeff2, vgsteff, vgsteff 2, Qs2 and I_{ij} derivative calculation.

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

6. Bug-fix for missing number of finger in some calculation.
7. Add source and drain edge components of Gate-source, Gate-drain diffusion tunneling currents.
8. I_{gisl} and I_{gidl} current formulations revised for continuity and consistency.

Version 4.31

1. No new features are added in this version.
2. Bug-fix for new material model
3. Bug-fix for missing number of finger in I_{g_agbcp2} current.
4. Bug-fix for I_{gcs}/I_{gcd} derivative calculation.

Version 4.4

1. Extensive derivative fixes for $SOIMOD=1$ and 2 are provided
2. A new sidewall fringe capacitance model parameter $c_{frcoeff}$ is added.
3. Limiting for peak channel doping concentration parameter n_{ch} when $soimod=2$.

Version 4.5

1. Support added for correlated thermal noise at $t_{noimod}=3$.
2. dc and ac DIBL parameters have been decoupled
3. New model parameters $EGGBCP2$, $EGGDEP$, $AGB1$, $BGB1$, $AGB2$, $BGB2$, $AGBC2N$, $AGBC2P$, $BGBC2N$, $BGBC2P$, and $VTM00$ have been added.
4. The source/drain conductance is now set to $1.0e3$ instead of 0 when the value of NRS and NRD is 0 .
5. Inconsistency in drain current when selfheating is on has been addressed.
6. $GISL/GIDL$ model for $gidlMod=0$ and $gidlMod=1$ has been modified.
7. In $capmod=3$, XDC calculation has been modified.
8. pwr is now positive in $white_noise(pwr, name)$ in the thermal noise model implementation.
9. $NTNOI$ and $NOIF$ parameters are now limited to positive values only.

10. Thermal noise contribution due to `rbody` has been included.
11. Calculation of A_{bulk} has been updated to avoid non-monotonic behavior at high body bias.
12. Some bugs have been fixed.

Special bug fixed

Rth thermal resistance

R_{th} is the thermal resistance of one device and should be the total resistance of the shunt connected fingers.

UC Berkeley

```
Rth = Rth0 / (Weff + Wth0) * Nseg;
```

Cadence

```
Rth = Rth0 / (NF* (Weff + Wth0)) * Nseg;
```

It is fixed in MMSIM611_ISR16

Cth thermal capacity

C_{th} is the thermal capacity of one device and should be the total resistance of the shunt connected fingers.

UC Berkeley

```
Cth = Cth0 * (Weff + Wth0) / Nseg;
```

Cadence

```
Cth = Cth0 * (NF* (Weff + Wth0)) / Nseg;
```

It is fixed in MMSIM611_ISR16

ExpVgst bug handling

In the original BSIMSOI model, `ExpVgst` was multiplied by itself by a mistake when calculate the effective `Vgst` for charge model. To fix this issue UC Berkeley added `Vgstcvmod` flag in BSIMSOI 4.1

`Vgstcvmod=0`: keep the bug (Cadence fixed it for version > 4.0)

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

Vgstcvmod=1: the bug fixed in UC Berkeley code

Vgstcvmod=2: New charge model (introduced in 4.1)

It is released in MMSIM711 with BSIMSOI version 4.1. The default value of Vgstcvmod is 0.

In BSIMSOI version 4.2 released in MMSIM72, the default value of $V_{gstcvmod}$ is changed to 1.

Temperature node tolerance and quantity

Spectre supports handling different node behavior and temperature node property should be different from electric node. BSIMSOI temperature node is not properly implemented in Spectre which may cause convergence issue.

It is fixed in MMSIM711_ISR6 (April, 2009)

I_{ij} (substrate current)

I_{ij} is the impact ionization current from channel to bulk body for one finger and should multiply with number of ginger to get the total impact ionization current. Cadence fixed it as $I_{ij} * NF$

It is fixed in MMSIM72 base release with BSIMSOI version 4.2.

Bugfix control methodology

Spectre BSIMSOI model introduced a new methodology to control all bugfix Cadence did. A new model flag parameter "bugfix_selector" was add to BSIMSOI model to control the special bugfix cadence did in BSIMSOI model. It is an unsigned int. Every bit of its binary format controls one bugfix. With this methodology, every bugfix can be turned on or off independently.

Currently, there are three bugfixes are controlled:

1. Bit0 for bugfix of double ExpVgst when VgstcvMod = 0. (Version != 4.01)
2. Bit1 for bugfix of Vgsteff derivative when VgstcvMod = 0. (Version >= 3.2)

Bit2 for bugfix of channel thermal noise when nf > 1. (Version < 4.31)

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

That means:

bugfix_selecor		Bugfix list		
Value in base 10	Value in base 2	a	b	c
0	0000-0000-0000-0000	×	×	×
1	0000-0000-0000-0001	●	×	×
2	0000-0000-0000-0010	×	●	×
3	0000-0000-0000-0011	●	●	×
4	0000-0000-0000-0100	×	×	●
5	0000-0000-0000-0101	●	×	●
6	0000-0000-0000-0110	×	●	●
7	0000-0000-0000-0111	●	●	●
8	0000-0000-0000-1000	×	×	×
...

Model Equations

DC current

$$I_{ds, MOSFET} = \frac{I_{ds0}}{1 + \frac{R_{ds} I_{ds0}}{V_{dseff}}} \left(1 + \frac{V_{ds} - V_{dseff}}{V_A} \right)$$

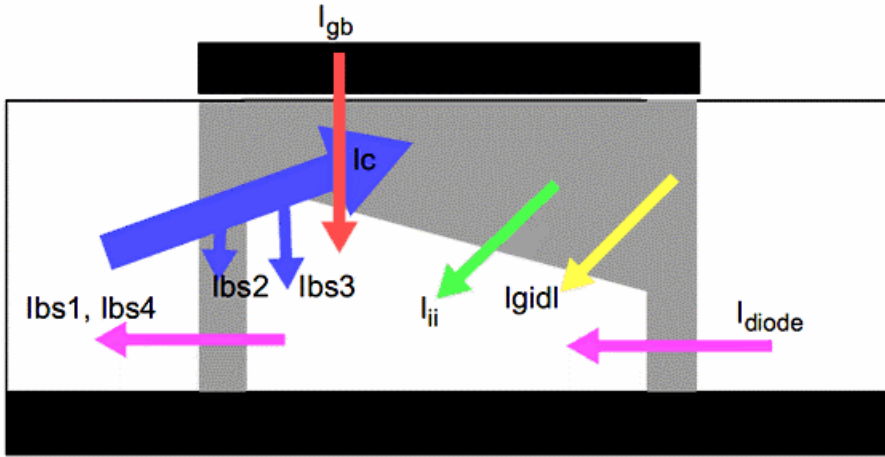
$$I_{ds0} = \frac{\beta V_{gsteff} \left(1 - A_{bulk} \frac{V_{dseff}}{2(V_{gsteff} + 2V_t)} \right) V_{dseff}}{1 + \frac{V_{dseff}}{E_{sat} L_{eff}}}$$

$$\beta = \mu_{eff} fC_{ox} \frac{W_{eff}}{L_{eff}}$$

Where A_{bulk} is the bulk charge factor:

$$A_{bulk} = 1 + \left(\frac{K_{lox} \cdot \sqrt{1 + \frac{LPEB}{L_{eff}}}}{2 \sqrt{(\phi_s + Keta) - \frac{V_{bsh}}{1 + Keta V_{bsh}}}} \left(\frac{A_0 L_{eff}}{L_{eff} + 2\sqrt{T_{si} X_{dep}}} \left(1 - A_{gs} V_{gsteff} \left(\frac{L_{eff}}{L_{eff} + 2\sqrt{T_{si} X_{dep}}} \right)^2 \right) + \frac{B_0}{W_{eff} + B_1} \right) \right)$$

Body current



The backward injection current in the B-S/D diode can be expressed as

$$I_{bs1} = W_{dios} T_{si} j_{sdif} \left(e^{\frac{V_{ds}}{n_{diode} V_t}} - 1 \right)$$

$$I_{bd1} = W_{diode} T_{si} j_{ddif} \left(e^{\frac{V_{dd}}{n_{diode} V_t}} - 1 \right)$$

The carrier recombination and trap-assisted tunneling current in the space-charge region is modeled by

$$I_{bs2} = W_{dios} T_{si} j_{srec} \left(e^{\frac{V_{ds}}{0.026 n_{recf}}} - e^{\frac{V_{sb}}{0.026 n_{recr}} \frac{V_{rec0}}{V_{rec0} + V_{sb}}} \right)$$

$$I_{bd2} = W_{diode} T_{si} j_{drec} \left(e^{\frac{V_{dd}}{0.026 n_{recfd}}} - e^{\frac{V_{db}}{0.026 n_{recrd}} \frac{V_{rec0d}}{V_{rec0d} + V_{db}}} \right)$$

Virtuoso Simulator Components and Device Models Reference
BSIMSOI MOSFET Model (bsimsoi)

The reverse bias tunneling current, which may be significant in junctions with high doping concentration, can be expressed as

$$I_{bs4} = W_{di0s} T_{si} j_{stun} \left(1 - e^{-\frac{V_{s\delta} V_{tun0}}{0.026 n_{tun} V_{tun0} + V_{s\delta}}} \right)$$

$$I_{bd4} = W_{di0d} T_{si} j_{dtun} \left(1 - e^{-\frac{V_{d\delta} V_{tun0d}}{0.026 n_{tun d} V_{tun0d} + V_{d\delta}}} \right)$$

The recombination current in the neutral body can be described by

$$I_{bs3} = (1 - \alpha_{bjt}) I_{en} \left(e^{\frac{V_{bs}}{n_{di0d} V_t}} - 1 \right) \frac{1}{\sqrt{E_{hli3} + 1}}$$

$$I_{bd3} = (1 - \alpha_{bjt}) I_{en} \left(e^{\frac{V_{bd}}{n_{di0d} V_t}} - 1 \right) \frac{1}{\sqrt{E_{hli4} + 1}}$$

$$I_{en} = W_{eff}' T_{si} j_{sbjt} \left(L_{bjt0} \left(\frac{1}{L_{eff}} + \frac{1}{L_n} \right) \right)^N$$

$$E_{hli3} = A_{hli_eff} \left(e^{\frac{V_{bs}}{n_{di0} V_t}} - 1 \right)$$

$$E_{hli4} = A_{hli_eff} \left(e^{\frac{V_{bd}}{n_{di0} V_t}} - 1 \right)$$

$$\alpha_{bjt} = e^{-0.5 \left(\frac{L_{eff}}{L_n} \right)^2}$$

Virtuoso Simulator Components and Device Models Reference
BSIMSOI MOSFET Model (bsimsoi)

The BJT collector current is modeled as

$$I_c = \alpha_{bjt} I_{en} \left(e^{\frac{V_{bs}}{n_{diodes} V_t}} - e^{\frac{V_{bd}}{n_{diodes} V_t}} \right) \frac{1}{E_{2nd}}$$

$$E_{2nd} = \frac{E_{ely} + \sqrt{E_{ely}^2 + 4E_{hli}}}{2}$$

$$E_{ely} = 1 + \frac{V_{bs} + V_{bd}}{V_{Abjt} + A_{ely} L_{eff}}$$

$$E_{hli} = E_{hlis} + E_{hlid}$$

Impact Ionization Current Equation is modeled as

$$I_{ii} = \alpha_0 \left(I_{ds, MOSFET} + I_{ii_BJT} \right) e^{\frac{V_{ds}}{\beta_2 + \beta_1 V_{ds} + \beta_0 V_{ds}^2}}$$

In this expression, the parasitic BJT effect current is modeled as

- $I_{iiMod} = 0$

$$I_{ii_BJT} = F_{bji} I_c$$

$$V_{diff} = V_{ds} - V_{dsatii}$$

$$V_{dsatii} = V_{gsStep} + \left(V_{dsatii0} \left(1 + T_{ii} \left(\frac{T}{T_{nom}} - 1 \right) \right) - \frac{L_{ii}}{L_{eff}} \right)$$

$$V_{gsStep} = \left(\frac{E_{satii} L_{eff}}{1 + E_{satii} L_{eff}} \right) \left(\frac{1}{1 + S_{ii1} V_{gsteff}} + S_{ii2} \left(\frac{S_{ii0} V_{gst}}{1 + S_{iid} V_{ds}} \right) \right)$$

- $I_{iiMod} = 1$

$$I_{ii_BJT} = \frac{CBJTII + EBJTII \cdot L_{eff}}{L_{eff}} I_c (V_{bci} - V_{bd}) e^{-ABJTII \cdot (V_{bci} - V_{bd})^{(MBJTII-1)}}$$

$$V_{bci} = VBCI \left(1 + TVBCI \left(\frac{T}{T_{nom}} - 1 \right) \right)$$

If body contact is applied, there is one more bulk contact current flow into bulk. It is modeled as:

$$I_{bp} = \frac{V_{bp}}{R_{bp} + R_{bodyext}}$$

$$R_{bp} = \left(R_{body} \frac{W'_{eff}}{L_{eff}} \right) \parallel \left(R_{halo} \frac{W'_{eff}}{2} \right)$$

$$R_{bodyext} = R_{bsh} N_{rb}$$

Leakage current

Gate Induced Source/Drain Leakage Current is modeled as:

gidlMod = 0

$$I_{GIDL} = A_{GIDL} \cdot W_{diod} \cdot Nf \frac{V_{ds} - V_{gse} - E_{GIDL} + V_{fbsd}}{3T_{oxe}} e^{-\frac{\alpha_{oxe} E_{GIDL}}{V_{ds} - V_{gse} - E_{GIDL}}} \frac{V_{db}^3}{C_{GIDL} + V_{db}^3}$$

$$I_{GISL} = A_{GISL} \cdot W_{dios} \cdot Nf \frac{-V_{ds} - V_{gde} - E_{GISL} + V_{fbsd}}{3T_{oxe}} e^{-\frac{3T_{oxe} E_{GISL}}{-V_{ds} - V_{gde} - E_{GISL}}} \frac{V_{sb}^3}{C_{GISL} + V_{sb}^3}$$

gidlMod = 1

$$I_{GIDL} = A_{GIDL} \cdot W_{diod} \cdot Nf \frac{V_{ds} - R_{GIDL} V_{gse} - E_{GIDL} + V_{fbsd}}{3T_{oxe}} e^{-\frac{3T_{oxe} E_{GIDL}}{V_{ds} - V_{gse} - E_{GIDL}}} e^{\frac{K_{GIDL}}{V_{db} - F_{GIDL}}}$$

$$I_{GISL} = A_{GISL} \cdot W_{dios} \cdot Nf \frac{-V_{ds} - R_{GISL} V_{gde} - E_{GISL} + V_{fbsd}}{3T_{oxe}} e^{-\frac{3T_{oxe} E_{GISL}}{-V_{ds} - V_{gde} - E_{GISL}}} e^{\frac{K_{GISL}}{V_{sb} - F_{GISL}}}$$

For thin oxide (below 2nm), oxide tunneling is important in the determination of floating-body potential. In inversion, the tunneling current is:

$$J_{gb} = A \frac{V_{gb} V_{aux}}{T_{ox}^2} \left(\frac{T_{oxref}}{T_{oxqm}} \right)^{N_{tox}} e^{\frac{-B(\alpha_{gb1} - \beta_{gb1} |V_{ox}|) |V_{ox}|}{1 - \frac{|V_{ox}|}{V_{gb1}}}}$$

$$V_{aux} = V_{EVB} \ln \left(1 + e^{\frac{|V_{ox}| - \phi_b}{V_{EVB}}} \right)$$

$$A = \frac{q^3}{8\pi h \phi_b}$$

$$B = \frac{8\pi \sqrt{2m_{ox}} \phi_b^{3/2}}{3hq}$$

$$\phi_b = 4.2eV$$

$$m_{ox} = 0.3m_0$$

In accumulation, the tunneling current is:

$$J_{gb} = A \frac{V_{gb} V_{aux}}{T_{ox}^2} \left(\frac{T_{oxref}}{T_{oxqm}} \right)^{N_{tox}} e^{\frac{-B(\alpha_{gb2} - \beta_{gb2} |V_{ox}|) V_{ox}}{1 - \frac{|V_{ox}|}{V_{gb2}}}}$$

$$V_{aux} = V_{ECB} \ln \left(1 + e^{\frac{V_{gb} - V_{fb}}{V_{ECB}}} \right)$$

$$A = \frac{q^3}{8\pi h \phi_b}$$

$$B = \frac{8\pi \sqrt{2m_{ox}} \phi_b^{3/2}}{3hq}$$

$$\phi_b = 3.2eV$$

$$m_{ox} = 0.4m_0$$

In BSIMSOI4.1, the instance parameter Agbcp2 represents the parasitic gate to body overlap area due to the body contact. This parameter applies for the opposite-type gate. The tunneling current in this region is modeled as:

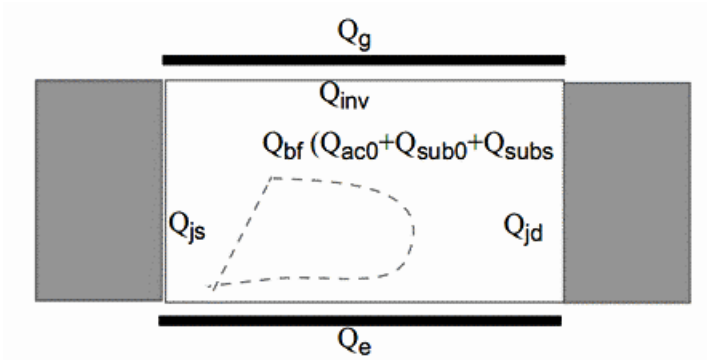
$$I_{g_agbcp2} = A \cdot A_{agbcp2} \min(V_{gp} - V_{fb2}, 0) \cdot V_{gp_eff} T_{oxRatio} e^{-B \cdot T_{oxqm} (A_{IGBCP2} - B_{IGBCP2} V_{gp_eff}) (1 + C_{IGBCP2} V_{gp_eff})}$$

$$V_{gp_eff} = 0.5 \left(\sqrt{(V_{gp} - V_{fb2})^2 + \delta^2} - (V_{gp} - V_{fb2}) - \delta \right)$$

$$\delta = 0.01$$

Charge and Capacitance

The following is the schematic of Charge model in BSIMSOI model.



For intrinsic charge, BSIMSOI PD model uses similar expressions to BSIM_{3V3} for inversion charge (Q_{inv}) and front gate body charge (Q_{Bf}). The bulk charge constant A_{bulkCV} is defined as:

$$A_{bulkCV} = A_{bulk0} \left(1 + \left(\frac{CLC}{L_{active}} \right)^{CLE} \right)$$

$$A_{bulk0} = A_{bulk} (V_{gsteff} = 0)$$

The effective CV V_{gst} has two equations selected by model parameter `vgstcvmod`:

vg4stcvmod = 0 and 1

$$V_{gsteffCV} = nV_f \ln \left(1 + e^{\frac{V_{gs} - V_{th}}{nV_f}} \cdot e^{-\frac{delvt}{nV_f}} \right)$$

The difference between `vgstcvmod = 0` and `1` is that `vgstcvmod = 1` fixed the bug of `vgstcvmod = 0`. The default value for `vgstcvmod` has been changed to `1` from `0` after BSIMSOI model version 4.2.

vgstcvmod = 2

$$V_{gsteffCV} = \frac{nV_t \ln \left(1 + e^{\frac{m^{*CV} (V_{gs_eff} - V_{th} - delvt)}{nV_t}} \right)}{m^{*CV} + nC_{ox} \sqrt{\frac{2\phi_s}{q\epsilon_{si} N_{dep}}} e^{\frac{(1-m^{*CV})(V_{gs_eff} - V_{th} - delvt) - V_{offCV}}{nV_t}}}$$

$$m^{*CV} = 0.5 + \frac{\arctan(MINCV)}{\pi}$$

Then the inversion charge can be expressed as:

$$Q_{inv} = -W_{active} L_{active} C_{ox} \left(\left(V_{gsteffCV} - \frac{A_{bulkCV}}{2} V_{dsCV} \right) + \frac{A_{bulkCV}^2 V_{dsCV}^2}{12 \left(V_{gsteffCV} - \frac{A_{bulkCV}}{2} V_{dsCV} \right)} \right)$$

$$V_{dsCV} = V_{dsatCV} - \frac{1}{2} \left(V_{dsatCV} - V_{ds} - \delta + \sqrt{(V_{dsatCV} - V_{ds} - \delta)^2 + 4\delta V_{dsatCV}} \right)$$

$$V_{dsatCV} = V_{gsteffCV} / A_{bulkCV}$$

The accumulation charge can be calculated as:

$$Q_{ac0} = -F_{body} W_{active} L_{active} C_{ox} (V_{FBeff} - V_{fb})$$

$$V_{FBeff} = V_{fb} - 0.5 \left((V_{fb} - V_{gb} - \delta) + \sqrt{(V_{fb} - V_{gb} - \delta)^2 + \delta^2} \right)$$

$$V_{gb} = V_{gs} - V_{bseff}$$

$$V_{fb} = V_{th} - \phi_s - K_{1eff} \sqrt{\phi_s - V_{bseff}}$$

The gate-induced depletion charge and drain-induced depletion charge can be expressed as:

$$Q_{sub0} = -F_{body} W_{active} L_{activeE} C_{ox} \frac{K_{1eff}^2}{2} \left(-1 + \sqrt{1 + \frac{4(V_{gs} - V_{FEff} - V_{gsteffCV} - V_{bseff})}{K_{1eff}^2}} \right)$$

$$Q_{subs} = F_{body} W_{active} L_{activeE} K_{1eff} C_{ox} (1 - A_{bulkCV}) \left(\frac{V_{dsCV}}{2} - \frac{A_{bulkCV} V_{dsCV}^2}{12(V_{gsteffCV} - A_{bulkCV} V_{dsCV}/2)} \right)$$

The back gate body charge can be modeled by

$$Q_e = F_{body} W_{active} L_{activeEG} C_{box} (V_{es} - V_{jbb} - V_{bseff})$$

For `capmod=3`, the flat band voltage is calculated from the bias-independent threshold voltage, which is different from `capMod=2`.

In BSIMSOI PD model, both the depletion and diffusion capacitance of the junction are considered. The diffusion charges Q_{bddif}/Q_{bsdif} are modeled as:

$$Q_{bsdif} = \tau \frac{W'_{eff}}{N_{seg}} T_{si} J_{sbf} \left(1 + L_{dif0} \left(L_{bj0} \left(\frac{1}{L_{eff}} - \frac{1}{L_n} \right) \right)^{N_{dif}} \right) \left(e^{\frac{V_{bs}}{n_{dio} V_t}} - 1 \right) \frac{1}{\sqrt{E_{hlis} + 1}}$$

$$Q_{bddif} = \tau \frac{W'_{eff}}{N_{seg}} T_{si} J_{dbf} \left(1 + L_{dif0} \left(L_{bj0} \left(\frac{1}{L_{eff}} - \frac{1}{L_n} \right) \right)^{N_{dif}} \right) \left(e^{\frac{V_{bd}}{n_{dio} V_t}} - 1 \right) \frac{1}{\sqrt{E_{hlid} + 1}}$$

The depletion charges Q_{bddep}/Q_{bsdep} are modeled as:

$$Q_{bsdep} = W_{dioCV} C_{jswgs} \frac{T_{si}}{10^{-7}} \frac{P_{bswgs}}{1 - M_{jswgs}} \left(1 - \left(1 - \frac{V_{bs}}{P_{bswgs}} \right)^{1 - M_{jswgs}} \right)$$

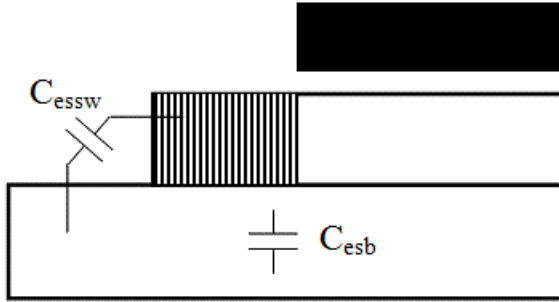
$$Q_{bddep} = W_{dioCV} C_{jswgd} \frac{T_{si}}{10^{-7}} \frac{P_{bswgd}}{1 - M_{jswgd}} \left(1 - \left(1 - \frac{V_{bd}}{P_{bswgd}} \right)^{1 - M_{jswgd}} \right)$$

Virtuoso Simulator Components and Device Models Reference
BSIMSOI MOSFET Model (bsimsoi)

For $capmod=3$, the inversion charge layer thickness is given by:

$$X_{dc} = \frac{ADOS \times 1.9 \times 10^{-9} m}{1 + \left(\frac{V_{gsteff} + 4(V_{TH0} - V_{FB} - \Phi_s)}{2TOXP} \right) 0.7 \times BDOS}$$

Expressions for source/drain-to-gate overlap capacitance and source/drain-to-gate fringing capacitance are taken from BSIM3v3. New SOI-specific parameters added are substrate-to-source sidewall capacitance (C_{esw}), substrate-to-drain sidewall capacitance (C_{edw}), substrate-to-source bottom capacitance (C_{esb}), and substrate-to-drain bottom capacitance (C_{edb}). The following figure shows the BSIMSOI extrinsic charge components.



The substrate-to-source bottom capacitance (per unit source/drain area) C_{esb} is:

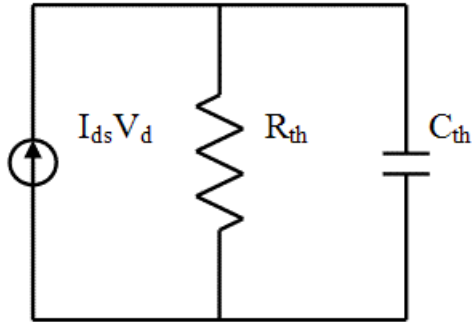
$$C_{esb} = \begin{cases} C_{box} & \text{if } V_{se} < V_{sdfb} \\ C_{box} - \frac{1}{A_{sd}} (C_{box} - C_{min}) \left(\frac{V_{se} - V_{sdfb}}{V_{sdth} - V_{sdfb}} \right)^2 & \text{elseif } V_{se} < V_{sdfb} + A_{sd} (V_{sdth} - V_{sdfb}) \\ C_{min} - \frac{1}{1 - A_{sd}} (C_{box} - C_{min}) \left(\frac{V_{se} - V_{sdth}}{V_{sdth} - V_{sdfb}} \right)^2 & \text{elseif } V_{se} < V_{sdth} \\ C_{min} & \text{else} \end{cases}$$

The sidewall source/drain to substrate capacitance (per unit source/drain perimeter length) $C_{s/d,esw}$ is:

$$C_{s/d,esw} = C_{sdesw} \log \left(1 + \frac{T_{si}}{T_{box}} \right)$$

Selfheating

An equivalent circuit for self-heating simulation is shown below:



BSIMPD models the self-heating by an auxiliary $R_{th}C_{th}$ circuit shown in the figure above. The temperature node (T node) is created in SPICE simulation if the self-heating selector shMod is on and the thermal resistance is non-zero. The T node is treated as a voltage node and is connected to ground through a thermal resistance R_{th} and a thermal capacitance C_{th} .

$$R_{th} = \frac{R_{th0}}{W_{eff}' + W_{th0}}$$

$$C_{th} = C_{th0} (W_{eff}' + W_{th0})$$

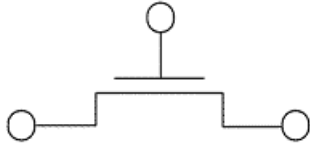
where R_{th0} and C_{th0} are normalized thermal resistance and capacitance respectively. W_{th0} is the minimum width for thermal resistance calculation. The current source is driving a current equal to the power dissipated in the device.

$$P = |I_{ds} V_{ds}|$$

RF model

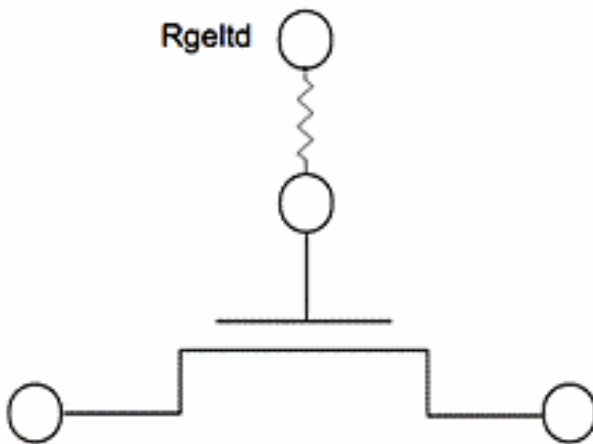
BSIMSOI provides the gate resistance model used in RF application. You have the following options for modeling gate electrode resistance (bias independent) and intrinsic-input resistance (R_{ij} , bias-dependent):

RgateMod=0 (zero-resistance)



In this case, no gate resistance is generated.

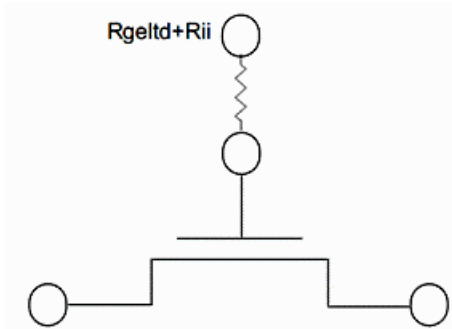
RgateMod=1 (constant-resistance)



In this case, only electrode gate resistance (bias-independent) is generated by adding an internal gate node. The electrode gate resistance is given by

$$R_{geltd} = \frac{R_{SHG} \left(X_{GW} + \frac{W_{eff}}{3N_{GCON} \cdot N_{seg}} \right)}{N_{GCON} (L_{drawn} - X_{GL})}$$

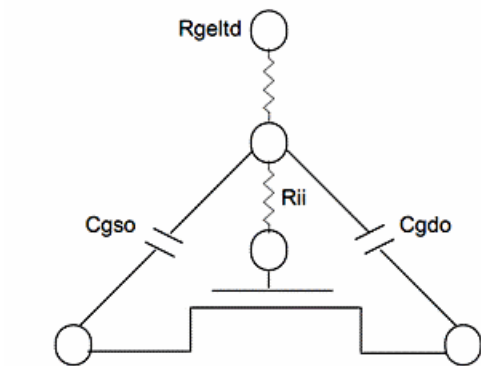
RgateMod=2 (R_{||} model with variable resistance)



The gate resistance here is the sum of the electrode resistance and the intrinsic-input resistance R_{ii} , as given by:

$$\frac{1}{R_{ii}} = X_{RGRFG1} \left(\frac{I_{ds}}{V_{dseff}} + X_{RCRG2} \frac{W_{eff} \mu_{eff} C_{oxeff} k_B T}{qL_{eff}} \right)$$

RgateMod=3 (R_{||} model with two nodes)



The gate electrode resistance here is in series with the intrinsic-input resistance R_{ii} through the two internal gate nodes so the overlap capacitance current does not pass through the intrinsic-input resistance.

Noise

In BSIMSOI model, flicker noise and thermal noise models are compatible with BSIM4. Gate tunneling induced shot noise and thermal noise due to gate electrode resistance are also included.

Two flicker noise models are provided in BSIMSOI model:

fnoiMod=0

$$S_{id}(f) = \left(\frac{W_{eff}}{W_{0FLK}} \right)^{1-\alpha_f} \frac{K_f I_{ds}^{\alpha_f}}{C_{oxe} L_{eff}^2 f^{\alpha_f}}$$

fnoiMod=1

The noise density in inversion region is given by:

$$S_{id,inv}(f) = \frac{k_B T q^2 \mu_{eff} I_{ds}}{C_{oxe} L_{eff}^2 A_{bulk} f^{\alpha_f} \cdot 10^{10}} \left(Noia \left(\frac{N_0 + N^*}{N_i + N^*} \right) + Noib(N_0 - N_i) + \frac{Noic}{2} (N_0^2 - N_i^2) \right) + \frac{k_B T \cdot I_{ds}^2 \Delta L_{clm}}{W_{eff} L_{eff}^2 f^{\alpha_f} \cdot 10^{10}} \frac{Noia + Noib \cdot N_i + Noic \cdot N_i^2}{(N_i + N^*)^2}$$

The noise density in subthreshold region is given by:

$$S_{id,subV_t}(f) = \frac{Noia \cdot k_B T \cdot I_{ds}^2}{W_{eff} L_{eff} f^{\alpha_f} (N^*)^2 \cdot 10^{10}}$$

The total flicker noise density is:

$$S_{id}(f) = \frac{S_{id,inv}(f) \times S_{id,subV_t}(f)}{S_{id,inv}(f) + S_{id,subV_t}(f)}$$

Following thermal noise models are provided in BSIMSOI model:

tnoiMod=0

$$\overline{i_d^2} = \frac{4k_B T \Delta f}{R_{ds} + \frac{L_{eff}^2}{\mu_{eff} |Q_{inv}|}} N_{tnoi}$$

tnoiMod=1

The noise voltage source partitioned to the source side is given by:

$$\overline{v_d^2} = 4k_B T \cdot \theta_{tnoi}^2 \frac{V_{dseff} \Delta f}{I_{ds}}$$

The noise current source put in the channel region with gate and body amplification is given by:

$$\overline{i_d^2} = 4k_B T \frac{V_{dseff} \Delta f}{I_{ds}} (G_{ds} + \beta_{tnoi} (G_m + G_{mbs}))^2 - \overline{v_d^2} (G_{ds} + G_m + G_{mbs})^2$$

The junction currents (I_{bs} , I_{bd}) for shot noise (fb_ibs, fb_ibd) are given by:

$$\overrightarrow{I_{bs}^2} = 2qI_{bs} = 2q(I_{bs1} + I_{bs2} + I_{bs3} + I_{bs4})$$

$$\overrightarrow{I_{bd}^2} = 2qI_{bd} = 2q(I_{bd1} + I_{bd2} + I_{bd3} + I_{bd4})$$

tnoimod=2 (SPICE2 model)

$$\overline{i_d^2} = \frac{8k_B T \Delta f}{3} \cdot NTNOI \cdot (G_m + G_{mbs} + G_{ds})$$

The NTNOI parameter provides the flexibility to tune the magnitude of noise density.

tnomod=3

In this noise model, noise for both gate and drain is implemented as current noise sources. The drain current noise flows from drain to source, whereas the induced gate current noise flows from gate to source and drain. The correlatoin between the two noise sources can be tuned with the parameter RNOIC.

$$V_b = \frac{V_{gsteff} + 2v_t}{A_{bulk}}$$

$$\eta = 1 - \frac{V_{dseff}}{V_b}$$

$$L_{vsat} = L_{eff} \cdot \left[1 + \frac{V_{dseff}}{E_{sat}L_{eff}} \right]$$

$$\alpha = A_{bulk}$$

$$\gamma = \frac{L}{L_{vsat}} \left[\frac{1 + \eta}{2} + \frac{(1 - \eta)^2}{6 \left[(1 + \eta) + \frac{2\alpha V_t}{V_{gsteff}} \right]} \right]$$

$$\delta = \frac{1}{6} \left(\frac{L_{vsat}}{L} \right)^3 \left[\frac{1 + \eta}{\left[(1 + \eta) + \frac{2\alpha V_t}{V_{gsteff}} \right]^2} - \frac{\left[6(1 + \eta) + \frac{2\alpha V_t}{V_{gsteff}} \right] (1 - \eta)^2}{15 \left[(1 + \eta) + \frac{2\alpha V_t}{V_{gsteff}} \right]^4} + \frac{(1 - \eta)^4}{9 \left[(1 + \eta) + \frac{2\alpha V_t}{V_{gsteff}} \right]^5} \right]$$

$$\epsilon = \frac{1}{6} \cdot \frac{L_{vsat}}{L} \left[\frac{1 - \eta}{\left[(1 + \eta) + \frac{2\alpha V_t}{V_{gsteff}} \right]} + \frac{(1 - \eta)^3}{3 \left[(1 + \eta) + \frac{2\alpha V_t}{V_{gsteff}} \right]^3} \right]$$

$$n_c = RNOIC \cdot \left[1 + TNOIC \cdot L_{eff} \cdot \left(\frac{V_{gsteff}}{E_{sat}L_{eff}} \right)^2 \right]$$

$$C_{tnoi} = \frac{\epsilon}{\sqrt{\gamma \cdot \delta}} \cdot \left(\frac{n_c}{0.395} \right)$$

$$n_\beta = RNOIA \cdot \left[1 + TNOIA \cdot L_{eff} \cdot \left(\frac{V_{gsteff}}{E_{sat}L_{eff}} \right)^2 \right]$$

$$n_{\theta} = RNOIB. \left[1 + TNOIB. L_{eff} \cdot \left(\frac{V_{gsteff}}{E_{sat} L_{eff}} \right)^2 \right]$$

$$g_{d0} = NF \times \frac{\mu_{eff} C_{oxeff} \frac{W_{eff}}{L_{eff}} V_{gsteff}}{1 + g_{che} \cdot R_{ds}}$$

$$S_{id} = 4kT \cdot \gamma \cdot (3n_{\beta}^2) g_{d0}$$

$$C_0 = NF \times C_{oxeff} W_{eff, CV} L_{eff, CV}$$

$$sf = \frac{g_{d0}}{\sqrt{\delta \times 3.75 \times n_{\theta}^2 / \gamma}}$$

$$I(di, si) <+ white_noise \left(S_{id} \times |1 - c_{tnoi}^2| \right)$$

$$I(N) <+ V(N) \times sf \times SCALEN$$

$$I(N) <+ white_noise \left(\frac{S_{id}}{sf^2 \times SCALEN^2} \right)$$

$$I(di, si) <+ c_{tnoi} \times V(N) \times sf \times SCALEN$$

$$I(gi, si) <+ ddt(0.5 \times C_0 \times SCALEN \times V(N))$$

$$I(gi, di) <+ ddt(0.5 \times C_0 \times SCALEN \times V(N))$$

Component Statements

This device is supported within altergroups.

Instance Parameters

1 w (m) Channel width(alias=lv2).

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BSIMSOI MOSFET Model (bsimsoi)

2	l (m)	Channel length(alias=lv1).
3	$nf=1.0$	Number of fingers.
4	as (m^2)	Area of source diffusion(alias=lv4).
5	ad (m^2)	Area of drain diffusion(alias=lv3).
6	ps (m)	Perimeter of source diffusion(alias=lv12).
7	pd (m)	Perimeter of drain diffusion(alias=lv11).
8	nrd (m/m)	Number of squares of drain diffusion.
9	nrs (m/m)	Number of squares of source diffusion.
10	nrb (m/m)	Number of body squares.
11	$nbc=0$ m/m	Number of body contact isolation edge.
12	$nseg=1$ m/m	Number of segments for channel width partitioning.
13	$pdbcpr=0$ m	Perimeter length for body contact parasitic at drain.
14	$psbcpr=0$ m	Perimeter length for body contact parasitic at source.
15	$agbcpr=0$ m^2	Gate to body overlap area for body contact parasitic.
16	$aebcpr=0$ m^2	Substrate to body overlap area for body contact parasitic.
17	$m=1$	Multiplicity factor (number of MOSFETs in parallel).
18	$soimod=0$	SOI model selector. SoiMod=0:PD module. SoiMod=1: DD module. SoiMod=2: FD module.
19	$rgatemod$	Rgate flag(available from Version 3.1).
20	$rbodymod$	Body R model selector.
21	$tnodeout$	Temperature node flag associated with T node(Given or NOT Given).

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

22	<code>isnoisy=yes</code>	Should device generate noise. Possible values are <code>no</code> and <code>yes</code> .
23	<code>region=triode</code>	Estimated operating region. Possible values are <code>off</code> , <code>triode</code> , <code>sat</code> , and <code>subth</code> .
24	<code>rth0 ((m C)/w)</code>	Thermal resistance.
25	<code>cth0 (w s/(m C))</code>	Thermal capacitance.
26	<code>bjtoff=0</code>	BJT off flag.
27	<code>vbsusr=0 V</code>	Optional initial value of <code>Vbs</code> for transient.
28	<code>frbody=1</code>	Layout dependent body-resistance coefficient.
29	<code>sa=0 m</code>	Distance between OD edge to poly of one side.
30	<code>sb=0 m</code>	Distance between OD edge to poly of the other side.
31	<code>sd=0 m</code>	Distance between neighbor fingers.
32	<code>rbdb (Ω)</code>	Body resistance.
33	<code>rbsb (Ω)</code>	Body resistance.
34	<code>agbcpd=agbcp m²</code>	Gate to body overlap area for bc parasitics in DC.
35	<code>agbcp2=0 m²</code>	Parasitic Gate to body overlap area for bc parasitics.
36	<code>delvto=0 V</code>	Zero bias threshold voltage variation.
37	<code>trise (C)</code>	Temperature rise from ambient.

Note:

1. `tnodeout` is a flag parameter of instance. If it is specified and the instance has more than 4 terminals, then the last terminal is interpreted as temperature node. It does not need to assign any value for this parameter. `tnodeout`, `tnodeout=0` and `tnodeout=1` all indicate that `tnodeout` is specified in instance statement, it will treat the last terminal as temperature terminal.
2. `region` can set the initial device work state for simulator, a correct `region` value can help simulator converge faster but will not effect the final result.

Model Parameters

Device type parameters

1	<code>type=n</code>	Transistor type. Possible values are <code>n</code> and <code>p</code> .
2	<code>version=3.0</code>	Model parameter "version" only accepts real number value, like 2.23 for version=2.2.3. The available version is 2.23(2.2.3), 3.0, 3.11(3.1.1), 3.2, 4.0, 4.1, 4.2, 4.3, 4.31(4.3.1), 4.4 and 4.5.
3	<code>binunit=1</code>	Bin parameter unit selector. 1 for microns and 2 for meters.
4	<code>cdnver=1</code>	Cadence version selector.
5	<code>soimod=0</code>	SOI model selector. SoiMod=0: PD module. SoiMod=1: DD module. SoiMod=2: FD module.
6	<code>mtrlmod=0</code>	parameter for non-silicon substrate or metal gate selector.
7	<code>mobmod=1</code>	Mobility model selector.
8	<code>fdmod=0</code>	Improved dVbi model selector.
9	<code>gidlmod=0</code>	parameter for GIDL selector.
10	<code>gatetype=h</code>	Gate structure type selector. Possible values are <code>h</code> and <code>non_h</code> .
11	<code>capmod=2</code>	Intrinsic charge model.
12	<code>vgstcvmod=0</code>	Improved VgsteffCV selector.
13	<code>igmod=0</code>	Gate tunneling current model selector.
14	<code>igbmod=0</code>	Gate-body tunneling current model selector.
15	<code>igcmmod=0</code>	Gate-channel tunneling current model selector.
16	<code>iiimod=0</code>	parameter for Iii selector.
17	<code>rbodymod=0</code>	Body R model selector.

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

18	<code>rdsmod=0</code>	Bias-dependent S/D resistance model selector.
19	<code>rgatemod=0</code>	Rgate flag.
20	<code>shmod=0</code>	Self-heating selector.
21	<code>tlev=0</code>	DC temperature selector.
22	<code>tlevc=0</code>	AC temperature selector.
23	<code>noimod=1</code>	Noise model selector.
24	<code>fnoimod=1</code>	Flicker Noise model selector.
25	<code>tnoimod=0</code>	Thermal Noise model selector.

Process parameters

26	<code>nsub=6e16 cm⁻³</code>	Substrate doping concentration.
27	<code>nch=1.7e17 cm⁻³</code>	Peak channel doping concentration.
28	<code>ngate=0 cm⁻³</code>	Poly-gate doping concentration.
29	<code>nsd=1.0e20 cm⁻³</code>	S/D doping concentration.
30	<code>xj=0.15e-6 m</code>	Source/drain junction depth.
31	<code>tsi=1e-7 m</code>	Silicon film thickness.
32	<code>etsi=1e-7 m</code>	Effective Silicon-on-insulator thickness in meters.
33	<code>tbox=3e-7 m</code>	Buried oxide thickness.
34	<code>tox=1e-8 m</code>	Gate oxide thickness.
35	<code>toxm (m)</code>	Gate oxide thickness used in extraction.
36	<code>toxp=tox</code>	Physical gate oxide thickness.
37	<code>xt=1.55e-7 m</code>	Doping depth.

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

38	$rdsw=100 \Omega \mu m^{wr}$	Width dependence of drain-source resistance.
39	$prwb=0 \text{ } 1/ V$	Body-effect coefficient for Rds.
40	$prwg=0 \text{ } 1/V$	Gate-effect coefficient for Rds.
41	$wr=1$	Width offset for parasitic resistance.
42	$dwg=0 \text{ } m/V$	Gate-bias dependence of channel width.
43	$dwb=0 \text{ } m/ V$	Body-bias dependence of channel width.
44	$dwbc=0 \text{ } m$	Width offset for body contact isolation edge.
45	$lint=0 \text{ } m$	Lateral diffusion for one side.
46	$wint=0 \text{ } m$	Width reduction for one side.
47	$ll=0 \text{ } m^{lln}$	Length dependence of delta L.
48	$lln=1$	Length exponent of delta L.
49	$llc=0 \text{ } m^{lln}$	Length dependence of delta LC.
50	$lwc=0 \text{ } m^{wln}$	Width dependence of delta LC.
51	$lwlc=0 \text{ } m^{(lln+lwn)}$	Area dependence of delta LC.
52	$lw=0 \text{ } m^{lwn}$	Width dependence of delta L.
53	$lwn=1$	Width exponent of delta L.
54	$lwl=0 \text{ } m^{(lln+lwn)}$	Area dependence of delta L.
55	$wl=0 \text{ } m^{wln}$	Length dependence of delta W.
56	$wlc=0 \text{ } m^{wln}$	Length dependence of delta WC.
57	$wwc=0 \text{ } m^{wwn}$	Width dependence of delta WC.

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

- 58 $wwlc=0 \text{ m}^{(wwn+wln)}$ Area dependence of delta WC.
- 59 $wln=1$ Length exponent of delta W.
- 60 $ww=0 \text{ m}^{wwn}$ Width dependence of delta W.
- 61 $wwn=1$ Width exponent of delta W.
- 62 $wwl=0 \text{ m}^{(wwn+wln)}$ Area dependence of delta W.
- 63 $xl=0 \text{ m}$ Length variation due to masking and etching.
- 64 $xw=0 \text{ m}$ Width variation due to masking and etching.

Material model parameters (Version 4.1 or later)

- 65 $eot=100.0e-10 \text{ m}$ Effective SiO2 thickness.
- 66 $epsrox=3.9$ Dielectric constant of the gate oxide relative to vacuum.
- 67 $epsrsub=11.7$ Dielectric constant of substrate relative to vacuum.
- 68 $ni0sub=1.45e10 \text{ cm}^{-3}$ Intrinsic carrier concentration of substrate at Tnom.
- 69 $bg0sub=1.16 \text{ eV}$ Band-gap of substrate at T=0K.
- 70 $tbgasub=7.02e-4 \text{ V/K}$ First parameter of band-gap change due to temperature.
- 71 $tbgbsub=1108.0 \text{ K}$ Second parameter of band-gap change due to temperature.
- 72 $phig=4.05 \text{ eV}$ Work function of gate.
- 73 $easub=4.05 \text{ eV}$ Electron affinity of substrate.
- 74 $leffeot=1.0 \text{ }\mu\text{m}$ Effective length for extraction of EOT.
- 75 $weffeot=10.0 \text{ }\mu\text{m}$ Effective width for extraction of EOT.
- 76 $vddeot=1.5 \text{ V}$ Voltage for extraction of EOT.

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

77	<code>tempeot=300.15 K</code>	Temperature for extraction of EOT.
78	<code>ados=1.0</code>	Charge centroid parameter.
79	<code>bdos=1.0</code>	Charge centroid parameter.
80	<code>epsrgate=11.7</code>	Dielectric constant of gate relative to vacuum.

Threshold voltage parameters

81	<code>vtho (V)</code>	Threshold voltage at zero body bias for long-channel devices. For enhancement-mode devices, $v_{tho} > 0$ for n-channel and $v_{th} < 0$ for p-channel. Default value is calculated from other model parameters.
82	<code>k1=0.53 V</code>	Body-effect coefficient.
83	<code>k1w1=0 m</code>	First body effect width dependent parameter.
84	<code>k1w2=0 m</code>	Second body effect width dependent parameter.
85	<code>k2=-0.0186</code>	Charge-sharing parameter.
86	<code>k3=0</code>	Narrow width coefficient.
87	<code>k3b=0 1/V</code>	Narrow width coefficient.
88	<code>w0=2.5e-6 m</code>	Narrow width coefficient.
89	<code>lpe0=1.74e-7 m</code>	Lateral nonuniform doping coefficient.
90	<code>n1x=1.74e-7 m</code>	Lateral nonuniform doping coefficient.
91	<code>lpeb=0 m</code>	Lateral non-uniform doping effect for body bias.
92	<code>dvt0=2.2</code>	First coefficient of short-channel effects.
93	<code>dvt1=0.53</code>	Second coefficient of short-channel effects.
94	<code>dvt2=-0.032 1/V</code>	Body-bias coefficient of short-channel effects.
95	<code>dvt0w=0</code>	First coefficient of narrow-width effects.

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BSIMSOI MOSFET Model (bsimsoi)

96	$dvt1w=5.3e6$	Second coefficient of narrow-width effects.
97	$dvt2w=-0.032$ 1/V	Body-bias coefficient of narrow-width effects.
98	$vbx=0$ V	Threshold voltage transition body voltage.
99	$vbm=-3$ V	Maximum applied body voltage.
100	$vfb=-1.0$ V	Flat Band Voltage.
101	$a0=1$	Nonuniform depletion width effect coefficient.
102	$b0=0$ m	Bulk charge coefficient due to narrow width effect.
103	$b1=0$ m	Bulk charge coefficient due to narrow width effect.
104	$a1=0$	No-saturation coefficient.
105	$a2=1$	No-saturation coefficient.
106	$ags=0$ 1/V	Gate-bias dependence of abulk.
107	$keta=-0.6$ 1/V	Body-bias coefficient for non-uniform depletion width effect.
108	$ketas=0$ V	Surface Potential adjustment for bulk charge effect.
109	$dvtp0=0$ m	First parameter for Vth shift due to pocket.
110	$dvtp1=0$ 1/V	Second parameter for Vth shift due to pocket.
111	$dvtp2=0$	Third parameter for Vth shift due to pocket.
112	$dvtp3=0$	Forth parameter for Vth shift due to pocket.
113	$dvtp4=0$	Fifth parameter for Vth shift due to pocket.
114	$minv=0$	For moderate inversion in Vgsteff.
115	$pdits=1e-20$ 1/V	Coefficient for drain-induced Vth shifts.
116	$pditsl=0$ 1/m	Length dependence of drain-induced Vth shifts.
117	$pditsd=0$ 1/V	Vds dependence of drain-induced Vth shifts.

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

118 $\gamma_{1=0}$ |V Body-effect coefficient near the surface.

119 $\gamma_{2=0}$ |V Body-effect coefficient in the bulk.

Mobility parameters

120 $\mu_0=670$ cm²/V s Low-field surface mobility at t_{nom} . Default is 250 for PMOS.

121 $v_{sat}=8e4$ m/s Carrier saturation velocity at t_{nom} .

122 $\mu_a=2.25e-9$ m/V First-order mobility reduction coefficient.

123 $\mu_b=5.87e-19$ m²/V² Second-order mobility reduction coefficient.

124 $\mu_c=-4.65e-11$ m/V² Body-bias dependence of mobility. Default is -0.046 and unit is 1/V for $mobmod=3$.

125 $\mu_d=0$ /m² Coulomb scattering factor of mobility.

126 $\mu_e=1.67$ Mobility exponent.

127 $\mu_{cs}=1.67$ Mobility exponent.

Subthreshold parameters

128 $c_{dsc}=2.4e-4$ F/m² Source/drain and channel coupling capacitance.

129 $c_{dscb}=0$ F/m² V Body-bias dependence of c_{dsc} .

130 $c_{dscd}=0$ F/m² V Drain-bias dependence of c_{dsc} .

131 $n_{factor}=1$ Subthreshold swing coefficient.

132 $c_{it}=0$ F/m² Interface trap parameter for subthreshold swing.

133 $v_{off}=-0.08$ V Threshold voltage offset.

134 $n_{off}=1.0$ 1/V C-V turn-on/off parameter.

135 $d_{sub}=d_{rout}$ DIBL effect in subthreshold region.

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136 $\text{eta0}=0.08$ DIBL coefficient subthreshold region.

137 $\text{etab}=-0.07 \text{ 1/V}$ Body-bias dependence of et0 .

Output resistance parameters

138 $\text{drout}=0.56$ DIBL effect on output resistance coefficient.

139 $\text{fprout}=0 \text{ V/}\mu\text{m}$
Rout degradation coefficient for pocket devices.

140 $\text{pclm}=1.3$ Channel length modulation coefficient.

141 $\text{pdiblc1}=0.39$ First coefficient of drain-induced barrier lowering.

142 $\text{pdiblc2}=8.6\text{e-}3$ Second coefficient of drain-induced barrier lowering.

143 $\text{pdiblcB}=0 \text{ 1/V}$ Body-effect coefficient for DIBL.

144 $\text{pvag}=0$ Gate dependence of Early voltage.

145 $\text{delta}=0.01 \text{ V}$ Effective drain voltage smoothing parameter.

Substrate current parameters

146 $\text{alpha0}=0 \text{ m/V}$ Substrate current impact ionization coefficient.

147 $\text{beta0}=0 \text{ 1/V}$ First V_{ds} dependent parameter of impact ionization current.

148 $\text{fbjtii}=0$ Fraction of bipolar current affecting the impact ionization.

149 $\text{beta1}=0$ Second V_{ds} dependent parameter of impact ionization current.

150 $\text{beta2}=0 \text{ V}$ Third V_{ds} dependent parameter of impact ionization current.

151 $\text{vdsatii0}=0.9 \text{ V}$ Nominal drain saturation voltage at threshold for impact ionization current.

152 $\text{vbci}=0 \text{ V}$ Internal B-C built-in potential.

153 $\text{tii}=0$ Temperature dependent parameter for impact ionization current.

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154	$l_{ii}=0$	Channel length dependent parameter at threshold for impact ionization current.
155	$esat_{ii}=1e7$ V/m	Saturation channel electric field for impact ionization current.
156	$s_{ii0}=0.5$ 1/V	First V_{gs} dependent parameter for impact ionization current.
157	$s_{ii1}=0.1$ 1/V	Second V_{gs} dependent parameter for impact ionization current.
158	$s_{ii2}=0$ 1/V	Third V_{gs} dependent parameter for impact ionization current.
159	$s_{iid}=0$ 1/V	V_{ds} dependent parameter of drain saturation voltage for impact ionization current.
160	$ebj_{tii}=0$ 1/V	Impact ionization parameter for BJT part.
161	$cbj_{tii}=0$ 1/m/V	Length scaling parameter for II BJT part.
162	$abj_{tii}=0$	Exponent factor for avalanche current.
163	$mbj_{tii}=0.4$	Internal B-C grading coefficient.

SOI specific parameters

164	$ngidl=1.2$ V	GIDL V_{ds} enhancement coefficient.
165	$egidl=1.2$ V	GIDL first parameter.
166	$agidl=0$ S	GIDL constant.
167	$bgidl=0$ V/m	GIDL exponential coefficient.
168	$cgidl=0$ V ³	GIDL v_b parameter.
169	$rgidl=1.0$ 1/V	GIDL v_g parameter.
170	$kgidl=0$ 1/V	GIDL v_b parameter.
171	$fgidl=0$ V	GIDL v_b parameter.
172	$egisl=egidl$	GISL first parameter.
173	$agisl=agidl$	GISL constant.

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174	<code>bgisl=bgidl</code>	GISL exponential coefficient.
175	<code>cgisl=cgidl</code>	GISL vb parameter.
176	<code>rgisl=Rgidl</code>	GISL vg parameter.
177	<code>kgisl=kgidl</code>	GISL vb parameter.
178	<code>fgisl=fgidl</code>	GISL vb parameter.
179	<code>ntun=10</code>	Reverse tunneling non-ideality factor.
180	<code>ntund=ntun</code>	Reverse tunneling non-ideality factor.
181	<code>ndioded=ndiode</code>	Diode non-ideality factor.
182	<code>nrecf0=2.0</code>	Recombination non-ideality factor at forward bias.
183	<code>nrecr0=10</code>	Recombination non-ideality factor at reversed bias.
184	<code>nrecf0d=nrecf0</code>	Recombination non-ideality factor at forward bias.
185	<code>nrecr0d=nrecr0</code>	Recombination non-ideality factor at reversed bias.
186	<code>isbjt=1e-6 A/m²</code>	BJT saturation current.
187	<code>isdif=0 A/m²</code>	Diffusion saturation current.
188	<code>isrec=1e-5 A/m²</code>	Recombination saturation current.
189	<code>istun=0 A/m²</code>	Tunneling saturation current.
190	<code>idbjt=isbjt A/m²</code>	BJT injection saturation current.
191	<code>iddif=isdif A/m²</code>	Body to source/drain injection saturation current.
192	<code>idrec=isrec A/m²</code>	Recombination saturation current.
193	<code>idtun=idtun A/m²</code>	Tunneling saturation current.
194	<code>ln=2e-6 m</code>	Electron diffusion length.
195	<code>vrec0=0 V</code>	Voltage dependent parameter for recombination current.

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196	<code>vtun0=0 V</code>	Voltage dependent parameter for tunneling current.
197	<code>vrec0d=vrec0 V</code>	Voltage dependent parameter for recombination current.
198	<code>vtun0d=vtun0 V</code>	Voltage dependent parameter for tunneling current.
199	<code>nbjt=1</code>	Power coefficient of channel length dependency for bipolar current.
200	<code>lbjt0=0.20e-6 m</code>	Reference channel length for bipolar current.
201	<code>vabjt=10 V</code>	Early voltage for bipolar current.
202	<code>aely=0 V/m</code>	Channel length dependency of early voltage for bipolar current.
203	<code>ahli=0</code>	High level injection parameter for bipolar current.
204	<code>ahlid=ahli</code>	High level injection parameter for bipolar current.
205	<code>ndiode=1</code>	Diode non-ideality factor.
206	<code>vbsa=0 V</code>	Non-ideal offset voltage.
207	<code>nofffd=1.0</code>	Smooth parameter in FD module.
208	<code>vofffd=0</code>	Smooth parameter in FD module.
209	<code>k1b=1.0</code>	First backgate body effect parameter.
210	<code>k2b=0</code>	Second backgate body effect parameter for short channel effect.
211	<code>dk2b=0</code>	Third backgate body effect parameter for short channel effect.
212	<code>dvbd0=0</code>	First short-channel effect parameter in FD module.
213	<code>dvbd1=0</code>	Second short-channel effect parameter in FD module.
214	<code>moinfd=1.0e3</code>	Gate bias dependence coefficient of surface potential.
215	<code>vbs0pd=0 V</code>	Upper bound of built-in potential lowering for PD operation.
216	<code>vbs0fd=0.5 V</code>	Lower bound of built-in potential lowering for FD operation.

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Parasitic resistance parameters

217	$r_{body}=0 \ \Omega$	Body resistance.
218	$r_{bsh}=0 \ \Omega$	Extrinsic body contact sheet resistance.
219	$r_{sh}=0 \ \Omega/\text{sqr}$	Source/drain diffusion sheet resistance.
220	$r_s=0 \ \Omega$	Source resistance.
221	$r_d=0 \ \Omega$	Drain resistance.
222	$r_{sc}=0 \ \Omega$	Source contact resistance.
223	$r_{dc}=0 \ \Omega$	Drain contact resistance.
224	$r_{sw}=50 \ \Omega$	Source resistance per width.
225	$r_{dw}=50 \ \Omega$	Drain resistance per width.
226	$r_{swmin}=0 \ \Omega$	Source resistance per width at high V_g .
227	$r_{dwmin}=0 \ \Omega$	Drain resistance per width at high V_g .
228	$r_{ss}=0 \ \Omega \ \text{m}$	Scalable source resistance.
229	$r_{dd}=0 \ \Omega \ \text{m}$	Scalable drain resistance.
230	$r_{halo}=1.0\text{e}15 \ \Omega/\text{sqr}$	Body halo sheet resistance.
231	$f_{rbody}=1$	Layout dependent body-resistance coefficient.
232	$minr=0.1 \ \Omega$	Minimum source/drain resistance.
233	$hdif=0 \ \text{m}$	Length of heavily doped diffusion.
234	$ldif=0 \ \text{m}$	Lateral diffusion beyond the gate.

Gate tunneling parameters

235	$ntox=1.0$	Power term of gate current.
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236	$\text{toxqm}=\text{Tox}$ m	Effective oxide thickness considering quantum effects.
237	$\text{toxref}=2.5\text{e-}9$ m	Target oxide thickness.
238	$\text{ebg}=1.2$ V	Effective bandgap in gate current calculation.
239	$\text{alphagb1}=0.35$	First V_{ox} dependent parameter for gate current in inversion.
240	$\text{betagb1}=0.03$	Second V_{ox} dependent parameter for gate current in inversion.
241	$\text{vgb1}=300$	Third V_{ox} dependent parameter for gate current in inversion.
242	$\text{vevb}=0.075$	Vaux parameter for valence-band electron tunneling.
243	$\text{nevb}=3.0$	Valence-band electron non-ideality factor.
244	$\text{alphagb2}=0.43$	First V_{ox} dependent parameter for gate current in accumulation.
245	$\text{betagb2}=0.05$	Second V_{ox} dependent parameter for gate current in accumulation.
246	$\text{vgb2}=17$	Third V_{ox} dependent parameter for gate current in accumulation.
247	$\text{vecb}=0.026$	Vaux parameters for conduction-band electron tunneling.
248	$\text{necb}=1.0$	Conduction-band electron non-ideality factor.
249	$\text{aigc}=0.43$	Parameter for I_{gc} .
250	$\text{bigc}=0.054$	Parameter for I_{gc} .
251	$\text{cigc}=0.075$ 1/V	Parameter for I_{gc} .
252	$\text{aigsd}=0.43$	Parameter for I_{gs}/I_{gd} .
253	$\text{bigsd}=0.054$	Parameter for I_{gs}/I_{gd} .
254	$\text{cigsd}=0.075$ 1/V	parameter for I_{gs}/I_{gd} .
255	$\text{nigc}=1.0$	Parameter for I_{gc} slope.
256	$\text{pigcd}=1.0$	Parameter for I_{gc} partition.

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257	<code>poxedge=1.0</code>	Factor for the gate edge T_{ox} .
258	<code>dlcig=lint m</code>	Delta Length for I_g model.
259	<code>voxh=5.0 V</code>	Limit of V_{ox} in gate current calculation.
260	<code>deltavox=0.005 V</code>	Smoothing parameter in the V_{ox} smoothing function.
261	<code>aigbcp2=0.043</code>	First V_{gp} dependent parameter for gate current in accumulation in AGBCP2 region.
262	<code>bigbcp2=0.0054</code>	Second V_{gp} dependent parameter for gate current in accumulation in AGBCP2 region.
263	<code>cigbcp2=0.0075</code>	Third V_{gp} dependent parameter for gate current in accumulation in AGBCP2 region.

Overlap capacitance parameters

264	<code>cgso=0 F/m</code>	Gate-source overlap capacitance.
265	<code>cgdo=0 F/m</code>	Gate-drain overlap capacitance.
266	<code>cgeo=0 F/m</code>	Gate-substrate overlap capacitance.
267	<code>cgbo=0 F/m</code>	Gate-bulk overlap capacitance.
268	<code>cgs1=0 F/m</code>	Gate-source overlap capacitance in LDD region.
269	<code>cgdl=0 F/m</code>	Gate-drain overlap capacitance in LDD region.
270	<code>ckappa=0.6</code>	Overlap capacitance fitting parameter.

Junction capacitance model parameters

271	<code>cjswg=1e-10 F/m²</code>	Zero-bias gate-side junction capacitance density.
272	<code>mjswg=0.5</code>	Gate-side junction grading coefficient.
273	<code>pbswg=0.7 V</code>	Gate-side junction built-in potential.

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BSIMSOI MOSFET Model (bsimsoi)

274	$cjswgd=cjswg$	F/m^2	Drain (gate side) sidewall junction capacitance per unit width.
275	$mjswgd=mjswg$	V	Drain (gate side) sidewall junction capacitance grading coefficient.
276	$pbswgd=pbswg$	V	Drain (gate side) sidewall junction capacitance built in potential.
277	$tt=1e-12$	s	Transit time.
278	$ndif=-1$		Power coefficient of channel length dependency for diffusion capacitance.
279	$ldif0=1$		Power coefficient of channel length dependency for diffusion capacitance.
280	$asd=0.3$		Source/Drain diffusion smoothing parameter.
281	$vsdfb$	(F/m)	Source/Drain diffusion flatband voltage.
282	$vsdth$		Source/Drain diffusion threshold voltage.
283	$csdmin$	(F)	Source/Drain diffusion bottom minimum capacitance.
284	$csdesw=0$	F/m	Source/drain sidewall fringing constant.

Charge model selection parameters

285	$cf=0$	F/m	Fringe capacitance parameter.
286	$cfrcoeff=1.0$		Sidewall fringe capacitance parameter.
287	$clc=1e-8$	m	Intrinsic capacitance fitting parameter.
288	$cle=0$		Intrinsic capacitance fitting parameter.
289	$dlc=lint$	m	Delta L for capacitance model.
290	$dlcb=0$	m	Length offset fitting parameter for body charge.
291	$dlbg=0$	m	Length offset fitting parameter for backgate charge.
292	$dwc=wint$	m	Delta W for capacitance model.

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BSIMSOI MOSFET Model (bsimsoi)

293	$\text{delvt}=0$ V	Threshold voltage adjustment for C-V.
294	$\text{fbody}=1.0$	Scaling factor for body charge.
295	$\text{voffcv}=-0.08$ V	CV Threshold voltage offset.
296	$\text{minvcv}=0$	For moderate inversion in VgsteffCV .
297	$\text{dtoxcv}=0$ m	Delta oxide thickness in Capmod3 .
298	$\text{kb1}=1$	Scaling factor for backgate charge.
299	$\text{kb3}=1$	Backgate coupling coefficient at subthreshold.
300	$\text{xpart}=0$	Drain/source channel charge partition in saturation for BSIM charge model, use 0.0 for 40/60, 0.5 for 50/50, or 1.0 for 0/100.
301	$\text{vsce}=0$ V	SCE parameter for improved dVbi model.
302	$\text{cdsbs}=0$ F/m ²	coupling from V_d to V_{bs} for improved dVbi model.

RF model parameters

303	$\text{rshg}=0.1$	Gate sheet resistance.
304	xrcrg1	First fitting parameter the bias-dependent R_g .
305	xrcrg2	Second fitting parameter the bias-dependent R_g .
306	ngcon	Number of gate contact.
307	xgw	Distance from gate contact center to device edge.
308	xgl	Variation in L_{drawn} .
309	$\text{rbdb}=50$ Ω	Resistance between bNode and dbNode.
310	$\text{rbsb}=50$ Ω	Resistance between bNode and sbNode.
311	$\text{gbmin}=1e-12$ S	Minimum body conductance.

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BSIMSOI MOSFET Model (bsimsoi)

Temperature effects parameters

312	$t_{nom}=27.0$ C	Parameters measurement temperature. Default set by <code>options</code> .
313	$t_{rise}=0$ C	Temperature rise from ambient.
314	$t_{max}=500$ C	Maximum device temperature above ambient.
315	$kt1=-0.11$ V	Temperature coefficient for threshold voltage.
316	$kt11=0$ V m	Temperature coefficient for threshold voltage.
317	$kt2=0.022$	Temperature coefficient for threshold voltage.
318	$a_t=3.3e4$ m/s	Temperature coefficient for v_{sat} .
319	$tc_{jswg}=0$ 1/K	Temperature coefficient of C_{jswg} .
320	$tp_{bswg}=0$ V/K	Temperature coefficient of P_{bswg} .
321	$tc_{jswgd}=tc_{jswg}$ 1/K	Temperature coefficient of C_{jswgd} .
322	$tp_{bswgd}=tp_{bswg}$ V/K	Temperature coefficient of P_{bswgd} .
323	$ua1=4.31e-9$ m/V	Temperature coefficient for u_a .
324	$ub1=-7.61e-18$ m ² /V ²	Temperature coefficient for u_b .
325	$uc1=-5.5e-11$ m/V ²	Temperature coefficient for u_c . Default is -0.056 for <code>mobmod=3</code> .
326	$ucste=-4.775e-3$ 1/K	Temperature coefficient of UCS.
327	$ud1=0$ /m ² /K	Temperature coefficient of u_d .
328	$prt=0$ Ω	Temperature coefficient for R_{ds} .
329	$ute=-1.5$	Mobility temperature exponent.

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330	$cth0=1e-5$ w s / (m C)	Self-heating thermal capacitance.
331	$rth0=0$ (m C) /w	Self-heating thermal resistance.
332	$ntrecf=0$	Temperature coefficient of Nref.
333	$ntreocr=0$	Temperature coefficient of Nrecr.
334	$xbjt=1$	BJT current temperature exponent.
335	$xdif=2$	Diffusion current temperature exponent.
336	$xrec=1$	Recombination current temperature exponent.
337	$xtun=0$	Tunneling current temperature exponent.
338	$xdifd=xdif$	Temperature coefficient for Iddif.
339	$xrecd=xrec$	Temperature coefficient for Idrec.
340	$xtund=xtun$	Temperature coefficient for Idtun.
341	$wth0=0$ μ m	Minimum width for thermal resistance calculation.
342	$tvbci=0$ V/K	Temperature coefficient for vbci.
343	$trs=0$ 1/C	Temperature parameter for source resistance.
344	$trd=0$ 1/C	Temperature parameter for drain resistance.

Noise model parameters

345	$tnoia=1.5$	Thermal noise parameter.
346	$tnoib=3.5$	Thermal noise parameter.
347	$rnoia=0.577$	Thermal noise coefficient.
348	$rnoib=0.37$	Thermal noise coefficient.
349	$ntnoi=1.0$	Thermal noise coefficient.

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350	<code>noif=1</code>	Floating body excess noise ideality factor.
351	<code>w0flk=0</code> m	Width constant for flicker noise equation.
352	<code>bf=2.0</code>	Flicker noise length dependence exponent.
353	<code>kf=0</code>	Flicker (1/f) noise coefficient.
354	<code>af=1</code>	Flicker (1/f) noise exponent.
355	<code>ef=1</code>	Flicker (1/f) noise frequency exponent.
356	<code>noia=1e20</code>	Oxide trap density coefficient. Default is 9.9e18 for pmos.
357	<code>noib=5e4</code>	Oxide trap density coefficient. Default is 2.4e3 for pmos.
358	<code>noic=-1.4e-12</code>	Oxide trap density coefficient. Default is 1.4e-8 for pmos.
359	<code>em=4.1e7</code> V/m	Maximum electric field.

Stress model parameters

360	<code>saref=1e-6</code> m	Reference distance between OD edge to poly of one side.
361	<code>sbref=1e-6</code> m	Reference distance between OD edge to poly of the other side.
362	<code>wlod=0</code> m	Width parameter for stress effect.
363	<code>ku0=0</code> m	Mobility degradation/enhancement coefficient for LOD.
364	<code>tku0=0</code>	Temperature coefficient of KU0.
365	<code>llodku0=0</code>	Length parameter for u0 LOD effect.
366	<code>wlodku0=0</code>	Width parameter for u0 LOD effect.
367	<code>kvth0=0</code> V m	Threshold degradation/enhancement parameter for LOD.
368	<code>llodvth=0</code>	Length parameter for vth LOD effect.
369	<code>wlodvth=0</code>	Width parameter for vth LOD effect.

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370	<code>kvsat=0</code>	m	Saturation velocity degradation/enhancement parameter for LOD.
371	<code>stk2=0</code>	m	K2 shift factor related to stress effect on vth.
372	<code>lodk2=1.0</code>		K2 shift modification factor for stress effect.
373	<code>steta0=0</code>	m	eta0 shift factor related to stress effect on vth.
374	<code>lodeta0=1.0</code>		eta0 shift modification factor for stress effect.

Default instance parameters

375	<code>w=5e-6</code>	m	Default channel width.
376	<code>l=5e-6</code>	m	Default channel length.
377	<code>as=0</code>	m ²	Default area of source diffusion.
378	<code>ad=0</code>	m ²	Default area of drain diffusion.
379	<code>ps=0</code>	m	Default perimeter of source diffusion.
380	<code>pd=0</code>	m	Default perimeter of drain diffusion.
381	<code>nrd=1</code>	m/m	Default number of squares of drain diffusion.
382	<code>nrs=1</code>	m/m	Default number of squares of source diffusion.
383	<code>nrb=1</code>	m/m	Default body squares.
384	<code>paramchk=1</code>		Model parameter checking selector.

Auto Model Selector parameters

385	<code>wmax=1</code>	m	Maximum channel width for which the model is valid.
386	<code>wmin=0</code>	m	Minimum channel width for which the model is valid.
387	<code>lmax=1</code>	m	Maximum channel length for which the model is valid.
388	<code>lmin=0</code>	m	Minimum channel length for which the model is valid.

Compatibility model parameters

389 compatible=spectre
Encourage device equations to be compatible with a foreign simulator. This option does not affect input syntax.
Possible values are spectre, spice2, spice3, cdsspice, hspice, spiceplus, eldo, sspice, and mica.

Junction diode model parameters

390 dskip=yes
Use simple piece-wise linear model for diode currents below $0.1 \cdot i_{abstol}$.
Possible values are no and yes.

Operating region warning control parameters

391 alarm=none
Forbidden operating region.
Possible values are none, off, triode, sat, subth, and rev.

392 imax=1 A
Maximum allowable current.

393 bvj=infinity V
Junction reverse breakdown voltage.

394 vbox=1e9 tox V
Oxide breakdown voltage.

395 warn=on
Parameter to turn warnings on and off.
Possible values are off and on.

DC-mismatch dependent parameters

396 mismatchmod=0
select Mismatch mode.

397 mismatchdist=0 m
Mismatch Distance.

398 mvtwl=0 V m
Threshold mismatch area dependence.

399 mvtwl2=0 V m^{1.5}
Threshold mismatch area square dependence.

400 mvt0=0 V
Threshold mismatch intercept.

401 mbewl=0 m
Beta mismatch area dependence.

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402 $mbe0=0$ Beta mismatch intercept.

Length dependent parameters

403 $lnch=0$ Length dependence of nch .

404 $lnsub=0$ Length dependence of $nsub$.

405 $lngate=0$ Length dependence of $ngate$.

406 $lvtho=0$ Length dependence of $vtho$.

407 $lk1=0$ Length dependence of $k1$.

408 $lk1w1=0$ Length dependence of $k1w1$.

409 $lk1w2=0$ Length dependence of $k1w2$.

410 $lk2=0$ Length dependence of $k2$.

411 $lk3=0$ Length dependence of $k3$.

412 $lk3b=0$ Length dependence of $k3b$.

413 $lkb1=0$ Length dependence of $kb1$.

414 $lw0=0$ Length dependence of $w0$.

415 $lnlx=0$ Length dependence of nix .

416 $ldvt0=0$ Length dependence of $dvt0$.

417 $ldvt1=0$ Length dependence of $dvt1$.

418 $ldvt2=0$ Length dependence of $dvt2$.

419 $ldvt0w=0$ Length dependence of $dvt0w$.

420 $ldvt1w=0$ Length dependence of $dvt1w$.

421 $ldvt2w=0$ Length dependence of $dvt2w$.

422 $lu0=0$ Length dependence of $u0$.

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423	lua=0	Length dependence of ua.
424	lub=0	Length dependence of ub.
425	luc=0	Length dependence of uc.
426	lvsat=0	Length dependence of vsat.
427	la0=0	Length dependence of a0.
428	lags=0	Length dependence of ags.
429	lb0=0	Length dependence of b0.
430	lb1=0	Length dependence of b1.
431	lketas=0	Length dependence of keta.
432	lketas=0	Length dependence of ketas.
433	la1=0	Length dependence of a1.
434	la2=0	Length dependence of a2.
435	lrds=0	Length dependence of rds.
436	lprwb=0	Length dependence of prwb.
437	lprwg=0	Length dependence of prwg.
438	lwr=0	Length dependence of wr.
439	lnfactor=0	Length dependence of nfactor.
440	ldwg=0	Length dependence of dwg.
441	ldwb=0	Length dependence of dwb.
442	lvoff=0	Length dependence of voff.
443	leta0=0	Length dependence of eta0.
444	letab=0	Length dependence of etab.

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

445	ldsub=0	Length dependence of dsub.
446	lcit=0	Length dependence of cit.
447	lcdsc=0	Length dependence of cdsc.
448	lcdscb=0	Length dependence of cdscb.
449	lcdscd=0	Length dependence of cdsd.
450	lpclm=0	Length dependence of pclm.
451	lpdiblc1=0	Length dependence of pdiblc1.
452	lpdiblc2=0	Length dependence of pdiblc2.
453	lpdiblcb=0	Length dependence of pdiblcb.
454	ldrout=0	Length dependence of drout.
455	lpvag=0	Length dependence of pvag.
456	ldelta=0	Length dependence of delta.
457	lalpha0=0	Length dependence of alpha0.
458	lfbjtii=0	Length dependence of fbjtii.
459	lbeta0=0	Length dependence of beta0.
460	lbeta1=0	Length dependence of beta1.
461	lbeta2=0	Length dependence of beta2.
462	lvdsatii0=0	Length dependence of vdstaii0.
463	llii=0	Length dependence of lii.
464	lesatii=0	Length dependence of esatii.
465	lsi0=0	Length dependence of sii0.
466	lsi1=0	Length dependence of sii1.

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

467	lsii2=0	Length dependence of sii2.
468	lsiid=0	Length dependence of siid.
469	lagidl=0	Length dependence of agidl.
470	lbgidl=0	Length dependence of bgidl.
471	lngidl=0	Length dependence of ngidl.
472	lntun=0	Length dependence of ntun.
473	lndiode=0	Length dependence of ndoide.
474	lnrecf0=0	Length dependence of nrecf0.
475	lnreocr0=0	Length dependence of nreocr0.
476	lisbjt=0	Length dependence of isbjt.
477	lisdif=0	Length dependence of isdif.
478	lisrec=0	Length dependence of isrec.
479	listun=0	Length dependence of istun.
480	lvrec0=0	Length dependence of vrec0.
481	lvtun0=0	Length dependence of vtun0.
482	lnbjt=0	Length dependence of nbjt.
483	llbjt0=0	Length dependence of lbjt0.
484	lvabjt=0	Length dependence of vabjt.
485	laely=0	Length dependence of aely.
486	lahli=0	Length dependence of ahli.
487	lxrcrg1=0	Length dependence of xrcrg1.
488	lxrcrg2=0	Length dependence of xrcrg2.

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

489	lv _{sdfb} =0	Length dependence of vsdfb.
490	lv _{sdth} =0	Length dependence of vsdth.
491	ld _{elvt} =0	Length dependence of delvt.
492	lac _{de} =0	Length dependence of acde.
493	lm _{oin} =0	Length dependence of moin.
494	la _{igc} =0	Length dependence of aigc.
495	lb _{igc} =0	Length dependence of bigc.
496	lc _{igc} =0	Length dependence of cigc.
497	la _{igsd} =0	Length dependence of aigsd.
498	lb _{igsd} =0	Length dependence of bigsd.
499	lc _{igsd} =0	Length dependence of cigsd.
500	ln _{igc} =0	Length dependence of nigc.
501	lp _{igcd} =0	Length dependence of pigcd.
502	lp _{oxedge} =0	Length dependence of poxedge.
503	lx _j =0	Length dependence of xj.
504	l _{alphagb1} =0	Length dependence of alphagb1.
505	l _{alphagb2} =0	Length dependence of alphagb2.
506	l _{betagb1} =0	Length dependence of betagb1.
507	l _{betagb2} =0	Length dependence of betagb2.
508	lc _{gs1} =0	Length dependence of cgsl.
509	lc _{gd1} =0	Length dependence of cgdl.
510	lc _{kappa} =0	Length dependence of ckappa.

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

511	lndif=0	Length dependence of ndif.
512	lute=0	Length dependence of ute.
513	lkt1=0	Length dependence of kt1.
514	lkt1l=0	Length dependence of kt1l.
515	lkt2=0	Length dependence of kt2.
516	lua1=0	Length dependence of ua1.
517	lub1=0	Length dependence of ub1.
518	luc1=0	Length dependence of uc1.
519	lat=0	Length dependence of at.
520	lp _{prt} =0	Length dependence of prt.
521	lntrecf=0	Length dependence of ntrecf.
522	lntre _{cr} =0	Length dependence of ntrecr.
523	lxbj _t =0	Length dependence of xbjt.
524	lxdif=0	Length dependence of xdif.
525	lxrec=0	Length dependence of xrec.
526	lxtun=0	Length dependence of xtun.
527	lxdif _d =0	Length dependence of xdifd.
528	lxrec _d =0	Length dependence of xrecd.
529	lxtun _d =0	Length dependence of xtund.
530	llpe0=0	Length dependence of lpe0.
531	llpeb=0	Length dependence of lpeb.
532	lrsw=0	Length dependence of Rsw.

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

533	lrdw=0	Length dependence of Rdw.
534	lcgidl=0	Length dependence of cgidl.
535	legidl=0	Length dependence of egidl.
536	lntund=0	Length dependence of ntund.
537	lndioded=0	Length dependence of ndioded.
538	lnrecf0d=0	Length dependence of nrecf0d.
539	lnreocr0d=0	Length dependence of nreocr0d.
540	lidbjt=0	Length dependence of idbjt.
541	liddif=0	Length dependence of iddif.
542	lidrec=0	Length dependence of idrec.
543	lidtun=0	Length dependence of idtun.
544	lvrec0d=0	Length dependence of vrec0d.
545	lvtun0d=0	Length dependence of vtun0d.
546	lahlid=0	Length dependence of lahlid.
547	lnoff=0	Length dependence of noff.
548	ldvtp0=0	Length dependence of dvtp0.
549	ldvtp1=0	Length dependence of dvtp1.
550	lminv=0	Length dependence of minv.
551	lfprout=0	Length dependence of pdiblcb.
552	lpdits=0	Length dependence of pdits.
553	lpditsd=0	Length dependence of pditsd.
554	lku0=0	Length dependence of ku0.

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

555	lkvth0=0	Length dependence of kvth0.
556	lvoffcv=0	Length dependence of voffcv.
557	lminvcv=0	Length dependence of minvcv.
558	lud=0	Length dependence of ud.
559	lud1=0	Length dependence of ud1.
560	lebjtii=0	Length dependence of ebjtii.
561	lcbjtii=0	Length dependence of cbjtii.
562	labjtii=0	Length dependence of abjtii.
563	lmbjtii=0	Length dependence of mbjtii.
564	lvbci=0	Length dependence of vbci.
565	ldvtp2=0	Length dependence of dvtp2.
566	ldvtp3=0	Length dependence of dvtp3.
567	ldvtp4=0	Length dependence of dvtp4.
568	laigbcp2=0	Length dependence of aigbcp2.
569	lbigbcp2=0	Length dependence of bigbcp2.
570	lcigbcp2=0	Length dependence of cigbcp2.
571	lnsd=0	Length dependence of nsd.
572	lvfb=0	Length dependence of vfb.
573	leu=0	Length dependence of eu.
574	lucs=0	Length dependence of ucs.
575	lucste=0	Length dependence of ucste.
576	legisl=0	Length dependence of egisl.

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

577	lagisl=0	Length dependence of agisl.
578	lbgisl=0	Length dependence of bgisl.
579	lcgisl=0	Length dependence of cgisl.
580	lrgidl=0	Length dependence of rgidl.
581	lkgidl=0	Length dependence of kgidl.
582	lfgidl=0	Length dependence of fgidl.
583	lrgisl=0	Length dependence of rgisl.
584	lkgisl=0	Length dependence of kgisl.
585	lfgisl=0	Length dependence of fgisl.

Width dependent parameters

586	wrch=0	Width dependence of nch.
587	wsub=0	Width dependence of nsub.
588	wngate=0	Width dependence of ngate.
589	wvtho=0	Width dependence of vto.
590	wk1=0	Width dependence of k1.
591	wk1w1=0	Width dependence of k1w1.
592	wk1w2=0	Width dependence of k1w2.
593	wk2=0	Width dependence of k2.
594	wk3=0	Width dependence of k3.
595	wk3b=0	Width dependence of k3b.
596	wkb1=0	Width dependence of kb1.
597	ww0=0	Width dependence of w0.

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

598	$w_{nlx}=0$	Width dependence of nlx .
599	$w_{dvt0}=0$	Width dependence of $dvt0$.
600	$w_{dvt1}=0$	Width dependence of $dvt1$.
601	$w_{dvt2}=0$	Width dependence of $dvt2$.
602	$w_{dvt0w}=0$	Width dependence of $dvt0w$.
603	$w_{dvt1w}=0$	Width dependence of $dvt1w$.
604	$w_{dvt2w}=0$	Width dependence of $dvt2w$.
605	$w_{u0}=0$	Width dependence of $u0$.
606	$w_{ua}=0$	Width dependence of ua .
607	$w_{ub}=0$	Width dependence of ub .
608	$w_{uc}=0$	Width dependence of uc .
609	$w_{vsat}=0$	Width dependence of $vsat$.
610	$w_{a0}=0$	Width dependence of $a0$.
611	$w_{ags}=0$	Width dependence of ags .
612	$w_{b0}=0$	Width dependence of $b0$.
613	$w_{b1}=0$	Width dependence of $b1$.
614	$w_{keta}=0$	Width dependence of $keta$.
615	$w_{ketas}=0$	Width dependence of $ketas$.
616	$w_{a1}=0$	Width dependence of $a1$.
617	$w_{a2}=0$	Width dependence of $a2$.
618	$w_{rdsw}=0$	Width dependence of $rdsw$.
619	$w_{prwb}=0$	Width dependence of $prwb$.

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

620	wprwg=0	Width dependence of prwg.
621	wwr=0	Width dependence of wr.
622	wnfactor=0	Width dependence of nfactor.
623	wdwg=0	Width dependence of dwg.
624	wdwb=0	Width dependence of dwb.
625	wvoff=0	Width dependence of voff.
626	weta0=0	Width dependence of eta0.
627	wetab=0	Width dependence of etab.
628	wdsub=0	Width dependence of dsub.
629	wcit=0	Width dependence of cit.
630	wcdsc=0	Width dependence of cdsc.
631	wcdscb=0	Width dependence of cdscb.
632	wcdscd=0	Width dependence of cdscd.
633	wpclm=0	Width dependence of pclm.
634	wpdiblc1=0	Width dependence of pdiblc1.
635	wpdiblc2=0	Width dependence of pdiblc2.
636	wpdiblcb=0	Width dependence of pdiblcb.
637	wdrout=0	Width dependence of drout.
638	wpvag=0	Width dependence of pvag.
639	wdelta=0	Width dependence of delta.
640	walpha0=0	Width dependence of alpha0.
641	wfbjtii=0	Width dependence of fbjtii.

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

642	wbeta0=0	Width dependence of beta0.
643	wbeta1=0	Width dependence of beta1.
644	wbeta2=0	Width dependence of beta2.
645	wvdsatii0=0	Width dependence of vdsatii0.
646	wlii=0	Width dependence of lii.
647	wesatii=0	Width dependence of esatii.
648	wsii0=0	Width dependence of sii0.
649	wsii1=0	Width dependence of sii1.
650	wsii2=0	Width dependence of sii2.
651	wsiid=0	Width dependence of siid.
652	wagidl=0	Width dependence of agidl.
653	wbgidl=0	Width dependence of bgidl.
654	wngidl=0	Width dependence of ngidl.
655	wntun=0	Width dependence of wntun.
656	wndiode=0	Width dependence of ndiode.
657	wnrecf0=0	Width dependence of nrecf0.
658	wnrecr0=0	Width dependence of nrecr0.
659	wisbjt=0	Width dependence of isbjt.
660	wisdif=0	Width dependence of isdif.
661	wisrec=0	Width dependence of isrec.
662	wistun=0	Width dependence of istun.
663	wvrec0=0	Width dependence of vrec0.

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

664	wvtun0=0	Width dependence of vtun0.
665	wnbjt=0	Width dependence of nbjt.
666	wlbjt0=0	Width dependence of lbjt0.
667	wvabjt=0	Width dependence of vabjt.
668	waely=0	Width dependence of aely.
669	wahli=0	Width dependence of ahli.
670	wxrcrg1=0	Width dependence of xrcrg1.
671	wxrcrg2=0	Width dependence of xrcrg2.
672	wvsdfb=0	Width dependence of vsdfb.
673	wvsdth=0	Width dependence of vsdth.
674	wdelvt=0	Width dependence of delvt.
675	wacde=0	Width dependence of acde.
676	wmoin=0	Width dependence of moin.
677	waigc=0	Width dependence of aigc.
678	wbigc=0	Width dependence of bigc.
679	wcigc=0	Width dependence of cigc.
680	waigsd=0	Width dependence of aigsd.
681	wbigsd=0	Width dependence of bigsd.
682	wcigsd=0	Width dependence of cigsd.
683	wnigc=0	Width dependence of nigc.
684	wpigcd=0	Width dependence of pigcd.
685	wpoxedge=0	Width dependence of poxedge.

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

686	wxj=0	Width dependence of xj.
687	walphagb1=0	Width dependence of alphagb1.
688	walphagb2=0	Width dependence of alpagb2.
689	wbetagb1=0	Width dependence of betagb1.
690	wbetagb2=0	Width dependence of betabg2.
691	wcgsl=0	Width dependence of cgsl.
692	wcgdl=0	Width dependence of cgdl.
693	wckappa=0	Width dependence of ckappa.
694	wndif=0	Width dependence of ndif.
695	wute=0	Width dependence of ute.
696	wkt1=0	Width dependence of kt1.
697	wkt1l=0	Width dependence of kt1l.
698	wkt2=0	Width dependence of kt2.
699	wua1=0	Width dependence of ua1.
700	wub1=0	Width dependence of ub1.
701	wuc1=0	Width dependence of uc1.
702	wat=0	Width dependence of at.
703	wprt=0	Width dependence of prt.
704	wntrecf=0	Width dependence of ntrecf.
705	wntreocr=0	Width dependence of ntrecr.
706	wxbjt=0	Width dependence of xbjt.
707	wxdif=0	Width dependence of xdif.

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

708	wxrec=0	Width dependence of xrec.
709	wxdifd=0	Width dependence of xdifd.
710	wxrecd=0	Width dependence of xrecd.
711	wxtund=0	Width dependence of xtund.
712	wlpe0=0	Width dependence of lpe0.
713	wlpeb=0	Width dependence of lpeb.
714	wrs=0	Width dependence of rsw.
715	wrdw=0	Width dependence of rdw.
716	wcgidl=0	Width dependence of Cgidl.
717	wegidl=0	Width dependence of Egidl.
718	wntund=0	Width dependence of ntund.
719	wndioded=0	Width dependence of ndioded.
720	wnrecf0d=0	Width dependence of nrecf0d.
721	wnrecr0d=0	Width dependence of nrecr0d.
722	widbjt=0	Width dependence of ldbjt.
723	widdif=0	Width dependence of iddif.
724	widrec=0	Width dependence of idrec.
725	widtun=0	Width dependence of idtun.
726	wvrec0d=0	Width dependence of Vrec0d.
727	wvtun0d=0	Width dependence of Vtun0d.
728	wahlid=0	Width dependence of Ahlid.
729	wxtun=0	Width dependence of xtun.

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

730	<code>wnoff=0</code>	Width dependence of <code>noff</code> .
731	<code>wdvtp0=0</code>	Width dependence of <code>dvtp0</code> .
732	<code>wdvtp1=0</code>	Width dependence of <code>dvtp1</code> .
733	<code>wminv=0</code>	width dependence of <code>minv</code> .
734	<code>wfprout=0</code>	Width dependence of <code>pdiblcb</code> .
735	<code>wpdits=0</code>	Width dependence of <code>pdits</code> .
736	<code>wpditsd=0</code>	Width dependence of <code>pditsd</code> .
737	<code>wku0=0</code>	Width dependence of <code>ku0</code> .
738	<code>wkvth0=0</code>	Width dependence of <code>kvth0</code> .
739	<code>wvoffcv=0</code>	Width dependence of <code>voffcv</code> .
740	<code>wminvcv=0</code>	Width dependence of <code>minvcv</code> .
741	<code>wud=0</code>	Width dependence of <code>ud</code> .
742	<code>wud1=0</code>	Width dependence of <code>ud1</code> .
743	<code>webjtii=0</code>	Width dependence of <code>ebjtii</code> .
744	<code>wcbjtii=0</code>	Width dependence of <code>cbjtii</code> .
745	<code>wabjtii=0</code>	Width dependence of <code>abjtii</code> .
746	<code>wmbjtii=0</code>	Width dependence of <code>mbjtii</code> .
747	<code>wvbc_i=0</code>	Width dependence of <code>vbc_i</code> .
748	<code>wdvtp2=0</code>	Width dependence of <code>dvtp2</code> .
749	<code>wdvtp3=0</code>	Width dependence of <code>dvtp3</code> .
750	<code>wdvtp4=0</code>	Width dependence of <code>dvtp4</code> .
751	<code>waigbcp2=0</code>	Width dependence of <code>aigbcp2</code> .

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

752	wbigbcp2=0	Width dependence of bigbcp2.
753	wcigbcp2=0	Width dependence of cigbcp2.
754	wnsd=0	Width dependence of nsd.
755	wvfb=0	Width dependence of vfb.
756	weu=0	Width dependence of eu.
757	wucs=0	Width dependence of ucs.
758	wucste=0	Width dependence of ucste.
759	wegisl=0	Width dependence of egisl.
760	wagisl=0	Width dependence of agisl.
761	wbgisl=0	Width dependence of bgisl.
762	wcgisl=0	Width dependence of cgisl.
763	wrgidl=0	Width dependence of rgidl.
764	wkgidl=0	Width dependence of kgidl.
765	wfgidl=0	Width dependence of fgidl.
766	wrgisl=0	Width dependence of rgisl.
767	wkgisl=0	Width dependence of kgisl.
768	wfgisl=0	Width dependence of fgisl.

Cross-term dependent parameters

769	pnch=0	Cross-term dependence of nch.
770	pnsb=0	Cross-term dependence of nsb.
771	pngate=0	Cross-term dependence of ngate.
772	pvtho=0	Cross-term dependence of vto.

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

773	$pk1=0$	Cross-term dependence of $k1$.
774	$pk1w1=0$	Cross-term dependence of $k1w1$.
775	$pk1w2=0$	Cross-term dependence of $k1w2$.
776	$pk2=0$	Cross-term dependence of $k2$.
777	$pk3=0$	Cross-term dependence of $k3$.
778	$pk3b=0$	Cross-term dependence of $k3b$.
779	$pkb1=0$	Cross-term dependence of $kb1$.
780	$pw0=0$	Cross-term dependence of $w0$.
781	$pnlx=0$	Cross-term dependence of nlx .
782	$pdvt0=0$	Cross-term dependence of $dvt0$.
783	$pdvt1=0$	Cross-term dependence of $dvt1$.
784	$pdvt2=0$	Cross-term dependence of $dvt2$.
785	$pdvt0w=0$	Cross-term dependence of $dvt0w$.
786	$pdvt1w=0$	Cross-term dependence of $dvt1w$.
787	$pdvt2w=0$	Cross-term dependence of $dvt2w$.
788	$pu0=0$	Cross-term dependence of $u0$.
789	$pua=0$	Cross-term dependence of ua .
790	$pub=0$	Cross-term dependence of ub .
791	$puc=0$	Cross-term dependence of uc .
792	$pvsat=0$	Cross-term dependence of $vsat$.
793	$pa0=0$	Cross-term dependence of $a0$.
794	$pag=0$	Cross-term dependence of ag .

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

795	pb0=0	Cross-term dependence of b0.
796	pb1=0	Cross-term dependence of b1.
797	pketa=0	Cross-term dependence of keta.
798	pketas=0	Cross-term dependence of ketas.
799	pa1=0	Cross-term dependence of a1.
800	pa2=0	Cross-term dependence of a2.
801	prdsw=0	Cross-term dependence of rdsw.
802	pprwb=0	Cross-term dependence of prwb.
803	pprwg=0	Cross-term dependence of prwg.
804	pwr=0	Cross-term dependence of wr.
805	pnfactor=0	Cross-term dependence of nfactor.
806	pdwg=0	Cross-term dependence of dwg.
807	pdwb=0	Cross-term dependence of dwb.
808	pvoff=0	Cross-term dependence of voff.
809	peta0=0	Cross-term dependence of eta0.
810	petab=0	Cross-term dependence of etab.
811	pdsb=0	Cross-term dependence of dsb.
812	pcit=0	Cross-term dependence of cit.
813	pcdsc=0	Cross-term dependence of cdsc.
814	pcdsb=0	Cross-term dependence of cdsb.
815	pcdscd=0	Cross-term dependence of cdsd.
816	ppclm=0	Cross-term dependence of pclm.

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

817	ppdiblc1=0	Cross-term dependence of pdiblc1.
818	ppdiblc2=0	Cross-term dependence of pdiblc2.
819	ppdiblcb=0	Cross-term dependence of pdiblcb.
820	pdrout=0	Cross-term dependence of drout.
821	ppvag=0	Cross-term dependence of pvag.
822	pdelta=0	Cross-term dependence of delta.
823	palpha0=0	Cross-term dependence of alpha0.
824	pfbjtii=0	Cross-term dependence of fbjtii.
825	pbeta0=0	Cross-term dependence of beta0.
826	pbeta1=0	Cross-term dependence of beta1.
827	pbeta2=0	Cross-term dependence of beta2.
828	pvdsatii0=0	Cross-term dependence of vdsatii0.
829	plii=0	Cross-term dependence of lii.
830	pesatii=0	Cross-term dependence of esatii.
831	psii0=0	Cross-term dependence of sii0.
832	psii1=0	Cross-term dependence of sii1.
833	psii2=0	Cross-term dependence of sii2.
834	psiid=0	Cross-term dependence of siid.
835	pagidl=0	Cross-term dependence of agidl.
836	pbgidl=0	Cross-term dependence of bgidl.
837	pngidl=0	Cross-term dependence of ngidl.
838	pntun=0	Cross-term dependence of ntun.

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

839	pnodiode=0	Cross-term dependence of ndiode.
840	pnrecf0=0	Cross-term dependence of nrecf0.
841	pnreocr0=0	Cross-term dependence of nreocr0.
842	pisbjt=0	Cross-term dependence of isbjt.
843	pisdif=0	Cross-term dependence of isdif.
844	pisrec=0	Cross-term dependence of isrec.
845	pistun=0	Cross-term dependence of istun.
846	pvrec0=0	Cross-term dependence of vrec0.
847	pvtun0=0	Cross-term dependence of vtun0.
848	pnbjt=0	Cross-term dependence of nbjt.
849	plbjt0=0	Cross-term dependence of lbjt0.
850	pvabjt=0	Cross-term dependence of vabjt.
851	paely=0	Cross-term dependence of aely.
852	pahli=0	Cross-term dependence of ahli.
853	pxrcrg1=0	Cross-term dependence of xrcrg1.
854	pxrcrg2=0	Cross-term dependence of xrcrg2.
855	pvsdffb=0	Cross-term dependence of vsdffb.
856	pvsdth=0	Cross-term dependence of vsdth.
857	pdelvt=0	Cross-term dependence of delvt.
858	pacde=0	Cross-term dependence of acde.
859	pmoin=0	Cross-term dependence of moin.
860	paigc=0	Cross-term dependence of aigc.

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

861	pbigc=0	Cross-term dependence of bigc.
862	pcigc=0	Cross-term dependence of cigc.
863	paigsd=0	Cross-term dependence of aigsd.
864	pbigsd=0	Cross-term dependence of bigsd.
865	pcigsd=0	Cross-term dependence of cigsd.
866	pnigc=0	Cross-term dependence of nigc.
867	ppigcd=0	Cross-term dependence of pigcd.
868	ppoxedge=0	Cross-term dependence of poxedge.
869	pxj=0	Cross-term dependence of xj.
870	palphagb1=0	Cross-term dependence of alphagb1.
871	palphagb2=0	Cross-term dependence of alphagb2.
872	pbetagb1=0	Cross-term dependence of betagb1.
873	pbetagb2=0	Cross-term dependence of betagb2.
874	pcgsl=0	Cross-term dependence of cgsl.
875	pcgdl=0	Cross-term dependence of cgdl.
876	pckappa=0	Cross-term dependence of ckappa.
877	pndif=0	Cross-term dependence of ndif.
878	pute=0	Cross-term dependence of ute.
879	pkt1=0	Cross-term dependence of kt1.
880	pkt1l=0	Cross-term dependence of kt1l.
881	pkt2=0	Cross-term dependence of kt2.
882	pua1=0	Cross-term dependence of ua1.

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

883	pub1=0	Cross-term dependence of ub1.
884	puc1=0	Cross-term dependence of uc1.
885	pat=0	Cross-term dependence of at.
886	pprt=0	Cross-term dependence of prt.
887	pntrecf=0	Cross-term dependence of ntrecf.
888	pntreocr=0	Cross-term dependence of ntrecr.
889	pxbjt=0	Cross-term dependence of xbjt.
890	pxdif=0	Cross-term dependence of xdif.
891	pxrec=0	Cross-term dependence of xrec.
892	pxtun=0	Cross-term dependence of xtun.
893	pxdifd=0	Cross-term dependence of xdifd.
894	pxrecd=0	Cross-term dependence of xrecd.
895	pxtund=0	Cross-term dependence of xtund.
896	plpe0=0	Cross-term dependence of lpe0.
897	plpeb=0	Cross-term dependence of lpeb.
898	prsw=0	Cross-term dependence of rsw.
899	prdw=0	Cross-term dependence of rdw.
900	pcgidl=0	Cross-term dependence of cgidl.
901	pegidl=0	Cross-term dependence of egidl.
902	pntund=0	Cross-term dependence of ntund.
903	pndioded=0	Cross-term dependence of ndioded.
904	pnrecf0d=0	Cross-term dependence of nrecf0d.

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

905	pnrecr0d=0	Cross-term dependence of nrecr0d.
906	pidbjt=0	Cross-term dependence of ldbjt.
907	piddif=0	Cross-term dependence of lddif.
908	pidrec=0	Cross-term dependence of ldrec.
909	pidtun=0	Cross-term dependence of idtun.
910	pvrec0d=0	Cross-term dependence of vrec0d.
911	pvtun0d=0	Cross-term dependence of vtun0d.
912	pahlid=0	Cross-term dependence of ahlid.
913	pnoff=0	Cross-term dependence of noff.
914	pdvtp0=0	Cross-term dependence of dvtp0.
915	pdvtp1=0	Cross-term dependence of dvtp1.
916	pminv=0	Cross-term dependence of minv.
917	pfprout=0	Cross-term dependence of pdiblcb.
918	ppdits=0	Cross-term dependence of pdits.
919	ppditsd=0	Cross-term dependence of pditsd.
920	pku0=0	Cross-term dependence of ku0.
921	pkvth0=0	Cross-term dependence of kvth0.
922	pvoffcv=0	Cross-term dependence of voffcv.
923	pminvcv=0	Cross-term dependence of minvcv.
924	pud=0	Cross-term dependence of ud.
925	pud1=0	Cross-term dependence of ud1.
926	pebjtii=0	Cross-term dependence of ebjtii.

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

927	pcbjtii=0	Cross-term dependence of cbjtii.
928	pabjtii=0	Cross-term dependence of abjtii.
929	pmbjtii=0	Cross-term dependence of mbjtii.
930	pvbci=0	Cross-term dependence of vbci.
931	pdvtp2=0	Cross-term dependence of dvtp2.
932	pdvtp3=0	Cross-term dependence of dvtp3.
933	pdvtp4=0	Cross-term dependence of dvtp4.
934	paigbcp2=0	Cross-term dependence of aigbcp2.
935	pbigbcp2=0	Cross-term dependence of bigbcp2.
936	pcigbcp2=0	Cross-term dependence of cigbcp2.
937	pnsd=0	Cross-term dependence of nsd.
938	pvfb=0	Cross-term dependence of vfb.
939	peu=0	Cross-term dependence of eu.
940	pucs=0	Cross-term dependence of ucs.
941	pucste=0	Cross-term dependence of ucste.
942	pegisl=0	Cross-term dependence of egisl.
943	pagisl=0	Cross-term dependence of agisl.
944	pbgisl=0	Cross-term dependence of bgisl.
945	pcgisl=0	Cross-term dependence of cgisl.
946	prgidl=0	Cross-term dependence of rgidl.
947	pkgidl=0	Cross-term dependence of kgidl.
948	pfgidl=0	Cross-term dependence of fgidl.

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

949	<code>prgisl=0</code>	Cross-term dependence of <code>rgisl</code> .
950	<code>pkgisl=0</code>	Cross-term dependence of <code>kgisl</code> .
951	<code>pfgisl=0</code>	Cross-term dependence of <code>fgisl</code> .
952	<code>eta0cv=0.08</code>	Subthreshold region DIBL coefficient for C-V.
953	<code>etabcv=(-0.07)</code>	Subthreshold region DIBL coefficient for C-V.
954	<code>steta0cv=0.0</code>	<code>eta0cv</code> shift factor related to stress effect on <code>vth</code> .
955	<code>lodeta0cv=1.0</code>	<code>eta0cv</code> shift modification factor for stress effect.
956	<code>leta0cv=0.0</code>	Length dependence of <code>eta0cv</code> .
957	<code>letabcv=0.0</code>	Length dependence of <code>etabcv</code> .
958	<code>weta0cv=0.0</code>	Width dependence of <code>eta0cv</code> .
959	<code>wetabcv=0.0</code>	Width dependence of <code>etabcv</code> .
960	<code>peta0cv=0.0</code>	Cross-term dependence of <code>eta0cv</code> .
961	<code>petabcv=0.0</code>	Cross-term dependence of <code>etabcv</code> .
962	<code>tnoic=3.5</code>	Length dependent parameter for Correlation Coefficient.
963	<code>rnoic=0.395</code>	Correlation Coefficient parameter.
964	<code>scalen=1e5</code>	scale factor for correlated noise.
965	<code>eggbc2=1.12</code>	Bandgap in <code>Agbc2</code> region.
966	<code>eggdep=1.12</code>	Bandgap for gate depletion effect.
967	<code>agb1=3.7622e-7</code>	'A' for <code>Igb1</code> Tunneling current model.
968	<code>bgb1=(-3.1051e10)</code>	'B' for <code>Igb1</code> Tunneling current model.
969	<code>agb2=4.9758e-7</code>	'A' for <code>Igb2</code> Tunneling current model.

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

- 970 `bgb2=(-2.357e10)` 'B' for Igb2 Tunneling current model.
- 971 `agbc2n=3.4254e-7` NMOS 'A' for tunneling current model.
- 972 `agbc2p=4.9723e-7` PMOS 'A' for tunneling current model.
- 973 `bgb2n=1.1665e12` NMOS 'B' for tunneling current model.
- 974 `bgb2p=7.4567e11` PMOS 'B' for tunneling current model.
- 975 `vtm00=0.026` Thermal voltage at 25 degC.

Auto Model Selection

Many models need to be characterized for different geometries in order to obtain accurate results for model development. The model selector program automatically searches for a model with the length and width range specified in the instance statement and uses this model in the simulations.

For the auto model selector program to find a specific model, the models to be searched should be grouped together within braces. Such a group is called a model group. An opening brace is required at the end of the line defining each model group. Every model in the group is given a name followed by a colon and the list of parameters. Also, the four geometric parameters `lmax`, `lmin`, `wmax`, and `wmin` should be given. The selection criteria to choose a model is as follows:

```
lmin <= inst_length < lmax and wmin <= inst_width < wmax
```

Example:

```
model ModelName ModelType {  
    1: <model parameters> lmin=2 lmax=4 wmin=1 wmax=2  
    2: <model parameters> lmin=1 lmax=2 wmin=2 wmax=4  
    3: <model parameters> lmin=2 lmax=4 wmin=4 wmax=6  
}
```

Then for a given instance

```
M1 1 2 3 4 ModelName w=3 l=1.5
```

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

the program would search all the models in the model group with the name `ModelName` and then pick the first model whose geometric range satisfies the selection criteria. In the preceding example, the auto model selector program would choose `ModelName.2`.

You must specify both length (l) and width (w) on the device instance line to enable automatic model selection.

Output Parameters

1	<code>tempeff</code> (C)	Effective temperature for a single device.
2	<code>meff</code>	Effective multiplicity factor (m-factor).
3	<code>weff</code> (m)	Effective channel width(alias= <code>lx62</code>).
4	<code>leff</code> (m)	Effective channel length(alias= <code>lx63</code>).
5	<code>lpoly</code> (m)	Effective Poly Length.
6	<code>leffcv</code> (m)	Effective channel length for CV(alias= <code>lx65</code>).
7	<code>weffcv</code> (m)	Effective channel width for CV(alias= <code>lx64</code>).
8	<code>rtheff</code> (Ω)	Effective thermal resistance.
9	<code>ctheff</code> (F)	Effective thermal capacitance.
10	<code>rseff</code> (Ω)	Effective source resistance.
11	<code>rdeff</code> (Ω)	Effective drain resistance.
12	<code>phi</code> (V)	Surface potential (phi alias= <code>lv50</code>).
13	<code>tox</code> (m)	Oxide thickness (tox alias= <code>lv51</code>).
14	<code>gseff</code> (S)	Effective source parasitic conductance(alias= <code>lv16</code>).
15	<code>gdeff</code> (S)	Effective drain parasitic conductance(alias= <code>lv17</code>).
16	<code>rds</code> (Ω)	Drain resistance (squares) (alias= <code>lv13</code>).
17	<code>rss</code> (Ω)	Source resistance (squares)(alias= <code>lv14</code>).

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

Operating-Point Parameters

1	<code>type=n</code>	Transistor type. Possible values are <code>n</code> and <code>p</code> .
2	<code>region=triode</code>	Estimated operating region. Possible values are <code>off</code> , <code>triode</code> , <code>sat</code> , and <code>subth</code> .
3	<code>reversed</code>	Reverse mode indicator. Possible values are <code>no</code> and <code>yes</code> .
4	<code>vgs (V)</code>	Gate-source voltage.
5	<code>vds (V)</code>	Drain-source voltage.
6	<code>vbs (V)</code>	Bulk-source voltage.
7	<code>vbgs (V)</code>	Back-Gate-source voltage.
8	<code>ids (A)</code>	Resistive drain-to-source current.
9	<code>ido (A)</code>	Alias for <code>ids</code> , opposite sign when <code>reversed</code> (alias= <code>lx4</code>).
10	<code>ibp (A)</code>	Bulk to source substrate current(alias= <code>lx50</code>).
11	<code>ic (A)</code>	BJT collector current(alias= <code>lx45</code>).
12	<code>igisl (A)</code>	Source GIDL current.
13	<code>igidl (A)</code>	Drain GIDL current.
14	<code>iii (A)</code>	Impact ionization current(alias= <code>lx46</code>).
15	<code>ibd (A)</code>	Resistive bulk-to-drain junction current.
16	<code>igbt (A)</code>	Gate-to-body tunneling current.
17	<code>ibs (A)</code>	Resistive bulk-to-source junction current.
18	<code>vth (V)</code>	Threshold voltage.
19	<code>vdsat (V)</code>	Drain-source saturation voltage.

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

20	$v_{f_{beff}}$ (V)	Flat-band voltage ($v_{f_{beff}}=lv26$).
21	g_m (S)	Common-source transconductance(alias=lx7).
22	g_{ds} (S)	Common-source output conductance(alias=lx8).
23	g_{mb} (S)	Body-transconductance(alias=lx9).
24	g_{mbg} (S)	Back-gate-transconductance.
25	μ_{eff} ($cm^2/V s$)	Effective mobility.
26	β_{aeff} (A/V^2)	Effective β .
27	q_g (Coul)	Gate charge.
28	q_d (Coul)	Drain charge.
29	q_s (Coul)	Source charge.
30	q_b (Coul)	Body charge.
31	q_{bg} (Coul)	Back-Gate charge.
32	c_{gg} (F)	dQ_g_{dVg} (alias=lx18).
33	c_{gd} (F)	dQ_g_{dVd} .
34	c_{gs} (F)	dQ_g_{dVs} .
35	c_{gb} (F)	dQ_g_{dVb} .
36	c_{dg} (F)	dQ_d_{dVg} (alias=lx32).
37	c_{dd} (F)	dQ_d_{dVd} (alias=lx33).
38	c_{ds} (F)	dQ_d_{dVs} (alias=lx34).
39	c_{db} (F)	dQ_d_{dVb} .
40	c_{sg} (F)	dQ_s_{dVg} (alias=lx59).
41	c_{sd} (F)	dQ_s_{dVd} (alias=lx60).

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

42	<code>css</code> (F)	<code>dQs_dVs(alias=lx58)</code> .
43	<code>csb</code> (F)	<code>dQs_dVb</code> .
44	<code>cbg</code> (F)	<code>dQb_dVg(alias=lx21)</code> .
45	<code>cbd</code> (F)	<code>dQb_dVd(alias=lx22)</code> .
46	<code>cbs</code> (F)	<code>dQb_dVs(alias=lx23)</code> .
47	<code>cbb</code> (F)	<code>dQb_dVb</code> .
48	<code>id</code> (A)	Total resistive drain current.
49	<code>is</code> (A)	Total resistive source current.
50	<code>ib</code> (A)	Total resistive bulk current.
51	<code>pwr</code> (W)	Power at op point.
52	<code>gmoverid</code> (1/V)	Gm/Ids.
53	<code>tdev</code> (C)	Temperature rise from ambient.
54	<code>qbint</code> (Coul)	Qb intrinsic, opposite sign for pmos(alias=lx12).
55	<code>qgint</code> (Coul)	Qg intrinsic, opposite sign for pmos(alias=lx14).
56	<code>qdint</code> (Coul)	Qd intrinsic, opposite sign for pmos(alias=lx16).
57	<code>qbs</code> (Coul)	Source junction diode charge(alias=lx26).
58	<code>qbd</code> (Coul)	Drain junction diode charge(alias=lx24).
59	<code>ibdo</code> (A)	Drain junction diode current(alias=lx6).
60	<code>ibso</code> (A)	Source junction diode current(alias=lx5).
61	<code>cap_bs</code> (F)	Extrinsic drain to substrate Capacitances(alias=lx28).
62	<code>cap_bd</code> (F)	Extrinsic source to substrate Capacitances(alias=lx29).
63	<code>cdebo</code> (F)	intrinsic drain-to-substrate capacitance(alias=lx37).

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

64	cbebo (F)	intrinsic floating body-to-substrate capacitance(alias=lx38).
65	ceebo (F)	intrinsic substrate capacitance(alias=lx39).
66	i2 (A)	Hspice alias of Total tunneling gate current.
67	i3 (A)	Hspice alias of Total resistive source current.
68	igcs (A)	Igcs.
69	igcd (A)	Igcd.
70	cbgg (F)	intrinsic substrate-to-gate capacitance(alias=lx40).
71	cbgd (F)	intrinsic substrate-to-drain capacitance(alias=lx41).
72	cbgs (F)	intrinsic substrate-to-drain capacitance(alias=lx41).
73	rbp (Ω)	
74	cgbg (F)	intrinsic gate-to-substrate capacitance(alias=lx57).
75	csbg (F)	intrinsic source-to-substrate capacitance(alias=lx61).
76	cggbm (F)	Total gate capacitance, and all overlap and fringing components(alias=lx82).
77	cgdbm (F)	Total gate-to-drain capacitance, and all overlap and fringing components(alias=lx83).
78	cgsbm (F)	Total gate-to-source capacitance, and all overlap and fringing components(alias=lx84).
79	cddbm (F)	Total drain capacitance, and all overlap and fringing components(alias=lx85).
80	cdsbm (F)	Total drain-to-source capacitance(alias=lx86).
81	cdgbm (F)	Total drain-to-gate capacitance, and overlap and fringing components(alias=lx87).
82	cbgbm (F)	Total bulk-to-gate capacitance, and overlap and fringing components(alias=lx88).

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

83	<code>cbdbm</code> (F)	Total floating body-to-drain capacitance, and overlap and fringing components(alias=lx89).
84	<code>cbsbm</code> (F)	Total floating body-to-gate capacitance, and overlap and fringing components(alias=lx90).
85	<code>cdbgbm</code> (F)	Total drain-to-substrate capacitance, and overlap and fringing components(alias=lx92).
86	<code>csgbm</code> (F)	Total source-to-gate capacitance, and overlap and fringing components(alias=lx93).
87	<code>cssbm</code> (F)	Total source capacitance, and overlap and fringing components(alias=lx94).
88	<code>csbgbm</code> (F)	Total source-to-substrate capacitance, and overlap and fringing components(alias=lx95).
89	<code>cbgbgbm</code> (F)	Total substrate capacitance, and overlap and fringing components(alias=lx96).
90	<code>ig</code> (A)	Total tunneling gate current.
91	<code>vth_cv</code> (V)	Threshold voltage for C-V.

Note:

1. The output of charge “qb”, “qd”, and “qs” are the sum of intrinsic charge and junction charge. The output of capacitors “cdd”, “cdb”, “csb”, “cbd”, “cbb”, and “cbs” are the sum of intrinsic capacitors and junction capacitors.
2. “reversed” means that v_{ds} is negative for NMOS or nonnegative for PMOS devices. It is not the same with SPICE3.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

description for that parameter. For example, a reference of M-35 means the 35th model parameter.

a0	M-101	lbetagb1	M-506	pbswg	M-273	type	M-1
a1	M-104	lbetagb2	M-507	pbswgd	M-276	type	OP-1
a2	M-105	lbgidl	M-470	pcbjtii	M-927	u0	M-120
abjtii	M-162	lbgisl	M-578	pcdsc	M-813	ua	M-122
ad	I-5	lbigbcp2	M-569	pcdscb	M-814	ua1	M-323
ad	M-378	lbigc	M-495	pcdscd	M-815	ub	M-123
ados	M-78	lbigsd	M-498	pcgdl	M-875	ub1	M-324
aebcp	I-16	lbjt0	M-200	pcgidl	M-900	uc	M-124
aely	M-202	lcbjtii	M-561	pcgisl	M-945	uc1	M-325
af	M-354	lcdsc	M-447	pcgsl	M-874	ucs	M-127
agb1	M-967	lcdscb	M-448	pcigbcp2	M-936	ucste	M-326
agb2	M-969	lcdscd	M-449	pcigc	M-862	ud	M-125
agbc2n	M-971	lcgdl	M-509	pcigsd	M-865	ud1	M-327
agbc2p	M-972	lcgidl	M-534	pcit	M-812	ueff	OP-25
agbcp	I-15	lcgisl	M-579	pckappa	M-876	ute	M-329
agbcp2	I-35	lcgsl	M-508	pclm	M-140	vabjt	M-201
agbcpd	I-34	lcigbcp2	M-570	pd	I-7	vbc1	M-152
agidl	M-166	lcigc	M-496	pd	M-380	vbgs	OP-7
agisl	M-173	lcigsd	M-499	pdbcp	I-13	vbm	M-99
ags	M-106	lcit	M-446	pdelta	M-822	vbox	M-394

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BSIMSOI MOSFET Model (bsimsoi)

ahli	M-203	lckappa	M-510	pdelvt	M-857	vbs	OP-6
ahlid	M-204	ldelta	M-456	pdiblc1	M-141	vbs0fd	M-216
aigbcp2	M-261	ldelvt	M-491	pdiblc2	M-142	vbs0pd	M-215
aigc	M-249	ldif	M-234	pdiblcb	M-143	vbsa	M-206
aigsd	M-252	ldif0	M-279	pdits	M-115	vbsusr	I-27
alarm	M-391	ldrout	M-454	pditsd	M-117	vbv	M-98
alpha0	M-146	ldsub	M-445	pditsl	M-116	vddeot	M-76
alphagb1	M-239	ldvt0	M-416	pdroul	M-820	vds	OP-5
alphagb2	M-244	ldvt0w	M-419	pdsul	M-811	vdsat	OP-19
as	I-4	ldvt1	M-417	pdvt0	M-782	vdsatii0	M-151
as	M-377	ldvt1w	M-420	pdvt0w	M-785	vecb	M-247
asd	M-280	ldvt2	M-418	pdvt1	M-783	version	M-2
at	M-318	ldvt2w	M-421	pdvt1w	M-786	vevb	M-242
b0	M-102	ldvtp0	M-548	pdvt2	M-784	vfb	M-100
b1	M-103	ldvtp1	M-549	pdvt2w	M-787	vfbefl	OP-20
bdos	M-79	ldvtp2	M-565	pdvtp0	M-914	vgb1	M-241
beta0	M-147	ldvtp3	M-566	pdvtp1	M-915	vgb2	M-246
beta1	M-149	ldvtp4	M-567	pdvtp2	M-931	vgs	OP-4
beta2	M-150	ldwb	M-441	pdvtp3	M-932	vgstcvmod	M-12
betaeff	OP-26	ldwg	M-440	pdvtp4	M-933	voff	M-133
betagb1	M-240	lebjtii	M-560	pdwb	M-807	voffcv	M-295

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

betagb2	M-245	leff	O-4	pdwg	M-806	vofffd	M-208
bf	M-352	leffcv	O-6	pebjtii	M-926	voxh	M-259
bg0sub	M-69	leffeot	M-74	pegidl	M-901	vrec0	M-195
bgb1	M-968	legidl	M-535	pegisl	M-942	vrec0d	M-197
bgb2	M-970	legisl	M-576	pesatii	M-830	vsat	M-121
bgbc2n	M-973	lesatii	M-464	peta0	M-809	vsce	M-301
bgbc2p	M-974	leta0	M-443	peta0cv	M-960	vsdfb	M-281
bgidl	M-167	leta0cv	M-956	petab	M-810	vsdth	M-282
bgisl	M-174	letab	M-444	petabcv	M-961	vth	OP-18
bigbcp2	M-262	letabcv	M-957	peu	M-939	vth_cv	OP-91
bigc	M-250	leu	M-573	pfbjtii	M-824	vtho	M-81
bigsd	M-253	lfbjtii	M-458	pfgidl	M-948	vtm00	M-975
binunit	M-3	lfgidl	M-582	pfgisl	M-951	vtun0	M-196
bjtoff	I-26	lfgisl	M-585	pfprout	M-917	vtun0d	M-198
bvj	M-393	lfprout	M-551	phi	O-12	w	I-1
cap_bd	OP-62	lidbjt	M-540	phig	M-72	w	M-375
cap_bs	OP-61	liddif	M-541	pidbjt	M-906	w0	M-88
capmod	M-11	lidrec	M-542	piddif	M-907	w0flk	M-351
cbb	OP-47	lidtun	M-543	pidrec	M-908	wa0	M-610
cbd	OP-45	lii	M-154	pidtun	M-909	wa1	M-616
cbdbm	OP-83	lint	M-45	pigcd	M-256	wa2	M-617

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

cbebo	OP-64	lisbjt	M-476	pisbjt	M-842	wabjtii	M-745
cbg	OP-44	lisdif	M-477	pisdif	M-843	wacde	M-675
cbgbgbm	OP-89	lisrec	M-478	pisrec	M-844	waely	M-668
cbgbm	OP-82	listun	M-479	pistun	M-845	wagidl	M-652
cbgd	OP-71	lk1	M-407	pk1	M-773	wagisl	M-760
cbgg	OP-70	lk1w1	M-408	pk1w1	M-774	wags	M-611
cbgs	OP-72	lk1w2	M-409	pk1w2	M-775	wahli	M-669
cbjtii	M-161	lk2	M-410	pk2	M-776	wahlid	M-728
cbs	OP-46	lk3	M-411	pk3	M-777	waigbcp2	M-751
cbsbm	OP-84	lk3b	M-412	pk3b	M-778	waigc	M-677
cdb	OP-39	lkb1	M-413	pkb1	M-779	waigsd	M-680
cdbgbm	OP-85	lketa	M-431	pketa	M-797	walpha0	M-640
cdd	OP-37	lketas	M-432	pketas	M-798	walphagb1	M-687
cddb	OP-79	lkgidl	M-581	pkgidl	M-947	walphagb2	M-688
cdebo	OP-63	lkgisl	M-584	pkgisl	M-950	warn	M-395
cdg	OP-36	lkt1	M-513	pkt1	M-879	wat	M-702
cdgbm	OP-81	lkt11	M-514	pkt11	M-880	wb0	M-612
cdnver	M-4	lkt2	M-515	pkt2	M-881	wb1	M-613
cds	OP-38	lku0	M-554	pku0	M-920	wbeta0	M-642
cdsbm	OP-80	lkvth0	M-555	pkvth0	M-921	wbeta1	M-643
cdsbs	M-302	ll	M-47	plbjt0	M-849	wbeta2	M-644

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

cdsc M-128	llbjt0 M-483	plii M-829	wbetagb1 M-689
cdscb M-129	llc M-49	plpe0 M-896	wbetagb2 M-690
cdscd M-130	llii M-463	plpeb M-897	wbgidl M-653
ceebo OP-65	lln M-48	pmbjtii M-929	wbgisl M-761
cf M-285	llodku0 M-365	pminv M-916	wbigbcp2 M-752
cfrcoeff M-286	llodvth M-368	pminvcv M-923	wbigc M-678
cgb OP-35	llpe0 M-530	pmoin M-859	wbigsd M-681
cgbg OP-74	llpeb M-531	pnbjt M-848	wcbjtii M-744
cgbo M-267	lmax M-387	pnch M-769	wcdsc M-630
cgd OP-33	lmbjtii M-563	pndif M-877	wcdscb M-631
cgdbm OP-77	lmin M-388	pndiode M-839	wcdscd M-632
cgdl M-269	lminv M-550	pndioded M-903	wcgdl M-692
cgdo M-265	lminvcv M-557	pnfactor M-805	wcgidl M-716
cgeo M-266	lmoin M-493	pngate M-771	wcgisl M-762
cgg OP-32	ln M-194	pngidl M-837	wcgs1 M-691
cggbm OP-76	lnbjt M-482	pnigc M-866	wcigbcp2 M-753
cgidl M-168	lnch M-403	pnlx M-781	wcigc M-679
cgisl M-175	lndif M-511	pnoff M-913	wcigsd M-682
cgs OP-34	lndiode M-473	pnrecf0 M-840	wcit M-629
cgsbm OP-78	lndioded M-537	pnrecf0d M-904	wckappa M-693
cgs1 M-268	lnfactor M-439	pnrecr0 M-841	wdelta M-639

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

cgso M-264	lngate M-405	pnrecr0d M-905	wdelvt M-674
cigbcp2 M-263	lngidl M-471	pnsd M-937	wdrout M-637
cigc M-251	lnigc M-500	pnsb M-770	wdsub M-628
cigsd M-254	lnlx M-415	pntrcf M-887	wdvt0 M-599
cit M-132	lnoff M-547	pntrcr M-888	wdvt0w M-602
cjswg M-271	lnrcf0 M-474	pnun M-838	wdvt1 M-600
cjswgd M-274	lnrcf0d M-538	pnund M-902	wdvt1w M-603
ckappa M-270	lnrecr0 M-475	poxedge M-257	wdvt2 M-601
clc M-287	lnrecr0d M-539	ppclm M-816	wdvt2w M-604
cle M-288	lnsd M-571	ppdiblc1 M-817	wdvtp0 M-731
compatible M-389	lnsub M-404	ppdiblc2 M-818	wdvtp1 M-732
csb OP-43	lntrcf M-521	ppdiblc3 M-819	wdvtp2 M-748
csbg OP-75	lntrcr M-522	ppdits M-918	wdvtp3 M-749
csbgbm OP-88	lnun M-472	ppditsd M-919	wdvtp4 M-750
csd OP-41	lnund M-536	ppigcd M-867	wdwb M-624
csdesw M-284	lodeta0 M-374	ppoxedge M-868	wdwg M-623
csdmin M-283	lodeta0cv M-955	pprt M-886	webjtii M-743
csg OP-40	lodk2 M-372	pprwb M-802	weff O-3
csgbm OP-86	lpclm M-450	pprg M-803	weffcv O-7
css OP-42	lpdiblc1 M-451	ppvag M-821	weffeot M-75
cssbm OP-87	lpdiblc2 M-452	prds M-801	wegidl M-717

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

cth0	I-25	lpdiblcb	M-453	prdw	M-899	wegisl	M-759
cth0	M-330	lpdits	M-552	prgidl	M-946	wesatii	M-647
ctheff	O-9	lpditsd	M-553	prgisl	M-949	weta0	M-626
delta	M-145	lpe0	M-89	prsw	M-898	weta0cv	M-958
deltavox	M-260	lpeb	M-91	prrt	M-328	wetab	M-627
delvt	M-293	lpigcd	M-501	prwb	M-39	wetabcv	M-959
delvto	I-36	lpoly	O-5	prwg	M-40	weu	M-756
dk2b	M-211	lpoxedge	M-502	ps	I-6	wfbjtii	M-641
dlbg	M-291	lprrt	M-520	ps	M-379	wfgidl	M-765
dlc	M-289	lprwb	M-436	psbcp	I-14	wfgisl	M-768
dlcb	M-290	lprwg	M-437	psii0	M-831	wfprout	M-734
dlcig	M-258	lpvag	M-455	psii1	M-832	widbjt	M-722
drout	M-138	lrds	M-435	psii2	M-833	widdif	M-723
dskip	M-390	lrdr	M-533	psiid	M-834	widrec	M-724
dsub	M-135	lrgidl	M-580	pu0	M-788	widtun	M-725
dtoxcv	M-297	lrgisl	M-583	pua	M-789	wint	M-46
dvbd0	M-212	lrsw	M-532	pua1	M-882	wisbjt	M-659
dvbd1	M-213	lsii0	M-465	pub	M-790	wisdif	M-660
dvt0	M-92	lsii1	M-466	pub1	M-883	wisrec	M-661
dvt0w	M-95	lsii2	M-467	puc	M-791	wistun	M-662
dvt1	M-93	lsiid	M-468	puc1	M-884	wk1	M-590

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

dvt1w M-96	lu0 M-422	pucs M-940	wk1w1 M-591
dvt2 M-94	lua M-423	pucste M-941	wk1w2 M-592
dvt2w M-97	lua1 M-516	pud M-924	wk2 M-593
dvtp0 M-109	lub M-424	pud1 M-925	wk3 M-594
dvtp1 M-110	lub1 M-517	pute M-878	wk3b M-595
dvtp2 M-111	luc M-425	pvabjt M-850	wkb1 M-596
dvtp3 M-112	luc1 M-518	pvag M-144	wketa M-614
dvtp4 M-113	lucs M-574	pvbci M-930	wketas M-615
dwb M-43	lucste M-575	pvsatii0 M-828	wkgidl M-764
dwbc M-44	lud M-558	pvfb M-938	wkgisl M-767
dwc M-292	lud1 M-559	pvoff M-808	wkt1 M-696
dwg M-42	lute M-512	pvoffcv M-922	wkt11 M-697
easub M-73	lvabjt M-484	pvrec0 M-846	wkt2 M-698
ebg M-238	lvbci M-564	pvrec0d M-910	wku0 M-737
ebjtii M-160	lvdsatii0 M-462	pvsat M-792	wkvth0 M-738
ef M-355	lvfb M-572	pvsdfb M-855	wl M-55
eggbc2 M-965	lvoff M-442	pvsdth M-856	wlbjt0 M-666
eggdep M-966	lvoffcv M-556	pvtho M-772	wlc M-56
egidl M-165	lvrec0 M-480	pvtun0 M-847	wlii M-646
egisl M-172	lvrec0d M-544	pvtun0d M-911	wln M-59
em M-359	lvsat M-426	pw0 M-780	wlod M-362

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

eot M-65	lvdfb M-489	pwr M-804	wlodku0 M-366
epsrgate M-80	lvsdth M-490	pwr OP-51	wlodvth M-369
epsrox M-66	lvtho M-406	pxbjt M-889	wlpe0 M-712
epsrsub M-67	lvtun0 M-481	pxdif M-890	wlpeb M-713
esatii M-155	lvtun0d M-545	pxdifd M-893	wmax M-385
eta0 M-136	lw M-52	pxj M-869	wmbjtii M-746
eta0cv M-952	lw0 M-414	pxrcrg1 M-853	wmin M-386
etab M-137	lwc M-50	pxrcrg2 M-854	wminv M-733
etabcv M-953	lw1 M-54	pxrec M-891	wminvcv M-740
etsi M-32	lwlc M-51	pxrecd M-894	wmoin M-676
eu M-126	lwn M-53	pxtun M-892	wnbjt M-665
fbjtii M-148	lwr M-438	pxtund M-895	wnch M-586
fbody M-294	lxbjt M-523	qj OP-30	wndif M-694
fdmod M-8	lxdif M-524	qjd OP-58	wndiode M-656
fgidl M-171	lxdifd M-527	qjg OP-31	wndioded M-719
fgisl M-178	lxj M-503	qjint OP-54	wnfactor M-622
fnoimod M-24	lxrcrg1 M-487	qjs OP-57	wngate M-588
fprout M-139	lxrcrg2 M-488	qd OP-28	wngidl M-654
frbody I-28	lxrec M-525	q dint OP-56	wnigc M-683
frbody M-231	lxrecd M-528	qg OP-27	wnlx M-598
gamma1 M-118	lxtun M-526	qgint OP-55	wnoff M-730

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

gamma2	M-119	lxtund	M-529	qs	OP-29	wnrecf0	M-657
gatetype	M-10	m	I-17	rbdb	I-32	wnrecf0d	M-720
gbmin	M-311	mbe0	M-402	rbdb	M-309	wnrecr0	M-658
gdeff	O-15	mbewl	M-401	rbody	M-217	wnrecr0d	M-721
gds	OP-22	mbjtii	M-163	rbodymod	I-20	wnsd	M-754
gidlmod	M-9	meff	O-2	rbodymod	M-17	wnsub	M-587
gm	OP-21	minr	M-232	rbp	OP-73	wntrecf	M-704
gmb	OP-23	minv	M-114	rbsb	I-33	wntrecr	M-705
gmbg	OP-24	minvcv	M-296	rbsb	M-310	wntun	M-655
gmoverid	OP-52	mismatchdist	M-397	rbsh	M-218	wntund	M-718
gseff	O-14	mismatchmod	M-396	rd	M-221	wpclm	M-633
hdif	M-233	mjswg	M-272	rdc	M-223	wpdiblc1	M-634
i2	OP-66	mjswgd	M-275	rdd	M-229	wpdiblc2	M-635
i3	OP-67	mobmod	M-7	rdeff	O-11	wpdiblc3	M-636
ib	OP-50	moinfd	M-214	rds	O-16	wpdits	M-735
ibd	OP-15	mtrlmod	M-6	rdsmod	M-18	wpditsd	M-736
ibdo	OP-59	mvt0	M-400	rdswh	M-38	wpigcd	M-684
ibp	OP-10	mvtwl	M-398	rdw	M-225	wpoxedge	M-685
ibs	OP-17	mvtwl2	M-399	rdwmin	M-227	wpert	M-703
ibso	OP-60	nbc	I-11	region	I-23	wprwb	M-619
ic	OP-11	nbjt	M-199	region	OP-2	wprwg	M-620

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

id	OP-48	nch	M-27	reversed	OP-3	wpvag	M-638
idbjt	M-190	ndif	M-278	rgatemod	I-19	wr	M-41
iddif	M-191	ndiode	M-205	rgatemod	M-19	wrdsw	M-618
ido	OP-9	ndioded	M-181	rgidl	M-169	wrdw	M-715
idrec	M-192	necb	M-248	rgisl	M-176	wrgidl	M-763
ids	OP-8	nevb	M-243	rhalo	M-230	wrgisl	M-766
idtun	M-193	nf	I-3	rnoia	M-347	wrs	M-714
ig	OP-90	nfactor	M-131	rnoib	M-348	wsii0	M-648
igbmod	M-14	ngate	M-28	rnoic	M-963	wsii1	M-649
igbt	OP-16	ngcon	M-306	rs	M-220	wsii2	M-650
igcd	OP-69	ngidl	M-164	rsc	M-222	wsiid	M-651
igcmmod	M-15	ni0sub	M-68	rseff	O-10	wth0	M-341
igcs	OP-68	nigc	M-255	rsh	M-219	wu0	M-605
igidl	OP-13	nlx	M-90	rshg	M-303	wua	M-606
igisl	OP-12	noff	M-134	rss	M-228	wua1	M-699
igmod	M-13	nofffd	M-207	rss	O-17	wub	M-607
iii	OP-14	noia	M-356	rsw	M-224	wub1	M-700
iiimod	M-16	noib	M-357	rswmin	M-226	wuc	M-608
imax	M-392	noic	M-358	rth0	I-24	wuc1	M-701
is	OP-49	noif	M-350	rth0	M-331	wucs	M-757
isbjt	M-186	noimod	M-23	rtheff	O-8	wucste	M-758

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

isdif	M-187	nrb	I-10	sa	I-29	wud	M-741
isnoisy	I-22	nrb	M-383	saref	M-360	wud1	M-742
isrec	M-188	nrd	I-8	sb	I-30	wute	M-695
istun	M-189	nrd	M-381	sbref	M-361	wvabjt	M-667
k1	M-82	nrecf0	M-182	scalen	M-964	wvbci	M-747
k1b	M-209	nrecf0d	M-184	sd	I-31	wvdsatii0	M-645
k1w1	M-83	nrecr0	M-183	shmod	M-20	wvfb	M-755
k1w2	M-84	nrecr0d	M-185	sii0	M-156	wvoff	M-625
k2	M-85	nrs	I-9	sii1	M-157	wvoffcv	M-739
k2b	M-210	nrs	M-382	sii2	M-158	wvrec0	M-663
k3	M-86	nsd	M-29	siid	M-159	wvrec0d	M-726
k3b	M-87	nseg	I-12	soimod	I-18	wvsat	M-609
kb1	M-298	nsub	M-26	soimod	M-5	wvsdfb	M-672
kb3	M-299	ntnoi	M-349	steta0	M-373	wvsdth	M-673
keta	M-107	ntox	M-235	steta0cv	M-954	wvtho	M-589
ketas	M-108	ntrecf	M-332	stk2	M-371	wvtun0	M-664
kf	M-353	ntrecre	M-333	tbgasub	M-70	wvtun0d	M-727
kgidl	M-170	ntun	M-179	tbgbsub	M-71	ww	M-60
kgisl	M-177	ntund	M-180	tbox	M-33	ww0	M-597
kt1	M-315	pa0	M-793	tcjswg	M-319	wwc	M-57
kt11	M-316	pa1	M-799	tcjswgd	M-321	ww1	M-62

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

kt2 M-317	pa2 M-800	tdev OP-53	wwlc M-58
ku0 M-363	pabjtii M-928	tempeff O-1	wnn M-61
kvsat M-370	pacde M-858	tempeot M-77	wwr M-621
kvth0 M-367	paely M-851	tii M-153	wxbjt M-706
l I-2	pagidl M-835	tku0 M-364	wxdif M-707
l M-376	pagisl M-943	tlev M-21	wxdifd M-709
la0 M-427	pags M-794	tlevc M-22	wxj M-686
la1 M-433	pahli M-852	tmax M-314	wxrcrg1 M-670
la2 M-434	pahlid M-912	tnodeout I-21	wxrcrg2 M-671
labjtii M-562	paigbcp2 M-934	tnoia M-345	wxrec M-708
lacde M-492	paigc M-860	tnoib M-346	wxrecd M-710
laely M-485	paigsd M-863	tnoic M-962	wxtun M-729
lagidl M-469	palpha0 M-823	tnoimod M-25	wxtund M-711
lagisl M-577	palphagb1 M-870	tnom M-312	xbjt M-334
lags M-428	palphagb2 M-871	tox M-34	xdif M-335
lahli M-486	paramchk M-384	tox O-13	xdifd M-338
lahlid M-546	pat M-885	toxm M-35	xgl M-308
laigbcp2 M-568	pb0 M-795	toxp M-36	xgw M-307
laigc M-494	pb1 M-796	toxqm M-236	xj M-30
laigsd M-497	pbeta0 M-825	toxref M-237	xl M-63
lalpha0 M-457	pbeta1 M-826	tpbswg M-320	xpart M-300

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

lalphagb1	M-504	pbeta2	M-827	tpbswgd	M-322	xrcrg1	M-304
lalphagb2	M-505	pbetagb1	M-872	trd	M-344	xrcrg2	M-305
lat	M-519	pbetagb2	M-873	trise	I-37	xrec	M-336
lb0	M-429	pbgid1	M-836	trise	M-313	xrecd	M-339
lb1	M-430	pbgis1	M-944	trs	M-343	xt	M-37
lbeta0	M-459	pbigbcp2	M-935	tsi	M-31	xtun	M-337
lbeta1	M-460	pbigc	M-861	tt	M-277	xtund	M-340
lbeta2	M-461	pbigsd	M-864	tvbci	M-342	xw	M-64

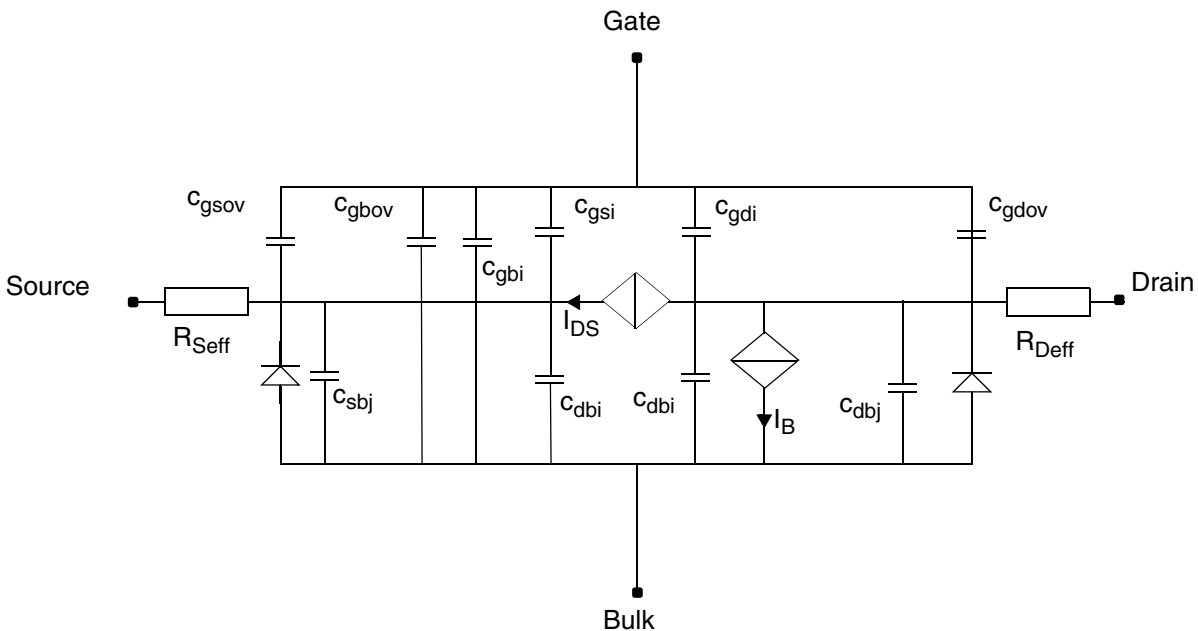
B3SOI-PD Transistor Model (b3soipd)

The B3SOIPD model was developed by the BSIM/SOI modeling group at the University of California, Berkeley. This chapter contains the following information for for the B3SOI-PD transistor model:

- [BSIMPD2.0.1 IV](#) on page 2306
- [BSIMPD2.0.1 CV](#) on page 2320
- [BSIMPD2.2](#) on page 2333
- [Scaling Effects](#) on page 2335
- [Component Statements](#) on page 2335

Virtuoso Simulator Components and Device Models Reference

B3SOI-PD Transistor Model (b3soipd)



BSIMPD2.0.1 IV

Model Parameter Notes

1. BSIMPD2.0 supports $capmod=2$ and 3 only. $capmod=0$ and 1 are not supported.
2. In modern SOI technology, source/drain extension or LDD is commonly used. As a result, the source/drain junction depth (X_j) can be different from the silicon film thickness (T_{si}). By default, if X_j is not given, it is set to T_{si} . X_j is not allowed to be greater than T_{si} .
3. BSIM3 SOI refers to the silicon substrate beneath the buried oxide, not to the well region in BSIM3. It is used to calculate backgate flat-band voltage (V_{fbb}) and parameters related to the source/drain diffusion bottom capacitance (V_{sdth} , V_{sdfb} , and C_{sdmin}). Positive n_{sub} means the same type of doping as the body, and negative n_{sub} means the opposite type of doping.

Body Voltages

1. If $cgso$ is not given, it is calculated using the following:
If dlc is given and is greater than 0, then

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B3SOI-PD Transistor Model (b3soipd)

$$c_{gso} = p1 = (dlc \times cox) - c_{gs1}$$

If the previously calculated $c_{gso} < 0$, then

$$c_{gso} = 0$$

else

$$c_{gso} = 0.6 \times Tsi \times cox$$

2. C_{gdo} is calculated in a way similar to C_{sdo} .

3. If n_{sub} is positive,

$$V_{sdfb} = -\frac{kT}{q} \log\left(\frac{10^{20} \cdot n_{sub}}{n_i \cdot n_i}\right) - 0.3$$

else

$$V_{sdfb} = -\frac{kT}{q} \log\left(\frac{10^{20}}{n_{sub}}\right) + 0.3$$

4. If n_{sub} is positive,

$$\phi_{sd} = 2\frac{kT}{q} \log\left(\frac{n_{sub}}{n_i}\right), \Upsilon_{sd} = \frac{5.753 \times 10^{-12} \sqrt{n_{sub}}}{C_{box}}$$

$$V_{sdth} = V_{sdfb} + \phi_{sd} + \Upsilon_{sd} \sqrt{\phi_{sd}}$$

else

$$\phi_{sd} = 2\frac{kT}{q} \log\left(-\frac{n_{sub}}{n_i}\right), \Upsilon_{sd} = \frac{5.753 \times 10^{-12} \sqrt{-n_{sub}}}{C_{box}}$$

$$V_{sdth} = V_{sdfb} - \phi_{sd} - \Upsilon_{sd} \sqrt{\phi_{sd}}$$

5.

$$X_{sddep} = \sqrt{\frac{2\varepsilon_{si}\phi_{sd}}{q|n_{sub} \cdot 10^6|}}$$

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$$C_{sddep} = \frac{\epsilon_{si}}{X_{sddep}}$$

$$C_{sdmin} = \frac{C_{sddep}C_{box}}{C_{sddep} + C_{box}}$$

6. If CF is not given, it is calculated using

$$CF = \frac{2\epsilon_{ox}}{\pi} \ln\left(1 + \frac{4 \times 10^{-7}}{T_{ox}}\right)$$

7. For $mobmod=1$ and 2 , the unit is m/V^2 . The default is -5.6×10^{-11} . For $mobmod=3$, the unit is $1/V$, and the default is -0.056 .

V_{bsh} is equal to the V_{bs} bounded between (V_{bsc}, ϕ_{s1}) . V_{bsh} is used in V_{th} and A_{bulk} calculation.

$$T1 = V_{bsc} + 0.5 \left[V_{bs} - V_{bsc} - \delta + \sqrt{(V_{bs} - V_{bsc} - \delta)^2 - 4\delta V_{bsc}} \right], V_{bsc} = -5V$$

$$V_{bsh} = \phi_{s1} - 0.5 \left[\phi_{s1} - T1 - \delta + \sqrt{(\phi_{s1} - T1 - \delta)^2 + 4\delta T1} \right], \phi_{s1} = 1.5V$$

V_{bsh} is further limited to $0.95\phi_s$ to give V_{bseff} .

$$V_{bseff} = \phi_{s0} - 0.5 \left[\phi_{s0} - V_{bsh} - \delta + \sqrt{(\phi_{s0} - V_{bsh} - \delta)^2 + 4\delta V_{bsh}} \right], \phi_{s0} = 0.95\phi_s$$

Effective Channel Length and Width

$$dW = W_{int} + \frac{W_l}{L W_{ln}} + \frac{W_w}{W W_{wn}} + \frac{W_{wl}}{L W_{ln} W_{wn}}$$

$$dW = dW + dW_g V_{gsteff} + dW_b (\sqrt{\Phi_s - V_{bseff}} - \sqrt{\Phi_s})$$

$$dL = L_{int} + \frac{L_l}{L L_{ln}} + \frac{L_w}{W L_{wn}} + \frac{L_{wl}}{L L_{ln} W L_{wn}}$$

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$$L_{eff} = L_{drawn} - 2dL$$

$$W_{eff} = W_{drawn} - N_{bc}dW_{bc} - (2 - N_{bc})dW$$

$$W_{eff}' = W_{drawn} - N_{bc}dW_{bc} - (2 - N_{bc})dW$$

$$W_{diod} = \frac{W_{eff}'}{N_{seg}} + P_{dbcp}$$

$$W_{dios} = \frac{W_{eff}'}{N_{seg}} + P_{sbcp}$$

Threshold Voltage

$$V_{TH} = V_{tho} - K_{1eff}(sqrtPhisExt - \sqrt{\Phi_s})$$

$$- K_2 V_{bseff} + K_{1eff} \left(\sqrt{1 + \frac{N_{LX}}{L_{eff}}} - 1 \right) \sqrt{\Phi_s} + (K_3 + K_{3b} V_{bseff}) \frac{T_{ox}}{W_{eff} + W_o} \Phi_s$$

$$- D_{VT0w} \left(\exp \left(-D_{VT1w} \frac{W_{eff} L_{eff}}{2l_{tw}} \right) + 2 \exp \left(-D_{VT1w} \frac{W_{eff} L_{eff}}{l_{tw}} \right) \right) (V_{bi} - \Phi_s)$$

$$- D_{VT0} \left(\exp \left(-D_{VT1} \frac{L_{eff}}{2l_t} \right) + 2 \exp \left(-D_{VT1} \frac{L_{eff}}{l_t} \right) \right) (V_{bi} - \Phi_s)$$

$$- \left(\exp \left(-D_{sub} \frac{L_{eff}}{2l_{to}} \right) + 2 \exp \left(-D_{sub} \frac{L_{eff}}{l_{to}} \right) \right) (E_{tao} + E_{tab} V_{bseff}) V_{ds}$$

$$l_t = \sqrt{\epsilon_{si} X_{dep} / C_{ox}} (1 + D_{VT2} V_{bseff})$$

$$sqrtPhisExt = \sqrt{\Phi_s - V_{bseff}} + s(V_{bsh} - V_{bseff})$$

$$s = -\frac{1}{2\sqrt{\Phi_s - \Phi_{s0}}}$$

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$$K_{1eff} = K_1 \left(1 + \frac{K_{1w1}}{W_{eff} + K_{1w2}} \right)$$

$$l_{tw} = \sqrt{\varepsilon_{si} X_{dep} / C_{ox}} (1 + D_{VT2w} V_{bseff})$$

$$l_{to} = \sqrt{\varepsilon_{si} X_{dep0} / C_{ox}}$$

$$X_{dep} = \sqrt{\frac{2\varepsilon_{si}(\Phi_s - V_{bseff})}{qN_{ch}}}$$

$$X_{dep0} = \sqrt{\frac{2\varepsilon_{si}\Phi_s}{qN_{ch}}}$$

$$V_{bi} = v_t \ln \left(\frac{N_{ch} N_{DS}}{n_i^2} \right)$$

Poly Depletion Effect

$$V_{poly} + \frac{1}{2} X_{poly} E_{poly} = \frac{qN_{gate} X_{poly}^2}{2\varepsilon_{si}}$$

$$\varepsilon_{ox} E_{ox} = \varepsilon_{si} E_{poly} = \sqrt{2q\varepsilon_{si} N_{gate} V_{poly}}$$

$$V_{gs} - V_{FB} - \phi_x = V_{poly} + V_{ox}$$

$$a(V_{gs} - V_{FB} - \phi_s - V_{poly})^2 - V_{poly} = 0$$

$$a = \frac{\varepsilon_{ox}^2}{2q\varepsilon_{si} N_{gate} T_{ox}^2}$$

$$V_{gs_eff} = V_{FB} + \phi_s + \frac{q\epsilon_{si}N_{gate}T_{ox}^2}{\epsilon_{ox}^2} \times \left(\sqrt{1 + \frac{2\epsilon_{ox}^2(V_{gs} - V_{FB} - \phi_s)}{q\epsilon_{si}N_{gate}T_{ox}^2}} - 1 \right)$$

Effective Vgst for All Regions (with Polysilicon Depletion Effect)

$$V_{gsteff} = \frac{2nv_t \ln \left[1 + \exp \left(\frac{V_{gs_eff} - V_{th}}{2nv_t} \right) \right]}{1 + 2nC_{ox} \sqrt{\frac{2\Phi_s}{q\epsilon_{si}N_{ch}}} \exp \left(-\frac{V_{gs_eff} - V_{th} - 2V_{off}}{2nv_t} \right)}$$

$$n = 1 + N_{factor} \frac{\epsilon_{si}/X_{dep}}{C_{ox}} + \frac{C_{it}}{C_{ox}}$$

$$\frac{(C_{dsc} + C_{dscd}V_{ds} + C_{dscb}V_{bseff}) \left[\exp \left(-D_{VT1} \frac{L_{eff}}{2l_t} \right) + 2 \exp \left(-D_{VT1} \frac{L_{eff}}{l_t} \right) \right]}{C_{ox}}$$

Effective Bulk Charge Factor

$$A_{bulk} = 1 + \left[\frac{K_{1eff}}{2 \sqrt{(\phi_s + Ketas) - \frac{V_{bsh}}{1 + Keta \cdot V_{bsh}}}} \right] \times$$

$$\left(\frac{A_0 L_{eff}}{L_{eff} + 2 \sqrt{T_{si} X_{dep}}} \left(1 - A_{gs} V_{gsteff} \left(\frac{L_{eff}}{L_{eff} + 2 \sqrt{T_{si} X_{dep}}} \right)^2 \right) + \frac{B_0}{W_{eff} + B_1} \right)$$

$$A_{bulk0} = A_{bulk}(V_{gsteff} = 0)$$

Mobility and Saturation Velocity

For Mobmod=1

$$\mu_{eff} = \frac{\mu_0}{1 + (U_a + U_c V_{bseff}) \left(\frac{V_{gsteff} + 2V_{th}}{T_{ox}} \right) + U_b \left(\frac{V_{gsteff} + 2V_{th}}{T_{ox}} \right)^2}$$

For Mobmod=2

$$\mu_{eff} = \frac{\mu_0}{1 + (U_a + U_c V_{bseff}) \left(\frac{V_{gsteff}}{T_{ox}} \right) + U_b \left(\frac{V_{gsteff}}{T_{ox}} \right)^2}$$

For Mobmod=3

$$\mu_{eff} = \frac{\mu_0}{1 + \left[U_a \left(\frac{V_{gsteff} + 2V_{th}}{T_{ox}} \right) + U_b \left(\frac{V_{gsteff} + 2V_{th}}{T_{ox}} \right)^2 \right] (1 + U_c V_{bseff})}$$

Drain Saturation Voltage

For $R_{ds} > 0$ or $\lambda \neq 1$,

$$V_{dsat} = \frac{-b - \sqrt{b^2 - 4ac}}{2a}$$

$$a = A_{bulk}^2 W_{eff}^v \nu_{sat} C_{ox} R_{ds} + \left(\frac{1}{\lambda} - 1 \right) A_{bulk}$$

$$b = - \left[(V_{gsteff} + 2v_t) \left(\frac{2}{\lambda} - 1 \right) + A_{bulk} E_{sat} L_{eff} + 3A_{bulk} (V_{gsteff} + 2v_t) W_{eff}^v \nu_{sat} C_{ox} R_{ds} \right]$$

$$c = (V_{gsteff} + 2v_t) E_{sat} L_{eff} + 2(V_{gsteff} + 2v_t)^2 W_{eff}^v \nu_{sat} C_{ox} R_{ds}$$

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$$\lambda = A_1 V_{gsteff} + A_2$$

For $R_{ds} = 0$ or $\lambda = 1$,

$$V_{dsat} = \frac{E_{sat} L_{eff} (V_{gsteff} + 2v_t)}{A_{bulk} E_{sat} L_{eff} + (V_{gsteff} + 2v_t)}$$

$$E_{sat} = \frac{2v_{sat}}{\mu_{eff}}$$

Vdseff

$$V_{dseff} = V_{dsat} - \frac{1}{2} \left(V_{dsat} - V_{ds} - \delta + \sqrt{(V_{dsat} - V_{ds} - \delta)^2 + 4\delta V_{dsat}} \right)$$

Drain Current Expression

$$I_{ds, MOSFET} = \frac{1}{N_{seg}} \frac{I_{dso}(V_{dseff})}{1 + \frac{R_{ds} I_{dso}(V_{dseff})}{V_{dseff}}} \left(1 + \frac{V_{ds} - V_{dseff}}{V_A} \right)$$

$$\beta = \mu_{eff} C_{ox} \frac{W_{eff}}{L_{eff}}$$

$$I_{dso} = \frac{\beta V_{gsteff} \left(1 - A_{bulk} \frac{V_{dseff}}{2(V_{gsteff} + 2v_t)} \right) V_{dseff}}{1 + \frac{V_{dseff}}{E_{sat} L_{eff}}}$$

$$V_A = V_{Asat} + \left(1 + \frac{P_{vag} V_{gsteff}}{E_{sat} L_{eff}} \right) \left(\frac{1}{V_{ACLM}} + \frac{1}{V_{ADIBLC}} \right)^{-1}$$

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$$V_{ACLM} = \frac{A_{bulk} E_{sat} L_{eff} + V_{gsteff}}{P_{clm} A_{bulk} E_{sat} litl} (V_{ds} - V_{dseff})$$

$$V_{ADIBLC} = \frac{(V_{gsteff} + 2v_t)}{\theta_{rout}(1 + P_{DIBLCB} V_{bseff})} \left(1 - \frac{A_{bulk} V_{dsat}}{A_{bulk} V_{dsat} + 2v_t} \right)$$

$$\theta_{rout} = P_{DIBLC1} \left[\exp\left(-D_{ROUT} \frac{L_{eff}}{2l_{i0}}\right) + 2 \exp\left(-D_{ROUT} \frac{L_{eff}}{l_{i0}}\right) \right] + P_{DIBLC2}$$

$$V_{Asat} = \frac{E_{sat} L_{eff} + V_{dsat} + 2R_{ds} v_{sat} C_{ox} W_{eff} V_{gsteff} \left[1 - \frac{A_{bulk} V_{dsat}}{2(V_{gsteff} + 2v_t)} \right]}{2/\lambda - 1 + R_{ds} v_{sat} C_{ox} W_{eff} A_{bulk}}$$

$$litl = \sqrt{\frac{\epsilon_{si} T_{ox} T_{Si}}{\epsilon_{ox}}}$$

Drain/Source Resistance

$$R_{ds} = R_{dsw} \frac{1 + P_{rwg} V_{gsteff} + P_{rwb} (\sqrt{\phi_s - V_{bseff}} - \sqrt{\phi_s})}{(10^6 W_{eff}) W_r}$$

Impact Ionization Current

$$I_{ii} = \alpha_0 (I_{ds, MOSFET} + F_{bjtii} I_c) \exp\left(\frac{V_{diff}}{\beta_2 + \beta_1 V_{diff} + \beta_0 V_{diff}^2}\right)$$

$$V_{diff} = V_{ds} - V_{dsatii}$$

$$V_{dsatii} = V_{gsStep} + \left[V_{dsatii0} \left(1 + T_{ii} \left(\frac{T}{T_{nom}} - 1 \right) \right) + \frac{L_{ii}}{L_{eff}} \right]$$

$$V_{gsStep} = \left(\frac{E_{sati} L_{eff}}{1 + E_{sati} L_{eff}} \right) \left(\frac{1}{1 + S_{ii1} V_{gsteff}} + S_{ii2} \right) \left(\frac{S_{ii0} V_{gst}}{1 + S_{iid} V_{ds}} \right)$$

Gate-Induced-Drain-Leakage (GIDL)

At drain,

$$I_{dgidl} = W_{diod} \alpha_{gidl} E_s \exp\left(-\frac{\beta_{gidl}}{E_s}\right)$$

$$E_s = \frac{V_{ds} - V_{gs} - \chi}{3T_{ox}}$$

At source,

$$I_{sgidl} = W_{dios} \alpha_{gidl} E_s \exp\left(-\frac{\beta_{gidl}}{E_s}\right)$$

$$E_s = \frac{-V_{gs} - \chi}{3T_{ox}}$$

If E_s is negative, I_{gidl} is set to zero for both drain and source.

Body Contact Current

$$R_{bp} = R_{body0} \frac{W_{eff} / N_{seg}}{L_{eff}}$$

$$R_{bodyext} = R_{bsh} N_{rb}$$

For 4-T device,

$$I_{bp} = 0$$

For 5-T device,

$$I_{bp} = \frac{V_{bp}}{R_{bp} + R_{bodyext}}$$

Diode and BJT Currents

Bipolar Transport Factor

$$\alpha_{bjt} = \exp\left[-0.5\left(\frac{L_{eff}}{L_n}\right)^2\right]$$

Body-to-Source/Drain Diffusion

$$I_{bs1} = W_{dios} T_{si} j_{sdif} \left(\exp\left(\frac{V_{bs}}{n_{dio} V_t}\right) - 1 \right)$$

$$I_{bd1} = W_{diod} T_{si} j_{sdif} \left(\exp\left(\frac{V_{bd}}{n_{dio} V_t}\right) - 1 \right)$$

Recombination/Trap-Assisted Tunneling Current in Depletion Region

$$I_{bs2} = W_{dios} T_{si} j_{srec} \left(\exp\left(\frac{V_{bs}}{0.026 n_{recf}}\right) - \exp\left(\frac{V_{sb}}{0.026 n_{recr} V_{rec0} + V_{sb}}\right) \right)$$

$$I_{bd2} = W_{diod} T_{si} j_{srec} \left(\exp\left(\frac{V_{bd}}{0.026 n_{recf}}\right) - \exp\left(\frac{V_{db}}{0.026 n_{recr} V_{rec0} + V_{db}}\right) \right)$$

Reversed Bias Tunneling Leakage

$$I_{bs4} = W_{dios} T_{si} j_{stun} \left(1 - \exp\left(\frac{n_{tun} V_{sb}}{V_{tun0} + V_{sb}}\right) \right)$$

$$I_{bd4} = W_{diod} T_{si} j_{stun} \left(1 - \exp\left(\frac{n_{tun} V_{db}}{V_{tun0} + V_{db}}\right) \right)$$

Recombination Current in Neutral Body

$$I_{bs3} = (1 - \alpha_{bjt}) I_{en} \left[\exp\left(\frac{V_{bs}}{n_{dio} V_t}\right) - 1 \right] \frac{1}{\sqrt{E_{hlis} + 1}}$$

$$I_{bd3} = (1 - \alpha_{bjt}) I_{en} \left[\exp\left(\frac{V_{bd}}{n_{dio} V_t}\right) - 1 \right] \frac{1}{\sqrt{E_{hlid} + 1}}$$

$$I_{en} = \frac{W_{eff}}{N_{seg}} T_{si} j_{sbjt} \left[L_{bjt0} \left(\frac{1}{L_{eff}} + \frac{1}{L_n} \right) \right]^{N_{bjt}}$$

$$E_{hlis} = A_{hli_eff} \left[\exp\left(\frac{V_{bs}}{n_{dio} V_t}\right) - 1 \right]$$

$$E_{hlid} = A_{hli_eff} \left[\exp\left(\frac{V_{bd}}{n_{dio} V_t}\right) - 1 \right]$$

BJT Collector Current

$$I_c = \alpha_{bjt} I_{en} \left\{ \exp\left[\frac{V_{bs}}{n_{dio} V_t}\right] - \exp\left[\frac{V_{bd}}{n_{dio} V_t}\right] \right\} \frac{1}{E_{2nd}}$$

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$$E_{2nd} = \frac{E_{ely} + \sqrt{E_{ely}^2 + 4E_{hli}}}{2}$$

$$E_{ely} = 1 + \frac{V_{bs} + V_{bd}}{V_{Abjt} + A_{ely}L_{eff}}$$

$$E_{hli} = E_{hlis} + E_{hlid}$$

Total Body-Source/Drain Current

$$I_{bs} = I_{bs1} + I_{bs2} + I_{bs3} + I_{bs4}$$

$$I_{bd} = I_{bd1} + I_{bd2} + I_{bd3} + I_{bd4}$$

Total Body Current

$$I_{ii} + I_{dgidl} + I_{sgidl} - I_{bs} - I_{bd} - I_{bp} = 0$$

Temperature Effects

$$A_{hli_eff} = A_{hli} \exp \left[\frac{-E_g(300K)}{n_{dio} V_t} X_{bjt} \left(1 - \frac{T}{T_{nom}} \right) \right]$$

$$V_{th(T)} = V_{th(T_{nom})} + (K_{T1} + K_{t1l}/L_{eff} + K_{T2}V_{bseff})(T/T_{nom} - 1)$$

$$\mu_o(T) = \mu_o(T_{nom}) \left(\frac{T}{T_{nom}} \right)^{\mu_{te}}$$

$$v_{sat(T)} = v_{sat(T_{nom})} - A_T(T/T_{nom} - 1)$$

$$R_{dsw(T)} = R_{dsw(T_{nom})} + P_{rt} \left(\frac{T}{T_{nom}} - 1 \right)$$

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$$U_{a(T)} = U_{a(T_{nom})} + U_{a1}(T/T_{nom} - 1)$$

$$U_{b(T)} = U_{b(T_{nom})} + U_{b1}(T/T_{nom} - 1)$$

$$U_{c(T)} = U_{c(T_{nom})} + U_{c1}(T/T_{nom} - 1)$$

$$R_{th} = \frac{R_{th0}}{W_{eff}/N_{seg}}, C_{th} = C_{th0} \frac{W_{eff}}{N_{seg}}$$

$$j_{sbjt} = j_{sbjt0} \exp \left[-\frac{E_g(300K)}{n_{dio} V_t} X_{bjt} \left(1 - \frac{T}{T_{nom}} \right) \right]$$

$$j_{sdif} = j_{sdif0} \exp \left[-\frac{E_g(300K)}{n_{dio} V_t} X_{dif} \left(1 - \frac{T}{T_{nom}} \right) \right]$$

$$j_{srec} = j_{srec0} \exp \left[-\frac{E_g(300K)}{n_{recf0} V_t} X_{rec} \left(1 - \frac{T}{T_{nom}} \right) \right]$$

$$j_{stun} = j_{stun0} \exp \left[X_{tun} \left(\frac{T}{T_{nom}} - 1 \right) \right]$$

$$n_{recf} = n_{recf0} \left[1 + nt_{recf} \left(\frac{T}{T_{nom}} - 1 \right) \right]$$

$$n_{recl} = n_{recl0} \left[1 + nt_{recl} \left(\frac{T}{T_{nom}} - 1 \right) \right]$$

E_g is the energy gap energy.

BSIMPD2.0.1 CV

Model Parameter Notes

1. If c_{gso} is not given, it is calculated using the following:

If d_{lc} is given and is greater than 0, then

$$c_{gso} = p1 = (d_{lc} \times c_{ox}) - c_{gs1}$$

If the previously calculated $c_{gso} < 0$, then

$$c_{gso} = 0$$

else

$$c_{gso} = 0.6 \times T_{si} \times c_{ox}$$

2. C_{gdo} is calculated in a way similar to C_{sdo} .

3. If n_{sub} is positive,

$$V_{sdfb} = -\frac{kT}{q} \log\left(\frac{10^{20} \cdot n_{sub}}{n_i \cdot n_i}\right) - 0.3$$

else

$$V_{sdfb} = -\frac{kT}{q} \log\left(\frac{10^{20}}{n_{sub}}\right) + 0.3$$

4. If n_{sub} is positive,

$$\phi_{sd} = 2\frac{kT}{q} \log\left(\frac{n_{sub}}{n_i}\right), \Upsilon_{sd} = \frac{5.753 \times 10^{-12} \sqrt{n_{sub}}}{C_{box}}$$

$$V_{sdth} = V_{sdfb} + \phi_{sd} + \Upsilon_{sd} \sqrt{\phi_{sd}}$$

else

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$$\phi_{sd} = 2 \frac{kT}{q} \log \left(\frac{n_{sub}}{n_i} \right), \gamma_{sd} = \frac{5.753 \times 10^{-12} \sqrt{-n_{sub}}}{C_{box}}$$

$$V_{sdth} = V_{sdfb} - \phi_{sd} - \gamma_{sd} \sqrt{\phi_{sd}}$$

5.

$$X_{sddep} = \sqrt{\frac{2 \epsilon_{si} \phi_{sd}}{q |n_{sub} \cdot 10^6|}}$$

$$C_{sddep} = \frac{\epsilon_{si}}{X_{sddep}}$$

$$C_{sdmin} = \frac{C_{sddep} C_{box}}{C_{sddep} + C_{box}}$$

6. If cf is not given, it is calculated using

$$CF = \frac{2 \epsilon_{ox}}{\pi} \ln \left(1 + \frac{4 \times 10^{-7}}{T_{ox}} \right)$$

7. For $mobmod=1$ and 2 , the unit is m/V^2 . The default is -5.6×10^{-11} . For $mobmod=3$, the unit is $1/V$, and the default is -0.056 .

Dimension Dependence

$$W_{active} = W_{drawn} - N_{bc} d W_{bc} - (2 - N_{bc}) \delta W_{eff}$$

$$\delta W_{eff} = DWC + \frac{W_{lc}}{L W_{ln}} + \frac{W_{wc}}{L W_{wn}} + \frac{W_{wlc}}{L W_{ln} W_{wn}}$$

$$L_{active} = L_{drawn} - 2 \delta L_{eff}$$

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$$\delta L_{eff} = DLC + \frac{L_{lc}}{L^{L_{in}}} + \frac{L_{wc}}{W^{L_{wn}}} + \frac{L_{wlc}}{L^{L_{in}} W^{L_{wn}}}$$

$$L_{activeB} = L_{active} - DLCB$$

$$L_{activeBG} = L_{activeB} + 2\delta L_{bg}$$

$$W_{diosCV} = \frac{W_{active}}{N_{seg}} + P_{sbcP}$$

$$W_{diodCV} = \frac{W_{active}}{N_{seg}} + P_{dbcP}$$

Charge Conservation

$$Q_{Bf} = Q_{acc} + Q_{sub0} + Q_{subs}$$

$$Q_{inv} = Q_{inv,s} + Q_{inv,d}$$

$$Q_g = -(Q_{inv} + Q_{Bf})$$

$$Q_b = Q_{Bf} - Q_e + Q_{js} + Q_{jd}$$

$$Q_s = Q_{inv,s} - Q_{js}$$

$$Q_d = Q_{inv,d} - Q_{jd}$$

$$Q_g + Q_e + Q_b + Q_s + Q_d = 0$$

Intrinsic Charges

capMod = 2

Front Gate Body Charge

Accumulation charge:

$$V_{fb\text{eff}} = V_{fb} - 0.5 \left((V_{fb} - V_{gb} - \delta) + \sqrt{(V_{fb} - V_{gb} - \delta)^2 + \delta^2} \right)$$

where

$$V_{gb} = V_{gs} - V_{b\text{seff}}$$

$$V_{fb} = V_{th} - \phi_s - K_{1\text{eff}} \sqrt{\phi_s - V_{b\text{seff}}} + \text{delvt}$$

$$V_{g\text{steff}CV} = n v_t \ln \left(1 + \exp \left[\frac{V_{gs} - V_{th}}{n v_t} \right] \cdot \exp \left[-\frac{\text{delvt}}{n v_t} \right] \right)$$

$$Q_{acc} = -F_{body} \left(\frac{W_{active} L_{activeB}}{N_{seg}} + A_{gbcp} \right) C_{ox} (V_{FB\text{eff}} - V_{fb})$$

Gate-induced depletion charge:

$$Q_{sub0} = -F_{body} \left(\frac{W_{active} L_{activeB}}{N_{seg}} + A_{gbcp} \right) C_{ox} \frac{K_{1\text{eff}}^2}{2} \left(-1 + \sqrt{1 + \frac{4(V_{gs} - V_{FB\text{eff}} - V_{g\text{steff}CV} - V_{b\text{seff}})^2}{K_{1\text{eff}}^2}} \right)$$

Drain-induced depletion charge:

Virtuoso Simulator Components and Device Models Reference
B3SOI-PD Transistor Model (b3soipd)

$$V_{dsat, cv} = V_{gsteffCV} / A_{bulkCV} A_{bulkCV} = A_{bulk0} \left[1 + \left(\frac{CLC}{L_{activeB}} \right)^{CLE} \right]$$

$$V_{dsCV} = V_{dsatCV} - \frac{1}{2} \left(V_{dsatCV} - V_{ds} - \delta + \sqrt{(V_{dsatCV} - V_{ds} - \delta)^2 + 4\delta V_{dsatCV}} \right)$$

$$Q_{subs} = F_{body} \left(\frac{W_{active} L_{activeB}}{N_{seg}} + A_{gbcp} \right) K_{1eff} C_{ox} (A_{bulkCV} - 1) \times$$

$$\left[\frac{V_{dsCV}}{2} - \frac{A_{bulkCV} V_{dsCV}^2}{12(V_{gsteffCV} - A_{bulkCV} V_{dsCV}/2)} \right]$$

Back Gate Body Charge

$$Q_e = k_{b1} F_{body} \left(\frac{W_{active} L_{activeBG}}{N_{seg}} + A_{ebcp} \right) C_{box} (V_{es} - V_{fbb} - V_{bseff})$$

Inversion Charge

$$V_{cveff} = V_{dsat, CV} - 0.5 \left(V_4 + \sqrt{V_4^2 + 4\delta_4 V_{dsat, CV}} \right)$$

where

$$V_4 = V_{dsat, CV} - V_{ds} - \delta_4; \delta_4 = 0.02$$

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B3SOI-PD Transistor Model (b3soipd)

$$Q_{inv} = - \left(\frac{W_{active} L_{active}}{N_{seg}} + A_{gbcp} \right) C_{ox} \times$$

$$\left(\left(V_{gsteffCV} - \frac{A_{bulkCV}}{2} V_{cveff} \right) + \frac{A_{bulkCV}^2 V_{cveff}^2}{12 \left(V_{gsteffCV} - \frac{A_{bulkCV}}{2} V_{cveff} \right)} \right)$$

50/50 charge partition:

$$Q_{inv,s} = Q_{inv,d} = 0.5 Q_{inv}$$

40/60 charge partition:

$$Q_{inv,s} = \frac{\left(\frac{W_{active} L_{active}}{N_{seg}} + A_{gbcp} \right) C_{ox}}{2 \left(V_{gsteffCV} - \frac{A_{bulkCV}}{2} V_{cveff} \right)^2} \times$$

$$\left(V_{gsteffCV}^3 - \frac{4}{3} V_{gsteffCV}^2 \left(A_{bulkCV} V_{cveff} \right) + \frac{2}{3} V_{gsteffCV} \left(A_{bulkCV} V_{cveff} \right)^2 - \frac{2}{15} \left(A_{bulkCV} V_{cveff} \right)^3 \right)$$

$$Q_{inv,d} = \frac{\left(\frac{W_{active} L_{active}}{N_{seg}} + A_{gbcp} \right) C_{ox}}{2 \left(V_{gsteffCV} - \frac{A_{bulkCV}}{2} V_{cveff} \right)^2} \times$$

$$\left(V_{gsteffCV}^3 - \frac{5}{3} V_{gsteffCV}^2 \left(A_{bulkCV} V_{cveff} \right) + V_{gsteffCV} \left(A_{bulkCV} V_{cveff} \right)^2 - \frac{1}{5} \left(A_{bulkCV} V_{cveff} \right)^3 \right)$$

0/100 charge partition:

$$Q_{inv,s} = -\frac{W_{active}L_{active} + A_{gbcp}}{N_{seg}}C_{ox} \times \left(\frac{V_{gsteff}CV}{2} + \frac{A_{bulk}CVV_{cveff}}{4} - \frac{(A_{bulk}CVV_{cveff})^2}{24\left(V_{gsteff}CV - \frac{A_{bulk}CV}{2}V_{cveff}\right)} \right)$$

$$Q_{inv,d} = -\frac{W_{active}L_{active} + A_{gbcp}}{N_{seg}}C_{ox} \times \left(\frac{V_{gsteff}CV}{2} + \frac{3A_{bulk}CVV_{cveff}}{4} + \frac{(A_{bulk}CVV_{cveff})^2}{8\left(V_{gsteff}CV - \frac{A_{bulk}CV}{2}V_{cveff}\right)} \right)$$

capMod = 3 (Charge-Thickness Model)

capMod = 3 supports only zero-bias flat-band voltage, which is calculated from bias-independent threshold voltage. This is different from capMod = 2. For the finite thickness (X_{DC}) formulation, refer to Chapter 4 of the *BSIM3v3.2 User's Manual*.

Front Gate Body Charge

Accumulation charge:

$$V_{fb\text{eff}} = V_{fb} - 0.5\left((V_{fb} - V_{gb} - \delta) + \sqrt{(V_{fb} - V_{gb} - \delta)^2 + \delta^2}\right)$$

where

$$V_{gb} = V_{gs} - V_{b\text{seff}}$$

$$V_{fb} = V_{th} - \phi_s - K_{1\text{eff}}\sqrt{\phi_s - V_{b\text{seff}}}$$

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$$Q_{acc} = -F_{body} \left(\frac{W_{active} L_{activeB}}{N_{seg}} + A_{gbcp} \right) C_{oxeff} V_{gbacc}$$

$$V_{gbacc} = 0.5 \left(V_0 + \sqrt{V_0^2 + 4\delta V_{fb}} \right)$$

$$V_0 = V_{fb} + V_{bseff} - V_{gs} - \delta$$

$$C_{oxeff} = \frac{C_{ox} C_{cen}}{C_{ox} + C_{cen}}$$

$$C_{cen} = \varepsilon_{Si} / X_{DC}$$

Gate-induced depletion charge:

$$Q_{sub0} = -F_{body} \left(\frac{W_{active} L_{activeB}}{N_{seg}} + A_{gbcp} \right) C_{oxeff} \frac{K_{1eff}^2}{2} \times$$

$$\left(-1 + \sqrt{1 + \frac{4(V_{gs} - V_{FBeff} - V_{gsteffCV} - V_{bseff})}{K_{1eff}^2}} \right)$$

Drain-induced depletion charge

$$V_{dsat,cv} = (V_{gsteffCV} - \Phi_{\delta}) / A_{bulkCV}$$

$$\Phi_{\delta} = \Phi_s - 2\Phi_B = v_t \ln \left[1 + \frac{V_{gsteffCV} (V_{gsteffCV} + 2K_{1eff} \beta_{ff} \sqrt{2\Phi_B})}{moin K_{1eff} v_t^2} \right]$$

$$V_{dsCV} = V_{dsatCV} - \frac{1}{2} \left(V_{dsatCV} - V_{ds} - \delta + \sqrt{(V_{dsatCV} - V_{ds} - \delta)^2 + 4\delta V_{dsatCV}} \right)$$

$$Q_{subs} = F_{body} \left(\frac{W_{active} L_{active} B}{N_{seg}} + A_{gbcp} \right) K_{1eff} C_{oxeff} (A_{bulkCV} - 1) \times \left[\frac{V_{dsCV}}{2} - \frac{A_{bulkCV} V_{dsCV}^2}{12(V_{gsteffCV} - \Phi_{\delta} - A_{bulkCV} V_{dsCV}/2)} \right]$$

Back Gate Body Charge

$$k_{b1} F_{body} \left(\frac{W_{active} L_{active} BG}{N_{seg}} + A_{ebcp} \right) C_{box} (V_{es} - V_{fbb} - V_{bseff})$$

Inversion Charge

$$V_{cveff} = V_{dsat, CV} - 0.5 \left(V_4 + \sqrt{V_4^2 + 4\delta_4 V_{dsat, CV}} \right)$$

where

$$V_4 = V_{dsat, CV} - V_{ds} - \delta_4; \delta_4 = 0.02$$

$$Q_{inv} = - \left(\frac{W_{active} L_{active}}{N_{seg}} + A_{gbcp} \right) C_{oxeff} \times \left(\left(V_{gsteffCV} - \Phi_{\delta} - \frac{A_{bulkCV}}{2} V_{cveff} \right) + \frac{A_{bulkCV}^2 V_{cveff}^2}{12 \left(V_{gsteffCV} - \Phi_{\delta} - \frac{A_{bulkCV}}{2} V_{cveff} \right)} \right)$$

50/50 charge partition:

$$Q_{inv, s} = Q_{inv, d} = 0.5 Q_{inv}$$

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B3SOI-PD Transistor Model (b3soipd)

40/60 charge partition:

$$Q_{inv, s} = -\frac{\left(\frac{W_{active}L_{active}}{N_{seg}} + A_{gbc p}\right)C_{oxeff}}{2\left(V_{gsteffCV} - \Phi_{\delta} - \frac{A_{bulkCV}}{2}V_{cveff}\right)^2} \times \left((V_{gsteffCV} - \Phi_{\delta})^3 - \frac{4}{3}(V_{gsteffCV} - \Phi_{\delta})^2(A_{bulkCV}V_{cveff}) + \frac{2}{3}(V_{gsteffCV} - \Phi_{\delta})(A_{bulkCV}V_{cveff})^2 - \frac{2}{15}(A_{bulkCV}V_{cveff})^3\right)$$

$$Q_{inv, d} = -\frac{\left(\frac{W_{active}L_{active}}{N_{seg}} + A_{gbc p}\right)C_{oxeff}}{2\left(V_{gsteffCV} - \Phi_{\delta} - \frac{A_{bulkCV}}{2}V_{cveff}\right)^2} \times \left((V_{gsteffCV} - \Phi_{\delta})^3 - \frac{5}{3}(V_{gsteffCV} - \Phi_{\delta})^2(A_{bulkCV}V_{cveff}) + (V_{gsteffCV} - \Phi_{\delta})(A_{bulkCV}V_{cveff})^2 - \frac{1}{5}(A_{bulkCV}V_{cveff})^3\right)$$

$$Q_{inv,s} = -\frac{W_{active}L_{active} + A_{gbcp}}{N_{seg}}C_{oxeff} \times \left(\frac{V_{gsteffCV} - \Phi_{\delta}}{2} + \frac{A_{bulkCV}V_{cveff}}{4} - \frac{(A_{bulkCV}V_{cveff})^2}{24(V_{gsteffCV} - \Phi_{\delta} - \frac{A_{bulkCV}}{2}V_{cveff})} \right)$$

0/100 charge partition:

$$Q_{inv,s} = -\frac{W_{active}L_{active} + A_{gbcp}}{N_{seg}}C_{oxeff} \times \left(\frac{V_{gsteffCV} - \Phi_{\delta}}{2} + \frac{A_{bulkCV}V_{cveff}}{4} - \frac{(A_{bulkCV}V_{cveff})^2}{24(V_{gsteffCV} - \Phi_{\delta} - \frac{A_{bulkCV}}{2}V_{cveff})} \right)$$

Overlap Capacitance

Source Overlap Charge

$$Q_{inv,d} = -\frac{W_{active}L_{active} + A_{gbcp}}{N_{seg}}C_{oxeff} \times \left(\frac{V_{gsteffCV} - \Phi_{\delta}}{2} - \frac{3A_{bulkCV}V_{cveff}}{4} + \frac{(A_{bulkCV}V_{cveff})^2}{8(V_{gsteffCV} - \Phi_{\delta} - \frac{A_{bulkCV}}{2}V_{cveff})} \right)$$

$$V_{gs,overlap} = \frac{1}{2} \left\{ (V_{gs} + \delta) + \sqrt{(V_{gs} + \delta)^2 + 4\delta} \right\}$$

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$$\frac{Q_{overlap,s}}{W_{diosCV}} = CGS0 \cdot V_{gs} + CGS1 \left\{ V_{gs} - V_{gs_overlap} + \frac{CKAPPA}{2} \left(-1 + \sqrt{1 + \frac{4V_{gs_overlap}}{CKAPPA}} \right) \right\}$$

Drain Overlap Charge

$$V_{gd,overlap} = \frac{1}{2} \left\{ (V_{gd} + \delta) + \sqrt{(V_{gd} + \delta)^2 + 4\delta} \right\}$$

$$\frac{Q_{overlap,d}}{W_{diodCV}} = CGD0 \cdot V_{gd} + CGD1 \left\{ V_{gd} - V_{gd_overlap} + \frac{CKAPPA}{2} \left(-1 + \sqrt{1 + \frac{4V_{gd_overlap}}{CKAPPA}} \right) \right\}$$

Gate Overlap Charge

$$Q_{overlap,g} = -(Q_{overlap,s} + Q_{overlap,d})$$

Source/Drain Junction Charge

For $V_{bs} < 0.95\phi_s$

$$Q_{jswg} = Q_{bsdep} + Q_{bsdif}$$

else

$$Q_{jswg} = C_{bsdep}(0.95\phi_s)(V_{bs} - 0.95\phi_s) + Q_{bsdif}$$

For $V_{bd} < 0.95\phi_s$

$$Q_{jdwg} = Q_{bddep} + Q_{bddif}$$

else

$$Q_{jdwg} = C_{bddep}(0.95\phi_s)(V_{bd} - 0.95\phi_s) + Q_{bddif}$$

where

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$$Q_{bsdep} = W_{dios} C V C_{jswg} \frac{T_{si}}{10^{-7}} \frac{P_{bswg}}{1 - M_{jswg}} \left[1 - \left(1 - \frac{V_{bs}}{P_{bswg}} \right)^{1 - M_{jswg}} \right]$$

$$Q_{bddep} = W_{diod} C V C_{jswg} \frac{T_{si}}{10^{-7}} \frac{P_{bswg}}{1 - M_{jswg}} \left[1 - \left(1 - \frac{V_{bd}}{P_{bswg}} \right)^{1 - M_{jswg}} \right]$$

$$Q_{bsdif} = \frac{W_{eff}'}{N_{seg}} T_{si} J_{sbt} \left[1 + L_{dif0} \cdot \left(L_{bj0} \cdot \left(\frac{1}{L_{eff}} + \frac{1}{L_n} \right)^{N_{dif}} \right) \right] \left[\exp \left(\frac{V_{bs}}{n_{dio} V_t} \right) - 1 \right] \frac{1}{\sqrt{E_{hlis} + 1}}$$

$$Q_{bddif} = \frac{W_{eff}'}{N_{seg}} T_{si} J_{sbt} \left[1 + L_{dif0} \cdot \left(L_{bj0} \cdot \left(\frac{1}{L_{eff}} + \frac{1}{L_n} \right)^{N_{dif}} \right) \right] \left[\exp \left(\frac{V_{bd}}{n_{dio} V_t} \right) - 1 \right] \frac{1}{\sqrt{E_{hlid} + 1}}$$

$$C_{jswg} = C_{jswg0} [1 + t_{cjswg} (T - T_{nom})]$$

$$P_{bswg} = P_{bswg0} - t_{pbswg} (T - T_{nom})$$

Extrinsic Capacitance

Bottom S/D to Substrate Capacitance

$$C_{sld, \bar{e}} = \begin{cases} C_{box} & \text{if } V_{sld, e} < V_{sdfb} \\ C_{box} - \frac{1}{A_{sd}} (C_{box} - C_{min}) \left(\frac{V_{sld, e} - V_{sdfb}}{V_{sdth} - V_{sdfb}} \right)^2 & \text{else if } V_{sld, e} < V_{sdfb} + A_{sd} (V_{sdth} - V_{sdfb}) \\ C_{min} + \frac{1}{1 - A_{sd}} (C_{box} - C_{min}) \left(\frac{V_{sld, e} - V_{sdth}}{V_{sdth} - V_{sdfb}} \right)^2 & \text{else if } V_{sld, e} < V_{sdth} \\ C_{min} & \text{else} \end{cases}$$

Sidewall S/D to Substrate Capacitance

$$C_{sld,esw} = C_{sdesw} \log\left(1 + \frac{T_{si}}{T_{box}}\right)$$

BSIMPD2.2

If the parameters *Wth0* and *Rhalo* are set to default values, version 2.2 is compliant with version 2.1.

If *IgbMod*=0, the model version is 2.0.

If *IgbMod*=1, the model version is 2.2.

Oxide Tunneling Current

Oxide tunneling is important in the determination of floating-body potential for thin oxide (below 20Å).

In inversion

$$J_{gb} = A \frac{V_{gb} V_{aux}}{T_{ox}^2} \left(\frac{T_{oxref}}{T_{oxqm}}\right)^{N_{iox}} \exp\left(\frac{-B(\alpha_{gb1} - \beta_{gb1} |V_{ox}|) T_{ox}}{1 - |V_{ox}|/V_{gb1}}\right)$$

$$V_{aux} = V_{EVB} \ln\left(1 + \exp\left(\frac{|V_{ox}| - \phi_g}{V_{EVB}}\right)\right)$$

$$A = \frac{q^3}{8\pi h \phi_b}$$

$$B = \frac{8\pi \sqrt{2m_{ox}} \phi_b^{3/2}}{3hq}$$

$$\phi_b = 4.2eV$$

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B3SOI-PD Transistor Model (b3soipd)

$$m_{ox} = 0.3m_0$$

In accumulation,

$$J_{gb} = A \frac{v_{gb} V_{aux}}{T_{ox}^2} \left(\frac{T_{oxref}}{T_{oxqm}} \right)^{N_{tox}} \exp \left(\frac{-B(\alpha_{gb2} - \beta_{gb2} |V_{ox}|) T_{ox}}{1 - |V_{ox}|/V_{gb2}} \right)$$

$$V_{aux} = V_{ECB} V_t \ln \left(1 + \exp \left(-\frac{V_{gb} - V_{fb}}{V_{ECB}} \right) \right)$$

$$A = \frac{q^3}{8\pi h \phi_b}$$

$$B = \frac{8\pi \sqrt{2m_{ox}} \phi_b^{3/2}}{3hq}$$

$$\phi_b = 3.1eV$$

$$m_{ox} = 0.4m_0$$

Body Contact Current

In BSIMPD2.2, a body resistor is connected between the body (B node) and the body contact (P node) if the transistor has a body-tie. The body resistance is modeled by

$$R_{bp} = \left(R_{body} \frac{W_{eff}}{L_{eff}} \right) \parallel \left(R_{halo} \frac{W_{eff}}{2} \right) R_{bodytext} = R_{bsh} N_{rb}$$

where R_{bp} is intrinsic body resistance

$R_{bodytext}$ is extrinsic body resistance

R_{body} is intrinsic body sheet resistance

R_{halo} is the halo implant effect

N_{rb} is the number of squares from body contact to device edge and

R_{bsh} is the sheet resistance of the body contact diffusion.

The body contact current I_{bp} is defined as the current flowing through the body resistor and is calculated by the following equation.

$$I_{bp} = \frac{V_{bp}}{R_{bp} + R_{bodytext}}$$

where V_{bp} is the voltage across node B and P.

Note: $I_{bp}=0$ if the transistor has a floating body.

Scaling Effects

For scaling effects, see [Scaling Factors \(scale and scalem\)](#) on page 242.

Component Statements

Instance Definition

Name d g s e [p] [b] [t] ModelName parameter=value ...

Instance Parameters

1	w (m)	Channel width.
2	l (m)	Channel length.
3	as (m ²)	Area of source diffusion.
4	ad (m ²)	Area of drain diffusion.
5	ps (m)	Perimeter of source diffusion.
6	pd (m)	Perimeter of drain diffusion.
7	nrd (m/m)	Number of squares of drain diffusion.

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B3SOI-PD Transistor Model (b3soipd)

8	<code>nrs</code> (m/m)	Number of squares of source diffusion.
9	<code>nrb</code> (m/m)	Number of body squares.
10	<code>m=1</code>	Multiplicity factor (number of MOSFETs in parallel).
11	<code>region=triode</code>	Estimated operating region. Spectre outputs number (0-3) in a rawfile. Possible values are <code>off</code> , <code>triode</code> , <code>sat</code> , or <code>subth</code> .
12	<code>rth0</code> (Ω)	Thermal resistance.
13	<code>cth0</code> (F)	Thermal capacitance.
14	<code>bjtoff=0</code>	BJT off flag.
15	<code>nbc=0</code> m/m	Number of body contact isolation edge.
16	<code>nseg=1</code> m/m	Number of segments for channel width partitioning.
17	<code>pdbcpr=0</code> m	Perimeter length for body contact parasitic at drain.
18	<code>psbcpr=0</code> m	Perimeter length for body contact parasitic at source.
19	<code>agbcpr=0</code> m	Gate to body overlap for body contact parasitic.
20	<code>aebcpr=0</code> m	Gate to body overlap for body contact parasitic.
21	<code>vbsusr=0.0</code> V	Optional initial value of V_{bs} for transient.
22	<code>tnodeout=0</code>	Temperature node flag associated with T node.
23	<code>isnoisy=yes</code>	Should resistor generate noise. Possible values are <code>no</code> or <code>yes</code> .

Model Definition

```
model modelName b3soipd parameter=value ...
```


Virtuoso Simulator Components and Device Models Reference

B3SOI-PD Transistor Model (b3soipd)

Model Parameters

Device type parameters

- | | | |
|---|--------------------------|--|
| 1 | <code>type=n</code> | Transistor type.
Possible values are n or p. |
| 2 | <code>version=2.2</code> | Model version selector. The available versions are 2.2, 2.22 and 2.23. |

Threshold voltage parameters

- | | | |
|----|---|--|
| 3 | <code>vtho (V)</code> | Threshold voltage at zero body bias for long-channel devices. For enhancement-mode devices, $v_{tho} > 0$ for n-channel and $v_{th} < 0$ for p-channel. Default value is calculated from other model parameters. |
| 4 | <code>k1=0.5 \sqrt{V}</code> | Body-effect coefficient. |
| 5 | <code>k1w1=0.0 m</code> | First body effect width dependent parameter. |
| 6 | <code>k1w2=0.0 m</code> | Second body effect width dependent parameter. |
| 7 | <code>k2=-0.0186</code> | Charge-sharing parameter. |
| 8 | <code>k3=0</code> | Narrow width coefficient. |
| 9 | <code>k3b=0 1/V</code> | Narrow width coefficient. |
| 10 | <code>w0=2.5e-6 m</code> | Narrow width coefficient. |
| 11 | <code>n1x=1.74e-7 m</code> | Lateral nonuniform doping coefficient. |
| 12 | <code>gamma1 (\sqrt{V})</code> | Body-effect coefficient near the surface. |
| 13 | <code>gamma2 (\sqrt{V})</code> | Body-effect coefficient in the bulk. |
| 14 | <code>vbx (V)</code> | Threshold voltage transition body voltage. |
| 15 | <code>vbm=-3 V</code> | Maximum applied body voltage. |
| 16 | <code>dvt0=2.2</code> | First coefficient of short-channel effects. |

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B3SOI-PD Transistor Model (b3soipd)

17	$dvt1=0.53$	Second coefficient of short-channel effects.
18	$dvt2=-0.032 \text{ 1/V}$	Body-bias coefficient of short-channel effects.
19	$dvt0w=0$	First coefficient of narrow-width effects.
20	$dvt1w=5.3e6$	Second coefficient of narrow-width effects.
21	$dvt2w=-0.032 \text{ 1/V}$	Body-bias coefficient of narrow-width effects.
22	$a0=1$	Nonuniform depletion width effect coefficient.
23	$b0=0 \text{ m}$	Bulk charge coefficient due to narrow width effect.
24	$b1=0 \text{ m}$	Bulk charge coefficient due to narrow width effect.
25	$a1=0$	No-saturation coefficient.
26	$a2=1$	No-saturation coefficient.
27	$ags=0 \text{ F/m}^2 \text{ V}$	Gate-bias dependence of abulk.
28	$keta=-0.6 \text{ 1/V}$	Body-bias coefficient for non-uniform depletion width effect.
29	$ketas=0.0 \text{ V}$	Surface Potential adjustment for bulk charge effect.

Process parameters

30	$nsub=6e16 \text{ cm}^{-3}$	Substrate doping concentration.
31	$nch=1.7e17 \text{ cm}^{-3}$	Peak channel doping concentration.
32	$ngate \text{ (cm}^{-3}\text{)}$	Poly-gate doping concentration.
33	$xj=0.15e-6 \text{ m}$	Source/drain junction depth.
34	$lint=0 \text{ m}$	Lateral diffusion for one side.
35	$wint=0 \text{ m}$	Width reduction for one side.
36	$ll=0 \text{ m}$	Length dependence of delta L.
37	$lln=1$	Length exponent of delta L.

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38	$lw=0$	m	Width dependence of delta L.
39	$lwn=1$		Width exponent of delta L.
40	$lwl=0$	m^2	Area dependence of delta L.
41	$wl=0$	m	Length dependence of delta W.
42	$wln=1$		Length exponent of delta W.
43	$ww=0$	m	Width dependence of delta W.
44	$wwn=1$		Width exponent of delta W.
45	$wwl=0$	m^2	Area dependence of delta W.
46	$dwg=0$	m/v	Gate-bias dependence of channel width.
47	$dwb=0$	m/ \sqrt{v}	Body-bias dependence of channel width.
48	$dwb=0.0$	m	Width offset for body contact isolation edge.
49	$tox=1e-8$	m	Gate oxide thickness.
50	$tbox=3e-7$	m	Buried oxide thickness.
51	$tsi=1e-7$	m	Silicon film thickness.
52	$xt=1.55e-7$	m	Doping depth.
53	$rdsw=100$	$\Omega \mu m$	Width dependence of drain-source resistance.
54	$prwb=0$	1/ \sqrt{v}	Body-effect coefficient for Rds.
55	$prwg=0$	1/V	Gate-effect coefficient for Rds.
56	$wr=1$		Width offset for parasitic resistance.
57	$xl=0$	m	Length variation due to masking and etching.
58	$xw=0$	m	Width variation due to masking and etching.
59	$binunit=1$		Bin parameter unit selector. 1 for microns and 2 for meters.

Virtuoso Simulator Components and Device Models Reference

B3SOI-PD Transistor Model (b3soipd)

Mobility parameters

- 60 `mobmod=1` Mobility model selector.
- 61 `u0=670 cm2/V s` Low-field surface mobility at t_{nom} . Default is 250 for PMOS.
- 62 `vsat=8e4 m/s` Carrier saturation velocity at t_{nom} .
- 63 `ua=2.25e-9 m/v` First-order mobility reduction coefficient.
- 64 `ub=5.87e-19 m2/v2` Second-order mobility reduction coefficient.
- 65 `uc=-4.65e-11 m/v2` Body-bias dependence of mobility. Default is -0.046 and unit is 1/V for `mobmod=3`.

Output resistance parameters

- 66 `drout=0.56` DIBL effect on output resistance coefficient.
- 67 `pclm=1.3` Channel length modulation coefficient.
- 68 `pdiblc1=0.39` First coefficient of drain-induced barrier lowering.
- 69 `pdiblc2=8.6e-3` Second coefficient of drain-induced barrier lowering.
- 70 `pdiblcb=0 1/V` Body-effect coefficient for DIBL.
- 71 `pvag=0` Gate dependence of Early voltage.
- 72 `delta=0.01 V` Effective drain voltage smoothing parameter.

Subthreshold parameters

- 73 `cdsc=2.4e-4 F/m2` Source/drain and channel coupling capacitance.
- 74 `cdscb=0 F/m2 V` Body-bias dependence of `cdsc`.
- 75 `cdscd=0 F/m2 V` Drain-bias dependence of `cdsc`.
- 76 `nfactor=1` Subthreshold swing coefficient.

Virtuoso Simulator Components and Device Models Reference

B3SOI-PD Transistor Model (b3soipd)

77	$c_{it}=0$ F	Interface trap parameter for subthreshold swing.
78	$v_{off}=-0.08$ V	Threshold voltage offset.
79	$d_{sub}=d_{rout}$	DIBL effect in subthreshold region.
80	$\eta_{a0}=0.08$	DIBL coefficient subthreshold region.
81	$\eta_{ab}=-0.07$ 1/V	Body-bias dependence of η_{t0} .

Substrate current parameters

82	$\alpha_{a0}=0$ m/v	Substrate current impact ionization coefficient.
83	$\beta_{a0}=0$ 1/V	First V_{ds} dependent parameter of impact ionization current.
84	$f_{bjt_{ii}}=0.0$	Fraction of bipolar current affecting the impact ionization.
85	$\beta_{a1}=0$	Second V_{ds} dependent parameter of impact ionization current.
86	$\beta_{a2}=0$ V	Third V_{ds} dependent parameter of impact ionization current.
87	$v_{dsat_{ii0}}=0.9$ V	Nominal drain saturation voltage at threshold for impact ionization current.
88	$t_{ii}=0$	Temperature dependent parameter for impact ionization current.
89	$l_{ii}=0$	Channel length dependent parameter at threshold for impact ionization current.
90	$e_{sat_{ii}}=1e7$ V/m	Saturation channel electric field for impact ionization current.
91	$s_{ii0}=0.5$ 1/V	First V_{gs} dependent parameter for impact ionization current.
92	$s_{ii1}=0.1$ 1/V	Second V_{gs} dependent parameter for impact ionization current.
93	$s_{ii2}=0.0$ 1/V	Third V_{gs} dependent parameter for impact ionization current.
94	$s_{iid}=0$ 1/V	V_{ds} dependent parameter of drain saturation voltage for impact ionization current.

Virtuoso Simulator Components and Device Models Reference

B3SOI-PD Transistor Model (b3soipd)

Parasitic resistance parameters

95	$r_{bsh}=0 \ \Omega$	Extrinsic body contact sheet resistance.
96	$r_{sh}=0 \ \Omega/\text{sqr}$	Source/drain diffusion sheet resistance.
97	$r_s=0 \ \Omega$	Source resistance.
98	$r_d=0 \ \Omega$	Drain resistance.
99	$r_{body}=0 \ \text{F}$	Body resistance.
100	$r_{sc}=0 \ \Omega$	Source contact resistance.
101	$r_{dc}=0 \ \Omega$	Drain contact resistance.
102	$r_{ss}=0 \ \Omega \ \text{m}$	Scalable source resistance.
103	$r_{dd}=0 \ \Omega \ \text{m}$	Scalable drain resistance.
104	$h_{dif}=0 \ \text{m}$	Length of heavily doped diffusion.
105	$l_{dif}=0 \ \text{m}$	Lateral diffusion beyond the gate.
106	$minr=0.1 \ \Omega$	Minimum source/drain resistance.

Junction diode model parameters

107	$dskip=yes$	Use simple piece-wise linear model for diode currents below $0.1 \cdot i_{abstol}$. Possible values are <code>no</code> or <code>yes</code> .
108	$imelt='imax' \ \text{A}$	Explosion current.

Overlap capacitance parameters

109	$c_{gso} \ (\text{F}/\text{m})$	Gate-source overlap capacitance.
110	$c_{gdo} \ (\text{F}/\text{m})$	Gate-drain overlap capacitance.
111	$c_{geo}=0.0 \ \text{F}/\text{m}$	Gate-substrate overlap capacitance.

Virtuoso Simulator Components and Device Models Reference

B3SOI-PD Transistor Model (b3soipd)

112	$c_{gbo}=2$	Dwc Cox F/m	Gate-bulk overlap capacitance..
113	$meto=0$	m	Metal overlap in fringing field.
114	$c_{gsl}=0$	F/m	Gate-source overlap capacitance in LDD region.
115	$c_{gd1}=0$	F/m	Gate-drain overlap capacitance in LDD region.
116	$ckappa=0.6$		Overlap capacitance fitting parameter.

Junction capacitance model parameters

117	$c_{jswg}=c_{jsw}$	F/m	Zero-bias gate-side junction capacitance density.
118	$m_{jswg}=0.5$		Gate-side junction grading coefficient.
119	$p_{bswg}=0.7$	V	Gate-side junction built-in potential.
120	$tt=1e-12$	s	Transit time.
121	$ndif=1$		Power coefficient of channel length dependency for diffusion capacitance.
122	$ldif0=1$		Power coefficient of channel length dependency for diffusion capacitance.

Charge model selection parameters

123	$capmod=2$		Intrinsic charge model.
124	$\bar{d}wc=wint$	m	Delta W for capacitance model.
125	$\bar{d}elvt=0.0$	V	Threshold voltage adjustment for C-V.
126	$fbody=1.0$		Scaling factor for body charge.
127	$\bar{d}lc=lint$	m	Delta L for capacitance model.
128	$\bar{d}lcb=lint$	m	Length offset fitting parameter for body charge.
129	$\bar{d}lbg=0.0$	m	Length offset fitting parameter for backgate charge.

Virtuoso Simulator Components and Device Models Reference

B3SOI-PD Transistor Model (b3soipd)

130	$c_{lc}=1e-8$ m	Intrinsic capacitance fitting parameter.
131	$c_{le}=0.0$	Intrinsic capacitance fitting parameter.
132	c_f (F/m)	Fringe capacitance parameter.
133	$v_{fbcv}=-1$	Flat-band voltage for $capmod=0$.
134	$x_{part}=0$	Drain/source channel charge partition in saturation for BSIM charge model, use 0.0 for 40/60, 0.5 for 50/50, or 1.0 for 0/100.

Default instance parameters

135	$w=5e-6$ m	Default channel width.
136	$l=5e-6$ m	Default channel length.
137	$a_s=0$ m ²	Default area of source diffusion.
138	$a_d=0$ m ²	Default area of drain diffusion.
139	$p_s=0$ m	Default perimeter of source diffusion.
140	$p_d=0$ m	Default perimeter of drain diffusion.
141	$n_{rd}=0$ m/m	Default number of squares of drain diffusion.
142	$n_{rs}=0$ m/m	Default number of squares of source diffusion.
143	$n_{rb}=0$ m/m	Default body squares.

Temperature effects parameters

144	t_{nom} (C)	Parameters measurement temperature. Default set by <code>options</code> .
145	$t_{max}=500$ C	Maximum device temperature above ambient.
146	$shmod=0$	Self-heating selector.
147	$t_{lev}=0$	DC temperature selector.
148	$t_{levc}=0$	AC temperature selector.

Virtuoso Simulator Components and Device Models Reference

B3SOI-PD Transistor Model (b3soipd)

149	$eg=1.12452$	V	Energy band gap.
150	$gap1=7.02e-4$	V/C	Band gap temperature coefficient.
151	$gap2=1108$	C	Band gap temperature offset.
152	$kt1=-0.11$	V	Temperature coefficient for threshold voltage.
153	$kt11=0$	v m	Temperature coefficient for threshold voltage.
154	$kt2=0.022$		Temperature coefficient for threshold voltage.
155	$at=3.3e4$	m/s	Temperature coefficient for v_{sat} .
156	$tcjswg=0$	1/K	Temperature coefficient of C_{jswg} .
157	$tpbswg=0$	V/K	Temperature coefficient of P_{bswg} .
158	$ua1=4.31e-9$	m/v	Temperature coefficient for u_a .
159	$ub1=-7.61e-18$	m^2/v^2	Temperature coefficient for u_b .
160	$uc1=-5.5e-11$	m/v^2	Temperature coefficient for u_c . Default is -0.056 for $mobmod=3$.
161	$prt=0$	Ω	Temperature coefficient for R_{ds} .
162	$trs=0$	1/C	Temperature parameter for source resistance.
163	$trd=0$	1/C	Temperature parameter for drain resistance.
164	$ute=-1.5$		Mobility temperature exponent.
165	$dt1=0$		First temperature coefficient for τ .
166	$dt2=0$		Second temperature coefficient for τ .
167	$cth0=0$	F	Self-heating thermal capacitance.
168	$rth0=0$	Ω	Self-heating thermal resistance.
169	$ntrecf=0$		Temperature coefficient of N_{trecf} .

Virtuoso Simulator Components and Device Models Reference

B3SOI-PD Transistor Model (b3soipd)

170	<code>ntrecr=0</code>	Temperature coefficient of Ntrecr.
171	<code>xbjt=2</code>	BJT current temperature exponent.
172	<code>xdif=2</code>	Diffusion current temperature exponent.
173	<code>xrec=20</code>	Recombination current temperature exponent.
174	<code>xtun=0</code>	Tunneling current temperature exponent.

Noise model parameters

175	<code>noimod=1</code>	Noise model selector.
176	<code>kf=0</code>	Flicker (1/f) noise coefficient.
177	<code>af=1</code>	Flicker (1/f) noise exponent.
178	<code>ef=1</code>	Flicker (1/f) noise frequency exponent.
179	<code>noia=1e20</code>	Oxide trap density coefficient. Default is 9.9e18 for pmos.
180	<code>noib=5e4</code>	Oxide trap density coefficient. Default is 2.4e3 for pmos.
181	<code>noic=-1.4e-12</code>	Oxide trap density coefficient. Default is 1.4e-8 for pmos.
182	<code>em=4.1e7 V/m</code>	Maximum electric field.

Auto Model Selector parameters

183	<code>wmax=1 m</code>	Maximum channel width for which the model is valid.
184	<code>wmin=0 m</code>	Minimum channel width for which the model is valid.
185	<code>lmax=1 m</code>	Maximum channel length for which the model is valid.
186	<code>lmin=0 m</code>	Minimum channel length for which the model is valid.

Operating region warning control parameters

187	<code>alarm=none</code>	Forbidden operating region. Possible values are <code>none</code> , <code>off</code> , <code>triode</code> , <code>sat</code> , <code>subth</code> , or <code>rev</code> .
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Virtuoso Simulator Components and Device Models Reference

B3SOI-PD Transistor Model (b3soipd)

188	$i_{max}=1$ A	Maximum allowable current.
189	$b_{vj}=\infty$ V	Junction reverse breakdown voltage.
190	$v_{box}=1e9$ t_{ox} V	Oxide breakdown voltage.
191	$warn=on$	Parameter to turn warnings on and off. Possible values are <code>off</code> or <code>on</code> .
SOI specific parameters		
192	$v_{bsa}=0$ V	V _{bs0t} offset voltage.
193	$del_p=0.02$	Offset constant for limiting V _{bseff} to Phis.
194	$kb1=1$	Scaling factor for backgate charge.
195	$kb3=1$	Backgate coupling coefficient at subthreshold.
196	$dvbd0=0$ V	First coefficient of short-channel effect on V _{bs0t} .
197	$dvbd1=0$	First coefficient of short-channel effect on V _{bs0t} .
198	$abp=1$	Gate bias coefficient for X _{csat} calculation.
199	$mxc=-0.9$	A smoothing parameter for X _{csat} calculation.
200	$agidl=0$	GIDL constant.
201	$bgidl=0$ V/m	GIDL exponential coefficient.
202	$ngidl=1.2$ V	GIDL V _{ds} enhancement coefficient.
203	$ntun=10$	Reverse tunneling non-ideality factor.
204	$nrecf0=2.0$	Recombination non-ideality factor at forward bias.
205	$nrecr0=10$	Recombination non-ideality factor at reversed bias.
206	$vsdfb$ (F/m)	Source/Drain diffusion flatband voltage.
207	$vsdth$	Source/Drain diffusion threshold voltage.

Virtuoso Simulator Components and Device Models Reference

B3SOI-PD Transistor Model (b3soipd)

208	<code>csdmin</code> (F)	Source/Drain diffusion bottom minimum capacitance.
209	<code>csdesw=0</code>	Source/drain sidewall fringing constant.
210	<code>aii=0</code>	First parameter for critical field.
211	<code>bii=0</code>	Second parameter for critical field.
212	<code>cii=0</code>	Gate dependence of critical field.
213	<code>dii=-1</code>	Body dependence of critical field.
214	<code>ndiode=1</code>	Diode non-ideality factor.
215	<code>asd=0.3</code>	Source/Drain diffusion smoothing parameter.
216	<code>isbjt=1e-6</code> A	BJT saturation current.
217	<code>isdif=0</code> A	Diffusion saturation current.
218	<code>isrec=1e-5</code> A	Recombination saturation current.
219	<code>istun=0</code> A	Tunneling saturation current.
220	<code>ln=2e-6</code> m	Electron diffusion length.
221	<code>vrec0=0</code> V	Voltage dependent parameter for recombination current.
222	<code>vtun0=0</code> V	Voltage dependent parameter for tunneling current.
223	<code>nbjt=1</code>	Power coefficient of channel length dependency for bipolar current.
224	<code>lbjt0=0.20e-6</code> m	Reference channel length for bipolar current.
225	<code>vabjt=10</code> V	Early voltage for bipolar current.
226	<code>aely=0</code> V	Channel length dependency of early voltage for bipolar current.
227	<code>ahli=0</code>	High level injection parameter for bipolar current.
228	<code>kbjt1=0</code> m	Parasitic bipolar base width.

Virtuoso Simulator Components and Device Models Reference

B3SOI-PD Transistor Model (b3soipd)

Gate tunneling parameters

229	$w_{th0}=0.0 \mu\text{m}$	Minimum width for thermal resistance calculation..
230	$r_{halo}=1.0e15 \Omega/\text{sqr}$	Body halo sheet resistance.
231	$n_{tox}=1.0$	Power term of gate current.
232	$tox_{ref}=2.5e-9 \text{ m}$	Target oxide thickness.
233	$ebg=1.2 \text{ V}$	Effective bandgap in gate current calculation.
234	$nev_{b}=3.0$	Valence-band electron non-ideality factor.
235	$alphag_{b1}=0.35$	First V_{ox} dependent parameter for gate current in inversion..
236	$betag_{b1}=0.03$	Second V_{ox} dependent parameter for gate current in inversion..
237	$v_{gb1}=300$	Third V_{ox} dependent parameter for gate current in inversion..
238	$alphag_{b2}=0.43$	First V_{ox} dependent parameter for gate current in accumulation..
239	$betag_{b2}=0.05$	Second V_{ox} dependent parameter for gate current in accumulation..
240	$nev_{cb}=1.0$	Conduction-band electron non-ideality factor.
241	$v_{gb2}=17$	Third V_{ox} dependent parameter for gate current in accumulation..
242	$tox_{qm}=Tox \text{ m}$	Effective oxide thickness considering quantum effects..
243	$vox_{h}=5.0 \text{ V}$	Limit of V_{ox} in gate current calculation..
244	$\delta_{lavox}=0.005 \text{ V}$	Smoothing parameter in the V_{ox} smoothing function..
245	$ig_{mod}=0$	Gate current model selector.

Virtuoso Simulator Components and Device Models Reference

B3SOI-PD Transistor Model (b3soipd)

Length dependent parameters (Not listed)

Width dependent parameters (Not listed)

Cross-term dependent parameters

246	<code>paramchk=1</code>	Model parameter checking selector.
247	<code>noif=1</code>	Floating body excess noise ideality factor.
248	<code>w0flk=0 m</code>	Width constant for flicker noise equation.
249	<code>frbody=1</code>	Layout dependent body-resistance coefficient.
250	<code>vevb=0.075</code>	Vaux parameter for valence-band electron tunneling.
251	<code>vecb=0.026</code>	Vaux parameters for conduction-band electron tunneling.
252	<code>dtoxcv=0.0 m</code>	Delta oxide thickness in Capmod3.
253	<code>llc=0 m</code>	Length dependence of delta LC.
254	<code>lwc=0 m</code>	Width dependence of delta LC.
255	<code>lwlc=0 m²</code>	Area dependence of delta LC.
256	<code>wlc=0 m</code>	Length dependence of delta WC.
257	<code>wwc=0 m</code>	Width dependence of delta WC.
258	<code>wwlc=0 m²</code>	Area dependence of delta WC.

Shrink Parameters

259	<code>shrink=0</code>	linear shrink parameter.
260	<code>shrink2=0</code>	area shrink parameter.

The `jmelt` parameter is used to aid convergence and prevent numerical overflow. The junction characteristics of the FET are accurately modeled for current (density) up to `jmelt`. For current density above `jmelt`, the junction is modeled as a linear resistor and a warning is printed.

Virtuoso Simulator Components and Device Models Reference

B3SOI-PD Transistor Model (b3soipd)

Auto Model Selection:

Many models need to be characterized for different geometries in order to obtain accurate results for model development. The model selector program automatically searches for a model with the length and width range specified in the instance statement and uses this model in the simulations.

For the auto model selector program to find a specific model, the models to be searched should be grouped together within braces. Such a group is called a model group. An opening brace is required at the end of the line defining each model group. Every model in the group is given a name followed by a colon and the list of parameters. Also, the four geometric parameters `lmax`, `lmin`, `wmax`, and `wmin` should be given. The selection criteria to choose a model is as follows:

$$l_{min} \leq inst_length < l_{max} \text{ and } w_{min} \leq inst_width < w_{max}$$

Example:

```
model ModelName ModelType {  
    1: <model parameters> lmin=2 lmax=4 wmin=1 wmax=2  
    2: <model parameters> lmin=1 lmax=2 wmin=2 wmax=4  
    3: <model parameters> lmin=2 lmax=4 wmin=4 wmax=6  
}
```

Then for a given instance

```
M1 1 2 3 4 ModelName w=3 l=1.5
```

the program would search all the models in the model group with the name `ModelName` and then pick the first model whose geometric range satisfies the selection criteria. In the preceding example, the auto model selector program would choose `ModelName.2`.

You must specify both length (`l`) and width (`w`) on the device instance line to enable automatic model selection.

Output Parameters

- | | | |
|---|----------------------------------|---------------------------|
| 1 | <code>w_{eff}</code> (m) | Effective channel width. |
| 2 | <code>l_{eff}</code> (m) | Effective channel length. |

Virtuoso Simulator Components and Device Models Reference

B3SOI-PD Transistor Model (b3soipd)

3	<code>rtheff</code> (Ω)	Effective thermal resistance.
4	<code>ctheff</code> (F)	Effective thermal capacitance.
5	<code>rseff</code> (Ω)	Effective source resistance.
6	<code>rdeff</code> (Ω)	Effective drain resistance.

Operating-Point Parameters

1	<code>type=n</code>	Transistor type. Possible values are <code>n</code> or <code>p</code> .
2	<code>region=triode</code>	Estimated operating region. Spectre outputs number (0-3) in a rawfile. Possible values are <code>off</code> , <code>triode</code> , <code>sat</code> , or <code>subth</code> .
3	<code>reversed</code>	Reverse mode indicator. Possible values are <code>no</code> or <code>yes</code> .
4	<code>vgs</code> (V)	Gate-source voltage.
5	<code>vds</code> (V)	Drain-source voltage.
6	<code>vbs</code> (V)	Bulk-source voltage.
7	<code>vbgs</code> (V)	Back-Gate-source voltage.
8	<code>ids</code> (A)	Resistive drain-to-source current.
9	<code>ic</code> (A)	BJT collector current.
10	<code>isgidl</code> (A)	Source GIDL current.
11	<code>idgidl</code> (A)	Drain GIDL current.
12	<code>iii</code> (A)	Impact ionization current.
13	<code>ibd</code> (A)	Resistive bulk-to-drain junction current.
14	<code>igbt</code> (A)	Gate-to-body tunneling current.
15	<code>ibs</code> (A)	Resistive bulk-to-source junction current.

Virtuoso Simulator Components and Device Models Reference

B3SOI-PD Transistor Model (b3soipd)

16	v_{th} (V)	Threshold voltage.
17	v_{dsat} (V)	Drain-source saturation voltage.
18	g_m (S)	Common-source transconductance.
19	g_{ds} (S)	Common-source output conductance.
20	g_{mb} (S)	Body-transconductance.
21	g_{mbg} (S)	Back-gate-transconductance.
22	μ_{eff} ($cm^2/V\ s$)	Effective mobility.
23	β_{eff} (A/V^2)	Effective β .
24	q_g (Coul)	Gate charge.
25	q_d (Coul)	Drain charge.
26	q_s (Coul)	Source charge.
27	q_b (Coul)	Body charge.
28	q_{bg} (Coul)	Back-Gate charge.
29	c_{gg} (F)	$dQ_g_dV_g$.
30	c_{gd} (F)	$dQ_g_dV_d$.
31	c_{gs} (F)	$dQ_g_dV_s$.
32	c_{gb} (F)	$dQ_g_dV_b$.
33	c_{dg} (F)	$dQ_d_dV_g$.
34	c_{dd} (F)	$dQ_d_dV_d$.
35	c_{ds} (F)	$dQ_d_dV_s$.
36	c_{db} (F)	$dQ_d_dV_b$.
37	c_{sg} (F)	$dQ_s_dV_g$.

Virtuoso Simulator Components and Device Models Reference

B3SOI-PD Transistor Model (b3soipd)

38	<code>csd</code> (F)	<code>dQs_dVd</code> .
39	<code>css</code> (F)	<code>dQs_dVs</code> .
40	<code>csb</code> (F)	<code>dQs_dVb</code> .
41	<code>cbg</code> (F)	<code>dQb_dVg</code> .
42	<code>cbd</code> (F)	<code>dQb_dVd</code> .
43	<code>cbs</code> (F)	<code>dQb_dVs</code> .
44	<code>cbb</code> (F)	<code>dQb_dVb</code> .
45	<code>id</code> (A)	Total resistive drain current.
46	<code>is</code> (A)	Total resistive source current.
47	<code>ib</code> (A)	Total resistive bulk current.
48	<code>pwr</code> (W)	Power at op point.
49	<code>gmoverid</code> (1/V)	<code>Gm/Ids</code> .
50	<code>tdev</code> (C)	Temperature rise from ambient.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

<code>Ctheff</code> O-4	<code>dt2</code> M-166	<code>lwlc</code> M-255	<code>siid</code> M-94
<code>a0</code> M-22	<code>dtoxcv</code> M-252	<code>lwn</code> M-39	<code>tbox</code> M-50
<code>a1</code> M-25	<code>dvbd0</code> M-196	<code>m</code> I-10	<code>tcjswg</code> M-156
<code>a2</code> M-26	<code>dvbd1</code> M-197	<code>meto</code> M-113	<code>tdev</code> OP-50

Virtuoso Simulator Components and Device Models Reference

B3SOI-PD Transistor Model (b3soipd)

abp	M-198	dvt0	M-16	minr	M-106	tii	M-88
ad	I-4	dvt0w	M-19	mjswg	M-118	tlev	M-147
ad	M-138	dvt1	M-17	mobmod	M-60	tlevc	M-148
aebcp	I-20	dvt1w	M-20	mxo	M-199	tmax	M-145
aely	M-226	dvt2	M-18	nbc	I-15	tnodeout	I-22
af	M-177	dvt2w	M-21	nbjt	M-223	tnom	M-144
agbcp	I-19	dwb	M-47	nch	M-31	tox	M-49
agidl	M-200	dwbc	M-48	ndif	M-121	toxqm	M-242
ags	M-27	dwc	M-124	ndiode	M-214	toxref	M-232
ahli	M-227	dwg	M-46	necb	M-240	tpbswg	M-157
aii	M-210	ebg	M-233	nevb	M-234	trd	M-163
alarm	M-187	ef	M-178	nfactor	M-76	trs	M-162
alpha0	M-82	eg	M-149	ngate	M-32	tsi	M-51
alphagb1	M-235	em	M-182	ngidl	M-202	tt	M-120
alphagb2	M-238	esatii	M-90	nlx	M-11	type	M-1
as	I-3	eta0	M-80	noia	M-179	type	OP-1
as	M-137	etab	M-81	noib	M-180	u0	M-61
asd	M-215	fbjtii	M-84	noic	M-181	ua	M-63
at	M-155	fbody	M-126	noif	M-247	ua1	M-158
b0	M-23	frbody	M-249	noimod	M-175	ub	M-64
b1	M-24	gamma1	M-12	nrb	I-9	ub1	M-159

Virtuoso Simulator Components and Device Models Reference

B3SOI-PD Transistor Model (b3soipd)

beta0	M-83	gamma2	M-13	nrb	M-143	uc	M-65
beta1	M-85	gap1	M-150	nrd	I-7	uc1	M-160
beta2	M-86	gap2	M-151	nrd	M-141	ueff	OP-22
betaeff	OP-23	gds	OP-19	nrecf0	M-204	ute	M-164
betagb1	M-236	gm	OP-18	nrecr0	M-205	vabjt	M-225
betagb2	M-239	gmb	OP-20	nrs	I-8	vbgs	OP-7
bgidl	M-201	gmbg	OP-21	nrs	M-142	vbm	M-15
bii	M-211	gmoverid	OP-49	nseg	I-16	vbox	M-190
binunit	M-59	hdif	M-104	nsub	M-30	vbs	OP-6
bjtoff	I-14	ib	OP-47	ntox	M-231	vbsa	M-192
bvj	M-189	ibd	OP-13	ntrecf	M-169	vbsusr	I-21
capmod	M-123	ibs	OP-15	ntrecre	M-170	vbv	M-14
cbb	OP-44	ic	OP-9	ntun	M-203	vds	OP-5
cbd	OP-42	id	OP-45	paramchk	M-246	vdsat	OP-17
cbg	OP-41	idgidl	OP-11	pbswg	M-119	vdsatii0	M-87
cbs	OP-43	ids	OP-8	pclm	M-67	vecb	M-251
cdb	OP-36	igbt	OP-14	pd	I-6	version	M-2
cdd	OP-34	igmod	M-245	pd	M-140	vevb	M-250
cdg	OP-33	iii	OP-12	pdbc	I-17	vfbcv	M-133
cds	OP-35	imax	M-188	pdiblc1	M-68	vgb1	M-237
cdsc	M-73	imelt	M-108	pdiblc2	M-69	vgb2	M-241

Virtuoso Simulator Components and Device Models Reference

B3SOI-PD Transistor Model (b3soipd)

cdscb M-74	is OP-46	pdiblcb M-70	vgs OP-4
cdscd M-75	isbjt M-216	prt M-161	voff M-78
cf M-132	isdif M-217	prwb M-54	voxh M-243
cgb OP-32	isgidl OP-10	prwg M-55	vrec0 M-221
cgbo M-112	isnoisy I-23	ps I-5	vsat M-62
cgd OP-30	isrec M-218	ps M-139	vsdfb M-206
cgdl M-115	istun M-219	psbcp I-18	vsdth M-207
cgdo M-110	k1 M-4	pvag M-71	vth OP-16
cgeo M-111	k1w1 M-5	pwr OP-48	vtho M-3
cgg OP-29	k1w2 M-6	qjb OP-27	vtun0 M-222
cgs OP-31	k2 M-7	qjbg OP-28	w I-1
cgs1 M-114	k3 M-8	qd OP-25	w M-135
cgso M-109	k3b M-9	qg OP-24	w0 M-10
cii M-212	kb1 M-194	qs OP-26	w0flk M-248
cit M-77	kb3 M-195	rbody M-99	warn M-191
cjswg M-117	kbjt1 M-228	rbsh M-95	weff O-1
ckappa M-116	keta M-28	rd M-98	wint M-35
clc M-130	ketas M-29	rdc M-101	wl M-41
cle M-131	kf M-176	rdd M-103	wlc M-256
csb OP-40	kt1 M-152	rdeff O-6	wln M-42
csd OP-38	kt11 M-153	rdsb M-53	wmax M-183

Virtuoso Simulator Components and Device Models Reference

B3SOI-PD Transistor Model (b3soipd)

csdesw	M-209	kt2	M-154	region	I-11	wmin	M-184
csdmin	M-208	l	I-2	region	OP-2	wr	M-56
csg	OP-37	l	M-136	reversed	OP-3	wth0	M-229
css	OP-39	lbjt0	M-224	rhalo	M-230	ww	M-43
cth0	I-13	ldif	M-105	rs	M-97	wwc	M-257
cth0	M-167	ldif0	M-122	rsc	M-100	wwl	M-45
delp	M-193	leff	O-2	rseff	O-5	wwlc	M-258
delta	M-72	lii	M-89	rsh	M-96	wwn	M-44
deltavox	M-244	lint	M-34	rss	M-102	xbjt	M-171
delvt	M-125	ll	M-36	rth0	I-12	xdif	M-172
dii	M-213	llc	M-253	rth0	M-168	xj	M-33
dlbg	M-129	lln	M-37	rtheff	O-3	xl	M-57
dlc	M-127	lmax	M-185	shmod	M-146	xpart	M-134
dlcb	M-128	lmin	M-186	shrink	M-259	xrec	M-173
drout	M-66	ln	M-220	shrink2	M-260	xt	M-52
dskip	M-107	lw	M-38	sii0	M-91	xtun	M-174
dsub	M-79	lwc	M-254	sii1	M-92	xw	M-58
dtl	M-165	lwl	M-40	sii2	M-93		

HiSIM2 Model (hisim2)

The HiSIM2 (Hiroshima-university STARC IGFET Model) model was developed at Hiroshima University in collaboration with the STARC research center. This is the first complete surface-potential-based MOSFET model for circuit simulation based on the drift-diffusion approximation, which was originally developed by Pao and Sah. The most important advantage of the surface-potential-based modeling is the unified description of device characteristics for all bias conditions. The physical reliability of the drift-diffusion approximation has been proved by 2D device simulations with channel lengths even down to below 0.1 μ m.

This chapter contains the following information about the HiSIM2 model:

- [Model Concepts](#) on page 2360
- [Model Usage](#) on page 2361
 - [Instance Syntax](#) on page 2361
 - [Model Syntax](#) on page 2361
- [Model Version and Development](#) on page 2361
- [Version Update and Enhancement](#) on page 2362
 - [Version 2.70 Enhancement](#) on page 2362
 - [Version 2.70 Enhancement](#) on page 2362
 - [Version 2.61 Enhancement](#) on page 2363
 - [Version 2.60 Enhancement](#) on page 2363
- [Reference](#) on page 2363
 - [Model Equations](#) on page 2363
 - [Component Statements](#) on page 2401

Model Concepts

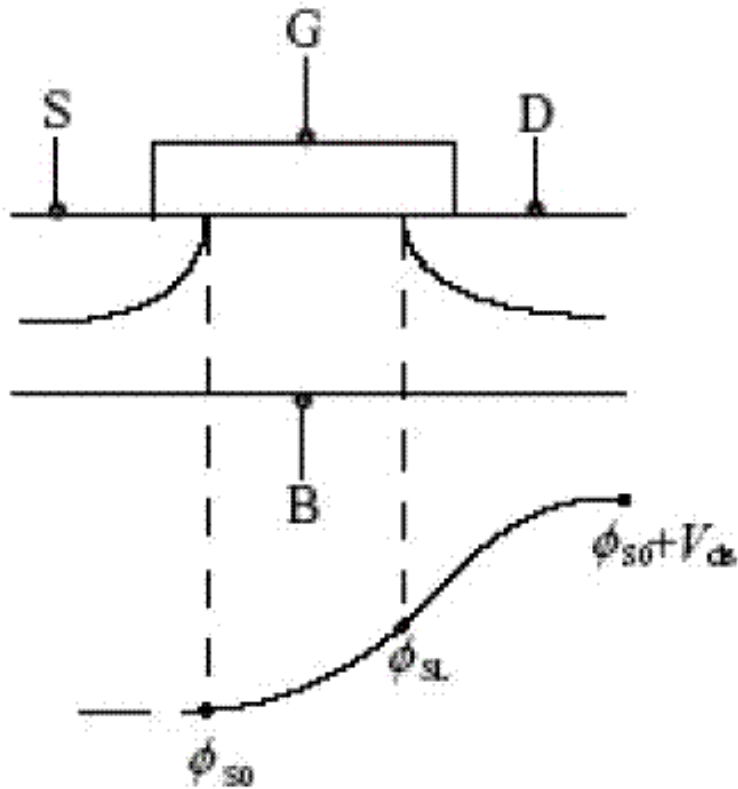


Figure 30-1 Schematic of the surface potential distribution in the channel

The figure shows the schematic of the surface potential distribution in the channel. To obtain analytical solutions for describing device performances, the charge sheet approximation of the inversion layer with zero thickness has been introduced. Together with the gradual-channel approximation all device characteristics are then described analytically by the channel-surface potentials at the source side (ϕ_{S0}) and at the drain side (ϕ_{SL}). These surface potentials are functions of applied voltages on the four MOSFET terminals; the gate voltage V_g , the drain voltage V_d , the bulk voltage V_b and the reference potential of the source V_s . This is the long-channel basis of the HiSIM model, and extensions of the model approximations are done for advanced technologies. All newly appearing phenomena such as short-channel and reverse-short-channel effects are included in the surface potential calculations causing modifications resulting from the features of these advanced technologies.

Model Usage

HiSIM2 model definition is used to describe the behavior of devices which has same model characteristic and the instance parameters can be used to describe the characteristics that belong to the specific device.

Instance Syntax

HiSIM2 instance need specify 4 terminals. To specify HiSIM2 instance element, the ModelName has to be associated with a HiSIM2 model card.

```
InstanceName d g s b [th] HiSIM2ModelName parameter=value ...
```

Sample Instance Statement

```
m1 (vdd vgg vss vbb) n_ch w=10u l=2u m=1 nf=10
```

For more instance parameters, refer to [Reference](#) on page 2363.

Model Syntax

The following syntax specifies HiSIM2 model:

```
model ModelName hisim2 parameter=value ...
```

The third parameter, `hisim2`, is the master to indicate this model card is a HiSIM2 model card.

Sample Model Statement

```
model n_ch hisim2 type=n version=2.60 tox=3e-8 corsrd=-1 rs=1e-3 rd=5e-2
```

For more model parameters, refer to [Reference](#) on page 2363.

Model Version and Development

Cadence Virtuoso® Spectre/APS and Ultrasim supports the following versions of HiSIM2 model: 2.50, 2.51, 2.60, 2.61, and 2.70. Different model versions can be obtained by setting different model parameter `VERSION = 2.50/2.51/2.60/2.61/2.70`. 2.50 is set as the default version.

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

The following lists the recent model versions and their corresponding simulator version for your reference:

HiSIM2 Version 2.51	MMSIM101_ISR10
HiSIM2 Version 2.60	MMSIM111_ISR6
HiSIM2 Version 2.61	MMSIM111_ISR11
HiSIM2 Version 2.70	MMSIM131

If you still have any questions, please contact with Cadence support team.

Version Update and Enhancement

Version 2.70 Enhancement

- Unit conversion from CGS to MKS
- Change in model descriptions
 - Suppression of error messages from the range check when new the model flag COERRREP is set to 0
 - Improvement of GIDL current model with new model parameters GIDL6 and GIDL7
 - Improvement of STI effect model with new model parameters NSUBCSTI1, NSUBCSTI2, and NSUBCSTI3
 - Introduction of gate length dependence for VFBC with new model parameters VFBCL and VFBCLP
 - Improvement of smoothness of the NSUBPFAC model with the new model parameter NSUBPDLT
 - Invalidation of the NSUBPFAC model when $NSUBPFAC = 1$
 - Range check of model parameters NSUBPFAC and NSUBPDLT
- Bug fixes:
 - Calculation of MUEPH1 when CODFM=1
 - Resetting of SC4 value when CORECIP=1
 - Calculation of some derivatives

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

- ❑ Floating point exception in the smoothing functions
- ❑ High-field effect model with model parameter `GDL D`
- ❑ Code improvements of `Fn_POW` and `Fn_SZ` functions for higher exception robustness

Version 2.61 Enhancement

- Missing initialization of `NSUBC`, `NSUBP`, and `MUEPH1` in the Initialize for repeating simulation
- Unit converting in the Initialize
- Derivative calculations in the `Qover` model code
- Floating point exception in the `QME` model code
- Floating point exception in the smoothing functions

Version 2.60 Enhancement

- Introduction of the Well Proximity Effect model with new parameters:
 - ❑ Instance parameters: `SCA` , `SCB`, and `SCC`
 - ❑ Model parameters: `WEB` , `WEC` , `NSUBCWPE` , `NSUBPWPE`, and `NPEXTWPE`
- Improvement of the overlap capacitance model
- Activation of Induced Gate Noise model
- Change the default value of the instance parameters `NRD` and `NRS`.

Reference

Model Equations

Effective Length and Width

L_{gate} and W_{gate} are the gate length and gate width. They are calculated from the gate drawn length and width.

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

$$L_{gate} = L_{drawn} + XL$$

$$W_{gate} = \frac{W_{drawn}}{NF} + XW$$

$$L_{poly} = L_{gate}^{-2} \times \frac{LL}{(L_{gate} + LLD)^{LLN}}$$

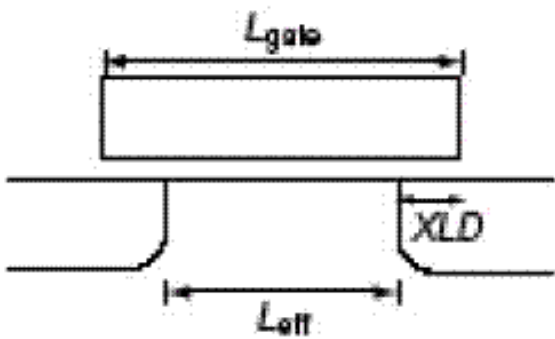
$$W_{poly} = W_{gate}^{-2} \times \frac{WL}{(W_{gate} + WLD)^{WLN}}$$

$$L_{eff} = L_{poly}^{-2} \times XLD$$

$$W_{eff} = W_{poly}^{-2} \times XWD$$

where XLD and XWD account for the overlaps of source/drain contact and gate oxide. LL, LLD, LLN, WL, WLD, and WLN are further model parameters for including L_{gate} or W_{gate} dependencies on L_{eff} and W_{eff} .

Figure 30-2 Cross section of the device



Charge

All device characteristics are determined on the basis of the charge control by applied voltages and by expressing the MOSFET charges as functions of the surface potentials.

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

Under the charge-sheet approximation the charges on the four MOSFET terminals Q_G (gate), Q_B (bulk), Q_D (drain), and Q_S (source), are described as:

$$Q_G = -(Q_B + Q_I) = -Q_{SP}$$

$$Q_B = W_{eff} * NF * \int_0^{L_{eff}} Q_b(y) dy$$

$$Q_I = W_{eff} \int_0^{L_{eff}} Q_i(y) dy$$

$$Q_D = W_{eff} \int_0^{L_{eff}} \frac{y}{L_{eff}} Q_i(y) dy$$

$$Q_S = Q_I - Q_D$$

where Q_I is the inversion charge, Q_{SP} is the space charge, and y is the position along the channel. L_{eff} and 0 are the channel-end positions at the drain side and the source side, respectively.

By applying the Gauss law, the space charge density Q_{SP} is derived from the Poisson equation.

$$-Q_{SP} = C_{ox}(V_G' - \phi_s(y))$$

$$C_{ox} = \frac{\epsilon_{ox}}{TOX}$$

$$V_G' = V_{gs} - VFBC + \Delta V_{th}$$

$$\beta = \frac{q}{kT}$$

where VFBC is the at-band voltage, TOX is the physical gate-oxide thickness, and ΔV_{th} is the threshold voltage shift in comparison to the threshold voltage of a long-channel transistor. The electron charge is denoted by q , and ϵ_{si} and N_{sub} are the silicon permittivity and the substrate impurity concentration, respectively. The Boltzmann constant and the lattice temperature in Kelvin are k and T , respectively.

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

The quasi-Fermi potential ϕ_f (f) preserves the following relationship:

$$\phi_f(L_{eff}) - \phi_f(0) = V_{ds,eff}$$

The electron concentration at equilibrium condition n_{p0} is

$$n_{p0} = \frac{n_i^2}{P_{p0}}$$

where the intrinsic carrier concentration n_i is

$$n_i = n_{i0} T^{\frac{1}{2}} \exp\left(-\frac{E_g}{2q\beta}\right)$$

p_{p0} is approximated to be N_{sub} , and E_g describes the temperature dependence of the bandgap.

The Poisson equation and the Gauss law are used to derive the inversion charge and bulk charge related charge-density equations under the assumption of a homogeneous substrate impurity distribution as

$$Q_b(y) = -\sqrt{\frac{2\varepsilon_{si}qN_{sub}}{\beta}} [\exp\{-\beta(\varphi_s(y) - V_{bs})\} + \beta(\varphi_s(y) - V_{bs})]^{1/2}$$

$$Q_i(y) = -C_{ox}(V_G' - \varphi_s(y)) + \sqrt{\frac{2\varepsilon_{si}qN_{sub}}{\beta}} [\exp\{-\beta(\varphi_s(y) - V_{bs})\} + \beta(\varphi_s(y) - V_{bs}) - 1]^{1/2}$$

Drain Current

Under gradual-channel approximation with further approximations of an idealized gate structure and uniform channel doping, the drift-diffusion approximation describes the drain current I_{ds} as:

$$I_{ds} = \frac{W_{eff} * NF}{L_{eff}} * \mu * \frac{I_{dd}}{\beta}$$

$$I_{dd} = C_{ox}(\beta V_{G'} + 1)(\varphi_{SL} - \varphi_{S0}) - \frac{\beta}{2} C_{ox}(\varphi_{SL}^2 - \varphi_{S0}^2)$$

$$- \frac{2}{3} const0 [\{ \beta(\varphi_{SL} - V_{bs}) - 1 \}^{3/2} - \{ \beta(\varphi_{S0} - V_{bs}) - 1 \}^{3/2}]$$

$$+ const0 [\{ \beta(\varphi_{SL} - V_{bs}) - 1 \}^{1/2} - \{ \beta(\varphi_{S0} - V_{bs}) - 1 \}^{1/2}]$$

$$\varphi_{S0} = 2\varphi_B \cdot \varphi_B = \frac{2}{\beta} 1n \left(\frac{N_{sub}}{n_i} \right)$$

$$\varphi_{SL} = 2\varphi_B + V_{ds}$$

The description for the long-channel case is obtained as:

$$I_{ds} = \frac{W_{eff} * NF}{L_{eff}} \mu * C_{ox} \left[(V_{G'} - V_{th}) V_{ds} - \left(\frac{1}{2} + \frac{\sqrt{2\varepsilon_{si} \cdot q N_{sub}}}{4C_{ox}\sqrt{2\varphi_B}} \right) V_{ds}^2 \right]$$

$$V_{th} = VFBC + 2\varphi_B + \frac{\sqrt{2\varepsilon_{si} \cdot q N_{sub}}}{C_{ox}} \sqrt{2\varphi_B}$$

Threshold Voltage Shift

Different from the drift approximation, the drift-diffusion approximation does not require a threshold voltage parameter V_{th} for describing device performances. The MOSFET device parameters, such as the oxide thickness T_{OX} and the substrate doping concentration N_{SUBC} determine the complete MOSFET behavior including the subthreshold characteristics automatically and consistently. The measured V_{th} is influenced by various phenomena, such as the short-channel effects, which cause a reduction of V_{th} for short-channel transistors in comparison to long-channel transistors as shown in Fig. 5. This so-called ΔV_{th} roll-off is very much dependent on the technology applied for MOSFET fabrication. Therefore, HiSIM can derive many detailed information on the MOSFET fabrication technology, which is relevant for

modeling device characteristics, from the V_{th} changes (ΔV_{th}) as a function of gate length (L_{gate}). The modeled ΔV_{th} is incorporated in the ϕ_S iteration, and can be viewed as consisting of two main effects or components:

1. The short-channel effect: $\Delta V_{th,SC}$
2. The reverse-short-channel effect: $\Delta V_{th,R}$ and $\Delta V_{th,P}$

The separation into these components is shown below:

Short-Channel Effect

Four important phenomena are observed:

1. Reduction of V_{th} for reduced L_{gate}
2. V_{th} dependence on V_{ds}
3. Reduction of the body effect
4. Increase of the subthreshold swing, which is often not obvious for the normal case of fabrication technologies. Recent advanced technologies utilize aggressive scaling, which induces observable subthreshold degradation.

$$\Delta V_{th,SC} = \frac{\epsilon_{si}}{C_{ox}} W_d \frac{dE_y}{dy}$$

where W_d is the depletion-layer thickness written as

$$W_d = \sqrt{\frac{2\epsilon_{si}(2\phi_B - V_{bs})}{qN_{sub}}}$$

$$2\phi_B = \frac{2}{\beta} 1n\left(\frac{N_{sub}}{n_i}\right)$$

dE_y/dy is derived with model parameters in the form

$$\frac{dE_y}{dy} = \frac{2\{VBI - 2\phi_B\}}{(L_{gate} - PARL2)^2} \left(SC1 + SC2 \cdot V_{ds} + SC3 \cdot \frac{2\phi_B - V_{bs}}{L_{gate}} + SC4 \cdot V_{ds}(2\phi_B - V_{bs}) \right)$$

Reverse-Short-Channel Effects

Impurity concentration inhomogeneity in the direction vertical to the channel (Retrograded Implantation)

$$\Delta V_{th,R} = \frac{Q_{dep}}{C_{ox}} - \frac{Q_{dep}(long)}{C_{ox}}$$

$$Q_{dep} = q \int_0^{Wd} N_{sub}(\chi) d\chi$$

$$Q_{dep} = QDEPCC + \frac{QDEPCL}{L_{gate} QDEPCS} + \left(QDEPBC + \frac{QDEPBL}{L_{gate} QDEPBS} \right) \sqrt{2\phi_B - V_{bs}}$$

$$Q_{Bmod} = \sqrt{2q \cdot N_{sub} \cdot \epsilon_{si} \cdot \left(2\phi_B - V_{bs} - \frac{BS1}{BS2 - V_{bs}} \right)}$$

where BS1 represents the strength of the deviation and BS2 is the starting value of Vbs where the deviation becomes visible.

Virtuoso Simulator Components and Device Models Reference
HiSIM2 Model (hisim2)

Impurity concentration inhomogeneity in the lateral direction parallel to the channel (Pocket Implantation)

$$\Delta V_{th,P} = (\Delta V_{th,R} - V_{th0}) \frac{\epsilon_{si}}{C_{ox}} W_d \frac{dE_{y,P}}{dy} + dq_p$$

$$V_{th,R} = VFBC + 2\phi_B + \frac{Q_{B0}}{C_{ox}} + \frac{1}{\beta} \log\left(\frac{N_{subb}}{NSUBC}\right)$$

$$Q_{B0} = \sqrt{2q \cdot N_{sub} \cdot \epsilon_{si} \cdot (2\phi_B - V_{bs})}$$

$$V_{th0} = VFBC + 2\phi_{BC} + \frac{\sqrt{2q \cdot NSUBC \cdot \epsilon_{si} \cdot (2\phi_{BC} - V_{bs})}}{C_{ox}}$$

$$N_{subb} = 2 \cdot NSUBP - \frac{(NSUBP - NSUBC) \cdot L_{gate}}{LP} - NSUBC$$

$$dq_p = \frac{Q_{B0} - Q_{Bmod}}{C_{ox}}$$

$$\phi_{BC} = \frac{2}{\beta} 1n\left(\frac{NSUBC}{n_i}\right)$$

$$\phi_B = \frac{2}{\beta} 1n\left(\frac{N_{sub}}{n_i}\right)$$

$$N_{sub} = \frac{NSUBC(L_{gate} - LP) + NSUBP \cdot LP}{L_{gate}}$$

$$\Delta V_{th,P} = \Delta V_{th,P} - \frac{SCP22}{(SCP21 + V_{ds})^2}$$

$$N_{sub} = N_{sub} + \frac{NPEXT - N_{subc}}{\left(\frac{1}{\chi\chi} + \frac{1}{LPEXT}\right) L_{gate}}$$

where

$$\chi\chi = 0.5 \cdot L_{gate}^{-LP}$$

CORECIP = 1 for Accurate Reciprocity Calculation of Capacitances

The model CORECIP enables accurate calculation of the capacitance reciprocity. If CORECIP = 1 is selected, the V_{ds} dependence is moved to the punchthrough model described in the next section. Accordingly, model parameters SC2, SC4, SCP2 and SCP4 must be set to zero, and PT2 and PT4 activated.

Short Channel Effects

Punchthrough Effect

The origin of the punchthrough effect is the bipolar effect through source, substrate, and drain. The effect is described by a power function of the potential difference instead of the exponential function as

$$POTENTIAL = (VBI - \varphi_{s0})^{PTP}$$

The final drain current I_{ds} is written

$$I_{ds} = I_{ds} + PUNCH$$

$$PUNCH = \frac{W_{eff} \cdot NF}{L_{eff}} \frac{\mu}{\beta} \cdot (\varphi_{SL} - \varphi_{S0})$$

$$\left\{ C_{ox} \cdot \beta \frac{PTL}{(L_{gate} \cdot 10^6)^{PTLP}} \cdot POTENTIAL \cdot \left(1 + PT2 \cdot V_{ds} + \frac{PT4 \cdot (\varphi_{s0} - V_{bs})}{(L_{gate} \cdot 10^6)^{PT4P}} \right) \right\}$$

Channel Conductance

The high field under the saturation condition causes the pinch-off region and the current flows away from the surface. This effect is considered as the lateral-field-induced charge for the capacitance. The simplified formulation is applied to consider the effect as

$$I_{ds} = I_{ds} + \frac{W_{eff} \cdot NF}{L_{eff}} \frac{\mu}{\beta} \cdot (\varphi_{SL} - \varphi_{S0}) \cdot CONDUCTANCE$$

$$CONDUCTANCE = C_{ox} \cdot \beta \frac{GDL}{(L_{gate} \cdot 10^6 + GDLD \cdot 10^6)^{GDLP}} \cdot V_{ds}$$

Pocket Impurity Concentration Reduction

If the gate length becomes shorter, the pocket-impurity concentration may become lower than for long channels. This effect is modeled as:

$$N_{subp} = NSUBP \cdot \left(\frac{2 \cdot (1 - NSUBPFAC)}{NSUBPL} \cdot L_{gate} \cdot 10^6 + 2 \cdot NSUBPFAC - 1 \right)$$

Depletion Effect of the Gate Poly-Si

Carrier depletion in the gate poly-Si occurs due to the relatively low impurity concentration of the poly-Si in the region above the gate-oxide. Nevertheless, this concentration is usually much higher than the impurity concentration in the substrate. Therefore, carrier depletion in the poly-Si near the gate-oxide interface starts after the formation of the inversion layer in the

substrate. For modeling the gate poly-Si depletion a physical model parameter, namely the impurity concentration in the gate poly-Si (N_{pg}), is introduced.

$$V_G' - \varphi_S - \varphi_{Sp_g} = -\frac{Q_{SP}}{C_{ox}} = \frac{\varepsilon_{si} E_{Si}}{C_{ox}}$$

$$E_{pg} = qN_{pg}L_{D,pg}\sqrt{2}\left[\{\exp(-\beta\varphi_{Sp_g}) + \beta\varphi_{Sp_g} - 1\} + \frac{n_{p0,pg}}{p_{p0,pg}}\{\exp(-\beta\varphi_{Sp_g}) - \beta\varphi_{Sp_g} - 1\}\right]^{\frac{1}{2}}$$

$$E_{pg} = qN_{pg}L_{D,pg}\sqrt{2}(\beta\varphi_{Sp_g} - 1)^{\frac{1}{2}}$$

$$\varphi_{Sp_g} = PGD1\left(1 + \frac{1}{L_{gate} \cdot 10^6}\right)^{PGD4} \exp\left(\frac{V_{gs} - PGD2}{V}\right)$$

Quantum-Mechanical Effects

The main quantum-mechanical phenomenon, which has to be included into a MOSFET model for circuit simulation, is the repulsion of the channel's carrier-density peak into the substrate away from the surface. This can be described phenomenologically by an increased effective oxide thickness T_{ox} . Two major approximations are introduced to derive a simple set of equations for T_{ox} : First, a triangular potential perpendicular to the channel is approximated and second, carriers are assumed to occupy only the lowest quantized energy level. The resulting effective oxide thickness T_{ox} can be written as:

$$T_{ox} = TOX + \Delta T_{ox}$$

For HiSIM2.5

$$\Delta T_{ox} = \frac{QME1}{QME2^2}(V_{gs} - V_{th}(T_{ox} = TOX) - QME2)^2 + QME3$$

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

For HiSIM2.5.1

$$\Delta T_{ox} = \frac{QME1}{V_{gb} - V_{th}(T_{ox} = TOX) + QME2} + QME3$$

Mobility Model

Here E_{eff} is the effective field normal to the surface and is written as:

$$\frac{1}{\mu_0} = \frac{1}{\mu_{CB}} + \frac{1}{\mu_{PH}} + \frac{1}{\mu_{SR}}$$

$$\mu_{CB}(Coulomb) = M_{Coulomb0} + M_{Coulomb1} \frac{Q_i}{q \cdot 10^{11}}$$

$$\mu_{PH}(phonon) = \frac{Muephonon}{E_{eff} \cdot MUEPH0}$$

$$\mu_{SR}(roughness) = \frac{MUESR1}{E_{eff} \cdot Muesurface}$$

Here E_{eff} is the effective field normal to the surface and is written as

$$E_{eff} = \frac{1}{\epsilon_{Si}} (N_{dep} \cdot Q_b + N_{INV} \cdot Q_i) \cdot f(\varphi_s)$$

$$f(\varphi_s) = \frac{1}{1 + (\varphi_{S0} - \varphi_{SL}) \cdot N_{INVD}}$$

where N_{dep} considers the gate length dependence with two model parameters NDEPL and NDEPLP as:

$$N_{dep} = NDEP \frac{(L_{gate} \cdot 10^6)^{NDEPLP}}{NDEPL + (L_{gate} \cdot 10^6)^{NDEPLP}}$$

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

The mobility preserves the following conditions:

$$MUEPH0 \approx 0.3$$

$$M_{uesurface} = 2.0$$

$$NDEP = 1.0$$

$$NINV = 0.5$$

Due to the carrier ow at increasing distance from the surface with reducing Lgate, the electric field experienced by the carriers is different from the field in the long Lgate case. This results in a modification of $M_{uephonon}$, which is modeled as:

$$M_{uephonon} = MUEPH1 \cdot \left(1 + \frac{MUEPHL}{(L_{gate} \cdot 10^6 + MUEPLD \cdot 10^6)^{MUEPLP}} \right) \cdot \left(1 + \frac{MUEPHL2}{(L_{gate} \cdot 10^6)^{MUEPLP2}} \right)$$

The surface roughness co-efficient $M_{uesurface}$ is modelled to have a similar channel length dependence written as:

$$M_{uesurface} = MUESR0 \cdot \left(1 + \frac{MUESRL}{(L_{gate} \cdot 10^6)^{MUESLP}} \right)$$

The high field mobility is modeled as:

$$\mu = \frac{\mu_0}{\left(1 + \left(\frac{\mu_0 E_y}{V_{max}} \right)^{BB} \right)^{\frac{1}{BB}}}$$

where the maximum velocity V_{max} is temperature dependent. V_{max} should be the maximum electron-saturation velocity ($\approx 1.07 \times 10^7 \text{cm/s}$), which is exceeded at reduced L_{gate} . This is called velocity overshoot, and is included in the mobility model in the following manner:

$$V_{max} = VMAX \cdot \left(1 + \frac{VOVER}{(L_{gate} \cdot 10^6)^{VOVERP}} \right)$$

Channel-Length Modulation

The gradual-channel approximation is applied to derive analytical equations for describing device characteristics. However, this approximation is not valid for large V_{ds} causing the pinch-off phenomenon in the channel. Without taking into account the pinch-off phenomenon, the calculated channel conductance g_{ds} enters abruptly into the saturation condition. To include the pinch-off phenomenon in HiSIM, we apply the conventional method of modeling the pinch-off region (ΔL) separately from the rest of the channel.

$$\Delta L = \epsilon_{Si} \frac{E_D - E_C}{qN_{sub} + Q_i/W_d}$$

where

$$E_D^2 = E_C^2 + \frac{2qN_{sub}}{\epsilon_{Si}} (\phi_S(\Delta L) - \phi_{SL})$$

and E_C is the electric field at $y=0$.

$$E_C = \frac{I_{dd}}{\beta(L_{eff} - \Delta L)Q_i}$$

The above equation can be simplified as follows:

$$E_C = \frac{I_{dd}}{\beta L_{eff} Q_i}$$

$$\phi_S(\Delta L) = (1 - CLM1) \cdot \phi_{SL} + CLM1 \cdot (\phi_{S0} + V_{ds})$$

Narrow Channel Effects

Threshold Voltage Modification

$$\Delta V_{th,W} = \left(\frac{1}{C_{ox}} - \frac{1}{C_{ox} + 2C_{ef}/(L_{eff}W_{eff})} \right) qN_{sub}W_d + \frac{WVTH0}{W_{gate} \cdot 10^6}$$

where WVTH0 is the parameter for including the basic width dependence and

$$C_{ef} = \frac{2\varepsilon_{ox}}{\pi} L_{eff} 1n \left(\frac{2T_{fox}}{T_{ox}} \right) = \frac{WFC}{2} L_{eff}$$

Here, T_{fox} is the thickness of the oxide at the trench edge, and WFC is the model parameter for including the edge-fringing-capacitance effects.

$$\Delta V_{th} = \Delta V_{th,SC} + \Delta V_{th,R} + \Delta V_{th,P} + \Delta V_{th,W} - \varphi_{Sp_g}$$

Mobility Change

$$M_{uephonon} = M_{uephonon} \cdot \left(1 + \frac{MUEPHW}{(W_{gate} \cdot 10^6 + MUEPWP \cdot 10^6)^{MUEPWP}} \right) \cdot \left(1 + \frac{MUEPHW2}{(W_{gate} \cdot 10^6)^{MUEPWP2}} \right)$$

$$M_{uesurface} = M_{uesurface} \cdot \left(1 + \frac{MUESRW}{(W_{gate} \cdot 10^6)^{MUESWP}} \right)$$

Transistor Leakage due to Shallow Trench Isolation (STI): Hump in I_{ds}

The shallow trench isolation induces also an undesired hump in the subthreshold region of the I_{ds} - V_{gs} characteristics. This is due to an increased electric field at the edge of the trench. At this trench edge, the impurity concentration as well as the oxide thickness are different from the MOSFET middle position along the width direction. Therefore, the surface potential values are expected to be different at the trench edge and are found to cause a V_{th} reduction there. Thus a MOSFET leakage current occurs at these edges, which is smaller than the main MOSFET. The leakage current equation is written as:

$$I_{ds,STI} = 2 \frac{W_{STI}}{L_{eff} - \Delta L} \mu \frac{Q_{i,STI}}{\beta} [1 - \exp(-\beta V_{ds})]$$

where W_{STI} determines the width of the high-field region.

$$W_{STI} = W_{STI} \left(1 + \frac{W_{STIL}}{(L_{gate,sm} \cdot 10^6)^{W_{STILP}}} \right) \left(1 + \frac{W_{STIW}}{(W_{gate} \cdot 10^6)^{W_{STIWP}}} \right)$$

Small Geometry

Small size devices do not show the same scaling characteristic as long-channel or wide-channel devices, but deviate significantly. The reason is mainly due to the resolution inaccuracy of the lithography. The small geometry effects are modeled first as the threshold voltage shift

$$\Delta V_{th} = \Delta V_{th,SC} + \Delta V_{th,R} + \Delta V_{th,P} + \Delta V_{th,W} + \Delta V_{th,sm} - \varphi_{Spg}$$

$$\Delta V_{th,sm} = \frac{WL2}{wl^{WL2P}}$$

The mobility modification due to the small device geometry is also modeled in the phonon scattering as

$$M_{uephonon} = M_{uephonon} \cdot \left(1 + \frac{MUEPHS}{wl \cdot MUEPSP} \right)$$

$$V_{max} = V_{max} \cdot \left(1 + \frac{VOVERS}{wl \cdot VOVERSP} \right)$$

Effects of the Source/Drain Diffusion Length for Shallow Trench Isolation (STI) Technologies

The diffusion length, LOD between MOSFET gate and STI edge affects the MOSFET characteristics.

$$N_{substi} = \frac{1 + T1 \cdot T2}{1 + T1 \cdot T3}$$

where

$$T1 = \frac{1}{1 + NSUBPSTI2}$$

$$T2 = \left(\frac{NSUBPSTI1}{L_{od_half}} \right)^{NSUBPSTI3}$$

$$T3 = \left(\frac{NSUBPSTI1}{L_{od_half_ref}} \right)^{NSUBPSTI3}$$

$$N_{subp} = N_{subp} \cdot N_{substi}$$

$$M_{uesti} = \frac{1 + T1 \cdot T2}{1 + T1 \cdot T3}$$

where

$$T1 = \frac{1}{1 + MUESTI2}$$

$$T2 = \left(\frac{MUESTI1}{L_{od_half}} \right)^{MUESTI3}$$

$$T3 = \left(\frac{MUESTI1}{L_{od_half_ref}} \right)^{MUESTI3}$$

$$M_{uephonon} = M_{uephonon} \cdot M_{uesti}$$

Temperature Dependences

The temperature dependence is included automatically in the surface potentials through β , which is the inverse of the thermal voltage. Additionally the bandgap, the intrinsic carrier concentration, the carrier mobility, and the carrier saturation velocity are also temperature dependent. The temperature dependence of the bandgap determines the temperature dependence of V_{th} and is modeled as:

$$E_g = E_{g,TNOM} - BGTMP1 \cdot (T - TNOM) - BGTMP2 \cdot (T^2 - TNOM^2)$$

where T is the given temperature, and

$$E_{g,TNOM} = EG0 - 90.25 \times 10^{-6} \cdot TNOM - 1.0 \times 10^{-7} \cdot TNOM^2$$

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

where T is the given temperature. The temperature dependence of the intrinsic carrier concentration is given by

$$n_i = n_{i0} \cdot T^{\frac{3}{2}} \cdot \exp\left(-\frac{E_g}{2q}\beta\right)$$

$$\mu_{PH}(phonon) = \frac{M_{uephonon}}{(T/TNOM)^{MUETMP} \times E_{eff}^{MUEPH0}}$$

$$V_{max} = \frac{VMAX}{1.8 + 0.4(T/TNOM) + 0.1(T/TNOM)^2 - VTMP \times (1 - T/TNOM)}$$

The temperature dependence of the gate current is given by modifying the bandgap specific for the gate current as:

$$E_{gp} = E_{g,TNOM} + EGIG + IGTEMP2\left(\frac{1}{T} - \frac{1}{TNOM}\right) + IGTEMP3\left(\frac{1}{T^2} - \frac{1}{TNOM^2}\right)$$

Resistances

The source and the drain resistances R_s and R_d are considered by voltage drops on each terminal as:

$$V_{gs,eff} = V_{gs} - I_{ds} \cdot R_s$$

$$V_{ds,eff} = V_{ds} - I_{ds} \cdot (R_s + R_d)$$

$$V_{bs,eff} = V_{bs} - I_{ds} \cdot R_s$$

where

$$R_s = \frac{RS}{W_{eff} \cdot NF} + NRS \cdot RSH$$

$$R_d = \frac{RD}{W_{eff} \cdot NF} + NRD \cdot RSH$$

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

The flag **CORSRD** is provided for the selection of one of the possible approaches. **CORSRD = 0** refers to no contact resistance. **CORSRD = 1, 2, -1** means "internal", "analytical", and "external" source/drain resistances, respectively. **CORSRD = 0** is the default. **CORSRD=2** is introduced to avoid simulation time penalty with an analytical description of the resistance effect as:

$$I_{ds} = \frac{I_{ds0}}{1 + I_{ds0} \frac{R_d}{V_{ds}}}$$

where I_{ds0} is the drain current without the resistance effect.

$$R_g = \frac{RSHG \cdot \left(XGW + \frac{W_{eff}}{3 \cdot NGCON} \right)}{NGCON \cdot (L_{drawn} - XGL) \cdot NF}$$

Capacitances

Intrinsic Capacitances

$$Q_y = \varepsilon_{Si} W_{eff} \cdot NF \cdot W_d \left(\frac{\varphi_{S0} + V_{ds} - \varphi_S(\Delta L)}{XQY} \right) + \frac{XQY1 \cdot W_{eff} \times 10^6 \cdot NF}{(L_{gate} \times 10^6)^{XQY2}} V_{bs}$$

Overlap Capacitances

Surface Potential-Based Model

under the depletion and the accumulation conditions

$$Q_{over} = W_{eff} \cdot NF \cdot LOVER \left(\sqrt{\frac{2\varepsilon_{Si} q NOVER}{\beta}} \sqrt{\beta(\varphi_S + V_{ds}) - 1} \right)$$

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

under inverse condition

$$Q_{over} = W_{eff} \cdot NF \cdot LOVER \cdot C_{ox} (V_{gs} - VFBOVER - \phi_S)$$

Simplified Bias Dependent Model

$$Q_{god} = W_{eff} NF C_{ox} [(V_{gs} - V_{ds}) LOVER - OVSLP \cdot (1.2 - (\phi_{SL} - V_{ds})) \cdot (OVMAG + (V_{gs} - V_{ds}))]$$

Extrinsic Capacitances

$$C_f = \frac{\epsilon_{ox}}{\pi/2} W_{gate} \cdot NF \cdot 1n \left(1 + \frac{TPOLY}{T_{ox}} \right)$$

Leakage Currents

Substrate Current

$$I_{sub} = X_{sub1} \cdot P_{sisubsat} \cdot I_{ds} \cdot \exp\left(-\frac{X_{sub2}}{P_{sisubsat}}\right)$$

$$X_{sub1} = SUB1 \cdot \left(1 + \frac{SUB1L}{L_{gate} \cdot SUB1LP}\right)$$

$$X_{sub2} = SUB2 \cdot \left(1 + \frac{SUB2L}{L_{gate}}\right)$$

$$P_{sisubsat} = SVDS \cdot V_{ds} + \phi_{S0} - \frac{L_{gate} \cdot P_{sislsat}}{X_{gate} + L_{gate}}$$

$$X_{gate} = SLG \cdot \left(1 + \frac{SIGL}{L_{gate} \cdot SLGLP}\right)$$

$$P_{sislsat} = V_{g2} + \frac{q \cdot \epsilon_{Si} \cdot N_{sub}}{C_{ox}} \cdot \left\{1 - \sqrt{1 + \frac{2C_{ox}^2}{q \cdot \epsilon_{Si} \cdot N_{sub}} \left(V_{g2} - \frac{1}{\beta} - X_{vbs} \cdot V_{bs}\right)}\right\}$$

$$X_{vbs} = SVBS \cdot \left(1 + \frac{SVBSL}{L_{gate} \cdot SVBSLP}\right)$$

$$V_{g2} = SVGS \cdot \left(1 + \frac{SVGSL}{L_{gate} \cdot SVGSLP}\right) \cdot \frac{W_{gate} \cdot SVGSWP}{W_{gate} \cdot SVGSWP + SVGSW} \cdot V_{gp}$$

Impact-Ionization Induced Bulk Potential Change

$$\begin{aligned} \Delta I_{ds} = & \frac{2}{3} \sqrt{\frac{2\varepsilon_{Si} q N_{sub}}{\beta}} [\{\beta(\phi_{SL} - V_{bs}) - 1\}^{\frac{3}{2}} \frac{\beta \Delta V_{bulk}}{2\beta(\phi_{SL} - V_{bs}) - 1} \\ & - \{\beta(\phi_{S0} - V_{bs}) - 1\}^{\frac{3}{2}} \frac{\beta \Delta V_{bulk}}{2\beta(\phi_{S0} - V_{bs}) - 1}] \\ & - \sqrt{\frac{2\varepsilon_{Si} q N_{sub}}{\beta}} [\{\beta(\phi_{SL} - V_{bs}) - 1\}^{\frac{1}{2}} \frac{\beta \Delta V_{bulk}}{2\beta(\phi_{SL} - V_{bs}) - 1} \\ & - \{\beta(\phi_{S0} - V_{bs}) - 1\}^{\frac{1}{2}} \frac{\beta \Delta V_{bulk}}{2\beta(\phi_{S0} - V_{bs}) - 1}] \end{aligned}$$

where

$$\Delta V_{bulk} = IBPC1(1 + IBPC2 \cdot \Delta V_{th}) \cdot I_{sub}$$

IBPC1 and IBPC2 are model parameters.

Gate Current

Between Gate and Channel, I_{gate}

$$\begin{aligned} I_{gate} = & q \cdot GLEAK1 \cdot \frac{E^2}{E_{gp}^{\frac{1}{2}}} \cdot \exp\left(-\frac{E_{gp}^{\frac{3}{2}} \times GLEAK2}{E}\right) \cdot \sqrt{\frac{Q_i}{const0}} \cdot W_{eff} \cdot NF \cdot L_{eff} \\ & \cdot \frac{GLEAK6}{GLEAK6 + V_{ds}} \cdot \frac{GLEAK7}{GLEAK7 + W_{eff} + L_{eff}} \end{aligned}$$

where

$$E = \frac{V_G - GLEAK3 \times \phi_S(\Delta L)}{T_{ox}} \cdot \left(1 + \frac{E_y}{GLEAK5}\right)$$

$$V_G = V_{gs} - VFBC + GLEAK4 \cdot \Delta V_{th} \cdot L_{eff}$$

$$\Delta V_{th} = \Delta V_{th,SC} + \Delta V_{th,P} + \Delta V_{th,W} + \phi_{Spg}$$

$$I_{gate} = I_{gate,s} + I_{gate,d}$$

$$I_{gate,s} = (1 - P_{artition}) \cdot I_{gate}$$

$$I_{gate,d} = P_{artition} \cdot I_{gate}$$

$$I_{gate,d} = \int_0^{L_{ff}} \frac{y}{L_{eff}} I_{gate}(y) dy = P_{artition} \cdot I_{gate}$$

Between Gate and Bulk, I_{gb}

$$E_{gb} = -\frac{V_{gb} - VFBC + GLKB3}{T_{ox}}$$

$$I_{gb} = GLKB1 \cdot E_{gb}^2 \cdot \exp\left(-\frac{GLKB2}{E_{gb}}\right) W_{eff} \cdot NF \cdot L_{eff}$$

Between Gate and Source/Drain. I_{gs}/I_{gd}

$$I_{gs} = sign \cdot GLKSD1 \cdot E_{gs}^2 \exp(T_{ox}(-GLKSD2 \cdot V_{gs} + GLKSD3)) W_{eff} \cdot NF$$

$$E_{gs} = \frac{V_{gs}}{T_{ox}}$$

$$I_{gd} = sign \cdot GLKSD1 \cdot E_{gd}^2 \exp(T_{ox}(-GLKSD2 \cdot V_{gd} + GLKSD3)) W_{eff} \cdot NF$$

$$E_{gd} = \frac{V_{gs} - V_{lds}}{T_{ox}}$$

Gate-Induced Drain Leakage (GIDL)

HiSIM 2.5

$$I_{GIDL} = q \cdot GIDL1 \cdot \frac{E^2}{E_g^{\frac{1}{2}}} \cdot \exp\left(-GIDL2 \cdot \frac{E_g^{\frac{3}{2}}}{E}\right) \cdot W_{eff} \cdot NF$$

HiSIM 2.5.1

$$I_{GIDL} = q \cdot GIDL1 \cdot \frac{E^2}{E_g^{\frac{1}{2}}} \cdot \exp\left(-GIDL2 \cdot \frac{E_g^{\frac{3}{2}}}{E}\right) \cdot W_{eff} \cdot NF \cdot \frac{V_{db}^3}{V_{db}^3 + small}$$

$$E = \frac{GIDL3 \cdot (V_{ds} + GIDL4) - V_G'}{T_{ox}}$$

$$V_G' = V_{gs} + \Delta V_{th} \cdot GIDL5$$

$$\Delta V_{th} = \Delta V_{th,SC} + \Delta V_{th,P}$$

$$V_{db} = V_{ds} - V_{bs}$$

$$small = 0.5$$

Conservation of Symmetry at Vds=0

HiSIM preserves the symmetry at $V_{ds} = 0$ automatically due to the drift-diffusion approximation. However, modeling of the short-channel effects induces a small asymmetry. To eliminate the asymmetry caused by the artifacts of the modeling, the V_{th} modeling has to include a damping of the short-channel effects as V_{ds} approaches zero. This corresponds to a vanishing of shortchannel effects as V_{ds} gets near to zero, which is actually also observed in 2D simulations. In HiSIM, the damping is done by a mathematical function with two parameters: VZADD0 and PZADD0.

The values of these parameters are fixed, and it is recommended not to change them. Other modeled phenomena, which include a V_{ds} dependence, cause a similar symmetry problem as the short-channel effects. They are therefore also damped.

Source/Bulk and Drain/Bulk Diode Model

Diode Current

The model equations for the source/bulk and drain/bulk diode currents are based on the concepts of BSIM3v3, but include a number of modifications.

These regions are distinguished in the modeling and are treated separately according to their origins.

Between Drain and Bulk

With these current densities and the area parameter AD and the perimeter parameter PD of the drain region, the forward and backward currents between drain and bulk are calculated as

$$I_{sbd} = AD \cdot j_s + PD \cdot J_{ssw}$$

$$I_{sbd2} = AD \cdot j_{s2} + PD \cdot J_{ssw2}$$

Virtuoso Simulator Components and Device Models Reference
HiSIM2 Model (hisim2)

$$T_{tnom} = \frac{T}{TNOM}$$

$$j_s = JS0 \cdot \exp\left\{\frac{E_g(T = TNOM) \cdot \beta(T = TNOM) - E_g \beta + XTI \cdot \log(T_{tnom})}{NJ}\right\}$$

$$j_{ssw} = JS0SW \cdot \exp\left\{\frac{E_g(T = TNOM) \cdot \beta(T = TNOM) - E_g \beta + XTI \cdot \log(T_{tnom})}{NJSW}\right\}$$

$$j_{s2} = JS0 \cdot \exp\left\{\frac{E_g(T = TNOM) \cdot \beta(T = TNOM) - E_g \beta + XTI2 \cdot \log(T_{tnom})}{NJ}\right\}$$

$$j_{ssw2} = JS0SW \cdot \exp\left\{\frac{E_g(T = TNOM) \cdot \beta(T = TNOM) - E_g \beta + XTI2 \cdot \log(T_{tnom})}{NJSW}\right\}$$

$$N_{vtm} = \frac{NJ}{\beta}$$

a) $V_{bd} \geq T1$

$$I_{bd} = I_{sbd} \left\{ \exp\left(\frac{T1}{N_{vtm}}\right) - 1 \right\} + \frac{I_{sbd}}{N_{vtm}} \exp\left(\frac{T1}{N_{vtm}}\right) (V_{bd} - T1)$$

$$+ I_{sbd2} \cdot CISB \left\{ \exp\left(\frac{-V_{bd} CVBK}{N_{vtm}}\right) - 1 \right\} \exp\{(T_{nom} - 1) CTEMP\}$$

$$+ CISBK \left\{ \exp\left(\frac{-V_{bd} CVBK}{N_{vtm}}\right) - 1 \right\}$$

b) $T1 \geq Vbd$

$$\begin{aligned}
 I_{bd} &= I_{sbd} \left\{ \exp\left(\frac{V_{bd}}{N_{vtm}}\right) - 1 \right\} \\
 &+ I_{sbd2} \cdot C_{ISB} \left\{ \exp\left(\frac{-V_{bd} C_{VB}}{N_{vtm}}\right) - 1 \right\} \exp\{(T_{nom} - 1) C_{TEMP}\} \\
 &+ C_{ISBK} \left\{ \exp\left(\frac{-V_{bd} C_{VBK}}{N_{vtm}}\right) - 1 \right\} \\
 T_1 &= N_{vtm} \cdot \log \left\{ \frac{VDIFFJ}{I_{sbd}} \cdot (T_{tnom})^2 + 1 \right\} \\
 I_{bd} &= I_{bd} + DIVX \cdot I_{sbd2} \cdot V_{bd}
 \end{aligned}$$

Between Source and Bulk

The area parameter AS and the perimeter parameter PS of the source region are used to calculate the forward and backward currents between source and bulk.

$$I_{sbs} = AS \cdot j_s + PS + j_{ssw}$$

$$I_{sbs2} = AS \cdot j_{s2} + PS \cdot J_{ssw2}$$

a) $Vbs \geq T2$

$$\begin{aligned}
 I_{bs} &= I_{sbs} \left\{ \exp\left(\frac{T_2}{N_{vtm}}\right) - 1 \right\} + \frac{I_{sbs}}{N_{vtm}} \exp\left(\frac{T_2}{N_{vtm}}\right) (V_{bs} - T_2) \\
 &+ I_{sbs2} \cdot C_{ISB} \left\{ \exp\left(\frac{-V_{bs} C_{VBK}}{N_{vtm}}\right) - 1 \right\} \exp\{(T_{nom} - 1) C_{TEMP}\} \\
 &+ C_{ISBK} \left\{ \exp\left(\frac{-V_{bs} C_{VBK}}{N_{vtm}}\right) - 1 \right\}
 \end{aligned}$$

b) $T_2 \geq V_{bs}$

$$I_{bs} = I_{sbs} \left\{ \exp\left(\frac{V_{bs}}{N_{vtm}}\right) - 1 \right\}$$

$$+ I_{sbs2} \cdot C_{ISB} \left\{ \exp\left(\frac{-V_{bs} C_{VB}}{N_{vtm}}\right) - 1 \right\} \exp\{(T_{nom} - 1) C_{TEMP}\}$$

$$+ C_{ISBK} \left\{ \exp\left(\frac{-V_{bs} C_{VBK}}{N_{vtm}}\right) - 1 \right\}$$

$$T_2 = N_{vtm} \cdot \log \left\{ \frac{VDIFFJ}{I_{sbs}} \cdot (T_{tnom})^2 + 1 \right\}$$

$$I_{bs} = I_{bs} + DIVX \cdot I_{sbs2} \cdot V_{bs}$$

Diode Capacitance

The notations

$\Theta = S$; $\theta = s$ (for source/bulk junction) and

$\Theta = D$; $\theta = d$ (for drain/bulk junction) apply.

$$c_{zb\theta} = CJ \cdot A^\Theta$$

Virtuoso Simulator Components and Device Models Reference
HiSIM2 Model (hisim2)

$P_{\Theta} > W_{eff}$

$$c_{zb\theta sw} = CJSW(P_{\Theta} - W_{eff} \cdot NF)$$

$$C_{zb\theta swg} = CJSWG \cdot W_{eff} \cdot NF$$

(i) $V_{b\theta} = 0$

$$Q_{b\theta} = 0$$

$$C_{apb\theta} = c_{zb\theta} + c_{zb\theta sw} + c_{zb\theta swg}$$

(ii) $V_{b\theta} < 0$

1-1 $C_{zb\theta} > 0$

$$\arg = 1 - \frac{V_{b\theta}}{PB}$$

α) $MJ = 0.5$

$$sarg = \frac{1}{\sqrt{\arg}}$$

β) $MJ \neq 0.5$

$$sarg = \exp(-MJ \cdot \log(\arg))$$

$$Q_{b\theta} = \frac{PB \cdot C_{zb\theta} (1 - \arg \cdot sarg)}{1 - MJ}$$

$$C_{apb\theta} = c_{zb\theta} \cdot sarg$$

1-2 $c_{zb\theta} \leq 0$

$$Q_{b\theta} = 0$$

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

$$C_{apb\theta} = 0$$

$$2) c_{zb\theta_{sw}} > 0$$

$$\text{arg} = 1 - \frac{V_{b\theta}}{PBSW}$$

$$\alpha) MJSW = 0.5$$

$$\text{sarg} = \frac{1}{\sqrt{\text{arg}}}$$

$$\beta) MJSW \neq 0.5$$

$$\text{sarg} = \exp(-MJSW \cdot \log(\text{arg}))$$

$$Q_{b\theta^+} = \frac{PBSW \cdot c_{zb\theta_{sw}} (1 - \text{arg} \cdot \text{sarg})}{1 - MJSW}$$

$$C_{apb\theta} = C_{zb\theta_{sw}} \cdot \text{sarg}$$

$$3) c_{zb\theta_{swg}} > 0$$

$$\text{arg} = 1 - \frac{V_{b\theta}}{PBSWG}$$

$$\alpha) MJSWG = 0.5$$

$$\text{sarg} = \frac{1}{\sqrt{\text{arg}}}$$

$$\beta) MJSWG \neq 0.5$$

$$\text{sarg} = \exp(-MJSWG \cdot \log(\text{arg}))$$

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

$$Q_{b\theta^+} = \frac{PBSWG \cdot c_{zb\theta_{swg}}(1 - \text{arg} \cdot \text{sarg})}{1 - MJSWG}$$

$$C_{apb\theta} = c_{zb\theta_{swg}} \cdot \text{sarg}$$

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

$P_{\Theta} \leq W_{\text{eff}}$

$$c_{zb\theta_{\text{swg}}} = C_{\text{JSWG}} \cdot P_{\Theta}$$

(i) $V_{b\theta} = 0$

$$Q_{b\theta} = 0$$

$$C_{apb\theta} = c_{zb\theta} + c_{zb\theta_{\text{swg}}}$$

(ii) $V_{b\theta} < 0$

1-1 $C_{zb\theta} > 0$

$$\text{arg} = 1 - \frac{V_{b\theta}}{PB}$$

α) $MJ = 0.5$

$$\text{sarg} = \frac{1}{\sqrt{\text{arg}}}$$

β) $MJ \neq 0.5$

$$\text{sarg} = \exp(-MJ \cdot \log(\text{arg}))$$

$$Q_{b\theta} = \frac{PB \cdot c_{zb\theta} (1 - \text{arg} \cdot \text{sarg})}{1 - MJ}$$

$$C_{apb\theta} = c_{zb\theta} \cdot \text{sarg}$$

1-2 $C_{zb\theta} \leq 0$

$$Q_{b\theta} = 0$$

Virtuoso Simulator Components and Device Models Reference
HiSIM2 Model (hisim2)

$$C_{apb\theta} = 0$$

$$c_{zb\theta_{swg}} > 0$$

$$\text{arg} = 1 - \frac{V_{b\theta}}{PBSWG}$$

$$\alpha) MJSWG = 0.5$$

$$\text{sarg} = \frac{1}{\sqrt{\text{arg}}}$$

$$\beta) MJSWG \neq 0.5$$

$$\text{sarg} = \exp(-MJSWG \cdot \log(\text{arg}))$$

$$Q_{b\theta^+} = \frac{PBSWG \cdot c_{zb\theta_{swg}} (1 - \text{arg} \cdot \text{sarg})}{1 - MJSWG}$$

$$C_{apb\theta^+} = c_{zb\theta_{swg}} \cdot \text{sarg}$$

$$(iii) V_{b\theta} > 0$$

$$Q_{b\theta} = V_{b\theta} (c_{zb\theta} + c_{zb\theta_{swg}}) + V_{b\theta}^2 \left(\frac{1}{2} \frac{c_{zb\theta} \cdot MJ}{PB} + \frac{1}{2} \frac{c_{zb\theta_{swg}} \cdot MJSWG}{PBSWG} \right)$$

$$Q_{apb\theta} = c_{zb\theta} + c_{zb\theta_{swg}} + V_{b\theta} \left(\frac{c_{zb\theta} \cdot MJ}{PB} + \frac{c_{zb\theta_{swg}} \cdot MJSWG}{PBSWG} \right)$$

Noise Models

1/f Noise Model

$$fn = \frac{I_{ds}^2 NFTRP}{\beta f^{FALPH} (L_{eff} - \Delta L) W_{eff} \cdot NF}$$

$$\cdot \left[\frac{1}{(N_0 + N^*)(N_L + N^*)} + \frac{2\mu E_y NFALP}{N_L - N_0} 1n \left(\frac{N_L + N^*}{N_0 + N^*} \right) + (\mu E_y NFALP)^2 \right]$$

$$N^* = \frac{C_{ox} - C_{dep} + CIT}{q\beta}$$

$$N_{flick} = fn \cdot f^{FALPH}$$

Thermal Noise Model

$$id = 4kT \frac{W_{eff} \cdot NF \cdot C_{ox} V_g V_t \mu}{(L_{eff} - \Delta L)} \cdot \frac{(1 + 3\eta + 6\eta^2)\mu_d^2 + (3 + 4\eta + 3\eta^2)\mu_d \mu_s + (6 + 3\eta + \eta^2)\mu_s}{15(1 + \eta)\mu_{av}^2}$$

where where μ_s , μ_d and μ_{av} are mobility at the source side, the drain side, and averaged, respectively.

$$\eta = 1 - \frac{(\varphi_{SL} - \varphi_0) + \chi(\varphi_{SL} - \varphi_0)}{V_g V_t}$$

$$\chi = 2 \frac{c_{nst0}}{C_{ox}} \left[\frac{\frac{2}{3} \frac{1}{\beta} \left\{ \beta(\varphi_{SL} - V_{bs}) - 1 \right\}^{\frac{3}{2}} - \left\{ \beta(\varphi_{S0} - V_{bs}) - 1 \right\}^{\frac{3}{2}}}{\varphi_{SL} - V_{bs}} - \sqrt{\beta(\varphi_{S0} - V_{bs}) - 1} \right]$$

$$N_{thrml} = id / (4kT)$$

Shot Noise

HiSIM 2.5

$$shot = 2q \cdot I_{ds}$$

HiSIM 2.5.1

shot noise due to I_{gs}

$$i_{gs} = 2q \cdot I_{gs}$$

shot noise due to I_{gd}

$$i_{gd} = 2q \cdot I_{gd}$$

shot noise due to I_{gb}

$$i_{gb} = 2q \cdot I_{gb}$$

Induced Gate Noise Model

$$N_{igate} = S_{igate}/f^2$$

Non-Quasi-Static (NQS) Model

Carrier Formation

$$q(t_i) = \frac{q(t_{i-1}) + \frac{\Delta t}{\tau} Q(t_i)}{1 + \frac{\Delta t}{\tau}}$$

Delay Mechanism

$$\tau_{diff} = DLY1$$

$$\tau_{cond} = DLY2 \cdot \frac{Q_i}{I_{ds}}$$

$$\frac{1}{\tau} = \frac{1}{\tau_{diff}} + \frac{1}{\tau_{cond}}$$

$$\tau_B = DLY3 \cdot C_{ox}$$

Time-Domain Analysis

The total drain/source/bulk terminal currents are derived from the superposition of the transport current and the charging current. The transport current is a function of the instantaneous terminal voltages and is approximated by the steady-state solution. The source/drain/bulk charging currents are the time derivatives of the associated non-quasi-static charges, q_S , q_D , and q_B , respectively.

AC Analysis

$$\left(i\omega \frac{\partial q_I}{\partial v} + \frac{1}{\tau} \left(\frac{\partial q_I}{\partial v} - \frac{\partial Q_I}{\partial v} \right) \right) \Bigg|_{v=v_0} \cdot V_e^{ist} = 0$$

$$\left(i\omega \frac{\partial q_B}{\partial v} + \frac{1}{\tau} \left(\frac{\partial q_B}{\partial v} - \frac{\partial Q_B}{\partial v} \right) \right) \Bigg|_{v=v_0} \cdot V_e^{ist} = 0$$

where

$$\frac{\partial q_I}{\partial v} = \frac{1}{1 + i\omega\tau} \frac{\partial Q_I}{\partial v}$$

$$\frac{\partial q_B}{\partial v} = \frac{1}{1 + i\omega\tau_B} \frac{\partial Q_B}{\partial v}$$

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

DFM Model

To support design for manufacturability (DFM) HiSIM2 introduces an option for considering the variation of device parameters.

Accurate prediction of device performance for a wide range of the substrate-impurity-concentration variations is secured by introducing an impurity concentration dependent mobility due to the phonon scattering as

$$M_{uephonon} = MUEPH1[MPHDFM\{1n(NSUBCDFM) - 1n(NSUBC)\} + 1]$$
$$NSUBP = NSUBP + (NSUBCDFM - NSUBC)$$
$$NPEXT = NPEXT + (NSUBCDFM - NSUBC)$$

where NSUBCDFM is an instance parameter and MPHDFM is a model parameter describing the mobility reduction as the substrate impurity concentration is increased. This model parameter MPHDFM is required, if the model flag CODFM is switched to one. The default value is sufficient for the most applications. The DFM model is activated, if the instance parameter NSUBCDFM is also given.

Binning Model

Binning option is introduced in HiSIM2.4 to secure enough accuracy of model calculation results, even though the effects observed are not modeled yet. The binning method is the same as that used in BSIM3/4

$$Bin_HiSIM_model_parameter = HiSSIM_model_parameter + \frac{P1}{L_{bin}} + \frac{P2}{W_{bin}} + \frac{P3}{L_{bin}W_{bin}}$$

where P1, P2, and P3 are model parameters for L HiSIM model parameter, W HiSIM model parameter, and L* HiSIM model parameter, respectively and

$$L_{bin} = (L_{gate} \cdot 10^6)^{LBINN}$$
$$W_{bin} = (W_{gate} \cdot 10^6)^{WBINN}$$

Component Statements

This device is supported within altergroups.

Sample Instance Statement

```
m4 (0 2 1 1) nch w=2u l=0.8u as=250p ad=250p pd=168p ps=168p m=2
```

Sample Model Statement

```
model nch hisim2 type=n version=2.50 corsrd=0 conqs=0 cgso=7.43e-10 cgdo=7.43e-10  
cgbo=2.56e-11
```

Instance Definition

```
Name d g s b ModelName parameter=value ...
```

Instance Parameters

1	w (m)	Gate width.
2	l (m)	Gate length.
3	as (m ²)	Area of source junction.
4	ad (m ²)	Area of drain junction.
5	ps (m)	Perimeter of source junction.
6	pd (m)	Perimeter of drain junction.
7	temp (C)	Device temperature.
8	dtemp (C)	Device temperature rise from ambient.
9	nrs=0	Number of squares of source diffusion, default value is 1.0 for version 2.50 and 2.51.
10	nrd=0	Number of squares of drain diffusion, default value is 1.0 for version 2.50 and 2.51.
11	corbnet	Substrate resistance network selector.

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

12	<code>rbpb</code> (Ω)	Substrate resistance network.
13	<code>rbpd</code> (Ω)	Substrate resistance network.
14	<code>rbps</code> (Ω)	Substrate resistance network.
15	<code>rbdb</code> (Ω)	Substrate resistance network.
16	<code>rbsb</code> (Ω)	Substrate resistance network.
17	<code>corg</code>	Gate-contact resistance selector.
18	<code>ngcon=1.0</code>	Number of gate contacts.
19	<code>xgw=0.0 m</code>	Distance from gate contact to channel edge.
20	<code>xgl=0.0 m</code>	Offset of gate length due to variation in patterning.
21	<code>nf=1.0</code>	Number of gate fingers.
22	<code>lod=1.0E-5 m</code>	Length of diffusion between gate and STI.
23	<code>m=1</code>	Multiplicity factor (number of MOSFETs in parallel).
24	<code>sa=0.0 m</code>	Distance from STI edge to Gate edge, existed from 2.40.
25	<code>sb=0.0 m</code>	Distance from STI edge to Gate edge, existed from 2.40.
26	<code>sd=0.0 m</code>	Distance from Gate edge to Gate edge, existed from 2.40.
27	<code>nsubcdfm</code> (cm^{-3})	Constant part of <code>Nsub</code> for DFM, existed from 2.40.
28	<code>mphdfm</code>	NSUBCDFM dependence of phonon scattering for DFM.
29	<code>isnoisy=yes</code>	Should device generate noise. Possible values are <code>no</code> and <code>yes</code> .
30	<code>sca=0.0</code>	WPE <code>sca</code> .
31	<code>scb=0.0</code>	WPE <code>scb</code> .
32	<code>scc=0.0</code>	WPE <code>scc</code> .

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

Model Definition

model modelName hisim2 parameter=value ...

Model Parameters

Device type parameters

- | | | |
|----|---------------|---|
| 1 | type=n | Transistor type.
Possible values are n and p. |
| 2 | version=2.50 | The available versions are 2.50, 2.51, 2.60, 2.61 and 2.70.. |
| 3 | subvers="sc8" | Model sub-version selector. |
| 4 | corsrd=0 | Contact resistances Rs and Rd selector. 0 : no(default). 1 : yes, as internal resistances. -1 : yes, as external resistances. |
| 5 | coiprv=1 | Previous Ids is used for calculating source/drain resistance effect. 0 : no. 1 : yes. |
| 6 | copprv=1 | Previous surface potential is used for the initial guess. 0 : no. 1 : yes. |
| 7 | coadov=1 | Selector for lateral field induced and overlap charges/ capacitances being added to intrinsic ones. 0 : no. 1 : yes(default). |
| 8 | coisub=0 | Substrate current selector. 0 : no(default). 1 : yes. |
| 9 | cogidl=0 | GIDL current calculation selector. 0 : no(default). 1 : yes. |
| 10 | coiigs=0 | Gate current calculation selector. 0 : no(default). 1 : yes. |
| 11 | coovlp=1 | Overlap capacitance calculation selector. 0 : constant overlap capacitance(default). 1 : yes. |
| 12 | coflick=0 | 1/f noise calculation selector. |
| 13 | coisti=0 | STI leakage current calculation selector. 0 : no(default). 1 : yes. |
| 14 | conqs=0 | Non-quasi-static mode selector. 0 : no(default). 1 : yes. |

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

15	<code>cothrml=0</code>	Thermal noise calculation selector. 0 : no(default). 1 : yes.
16	<code>tnom (C)</code>	Parameters measurement temperature. Default set by <code>options</code> .
17	<code>corg=0</code>	Gate-contact resistance calculation selector. 0 : no(default). 1 : yes.
18	<code>corbnet=0</code>	Substrate resistance network selector.
19	<code>coign=0</code>	Induced gate and cross correlation noise calculation selector.
20	<code>compatible</code>	Compatible with spice3, default is spectre compatible. Possible values are <code>spectre</code> , <code>spice2</code> , <code>spice3</code> , <code>cdsspice</code> , <code>hspice</code> , <code>spiceplus</code> , <code>eldo</code> , and <code>sspice</code> .
21	<code>alarm=none</code>	Forbidden operating region. Possible values are <code>none</code> , <code>off</code> , <code>triode</code> , <code>sat</code> , <code>subth</code> , and <code>rev</code> .
22	<code>codfm=0</code>	Calculation of model for DFM selector, existed from 2.40.
23	<code>corecip=1</code>	capacitance reciprocity takes first priority.
24	<code>coqy=0</code>	calculate lateral-field-induced charge/capacitance.

Safe Operating Areas Parameters

25	<code>vds_max=∞ V</code>	Maximum allowed voltage cross source and drain.
26	<code>vgd_max=∞ V</code>	Maximum allowed voltage cross drain and gate.
27	<code>vgs_max=∞ V</code>	Maximum allowed voltage cross source/bulk and gate.
28	<code>vbd_max=∞ V</code>	Maximum allowed voltage cross drain/source and bulk.
29	<code>vbs_max=∞ V</code>	Maximum allowed voltage cross source and bulk.
30	<code>vgb_max=∞ V</code>	Maximum allowed voltage cross gate and bulk.

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

Default for instance parameters

31	$w=5e-6$ m	Default gate width.
32	$l=5e-6$ m	Default gate length.
33	$a_s=0$ m ²	Default area of source junction.
34	$a_d=0$ m ²	Default area of drain junction.
35	$p_s=0$ m	Default perimeter of source junction.
36	$p_d=0$ m	Default perimeter of drain junction.
37	$t_{temp}=27$ C	Default device temperature.
38	$dt_{temp}=0$ C	Default device temperature rise from ambient.

Basic Device Parameters

39	$t_{ox}=3.0e-9$ m	Physical oxide thickness.
40	$x_{ld}=0$ m	Gate-overlap length.
41	$x_{wd}=0$ m	Gate-overlap width.
42	$t_{poly}=2.0E-7$ m	Height of the gate poly-si for fringing capacitance.
43	$n_{subc}=5.0e+17$ cm ⁻³	Substrate-impurity concentration.
44	$n_{subp}=1.0e+18$ cm ⁻³	Maximum pocket concentration.
45	$r_s=0.0$ Ω m	Source contact resistance in LDD region.
46	$r_d=0.0$ Ω m	Drain contact resistance in LDD region.
47	$v_{fbc}=-1.0$ V	Constant part of flat-band voltage.
48	$l_p=1.5e-8$ m	Length of the pocket penetration into the channel.

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

49	$x_{qy}=10e-9$ m	Distance from channel/drain junction to maximum electric field point.
50	$lover=5.0E-8$ m	overlap length.
51	$ll=0.0$	gate length parameter.
52	$lld=0.0$ m	gate length parameter.
53	$lln=0.0$	gate length parameter.
54	$wl=0.0$	gate width parameter.
55	$wld=0.0$ m	gate width parameter.
56	$wln=0.0$	gate width parameter.
57	$vbi=1.0$ V	built-in potential.
58	$nsubpw=0.0$ cm ⁻³	pocket implant parameter.
59	$nsubpwp=1.0$	pocket implant parameter.
60	$lpext=1.0E-50$ m	Pocket extension.
61	$npext=5.0E17$ cm ⁻³	Pocket extension.
62	$rsh=0.0$ V/A m	Source/drain diffusion sheet resistance.
63	$rshg=0.0$ V/A m	Gate-electrode sheet resistance.
64	$rbpb=50.0$ Ω	Substrate resistance network.
65	$rbpd=50.0$ Ω	Substrate resistance network.
66	$rbps=50.0$ Ω	Substrate resistance network.
67	$rbdb=50.0$ Ω	Substrate resistance network.
68	$rbsb=50.0$ Ω	Substrate resistance network.
69	$gbmin=1.0E-12$	Minimum conductance for substrate resistance network.

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

- 70 $x_{l=0}$ m Gate length offset due to mask/etch effect, existed from 2.40.
- 71 $x_{w=0}$ m Gate width offset due to mask/etch effect, existed from 2.40.
- 72 $x_{qy1}=0.0$ F $m^{\{XQY2\}}$
Vbs dependence of Q_y , existed from 2.40.
- 73 $x_{qy2}=2.0$ Lgate dependence of Q_y , existed from 2.40.
- 74 $n_{subp1}=0.001$ μm gate-length dependence of NSUBP.
- 75 $n_{subpfac}=1.0$ gate-length dependence of NSUBP.

Temperature dependence effects

- 76 $eg0=1.1785$ eV constant bandgap.
- 77 $bgtmp1=9.025e-5$ eV/K
First order temperature coefficient for band gap.
- 78 $bgtmp2=1.0e-7$ eV/K²
Second order temperature coefficient for band gap.

Quantum Mechanical Effects

- 79 $qme1=0.0$ m/V² Coefficient for quantum mechanical effect.
- 80 $qme2=0.0$ V Coefficient for quantum mechanical effect.
- 81 $qme3=0.0$ m Coefficient for quantum mechanical effect.
- 82 $kappa=3.9$ dielectric constant for high-k stacked gate.

Poly Depletion Effects

- 83 $pgd1=1.0E-4$ V Strength of poly depletion.
- 84 $pgd2=0.3$ V Threshold voltage of poly depletion.
- 85 $pgd3=0.8$ Vds dependence of poly depletion.

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

86 $pgd4=0.0$ parameter for gate-poly depletion.

Short Channel Effects

87 $par12=1.0e-8$ m Depletion width of channel/contact junction.

88 $sc1=1.0$ $1/V$ Short-channel coefficient 1.

89 $sc2=0.0$ $1/V^2$ Short-channel coefficient 2.

90 $sc2b=0.0$ $1/V^3$ Short-channel coefficient 2 V_b dependency coefficient.

91 $sc3=0.0$ m/V^2 Short-channel coefficient 3.

92 $scp1=1.0$ $1/V$ Short-channel coefficient 1 for pocket.

93 $scp2=0.0$ $1/V^2$ Short-channel coefficient 2 for pocket.

94 $scp3=0.0$ m/V^2 Short-channel coefficient 3 for pocket.

95 $scp22=0.0$ V^4 Short-channel-effect modification for small V_{ds} .

96 $scp21=0.0$ V Short-channel-effect modification for small V_{ds} .

97 $bs1=0.0$ V^2 Body-coefficient modification by impurity profile.

98 $bs2=0.9$ V Body-coefficient modification by impurity profile.

99 $sc4=0.0$ Short-channel coefficient 4.

Narrow channel effects

100 $wfc=0.0$ m F/cm^2 Threshold voltage reduction.

101 $mueph2=0.0$ Mobility reduction.

102 $w0=0.0$ $\log(cm)$ Minimum gate width.

103 $wvthsc=0.0$ Short-channel effect at the STI edge.

104 $nsti=1.0e17$ cm^{-3} Substrate-impurity concentration at the SIT edge.

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

105	<code>wsti=0.0 m</code>	Width of the high-field region at STI.
106	<code>muephw=0.0</code>	phonon scattering parameter.
107	<code>muepwp=1.0</code>	phonon scattering parameter.
108	<code>wvth0=0.0</code>	threshold voltage shift.
109	<code>mueswp=1.0</code>	change of surface roughness related mobility.
110	<code>vthsti=0.0</code>	parameter for STI.
111	<code>muesti1=0.0</code>	STI Stress mobility parameter.
112	<code>muesti2=0.0</code>	STI Stress mobility parameter.
113	<code>muesti3=1.0</code>	STI Stress mobility parameter.
114	<code>nsubpsti1=0.0 m</code>	STI Stress pocket implant parameter.
115	<code>nsubpsti2=0.0 m</code>	STI Stress pocket implant parameter.
116	<code>nsubpsti3=1.0 m</code>	STI Stress pocket implant parameter.
117	<code>wstil=0.0</code>	Parameter for STI.
118	<code>wstilp=1.0</code>	Parameter for STI.
119	<code>scsti1=0.0</code>	Parameter for STI.
120	<code>scsti2=0.0 1/V</code>	Parameter for STI.
121	<code>scsti3=0.0 m/V</code>	Parameter for STI.
122	<code>saref=1e-6 m</code>	Reference distance from STI edge to Gate edge,existed from 2.40.
123	<code>sbref=1e-6 m</code>	Reference distance from STI edge to Gate edge,existed from 2.40.
124	<code>wstiw=0.0</code>	Parameter for STI,existed from 2.40.
125	<code>wstiwp=1.0</code>	Parameter for STI,existed from 2.40.

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

- 126 $vdsti=0.0$ parameter for STI, existed from 2.40.
- 127 $nsubcw=0.0$ Parameter for narrow channel effect.
- 128 $nsubcwp=1.0$ Parameter for narrow channel effect.
- 129 $nsubcmax=5e18$ Parameter for narrow channel effect.

Mobility Effects

- 130 $vds0=0.05$ V Drain voltage for extracting the low-field mobility.
- 131 $muecb0=1000.0$ $cm^2/(V s)$
Coulomb scattering.
- 132 $muecb1=100.0$ $cm^2/(V s)$
Coulomb scattering.
- 133 $mueph0=0.3$ $cm^2 (V/cm)^{(muesr1)} / (V s)$
Phonon scattering.
- 134 $mueph1=2.5e4$ Phonon scattering.
- 135 $muetmp=1.5$ Temperature dependence of phonon scattering.
- 136 $muesr0=2.0$ $cm^2 (V/cm)^{(muesr1)} / (V s)$
Surface-roughness scattering.
- 137 $muesr1=1.0e15$ Surface-roughness scattering.
- 138 $ndep=1.0$ Coefficient of effective electric field.
- 139 $ninv=0.5$ Coefficient of effective electric field.
- 140 $bb=2.0$ High-field mobility degradation.
- 141 $vmax=1.0e7$ cm/s Maximum of electron saturation velocity.
- 142 $vover=0.3$ $cm^{(voverp)}$
Parameter for velocity overshoot.
- 143 $voverp=0.3$ Lgate dependence of velocity overshoot.

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

144	<code>vovers=0.0</code>	Parameter for overshoot.
145	<code>voversp=0.0</code>	Parameter for overshoot.
146	<code>vtmp=0.0</code> cm/s	Temperature dependence of the saturation velocity.
147	<code>muephl=0.0</code>	phonon scattering parameter.
148	<code>mueplp=1.0</code>	phonon scattering parameter.
149	<code>muesrl=0.0</code>	surface roughness parameter.
150	<code>muesrw=0.0</code>	change of surface roughness related mobility.
151	<code>mueslp=1.0</code>	surface roughness parameter.
152	<code>ndepl=0.0</code>	Modification of Qb contribution for short-channel case, existed from 2.40.
153	<code>ndeplp=1.0</code>	Modification of Qb contribution for short-channel case, existed from 2.40.
154	<code>ninvd=0.0</code> 1/V	modification of Vdse dependence on Eeff.

Small size parameters

155	<code>wl1=0.0</code>	Threshold voltage shift of STI leakage due to small size effect.
156	<code>wl1p=1.0</code>	Threshold voltage shift of STI leakage due to small size effect.
157	<code>wl2=0.0</code>	Threshold voltage shift due to small size effect.
158	<code>wl2p=1.0</code>	Threshold voltage shift due to small size effect.
159	<code>muephs=0.0</code>	Mobility modification due to small size.
160	<code>muepsp=1.0</code>	Mobility modification due to small size.
161	<code>muepwd=0.0</code>	phonon scattering parameter.
162	<code>muepld=0.0</code>	phonon scattering parameter.

Channel Length Modulation Effects

163	$c_{lm1}=0.7$	First parameter for CLM.
164	$c_{lm2}=2.0 \text{ 1/m}$	Second parameter for CLM.
165	$c_{lm3}=1.0$	Third parameter for CLM.
166	$c_{lm4}=5.0E-4$	Smoothing coefficient for gds.
167	$c_{lm5}=1.0$	Effect of pocket implantation.
168	$c_{lm6}=0.0$	Effect of pocket implantation.

Substrate Current Effects

169	$sub1=10.0 \text{ 1/V}$	First parameter for I_{sub} .
170	$sub2=25.0 \text{ V}$	Second parameter for I_{sub} .
171	$svgs=0.8$	Substrate current dependence on V_{gs} .
172	$svbs=0.5$	Substrate current dependence on V_{bs} .
173	$svbs1=0.0$	L_{gate} dependence of SVBS.
174	$svds=0.8$	Substrate current dependence on V_{ds} .
175	$slg=3.0E-8$	Substrate current dependence on L_{gate} .
176	$sub11=2.5E-3$	L_{gate} dependence of SUB1.
177	$sub21=2.0E-6$	L_{gate} dependence of SUB2.
178	$fn1=0.0$	Coefficient of Fowler-Nordheim-current contribution.
179	$fn2=0.0$	Coefficient of Fowler-Nordheim-current contribution.
180	$fn3=0.0$	Coefficient of Fowler-Nordheim-current contribution.
181	$fvbs=0.0$	Modification of V_{bs} dependence.
182	$svgs1=0.0$	L_{gate} dependence of SVGS.

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

183	svgs1p=1.0	Lgate dependence of SVGS.
184	svgswp=1.0	Wgate dependence of SVGS.
185	svgsww=0.0	Wgate dependence of SVGS.
186	svbs1p=1.0	Lgate dependence of SVBS.
187	slgl=0.0	Substrate current dependence on Lgate.
188	slglp=1.0	Substrate current dependence on Lgate.
189	sub11p=1.0	Lgate dependence of SUB1.
190	ibpc1=0.0	Impact-ionization induced bulk potential change.
191	ibpc2=0.0	Impact-ionization induced bulk potential change.

Gate Current Effects

192	glpart1=0.5	partitioning of gate current.
193	gleak1=50.0 A/(V ^(3/2) c ^(1/2))	First gate current coefficient.
194	gleak2=1.0E7 1/(V ^(1/2) c ^(3/2) m)	Second gate current coefficient.
195	gleak3=6.0E-2	Third gate current coefficient.
196	gleak4=4.0	parameter for gate current.
197	gleak5=7.5E3	parameter for gate current.
198	glksd1=1.0E-15	parameter for gate current.
199	glksd2=5e-6	parameter for gate current.
200	glksd3=-5e-6	parameter for gate current.
201	glkb0=0.0 V	parameter for gate current.
202	glkb1=5.0E-16	parameter for gate current.

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

203	$g_{lkb2}=1.0$	parameter for gate current.
204	$igtemp1=0.0$	parameter for gate current.
205	$igtemp2=0.0$	parameter for gate current.
206	$igtemp3=0.0$	parameter for gate current.
207	$gleak6=0.25 \text{ V}$	Parameter for gate current.
208	$gleak7=1.0E-6 \text{ m}^2$	Parameter for gate current.
209	$g_{lkb3}=0e0 \text{ V}$	parameter for gate current,existed from 2.40.
210	$egig=1.1 \text{ V}$	parameter for gate current,existed from 2.40.

GIDL Current Effects

211	$gidl1=2.0 \text{ A m} / (\text{V}^{(3/2)} \text{ c}^{(1/2)})$	First parameter for GIDL.
212	$gidl2=3.0E7 \text{ 1} / (\text{V}^{(1/2)} \text{ c}^{(3/2)} \text{ m})$	Second parameter for GIDL.
213	$gidl3=0.9$	Third parameter for GIDL.
214	$gidl4=0.9$	Parameter for GIDL.
215	$gidl5=0.2$	Parameter for GIDL.

Noise 1/f Effects

216	$nfalp=1.0e-19$	Flicker (1/f) noise contribution of the mobility fluctuation.
217	$nftrp=1.0e10$	Flicker (1/f) noise ratio of trap density to attenuation coefficient.
218	$cit=0.0$	Flicker (1/f) noise interface trapped carriers capacitance.
219	$falph=1.0$	parameter for 1/f noise.

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

Subthreshold swing parameters

220 $p_{throub}=0.0$ 1/V modify subthreshold sloop.

NQS parameters

221 $dly1=1.0E-10$ parameter for transit time.

222 $dly2=0.7$ parameter for transit time.

223 $dly3=8.0E-7$ Ω parameter for transforming bulk charge.

Symmetry for short-channel mosfet

224 $vzadd0=20.0e-3$ V V_{zadd} at $V_{ds}=0$.

225 $pzadd0=20.0e-3$ V P_{zadd} at $V_{ds}=0$.

P-N junctions parameters

226 $js0=5.0e-7$ A/m² Junction saturation current density.

227 $js0sw=0.0$ A/m Side-wall saturation current density.

228 $nj=1.0$ Junction emission coefficient.

229 $njsw=1.0$ Junction emission coefficient (sidewall).

230 $x_{ti}=2.0$ Junction saturation current temperature exponent coefficient.

231 $cj=5.0e-4$ F/m² Bottom junction capacitance per unit area at zero bias.

232 $cjsw=5e-10$ F/m Source/drain sidewall junction capacitance per unit length at zero bias.

233 $cjswg=5e-10$ F/m Source/drain sidewall junction capacitance grading coefficient per unit length at zero bias.

234 $mj=0.5$ Bulk junction bottom grading coefficient.

235 $mjsw=0.33$ Source/drain sidewall junction capacitance grading coefficient.

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

236	$mjswg=0.33$	Bottom junction capacitance grading coefficient.
237	$pb=1.0$ V	Bottom junction build-in potential.
238	$pbsw=1.0$ V	Source/drain sidewall junction build-in potential.
239	$pbswg=1.0$ V	Source/drain gate sidewall junction build-in potential.
240	$vdiffj=6.0E-4$ V	threshold voltage for S/D junction diode.
241	$xti2=0.0$	Temperature coefficient.
242	$cisb=0.0$	Reverse bias saturation current.
243	$cvb=0.0$	Bias dependence coefficient of $cisb$.
244	$ctemp=0.0$	Temperature coefficient.
245	$cisbk=0.0$ A	Reverse bias saturation current.
246	$cvbk=0.0$	Bias dependence coefficient of $cisb$.
247	$divx=0.0$ 1/V	Parameter for junction.
248	$tcjbs=0.0$	Temperature dependence of $czbs$.
249	$tcjbd=0.0$	Temperature dependence of $czbd$.
250	$tcjbssw=0.0$	Temperature dependence of $czbssw$.
251	$tcjbdsw=0.0$	Temperature dependence of $czbdsw$.
252	$tcjbsswg=0.0$	Temperature dependence of $czbsswg$.
253	$tcjbdswg=0.0$	Temperature dependence of $czbdswg$.

Overlap capacitance parameters

254	$cgso=0.0$ F/m	Gate-source overlap capacitance.
255	$cgdo=0.0$ F/m	Gate-drain overlap capacitance.
256	$cgbo=0.0$ F/m	Gate-bulk overlap capacitance.

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

257	ovslp=2.1E-7	Parameter for overlap capacitance.
258	ovmag=0.6	Parameter for overlap capacitance.
259	vfbover=0.0 V	Flat-band voltage in overlap region,existed from 2.40.
260	nover=1e19 cm ⁻³	Impurity concentration in overlap region,existed from 2.40.

Smoothing coefficient between linear and saturation

261	ddlmax=10.0	Coefficient of effective electric field,existed from 2.40.
262	ddltslp=0.0	Lgate dependence of smoothing coefficient,existed from 2.40.
263	ddlctic=10.0	Lgate dependence of smoothing coefficient,existed from 2.40.

DFM parameters

264	mphdfm=-0.3	NSUBCDFM dependence of phonon scattering for DFM,existed from 2.40.
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WPE: Well Proximity Effects parameters

265	web=0.0	Modification of layout characterization factor.
266	wec=0.0	Modification of layout characterization factor.
267	nsubcwpe=0.0 cm ⁻³	Channel concentration change due to WPE.
268	npextwpe=0.0 cm ⁻³	Pocket-tail concentration change due to WPE.
269	nsubpwpe=0.0 cm ⁻³	Pocket concentration change due to WPE.

Binning model parameters which are existed from 2.40

270	lbin=1.0	L modulation coefficient for binning.
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Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

271	wbinn=1.0	W modulation coefficient for binning.
272	lvmax=0.0 cm/s	Length dependence of vmax.
273	lbgtmp1=0.0 eV/K	Length dependence of bgtmp1.
274	lbgtmp2=0.0 eV/K ²	Length dependence of bgtmp2.
275	leg0=0.0 eV	Length dependence of eg0.
276	llover=0.0 m	Length dependence of lover.
277	lvfbover=0.0 V	Length dependence of vfbover.
278	lnover=0.0 cm ⁻³	Length dependence of nover.
279	lw12=0.0	Length dependence of w12.
280	lvfbc=0.0 V	Length dependence of vfbc.
281	lnsubc=0.0 cm ⁻³	Length dependence of nsubc.
282	lnsubp=0.0 cm ⁻³	Length dependence of nsubp.
283	lscp1=0.0 1/V	Length dependence of scp1.
284	lscp2=0.0 1/V ²	Length dependence of scp2.
285	lscp3=0.0 m/V ²	Length dependence of scp3.
286	lsc1=0.0 1/V	Length dependence of sc1.
287	lsc2=0.0 1/V ²	Length dependence of sc2.
288	lsc3=0.0 m/V ²	Length dependence of sc3.
289	lpgd1=0.0 V	Length dependence of pgd1.
290	lpgd3=0.0	Length dependence of pgd3.
291	lndep=0.0	Length dependence of ndep.

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

292	lninv=0.0	Length dependence of ninv.
293	lmuecb0=0.0 cm ² /(V s)	Length dependence of muecb0.
294	lmuecb1=0.0 cm ² /(V s)	Length dependence of muecb1.
295	lmueph1=0.0	Length dependence of mueph1.
296	lvtmp=0.0 cm/s	Length dependence of vtmp.
297	lwvth0=0.0	Length dependence of wvth0.
298	lmuesr1=0.0	Length dependence of muesr1.
299	lmuetmp=0.0	Length dependence of muetmp.
300	lsub1=0.0 1/V	Length dependence of sub1.
301	lsub2=0.0 V	Length dependence of sub2.
302	lsvds=0.0	Length dependence of svds.
303	lsvbs=0.0	Length dependence of svbs.
304	lsvgs=0.0	Length dependence of svgs.
305	lfn1=0.0	Length dependence of fn1.
306	lfn2=0.0	Length dependence of fn2.
307	lfn3=0.0	Length dependence of fn3.
308	lfvbs=0.0	Length dependence of fvbs.
309	lnsti=0.0 cm ⁻³	Length dependence of nsti.
310	lwsti=0.0 m	Length dependence of wsti.
311	lscsti1=0.0	Length dependence of scsti1.
312	lscsti2=0.0 1/V	Length dependence of scsti2.

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

313	$lvthsti=0.0$	Length dependence of $vthsti$.
314	$lmuesti1=0.0$	Length dependence of $muesti1$.
315	$lmuesti2=0.0$	Length dependence of $muesti2$.
316	$lmuesti3=0.0$	Length dependence of $muesti3$.
317	$lnsubpsti1=0.0$ m	Length dependence of $nsubpsti1$.
318	$lnsubpsti2=0.0$ m	Length dependence of $nsubpsti2$.
319	$lnsubpsti3=0.0$ m	Length dependence of $nsubpsti3$.
320	$lcgso=0.0$ F/m	Length dependence of $cgso$.
321	$lcgdo=0.0$ F/m	Length dependence of $cgdo$.
322	$ljs0=0.0$ A/m ²	Length dependence of $js0$.
323	$ljs0sw=0.0$ A/m	Length dependence of $js0sw$.
324	$lnj=0.0$	Length dependence of nj .
325	$lcisbk=0.0$ A	Length dependence of $cisbk$.
326	$lclm1=0.0$	Length dependence of $clm1$.
327	$lclm2=0.0$ 1/m	Length dependence of $clm2$.
328	$lclm3=0.0$	Length dependence of $clm3$.
329	$lwfc=0.0$ m F/cm ²	Length dependence of wfc .
330	$lgidl1=0.0$ A m / ($V^{(3/2)} c^{(1/2)}$)	Length dependence of $gidl1$.
331	$lgidl2=0.0$ 1 / ($V^{(1/2)} c^{(3/2)}$ m)	Length dependence of $gidl2$.
332	$lgleak1=0.0$ A / ($V^{(3/2)} c^{(1/2)}$)	Length dependence of $gleak1$.

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

333	$lg_{leak2}=0.0 \text{ 1/(V}^{(1/2)} \text{ c}^{(3/2)} \text{ m)}$	Length dependence of g_{leak2} .
334	$lg_{leak3}=0.0$	Length dependence of g_{leak3} .
335	$lg_{leak6}=0.0 \text{ V}$	Length dependence of g_{leak6} .
336	$lg_{lksd1}=0.0$	Length dependence of g_{lksd1} .
337	$lg_{lksd2}=0.0$	Length dependence of g_{lksd2} .
338	$lg_{lkb1}=0.0$	Length dependence of g_{lkb1} .
339	$lg_{lkb2}=0.0$	Length dependence of g_{lkb2} .
340	$lnf_{trp}=0.0$	Length dependence of n_{ftrp} .
341	$lnf_{alp}=0.0$	Length dependence of n_{falp} .
342	$lv_{diffj}=0.0 \text{ V}$	Length dependence of v_{diffj} .
343	$libpc1=0.0$	Length dependence of $ibpc1$.
344	$libpc2=0.0$	Length dependence of $ibpc2$.
345	$lsc4=0.0$	Length dependence of $sc4$.
346	$w_{vmax}=0.0 \text{ cm/s}$	Width dependence of v_{max} .
347	$w_{bgtmp1}=0.0 \text{ eV/K}$	Width dependence of $bgtmp1$.
348	$w_{bgtmp2}=0.0 \text{ eV/K}^2$	Width dependence of $bgtmp2$.
349	$w_{eg0}=0.0 \text{ eV}$	Width dependence of $eg0$.
350	$w_{lover}=0.0 \text{ m}$	Width dependence of $lover$.
351	$w_{vfbover}=0.0 \text{ V}$	Width dependence of $vfbover$.
352	$w_{nover}=0.0 \text{ cm}^{-3}$	Width dependence of $nover$.
353	$wwl2=0.0$	Width dependence of $wl2$.

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

354	$wvfb=0.0 \text{ V}$	Width dependence of vfb.
355	$wsubc=0.0 \text{ cm}^{-3}$	Width dependence of nsubc.
356	$wsubp=0.0 \text{ cm}^{-3}$	Width dependence of nsubp.
357	$wscp1=0.0 \text{ 1/V}$	Width dependence of scp1.
358	$wscp2=0.0 \text{ 1/V}^2$	Width dependence of scp2.
359	$wscp3=0.0 \text{ m/V}^2$	Width dependence of scp3.
360	$wsc1=0.0 \text{ 1/V}$	Width dependence of sc1.
361	$wsc2=0.0 \text{ 1/V}^2$	Width dependence of sc2.
362	$wsc3=0.0 \text{ m/V}^2$	Width dependence of sc3.
363	$wpgd1=0.0 \text{ V}$	Width dependence of pgd1.
364	$wpgd3=0.0$	Width dependence of pgd3.
365	$wndep=0.0$	Width dependence of ndep.
366	$wninv=0.0$	Width dependence of ninv.
367	$wmuecb0=0.0 \text{ cm}^2/(\text{V s})$	Width dependence of muecb0.
368	$wmuecb1=0.0 \text{ cm}^2/(\text{V s})$	Width dependence of muecb1.
369	$wmueph1=0.0$	Width dependence of mueph1.
370	$wvtmp=0.0 \text{ cm/s}$	Width dependence of vtmp.
371	$wvth0=0.0$	Width dependence of wvth0.
372	$wmuesr1=0.0$	Width dependence of muesr1.
373	$wmuetmp=0.0$	Width dependence of muetmp.
374	$wsub1=0.0 \text{ 1/V}$	Width dependence of sub1.

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HiSIM2 Model (hisim2)

375	$w_{sub2}=0.0$	V	Width dependence of sub2.
376	$w_{svds}=0.0$		Width dependence of svds.
377	$w_{svbs}=0.0$		Width dependence of svbs.
378	$w_{svgs}=0.0$		Width dependence of svgs.
379	$w_{fn1}=0.0$		Width dependence of fn1.
380	$w_{fn2}=0.0$		Width dependence of fn2.
381	$w_{fn3}=0.0$		Width dependence of fn3.
382	$w_{fvbs}=0.0$		Width dependence of fvbs.
383	$w_{nsti}=0.0$	cm^{-3}	Width dependence of nsti.
384	$w_{wsti}=0.0$	m	Width dependence of wsti.
385	$w_{scsti1}=0.0$		Width dependence of scsti1.
386	$w_{scsti2}=0.0$	1/V	Width dependence of scsti2.
387	$w_{vthsti}=0.0$		Width dependence of vthsti.
388	$w_{muesti1}=0.0$		Width dependence of muesti1.
389	$w_{muesti2}=0.0$		Width dependence of muesti2.
390	$w_{muesti3}=0.0$		Width dependence of muesti3.
391	$w_{nsubpsti1}=0.0$	m	Width dependence of nsubpsti1.
392	$w_{nsubpsti2}=0.0$	m	Width dependence of nsubpsti2.
393	$w_{nsubpsti3}=0.0$	m	Width dependence of nsubpsti3.
394	$w_{cgso}=0.0$	F/m	Width dependence of cgso.
395	$w_{cgdo}=0.0$	F/m	Width dependence of cgdo.
396	$w_{js0}=0.0$	A/m^2	Width dependence of js0.

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

397	$w_{js0sw}=0.0$	A/m	Width dependence of js0sw.
398	$w_{nj}=0.0$		Width dependence of nj.
399	$w_{cisbk}=0.0$	A	Width dependence of cisbk.
400	$w_{clm1}=0.0$		Width dependence of clm1.
401	$w_{clm2}=0.0$	1/m	Width dependence of clm2.
402	$w_{clm3}=0.0$		Width dependence of clm3.
403	$w_{wfc}=0.0$	m F/cm ²	Width dependence of wfc.
404	$w_{gidl1}=0.0$	A m / (V ^(3/2) c ^(1/2))	Width dependence of gidl1.
405	$w_{gidl2}=0.0$	1 / (V ^(1/2) c ^(3/2) m)	Width dependence of gidl2.
406	$w_{gleak1}=0.0$	A / (V ^(3/2) c ^(1/2))	Width dependence of leak1.
407	$w_{gleak2}=0.0$	1 / (V ^(1/2) c ^(3/2) m)	Width dependence of leak2.
408	$w_{gleak3}=0.0$		Width dependence of leak3.
409	$w_{gleak6}=0.0$	V	Width dependence of leak6.
410	$w_{glksd1}=0.0$		Width dependence of glksd1.
411	$w_{glksd2}=0.0$		Width dependence of glksd2.
412	$w_{glkb1}=0.0$		Width dependence of glkb1.
413	$w_{glkb2}=0.0$		Width dependence of glkb2.
414	$w_{nftrp}=0.0$		Width dependence of nftrp.
415	$w_{nfalp}=0.0$		Width dependence of nfalp.
416	$w_{vdifffj}=0.0$	V	Width dependence of vdiffj.

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

417	wibpc1=0.0	Width dependence of ibpc1.
418	wibpc2=0.0	Width dependence of ibpc2.
419	wsc4=0.0	Width dependence of sc4.
420	pvmax=0.0 cm/s	Cross-term dependence of vmax.
421	pbgtmp1=0.0 eV/K	Cross-term dependence of bgtmp1.
422	pbgtmp2=0.0 eV/K ²	Cross-term dependence of bgtmp2.
423	peg0=0.0 eV	Cross-term dependence of eg0.
424	plover=0.0 m	Cross-term dependence of lover.
425	pvfbover=0.0 V	Cross-term dependence of vfbover.
426	pnover=0.0 cm ⁻³	Cross-term dependence of nover.
427	pwl2=0.0	Cross-term dependence of wl2.
428	pvfbc=0.0 V	Cross-term dependence of vfbc.
429	pnsupbc=0.0 cm ⁻³	Cross-term dependence of nsupbc.
430	pnsupbp=0.0 cm ⁻³	Cross-term dependence of nsupbp.
431	pscp1=0.0 1/V	Cross-term dependence of scp1.
432	pscp2=0.0 1/V ²	Cross-term dependence of scp2.
433	pscp3=0.0 m/V ²	Cross-term dependence of scp3.
434	psc1=0.0 1/V	Cross-term dependence of sc1.
435	psc2=0.0 1/V ²	Cross-term dependence of sc2.
436	psc3=0.0 m/V ²	Cross-term dependence of sc3.
437	ppgd1=0.0 V	Cross-term dependence of pgd1.

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

438	ppgd3=0.0	Cross-term dependence of pgd3.
439	pndep=0.0	Cross-term dependence of ndep.
440	pninv=0.0	Cross-term dependence of ninv.
441	pmuecb0=0.0 $\text{cm}^2/(\text{V s})$	Cross-term dependence of muecb0.
442	pmuecb1=0.0 $\text{cm}^2/(\text{V s})$	Cross-term dependence of muecb1.
443	pmueph1=0.0	Cross-term dependence of mueph1.
444	pvtmp=0.0 cm/s	Cross-term dependence of vtmp.
445	pwvth0=0.0	Cross-term dependence of wvth0.
446	pmuesr1=0.0	Cross-term dependence of muesr1.
447	pmuetmp=0.0	Cross-term dependence of muetmp.
448	psub1=0.0 $1/\text{V}$	Cross-term dependence of sub1.
449	psub2=0.0 V	Cross-term dependence of sub2.
450	psvds=0.0	Cross-term dependence of svds.
451	psvbs=0.0	Cross-term dependence of svbs.
452	psvgs=0.0	Cross-term dependence of svgs.
453	pfn1=0.0	Cross-term dependence of fn1.
454	pfn2=0.0	Cross-term dependence of fn2.
455	pfn3=0.0	Cross-term dependence of fn3.
456	pfvbs=0.0	Cross-term dependence of fvbs.
457	pnsti=0.0 cm^{-3}	Cross-term dependence of nsti.
458	pwsti=0.0 m	Cross-term dependence of wsti.

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

459	<code>pscsti1=0.0</code>		Cross-term dependence of <code>scsti1</code> .
460	<code>pscsti2=0.0</code>	$1/V$	Cross-term dependence of <code>scsti2</code> .
461	<code>pvthsti=0.0</code>		Cross-term dependence of <code>vthsti</code> .
462	<code>pmuesti1=0.0</code>		Cross-term dependence of <code>muesti1</code> .
463	<code>pmuesti2=0.0</code>		Cross-term dependence of <code>muesti2</code> .
464	<code>pmuesti3=0.0</code>		Cross-term dependence of <code>muesti3</code> .
465	<code>pnsubpsti1=0.0</code>	m	Cross-term dependence of <code>nsubpsti1</code> .
466	<code>pnsubpsti2=0.0</code>	m	Cross-term dependence of <code>nsubpsti2</code> .
467	<code>pnsubpsti3=0.0</code>	m	Cross-term dependence of <code>nsubpsti3</code> .
468	<code>pcgso=0.0</code>	F/m	Cross-term dependence of <code>cgso</code> .
469	<code>pcgdo=0.0</code>	F/m	Cross-term dependence of <code>cgdo</code> .
470	<code>pjs0=0.0</code>	A/m^2	Cross-term dependence of <code>js0</code> .
471	<code>pjs0sw=0.0</code>	A/m	Cross-term dependence of <code>js0sw</code> .
472	<code>pnj=0.0</code>		Cross-term dependence of <code>nj</code> .
473	<code>pcisbk=0.0</code>	A	Cross-term dependence of <code>cisbk</code> .
474	<code>pclm1=0.0</code>		Cross-term dependence of <code>clm1</code> .
475	<code>pclm2=0.0</code>	$1/m$	Cross-term dependence of <code>clm2</code> .
476	<code>pclm3=0.0</code>		Cross-term dependence of <code>clm3</code> .
477	<code>pwfc=0.0</code>	$m F/cm^2$	Cross-term dependence of <code>wfc</code> .
478	<code>pgidl1=0.0</code>	$A m / (V^{(3/2)} c^{(1/2)})$	Cross-term dependence of <code>gidl1</code> .
479	<code>pgidl2=0.0</code>	$1 / (V^{(1/2)} c^{(3/2)} m)$	Cross-term dependence of <code>gidl2</code> .

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

480	$\text{pgleak1}=0.0 \text{ A}/(\text{V}^{(3/2)} \text{ c}^{(1/2)})$	Cross-term dependence of gleak1.
481	$\text{pgleak2}=0.0 \text{ 1}/(\text{V}^{(1/2)} \text{ c}^{(3/2)} \text{ m})$	Cross-term dependence of gleak2.
482	$\text{pgleak3}=0.0$	Cross-term dependence of gleak3.
483	$\text{pgleak6}=0.0 \text{ V}$	Cross-term dependence of gleak6.
484	$\text{pglksd1}=0.0$	Cross-term dependence of glksd1.
485	$\text{pglksd2}=0.0$	Cross-term dependence of glksd2.
486	$\text{pglkb1}=0.0$	Cross-term dependence of glkb1.
487	$\text{pglkb2}=0.0$	Cross-term dependence of glkb2.
488	$\text{pnftrp}=0.0$	Cross-term dependence of nftrp.
489	$\text{pnfalp}=0.0$	Cross-term dependence of nfalp.
490	$\text{pvdifffj}=0.0 \text{ V}$	Cross-term dependence of vdiffj.
491	$\text{pibpc1}=0.0$	Cross-term dependence of ibpc1.
492	$\text{pibpc2}=0.0$	Cross-term dependence of ibpc2.
493	$\text{psc4}=0.0$	Cross-term dependence of sc4.
494	$\text{vgsmin}=-5 \text{ type V}$	minimal/maximal expected Vgs (NMOS/PMOS).
495	$\text{sc3vbs}=0.0 \text{ V}$	Vbs value for clamping sc3.
496	$\text{muecb0lp}=0.0$	L dependence of MUECB0.
497	$\text{muecb1lp}=0.0$	L dependence of MUECB1.
498	$\text{coqovsm}=1$	select smoothing method of Qover.
499	$\text{ndepw}=0.0$	coeff. of Qbm for Eeff.

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

500	$n_{depwp}=1.0$	coeff. of Q_{bm} for E_{eff} .
501	$n_{pextw}=0.0$	
502	$n_{pextwp}=0.0$	
503	$minr=0.001 \Omega$	Minimum source/drain resistance.

Auto Model Selector parameters

504	$w_{max}=1 \text{ m}$	Maximum channel width for which the model is valid.
505	$w_{min}=0 \text{ m}$	Minimum channel width for which the model is valid.
506	$l_{max}=1 \text{ m}$	Maximum channel length for which the model is valid.
507	$l_{min}=0 \text{ m}$	Minimum channel length for which the model is valid.
508	$n_{subcsti1}=0.0 \text{ m}$	STI Stress Parameter for N_{subc} [-].
509	$n_{subcsti2}=0.0 \text{ m}$	STI Stress Parameter for N_{subc} [-].
510	$n_{subcsti3}=1.0 \text{ m}$	STI Stress Parameter for N_{subc} [-].
511	$gidl6=0$	parameter for GIDL [-].
512	$gidl7=1$	parameter for GIDL [-].
513	$ln_{subcsti1}=0.0 \text{ m}$	Length dependence of $n_{subcsti1}$.
514	$ln_{subcsti2}=0.0 \text{ m}$	Length dependence of $n_{subcsti2}$.
515	$ln_{subcsti3}=0.0 \text{ m}$	Length dependence of $n_{subcsti3}$.
516	$wn_{subcsti1}=0.0 \text{ m}$	Wength dependence of $n_{subcsti1}$.
517	$wn_{subcsti2}=0.0 \text{ m}$	Wength dependence of $n_{subcsti2}$.
518	$wn_{subcsti3}=0.0 \text{ m}$	Wength dependence of $n_{subcsti3}$.
519	$pn_{subcsti1}=0.0 \text{ m}$	Cross-term dependence of $n_{subcsti1}$.
520	$pn_{subcsti2}=0.0 \text{ m}$	Cross-term dependence of $n_{subcsti2}$.

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HiSIM2 Model (hisim2)

521	<code>pnsbcti3=0.0</code>	m	Cross-term dependence of <code>nsubcti3</code> .
522	<code>nsubpdlr=0.01</code>		Delta for <code>nsubp</code> smoothing [-].
523	<code>vfbcl=0.0</code>		gate-length dependence of VFBC [μm].
524	<code>vfbclp=1.0</code>		gate-length dependence of VFBC [-].
525	<code>coerrrep=1</code>		selector for error report.

Output Parameters

1	<code>tempeff</code>	(C)	Effective temperature for a single device.
2	<code>weff</code>	(m)	Effective channel width.
3	<code>leff</code>	(m)	Effective channel length.
4	<code>rseff</code>	(Ω)	Effective source resistance.
5	<code>rdeff</code>	(Ω)	Effective drain resistance.

Operating-Point Parameters

1	<code>reversed</code>		Reverse mode indicator. Possible values are <code>no</code> and <code>yes</code> .
2	<code>ids</code>	(A)	Resistive drain-to-source current.
3	<code>vgs</code>	(V)	Gate-source voltage.
4	<code>vds</code>	(V)	Drain-source voltage.
5	<code>vbs</code>	(V)	Bulk-source voltage.
6	<code>vth</code>	(V)	Threshold voltage.
7	<code>vdsat</code>	(V)	Drain-source saturation voltage.
8	<code>gm</code>	(S)	Common-source transconductance.
9	<code>gds</code>	(S)	Common-source output conductance.

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

10	gmbs (S)	Body-transconductance.
11	qb (Coul)	Total bulk charge.
12	qd (Coul)	Total drain charge.
13	qg (Coul)	Total gate charge.
14	qs (Coul)	Total source charge.
15	cjd (F)	Drain-bulk junction capacitance.
16	cjs (F)	Source-bulk junction capacitance.
17	cgg (F)	dQg_dVg .
18	cgd (F)	dQg_dVd .
19	cgs (F)	dQg_dVs .
20	cgb (F)	dQg_dVb .
21	cdg (F)	dQd_dVg .
22	cd d (F)	dQd_dVd .
23	cds (F)	dQd_dVs .
24	cdb (F)	dQd_dVb .
25	csg (F)	dQs_dVg .
26	csd (F)	dQs_dVd .
27	css (F)	dQs_dVs .
28	csb (F)	dQs_dVb .
29	cbg (F)	dQb_dVg .
30	cbd (F)	dQb_dVd .
31	cbs (F)	dQb_dVs .

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

32	cbb (F)	dQb_dVb.
33	id (A)	Resistive drain current.
34	ig (A)	Gate current.
35	is (A)	Resistive source current.
36	ibulk (A)	Resistive bulk current.
37	pwr (W)	Power at operating point.
38	ps0 (V)	Surface potential at source side.
39	ps1 (V)	Surface potential at drain side.
40	pds (V)	Delta surface potential between ps1 and ps0.
41	isub (A)	Substrate current Isub.
42	gbds (S)	Substrate trans conductance (dIsub/dVds).
43	gbgs (S)	Substrate trans conductance (dIsub/dVgs).
44	gbbs (S)	Substrate transconductance (dIsub/dVbs).
45	igate (A)	Gate current due to tunneling.
46	igates (A)	Tunneling current from gate to source.
47	igateb (A)	Tunneling current from gate to bulk.
48	igated (A)	Tunneling current from gate to drain.
49	igisl (A)	Gate-induced source leakage current.
50	igidl (A)	Gate-induced drain leakage current.
51	ibs (A)	Source-bulk diode current.
52	ibd (A)	Source-drain diode current.
53	cgso (F)	Gate-source overlap capacitance.

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HiSIM2 Model (hisim2)

- 54 `cgbo` (F) Gate-bulk overlap capacitance.
- 55 `cgdo` (F) Gate-drain overlap capacitance.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

<code>ad</code>	I-4	<code>lfn2</code>	M-305	<code>pcgso</code>	M-467	<code>tcjbdsw</code>	M-250
<code>ad</code>	M-33	<code>lfn3</code>	M-306	<code>pcisbk</code>	M-472	<code>tcjbdswg</code>	M-252
<code>alarm</code>	M-20	<code>lfvbs</code>	M-307	<code>pclm1</code>	M-473	<code>tcjbs</code>	M-247
<code>as</code>	I-3	<code>lgidl1</code>	M-329	<code>pclm2</code>	M-474	<code>tcjbssw</code>	M-249
<code>as</code>	M-32	<code>lgidl2</code>	M-330	<code>pclm3</code>	M-475	<code>tcjbsswg</code>	M-251
<code>bb</code>	M-139	<code>lgleak1</code>	M-331	<code>pd</code>	I-6	<code>temp</code>	I-7
<code>bgtmp1</code>	M-76	<code>lgleak2</code>	M-332	<code>pd</code>	M-35	<code>temp</code>	M-36
<code>bgtmp2</code>	M-77	<code>lgleak3</code>	M-333	<code>pds</code>	OP-40	<code>tnom</code>	M-16
<code>bs1</code>	M-96	<code>lgleak6</code>	M-334	<code>peg0</code>	M-422	<code>tox</code>	M-38
<code>bs2</code>	M-97	<code>lglkb1</code>	M-337	<code>pfn1</code>	M-452	<code>tpoly</code>	M-41
<code>cbb</code>	OP-32	<code>lglkb2</code>	M-338	<code>pfn2</code>	M-453	<code>type</code>	M-1
<code>cbd</code>	OP-30	<code>lglksd1</code>	M-335	<code>pfn3</code>	M-454	<code>vbd_max</code>	M-27
<code>cbg</code>	OP-29	<code>lglksd2</code>	M-336	<code>pfvbs</code>	M-455	<code>vbi</code>	M-56
<code>cbs</code>	OP-31	<code>libpc1</code>	M-342	<code>pgd1</code>	M-82	<code>vbs</code>	OP-5
<code>cdb</code>	OP-24	<code>libpc2</code>	M-343	<code>pgd2</code>	M-83	<code>vbs_max</code>	M-28

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cdd	OP-22	ljs0	M-321	pgd3	M-84	vdiffj	M-239
cdg	OP-21	ljs0sw	M-322	pgd4	M-85	vds	OP-4
cds	OP-23	ll	M-50	pgidl1	M-477	vds0	M-129
cgb	OP-20	lld	M-51	pgidl2	M-478	vds_max	M-24
cgbo	M-255	lln	M-52	pgleak1	M-479	vdsat	OP-7
cgbo	OP-54	llover	M-275	pgleak2	M-480	vdsti	M-125
cgd	OP-18	lmax	M-505	pgleak3	M-481	version	M-2
cgdo	M-254	lmin	M-506	pgleak6	M-482	vfbc	M-46
cgdo	OP-55	lmuecb0	M-292	pglkb1	M-485	vfbover	M-258
cgg	OP-17	lmuecb1	M-293	pglkb2	M-486	vgb_max	M-29
cgs	OP-19	lmueph1	M-294	pglksd1	M-483	vgd_max	M-25
cgso	M-253	lmuesr1	M-297	pglksd2	M-484	vgs	OP-3
cgso	OP-53	lmuesti1	M-313	pibpc1	M-490	vgs_max	M-26
cisb	M-241	lmuesti2	M-314	pibpc2	M-491	vgsmin	M-493
cisbk	M-244	lmuesti3	M-315	pjs0	M-469	vmax	M-140
cit	M-217	lmuetmp	M-298	pjs0sw	M-470	vover	M-141
cj	M-230	lndep	M-290	plover	M-423	voverp	M-142
cjd	OP-15	lnfalp	M-340	pmuecb0	M-440	vovers	M-143
cjs	OP-16	lnftrp	M-339	pmuecb1	M-441	voversp	M-144
cjsw	M-231	lninv	M-291	pmueph1	M-442	vth	OP-6
cjswg	M-232	lnj	M-323	pmuesr1	M-445	vthsti	M-109

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HiSIM2 Model (hisim2)

clm1	M-162	lnover	M-277	pmuesti1	M-461	vtmp	M-145
clm2	M-163	lnsti	M-308	pmuesti2	M-462	vzadd0	M-223
clm3	M-164	lnsubc	M-280	pmuesti3	M-463	w	I-1
clm4	M-165	lnsubp	M-281	pmuetmp	M-446	w	M-30
clm5	M-166	lnsubpstil	M-316	pndep	M-438	w0	M-101
clm6	M-167	lnsubpsti2	M-317	pnfalp	M-488	wbgtmp1	M-346
coadov	M-7	lnsubpsti3	M-318	pnftrp	M-487	wbgtmp2	M-347
codfm	M-21	lod	I-22	pninv	M-439	wbinn	M-270
coflick	M-12	lover	M-49	pnj	M-471	wcgdo	M-394
cogidl	M-9	lp	M-47	pnover	M-425	wcgso	M-393
coign	M-19	lpext	M-59	pnsti	M-456	wcisbk	M-398
coiigs	M-10	lpgd1	M-288	pnsbc	M-428	wclm1	M-399
coiprv	M-5	lpgd3	M-289	pnsbpc	M-429	wclm2	M-400
coisti	M-13	lsc1	M-285	pnsbpcsti1	M-464	wclm3	M-401
coisub	M-8	lsc2	M-286	pnsbpcsti2	M-465	web	M-264
conqs	M-14	lsc3	M-287	pnsbpcsti3	M-466	wec	M-265
coovlp	M-11	lsc4	M-344	ppgd1	M-436	weff	O-1
copprv	M-6	lscp1	M-282	ppgd3	M-437	weg0	M-348
coqovsm	M-497	lscp2	M-283	ps	I-5	wfc	M-99
coqy	M-23	lscp3	M-284	ps	M-34	wfn1	M-378
corbnet	I-11	lscsti1	M-310	ps0	OP-38	wfn2	M-379

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HiSIM2 Model (hisim2)

corbnet M-18	lscsti2 M-311	psc1 M-433	wfn3 M-380
corecip M-22	lsub1 M-299	psc2 M-434	wfvbs M-381
corg I-17	lsub2 M-300	psc3 M-435	wgidl1 M-403
corg M-17	lsvbs M-302	psc4 M-492	wgidl2 M-404
corsrd M-4	lsvds M-301	pscp1 M-430	wgleak1 M-405
cothrml M-15	lsvgs M-303	pscp2 M-431	wgleak2 M-406
csb OP-28	lvdiffj M-341	pscp3 M-432	wgleak3 M-407
csd OP-26	lvfbc M-279	pscsti1 M-458	wgleak6 M-408
csg OP-25	lvfbover M-276	pscsti2 M-459	wglkb1 M-411
css OP-27	lvmax M-271	psl OP-39	wglkb2 M-412
ctemp M-243	lvthsti M-312	psub1 M-447	wglksd1 M-409
cvb M-242	lvtmp M-295	psub2 M-448	wglksd2 M-410
cvbk M-245	lwfc M-328	psvbs M-450	wibpc1 M-416
ddltict M-262	lw12 M-278	psvds M-449	wibpc2 M-417
ddltmax M-260	lwsti M-309	psvgs M-451	wjs0 M-395
ddltslp M-261	lvwth0 M-296	pthroub M-219	wjs0sw M-396
divx M-246	m I-23	pvdifffj M-489	w1 M-53
dly1 M-220	minr M-502	pvfbc M-427	w11 M-154
dly2 M-221	mj M-233	pvfbover M-424	w11p M-155
dly3 M-222	mjsw M-234	pvmx M-419	w12 M-156
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dtemp	M-37	mphdfm	I-28	pvtmp	M-443	wld	M-54
eg0	M-75	mphdfm	M-263	pwfc	M-476	wln	M-55
egig	M-209	muecb0	M-130	pw12	M-426	wlover	M-349
falph	M-218	muecb0lp	M-495	pwr	OP-37	wmax	M-503
fn1	M-177	muecb1	M-131	pwsti	M-457	wmin	M-504
fn2	M-178	muecb1lp	M-496	pwvth0	M-444	wmuecb0	M-366
fn3	M-179	mueph0	M-132	pzadd0	M-224	wmuecb1	M-367
fvbs	M-180	mueph1	M-133	qj	OP-11	wmueph1	M-368
gbbs	OP-44	mueph2	M-100	qd	OP-12	wmuesr1	M-371
gbds	OP-42	mueph1	M-146	qg	OP-13	wmuesti1	M-387
gbgs	OP-43	muephs	M-158	qme1	M-78	wmuesti2	M-388
gbmin	M-68	muephw	M-105	qme2	M-79	wmuesti3	M-389
gds	OP-9	muepld	M-161	qme3	M-80	wmuetmp	M-372
gidl1	M-210	mueplp	M-147	qs	OP-14	wndep	M-364
gidl2	M-211	muepsp	M-159	rddb	I-15	wnfalp	M-414
gidl3	M-212	muepwd	M-160	rddb	M-66	wnftrp	M-413
gidl4	M-213	muepwp	M-106	rbpb	I-12	wninv	M-365
gidl5	M-214	mueslp	M-150	rbpb	M-63	wnj	M-397
gleak1	M-192	muesr0	M-135	rbpd	I-13	wnover	M-351
gleak2	M-193	muesr1	M-136	rbpd	M-64	wnsti	M-382
gleak3	M-194	muesr1	M-148	rbps	I-14	wnsubc	M-354

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gleak4	M-195	muesrw	M-149	rbps	M-65	wnsubp	M-355
gleak5	M-196	muesti1	M-110	rbsb	I-16	wnsubpsti1	M-390
gleak6	M-206	muesti2	M-111	rbsb	M-67	wnsubpsti2	M-391
gleak7	M-207	muesti3	M-112	rd	M-45	wnsubpsti3	M-392
glkb0	M-200	mueswp	M-108	rdeff	O-4	wpgd1	M-362
glkb1	M-201	muetmp	M-134	reversed	OP-1	wpgd3	M-363
glkb2	M-202	ndep	M-137	rs	M-44	wsc1	M-359
glkb3	M-208	ndep1	M-151	rseff	O-3	wsc2	M-360
glksd1	M-197	ndeplp	M-152	rsh	M-61	wsc3	M-361
glksd2	M-198	ndepw	M-498	rshg	M-62	wsc4	M-418
glksd3	M-199	ndepwp	M-499	sa	I-24	wscp1	M-356
glpart1	M-191	nf	I-21	saref	M-121	wscp2	M-357
gm	OP-8	nfalp	M-215	sb	I-25	wscp3	M-358
gmbs	OP-10	nftrp	M-216	sbref	M-122	wscsti1	M-384
ibd	OP-52	ngcon	I-18	sc1	M-87	wscsti2	M-385
ibpc1	M-189	ninv	M-138	sc2	M-88	wsti	M-104
ibpc2	M-190	ninvd	M-153	sc2b	M-89	wstil	M-116
ibs	OP-51	nj	M-227	sc3	M-90	wstilp	M-117
ibulk	OP-36	njsw	M-228	sc3vbs	M-494	wstiw	M-123
id	OP-33	nover	M-259	sc4	M-98	wstiwip	M-124
ids	OP-2	npext	M-60	sca	I-30	wsub1	M-373

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HiSIM2 Model (hisim2)

ig	OP-34	npextw	M-500	scb	I-31	wsub2	M-374
igate	OP-45	npextwp	M-501	scc	I-32	wsvbs	M-376
igateb	OP-47	npextwpe	M-267	scp1	M-91	wsvds	M-375
igated	OP-48	nrd	I-10	scp2	M-92	wsvgs	M-377
igates	OP-46	nrs	I-9	scp21	M-95	wvdiffj	M-415
igidl	OP-50	nsti	M-103	scp22	M-94	wvfbc	M-353
igisl	OP-49	nsubc	M-42	scp3	M-93	wvfbover	M-350
igtemp1	M-203	nsubcdfm	I-27	scsti1	M-118	wvmax	M-345
igtemp2	M-204	nsubcmax	M-128	scsti2	M-119	wvth0	M-107
igtemp3	M-205	nsubcw	M-126	scsti3	M-120	wvthsc	M-102
is	OP-35	nsubcwp	M-127	sd	I-26	wvthsti	M-386
isnoisy	I-29	nsubcwpe	M-266	slg	M-174	wvtmp	M-369
isub	OP-41	nsubp	M-43	slgl	M-186	wwfc	M-402
js0	M-225	nsubpfac	M-74	slglp	M-187	wwl2	M-352
js0sw	M-226	nsubpl	M-73	sub1	M-168	wwsti	M-383
kappa	M-81	nsubpsti1	M-113	sub11	M-175	wwvth0	M-370
l	I-2	nsubpsti2	M-114	sub1lp	M-188	xgl	I-20
l	M-31	nsubpsti3	M-115	sub2	M-169	xgw	I-19
lbgtmp1	M-272	nsubpw	M-57	sub21	M-176	xl	M-69
lbgtmp2	M-273	nsubpwp	M-58	subvers	M-3	xld	M-39
lbinn	M-269	nsubpwpe	M-268	svbs	M-171	xqy	M-48

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HiSIM2 Model (hisim2)

lcgdo	M-320	ovmag	M-257	svbsl	M-172	xqy1	M-71
lcgso	M-319	ovslp	M-256	svbslp	M-185	xqy2	M-72
lcisbk	M-324	parl2	M-86	svds	M-173	xti	M-229
lclm1	M-325	pb	M-236	svgs	M-170	xti2	M-240
lclm2	M-326	pbgtmp1	M-420	svgs1	M-181	xw	M-70
lclm3	M-327	pbgtmp2	M-421	svgs1p	M-182	xwd	M-40
leff	O-2	pbsw	M-237	svgs	M-184		
leg0	M-274	pbswg	M-238	svgswp	M-183		
lfn1	M-304	pcgdo	M-468	tcjbd	M-248		

HISIM_HV Model (hisim_hv)

HiSIM_HV is an extension of HiSIM model that is a surface potential based MOSFET model. HiSIM_HV added high voltage device specific feature, like drift region resistance, etc. It can be used to model both laterally diffused MOS (LDMOS) and high voltage MOS (HVMOS) types of device structures. HiSIM_HV is elected as CMC's standard high voltage device model. The latest model version is HiSIM_HV 2.10.

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- [Model Version and Development](#) on page 2447
- [Version Update and Enhancement](#) on page 2449
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Virtuoso Simulator Components and Device Models Reference

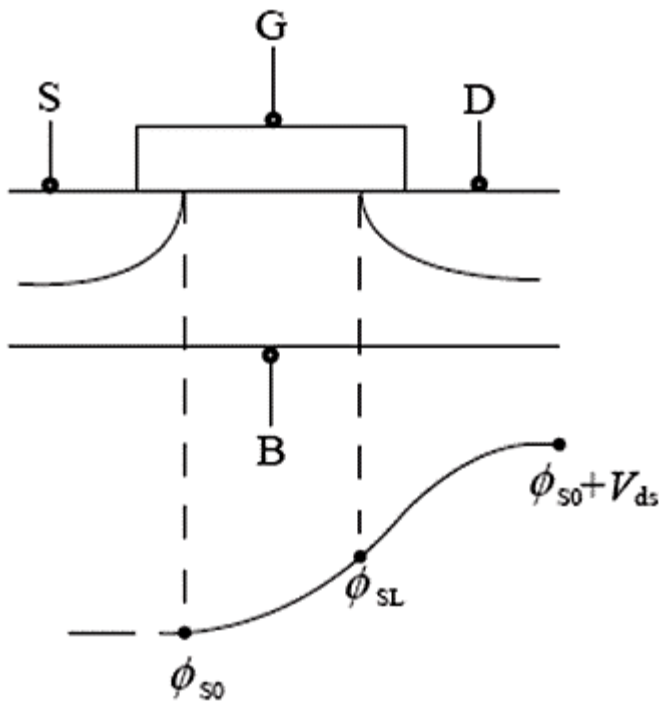
HISIM_HV Model (hisim_hv)

- [Model Equations](#) on page 2455
- [Component Statements](#) on page 2472

Model Concepts

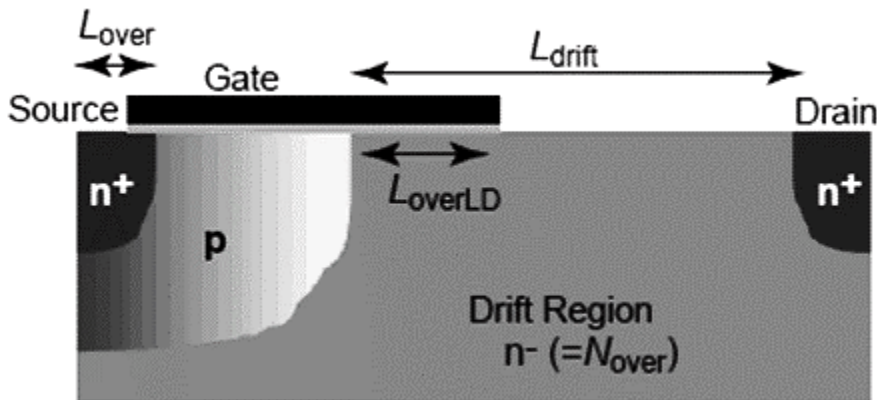
HiSIM (Hiroshima-university STARC IGFET Model) is the first complete surface-potential-based MOSFET model for circuit simulation based on the drift-diffusion theory, which was originally developed by Pao and Sah. The most important advantage of the surface-potential-based modeling is the unified description of device characteristics for all bias conditions. The physical reliability of the drift-diffusion theory has been proved by 2D device simulations with channel lengths even down to below 0.1 μm .

Figure 31-1 Schematic of the surface potential distribution in the channel



The most important feature of LDMOS/HVMOS devices, different from the conventional MOSFET, is that the drift region is introduced to achieve the sustainable high voltages. By varying the length as well as the dopant concentration of the drift region, various devices with various operating bias conditions are realized as shown in Fig. 31-2 or the LDMOS structure. In any cases, the drift region affects as the resistance for the current flow and also induces additional charge, which causes the especially unique features of the LDMOS capacitances. Thus accurate modeling of the drift region is the main task of HiSIM_HV.

Figure 31-2 Schematic of the typical LDMOS structure and device parameters



For the LDMOS/HVMOS device the iterative solution is only one possible solution to model the specific features of this device accurately, because the resistance effect in the drift region is dependent on the bias condition as well as the geometrical structure. The basic modeling method is taken over from the HiSIM2 model, and additional equations for capturing the drift-region effects are included. Since the overlap length is relatively long for LDMOS/HVMOS, accurate surface potential calculation for the overlap region is also necessary for accurate prediction of the high-voltage MOS capacitances.

For the LDMOS/HVMOS device the iterative solution is only one possible solution to model the specific features of this device accurately, because the resistance effect in the drift region is dependent on the bias condition as well as the geometrical structure. The basic modeling method is taken over from the HiSIM2 model, and additional equations for capturing the drift-region effects are included. Since the overlap length is relatively long for LDMOS/HVMOS, accurate surface potential calculation for the overlap region is also necessary for accurate prediction of the high-voltage MOS capacitances.

Three types of devices structure can be modeled since HiSIM_HV version 1.2.0 and 1.1.1: Asymmetrical LDMOS, Symmetrical HV-MOS and Asymmetrical HV-MOS. Model parameter **COSYM** determines the devices symmetry and L_{drift} , the overlap length L_{over} , as well as the impurity concentration of the drift region N_{over} determine the characteristics of respectively side. In the LDMOS case independent structures at the source side and the drain side are distinguished, and the L_{drift} region is not introduced at the source side. In the HVMOS case, the parameter values for the drain side have to be determined, and are copied to the source side automatically. If parameters for the source side are determined explicitly, these values are taken. If parameters are not determined, values at the drain side are taken. If the parameter values are not determined, default values are taken. This is valid for any structural cases. Fig. 31-3 shows three different devices structures and table 31-1 shows the model parameters used by different structures.

Figure 31-3 Three different devices structure and related model parameters

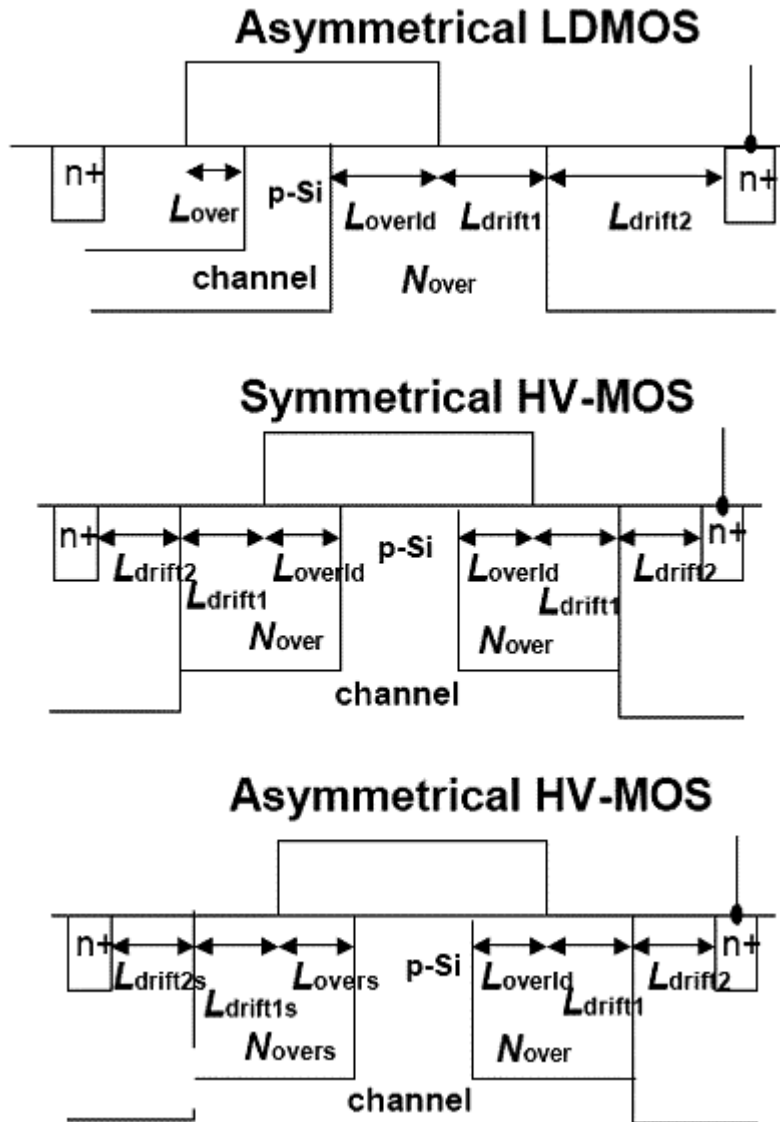


Table 31-1 The different model parameters used by different structures

	Structure	Source	Drain
COSYM=0	LDMOS	LOVERS	LOVERLD LDRIFT1 LDRIFT2 NOVER
COSYM=1	Symmetrical HVMOS		LOVERLD LDRIFT1 LDRIFT2 NOVER
COSYM=1	Asymmetrical HVMOS	LOVERS LDRIFT1S LDRIFT2S NOVERS	LOVERLD LDRIFT1 LDRIFT2 NOVER

Model Usage

HiSIM_HV model definition is used to describe the behavior of devices which has same model characteristics and the instance parameters can be used to describe the characteristics that belong to the specific device.

Instance Syntax

HiSIM_HV instance need specify at least 4 terminals and up to 6 terminals can be supplied. If the 5th terminal is given and **COSUBNODE=0**, it is used as external self-heating node and the self-heating information can be obtained with it when the self-heating effect is activated. If 5th terminal is not given and the self-heating effect is activated, another internal self-heating node is created and used to save related information. If the 5th terminal is given and **COSUBNODE=1**, it is used as substrate node and the self-heating information will be saved with internal node when **COSELFHEAT=1**. If 6 nodes are specified, the 5th node is substrate node and the 6th node is thermal node. To specify HiSIM_HV instance element, the ModelName has to be associated with a HiSIM_HV model card.

```
InstanceName d g s b [sub|th][th] ModelName parameter=value ...
```

Sample Instance Statement

```
m4 (d g s b) nch w=2u l=0.8u as=250p ad=250p pd=168p ps=168p m=2
```

Model Syntax

The following syntax specifies HiSIM_HV model:

```
model ModelName hisim_hv parameter=value ...
```

The third parameter, “hisim_hv”, is the master to indicate this model card is a HiSIM_HV model card.

Sample Model Statement

```
model nch hisim_hv type=n version=2.10 corsrd=3 rs=2.0e-3 rd=1.0e-3 rdtemp1=1e-4  
xldld=0
```

Model Version and Development

Cadence Virtuoso[®] Spectre and Ultrasim support all HiSIM_HV versions with different simulator versions. Version control takes effect with all MMSIM versions starting with MMSIM711. Different model versions are supported by different MMSIM releases. For example, MMSIM72 supports version 1.11, 1.12, 1.20, and 1.21, MMSIM101, MMSIM 111, MMSIM121, and MMSIM 131 support version 1.11, 1.12, 1.20, 1.21, 1.22, 1.23, 1.24, 2.00, 2.01, and 2.10. The latest model version is 2.10. Different model versions can be obtained by setting different model parameter VERSION = 1.11/1.12/1.20/1.21/1.22/1.23/1.24/2.00/2.01/2.10. If no version is set in the model card, the latest version is used by different versions of simulator. For example, 2.10 is used by MMSIM131 and 1.21 is used by MMSIM72.

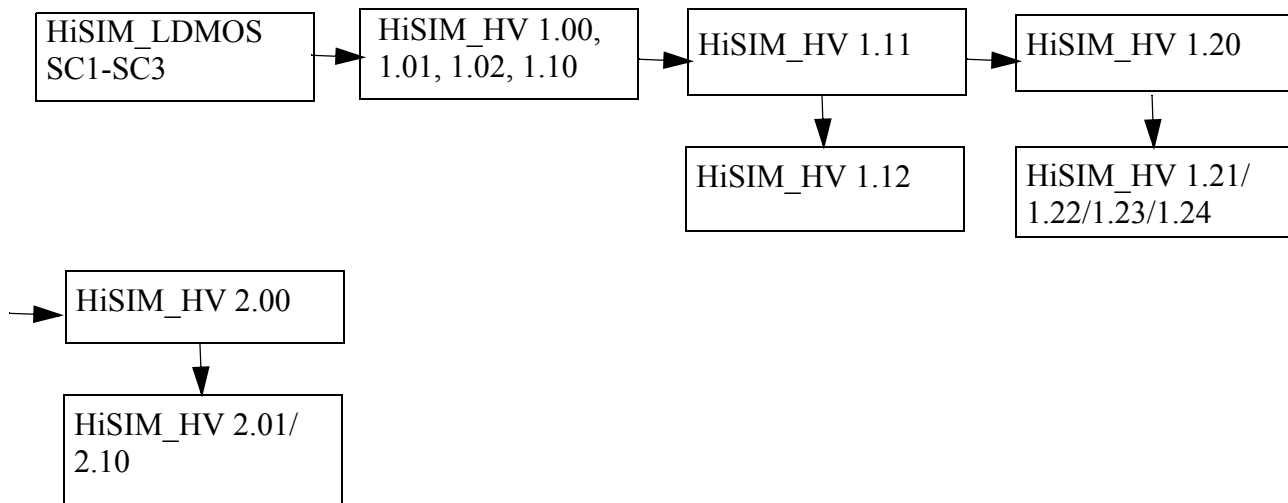
There are some known issues in the old model versions 1.11 and 1.12. These issues have been resolved in versions 1.2X and 2.XX. Therefore, starting with the MMSIM 121 ISR12 release, the old versions 1.11 and 1.12 have been retired. However, you can use the `enable_pre_ver=yes` option to activate these versions.

The following figure shows the model version and development flow for the HiSIM_HV model.

Virtuoso Simulator Components and Device Models Reference

HiSIM_HV Model (hisim_hv)

Figure 31-4 HiSIM_HV Model Version and Development Flow



Following lists the model versions and their corresponding simulator version for your reference:

HiSIM_LDMOS SC3	MMSIM 7.0
HiSIM_HV 1.00 (LDMOS SC4)	MMSIM 7.0 ISR
HiSIM_HV 1.02	MMSIM 7.1
HiSIM_HV 1.11/1.12	MMSIM 7.1.1
HiSIM_HV 1.11/1.12/1.20/1.21	MMSIM 7.2ISR
HiSIM_HV 1.11/1.12/1.20/1.21/1.22	MMSIM 10.1ISR
HiSIM_HV 1.11/1.12/1.20/1.21/1.22/2.00 beta version	MMSIM 10.1ISR14
HiSIM_HV 1.11/1.12/1.20/1.21/1.22/2.00 final version	MMSIM 10.1ISR17
HiSIM_HV 1.11/1.12/1.20/1.21/1.22/2.00 default	MMSIM 10.1ISR20
HiSIM_HV 1.11/1.12/1.20/1.21/1.22/2.00/ 2.01	MMSIM 11.1 ISR9
HiSIM_HV 1.11/1.12/1.20/1.21/1.22/1.23/ 2.00/2.01	MMSIM 11.1 ISR10

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

HiSIM_HV 1.11/1.12/1.20/1.21/1.22/1.23/
2.00/2.01/2.10 MMSIM 12.1 ISR8

HiSIM_HV 1.11/1.12/1.20/1.21/1.22/1.23/
1.24/2.00/2.01/2.10 MMSIM 12.1 ISR12

HiSIM_HV 1.11/1.12/1.20/1.21/1.22/1.23/
1.24/2.00/2.01/2.10 MMSIM 13.1

For any questions, please contact the Cadence support team.

Version Update and Enhancement

Version 1.24 Enhancement

The 1.24 version of HiSIM_HV contains the following bug fixes:

- Incorrect referencing to total W instead of W per finger
- Derivative calculations with respect to the temperature

Version 2.10 Enhancement

The 2.10 version of HiSIM_HV contains the following enhancements and bug fixes:

- Degradation of mobility in the drift region with new model parameter RDRBB.
- Additional overlap capacitance with new model parameter QOVADD.
- Improved smoothness of drift resistance at $V_{ds}=0$.
- Changed default/min/max values of model parameters NOVER, NOVERS, SCP1, SC1, FN1, NSTI, RDRMAX, RDRQOVER, QME1 and QME2 in the source code.
- Changed range check method for model parameter VBFC.
- Bug fixes done for:
 - Range check of CGSO, CGDO, CGBO, NSUBCDFM, SUB2L, and SSC4.
 - Calculation of derivatives
 - Temperature dependence of the output parameter VOH for the threshold voltage
 - NF dependence of RD, RDVD, RD23, and RTH

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

- ❑ Calculation of the temperature derivatives
- ❑ Temperature dependence of the output parameter V_{th}
- ❑ Calculation of the output parameter V_{dsat}

Version 2.01 Enhancement

Version 2.01 is a bug fix version of 2.00 and includes the following bug fixes and enhancements:

- Reference voltage ($V_{bs} \rightarrow V_{bse}$) in the Q_{over} model is used when model parameter $CVDSOVER \neq 0$
- Derivative calculations with respect to temperature
- Derivative calculations in the Q_{over} model code.
- Floating point exception in the QME model code
- Floating point exception in the smoothing functions
- Floating point exception when model parameters $RDVDL \ll 0$ and $RD23L \ll 0$
- Floating point exception when model flag/parameters $COSUBNODE \neq 0$, $COSYM=0$, and $NOVER * (NSUBSUB+NOVER) = 0$
- Floating point exception when model flag $CORDRIFT=1$ and model parameter $RDRDJUNC = 0$
- Derivative calculations when model parameter $COSUBNODE = 1$

Version 1.23 Enhancement

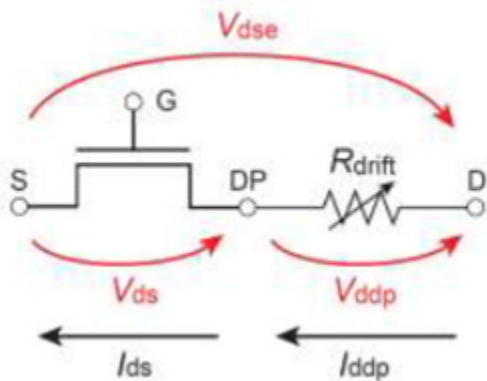
Version 1.23 is a bug fix version of 1.22, which includes the same bug fixes and enhancement as version 2.01 compared with version 2.00.

Version 2.00 Enhancement

Based on version 1.22, following enhancements are done in version 2.00:

New Rdrift Model

A new Rdrift model has been introduced in version 2.00. A flag `CORDIFT` (default= 1) has been introduced to control the evaluation of R_{drift} . The R_{drift} depends on V_{ddp} as well as the V_g in the new version. The mechanism of R_{drift} is shown as following figure:

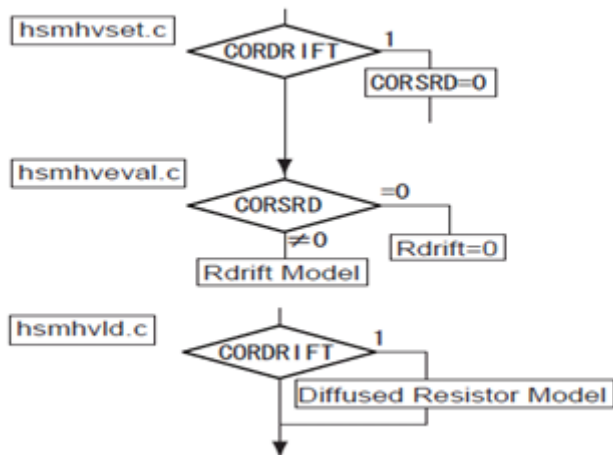


$$I_{ds} = f(V_{ds}, V_{gs}, V_{bs})$$

$$I_{ddp} = f(V_{ddp}) = \frac{V_{ddp}}{R_{drift}}$$

$$R_{drift} = f(V_{ddp}, V_{gse})$$

The usage of the flag is shown in the following figure:



When `CORDIFT`=1 (default value), R_{drift} is re-evaluated, otherwise, the old evaluation of R_{drift} is used.

Fitting Improvements

Smoothing of C_{gg} with new model parameter `VGSMIN`.

Asymmetrical Diode Model

Introduction of new model parameters for source/drain independently.

Change of Model Descriptions

- Introduction of new impact-ionization description in drift region with new model parameters `XPDV`, `XPVDH`, and `XPVDHG`
- Improvement of the impact-ionization model in channel of core MOSFET with new model parameters `IBPC1L`, `IBPC1LP`, `SUBLDL`, and `SUBLDLP`
- Independent fitting capability for C-V and I-V characteristics by selectively using model parameters `LOVERLD` and `XLDDL`
- Introduction of new punch-through model for core MOSFET
- Improvement of quantum effect model for core MOSFET
- Improvement of gate-poly depletion model for core MOSFET
- Introduction of the channel leakage conductance with new model parameter `DSLEAK`
- Removing of the following model parameters `PGD3`, `PTHROU`, `RD26`, and `QOVSM`
- Resetting of parameter values to within the defined ranges for the following critical model parameters: `VFBC`, `XLDDL`, `SCP22`, and `RDRCX`

Fixed Bugs

Following bugs are fixed in version 2.00:

- Derivative calculation of drain current with respect to the temperature
- Inaccurate capacitance reciprocity when model parameter `CVDSOVER` is not equal to 0
- Incorrect recognition of the fifth terminal connected to ground (0) when `COSUBNODE=0` is chosen
- Derivative calculation in self-heating model

Version 1.22 Enhancement

Based on version 1.21, following enhancements have been made in version 1.22:

1. The default value of `RDSL1` changed to 1.0

2. Qover model is enhanced

Version 1.12 Enhancement

Based on version 1.11, much enhancement is done and some bugs are fixed, thus version 1.12 is presented. The difference from version 1.11 to 1.12 consists of two parts: 1) the bug fix that had been included by version 1.20, please refer to session 32.5.5 for the details; 2) the enhancement from version 1.20 to 1.21.

Version 1.21 Enhancement

Based on version 1.20, enhancement is done with the overlap charge and capacitance evaluation, thus latest version 1.21 comes into being to include the change. Following lists the enhancement:

1. Improvements in the lateral-field-induced charge (Qy) model
2. Improvements in the overlap capacitance (Qover) model

New options are provided to calculate Qover. These options are selected by new model parameter COQOVSM:

COQOVSM=0: Qover is calculated with an analytical equation excluding the inversion charge

COQOVSM=1: Qover is calculated with an iterative procedure including the inversion charge (Default)

COQOVSM=2: Qover is calculated with an analytical equation including the inversion charge

Version 1.20 Enhancement

Update information of HiSIM_HV 1.2.0 from HiSIM_HV 1.1.1.

Inclusion of LDMOS-device Structures with a Substrate Node Vsub

HiSIM_HV 1.2.0 additionally covers device structures with a substrate node V_{sub} . The substrate node bias $V_{sub,s}$ increases the depletion width W_{dep} at the drift/substrate (NSUBSUB) junction. The W_{dep} extension into the drift region causes a reduction of the effective drift depth (DDRIFT), and thus an increase of the sheet resistance.

Activate 5th and 6th Terminal

With the latest HiSIM_HV 1.20 model, up to 6 terminals are supported.

- If 5 nodes are specified and COSUBNODE=0, the 5th node is thermal node.
- If 5 nodes are specified and COSUBNODE=1, the 5th node is substrate node, if COSELFHEAT=1 is set too, internal thermal node is created.
- If 6 nodes are specified, the 5th node is substrate node and the 6th node is thermal node.

COSUBNODE is a new instance parameter at the same time recognized as a model parameter for the specification and the recognition of the node order.

Model and Instance Parameters Changes

Following new model parameters are added:

- XWDL: Increase of the effective device width in the drift region due to 2D spreading.
- XWDC: Different effective device width for capacitances.
- NINVDW and NINVDWP: Vds dependence in the low-field-mobility width dependence.
- VMAXT1 and VMAXT2: Temperature dependence of Vmax.
- NINVDT1 and NINVDT2: Temperature dependence in the low-field-mobility Vds dependence.
- RTHTEMP1 and RTHTEMP2: Temperature dependence of the self-heating effect.
- PRATTEMP1 and PRATTEMP1: Temperature dependence of the thermal dissipation.
- COTEMP: The model flag to select different temperature effects of rd, rs, rdvd, rsvd, vmax and ninvd.
- COLDRIFT: The flag to select different Ldrift.
- Following binning option are added for following model parameters: NPEXT FALPH RD RS RD22 RD23 RD24 RDVG11 RDICT1 RDOV13 RDSLP1 RDVB RDVD RTH0 VOVER CGBO CVDSOVER POWRAT
- COSUBNODE: The model and instance flag for substrate node.
- COSELFHEAT: The flag was model parameter with the older version model. New instance flag is added with version 1.20

Flag for Temperature Dependent Model Selection

In the HiSIM_HV 1.1.1 versions, temperature dependence of the drift resistance RDVD includes no self-heating effect, whereas RD includes the effect. To treat all temperature dependent models (RD, RDVD, VMAX, NINVD) after users convenience, the flag COTEMP is introduced. Following is the selection of COTEMP:

COTEMP	RD (RS)	RDVD (RSVD)	Vmax	Ninvd
0	T	T0	T0	T0
1	T0	T0	T0	T0
2	T	T	T	T
3	T	T	T0	T0

where T is $T_0 + \delta T$, and δT is the temperature increase due to the self-heating effect.

The Older Version Bug Fix

Following bugs are fixed with the latest 1.20 and the older 1.11 version.

- NF in Diode model
- Ra discontinuity at $V_{ds}=0$
- Rs temperature dependency
- Smoothing function in overlap capacitance model
- Other minor bugs

Reference

Model Equations

Some important model equations are listed as following for your reference:

Charge

All device characteristics are determined on the basis of the charge controlled by applied voltages and by expressing the MOSFET charges as functions of the surface potentials. Under the charge-sheet approximation the charges on the four MOSFET terminals Q_G (gate), Q_B (bulk), Q_D (drain), and Q_S (source), are described for the symmetrical the source/drain contacts as:

$$Q_G = -(Q_B + Q_I)$$

$$Q_B = W_{\text{eff}} \int_0^{L_{\text{eff}}} Q_b(y) dy$$

$$Q_I = W_{\text{eff}} \int_0^{L_{\text{eff}}} Q_i(y) dy$$

$$Q_D = W_{\text{eff}} \int_0^{L_{\text{eff}}} \frac{y}{L_{\text{eff}}} Q_i(y) dy$$

$$Q_S = Q_I - Q_D$$

where Q_B and Q_I are the depletion charge and the inversion charge, respectively, and y is the position along the channel. L_{eff} and 0 are the channel-end positions at the drain side and the source side, respectively.

Drain Current

The drift-diffusion theory describes the drain current I_{ds} as:

$$I_{ds} = W_{\text{eff}} \cdot NF \cdot q \cdot \mu \cdot n(y) \cdot \left(-\frac{d\phi_s(y)}{dy} + \frac{1}{\beta} \cdot \frac{d \ln n(y)}{dy} \right)$$

where $n(y)$ is the carrier density calculated from the relationship

$$Q_i(y) = q \cdot n(y)$$

Under the gradual-channel approximation with further approximations of an idealized gate structure and uniform channel doping, the final equation for I_{ds} is written:

$$I_{ds} = \frac{W_{eff} \cdot NF}{L_{eff}} \cdot \mu \cdot \frac{I_{dd}}{\beta}$$

$$I_{dd} = C_{ox} (\beta V_G' + 1) (\phi_{SL} - \phi_{SO}) - \frac{\beta}{2} C_{ox} (\phi_{SL}^2 - \phi_{SO}^2)$$

$$- \frac{2}{3} const0 \left[\{\beta (\phi_{SL} - V_{bs}) - 1\}^{\frac{3}{2}} - \{\beta (\phi_{SO} - V_{bs}) - 1\}^{\frac{3}{2}} \right]$$

$$+ const0 \left[\{\beta (\phi_{SL} - V_{bs}) - 1\}^{\frac{1}{2}} - \{\beta (\phi_{SO} - V_{bs}) - 1\}^{\frac{1}{2}} \right]$$

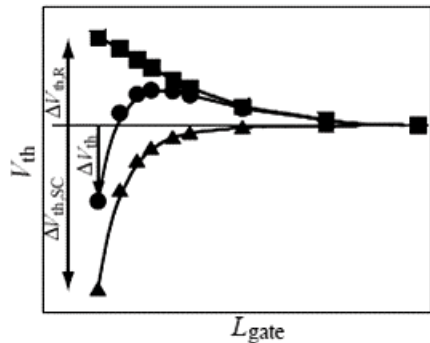
Threshold Voltage Shift

Different with convtional bsim model, all HiSIM_HV can be determined by oxide thickness T_{ox} and the substrate doping concentration **NSUBC**. The measured V_{th} is influenced by various phenomena such as the short-channel effects, which cause a reduction of V_{th} for short-channel transistors in comparison to long-channel transistors as shown in Figure 31-5. This so-called V_{th} roll-off is very much dependent on the technology applied for MOSFET fabrication. Therefore, HiSIM can derive many detailed information on the MOSFET fabrication technology, which are relevant for modeling device characteristics, from the V_{th} changes (ΔV_{th}) as a function of gate length (L_{gate}). The modeled V_{th} is incorporated in the ϕ S iteration can be viewed as consisting of two main effects or components:

- (I) the short-channel effect: $\Delta V_{th, SC}$
- (II) the reverse-short-channel effect: $\Delta V_{th, R}$ and $\Delta V_{th, P}$

The separation into these two components ($\Delta V_{th} = \Delta V_{th, SC} + \Delta V_{th, R}$ (or $\Delta V_{th, P}$)) is schematically shown in Figure 31-5.

Figure 31-5 Schematic plot of the separation of V_{th} into the contributions of the short-channel and the reverse short-channel effect.



Mobility Model

The low-field mobility is described with the following expressions and includes the three independent mechanisms of Coulomb, phonon and surface-roughness scattering:

$$\frac{1}{\mu_0} = \frac{1}{\mu_{CB}} + \frac{1}{\mu_{PH}} + \frac{1}{\mu_{SR}}$$

$$\mu_{CB}(\text{Coulomb}) = MUECB0 + MURCB1 \cdot \frac{Q_i}{q \times 10^{11}}$$

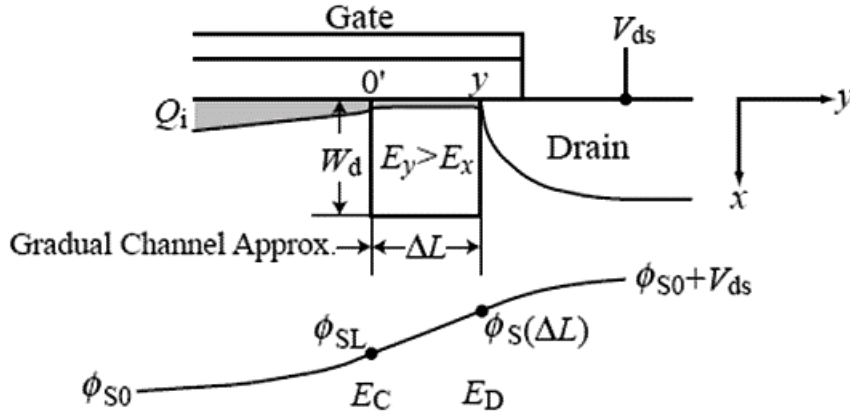
$$\mu_{PH}(\text{phonon}) = \frac{M_{uephonon}}{E_{eff}^{MUEPH0}}$$

$$\mu_{SR}(\text{surface roughness}) = \frac{MUESR1}{E_{eff}^{Muesurface}}$$

Channel-Length Modulation

As the gradual-channel approximation is not valid for large V_{ds} causing the pinch-off phenomenon in the channel. Without taking into account the pinch-off phenomenon, the calculated channel conductance g_{ds} enters abruptly into the saturation condition. To include the pinch-off phenomenon in HiSIM, we apply the conventional method of modeling the pinch-off region (ΔL) separately from the rest of the channel as depicted in Figure 31-6:

Figure 31-6 Schematic showing the correlation among physical quantities in the pinch-off region.



After taking into all effects, the final ΔL is derived as:

$$\Delta L = \frac{1}{2} \left[-\frac{1}{L_{eff}} \left(2 \frac{I_{dd}}{\beta Q_i} z + 2 \frac{N_{sub}}{\epsilon_{Si}} (\phi_s(\Delta L) - \phi_{SL}) z^2 + E_0 z^2 \right) \right]$$

$$+ \frac{1}{2} \sqrt{\frac{1}{L_{eff}^2} \left(2 \frac{I_{dd}}{\beta Q_i} z - 2 \frac{N_{sub}}{\epsilon_{Si}} (\phi_s(\Delta L) - \phi_{SL}) z^2 \right)^2 + 4 \left(2 \frac{N_{sub}}{\epsilon_{Si}} (\phi_s(\Delta L) - \phi_{SL}) z^2 + E_0 z^2 \right)}$$

Narrow-Channel Effects

The shallow-trench-isolation(STI) technology induces a V_{th} reduction for reduced channel width (W_{gate}). This phenomenon is modeled under inclusion of the edge-fringing capacitances C_{ef} at the edge of the trench as:

$$\Delta V_{th,W} = \left(\frac{1}{C_{ox}} - \frac{1}{C_{ox} + 2C_{ef}/(L_{eff}W_{eff})} \right) qN_{sub}W_d + \frac{WVTH0}{W_{gate} \times 10^4}$$

So the total threshold shift becomes:

$$\Delta V_{th} = \Delta V_{th,SC} + \Delta V_{th,R} + \Delta V_{th,P} + \Delta V_{th,W} - \phi_{spg}$$

In addition, the mobility should be adjusted with small geometrical size. The shallow trench isolation induces also an undesired hump in the sub-threshold region of the $I_{ds}-V_{gs}$ characteristics.

Temperature Dependences

The temperature dependence is included automatically in the surface potentials through β , which is the inverse of the thermal voltage. Additionally the band gap, the intrinsic carrier concentration, the carrier mobility, and the carrier saturation velocity are also temperature dependent.

$$E_g = EG0 - BGTMP1 \cdot (T - TNOM) - BGTMP2 \cdot (T - TNOM)^2$$

$$\mu_{PH}(phonon) = \frac{M_{uephonon}}{(T / TNOM)^{MUETMP} \times E_{eff}^{MUEPHO}}$$

$$V_{max} = \frac{VMAX}{1.8 + 0.4(T / TNOM) + 0.1(T / TNOM)^2 - VTMP \times (1 - T / TNOM)}$$

$$E_{gp} = E_{g0} + EGIG + IGTEMP2(1/T - 1/TNOM) + IGTEMP3(1/T^2 - 1/TNOM^2)$$

Resistances

$$R_{d0,temp} = RDTEMP1 \cdot (T - TNOM) + RDTEMP2 \cdot (T - TNOM)^2$$

$$R_{dvd,temp} = RDVDTEMP1 \cdot (TEMP - TNOM) + RDVDTEMP2 \cdot (TEMP^2 - TNOM^2)$$

Junction Capacitance at Drain side

$$CJ = CJ \cdot (1 + TCJBD \cdot (T - TNOM))$$

$$CJSW = CJSW \cdot (1 + TCJBDSW \cdot (T - TNOM))$$

$$CJSWG = CJSWG \cdot (1 + TCJBDSWG \cdot (T - TNOM))$$

Junction Capacitance at Drain side

$$CJ = CJ \cdot (1 + TCJBS \cdot (T - TNOM))$$

$$CJSW = CJSW \cdot (1 + TCJBSSW \cdot (T - TNOM))$$

$$CJSWG = CJSWG \cdot (1 + TCJBSSWG \cdot (T - TNOM))$$

Junction Current

$$T_{tnom} = \frac{T}{TNOM}$$

$$j_s = JS0 \exp \left\{ \frac{(E_g(T = TNOM) \cdot \beta(T = TNOM) - E_g \beta + XTI \cdot \log(T_{tnom}))}{NJ} \right\}$$

$$j_{ssw} = JS0SW \exp \left\{ \frac{(E_g(T = TNOM) \cdot \beta(T = TNOM) - E_g \beta + XTI \cdot \log(T_{tnom}))}{NJSW} \right\}$$

$$j_{s2} = JS0 \exp \left\{ \frac{(E_g(T = TNOM) \cdot \beta(T = TNOM) - E_g \beta + XTI2 \cdot \log(T_{tnom}))}{NJ} \right\}$$

$$j_{ssw2} = JS0SW \exp \left\{ \frac{(E_g(T = TNOM) \cdot \beta(T = TNOM) - E_g \beta + XTI2 \cdot \log(T_{tnom}))}{NJSW} \right\}$$

$$CISB = CISB \cdot \exp \{ (T_{tnom} - 1) CTEMP \}$$

$$VDIFFJ = VDIFFJ \cdot (T_{tnom})^2$$

Resistance

For the symmetrical/asymmetrical HVMOS case, the resistance at the source side is modeled with the same equations for the drain side without the V_{ds} dependence. The source and the drain resistances R_s and R_d are considered by voltage drops on each terminal as

$$V_{gs,eff} = V_{gs} - I_{ds} \cdot R_s$$

$$V_{ds,eff} = V_{ds} - I_{ds} \cdot (R_s + R_{drift})$$

$$V_{bs,eff} = V_{bs} - I_{ds} \cdot R_s$$

for the DC condition, where the effective voltages are referred as internal node potentials. The resistance values are modeled as

$$R_s = \frac{RS}{W_{eff}} + NRS \cdot RSH$$

$$R_{drift} = (R_d + V_{ds} \cdot R_{DVD})(1 + RDVG11 - \frac{RDVG11}{RDVG12} \cdot V_{gs}) \cdot (1 - V_{bs} \cdot RDVB)$$

$$R_d = \frac{R_{d0}}{W_{eff}} \left(1 + \frac{RDS}{(W_{gate} \cdot 10^4 \times L_{gate} \cdot 10^4)^{RDSF}}\right) + RSH \cdot NRD$$

$$R_{d0} = (RD + R_{d0,temp}) \cdot f_1 \cdot f_2$$

$$R_{DVD} = \frac{RDVD + R_{dvd,temp} \cdot \exp(-RDVDL \times (L_{gate} \cdot 10^4)^{RDVDLP})}{W_{eff}} \cdot \left(1 + \frac{RDVDS}{(W_{gate} \cdot 10^4 \times L_{gate} \cdot 10^4)^{RDVDSF}}\right) \cdot f_1 \cdot f_2 \cdot f_3$$

$$f_1(L_{drift1}) = \frac{LDRIFT1}{lum} \cdot RDSLPI + RDICT1$$

$$f_2(L_{drift2}) = \frac{LDRIFT2}{lum} \cdot RDSLPI2 + RDICT2$$

$$f_3(L_{over}) = 1 + (RDOV11 - \frac{RDOV11}{RDOV12}) \cdot \frac{LOVERLD}{lum} + (1 - RDOV13) \cdot \frac{LOVERLD}{lum}$$

Different resistance effects modeling approaches are supplies by HiSIM_HV model, it can be treated as external resistance or the total current can be obtained by a simple analytical description. Flag **CORSRD** is provided for the selection of one of the possible approaches. In the HiSIM HV 1.1.1 version the resistances is treated only as the extrinsic resistances.

CORSRD=2 is originally introduced to avoid simulation time penalty with an analytical description of the resistance effect as

$$I_{ds} = \frac{I_{ds0}}{1 + I_{ds0} \frac{R_d}{V_{ds}}}$$

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

where I_{ds0} is the drain current without the resistance effect and

$$R_d = \frac{1}{W_{eff}} (R'_d \cdot V_{ds}^{RD21} + V_{bs} \cdot V_{ds}^{RD22D} \cdot RD22)$$

The selection of the resistance model is summarized here:

CORSRD = 0 : no resistance

CORSRD = 1 : solved by circuit simulator with internal nodes

Model parameters are:

RS, NRS, RSH

RDVG11, RDVG12, RDVB, RDS, RDSP, NRD

RD, RDVD, RDVDL, RDVDLP, RDVDS, RDVDSP

RDSL1, RDICT1, RDSL2, RDICT2, RDOV11, RDOV12, RDOV13

CORSRD = 2 : solved with the analytical approach

Model parameters are:

RD21, RD22, RD22D, RD23, RD23L, RD23LP

RD23S, RD23SP, RD24, RD25, RD20

CORSRD = 3 : Both **CORSRD = 1** and **CORSRD = 2** are considered.

	Structure	Source	Drain
COSYM=0	LDMOS	RS (bias independent)	RD
COSYM=1	Symmetrical HVMOS		RD
COSYM=1	Asymmetrical HVMOS	RS	RD

Capacitance

Intrinsic Capacitance

The intrinsic capacitances are derivatives of the node charges determined as

$$C_{jk} = \delta \frac{\partial Q_j}{\partial V_k}$$

$\delta = -1$ for $j \neq k$
 $\delta = 1$ for $j = k$

Overlap Capacitance

Three different overlap capacitance models are supplied to modeling the overlap capacitance: Constant model, Simplified model and Surface-potential-based model. Flag COOVLP (COOVLPS) and NOVER (NOVERS) are used to select the corresponding model.

Figure 31-7 Model options of the overlap capacitance at the drain side are summarized.

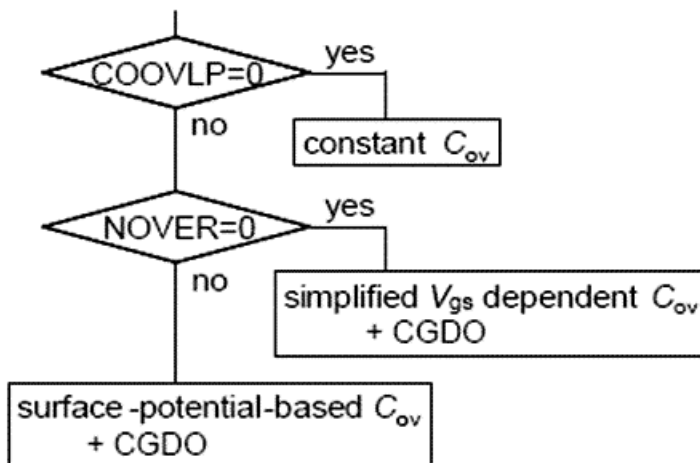
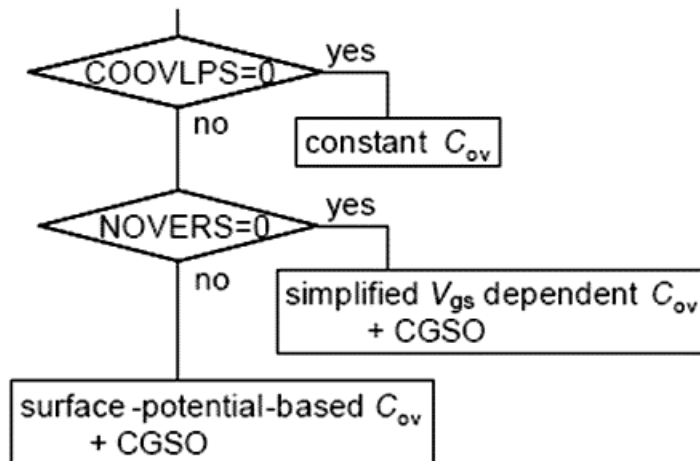


Figure 31-8 Model options of the overlap capacitance at the source side are summarized.

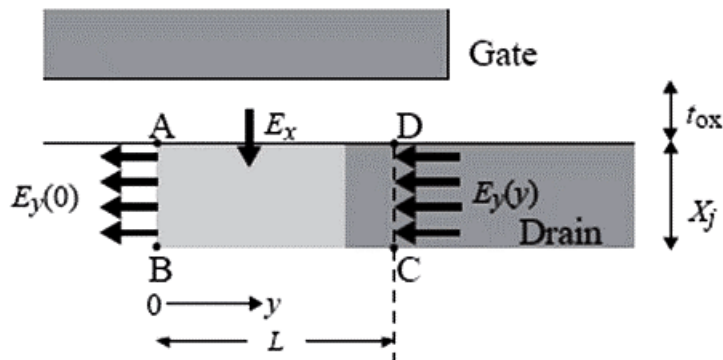


Leakage Currents

Substrate Current

The substrate current I_{sub} is generated by impact ionization in the depletion region at the drain junction

$$I_{sub} = \int_0^{\delta L} I_{ds} C_1 \exp\left(-\frac{C_2}{E_y}\right) dy.$$



where C_1 and C_2 are fitting parameters.

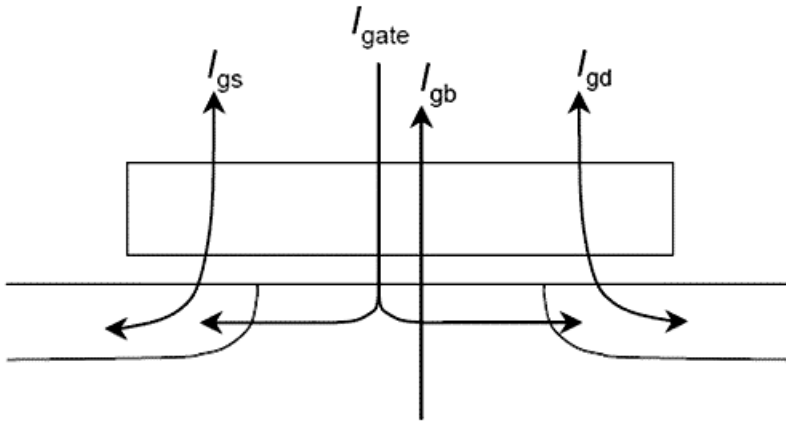
Gate Current

All possible gate leakage currents are schematically shown in Fig. 32.8

Between Gate and Channel, I_{gate}

$$I_{gate} = q \cdot GLEAK1 \cdot \frac{E^2}{E_{gp}^{\frac{1}{2}}} \cdot \exp\left(-\frac{E_{gp}^{\frac{3}{2}} \times GLEAK2}{E}\right) \cdot \sqrt{\frac{Q_i}{const0}} \cdot W_{eff} \cdot NF \cdot L_{eff}$$

$$\cdot \frac{GLEAK6}{GLEAK6 + V_{ds}} \cdot \frac{GLEAK7}{GLEAK7 + W_{eff} \cdot NF \cdot L_{eff}}$$



Between Gate and Bulk, I_{gb}

The I_{gb} current under the accumulation condition is modeled as

$$I_{gb} = GLKB1 \cdot E_{gb}^2 \cdot \exp\left(-\frac{GLKB2}{E_{gb}}\right) W_{eff} \cdot NF \cdot L_{eff}$$

$$E_{gb} = -\frac{V_{gs} - VFBC + GLKB3}{T_{ox}}$$

The Fowler-Nordheim tunneling mechanism is also considered

$$I_{FN} = \frac{q \cdot FN1 \cdot E_{FN}^2}{E_{g12}} \cdot \exp\left(-\frac{FN2 \cdot E_{g32}}{E_{FN}}\right) \cdot W_{eff} \cdot NF \cdot L_{eff}$$

Total substrate current is the sum of the two components as

$$I_{gb} = I_{gb} + I_{FN}$$

Between Gate and Source/Drain, I_{gs}/I_{gd}

$$I_{gs} = \text{signGIKSD1} \cdot E_{gs}^2 \exp(T_{ox} (GLKSD2 \cdot V_{gs} + GLKSD3)) \cdot W_{\text{eff}} \cdot NF$$

$$I_{gd} = \text{signGIKSD1} \cdot E_{gd}^2 \exp(T_{ox} (GLKSD2 \cdot (-V_{gs} + V_{ds}) + GLKSD3)) \cdot W_{\text{eff}} \cdot NF$$

GIDL (Gate-Induced Drain Leakage)

$$I_{GIDL} = q \cdot GIDL1 \cdot \frac{E^2}{E_g^{\frac{1}{2}}} \cdot \exp(-GIDL2 \cdot \frac{E_g^{\frac{3}{2}}}{E}) \cdot W_{\text{eff}} \cdot NF$$

Source/Bulk and Drain/Bulk Diode Models

Diode Current

$$j_s = JS0$$

$$j_{ssw} = JS0SW$$

$$j_{s2} = JS0$$

$$j_{ssw2} = JS0SW$$

Between Drain and Bulk

$$V_{bd} \geq V_1$$

$$I_{bd} = I_{sbd} \cdot \left\{ \exp\left(\frac{V_1}{N_{vtm}}\right) - 1 \right\} + \frac{I_{sbd}}{N_{vtm}} \exp\left(\frac{V_1}{N_{vtm}}\right) (V_{bd} - V_1) \\ + I_{sbd2} \cdot CISB \cdot \left\{ \exp\left(-\frac{V_{bd} \cdot CVB}{N_{vtm}}\right) - 1 \right\} + CISBK \cdot \left\{ \exp\left(-\frac{V_{bd} \cdot CVB}{N_{vtm}}\right) - 1 \right\}$$

$$V_1 \geq V_{bd}$$

$$I_{bd} = I_{sbd} \cdot \left\{ \exp\left(\frac{V_{bd}}{N_{vtm}}\right) - 1 \right\} + I_{sbd2} \cdot CISB \cdot \left\{ \exp\left(-\frac{V_{bd} \cdot CVB}{N_{vtm}}\right) - 1 \right\} + CISBK \cdot \left\{ \exp\left(-\frac{V_{bd} \cdot CVB}{N_{vtm}}\right) - 1 \right\}$$

$$N_{vtm} = \frac{NJ}{\beta}$$

$$V_1 = N_{vtm} \cdot \log\left\{ \frac{VDIFFJ}{I_{sbd}} + 1 \right\}$$

$$I_{bd} = I_{bd} + DIVX \cdot I_{sbd2} \cdot V_{bd}$$

Between Source and Bulk

$$V_{bs} \geq V_2$$

$$I_{bs} = I_{sbs} \cdot \left\{ \exp\left(\frac{V_2}{N_{vtm}}\right) - 1 \right\} + \frac{I_{sbs}}{N_{vtm}} \exp\left(\frac{V_2}{N_{vtm}}\right) (V_{bs} - V_2) \\ + I_{sbs2} \cdot CISB \cdot \left\{ \exp\left(-\frac{V_{bs} \cdot CVB}{N_{vtm}}\right) - 1 \right\} + CISBK \cdot \left\{ \exp\left(-\frac{V_{bs} \cdot CVB}{N_{vtm}}\right) - 1 \right\}$$

$$V_2 \geq V_{bs}$$

$$I_{bs} = I_{sbs} \cdot \left\{ \exp\left(\frac{V_{bs}}{N_{vtm}}\right) - 1 \right\} + I_{sbs2} \cdot CISB \cdot \left\{ \exp\left(-\frac{V_{bs} \cdot CVB}{N_{vtm}}\right) - 1 \right\} + CISBK \cdot \left\{ \exp\left(-\frac{V_{bs} \cdot CVB}{N_{vtm}}\right) - 1 \right\}$$

$$V_2 = N_{vtm} \cdot \log\left\{ \frac{VDIFFJ}{I_{sbs}} + 1 \right\}$$

$$I_{bs} = I_{bs} + DIVX \cdot I_{sbs2} \cdot V_{bs}$$

Noise Models

1/f Noise Models

The 1/f noise is caused by both the carrier fluctuation and the mobility fluctuation. The final description for the drift-diffusion model is

$$S_{I_{ds}} = \frac{I_{ds}^2 NFTRP}{\beta f (L_{eff} - \Delta L) W_{eff} \cdot NF} \left[\frac{1}{(N_0 + N^*)(N_L + N^*)} + \frac{2\mu E_y NFALP}{N_L - N_0} \ln \left(\frac{N_L + N^*}{N_0 + N^*} \right) + (\mu E_y NFALP)^2 \right]$$

where the parameters **NFALP** and **NFTRP** represent the contribution of the mobility fluctuation and the ratio of trap density to attenuation coefficient, respectively.

Thermal Noise Model

Van der Ziel derived the equation for the spectral density of the thermal drain-noise current at temperature T by integrating the trans-conductance along the channel direction y based on the Nyquist theorem

$$S_{id} = 4kT \frac{W_{eff} \cdot NF \cdot C_{ox} \cdot Vg \cdot Vt \cdot \mu}{(L_{eff} - \Delta L)} \frac{(1 + 3\eta + 6\eta^2)\mu_d^2 + (3 + 4\eta + 3\eta^2)\mu_d\mu_s + (6 + 3\eta + \eta^2)\mu_s}{15(1 + \eta)\mu_{av}^2}$$

where μ_s , μ_d and μ_{av} are mobilities at the source side, the drain side, and averaged, respectively.

Induced Gate Noise Model

$$N_{igate} = S_{igate} / f^2$$

Coupling Noise Model

$$N_{cross} = \frac{S_{igid}}{\sqrt{S_{igate} \cdot S_{id}}}$$

Non-Quasi-Static (NQS) Model

Formation of carrier

Carriers in the channel take time to build-up as opposed to the Quasi-Static (QS) approximation. To consider this phenomenon in HiSIM, the carrier formation is modeled as

$$q(t_i) = \frac{q(t_{i-1}) + \frac{\Delta t}{\tau} Q(t_i)}{1 + \frac{\Delta t}{\tau}}$$

where $q(t_i)$ and $Q(t_i)$ represent the non-quasi-static and the quasi-static carrier density at time t_i , respectively, and $\Delta t = t_i - t_{i-1}$ is valid. Above equation implies that the formation of carriers under the NQS approximation is always delayed in comparison to the QS approximation, which is the basic origin of the NQS effect.

Delay Mechanisms

Weak inversion

$$\tau_{diff} = DLY1$$

Strong inversion

$$\tau_{cond} = DLY2 \cdot \frac{Q_i}{I_{ds}}$$

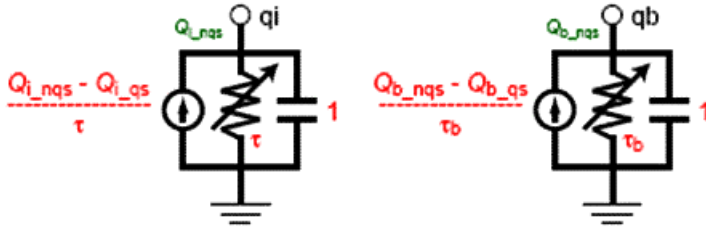
These two delay mechanisms (diffusion and conduction) are combined using the Matthiessen rule:

$$\frac{1}{\tau} = \frac{1}{\tau_{diff}} + \frac{1}{\tau_{cond}}$$

Applying the same approach for the formation of bulk carriers, leads to the approximation of the bulk carrier delay as an RC delay in the form

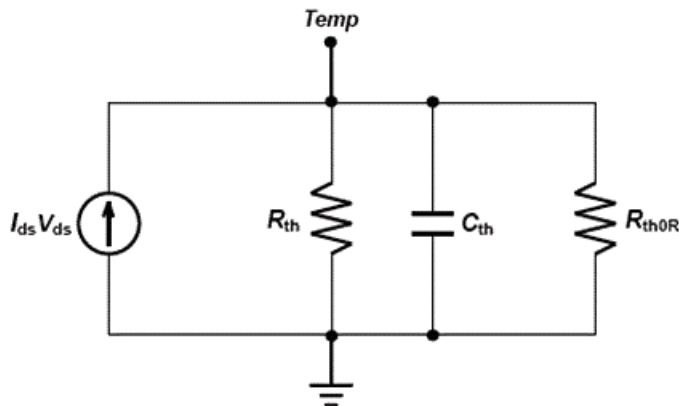
$$\tau_B = DLY3 \cdot C_{ox}$$

NQS model implementation into circuit simulator is listed as following figure:



Self-Heating Effect Model

The self-heating effect is modeled with the thermal network shown in the following figure. The flag COSELFHEAT must be equal to one and RTH0 must not be equal to zero to activate the model.



The total temperature of the devices is the sum of the original temperature and the temperature rise due to self-heating.

$$T = T + R_{th} \cdot I_{ds} \cdot V_{ds}$$

where R_{th} as well as C_{th} are a function of W_{eff} as

$$R_{th} = \frac{RTH0}{W_{eff}} \cdot \left(\frac{1}{NF^{RTHONF}} \right) \left(1 + \frac{RTHOW}{(W_{gate} \cdot 10^4)^{RTHOWP}} \right)$$

$$C_{th} = CTH0 \cdot W_{eff}$$

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

HiSIM HV 1.1.1 models the thermal dissipation in a different way with that of previous version as:

$$T = T + R_{th} \cdot I_{ds} \cdot V'_{ds}$$
$$V'_{ds} = V_{dsi} + POWRAT(V_{ds} - V_{dsi})$$

where **POWRAT** is a model parameter. The external node potential is represented by V_{ds} and the internal node potential within the drift region at the channel/drift junction is by V_{dsi} , which is calculated during the simulation.

DFM Model

To support design for manufacturability (DFM) HiSIM introduces an option for considering the variation of device parameters.

$$M_{\text{usphonon}} = MUEPHI[MPHDFN\{\ln(NSUBCDFM) - \ln(N_{SUBC})\} + 1]$$

$$NSUBP = NSUBP + (N_{SUBCDFM} - N_{SUBC})$$

$$NEXT = NEXT + (NSUBCDFM - N_{SUBC})$$

Component Statements

Instance Parameters

1	w (m)	Gate width.
2	l (m)	Gate length.
3	as (m ²)	Area of source junction.
4	ad (m ²)	Area of drain junction.
5	ps (m)	Perimeter of source junction.
6	pd (m)	Perimeter of drain junction.
7	dtemp (C)	Device temperature rise from ambient.

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

8	nrs=1	Number of squares of source diffusion.
9	nrd=1	Number of squares of drain diffusion.
10	corbnet=0	Substrate resistance network selector.
11	rbpb (Ω)	Substrate resistance network.
12	rbpd (Ω)	Substrate resistance network.
13	rbps (Ω)	Substrate resistance network.
14	cosubnode=0	Instance flag to switch tempnode to subnode. 1: 5th node is subnode; 0: 5th node is thermal node.
15	coselfheat=0	Calculation of self heating model.
16	corg=0	Gate-contact resistance selector.
17	ngcon=1.0	Number of gate contacts.
18	xgw=0.0 m	Distance from gate contact to channel edge.
19	xgl=0.0 m	Offset of gate length due to variation in patterning.
20	nf=1.0	Number of gate fingers.
21	lod=1.0e-5 m	Length of diffusion between gate and STI.
22	m=1	Multiplicity factor (number of MOSFETs in parallel).
23	subld1	Parameter for impact-ionization current in the drift region.
24	subld2 $((V^{3/2})/m)$	Parameter for impact-ionization current in the drift region.
25	ldrift1 (m)	Parameter for drift region length-1.
26	ldrift2 (m)	Parameter for drift region length-2.
27	lover (m)	Overlap length on source side.
28	lovers (m)	Overlap length on source side.

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

29	loverld (m)	Overlap length on drain side.
30	ldrifft1s (m)	Parameter for drift region length-1 on source side.
31	ldrifft2s (m)	Parameter for drift region length-2 on source side.
32	sa=0.0 m	Distance from STI edge to Gate edge.
33	sb=0.0 m	Distance from STI edge to Gate edge.
34	sd=0.0 m	Distance from Gate edge to Gate edge.
35	nsubcdfm (cm ⁻³)	Constant part of Nsub for DFM.
36	isnoisy=yes	Should device generate noise. Possible values are no and yes.

Model Definition

model modelName hisim_hv parameter=value ...

Model Parameters

Device type parameters

1	type=n	Transistor type. Possible values are n and p.
2	level=73	Level selector for spice compatible. 73 is valid level for hisim_hv model.
3	version=2.10	2.10 is the latest version of HiSIM_HV. The available versions are 1.11/1.12, 1.20/1.21/1.22/1.23/1.24, 2.00/2.01/2.10. Version 1.11/1.12 are not maintained and options of enable_pre_ver=yes is necessary to activate such old versions..
4	corsrd=3	Contact resistances Rs and Rd selector. 0 : no. 1 : yes, as external resistances. 2 : yes, as analytical resistances. 3: yes, as external and analytical resistance.
5	coiprv=1	Previous lds is used for calculating source/drain resistance effect. 0 : no(default). 1 : yes.

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

6	<code>copprv=1</code>	Previous surface potential is used for the initial guess. 0 : no(default). 1 : yes.
7	<code>coadov=1</code>	Selector for lateral field induced and overlap charges/ capacitances being added to intrinsic ones. 0 : no. 1 : yes(default).
8	<code>coisub=0</code>	Substrate current selector. 0 : no(default). 1 : yes.
9	<code>cogidl=0</code>	GIDL current calculation selector. 0 : no(default). 1 : yes.
10	<code>coiigs=0</code>	Gate current calculation selector. 0 : no(default). 1 : yes.
11	<code>coovlp=1</code>	Overlap capacitance calculation selector on drain side. 0 : constant overlap capacitance. 1 : including the bias dependent overlap capacitances(default).
12	<code>coovlps=0</code>	Overlap capacitance calculation selector on source side. 0 : constant overlap capacitance(default). 1 : including the bias dependent overlap capacitances.
13	<code>coflick=0</code>	1/f noise calculation selector.
14	<code>coisti=0</code>	STI leakage current calculation selector. 0 : no(default). 1 : yes.
15	<code>conqs=0</code>	Non-quasi-static mode selector. 0 : no(default). 1 : yes.
16	<code>cothrm1=0</code>	Thermal noise calculation selector. 0 : no(default). 1 : yes.
17	<code>tnom (C)</code>	Parameters measurement temperature. Default set by <code>options</code> .
18	<code>corg=0</code>	Gate-contact resistance calculation selector. 0 : no(default). 1 : yes.
19	<code>corbnet=0</code>	Substrate resistance network selector.
20	<code>coign=0</code>	Induced gate and cross correlation noise calculation selector..
21	<code>compatible</code>	Compatible with <code>spice3</code> , default is <code>spectre</code> compatible. Possible values are <code>spectre</code> , <code>spice2</code> , <code>spice3</code> , <code>cdsspice</code> , <code>hspice</code> , <code>spiceplus</code> , <code>eldo</code> , and <code>sspice</code> .

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

22	alarm=none	Forbidden operating region. Possible values are none, off, triode, sat, subth, and rev.
23	codfm=0	Calculation of model for DFM selector.
24	coselfheat=0	Calculation of self heating model.
25	cosubnode=0	Flag to switch tempnode to subnode. 1: 5th node is subnode; 0: 5th node is thermal node.
26	cosym=0	Model selector for symmetry device.
27	coqovsm=1	Selector for smoothing method of Qover. 0: analytically solved without inversion condition; 1: iteratively solved (default); 2: analytically solved with inversion condition (Old model).
28	cotemp=0	Model flag for temperature dependence.
29	coldrift=0	Selector for Ldrift parameter.
30	cordrift=1	Flag for rdrift evaluation.

Default for instance parameters

31	w=5e-6 m	Default gate width.
32	l=2e-6 m	Default gate length.
33	as=0 m ²	Default area of source junction.
34	ad=0 m ²	Default area of drain junction.
35	ps=0 m	Default perimeter of source junction.
36	pd=0 m	Default perimeter of drain junction.
37	temp=27 C	Default device temperature.
38	dtemp=0 C	Default device temperature rise from ambient.

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

Basic Device Parameters

39	$t_{ox}=3e-8$ m	Physical oxide thickness. The default value is 7e-9 since version 2.00.
40	$x_{ld}=3e-8$ m	Gate-overlap length. The default value is 0 for version 2.00/2.01 and 1.23.
41	$x_{wd}=0$ m	Gate-overlap width.
42	$x_{wdc}=0.0$ m	Gate-overlap width, for capacitance.
43	$t_{poly}=2.0e-7$ m	Height of the gate poly-si for fringing capacitance on source side.
44	$n_{subc}=1.0e17$ cm ⁻³	Substrate-impurity concentration. The default value is 5.0e17 for version 1.23 and 3.0e17 for version 2.00/2.01.
45	$n_{subp}=1.0e17$ cm ⁻³	Maximum pocket concentration. The default value is 1.0e18 for version 2.00/2.01 and version 1.23.
46	$r_s=0.0$ Ω m	Source contact resistance in LDD region.
47	$r_d=5.0e-3$ Ω m	Drain contact resistance in LDD region. The default value is 0.0 since version 2.00.
48	$v_{fbc}=-1.0$ V	Constant part of flat-band voltage.
49	$l_p=0.0$ m	Length of the pocket penetration into the channel. The default value is 1.5e-8 since version 2.00.
50	$x_{qy}=0.0$ m	Distance from channel/drain junction to maximum electric field point.
51	$l_{over}=3.0e-8$ m	Overlap length on source side.
52	$l_1=0.0$	Gate length parameter.
53	$l_{1d}=0.0$ m	Gate length parameter.
54	$l_{1n}=0.0$	Gate length parameter.

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

55	$wl=0.0$	Gate width parameter.
56	$wld=0.0$ m	Gate width parameter.
57	$wln=0.0$	Gate width parameter.
58	$vbi=1.1$ V	Built-in potential.
59	$nsubp0=0.0$ cm ⁻³	Pocket implant parameter.
60	$nsubwp=1.0$	Pocket implant parameter.
61	$lpext=1.0E-50$ m	Pocket extension.
62	$npext=1.0e17$ cm ⁻³	Pocket extension. The default value is 5.0e17 since version 2.00.
63	$rsh=0.0$ V/A m	Source/drain diffusion sheet resistance.
64	$rshg=0.0$ V/A m	Gate-electrode sheet resistance.
65	$rbpb=50.0$ Ω	Substrate resistance network.
66	$rbpd=50.0$ Ω	Substrate resistance network.
67	$rbps=50.0$ Ω	Substrate resistance network.
68	$gbmin=1.0e-12$	Minimum conductance for substrate resistance network.
69	$xl=0$ m	Gate length offset due to mask/etch effect.
70	$xw=0$ m	Gate width offset due to mask/etch effect.
71	$xqy1=0.0$ F m ^{XQY2}	V _{bs} dependence of Q _y .
72	$xqy2=0.0$	L _{gate} dependence of Q _y . The default value is 2.0 since version 2.00.
73	$xldld=1.0e-6$ m	Lateral diffusion of Drain under the gate.
74	$xwdld=1.0e-6$ m	Widening of drift width.

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

75	<code>rdov11=0.0</code>	Dependence coeff. for overlap length.
76	<code>rdov12=1.0</code>	Dependence coeff. for overlap length.
77	<code>rdov13=1.0</code>	Dependence coeff. for overlap length.
78	<code>rds1p1=0.0</code>	LDRIFT1 dependence of resistance for CORSRD=1,3. Default value changed to 1.0 for version 1.22 and later.
79	<code>rdict1=1.0</code>	LDRIFT1 dependence of resistance for CORSRD=1,3.
80	<code>rds1p2=1.0</code>	LDRIFT2 dependence of resistance for CORSRD=1,3.
81	<code>rdict2=0.0</code>	LDRIFT2 dependence of resistance for CORSRD=1,3.
82	<code>loverld=1.0e-6 m</code>	Overlap length on the drain side.
83	<code>lovers=3.0e-8 m</code>	Overlap length on source side.
84	<code>ldrifft1=1.0e-6 m</code>	Drift region length-1 on the drain side.
85	<code>ldrifft1s=0.0 m</code>	Drift region length-1 on the source side.
86	<code>ldrifft2=1.0e-6 m</code>	Drift region length-2 on the drain side.
87	<code>ldrifft2s=1.0e-6 m</code>	Drift region length-2 on the source side.
88	<code>subld1=0.0</code>	Impact-ionization current in the drift region.
89	<code>subld1l=0.0 $\mu\text{m}^{\text{subld1lp}}$</code>	Parameter for impact-ionization current in the drift region.
90	<code>subld1lp=1.0</code>	Parameter for impact-ionization current in the drift region.
91	<code>subld2=0.0 $(V^{(3/2)})/m$</code>	Impact-ionization current in the drift region.
92	<code>xpdv=0.0 1/m</code>	Parameter for impact-ionization current in the drift region.
93	<code>xpvdth=20.0 V</code>	Parameter for impact-ionization current in the drift region.
94	<code>xpvdthg (1/V)</code>	Parameter for impact-ionization current in the drift region.

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

- 95 $q_{ovadd}=0.0$ Parameter for additional Qover Charge.
- 96 $r_{drbb}=1.0$ Degradation of the mobility in drift region.

Temperature dependence effects

- 97 $eg_0=1.1785$ eV Constant bandgap.
- 98 $bgtmp_1=9.025e-5$ eV/K
First order temperature coefficient for band gap.
- 99 $bgtmp_2=1.0e-7$ eV/K²
Second order temperature coefficient for band gap.
- 100 $igtemp_2=0.0$ 1/K Temperature dependence of gate current.
- 101 $igtemp_3=0.0$ 1/K² Temperature dependence of gate current.
- 102 $vmaxt_1=0.0$ 1/K Temperature dependence of velocity.
- 103 $vmaxt_2=0.0$ 1/K² Temperature dependence of velocity.
- 104 $ninvdt_1=0.0$ 1/K Temperature dependence of universal mobility model.
- 105 $ninvdt_2=0.0$ 1/K² Temperature dependence of universal mobility model.
- 106 $rdtemp_1=0.0$ 1/K Temperature-dependence of Rd.
- 107 $rdtemp_2=0.0$ 1/K² Temperature-dependence of Rd.
- 108 $rdvdtemp_1=0.0$ 1/K Temperature-dependence of RDVD.
- 109 $rdvdtemp_2=0.0$ 1/K²
Temperature-dependence of RDVD.
- 110 $rthtemp_1=0.0$ 1/K Temperature dependence of thermal resistance.
- 111 $rthtemp_2=0.0$ 1/K²
Temperature dependence of thermal resistance.
- 112 $prattemp_1=0.0$ 1/K Temperature dependence of thermal dissipation.

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

113 $\text{prattemp2}=0.0 \text{ 1/K}^2$ Temperature dependence of thermal dissipation.

Quantum Mechanical Effects

114 $\text{qme1}=0.0 \text{ m/V}^2$ Coefficient for quantum mechanical effect.

115 $\text{qme2}=1.0 \text{ V}$ Coefficient for quantum mechanical effect. Default as 0.0 for version 1.23, 2.0 for version 2.10.

116 $\text{qme3}=0.0 \text{ m}$ Coefficient for quantum mechanical effect.

117 $\text{kappa}=3.9$ Dielectric constant for high-k stacked gate.

Poly Depletion Effects

118 $\text{pgd1}=0.0 \text{ V}$ Strength of poly depletion.

119 $\text{pgd2}=1.0 \text{ V}$ Threshold voltage of poly depletion.

120 $\text{pgd3}=0.8$ Vds dependence of poly depletion.

121 $\text{pgd4}=0.0$ Parameter for gate-poly depletion.

Short Channel Effects

122 $\text{par12}=1.0\text{e-}8 \text{ m}$ Depletion width of channel/contact junction.

123 $\text{sc1}=1.0 \text{ 1/V}$ Short-channel coefficient 1, defaulted as 0 since version 2.10 .

124 $\text{sc2}=1.0 \text{ 1/V}^2$ Short-channel coefficient 2. The default value is 0.0 for version 2.00/2.01 and version 1.23.

125 $\text{sc3}=0.0 \text{ m/V}^2$ Short-channel coefficient 3.

126 $\text{sc4}=0.0 \text{ 1/V}$ Parameter for SCE.

127 $\text{scp1}=1.0 \text{ 1/V}$ Short-channel coefficient 1 for pocket, defaulted as 0.0 since version 2.10.

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

128	$scp2=0.1 \text{ } 1/V^2$	Short-channel coefficient 2 for pocket. The default value is 0.0 for version 2.00/2.01 and version 1.23.
129	$scp3=0.0 \text{ } m/V^2$	Short-channel coefficient 3 for pocket.
130	$scp22=0.0 \text{ } V^4$	Short-channel-effect modification for small Vds.
131	$scp21=0.0 \text{ } V$	Short-channel-effect modification for small Vds.
132	$bs1=0.0 \text{ } V^2$	Body-coefficient modification by impurity profile.
133	$bs2=0.9 \text{ } V$	Body-coefficient modification by impurity profile.

Narrow channel effects

134	$wfc=0.0 \text{ } m \text{ } F/cm^2$	Threshold voltage reduction.
135	$nsubcw=0.0$	Width dependence of substrate-impurity concentration.
136	$nsubcwp=1.0$	Width dependence of substrate-impurity concentration.
137	$nsti=1.0e17 \text{ } cm^{-3}$	Substrate-impurity concentration at the SIT edge, defaulted as $5e17$ since version 2.10.
138	$wsti=0.0 \text{ } m$	Width of the high-field region at STI.
139	$muephw=0.0$	Phonon scattering parameter.
140	$muepwp=1.0$	Phonon scattering parameter.
141	$wvth0=0.0$	Threshold voltage shift.
142	$mueswp=1.0$	Change of surface roughness related mobility.
143	$vthsti=0.0$	Parameter for STI.
144	$muesti1=0.0$	STI Stress mobility parameter.
145	$muesti2=0.0$	STI Stress mobility parameter.
146	$muesti3=1.0$	STI Stress mobility parameter.
147	$nsubpsti1=0.0 \text{ } m$	STI Stress pocket implant parameter.

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

148	$n_{subpsti2}=0.0$ m	STI Stress pocket implant parameter.
149	$n_{subpsti3}=1.0$ m	STI Stress pocket implant parameter.
150	$w_{stil}=0.0$	Parameter for STI.
151	$w_{stilp}=1.0$	Parameter for STI.
152	$scsti1=0.0$	Parameter for STI.
153	$scsti2=0.0$ 1/V	Parameter for STI.
154	$saref=1e-6$ m	Reference distance from STI edge to Gate edge.
155	$sbref=1e-6$ m	Reference distance from STI edge to Gate edge.
156	$w_{stiw}=0.0$	Parameter for STI.
157	$w_{stiwp}=1.0$	Parameter for STI.
158	$vdsti=0.0$	Parameter for STI.

Mobility Effects

159	$\mu_{uecb0}=1.0e3$ cm ² /(V s)	Coulomb scattering.
160	$\mu_{uecb1}=1.0e2$ cm ² /(V s)	Coulomb scattering.
161	$\mu_{ueph0}=0.3$ cm ² (V/cm) ^(Muesr1) /(V s)	Phonon scattering.
162	$\mu_{ueph1}=2.5e4$	Phonon scattering. The default value is 2.0e4 since version 2.00.
163	$\mu_{uetmp}=1.7$	Temperature dependence of phonon scattering. The default value is 1.5 for version 2.00/2.01 and version 1.23.
164	$\mu_{uesr0}=2.0$ cm ² (V/cm) ^(Muesr1) /(V s)	Surface-roughness scattering.
165	$\mu_{uesr1}=1.0e16$	Surface-roughness scattering. The default value is 6.0e14 since version 2.00.

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HISIM_HV Model (hisim_hv)

166	$n_{dep}=1.0$	Coefficient of effective electric field.
167	$n_{inv}=0.5$	Coefficient of effective electric field.
168	$n_{invd}=0.0$ 1/V	Modification of V_{dse} dependence on E_{eff} .
169	$n_{invdw}=0.0$	Coeff of modification of V_{dse} dependence on E_{eff} .
170	$n_{invdwp}=1.0$	Coeff of modification of V_{dse} dependence on E_{eff} .
171	$bb=2.0$	High-field mobility degradation.
172	$v_{max}=1.0e7$ cm/s	Saturation velocity.
173	$v_{over}=0.3$ cm ^(v_{overp})	Parameter for velocity overshoot.
174	$v_{overp}=0.3$	Lgate dependence of velocity overshoot.
175	$v_{overs}=0.0$	Parameter for overshoot.
176	$v_{oversp}=0.0$	Parameter for overshoot.
177	$v_{tmp}=0.0$ cm/s	Temperature dependence of the saturation velocity.
178	$\mu_{eph1}=0.0$	Phonon scattering parameter.
179	$\mu_{eplp}=1.0$	Phonon scattering parameter.
180	$\mu_{esr1}=0.0$	Surface roughness parameter.
181	$\mu_{esrw}=0.0$	Change of surface roughness related mobility.
182	$\mu_{eslp}=1.0$	Surface roughness parameter.
183	$n_{depl}=0.0$	Modification of Q_b contribution for short-channel case.
184	$n_{deplp}=1.0$	Modification of Q_b contribution for short-channel case.

Small size parameters

185	$w_{l1}=0.0$	Threshold voltage shift of STI leakage due to small size effect.
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Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

186	wl1p=1.0	Threshold voltage shift of STI leakage due to small size effect.
187	wl2=0.0	Threshold voltage shift due to small size effect.
188	wl2p=1.0	Threshold voltage shift due to small size effect.
189	muephs=0.0	Mobility modification due to small size.
190	muepsp=1.0	Mobility modification due to small size.

Channel Length Modulation Effects

191	clm1=50e-3	First parameter for CLM. Default as 0.7 for version 1.23.
192	clm2=2.0 1/m	Second parameter for CLM.
193	clm3=1.0	Third parameter for CLM.
194	clm5=1.0	Effect of pocket implantation.
195	clm6=0.0	Effect of pocket implantation.

Substrate Current Effects

196	sub1=50e-3 1/V	First parameter for I_{sub} . The default value is 10 for version 2.00/2.01 and version 1.23.
197	sub2=1.0e2 V	Second parameter for I_{sub} . The default value is 25 for version 2.00/2.01 and version 1.23.
198	svgs=0.8	Substrate current dependence on V_{gs} .
199	svbs=0.5	Substrate current dependence on V_{bs} .
200	svbs1=0.0	L_{gate} dependence of SVBS.
201	svds=0.8	Substrate current dependence on V_{ds} .
202	slg=3.0e-8	Substrate current dependence on L_{gate} .
203	sub11=2.5e-3	L_{gate} dependence of SUB1.

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HISIM_HV Model (hisim_hv)

204	sub2l=2.0e-6	Lgate dependence of SUB2.
205	fn1=50.0	Coefficient of Fowler-Nordheim-current contribution. The default value is 0.0 since version 2.00.
206	fn2=1.7e-4	Coefficient of Fowler-Nordheim-current contribution.
207	fn3=0.0	Coefficient of Fowler-Nordheim-current contribution.
208	fvbs=1.2e-2	Modification of Vbs dependence.
209	svgs1=0.0	Lgate dependence of SVGS.
210	svgs1p=1.0	Lgate dependence of SVGS.
211	svgswp=1.0	Wgate dependence of SVGS.
212	svgsw=0.0	Wgate dependence of SVGS.
213	svbs1p=1.0	Lgate dependence of SVBS.
214	slg1=0.0	Substrate current dependence on Lgate.
215	slg1p=1.0	Substrate current dependence on Lgate.
216	sub1lp=1.0	Lgate dependence of SUB1.
217	ibpc1=0.0	Impact-ionization induced bulk potential change.
218	ibpc1l=0.0	Parameter for impact-ionization induced bulk potential change.
219	ibpc1lp=-1.0	Parameter for impact-ionization induced bulk potential change.
220	ibpc2=0.0	Impact-ionization induced bulk potential change.

Gate Current Effects

221	glpart1=0.5	Partitioning of gate current.
222	gleak1=50.0 A/(V ^(3/2) c ^(1/2))	First gate current coefficient.

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

- 223 $g_{leak2}=1.0e7 \text{ } 1/(V^{(1/2)} \text{ } c^{(3/2)} \text{ } m)$
Second gate current coefficient.
- 224 $g_{leak3}=6.0e-2$ Third gate current coefficient.
- 225 $g_{leak4}=4.0$ Parameter for gate current.
- 226 $g_{leak5}=7.5e3$ Parameter for gate current.
- 227 $g_{lksd1}=1.0e-15$ Parameter for gate current.
- 228 $g_{lksd2}=5e6$ Parameter for gate current. The default value is $1e3$ since version 2.00.
- 229 $g_{lksd3}=-5e6$ Parameter for gate current. The default value is $-1e3$ since version 2.00.
- 230 $g_{lkb1}=5.0e-16$ Parameter for gate current.
- 231 $g_{lkb2}=1.0$ Parameter for gate current.
- 232 $g_{leak6}=0.25 \text{ } V$ Parameter for gate current.
- 233 $g_{leak7}=1.0e-6 \text{ } m^2$ Parameter for gate current.
- 234 $g_{lkb3}=0.0 \text{ } V$ Parameter for gate current.
- 235 $egig=0.0 \text{ } V$ Parameter for gate current.

GIDL Current Effects

- 236 $gidl1=2.0 \text{ } A \text{ } m/(V^{(3/2)} \text{ } c^{(1/2)})$
First parameter for GIDL.
- 237 $gidl2=3.0E7 \text{ } 1/(V^{(1/2)} \text{ } c^{(3/2)} \text{ } m)$
Second parameter for GIDL.
- 238 $gidl3=0.9$ Third parameter for GIDL.
- 239 $gidl4=0.9$ Parameter for GIDL. The default value is 0.0 for version 2.00/2.01 and version 1.23.
- 240 $gidl5=0.2$ Parameter for GIDL.

Noise 1/f Effects

241	$nfalp=1.0e-19$	Flicker (1/f) noise contribution of the mobility fluctuation.
242	$falph=1.0$	Parameter for 1/f noise.
243	$nftrp=1.0e10$	Flicker (1/f) noise ratio of trap density to attenuation coefficient.
244	$cit=0.0$	Flicker (1/f) noise interface trapped carriers capacitance.

Subthreshold swing parameters

245	$pthrou=0.0$	Modify subthreshold sloop.
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NQS parameters

246	$dly1=1.0e-10$	Parameter for transit time.
247	$dly2=0.7$	Parameter for transit time.
248	$dly3=8.0e-7 \Omega$	Parameter for transforming bulk charge.
249	$dlyov=0.0 \Omega$	Parameter for transforming overlap charge.
250	$minr=1.0e-3$	Minimum parasitic resistance, resistance smaller than minr will be clamped as minr.
251	$minc=1.0e-30$	Minimum diagonal capacitance.
252	$coclampc=1$	The flag of clamp minc.

Symmetry for short-channel mosfet

253	$vzadd0=1.0e-2 V$	V_{zadd} at $V_{ds}=0$.
254	$pzadd0=5.0e-3 V$	P_{zadd} at $V_{ds}=0$.

P-N junctions parameters

255	$js0=5.0e-7 A/m^2$	Junction saturation current density.
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Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

256	$j_{s0sw}=0.0$	A/m	Side-wall saturation current density.
257	$n_j=1.0$		Junction emission coefficient.
258	$n_{jsw}=1.0$		Junction emission coefficient (sidewall).
259	$x_{ti}=2.0$		Junction saturation current temperature exponent coefficient.
260	$c_j=5.0e-4$	F/m ²	Bottom junction capacitance per unit area at zero bias.
261	$c_{jsw}=5e-10$	F/m	Source/drain sidewall junction capacitance per unit length at zero bias.
262	$c_{jswg}=5e-10$	F/m	Source/drain sidewall junction capacitance grading coefficient per unit length at zero bias.
263	$t_{cjb\delta}=0.0$		Temperature dependence of c_{zbd} .
264	$t_{cjb\delta sw}=0.0$		Temperature dependence of c_{zbdsw} .
265	$t_{cjb\delta swg}=0.0$		Temperature dependence of c_{zbdswg} .
266	$t_{cjb\delta s}=0.0$		Temperature dependence of c_{zbs} .
267	$t_{cjb\delta ssw}=0.0$		Temperature dependence of c_{zbssw} .
268	$t_{cjb\delta sswg}=0.0$		Temperature dependence of c_{zbsswg} .
269	$m_j=0.5$		Bulk junction bottom grading coefficient.
270	$m_{jsw}=0.33$		Source/drain sidewall junction capacitance grading coefficient.
271	$m_{jswg}=0.33$		Bottom junction capacitance grading coefficient.
272	$p_b=1.0$	V	Bottom junction build-in potential.
273	$p_{bsw}=1.0$	V	Source/drain sidewall junction build-in potential.
274	$p_{bswg}=1.0$	V	Source/drain gate sidewall junction build-in potential.
275	$v_{diffj}=6.0e-4$	V	Threshold voltage for S/D junction diode.
276	$x_{ti2}=0.0$		Temperature coefficient.

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

277	<code>cisb=0.0</code>	Reverse bias saturation current.
278	<code>cvb=0.0</code>	Bias dependence coefficient of <code>cisb</code> .
279	<code>ctemp=0.0</code>	Temperature coefficient.
280	<code>cisbk=0.0 A</code>	Reverse bias saturation current.
281	<code>cvbk=0.0</code>	Bias dependence coefficient of <code>cisb</code> .
282	<code>divx=0.0 1/V</code>	Parameter for junction.

Overlap capacitance parameters

283	<code>cgso=0.0 F/m</code>	Gate-source overlap capacitance.
284	<code>cgdo=0.0 F/m</code>	Gate-drain overlap capacitance.
285	<code>cgbo=0.0 F/m</code>	Gate-bulk overlap capacitance.
286	<code>ovslp=2.0e-8</code>	Parameter for overlap capacitance. The default value is $2.1e-7$ for version 2.00/2.01 and version 1.23.
287	<code>ovmag=500.0</code>	Parameter for overlap capacitance. The default value is 0.6 for version 2.00/2.01 and version 1.23.
288	<code>vfbover=-0.5 V</code>	Flat-band voltage in overlap region.
289	<code>nover=3.0e16 cm⁻³</code>	Impurity concentration in overlap region. Defaulted as $1.0e17$ for version 2.00/2.01.
290	<code>novers=0.0 cm⁻³</code>	Impurity concentration in overlap region. Defaulted as $1.0e17$ since version 2.10.

Smoothing coefficient between linear and saturation

291	<code>ddl_{tmax}=1.0</code>	Coefficient of effective electric field. The default value is 10 for version 2.00/2.01 and 1.23.
292	<code>ddl_{tslp}=0.0</code>	Lgate dependence of smoothing coefficient.

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

293 `ddltict=10.0` Lgate dependence of smoothing coefficient.

DFM parameters

294 `mphdfm=-0.3` NSUBCDFM dependence of phonon scattering for DFM.

Substrate model parameters

295 `rdvsub=1.0` V_{sub} dependence of depletion width.

296 `rdvds=0.3` V_{ds} dependence of depletion width.

297 `dddrift=1.0e-6 m` Depth of the drift region.

298 `vbisub=0.7 V` Built-in potential at the drift/substrate junction.

299 `nsubsub=1.0e15 cm-3`
Impurity concentration of the substrate required for V_{sub} dependence.

Operating region warning control parameters

300 `warn=off` Parameter to turn warnings on and off.
Possible values are `off` and `on`.

301 `bvd (V)` Drain diode breakdown voltage, take effect when `bvj` not given.

302 `bvs (V)` Source diode breakdown voltage, take effect when `bvj` not given.

303 `bvj (V)` Junction reverse breakdown voltage.

304 `vbox=3e9 tox V` Oxide breakdown voltage.

Mismatch parameters

305 `mvtwl=0.0 V m` Threshold mismatch area dependence.

306 `mvt0=0.0 V` Threshold mismatch intercept.

307 `mbewl=0.0 m` Beta mismatch area dependence.

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

- 308 $mbe0=0.0$ Beta mismatch intercept.
- 309 $mvtwl2=0.0 \text{ V m}^{1.5}$ Threshold mismatch area square dependence.
- 310 $mismatchmod=0$ Mismatch mode selector. The available modes are 0, 1, 2 and 3.
- 311 $mismatchdist=0 \text{ m}$ Mismatch Distance.

LDMOS special parameters

- 312 $rdvg11=0.0$ Vgs dependence of RD.
- 313 $rdvg12=1.0e2$ Vgs dependence of RD.
- 314 $vbsmin=-10.5 \text{ V}$ Minimum back bias voltage to be treated in hsmhveval.
- 315 $rth0=0.1 \text{ Kcm/W}$ Thermal resistance.
- 316 $cth0=1.0e-7 \text{ Ws/Kcm}$ Thermal capacitance.
- 317 $qdf tvd=1.0$ Qdrift Vd dependence.
- 318 $rdvd=7.0e-2$ Vds dependence of RD.
- 319 $rdvb=0.0$ Vbs dependence of RD.
- 320 $rd20=0.0$ RD23 boundary.
- 321 $rd21=1.0$ Vds dependence of RD.
- 322 $rd22=0.0$ Vbs dependence of RD.
- 323 $rd22d=0.0$ Vbs dependence of RD.
- 324 $rd23=5e-3$ Modification of RD.
- 325 $rd24=0.0$ Vgs dependence of RD.
- 326 $rd25=0.0$ Vgs dependence of RD.
- 327 $rd26=0.2$ Smoothing Qover at depletion/inversion transition.

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HISIM_HV Model (hisim_hv)

328	qovsm=0.2	Smoothing Qover at depletion/inversion transition.
329	rdvdl=0.0	Lgate dependence of RD.
330	rdvd1p=1.0	Lgate dependence of RD.
331	rdvds=0.0	Small size dependence of RD.
332	rdvdsp=1.0	Small size dependence of RD.
333	rd231=0.0	Lgate dependence of RD23 boundary.
334	rd231p=1.0	Lgate dependence of RD23 boundary.
335	rd23s=0.0	Small size dependence of RD23.
336	rd23sp=1.0	Small size dependence of RD23.
337	rdS=0.0	Small size dependence of RD.
338	rdsp=1.0	Small size dependence of RD.
339	ldrifft=1.0e-6	Length of drift region.
340	rth0r=0.0	Heat radiation for SHE.
341	rth0w=0.0	Width-dependence of RTH0.
342	rth0wp=1.0	Width-dependence of RTH0.
343	rth0nf=0.0	Nf-dependence of RTH0.
344	cvdsover=0.0	Modification of the Cgg spikes for Vds is not zero.
345	powrat=1.0	Thermal dissipation.
346	shemax=500.0 K	The maximum temperature rise due to the selfheating.
347	vgSmin=-100 V	Minimal/maximal expected Vgs (NMOS/PMOS).

Auto Model Selector parameters

348	wmax=1 m	Maximum channel width for which the model is valid.
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Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

349	$w_{min}=0$ m	Minimum channel width for which the model is valid.
350	$l_{max}=1$ m	Maximum channel length for which the model is valid.
351	$l_{min}=0$ m	Minimum channel length for which the model is valid.

Safe Operating Areas Parameters

352	$v_{ds_max}=\infty$ V	Maximum allowed voltage cross source and drain.
353	$v_{gd_max}=\infty$ V	Maximum allowed voltage cross drain and gate.
354	$v_{gs_max}=\infty$ V	Maximum allowed voltage cross source/bulk and gate.
355	$v_{bd_max}=\infty$ V	Maximum allowed voltage cross drain/source and bulk.
356	$v_{bs_max}=\infty$ V	Maximum allowed voltage cross source and bulk.
357	$v_{gb_max}=\infty$ V	Maximum allowed voltage cross gate and bulk.
358	$v_{gdr_max}=\infty$ V	Maximum allowed reverse voltage cross gate and drain.
359	$v_{gsr_max}=\infty$ V	Maximum allowed reverse voltage cross gate and source.
360	$v_{gbr_max}=\infty$ V	Maximum allowed reverse voltage cross gate and bulk.
361	$pt1=0.0$	Strength for punchthrough effect.
362	$ptp=3.5$	Strength for punchthrough effect.
363	$pt2=0.0$	Vds dependence of punchthrough effect.
364	$ptlp=1.0$	Channel-length dependence of punchthrough effect.

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

365	<code>gd1=0.0</code>	Strength of high-field effect.
366	<code>gd1p=0.0</code>	Channel-length dependence of high-field effect.
367	<code>gd1d=0.0</code>	Channel-length dependence of high-field effect.
368	<code>pt4=0.0</code>	Vbs dependence of punchthrough effect.
369	<code>pt4p=1.0</code>	Vbs dependence of punchthrough effect.
370	<code>rdrmue=2.0e3</code>	Field dependent mobility in the drift region for <code>cordrift=1</code> .
371	<code>rdrvmax=1.0e7</code>	Saturation velocity in drift region, defaulted as $3e7$ since version 2.10.
372	<code>rdrmuetmp=0.0</code>	Temperature dependence of resistance for <code>cordrift=1</code> .
373	<code>rdrvtmp=0.0</code>	Temperature dependence of resistance for <code>cordrift=1</code> .
374	<code>rdrdjunc=1.0e-6</code>	Junction depth at channel/drift region.
375	<code>rdrctx=0.0</code>	Exude of current flow from Xov.
376	<code>rdracar=0.0</code>	High field injection in drift region.
377	<code>rdrdl1=0.0</code>	Effective l_{drift} of current in drift region.
378	<code>rdrdl2=0.0</code>	Pinch-off length in drift region.
379	<code>rdrvmaxw=0.0</code>	Saturation velocity W_{gate} dependence.
380	<code>rdrvmaxwp=1.0</code>	Saturation velocity W_{gate} dependence.
381	<code>rdrvmaxl=0.0</code>	Saturation velocity L_{gate} dependence.
382	<code>rdrvmaxlp=1.0</code>	Saturation velocity L_{gate} dependence.
383	<code>rdrmuel=0.0</code>	Mobility in drift region L_{gate} dependence.
384	<code>rdrmuelp=1.0</code>	Mobility in drift region L_{gate} dependence.
385	<code>rdrqover=0.0</code>	Inclusion of the overlap charge into <code>rdrift</code> , defaulted as $1.0e5$ since version 2.10.

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

386	$j_{s0d}=j_{s0}$	A/m ²	Saturation current density for drain junction.
387	$j_{s0swd}=j_{s0sw}$	A/m	Side wall saturation current density for drain junction.
388	$n_{jd}=n_j$		Emission coefficient for drain junction.
389	$n_{jswd}=n_{jsw}$		Emission coefficient for drain junction.
390	$x_{tid}=x_{ti}$		Junction current temperature exponent coefficient for drain junction.
391	$c_{jd}=c_j$	F/m ²	Bottom junction capacitance per unit area at zero bias for drain junction.
392	$c_{jswd}=c_{jsw}$	F/m	Sidewall junction capacitance grading coefficient per unit length at zero bias for drain junction.
393	$c_{jswgd}=c_{jswg}$	F/m	Gate sidewall junction capacitance per unit length at zero bias for drain junction.
394	$m_{jd}=m_j$		Bottom junction capacitance grading coefficient for drain junction.
395	$m_{jswd}=m_{jsw}$		Sidewall junction capacitance grading coefficient for drain junction.
396	$m_{jswgd}=m_{jswg}$		Gate sidewall junction capacitance grading coefficient for drain junction.
397	$p_{bd}=p_b$	V	Bottom junction build-in potential for drain junction.
398	$p_{bswd}=p_{bsw}$	V	Sidewall junction build-in potential for drain junction.
399	$p_{bswgd}=p_{bswg}$	V	Gate sidewall junction build-in potential for drain junction.
400	$x_{ti2d}=x_{ti2}$		Temperature coefficient for drain junction.
401	$c_{isbd}=c_{isb}$		Reverse bias saturation current for drain junction.
402	$c_{vbd}=c_{vb}$		Bias dependence coefficient of c_{isb} for drain junction.
403	$c_{tempd}=c_{temp}$		Temperature coefficient for drain junction.

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HISIM_HV Model (hisim_hv)

404	$c_{isbk\bar{d}}=c_{isbk}$	A	Reverse bias saturation current for drain junction.
405	$div_{xd}=div_x$	1/V	Reverse coefficient coefficient for drain junction.
406	$vd_{iffj\bar{d}}=vd_{iffj}$	V	Reverse coefficient coefficient for drain junction.
407	$j_{s0s}=j_{s0\bar{d}}$	A/m ²	Saturation current density for source junction.
408	$j_{s0s_{ws}}=j_{s0s_{w\bar{d}}}$	A/m	Side wall saturation current density for source junction.
409	$n_{js}=n_{j\bar{d}}$		Emission coefficient for source junction.
410	$n_{js_{ws}}=n_{js_{w\bar{d}}}$		Sidewall emission coefficient for source junction.
411	$x_{tis}=x_{ti\bar{d}}$		Junction current temperature exponent coefficient for source junction.
412	$c_{js}=c_{j\bar{d}}$	F/m ²	Bottom junction capacitance per unit area at zero bias for source junction.
413	$c_{js_{ws}}=c_{js_{w\bar{d}}}$	F/m	Sidewall junction capacitance grading coefficient per unit length at zero bias for source junction.
414	$c_{js_{wgs}}=c_{js_{w\bar{g}\bar{d}}}$	F/m	Gate sidewall junction capacitance per unit length at zero bias for source junction.
415	$m_{js}=m_{j\bar{d}}$		Bottom junction capacitance grading coefficient for source junction.
416	$m_{js_{ws}}=m_{js_{w\bar{d}}}$		Sidewall junction capacitance grading coefficient for source junction.
417	$m_{js_{wgs}}=m_{js_{w\bar{g}\bar{d}}}$		Gate sidewall junction capacitance grading coefficient for source junction.
418	$p_{bs}=p_{b\bar{d}}$	V	Bottom junction build-in potential for source junction.
419	$p_{bs_{ws}}=p_{bs_{w\bar{d}}}$	V	Sidewall junction build-in potential for source junction.
420	$p_{bs_{wgs}}=p_{bs_{w\bar{g}\bar{d}}}$	V	Gate sidewall junction build-in potential for source junction.
421	$x_{ti2s}=x_{ti2\bar{d}}$		Temperature coefficient for source junction.

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HISIM_HV Model (hisim_hv)

422	<code>cisbs=cisbd</code>	Reverse bias saturation current for source junction.
423	<code>cvbs=cvbd</code>	Bias dependence coefficient of <code>cisb</code> for source junction.
424	<code>ctemps=ctempd</code>	Temperature coefficient for source junction.
425	<code>cisbks=cisbkd</code> A	Reverse bias saturation current for source junction.
426	<code>divxs=divxd</code> 1/V	Reverse coefficient coefficient for source junction.
427	<code>vdifffjs=vdifffd</code> V	Threshold voltage for junction diode for source junction.

Binning model parameters

428	<code>lbinn=1.0</code>	L modulation coefficient for binning.
429	<code>wbinn=1.0</code>	W modulation coefficient for binning.
430	<code>lvmax=0.0</code> cm/s	Length dependence of <code>vmax</code> .
431	<code>lbgtmp1=0.0</code> eV/K	Length dependence of <code>bgtmp1</code> .
432	<code>lbgtmp2=0.0</code> eV/K ²	Length dependence of <code>bgtmp2</code> .
433	<code>leg0=0.0</code> eV	Length dependence of <code>eg0</code> .
434	<code>lnovers=0.0</code> cm ⁻³	Length dependence of <code>novers</code> .
435	<code>lvfbover=0.0</code> V	Length dependence of <code>vfbover</code> .
436	<code>lnover=0.0</code> cm ⁻³	Length dependence of <code>nover</code> .
437	<code>lw12=0.0</code>	Length dependence of <code>w12</code> .
438	<code>lvfbc=0.0</code> V	Length dependence of <code>vfbc</code> .
439	<code>lnsubc=0.0</code> cm ⁻³	Length dependence of <code>nsubc</code> .
440	<code>lnsubp=0.0</code> cm ⁻³	Length dependence of <code>nsubp</code> .
441	<code>lscp1=0.0</code> 1/V	Length dependence of <code>scp1</code> .

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HISIM_HV Model (hisim_hv)

442	$l_{scp2}=0.0$	$1/V^2$	Length dependence of scp2.
443	$l_{scp3}=0.0$	m/V^2	Length dependence of scp3.
444	$l_{sc1}=0.0$	$1/V$	Length dependence of sc1.
445	$l_{sc2}=0.0$	$1/V^2$	Length dependence of sc2.
446	$l_{sc3}=0.0$	m/V^2	Length dependence of sc3.
447	$l_{pgd1}=0.0$	V	Length dependence of pgd1.
448	$l_{pgd3}=0.0$		Length dependence of pgd3.
449	$l_{ndep}=0.0$		Length dependence of ndep.
450	$l_{ninv}=0.0$		Length dependence of ninv.
451	$l_{muecb0}=0.0$	$cm^2/(V \cdot s)$	Length dependence of muecb0.
452	$l_{muecb1}=0.0$	$cm^2/(V \cdot s)$	Length dependence of muecb1.
453	$l_{mueph1}=0.0$		Length dependence of mueph1.
454	$l_{vtmp}=0.0$	cm/s	Length dependence of vtmp.
455	$l_{wvth0}=0.0$		Length dependence of wvth0.
456	$l_{muesr1}=0.0$		Length dependence of muesr1.
457	$l_{muetmp}=0.0$		Length dependence of muetmp.
458	$l_{sub1}=0.0$	$1/V$	Length dependence of sub1.
459	$l_{sub2}=0.0$	V	Length dependence of sub2.
460	$l_{svds}=0.0$		Length dependence of svds.
461	$l_{svbs}=0.0$		Length dependence of svbs.
462	$l_{svgs}=0.0$		Length dependence of svgs.

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HISIM_HV Model (hisim_hv)

463	lfn1=0.0	Length dependence of fn1.
464	lfn2=0.0	Length dependence of fn2.
465	lfn3=0.0	Length dependence of fn3.
466	lfvbs=0.0	Length dependence of fvbs.
467	lnsti=0.0 cm ⁻³	Length dependence of nsti.
468	lwsti=0.0 m	Length dependence of wsti.
469	lscsti1=0.0	Length dependence of scsti1.
470	lscsti2=0.0 1/V	Length dependence of scsti2.
471	lvthsti=0.0	Length dependence of vthsti.
472	lmuesti1=0.0	Length dependence of muesti1.
473	lmuesti2=0.0	Length dependence of muesti2.
474	lmuesti3=0.0	Length dependence of muesti3.
475	lnsubpsti1=0.0 m	Length dependence of nsubpsti1.
476	lnsubpsti2=0.0 m	Length dependence of nsubpsti2.
477	lnsubpsti3=0.0 m	Length dependence of nsubpsti3.
478	lcgso=0.0 F/m	Length dependence of cgso.
479	lcgdo=0.0 F/m	Length dependence of cgdo.
480	ljs0=0.0 A/m ²	Length dependence of js0.
481	ljs0sw=0.0 A/m	Length dependence of js0sw.
482	lnj=0.0	Length dependence of nj.
483	lcisbk=0.0 A	Length dependence of cisbk.
484	lclm1=0.0	Length dependence of clm1.

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

485	$l_{clm2}=0.0$	$1/m$	Length dependence of $clm2$.
486	$l_{clm3}=0.0$		Length dependence of $clm3$.
487	$l_{wfc}=0.0$	$m \text{ F}/cm^2$	Length dependence of wfc .
488	$l_{gidl1}=0.0$	$A \text{ m}/(V^{(3/2)} c^{(1/2)})$	Length dependence of $gidl1$.
489	$l_{gidl2}=0.0$	$1/(V^{(1/2)} c^{(3/2)} m)$	Length dependence of $gidl2$.
490	$l_{gleak1}=0.0$	$A/(V^{(3/2)} c^{(1/2)})$	Length dependence of $gleak1$.
491	$l_{gleak2}=0.0$	$1/(V^{(1/2)} c^{(3/2)} m)$	Length dependence of $gleak2$.
492	$l_{gleak3}=0.0$		Length dependence of $gleak3$.
493	$l_{gleak6}=0.0$	V	Length dependence of $gleak6$.
494	$l_{glksd1}=0.0$		Length dependence of $glksd1$.
495	$l_{glksd2}=0.0$		Length dependence of $glksd2$.
496	$l_{glkb1}=0.0$		Length dependence of $glkb1$.
497	$l_{glkb2}=0.0$		Length dependence of $glkb2$.
498	$l_{nftrp}=0.0$		Length dependence of $nftrp$.
499	$l_{nfalp}=0.0$		Length dependence of $nfalp$.
500	$l_{pthrou}=0.0$		Length dependence of $pthrou$.
501	$l_{vdifffj}=0.0$	V	Length dependence of $vdifffj$.
502	$l_{ibpc1}=0.0$		Length dependence of $ibpc1$.
503	$l_{ibpc2}=0.0$		Length dependence of $ibpc2$.
504	$l_{cgbo}=0.0$		Length dependence of $cgbo$.

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HISIM_HV Model (hisim_hv)

505	lcvdsover=0.0	Length dependence of cvdsover.
506	lfalph=0.0	Length dependence of falph.
507	lnpext=0.0	Length dependence of npext.
508	lpowrat=0.0	Length dependence of powrat.
509	lrd=0.0	Length dependence of rd.
510	lrd22=0.0	Length dependence of rd22.
511	lrd23=0.0	Length dependence of rd23.
512	lrd24=0.0	Length dependence of rd24.
513	lrdict1=0.0	Length dependence of rdict1.
514	lrdov13=0.0	Length dependence of rdov13.
515	lrdslp1=0.0	Length dependence of rdslp1.
516	lrdvb=0.0	Length dependence of rdvb.
517	lrdvd=0.0	Length dependence of rdvd.
518	lrdvg11=0.0	Length dependence of rdvg11.
519	lrs=0.0	Length dependence of rs.
520	lrth0=0.0	Length dependence of rth0.
521	lvover=0.0	Length dependence of vover.
522	ljs0d=ljs0	Length dependence of js0d.
523	ljs0swd=ljs0sw	Length dependence of js0swd.
524	lnjd=lnj	Length dependence of njd.
525	lcisbkd=lcisbk	Length dependence of cisbkd.
526	lvdiffjd=lvdiffj	Length dependence of vdiffjd.

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HISIM_HV Model (hisim_hv)

527	$ljs0s=ljs0d$	Length dependence of $js0s$.
528	$ljs0sws=ljs0swd$	Length dependence of $js0sws$.
529	$lnjs=lnjd$	Length dependence of njs .
530	$lcisbks=lcisbkd$	Length dependence of $cisbks$.
531	$lvdiffjs=lvdiffjd$	Length dependence of $vdiffjs$.
532	$wvmax=0.0$ cm/s	Width dependence of $vmax$.
533	$wbgtmp1=0.0$ eV/K	Width dependence of $bgtmp1$.
534	$wbgtmp2=0.0$ eV/K ²	Width dependence of $bgtmp2$.
535	$weg0=0.0$ eV	Width dependence of $eg0$.
536	$wnovers=0.0$ cm ⁻³	Width dependence of $novers$.
537	$wvfbover=0.0$ V	Width dependence of $vfbover$.
538	$wnover=0.0$ cm ⁻³	Width dependence of $nover$.
539	$wwl2=0.0$	Width dependence of $wl2$.
540	$wvfbc=0.0$ V	Width dependence of $vfbc$.
541	$wnsubc=0.0$ cm ⁻³	Width dependence of $nsubc$.
542	$wnsubp=0.0$ cm ⁻³	Width dependence of $nsubp$.
543	$wscp1=0.0$ 1/V	Width dependence of $scp1$.
544	$wscp2=0.0$ 1/V ²	Width dependence of $scp2$.
545	$wscp3=0.0$ m/V ²	Width dependence of $scp3$.
546	$wsc1=0.0$ 1/V	Width dependence of $sc1$.
547	$wsc2=0.0$ 1/V ²	Width dependence of $sc2$.

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HISIM_HV Model (hisim_hv)

548	$w_{sc3}=0.0 \text{ m/V}^2$	Width dependence of sc3.
549	$w_{pgd1}=0.0 \text{ V}$	Width dependence of pgd1.
550	$w_{pgd3}=0.0$	Width dependence of pgd3.
551	$w_{ndep}=0.0$	Width dependence of ndep.
552	$w_{ninvs}=0.0$	Width dependence of ninvs.
553	$w_{muecb0}=0.0 \text{ cm}^2/(\text{V s})$	Width dependence of muecb0.
554	$w_{muecb1}=0.0 \text{ cm}^2/(\text{V s})$	Width dependence of muecb1.
555	$w_{mueph1}=0.0$	Width dependence of mueph1.
556	$w_{vtmp}=0.0 \text{ cm/s}$	Width dependence of vtmp.
557	$w_{wvth0}=0.0$	Width dependence of wvth0.
558	$w_{muesr1}=0.0$	Width dependence of muesr1.
559	$w_{muetmp}=0.0$	Width dependence of muetmp.
560	$w_{sub1}=0.0 \text{ 1/V}$	Width dependence of sub1.
561	$w_{sub2}=0.0 \text{ V}$	Width dependence of sub2.
562	$w_{svds}=0.0$	Width dependence of svds.
563	$w_{svbs}=0.0$	Width dependence of svbs.
564	$w_{svgs}=0.0$	Width dependence of svgs.
565	$w_{fn1}=0.0$	Width dependence of fn1.
566	$w_{fn2}=0.0$	Width dependence of fn2.
567	$w_{fn3}=0.0$	Width dependence of fn3.
568	$w_{fvbs}=0.0$	Width dependence of fvbs.

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

569	$w_{nsti}=0.0 \text{ cm}^{-3}$	Width dependence of n_{sti} .
570	$w_{wsti}=0.0 \text{ m}$	Width dependence of w_{sti} .
571	$w_{scsti1}=0.0$	Width dependence of $scsti1$.
572	$w_{scsti2}=0.0 \text{ 1/V}$	Width dependence of $scsti2$.
573	$w_{vthsti}=0.0$	Width dependence of $vthsti$.
574	$w_{muesti1}=0.0$	Width dependence of $muesti1$.
575	$w_{muesti2}=0.0$	Width dependence of $muesti2$.
576	$w_{muesti3}=0.0$	Width dependence of $muesti3$.
577	$w_{nsubpsti1}=0.0 \text{ m}$	Width dependence of $nsubpsti1$.
578	$w_{nsubpsti2}=0.0 \text{ m}$	Width dependence of $nsubpsti2$.
579	$w_{nsubpsti3}=0.0 \text{ m}$	Width dependence of $nsubpsti3$.
580	$w_{cgso}=0.0 \text{ F/m}$	Width dependence of $cgso$.
581	$w_{cgdo}=0.0 \text{ F/m}$	Width dependence of $cgdo$.
582	$w_{js0}=0.0 \text{ A/m}^2$	Width dependence of $js0$.
583	$w_{js0sw}=0.0 \text{ A/m}$	Width dependence of $js0sw$.
584	$w_{nj}=0.0$	Width dependence of nj .
585	$w_{cisbk}=0.0 \text{ A}$	Width dependence of $cisbk$.
586	$w_{clm1}=0.0$	Width dependence of $clm1$.
587	$w_{clm2}=0.0 \text{ 1/m}$	Width dependence of $clm2$.
588	$w_{clm3}=0.0$	Width dependence of $clm3$.
589	$w_{wfc}=0.0 \text{ m F/cm}^2$	Width dependence of wfc .

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

- 590 $wgidl1=0.0$ A m / ($V^{(3/2)} c^{(1/2)}$)
Width dependence of gidl1.
- 591 $wgidl2=0.0$ 1 / ($V^{(1/2)} c^{(3/2)} m$)
Width dependence of gidl2.
- 592 $wgleak1=0.0$ A / ($V^{(3/2)} c^{(1/2)}$)
Width dependence of gleak1.
- 593 $wgleak2=0.0$ 1 / ($V^{(1/2)} c^{(3/2)} m$)
Width dependence of gleak2.
- 594 $wgleak3=0.0$ Width dependence of gleak3.
- 595 $wgleak6=0.0$ V Width dependence of gleak6.
- 596 $wglksd1=0.0$ Width dependence of glksd1.
- 597 $wglksd2=0.0$ Width dependence of glksd2.
- 598 $wglkb1=0.0$ Width dependence of glkb1.
- 599 $wglkb2=0.0$ Width dependence of glkb2.
- 600 $wnftrp=0.0$ Width dependence of nfrp.
- 601 $wnfalp=0.0$ Width dependence of nfalp.
- 602 $wpthrou=0.0$ Width dependence of pthrou.
- 603 $wvdiffj=0.0$ V Width dependence of vdiffj.
- 604 $wibpc1=0.0$ Width dependence of ibpc1.
- 605 $wibpc2=0.0$ Width dependence of ibpc2.
- 606 $wcgbo=0.0$ Width dependence of cgbo.
- 607 $wcvdsover=0.0$ Width dependence of cvdsover.
- 608 $wfalph=0.0$ Width dependence of falph.
- 609 $wnpext=0.0$ Width dependence of npext.

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

610	wpowrat=0.0	Width dependence of powrat.
611	wrd=0.0	Width dependence of rd.
612	wrd22=0.0	Width dependence of rd22.
613	wrd23=0.0	Width dependence of rd23.
614	wrd24=0.0	Width dependence of rd24.
615	wrdict1=0.0	Width dependence of rdict1.
616	wrdov13=0.0	Width dependence of rdov13.
617	wrdslp1=0.0	Width dependence of rds1p1.
618	wrdvb=0.0	Width dependence of rdvb.
619	wrdvd=0.0	Width dependence of rdvd.
620	wrdvg11=0.0	Width dependence of rdvg11.
621	wrs=0.0	Width dependence of rs.
622	wrth0=0.0	Width dependence of rth0.
623	wvover=0.0	Width dependence of vover.
624	wjs0d=wjs0	Width dependence of js0d.
625	wjs0swd	Width dependence of js0swd.
626	wnjd	Width dependence of njd.
627	wcisbkd	Width dependence of cisbkd.
628	wvdiffjd	Width dependence of vdiffjd.
629	wjs0s	Width dependence of js0s.
630	wjs0sws	Width dependence of js0sws.
631	wnjs	Width dependence of njs.

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HISIM_HV Model (hisim_hv)

632	wc isbks	Width dependence of cisbks .
633	wv diffjs	Width dependence of vdiffjs .
634	pv max=0.0 cm/s	Cross-term dependence of vmax .
635	pb gtmp1=0.0 eV/K	Cross-term dependence of bgtmp1 .
636	pb gtmp2=0.0 eV/K ²	Cross-term dependence of bgtmp2 .
637	peg 0=0.0 eV	Cross-term dependence of eg0 .
638	pn overs=0.0 cm ⁻³	Cross-term dependence of novers .
639	pv fbover=0.0 V	Cross-term dependence of vfbover .
640	pn over=0.0 cm ⁻³	Cross-term dependence of nover .
641	pw l2=0.0	Cross-term dependence of wl2 .
642	pv fbc=0.0 V	Cross-term dependence of vfbc .
643	pn subc=0.0 cm ⁻³	Cross-term dependence of nsubc .
644	pn subp=0.0 cm ⁻³	Cross-term dependence of nsubp .
645	ps cp1=0.0 1/V	Cross-term dependence of scp1 .
646	ps cp2=0.0 1/V ²	Cross-term dependence of scp2 .
647	ps cp3=0.0 m/V ²	Cross-term dependence of scp3 .
648	ps c1=0.0 1/V	Cross-term dependence of sc1 .
649	ps c2=0.0 1/V ²	Cross-term dependence of sc2 .
650	ps c3=0.0 m/V ²	Cross-term dependence of sc3 .
651	pp gd1=0.0 V	Cross-term dependence of pgd1 .
652	pp gd3=0.0	Cross-term dependence of pgd3 .

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

653	<code>pndep=0.0</code>		Cross-term dependence of <code>ndep</code> .
654	<code>pninv=0.0</code>		Cross-term dependence of <code>ninv</code> .
655	<code>pmuecb0=0.0</code>	$\text{cm}^2/(\text{V s})$	Cross-term dependence of <code>muecb0</code> .
656	<code>pmuecb1=0.0</code>	$\text{cm}^2/(\text{V s})$	Cross-term dependence of <code>muecb1</code> .
657	<code>pmueph1=0.0</code>		Cross-term dependence of <code>mueph1</code> .
658	<code>pvtmp=0.0</code>	cm/s	Cross-term dependence of <code>vtmp</code> .
659	<code>pwvth0=0.0</code>		Cross-term dependence of <code>wvth0</code> .
660	<code>pmuesr1=0.0</code>		Cross-term dependence of <code>muesr1</code> .
661	<code>pmuetmp=0.0</code>		Cross-term dependence of <code>muetmp</code> .
662	<code>psub1=0.0</code>	$1/\text{V}$	Cross-term dependence of <code>sub1</code> .
663	<code>psub2=0.0</code>	V	Cross-term dependence of <code>sub2</code> .
664	<code>psvds=0.0</code>		Cross-term dependence of <code>svds</code> .
665	<code>psvbs=0.0</code>		Cross-term dependence of <code>svbs</code> .
666	<code>psvgs=0.0</code>		Cross-term dependence of <code>svgs</code> .
667	<code>pfn1=0.0</code>		Cross-term dependence of <code>fn1</code> .
668	<code>pfn2=0.0</code>		Cross-term dependence of <code>fn2</code> .
669	<code>pfn3=0.0</code>		Cross-term dependence of <code>fn3</code> .
670	<code>pfvbs=0.0</code>		Cross-term dependence of <code>fvbs</code> .
671	<code>pnsti=0.0</code>	cm^{-3}	Cross-term dependence of <code>nsti</code> .
672	<code>pwsti=0.0</code>	m	Cross-term dependence of <code>wsti</code> .
673	<code>pscsti1=0.0</code>		Cross-term dependence of <code>scsti1</code> .

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

674	$p_{scsti2}=0.0$	1/V	Cross-term dependence of scsti2.
675	$p_{vthsti}=0.0$		Cross-term dependence of vthsti.
676	$p_{muesti1}=0.0$		Cross-term dependence of muesti1.
677	$p_{muesti2}=0.0$		Cross-term dependence of muesti2.
678	$p_{muesti3}=0.0$		Cross-term dependence of muesti3.
679	$p_{nsubpsti1}=0.0$	m	Cross-term dependence of nsubpsti1.
680	$p_{nsubpsti2}=0.0$	m	Cross-term dependence of nsubpsti2.
681	$p_{nsubpsti3}=0.0$	m	Cross-term dependence of nsubpsti3.
682	$p_{cgso}=0.0$	F/m	Cross-term dependence of cgso.
683	$p_{cgdo}=0.0$	F/m	Cross-term dependence of cgdo.
684	$p_{js0}=0.0$	A/m ²	Cross-term dependence of js0.
685	$p_{js0sw}=0.0$	A/m	Cross-term dependence of js0sw.
686	$p_{nj}=0.0$		Cross-term dependence of nj.
687	$p_{cisbk}=0.0$	A	Cross-term dependence of cisbk.
688	$p_{clm1}=0.0$		Cross-term dependence of clm1.
689	$p_{clm2}=0.0$	1/m	Cross-term dependence of clm2.
690	$p_{clm3}=0.0$		Cross-term dependence of clm3.
691	$p_{wfc}=0.0$	m F/cm ²	Cross-term dependence of wfc.
692	$p_{gidl1}=0.0$	A m/(V ^(3/2) c ^(1/2))	Cross-term dependence of gidl1.
693	$p_{gidl2}=0.0$	1/(V ^(1/2) c ^(3/2) m)	Cross-term dependence of gidl2.

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

694	$pgleak1=0.0 \ A / (V^{(3/2)} \ c^{(1/2)})$	Cross-term dependence of gleak1.
695	$pgleak2=0.0 \ 1 / (V^{(1/2)} \ c^{(3/2)} \ m)$	Cross-term dependence of gleak2.
696	$pgleak3=0.0$	Cross-term dependence of gleak3.
697	$pgleak6=0.0 \ V$	Cross-term dependence of gleak6.
698	$pglksd1=0.0$	Cross-term dependence of glksd1.
699	$pglksd2=0.0$	Cross-term dependence of glksd2.
700	$pglkb1=0.0$	Cross-term dependence of glkb1.
701	$pglkb2=0.0$	Cross-term dependence of glkb2.
702	$pnftrp=0.0$	Cross-term dependence of nftrp.
703	$pnfalp=0.0$	Cross-term dependence of nfalp.
704	$ppthrou=0.0$	Cross-term dependence of pthrou.
705	$pvdifffj=0.0 \ V$	Cross-term dependence of vdiffj.
706	$pibpc1=0.0$	Cross-term dependence of ibpc1.
707	$pibpc2=0.0$	Cross-term dependence of ibpc2.
708	$pcgbo=0.0$	Cross-term dependence of cgbo.
709	$pcvdsover=0.0$	Cross-term dependence of cvdsover.
710	$pfalph=0.0$	Cross-term dependence of falph.
711	$pnpext=0.0$	Cross-term dependence of npext.
712	$ppowrat=0.0$	Cross-term dependence of powrat.
713	$prd=0.0$	Cross-term dependence of rd.
714	$prd22=0.0$	Cross-term dependence of rd22.

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HISIM_HV Model (hisim_hv)

715	prd23=0.0	Cross-term dependence of rd23.
716	prd24=0.0	Cross-term dependence of rd24.
717	prdict1=0.0	Cross-term dependence of rdict1.
718	prdov13=0.0	Cross-term dependence of rdov13.
719	prdslp1=0.0	Cross-term dependence of rds1p1.
720	prdvb=0.0	Cross-term dependence of rdvb.
721	prdvd=0.0	Cross-term dependence of rdvd.
722	prdv11=0.0	Cross-term dependence of rdvg11.
723	prs=0.0	Cross-term dependence of rs.
724	prth0=0.0	Cross-term dependence of rth0.
725	plover=0.0	Cross-term dependence of vover.
726	pjs0d	Cross-term dependence of js0d.
727	pjs0swd	Cross-term dependence of js0swd.
728	pnjd	Cross-term dependence of njd.
729	pcisbkd	Cross-term dependence of cisbkd.
730	pvdifffd	Cross-term dependence of vdiffjd.
731	pjs0s	Cross-term dependence of js0s.
732	pjs0sws	Cross-term dependence of js0sws.
733	pnjs	Cross-term dependence of njs.
734	pcisbks	Cross-term dependence of cisbks.
735	pvdiffjs	Cross-term dependence of vdiffjs.
736	gdsleak=0.0 S	Channel leakage conductance.

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

737 `coerrrep=1` selector for error report.

Output Parameters

1 `tempeff` (C) Effective temperature for a single device.
2 `weff` (m) Effective channel width.
3 `leff` (m) Effective channel length.

Operating-Point Parameters

1 `temp` (C) Device temperature.
2 `shetemp` (C) Temperature rise due to self-heating.
3 `reversed` Reverse mode indicator.
Possible values are `no` and `yes`.
4 `ids` (A) Resistive drain-to-source current.
5 `vgs` (V) Gate-source voltage.
6 `vds` (V) Drain-source voltage.
7 `vbs` (V) Bulk-source voltage.
8 `vth` (V) Threshold voltage.
9 `vdsat` (V) Drain-source saturation voltage.
10 `gm` (S) Common-source transconductance.
11 `gds` (S) Common-source output conductance.
12 `gmbs` (S) Body-transconductance.
13 `qb` (Coul) Total bulk charge.
14 `qd` (Coul) Total drain charge.
15 `qg` (Coul) Total gate charge.

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HISIM_HV Model (hisim_hv)

16	qs (Coul)	Total source charge.
17	qb_itr (Coul)	Intrinsic bulk charge.
18	qd_itr (Coul)	Intrinsic drain charge.
19	qg_itr (Coul)	Intrinsic gate charge.
20	qs_itr (Coul)	Intrinsic source charge.
21	qdp (Coul)	Total external drain charge.
22	qsp (Coul)	Total external source charge.
23	cjd (F)	Drain-bulk junction capacitance.
24	cjs (F)	Source-bulk junction capacitance.
25	cgg (F)	Intrinsic dQg_dVg .
26	cgd (F)	dQg_dVd .
27	cgs (F)	dQg_dVs .
28	cgb (F)	dQg_dVb .
29	cdg (F)	dQd_dVg .
30	cdđ (F)	Intrinsic dQd_dVd .
31	cds (F)	dQd_dVs .
32	cdb (F)	dQd_dVb .
33	csg (F)	dQs_dVg .
34	csđ (F)	dQs_dVd .
35	css (F)	Intrinsic dQs_dVs .
36	csb (F)	dQs_dVb .
37	cbg (F)	dQb_dVg .

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

38	cbd (F)	dQb_{dVd} .
39	cbs (F)	dQb_{dVs} .
40	cbb (F)	Intrinsic dQb_{dVb} .
41	cdd_{tot} (F)	Total dQd_{dVd} .
42	cgg_{tot} (F)	Total dQg_{dVg} .
43	css_{tot} (F)	Total dQs_{dVs} .
44	cbb_{tot} (F)	Total dQb_{dVb} .
45	id (A)	Resistive drain current.
46	ig (A)	Gate current.
47	is (A)	Resistive source current.
48	$ibulk$ (A)	Resistive bulk current.
49	pwr (W)	Power at operating point.
50	$ps0$ (V)	Surface potential at source side.
51	$ps1$ (V)	Surface potential at drain side.
52	pds (V)	Delta surface potential between $ps1$ and $ps0$.
53	$isub$ (A)	Substrate current I_{sub} .
54	$isubld$ (A)	Substrate current I_{subLD} .
55	$idsibpc$ (A)	Impact-Ionization Induced Bulk Potential Change (IBPC).
56	$gbds$ (S)	Substrate trans conductance (dI_{sub}/dV_{ds}).
57	$gbgs$ (S)	Substrate trans conductance (dI_{sub}/dV_{gs}).
58	$gbbs$ (S)	Substrate transconductance (dI_{sub}/dV_{bs}).
59	$igate$ (A)	Gate current due to tunneling.

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

60	<code>igates</code> (A)	Tunneling current from gate to source.
61	<code>igateb</code> (A)	Tunneling current from gate to bulk.
62	<code>igated</code> (A)	Tunneling current from gate to drain.
63	<code>igisl</code> (A)	Gate-induced source leakage current.
64	<code>igidl</code> (A)	Gate-induced drain leakage current.
65	<code>ibs</code> (A)	Source-bulk diode current.
66	<code>ibd</code> (A)	Source-drain diode current.
67	<code>cgso</code> (F)	Gate-source overlap capacitance.
68	<code>cgbo</code> (F)	Gate-bulk overlap capacitance.
69	<code>cgdo</code> (F)	Gate-drain overlap capacitance.
70	<code>cggo</code> (F)	Gate-gate overlap capacitance.
71	<code>cd do</code> (F)	Drain-drain overlap capacitance.
72	<code>csso</code> (F)	Source-source overlap capacitance.
73	<code>cbbo</code> (F)	Bulk-bulk overlap capacitance.
74	<code>rseff</code> (Ω)	Effective source resistance.
75	<code>rdeff</code> (Ω)	Effective drain resistance.
76	<code>rsdrift</code> (Ω)	The resistance of drift region for source side.
77	<code>rdrift</code> (Ω)	The resistance of drift region for drain side.
78	<code>gmt</code> (S)	Temp transconductance.
79	<code>lx4</code> (A)	Resistive drain-to-source current.
80	<code>lx7</code> (S)	Common-source transconductance.
81	<code>lx8</code> (S)	Common-source output conductance.

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

82 lv9 (V) Threshold voltage.

Parameter Index

In the following index, I refers to instance parameters, M refers to the model parameters section, O refers to the output parameters section, and OP refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of M-35 means the 35th model parameter.

ad	I-4	lfn1	M-463	pgd1	M-118	sub1	M-196
ad	M-34	lfn2	M-464	pgd2	M-119	sub11	M-203
alarm	M-22	lfn3	M-465	pgd3	M-120	sub11p	M-216
as	I-3	lfvbs	M-466	pgd4	M-121	sub2	M-197
as	M-33	lgidl1	M-488	pgidl1	M-692	sub21	M-204
bb	M-171	lgidl2	M-489	pgidl2	M-693	sub1d1	I-23
bgtmp1	M-98	lgleak1	M-490	pgleak1	M-694	sub1d1	M-88
bgtmp2	M-99	lgleak2	M-491	pgleak2	M-695	sub1d11	M-89
bs1	M-132	lgleak3	M-492	pgleak3	M-696	sub1d11p	M-90
bs2	M-133	lgleak6	M-493	pgleak6	M-697	sub1d2	I-24
bvd	M-301	lg1kb1	M-496	pg1kb1	M-700	sub1d2	M-91
bvj	M-303	lg1kb2	M-497	pg1kb2	M-701	svbs	M-199
bvs	M-302	lg1ksd1	M-494	pg1ksd1	M-698	svbs1	M-200
cbb	OP-40	lg1ksd2	M-495	pg1ksd2	M-699	svbs1p	M-213
cbb_tot	OP-44	libpc1	M-502	piibpc1	M-706	svds	M-201

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HISIM_HV Model (hisim_hv)

cbbo	OP-73	libpc2	M-503	pibpc2	M-707	svgs	M-198
cbd	OP-38	ljs0	M-480	pjs0	M-684	svgs1	M-209
cbg	OP-37	ljs0d	M-522	pjs0d	M-726	svgs1p	M-210
cbs	OP-39	ljs0s	M-527	pjs0s	M-731	svgsw	M-212
cdb	OP-32	ljs0sw	M-481	pjs0sw	M-685	svgswp	M-211
cdd	OP-30	ljs0swd	M-523	pjs0swd	M-727	tcjbd	M-263
cdd_tot	OP-41	ljs0sws	M-528	pjs0sws	M-732	tcjbdsw	M-264
cddo	OP-71	l1	M-52	pmuecb0	M-655	tcjbdswg	M-265
cdg	OP-29	l1d	M-53	pmuecb1	M-656	tcjbs	M-266
cds	OP-31	l1n	M-54	pmueph1	M-657	tcjbssw	M-267
cgb	OP-28	lmax	M-350	pmuesr1	M-660	tcjbsswg	M-268
cgbo	M-285	lmin	M-351	pmuesti1	M-676	temp	M-37
cgbo	OP-68	lmuecb0	M-451	pmuesti2	M-677	temp	OP-1
cgd	OP-26	lmuecb1	M-452	pmuesti3	M-678	tempeff	O-1
cgdo	M-284	lmueph1	M-453	pmuetmp	M-661	tnom	M-17
cgdo	OP-69	lmuesr1	M-456	pndep	M-653	tox	M-39
cgg	OP-25	lmuesti1	M-472	pnfalp	M-703	tpoly	M-43
cgg_tot	OP-42	lmuesti2	M-473	pnftrp	M-702	type	M-1
cggo	OP-70	lmuesti3	M-474	pninv	M-654	vbd_max	M-355
cgs	OP-27	lmuetmp	M-457	pnj	M-686	vbi	M-58
cgso	M-283	lndep	M-449	pnjd	M-728	vbisub	M-298

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HISIM_HV Model (hisim_hv)

cgso	OP-67	lnfalp	M-499	pnjs	M-733	vbox	M-304
cisb	M-277	lnftrp	M-498	pnover	M-640	vbs	OP-7
cisbd	M-401	lninv	M-450	pnovers	M-638	vbs_max	M-356
cisbk	M-280	lnj	M-482	pnpext	M-711	vbsmin	M-314
cisbkd	M-404	lnjd	M-524	pnsti	M-671	vdiffj	M-275
cisbks	M-425	lnjs	M-529	pnsbuc	M-643	vdiffjd	M-406
cisbs	M-422	lnover	M-436	pnsbucp	M-644	vdiffjs	M-427
cit	M-244	lnovers	M-434	pnsbucpsti1	M-679	vds	OP-6
cj	M-260	lnpext	M-507	pnsbucpsti2	M-680	vds_max	M-352
cjd	M-391	lnsti	M-467	pnsbucpsti3	M-681	vdsat	OP-9
cjd	OP-23	lnsubc	M-439	powrat	M-345	vdsti	M-158
cjs	M-412	lnsubp	M-440	ppgd1	M-651	version	M-3
cjs	OP-24	lnsubpsti1	M-475	ppgd3	M-652	vfbc	M-48
cjsw	M-261	lnsubpsti2	M-476	ppowrat	M-712	vfbover	M-288
cjswd	M-392	lnsubpsti3	M-477	ppthrou	M-704	vgb_max	M-357
cjswg	M-262	lod	I-21	prattemp1	M-112	vgbr_max	M-360
cjswgd	M-393	lover	I-27	prattemp2	M-113	vgd_max	M-353
cjswgs	M-414	lover	M-51	prd	M-713	vgdr_max	M-358
cjsws	M-413	loverld	I-29	prd22	M-714	vgs	OP-5
clm1	M-191	loverld	M-82	prd23	M-715	vgs_max	M-354
clm2	M-192	lovers	I-28	prd24	M-716	vgsmin	M-347

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clm3	M-193	lovers	M-83	prdict1	M-717	vgsr_max	M-359
clm5	M-194	lp	M-49	prdov13	M-718	vmax	M-172
clm6	M-195	lpext	M-61	prdslp1	M-719	vmxt1	M-102
coadov	M-7	lpgd1	M-447	prdvb	M-720	vmxt2	M-103
coclampc	M-252	lpgd3	M-448	prdvd	M-721	vover	M-173
codfm	M-23	lpowrat	M-508	prdvgl1	M-722	voverp	M-174
coerrrep	M-737	lpthrou	M-500	prs	M-723	vovers	M-175
coflick	M-13	lrd	M-509	prth0	M-724	voversp	M-176
cogidl	M-9	lrd22	M-510	ps	I-5	vth	OP-8
coign	M-20	lrd23	M-511	ps	M-35	vthsti	M-143
coiigs	M-10	lrd24	M-512	ps0	OP-50	vtmp	M-177
coiprv	M-5	lrdict1	M-513	psc1	M-648	vzadd0	M-253
coisti	M-14	lrdov13	M-514	psc2	M-649	w	I-1
coisub	M-8	lrdslp1	M-515	psc3	M-650	w	M-31
coldrift	M-29	lrdvb	M-516	pscp1	M-645	warn	M-300
compatible	M-21	lrdvd	M-517	pscp2	M-646	wbgtmp1	M-533
conqs	M-15	lrdvg11	M-518	pscp3	M-647	wbgtmp2	M-534
coovlp	M-11	lrs	M-519	pscsti1	M-673	wbinn	M-429
coovlps	M-12	lrth0	M-520	pscsti2	M-674	wcgbo	M-606
copprv	M-6	lsc1	M-444	psl	OP-51	wcgdo	M-581
coqovsm	M-27	lsc2	M-445	psub1	M-662	wcgso	M-580

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corbnet	I-10	lsc3	M-446	psub2	M-663	wcisbk	M-585
corbnet	M-19	lscp1	M-441	psvbs	M-665	wcisbkd	M-627
cordrift	M-30	lscp2	M-442	psvds	M-664	wcisbks	M-632
corg	I-16	lscp3	M-443	psvgs	M-666	wclm1	M-586
corg	M-18	lscsti1	M-469	pt2	M-363	wclm2	M-587
corsrd	M-4	lscsti2	M-470	pt4	M-368	wclm3	M-588
coselfheat	I-15	lsub1	M-458	pt4p	M-369	wcvdsover	M-607
coselfheat	M-24	lsub2	M-459	pthrou	M-245	weff	O-2
cosubnode	I-14	lsvbs	M-461	pt1	M-361	weg0	M-535
cosubnode	M-25	lsvds	M-460	ptlp	M-364	wfalph	M-608
cosym	M-26	lsvgs	M-462	ptp	M-362	wfc	M-134
cotemp	M-28	lv9	OP-82	pvdifffj	M-705	wfn1	M-565
cothrml	M-16	lvdiffj	M-501	pvdifffjd	M-730	wfn2	M-566
csb	OP-36	lvdiffjfd	M-526	pvdifffjs	M-735	wfn3	M-567
csd	OP-34	lvdifffjs	M-531	pvfbc	M-642	wfvbs	M-568
csg	OP-33	lvfbc	M-438	pvfbover	M-639	wgidl1	M-590
css	OP-35	lvfbover	M-435	pvmx	M-634	wgidl2	M-591
css_tot	OP-43	lvmax	M-430	pvoover	M-725	wgleak1	M-592
csso	OP-72	lvover	M-521	pvthsti	M-675	wgleak2	M-593
ctemp	M-279	lvthsti	M-471	pvtmp	M-658	wgleak3	M-594
ctempd	M-403	lvtmp	M-454	pwfc	M-691	wgleak6	M-595

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ctemps	M-424	lwfc	M-487	pwl2	M-641	wglkb1	M-598
cth0	M-316	lw12	M-437	pwr	OP-49	wglkb2	M-599
cvb	M-278	lwsti	M-468	pwsti	M-672	wglksd1	M-596
cvbd	M-402	lvvth0	M-455	pvvth0	M-659	wglksd2	M-597
cvbk	M-281	lx4	OP-79	pzadd0	M-254	wibpc1	M-604
cvbs	M-423	lx7	OP-80	qjb	OP-13	wibpc2	M-605
cvdsover	M-344	lx8	OP-81	qjb_itr	OP-17	wjs0	M-582
ddltict	M-293	m	I-22	qd	OP-14	wjs0d	M-624
ddltmax	M-291	mbe0	M-308	qd_itr	OP-18	wjs0s	M-629
ddltslp	M-292	mbew1	M-307	qdfvtd	M-317	wjs0sw	M-583
ddrift	M-297	minc	M-251	qdp	OP-21	wjs0swd	M-625
divx	M-282	minr	M-250	qg	OP-15	wjs0sws	M-630
divxd	M-405	mismatchdist	M-311	qg_itr	OP-19	wl	M-55
divxs	M-426	mismatchmod	M-310	qme1	M-114	wl1	M-185
dly1	M-246	mj	M-269	qme2	M-115	wl1p	M-186
dly2	M-247	mjd	M-394	qme3	M-116	wl2	M-187
dly3	M-248	mjs	M-415	qovadd	M-95	wl2p	M-188
dlyov	M-249	mjsw	M-270	qovsm	M-328	wld	M-56
dtemp	I-7	mjswd	M-395	qs	OP-16	wln	M-57
dtemp	M-38	mjswg	M-271	qs_itr	OP-20	wmax	M-348

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HISIM_HV Model (hisim_hv)

eg0	M-97	mjswgd	M-396	qsp	OP-22	wmin	M-349
egig	M-235	mjswgs	M-417	rbpb	I-11	wmuecb0	M-553
falph	M-242	mjsws	M-416	rbpb	M-65	wmuecb1	M-554
fn1	M-205	mphdfm	M-294	rbpd	I-12	wmueph1	M-555
fn2	M-206	muecb0	M-159	rbpd	M-66	wmuesr1	M-558
fn3	M-207	muecb1	M-160	rbps	I-13	wmuesti1	M-574
fvbs	M-208	mueph0	M-161	rbps	M-67	wmuesti2	M-575
gbbs	OP-58	mueph1	M-162	rd	M-47	wmuesti3	M-576
gbds	OP-56	mueph1	M-178	rd20	M-320	wmuetmp	M-559
gbgs	OP-57	muephs	M-189	rd21	M-321	wndep	M-551
gbmin	M-68	muephw	M-139	rd22	M-322	wnfalp	M-601
gdl	M-365	mueplp	M-179	rd22d	M-323	wnftrp	M-600
gdld	M-367	muepsp	M-190	rd23	M-324	wninv	M-552
gdlp	M-366	muepwp	M-140	rd231	M-333	wnj	M-584
gds	OP-11	mueslp	M-182	rd231p	M-334	wnjd	M-626
gdsleak	M-736	muesr0	M-164	rd23s	M-335	wnjs	M-631
gidl1	M-236	muesr1	M-165	rd23sp	M-336	wnover	M-538
gidl2	M-237	muesr1	M-180	rd24	M-325	wnovers	M-536
gidl3	M-238	muesrw	M-181	rd25	M-326	wnpext	M-609
gidl4	M-239	muesti1	M-144	rd26	M-327	wnsti	M-569
gidl5	M-240	muesti2	M-145	rdef	OP-75	wnsubc	M-541

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

gleak1	M-222	muesti3	M-146	rdict1	M-79	wnsubp	M-542
gleak2	M-223	mueswp	M-142	rdict2	M-81	wnsubpsti1	M-577
gleak3	M-224	muetmp	M-163	rdov11	M-75	wnsubpsti2	M-578
gleak4	M-225	mvt0	M-306	rdov12	M-76	wnsubpsti3	M-579
gleak5	M-226	mvtw1	M-305	rdov13	M-77	wpgd1	M-549
gleak6	M-232	mvtw12	M-309	rdrbb	M-96	wpgd3	M-550
gleak7	M-233	ndep	M-166	rdrCAR	M-376	wpowrat	M-610
glkb1	M-230	ndep1	M-183	rdrCX	M-375	wpthrou	M-602
glkb2	M-231	ndep1p	M-184	rdrdjunc	M-374	wrd	M-611
glkb3	M-234	nf	I-20	rdrdl1	M-377	wrd22	M-612
glksd1	M-227	nfalp	M-241	rdrdl2	M-378	wrd23	M-613
glksd2	M-228	nftrp	M-243	rdrift	OP-77	wrd24	M-614
glksd3	M-229	ngcon	I-17	rdrmue	M-370	wrdict1	M-615
glpart1	M-221	ninv	M-167	rdrmuel	M-383	wrdov13	M-616
gm	OP-10	ninvd	M-168	rdrmuelp	M-384	wrdslp1	M-617
gmbs	OP-12	ninvdt1	M-104	rdrmuetmp	M-372	wrdvb	M-618
gmt	OP-78	ninvdt2	M-105	rdrqover	M-385	wrdvd	M-619
ibd	OP-66	ninvdw	M-169	rdrvmax	M-371	wrdvg11	M-620
ibpc1	M-217	ninvdwp	M-170	rdrvmax1	M-381	wrs	M-621
ibpc11	M-218	nj	M-257	rdrvmax1p	M-382	wrth0	M-622
ibpc11p	M-219	njd	M-388	rdrvmaxw	M-379	wsc1	M-546

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

ibpc2	M-220	njs	M-409	rdrvmaxwp	M-380	wsc2	M-547
ibs	OP-65	njsw	M-258	rdrvtmp	M-373	wsc3	M-548
ibulk	OP-48	njswd	M-389	rds	M-337	wscp1	M-543
id	OP-45	njsws	M-410	rds1p1	M-78	wscp2	M-544
ids	OP-4	nover	M-289	rds1p2	M-80	wscp3	M-545
idsibpc	OP-55	novers	M-290	rdsp	M-338	wscsti1	M-571
ig	OP-46	npext	M-62	rdtemp1	M-106	wscsti2	M-572
igate	OP-59	nrd	I-9	rdtemp2	M-107	wsti	M-138
igateb	OP-61	nrs	I-8	rdvb	M-319	wstil	M-150
igated	OP-62	nsti	M-137	rdvd	M-318	wstilp	M-151
igates	OP-60	nsubc	M-44	rdvdl	M-329	wstiw	M-156
igidl	OP-64	nsubcdfm	I-35	rdvd1p	M-330	wstiwp	M-157
igisl	OP-63	nsubcw	M-135	rdvds	M-331	wsub1	M-560
igtemp2	M-100	nsubcwp	M-136	rdvdsp	M-332	wsub2	M-561
igtemp3	M-101	nsubp	M-45	rdvdsub	M-296	wsvbs	M-563
is	OP-47	nsubp0	M-59	rdvdtemp1	M-108	wsvds	M-562
isnoisy	I-36	nsubpsti1	M-147	rdvdtemp2	M-109	wsvgs	M-564
isub	OP-53	nsubpsti2	M-148	rdvg11	M-312	wvdiffj	M-603
isubld	OP-54	nsubpsti3	M-149	rdvg12	M-313	wvdiffjd	M-628
js0	M-255	nsubsub	M-299	rdvsub	M-295	wvdiffjs	M-633
js0d	M-386	nsubwp	M-60	reversed	OP-3	wvfbc	M-540

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

js0s	M-407	ovmag	M-287	rs	M-46	wvfbover	M-537
js0sw	M-256	ovslp	M-286	rsdrift	OP-76	wvmax	M-532
js0swd	M-387	parl2	M-122	rseff	OP-74	wvover	M-623
js0sws	M-408	pb	M-272	rsh	M-63	wvth0	M-141
kappa	M-117	pbd	M-397	rshg	M-64	wvthsti	M-573
l	I-2	pbgtmp1	M-635	rth0	M-315	wvtmp	M-556
l	M-32	pbgtmp2	M-636	rth0nf	M-343	wwfc	M-589
lbgtmp1	M-431	pbs	M-418	rth0r	M-340	wwl2	M-539
lbgtmp2	M-432	pbsw	M-273	rth0w	M-341	wwsti	M-570
lbinn	M-428	pbswd	M-398	rth0wp	M-342	wwvth0	M-557
lcgbo	M-504	pbswg	M-274	rthtemp1	M-110	xgl	I-19
lcgdo	M-479	pbswgd	M-399	rthtemp2	M-111	xgw	I-18
lcgso	M-478	pbswgs	M-420	sa	I-32	xl	M-69
lcisbk	M-483	pbsws	M-419	saref	M-154	xld	M-40
lcisbkd	M-525	pcgbo	M-708	sb	I-33	xldld	M-73
lcisbks	M-530	pcgdo	M-683	sbref	M-155	xpdv	M-92
lclm1	M-484	pcgso	M-682	sc1	M-123	xpvdth	M-93
lclm2	M-485	pcisbk	M-687	sc2	M-124	xpvdthg	M-94
lclm3	M-486	pcisbkd	M-729	sc3	M-125	xqy	M-50
lcvdsover	M-505	pcisbks	M-734	sc4	M-126	xqy1	M-71
ldrift	M-339	pclm1	M-688	scpl	M-127	xqy2	M-72

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

ldrifft1	I-25	pclm2	M-689	scp2	M-128	xti	M-259
ldrifft1	M-84	pclm3	M-690	scp21	M-131	xti2	M-276
ldrifft1s	I-30	pcvdsover	M-709	scp22	M-130	xti2d	M-400
ldrifft1s	M-85	pd	I-6	scp3	M-129	xti2s	M-421
ldrifft2	I-26	pd	M-36	scsti1	M-152	xtid	M-390
ldrifft2	M-86	pds	OP-52	scsti2	M-153	xtis	M-411
ldrifft2s	I-31	peg0	M-637	sd	I-34	xw	M-70
ldrifft2s	M-87	pfalph	M-710	shemax	M-346	xwd	M-41
leff	O-3	pfn1	M-667	shetemp	OP-2	xwdc	M-42
leg0	M-433	pfn2	M-668	slg	M-202	xwdld	M-74
level	M-2	pfn3	M-669	slgl	M-214		
lfalph	M-506	pfvbs	M-670	slglp	M-215		

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

HiSIM_IGBT Model (hisim_igbt)

HiSIM_IGBTs (Insulated Gate Bipolar Transistors) have been developed for high voltage applications at 500V and above, which require low switching power and fast switching speed. The complicated IGBT structure, which combines a bipolar junction transistor (BJT) with a MOSFET for base-current switching, imposes challenging problems on compact modeling for circuit simulation. HiSIM_IGBT model combines surface-potential-based HiSIM_HV model with a thick base BJT model and make is possible to modeling real device and complicated circuit.

This chapter contains the following information:

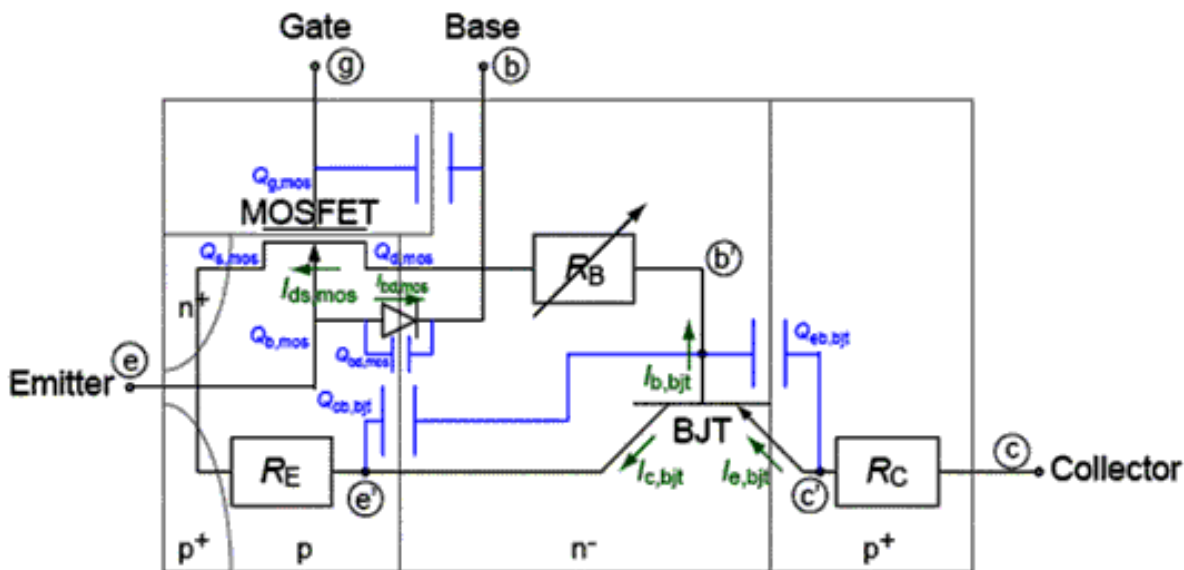
- [Model Concepts](#) on page 2530
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Model Concepts

While an IGBT generally has 3 terminals (Collector, Gate, and Emitter), HiSIM_IGBT considers 4 terminals (Collector, Gate, Emitter, and Base). HiSIM_IGBT has been developed based on the MOSFET-model framework, together with the bipolar-junction-transistor (BJT) model. Therefore newly developed MOSFET models as well as BJT models can be easily incorporated with future model extensions. Since the HiSIM_IGBT has been developed as a 4-terminal device, users have to treat the model as a 4-terminal device and let the base terminal float by connecting a zero-ampere current source between the base terminal and the ground, or by not connecting any circuit element to the base terminal.

The circuit diagram of HiSIM-IGBT is shown in Fig. 34.1. In addition to 4 external terminals, three internal nodes (b', c', e') are considered to describe all important features of IGBT. Between the internal and the external nodes, resistances are inserted to describe potential drops. Among the resistances the base resistance between the MOSFET part and the BJT part, determines the most IGBT characteristics. All current flows and induced charges are also considered.

Figure 32-1 Equivalent circuit for HiSIM_IGBT



A surface-potential-based model for high-voltage MOSFET HiSIM_HV 1.1.1 is applied as the MOSFET part. Its source and bulk terminals are connected together and are named as the “emitter” terminal. The drain terminal is connected to the “base” node within the IGBT framework. The surplus models of HiSIM_HV 1.1.1 for HiSIM_IGBT are inactivated by setting model parameters to zero. The activated model parts include: Drain-source current and related conductance; Intrinsic charges/capacitances; Overlap/parasitic charges/

Virtuoso Simulator Components and Device Models Reference

HiSIM_IGBT Model (hisim_igbt)

capacitances; STI leakage current; Bulk-drain junction diode currents/conductance; Bulk-drain junction diode charges/capacitances; Binning options. The inactivated model parts include: Source/drain drift resistances; Gate resistance; Bulk resistance network; NQS effect; Substrate leakage current; Gate leakage currents; Gate-induced drain leakage currents; Noises; Self-heating effect. As some HiSIM_HV model effects are inactivated in HiSIM_IGBT model, some redundant model parameters exist there, which will be cleaned with coming version. For the effects details of MOSFET part, please refer to the HiSIM_HV model.

Model Usage

Instance Syntax

HiSIM_IGBT instance need specify 4 or 5 terminals. The 4th terminal needs to be set as float by connecting a zero-ampere current source between the base terminal and the ground, or by not connecting any circuit element to the base terminal. Although selfheating is inactivate now and being testing, the 5th terminal can be set and will be treated as external selfheating node. To specify HiSIM_IGBT instance element, the Model Name has to be associated with a HiSIM_IGBT model card.

```
InstanceName c g e b ModelName parameter=value ...
```

Sample Instance Statement

```
m1 (vcc vgg vee vbb) n_ch w=0.1u l=0.21 m=1e-7
```

For more instance parameters, refer to the Reference of this model.

Model Syntax

The following syntax specifies HiSIM_IGBT model:

```
model ModelName hisim_igbt parameter=value ...
```

The third parameter, "hisim_igbt", is the master to indicate this model card is a HiSIM_IGBT model card.

Sample Model Statement

```
model n_ch hisim_igbt coadov=1 tox=1e-7 nsubc=1e17
```

For more model parameters, refer to the Reference of this model.

Reference

Component Statements

Instance Parameters

1	w (m)	Gate width.
2	l (m)	Gate length.
3	as (m ²)	Area of source junction.
4	ad (m ²)	Area of drain junction.
5	ps (m)	Perimeter of source junction.
6	pd (m)	Perimeter of drain junction.
7	temp (C)	Device temperature.
8	dtemp (K)	Device temperature rise from ambient.
9	nrs=1	Number of squares of source diffusion.
10	nrd=1	Number of squares of drain diffusion.
11	corbnet	Substrate resistance network selector. Inactive in HiSIM_IGBT model.
12	rbpb (Ohm)	Substrate resistance network.
13	rbpd (Ohm)	Substrate resistance network.
14	rbps (Ohm)	Substrate resistance network.
15	rbdb (Ohm)	Substrate resistance network.
16	rbsb (Ohm)	Substrate resistance network.
17	corg	Gate-contact resistance selector. Inactive in HiSIM_IGBT model.

Virtuoso Simulator Components and Device Models Reference

HiSIM_IGBT Model (hisim_igbt)

18	ngcon=1.0	Number of gate contacts.
19	xgw=0.0 m	Distance from gate contact to channel edge.
20	xgl=0.0 m	Offset of gate length due to variation in patterning.
21	nf=1.0	Number of gate fingers.
22	lod=1.0e-5 m	Length of diffusion between gate and STI.
23	m=1	Multiplicity factor (number of MOSFETs in parallel).
24	subld1	Parameter for impact-ionization current in the drift region.
25	subld2 ((V ^{3/2})/m)	Parameter for impact-ionization current in the drift region.
26	ldrift1 (m)	Parameter for drift region length-1.
27	ldrift2 (m)	Parameter for drift region length-2.
28	lover (m)	Overlap length on source side.
29	lovers (m)	Overlap length on source side.
30	loverld (m)	Overlap length on drain side.
31	ldrift1s (m)	Parameter for drift region length-1 on source side.
32	ldrift2s (m)	Parameter for drift region length-2 on source side.
33	sa=0.0 m	Distance from STI edge to Gate edge.
34	sb=0.0 m	Distance from STI edge to Gate edge.
35	sd=0.0 m	Distance from Gate edge to Gate edge.
36	nsubcdfm (cm ⁻³)	Constant part of Nsub for DFM.
37	isnoisy=yes	Should device generate noise. Possible values are no and yes.

Virtuoso Simulator Components and Device Models Reference

HiSIM_IGBT Model (hisim_igbt)

Model Parameters

Device type parameters:

1	type=n	Transistor type. Possible values are n and p.
2	version=1.00	Model version 1.00. 1.00 is the latest version of HiSIM_IGBT.
3	corsrd=0	Contact resistances R_s and R_d selector. Inactive in HiSIM_IGBT model.
4	coiprv=0	Previous I_{ds} is used for calculating source/drain resistance effect. 0 : no(default). 1 : yes.
5	copprv=1	Previous surface potential is used for the initial guess. 0 : no(default). 1 : yes.
6	coadov=1	Selector for lateral field induced and overlap charges/capacitances being added to intrinsic ones. 0 : no. 1 : yes(default).
7	coisub=0	Substrate current selector. Inactive in HiSIM_IGBT model.
8	cogidl=0	GIDL current calculation selector. Inactive in HiSIM_IGBT model.
9	coiigs=0	Gate current calculation selector. Inactive in HiSIM_IGBT model.
10	coovlp=1	Overlap capacitance calculation selector on drain side. 0 : constant overlap capacitance(default). 1 : yes.
11	coovlps=0	Overlap capacitance calculation selector on source side. 0 : constant overlap capacitance(default). 1 : yes.
12	coflick=0	1/f noise calculation selector. Inactive in HiSIM_IGBT model.
13	coisti=0	STI leakage current calculation selector. 0 : no(default). 1 : yes.
14	conqs=0	Non-quasi-static mode selector. Inactive in HiSIM_IGBT model.
15	cothrml=0	Thermal noise calculation selector. Inactive in HiSIM_IGBT model.

Virtuoso Simulator Components and Device Models Reference

HiSIM_IGBT Model (hisim_igbt)

16	tnom (C)	Parameters measurement temperature. Default set by `options`.
17	corg=0	Gate-contact resistance calculation selector. Inactive in HiSIM_IGBT model.
18	corbnet=0	Substrate resistance network selector. Inactive in HiSIM_IGBT model.
19	coign=0	Induced gate and cross correlation noise calculation selector. Inactive in HiSIM_IGBT model.
20	compatible	Compatible with spice3, default is spectre compatible. Possible values are spectre, spice3 and hspice.
21	alarm=none	Forbidden operating region. Possible values are none, off, triode, sat, subth, and rev.
22	codfm=0	Calculation of model for DFM selector.
23	coselfheat=0	Calculation of self heating model.
24	cosym=0	Model selector for symmetry device.

Default for instance parameters:

25	w=5e-6 m	Default gate width.
26	l=2e-6 m	Default gate length.
27	as=0 m ²	Default area of source junction.
28	ad=0 m ²	Default area of drain junction.
29	ps=0 m	Default perimeter of source junction.
30	pd=0 m	Default perimeter of drain junction.
31	temp=27 C	Default device temperature.
32	dtemp=0 K	Default device temperature rise from ambient.

Virtuoso Simulator Components and Device Models Reference

HiSIM_IGBT Model (hisim_igbt)

Basic Device Parameters:

33	$\text{tox}=1\text{e-}7\text{ m}$	Physical oxide thickness.
34	$\text{xld}=3\text{e-}8\text{ m}$	Gate-overlap length.
35	$\text{xwd}=0\text{ m}$	Gate-overlap width.
36	$\text{tpoly}=2.0\text{e-}7\text{ m}$	Height of the gate poly-si for fringing capacitance on source side.
37	$\text{nsubc}=1.0\text{e}17\text{ cm}^{-3}$	Substrate-impurity concentration.
38	$\text{nsubp}=1.0\text{e}17\text{ cm}^{-3}$	Maximum pocket concentration.
39	$\text{rs}=0.0\text{ Ohm}\cdot\text{m}$	Source contact resistance in LDD region.
40	$\text{rd}=5.0\text{e-}3\text{ Ohm}\cdot\text{m}$	Drain contact resistance in LDD region.
41	$\text{vfbc}=-1.0\text{ V}$	Constant part of flat-band voltage.
42	$\text{lp}=0.0\text{ m}$	Length of the pocket penetration into the channel.
43	$\text{xqy}=0.0\text{ m}$	Distance from channel/drain junction to maximum electric field point.
44	$\text{lover}=3.0\text{e-}8\text{ m}$	Overlap length on source side.
45	$\text{ll}=0.0$	Gate length parameter.
46	$\text{lld}=0.0\text{ m}$	Gate length parameter.
47	$\text{lln}=0.0$	Gate length parameter.
48	$\text{wl}=0.0$	Gate width parameter.
49	$\text{wld}=0.0\text{ m}$	Gate width parameter.
50	$\text{wln}=0.0$	Gate width parameter.

Virtuoso Simulator Components and Device Models Reference

HiSIM_IGBT Model (hisim_igbt)

51	vbi=1.0 V	Built-in potential.
52	nsubp0=0.0 cm ⁻³	Pocket implant parameter.
53	nsubwp=1.0	Pocket implant parameter.
54	lpext=1.0E-50 m	Pocket extension.
55	npext=1.0e17 cm ⁻³	Pocket extension.
56	rsh=0.0 V/A*m	Source/drain diffusion sheet resistance.
57	rshg=0.0 V/A*m	Gate-electrode sheet resistance.
58	rbpb=50.0 Ohm	Substrate resistance network.
59	rbpd=50.0 Ohm	Substrate resistance network.
60	rbps=50.0 Ohm	Substrate resistance network.
61	rbdb=50.0 Ohm	Substrate resistance network.
62	rbsb=50.0 Ohm	Substrate resistance network.
63	gbmin=1.0e-12	Minimum conductance for substrate resistance network.
64	xl=0 m	Gate length offset due to mask/etch effect.
65	xw=0 m	Gate width offset due to mask/etch effect.
66	xqy1=0.0 F m ^{XQY2}	V _{bs} dependence of Q _y .
67	xqy2=2.0	L _{gate} dependence of Q _y .
68	xldld=1.0e-6 m	Lateral diffusion of Drain under the gate.
69	rd2=0.0 Ohm*m	Drain contact resistance in LDD region.
70	rd3=0.0 Ohm*m	Drain contact resistance in LDD region.
71	rdov11=0.0	Dependence coeff. for overlap length.
72	rdov12=1.0	Dependence coeff. for overlap length.

Virtuoso Simulator Components and Device Models Reference

HiSIM_IGBT Model (hisim_igbt)

73	rdov13=1.0	Dependence coeff. for overlap length.
74	rdslp1=0.0	LDRIFT1 dependence of resistance for CORSRD=1,3.
75	rdict1=1.0	LDRIFT1 dependence of resistance for CORSRD=1,3.
76	rdslp2=1.0	LDRIFT2 dependence of resistance for CORSRD=1,3.
77	rdict2=0.0	LDRIFT2 dependence of resistance for CORSRD=1,3.
78	loverld=1.0e-6 m	Overlap length on the drain side.
79	lovers=3.0e-8 m	Overlap length on source side.
80	ldrift1=1.0e-6 m	Drift region length-1 on the drain side.
81	ldrift1s=0.0 m	Drift region length-1 on the source side.
82	ldrift2=1.0e-6 m	Drift region length-2 on the drain side.
83	ldrift2s=1.0e-6 m	Drift region length-2 on the source side.
84	subld1=0.0	Impact-ionization current in the drift region.
85	subld2=0.0 (V^(3/2))/m	Impact-ionization current in the drift region.

Temperature dependence effects:

86	eg0=1.1785 eV	Constant bandgap.
87	bgtmp1=9.025e-5 eV/K	First order temperature coefficient for band gap.
88	bgtmp2=1.0e-7 eV/K^2	Second order temperature coefficient for band gap.
89	rdtemp1=0.0 1/K	Temperature-dependence of Rd.
90	rdtemp2=0.0 1/K^2	Temperature-dependence of Rd.
91	rdvdtemp1=0.0 1/K	Temperature-dependence of RDVD.

Virtuoso Simulator Components and Device Models Reference

HiSIM_IGBT Model (hisim_igbt)

92 rdvdtemp2=0.0 1/K² Temperature-dependence of RDVD.

Quantum Mechanical Effects:

93 qme1=0.0 m/V² Coefficient for quantum mechanical effect.

94 qme2=1.0 V Coefficient for quantum mechanical effect.

95 qme3=0.0 m Coefficient for quantum mechanical effect.

96 kappa=3.9 Dielectric constant for high-k stacked gate.

Poly Depletion Effects:

97 pgd1=0.0 V Strength of poly depletion.

98 pgd2=1.0 V Threshold voltage of poly depletion.

99 pgd3=0.8 Vds dependence of poly depletion.

100 pgd4=0.0 Parameter for gate-poly depletion.

Short Channel Effects:

101 parl2=1.0e-8 m Depletion width of channel/contact junction.

102 sc1=1.0 1/V Short-channel coefficient 1.

103 sc2=1.0 1/V² Short-channel coefficient 2.

104 sc2b=0.0 1/V³ Short-channel coefficient 2 Vb dependency coefficient.

105 sc3=0.0 m/V² Short-channel coefficient 3.

106 sc4=0.0 1/V Parameter for SCE.

107 scp1=1.0 1/V Short-channel coefficient 1 for pocket.

108 scp2=0.1 1/V² Short-channel coefficient 2 for pocket.

Virtuoso Simulator Components and Device Models Reference

HiSIM_IGBT Model (hisim_igbt)

109	scp3=0.0 m/V ²	Short-channel coefficient 3 for pocket.
110	scp22=0.0 V ⁴	Short-channel-effect modification for small Vds.
111	scp21=0.0 V	Short-channel-effect modification for small Vds.
112	bs1=0.0 V ²	Body-coefficient modification by impurity profile.
113	bs2=0.9 V	Body-coefficient modification by impurity profile.

Narrow channel effects:

114	wfc=0.0 m ² /cm ²	Threshold voltage reduction.
115	nsubcw=0.0	Parameter for narrow channel effect.
116	nsubcwp=1.0	Parameter for narrow channel effect.
117	mueph2=0.0	Mobility reduction.
118	w0=0.0 log(cm)	Minimum gate width.
119	wvthsc=0.0	Short-channel effect at the STI edge.
120	nsti=1.0e17 cm ⁻³	Substrate-impurity concentration at the SIT edge.
121	wsti=0.0 m	Width of the high-field region at STI.
122	muephw=0.0	Phonon scattering parameter.
123	muepwp=1.0	Phonon scattering parameter.
124	wvth0=0.0	Threshold voltage shift.
125	mueswp=1.0	Change of surface roughness related mobility.
126	vthsti=0.0	Parameter for STI.
127	muesti1=0.0	STI Stress mobility parameter.
128	muesti2=0.0	STI Stress mobility parameter.

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HiSIM_IGBT Model (hisim_igbt)

129	muesti3=1.0	STI Stress mobility parameter.
130	nsubpsti1=0.0 m	STI Stress pocket implant parameter.
131	nsubpsti2=0.0 m	STI Stress pocket implant parameter.
132	nsubpsti3=1.0 m	STI Stress pocket implant parameter.
133	wstil=0.0	Parameter for STI.
134	wstilp=1.0	Parameter for STI.
135	scsti1=0.0	Parameter for STI.
136	scsti2=0.0 1/V	Parameter for STI.
137	scsti3=0.0 m/V	Parameter for STI.
138	saref=1e-6 m	Reference distance from STI edge to Gate edge.
139	sbref=1e-6 m	Reference distance from STI edge to Gate edge.
140	wstiw=0.0	Parameter for STI.
141	wstiwlp=1.0	Parameter for STI.
142	vdsti=0.0	parameter for STI.

Mobility Effects:

143	vds0=0.05 V	Drain voltage for extracting the low-field mobility.
144	muecb0=1.0e3 cm ² /(V*s)	Coulomb scattering.
145	muecb1=1.0e2 cm ² /(V*s)	Coulomb scattering.
146	mueph0=0.3 cm ² *(V/cm) ^(Muesr1) /(V*s)	Phonon scattering.
147	mueph1=2.5e4	Phonon scattering.

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HiSIM_IGBT Model (hisim_igbt)

148	<code>muetmp=1.7</code>	Temperature dependence of phonon scattering.
149	<code>muesr0=2.0 cm^2*(V/cm)^(Muesr1)/(V*s)</code>	Surface-roughness scattering.
150	<code>muesr1=1.0e16</code>	Surface-roughness scattering.
151	<code>ndep=1.0</code>	Coefficient of effective electric field.
152	<code>ninv=0.5</code>	Coefficient of effective electric field.
153	<code>ninvd=0.0 1/V</code>	Modification of V_{dse} dependence on E_{eff} .
154	<code>bb=2.0</code>	High-field mobility degradation.
155	<code>vmax=1.0e7 cm/s</code>	Maximum of electron saturation velocity.
156	<code>vover=0.3 cm^(voverp)</code>	Parameter for velocity overshoot.
157	<code>voverp=0.3</code>	L_{gate} dependence of velocity overshoot.
158	<code>vovers=0.0</code>	Parameter for overshoot.
159	<code>voversp=0.0</code>	Parameter for overshoot.
160	<code>vtmp=0.0 cm/s</code>	Temperature dependence of the saturation velocity.
161	<code>muephi=0.0</code>	Phonon scattering parameter.
162	<code>mueplp=1.0</code>	Phonon scattering parameter.
163	<code>muesrl=0.0</code>	Surface roughness parameter.
164	<code>muesrw=0.0</code>	Change of surface roughness related mobility.
165	<code>mueslp=1.0</code>	Surface roughness parameter.
166	<code>ndepl=0.0</code>	Modification of Q_b contribution for short-channel case.
167	<code>ndeplp=1.0</code>	Modification of Q_b contribution for short-channel case.

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HiSIM_IGBT Model (hisim_igbt)

Small size parameters:

168	wl1=0.0	Threshold voltage shift of STI leakage due to small size effect.
169	wl1p=1.0	Threshold voltage shift of STI leakage due to small size effect.
170	wl2=0.0	Threshold voltage shift due to small size effect.
171	wl2p=1.0	Threshold voltage shift due to small size effect.
172	muephs=0.0	Mobility modification due to small size.
173	muepsp=1.0	Mobility modification due to small size.

Channel Length Modulation Effects:

174	clm1=50e-3	First parameter for CLM.
175	clm2=2.0 1/m	Second parameter for CLM.
176	clm3=1.0	Third parameter for CLM.
177	clm4=5.0e-4	Smoothing coefficient for gds.
178	clm5=1.0	Effect of pocket implantation.
179	clm6=0.0	Effect of pocket implantation.

Substrate Current Effects:

180	sub1=50e-3 1/V	First parameter for Isub.
181	sub2=1.0e2 V	Second parameter for Isub.
182	svgs=0.8	Substrate current dependence on Vgs.
183	svbs=0.5	Substrate current dependence on Vbs.
184	svbsl=0.0	Lgate dependence of SVBS.
185	svds=0.8	Substrate current dependence on Vds.

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HiSIM_IGBT Model (hisim_igbt)

186	slg=3.0e-8	Substrate current dependence on Lgate.
187	sub1l=2.5e-3	Lgate dependence of SUB1.
188	sub2l=2.0e-6	Lgate dependence of SUB2.
189	fn1=50.0	Coefficient of Fowler-Nordheim-current contribution.
190	fn2=1.7e-4	Coefficient of Fowler-Nordheim-current contribution.
191	fn3=0.0	Coefficient of Fowler-Nordheim-current contribution.
192	fvbs=1.2e-2	Modification of Vbs dependence.
193	svgsl=0.0	Lgate dependence of SVGS.
194	svgslp=1.0	Lgate dependence of SVGS.
195	svgswp=1.0	Wgate dependence of SVGS.
196	svgsw=0.0	Wgate dependence of SVGS.
197	svbslp=1.0	Lgate dependence of SVBS.
198	slgl=0.0	Substrate current dependence on Lgate.
199	slglp=1.0	Substrate current dependence on Lgate.
200	sub1lp=1.0	Lgate dependence of SUB1.
201	ibpc1=0.0	Impact-ionization induced bulk potential change.
202	ibpc2=0.0	Impact-ionization induced bulk potential change.

Gate Current Effects

203	glpart1=0.5	Partitioning of gate current.
204	gleak1=50.0 $A/(V^{3/2} \cdot c^{1/2})$	First gate current coefficient.
205	gleak2=1.0e7 $1/(V^{1/2} \cdot c^{3/2} \cdot m)$	Second gate current coefficient.

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HiSIM_IGBT Model (hisim_igbt)

206	gleak3=6.0e-2	Third gate current coefficient.
207	gleak4=4.0	Parameter for gate current.
208	gleak5=7.5e3	Parameter for gate current.
209	glksd1=1.0e-15	Parameter for gate current.
210	glksd2=5e6	Parameter for gate current.
211	glksd3=-5e6	Parameter for gate current.
212	glkb0=0.0 V	Parameter for gate current.
213	glkb1=5.0e-16	Parameter for gate current.
214	glkb2=1.0	Parameter for gate current.
215	igtemp1=0.0	Temperature dependence of gate current.
216	igtemp2=0.0 1/K	Temperature dependence of gate current.
217	igtemp3=0.0 1/K ²	Temperature dependence of gate current.
218	gleak6=0.25 V	Parameter for gate current.
219	gleak7=1.0e-6 m ²	Parameter for gate current.
220	glkb3=0.0 V	Parameter for gate current.
221	egig=0.0 V	Parameter for gate current.

GIDL Current Effects

222	gidl1=2.0 A*m/(V ^(3/2) *c ^(1/2))	First parameter for GIDL.
223	gidl2=3.0E7 1/(V ^(1/2) *c ^(3/2) *m)	Second parameter for GIDL.
224	gidl3=0.9	Third parameter for GIDL.

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HiSIM_IGBT Model (hisim_igbt)

225 gidl4=0.9 Parameter for GIDL.

226 gidl5=0.2 Parameter for GIDL.

Noise 1/f Effects:

227 nfalp=1.0e-19 Flicker (1/f) noise contribution of the mobility fluctuation.

228 falph=1.0 Parameter for 1/f noise.

229 nfrp=1.0e10 Flicker (1/f) noise ratio of trap density to attenuation coefficient.

230 cit=0.0 Flicker (1/f) noise interface trapped carriers capacitance.

Subthreshold swing parameters:

231 pthrou=0.0 Modify subthreshold sloop.

232 pthroub=0.0 1/V Modify subthreshold sloop.

NQS parameters:

233 dly1=1.0e-10 Parameter for transit time.

234 dly2=0.7 Parameter for transit time.

235 dly3=8.0e-7 Ohm Parameter for transforming bulk charge.

236 dlyov=0.0 Ohm Parameter for transforming overlap charge.

Symmetry for short-channel mosfet:

237 vzadd0=1.0e-2 V Vzadd at Vds=0.

238 pzadd0=5.0e-3 V Pzadd at Vds=0.

P-N junctions parameters

239 js0=5.0e-7 A/m² J junction saturation current density.

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HiSIM_IGBT Model (hisim_igbt)

240	js0sw=0.0 A/m	Side-wall saturation current density.
241	nj=1.0	Junction emission coefficient.
242	njsw=1.0	Junction emission coefficient (sidewall).
243	xti=2.0	Junction saturation current temperature exponent coefficient.
244	cj=5.0e-4 F/m ²	Bottom junction capacitance per unit area at zero bias.
245	cjsw=5e-10 F/m	Source/drain sidewall junction capacitance per unit length at zero bias.
246	cjswg=5e-10 F/m	Source/drain sidewall junction capacitance grading coefficient per unit length at zero bias.
247	tcjbd=0.0	Temperature dependence of czbd.
248	tcjbds=0.0	Temperature dependence of czbds.
249	tcjbds=0.0	Temperature dependence of czbds.
250	tcjbs=0.0	Temperature dependence of czbs.
251	tcjbss=0.0	Temperature dependence of czbss.
252	tcjbss=0.0	Temperature dependence of czbss.
253	mj=0.5	Bulk junction bottom grading coefficient.
254	mjsw=0.33	Source/drain sidewall junction capacitance grading coefficient.
255	mjswg=0.33	Bottom junction capacitance grading coefficient.
256	pb=1.0 V	Bottom junction build-in potential.
257	pbsw=1.0 V	Source/drain sidewall junction build-in potential.
258	pbswg=1.0 V	Source/drain gate sidewall junction build-in potential.
259	vdifj=6.0e-4 V	Threshold voltage for S/D junction diode.
260	xti2=0.0	Temperature coefficient.

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HiSIM_IGBT Model (hisim_igbt)

261	cisb=0.0	Reverse bias saturation current.
262	cvb=0.0	Bias dependence coefficient of cisb.
263	ctemp=0.0	Temperature coefficient.
264	cisbk=0.0 A	Reverse bias saturation current.
265	cvbk=0.0	Bias dependence coefficient of cisb.
266	divx=0.0 1/V	Parameter for junction.

Overlap capacitance parameters:

267	cgso=0.0 F/m	Gate-source overlap capacitance.
268	cgdo=0.0 F/m	Gate-source overlap capacitance.
269	cgbo=0.0 F/m	Gate-source overlap capacitance.
270	ovslp=2.0e-8	Parameter for overlap capacitance.
271	ovmag=500.0	Parameter for overlap capacitance.
272	vfbover=-0.5 V	Flat-band voltage in overlap region.
273	nover=1.0e14 cm ⁻³	Impurity concentration in overlap region.
274	novers=0.0 cm ⁻³	Impurity concentration in overlap region.

Smoothing coefficient between linear and saturation:

275	ddlmax=1.0	Coefficient of effective electric field.
276	ddltslp=0.0	Lgate dependence of smoothing coefficient.
277	ddlctict=10.0	Lgate dependence of smoothing coefficient.

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HiSIM_IGBT Model (hisim_igbt)

DFM parameters:

278 mphdfm=-0.3 NSUBCDFM dependence of phonon scattering for DFM.

Operating region warning control parameters:

279 warn=off Parameter to turn warnings on and off. Possible values are off and on.

280 bvd (V) Drain diode breakdown voltage.

281 bvs (V) Source diode breakdown voltage.

282 bvj (V) Junction reverse breakdown voltage, take effect when bvd and bvs not given.

283 vbox=3e9*tox V Oxide breakdown voltage.

Mismatch parameters:

284 mvtwl=0.0 V*m Threshold mismatch area dependence.

285 mvt0=0.0 V Threshold mismatch intercept.

286 mbewl=0.0 m Beta mismatch area dependence.

287 mbe0=0.0 Beta mismatch intercept.

288 mvtwl2=0.0 V*m^{1.5}
Threshold mismatch area square dependence.

289 mismatchmod=0 Mismatch mode selector. The available modes are 0, 1, 2 and 3.

290 mismatchdist=0 m Mismatch Distance.

LDMOS special parameters:

291 rdvg11=0.0 Vgs dependence of RD.

292 rdvg12=1.0e2 Vgs dependence of RD.

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HiSIM_IGBT Model (hisim_igbt)

293	vbsmin=-10.5 V	Minimum back bias voltage to be treated in hsmigbteval.
294	rth0=0.1 Kcm/W	Thermal resistance.
295	cth0=1.0e-7 Ws/Kcm	Thermal capacitance.
296	qdfvtd=1.0	Qdrift Vd dependence.
297	rdvd=7.0e-2	Vds dependence of RD.
298	rdvb=0.0	Vbs dependence of RD.
299	rd20=0.0	RD23 boundary.
300	rd21=1.0	Vds dependence of RD.
301	rd22=0.0	Vbs dependence of RD.
302	rd22d=0.0	Vbs dependence of RD.
303	rd23=5e-3	Modification of RD.
304	rd24=0.0	Vgs dependence of RD.
305	rd25=0.0	Vgs dependence of RD.
306	rd26=0.2	Smoothing Qover at depletion/inversion transition.
307	qovsm=0.2	Smoothing Qover at depletion/inversion transition.
308	rdvdl=0.0	Lgate dependence of RD.
309	rdvdlp=1.0	Lgate dependence of RD.
310	rdvds=0.0	Small size dependence of RD.
311	rdvdsp=1.0	Small size dependence of RD.
312	rd23l=0.0	Lgate dependence of RD21 boundary.
313	rd23lp=1.0	Lgate dependence of RD21 boundary.

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HiSIM_IGBT Model (hisim_igbt)

314	rd23s=0.0	Small size dependence of RD21.
315	rd23sp=1.0	Small size dependence of RD21.
316	rds=0.0	Small size dependence of RD.
317	rdsp=1.0	Small size dependence of RD.
318	ldrft=1.0e-6	Length of drift region.
319	rth0r=0.0	Heat radiation for SHE.
320	rth0w=0.0	Width-dependence of RTH0.
321	rth0wp=1.0	Width-dependence of RTH0.
322	rth0nf=0.0	Nf-dependence of RTH0.
323	cvdsover=0.0	Modification of the Cgg spikes for Vds is not zero.
324	powrat=1.0	Thermal dissipation.

Parameters for bjt part:

325	bjtninj=0	Electron injection into the depletion layer.
326	bjtninjmax=1.0	Parameter for Wdep.
327	bjtwdepmax=1.0	Parameter for Wdep.
328	bjtmuep=50.0 cm ² /(V*s)	Hole mobility in the quasi-neutral region.
329	bjtmuen=100.0 cm ² /(V*s)	Elec. mobility in the quasi-neutral region.
330	bjtmueqn=1.0	Parameter for mobility.
331	bjttaue=3.0e-5 s	Basic lifetime in the emitter.
332	bjttaub=1.0e-5 s	Basic lifetime in the base.
333	bjttauc=3.0e-5 s	Basic lifetime in the collector.

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HiSIM_IGBT Model (hisim_igbt)

334	$\text{bjtnref}=1.0\text{e}17 \text{ cm}^{-3}$	Reference doping concentration.
335	$\text{bjtgminc}=0$	Coefficient for minimum conductance.
336	$\text{bjtgmine}=0$	Coefficient for minimum conductance.
337	$\text{bjtldec}=1.0$	Parameter for excess carrier distribution.
338	$\text{bjtpmin}=1.0\text{e}14 \text{ cm}^{-3}$	Minimum carrier density in the base.
339	$\text{bjtrb}=1.0$	Coefficient for base resistance.
340	$\text{bjtrbvg11}=0$	Gate-voltage dependence on RBase.
341	$\text{bjtrbvg12}=20.0 \text{ V}$	Gate-voltage dependence on RBase.
342	$\text{bjtrc}=1.0\text{e}4 \text{ Ohm}\cdot\text{m}$	Collector resistance.
343	$\text{bjtre}=0 \text{ Ohm}\cdot\text{m}$	Emitter resistance.
344	$\text{bjtqdep}=1.0$	Coefficient for Qdep.
345	$\text{bjtqex}=1.0$	Coefficient for Qexcess.
346	$\text{bjtne}=1.0\text{e}17 \text{ cm}^{-3}$	Emitter impurity concentration.
347	$\text{bjtnb}=1.0\text{e}14 \text{ cm}^{-3}$	Base impurity concentration.
348	$\text{bjtnc}=1.0\text{e}18 \text{ cm}^{-3}$	Base impurity concentration.
349	$\text{bjtwb}=1.0\text{e}-4 \text{ m}$	Base width.
350	$\text{bjtwhalfcell}=2.0\text{e}-6 \text{ m}$	Half cell width.

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HiSIM_IGBT Model (hisim_igbt)

Auto Model Selector parameters:

351	wmax=1 m	Maximum channel width for which the model is valid.
352	wmin=0 m	Minimum channel width for which the model is valid.
353	lmax=1 m	Maximum channel length for which the model is valid.
354	lmin=0 m	Minimum channel length for which the model is valid.

Safe Operating Areas Parameters:

355	vds_max=infinity V	Maximum allowed voltage cross source and drain.
356	vgd_max=infinity V	Maximum allowed voltage cross drain and gate.
357	vgs_max=infinity V	Maximum allowed voltage cross source/bulk and gate.
358	vbd_max=infinity V	Maximum allowed voltage cross drain/source and bulk.

Binning model parameters :

359	lbinn=1.0	L modulation coefficient for binning.
360	wbinn=1.0	W modulation coefficient for binning.
361	lvmax=0.0 cm/s	Length dependence of v _{max} .
362	lbgtmp1=0.0 eV/K	Length dependence of bgtmp1.
363	lbgtmp2=0.0 eV/K ²	Length dependence of bgtmp2.
364	leg0=0.0 eV	Length dependence of eg0.
365	lnovers=0.0 cm ⁻³	Length dependence of novers.

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HiSIM_IGBT Model (hisim_igbt)

366	lvfbover=0.0 V	Length dependence of vfbover.
367	Inover=0.0 cm ⁻³	Length dependence of nover.
368	lwl2=0.0	Length dependence of wl2.
369	lvfbc=0.0 V	Length dependence of vfbc.
370	Insubc=0.0 cm ⁻³	Length dependence of nsubc.
371	Insubp=0.0 cm ⁻³	Length dependence of nsubp.
372	lscp1=0.0 1/V	Length dependence of scp1.
373	lscp2=0.0 1/V ²	Length dependence of scp2.
374	lscp3=0.0 m/V ²	Length dependence of scp3.
375	lsc1=0.0 1/V	Length dependence of sc1.
376	lsc2=0.0 1/V ²	Length dependence of sc2.
377	lsc3=0.0 m/V ²	Length dependence of sc3.
378	lpgd1=0.0 V	Length dependence of pgd1.
379	lpgd3=0.0	Length dependence of pgd3.
380	lndep=0.0	Length dependence of ndep.
381	lninv=0.0	Length dependence of ninv.
382	lmuecb0=0.0 cm ² /(V*s)	Length dependence of muecb0.
383	lmuecb1=0.0 cm ² /(V*s)	Length dependence of muecb1.
384	lmueph1=0.0	Length dependence of mueph1.
385	lvtmp=0.0 cm/s	Length dependence of vtmp.
386	lvvth0=0.0	Length dependence of vvth0.

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HiSIM_IGBT Model (hisim_igbt)

387	Imuesr1=0.0	Length dependence of muesr1.
388	Imuetmp=0.0	Length dependence of muetmp.
389	lsub1=0.0 1/V	Length dependence of sub1.
390	lsub2=0.0 V	Length dependence of sub2.
391	lsvds=0.0	Length dependence of svds.
392	lsvbs=0.0	Length dependence of svbs.
393	lsvgs=0.0	Length dependence of svgs.
394	lfn1=0.0	Length dependence of fn1.
395	lfn2=0.0	Length dependence of fn2.
396	lfn3=0.0	Length dependence of fn3.
397	lfvbs=0.0	Length dependence of fvbs.
398	lnsti=0.0 cm ⁻³	Length dependence of nsti.
399	lwsti=0.0 m	Length dependence of wsti.
400	lscsti1=0.0	Length dependence of scsti1.
401	lscsti2=0.0 1/V	Length dependence of scsti2.
402	lvthsti=0.0	Length dependence of vthsti.
403	lmuesti1=0.0	Length dependence of muesti1.
404	lmuesti2=0.0	Length dependence of muesti2.
405	lmuesti3=0.0	Length dependence of muesti3.
406	Insubpsti1=0.0 m	Length dependence of nsubpsti1.
407	Insubpsti2=0.0 m	Length dependence of nsubpsti2.
408	Insubpsti3=0.0 m	Length dependence of nsubpsti3.

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HiSIM_IGBT Model (hisim_igbt)

409	l _{cgso} =0.0 F/m	Length dependence of c _{gso} .
410	l _{cgdo} =0.0 F/m	Length dependence of c _{gdo} .
411	l _{js0} =0.0 A/m ²	Length dependence of j _{s0} .
412	l _{js0sw} =0.0 A/m	Length dependence of j _{s0sw} .
413	l _{nj} =0.0	Length dependence of n _j .
414	l _{cisbk} =0.0 A	Length dependence of c _{isbk} .
415	l _{clm1} =0.0	Length dependence of c _{lm1} .
416	l _{clm2} =0.0 1/m	Length dependence of c _{lm2} .
417	l _{clm3} =0.0	Length dependence of c _{lm3} .
418	l _{wfc} =0.0 m*F/cm ²	Length dependence of w _{fc} .
419	l _{gidl1} =0.0 A*m/(V ^(3/2) *c ^(1/2))	Length dependence of g _{idl1} .
420	l _{gidl2} =0.0 1/(V ^(1/2) *c ^(3/2) *m)	Length dependence of g _{idl2} .
421	l _{gleak1} =0.0 A/(V ^(3/2) *c ^(1/2))	Length dependence of g _{leak1} .
422	l _{gleak2} =0.0 1/(V ^(1/2) *c ^(3/2) *m)	Length dependence of g _{leak2} .
423	l _{gleak3} =0.0	Length dependence of g _{leak3} .
424	l _{gleak6} =0.0 V	Length dependence of g _{leak6} .
425	l _{glksd1} =0.0	Length dependence of g _{lksd1} .
426	l _{glksd2} =0.0	Length dependence of g _{lksd2} .
427	l _{glkb1} =0.0	Length dependence of g _{lkb1} .

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HiSIM_IGBT Model (hisim_igbt)

428	lgk _{b2} =0.0	Length dependence of gk _{b2} .
429	lnftrp=0.0	Length dependence of nftrp.
430	lnfalp=0.0	Length dependence of nfalp.
431	lpthrou=0.0	Length dependence of pthrou.
432	lvdiffj=0.0 V	Length dependence of vdiffj.
433	libpc1=0.0	Length dependence of ibpc1.
434	libpc2=0.0	Length dependence of ibpc2.
435	wvmax=0.0 cm/s	Width dependence of vmax.
436	wbgtmp1=0.0 eV/K	Width dependence of bgtmp1.
437	wbgtmp2=0.0 eV/K ²	Width dependence of bgtmp2.
438	weg0=0.0 eV	Width dependence of eg0.
439	wnovers=0.0 cm ⁻³	Width dependence of novers.
440	wvfbover=0.0 V	Width dependence of vfbover.
441	wnover=0.0 cm ⁻³	Width dependence of nover.
442	wwl2=0.0	Width dependence of wl2.
443	wvfbc=0.0 V	Width dependence of vfbc.
444	wnsubc=0.0 cm ⁻³	Width dependence of nsubc.
445	wnsubp=0.0 cm ⁻³	Width dependence of nsubp.
446	wscp1=0.0 1/V	Width dependence of scp1.
447	wscp2=0.0 1/V ²	Width dependence of scp2.
448	wscp3=0.0 m/V ²	Width dependence of scp3.

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HiSIM_IGBT Model (hisim_igbt)

449	wsc1=0.0 1/V	Width dependence of sc1.
450	wsc2=0.0 1/V ²	Width dependence of sc2.
451	wsc3=0.0 m/V ²	Width dependence of sc3.
452	wpgd1=0.0 V	Width dependence of pgd1.
453	wpgd3=0.0	Width dependence of pgd3.
454	wndep=0.0	Width dependence of ndep.
455	wninv=0.0	Width dependence of ninv.
456	wmuecb0=0.0 cm ² /(V*s)	Width dependence of muecb0.
457	wmuecb1=0.0 cm ² /(V*s)	Width dependence of muecb1.
458	wmueph1=0.0	Width dependence of mueph1.
459	wvtmp=0.0 cm/s	Width dependence of vtmp.
460	wvth0=0.0	Width dependence of vth0.
461	wmuesr1=0.0	Width dependence of muesr1.
462	wmuetmp=0.0	Width dependence of muetmp.
463	wsub1=0.0 1/V	Width dependence of sub1.
464	wsub2=0.0 V	Width dependence of sub2.
465	wsvds=0.0	Width dependence of svds.
466	wsvbs=0.0	Width dependence of svbs.
467	wsvgs=0.0	Width dependence of svgs.
468	wfn1=0.0	Width dependence of fn1.
469	wfn2=0.0	Width dependence of fn2.

Virtuoso Simulator Components and Device Models Reference

HiSIM_IGBT Model (hisim_igbt)

470	wfn3=0.0	Width dependence of fn3.
471	wfvbs=0.0	Width dependence of fvbs.
472	wnsti=0.0 cm ⁻³	Width dependence of nsti.
473	wwsti=0.0 m	Width dependence of wsti.
474	wscsti1=0.0	Width dependence of scsti1.
475	wscsti2=0.0 1/V	Width dependence of scsti2.
476	wvthsti=0.0	Width dependence of vthsti.
477	wmuesti1=0.0	Width dependence of muesti1.
478	wmuesti2=0.0	Width dependence of muesti2.
479	wmuesti3=0.0	Width dependence of muesti3.
480	wnsubpsti1=0.0 m	Width dependence of nsubpsti1.
481	wnsubpsti2=0.0 m	Width dependence of nsubpsti2.
482	wnsubpsti3=0.0 m	Width dependence of nsubpsti3.
483	wcgso=0.0 F/m	Width dependence of cgso.
484	wcgdo=0.0 F/m	Width dependence of cgdo.
485	wjs0=0.0 A/m ²	Width dependence of js0.
486	wjs0sw=0.0 A/m	Width dependence of js0sw.
487	wnj=0.0	Width dependence of nj.
488	wcisbk=0.0 A	Width dependence of cisbk.
489	wclm1=0.0	Width dependence of clm1.
490	wclm2=0.0 1/m	Width dependence of clm2.
491	wclm3=0.0	Width dependence of clm3.

Virtuoso Simulator Components and Device Models Reference

HiSIM_IGBT Model (hisim_igbt)

492	$wwfc=0.0 \text{ m}^2/\text{cm}^2$	Width dependence of wfc.
493	$wgidl1=0.0 \text{ A}^2\text{m}/(\text{V}^{3/2}\text{c}^{1/2})$	Width dependence of gidl1.
494	$wgidl2=0.0 \text{ 1}/(\text{V}^{1/2}\text{c}^{3/2}\text{m})$	Width dependence of gidl2.
495	$wgleak1=0.0 \text{ A}/(\text{V}^{3/2}\text{c}^{1/2})$	Width dependence of gleak1.
496	$wgleak2=0.0 \text{ 1}/(\text{V}^{1/2}\text{c}^{3/2}\text{m})$	Width dependence of gleak2.
497	$wgleak3=0.0$	Width dependence of gleak3.
498	$wgleak6=0.0 \text{ V}$	Width dependence of gleak6.
499	$wglksd1=0.0$	Width dependence of glksd1.
500	$wglksd2=0.0$	Width dependence of glksd2.
501	$wglkb1=0.0$	Width dependence of glkb1.
502	$wglkb2=0.0$	Width dependence of glkb2.
503	$wnfrp=0.0$	Width dependence of nfrp.
504	$wnfalp=0.0$	Width dependence of nfalp.
505	$wpthrou=0.0$	Width dependence of pthrou.
506	$wvdiffj=0.0 \text{ V}$	Width dependence of vdiffj.
507	$wibpc1=0.0$	Width dependence of ibpc1.
508	$wibpc2=0.0$	Width dependence of ibpc2.
509	$pvmax=0.0 \text{ cm/s}$	Cross-term dependence of vmax.
510	$pbgtmp1=0.0 \text{ eV/K}$	Cross-term dependence of bgtmp1.

Virtuoso Simulator Components and Device Models Reference

HiSIM_IGBT Model (hisim_igbt)

511	$\text{pbgtmp2}=0.0 \text{ eV/K}^2$	Cross-term dependence of bgtmp2 .
512	$\text{peg0}=0.0 \text{ eV}$	Cross-term dependence of eg0 .
513	$\text{pnovers}=0.0 \text{ cm}^{-3}$	Cross-term dependence of novers .
514	$\text{pvfbover}=0.0 \text{ V}$	Cross-term dependence of vfbover .
515	$\text{pnover}=0.0 \text{ cm}^{-3}$	Cross-term dependence of nover .
516	$\text{pwl2}=0.0$	Cross-term dependence of wl2 .
517	$\text{pvfbc}=0.0 \text{ V}$	Cross-term dependence of vfbc .
518	$\text{pnsubc}=0.0 \text{ cm}^{-3}$	Cross-term dependence of nsubc .
519	$\text{pnsubp}=0.0 \text{ cm}^{-3}$	Cross-term dependence of nsubp .
520	$\text{psc1}=0.0 \text{ 1/V}$	Cross-term dependence of scp1 .
521	$\text{psc2}=0.0 \text{ 1/V}^2$	Cross-term dependence of scp2 .
522	$\text{psc3}=0.0 \text{ m/V}^2$	Cross-term dependence of scp3 .
523	$\text{psc1}=0.0 \text{ 1/V}$	Cross-term dependence of sc1 .
524	$\text{psc2}=0.0 \text{ 1/V}^2$	Cross-term dependence of sc2 .
525	$\text{psc3}=0.0 \text{ m/V}^2$	Cross-term dependence of sc3 .
526	$\text{ppgd1}=0.0 \text{ V}$	Cross-term dependence of pgd1 .
527	$\text{ppgd3}=0.0$	Cross-term dependence of pgd3 .
528	$\text{pndep}=0.0$	Cross-term dependence of ndep .
529	$\text{pninv}=0.0$	Cross-term dependence of ninv .
530	$\text{pmuecb0}=0.0 \text{ cm}^2/(\text{V}\cdot\text{s})$	Cross-term dependence of muecb0 .

Virtuoso Simulator Components and Device Models Reference

HiSIM_IGBT Model (hisim_igbt)

531	$\text{pmuecb1}=0.0 \text{ cm}^2/(\text{V}\cdot\text{s})$	Cross-term dependence of <code>muecb1</code> .
532	$\text{pmueph1}=0.0$	Cross-term dependence of <code>mueph1</code> .
533	$\text{pvtmp}=0.0 \text{ cm/s}$	Cross-term dependence of <code>vtmp</code> .
534	$\text{pwvth0}=0.0$	Cross-term dependence of <code>wvth0</code> .
535	$\text{pmuesr1}=0.0$	Cross-term dependence of <code>muesr1</code> .
536	$\text{pmuetmp}=0.0$	Cross-term dependence of <code>muetmp</code> .
537	$\text{psub1}=0.0 \text{ 1/V}$	Cross-term dependence of <code>sub1</code> .
538	$\text{psub2}=0.0 \text{ V}$	Cross-term dependence of <code>sub2</code> .
539	$\text{psvds}=0.0$	Cross-term dependence of <code>svds</code> .
540	$\text{psvbs}=0.0$	Cross-term dependence of <code>svbs</code> .
541	$\text{psvgs}=0.0$	Cross-term dependence of <code>svgs</code> .
542	$\text{pfn1}=0.0$	Cross-term dependence of <code>fn1</code> .
543	$\text{pfn2}=0.0$	Cross-term dependence of <code>fn2</code> .
544	$\text{pfn3}=0.0$	Cross-term dependence of <code>fn3</code> .
545	$\text{pfvbs}=0.0$	Cross-term dependence of <code>fvbs</code> .
546	$\text{pnsti}=0.0 \text{ cm}^{-3}$	Cross-term dependence of <code>nsti</code> .
547	$\text{pwsti}=0.0 \text{ m}$	Cross-term dependence of <code>wsti</code> .
548	$\text{pscsti1}=0.0$	Cross-term dependence of <code>scsti1</code> .
549	$\text{pscsti2}=0.0 \text{ 1/V}$	Cross-term dependence of <code>scsti2</code> .
550	$\text{pvthsti}=0.0$	Cross-term dependence of <code>vthsti</code> .
551	$\text{pmuesti1}=0.0$	Cross-term dependence of <code>muesti1</code> .

Virtuoso Simulator Components and Device Models Reference

HiSIM_IGBT Model (hisim_igbt)

552	pmuesti2=0.0	Cross-term dependence of muesti2.
553	pmuesti3=0.0	Cross-term dependence of muesti3.
554	pnsupsti1=0.0 m	Cross-term dependence of nsupsti1.
555	pnsupsti2=0.0 m	Cross-term dependence of nsupsti2.
556	pnsupsti3=0.0 m	Cross-term dependence of nsupsti3.
557	pcgso=0.0 F/m	Cross-term dependence of cgso.
558	pcgdo=0.0 F/m	Cross-term dependence of cgdo.
559	pjs0=0.0 A/m ²	Cross-term dependence of js0.
560	pjs0sw=0.0 A/m	Cross-term dependence of js0sw.
561	pnj=0.0	Cross-term dependence of nj.
562	pcisbk=0.0 A	Cross-term dependence of cisbk.
563	pclm1=0.0	Cross-term dependence of clm1.
564	pclm2=0.0 1/m	Cross-term dependence of clm2.
565	pclm3=0.0	Cross-term dependence of clm3.
566	pwfc=0.0 m ² F/cm ²	Cross-term dependence of wfc.
567	pgidl1=0.0 A*m/(V ^{3/2} *c ^{1/2})	Cross-term dependence of gidl1.
568	pgidl2=0.0 1/(V ^{1/2} *c ^{3/2} *m)	Cross-term dependence of gidl2.
569	pgleak1=0.0 A/(V ^{3/2} *c ^{1/2})	Cross-term dependence of gleak1.
570	pgleak2=0.0 1/(V ^{1/2} *c ^{3/2} *m)	Cross-term dependence of gleak2.

Virtuoso Simulator Components and Device Models Reference

HiSIM_IGBT Model (hisim_igbt)

571	pgleak3=0.0	Cross-term dependence of gleak3.
572	pgleak6=0.0 V	Cross-term dependence of gleak6.
573	pglksd1=0.0	Cross-term dependence of glksd1.
574	pglksd2=0.0	Cross-term dependence of glksd2.
575	pglkb1=0.0	Cross-term dependence of glkb1.
576	pglkb2=0.0	Cross-term dependence of glkb2.
577	pnftrp=0.0	Cross-term dependence of nftrp.
578	pnfalp=0.0	Cross-term dependence of nfalp.
579	ppthrou=0.0	Cross-term dependence of pthrou.
580	pvdifj=0.0 V	Cross-term dependence of vdifj.
581	pibpc1=0.0	Cross-term dependence of ibpc1.
582	pibpc2=0.0	Cross-term dependence of ibpc2.

Operating Point Parameters

1	shetemp (C)	Temperature rise due to self-heating.
2	reversed	Reverse mode indicator. Possible values are no and yes.
3	ids (A)	Resistive drain-to-source current.
4	vgs (V)	Gate-source voltage.
5	vds (V)	Drain-source voltage.
6	vbs (V)	Bulk-source voltage.
7	vth (V)	Threshold voltage.
8	vdsat (V)	Drain-source saturation voltage.
9	gm (S)	Common-source transconductance.

Virtuoso Simulator Components and Device Models Reference

HiSIM_IGBT Model (hisim_igbt)

10	gds (S)	Common-source output conductance.
11	gmbs (S)	Body-transconductance.
12	qb (Coul)	Total bulk charge.
13	qd (Coul)	Total drain charge.
14	qg (Coul)	Total gate charge.
15	qs (Coul)	Total source charge.
16	qb_itr (Coul)	Intrinsic bulk charge.
17	qd_itr (Coul)	Intrinsic drain charge.
18	qg_itr (Coul)	Intrinsic gate charge.
19	qs_itr (Coul)	Intrinsic source charge.
20	qdp (Coul)	Total external drain charge.
21	qsp (Coul)	Total external source charge.
22	cjd (F)	Drain-bulk junction capacitance.
23	cjs (F)	Source-bulk junction capacitance.
24	cgg (F)	Intrinsic dQg_dVg .
25	cgd (F)	dQg_dVd .
26	cgs (F)	dQg_dVs .
27	cgb (F)	dQg_dVb .
28	cdg (F)	dQd_dVg .
29	cdd (F)	Intrinsic dQd_dVd .
30	cds (F)	dQd_dVs .
31	cdb (F)	dQd_dVb .

Virtuoso Simulator Components and Device Models Reference

HiSIM_IGBT Model (hisim_igbt)

32	csg (F)	dQs_dVg.
33	csd (F)	dQs_dVd.
34	css (F)	Intrinsic dQs_dVs.
35	csb (F)	dQs_dVb.
36	cbg (F)	dQb_dVg.
37	cbd (F)	dQb_dVd.
38	cbs (F)	dQb_dVs.
39	cbb (F)	Intrinsic dQb_dVb.
40	cdd_tot (F)	Total dQd_dVd.
41	cgg_tot (F)	Total dQg_dVg.
42	css_tot (F)	Total dQs_dVs.
43	cbb_tot (F)	Total dQb_dVb.
44	id (A)	Resistive drain current.
45	ig (A)	Gate current.
46	is (A)	Resistive source current.
47	ibulk (A)	Resistive bulk current.
48	pwr (W)	Power at operating point.
49	ps0 (V)	Surface potential at source side.
50	psl (V)	Surface potential at drain side.
51	pds (V)	Delta surface potential between psl and ps0.
52	isub (A)	Substrate current Isub.
53	gbds (S)	Substrate trans conductance (dIsub/dVds).

Virtuoso Simulator Components and Device Models Reference

HiSIM_IGBT Model (hisim_igbt)

54	gbgs (S)	Substrate trans conductance (dI_{sub}/dV_{gs}).
55	gbbs (S)	Substrate transconductance (dI_{sub}/dV_{bs}).
56	igate (A)	Gate current due to tunneling.
57	igates (A)	Tunneling current from gate to source.
58	igateb (A)	Tunneling current from gate to bulk.
59	igated (A)	Tunneling current from gate to drain.
60	igisl (A)	Gate-induced source leakage current.
61	igidl (A)	Gate-induced drain leakage current.
62	ibs (A)	Source-bulk diode current.
63	ibd (A)	Source-drain diode current.
64	cgso (F)	Gate-source overlap capacitance.
65	cgbo (F)	Gate-bulk overlap capacitance.
66	cgdo (F)	Gate-drain overlap capacitance.
67	cggo (F)	Gate-gate overlap capacitance.
68	cddo (F)	Drain-drain overlap capacitance.
69	w _{eff} (m)	Effective channel width.
70	l _{eff} (m)	Effective channel length.
71	r _{seff} (Ohm)	Effective source resistance.
72	r _{deff} (Ohm)	Effective drain resistance.
73	r _{sdrift} (Ohm)	The resistance of drift region for source side.
74	r _{drift} (Ohm)	The resistance of drift region for drain side.
75	gmt (S)	Temp transconductance.

Virtuoso Simulator Components and Device Models Reference

HiSIM_IGBT Model (hisim_igbt)

76	ic_bjt (A)	Internal collector current of BJT.
77	ie_bjt (A)	Internal emitter current of BJT.
78	ibase_bjt (A)	Internal base current of BJT.
79	ice (A)	Collector-Emitter current of HiSIM_IGBT.
80	vce (A)	Collector-Emitter voltage of HiSIM_IGBT.
81	qex (Coul)	Excess charge in the base.
82	qdep (Coul)	Depletion charge in the base at the emitter side.
83	rbase (Ohm)	Effective internal base resistance.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

ad	I-4	isub	OP-52	pclm1	M-563	scsti1	M-135
ad	M-28	js0	M-239	pclm2	M-564	scsti2	M-136
alarm	M-21	js0sw	M-240	pclm3	M-565	scsti3	M-137
as	I-3	kappa	M-96	pd	I-6	sd	I-35
as	M-27	l	I-2	pd	M-30	shetemp	OP-1
bb	M-154	l	M-26	pds	OP-51	slg	M-186
bgtmp1	M-87	lbgtmp1	M-362	peg0	M-512	slg1	M-198
bgtmp2	M-88	lbgtmp2	M-363	pfm1	M-542	slglp	M-199

Virtuoso Simulator Components and Device Models Reference

HiSIM_IGBT Model (hisim_igbt)

bjtgminc	M-335	lbinn	M-359	pfn2	M-543	sub1	M-180
bjtgmine	M-336	lcgdo	M-410	pfn3	M-544	sub11	M-187
bjtldec	M-337	lcgso	M-409	pfvbs	M-545	sub11p	M-200
bjtmuen	M-329	lcisbk	M-414	pgd1	M-97	sub2	M-181
bjtmuep	M-328	lclm1	M-415	pgd2	M-98	sub21	M-188
bjtmueqn	M-330	lclm2	M-416	pgd3	M-99	subld1	I-24
bjtnb	M-347	lclm3	M-417	pgd4	M-100	subld1	M-84
bjtnc	M-348	ldrifft	M-318	pgidl1	M-567	subld2	I-25
bjtne	M-346	ldrifft1	I-26	pgidl2	M-568	subld2	M-85
bjtninj	M-325	ldrifft1	M-80	pgleak1	M-569	svbs	M-183
bjtninjmax	M-326	ldrifft1s	I-31	pgleak2	M-570	svbs1	M-184
bjtnref	M-334	ldrifft1s	M-81	pgleak3	M-571	svbslp	M-197
bjtppmin	M-338	ldrifft2	I-27	pgleak6	M-572	svds	M-185
bjtqdep	M-344	ldrifft2	M-82	pglkb1	M-575	svgs	M-182
bjtqex	M-345	ldrifft2s	I-32	pglkb2	M-576	svgs1	M-193
bjtrb	M-339	ldrifft2s	M-83	pglksd1	M-573	svgs1p	M-194
bjtrbvg11	M-340	leff	OP-70	pglksd2	M-574	svgs1sw	M-196
bjtrbvg12	M-341	leg0	M-364	pibpc1	M-581	svgs1swp	M-195
bjtrc	M-342	lfn1	M-394	pibpc2	M-582	tcjbd	M-247
bjtre	M-343	lfn2	M-395	pjs0	M-559	tcjbdsw	M-248
bjttaub	M-332	lfn3	M-396	pjs0sw	M-560	tcjbdswg	M-249

Virtuoso Simulator Components and Device Models Reference

HiSIM_IGBT Model (hisim_igbt)

bjttauc	M-333	lfvbs	M-397	pmuecb0	M-530	tcjbs	M-250
bjttaue	M-331	lgidl1	M-419	pmuecb1	M-531	tcjbssw	M-251
bjtwb	M-349	lgidl2	M-420	pmueph1	M-532	tcjbsswg	M-252
bjtwdepmax	M-327	lgleak1	M-421	pmuesr1	M-535	temp	I-7
bjtwhalfcell	M-350	lgleak2	M-422	pmuesti1	M-551	temp	M-31
bs1	M-112	lgleak3	M-423	pmuesti2	M-552	tnom	M-16
bs2	M-113	lgleak6	M-424	pmuesti3	M-553	tox	M-33
bvd	M-280	lglkb1	M-427	pmuetmp	M-536	tpoly	M-36
bvj	M-282	lglkb2	M-428	pndep	M-528	type	M-1
bvs	M-281	lglksd1	M-425	pnfalp	M-578	vbd_max	M-358
cbb	OP-39	lglksd2	M-426	pnftrp	M-577	vbi	M-51
cbb_tot	OP-43	libpc1	M-433	pninv	M-529	vbox	M-283
cbd	OP-37	libpc2	M-434	pnj	M-561	vbs	OP-6
cbg	OP-36	ljs0	M-411	pnover	M-515	vbsmin	M-293
cbs	OP-38	ljs0sw	M-412	pnovers	M-513	vce	OP-80
cdb	OP-31	ll	M-45	pnsti	M-546	vdifffj	M-259
cdd	OP-29	lld	M-46	pnsbc	M-518	vds	OP-5
cdd_tot	OP-40	lln	M-47	pnsbpc	M-519	vds0	M-143
cddo	OP-68	lmax	M-353	pnsbpcsti1	M-554	vds_max	M-355
cdg	OP-28	lmin	M-354	pnsbpcsti2	M-555	vdsat	OP-8

Virtuoso Simulator Components and Device Models Reference

HiSIM_IGBT Model (hisim_igbt)

cds	OP-30	lmuecb0	M-382	pnsbsti3	M-556	vdsti	M-142
cgb	OP-27	lmuecb1	M-383	powrat	M-324	version	M-2
cgbo	M-269	lmueph1	M-384	ppgd1	M-526	vfbc	M-41
cgbo	OP-65	lmuesr1	M-387	ppgd3	M-527	vfbover	M-272
cgd	OP-25	lmuesti1	M-403	ppthrou	M-579	vgd_max	M-356
cgdo	M-268	lmuesti2	M-404	ps	I-5	vgs	OP-4
cgdo	OP-66	lmuesti3	M-405	ps	M-29	vgs_max	M-357
cgg	OP-24	lmuetmp	M-388	ps0	OP-49	vmax	M-155
cgg_tot	OP-41	lndep	M-380	psc1	M-523	vover	M-156
cggo	OP-67	lnfalp	M-430	psc2	M-524	voverp	M-157
cgs	OP-26	lnftrp	M-429	psc3	M-525	vovers	M-158
cgso	M-267	lninv	M-381	pscp1	M-520	voversp	M-159
cgso	OP-64	lnj	M-413	pscp2	M-521	vth	OP-7
cisb	M-261	lnover	M-367	pscp3	M-522	vthsti	M-126
cisbk	M-264	lnovers	M-365	pscsti1	M-548	vtmp	M-160
cit	M-230	lnsti	M-398	pscsti2	M-549	vzadd0	M-237
cj	M-244	lnsubc	M-370	ps1	OP-50	w	I-1
cjd	OP-22	lnsubp	M-371	psub1	M-537	w	M-25
cjs	OP-23	lnsubpsti1	M-406	psub2	M-538	w0	M-118
cjsw	M-245	lnsubpsti2	M-407	psvbs	M-540	warn	M-279
cjswg	M-246	lnsubpsti3	M-408	psvds	M-539	wbgtmp1	M-436

Virtuoso Simulator Components and Device Models Reference

HiSIM_IGBT Model (hisim_igbt)

clm1	M-174	lod	I-22	psvgs	M-541	wbgtmp2	M-437
clm2	M-175	lover	I-28	pthrou	M-231	wbinn	M-360
clm3	M-176	lover	M-44	pthroub	M-232	wcgdo	M-484
clm4	M-177	loverld	I-30	pvdifffj	M-580	wcgso	M-483
clm5	M-178	loverld	M-78	pvfbc	M-517	wcisbk	M-488
clm6	M-179	lovers	I-29	pvfbover	M-514	wclm1	M-489
coadov	M-6	lovers	M-79	pvmx	M-509	wclm2	M-490
codfm	M-22	lp	M-42	pvthsti	M-550	wclm3	M-491
coflick	M-12	lpext	M-54	pvtmp	M-533	weff	OP-69
cogidl	M-8	lpgd1	M-378	pwfc	M-566	weg0	M-438
coign	M-19	lpgd3	M-379	pwl2	M-516	wfc	M-114
coiigs	M-9	lpthrou	M-431	pwr	OP-48	wfn1	M-468
coiprv	M-4	lsc1	M-375	pwsti	M-547	wfn2	M-469
coisti	M-13	lsc2	M-376	pwvth0	M-534	wfn3	M-470
coisub	M-7	lsc3	M-377	pzadd0	M-238	wfvbs	M-471
compatible	M-20	lscp1	M-372	qb	OP-12	wgidl1	M-493
conqs	M-14	lscp2	M-373	qb_itr	OP-16	wgidl2	M-494
coovlp	M-10	lscp3	M-374	qd	OP-13	wgleak1	M-495
coovlps	M-11	lscsti1	M-400	qd_itr	OP-17	wgleak2	M-496
copprv	M-5	lscsti2	M-401	qdep	OP-82	wgleak3	M-497
corbnet	I-11	lsub1	M-389	qdftvd	M-296	wgleak6	M-498

Virtuoso Simulator Components and Device Models Reference

HiSIM_IGBT Model (hisim_igbt)

corbnet	M-18	lsub2	M-390	qdp	OP-20	wglkb1	M-501
corg	I-17	lsvbs	M-392	qex	OP-81	wglkb2	M-502
corg	M-17	lsvds	M-391	qg	OP-14	wglksd1	M-499
corsrd	M-3	lsvgs	M-393	qg_itr	OP-18	wglksd2	M-500
coselfheat	M-23	lvdiffj	M-432	qme1	M-93	wibpc1	M-507
cosym	M-24	lvfbc	M-369	qme2	M-94	wibpc2	M-508
cothtml	M-15	lvfbover	M-366	qme3	M-95	wjs0	M-485
csb	OP-35	lvmax	M-361	qovsm	M-307	wjs0sw	M-486
csd	OP-33	lvthsti	M-402	qs	OP-15	wl	M-48
csg	OP-32	lvtmp	M-385	qs_itr	OP-19	wl1	M-168
css	OP-34	lwfc	M-418	qsp	OP-21	wl1p	M-169
css_tot	OP-42	lw12	M-368	rbase	OP-83	wl2	M-170
ctemp	M-263	lwsti	M-399	rbdb	I-15	wl2p	M-171
cth0	M-295	lwwth0	M-386	rbdb	M-61	wld	M-49
cvb	M-262	m	I-23	rbpb	I-12	wln	M-50
cvbk	M-265	mbe0	M-287	rbpb	M-58	wmax	M-351
cvdsover	M-323	mbew1	M-286	rbpd	I-13	wmin	M-352
ddltict	M-277	mismatchdist	M-290	rbpd	M-59	wmuecb0	M-456
ddltmax	M-275	mismatchmod	M-289	rbps	I-14	wmuecb1	M-457
ddltslp	M-276	mj	M-253	rbps	M-60	wmueph1	M-458

Virtuoso Simulator Components and Device Models Reference

HiSIM_IGBT Model (hisim_igbt)

divx	M-266	mjsw	M-254	rbsb	I-16	wmuesr1	M-461
dly1	M-233	mjswg	M-255	rbsb	M-62	wmuesti1	M-477
dly2	M-234	mphdfm	M-278	rd	M-40	wmuesti2	M-478
dly3	M-235	muecb0	M-144	rd2	M-69	wmuesti3	M-479
dlyov	M-236	muecb1	M-145	rd20	M-299	wmuetmp	M-462
dtemp	I-8	mueph0	M-146	rd21	M-300	wndep	M-454
dtemp	M-32	mueph1	M-147	rd22	M-301	wnfalp	M-504
eg0	M-86	mueph2	M-117	rd22d	M-302	wnftrp	M-503
egig	M-221	mueph1	M-161	rd23	M-303	wninv	M-455
falph	M-228	muephs	M-172	rd231	M-312	wnj	M-487
fn1	M-189	muephw	M-122	rd231p	M-313	wnover	M-441
fn2	M-190	mueplp	M-162	rd23s	M-314	wnovers	M-439
fn3	M-191	muepsp	M-173	rd23sp	M-315	wnsti	M-472
fvbs	M-192	muepwp	M-123	rd24	M-304	wnsubc	M-444
gbbs	OP-55	mueslp	M-165	rd25	M-305	wnsubp	M-445
gbds	OP-53	muesr0	M-149	rd26	M-306	wnsubpsti1	M-480
gbgs	OP-54	muesr1	M-150	rd3	M-70	wnsubpsti2	M-481
gbmin	M-63	muesr1	M-163	rdeff	OP-72	wnsubpsti3	M-482
gds	OP-10	muesrw	M-164	rdict1	M-75	wpgd1	M-452
gidl1	M-222	muesti1	M-127	rdict2	M-77	wpgd3	M-453
gidl2	M-223	muesti2	M-128	rdov11	M-71	wpthrou	M-505

Virtuoso Simulator Components and Device Models Reference

HiSIM_IGBT Model (hisim_igbt)

gidl3	M-224	muesti3	M-129	rdov12	M-72	wsc1	M-449
gidl4	M-225	mueswp	M-125	rdov13	M-73	wsc2	M-450
gidl5	M-226	muetmp	M-148	rdrift	OP-74	wsc3	M-451
gleak1	M-204	mvt0	M-285	rds	M-316	wscp1	M-446
gleak2	M-205	mvtw1	M-284	rdslp1	M-74	wscp2	M-447
gleak3	M-206	mvtw12	M-288	rdslp2	M-76	wscp3	M-448
gleak4	M-207	ndep	M-151	rdsp	M-317	wscstil	M-474
gleak5	M-208	ndep1	M-166	rdtemp1	M-89	wscsti2	M-475
gleak6	M-218	ndep1p	M-167	rdtemp2	M-90	wsti	M-121
gleak7	M-219	nf	I-21	rdvb	M-298	wstil	M-133
glkb0	M-212	nfalp	M-227	rdvd	M-297	wstilp	M-134
glkb1	M-213	nftrp	M-229	rdvd1	M-308	wstiw	M-140
glkb2	M-214	ngcon	I-18	rdvd1p	M-309	wstiwp	M-141
glkb3	M-220	ninv	M-152	rdvds	M-310	wsub1	M-463
glksd1	M-209	ninvd	M-153	rdvdsp	M-311	wsub2	M-464
glksd2	M-210	nj	M-241	rdvdtemp1	M-91	wsvbs	M-466
glksd3	M-211	njsw	M-242	rdvdtemp2	M-92	wsvds	M-465
glpart1	M-203	nover	M-273	rdvg11	M-291	wsvgs	M-467
gm	OP-9	novers	M-274	rdvg12	M-292	wvdiffj	M-506
gmb	OP-11	npext	M-55	reversed	OP-2	wvfbc	M-443
gmt	OP-75	nrd	I-10	rs	M-39	wvfbover	M-440

Virtuoso Simulator Components and Device Models Reference

HiSIM_IGBT Model (hisim_igbt)

ibase_bjt	OP-78	nrs	I-9	rsdrift	OP-73	wvmax	M-435
ibd	OP-63	nsti	M-120	rseff	OP-71	wvth0	M-124
ibpc1	M-201	nsubc	M-37	rsh	M-56	wvthsc	M-119
ibpc2	M-202	nsubcdfm	I-36	rshg	M-57	wvthsti	M-476
ibs	OP-62	nsubcw	M-115	rth0	M-294	wvtmp	M-459
ibulk	OP-47	nsubcwp	M-116	rth0nf	M-322	wwfc	M-492
ic_bjt	OP-76	nsubp	M-38	rth0r	M-319	wwl2	M-442
ice	OP-79	nsubp0	M-52	rth0w	M-320	wwsti	M-473
id	OP-44	nsubpstil	M-130	rth0wp	M-321	wwvth0	M-460
ids	OP-3	nsubpsti2	M-131	sa	I-33	xgl	I-20
ie_bjt	OP-77	nsubpsti3	M-132	saref	M-138	xgw	I-19
ig	OP-45	nsubwp	M-53	sb	I-34	xl	M-64
igate	OP-56	ovmag	M-271	sbref	M-139	xld	M-34
igateb	OP-58	ovslp	M-270	sc1	M-102	xldld	M-68
igated	OP-59	parl2	M-101	sc2	M-103	xqy	M-43
igates	OP-57	pb	M-256	sc2b	M-104	xqy1	M-66
igid1	OP-61	pbgtmp1	M-510	sc3	M-105	xqy2	M-67
igisl	OP-60	pbgtmp2	M-511	sc4	M-106	xti	M-243
igtemp1	M-215	pbsw	M-257	scp1	M-107	xti2	M-260
igtemp2	M-216	pbswg	M-258	scp2	M-108	xw	M-65
igtemp3	M-217	pcgdo	M-558	scp21	M-111	xwd	M-35

Virtuoso Simulator Components and Device Models Reference

HiSIM_IGBT Model (hisim_igbt)

is	OP-46	pcgso	M-557	scp22	M-110
isnoisy	I-37	pcisbk	M-562	scp3	M-109

Virtuoso Simulator Components and Device Models Reference

HiSIM_IGBT Model (hisim_igbt)

HiSIM_Diode Model (hisim_diode)

HiSIM_Diode is a compact diode model with reverse recovery. It supports DC, AC and transient analyses.

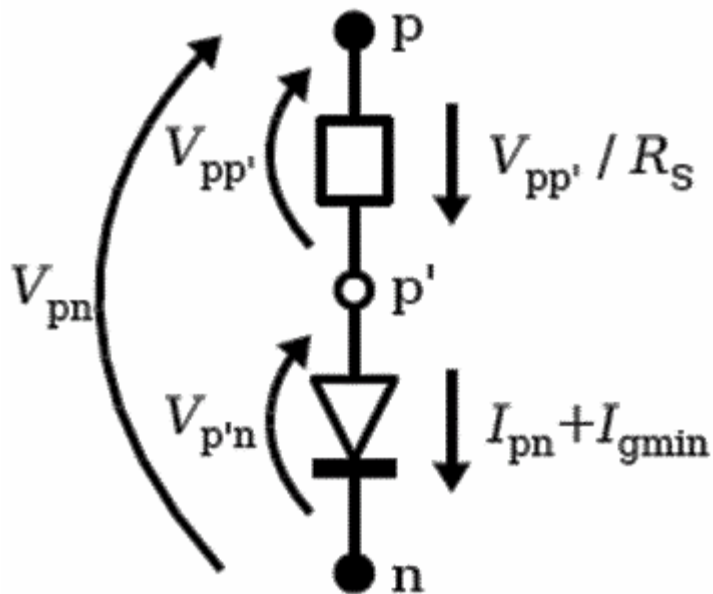
This chapter contains the following information:

- [Model Concepts](#) on page 2580
- [Model Usage](#) on page 2581
 - [Instance Syntax](#) on page 2581
 - [Model Syntax](#) on page 2581
 - [Sample Model Statement](#) on page 2581
- [Reference](#) on page 2581
 - [Component Statements](#) on page 2581

Model Concepts

Elements considered in HiSIM_Diode model are summarized in Fig. 35.1. The internal node p' is determined when the parasitical resistor is given. The applied voltage V_{pn} is reduced effectively to $V_{p'n}$ due to the potential drop $V_{pp'}$ induced by the resistance R_S .

Figure 33-1 Framework of HiSIM_Diode Model



The basic model concept is consistent with that of conventional diode. The reverse recovery effect is additionally introduced in the HiSIM_Diode model. A high voltage p-i-n structure operating in high level injection is assumed as typical for most power diodes. In actual diodes, reverse recovery is caused by diffusion of charge from the center of the i region, thus, one or more charge storage nodes must be added to provide for this diffusion current. In HiSIM_Diode model, modified lumped charge concept is implemented and charge storage node is adopted. Two model parameters are introduced in the model: The carrier transit time TAUTRAN and the recovery time TAUREC.

Model Usage

Instance Syntax

HiSIM_Diode instance need specify 2 terminals, anode and cathode node respectively. To specify HiSIM_Diode instance element, the Model Name has to be associated with a HiSIM_Diode model card.

```
InstanceName p n ModelName parameter=value ...
```

Sample Instance Statement

```
d1 (vpp vnn) n_dio area=1e-12
```

For more instance parameters, refer to the Reference of this model.

Model Syntax

The following syntax specifies HiSIM_Diode model:

```
model ModelName hisim_diode parameter=value ...
```

The third parameter, “hisim_diode”, is the master to indicate this model card is a HiSIM_Diode model card.

Sample Model Statement

```
model n_dio hisim_diode eg0=1.17 rs=1e-1 bgtmp1=1e-4 rst1=1e-3
```

For more model parameters, refer to the Reference of this model.

Reference

Component Statements

Instance Parameters

1 area=1.0 m² Junction area.

Virtuoso Simulator Components and Device Models Reference

HiSIM_Diode Model (hisim_diode)

2 trise=0 C Temperature rise from ambient.

Model Parameters

Junction hsmdiode model parameters

1 compatible=spectre Spice compatible flag. Possible values are spectre, spice2, spice3, cdsspice, hspice, spiceplus, eldo, sspice, and mica.

2 js0=5.0e-7 A/m² Saturation current.

3 eg0=1.1785 V Band gap.

4 nj=1 Emission coefficient.

5 vdiffj=0.6e-3 V Diode threshold voltage..

6 cj=5.0e-4 F/m² Bottom junction capacitance per unit area at zero bias.

7 pb=1.0 V Bottom junction build-in potential..

8 mj=0.5 Bottom junction capacitance grading coefficient.

9 divx=0.0 1/V Reverse current coefficient.

10 tautran=5.0e-8 s Transit time.

11 taurec=1.0e-9 s Recovery time.

Parasitic resistance parameters

12 rs=0 ohmm² Series resistance per unit area.

13 rsv1=0 1/C Voltage dependence for the resistance.

14 rsv2=0 C⁻² Voltage dependence for the resistance.

15 rsi1=0 1/C Current dependence for the resistance.

16 rsi2=0 C⁻² Current dependence for the resistance.

Virtuoso Simulator Components and Device Models Reference

HiSIM_Diode Model (hisim_diode)

Temperature effects parameters

17	tnom (C)	Parameters measurement temperature. Default set by `options`.
18	bgtmp1=90.25e-6 1/C	Temperature dependence of bandgap.
19	bgtmp2=1.0e-7 C^-2	Temperature dependence of bandgap.
20	rst1=0 1/C	Temperature dependence for the resistance.
21	rst2=0 C^-2	Temperature dependence for the resistance.
22	tcjbd=0 1/C	Temperature dependence of hsmdiode capacitance.
23	x _{ti} =2	Temperature coefficient for forward-current densities.

Operating Point Parameters

1	vd (V)	Diode voltage.
2	id (A)	Diode current .
3	gd (S)	Diode conductance .
4	cd (F)	Diode capacitance .
5	rdio (Ohm)	Diode equivalent resistance .
6	charge (Coul)	Diode capacitor charge.
7	p (W)	Diode power.
8	region	Estimated operating region. Spectre outputs number (0-2) in a rawfile. Possible values are off and on.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the

Virtuoso Simulator Components and Device Models Reference

HiSIM_Diode Model (hisim_diode)

description for that parameter. For example, a reference of M-35 means the 35th model parameter.

area	I-1	gd	OP-3	rs	M-12	tcjbd	M-22
bgtmp1	M-18	id	OP-2	rsi1	M-15	tnom	M-17
bgtmp2	M-19	js0	M-2	rsi2	M-16	trise	I-2
cd	OP-4	mj	M-8	rst1	M-20	vd	OP-1
charge	OP-6	nj	M-4	rst2	M-21	vdifffj	M-5
cj	M-6	p	OP-7	rsv1	M-13	xti	M-23
compatible	M-1	pb	M-7	rsv2	M-14		
divx	M-9	rdio	OP-5	taurec	M-11		
eg0	M-3	region	OP-8	tautran	M-10		

Surface Potential Based Compact MOSFET Model (spmos)

This chapter contains the following information about the SPMOS model:

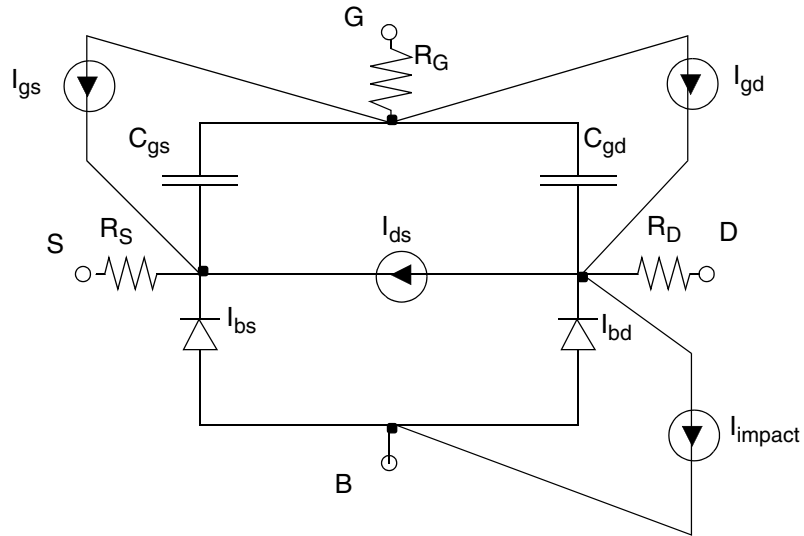
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 - [Equivalent Circuit](#) on page 2587
 - [Lateral Gradient Factor](#) on page 2587
 - [Effective Drain-Source Voltage](#) on page 2588
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Virtuoso Simulator Components and Device Models Reference

Surface Potential Based Compact MOSFET Model (spmoss)

- [Parameters with Different Default Values for SPMOS Version 34](#) on page 2625

Equivalent Circuit



Core Model

Lateral Gradient Factor

The lateral field gradient in SPMOS is reduced with surface potential through the following semi-empirical formula:

$$f = f_0 + B_f x_f$$

where

$$f_0 = \frac{F_0}{1 + B_f V_{sbx1} + (C_f V_{dsx} + A_f V_{sbx1})(1 + EF \cdot A_f V_{sbx1}) + h_{lo}} + 0.01$$

$$h_{lo} = H_{lo1} \cdot V_{hlo}^2 \left| H_{lo2} \cdot \sqrt{V_{hlo}} \right.$$

$$V_{hlo} = \frac{V_{dsx} \cdot W_{hlo}}{V_{dsx} + W_{hlo} + 10^{-8}}$$

Virtuoso Simulator Components and Device Models Reference
Surface Potential Based Compact MOSFET Model (spmos)

$$V_{dsx} = \sqrt{V_{hlo}^2 + 0.01} - 0.1$$

$$V_{sbx1} = \text{MAXA}(V_{sbx}, 0, 10^{-4})$$

$$v_{sbx} = V_{sb} + \frac{1}{2}(V_{ds} - V_{dsx})$$

$$B_t = (f_0 - 0.01)B_f V_t$$

$$x_f = \frac{\phi_f}{V_t}$$

Effective Drain-Source Voltage

The saturation voltage is given by

$$V_{dsat} = \phi_{sat} - V_t \cdot \ln \left[1 + \frac{\phi_{sat} \cdot (\phi_{sat} - (2 \cdot a_{sat} \cdot V_t))}{G_f^2 \cdot \Delta_s \cdot V_t^2} \right]$$

where

$$a_{sat} = x_{gs} + \frac{1}{2} \cdot G_f^2$$

$$\phi_{sat} = \frac{2 \cdot \phi_0 \cdot \phi_2}{\phi_0 + \phi_2 + \sqrt{(\phi_0 + \phi_2)^2 - 3.96 \cdot \phi_0 \cdot \phi_2}}$$

$$\phi_0 = \psi_0 \cdot \frac{V_c + \frac{V_2}{4} + \psi_0 \cdot \left(\frac{1}{8} + \frac{\delta_0^2}{2} \right)}{V_c + V_2 \cdot \delta_0 \cdot (1 - \delta_0) + \psi_0 \cdot \delta_0^2}$$

$$\phi_2 = \frac{V_t \cdot G_f^2 \cdot \Delta_s \cdot S_0}{a_{sat} + \sqrt{a_{sat}^2 - G_f^2 \cdot \Delta_s \cdot S_0}}$$

Virtuoso Simulator Components and Device Models Reference
Surface Potential Based Compact MOSFET Model (spmos)

$$\delta_0 = \frac{\Psi_0}{\Psi_0 + G_{hf}V_c}$$

$$\Psi_0 = \frac{2 \cdot V_2}{1 + \frac{V_2}{4 \cdot V_c} + \sqrt{1 + \frac{V_2}{V_c} + \left(\frac{V_2}{4 \cdot V_c}\right)^2}}$$

$$V_2 = \frac{V_1}{\alpha_s} + V_t$$

$$V_c = \frac{u_{sat}L}{\mu_s}$$

$$u_{sat} = \frac{VSAT}{1 + K_{sm} \cdot w_{sat}}$$

$$w_{sat} = \frac{100 \cdot V_1 \cdot (1 + STX \cdot V_{sbx})}{100 + V_1 \cdot (1 + STX \cdot V_{sbx})}$$

$$\alpha_s = 1 + \frac{G_f \cdot (1 - E_s)}{2 \cdot S_s}$$

The effective drain-source voltage is given by

$$V_{dse} = \frac{V_{ds}}{\left[1 + \left(\frac{V_{ds}}{V_{dsat}}\right)^{a_x}\right]^{\frac{1}{a_x}}}$$

Surface Potential

Surface Potential at Source End of Channel

The approximate analytical solution for surface potential is

$$x = \theta(V_{gb}, \phi_n)$$

Virtuoso Simulator Components and Device Models Reference

Surface Potential Based Compact MOSFET Model (spm05)

where the normalized imref splitting is

$$\phi_n = (F_p - F_n)/q$$

$$x_s = \theta(V_{gb}, V_{sb})$$

In the process of computing surface potential, the following are computed as well

$$E_s = \exp(-x_s)$$

$$\Delta_s = \Delta_{ns}/E_s$$

$$D_s = (E_s^{-1} + E_s - 2x_s) \cdot \Delta_{ns}$$

where

$$\Delta_{ns} = \frac{1}{f} \cdot \exp(-x_{ns})$$

and

$$x_{ns} = (2\phi_b + V_{sb})/V_t$$

The evaluation of $E_s, \Delta_s, \Delta_{ns}$ is carefully ordered to avoid over/underflow problems.

After evaluating surface potential x_s , you can compute the normalized inversion charge at the source

$$V_1 = \frac{G_f^2 V_t D_s}{x_{gs} + G_f S_s}$$

where

$$S_s = \sqrt{P_s}$$

$$P_s = x_s - 1 + E_s$$

Virtuoso Simulator Components and Device Models Reference
Surface Potential Based Compact MOSFET Model (spmos)

$$x_{gs} = G_f \sqrt{D_s + P_s}$$

$$G_f = G \sqrt{f}$$

Series resistance is given by:

$$R_t = \frac{R_{t1}(1 + RB \cdot V_{sbx})}{1 + R_g V_1}$$

Series resistance factor is given by:

$$\rho = MU0(C_{ox}/L)R_t V_1$$

Effective vertical field is given by:

$$E_{eff} = E_{eff0}(q_b + \eta_\mu V_1)$$

$$q_b = V_t G_f S_s$$

where $\eta_\mu = 1/2$ for n-channel and $\eta_\mu = 1/3$ for p-channel MOSFETs.

Effective mobility at the source end of the channel is given by:

$$\mu_s = \frac{MU0 \cdot \mu_x}{1 + (\mu_E \cdot E_{eff})^{\theta_{MU}} + CS \cdot \frac{q_b^2}{(V_1 + q_b)^2} + \rho}$$

The variable is given by

$$\mu_x = (1 + X_{cor} \cdot V_{sbx}) / (1 + 0.2X_{cor} \cdot V_{sbx})$$

where the term $(1 + X_{cor} \cdot V_{sbx})$ introduces non-universality. The denominator assures that μ_x does not exceed 5 for extreme (and unphysical) V_{sbx} .

V_1 and μ_s are temporary variables. Eventually these will be changed to assure the symmetry of the model. Also, $\rho = 0$ if external model of series resistance is used.

Surface Potential at Drain End of Channel

Surface potential at the drain end of the channel is

$$\phi_{sd} = x_d V_t$$

where

$$x_d = \theta(V_{gb}, V_{sb} + V_{dse})$$

The above equation is used when

$$x_g > x_{g23} = x_{g23} + G \sqrt{f_{23}(x_{23} - 1)}$$

where

$$f_{23} = f_0 + B_t x_{23}$$

$$x_{23} = \begin{cases} (\phi_b + V_{sb})/V_t & \text{for } V_{sb} \geq 0 \\ (\phi_b + 0.5V_{sb})/V_t & \text{for } V_{sb} < 0 \end{cases}$$

For $x_g < x_{g23}$, it is more efficient to:

1. Compute x_s
2. Determine normalized drain-source surface potential difference $\varphi = \phi/V_t$
3. Compute $x_d = x_s + \varphi$.

While computing x_d , the following variables are computed as well:

$$E_d = \exp(-x_d)$$

$$D_d = (E_d^{-1} - E_d - 2x_d)\Delta_{nd}$$

where

$$\Delta_{nd} = \frac{1}{f} \exp(-x_{nd})$$

$$x_{nd} = (2\phi_b + V_{sb} + V_{dse})/V_t$$

Mid-Point Surface Potential

$$\phi_m = \frac{1}{2}(\phi_{ss} + \phi_{sd})$$

The following variables are used:

$$x_m = \frac{1}{2}(x_s + x_d)$$

$$E_m = \sqrt{E_s E_d}$$

$$D_m = \frac{1}{2}(D_s + D_d) + \frac{1}{8}\phi^2 \left(E_m - \frac{2}{G_f} \right)$$

$$P_m = x_m - 1 + E_m$$

$$x_{gm} = G_f \sqrt{D_m + P_m}$$

$$S_m = \sqrt{P_m}$$

Normalized inversion charge is calculated by:

$$V_m = \frac{G_f^2 V_t D_m}{x_{gm} + G_f S_m}$$

Linearization coefficient is

$$\alpha = 1 + \frac{G_f(1 - E_m)}{2S_m}$$

Series resistance:

Virtuoso Simulator Components and Device Models Reference
Surface Potential Based Compact MOSFET Model (spm0s)

$$R_t = \frac{R_{t1}(1 + RB \cdot V_{sbx})}{1 + R_g V_m}$$

Series resistance factor:

$$\rho = MU0(C_{ox}/L)R_t V_m$$

Effective vertical field is

$$E_{eff} = E_{eff0}(q_b + \eta_\mu V_m)$$

$$q_b = V_t G_f S_m$$

where $\eta_\mu = 1/2$ for n-channel and $\eta_\mu = 1/3$ for p-channel MOSFETs.

Effective mobility

$$\mu_m = \frac{MU0 \cdot \mu_x}{1 + (\mu_E \cdot E_{eff})^{\theta_{MU} + CS} \cdot \frac{q_b^2}{(V_m + q_b)^2} + \rho}$$

Quantum Mechanical Corrections

In SPMOS quantum-mechanical (QM) corrections are considered in the most common case $\phi_s \geq 3V_t$ which is of interest for the charge-sheet models.

QM corrections are directly used for $x_m = \phi_m/V_t$ and $\varphi = (\phi_{sd} - \phi_{ss})/V_t$.

This is preferable to correcting ϕ_{ss} and ϕ_{sd} , especially in the case when φ is a small difference of two large variables.

In the following equations, superscript 0 refers to variables uncorrected for QM effects.

For $x_g \geq 0$ (i.e. for $V_{gb} \geq V_{fb}$)

$$x_m = x_m^{(0)} + u_{QM}$$

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 Surface Potential Based Compact MOSFET Model (spmos)

$$\varphi = \varphi^{(0)} \cdot \frac{k_m(\bar{D} + d_0)}{d + k_m\bar{D}\alpha_{QM}}$$

where

$$u_{QM} = \frac{q_{QM}}{p_{QM} - q_{QM}/p_{QM}}$$

$$q_{QM} = G_f^2 D_m^{(0)} \Delta e'_g$$

$$\Delta e'_g = g_{QMP} \Delta e_g$$

$$\Delta e_g = q_q x_{gm}^{2/3}$$

$$g_{QMP} = \frac{D_m^{(0)}}{D_m^{(0)} + P_m^{(0)}}$$

$$p_{QM} = 2x_{gm} + G_f^2 [1 - E_m^{(0)} + D_m^{(0)} \alpha_{QM}]$$

$$\alpha_{QM} = 1 + \frac{2\Delta e'_g}{3x_{gm}}$$

$$k_m = \exp(\alpha_{QM} u_{QM} - \Delta e'_g)$$

$$\bar{D} = \frac{D_s + D_d}{2}$$

$$d_0 = 1 - E_m^{(0)} + 2x_{gm}/G_f^2$$

$$d = d_0 + (E_m^{(0)} - 2/G_f^2) u_{QM}$$

For $x_g < 0$,

$$x_m = x_m^{(0)} - \frac{\Delta e'_g \phi_m^2}{\phi_m^2 + \frac{0.04}{1 + 3|\phi_m|}}$$

There is no correction for ϕ . This form is introduced to eliminate the singularity or unphysical behavior near $V_{gb} = V_{fb}$. Coefficients 0.04 and 3 are not affected by model parameters and are fixed.

In addition to correcting ϕ_m and x_m , QM effects are introduced into

$$D_m = k_m D_m^{(0)}$$

and variables P_m, x_{gm} , which are given by the above expressions but with x_m corrected for QM effects.

Polysilicon Depletion

In SPMOS polysilicon depletion equations are conditioned to provide smooth device characteristics for a wide voltage range but at present the poly effects are only included for $v_{gb} > V_{fb}$.

The normalized poly surface potential at midpoint

$$x_{pm} = k_p \left[\frac{x_{gm}^{(0)}}{1 + \eta_p^{-1}} \right]^2$$

where

$$\eta_p = [1 + k_p x_{gm}^{(0)}]^{-1/2}$$

In this section the superscript 0 indicates that the variable is not corrected for poly depletion effect.

Poly corrections are introduced into $x_m = \phi_m / V_t$ and $\phi = (\phi_{sd} - \phi_{ss}) / V_t$ rather than into ϕ_{ss} and ϕ_{sd} directly.

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Surface Potential Based Compact MOSFET Model (spm0s)

The corrected midpoint surface potential is

$$x_m = x_m^{(0)} + u_p$$

where

$$u_p = \frac{q}{p - q/p}$$

$$p = 2[x_{gm}^{(0)} - x_{pm}] + G_f^2 [1 - E_m^{(0)} + D_m^{(0)}]$$

$$q = x_{pm} [x_{pm} - 2x_{gm}^{(0)}]$$

The correction to normalized surface potential difference ϕ is as follows

$$\phi = \phi^{(0)} \cdot \frac{k_m (d_0 + \bar{D})}{d + k_m \bar{D}}$$

where d_0 is given in section [“Quantum Mechanical Corrections”](#) on page 2594 with superscript 0 indicating that the variable is not corrected for poly depletion effect

$$d = 1 + E_m^{(0)} - 2\eta_p x_{gm} / G_f^2$$

$$k_m = \exp(u_p)$$

In addition to changing the surface potentials, poly correction affects the linearization of inversion charge and intrinsic charges. The expressions in sections [“Drain Current”](#) on page 2598 and [“Intrinsic Charges”](#) on page 2599 include these corrections.

The case of no poly effect can be recovered by setting $\eta_p = 1$. While physically this corresponds to $NP \rightarrow \infty$, in SPMOS eliminating poly effects is formally prescribed by setting $NP = 0$ in the parameter file.

Drain Current

$$V_c = L \cdot \frac{u_{sat}}{\mu_m}$$

$$u_{sat} = \frac{VSAT}{1 + K_{sm} \cdot w_{sat}}$$

$$w_{sat} = \frac{100 \cdot V_m \cdot (1 + STX \cdot V_{sbx})}{100 + V_m \cdot (1 + STX \cdot V_{sbx})}$$

This ensures that $w_{sat} < 100$ and $u_{sat} < 0.3 VSAT$ during SPICE convergence when V_m can be unphysically high.

$$\delta = \frac{\phi}{\phi + G_{hf} \cdot V_c}$$

$$L_{sat} = \frac{\delta \phi \mu_m}{u_{sat}}$$

The channel length modulation factor is calculated by the following equation:

$$L_{CLM} = \delta L_{q2d} \ln[1 + CLM3 \cdot (V_{ds} - \phi)]$$

Drain current is calculated by

$$I_d = \frac{\mu_m WC_{OX}(V_m + \alpha V_t)\phi}{L_{red} + L_{sat}}$$

where the inversion charge linearization (including polysilicon depletion effect) is:

$$\alpha = \eta_p + \frac{G_f(1 - E_m)}{2S_m}$$

The reduced channel length is

$$L_{red} = \frac{L}{1 + \frac{L_{CLM}}{L}}$$

Intrinsic Charges

All charges are normalized to C_{ox} .

$$C_{ox} = C_{ox}(L + 10^{-6}DLQ)(W + 10^{-6}DWQ)$$

Gate charge

$$Q_g = x_{gm} V_t + \frac{\eta_p \phi}{2} \left(\frac{\phi r_L}{6H} - 1 + r_L \right)$$

where

$$H = \frac{V_m / \alpha + V_t}{1 + L_{sat} / L_{red}}$$

$$r_L = L_{red} / L$$

Inversion layer charge

$$|Q_I| = r_L (V_m + \alpha \phi^2 / 12H) + Q_{CLM}$$

$$Q_{CLM} = (1 - r_L)(V_m - 0.5\alpha\phi)$$

Drain charge (computed using Ward-Dutton partition)

$$|Q_D| = \frac{1}{2} r_L^2 \left\{ V_m - \frac{\alpha \phi}{6} \left[1 - \frac{\phi}{2H} - \frac{1}{5} \left(\frac{\phi}{2H} \right)^2 \right] \right\} + \frac{1}{2} Q_{CLM} (1 + r_L)$$

Source charge

$$|Q_S| = |Q_I| - |Q_D|$$

Bulk charge

$$|Q_B| = Q_G - |Q_I|$$

Bias-Dependent Body Factor

If $NSLP > 10^{-3}$,

$$\gamma = \gamma_0 \sqrt{1 + D_{nsub}}$$

$$D_{nsub} = D_{nsubL} \cdot \text{MAXA}(0, (V_{gs} + VNSUB) \cdot NSLP, 0.1)$$

Otherwise

$$\gamma = \gamma_0$$

Normalized body factor is

$$G = \gamma / (\sqrt{V_t})$$

Extrinsic Model

Bias-Independent Variables

Overlap capacitance

$$C_{oxov} = \frac{\epsilon_{ox}}{TOXOV}$$

Overlap body factor

$$\gamma_{ov} = \frac{\sqrt{2q\epsilon_{Si}NOV}}{C_{oxov}}$$

Normalized overlap body factor ° ° ° ° ° °

$$G_{ov} = \frac{\gamma_{ov}}{\sqrt{V_t}}$$

Tunneling current density constant (in A/m^2)

Virtuoso Simulator Components and Device Models Reference

Surface Potential Based Compact MOSFET Model (spmos)

$$J_0 = \frac{qm_0k_B^2TABS^2}{2\pi^2h^3} = 1.082 \cdot 10^{11} \cdot \left(\frac{TABS}{300}\right)^2$$

Channel tunneling current density exponential constant (dimensionless)

$$B = 2TOX(2qm_0\chi_B)^{1/2}/h = 6.831 \cdot 10^9 \cdot TOX \cdot \sqrt{\chi_B}$$

Overlap tunneling current density exponential constant (dimensionless)

$$B_{ov} = 2TOXOV((2qm_0\chi_B)^{1/2}/h) = 6.831 \cdot 10^9 TOXOV \sqrt{\chi_B}$$

Auxiliary variable of gate current model

$$\alpha_b = E_g/(2q) + \phi_b$$

The *Si* / *SiO₂* conduction band offset

$$\chi_B = 3.13V$$

Streamlined Surface Potential Approximation

The availability of the surface potential in the overlap regions is essential to the physical modeling of the charge and gate current components. The streamlined analytical approximation of the surface potential excludes the effects of minority carriers and consequently is even simpler and more efficient than the one employed in the channel region.

Let

$$\xi = 1 + G_{ov}/\sqrt{2}$$

and

$$x_{margin} = 10^{-7} \xi$$

If $|x| < x_{margin}$

$$x = -x_g/\xi$$

Virtuoso Simulator Components and Device Models Reference
Surface Potential Based Compact MOSFET Model (spmos)

For $x_g < -x_{margin}$, proceed in the follow steps

$$y_g = -x_g$$

$$z = 1.25y_g/\xi$$

$$\eta = \frac{1}{2}\{z + 10 - [(z - 6)^2 + 64]^{1/2}\}$$

$$a = (y_g - \eta)^2 + G_{ov}^2(\eta + 1)$$

$$c = 2(y_g - \eta) - G_{ov}^2$$

$$\tau = -\eta + \log\left(\frac{a}{G_{ov}^2}\right)$$

$$y_0 = \eta + \sigma(a, c, \tau)$$

$$\Delta_0 = \exp(y_0)$$

$$p = 2(y_g - y_0) + G_{ov}^2(\Delta_0 - 1)$$

$$q = (y_g - y_0)^2 + G_{ov}^2(y_0 - \Delta_0 + 1)$$

$$x = -y_0 - \frac{2q}{p + \sqrt{p^2 - 2q(2 - G_{ov}^2\Delta_0)}}$$

For $x_g > x_{margin}$, compute

$$x_1 = 1.25$$

$$x_{g1} = x_1 + G_{ov}\sqrt{\exp(-x_1) + x_1 - 1}$$

Virtuoso Simulator Components and Device Models Reference
Surface Potential Based Compact MOSFET Model (spmos)

$$\bar{x} = \left(\frac{x_g}{\xi}\right) \left[1 + x_g \frac{(\xi x_1 - x_{g1})}{x_{g1}^2} \right]$$

$$\bar{E} = \exp(-\bar{x})$$

$$\omega = 1 - \bar{E}$$

$$x_0 = x_g + \frac{G_{ov}^2}{2} - G_{ov} \left(x_g + \frac{G_{ov}^2}{4} - \omega \right)^{1/2}$$

$$\Delta_1 = \exp(-x_0)$$

$$p = 2(x_g - x_0) + G_{ov}^2(1 - \Delta_1)$$

$$q = (x_g - x_0)^2 - G_{ov}^2(x_0 + \Delta_1 - 1)$$

$$x = x_0 + \frac{2q}{p + \sqrt{p^2 - 2q(2 - G_{ov}^2\Delta_1)}}$$

The evaluation of Δ_0 and Δ_1 is carefully ordered to avoid over/underflow problems.

Charge Model

Source overlap region charge

$$Q_{sov} = W \cdot LOV \cdot C_{oxov} \cdot (V_{gs} - \phi_{sov})$$

Drain overlap region charge

$$Q_{dov} = W \cdot LOV \cdot C_{oxov} \cdot (V_{gd} - \phi_{dov})$$

Bulk overlap region charge

$$Q_{bov} = L \cdot CGBO \cdot V_{gb}$$

Virtuoso Simulator Components and Device Models Reference

Surface Potential Based Compact MOSFET Model (spmos)

Inner fringe charge correction

$$\Delta Q_G = -\Delta Q_S - \Delta Q_D$$

$$\Delta Q_S = IFKJ \cdot W(1 + IFCJV_{sb})(IFVBI + V_{sb} - \phi_{ss})^{1/2}$$

$$\Delta Q_D = IFKJ \cdot W(1 + IFCJV_{db})(IFVBI + V_{db} - \phi_{sd})^{1/2}$$

Outer fringe charge

$$Q_{ofs} = W \cdot CF \cdot V_{gs}$$

$$Q_{ofd} = W \cdot CF \cdot V_{gd}$$

Terminal charges

$$Q_G = Q_G^{(i)} + Q_{sov} + Q_{dov} + \Delta Q_G + Q_{ofs} + Q_{ofd} + Q_{bov}$$

$$Q_S = Q_S^{(i)} - Q_{sov} + \Delta Q_S - Q_{ofs}$$

$$Q_D = Q_D^{(i)} - Q_{dov} + \Delta Q_D - Q_{ofd}$$

$$Q_B = Q_B^{(i)} - Q_{bov}$$

where the superscript (*i*) indicates that the value for that parameter is taken from the SP intrinsic model.

Gate Current Model

$$I_g = I_{gc} + I_{gsov} + I_{gdov}$$

Channel contribution

$$I_{gc} = I_{gc0} \cdot i_{gc}$$

$$I_{gc0} = W \cdot L \cdot J_{gc}$$

Virtuoso Simulator Components and Device Models Reference
Surface Potential Based Compact MOSFET Model (spmoss)

$$J_{gc} = (J_0 \cdot F_s) \cdot \exp\left\{B \cdot \left[-GC1 + \frac{U_{oxm}}{\chi_B} \left(GC2 + \frac{GC3 \cdot U_{oxm}}{\chi_B}\right)\right]\right\}$$

$$U_{oxm} = \sqrt{V_{oxm}^2 + 10^{-6}}$$

where F_s is the supply function describing the difference of the population of carriers across the oxide at mid-point and is given by

$$F_s = \ln\left[\frac{1 + \Delta_{Si}}{1 + \Delta_{Si} \exp(-V_{gs}/V_t)}\right]$$

$$\Delta_{Si} = \exp\left[\frac{\phi_{ss} - \alpha_b - V_x - \psi_t}{V_t}\right]$$

$$\psi_t = MINA(0, V_{ox} + D, 0.05)$$

$$D = GC0 \cdot V_t$$

$$i_{gc} = (1 - b) \frac{\sinh(x)}{x} + b \cdot \cosh(x)$$

$$x = \frac{\phi}{2u_0}$$

$$b = \frac{u_0}{H}$$

$$u_0 = \frac{\chi_B}{[GC2 + 2GC3 \cdot (U_{oxm}/\chi_B)]}$$

Source-Drain Partition

The partition of the gate current in the channel area into the source and drain is essential for the MOSFET compact modeling, which is accomplished in SPMOS using the symmetrical linearization method.

The drain portion is given by

$$I_{gcd} = I_{gc0} i_{gcd}$$

$$i_{gcd} = \frac{i_{gc}}{2} - B_g \sinh(x) - A_g \frac{\sinh(x)}{x} \left[\coth(x) - \frac{1}{x} \right]$$

$$A_g = (1 - 3b + 3b^2)/2$$

$$B_g = b(1 - b)/2$$

and the source portion is given by

$$I_{gcs} = I_{gc} - I_{gcd}$$

Source Overlap Region Contribution

$$I_{gsov} = W \cdot LOV \cdot J_{gsov}$$

$$J_{gsov} = J_0 F_{sovs} \exp \left\{ B_{ov} \cdot \left[-GC1 + \frac{U_{oxovs}}{\chi_B} \left(GC2 + \frac{GC3 \cdot U_{oxovs}}{\chi_B} \right) \right] \right\}$$

$$U_{oxovs} = \sqrt{V_{oxovs}^2 + 10^{-6}}$$

The supply function, F_{sovs} , describing the difference of the population of carriers across the oxide in the source overlap region, given by

$$F_{sovs} = \ln \left[\frac{1 + \Delta_{Siovs}}{1 + \Delta_{Siovs} \exp(-V_{gs}/V_t)} \right]$$

$$\Delta_{Siovs} = \exp \left[\frac{3.0 + \phi_{sov} + \psi_{tovs}}{V_t} \right]$$

$$\psi_{tovs} = MINA(0, V_{oxovs} + GC0 \cdot V_p, 0.05)$$

Drain overlap region contribution

$$I_{gdov} = W \cdot LOV \cdot J_{gdov}$$

$$J_{gdov} = J_0^F F_{sovd} \exp \left\{ B_{ov} \cdot \left[-GC1 + \frac{U_{oxovd}}{\chi_B} \left(GC2 + \frac{GC3 \cdot U_{oxovd}}{\chi_B} \right) \right] \right\}$$

$$U_{oxovd} = \sqrt{V_{oxovd}^2 + 10^{-6}}$$

The supply function, F_{sovd} , describing the difference of the population of carriers across the oxide in the drain overlap region, given by

$$F_{sovd} = \ln \left[\frac{1 + \Delta_{Siovd}}{1 + \Delta_{Siovd} \exp(-V_{gd}/V_t)} \right]$$

$$\Delta_{Siovd} = \exp \left[\frac{3.0 + \phi_{dov} + \psi_{tovd}}{V_t} \right]$$

$$\psi_{tovd} = MINA(0, V_{oxovd} + GC0 \cdot V_p, 0.05)$$

By setting SW_IGATE to 0 (default value) gate current model is turned off.

Substrate Current Model

The substrate current of MOSFETs due to impact ionization is given by

$$I_b = a_1 \cdot (V_{ds} - a_3 \phi) \cdot \exp \left(-\frac{a_2}{(V_{ds} - a_3 \phi)} \right) \cdot I_d$$

$$a_1 = IIA1 + IIA1L \cdot A_L + IIA1W \cdot B_w + IIA1P \cdot A_L \cdot B_w$$

$$a_2 = IIA2 \left[1 + a_4 \left(\sqrt{V_{sb} + 2\phi_b} - \sqrt{2\phi_b} \right) \right] \left(\frac{TABS}{T_n} \right)^{TK_IIA2}$$

$$a_3 = IIA3 + IIA3L \cdot A_L$$

$$a_4 = IIA4 + IIA4L \cdot A_L$$

Total Terminal Currents

The effect of I_b and I_g on the gate, source, drain and body components are as follows

$$I_G = I_{gc} + I_{gsov} + I_{gdov}$$

$$I_S = I_S^{(i)} - (1 - IIPARTITION)I_b - I_{gcs}S_g(x_g) - I_{gsov}$$

$$I_D = I_D^{(i)} + I_b - I_{gcd}S_g(x_g) - I_{gdov}$$

$$I_B = I_B^{(i)} - IIPARTITION \cdot I_b - I_{gc}[1 - S_g(x_g)]$$

where $I_S^{(i)}$, $I_D^{(i)}$ and $I_B^{(i)}$ are terminal currents produced by the intrinsic (core) SP MOS model and

$$S_g(x_g) = \frac{1}{2} \left(1 + \frac{x_g}{\sqrt{x_g^2 + \epsilon}} \right)$$

The computation of the impact ionization current be turned off by setting the parameter SW_IMPACT to 0 (default) and turned on by setting SW_IMPACT to 1.

Noise Model

Channel Thermal Noise

$$S_{I_d^2} = \frac{4k_B \cdot TABS}{L_{red}^2} \cdot \left(\mu_m Q_{inv} + NDELTA \frac{I_d/m\phi}{E_{crit}^2} \right)$$

$$Q_{inv} = WLC_{ox}(Q_I - Q_{CLM})$$

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Surface Potential Based Compact MOSFET Model (spmos)

$$E_{crit} = VSAT/\mu_m$$

Flicker Noise

if SW_FLICKER = 0 (default)

$$S_{I_d^2}(f) = S_{I_d^2}(drift) + S_{I_d^2}(diff)$$

$$S_{I_d^2}(drift) = \frac{C_{ox}\phi_t I_d \mu_m}{\alpha_m \gamma_{FN} L_{red}^2 f^{NEF}} \left\{ [NOIC \cdot (V_m - 2 \cdot V_*) + B^* - u_n V_*] \alpha_m \phi + \right. \\ \left. (A^* - 2B^* \cdot V_* + 3 \cdot NOIC \cdot V_*^2) \ln(q_+/q_-) \right\}$$

$$S_{I_d^2}(diff) = \frac{C_{ox}\phi_t^2 I_d \mu_m}{\gamma_{FN} L_{red}^2 f^{NEF}} \{ [(NOIC + u_n) \alpha_m \phi + (B^* - 2 \cdot NOIC \cdot V_*) \ln(q_+/q_-)] \}$$

$$\gamma_{FN} = 10^{10} [m^{-1}]$$

$$V_* = \phi_t \left(1 + \frac{G}{2\sqrt{x_m + 10^{-6}}} \right)$$

$$A^* = NOIA \cdot q^2 / C_{ox}^2$$

$$B^* = NOIB \cdot q / C_{ox}$$

$$u_n = (A^* - B^* \cdot V_* + NOIC \cdot V_*^2) / (q_+ q_-)$$

$$q_+ = V_* + V_m + \alpha_m \phi$$

$$q_- = V_* + V_m - \alpha_m \phi$$

Virtuoso Simulator Components and Device Models Reference
Surface Potential Based Compact MOSFET Model (spmos)

If SW_FLICKER is set to 1 then

$$S_{I_d^2} = \frac{KF \cdot g_m^2}{C_{ox} W L_f^{NEF}}$$

Series resistance thermal noise

$$S_{R_D} = \frac{4kT}{r_{drain}}$$

$$S_{R_S} = \frac{4kT}{r_{source}}$$

$$S_{R_G} = \frac{4kT}{r_{gate}}$$

where

$$r_{drain} = RSH \cdot NRD$$

$$r_{source} = RSH \cdot NRS$$

$$r_{gate} = RGS \cdot \frac{W_{drawn}}{L_{drawn} \cdot NF}$$

Channel induced gate noise

$$S_{I_g^2} = DVDZ \cdot \frac{TABS \cdot 16k_B \pi^2 f^2 W C_{ox} L_{red}^3}{\mu_m \alpha_m H^3} \left[\frac{\phi^4}{1728 H^2} - \phi^2 \left(\frac{1}{720} + \frac{H'}{144 H} \right) + \frac{H H'}{12} \right]$$

where

$$H' = \frac{V_m / \alpha - V_t L_{sat} / L_{red}}{1 + L_{sat} / L_{red}}$$

Cross correlation coefficient

$$S_{I_g I_d} = j \cdot \frac{TABS \cdot 8k_B \pi f W C_{ox} L_{red} \left(\frac{H\phi}{12} - \frac{\phi^3}{144H} \right)}{H^2}$$

$$c = \frac{S_{I_g I_d}}{\sqrt{S_{I_g}^2 \cdot S_{I_d}^2}}$$

Gate Induced Drain/Source Leakage Current Model

GIDL Model Equations

For $V_{oxovd} \geq 0$

$$I_{GIDL} = 0$$

For $V_{oxovd} < 0$

$$I_{GIDL} = -A_{GIDL0} V_{db} V_{oxovd} V_{tovd} \exp\left(-\frac{B_{GIDL0}}{V_{tovd}}\right)$$

$$A_{GIDL0} = 10^{13} \cdot A_{GIDL} \cdot W_{eff} L_{OV}$$

$$B_{GIDL0} = B_{GIDL} \cdot (1 + dt \cdot TK_BGIDL)$$

$$V_{tovd} = \sqrt{V_{oxovd}^2 + CGIDL^2 \cdot V_{db}^2 + 10^{-6}}$$

GISL Model Equations

$$I_{GISL} = -A_{GIDL0} V_x V_{oxovs}^2 \exp\left(-\frac{B_{GIDL0}}{V_{tovs}}\right)$$

$$V_{tovs} = \sqrt{V_{oxovs}^2 + CGIDL^2 \cdot V_{sb}^2 + 10^{-6}}$$

Scaling Equations

The drawn channel dimensions are denoted as L_{DR} , W_{DR} (in m) or as $L_{DR,\mu m}$, $W_{DR,\mu m}$ (in μm). The minimum device dimensions for a given technology are L_{REF} , W_{REF} (in m) or as $L_{REF,\mu m}$, $W_{REF,\mu m}$ (in μm).

Effective channel length in μm

$$L_{\mu m} = L_{DR,\mu m} - DL0 - DLL \cdot A_L - DLW \cdot B_w$$

where

$$A_L = \frac{1}{L_{REF,\mu m}} - \frac{1}{L_{DR,\mu m}}$$

$$B_w = \frac{1}{W_{REF,\mu m}} - \frac{1}{W_{DR,\mu m}}$$

Effective channel length in m

$$L = 10^{-6} L_{\mu m}$$

Effective channel width in μm ,

$$W_{\mu m} = W_{DR,\mu m} - DW0 - DWL \cdot A_l - DWW \cdot B_W - DWP \cdot A_L \cdot B_W$$

Effective channel width in m

$$W = 10^{-6} W_{\mu m}$$

Total oxide capacitance,

$$C_{oxl} = C_{ox}(L + 10^{-6} \cdot DLQ)(W + 10^{-6} \cdot DWQ)$$

Flat-band voltage (which in SPMOS includes reverse short-channel effect if any)

$$V_{fb} = FB0 + \frac{FB1}{W_{\mu m}} + \frac{FB2}{W_{\mu m}^2} + \Delta V_{RSE}$$

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 Surface Potential Based Compact MOSFET Model (spmos)

$$\Delta V_{RSE} = \left(1 + \frac{FB3}{W_{\mu m}} + \frac{FB4}{W_{\mu m}^2} \right) \cdot \left(\frac{FB5}{L_{DR, \mu m}} + \frac{FB6}{L_{DR, \mu m}^2} + \frac{FB7}{L_{DR, \mu m}^3} \right)$$

Drift velocity local parameters

$$K_{sm} = ST0 + ST1 \cdot B_W$$

$$G_{hf} = \left(GH0 + \frac{GH1}{L_{\mu m}} + \frac{GH2}{L_{\mu m}^2} \right) \cdot \left(1 + \frac{GH3}{W_{\mu m}} \right) + \frac{GH4}{L_{\mu m}^2 W_{\mu m}^2}$$

Local parameters for the lateral field gradient

$$F_0 = 1 - \frac{FL1}{L_{\mu m}} - \frac{FL2}{L_{\mu m}^2}$$

$$A_f = \left(AF0 + \frac{AFL}{L_{\mu m}^2} \right) \cdot C_{LW}$$

$$B_f = \min \left\{ \frac{BFL}{L_{\mu m}^2}, \frac{1 - F_0}{F_0 + 0.01} \right\}$$

$$C_f = \left(CF0 + \frac{CFL}{L_{\mu m}^2} \right) \left(1 + KL \cdot \frac{AL}{L_{\mu m}} \right) C_{LW}$$

and

$$C_{LW} = \frac{1}{1 + KW/W_{\mu m}}$$

Mobility model parameter

$$\mu_E = MU1 \left(1 + \frac{MU1W}{W_{\mu m}} \right)$$

$$\theta_{MU} = MU2 \left(1 + \frac{MU3}{W_{\mu m}} \right)$$

Virtuoso Simulator Components and Device Models Reference

Surface Potential Based Compact MOSFET Model (spmos)

Mobility model parameter (correction for “non-universality”)

$$X_{cor} = NU0 + \frac{NUL}{L_{\mu m}}(1 + NUW \cdot W_{\mu m})$$

Bias-independent part of the series resistance

$$R_{t1} = R0 + R1 \cdot A_L + R2 \cdot B_W + R3 \cdot A_L \cdot B_W$$

Constant used to describe gate bias dependence of the series resistance

$$R_g = R4 + R5 \cdot A_L + R6 \cdot W_{\mu m}$$

Triode-saturation transition variable

$$a_x = \frac{AS0}{1 + ASL/L_{\mu m}}$$

Characteristic length of the quasi-2D theory

$$L_{q2d} = (1 + GDL \cdot L_{\mu m})(CLM0 + CLM1 \cdot A_L + CLM2 \cdot B_W) \sqrt{2 \cdot 10^{-7} \epsilon_{si} / C_{OX}}$$

Subthreshold slope parameter

$$cT = 1 + \frac{T_n}{TABS} \cdot \frac{ITL}{L_{\mu m}^2}$$

Substrate doping variable

$$D_{nsubL} = (1 + NPKT \cdot A_L)^{-1}$$

Halo-doping effect parameters

$$HI01 = GDS1 + GDS1L \cdot L_{DR, \mu m} + GDS1A \cdot A_L$$

$$HI02 = GDS2 + GDS2L \cdot L_{DR, \mu m} + GDS2A \cdot A_L$$

Effective doping

$$N_{sub} = NSUB \left[1 + \frac{LPKT}{L_{\mu m}} (1 - e^{-L_{\mu m}/(YPKT)}) \right]$$

Temperature Dependence (-55^o to 150^o)

SPMOS uses up to 13 temperature coefficients.

Flat-band voltage: TK_VFB0, TK_VFBL, TK_VFBW, TK_VFBP.

Mobility: TK_MU0, TK_MUW, TK_MUL, TK_MUP, TK_MU1, TK_THM, TK_CS.

Saturation velocity: TK_VS, TK_AS.

Coefficients TK_VFBL, TK_VFBW, TK_VFBP, TK_MUL, TK_MUP and TK_AS are expected to be zero for mature processes.

The temperature dependence of bulk and surface potentials is not adjusted and is obtained essentially from the first principles. The temperature dependence of the flat-band voltage, mobility and saturation velocity is as follows. In these equations T_n is nominal temperature and

$$\Delta T = TABS - T_n$$

Flat-band voltage

$$V_{fb} = V_{fb}(T_n) + \frac{k_B \Delta T}{q} \left(TK_VFB + \frac{TK_VFBL}{L_{\mu m}} + \frac{TK_VFBW}{W_{\mu m}} + \frac{TK_VFBP}{W_{\mu m} L_{\mu m}} \right)$$

Mobility

$$\mu_{0} = \mu_{0}(T_n) \left(\frac{T_n}{TABS} \right)^{n_{\mu 0}}$$

$$n_{\mu 0} = TK_MU0 + \frac{\Delta T}{T_n} \left(\frac{TK_MUL}{L_{\mu m}} + \frac{TK_MUW}{W_{\mu m}} + \frac{TK_MUP}{W_{\mu m} L_{\mu m}} \right)$$

$$\theta_{mu} = \theta_{mu}(T_n) \left(\frac{T_n}{TABS} \right)^{TK_THM}$$

$$\mu_E = \mu_E(T_n) \frac{1 + TK_MU1 \exp(\Delta T/20)}{1 + TK_MU1}$$

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$$X_{cor} = X_{cor}(T_n) \left(\frac{T_n}{TABS} \right)^{n_{\mu 0}}$$

$$CS = CS(T_n) \left(\frac{T_n}{TABS} \right)^{TK_CS}$$

Saturation velocity

$$VSAT = VSAT(T_n)(1 + TK_VS \cdot \Delta T)$$

$$G_{hf} = G_{hf}(T_n) \frac{1 + TK_VS/W_{\mu m}}{1 + (TK_VS/W_{\mu m}) \exp(\Delta T/20)}$$

The default values and ranges for temperature coefficients are given in the table below.

Table 34-1 Temperature Coefficients

Parameter	Unit	Description	Default	MIN	MAX
TK_VFB0	None	$V_{fb}(T)$ parameter	0	None	None
TK_VFBL	μm	$V_{fb}(T)$ scaling parameter (L)	0	None	None
TK_VFBW	μm	$V_{fb}(T)$ scaling parameter (W)	0	None	None
TK_VFBP	μm^2	$V_{fb}(T)$ scaling parameter (LW)	0	None	None
TK_MU0	None	MU0(T) parameter	1.5	See Note ¹	
TK_MUL	μm	MU0(T) scaling parameter (L)	0		
TK_MUW	μm	MU0(T) scaling parameter (W)	0		
TK_MUP	μm^2	MU0(T) scaling parameter (LW)	0		
TK_MU1	None	$\mu_E(T)$ parameter	0	0	0.1
TK_THM	None	$\theta_{mu}(T)$ parameter	0	-5	5
TK_CS	None	CS(T) parameter	0	-5	5

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TK_VS	K ⁻¹	VSAT(T) parameter	0	-0	005
TK_AS	μm	A _s (T) parameter	0	0	0.1

1. Instead of limiting TK_MU0, TK_MUL, TK_MUW and TK_MUP, SPMOS sets

$$n_{\mu 0} = \min \left\{ 5, \max \left[-5, TK_MU0 + \frac{\Delta T}{T_n} \left(\frac{TK_MUL}{L_{\mu m}} + \frac{TK_MUW}{W_{\mu m}} + \frac{TK_MUP}{L_{\mu m} W_{\mu m}} \right) \right] \right\}$$

Parameter Descriptions

Table 34-2 Process Parameters Group

Parameter	Unit	Description	Default	MIN	MAX
ITL	μm ²	Interface states scaling factor	0	0	$2P_L^2 L_{CLAMP}^2, \mu m$
LPKT	μm	Pocket length	0	$-\frac{3}{4} PL_L L_{CLAMP}, \mu m$	$9L_{CLAMP}, \mu m$
NP	cm ⁻³	Polysilicon doping	10 ²²	$\max(3 \cdot 10^{19}, 80/TOX^2)$ (See Note ¹)	None
NSUB	cm ⁻³	Substrate doping	$5 \cdot 10^{17}$	10 ¹⁵	$5 \cdot 10^{18}$
QMC None	None	QM correction factor	0	0	$\min(0.6, 3 \cdot 10^{26} \cdot TOX/NSUB)$
TOX	m	Oxide thickness	$4 \cdot 10^{-9}$	10 ⁻⁹	$2 \cdot 10^{-7}$

1. Setting NP=0 or NP > 10²⁸m⁻³ turns off polysilicon depletion effect.

At present, PL = 0.2.

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Surface Potential Based Compact MOSFET Model (spmoss)

Table 34-3 Effective Geometry Group

Parameter	Unit	Description	Default	MIN	MAX
DL0	μm	Channel length offset	0	See Note ¹	
DLL	μm ²	Channel length adjustment (L)	0		
DLW	μm ²	Channel length adjustment (W)	0		
DW0	μm	Channel width offset	0	See Note ²	
DWL	μm ²	Channel width adjustment (L)	0		
DWW	μm ²	Channel width adjustment (W)	0		
DWP	μm ³	Channel width perimeter factor	0		
DLQ	μm	Decoupling parameter	0	$-L_{\mu m}/2$	none
DWQ	μm	Decoupling parameter	0	$-W_{\mu m}/2$	none

1. Instead of limiting the values of DL0, DLL and DLW, SPMOS sets the channel length offset as

$$DL_{\mu m} = DL0 + DLL \cdot A_L + DLW \cdot B_W$$

and the effective channel length (in μm) as

$$L_{\mu m} = \max\{L_{DR, \mu m} - DL_{\mu m}, P_L L_{CLAMP, \mu m}\}$$

2. Instead of limiting parameter values of DW0, DWL, DWW and DWP, SPMOS sets the channel width offset as

$$DW_{\mu m} = DW0 + DWL \cdot A_L + DWW \cdot B_W + DWP \cdot A_L \cdot B_W$$

and the effective channel length (in μm) as

$$W_{\mu m} = \max\{W_{DR, \mu m} - DW_{\mu m}, P_W L_{CLAMP, \mu m}\}$$

At present, $P_w=1/4$.

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Surface Potential Based Compact MOSFET Model (spmoss)

Table 34-4 Mobility Group

Parameter	Unit	Description	Default	MIN	MAX
MU0	cm^2/Vs	Low-field mobility	500	0.01	10^4
NU0	V^{-1}	Non-universality factor	0	0	1
NUL	μm	Non-universality factor (L)	0	See Note ¹	
NUW	μm^{-1}	Non-universality factor (W)	0		
MU1	m/V	Magnitude of the vertical field dependence	0.5	0	$5 \cdot 10^8 TOX$
MU1W	μm	Scaling parameter (W)	0	$-0.9P_W W_{CLAMP\mu m}$	$0.9P_W W_{CLAMP\mu m}$
MU2	None	Sharpness of the vertical field dependence	1.5	0	3
MU3	μm	Scaling parameter (W)	0	$-0.9P_W W_{CLAMP\mu m}$	$0.9P_W W_{CLAMP\mu m}$
CS	None	Coulomb scattering	0	0	10

1. Instead of limiting NU0, NUL and NUW, SPMOS sets

$$X_{cor} = \max\{X_{cor}, 0\}$$

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Table 34-5 Series Resistance Group

Parameter	Unit	Description	Default	MIN	MAX
R0	$\Omega \cdot m$	Fixed component of series resistance	$2 \cdot 10^{-3}$	See Note ¹	
R1	$\Omega \cdot m \cdot \mu m$	Scaling factor (L)	0		
R2	$\Omega \cdot m \cdot \mu m$	Scaling factor (W)	0		
R3	$\Omega \cdot m \cdot \mu m^2$	Scaling factor (L,W)	0		
R4	V^{-1}	Gate bias dependence	0	0	None
R5	$\mu m/V$	Scaling factor (L) gate bias dependence	0.02	$-\frac{P_L}{2} R_4 L_{CLAMP, \mu m}$	$\frac{R_4}{2A_{mr}}$
R6	$\mu m/V$	Scaling factor (W) for gate bias dependence	0	See Note ²	
RB	V^{-1}	Back bias factor	0	0	1.0

1. Instead of limiting the values of R0, R1, R2, and R3, SPMOS sets

$$R_{t1} = \max\{R_0 + R_1 \cdot A_L + R_2 \cdot B_W + R_3 \cdot A_L \cdot B_W, 0\}$$

2. Instead of limiting the values of R6, SPMOS sets

$$R_g = \max\{R_4 + R_5 \cdot A_L + R_6 \cdot W_{\mu m}, 0\}$$

Table 34-6 Velocity Saturation Group

Parameter	Unit	Description	Default	MIN	MAX
VSAT	m/s	Saturation velocity	80,000	50,000	150,000
ST0	V^{-1}	Gate bias dependence of saturation velocity	0	0	0.3
ST1	$\mu m/V$	Adjustment of saturation velocity (W)	0	ST1 _{min} See Note ¹	ST1 _{max} See Note ²

Virtuoso Simulator Components and Device Models Reference
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Parameter	Unit	Description	Default	MIN	MAX
STX	V^{-1}	Back bias dependence of saturation velocity	0	0	1
GH0	None	Grotrjohn/Hofflinger (GH) factor	0.5	0.05	5
GH1	μm	GH Scaling parameter (L^{-1})	0	See Note ³	
GH2	μm^2	GH Scaling parameter (L^{-2})	0		
GH3	μm^3	GH Scaling parameter ($L^{-2}W^{-1}$)	0		
GH4	μm^4	GH Scaling parameter ($L^{-2}W^{-2}$)	0		
AS0	None	Transition from triode to saturation	12	6	100
ASL	None	Scaling factor (L) for triode-saturation	0.6	See Note ⁴	
S0	None	V_{dsat} adjustment	0.98	0.9	0.99

1. $ST1_{min} = -\min\{(0.3 - ST0)/B_{mr}, ST0 \cdot W_{CLAMP, \mu m}\}$

2. $ST1_{max} = \min\{(0.3 - ST0)W_{CLAMP, \mu m}, ST0/B_{mr}\}$

3. Instead of limiting the values of GH1, GH2, GH3, and GH4, SPMOS forces G_{hf} to be in the range [0.05, 5]

$$G_{hf} = \min\left\{5, \max\left[0.05, \left(GH0 + \frac{GH1}{L_{\mu m}} + \frac{GH2}{L_{\mu m}^2}\right)\left(\left(1 + \frac{GH3}{W_{\mu m}}\right) + \frac{GH4}{L_{\mu m}^2 W_{\mu m}^2}\right)\right]\right\}$$

4. Instead of limiting the values of ASL, SPMOS forces a_x to be in the range [2,20]

$$a_x = \min\{20, \max\{2, a_x\}\}$$

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Table 34-7 Flat-band Voltage Group

Parameter	Unit	Description	Default
FB0	V	V_{fb} for long wide devices $L, W \rightarrow \infty$	-1
FB1	$V \cdot \mu m$	Scaling parameter (W^{-1})	0
FB2	$V \cdot \mu m^2$	Scaling parameter (W^{-2})	0
FB3	μm	RSE parameter (W^{-1})	0
FB4	μm^2	RSE parameter (W^{-2})	0
FB5	$V \cdot \mu m$	RSE parameter (L^{-1})	0
FB6	$V \cdot \mu m^2$	RSE parameter (L^{-2})	0
FB7	$V \cdot \mu m^2$	RSE parameter (L^{-3})	0

There are no limits on flat-band voltage parameters.

Table 34-8 Lateral Gradient Factor Group

Parameter	Unit	Description	Default	MIN	MAX
FL1	μm	Scaling parameter for F_0	0.1	See Note ¹	
FL2	μm^2	Scaling parameter for F_0	0.01		
AF0	V^{-1}	Scaling parameter for A_f	0.004	0	10
AFL	$\mu m^2 / V$	Scaling parameter for A_f	0	$-AF0 \cdot P_L^2 L_{CLAMP}^2, \mu m$	10
BFL	$\mu m^2 / V$	Scaling parameter for B_f	0.015	0	10
CF0	V^{-1}	Scaling parameter for C_f	0.0005	0	10
CFL	$\mu m^2 / V$	Scaling parameter for C_f	0.01	$-CF0 \cdot P_L^2 L_{CLAMP}^2, \mu m$	10
KL	μm^2	Scaling parameter for C_{LW}	0	$-KL0$ (See Note ²)	KLO

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Parameter	Unit	Description	Default	MIN	MAX
KW	μm	Scaling parameter for C_{LW}	0	$-0.9P_W W_{CLAMP, \mu m}$	10
DF	None	Sharpness of $f(V_{ds})$ dependence	0	0	3
EF	None	Sharpness of $f(V_{sb})$ dependence	0	0	3

1. Instead of limiting the values of FL1 and FL2, SPMOS forces F_0 to be in the range [0.001, 1]

$$F_0 = \min\{1, \max\{0.001, F_0\}\}$$

2. Instead of limiting the values of GDS1 and GDS2, SPMOS forces

$$\frac{\partial}{\partial V_{dsx}} \left(\frac{F_0}{f_0} - 1 - B_f V_{sbx1} \right) > 0$$

$$KL0 = \min\left\{ 3.6L_{CLAMP, \mu m}^2, 0.9L_{CLAMP, \mu m}/A_{mr} \right\}$$

Table 34-9 Channel Length Modulation Group

Parameter	Unit	Description	Default	MIN	MAX
CLM0	None	L_{q2d} parameter	0.1	0	none
CLM1	μm	L_{q2d} scaling parameter (L)	0	$-\frac{1}{2}CLM0 \cdot L_{CLAMP, \mu m}$	$\min\{10, CLM0/2A_{mr}\}$
CLM2	μm	L_{q2d} scaling parameter (W)	0	$-\frac{1}{2}CLM0 \cdot W_{CLAMP, \mu m}$	$\min\{10, CLM0/2B_{mr}\}$
CLM3	V^{-1}	Logarithm dependence factor	10	0	1000
GDL	μm^{-1}	Scaling parameter (L)	0	0	0.9

New Parameters for SPMOS Version 34

The following parameters have been added to version 34.

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Surface Potential Based Compact MOSFET Model (spmos)

I

Parameter	Unit	Description	Default	MIN	MAX
NCG		Instance parameter for factor of Rgate	1	1	2
SW_GIDL		Flag og gidl	0	0	1
ITO		Interface states scaling factor	0	0	2
NPKT	um	Effective doping parameter	1.0	0	2
NSLP	1/V	Effective doping parameter	0	0	2
YPKT		Effective doping parameter	0.001	0.001	2
VNSUB	V	Effective doping parameter	0		
GDS1		V_{ds} dependence of G_{ds} slope	0		
GDS2		V_{ds} dependence of G_{ds} slope	0		
GDS1L	$1/\mu m$	Scaling parameter for Hlo1	0		
GDS2L	$1/\mu m$	Scaling parameter for Hlo2	0		
GDS1A	μm	Scaling parameter for Hlo1	0		

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Parameter	Unit	Description	Default	MIN	MAX
GDS2A	μm	Scaling parameter for Hlo1	0		
TK_BGIDL	1/K	Temperature dependence	0.0	0.0	1.0
TK_IIA2		Substrate current scaling parameter	0.0	0.0	1.0
KGOV		Decouples tunneling and CV overlap fitting	1	0.1	10
CHIB	eV	Band offset	3.13	2.5	4
AGIDL		I_{GIDL} coefficient	0.7	0	
BGIDL	V	Tunnelling barrier adjustment	28	1	100
CGIDL	1/V	Lateral field dependence	0.007	0	1
IIA1W	$\mu m / \sqrt{V}$	Substrate current scaling parameter	0	-1	1
IIA1P	$\mu m / \sqrt{V}$	Substrate current scaling parameter	0	-1	1

Parameters with Different Default Values for SPMOS Version 34

Model Parameter	Old Default Value	New Default Value
noia	0.0	1.0e+20
noib	0.0	5.0e+04
noic	0.0	1.4e-12

Virtuoso Simulator Components and Device Models Reference
Surface Potential Based Compact MOSFET Model (spmos)

MOS Level-0 Transistor (mos0)

The MOS0 model is a simplified MOS level-1 model. The MOS0 DC drain current model is different from the Shichman and Hodges model because body effects are not modeled. The intrinsic MOS gate capacitances are replaced by the following linear overlap capacitances:

Gate to source/drain (`capmod = overlap`)

Gate to bulk (`capmod = bulk`)

Gate, source, and drain to ground (`capmod = gnd`)

MOS0 is usually used as a MOS switch. This model recognizes all the MOS and BSIM instance parameters but only uses `l` and `w`, ignoring all other parameters. MOS0 transistors require that you use a model statement.

This device is not supported within `altergroup`.

Sample Instance Statement

```
mp1 (0 1 2 2) pchmod0 l=2u w=30u ad=120p as=75p pd=36u ps=6u
```

Sample Model Statement

```
model pchmod0 mos0 type=p vto=-0.683 tox=0.21e-7 ld=0.45e-6 tnom=27
```

Instance Definition

```
Name d g s b ModelName parameter=value ...
```

Instance Parameters

- | | | |
|---|--------------------|-----------------|
| 1 | <code>w</code> (m) | Channel width. |
| 2 | <code>l</code> (m) | Channel length. |

Virtuoso Simulator Components and Device Models Reference

MOS Level-0 Transistor (mos0)

3 `m=1` Multiplicity factor (number of MOSFETs in parallel).

Model Definition

model modelName mos0 parameter=value ...

Model Parameters

Device type parameters

1 `type=n` Transistor type.
Possible values are `n` or `p`.

Drain current model parameters

2 `vto=0 V` Threshold voltage at zero body bias.

3 `kp=2.0718e-5 A/V2` Transconductance parameter.

4 `lambda=0.02 1/V` Channel length modulation parameter.

5 `tox=1e-7 m` Gate oxide thickness.

6 `ld=0 m` Lateral diffusion.

7 `wd=0 m` Field-oxide encroachment.

Charge model selection parameters

8 `capmod=gnd` Intrinsic charge model.
Possible values are `none`, `overlap`, `bulk`, or `gnd`.

Temperature parameters

9 `tnom (C)` Parameters measurement temperature. Default set by `options`.

10 `trise=0 C` Temperature rise from ambient.

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MOS Level-0 Transistor (mos0)

Default device parameters

11	$w=3e-6$ m	Default channel width.
12	$l=3e-6$ m	Default channel length.

Operating-Point Parameters

1	<code>type=n</code>	Transistor type. Possible values are <code>n</code> or <code>p</code> .
2	<code>id</code> (A)	Resistive drain current.
3	<code>vgs</code> (V)	Gate-source voltage.
4	<code>vds</code> (V)	Drain-source voltage.
5	<code>vbs</code> (V)	Bulk-source voltage.
6	<code>vth</code> (V)	Threshold voltage.
7	<code>vdsat</code> (V)	Drain-source saturation voltage.
8	<code>gm</code> (S)	Common-source transconductance.
9	<code>gds</code> (S)	Common-source output conductance.
10	<code>cgs</code> (F)	Gate-source capacitance.
11	<code>cgd</code> (F)	Gate-drain capacitance.
12	<code>cgate</code> (F)	Gate-Ground capacitance.
13	<code>ron</code> (Ω)	On-resistance.
14	<code>pwr</code> (W)	Power at op point.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the

Virtuoso Simulator Components and Device Models Reference

MOS Level-0 Transistor (mos0)

description for that parameter. For example, a reference of M-35 means the 35th model parameter.

capmod	M-8	1	I-2	tox	M-5	vth	OP-6
cgate	OP-12	1	M-12	trise	M-10	vto	M-2
cgd	OP-11	lambda	M-4	type	M-1	w	I-1
cgs	OP-10	ld	M-6	type	OP-1	w	M-11
gds	OP-9	m	I-3	vbs	OP-5	wd	M-7
gm	OP-8	pwr	OP-14	vds	OP-4		
id	OP-2	ron	OP-13	vdsat	OP-7		
kp	M-3	tnom	M-9	vgs	OP-3		

MOS Level-15 Transistor (mos15)

The MOS15 model is the AMS level 15 model which is the modified Berkeley SPICE level-2 model with the DC model replaced by that of AMS. It is an analytical one-dimensional model that incorporates most of the second-order small-size effects. A smoother version of the level-15 model (with continuous Gds at Vdsat) was also developed. Three charge models are available. MOS15 transistors require the use of a model statement.

This device is not supported within altergroup.

This device is dynamically loaded from the shared object /vobs/spectre_dev/tools.sun4v/cmi/lib/5.0.doc/libstmodels_sh.so

Instance Definition

```
Name d g s b ModelName parameter=value ...
```

Instance Parameters

1	w (m)	Channel width.
2	l (m)	Channel length.
3	as (m ²)	Area of source diffusion.
4	ad (m ²)	Area of drain diffusion.
5	ps (m)	Perimeter of source diffusion.
6	pd (m)	Perimeter of drain diffusion.
7	nrd (m/m)	Number of squares of drain diffusion.
8	nrs (m/m)	Number of squares of source diffusion.
9	ld (m)	Length of drain diffusion region.

Virtuoso Simulator Components and Device Models Reference

MOS Level-15 Transistor (mos15)

10	<code>ls (m)</code>	Length of source diffusion region.
11	<code>m=1</code>	Multiplicity factor (number of MOSFETs in parallel).
12	<code>region=triode</code>	Estimated operating region. Spectre outputs number (0-3) in a rawfile. Possible values are <code>off</code> , <code>triode</code> , <code>sat</code> , or <code>subth</code> .
13	<code>trise</code>	Temperature rise from ambient.

Model Definition

```
model modelName mos15 parameter=value ...
```

Model Parameters

Device type parameters

1	<code>type=n</code>	Transistor type. Possible values are <code>n</code> or <code>p</code> .
---	---------------------	--

Drain current model parameters

2	<code>vto=0.5 V</code>	Threshold voltage at zero body bias.
3	<code>kp=2.0718e-5 A/V²</code>	Transconductance parameter.
4	<code>lambda=0.5 1/V</code>	Channel length modulation parameter.
5	<code>phi=0.7 V</code>	Surface potential at strong inversion.
6	<code>gamma=1.0 \sqrt{V}</code>	Body-effect parameter.
7	<code>uo=600 cm²/V s</code>	Carrier surface mobility.
8	<code>vmax=8.0e4 m/s</code>	Carrier saturation velocity.
9	<code>ucrit=2.0e6 V/cm</code>	Critical field for mobility degradation.
10	<code>uexp=0</code>	Critical field exponent for mobility degradation.

Virtuoso Simulator Components and Device Models Reference

MOS Level-15 Transistor (mos15)

- 11 $utra=0$ 1/V Transverse field for mobility.
- 12 $neff=1$ Total channel charge coefficient.
- 13 $delta=0$ Width effect on threshold voltage.

Process parameters

- 14 $nsub=1.13e16$ cm^{-3} Channel doping concentration.
- 15 $nss=0$ cm^{-2} Surface state density.
- 16 $nfs=0$ cm^{-2} Fast surface state density.
- 17 $tpg=+1$ Type of gate (+1 = opposite of substrate, -1 = same as substrate, 0 = aluminum).
- 18 $tox=1e-7$ m Gate oxide thickness.
- 19 $ld=0$ m Lateral diffusion.
- 20 $wd=0$ m Field-oxide encroachment.
- 21 $xw=0$ m Width variation due to masking and etching.
- 22 $xl=0$ m Length variation due to masking and etching.
- 23 $xj=0.15e-6$ m Source/drain junction depth.

Impact ionization parameters

- 24 $ai0=0$ 1/V Impact ionization current coefficient.
- 25 $lai0=0$ $\mu m/V$ Length sensitivity of $ai0$.
- 26 $wai0=0$ $\mu m/V$ Width sensitivity of $ai0$.
- 27 $bi0=0$ V Impact ionization current exponent.
- 28 $lbi0=0$ μm V Length sensitivity of $bi0$.

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MOS Level-15 Transistor (mos15)

29 $w_{bi0}=0 \mu\text{m V}$ Width sensitivity of $bi0$.

Overlap capacitance parameters

30 $c_{gso}=0 \text{ F/m}$ Gate-source overlap capacitance.

31 $c_{gdo}=0 \text{ F/m}$ Gate-drain overlap capacitance.

32 $c_{gbo}=0 \text{ F/m}$ Gate-bulk overlap capacitance.

33 $meto=0 \text{ m}$ Metal overlap in fringing field.

Charge model selection parameters

34 $capmod=bsim$ Intrinsic charge model.
Possible values are *none*, *meyer*, *yang*, or *bsim*.

35 $xpart=1$ Drain/source channel charge partition in saturation for BSIM charge model, use 0.0 for 40/60, 0.5 for 50/50, or 1.0 for 0/100.

36 $xqc=0$ Drain/source channel charge partition in saturation for charge models, e.g. use 0.4 for 40/60, 0.5 for 50/50, 0 for 0/100.

Parasitic resistance parameters

37 $r_s=0 \Omega$ Source resistance.

38 $r_d=0 \Omega$ Drain resistance.

39 $r_{sh}=0 \Omega/\text{sqr}$ Source/drain diffusion sheet resistance.

40 $r_{ss}=0 \Omega \text{ m}$ Scalable source resistance.

41 $r_{dd}=0 \Omega \text{ m}$ Scalable drain resistance.

42 $r_{sc}=0 \Omega$ Source contact resistance.

43 $r_{dc}=0 \Omega$ Drain contact resistance.

44 $minr=0.1 \Omega$ Minimum source/drain resistance.

45 $ldif=0 \text{ m}$ Lateral diffusion beyond the gate.

Virtuoso Simulator Components and Device Models Reference

MOS Level-15 Transistor (mos15)

46	hdif=0 m	Length of heavily doped diffusion.
47	lgcs=0 m	Gate-to-contact length of source side.
48	lgcd=0 m	Gate-to-contact length of drain side.
49	sc= ∞ m	Spacing between contacts.

Junction diode model parameters

50	js (A/m ²)	Bulk junction reverse saturation current density.
51	is=1e-14 A	Bulk junction reverse saturation current.
52	n=1	Junction emission coefficient.
53	dskip=yes	Use simple piece-wise linear model for diode currents below 0.1*iabstol. Possible values are no or yes.
54	imax=1 A	Explosion current.
55	jmax=1e8 A/m ²	Explosion current density.

Junction capacitance model parameters

56	cbs=0 F	Bulk-source zero-bias junction capacitance.
57	cbd=0 F	Bulk-drain zero-bias junction capacitance.
58	cj=0 F/m ²	Zero-bias junction bottom capacitance density.
59	mj=1/2	Bulk junction bottom grading coefficient.
60	pb=0.8 V	Bulk junction built-in potential.
61	fc=0.5	Forward-bias depletion capacitance threshold.
62	cjsw=0 F/m	Zero-bias junction sidewall capacitance density.
63	mjsw=1/3	Bulk junction sidewall grading coefficient.

Virtuoso Simulator Components and Device Models Reference

MOS Level-15 Transistor (mos15)

- 64 `pbsw=0.8 V` Side-wall junction built-in potential.
- 65 `fcsw=0.5` Side-wall forward-bias depletion capacitance threshold.

Operating region warning control parameters

- 66 `alarm=none` Forbidden operating region.
Possible values are `none`, `off`, `triode`, `sat`, `subth`, or `rev`.
- 67 `bvj= ∞ V` Junction reverse breakdown voltage.

Temperature effects parameters

- 68 `tnom (C)` Parameters measurement temperature. Default set by options.
- 69 `trise=0 C` Temperature rise from ambient.
- 70 `uto=0 C` Mobility temperature offset.
- 71 `ute=-1.5` Mobility temperature exponent.
- 72 `tlev=0` DC temperature selector.
- 73 `tlevc=0` AC temperature selector.
- 74 `eg=1.12452 V` Energy band gap.
- 75 `gap1=7.02e-4 V/C` Band gap temperature coefficient.
- 76 `gap2=1108 C` Band gap temperature offset.
- 77 `flex=0` Temperature exponent for `ucrit`.
- 78 `lamex=0 1/C` Temperature parameter for `lambda` and `kappa`.
- 79 `trs=0 1/C` Temperature parameter for source resistance.
- 80 `trd=0 1/C` Temperature parameter for drain resistance.
- 81 `xti=3` Saturation current temperature exponent.
- 82 `ptc=0 V/C` Surface potential temperature coefficient.

Virtuoso Simulator Components and Device Models Reference

MOS Level-15 Transistor (mos15)

83	$t_{cv}=0$ V/C	Threshold voltage temperature coefficient.
84	$p_{ta}=0$ V/C	Junction potential temperature coefficient.
85	$p_{tp}=0$ V/C	Sidewall junction potential temperature coefficient.
86	$c_{ta}=0$ 1/C	Junction capacitance temperature coefficient.
87	$c_{tp}=0$ 1/C	Sidewall junction capacitance temperature coefficient.

Default instance parameters

88	$w=3e-6$ m	Default channel width.
89	$l=3e-6$ m	Default channel length.
90	$a_s=0$ m ²	Default area of source diffusion.
91	$a_d=0$ m ²	Default area of drain diffusion.
92	$p_s=0$ m	Default perimeter of source diffusion.
93	$p_d=0$ m	Default perimeter of drain diffusion.
94	$n_{rd}=0$ m/m	Default number of squares of drain diffusion.
95	$n_{rs}=0$ m/m	Default number of squares of source diffusion.
96	$l_{dd}=0$ m	Default length of drain diffusion region.
97	$l_{ds}=0$ m	Default length of source diffusion region.

Noise model parameters

98	$k_f=0$	Flicker (1/f) noise coefficient.
99	$a_f=1$	Flicker (1/f) noise exponent.
100	$e_f=1$	Flicker (1/f) noise frequency exponent.
101	$noisemod=1$	Noise model selector.

Virtuoso Simulator Components and Device Models Reference

MOS Level-15 Transistor (mos15)

The i_{max} (j_{max}) parameter is used to aid convergence and prevent numerical overflow. The junction characteristics of the FET are accurately modeled for current (density) up to i_{max} (j_{max}). For currents (density) above i_{max} (j_{max}), the junction is modeled as a linear resistor and a warning is printed.

Output Parameters

1	w_{eff} (m)	Effective channel width.
2	l_{eff} (m)	Effective channel length.
3	r_{seff} (Ω)	Effective source resistance.
4	r_{deff} (Ω)	Effective drain resistance.

Operating-Point Parameters

1	$type=n$	Transistor type. Possible values are <code>n</code> or <code>p</code> .
2	$region=triode$	Estimated operating region. Spectre outputs number (0-3) in a rawfile. Possible values are <code>off</code> , <code>triode</code> , <code>sat</code> , or <code>subth</code> .
3	$reversed$	Reverse mode indicator. Possible values are <code>no</code> or <code>yes</code> .
4	i_d (A)	Resistive drain current.
5	v_{gs} (V)	Gate-source voltage.
6	v_{ds} (V)	Drain-source voltage.
7	v_{bs} (V)	Bulk-source voltage.
8	v_{th} (V)	Threshold voltage.
9	v_{dsat} (V)	Drain-source saturation voltage.
10	g_m (S)	Common-source transconductance.
11	g_{ds} (S)	Common-source output conductance.

Virtuoso Simulator Components and Device Models Reference

MOS Level-15 Transistor (mos15)

12	gmbs (S)	Body-transconductance.
13	gameff (\sqrt{V})	Effective body effect coefficient.
14	betaeff (A/V ²)	Effective beta.
15	cbd (F)	Drain-bulk junction capacitance.
16	cbs (F)	Source-bulk junction capacitance.
17	cgs (F)	Gate-source capacitance.
18	cgd (F)	Gate-drain capacitance.
19	cgb (F)	Gate-bulk capacitance.
20	ron (Ω)	On-resistance.
21	ib (A)	Resistive bulk current.
22	pwr (W)	Power at op point.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

ad	I-4	gap2	M-76	nfs	M-16	tlevc	M-73
ad	M-91	gds	OP-11	noisemod	M-101	tnom	M-68
af	M-99	gm	OP-10	nrd	I-7	tox	M-18
ai0	M-24	gmbs	OP-12	nrd	M-94	tpg	M-17
alarm	M-66	hdif	M-46	nrs	I-8	trd	M-80

Virtuoso Simulator Components and Device Models Reference

MOS Level-15 Transistor (mos15)

as	I-3	ib	OP-21	nrs	M-95	trise	I-13
as	M-90	id	OP-4	nss	M-15	trise	M-69
betaeff	OP-14	imax	M-54	nsub	M-14	trs	M-79
bi0	M-27	is	M-51	pb	M-60	type	M-1
bvj	M-67	jmax	M-55	pbsw	M-64	type	OP-1
capmod	M-34	js	M-50	pd	I-6	ucrit	M-9
cbd	M-57	kf	M-98	pd	M-93	uexp	M-10
cbd	OP-15	kp	M-3	phi	M-5	uo	M-7
cbs	M-56	l	I-2	ps	I-5	ute	M-71
cbs	OP-16	l	M-89	ps	M-92	uto	M-70
cgb	OP-19	lai0	M-25	pta	M-84	utra	M-11
cgbo	M-32	lambda	M-4	ptc	M-82	vbs	OP-7
cgd	OP-18	lamex	M-78	ptp	M-85	vds	OP-6
cgdo	M-31	lbi0	M-28	pwr	OP-22	vdsat	OP-9
cgs	OP-17	ld	I-9	rd	M-38	vgs	OP-5
cgso	M-30	ld	M-19	rdc	M-43	vmax	M-8
cj	M-58	ldd	M-96	rdd	M-41	vth	OP-8
cjsw	M-62	ldif	M-45	rdef	O-4	vto	M-2
cta	M-86	lds	M-97	region	I-12	w	I-1
ctp	M-87	leff	O-2	region	OP-2	w	M-88
delta	M-13	lgcd	M-48	reversed	OP-3	wai0	M-26

Virtuoso Simulator Components and Device Models Reference

MOS Level-15 Transistor (mos15)

dskip	M-53	lgcs	M-47	ron	OP-20	wbi0	M-29
ef	M-100	ls	I-10	rs	M-37	wd	M-20
eg	M-74	m	I-11	rsc	M-42	weff	O-1
flex	M-77	meto	M-33	rseff	O-3	xj	M-23
fc	M-61	minr	M-44	rsh	M-39	xl	M-22
fcsw	M-65	mj	M-59	rss	M-40	xpart	M-35
gameff	OP-13	mjsw	M-63	sc	M-49	xqc	M-36
gamma	M-6	n	M-52	tcv	M-83	xti	M-81
gap1	M-75	neff	M-12	tlev	M-72	xw	M-21

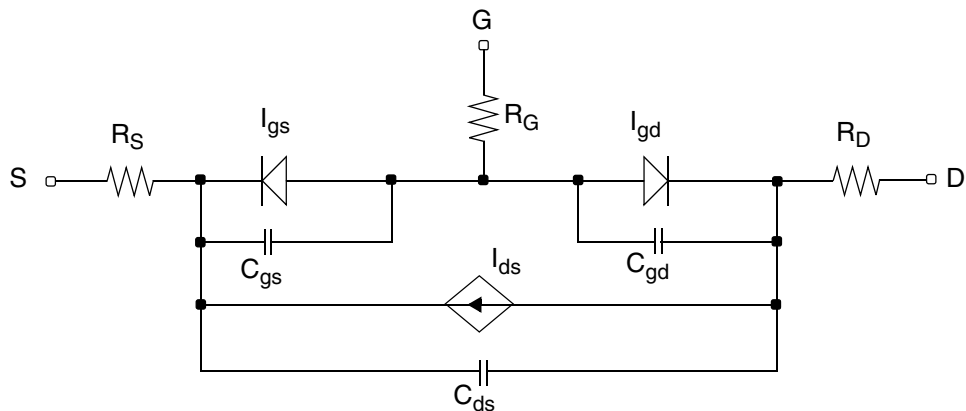
Virtuoso Simulator Components and Device Models Reference

MOS Level-15 Transistor (mos15)

GaAs Model (gaas)

The GaAs MESFET model is derived from the model by H. Statz and others at Raytheon. The model is completely symmetric and is slightly modified to make it conserve charge. This chapter contains the following information for the GaAs MESFET model:

- [Drain Current for the Subthreshold Region](#) on page 2644
- [Drain Current for the Triode Region](#) on page 2644
- [Drain Current for the Saturation Region](#) on page 2645
- [Gate Junction Currents](#) on page 2645
- [Gate Junction Capacitance](#) on page 2646
- [Temperature Effect](#) on page 2647
- [Noise Model](#) on page 2648
- [Scaling Effects](#) on page 2649
- [Component Statements](#) on page 2649



Note: The charge model in GaAs is a charge-conserving model. The capacitances are nonreciprocal.

$$V_{GST} \equiv V_{GS} - v_{to}$$

$$V_{GDT} \equiv V_{GST} - V_{DS}$$

Drain Current for the Subthreshold Region

Note: This equation applies when $V_{GST} \leq 0$.

$$I_{DS} = 0$$

Drain Current for the Triode Region

Note: These equations apply when $V_{GST} \geq 0$, $V_{DS} \leq 3/\alpha$.

$$I_{DS} = \frac{\beta V_{GST}^2}{1 + \beta V_{GST}} (1 + \lambda V_{DS}) (1 - F_{ac}^3)$$

where

$$Fac = 1 - \frac{\alpha V_{DS}}{3}$$

Drain Current for the Saturation Region

Note: This equation applies when $V_{GST} \geq 0$ and $V_{DS} \geq 3/\alpha$.

$$I_{DS} = \frac{\beta V_{GST}^2}{1 + \beta V_{GST}} (1 + \lambda V_{DS})$$

Gate Junction Currents

$$I_{GS(GD)} = \begin{cases} is \left(e^{\frac{V_{GS(GD)}}{nV_t}} - 1 \right) & \text{if } V_{GS(GD)} \leq V_{Expl} \\ I_{offset} + G_{Expl} V_{GS(GD)} & \text{otherwise} \end{cases}$$

where V_t is the thermal voltage given by

$$V_t = \frac{kT}{q} ,$$

$$V_{Expl} = nV_t \ln \left[1 + \frac{imelt}{is} \right]$$

is the forward explosion voltage,

$$G_{Expl} = \frac{(imelt + is)}{nV_t}$$

is the conductance at V_{Expl} , and

$$I_{offset} = imelt - V_{Expl} G_{Expl}$$

is the current linearly extrapolated to $V = 0$ from V_{Expl} .

Gate Junction Capacitance

$$C_{GS(V)} = \begin{cases} C_{gs, Fwd} & \text{if } V_{DS} \geq 1/\alpha \\ c_{gs} & \text{if } V_{DS} \leq -1/\alpha \\ T_{fs} C_{gs, Fwd} + T_{fd} c_{gs} & \text{otherwise} \end{cases}$$

$$C_{GD(V)} = \begin{cases} c_{gd} & \text{if } V_{DS} \geq 1/\alpha \\ C_{gd, Fwd} & \text{if } V_{DS} \leq -1/\alpha \\ T_{fs} c_{gd} + T_{fd} C_{gd, Fwd} & \text{otherwise} \end{cases}$$

where

$$C_{GS, Fwd} = \begin{cases} \frac{c_{gs} V_{GST}}{2\sqrt{1 - V_{ps}/pb} \sqrt{V_{GST}^2 + \delta^2}} & \text{if } V_{ps} \leq fc * pb \\ \frac{c_{gs} V_{GST}}{2\sqrt{1 - fc} \sqrt{V_{GST}^2 + \delta^2}} & \text{otherwise} \end{cases}$$

$$C_{GD, Fwd} = \begin{cases} \frac{c_{gd} V_{GDT}}{2\sqrt{1 - V_{pd}/pb} \sqrt{V_{GDT}^2 + \delta^2}} & \text{if } V_{pd} \leq fc * pb \\ \frac{c_{gd} V_{GDT}}{2\sqrt{1 - fc} \sqrt{V_{GDT}^2 + \delta^2}} & \text{otherwise} \end{cases}$$

$$V_{ps} \equiv \frac{1}{2}[V_{GS} + v_{to} + \sqrt{V_{GST}^2 + \delta^2}]$$

$$V_{pd} \equiv \frac{1}{2}[V_{GD} + v_{to} + \sqrt{V_{GDT}^2 + \delta^2}]$$

$$T_{fs} = \frac{1}{4}[2 + 3\alpha V_{DS} - (\alpha V_{DS})^3]$$

$$T_{fd} = 1 - T_{fs}$$

Temperature Effect

Junction Potential

$$pb = pb_{nom} \left(\frac{T}{T_{nom}} \right) - 3V_t \ln \left[\frac{T}{T_{nom}} \right] - E_{g,nom} \left(\frac{T}{T_{nom}} \right) + E_g$$

Gate Junction Current

$$is = is_{nom} \left(\frac{T}{T_{nom}} \right)^{xti} \exp \left[\frac{E_{g,nom}}{V_{t,nom}} - \frac{E_g}{V_t} \right]$$

where, if SPICE compatibility is required (set by the options),

$$E_g = 1.16 - \frac{7.02 \times 10^{-4} T^2}{1108 + T}$$

$$E_{g,nom} = 1.16 - \frac{7.02 \times 10^{-4} T_{nom}^2}{1108 + T_{nom}}$$

otherwise,

$$E_g = 1.17 - \frac{4.73 \times 10^{-4} T^2}{636 + T}$$

$$E_{g, nom} = 1.17 - \frac{4.73 \times 10^{-4} T_{nom}^2}{636 + T_{nom}}$$

Noise Model

Source Series Resistance Thermal Noise

$$\overline{i_{R_s}^2} = \frac{4kT}{r_s} \Delta f$$

Drain Series Resistance Thermal Noise

$$\overline{i_{R_d}^2} = \frac{4kT}{r_d} \Delta f$$

Channel Conductance Thermal and Flicker Noise

$$\overline{i_{DS}^2} = \frac{8kT(g_m + g_{ds})}{3} \left(\frac{3}{2} - \frac{V'_{DS}}{2V_{DSAT}} \right) + kf \frac{I_{DS}^{af}}{f} \Delta f$$

where

$$V'_{DS} = \text{MAX}(V_{DS}, V_{DSAT})$$

g_m is the transconductance, g_{ds} is the channel conductance, and kf and af are constants for a given device. The Virtuoso[®] Spectre[®] circuit simulator defaults for kf and af are 0.0 and 1.0, respectively.

Scaling Effects

The following are the Spectre scaling effects:

- *is*, *cgs*, *cgd*, and *beta* are multiplied by *area*.
- *rs* and *rd* are divided by *area*.
- All noises are multiplied by *area*.

Component Statements

This device is supported within altergroups.

There are some convergence problems with this model because of C_{gs} going to zero beyond pinchoff. The problems occur when the gate is driven from an inductive source, and there is no other capacitance at the gate. To prevent these problems, avoid setting C_{gd} to zero and add side wall capacitance to the gate-source and gate-drain junctions. A good estimate for these capacitors is $C = \pi \cdot \epsilon \cdot w / 2$ where w is the gate width in microns and $\epsilon = 0.116$ fF/micron.

Sample Instance Statement

```
m1 (1 2 0) nmes area=1 m=2
```

Sample Model Statement

```
model nmes gaas type=n vto=-2 beta=0.06 lambda=0 b=0.25 rs=3.65 alpha=1.9 rd=1.98  
is=1.1e-9 n=1.28 fc=0.5 cgs=0.365e-12
```

Instance Definition

```
Name d g s ModelName parameter=value ...
```

Instance Parameters

- | | | |
|---|--------------------|--|
| 1 | <i>area=1</i> | Junction area factor. |
| 2 | <i>m=1</i> | Multiplicity factor. |
| 3 | <i>isnoisy=yes</i> | Should resistor generate noise.
Possible values are <i>no</i> or <i>yes</i> . |

Virtuoso Simulator Components and Device Models Reference

GaAs Model (gaas)

4 `region=fwd` Estimated operating region. Spectre outputs number (0-4) in a rawfile.
Possible values are `off`, `triode`, `sat`, `subth`, or `breakdown`.

Model Definition

`model modelName gaas parameter=value ...`

Model Parameters

Device type parameters

1 `type=n` Transistor type.
Possible values are `n` or `p`.

Drain current parameters

2 `vto=-2 V` Pinch-off voltage.
3 `beta=0.0001 A/V2` Transconductance parameter.
4 `lambda=0 1/V` Channel length modulation parameter.
5 `b=0.3 1/V` Doping tail extending parameter.
6 `alpha=2 1/V` Saturation voltage parameter.

Parasitic resistance parameters

7 `rd=0 Ω` Drain resistance (/area).
8 `rs=0 Ω` Source resistance (/area).
9 `rg=0 Ω` Gate resistance (/area).
10 `minr=0.1 Ω` Minimum source/drain/gate resistance.

Junction diode model parameters

11 `is=1e-14 A` Gate saturation current (*area).

Virtuoso Simulator Components and Device Models Reference

GaAs Model (gaas)

- 12 `n=1` Emission coefficient for the gate junction.
- 13 `imelt=`imax' A` Explosion current (*area).
- 14 `dskip=yes` Use simple piece-wise linear model for diode currents below $0.1 \cdot i_{abstol}$.
Possible values are `no` or `yes`.

Junction capacitance model parameters

- 15 `capmod=2` Charge model selector.
- 16 `cgs=0 F` Gate-source zero-bias junction capacitance (*area).
- 17 `cgd=0 F` Gate-drain zero-bias junction capacitance (*area).
- 18 `pb=1 V` Gate junction potential.
- 19 `fc=0.5` Junction capacitor forward-bias threshold.
- 20 `delta=0.2 V` Gate capacitance pinch-off transition width.

Temperature effects parameters

- 21 `tnom (C)` Parameters measurement temperature. Default set by options.
- 22 `trise=0 C` Temperature rise from ambient.
- 23 `xti=3` Temperature exponent for effect on `is`.

Operating region warning control parameters

- 24 `alarm=none` Forbidden operating region.
Possible values are `none`, `off`, `triode`, `sat`, `subth`, or `rev`.
- 25 `imax=1 A` Maximum allowable current (*area).
- 26 `bvj=∞ V` Junction reverse breakdown voltage.

Noise model parameters

- 27 `kf=0` Flicker noise (1/f) coefficient.
- 28 `af=1` Flicker noise (1/f) exponent.

`Imax` and `Imelt`:

The `imax` parameter aids convergence and prevents numerical overflow. The junction characteristics of the device are accurately modeled for current up to `imax`. If `imax` is exceeded during iterations, the linear model is substituted until the current drops below `imax` or until convergence is achieved. If convergence is achieved with the current exceeding `imax`, the results are inaccurate, and Spectre prints a warning.

A separate model parameter, `imelt`, is used as a limit warning for the junction current. This parameter can be set to the maximum current rating of the device. When any component of the junction current exceeds `imelt`, note that base and collector currents are composed of many exponential terms, Spectre issues a warning and the results become inaccurate. The junction current is linearized above the value of `imelt` to prevent arithmetic exception, with the exponential term replaced by a linear equation at `imelt`.

The `bv` parameter detects the junction breakdown only. The breakdown currents of the junctions are not modeled.

Operating-Point Parameters

- 1 `type=n` Transistor type.
Possible values are `n` or `p`.
- 2 `region=fwd` Estimated operating region. Spectre outputs number (0-4) in a rawfile.
Possible values are `off`, `triode`, `sat`, `subth`, or `breakdown`.
- 3 `ids` (A) Resistive drain current.
- 4 `vth` (V) Threshold voltage.
- 5 `vgs` (V) Gate-source voltage.

Virtuoso Simulator Components and Device Models Reference

GaAs Model (gaas)

6	<code>vds</code> (V)	Drain-source voltage.
7	<code>vdsat</code> (V)	Drain saturation voltage.
8	<code>gm</code> (S)	Common-source transconductance.
9	<code>gds</code> (S)	Common-source output conductance.
10	<code>cgs</code> (F)	Gate-source capacitance.
11	<code>cgd</code> (F)	Gate-drain capacitance.
12	<code>ig</code> (A)	Resistive gate current.
13	<code>pwr</code> (W)	Power at operating point.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

<code>af</code> M-28	<code>delta</code> M-20	<code>lambda</code> M-4	<code>trise</code> M-22
<code>alarm</code> M-24	<code>dskip</code> M-14	<code>m</code> I-2	<code>type</code> M-1
<code>alpha</code> M-6	<code>fc</code> M-19	<code>minr</code> M-10	<code>type</code> OP-1
<code>area</code> I-1	<code>gds</code> OP-9	<code>n</code> M-12	<code>vds</code> OP-6
<code>b</code> M-5	<code>gm</code> OP-8	<code>pb</code> M-18	<code>vdsat</code> OP-7
<code>beta</code> M-3	<code>ids</code> OP-3	<code>pwr</code> OP-13	<code>vgs</code> OP-5
<code>bvj</code> M-26	<code>ig</code> OP-12	<code>rd</code> M-7	<code>vth</code> OP-4
<code>capmod</code> M-15	<code>imax</code> M-25	<code>region</code> I-4	<code>vto</code> M-2

Virtuoso Simulator Components and Device Models Reference

GaAs Model (gaas)

cgd	M-17	imelt	M-13	region	OP-2	xti	M-23
cgd	OP-11	is	M-11	rg	M-9		
cgs	M-16	isnoisy	I-3	rs	M-8		
cgs	OP-10	kf	M-27	tnom	M-21		

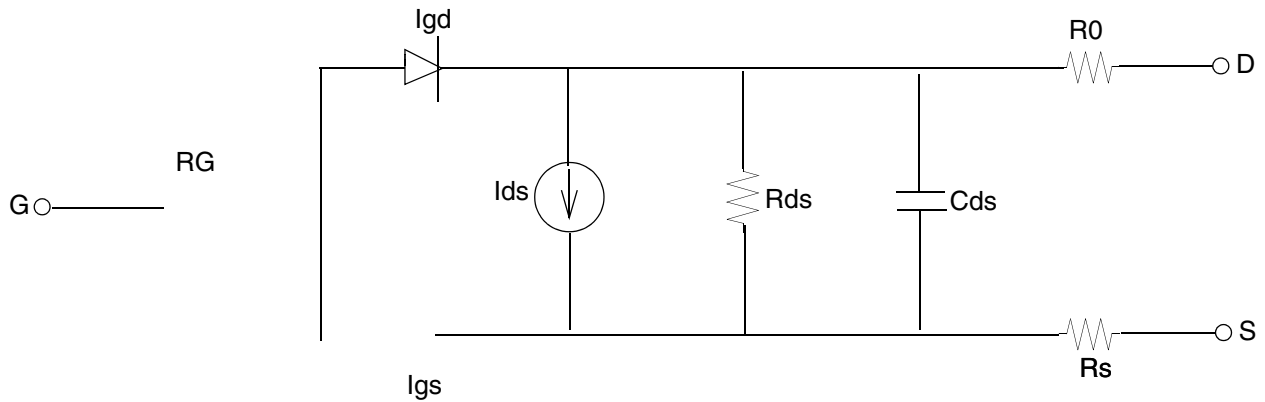
TriQuint Owned Models (tom2 and tom3/ tom3v1)

The TOM2 and TOM3/TOM3V1 models are developed by TriQuint. This chapter contains the following information for the two models:222

- [Circuit Diagrams](#) on page 2656
- [Channel Current Ids](#) on page 2657
- [Gate Current Ig](#) on page 2659
- [Gate Capacitance](#) on page 2660
- [Temperature Effect](#) on page 2663
- [Noise Model](#) on page 26640
- [Scaling Effects](#) on page 2665
- [Component Statements](#) on page 2665

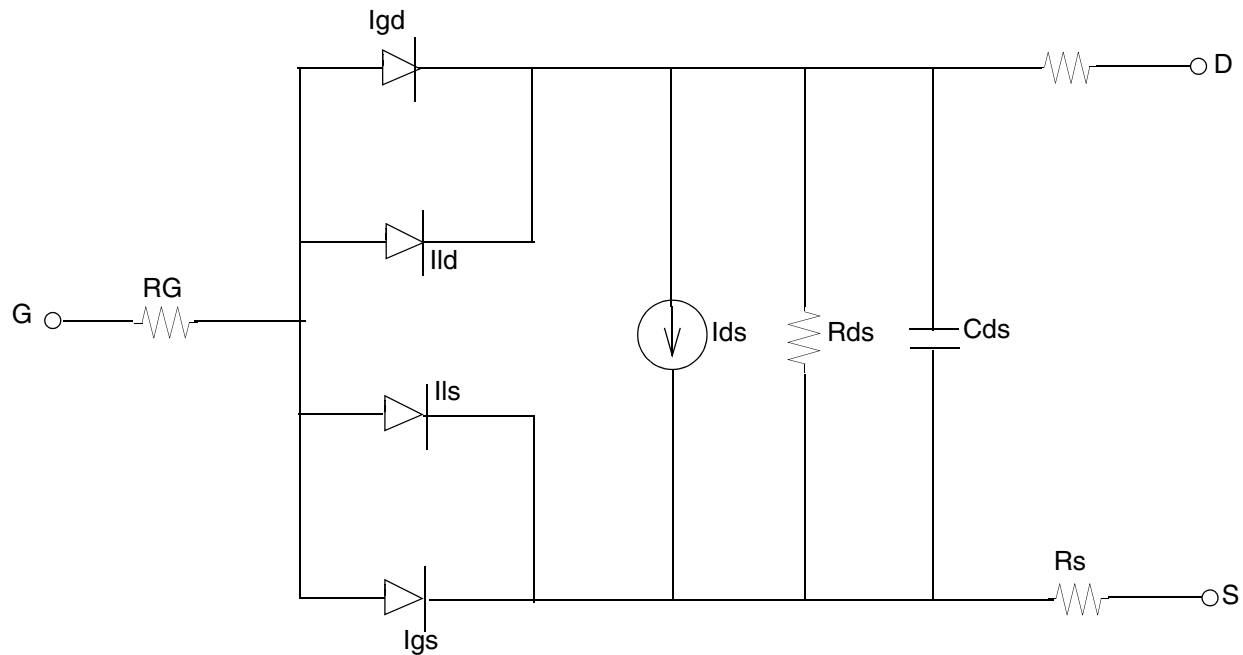
Circuit Diagrams

TOM2

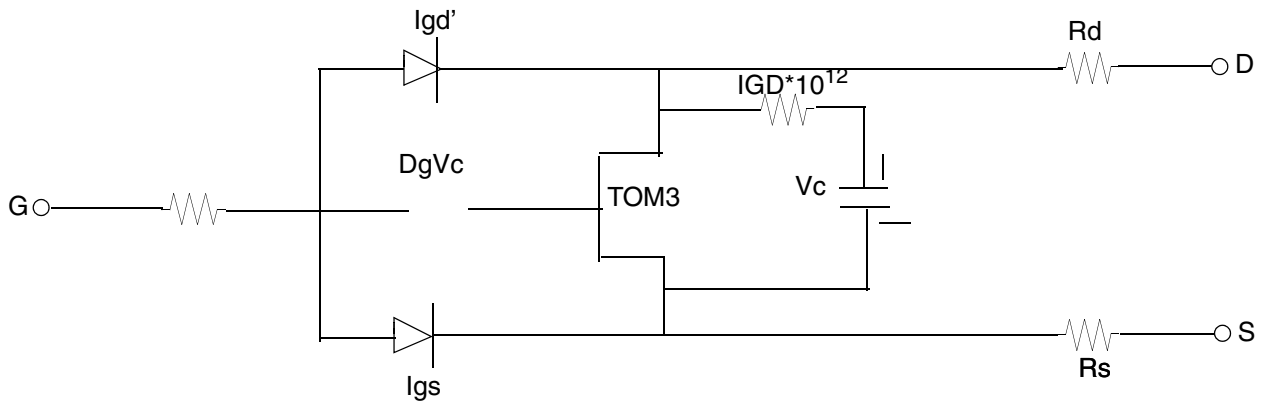


TOM3

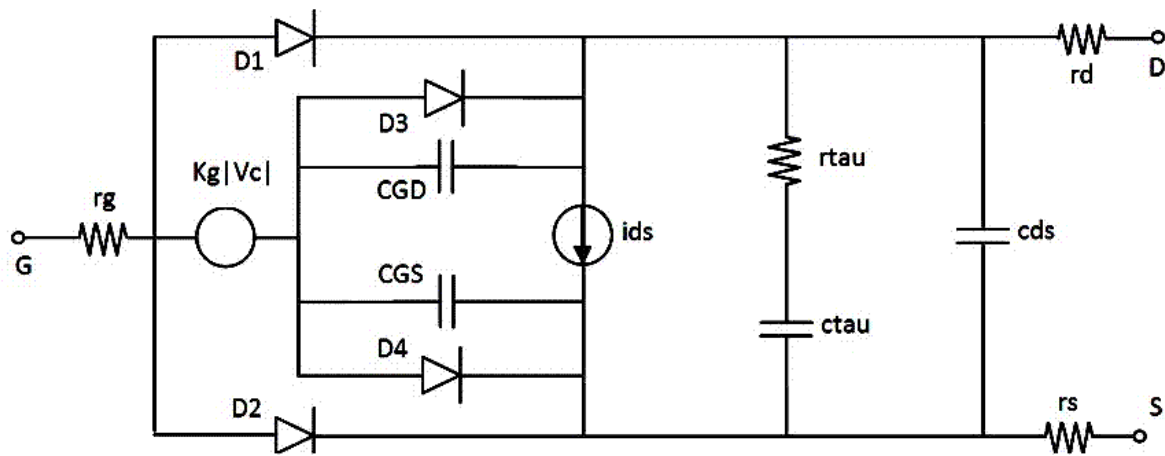
Spectre Implementation



TOM3 with SubCircuit



TOM3V1



Channel Current Ids

TOM2

$$I_{DS} = \frac{I_{ds0}}{1 + \delta V_{ds} I_{ds0}}$$

where

$$I_{ds0} = \beta V_{gsteff} \frac{Q}{\sqrt{(\alpha V_{ds})^2 + 1}} \alpha V_{ds}$$

TOM3/TOM3V1

$$I_{DS} = I_0(1 + \lambda V_{ds})$$

where

$$I_0 = \beta(V_G)^Q f_k$$

$$f_k = \frac{\alpha V_{ds}}{\left[1 + (\alpha V_{ds})^k\right]^{1/k}}$$

$$V_G = QV_{ST} \log[1 + \exp(u)]$$

$$u = \frac{V_{GSI} - V_{TO} + \gamma V_{ds}}{QV_{ST}}$$

$$V_{ST} = V_{ST0}(1 + M_{ST0} V_{ds})$$

Gate Current Ig

TOM2

$$I_{gs} = I_s \left(e^{\frac{V_{gs}}{\eta V_T}} - 1 \right)$$

$$I_{gd} = I_s \left(e^{\frac{V_{gd}}{\eta V_T}} - 1 \right)$$

TOM3/TOM3V1

$$I_{gs} = I_s \left(e^{\frac{V_{gs}}{\eta V_T}} - 1 \right)$$

$$I_{gd} = I_s \left(e^{\frac{V_{gd}}{\eta V_T}} - 1 \right)$$

$$I_{ls} = I_{LK} \left(1 - e^{\frac{-V_{gsi}}{\phi LK}} \right)$$

$$I_{ld} = I_{LK} \left(1 - e^{\frac{-V_{gdi}}{\phi LK}} \right)$$

Gate Capacitance

TOM2

In the TOM2 model, the calculation of capacitances follows the Statz charge model.

$$C_{gs} = \frac{C_{gs0}(T)}{\sqrt{1 - V_1/(V_{bi}(T))}} F_1 F_2 + C_{gs0}(T) F_3$$

$$C_{gd} = \frac{C_{gd0}(T)}{\sqrt{1 - V_1/(V_{bi}(T))}} F_1 F_2 + C_{gd0}(T) F_3$$

where

$$F_1 = 0.5 \frac{\partial V_2}{\partial x} \left(1 + \frac{V_2 - V_{toeff}}{\sqrt{(V_2 - V_{toeff})^2 + V_{\delta}^2}} \right)$$

$$x = V_{gs}, V_{gd}$$

$$F_2 = 0.5 \left[1 + \frac{V_{gs} - V_{gd}}{\sqrt{(V_{gs} - V_{gd})^2 + (1/(\alpha(T)))^2}} \right]$$

$$F_3 = 1 - F_2$$

$$V_1 = \begin{cases} A_1, A_1 < V_{max} \\ V_{max}, A_1 \geq V_{max} \end{cases}$$

$$A_1 = 0.5 \left[V_2 + V_{toeff} + \sqrt{(V_2 - V_{toeff})^2 + V_{\delta}^2} \right]$$

$$V_2 = 0.5 \left[V_{gs} + V_{gd} + \sqrt{(V_{gs} - V_{gd})^2 + (1/(\alpha(T)))^2} \right]$$

TOM3/TOM3V1

In the TOM3 model, the low and high power capacitance is combined with a transition function.

High power gate charge/capacitance

$$Q_{GH} = Q_{GQH} \log \left(1 + \frac{I_{ds}}{Q_{GIO}} \right) + Q_{GSH} V_{GSI} + Q_{GDH} V_{GDI}$$

$$C_{GSH} = (g_m + g_{ds}) \left(\frac{Q_{GQH}}{I_{ds} + Q_{GIO}} \right) + Q_{GSH}$$

$$C_{GDH} = -g_{ds} \left(\frac{Q_{GQH}}{I_{ds} + Q_{GIO}} \right) + Q_{GDH}$$

Low Power Gate Charge

$$Q_{GL} = qgl + Q_{GCL} (V_{GSI} + V_{GDI})$$

where

$$qgl = Q_{GQL} e^{[Q_{GAG}(V_{gsi} + V_{gdi})]} \cosh(Q_{GAD} V_{ds})$$

$$C_{GSL} = qgl [Q_{GAG} + Q_{GAD} \tanh(Q_{GAD} V_{ds})] + Q_{GCL}$$

$$C_{GDL} = qgl [Q_{GAG} - Q_{GAD} \tanh(Q_{GAD} V_{ds})] + Q_{GCL}$$

Transition Function

$$f_T = \exp[-Q_{GCB} I_{ds} V_{ds}]$$

The derivatives are as follows:

$$\frac{\partial f_T}{\partial V_{GSI}} = -Q_{GGB} [I_{ds} + (g_m + g_{ds}) V_{ds}] f_T$$

$$\frac{\partial f_T}{\partial V_{GDI}} = Q_{GGB} [I_{ds} + g_{ds} V_{ds}] f_T$$

Combined Gate Charge/Capacitance

$$Q_{GG} = Q_{GL} f_T + Q_{GH} (1 - f_T) + Q_{GG0} (V_{GSI} + V_{GDI})$$

$$C_{GS} = C_{GSL} f_T + C_{GSH} (1 - f_T) + (Q_{GL} - Q_{GH}) \left(\frac{\partial f_T}{\partial V_{GSI}} \right) + Q_{GG0}$$

$$C_{GD} = C_{GDL} f_T + C_{GDH} (1 - f_T) + (Q_{GL} - Q_{GH}) \left(\frac{\partial f_T}{\partial V_{GDI}} \right) + Q_{GG0}$$

TOM3V1

capmod=1

$$I_{CGS} = CGS \frac{dV_{gm,si}}{dt}$$

$$I_{CGD} = CGD \frac{dV_{gm,di}}{dt}$$

capmod=2

$$I_{CGS} = \frac{1}{2} \frac{dQGG}{dt}$$

$$I_{CGD} = \frac{1}{2} \frac{dQGG}{dt}$$

Temperature Effect

$$\alpha(T) = \alpha_0 \cdot 1.01^{\alpha_{ice} \Delta T}$$

$$\Gamma(T) = \Gamma_0 + \Gamma_{tc} \Delta T$$

TOM2

$$V_{bi}(T) = V_{bi0} + V_{bitc} \Delta T$$

TOM3/TOM3V1

$$V_{st}(T) = V_{st}(T_{nom}) + T_{V_{st}}(T - T_{nom})$$

$$M_{st}(T) = M_{st}(T_{nom}) + T_{M_{st}}(T - T_{nom})$$

Noise Model

Source Resistance Thermal Noise

$$i_{R_s}^2 = \frac{4kT}{R_s} \Delta f$$

Drain Resistance Thermal Noise

$$i_{R_d}^2 = \frac{4kT}{R_d} \Delta f$$

Channel Conductance Thermal and Flicker Noise

$$i_{DS}^2 = \frac{8kT(g_m + g_{ds})}{3} \left(\frac{3}{2} - \frac{V'_{ds}}{2V_{DSAT}} \right) + k_f \frac{I_{DS}^{af}}{f} \Delta f$$

where

$$V'_{DS} = \text{MAX}(V_{DS}, V_{DSAT})$$

Gate Resistance Thermal Noise (TOM3V1)

$$i_{Rg}^2 = \frac{4kT}{Rd} \Delta f$$

Channel Conductance Thermal and Flicker Noise (TOM3V1)

$$i_{DS}^2 = 4kTg_m P + k_f \frac{I_{DS}^{af}}{f} \Delta f$$

Scaling Effects

The following are the Spectre scaling effects:

- *is* and *beta* are multiplied by *area*.
- *rs* and *rd* are divided by *area*.
- All noises are multiplied by *area*.

New feature from TOM3 to TOM3v1

1. Added capmod to run a capacitance or charge based models for the gate-drain and gate-source reactance.
2. Noise implementation is enhanced.

Component Statements

TOM2

Sample Instance Statement

```
mt1 (2 1 0) tom2mos area=1 region=fwd
```

Virtuoso Simulator Components and Device Models Reference

TriQuint Owned Models (tom2 and tom3/tom3v1)

Sample Model Statement

```
model tom2mos tom2 vto=-0.55 alpha=3.9 beta=0.001 gamma=0.075 delta=100 ng=1 rd=550  
rs=550 rg=1 is=0.295e-14 n=1.2 cgs=1.4e-15 cgd=2e-16 cds=3e-16
```

Instance Definition

```
Name d g s ModelName parameter=value ...
```

Instance Parameters

- | | | |
|---|-------------|---|
| 1 | area=1 | Junction area factor. |
| 2 | m=1 | Multiplicity factor. |
| 3 | isnoisy=yes | Should resistor generate noise.
Possible values are no or yes. |
| 4 | trise=0 C | Temperature rise from ambient. |
| 5 | region=fwd | Estimated operating region. Spectre outputs number (0-3) in a rawfile.
Possible values are off, triode, sat, or subth. |

Model Definition

```
model modelName tom2 parameter=value ...
```

Model Parameters

Device type parameters

- | | | |
|---|--------|---|
| 1 | type=n | Transistor type.
Possible values are n or p. |
|---|--------|---|

Drain current parameters

- | | | |
|---|---------------------------|-----------------------------|
| 2 | vto=-2.5 V | Threshold voltage. |
| 3 | alpha=2 1/V | Knee-voltage parameter. |
| 4 | beta=0.1 A/V ² | Transconductance parameter. |

Virtuoso Simulator Components and Device Models Reference

TriQuint Owned Models (tom2 and tom3/tom3v1)

- 5 `gamma=0 1/V` Threshold shifting parameter.
- 6 `delta=0.2 V` Output feedback parameter.
- 7 `q=2` Power-law parameter.

Subthreshold parameters

- 8 `ng=0` Subthreshold slope gate parameter.
- 9 `nd=0 1/V` Subthreshold slope drain pull parameter.

Parasitic resistance parameters

- 10 `rd=0 Ω` Drain resistance (/area).
- 11 `rs=0 Ω` Source resistance (/area).
- 12 `rg=0 Ω` Gate resistance (/area).
- 13 `minr=0.1 Ω` Minimum source/drain/gate resistance.

Junction diode model parameters

- 14 `is=1e-14 A` Gate diode saturation current (*area).
- 15 `n=1` Emission coefficient for the gate junction.
- 16 `imelt='imax' A` Explosion current (*area).
- 17 `dskip=yes` Use simple piece-wise linear model for diode currents below $0.1 \cdot i_{abstol}$.
Possible values are `no` or `yes`.

Junction capacitance model parameters

- 18 `capmod=2` Charge model selector.
- 19 `cgs=0 F` Gate-source zero-bias junction capacitance (*area).

Virtuoso Simulator Components and Device Models Reference

TriQuint Owned Models (tom2 and tom3/tom3v1)

20	<code>cgd=0 F</code>	Gate-drain zero-bias junction capacitance (*area).
21	<code>cds=0 F</code>	Drain-to-source capacitance.
22	<code>vbi=1 V</code>	Gate diode built-in potential.
23	<code>vmax=0.95</code>	Gate diode capacitance limiting voltage.
24	<code>vdelta=0.2 V</code>	Capacitance transition voltage.
25	<code>tau=0 s</code>	Conduction current delay time.

Temperature effects parameters

26	<code>tnom (C)</code>	Parameters measurement temperature. Default set by options.
27	<code>xti=0</code>	Temperature exponent for effect on <code>is</code> .
28	<code>eg=1.11 V</code>	Energy band gap.
29	<code>vtotc=0 V/C</code>	Temperature coefficient for <code>vto</code> .
30	<code>vbitc=0 V/C</code>	Temperature coefficient for <code>vbi</code> .
31	<code>alphatce=0 1/C</code>	Temperature coefficient for <code>alpha</code> .
32	<code>betatce=0 1/C</code>	Temperature coefficient for <code>beta</code> .
33	<code>gammatc=0 1/C</code>	Temperature coefficient for <code>gamma</code> .
34	<code>trs1=0 1/C</code>	Temperature parameter for source resistance.
35	<code>trd1=0 1/C</code>	Temperature parameter for drain resistance.
36	<code>trg1=0 1/C</code>	Temperature parameter for gate resistance.
37	<code>cgdtce=0 1/C</code>	Drain junction capacitance temperature coefficient.
38	<code>cgstce=0 1/C</code>	Source junction capacitance temperature coefficient.

Operating region warning control parameters

- 39 `imax=1` A Maximum allowable current (*area).
40 `bvj= ∞` V Junction reverse breakdown voltage.

Noise model parameters

- 41 `kf=0` Flicker (1/f) noise coefficient.
42 `af=1` Flicker (1/f) noise exponent.
43 `kfd=0` Flicker noise (1/f) coefficient for gate diodes.
44 `afg=1` Flicker noise (1/f) exponent for gate diodes.

The `imax` parameter aids convergence and prevents numerical overflow. The junction characteristics of the FET are accurately modeled for currents up to `imax`. For currents above `imax`, the junction is modeled as a linear resistor and a warning is printed. The `bv` parameter detects the junction breakdown only. The breakdown currents of the junctions are not modeled.

Operating-Point Parameters

- 1 `type=n` Transistor type.
Possible values are `n` or `p`.
2 `region=fwd` Estimated operating region. Spectre outputs number (0-3) in a rawfile.
Possible values are `off`, `triode`, `sat`, or `subth`.
3 `vgs` (V) Gate-source voltage.
4 `vds` (V) Drain-source voltage.
5 `id` (A) Drain current.
6 `ig` (A) Gate current.
7 `ids` (A) Drain-to-source current.
8 `gm` (S) Common-source transconductance.

Virtuoso Simulator Components and Device Models Reference

TriQuint Owned Models (tom2 and tom3/tom3v1)

9	<code>gds</code> (S)	Common-source output conductance.
10	<code>vth</code> (V)	Threshold voltage.
11	<code>cgs</code> (F)	Gate-source capacitance.
12	<code>cgd</code> (F)	Gate-drain capacitance.
13	<code>cds</code> (F)	Drain-source capacitance.
14	<code>pwr</code> (W)	Power at op point.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

<code>af</code> M-42	<code>cgstce</code> M-38	<code>kfd</code> M-43	<code>trgl</code> M-36
<code>afg</code> M-44	<code>delta</code> M-6	<code>m</code> I-2	<code>trise</code> I-4
<code>alpha</code> M-3	<code>dskip</code> M-17	<code>minr</code> M-13	<code>trs1</code> M-34
<code>alphanatce</code> M-31	<code>eg</code> M-28	<code>n</code> M-15	<code>type</code> M-1
<code>area</code> I-1	<code>gamma</code> M-5	<code>nd</code> M-9	<code>type</code> OP-1
<code>beta</code> M-4	<code>gammatac</code> M-33	<code>ng</code> M-8	<code>vbi</code> M-22
<code>betatce</code> M-32	<code>gds</code> OP-9	<code>pwr</code> OP-14	<code>vbitc</code> M-30
<code>bvj</code> M-40	<code>gm</code> OP-8	<code>q</code> M-7	<code>vdelta</code> M-24
<code>capmod</code> M-18	<code>id</code> OP-5	<code>rd</code> M-10	<code>vds</code> OP-4
<code>cds</code> M-21	<code>ids</code> OP-7	<code>region</code> I-5	<code>vgs</code> OP-3

Virtuoso Simulator Components and Device Models Reference

TriQuint Owned Models (tom2 and tom3/tom3v1)

cds	OP-13	ig	OP-6	region	OP-2	vmax	M-23
cgd	M-20	imax	M-39	rg	M-12	vth	OP-10
cgd	OP-12	imelt	M-16	rs	M-11	vto	M-2
cgdtce	M-37	is	M-14	tau	M-25	vtotc	M-29
cgs	M-19	isnoisy	I-3	tnom	M-26	xti	M-27
cgs	OP-11	kf	M-41	trd1	M-35		

GaAs MESFET (tom3)

TOM3 stands for Triquint Own Model version-3. It is an improved GaAs MESFET developed by David H. Smith.

This device is supported within altergroups.

Sample Instance Statement

```
mt1 (2 1 0) tom3mos area=1 region=fwd
```

Sample Model Statement

```
model tom3mos tom3 vto=-0.55 alpha=3.9 beta=0.001 gamma=0.075 delta=100 rd=550  
rs=550 rg=1 is=1.0e-30 cds=3e-16
```

Instance Definition

```
Name d g s ModelName parameter=value ...
```

Instance Parameters

- 1 area=1 Junction area factor.
- 2 m=1 Multiplicity factor.
- 3 isnoisy=yes Should resistor generate noise.
Possible values are no or yes.

Virtuoso Simulator Components and Device Models Reference

TriQuint Owned Models (tom2 and tom3/tom3v1)

- 4 `region=triode` Estimated operating region.
Possible values are `off`, `triode`, `sat`, or `subth`.
- 5 `trise=0 C` Temperature rise from ambient.

Model Definition

```
model modelName tom3 parameter=value ...
```

Model Parameters

Device type parameters

- 1 `type=n` Transistor type.
Possible values are `n` or `p`.

Drain current parameters

- 2 `vto=-2.5 V` Threshold voltage.
- 3 `alpha=2 1/V` Knee-voltage parameter.
- 4 `beta=0.1 A/V2` Transconductance parameter.
- 5 `gamma=0 1/V` Threshold shifting parameter.
- 6 `lambda=0.0 V` Slope of drain characteristic.
- 7 `q=2` Power-law parameter.
- 8 `k=2.0` knee-function factor.

Subthreshold parameters

- 9 `vst=1 V` Subthreshold slope.
- 10 `mst=0 1/V` Subthreshold slope drain parameter.

Parasitic resistance parameters

11	<code>rd=0</code>	Ω	Drain resistance (/area).
12	<code>rs=0</code>	Ω	Source resistance (/area).
13	<code>rg=0</code>	Ω	Gate resistance (/area).
14	<code>minr=0.1</code>	Ω	Minimum source/drain/gate resistance.

Junction diode model parameters

15	<code>is=0.0</code>	A	Gate diode saturation current (*area).
16	<code>n=1</code>		Emission coefficient for the gate junction.
17	<code>imelt='imax'</code>	A	Explosion current (*area).
18	<code>dskip=yes</code>		Use simple piece-wise linear model for diode currents below $0.1 * i_{abstol}$. Possible values are <code>no</code> or <code>yes</code> .
19	<code>ilk=0.0</code>	A	Gate leakage diode saturation current (*area).
20	<code>plk=1.0</code>	V	Gate leakage diode potential.

Junction capacitance model parameters

21	<code>cds=0</code>	F	Drain-to-source capacitance.
22	<code>tau=0</code>	s	Conduction current delay time.
23	<code>qgqh=0.0</code>		Charge parameter.
24	<code>qgsh=0.0</code>		Charge parameter.
25	<code>qgdh=0.0</code>		Charge parameter.
26	<code>qgio=1.0e-06</code>		Charge parameter.
27	<code>qgql=0.0</code>		Charge parameter.

Virtuoso Simulator Components and Device Models Reference

TriQuint Owned Models (tom2 and tom3/tom3v1)

28	qgag=1.0	Charge parameter.
29	qgad=1.0	Charge parameter.
30	qgc1=0.0	Charge parameter.
31	qggb=1.0	Charge parameter.
32	qggo=0.0	Charge parameter.

Temperature effects parameters

33	tnom (C)	Parameters measurement temperature. Default set by options.
34	x _{ti} =0	Temperature exponent for effect on <i>i_s</i> .
35	e _g =1.11 V	Energy band gap.
36	v _{totc} =0 V/C	Temperature coefficient for <i>v_{to}</i> .
37	alpha _{tce} =0 1/C	Temperature coefficient for alpha.
38	beta _{tce} =0 1/C	Temperature coefficient for beta.
39	gamma _{tce} =0 1/C	Temperature coefficient for gamma.
40	tr _{s1} =0 1/C	Temperature parameter for source resistance.
41	tr _{d1} =0 1/C	Temperature parameter for drain resistance.
42	tr _{g1} =0 1/C	Temperature parameter for gate resistance.
43	v _{sttc} =0 1/C	Temperature coefficient for <i>V_{st}</i> .
44	m _{sttc} =0 1/C	Temperature coefficient for <i>M_{st}</i> .

Operating region warning control parameters

45	i _{max} =1 A	Maximum allowable current (*area).
46	b _{vj} =∞ V	Junction reverse breakdown voltage.

Noise model parameters

- | | | |
|----|--------------------|--|
| 47 | <code>kf=0</code> | Flicker (1/f) noise coefficient. |
| 48 | <code>af=1</code> | Flicker (1/f) noise exponent. |
| 49 | <code>kfd=0</code> | Flicker noise (1/f) coefficient for gate diodes. |
| 50 | <code>afd=1</code> | Flicker noise (1/f) exponent for gate diodes. |

The `imax` parameter aids convergence and prevents numerical overflow. The junction characteristics of the FET are accurately modeled for currents up to `imax`. For currents above `imax`, the junction is modeled as a linear resistor and a warning is printed. The `bv` parameter detects the junction breakdown only. The breakdown currents of the junctions are not modeled.

Operating-Point Parameters

- | | | |
|----|----------------------------|--|
| 1 | <code>type=n</code> | Transistor type.
Possible values are <code>n</code> or <code>p</code> . |
| 2 | <code>region=triode</code> | Estimated operating region.
Possible values are <code>off</code> , <code>triode</code> , <code>sat</code> , or <code>subth</code> . |
| 3 | <code>vgs (V)</code> | Gate-source voltage. |
| 4 | <code>vds (V)</code> | Drain-source voltage. |
| 5 | <code>id (A)</code> | Drain current. |
| 6 | <code>ig (A)</code> | Gate current. |
| 7 | <code>ids (A)</code> | Drain-to-source current. |
| 8 | <code>gm (S)</code> | Common-source transconductance. |
| 9 | <code>gds (S)</code> | Common-source output conductance. |
| 10 | <code>vth (V)</code> | Threshold voltage. |
| 11 | <code>cgs (F)</code> | Gate-source capacitance. |
| 12 | <code>cgd (F)</code> | Gate-drain capacitance. |

Virtuoso Simulator Components and Device Models Reference

TriQuint Owned Models (tom2 and tom3/tom3v1)

13	c_{ds} (F)	Drain-source capacitance.
14	q_g (Coul)	Gate charge.
15	q_d (Coul)	Drain charge.
16	q_s (Coul)	Source charge.
17	pwr (W)	Power at op point.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

af M-48	id OP-5	pwr OP-17	rg M-13
afd M-50	ids OP-7	q M-7	rs M-12
$alpha$ M-3	ig OP-6	q_d OP-15	tau M-22
$alphatce$ M-37	ilk M-19	q_g OP-14	$tnom$ M-33
$area$ I-1	$imax$ M-45	$qgad$ M-29	$trd1$ M-41
$beta$ M-4	$imelt$ M-17	$qgag$ M-28	$trgl$ M-42
$betatce$ M-38	is M-15	$qgc1$ M-30	$trise$ I-5
bvj M-46	$isnoisy$ I-3	$qgdh$ M-25	$trs1$ M-40
c_{ds} M-21	k M-8	$qggb$ M-31	$type$ M-1
c_{ds} OP-13	kf M-47	$qggo$ M-32	$type$ OP-1
c_{gd} OP-12	kfd M-49	$qgio$ M-26	v_{ds} OP-4

Virtuoso Simulator Components and Device Models Reference

TriQuint Owned Models (tom2 and tom3/tom3v1)

cgs	OP-11	lambda	M-6	qqqh	M-23	vgs	OP-3
dskip	M-18	m	I-2	qqql	M-27	vst	M-9
eg	M-35	minr	M-14	qqsh	M-24	vsttc	M-43
gamma	M-5	mst	M-10	qs	OP-16	vth	OP-10
gammatc	M-39	msttc	M-44	rd	M-11	vto	M-2
gds	OP-9	n	M-16	region	I-4	vtotc	M-36
gm	OP-8	plk	M-20	region	OP-2	xti	M-34

GaAs MESFET (TOM3V1)

TOM3_V1 stands for Triquint Own Model version-3. It is an improved GaAs MESFET.

This device is supported within altergroups.

Sample Instance Statement

```
mt1 (2 1 0) tom3v1mos w=5 ng=2 m=2
```

Sample Model Statement

```
model tom3v1mos tom3v1 vto=-1.9 alpha=2.8 beta=0.01 lambda=-0.044 gamma=0.2  
q=2.5 k=3.5 vst=0.03 mst=0.1 ilk=5.0e-7 plk=2 kgamma=0.66 taugd=5.0e-9  
ctau=5.0e-15 qqql=1.0e-16 qqqh=-3.0e-16 qgi0=3.0e-16 qqag=3.0 qqad=2.3  
qggb=90.0 qgc1=3.0e-16 qqsh=5.0e-16 qgdh=1e-16 qgg0=3e-16 capmod=2 cds=0.26e-15  
tau=3.0e-12 rd=0.01 rg=0.01 rgmet=0 rs=0.01 is=7.0e-12 eta=1.9  
alphanatce=6.7337e-3 gammatc=2.3e-3 msttc=2e-3 vsttc=0.00031 vtotc=-119e-6  
betatce=1e-3 rdtc=3e-3 rstc=3e-3 xti=2.0 eg=1.91 p=0.5 af=1.3 kf=3.86e-11 ffe=2.0
```

Instance Definition

```
Name ( d g s ) ModelName <parameter=value> ...
```

Virtuoso Simulator Components and Device Models Reference

TriQuint Owned Models (tom2 and tom3/tom3v1)

Instance Parameters

1	m=1	Multiplicity factor.
2	w=50 um	Gate width.
3	ng=6	Number of gate fingers.
4	trise=0.0 C	Temperature rise from ambient.

Model Definition

```
model ModelName tom3v1 <parameter=value> ...
```

Model Parameters

1	tnom=25 C	Parameters measurement temperature.
2	vto=-2.0 V	Threshold voltage.
3	alpha=3.0 1/V	Knee-voltage parameter.
4	beta=0.05 A/V ^q	Transconductance parameter.
5	lambda=0.0 1/V	Slope of drain characteristic.
6	gamma=0.1	Threshold shifting parameter.
7	q=2.0	Power-law parameter.
8	k=3.0	knee-function factor.
9	vst=0.05 V	Subthreshold slope.
10	mst=0.0 1/V	Subthreshold slope drain parameter.
11	ilk=1.0e-7 A/um	Gate leakage diode saturation current (/w).
12	plk=2.25 V	Gate leakage diode potential.
13	kgamma=0.33	Internal vcvs parameter.
14	taugd=1.0e-9 s	Time constant for Ctau.

Virtuoso Simulator Components and Device Models Reference

TriQuint Owned Models (tom2 and tom3/tom3v1)

15	$\text{ctau}=1.0\text{e-}15 \text{ F}$	Drain-to-source dispersion capacitance.
16	$\text{qgql}=5.0\text{e-}16 \text{ Coul/um}$	Charge parameter.
17	$\text{qgqh}=-2.0\text{e-}16 \text{ Coul/um}$	Charge parameter.
18	$\text{qgi0}=1.0\text{e-}16 \text{ A/um}$	Charge parameter.
19	$\text{qgag}=1.0 \text{ 1/V}$	Charge parameter.
20	$\text{qgad}=1.0 \text{ 1/V}$	Charge parameter.
21	$\text{qggb}=100.0 \text{ um/W}$	Charge parameter.
22	$\text{qgcl}=2.0\text{e-}16 \text{ F/um}$	Charge parameter.
23	$\text{qgsh}=1.0\text{e-}16 \text{ F/um}$	Charge parameter.
24	$\text{qgdh}=0.0 \text{ F/um}$	Charge parameter.
25	$\text{qgg0}=0.0 \text{ F/um}$	Charge parameter.
26	$\text{capmod}=1$	Capacitance model selector.
27	$\text{cds}=0.0 \text{ F}$	Drain-to-source capacitance.
28	$\text{tau}=1.0\text{e-}12 \text{ s}$	Conduction current delay time.
29	$\text{rd}=0.0 \text{ Ohm*um}$	Drain resistance (*w).
30	$\text{rg}=0.0 \text{ Ohm*um}$	Gate resistance (*w).
31	$\text{rgmet}=0.0 \text{ Ohm/um}$	Metal resistance in gate (/w).

Virtuoso Simulator Components and Device Models Reference

TriQuint Owned Models (tom2 and tom3/tom3v1)

32	$rs=0.0 \text{ Ohm} \cdot \mu\text{m}$	Source resistance (*w).
33	$is=1.0e-12 \text{ A}/\mu\text{m}$	Gate diode saturation current (/w).
34	$\eta=1.0$	Parameter for 'is'.
35	$\alpha_{tce}=7.7337e-3 \text{ 1/C}$	Temperature parameter for `alpha'.
36	$\gamma_{tce}=0.0 \text{ 1/C}$	Temperature parameter for `gamma'.
37	$m_{sttc}=0.0 \text{ 1}/(\text{V} \cdot \text{C})$	Temperature parameter for 'mst'.
38	$v_{sttc}=0.0 \text{ V/C}$	Temperature parameter for 'vst'.
39	$v_{totc}=-1.49e-4 \text{ V/C}$	Temperature parameter for `vto'.
40	$\beta_{tce}=0.0 \text{ 1/C}$	Temperature coefficient for `beta'.
41	$r_{dtc}=0.0 \text{ 1/C}$	Temperature parameter for rd.
42	$r_{stc}=0.0 \text{ 1/C}$	Temperature parameter for rs.
43	$x_{ti}=0.0$	Temperature exponent for effect on `is'.
44	$e_g=1.11 \text{ V}$	Energy band gap.
45	$p=0.32$	White noise coefficient.
46	$a_f=1.0$	Flicker (1/f) noise exponent.
47	$k_f=0.0$	Flicker (1/f) noise coefficient.
48	$f_{fe}=1.0$	Flicker (1/f) noise coefficient..

Operating-Point Parameters

1	vgs (V)	Gate-source voltage.
---	---------	----------------------

Virtuoso Simulator Components and Device Models Reference

TriQuint Owned Models (tom2 and tom3/tom3v1)

2	vds (V)	Drain-source voltage.
3	id (A)	Drain current.
4	ig (A)	Gate current.
5	is (A)	Source current.
6	ids (A)	Drain-to-source current.
7	gm (S)	Common-source transconductance.
8	gds (S)	Common-source output conductance.
9	vth (V)	Threshold voltage.
10	cgs (F)	Gate-source capacitance.
11	cgd (F)	Gate-drain capacitance.
12	pwr (W)	Power at operating point.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

af	M-46	gm	OP-7	plk	M-12	rgmet	M-31
alpha	M-3	id	OP-3	pwr	OP-12	rs	M-32
alphatce	M-35	ids	OP-6	q	M-7	rstc	M-42
beta	M-4	ig	OP-4	qgad	M-20	tau	M-28
betatce	M-40	ilk	M-11	qgag	M-19	taugd	M-14

Virtuoso Simulator Components and Device Models Reference

TriQuint Owned Models (tom2 and tom3/tom3v1)

capmod M-26	is M-33	qgc1 M-22	tnom M-1
cds M-27	is OP-5	qgdh M-24	trise I-4
cgd OP-11	k M-8	qgg0 M-25	vds OP-2
cgs OP-10	kf M-47	qggb M-21	vgs OP-1
ctau M-15	kgamma M-13	qgi0 M-18	vst M-9
eg M-44	lambda M-5	qqqh M-17	vsttc M-38
eta M-34	m I-1	qqql M-16	vth OP-9
ffe M-48	mst M-10	qgsh M-23	vto M-2
gamma M-6	msttc M-37	rd M-29	vtotc M-39
gammatc M-36	ng I-3	rdtc M-41	w I-2
gds OP-8	p M-45	rg M-30	xti M-43

RPI TFT Models

The Poly-Si (PSITFT) and amorphous-Si (ATFT) TFT models are developed by the Semiconductor Devices Research Group at Rensselaer Polytechnic Institute (RPI). This chapter contains the following information for these models:

- [Poly-Si TFT Model \(PSITFT\)](#) on page 2685
 - [Equivalent Circuit](#) on page 2685
 - [Model Features](#) on page 2685
 - [Channel Width and Length](#) on page 2686
 - [Drain and Source Parasitic Resistance](#) on page 2686
 - [Threshold Voltage](#) on page 2687
 - [Effective Mobility](#) on page 2687
 - [Unified Electron Sheet Charge Density Per Unit Area](#) on page 2688
 - [Channel Conductance](#) on page 2689
 - [Saturation Voltage](#) on page 2689
 - [Channel Current](#) on page 2689
 - [Kink Effect Current](#) on page 2690
 - [Subthreshold Leakage Current](#) on page 2690
 - [Parasitic Resistance Dependence](#) on page 2692
 - [Gate-Drain/Source Resistance](#) on page 2692
 - [Temperature Dependence](#) on page 2692
 - [Capacitance](#) on page 2693
 - [ACM Option](#) on page 2697
 - [Scaling Effects](#) on page 2697

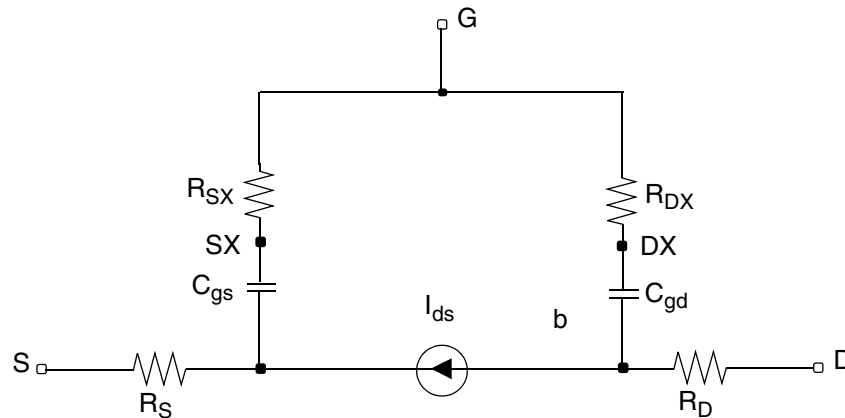
Virtuoso Simulator Components and Device Models Reference

RPI TFT Models

- [Component Statements](#) on page 2698
- [Amorphous-Si TFT Model \(ATFT\)](#) on page 2709
 - [Equivalent Circuit](#) on page 2709
 - [Model Features](#) on page 2709
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Poly-Si TFT Model (PSITFT)

Equivalent Circuit



Model Features

- Unified DC Model includes all four regimes for channel lengths down to 4 μm
 - Leakage (thermionic emission)
 - Sub-threshold (diffusion like model)
 - Above threshold (c-Si like with m FET)
 - Kink (impact ionization with feedback)
- AC model accurately reproduces C_{gs} frequency dispersion
- Automatic scaling of model parameters to accurately model a wide range of device geometries.
- Above threshold
 - Based on the crystalline MOSFET Model
 - Field effect mobility becomes a function of gate bias
 - Field effect mobility accounts for trap states
- Sub-threshold
 - Diffusion like model

■ Leakage Current

- Reverse bias drain current function of
 - Electric field near drain
 - Temperature
- Independent of channel length

Channel Width and Length

$$w = \begin{cases} w \cdot Wmlt + Xw - 2Wd, & \text{if ACM is given} \\ w, & \text{if ACM is not given} \end{cases}$$

$$l = \begin{cases} l \cdot Lmlt + Xl - 2Ld, & \text{if ACM is given} \\ l, & \text{if ACM is not given} \end{cases}$$

Drain and Source Parasitic Resistance

If ACM is not given,

$$rd = \begin{cases} rd, & \text{if rd is given} \\ rsh \cdot nrd, & \text{otherwise} \end{cases}$$

$$rs = \begin{cases} rs, & \text{if rs is given} \\ rsh \cdot nrs, & \text{otherwise} \end{cases}$$

ACM=0:

$$rd = \begin{cases} nrd \cdot rsh + rdc, & \text{if } (nrd \cdot rsh) > 0 \\ rd + rdc, & \text{otherwise} \end{cases}$$

$$rs = \begin{cases} nrs \cdot rsh + rsc, & \text{if } (nrs \cdot rsh) > 0 \\ rs + rsc, & \text{otherwise} \end{cases}$$

If ACM=1,

$$rd = (Ld + Ldif) \cdot rd/w + nrd \cdot rsh + rdc$$

Virtuoso Simulator Components and Device Models Reference

RPI TFT Models

$$rs = (Ld + Ldif) \cdot rs/w + nrs \cdot rsh + rsc$$

If ACM=2, 3,

$$rd = \begin{cases} (Ld + Ldif) \cdot rd/w + nrd \cdot rsh + rdc, & \text{if } nrd \text{ is given} \\ rdc + \frac{Hdif \cdot rsh + (Ld + Ldif) \cdot rd}{w}, & \text{otherwise} \end{cases}$$

$$rs = \begin{cases} (Ld + Ldif) \cdot rs/w + nrs \cdot rsh + rsc, & \text{if } nrd \text{ is given} \\ rsc + \frac{Hdif \cdot rsh + (Ld + Ldif) \cdot rs}{w}, & \text{otherwise} \end{cases}$$

Threshold Voltage

$$V_{TH} = V_{thx} - \frac{at \cdot V_{ds}^2 + bt}{l \cdot \left(1 + e^{\left(\frac{V_{gs} - V_{thx} - vsigmat}{vsigma} \right)} \right)}$$

Effective Mobility

$$mueff = mus + \frac{mufet}{1 + \frac{theta}{tox} \cdot V_{gte}}$$

$$\frac{1}{mufet} = \frac{1}{mu0} + \frac{1}{\mu_1 \cdot \left(\frac{2 \cdot V_{gte}}{eta_f \cdot V_t} \right)^{mmu}}$$

where

$$V_t = k \cdot T/q$$

$$V_{gte} = eta \cdot V_t \cdot \left(1 + \frac{\alpha_{sat} \cdot V_{gt}}{2 \cdot eta \cdot V_t} + \sqrt{\delta^2 + \left[\frac{\alpha_{sat} \cdot V_{gt}}{2 \cdot eta \cdot V_t} - 1 \right]^2} \right)$$

$$V_{gt} = V_{gs} - V_{th}$$

Unified Electron Sheet Charge Density Per Unit Area

$$\eta_f = \frac{\eta}{1 + \eta \cdot \text{reta} \cdot \frac{i1}{1+i1}}$$

where

$$\text{reta} = (\eta - 1) / \eta$$

$$i1 = \text{Kinkfac} \cdot (V_{ds} - V_{dse}) \cdot e^{-vkink / (V_{ds} - V_{dse})}$$

$$\text{Kinkfac} = A_{kink} \cdot w / l$$

$$A_{kink} = \frac{(lkink/l)^{mkink}}{vkink}$$

$$V_{dse} = \frac{V_{ds}}{\left(1 + \left(\frac{V_{ds}}{V_{dsat}}\right)^{mss}\right)^{1/mss}}$$

where

$$V_{sat} = V_{gte}$$

$$n_s = 2 \cdot n_0 \cdot \log \left(1 + \frac{1}{2} \cdot e^{\frac{V_{gt}}{\eta_f \cdot V_t}} \right)$$

$$n_0 = \frac{\epsilon_{SiO_2} \cdot \eta \cdot V_t}{2 \cdot q \cdot tox}$$

Channel Conductance

$$g_{ch} = \frac{g_{chi}}{1 + g_{chi} \cdot RT}$$

$$g_{chi} = q \cdot \frac{w}{l} \cdot \mu_{eff} \cdot n_s$$

Saturation Voltage

$$V_{DSAT} = \frac{I_{sat}}{g_{ch}}$$

$$I_{sat} = \frac{g_{chi} \cdot V_{gte}}{\left(1 + \frac{V_{gte}}{V_l}\right) + g_{chi} \cdot RSS + \sqrt{1 + 2 \cdot RSS \cdot g_{chi} + (1 + V_{gte}/V_l)^2}}$$

$$V_l = \frac{vmax \cdot l}{\mu_{eff}}$$

Channel Current

$$i_{choo} = \frac{g_{ch} \cdot V_{ds} \cdot (1 + \lambda \cdot V_{ds})}{\left[1 + \left(\frac{V_{ds}}{V_{dsat}}\right)^{me}\right]^{1/(me)}}$$

$$V_{satnew} = \frac{2 \cdot vmax \cdot l \cdot q \cdot (n_s - i_{choo} \cdot CRC)}{q \cdot (n_s - i_{choo} \cdot CRC) \cdot \mu_{eff} + 2 \cdot vmax \cdot l \cdot \frac{C_{ox}}{\alpha_{sat}}}$$

where

$$C_{ox} = \frac{\epsilon_{SiO_2}}{tox}$$

If lsubmod=1

lambda=0

$$I_{ds} = \frac{i_{choo}}{1 - \text{deltal}/l}$$

$$\text{deltal} = \frac{l_s \cdot \ln\left(1 + \frac{V_{disi} - V_{dsenew}}{v_p}\right) / (\ln(10))}{1 + \frac{V_{dsenew}}{V_p} + w \cdot CRL \cdot \text{mueff} \cdot V_{dsenew}}$$

$$V_{disi} = V_{ds} - i_{choo} \cdot RT$$

$$V_{dsenew} = \frac{V_{disi}}{\left(1 + \left(\frac{V_{disi}}{V_{satnew}}\right)^{mss}\right)^{1/mss}}$$

else

$$I_{ds} = i_{choo}$$

Kink Effect Current

$$I_{kink} = A_{kink} \cdot I_{ds} \cdot (V_{ds} - V_{dsenew}) \cdot e^{\left(\frac{vkink}{V_{ds} - V_{dsenew}}\right)}$$

Kink effect current is added to the drain current

Subthreshold Leakage Current

$$I_{leak} = clk \cdot w \cdot \left[e^{\frac{blk \cdot V_{ds}}{V_t}} - 1 \right] \cdot [X_{TFE} + X_{TE}] + I_{diode}$$

$$X_{TFE} = \frac{X_{TFE, lo} \cdot X_{TFE, hi}}{X_{TFE, lo} + X_{TFE, hi}}$$

$$X_{TE} = e^{-W_c}$$

Virtuoso Simulator Components and Device Models Reference

RPI TFT Models

$$W_C = (E_c - E_t)/(k \cdot T) = 0.55 eV / (k \cdot T)$$

$$X_{TFE, lo} = \left\{ \begin{array}{ll} \frac{4\sqrt{\pi}}{3} \cdot f \cdot e^{\left(\frac{4}{27} \cdot f^2 - W_C\right)} & \text{for } f \leq f_{lo} \\ X_{TFE, lo}(f_{lo}) \cdot e^{\left[\left(\frac{1}{f_{lo}} + \frac{8}{27} \cdot f_{lo}\right) \cdot (f - f_{lo})\right]} & \text{for } f > f_{lo} \end{array} \right.$$

$$f = \frac{1}{2} \cdot FMIN \cdot \left(1 + \frac{f_0}{FMIN} + \sqrt{\text{delta}^2 + \left(\frac{f_0}{FMIN} - 1\right)^2} \right)$$

where FMIN=0.0001

$$f_0 = \left(\frac{V_{ds}}{dd} - \frac{V_{gs} - v_{fb}}{dg} \right) / F_0$$

where

$$F_0 = (k \cdot T)^{3/2} \cdot \frac{4}{3} \cdot \frac{2\pi\sqrt{2m}}{qh}$$

$$m = 0.27 \cdot m_0$$

$$f_{lo} = \frac{3}{2} \cdot (\sqrt{W_C + 1} - 1)$$

$$X_{TFE, hi} = \left\{ \begin{array}{ll} \frac{2 \cdot W_C}{3} \cdot e^{\left(1 - \frac{2 \cdot W_C}{3}\right)} & \text{for } f \leq f_{hi} \\ \left(1 - \frac{W_C}{2 \cdot f}\right)^{-1} \cdot e^{\left(\frac{-W_C^{3/2}}{f}\right)} & \text{for } f > f_{hi} \end{array} \right.$$

$$f_{hi} = 3 \cdot \left(\frac{W_C^{3/2}}{2 \cdot W_C - 3} \right)$$

$$I_{diode} = i00 \cdot w \cdot e^{\left(\frac{eb}{k \cdot T}\right)} \cdot \left[1 - e^{\left(-\frac{V_{ds}}{V_t}\right)} \right]$$

Parasitic Resistance Dependence

If $intdsnod=0$, extrinsic characteristics are used.

$$RSS = rs$$

$$RT = rs + rd$$

$$CRC = C_{ox} \cdot rd / q$$

$$CRL = C_{ox} \cdot rs / l$$

Else, intrinsic characteristics are used.

$$RSS = RT = CRC = CRL = 0.0$$

Gate-Drain/Source Resistance

$$\frac{1}{R_{ch}} = \frac{dI_d}{dV_{ds}}$$

If rsx is not specified,

$$rsx = \left. \frac{Rch}{kss} \right|_{V_{ds}=0V}$$

If rdx is not specified

$$rdx = \left. \frac{Rch}{kss} \right|_{V_{ds}}$$

Temperature Dependence

$$V_{thx} = vto - dvto \cdot (T - T_{nom})$$

Virtuoso Simulator Components and Device Models Reference

RPI TFT Models

$$\mu_1 = \mu_{10} + d\mu_1 \cdot (T - T_{nom})$$

$$\alpha_{sat} = \alpha_{sat0} - \frac{l\alpha_{sat}}{l} - d\alpha_{sat} \cdot (T - T_{nom})$$

Capacitance

When `capmod=0`,

$$C_{gs} = C_f + \frac{2}{3} \cdot C_{gcs} \cdot \left[1 - \left(\frac{V_{dsat} - V_{dse}}{2 \cdot V_{dsat} - V_{dse}} \right)^2 \right]$$

$$C_{gd} = C_f + \frac{2}{3} \cdot C_{gcd} \cdot \left[1 - \left(\frac{V_{dsat}}{2 \cdot V_{dsat} - V_{dse}} \right)^2 \right]$$

$$C_f = \frac{1}{2} \cdot \epsilon_{si} \cdot w$$

$$C_{gcs} = \frac{w \cdot l \cdot \epsilon_{SiO_2} / tox}{1 + etac0 \cdot e^{\left(\frac{-V_{gt}}{etac0 \cdot V_t} \right)}}$$

$$C_{gcd} = \frac{w \cdot l \cdot \epsilon_{SiO_2} / tox}{1 + \eta_{cd} \cdot e^{\left(\frac{-V_{gt} - V_{dse}}{\eta_{cd} \cdot V_t} \right)}}$$

$$\eta_{cd} = etac0 + etac00 \cdot V_{dse}$$

$$V_{dsex} = \frac{V_{ds}}{\left(1 + \left(\frac{V_{ds}}{V_{dsat}} \right)^{mc} \right)^{1/mc}}$$

$$V_{gt} = V_{gs} - V_{thx}$$

When `capmod=1`

If `ZEROC=1`,

Virtuoso Simulator Components and Device Models Reference

RPI TFT Models

$$C_{gcs} = C_{gcd} = 0$$

If ZERO=0,

$$C_{gs} = C_{gd} = 0 \text{ if } V_{gt} < \frac{\phi_i}{2} \text{ where } \phi_i = 0.6$$

$$C_{gs} = w \cdot l \cdot \epsilon_{SiO_2} / tox \cdot \left(\frac{4 \cdot V_{gt}}{3 \cdot \phi_i} + \frac{2}{3} \right) \quad C_{gd} = 0 \text{ if } \frac{-\phi_i}{2} \leq V_{gt} < 0$$

if $V_{gt} < \frac{\phi_i}{2}$

$$\left(\begin{array}{l} C_{gs} = \frac{2 \cdot w \cdot l \cdot \epsilon_{SiO_2}}{3 \cdot tox}, C_{gd} = 0, V_{ds} \geq V_{dsat} \\ C_{gs} = \frac{2 \cdot w \cdot l \cdot \epsilon_{SiO_2}}{3 \cdot tox} \cdot \left[1 - \left(\frac{V_{dsat} - V_{dse}}{2 \cdot V_{dsat} - V_{dse}} \right)^2 \right], C_{gd} = \frac{2 \cdot w \cdot l \cdot \epsilon_{SiO_2}}{3 \cdot tox} \cdot \left[1 - \left(\frac{V_{dsat}}{2 \cdot V_{dsat} - V_{dse}} \right)^2 \right] \\ V_{ds} < V_{dsat} \end{array} \right)$$

When capmod=2

Charge conservation capacitance model

$$V_{gsteff, cv} = \text{noff} \cdot \text{eta} \cdot V_t \cdot \log \left(1 + e^{\left(\frac{V_{gs} - V_{thx} - \text{voffcv}}{\text{noff} \cdot \text{eta} \cdot V_t} \right)} \right)$$

$V_{gs} = V_{sxs}$ for Qs evaluation

$V_{gs} = V_{dxs}$ for Qd evaluation

$$V_{dsat, cv} = \frac{V_{gsteff, cv}}{A_{sat}}$$

$$A_{sat} = \left(1 + \left(\frac{CLC}{L_{activ}} \right)^{CLE} \right) / \alpha_{sat}$$

Virtuoso Simulator Components and Device Models Reference

RPI TFT Models

$$V_{cveff} = V_{dsat, cv} - 0.5 \left(V_4 + \sqrt{V_4^2 + 4\delta_4 V_{dsat, cv}} \right)$$

where

$$V_4 = V_{dsat, cv} - V_{ds} - \delta_4$$

$$\delta_4 = 0.02$$

$$L_{active} = l \cdot LMLT + XL - 2DLC$$

$$W_{active} = w \cdot WMLT + XW - 2DWC$$

$$Q_g = -W_{active} \cdot L_{active} \cdot \varepsilon_{SiO_2} / tox \left(\left(V_{gsteff, cv} - \frac{1}{2} V_{cveff} \right) + \frac{A_{sat} V_{cveff}^2}{12 \left(V_{gsteff, cv} - \frac{A_{sat}}{2} V_{cveff} \right)} \right)$$

$$Q_s = - \left(\frac{W_{active} \cdot L_{active} \cdot \varepsilon_{SiO_2} / tox}{2 \left(V_{gsteff, cv} - \frac{A_{sat}}{2} V_{cveff} \right)^2} \left(V_{gsteff, cv}^3 - \frac{1}{3} V_{gsteff, cv}^2 V_{cveff} - V_{gsteff, cv}^2 A_{sat} V_{cveff} + \right. \right.$$

$$\left. \left. \frac{5}{12} V_{gsteff, cv} A_{sat} V_{cveff}^2 + \frac{1}{4} V_{gsteff, cv} (A_{sat} V_{cveff})^2 - \frac{2}{15} (A_{sat} V_{cveff})^2 V_{cveff} \right) \right)$$

$$Q_d = - \left(\frac{W_{active} \cdot L_{active} \cdot \varepsilon_{SiO_2} / tox}{2 \left(V_{gsteff, cv} - \frac{A_{sat}}{2} V_{cveff} \right)^2} \left(V_{gsteff, cv}^3 - \frac{2}{3} V_{gsteff, cv}^2 V_{cveff} - V_{gsteff, cv}^2 A_{sat} V_{cveff} + \right. \right.$$

$$\left. \left. \frac{3}{4} V_{gsteff, cv} A_{sat} V_{cveff}^2 + \frac{1}{4} V_{gsteff, cv} (A_{sat} V_{cveff})^2 - \frac{1}{5} (A_{sat} V_{cveff})^2 V_{cveff} \right) \right)$$

$$Q_{sx} = -Q_s \quad Q_{dx} = -Q_d$$

$$Q_{dx} = -Q_d$$

Virtuoso Simulator Components and Device Models Reference

RPI TFT Models

$$C_{ss} = \frac{dQ_s}{dV_s} C_{sd} = \frac{dQ_s}{dV_d} C_{ssx} = \frac{dQ_s}{dV_{sx}} C_{sdx} = 0$$

$$C_{ds} = \frac{dQ_d}{dV_s} C_{dd} = \frac{dQ_d}{dV_d} C_{ddx} = \frac{dQ_d}{dV_{dx}} C_{dsx} = 0$$

$$C_{sxs} = \frac{dQ_{sx}}{dV_s} C_{sxd} = \frac{dQ_{sx}}{dV_d} C_{sxsx} = \frac{dQ_{sx}}{dV_{sx}} C_{sxdx} = 0$$

$$C_{dxs} = \frac{dQ_{dx}}{dV_s} C_{dxd} = \frac{dQ_{dx}}{dV_d} C_{dxdx} = \frac{dQ_{dx}}{dV_{dx}} C_{dxsx} = 0$$

$$C_{gs} = C_{sxs} + C_{dxs} \quad C_{gd} = C_{dxd} + C_{sxd} \quad C_{gg} = C_{gs} + C_{gd}$$

Overlap Capacitances

When `capmod=2`

$$\text{Overlap}C_{gs} = C_{gso} \cdot W_{active}$$

$$\text{Overlap}C_{gd} = C_{gdo} \cdot W_{active}$$

For other values of `capmod`

If `Acm` parameter is given,

$$\text{Overlap}C_{gs} = \begin{cases} (w + 2Wd) \cdot C_{gso}, & \text{if } C_{gso} \text{ is given} \\ (w + 2Wd) \cdot (Ld + Meto) \cdot \epsilon_{SiO_2} / tox, & \text{if } C_{gso} \text{ is not given} \end{cases}$$

$$\text{Overlap}C_{gd} = \begin{cases} (w + 2Wd) \cdot C_{gdo}, & \text{if } C_{gdo} \text{ is given} \\ (w + 2Wd) \cdot (Ld + Meto) \cdot \epsilon_{SiO_2} / tox, & \text{if } C_{gdo} \text{ is not given} \end{cases}$$

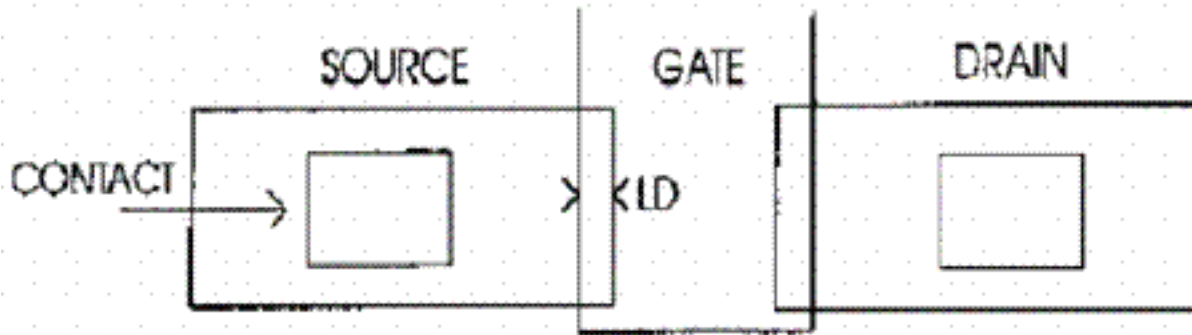
Else,

$$\text{Overlap}C_{gs} = w \cdot C_{gso}$$

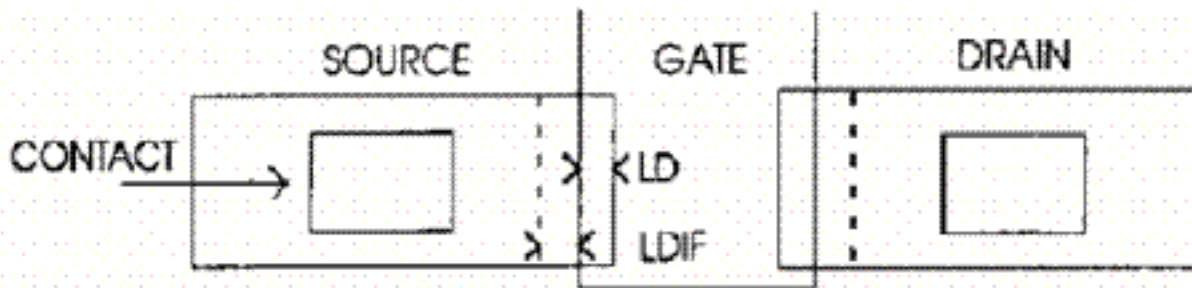
$$\text{Overlap}C_{gd} = w \cdot C_{gdo}$$

ACM Option

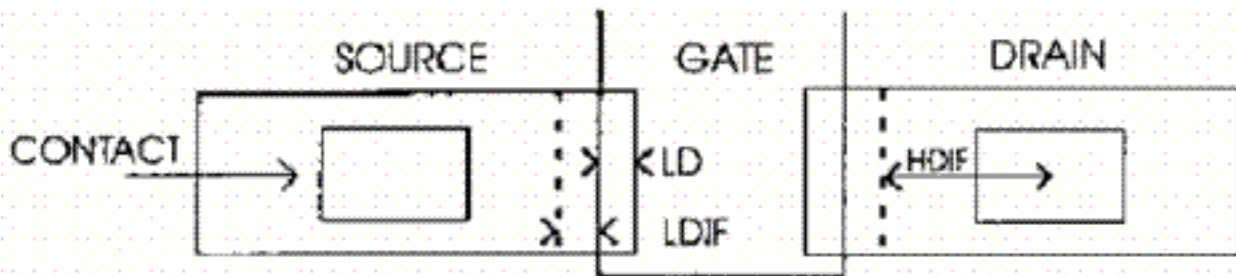
When ACM=0



When ACM=1



When ACM=2



Scaling Effects

For scaling effects, see [Scaling Factors \(scale and scalem\)](#) on page 242.

Component Statements

This device is supported within altergroups.

Sample Instance Statement

```
m4 (0 2 1 1) nch w=2u l=0.8u
```

Sample Model Statement

```
model nch psitft type=p
```

Instance Definition

```
Name d g s [b] [t] ModelName parameter=value ...
```

Instance Parameters

1	w (m)	Channel width.
2	l (m)	Channel length.
3	nrd (m/m)	Drain squares.
4	nrs (m/m)	Source squares.
5	m=1	Multiplicity factor (number of MOSFETs in parallel).
6	region=triode	Estimated operating region. Possible values are off, triode, sat, or subth.
7	isnoisy=yes	Should resistor generate noise. Possible values are no or yes.
8	rth0 (Ω)	Thermal resistance.
9	cth0 (F)	Thermal capacitance.
10	nseg=1 m/m	Number of segments for channel width partitioning.

Model Definition

```
model modelName psitft parameter=value ...
```

Model Parameters

Device type parameters

1 type=n Transistor type.
Possible values are n or p.

Drain current model parameters

2 vto=0 V Threshold voltage at zero body bias (BIN).

3 lambda=0.048 1/V Channel length modulation parameter (BIN).

4 tox=1e-7 m Gate oxide thickness.

5 eta=7 Subthreshold ideality factor (BIN).

6 etai Alias to eta (BIN).

7 asat=1 Proportionality constant of Vsat (BIN).

8 alphasat Alias to asat (BIN).

9 delta=4 Transition width parameter (BIN).

10 mus=1 cm²/V s Subthreshold mobility (BIN).

11 mu0=100 cm²/V s High field mobility (BIN).

12 muo (cm²/V s) Alias to mu0 (BIN).

13 mu1=0.004 cm²/V s Low field mobility parameter (BIN).

14 mmu=1.7 Low field mobility exponent (BIN).

15 m Alias to mmu (BIN).

16 vfb=-0.1 V Flat band voltage (BIN).

17 dd=1400e-10 m Vds field constant (BIN).

Virtuoso Simulator Components and Device Models Reference

RPI TFT Models

18	$dg=2000e-10$ m	Vds field constant (BIN).
19	$blk=0.001$	Leakage barrier lowering constant (BIN).
20	$clk=6$ A/m	Leakage scaling constant (BIN).
21	$i0=6.0$ A/m	Alias of clk (BIN).
22	$lkink=19e-6$ m	Kink effect constant (BIN).
23	$mkink=1.3$	Kink effect exponent (BIN).
24	$mk=1.3$	Alias of mkink (BIN).
25	$vkink=9.1$ V	Kink effect voltage (BIN).
26	$rs=0$ Ω	Source resistance.
27	$rd=0$ Ω	Drain resistance.
28	$rsx=0$ Ω	Resistance in series with Cgs.
29	$rdx=0$ Ω	Resistance in series with Cgd.
30	$at=3e-8$ m/V	DIBL parameter 1 (BIN).
31	$bt=1.9e-6$ m/V	DIBL parameter 2 (BIN).
32	$eb=0.68$ eV	Barrier height of diode (BIN).
33	$i00=150$ A/m	Reverse diode saturation current (BIN).
34	$i00$ (A/m)	Alias to i00 (BIN).
35	$etac0$	Capacitance subthreshold ideality factor at zero drain bias (BIN).
36	$etac00=0$ 1/V	Capacitance subthreshold coefficient of drain bias (BIN).
37	$mc=3$	Capacitance knee shape parameter (BIN).
38	$dvto=0$ V/C	Temperature coefficient of VTO (BIN).
39	$d\mu1=0$ cm^2/V s C	Temperature coefficient of MU1 (BIN).

Virtuoso Simulator Components and Device Models Reference

RPI TFT Models

40	<code>dasat=0 1/C</code>	Temperature coefficient of ASAT (BIN).
41	<code>lasat=0 m</code>	Coefficient of length dependence of ASAT (BIN).
42	<code>von=0 V</code>	On-Voltage (BIN).
43	<code>cgso=0 F/m</code>	Gate-source overlap capacitance.
44	<code>cgdo=0 F/m</code>	Gate-drain overlap capacitance.
45	<code>vsigma=0.2 V</code>	Above threshold DIBL parameter (BIN).
46	<code>vsigmat=1.7 V</code>	Above threshold DIBL parameter (BIN).
47	<code>me=2.5</code>	Long channel saturation transition parameter (BIN).
48	<code>ms</code>	Alias to me (BIN).
49	<code>minme=2.0</code>	Minimum value of me parameter..
50	<code>meta=1</code>	ETA floating-body parameter (BIN).
51	<code>ls=35e-9 m</code>	Channel-length modulation coefficient 1 (BIN).
52	<code>vp=0.2 V</code>	Channel-length modulation coefficient 2 (BIN).
53	<code>isubmod=0</code>	Channel-length modulation model version.
54	<code>vmax=4e4 m/s</code>	Carrier saturation velocity (BIN).
55	<code>theta=0 1/V</code>	Mobility modulation coefficient (BIN).
56	<code>mss=1.5</code>	Vdse transition parameter (BIN).
57	<code>kss=0</code>	Fractions of the channel resistance coefficient.
58	<code>rsh=0 Ω/sqr</code>	Source/drain diffusion sheet resistance.
59	<code>capmod=0</code>	Intrinsic charge model.
60	<code>zeroc=0</code>	Zero gate-source (gate-drain) capacitance flag (Cgs=Cgd=0 if zeroc=1 and capmod=1).

Virtuoso Simulator Components and Device Models Reference

RPI TFT Models

61	<code>intdsnod=0</code>	Intrinsic source and drain nodes usage flag.
62	<code>minr=0.1 Ω</code>	Minimum source/drain resistance.
63	<code>version=2</code>	Version control parameter. The available versions are 1, 2.
64	<code>compatible=spectre</code>	Spice compatible flag. Possible values are <code>spectre</code> , <code>spice2</code> , <code>spice3</code> , <code>cdsspice</code> , <code>hspice</code> , <code>spiceplus</code> , <code>eldo</code> , or <code>sspice</code> .
65	<code>cdnver=1</code>	Cadence version flag, 0 without improvement, 1 with improvement.

Temperature effects parameters

66	<code>tnom (C)</code>	Parameter measurement temperature.
67	<code>trise=0 C</code>	Temperature rise from ambient.
68	<code>shmod=0</code>	Self-heating selector.
69	<code>cth0=0.0 F</code>	Self-heating thermal capacitance.
70	<code>rth0=0 Ω</code>	Self-heating thermal resistance.
71	<code>wth0=0.0 μm</code>	Minimum width for thermal resistance calculation..
72	<code>tmax=500 C</code>	Maximum device temperature above ambient.

Operating region warning control parameters

73	<code>alarm=none</code>	Forbidden operating region. Possible values are <code>none</code> , <code>off</code> , <code>triode</code> , <code>sat</code> , <code>subth</code> , or <code>rev</code> .
----	-------------------------	---

Default device parameters

74	<code>w=3e-6 m</code>	Default channel width.
75	<code>l=3e-6 m</code>	Default channel length.

Virtuoso Simulator Components and Device Models Reference

RPI TFT Models

76 $nrd=1$ m/m Default drain squares.

77 $nrs=1$ m/m Default source squares.

Auto Model Selector parameters

78 $wmax=1$ m Maximum channel width for which the model is valid.

79 $wmin=0$ m Minimum channel width for which the model is valid.

80 $lmax=1$ m Maximum channel length for which the model is valid.

81 $lmin=0$ m Minimum channel length for which the model is valid.

Acm related parameters

82 $acm=0$ Area calculation method.

83 $x1=0.0$ m Accounts for masking and etching effects.

84 $xw=0.0$ m Accounts for masking and etching effects.

85 ld (m) Lateral diffusion into channel from source and drain diffusion.

86 $wd=0.0$ m Lateral diffusion into channel from bulk along width.

87 $lmlt=1.0$ Length diffusion layer shrink reduction factor.

88 $wmlt=1.0$ Width diffusion layer shrink reduction factor.

89 $ldif=0.0$ m Length of heavily doped diffusion adjacent to gate (BIN).

90 $hdif=0.0$ m Length of heavily doped diffusion from contact to lightly doped region.

91 $xj=1.5E-7$ m Metallurgical junction depth.

92 $meto=0.0$ m Fringing field factor for gate to source and gate to drain overlap capacitance.

93 $rdc=0.0$ Ω Additional drain resistance due to contact resistance.

Virtuoso Simulator Components and Device Models Reference

RPI TFT Models

94 `rsc=0.0` Ω Additional source resistance due to contact resistance.

Capmod=2 related parameters

Special parameters of version 1

95 `dvt=0` V The difference between `von` and the threshold (BIN).

96 `vsi=2.0` V Above threshold DIBL parameter (BIN).

97 `vst=2.0` V Above threshold DIBL parameter (BIN).

Binning parameters

98 `binunit=1` Bin parameter unit selector. 1 for microns and 2 for meters.

99 `binflag=0` Binflag=2 is to open xl/xw binning.

Length dependent parameters (Not listed)

Width dependent parameters (Not listed)

Cross-term dependent parameters (Not listed)

Output Parameters

1 `rtheff` (Ω) Effective thermal resistance.

2 `ctheff` (F) Effective thermal capacitance.

3 `weff` (m) Effective channel width.

4 `leff` (m) Effective channel length.

5 `rseff` (m) Effective source resistance.

6 `rdeff` (m) Effective drain resistance.

Virtuoso Simulator Components and Device Models Reference

RPI TFT Models

Operating-Point Parameters

1	<code>type=n</code>	Transistor type. Possible values are <code>n</code> or <code>p</code> .
2	<code>region=triode</code>	Estimated operating region. Possible values are <code>off</code> , <code>triode</code> , <code>sat</code> , or <code>subth</code> .
3	<code>reversed</code>	Reverse mode indicator. Possible values are <code>no</code> or <code>yes</code> .
4	<code>ids</code> (A)	Resistive drain-to-source current (alias = <code>lx4</code>).
5	<code>vgs</code> (V)	Gate-source voltage (alias = <code>lx2</code>).
6	<code>vds</code> (V)	Drain-source voltage (alias = <code>lx3</code>).
7	<code>vth</code> (V)	Threshold voltage (alias = <code>lv9</code>).
8	<code>vdsat</code> (V)	Drain-source saturation voltage (alias = <code>lv10</code>).
9	<code>gm</code> (S)	Common-source transconductance (alias = <code>lx7</code>).
10	<code>gds</code> (S)	Common-source output conductance (alias = <code>lx8</code>).
11	<code>tdev</code> (C)	Temperature rise from ambient.
12	<code>cgd</code> (F)	Gate-drain capacitance (alias = <code>lx19</code>).
13	<code>cgs</code> (F)	Gate-source capacitance (alias = <code>lx20</code>).
14	<code>cgg</code> (F)	<code>Cgg</code> (only for <code>capmod=2</code>).
15	<code>css</code> (F)	Intrinsic capacitance <code>dQs_dVs</code> (only for <code>capmod=2</code>).
16	<code>csd</code> (F)	Intrinsic capacitance <code>dQs_dVd</code> (only for <code>capmod=2</code>).
17	<code>cssx</code> (F)	Intrinsic capacitance <code>dQs_dVsx</code> (only for <code>capmod=2</code>).
18	<code>csdx</code> (F)	Intrinsic capacitance <code>dQs_dVdx</code> (only for <code>capmod=2</code>).
19	<code>cds</code> (F)	Intrinsic capacitance <code>dQd_dVs</code> (only for <code>capmod=2</code>).

Virtuoso Simulator Components and Device Models Reference

RPI TFT Models

20	c_{dd} (F)	Intrinsic capacitance $dQ_d_dV_d$ (only for $capmod=2$).
21	c_{dsx} (F)	Intrinsic capacitance $dQ_d_dV_{sx}$ (only for $capmod=2$).
22	c_{ddx} (F)	Intrinsic capacitance $dQ_d_dV_{dx}$ (only for $capmod=2$).
23	c_{sxs} (F)	Intrinsic capacitance $dQ_{sx}_dV_s$ (only for $capmod=2$).
24	c_{sxd} (F)	Intrinsic capacitance $dQ_{sx}_dV_d$ (only for $capmod=2$).
25	c_{sxsx} (F)	Intrinsic capacitance $dQ_{sx}_dV_{sx}$ (only for $capmod=2$).
26	c_{sxdx} (F)	Intrinsic capacitance $dQ_{sx}_dV_{dx}$ (only for $capmod=2$).
27	c_{dxs} (F)	Intrinsic capacitance $dQ_{dx}_dV_s$ (only for $capmod=2$).
28	$c_{dx d}$ (F)	Intrinsic capacitance $dQ_{dx}_dV_d$ (only for $capmod=2$).
29	c_{dxsx} (F)	Intrinsic capacitance $dQ_{dx}_dV_{sx}$ (only for $capmod=2$).
30	$c_{dx dx}$ (F)	Intrinsic capacitance $dQ_{dx}_dV_{dx}$ (only for $capmod=2$).
31	c_{gso} (F)	Gate-Source overlap capacitance.
32	c_{gdo} (F)	Gate-Drain overlap capacitance.
33	q_s (Coul)	Q_s (only for $capmod=2$).
34	q_d (Coul)	Q_d (only for $capmod=2$).
35	q_g (Coul)	Q_g (only for $capmod=2$).
36	q_{sx} (Coul)	Charge of sx internal node (only for $capmod=2$).
37	q_{dx} (Coul)	Charge of dx internal node (only for $capmod=2$).
38	r_{on} (Ω)	On-resistance.
39	i_d (A)	Resistive drain current.
40	i_s (A)	Resistive source current.
41	pwr (W)	Power at op point.

Virtuoso Simulator Components and Device Models Reference

RPI TFT Models

42	igs (A)	Gate-to-source current.
43	igd (A)	Gate-to-drain current.
44	i1 (A)	Resistive drain current.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

Ctheff	O-2	dd	M-17	m	M-15	rth0	I-8
acm	M-82	delta	M-9	mc	M-37	rth0	M-70
alarm	M-73	dg	M-18	me	M-47	rtheff	O-1
alphasat	M-8	dmu1	M-39	meta	M-50	shmod	M-68
asat	M-7	dvt	M-95	meto	M-92	tdev	OP-11
at	M-30	dvto	M-38	minme	M-49	theta	M-55
binflag	M-99	eb	M-32	minr	M-62	tmax	M-72
binunit	M-98	eta	M-5	mk	M-24	tnom	M-66
blk	M-19	etac0	M-35	mkink	M-23	tox	M-4
bt	M-31	etac00	M-36	mmu	M-14	trise	M-67
capmod	M-59	etai	M-6	ms	M-48	type	M-1
cdd	OP-20	gds	OP-10	mss	M-56	type	OP-1
cddx	OP-22	gm	OP-9	mu0	M-11	vds	OP-6

Virtuoso Simulator Components and Device Models Reference

RPI TFT Models

cdnver	M-65	hdif	M-90	mul	M-13	vdsat	OP-8
cds	OP-19	i0	M-21	muo	M-12	version	M-63
cdsx	OP-21	i00	M-33	mus	M-10	vfb	M-16
cdxd	OP-28	i1	OP-44	nrd	I-3	vgs	OP-5
cdxdx	OP-30	id	OP-39	nrd	M-76	vkink	M-25
cdxs	OP-27	ids	OP-4	nrs	I-4	vmax	M-54
cdxsx	OP-29	igd	OP-43	nrs	M-77	von	M-42
cgd	OP-12	igs	OP-42	nseg	I-10	vp	M-52
cgdo	M-44	intdsnod	M-61	pwr	OP-41	vsi	M-96
cgdo	OP-32	ioo	M-34	qd	OP-34	vsigma	M-45
cgg	OP-14	is	OP-40	qdx	OP-37	vsigmat	M-46
cgs	OP-13	isnoisy	I-7	qg	OP-35	vst	M-97
cgso	M-43	isubmod	M-53	qs	OP-33	vth	OP-7
cgso	OP-31	kss	M-57	qsx	OP-36	vto	M-2
clk	M-20	l	I-2	rd	M-27	w	I-1
compatible	M-64	l	M-75	rdc	M-93	w	M-74
csd	OP-16	lambda	M-3	rdeff	O-6	wd	M-86
csdx	OP-18	lasat	M-41	rdx	M-29	weff	O-3
css	OP-15	ld	M-85	region	I-6	wmax	M-78
cssx	OP-17	ldif	M-89	region	OP-2	wmin	M-79
csxd	OP-24	leff	O-4	reversed	OP-3	wmlt	M-88

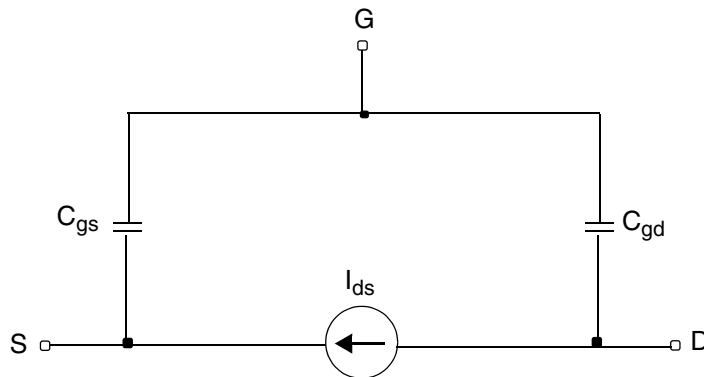
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RPI TFT Models

csxdx	OP-26	lkink	M-22	ron	OP-38	wth0	M-71
csxs	OP-23	lmax	M-80	rs	M-26	xj	M-91
csxsx	OP-25	lmin	M-81	rsc	M-94	x1	M-83
cth0	I-9	lmlt	M-87	rseff	O-5	xw	M-84
cth0	M-69	ls	M-51	rsh	M-58	zeroc	M-60
dasat	M-40	m	I-5	rsx	M-28		

Amorphous-Si TFT Model (ATFT)

Equivalent Circuit



Model Features

Features of the ATFT model include:

- The unified DC model covers all regimes of operation
- The model parameters are automatically scaled to accurately model a wide range of device geometries

- The modified charge control model includes induced charge trapped in localized states
- Above threshold includes:
 - Field effect mobility becoming a function of gate bias
 - Band mobility dominated by lattice scattering
- Below threshold includes:
 - Fermi level located in deep localized states
 - Realting position of fermi level, including deep DOS, back to the gate bias
- Emperical expression for current at large negative gate biases for hole-induced leakage current
- Temperature effects include:
 - Linear dependence of threshold voltage
 - Temperature activated field-effect mobility
 - Temperature activated leakage current
 - Dependence of subthreshold slope includinga possible back channel effect.

Drain Current

$$I_{ds} = I_{leakage} + I_{ab}$$

$$I_{leakage} = I_{hl} + I_{min}$$

where

$$I_{min} = \sigma_0 \cdot V_{ds}$$

$$I_{hl} = IOL \left[\exp\left(\frac{V_{ds}}{VDSL}\right) - 1 \right] \exp\left(-\frac{V_{gs}}{VGSL}\right) \exp\left[\frac{EL}{q} \left(\frac{1}{V_{tho}} - \frac{1}{V_{th}}\right)\right]$$

$$I_{ab} = g_{ch} V_{dse} (1 + LAMBDA \cdot V_{ds})$$

Virtuoso Simulator Components and Device Models Reference

RPI TFT Models

$$V_{dse} = \frac{V_{ds}}{\left[1 + \left(\frac{V_{ds}}{V_{sate}}\right)^M\right]^{\frac{1}{M}}}$$

$$V_{sate} = \alpha_{sat} V_{gte}$$

$$g_{ch} = \frac{g_{chi}}{1 + g_{chi}(RS + RD)}$$

$$g_{chi} = q \cdot n_s \cdot MUBAND \cdot \frac{W}{L}$$

$$n_s = \frac{n_{sa} n_{sb}}{n_{sa} + n_{sb}}$$

$$n_{sa} = \frac{EPSI \cdot V_{gte} \left(\frac{V_{gte}}{V_{aat}}\right)^{GAMMA}}{q \cdot TOX}$$

$$n_{sb} = n_{so} \left(\frac{t_m}{TOX} \frac{V_{gfb} EPSI}{V_0 EPS}\right)^{\frac{2VO}{V}}$$

$$n_{so} = N_c t_m \frac{V_e}{V_0} \exp\left(-\frac{DEF0}{V_{th}}\right)$$

$$N_c = 3.0 \cdot 10^{25} m^{-3}$$

$$V_e = \frac{2 \cdot V_0 \cdot V_{tho}}{2 \cdot V_0 - V_{th}}$$

$$t_m = \sqrt{\frac{EPS}{2q \cdot GMIN}}$$

$$V_{gte} = \frac{VMIN}{2} \left[1 + \frac{V_{gt}}{VMIN} + \sqrt{DELTA^2 + \left(\frac{V_{gt}}{VMIN} - 1\right)^2}\right]$$

Virtuoso Simulator Components and Device Models Reference

RPI TFT Models

$$V_{gt} = V_{gs} - V_T$$

$$V_{gfbe} = \frac{VMIN}{2} \left[1 + \frac{V_{gfb}}{VMIN} + \sqrt{DELTA^2 + \left(\frac{V_{gfb}}{VMIN} - 1 \right)^2} \right]$$

$$V_{gfb} = V_{gs} - VFB$$

Drain and Source Parasitic Resistance

If ACM is not given,

$$rd = \begin{cases} rd, & \text{if } rd \text{ is given} \\ rsh \cdot nrd, & \text{otherwise} \end{cases}$$

$$rs = \begin{cases} rs, & \text{if } rs \text{ is given} \\ rsh \cdot nrs, & \text{otherwise} \end{cases}$$

ACM=0:

$$rd = \begin{cases} nrd \cdot rsh + rdc, & \text{if } (nrd \cdot rsh) > 0 \\ rd + rdc, & \text{otherwise} \end{cases}$$

$$rs = \begin{cases} nrs \cdot rsh + rsc, & \text{if } (nrs \cdot rsh) > 0 \\ rs + rsc, & \text{otherwise} \end{cases}$$

If ACM=1,

$$rd = (Ld + Ldif) \cdot rd/w + nrd \cdot rsh + rdc$$

$$rs = (Ld + Ldif) \cdot rs/w + nrs \cdot rsh + rsc$$

If ACM=2, 3,

$$rd = \begin{cases} (Ld + Ldif) \cdot rd/w + nrd \cdot rsh + rdc, & \text{if } nrd \text{ is given} \\ rdc + \frac{Hdif \cdot rsh + (Ld + Ldif) \cdot rd}{w}, & \text{otherwise} \end{cases}$$

Virtuoso Simulator Components and Device Models Reference

RPI TFT Models

$$rs = \begin{cases} (Ld + Ldif) \cdot rs/w + nrs \cdot rsh + rsc, & \text{if nrd is given} \\ rsc + \frac{Hdif \cdot rsh + (Ld + Ldif) \cdot rs}{w}, & \text{otherwise} \end{cases}$$

Temperature Dependence

$$V_{tho} = k_B \cdot TNOM / q$$

$$V_{th} = k_B \cdot T / q$$

$$V_{aat} = VAA \cdot \exp \left[\frac{EMU}{q \cdot GAMMA} \left(\frac{1}{V_{th}} - \frac{1}{V_{tho}} \right) \right]$$

$$V_T = VTO + KVT(TEMP - TNOM)$$

$$\alpha_{sat} = ALPHASAT + KASAT(TEMP - TNOM)$$

Capacitance

$$C_{gs} = C_f + \frac{2}{3} C_{gc} \left[1 - \left(\frac{V_{sate} - V_{dse}}{2V_{sate} - V_{dse}} \right) \right]$$

$$C_{gd} = C_f + \frac{2}{3} C_{gc} \left[1 - \left(\frac{V_{sate}}{2V_{sate} - V_{dse}} \right) \right]$$

$$C_f = 0.5 \cdot EPS \cdot W$$

$$C_{gc} = q \frac{dn_{sc}}{dV_{gs} \cdot L_{eff} \cdot W_{eff}}$$

$$n_{sc} = \frac{n_{sac} n_{sbc}}{n_{sac} + n_{sbc}}$$

$$n_{sac} = \frac{EPSI \cdot V_{gte}}{q \cdot TOX}$$

$$n_{sbc} = n_{sb}$$

Scaling Effects

For scaling effects, see [Scaling Factors \(scale and scalem\)](#) on page 242.

Component Statements

This device is supported within altergroups.

Sample Instance Statement:

```
m4 (0 2 1 1) nch w=2u l=0.8u
```

Sample Model Statement

```
model nch atft type=n
```

Instance Definition

```
Name d g s [b] ModelName parameter=value ...
```

Instance Parameters

1	w (m)	Channel width.
2	l (m)	Channel length.
3	m=1	Multiplicity factor (number of MOSFETs in parallel).
4	trise=0	Temperature rise from ambient.
5	region=triode	Estimated operating region. Possible values are off, triode, sat, or subth.
6	nrd (m/m)	Drain squares.
7	nrs (m/m)	Source squares.

Model Definition

model modelName atft parameter=value ...

Model Parameters

Device type parameters

1 `type=n` Transistor type.
Possible values are `n` or `p`.

Drain current model parameters

2 `compatible=spectre` Spice compatible flag.
Possible values are `spectre`, `spice2`, `spice3`, `cdsspice`,
`hspice`, `spiceplus`, `eldo`, or `sspice`.

3 `cdnver=1` Cadence version selector.

4 `vto=0 V` Zero-bias threshold voltage.

5 `lambda=0.0008 1/V` Channel length modulation parameter.

6 `tox=1e-7 m` Thin-oxide thickness.

7 `def0=0.6 eV` Dark Fermi level position.

8 `alphasat=0.6` Saturation modulation parameter.

9 `delta=5` Transition width parameter.

10 `e1=0.35 eV` Activation energy of the hole leakage current.

11 `emu=0.06 eV` Field effect mobility activation energy.

12 `eps=11` Relative dielectric constant of substrate.

13 `epsi=7.4` Relative dielectric constant of gate insulator.

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RPI TFT Models

14	$v_{fb} = -3 \text{ V}$	Flat band voltage.
15	$\gamma = 0.4$	Power law mobility parameter.
16	$g_{min} = 1.0e23 \text{ 1/m}^3 \text{ eV}$	Minimum density of deep states.
17	$i_{ol} = 3.0e-14 \text{ A}$	Zero bias leakage current parameter.
18	$k_{asat} = 0.006 \text{ 1/C}$	Temperature coefficient of ALPHASAT.
19	$k_{vt} = -0.036 \text{ V/C}$	Threshold voltage temperature coefficient.
20	$m = 2.5$	Knee shape parameter.
21	$\mu_{band} = 0.001 \text{ m}^2/\text{V s}$	Conduction band mobility.
22	$r_s = 0 \text{ }\Omega$	Source resistance.
23	$r_d = 0 \text{ }\Omega$	Drain resistance.
24	$\sigma_0 = 1.0e-14 \text{ A}$	Minimum leakage current parameter.
25	$v_0 = 0.12 \text{ V}$	Characteristic voltage for deep states.
26	$v_{aa} = 7.5e3 \text{ V}$	Characteristic voltage for field effect mobility.
27	$v_{ds1} = 7 \text{ V}$	Hole leakage current drain voltage parameter.
28	$v_{gs1} = 7 \text{ V}$	Hole leakage current drain voltage parameter.
29	$v_{min} = 0.3 \text{ V}$	Convergence parameter.
30	$c_{gdo} = 0 \text{ F/m}$	Gate-drain overlap capacitance.
31	$c_{gso} = 0 \text{ F/m}$	Gate-source overlap capacitance.

ACM parameters

32	$a_{cm} = 0$	Area calculation method.
33	$x_w = 0.0 \text{ m}$	Accounts for masking and etching effects.

Virtuoso Simulator Components and Device Models Reference

RPI TFT Models

34	<code>xl=0.0 m</code>	Accounts for masking and etching effects.
35	<code>ld (m)</code>	Lateral diffusion into channel from source and drain diffusion.
36	<code>wd=0.0 m</code>	Lateral diffusion into channel from bulk along width.
37	<code>lmlt=1.0</code>	Length diffusion layer shrink reduction factor.
38	<code>wmlt=1.0</code>	Width diffusion layer shrink reduction factor.
39	<code>rsh=0 Ω/sqr</code>	Source/drain diffusion sheet resistance.
40	<code>rdc=0.0 Ω</code>	Additional drain resistance due to contact resistance.
41	<code>rsc=0.0 Ω</code>	Additional source resistance due to contact resistance.
42	<code>ldif=0.0 m</code>	Length of heavily doped diffusion adjacent to gate.
43	<code>hdif=0.0 m</code>	Length of heavily doped diffusion from contact to lightly doped region.
44	<code>meto=0.0 m</code>	Fringing field factor for gate to source and gate to drain overlap capacitance.
45	<code>xj=0.0 m</code>	Metallurgical junction depth.

Temperature effects parameters

46	<code>tnom (C)</code>	Parameter measurement temperature.
47	<code>trise=0 C</code>	Temperature rise from ambient.

Operating region warning control parameters

48	<code>alarm=none</code>	Forbidden operating region. Possible values are <code>none</code> , <code>off</code> , <code>triode</code> , <code>sat</code> , <code>subth</code> , or <code>rev</code> .
----	-------------------------	---

Auto Model Selector parameters

49	<code>wmax=1 m</code>	Maximum channel width for which the model is valid.
----	-----------------------	---

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RPI TFT Models

50	<code>wmin=0 m</code>	Minimum channel width for which the model is valid.
51	<code>lmax=1 m</code>	Maximum channel length for which the model is valid.
52	<code>lmin=0 m</code>	Minimum channel length for which the model is valid.

Noise model parameters

53	<code>noisemod=1</code>	Noise model selector.
54	<code>kf=0</code>	Flicker (1/f) noise coefficient.
55	<code>af=1</code>	Flicker (1/f) noise exponent.
56	<code>ef=1</code>	Flicker (1/f) noise frequency exponent.
57	<code>wnoi=1e-5 m</code>	Channel width at which noise parameters were extracted.

Operating-Point Parameters

1	<code>type=n</code>	Transistor type. Possible values are <code>n</code> or <code>p</code> .
2	<code>region=triode</code>	Estimated operating region. Possible values are <code>off</code> , <code>triode</code> , <code>sat</code> , or <code>subth</code> .
3	<code>reversed</code>	Reverse mode indicator. Possible values are <code>no</code> or <code>yes</code> .
4	<code>ids (A)</code>	Resistive drain-to-source current.
5	<code>vgs (V)</code>	Gate-source voltage.
6	<code>vds (V)</code>	Drain-source voltage.
7	<code>vth (V)</code>	Threshold voltage.
8	<code>vdsat (V)</code>	Drain-source saturation voltage.
9	<code>gm (S)</code>	Common-source transconductance.
10	<code>gds (S)</code>	Common-source output conductance.

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RPI TFT Models

11	cgd (F)	Gate-drain capacitance.
12	cgs (F)	Gate-source capacitance.
13	ron (Ω)	On-resistance.
14	id (A)	Resistive drain current.
15	pwr (W)	Power at op point.
16	i1 (A)	Resistive drain current.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

acm M-32	gmin M-16	noisemod M-53	v0 M-25
af M-55	hdif M-43	nrd I-6	vaa M-26
alarm M-48	i1 OP-16	nrs I-7	vds OP-6
alphasat M-8	id OP-14	pwr OP-15	vdsat OP-8
cdnver M-3	ids OP-4	rd M-23	vds1 M-27
cgd OP-11	iol M-17	rdc M-40	vfb M-14
cgdo M-30	kasat M-18	region I-5	vgs OP-5
cgs OP-12	kf M-54	region OP-2	vgs1 M-28
cgso M-31	kvt M-19	reversed OP-3	vmin M-29
compatible M-2	l I-2	ron OP-13	vth OP-7
def0 M-7	lambda M-5	rs M-22	vto M-4

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RPI TFT Models

delta	M-9	ld	M-35	rsc	M-41	w	I-1
ef	M-56	ldif	M-42	rsh	M-39	wd	M-36
el	M-10	lmax	M-51	sigma0	M-24	wmax	M-49
emu	M-11	lmin	M-52	tnom	M-46	wmin	M-50
eps	M-12	lmlt	M-37	tox	M-6	wmlt	M-38
epsi	M-13	m	I-3	trise	I-4	wnoi	M-57
gamma	M-15	m	M-20	trise	M-47	xj	M-45
gds	OP-10	meto	M-44	type	M-1	xl	M-34
gm	OP-9	muband	M-21	type	OP-1	xw	M-33

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RPI TFT Models

Three-Terminal Nonlinear (Diffused and Poly-Silicon) Resistor Model and JFET Model (r3)

The r3 model is a nonlinear 3-terminal resistor model that includes self-heating, velocity saturation, statistical variations, and parasitic capacitances and currents. The core depletion pinching model formulation is for p-n junctions of diffused resistors, but is also applicable for the MOS behavior of polysilicon resistors. As p-n junction depletion pinching controls JFET device behavior, the r3 model is also applicable to JFETs.

This chapter covers the following information about the r3 model:

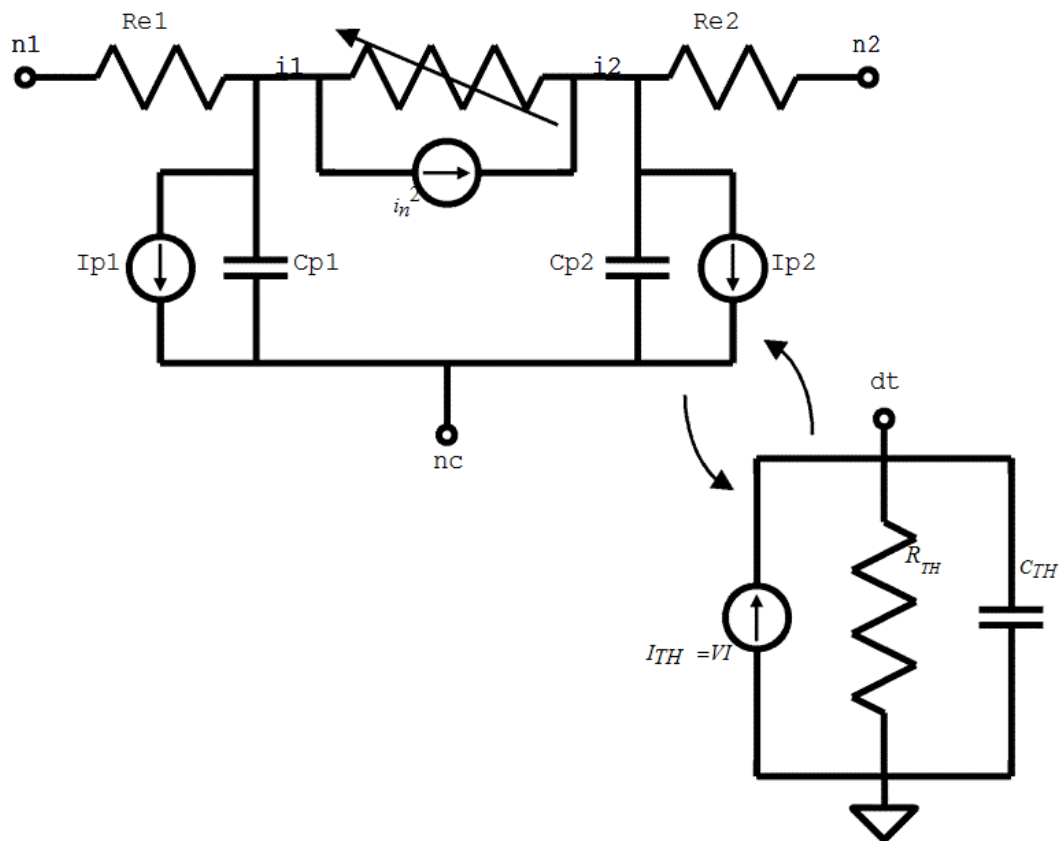
- [Usage](#) on page 2724
- [Bias Dependence of Resistor Body Current](#) on page 2725
- [Bias Dependence of Parasitics](#) on page 2728
- [Geometry Dependence](#) on page 2730
- [Temperature Dependence](#) on page 2734
- [Noise](#) on page 2736
- [Operating Point Information](#) on page 2737
- [Statistical Variation](#) on page 2738
- [Notes on Parameter Extraction](#) on page 2741
- [Reference](#) on page 2746
 - [Component Statements](#) on page 2746

Usage

Exact usage may be simulator dependent; e.g. whether the local temperature rise node for self-heating is made available or not, and whether the initial instance key-letter “r” is required.)

```
r<instanceName> (<n1> <nc> <n2>) <modelName> <instanceParameters>
.model <modelName> r3 <modelParameters>
```

Figure 40-1 r3 Model Equivalent Network



Example

```
r00 n1 n2 n3 p0 l = 2e-6 w = 10e-6 m = 10 sw_et = 1
```

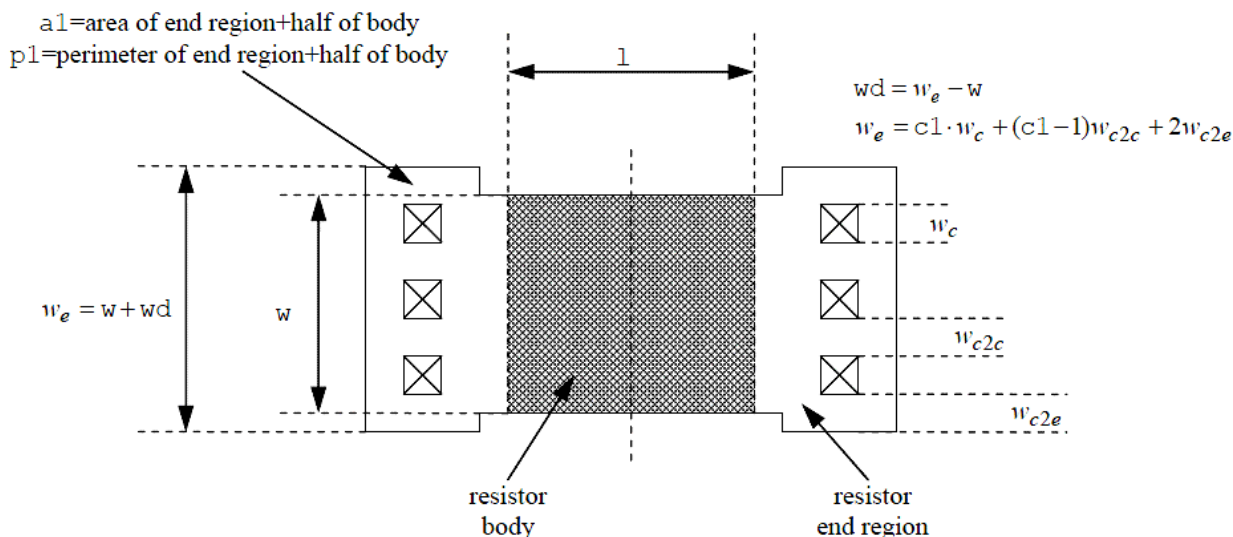
```
model p0 r3 type=1 shrink=50 xw=0.01 nwxw=0.1 wexw=0.1 xl=0.01xlw=0.2 dxlsat=0.01
+rcw=0.01 ca=1e-4 cja=1e-4 cp=1e-10 cjp=1e-10 dfw=1e-3 dfl=1e-3 dfwl=1e-3
+tc1=1e-3 tc2=1e-4 tc1l=1e-3 tc2l=1e-4 tc1w=1e-3 tc2w=1e-4 tc1rc=1e-3 tc2rc=1e-4
tc1kfn=1e-3
```

+tc1v_{bv}=1e-3 tc2v_{bv}=1e-4 tc1n_{bv}=1e-3 sw_dfgeo=0 rc=1

Instance Parameters

The parameter examples are given below. For a complete list of model parameters, please refer to section

Figure 40-2 Instance Parameter examples. The end region dogbone may be asymmetric.



Bias Dependence of Resistor Body Current

The r3 model includes three basic forms of bias dependence. First, from the depletion (p-n junction or MOS) pinching of the conducting channel of the resistor. Second, from velocity saturation. And third, from self-heating.

The basic p-n junction depletion pinching bias dependence comes from the analysis of [1], with the simplification of [2] (which merges the vertical and lateral bias dependence into a single bias dependent form with geometry dependent parameters). The applicability of the same general form of bias dependence for poly resistors, where the MOS depletion effect

Virtuoso Simulator Components and Device Models Reference

Three-Terminal Nonlinear (Diffused and Poly-Silicon) Resistor Model and JFET Model (r3)

pinches the resistor body, was shown in [3]. The fundamental form of the depletion pinching model is

$$I_{depl} = gV_{21}, \quad g = gf \cdot \left(1 - df \sqrt{dp + V_i}\right), \quad V_i = V_{21} + 2V_{1c}$$

where $V_{21} = V(i2) - V(i1)$ and $V_{1c} = V(i1) - V(nc)$. Here, dp is the depletion potential (which is just the model parameter dp), df is the depletion factor, and gf is the conductance factor; these are determined from instance and model parameters as detailed in the section on geometry dependence.

The velocity saturation model is a mobility reduction term that divides the conductance factor. The model is smooth and symmetric, has value 1 when $V_{21} = 0$, and asymptotically approaches $1 + (E_{corn}/ecrit)$ for large field $E = V_{21}/(leff_um + dx1sat)$ ($leff_um$ is defined in the next section).

$$\mu_{red} = 1 + \sqrt{\left(\frac{E - E_{ce}}{2ecrit}\right)^2 + \frac{du E_{ce}}{ecrit}} + \sqrt{\left(\frac{E + E_{ce}}{2ecrit}\right)^2 + \frac{du E_{ce}}{ecrit}} - \sqrt{\left(\frac{E_{ce}}{ecrit}\right)^2 + \frac{4 du E_{ce}}{ecrit}}$$

(see Figure 40-3) where

$$E_{ce} = \sqrt{ecorn^2 + (2 du \cdot ecrit)^2} - 2 du \cdot ecrit.$$

The V_{21} used in the above expressions is smoothly limited so as not to exceed a saturation voltage V_{sat} , which is calculated as the V_{21} at which the output conductance becomes zero. To determine V_{sat} a slightly modified form of the velocity saturation model is used (the asymptotic form noted above), that allows closed form solution and guarantees that any imprecision in calculation of V_{sat} is such that the output conductance at saturation is positive, so that there are no “wiggles” around the transition to saturation. The smooth transition is implemented through the above equation.

$$V_{21,eff} = \frac{2V_{21}V_{sat}}{\sqrt{(V_{21} - V_{sat})^2 + 4ats^2} + \sqrt{(V_{21} + V_{sat})^2 + 4ats^2}}$$

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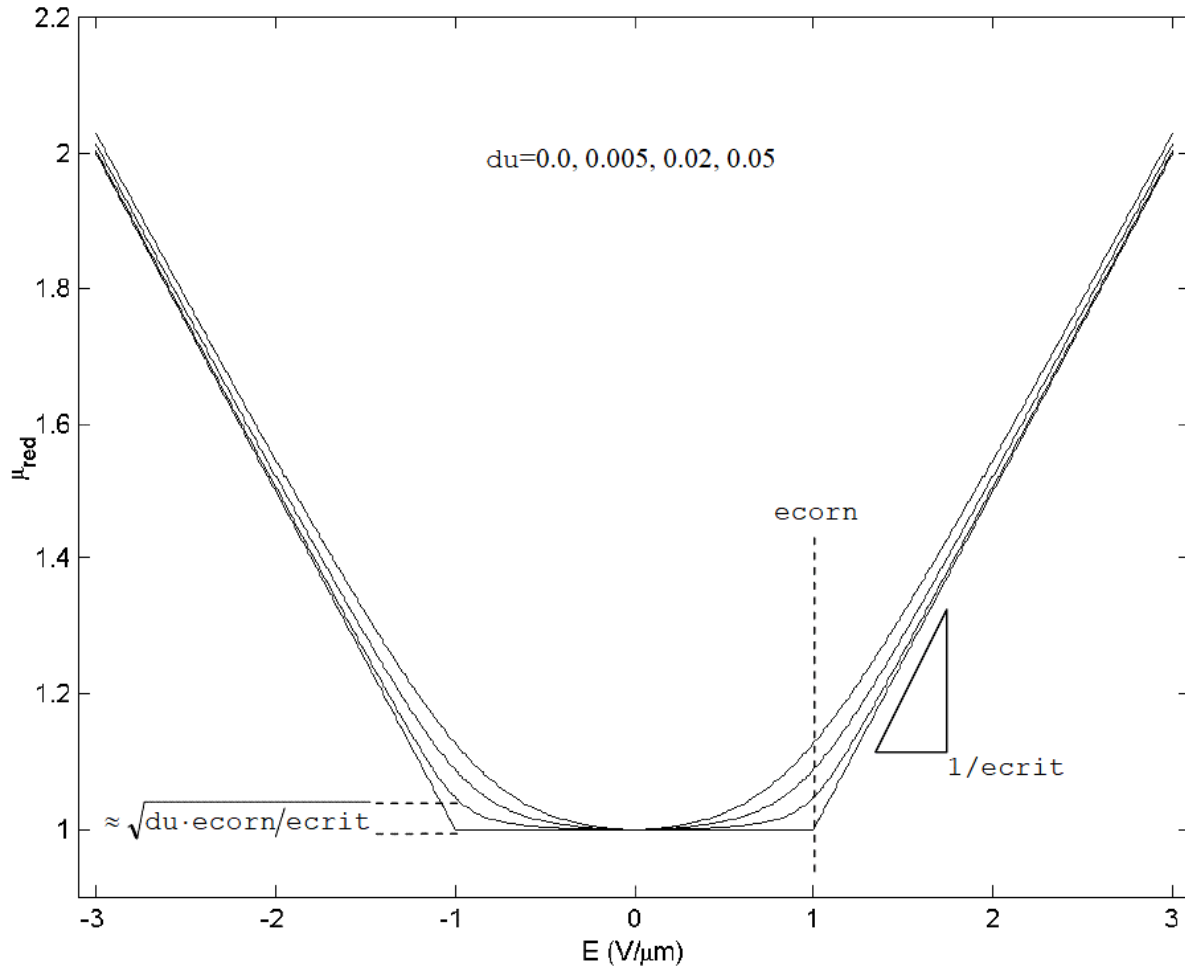
where ats is a model parameter that controls the limiting. This limiting function differs from those often used in compact MOSFET models; it preserves symmetry. The control voltage used is also limited, to the pinch-off voltage

$$V_{1c,eff} = V_{po} - nstV_{tv} \ln \left(1 + \exp \left(\frac{V_{po} - V_{1c}}{nstV_{tv}} \right) \right), \quad V_{po} = \frac{1}{2df^2} - 0.5dp, \quad V_{tv} = kT/q.$$

The self-heating affects the current through the temperature variation of the model parameters, primarily the sheet resistance. The current flowing between nodes n2 and n1 in Figure [40-1](#) is then

$$I_{21} = I_{depl} / \mu_{red}$$

Figure 40-3 Velocity Saturation Model



Bias Dependence of Parasitics

If there are no area or perimeter component of saturation current, e.g. for poly resistors,

$$I_{p1} = I_{p2} = 0$$

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Three-Terminal Nonlinear (Diffused and Poly-Silicon) Resistor Model and JFET Model (r3)

If there are area and/or perimeter components of saturation current, e.g. as for diffused resistors, the parasitic diode currents are

$$I_{p1} = p1_um \cdot I_{sp}(T) \left(\exp(V_{c1}/(np \cdot V_{tv})) - 1 \right) + a1_um2 \cdot I_{sa}(T) \left(\exp(V_{c1}/(na \cdot V_{tv})) - 1 \right) + gmin \cdot V_{c1}$$

$$I_{p2} = p2_um \cdot I_{sp}(T) \left(\exp(V_{c2}/(np \cdot V_{tv})) - 1 \right) + a2_um2 \cdot I_{sa}(T) \left(\exp(V_{c2}/(na \cdot V_{tv})) - 1 \right) + gmin \cdot V_{c2}$$

where $V_{c1} = V(nc) - V(i1)$ and $V_{c2} = V(nc) - V(i2)$. Each individual component of the diode currents is linearized for forward biases greater than the voltage at which the component is i_{max} .

The breakdown currents, which are added to each parasitic current, are

$$I_{b1} = -ibv \left(\exp(-(V_{c1} + V_{bv}(T))/(n_{bv}(T)V_{tv})) - \exp(-V_{bv}(T)/(n_{bv}(T)V_{tv})) \right),$$

$$I_{b2} = -ibv \left(\exp(-(V_{c2} + V_{bv}(T))/(n_{bv}(T)V_{tv})) - \exp(-V_{bv}(T)/(n_{bv}(T)V_{tv})) \right)$$

and each of these is linearized for reverse biases greater than the voltage as which the magnitude of the current is i_{max} .

The parasitic capacitances comprise a bias independent component (intended for poly resistor modeling) and a bias dependent component (intended for diffused resistor modeling). The capacitances are implemented as bias dependent charges, but the resulting capacitances are given here

$$C_{p1} = p1_um \left(c_p + \frac{C_{jp}(T)}{(1 - V_{c1}/P_p(T))^{mp}} \right) + a1_um2 \left(c_a + \frac{C_{ja}(T)}{(1 - V_{c1}/P_a(T))^{ma}} \right)$$

$$C_{p2} = p2_um \left(c_p + \frac{C_{jp}(T)}{(1 - V_{c2}/P_p(T))^{mp}} \right) + a2_um2 \left(c_a + \frac{C_{ja}(T)}{(1 - V_{c2}/P_a(T))^{ma}} \right)$$

The forward bias junction capacitance components are modified so that when the junction voltage (V_{c1} or V_{c2}) reaches f_c multiplied by the associated built-in potential, the capacitance becomes linear in voltage, to avoid the singularity at the built-in potential. If the smoothing parameters a_{ja} and a_{jp} are positive, then the transition from depletion to linear capacitance is done smoothly and not abruptly.

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Three-Terminal Nonlinear (Diffused and Poly-Silicon) Resistor Model and JFET Model (r3)

The thermal resistance and capacitance for the self-heating model are linear, and do not depend on temperature. The thermal power used for self-heating modeling is the sum of the powers of all dissipative (non-storage) elements in the equivalent circuit; i.e. the resistor body, the two end resistances, and two parasitic current sources.

Geometry Dependence

Unless otherwise noted, all r3 model quantities scale with the multiplicity parameter *m* as defined in the *Verilog-A Language Reference Manual (LRM)*, version 2.2.

The r3 model includes several mechanisms for deviations of the effective electrical length and width of a resistor from the drawn (design, or mask) values. The drawn length and width of the resistor, in units of microns, are

$$l_um = l \cdot scale \cdot (1 - shrink/100) \cdot 10^6,$$

$$w_um = w \cdot scale \cdot (1 - shrink/100) \cdot 10^6$$

Because subcircuit models for resistors can consist of multiple resistance sections connected in series, it is desirable to be able to switch on and off the “end corrections” for length to facilitate implementation of such multi-section models. This is the function of the *c1* and *c2* instance parameters of the r3 model. The effective length offset is

$$xleff = (x1 + x1w/w_um) \cdot ((c1 > 0) + (c2 > 0)) / 2$$

(which is zero if neither end is contacted, $x1 + x1w/w_um$ if both ends are contacted, and one half of the latter if only one end is contacted). The effective electrical length, in microns, is

$$leff_um = l_um + xleff$$

For flexibility of separately fitting low bias resistance and velocity saturation, an additional offset *dxlsat* is added to *leff_um* for calculation of the electric field used in the velocity saturation model.

The effective width offset includes the physical effect models derived in [4]. These comprise a fixed offset for mask bias, lithography, and etching effects, and geometry dependent offsets

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Three-Terminal Nonlinear (Diffused and Poly-Silicon) Resistor Model and JFET Model (r3)

for LOCOS, the webbing effect, and the finite dopant source effect. The effective electrical width, in microns, is

$$w_{eff_um} = \frac{w_um + xw + (nwxw/w_um) + fdxw \ln(1 - \exp(-w_um/fdrw))}{1 - wexw \cdot wd_um / (l_um \cdot w_um)}$$

where the width of the dogbone (see Figure 40-2), for the webbing effect model, in units of microns, is

$$wd_um = wd \cdot scale \cdot (1 - shrink/100) \cdot 10^6$$

The depletion potential does not have a geometry dependence, so $d_p = d_p$. The depletion factor depends on geometry as

$$df = df_{inf} + \frac{dfw}{W} + \frac{dfl}{L} + \frac{dfwl}{WL}$$

where the width W and length L are effective geometries if $sw_dfgeo=1$ and design geometries otherwise (in units of micron). The zero-bias resistance, which factors in the zero-bias depletion pinching, is then

$$R_0 = r_{sh} \frac{l_{eff_um}}{w_{eff_um}} (1.0 - df \sqrt{d_p}), \quad gf = 1/R_0$$

Although end effects, such as spreading resistance and contact resistance, are assumed to be modeled via the $x1$ parameter, the temperature coefficients of the end effects may differ from those of the body of the resistor. Simple analysis shows that these different temperature coefficients can be accounted for by introducing inverse length dependence to the temperature coefficients. A width dependence of temperature coefficients of resistance is also included in the model. Therefore in r3

$$T_{C1}^{eff} = tc1 + \frac{0.5((c1 > 0) + (c2 > 0))tc1l}{l_{eff_um}} + \frac{tc1w}{w_{eff_um}},$$

$$T_{C2}^{eff} = tc2 + \frac{0.5((c1 > 0) + (c2 > 0))tc2l}{l_{eff_um}} + \frac{tc2w}{w_{eff_um}}$$

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Three-Terminal Nonlinear (Diffused and Poly-Silicon) Resistor Model and JFET Model (r3)

where the length dependence is switched on, off, or halved, depending on whether the resistor is contacted at both ends, not contacted, or contacted at only one end, respectively. The dependence of the temperature coefficients on whether a resistor is contacted or not enables consistent modeling of temperature coefficients for single or multiple section models.

The thermal conductance and capacitance include area, perimeter, contact, and fixed components. Asymptotically for a large area device, the heat flow is perpendicular to the plane of heat generation in the resistor, and the heat energy stored in a device depends on its volume, hence the area dependent component. For a long resistor, as it becomes narrower more of the heat flow is conducted by a “fringe” path at the edges of the device, hence the perimeter dependent component. As both length and width decrease, the thermal conditions in the device asymptotically approach that of a point source in an infinite medium, hence the fixed component. Contacts conduct heat flow, hence the contact component. The thermal conductance and capacitance are therefore

$$g_{TH} = g_{th0} + g_{thp} \cdot p_{_um2} + g_{tha} \cdot a_{_um2} + g_{thc} \cdot (c1 + c2)$$

$$c_{TH} = c_{th0} + c_{thp} \cdot p_{_um2} + c_{tha} \cdot a_{_um2} + c_{thc} \cdot (c1 + c2)$$

the area and perimeter are calculated as

$$a_{_um2} = l_{_um} \cdot w_{_um}$$

$$p_{_um} = 2l_{_um} + ((c1 > 0) + (c2 > 0))w_{_um} .$$

The calculated perimeter therefore depends on whether the ends are contacted or not. Note that often the design dimensions of the body of a resistor differ from the overall dimensions of the device, for example if the design length is considered to be the unsalicated length of a poly resistor, the total resistor length will typically include silicided contact regions. So it is not readily apparent what dimension should be used in calculation of the thermal conductance and capacitance. That is why the design dimensions, rather than some effective dimensions (whose value is calculated to best fit DC electrical data), are used. This turns out to be reasonable (with the exception that differences between the perimeter components along length and width dimensions are ignored), because if there is some difference Δ between design and effective dimensions for thermal conductance modeling, then for a device contacted at both ends

$$\begin{aligned} g_{TH} &= g_{th0} + g_{thp}(2l_{_um} + 2w_{_um} + 4\Delta) + g_{tha}(l_{_um} + \Delta)(w_{_um} + \Delta) \\ &= (g_{th0} + 4g_{thp} \cdot \Delta + g_{tha} \cdot \Delta^2) + (g_{thp} + 0.5g_{tha} \cdot \Delta)p_{_um} + g_{tha} \cdot a_{_um2} \end{aligned}$$

Virtuoso Simulator Components and Device Models Reference

Three-Terminal Nonlinear (Diffused and Poly-Silicon) Resistor Model and JFET Model (r3)

therefore any difference between design and effective dimensions can be taken into account by appropriate characterization of the fixed, perimeter, and area component parameters.

Because the *local* thermal conductance differs between the edge of a device and the center of a device, it is higher at the edge because of *fringing* conductance, the temperature of a resistor undergoing self-heating is not spatially uniform, but is lower at the edges than in the middle. This is not taken into account in the r3 model.

The end resistances are calculated from the resistance per contact and the number of contacts (parallel to the width dimension; adding contacts parallel to the length dimension, which can be done for reliability purposes, does not alter the resistance much – unless the contact adjacent to the resistor body fails)

$$R_{e1} = \frac{rc + rcw/w_um}{c1}, \quad R_{e2} = \frac{rc + rcw/w_um}{c2}$$

The velocity saturation model includes geometry dependence in the bias dependent portion of the model evaluation, as it is formulated in terms of the electric field

$$E = V_{21} / (l_{eff_um} + dx_{lsat}).$$

The areas and perimeters of the end region partitions, used in parasitic calculations, are in units of microns

$$p1_um = p1 \cdot scale \cdot (1 - shrink/100) \cdot 10^6,$$

$$a1_um2 = a1 \cdot (scale \cdot (1 - shrink/100) \cdot 10^6)^2,$$

$$p2_um = p2 \cdot scale \cdot (1 - shrink/100) \cdot 10^6,$$

and

$$a2_um2 = a2 \cdot (scale \cdot (1 - shrink/100) \cdot 10^6)^2.$$

If the number of contacts is not known, it can be calculated (see Figure 40-2). Let the contact width (in the direction parallel to the resistor width) be w_c , the minimum spacing from a contact to the edge of the region it is in at the contact head of the resistor be w_{c2e} , and the (minimum)

Virtuoso Simulator Components and Device Models Reference

Three-Terminal Nonlinear (Diffused and Poly-Silicon) Resistor Model and JFET Model (r3)

spacing between contacts be w_{c2c} . If (as in some older technologies) contacts can be scaled, then r_c should be set to be the resistance of a minimum width contact and

$$c[1,2] = \frac{\max(w + wd, w_c + 2w_{c2e}) - 2w_{c2e}}{w_c}$$

and for technologies where the contact width is fixed (assuming the maximum possible number of contacts are places)

$$c[1,2] = \text{int} \left(\frac{\max(w + wd, w_c + 2w_{c2e}) - 2w_{c2e} + w_{c2c}}{w_c + w_{c2c}} \right).$$

Temperature Dependence

The zero-bias resistance R_0 varies with temperature as

$$R_0(T) = R_0 \left(1 + T_{C1}^{\text{eff}} dT + T_{C2}^{\text{eff}} dT^2 \right)$$

where R_0 is the nominal value of the zero-bias resistance at the nominal temperature t_{nom} , dT is the temperature difference (including self-heating) with respect to t_{nom} , and T_{C1}^{eff} and T_{C2}^{eff} are first (linear) and second (quadratic) order effective temperature coefficients. Smooth limiting of the resistance temperature coefficient is implemented to a minimum value of 0.01. The conductance factor is then

$$gf = 1/R_0(T).$$

The end resistances vary with temperature as

$$R_{e[1,2]}(T) = R_{e[1,2]} \left(1 + tc1rc \cdot dT + tc2rc \cdot dT^2 \right)$$

and again the temperature coefficient is limited to a lower value of 0.01.

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The parasitic diode saturation currents vary with temperature as

$$I_{sa}(T) = i_{sa} \cdot rT^{x_{is}/n_a} \exp\left(-e a \frac{1-rT}{n_a \cdot V_{tv}}\right)$$

$$I_{sp}(T) = i_{sp} \cdot rT^{x_{is}/n_p} \exp\left(-e a \frac{1-rT}{n_p \cdot V_{tv}}\right)$$

where rT is the ratio of device to nominal temperature (in Kelvin), and $V_{tv} = kT/q$ is the thermal voltage. The temperature dependence of the junction built-in potentials is

$$P_a(T) = p_a \cdot rT - 3V_{tv} \ln(rT) - e a (rT - 1)$$

$$P_p(T) = p_p \cdot rT - 3V_{tv} \ln(rT) - e a (rT - 1)$$

with a physically based modification to smoothly limit the potential to zero for high temperatures, and not allow it to become negative. The area and perimeter junction zero-bias capacitance temperature variations are

$$C_{ja}(T) = c_{ja} \left(\frac{p_a}{P_a(T)} \right)^{m_a}$$

and

$$C_{jp}(T) = c_{jp} \left(\frac{p_p}{P_p(T)} \right)^{m_p}$$

The flicker noise coefficient varies with temperature as

$$K_{FN}(T) = k_{fn} (1 + t_{c1kfn} \cdot dT)$$

where k_{fn} and t_{c1kfn} are model parameters (and the resulting K_{FN} is clipped to zero as a lower limit).

The breakdown voltage and ideality factor vary with temperature as

$$V_{bv}(T) = v_{bv} \left(1 + t_{c1} v_{bv} \cdot dT + t_{c2} v_{bv} \cdot dT^2 \right),$$

$$n_{bv}(T) = n_{bv} (1 + t_{c1} n_{bv} \cdot dT).$$

Noise

The noise model comprises two body components, a thermal (white) noise component and a flicker ($1/f$) noise component, thermal noise components for each contact resistance, and short noise components for each parasitic diode. These components are noise current spectral density (in A^2/Hz) that are implemented as a noise current sources in parallel with the associated element.

The thermal noise component of the resistor body is based on its DC conductance,

$$i_{thermal,body}^2 = 4kT_K G_{eff}(T)$$

where k is Boltzmann's constant, T_K is the device temperature (in Kelvin, including the effect of self-heating), and G_{eff} is the effective conductance of the resistor (at the temperature T). Similarly the thermal noise of each end resistances is

$$i_{thermal,end}^2 = 4kT_K / R_e(T).$$

The flicker noise component is DC current dependent and scales with geometry per the physical restrictions mentioned earlier.

$$i_{flicker,body}^2 = K_{FN}(T) \left(\frac{I_{21}}{W} \right)^{a_{fn}} \frac{W}{L} \frac{1}{f^{b_{fn}}}$$

where f is frequency (in Hz), a_{fn} and b_{fn} are model parameters, $K_{FN}(T)$ is the temperature dependent flicker noise coefficient, I_{21} is the DC current in the resistor body, and W and L are the resistor width and length respectively, in units micron (μm). If the switch parameter for flicker noise geometry calculation `sw_fngeo` is 0 (false) then W and L are

design geometries, w_um and l_um respectively, else if it is 1 (true) then W and L are effective geometries, w_{eff_um} and l_{eff_um} respectively.

The shot noise components are

$$i_{shot,diode}^2 = 2qI_{diode}$$

for each parasitic diode, where I_{diode} is the current in the diode.

Note that if self-heating is included, then possibly there is a frequency dependence to the flicker noise because of the thermal time constant. There is no data to verify this at present so a frequency independent noise current spectral density is used.

Operating Point Information

Name	Units	Description
v	V	voltage across resistor
ibody	A	current through resistor body
power	W	dissipated power
leff_um	μm	effective electrical length in μm
weff_um	μm	effective electrical width in μm
r0	Ω	zero-bias resistance
r_dc	Ω	DC Resistance (including bias dependence)
r_ac	Ω	AC Resistance (including bias dependence)
rth	K/W	thermal resistance
cth	sW/K	thermal capacitance
dt_et	K	self-heating temperature rise

Table 40-1 Operating Point Parameters

All flow and parameter quantities are for the overall device and include the effect of the multiplicity parameter m .

Statistical Variation

The `r3` model includes both global (inter-die, correlated between individual devices) and local (mismatch, uncorrelated between individual devices) variations. These can be added “on top” of a core model using sub-circuits, however this can involve increased complexity in model parameter files and increased computational overhead during simulation. Therefore statistical variation is “built-in” to the `r3` model, including instance parameters for control of mismatch variation for individual devices.

Besides convenience and efficiency, the statistical variation modeling in `r3` naturally embodies the geometry dependence of total variation in a device, which is not possible with statistical modeling based on a geometry independent global variation and geometry dependent correlation coefficients. Since it is based on independent statistical parameters for global variation and instance specific local variation, it does not require generation of correlated samples for distributional (i.e. Monte Carlo-like) simulation; if correlations were used then $N(N-1)/2$ of them are required for each statistical parameter for each of N devices.

Statistical variations are modeled in three parameters; the sheet resistance, the effective length variation, and the effective width variation. These are considered as the primary physical process parameters that determine the resistor behavior. At present, there is no variation (global or local) in other physical quantities such as contact resistance, other parasitics (zero-bias depletion capacitance for diffused resistors varies with doping), or the parameters that control the nonlinearity of the model. If experimental data shows that linkage to more fundamental physical quantities such as doping levels and layer thicknesses is required to model correlations and statistical variations, this will be added in the future.

The local variation of the effective width is controlled by line edge roughness in the length dimension; its variance is therefore inversely proportional to the resistor length L . The local variation of the effective length is controlled by line edge roughness in the width dimension; its variance is therefore inversely proportional to the resistor width W . The local variation of the sheet resistance is controlled by random dopant fluctuations; its variance is therefore inversely proportional to the area of the resistor, WL . For flexibility in fitting experimental data, the `sw_nmgeo` flag allows the controlling geometries W and L to be either drawn or effective (as calculated before the statistical variations are applied, to avoid an implicit dependency that requires an iterative solution).

The total variance of a parameter is the sum of the variances of the global variance (which is independent of geometry) and the local variance (which depends on geometry g , which can include area, width, and length),

$$\sigma_{total}^2 = \sigma_{global}^2 + \sigma_{local}^2(\bar{g}).$$

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Note that this naturally embodies the geometry dependence of the overall variance of a particular parameter. For statistical simulation, the perturbations of the global variation and the individual instance variation are expected to be statistically independent. But “proper” statistical simulation of a circuit requires inclusion of both global parameters and local parameters for every instance of a device type in a circuit. This can cause the number of statistical parameters included in a statistical simulation to increase proportionally with the number of devices in the circuit, with a concomitant explosion in the number of (local) statistical parameters needed to be included for a “proper” analysis. This is, for brute force statistical simulation, clearly impractical.

The `r3` model therefore includes a mechanism for more efficiently accounting for the geometry dependence of the overall variation. The `sw_mman` switch is provided to allow specification on an instance-by-instance basis of whether a device is being included in mismatch analysis. If yes, then both global and local (instance specific) statistical variation parameters are expected to be generated for each device instance, and the global and local variations are modeled separately. If no, which is appropriate for devices for which local variation is not expected to affect circuit performance, then the global variance for a device is adjusted to be the total variance for that device. This appropriately models the geometry dependent total variance for the device, with the consequence that it makes the total variation completely

correlated between all devices (that are not selected for individual mismatch analysis); this will cause overestimation of the variation of the circuit performances, i.e. the simulations from this will be pessimistic.

If mismatch analysis is selected, then the statistical variations are

$$weff_um = weff_um_{nom} + nsig_w \cdot sig_w + \frac{nsmm_w \cdot smm_w}{\sqrt{m \cdot L}}$$

$$leff_um = leff_um_{nom} + nsig_l \cdot sig_l + \frac{nsmm_l \cdot smm_l}{\sqrt{m \cdot W}}$$

$$rsh = rsh_{nom} \exp \left(0.01 \left(nsig_rsh \cdot sig_rsh + \frac{nsmm_rsh \cdot smm_rsh}{\sqrt{m \cdot WL}} \right) \right)$$

where the nominal values are those defined in the section on geometry dependence. (The above expressions are used to update the effective geometries and resistance values, and all previous model equations actually use the values calculated earlier. However, for clarity of

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presentation and ease of interpretation, the previous equations are not cluttered with the statistical variations).

Note that the variations in effective length and width are absolute, and are additive, and that the variation in sheet resistance is multiplicative. For small variations $\exp(\chi) \approx (1 + \chi)$ hence the r_{sh} variation is relative (it is more natural to think in terms of a % variation than an absolute variation). For large variations, as can be seen in some resistors, statistical sampling can generate very small or negative values of r_{sh} , which are unphysical. Quantities with large variations typically exhibit a log-normal distribution, and the exponential mapping transforms the normally distributed basic statistical parameters into a log-normal distribution for r_{sh} if the variation is large. Note that strictly the unit “%” for the standard deviations of r_{sh} is only for a small variation; if the variation is large then the exponential transformation modifies this.

This approach allows statistical modeling via uncorrelated normal variables, yet can capture log-normal distributions and correlations between parameters, via the dependencies on the fundamental process parameters that control the device behavior. Note that mismatch is modeled via independent perturbations in individual devices, which is physically correct. To simulate mismatch between two devices the mismatch instance parameters for both devices must be selected for statistical perturbation, and this easily extends to more than two devices, and implicitly accounts for geometry differences between different devices. If mismatch is characterized from differential measurements between two identically sized devices, then the measured standard deviations need to be divided by 2 when mapped into the model parameters s_{mm_w} , s_{mm_l} , and s_{mm_rsh} .

If mismatch analysis is not selected, then the total variance is used as the global variance,

$$w_{eff_um} = w_{eff_um_{nom}} + n_{sig_w} \sqrt{sig_w^2 + s_{mm_w}^2} / (m \cdot L)$$

$$l_{eff_um} = l_{eff_um_{nom}} + n_{sig_l} \sqrt{sig_l^2 + s_{mm_l}^2} / (m \cdot W)$$

$$r_{sh} = r_{sh_{nom}} \exp\left(0.01 \cdot n_{sig_rsh} \left(sig_rsh^2 + s_{mm_rsh}^2 / (m \cdot WL) \right)\right).$$

Note that the n_{sig} parameters should be equated to global statistical variables in model files, as they are model parameters, not instance parameters. These parameters then should vary with case/corner and distributional simulations.

Notes on Parameter Extraction

This section provides some information that can help in setting up parameter extraction algorithms. It describes techniques to get initial values that can then be refined by optimization. It does not give a complete and perfect procedure for parameter extraction. As this section does not deal with the details of the model, but how to determine parameters from measured data, V and I have been used in this section only as the voltage across, and current through, the complete resistor (and not just the core resistor body, as is done in previous sections).

Techniques for extraction of basic parameters, such as r_{sh} , x_l , and x_w , some temperature coefficients and their geometric scaling, etc. are provided earlier and are not repeated here. Additional extraction techniques for the core bias dependence are provided here.

The fundamental depletion (p-n junction or MOS) pinching component of the model is given earlier. Velocity saturation and self-heating affect the bias dependence for $E=V_L$ significantly different from zero. Therefore the basic parameters of the model for one geometry, g_f , d_f , and d_p , should come from analysis of data where depletion pinching dominates, i.e. from low V , ideally extrapolated to, or measured (from small-signal AC excitation) at $V=0$. (The large signal conductance $e_g=I/V$ cannot be directly calculated at $V=0$, but is equal to the small signal conductance $g=I/V$ at that bias).

There are at least three approaches to determine the basic depletion pinching parameters, for diffused resistors. If the conductance e_g is known from measurements at three different biases, then the parameters can be calculated as follows. For these biases, ($V_i=V+2V_{1c}$ for the i^{th} values of V and V_{1c})

$$g_i = g_f \left(1 - d_f \sqrt{d_p + V_i} \right)$$

therefore

$$g_i - g_j = g_f d_f \left(\sqrt{d_p + V_j} - \sqrt{d_p + V_i} \right)$$

and manipulating the above equation for two pairs of biases, and forming the difference, gives

$$\frac{\sqrt{d_p + V_2} - \sqrt{d_p + V_1}}{g_1 - g_2} - \frac{\sqrt{d_p + V_3} - \sqrt{d_p + V_1}}{g_1 - g_3} = 0.$$

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Starting with an initial estimate of $\bar{d}_p = 2$, the equation can be solved using Newton-Raphson iteration. Then

$$df = \frac{g_1 - g_3}{g_1 \sqrt{dp + V_3} - g_3 \sqrt{dp + V_1}}$$

and

$$gf = \frac{g_1}{1 - df \sqrt{dp + V_1}}.$$

An alternative is to, assuming that the depletion pinching effect is small, initialize gf to g at the lowest (zero) V_i , set $\bar{d}_p = 2$, and then calculate an initial $\bar{d}f$ at the highest V_i . A 3 dimensional Newton-Raphson iteration can then be used to solve for gf , $\bar{d}f$, and \bar{d}_p at the three V_i values.

A direct solution also exists.

$$\frac{1}{df^2} + \frac{g_i^2}{df^2 gf^2} - \frac{2g_i}{df^2 gf} = dp + V_i$$

and forming the difference between this quantity for two combinations of the selected three bias points gives

$$\begin{bmatrix} g_1^2 - g_2^2 & 2(g_2 - g_1) \\ g_1^2 - g_3^2 & 2(g_3 - g_1) \end{bmatrix} \begin{bmatrix} p_1 \\ p_2 \end{bmatrix} = \begin{bmatrix} V_1 - V_2 \\ V_1 - V_3 \end{bmatrix}$$

where

$$\text{where } p_1 = 1/df^2 gf^2 \text{ and } p_2 = 1/df^2 gf.$$

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These two quantities can be calculated from the V_i and g_i data using the above equation

$$gf = p_2 / p_1 ,$$

$$df = 1 / \sqrt{p_2 gf} ,$$

$$dp = \frac{1}{df^2} + \frac{g_1^2}{df^2 gf^2} - \frac{2g_1}{df^2 gf} - V_i .$$

The nonlinearity from the depletion pinching has the greatest sensitivity to d_p for small V_i , therefore one bias should be at as small a V as possible (zero, if small-signal conductance is being used as opposed to large signal conductance) and $V_{1c}=0$.

Preferably data should be taken for 3 or more V_{1c} values (including zero). If such data are available then the other points used for extraction should be at the smallest V_{ds} and the second lowest V_{1c} , and the smallest V and the highest V_{1c} . If data for only two V_{1c} values (including zero) are available, besides the lowest V and lowest V_{1c} point, use the lowest V_{1c} point with a V higher than the smallest value and both small enough to ensure self-heating and velocity saturation effects are negligible and large enough to be sufficiently different from the lowest V value (so as not to be sensitive to measurement noise), and again as a third bias use the smallest V and the highest V_{1c} point.

For poly resistors, the *pinching* effect is from the depletion region at the bottom of the resistor, and the conductance of a poly resistor is

$$g = \frac{XW}{\rho L} \left(1 - \frac{k_{Si} T_{ox}}{k_{ox} X \sqrt{V_0}} \sqrt{V_0 + 2V_{1c}} \right)$$

where X , W and L are the thickness, width, and length of the polysilicon film that makes up the resistor, k_{Si} and k_{ox} are the relative dielectric permittivities of silicon and silicon dioxide, T_{ox} is the oxide thickness, ρ is the resistivity, and $V_0 = q \epsilon_{Si} N / C_{ox}^2$. This can be seen to have the same general form, which is why the basic depletion pinching bias dependence of the r3 model is also, with appropriate parameters, suitable for modeling poly resistors.

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For typical poly resistors on relatively thick oxides, the V_0 , which can be identified as the several tens or hundreds of volts, compared to the 1-2V value (twice the built-in potential) for d_p resistor. Therefore the resistor conductance is

$$g \approx g_f \left(1 - df \sqrt{d_p} - df V_{1c} / \sqrt{d_p} \right).$$

which, as measured data also shows, has a linear $g(V_{1c})$ dependence. This means that there are only two independent quantities that can be extracted from measured data, the zero-bias value $g_0 = g_f \langle 1 - df \sqrt{d_p} \rangle$ and the slope $s = -(g_f df) / (\sqrt{d_p})$. Yet there are three parameters for the model. Physical quantities are needed to break this indeterminacy.

The value of $V_0 = \sqrt{q \epsilon_{Si} N / C_{ox}^2}$ can be calculated; however because of incomplete dopant activation this can overestimate its value. It is better to calculate it from the poly sheet resistance

$$d_p = \frac{\epsilon_{Si} T_{ox}^2}{\mu_0 X \rho_s \epsilon_{ox}^2}$$

where μ_0 and ρ_s are the low field mobility and sheet resistance of the poly, respectively. Therefore from the slope and zero-bias conductance

$$df = - \frac{s \sqrt{d_p}}{g_0 - s \sqrt{d_p}}$$

Calculating large signal conductance $g = I/V$ for small V can be problematic; V needs to be small enough so that self-heating and velocity saturation effects do not affect the device, but large enough so that g can be calculated reliably. For poly resistors, there is an alternative method to characterize the depletion pinching parameters. If $V_{1c} = 0$, and V is swept from a negative to a positive value (this is not possible for diffused resistors, as the parasitic junction diodes would become forward biased), then the conductance $g(V)$ has a roughly parabolic shape near $V=0$. For poly resistors with negative temperature coefficients of resistance, the conductance increases (from self-heating) as the magnitude of the applied V bias increases (for sufficiently high V the conductance starts to decrease from velocity saturation, leading to a *horned* characteristic in the plot). If the temperature coefficient of resistance is positive, the conductance will decrease as V increases (in roughly the same manner as the effect of velocity saturation, which makes them difficult to distinguish, without including additional data such as the frequency dependence of the output conductance).

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For some magnitude of applied v , of both positive and negative signs, the effects of velocity saturation and self-heating should be the same (with the difference noted below). Therefore the plot of $g(v)$ should, to first order, be symmetric about $v=0$.

However because the v_{2c} bias differs between the positive and negative v cases, the amount of depletion pinching is different, and this introduces a slight asymmetry in the characteristic. (If the currents differ then so will the self-heating, but this should be a second order effect and so is ignored here). Because the effects of velocity saturation and self-heating affect the zero bias conductance and the mobility reduction parts of the model, the ratio of the magnitudes of currents with positive and negative v of equal magnitude cancel these

$$gf = \frac{g_0}{1 - df\sqrt{dp}}.$$

and therefore reveal the effect of depletion pinching. As with the low v bias analysis above, dp can be calculated and then df , or at least in initial value of it for optimization, can be determined from the slope of the ratio in the above equation versus v (once it stabilizes, the ratio tends to be *noisy* for low v).

For poly resistors where self-heating dominates the non-linearity, at low v , the $g(v)$ parabolic shape is primarily determined from mobility reduction due to self-heating, therefore

$$\frac{I_p}{I_m} = \frac{I(+V)}{I(-V)} \Big|_{V_{el}=0} = \frac{1 - df\sqrt{dp+V}}{1 - df\sqrt{dp-V}} \approx 1 - V \frac{df}{\sqrt{dp}}$$

g_{tha} is allowed to be estimated.

One other recommendation is that one basic goal of the model is to model the deviation from linearity (which is important for distortion modeling), and to extract model parameters.

Because of local variation (mismatch), it can be difficult to merge data from different devices for model parameter extraction. Therefore extraction from individual devices can be beneficial. Modeling the deviation from linearity for individual devices does both of these.

Reference

Component Statements

Instance Parameters

- | | | |
|----|-------------------------|--|
| 1 | exp_cr=(80.0) | instance parameter. |
| 2 | cmi_limexp_method=(1.0) | instance parameter. |
| 3 | cmi_compactable=(1.0) | instance parameter. |
| 4 | m=(1.0) | instance parameter. |
| 5 | w=(1.0e-06) | design width of resistor body. |
| 6 | l=(1.0e-06) | design length of resistor body. |
| 7 | wd=(0.0) | dogbone width (total; not per side). |
| 8 | a1=(0.0) | area of node n1 partition. |
| 9 | p1=(0.0) | perimeter of node n1 partition. |
| 10 | c1=(0) | # contacts at node n1 terminal . |
| 11 | a2=(0.0) | area of node n2 partition . |
| 12 | p2=(0.0) | perimeter of node n2 partition . |
| 13 | c2=(0) | # contacts at node n2 terminal . |
| 14 | trise=(0.0) | local temperature delta to ambient (before self-heating) . |
| 15 | dta=(0.0) | alias of trise . |
| 16 | dtemp=(0.0) | alias of trise . |
| 17 | sw_noise=(1) | switch for including noise: 0=no and 1=yes . |

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18	sw_et=(1)	switch for self-heating: 0=no and 1=yes .
19	sw_mman=(0)	switch for mismatch analysis: 0=no and 1=yes .
20	nsmm_rsh=(0.0)	number of standard deviations of local variation for rsh.
21	nsmm_w=(0.0)	number of standard deviations of local variation for w.
22	nsmm_l=(0.0)	number of standard deviations of local variation for l.

Model Parameters

1	version=(1)	model parameter: model version.
2	subversion=(0)	model parameter: model subversion.
3	revision=(0)	model parameter: model revision.
4	level=(1003)	model parameter: model level.
5	type=((-1))	model parameter: resistor type: -1=n-body and +1=p-body.
6	scale=(1.0)	model parameter: scale factor for instance geometries.
7	shrink=(0.0)	model parameter: shrink percentage for instance geometries.
8	tmin=((-100.0))	model parameter: minimum ambient temperature.
9	tmax=(500.0)	model parameter: maximum ambient temperature.
10	rthresh=(1.0e-03)	model parameter: threshold to switch end resistance to $V=I \cdot R$ form.
11	gmin=(1.0e-12)	model parameter: minimum conductance.
12	imax=(1.0)	model parameter: current at which to linearize diode currents.
13	tnom=(27.0)	model parameter: nominal (reference) temperature.
14	lmin=(0.0)	model parameter: minimum allowed drawn length.
15	lmax=(9.9e09)	model parameter: maximum allowed drawn length.

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16	wmin=(0.0)	model parameter: minimum allowed drawn width.
17	wmax=(9.9e09)	model parameter: maximum allowed drawn width.
18	jmax=(100.0)	model parameter: maximum current density.
19	vmax=(9.9e09)	model parameter: maximum voltage w.r.t. control node nc.
20	tminclip=(-100.0)	model parameter: clip minimum temperature.
21	tmaxclip=(500.0)	model parameter: clip maximum temperature.
22	rsh=(100.0)	model parameter: sheet resistance.
23	xw=(0.0)	model parameter: width offset (total).
24	nwxw=(0.0)	model parameter: narrow width width offset correction coefficient.
25	wexw=(0.0)	model parameter: webbing effect width offset correction coefficient (for dogboned devices).
26	fdrw=(1.0)	model parameter: finite doping width offset reference width.
27	fdxwinf=(0.0)	model parameter: finite doping width offset width value for wide devices.
28	xl=(0.0)	model parameter: length offset (total).
29	xlw=(0.0)	model parameter: width dependence of length offset.
30	dxlsat=(0.0)	model parameter: additional length offset for velocity saturation calculation.
31	nst=(1.0)	model parameter: subthreshold slope parameter.
32	ats=(0.0)	model parameter: saturation smoothing parameter.
33	dfinf=(0.01)	model parameter: depletion factor for wide/long device.
34	dfw=(0.0)	model parameter: depletion factor 1/w coefficient.

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35	dfi=(0.0)	model parameter: depletion factor 1/l coefficient.
36	dfwl=(0.0)	model parameter: depletion factor 1/(w*l) coefficient.
37	sw_dfgeo=(1)	model parameter: switch for depletion factor geometry dependence: 0=drawn and 1=effective.
38	dp=(2.0)	model parameter: depletion potential.
39	ecrit=(4.0)	model parameter: velocity saturation critical field.
40	ecorn=(0.4)	model parameter: velocity saturation corner field.
41	du=(0.02)	model parameter: mobility reduction at ecorn.
42	rc=(0.0)	model parameter: resistance per contact.
43	rcw=(0.0)	model parameter: width adjustment for contact resistance.
44	fc=(0.9)	model parameter: depletion capacitance linearization factor.
45	isa=(0.0)	model parameter: diode saturation current per unit area.
46	na=(1.0)	model parameter: ideality factor for isa.
47	ca=(0.0)	model parameter: fixed capacitance per unit area.
48	cja=(0.0)	model parameter: depletion capacitance per unit area.
49	pa=(0.75)	model parameter: built-in potential for cja.
50	ma=(0.33)	model parameter: grading coefficient for cja.
51	aja=((-0.5))	model parameter: smoothing parameter for cja.
52	isp=(0.0)	model parameter: diode saturation current per unit perimeter.
53	np=(1.0)	model parameter: ideality factor for isp.
54	cp=(0.0)	model parameter: fixed capacitance per unit perimeter.
55	cjp=(0.0)	model parameter: depletion capacitance per unit perimeter.

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56	pp=(0.75)	model parameter: built-in potential for cjp.
57	mp=(0.33)	model parameter: grading coefficient for cjp.
58	ajp=(-0.5)	model parameter: smoothing parameter for cjp.
59	vbv=(0.0)	model parameter: breakdown voltage.
60	ibv=(1.0e-06)	model parameter: current at breakdown.
61	nbv=(1.0)	model parameter: ideality factor for breakdown current.
62	kfn=(0.0)	model parameter: flicker noise coefficient (unit depends on afn).
63	afn=(2.0)	model parameter: flicker noise current exponent.
64	bfm=(1.0)	model parameter: flicker noise 1/f exponent.
65	sw_fngco=(0)	model parameter: switch for flicker noise geometry calculation: 0=drawn and 1=effective.
66	ea=(1.12)	model parameter: activation voltage for diode temperature dependence.
67	xis=(3.0)	model parameter: exponent for diode temperature dependence.
68	tc1=(0.0)	model parameter: resistance linear TC.
69	tc2=(0.0)	model parameter: resistance quadratic TC.
70	tc1l=(0.0)	model parameter: resistance linear TC length coefficient.
71	tc2l=(0.0)	model parameter: resistance quadratic TC length coefficient.
72	tc1w=(0.0)	model parameter: resistance linear TC width coefficient.
73	tc2w=(0.0)	model parameter: resistance quadratic TC width coefficient.
74	tc1rc=(0.0)	model parameter: contact resistance linear TC.
75	tc2rc=(0.0)	model parameter: contact resistance quadratic TC.
76	tc1kfn=(0.0)	model parameter: flicker noise coefficient linear TC.

Virtuoso Simulator Components and Device Models Reference

Three-Terminal Nonlinear (Diffused and Poly-Silicon) Resistor Model and JFET Model (r3)

77	tc1vbw=(0.0)	model parameter: breakdown voltage linear TC.
78	tc2vbw=(0.0)	model parameter: breakdown voltage quadratic TC.
79	tc1nbw=(0.0)	model parameter: breakdown ideality factor linear TC.
80	gth0=(1.0e+06)	model parameter: thermal conductance fixed component.
81	gthp=(0.0)	model parameter: thermal conductance perimeter component.
82	gtha=(0.0)	model parameter: thermal conductance area component.
83	gthc=(0.0)	model parameter: thermal conductance contact component.
84	cth0=(0.0)	model parameter: thermal capacitance fixed component.
85	cthp=(0.0)	model parameter: thermal capacitance perimeter component.
86	ctha=(0.0)	model parameter: thermal capacitance area component.
87	cthc=(0.0)	model parameter: thermal capacitance contact component.
88	nsig_rsh=(0.0)	model parameter: number of standard deviations of global variation for rsh.
89	nsig_w=(0.0)	model parameter: number of standard deviations of global variation for w.
90	nsig_l=(0.0)	model parameter: number of standard deviations of global variation for l.
91	sig_rsh=(0.0)	model parameter: global variation standard deviation for rsh (relative).
92	sig_w=(0.0)	model parameter: global variation standard deviation for w (absolute).
93	sig_l=(0.0)	model parameter: global variation standard deviation for l (absolute).
94	smm_rsh=(0.0)	model parameter: local variation standard deviation for rsh (relative).

Virtuoso Simulator Components and Device Models Reference

Three-Terminal Nonlinear (Diffused and Poly-Silicon) Resistor Model and JFET Model (r3)

95	smm_w=(0.0)	model parameter: local variation standard deviation for w (absolute).
96	smm_l=(0.0)	model parameter: local variation standard deviation for l (absolute).
97	sw_mmgeo=(0)	model parameter: switch for flicker noise geometry calculation: 0=drawn and 1=effective.
98	mr=(0.0)	model parameter: resistor mismatch dependence.
99	mrl=(0.0)	model parameter: resistor mismatch length dependence.
100	mrlp=(0.0)	model parameter: resistor mismatch length power dependence.
101	mrw=(0.0)	model parameter: resistor mismatch width dependence.
102	mrwp=(0.0)	model parameter: resistor mismatch width power dependence.
103	mrlw1=(0.0)	model parameter: resistor mismatch area 1 dependence.
104	mrlw1p=(0.0)	model parameter: resistor mismatch area 1 power dependence.
105	mrlw2=(0.0)	model parameter: resistor mismatch area 2 dependence.
106	mrlw2p=(0.0)	model parameter: resistor mismatch area 2 power dependence.

Output Parameters

1	n1	node: external node.
2	nc	node: external node.
3	n2	node: external node.
4	i1	node: internal node.
5	i2	node: internal node.
6	dt	node: self-heating node.

Operating Point Parameters

1	exp_cr=(80.0)	i	instance parameter.
2	cmi_limexp_method=(1.0)		instance parameter.
3	cmi_compactable=(1.0)		instance parameter.
4	m=(1.0)		instance parameter.
5	w=(1.0e-06)		design width of resistor body.
6	l=(1.0e-06)		design length of resistor body.
7	wd=(0.0)		dogbone width (total; not per side).
8	a1=(0.0)		area of node n1 partition.
9	p1=(0.0)		perimeter of node n1 partition.
10	c1=(0)		# contacts at node n1 terminal .
11	a2=(0.0)		area of node n2 partition .
12	p2=(0.0)		perimeter of node n2 partition .
13	c2=(0)		# contacts at node n2 terminal .
14	trise=(0.0)		local temperature delta to ambient (before self-heating) .
15	sw_noise=(1)		switch for including noise: 0=no and 1=yes .
16	sw_et=(1)		switch for self-heating: 0=no and 1=yes .
17	sw_mman=(0)		switch for mismatch analysis: 0=no and 1=yes .
18	nsmm_rsh=(0.0)		number of standard deviations of local variation for rsh.
19	nsmm_w=(0.0)		number of standard deviations of local variation for w.
20	nsmm_l=(0.0)		number of standard deviations of local variation for l.

Virtuoso Simulator Components and Device Models Reference

Three-Terminal Nonlinear (Diffused and Poly-Silicon) Resistor Model and JFET Model (r3)

21	v	voltage across resistor.
22	ibody	current through resistor body.
23	power	dissipated power .
24	leff_um	effective electrical length in um .
25	weff_um	effective electrical width in um .
26	r0	zero-bias resistance (per segment).
27	r_dc	DC resistance (including bias dependence and m).
28	r_ac	AC resistance (including bias dependence and m).
29	rth	thermal resistance.
30	cth	thermal capacitance.
31	dt_et	self-heating temperature rise.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

a1	I-8	fc	M-44	nsig_l	M-90	sw_mmgeo	M-97
a1	OP-8	fdrw	M-26	nsig_rsh	M-88	sw_noise	I-17
a2	I-11	fdxwinf	M-27	nsig_w	M-89	sw_noise	OP-15
a2	OP-11	gmin	M-11	nsmm_l	I-22	tc1	M-68
afn	M-63	gth0	M-80	nsmm_l	OP-20	tc1kfn	M-76

Virtuoso Simulator Components and Device Models Reference

Three-Terminal Nonlinear (Diffused and Poly-Silicon) Resistor Model and JFET Model (r3)

aja	M-51	gtha	M-82	nsmm_rsh	I-20	tc1l	M-70
ajp	M-58	gthc	M-83	nsmm_rsh	OP-18	tc1nbv	M-79
ats	M-32	gthp	M-81	nsmm_w	I-21	tc1rc	M-74
bfm	M-64	i1	O-4	nsmm_w	OP-19	tc1vbv	M-77
c1	I-10	i2	O-5	nst	M-31	tc1w	M-72
c1	OP-10	ibody	OP-22	nwxw	M-24	tc2	M-69
c2	I-13	ibv	M-60	p1	I-9	tc2l	M-71
c2	OP-13	imax	M-12	p1	OP-9	tc2rc	M-75
ca	M-47	isa	M-45	p2	I-12	tc2vbv	M-78
cja	M-48	isp	M-52	p2	OP-12	tc2w	M-73
cjp	M-55	jmax	M-18	pa	M-49	tmax	M-9
cmi_compactable I-3		kfn	M-62	power	OP-23	tmaxclip	M-21
cmi_compactable OP-3		l	I-6	pp	M-56	tmin	M-8
cmi_limexp_method I-2		l	OP-6	r0	OP-26	tminclip	M-20
cmi_limexp_method OP-2		leff_um	OP-24	r_ac	OP-28	tnom	M-13
cp	M-54	level	M-4	r_dc	OP-27	trise	I-14
cth	OP-30	lmax	M-15	rc	M-42	trise	OP-14
cth0	M-84	lmin	M-14	rcw	M-43	type	M-5
ctha	M-86	m	I-4	revision	M-3	v	OP-21

Virtuoso Simulator Components and Device Models Reference

Three-Terminal Nonlinear (Diffused and Poly-Silicon) Resistor Model and JFET Model (r3)

cthc	M-87	m	OP-4	rsh	M-22	vbv	M-59
cthp	M-85	ma	M-50	rth	OP-29	version	M-1
dfinf	M-33	mp	M-57	rthresh	M-10	vmax	M-19
df1	M-35	mr	M-98	scale	M-6	w	I-5
dfw	M-34	mrl	M-99	shrink	M-7	w	OP-5
dfwl	M-36	mrlp	M-100	sig_l	M-93	wd	I-7
dp	M-38	mrlw1	M-103	sig_rsh	M-91	wd	OP-7
dt	O-6	mrlw1p	M-104	sig_w	M-92	weff_um	OP-25
dt_et	OP-31	mrlw2	M-105	smm_l	M-96	wexw	M-25
dta	I-15	mrlw2p	M-106	smm_rsh	M-94	wmax	M-17
dtemp	I-16	mrw	M-101	smm_w	M-95	wmin	M-16
du	M-41	mrwp	M-102	subversion	M-2	xis	M-67
dxlsat	M-30	n1	O-1	sw_dfgeo	M-37	xl	M-28
ea	M-66	n2	O-3	sw_et	I-18	xlw	M-29
ecorn	M-40	na	M-46	sw_et	OP-16	xw	M-23
ecrit	M-39	nbv	M-61	sw_fngeo	M-65		
exp_cr	I-1	nc	O-2	sw_mman	I-19		
exp_cr	OP-1	np	M-53	sw_mman	OP-17		

IGBT0 Model (igbt0)

The IGBT0 (Insulated Gate Bipolar Transistor Level 0) model is a simplified IGBT model that is compatible with Cadence PSpice IGBT model. IGBT0 model was introduced to model the application of high voltage and current. The voltage can be up to several thousand volts and the current up to several hundred amperes.

This chapter contains the following information:

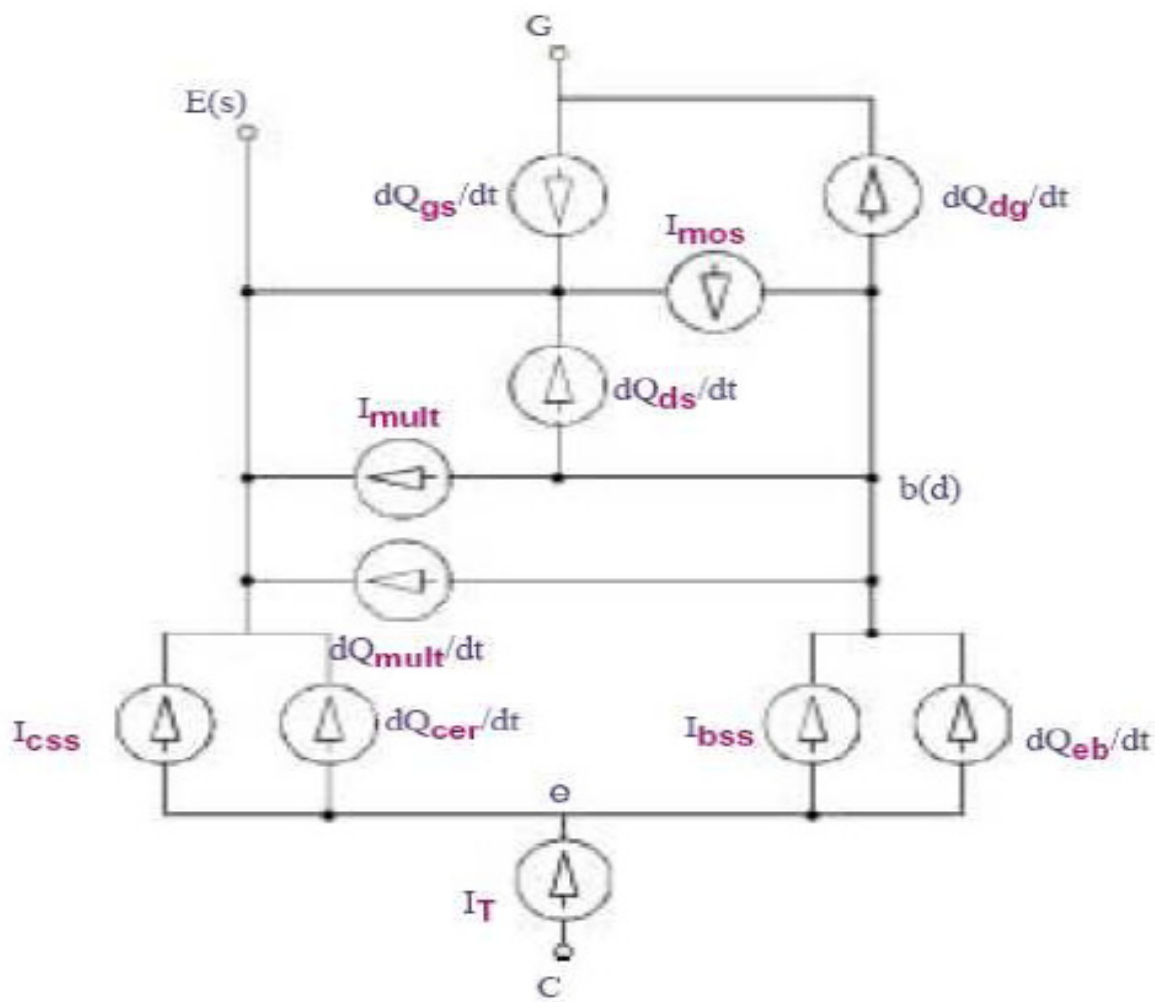
- [Model Concepts](#) on page 2758
- [Component Statements](#) on page 2759
 - [Instance Syntax](#) on page 2759
 - [Model Syntax](#) on page 2759
- [Reference](#) on page 2760
 - [Model Equations](#) on page 2760
 - [Instance Parameters](#) on page 2762
 - [Model Parameters](#) on page 2763
 - [Operating Point Parameters](#) on page 2764
 - [Parameter Index](#) on page 2765

Model Concepts

The equivalent circuit for the IGBT is shown in [Figure 41-1](#) on page 2758. It is modeled as a thick base BJT driven by MOSFET. Five DC current components and six charge (capacitive) components are included in the model. For the meaning of specific component, please refer to the Model Equation part of the model.

As the simplified IGBT model, only the basic characteristics are modeled by IGBT0 model. Combining BJT with MOSFET, p_type IGBT0 devices are hard to modeling and seldom used. Only N-type devices are supported. Different with MOSFET, there's only the leakage current exist when the devices are reversed ($V_c < V_e$)

Figure 41-1 The equivalent circuit for IGBT0



Component Statements

Instance Syntax

IGBT0 instance need specify 3 terminals and the number cannot be changed any more. To specify IGBT0 instance element, the Model Name has to be associated with a IGBT0 model card.

```
InstanceName c g e ModelName parameter=value ...
```

Sample Instance Statement

```
m1 (vcc vgg vee) n_ch area=0.1u kp=0.21 tau=1e-7 agd=1e-8
```

For more instance parameters, refer to [Reference](#) on page 2760.

Model Syntax

The following syntax specifies IGBT0 model:

```
model ModelName igbt0 parameter=value ...
```

The third parameter, "igbt0", is the master to indicate this model card is a IGBT0 model card.

Sample Model Statement

```
model n_ch igbt0 vt=4.5 mun=1.7e3 mup=5e2 cgs=1e-10 nb=3e14 jsne=1e-13
```

For more model parameters, refer to [Reference](#) on page 2760.

Reference

Model Equations

Some important model equations are listed as following for your reference:

Equations for DC current

MOSFET channel current

$$I_{ch} = \begin{cases} 0 & \text{For } V_{gs} < V_T \\ \frac{KF \cdot KP \cdot \left((V_{gs} - V_T) \cdot V_{ds} - \frac{KF \cdot V_{ds}^2}{2} \right)}{1 + THETA \cdot (V_{gs} - V_T)} & \text{For } V_{ds} \leq (V_{gs} - V_T) \\ \frac{KP \cdot (V_{gs} - V_T)^2}{2 \cdot (1 + THETA \cdot (V_{gs} - V_T))} & \text{For } V_{ds} > (V_{gs} - V_T) \end{cases}$$

Anode current: current through the resistor Rb

$$I_T = \frac{V_{Ce}}{R_b}$$

Steady-state collector current

$$I_{css} = \begin{cases} 0 & \text{For } V_{eb} \leq 0 \\ \left(\frac{1}{1+b} \right) \cdot I_T + \left(\frac{b}{1+b} \right) \cdot \left(\frac{4 \cdot D_p}{W^2} \right) \cdot Q_{eb} & \text{For } V_{eb} > 0 \end{cases}$$

Steady-state base current

$$I_{bss} = \begin{cases} 0 & \text{For } V_{eb} \leq 0 \\ \frac{Q_{eb}}{\text{TAU}} + \left(\frac{Q_{eb}^2}{Q_B}\right) \cdot \left(\frac{4 \cdot \text{NB}^2}{n_i^2}\right) \cdot (\text{JSNE} \cdot \text{AREA}) & \text{For } V_{eb} > 0 \end{cases}$$

Avalanche multiplication current

$$I_{mult} = (M - 1) \cdot (I_{mos} + I_{css}) + M \cdot I_{gen}$$

Equations for capacitance and charge

Gate Source

$$C_{gs} = \text{CGS} \quad Q_{gs} = \text{CGS} \cdot V_{gs}$$

Drain Source

$$C_{ds} = \frac{(\text{AREA} - \text{AGD}) \cdot \epsilon_{si}}{W_{dsj}} \quad Q_{ds} = q \cdot (\text{AREA} - \text{AGD}) \cdot \text{NB} \cdot W_{dsj}$$

Where

$$W_{dsj} = \sqrt{\frac{2 \cdot \epsilon_{si} \cdot (V_{ds} + 0.6)}{q \cdot \text{NB}}}$$

Gate Drain

For $V_{ds} < V_{gs} - V_{TD}$

$$C_{dg} = COXD \qquad Q_{dg} = COXD \cdot V_{dg}$$

For $V_{ds} \geq V_{gs} - V_{TD}$

$$C_{dg} = \frac{C_{dgj} \cdot COXD}{C_{dgj} + COXD}$$

$$Q_{dg} = \frac{q \cdot NB \cdot \epsilon_{si} \cdot AGD^2}{COXD} \left(\frac{COXD \cdot W_{dgj}}{\epsilon_{si} \cdot AGD} - \log \left(1 + \frac{COXD \cdot W_{dgj}}{\epsilon_{si} \cdot AGD} \right) \right) - COXD \cdot V_{TD}$$

where

$$C_{dgj} = \frac{AGD \cdot \epsilon_{si}}{W_{dgj}}$$

$$W_{dgj} = \sqrt{\frac{2 \cdot \epsilon_{si} \cdot (V_{dg} + V_{TD})}{q \cdot NB}}$$

Instance Parameters

1	area (m ²)	Area of the device.
2	wb (m)	Metallurgical base width.
3	tau (s)	Ambipolar recombination lifetime.
4	agd (m ²)	Gate-drain overlap area.
5	kp (A/V ²)	MOS transconductance.
6	trise (C)	Device temperature increased.

Virtuoso Simulator Components and Device Models Reference

IGBT0 Model (igbt0)

Model Parameters

Default for instance parameters

- | | | |
|---|----------------------------|---|
| 1 | area=1.0e-5 m ² | Default area of the device. |
| 2 | wb=9.0e-5 m | Default metallurgical base width. |
| 3 | tau=7.1e-6 s | Default ambipolar recombination lifetime. |
| 4 | agd=5.0e-6 m ² | Default gate-drain overlap area. |
| 5 | kp=0.38 A/V ² | Default MOS transconductance. |

Basic Device Parameters

- | | | |
|----|-----------------------------------|-------------------------------------|
| 6 | vt=4.7 V | Threshold voltage. |
| 7 | kf=1.0 | Triode region factor. |
| 8 | theta=0.02 1/V | Transverse field factor. |
| 9 | nb=2.0e14 cm ⁻³ | Base doping. |
| 10 | mun=1.5e3 cm ² /(V*s) | Electron mobility. |
| 11 | mup=4.5e2 cm ² /(V*s) | Hole mobility. |
| 12 | jsne=6.5e-13 A/(cm ²) | Emitter saturation current density. |
| 13 | bvn=4.0 | Avalanche multiplication exponent. |
| 14 | bvf=1.0 | Avalanche uniformity exponent. |
| 15 | cgs=1.24e-8 F/(cm ²) | |

Virtuoso Simulator Components and Device Models Reference

IGBT0 Model (igbt0)

Gate-source capacitance per unit area.

16 $\text{cox}d=3.5e-8 \text{ F}/(\text{cm}^2)$

Gate-drain oxide capacitance per unit area.

17 $\text{vtd}=1.0e-3 \text{ V}$

Gate-drain overlap depletion threshold.

Operating Point Parameters

1	ice (A)	Collector-emitter current.
2	vce (V)	Collector-emitter voltage.
3	vds (V)	Internal Vds of mosfet.
4	vge (V)	Gate-emitter voltage.
5	vdsat (V)	Drain-source saturation voltage.
6	gm (S)	Common-source transconductance.
7	ic_bjt (A)	Resistive collector current.
8	ie (A)	Resistive emitter current.
9	imult (A)	Avalanche multiplication current.
10	ib_bjt (A)	Steady-state base current.
11	imos (A)	MOSFET channel current.
12	cge (F)	dQg_dVe .
13	cgg (F)	dQg_dVg .
14	pwr (W)	Power at operating point.
15	cdg (F)	dQd_dVg .
16	cds (F)	dQd_dVs .
17	qgs (Coul)	Qgs for mosfet.

Virtuoso Simulator Components and Device Models Reference

IGBT0 Model (igbt0)

18	qds (Coul)	Qds for mosfet.
19	qdg (Coul)	Qdg for mosfet.
20	qeb (Coul)	Qeb for bjt.

Parameter Index

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

agd	I-4	cmult	OP-18	kp	M-5	tau	M-3
agd	M-4	coxd	M-16	mun	M-10	theta	M-8
area	I-1	gm	OP-7	mup	M-11	trise	I-6
area	M-1	ib_bjt	OP-11	nb	M-9	vce	OP-2
bvf	M-14	ic_bjt	OP-8	pwr	OP-15	vds	OP-4
bvn	M-13	ice	OP-1	qcer	OP-24	vdsat	OP-6
ccer	OP-14	ie	OP-9	qdg	OP-22	veb	OP-3
cdg	OP-16	imos	OP-12	qds	OP-21	vge	OP-5
cds	OP-17	imult	OP-10	qeb	OP-23	vt	M-6
ceb	OP-19	jsne	M-12	qgs	OP-20	vtd	M-17
cge	OP-13	kf	M-7	qmult	OP-25	wb	I-2
cgs	M-15	kp	I-5	tau	I-3	wb	M-2

Virtuoso Simulator Components and Device Models Reference

IGBT0 Model (igbt0)

Laterally Double Diffused Metal Oxide Semiconductor FET Model (LDMOS)

The LDMOS is a high voltage MOS device with a non-uniform channel doping profile. It was developed by Cadence Design Systems, Inc. This chapter covers the following information about the LDMOS model:

- [DC Model](#) on page 2768
- [CV Model](#) on page 2768
- [Equivalent Circuit](#) on page 2768
- [Model Features](#) on page 2769
- [Parameter Descriptions](#) on page 2771

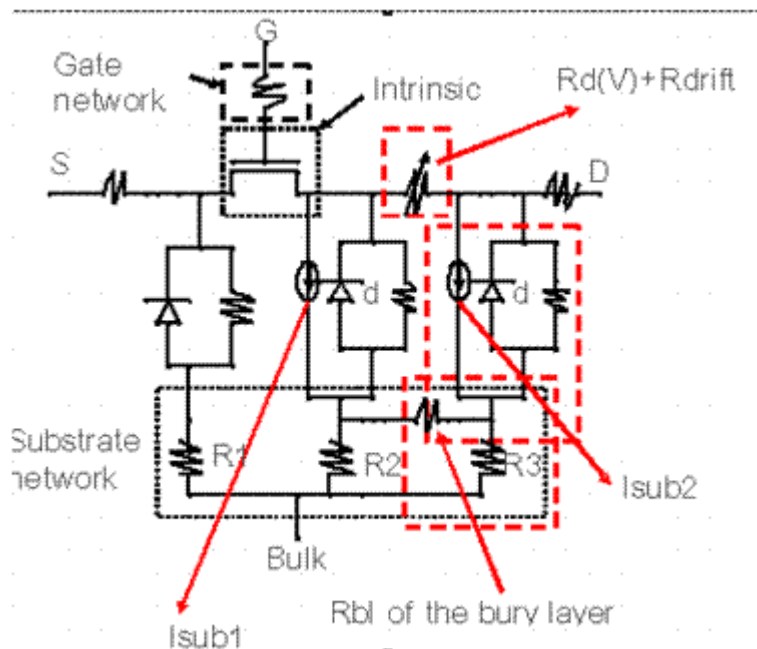
DC Model

The LDMOS DC model covers the pinch-off phenomenon and includes the self-heating effect. Its drain current rises when the value of V_{gs} increases.

CV Model

The LDMOS CV model is based on charge conservation. It includes gate and substrate network for RF modeling.

Equivalent Circuit

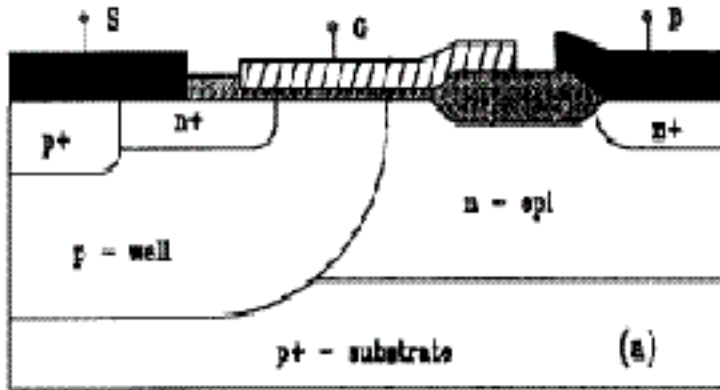


- The intrinsic transistor is the same as BSIM3.

Virtuoso Simulator Components and Device Models Reference

Laterally Double Diffused Metal Oxide Semiconductor FET Model (LDMOS)

- The LDMOS model consists of three diodes – source body junction diode, drain-body junction diode, and drain-substrate junction diode. The following shows a cross-section of a conventional diode:



- Different I_{sub} s are used for the Kirk effect (peak electric field shift with the drain current). I_{sub1} is for small drain current and I_{sub2} is for high drain current.
- The RF network (gate and substrate) is used for high frequency applications and is ignored for base band applications.

Model Features

The LDMOS model includes an accurate description of all physical effects important for LDMOS devices.

- Bias dependent drift region resistance modeling

LDMOS shows a significant quasi-saturation effect for the drain currents at high V_{gs} biases. This is caused by the bias-dependent drift region resistance, which is important for both current and capacitance modeling. In high I_{ds} region carrier, drift velocity may saturate and the effective conducting area changes as a result of the depletion width change controlled by the drain-to-substrate bias. In the model, the drift region resistance mainly depends on V_{gs} and V_{ds} .

- Overlap region resistance modeling

Gate-to-drain overlap region is under accumulation when device is turned on. The resistance in this region is modulated by the gate bias due to field dependent mobility and conduction width modulation from the junction depletion layer. The R_{dv} model used in LDMOS model is adopted from the BSIM4 model.

- Substrate current modeling with double-peak I_{sub}

Virtuoso Simulator Components and Device Models Reference

Laterally Double Diffused Metal Oxide Semiconductor FET Model (LDMOS)

Lateral electric field peak positions depend on the gate bias, resulting in different substrate current components at different biases and different positions. Two I_{sub} components are introduced to account for such effect.

■ Multiple junction effect

Two diodes between the drain and body are introduced for accurately modeling the drain leakage current and dynamic behavior of the device. In addition, one diode between the body and source is introduced.

■ Gate/substrate resistance network for RF modeling

LDMOS is widely used in RF power amplifier, and the gate/substrate resistor networks are used for accurately modeling high frequency behavior of the device.

■ Model scalability for both temperature and geometry

The scalabilities of the drift region length and device width are emphasized in this model for accurate DC and AC modeling. The model also considers the scalability for other geometry parameters, including the overlap region length and width and the channel length.

All parameter temperature dependences are the same as that in BSIM3, except the drift region resistor R_{drift} and the overlap region resistor $R_d(V)$. $R_d(V)$ is temperature independent while R_{drift} is temperature dependent.

■ Self-heating effect

Self-heating effect is significant in LDMOS devices and can be modeled by a thermal network. Self-heating function is implemented in LDMOS by adding a temperature node to the model as an inner node. The internal self-heating network can be turned on by switching the flag `shmod` from the default value 0 to 1.

■ Overlap capacitance model

In some technologies, LDMOS devices have much larger overlap region than channel region. In such devices, overlap capacitance dominates device CV behavior. Overlap region is working in accumulation region when device is on, and in depletion region and possibly inversion region when device is off. Overlap region charges are function of gate, body, internal drain and external drain voltage.

■ Non uniform lateral doping in the channel

The appearance of the non-uniform doping in the channel is due to the fact that the channel is formed by a lateral diffusion. As a result, threshold voltage is a function of position in the channel, the inversion charge density along the channel is not uniform even at $V_{ds}=0$, and the drain side channel gets inverted before the source side. In order

Virtuoso Simulator Components and Device Models Reference
Laterally Double Diffused Metal Oxide Semiconductor FET Model (LDMOS)

to describe LDMOS in a more accurate way, it's therefore necessary to adopt the non uniform doping channel model.

Parameter Descriptions

Table 42-1 Instance Parameters

Parameter Name	Description	Default Value	Unit
W	Channel width	5e-6	m
L	Channel length	5e-6	m
As	Area of source diffusion	0	m ²
Ad	Area of DRAIN diffusion	0	m ²
Ps	Perimeter of source diffusion	0	m
Pd	Perimeter of drain diffusion	0	m
Nrs	Number of squares of source diffusion	0	
Nrd	Number of squares of drain diffusion	0	
Trise	Temperature rise from ambient	0	
M	Multiplicity factor (number of MOSFETs in parallel)	1	
Rth0	Thermal resistance per unit width	0	
Cth0	Thermal capacitance per unit width	1e-5	
Ae	Area of external diffusion	0	m ²
Pe	Perimeter of external diffusion	0	m
Nseg	Number of segments for channel width partitioning	1	
Rdc	Drain contact resistance	0	Ω
Rsc	Source contact resistance	0	Ω

Virtuoso Simulator Components and Device Models Reference
Laterally Double Diffused Metal Oxide Semiconductor FET Model (LDMOS)

Parameter Name	Description	Default Value	Unit
Lov	Overlap region length	0.1e-6	m
Wov	Overlap region width		m
Ldrift	Drift region length	3e-6	m

Table 42-2 Model Selectors/Controllers

Parameter Name	Description	Default Value	Unit
ABULK0FLG	Specifies whether ABULK0 is bias dependent	1	
APWARN	When APWARN is greater than 0, it turns off the warning message for P_s , $P_d < W_{eff}$	0	
BINFLAG	If BINFLAG > 0.9, WREF and LREF are used for binning	0	
BINUNIT	Binning unit selector	1	NA
CALCHARGE	Specifies whether to calculate charge	1	
CALDDC	Calculates Diode IV	1	
CALMOSDC	Specifies whether to calculate MOSFET current	1	
CALNQS	Specifies whether to calculate NQS	0	
CAPMOD	Capacitance model selector (LDMOS uses CAPMOD=2 only)	2	
DEBUG	Specifies whether debug is on.		
DEFAD	Default area of drain diffusion	0	m ²
DEFAS	Default area of source diffusion	0	m ²
DEFPD	Default perimeter of drain diffusion	0	m

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Laterally Double Diffused Metal Oxide Semiconductor FET Model (LDMOS)

Parameter Name	Description	Default Value	Unit
DEFPS	Default perimeter of source diffusion	0	m
DIGITALMOD	Digital flag	0	
ERRMSG	Set to 1 to retrieve errors and warnings caused by UltraSim functions	0	
EXTRDS	Specifies whether to use external resistance	1	
GMIN	PN junction parallel transient conductance	1.00E-12	
ISDISPLAY	Set to 1 to perform additional converting calculations		
LEVEL	Model selector	99	
MOBMOD	Mobility model selector	1	
NLEV	NLEV noise model		
NOIMOD	Noise model selector	1	
NQSMOD	NQS model selector	0	
PARAMCHK	Switch for parameter value check	0	
RBODYMOD	Substrate network selector	0	
RDRIFTMOD	Drift region resistor selector	0	
SFVTFLAG	Spline function for VTH	0	
SHAREPARAS	Parameter sharing By UltraSim	2	
SHMOD	Self heating flag		
SIMULATOR	Compatible simulator (such as Spectre and HSPICE)	1	
TYPE	Channel type of MOSFET (nmos or pmos)	1	
VERSION	Model version number	1	
VFBFLAG	VFB selector for CAPMOD = 0	0	

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Laterally Double Diffused Metal Oxide Semiconductor FET Model (LDMOS)

Parameter Name	Description	Default Value	Unit
XPART	S/D partition	0	

Table 42-3 Process Parameters

Parameter Name	Description	Default Value	Unit
DLC	Length offset fitting parameter from CV	LINT	
DWC	Width offset fitting parameter from C-V	WINT	
HDIF	Length of heavily doped diffusion from contact to lightly doped region, acm=2, 3 only	0	
HDIF2	Length of drain-substrate junction, acm=2,3 only	0	
LD	Lateral diffusion into channel from source and drain diffusion	0	
LDIF	Length of lightly doped diffusion adjacent to gate acm12	0	
LINT	Length offset	0	
LMLT	diffusion layer length shrinking factor		
NI	Intrinsic carrier concentration	1.45E+10	cm ³
SETDEFAULT	Set model parameters to their default values (used by BSIMProPlus only).	0	
TNOM	Temperature at which parameters are extracted	25c=	c
TOX	Oxide thickness	1.50E-08	m
TOXM	Tox at which parameters are extracted	TOX	

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Laterally Double Diffused Metal Oxide Semiconductor FET Model (LDMOS)

Parameter Name	Description	Default Value	Unit
WINT	Width offset	0	
WMLT	Diffusion layer width shrinking factor	1	
XL	Length offset for masking and etching effects	0	
XW	Width offset for masking and etching effects	0	

Table 42-4 Noise Model Parameters

Parameter Name	Description	Default Value	Unit
AF	Flicker noise exponent	1	
EF	Flicker noise frequency exponent	1	
EM	Saturation electric field	4.10E+07	V/m
KF	Flicker noise coefficient	0	
NOIA	Noise parameter A	1.00E+20	
NOIB	Noise parameter B	5.00E+04	
NOIC	Noise parameter C	-1.40E-12	

Table 42-5 Junction Diode Parameters

Parameter Name	Description	Default Value	Unit
ACM		12	
CBD	Zero bias bulk-drain junction capacitance used only when CJ and CJSW=0		

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Parameter Name	Description	Default Value	Unit
CBDE	Zero bias bulk-ext-drain junction capacitance used only when CJ and CJSW=0		
CBS	Zero bias bulk-source junction saturation current used only when CJ and CJSW=0		
CJGATE	Zero bias gate edge sidewall bulk junction capacitance		
CJ	Bottom junction capacitance per unit area at zero bias	5.00E-04	f/m ²
CJSW	Source/drain side wall junction capacitance per unit area	5.00E-10	f/m
CJSWG	Source/drain gate side wall junction capacitance per unit area		
EG	Band gap	1.17e	V/k
FC	Forward bias depletion capacitance coefficient	0.5	
FCSW	Side-wall forward-bias depletion capacitance	0.5	
GAP1	First bandgap correction factor	7.02E-04e	V/k
GAP2	Second bandgap correction factor	1108k	
GEO	Stacked device		
IJTH	Diode Limiting Current	0.1	amp
IJTH2	External Diode Limiting Current	0.1	amp
JS	Bulk junction saturation current	1.00E-04	amp/m ²
JS2	External bulk junction saturation curr	1.00E-04	amp/m ²
JSW	Sidewall bulk junction saturation current	0	
JSW2	External sidewall bulk junction	0	amp/m

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Parameter Name	Description	Default Value	Unit
IGCD	Gate-to-contact length of drain side	0	m
IGCS	Gate-to-contact length of source side	0	m
LGCD			
LGCS			
LRD	Drain resistance length sensitivity. Use this parameter with WRD and PRD to factor model for device size		
LRS	Source resistance length sensitivity. Use this parameter with WRS and PRS to factor model for device size		
LS	Bulk junction saturation current for ASPEC=1	1.00E-14p	am
MINR	Minimum source/drain resistance	0.1	ohm
MJ	Bottom junction capacitance grading coefficient	0.5	
MJSW	Source/drain side wall junction capacitance grading coefficient	0.33	
MJSWG	Source/drain gate side wall junction capacitance grading coefficient		
NDS	Reverse bias slope coefficient	1	
NDS2	Reverse bias slope coefficient of external junction	1	
NJ	Emission coefficient of junction		
NJ2	Emission coefficient of external junction	1	
PB	Bottom junction built in potential	1	V
PBSW	Side wall junction built in potential	1	V

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Laterally Double Diffused Metal Oxide Semiconductor FET Model (LDMOS)

Parameter Name	Description	Default Value	Unit
PBSWG	Side wall junction built in potential		
PHP	Bulk sidewall junction contact potential	0.8	V
PRD	Drain resistance product sensitivity		
PRS	Source resistance product sensitivity		
PTA	Temperature coefficient for Pb	0	V/k
PTC	Potential phi temperature coefficient	0	V/k
PTP	PHP temperature coefficient	0	V/k
RD	Drain ohmic resistance. This parameter is usually the sheet resistance of a lightly-doped region for $acm \geq 1$.	0	ohm/sq
RDC	Additional drain resistance due to contact resistance	0	ohm
RDD	Scalable drain resistance	0	ohm*m
RSH	Source drain sheet resistance in ohm pre square	0	
RS	Source ohmic resistance. This parameter is usually the sheet resistance of a lightly-doped region for $acm \geq 1$		
RSC	Additional source resistance due to contact resistance	0	ohm
RSS	Scalable source resistance	0	ohm*m
SC	Spacing between contacts	1.00E+31	m
TCJ	Temperature coefficient of CJ	0	1/k
TCJSW	Temperature coefficient of CJSW	0	1/k
TCJSWG	Temperature coefficient of CJSWG	0	1/k

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Parameter Name	Description	Default Value	Unit
TLEV	Diode DC temperature model selector	0	
TLEVC	diode CV temperature model selector	0	
TPB	Temperature coefficient for PB	0	V/k
TPBSW	Temperature coefficient for PBSW	0	V/k
TPBSWG	Temperature coefficient for PBSWG	0	V/k
TRD	rd temperature coefficient	0	1/k
TRS	rs temperature coefficient	0	1/k
TT	Transit time	0	s
VNDS	Reverse diode current transition point	-1	V
VNDS2	Reverse diode current transition point of external junction	-1	V
WRD	Drain resistance width sensitivity used with Ird		
WRS	Source resistance width sensitivity used with IRS		
XTI	Junction current temperature exponent coefficient	0	
XTI2	External Junction current temperature exponent coefficient	0	

Table 42-6 Threshold Voltage Parameters

Parameter Name	Description	Default Value	Unit
CDSC	Drain/source to channel coupling capacitance	2.40E-04	F/m ²
CDSCB	Body bias sensitivity of CDSC	0	F/V/m ²

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Parameter Name	Description	Default Value	Unit
CDSCD	Drain bias sensitivity of CDSC	0	F/V/m ²
CIT	Interface trap capacitance	0	F/m ²
DVT0	First coefficient of short channel effect on VTH	2.2	
DVT1	Second coefficient of short channel effect on Vth	0.53	
DVT2	Body bias coefficient of short channel effect on VTH	-0.032	1/V
DVT0W	First coefficient of narrow channel effect on VTH	0	
DVT1W	Second coefficient of narrow channel effect on VTH	5.30E+06	
DVT2W	Body bias coefficient of narrow channel effect on VTH	-0.032	1/V
GAMMA1	Body-effect coefficient near the surface		
GAMMA2	Body-effect coefficient in the bulk		
K1	First order body effect coefficient	0.53	V ^{1/2}
K2	Second order body effect coefficient	-0.0186	
K3	Narrow width coefficient	80	
K3B	Body effect coefficient of K3		
NCH	Channel doping concentration	1.70E+17 ³	1/cm
NFACTOR	Subthreshold swing factor	1	
NLX	Lateral non-uniform doping parameter	1.74E-07	m
NSUB	Substrate doping concentration	6.00E+16	
VBM	Maximum applied body bias in VTH calculation	-3	V

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Parameter Name	Description	Default Value	Unit
VBX	Body bias to completely deplete channel		
VFB	Flat band voltage		
VOFF			
VTH0	Threshold Voltage at VBS=0 for large channel length	0.7	V

Table 42-7 Mobility Parameters

Parameter Name	Description	Default Value	Units
NGATE	Gate doping concentration	0	cm ³
PRWB	Body bias coefficient of RDSW	0	V ⁻⁵
PRWG	Gate bias coefficient of RDSW	0	1/V
RDSW	Parasitic resistance per unit width	0	ohm*um ^{WR}
U0	Constant Mobility	0.067	m ² /V/S
UA	First order mobility degradation coefficient	2.25E-09	m/V
UB	Second order mobility degradation coefficient	5.87E-19	m ² /V ²
UC	Bulk effect of mobility degradation coefficient	-4.65E-11	1/V
W0	Gate doping concentration	2.50E-06	m
WR	Width offset from WEFF for RDS	1	
XJ	Junction depth	1.50E-07	m
XT	Doping depth	1.55E-07	m

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Laterally Double Diffused Metal Oxide Semiconductor FET Model (LDMOS)

Table 42-8 Saturation Voltage Parameters

Parameter Name	Description	Default Value	Unit
A0	bulk charge effect coefficient for channel length	1	
A1	First non-saturation coefficient	0	1/V
A2	Second non-saturation coefficient	1	
AGS	gate bias dependence of ABULK	0	1/V
ALPHA0	First parameter of impact ionization current	0	m/V
ALPHA1	Isub parameter for length scaling	0	1/V
ALPHA2	Isub parameter for length scaling	0	1/V
B0	Bulk charge effect coefficient for channel width	0	m
B1	Bulk charge effect width offset	0	m
BETA0	Second parameter of impact ionization current	30V	V
DWB	Coefficient of Weff's body dependence	0	m/V ⁵
DWG	Coefficient of WEFF's gate dependence	0	m/V
KETA	Body-bias coefficient for non-uniform depletion width effect	-0.047	1/V
VSAT	Saturation velocity	8.00E+04	m/sec

Table 42-9 Output Resistance Parameters

Parameter Name	Description	Default Value	Unit
DELTA	Effective VDS parameter	0.01	V

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Parameter Name	Description	Default Value	Unit
DROUT	L dependence coefficient of the DIBL correction in Rout	0.56	
DSUB	DIBL coefficient exponent in subthreshold region	0.56	
ETA0	DIBL coefficient in subthreshold region	0.08	
ETAB	Body bias coefficient for subthreshold	-0.07	V
PCLM	channel length modulation	1.3	
PDIBLC1	First output resistance DIBL correction parameter	0.39	
PDIBLC2	Second output resistance DIBL correction parameter		
PDIBLCB	Body effect coefficient of DIBL correction on output resistance		
PSCBE1	First substrate current body effect parameter	4.24E+08	V/m
PSCBE2	Second substrate current body effect parameter	1.00E-05	V/m
PVAG	Gate dependence of Early voltage	0	

Table 42-10 Parasitic Resistance Parameters

Parameter Name	Description	Default Value	Unit
BETA1	Gate bias dependence of drift region resistance	1	1/V
GAMMA	Drain bias dependence of drift region resistance	1	

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Parameter Name	Description	Default Value	Unit
R1S	Substrate network resistance	50	ohm
R2S	substrate network resistance	50	ohm
R3S	substrate network resistance	50	ohm
RBL	Substrate network resistance for the bury layer under the drift region	50	ohm
RDW	Zero-biased gate-drain overlap resistance		ohm
RDWMIN	minimum gate-drain overlap region resistance	1	ohm
RGATE	Gate resistance	0	ohm
RSHDRIFT	Drift region sheet resistance	100	ohm/ square
THETA	Gate bias dependence of drift region resistance for RDRIFTMOD=0	1	
THETA1	Gate bias dependence of drift region resistance for RDRIFTMOD=1	1	
THETA2	Gate bias dependence of drift region resistance for RDRIFTMOD=2	1	

Table 42-11 Capacitance Parameters

Parameter Name	Description	Default Value	Unit
ACDE	Exponential Coefficient for charge thickness in CAPMOD=3 for accumulation and depletion regions	1	m/V
CF	Fringing field capacitance		

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Parameter Name	Description	Default Value	Unit
CGDL	Lightly doped drain-gate overlap region capacitance	0	F/m
CGDSLOPE	Offset coefficient of source and drain charge partition	1	
CGSL	Lightly doped source-gate overlap region capacitance		
CKAPPA	Coefficient for lightly doped region overlap capacitance	0.6	V
CLC	Constant term for short channel model	1.00E-07	m
CLE	Exponential term for short channel model	0.6	
MOIN	Coefficient for the gate-bias dependents	15	
NOFF	CV parameter in VGSTEFF CV for weak to strong inversion	1	
ULD_ALPHA	Work function difference between source and drain ends of channel	-0.002	
ULD_BETA	Square of characteristic length of lateral channel doping profile	1.00E-12	m ²
ULD_THETA	Offset voltage in threshold voltage	-0.2	V
VFBCV	Flat-band voltage parameter for CAPMOD=0 only	-1V	V
VOFFCV	CV parameter in VGSTEFF CV for weak to strong inversion	0	V

Table 42-12 Temperature Effects Parameters

Parameter Name	Description	Default Value	Unit
AT	Temperature coefficient for saturation	3.30E+04	m/sec

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Parameter Name	Description	Default Value	Unit
CTH0	Thermal capacitance per unit width	0	m/(w*sec)
KT1	temperature coefficient of threshold voltage	-0.11	v
KT2	body bias coefficient of threshold voltage temperature effect	0.022	
KT1L	channel length dependence of the temperature coefficient of threshold voltage	0	Vm
PRT	Temperature coefficient for RDSW	0	
PTE	Temperature coefficient of drift region	0	
RTH0	Thermal resistance per unit width	0	mc/w
UA1	Temperature coefficient for UA	4.31E-09	m/v
UB1	temperature coefficient for UB	-7.61E-18	m ² /V ²
UC1	temperature coefficient for UC	-5.60E-11	m/V ²
UTE	Mobility temperature exponent	-1.5	

Table 42-13 dW and dL Parameters

Parameter Name	Description	Default Value	Unit
LDRIFT	Drift region length	3.00E-06	m
LL	Coefficient of length dependence for length offset	0	m ^{Lln}
LLC	Coefficient of length dependence for CV channel length offset	0	m ^{Lln}
LLN	Power of length dependence of length offset	1	
LMAX	Maximum channel length	1	m

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Parameter Name	Description	Default Value	Unit
LMIN	Minimum channel length	0	m
LOV	Overlap region length	1.00E-07	m
LREF	Related to binning	1.00E+20	m
LW	Coefficient of width dependence for length offset	0	m^{Lwn}
LWC	Coefficient of width dependence for CV channel length offset	0	m^{Lwn}
LWL	Coefficient of length and width cross term for length offset	0	$m^{Lwn+Lin}$
LWLC	Coefficient of length and width dependence for CV channel length offset	0	$m^{Lwn+Lin}$
LWN	Power of width dependence of length offset	1	
SCALE	Instance scale factor	1	
SCALEM	Model parameter scale factor		
WL	Coefficient of length dependence for width offset	0	m^{Wln}
WLC	Coefficient of length dependence for CV channel width offset	0	m^{Wln}
WLN	Power of length dependence of width offset	1	
WMAX	Maximum channel width	1	m
WMIN	Minimum channel width	0	m
WOV	Overlap region width	5.00E-07	m
WREF	Related to binning	1.00E+20	m
WTH0	Width scaling factor for thermal resistance	0	
WW	Coefficient of width dependence for width offset	0	m^{Wwn}

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Parameter Name	Description	Default Value	Unit
WWC	Coefficient of width dependence for CV channel width offset	0	$m^{W_{wn}}$
WWL	Coefficient of length and width cross term for width offset	0	$m^{W_{wn}+W_{ln}}$
WWLC	Coefficient of length and width dependence for CV channel width	0	$m^{W_{wn}+W_{ln}}$
WWN	Power of width dependence of width offset		

Table 42-14 Capacitance Parameters

Parameter Name	Description	Default Value	Unit
CGBO	Gate-bulk overlap capacitance	0	F/m
CGDO	Gate-drain overlap capacitance		F/m
CGSO	Gate-source overlap capacitance		F/m
Vth0ov	Threshold voltage at $V_{bs}=0$ for the overlap region	0.7	V
K1ov	First order body effect coefficient for the overlap region	0.5	$V^{0.5}$
Nov	Doping concentration in the overlap region	1.7e17	1/cm
Noffov	Transition parameter for the overlap region	1	
Qminvov	Smooth coefficient for inversion charge in the overlap region	0	V
Voffcvov	Overlap region CV parameter in the V_{gsteff} calculation for weak to strong inversion	0	V
Qmacov	Smooth coefficient for accumulation charge in the overlap region	0.02	V^2

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Parameter Name	Description	Default Value	Unit
Delvfbcv	Flatband voltage shift due to overlap region coupling	0	V
K1cv	Capacitance body effect coefficient	0.5	$V^{0.5}$
K1ovw	Width dependent of body effect coefficient for overlap region	0	$V^{0.5}m$
K1cww	Width dependent of body effect coefficient for capacitance model	0	$V^{0.5}m$
Vth0ovw	Width dependent of threshold voltage for overlap region	0	Vm
Qminv	Smooth coefficient for inversion charge in channel region	0	$V^{0.5}m$
Partov	Smooth coefficient for accumulation charge in overlap region	0	$V^{0.5}m$

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Laterally Double Diffused Metal Oxide Semiconductor FET Model (LDMOS)

Distributed Components

This chapter describes component statements for the following components:

- [Microstrip Line \(msline\)](#) on page 2792
- [Multi-Conductor Transmission Line \(mtline\)](#) on page 2793
- [Delay Line \(delay\)](#) on page 2808
- [Four Terminal Relay \(relay\)](#) on page 2809
- [Linear Two Winding Ideal Transformer \(transformer\)](#) on page 2812

Microstrip Line (msline)

This is a microstrip line based on the equations of Hammerstad and Jensen. The model contains a thickness correction to the width and frequency dependent permittivity and characteristic impedance. The dispersion equations are those of Kirschning and Jansen.

This device is supported within altergroups.

Sample Instance Statement:

```
tl1 (in 0 out 0) msline l=0.15 w=0.01 h=0.01
```

Sample Instance Statement

```
tl1 (in 0 out 0) msline l=0.15 w=0.01 h=0.01
```

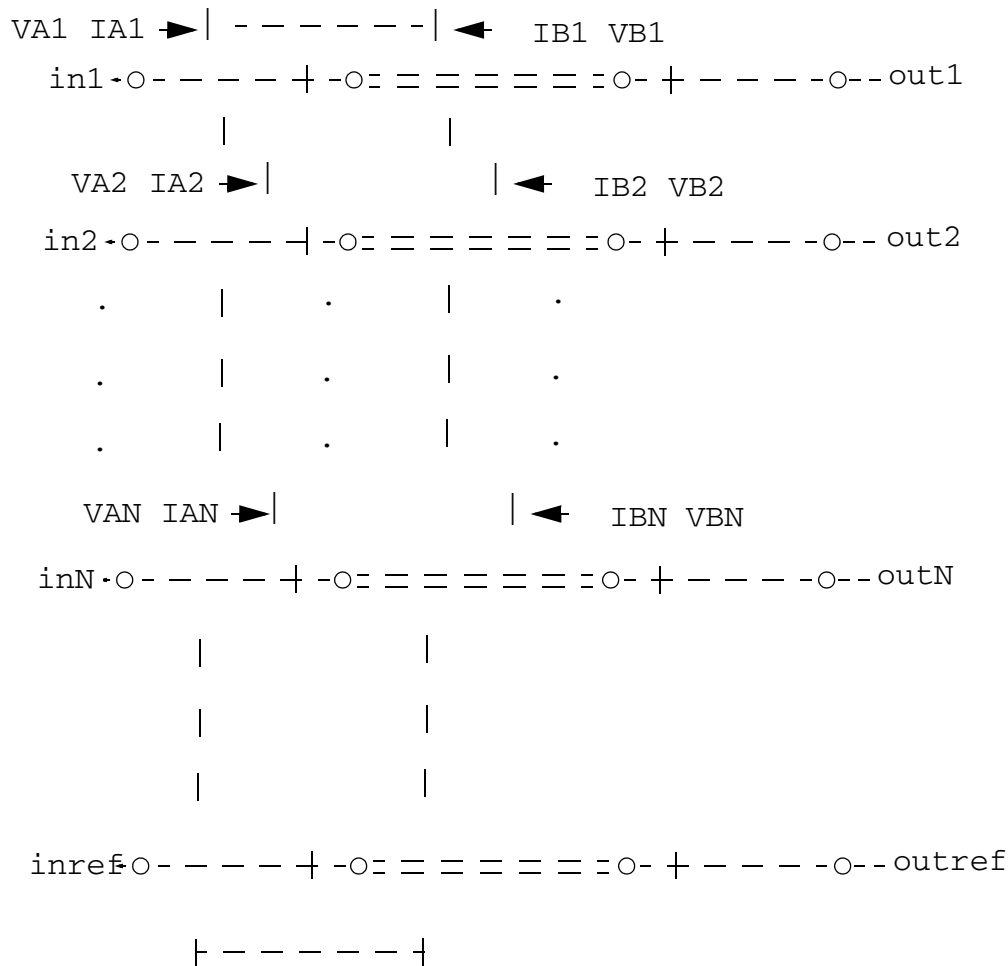
Instance Definition

```
Name t1 b1 t2 b2 msline parameter=value ...
```

Instance Parameters

1	<code>l=0 m</code>	Length.
2	<code>w (m)</code>	Width.
3	<code>h (m)</code>	Substrate height.
4	<code>t=0 m</code>	Conductor thickness.
5	<code>eps=1</code>	Substrate permittivity relative to a vacuum.
6	<code>m=1</code>	Multiplicity factor.
7	<code>fmax=10e9 Hz</code>	Maximum signal frequency.

Multi-Conductor Transmission Line (mtline)



A multi-conductor transmission line (MTLINE) is characterized by constant RLGC matrices or frequency dependent RLGC data. An MTLINE can have as many conductors as there are as described in the input. However, there must be at least two conductors with one conductor used as reference to define terminal voltages. The reference conductor can be ground. The order of the conductors is the same as the order of the data in the input.

All of the conductors are assumed to have the same length, and to be uniform along the length.

MTLINE takes five different types of input: per-unit-length constant RLGC matrices, per-unit-length frequency dependent RLGC data, 2-D field solver geometry and material property information, S-parameter data, or the old single-conductor TLINE parameters. These inputs are explained below.

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Distributed Components

All transmission line parameters (other than conductor length) can be provided through an instance line or model line. When a particular parameter is provided on both the instance and the model lines, the value on the instance line takes higher priority.

Constant RLGC Matrices

For narrow band applications, transmission line characteristics very often are assumed to be constant over the frequency of interest. The input to MTLINE are per-unit-length resistance (R), inductance (L), conductance (G), and capacitance (C) matrices, and they are usually generated by a third-party field solver. Because these matrices are generally symmetric, MTLINE accepts both full matrix description and lower half matrix description.

For example, to describe the resistance matrix of a four conductor line system:

$$R = \begin{bmatrix} 50 & 10 & 1 \\ 10 & 50 & 10 \\ 1 & 10 & 50 \end{bmatrix} \text{ Ohm/meter}$$

The following two model descriptions are equivalent:

```
model line mtline
```

```
+ r=[ 50 10 1  
+   10 50 10  
+   1 10 50 ]  
+ ...
```

```
model line mtline
```

```
+ r=[ 50  
+   10 50  
+   1 10 50 ]  
+ ...
```

In the past, the only information available to describe a transmission line system was constant RLGC matrices based on the narrow band assumption. Some approximation has been used in an effort to extend the model to better cover frequency dependent effects, such as skin effect and dielectric loss effect, in wide band applications.

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Distributed Components

The following simplified equation can be used to model skin effect together with the constant RLGC matrices

$$R(f) = r + \sqrt{f} * (1 + j) * r_{skin},$$

and the following equation can be used to model dielectric loss effect together with the constant RLGC matrices

$$G(f) = g + f * g_{dloss},$$

where f stands for frequency, or

$$G(f) = g + f * g_{dloss} / \sqrt{1 + (f/f_{gdloss})^2}$$

if the f_{gdloss} parameter is specified to limit the dielectric loss effect at higher frequencies.

User should be aware that these are overly simplified versions of the actual frequency dependent effects. And particularly the dielectric loss effect equation of $G(f)$ often results in non-physical models, and it could lead to a very inaccurate model over the frequency of interest.

To accurately model frequency-dependent effects, the user needs to provide true frequency-dependent RLGC data, or use MTLINES internal 2-D field solver to generate the frequency-dependent model.

Frequency-Dependent RLGC Data

Frequency dependent RLGC data are described in a data file through parameter `file`. The frequency axis can be scaled with the `scale` parameter. The frequencies in the data file are then multiplied by `scale` before the simulator uses them. The default scale factor is unity.

An example data file is listed below:

```
; Comments: rl.dat
FORMAT FREQ: R1:1 R2:1 R2:2
          L1:1 L2:1 L2:2
0.001e+9:  4.444 0.000383 4.444
          4.565 0.3545  4.565
0.010e+9:  4.447 0.003834 4.447
          4.565 0.3545  4.565
```

Virtuoso Simulator Components and Device Models Reference

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```
0.100e+9    4.476 0.03834 4.476
            4.565 0.3545 4.565
1.000e+9    4.762 0.3834 4.762
            3.103 0.2357 3.103
10.00e+9    13.96 1.082 13.96
            2.718 0.2058 2.718
100.0e+9    56.88 3.294 56.88
            2.531 0.1866 2.531
```

```
; end of file rl.dat
```

Note that lines starting with `;` are interpreted as comment lines. The data file has a format section, and a data section. In addition, both full matrix and lower half matrix descriptions are accepted.

The user can mix the constant RLGC parameters with frequency-dependent RLGC data. When a particular parameter (R, L, G or C) is provided in both constant matrices and frequency-dependent data file, the constant matrix is the first choice of input. If only one frequency point is provided in the `file`, the RLGC data are assumed to be constant over the frequency of interest.

When providing the frequency-dependent RLGC data, one should always try to provide accurate and sufficient data points. There should be data points to cover low-frequency characteristics, and there should be enough data points to capture the changing nature in the high-frequency range. A rule of thumb is that the lowest frequency point should be down to 1kHz, and there should be at least 5 points per decade, particularly in the high-frequency range where RLGC data tends to change rapidly.

2-D Field Solver Information

MTLINE directly supports a built-in 2-D field solver, it has the same modeling engine as the standalone LMG (Line Model Generator) utility. The output of the 2-D field solver is RLGC data, which can be stored for re-use through the `file` parameter. This makes the actual RLGC model generation a one-time cost, given the field solver input is unchanged.

Line Configuration (`linetype`)

MTLINE supports four interconnect line configurations: microstrip line, strip line, coplanar waveguide, and substrate lossy line.

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Distributed Components

Model Type (`modeltype`)

For each line configuration, you can choose between three model types. In the lossless model, the internal inductance of the conductor is disregarded by setting the frequency value high; 50 GHz for cases without substrate loss and 15 GHz for cases with substrate loss, and ignoring the value of f_{\max} . For the narrow band model, the RLGC data is calculated at frequency f_{\max} and assumed to be constant over the frequency of interest. The third choice is the wideband model where true frequency dependent RLGC data is calculated over the frequency of interest. For most applications, you should choose the wideband model as it provides the best model accuracy.

Ground Plane (`numgnd`)

For microstrip line, the number of ground planes is fixed to 1, at the bottom of the 2-D interconnect cross section.

For strip line, the number of ground planes is fixed to 2, at both the bottom and top of the 2-D interconnect cross section.

For coplanar waveguide and substrate lossy line, the number of ground planes can be 1 or 2, at the bottom and top of the 2-D interconnect cross section. For coplanar waveguide, you can also specify 0 ground planes because there will be two ground strips added automatically to the cross section. The width, height, thickness and spacing of these ground strips can be specified in a similar fashion as conductors are specified.

The `gndthickness` parameter can be used to specify the thickness of the ground plane(s), and the `gndsigma` parameter can be used to specify the ground plane conductivity.

Dielectric Layer (`numlayer`)

Dielectric layers are stacked above the ground plane (when `numgnd=1`), or between the ground planes (when `numgnd=2`). There can be many dielectric layers.

The thickness of the dielectric layer can be provided through the `layerthickness` parameter, and the relative dielectric constant of the dielectric layer can be provided through the `er` parameter. Note that both the `layerthickness` and `er` parameters are of vector type to handle different layer geometries and layer properties. When the number of elements in the vector is less than the number of layers, the value of the last element in the vector will be applied to all of the remaining layers.

A particular dielectric layer can be lossy, and either the loss tangent parameter ($\tan = \sigma / (w \cdot \epsilon_0)$) or the loss sigma parameter ($\sigma = \tan \cdot w \cdot \epsilon_0$) can be used. This is decided through the `dlossstype` parameter and the actual loss value(s) is provided through the `dloss` vector parameter.

Signal Line

The signal line conductivity can be specified using parameter `linesigma`.

There can be many signal lines. The geometry of the signal line(s) are decided through parameters `linewidth`, `linethickness`, `lineheight` and `linespace`. The parameter `lineheight` is the distance between the signal line and ground plane at the bottom of the 2-D interconnect cross section. The parameter `linespace` is the distance between the signal lines; it can be negative in order to describe overlapping signal lines.

Intermediate RLGC file (`file`)

The `file` parameter can be used to store the 2-D field solver output, to be used in subsequent simulations. This makes the RLGC model generation a one-time effort.

If the `file` parameter is given, MTLINE will first check the existence of the file. If the `file` does not exist, the RLGC model will be generated by the field solver and the output will be stored in `file`; if the `file` does exist, MTLINE will check if the RLGC data stored in the `file` matches the MTLINE 2-D field solver input. If it does not match, a new set of RLGC data will be generated and the `file` will be over-written. Otherwise, the data will be re-used.

If the `file` parameter is not given, then the RLGC data will be stored in the file `%C.rlgc` after the simulation.

S-Parameter Data File

MTLINE also supports S-parameter data file input describing a transmission line system using the `file` parameter. MTLINE will convert the frequency dependent S-parameter to frequency dependent RLGC data and store the results in the file `%C.rlgc` for reuse in subsequent simulations.

If the `file` parameter corresponds to S-parameter data, MTLINE will first check the existence of the file `%C.rlgc` to determine if the S-to-RLGC extraction has been performed in a previous simulation.

The S-parameter data file formats supported include Touchstone, Spectre and Citi.

The physical length of the line must also be specified using the `len` parameter.

The ordering of the S-parameter input file should be in the format of input ports followed by the output ports of the transmission line system, or `Pin1, Pin2, Pin3, ..., Pout1, Pout2, Pout3, ...`

The Old TLINE Parameters

Virtuoso Simulator Components and Device Models Reference

Distributed Components

MTLINE directly supports the old single-conductor TLINE parameters, in a way to ease customer migration, as MTLINE has a more accurate and robust modeling algorithm.

Due to a name conflict, the TLINE parameter *r* has been renamed to *seriesr* in MTLINE, and the TLINE parameter *g* has been renamed to *shuntg* in MTLINE.

In addition, note that the terminal maps between TLINE and MTLINE are different. The following TLINE syntax

```
Name ( t1 b1 t2 b2 ) tline <parameter=value> ...
```

should be mapped to the following MTLINE syntax

```
Name ( t1 t2 b1 b2 ) mtline <parameter=value> ...
```

For a detailed explanation of TLINE parameters, please refer to the TLINE help page (`spectre -h tline`).

This device is not supported within altergroup.

Sample Instance Statement

```
x1 (a1 b1 a2 b2 0 0) mtline len=0.01
+ r=[ 0.3
+   0.0 0.3 ]
+ c=[ 0.35p
+   -0.03p 0.35p ]
```

Sample Model Statement

```
model mtmodel mtline
```

```
+ r=[ 0.3
+   0.0 0.3 ]
+ c=[ 0.35p
+   -0.03p 0.35p ]
```

```
model mtmodel mtline
```

```
+ r=[ 0.3 0.0
+   0.0 0.3 ]
+ c=[ 0.35p -0.03p
+   -0.03p 0.35p ]
```

```
model mtmodel mtline
```

Virtuoso Simulator Components and Device Models Reference

Distributed Components

```
+ c=[ 0.35p
+   -0.03p 0.35p ]
+ file="rl.data" scale=1
```

Instance Definition

```
Name in1 out1 in2 [out2] ... modelName parameter=value ...
Name in1 out1 in2 [out2] ... mtline parameter=value ...
```

The last two terminals will be used as refin and refout respectively.

Instance Parameters

1 len=0.01 m Physical length of line.
2 m=1 Multiplicity factor.

RLGC data parameters

3 r=[...] Ω/m Resistance matrix per unit length.
4 l=[...] H/m Inductance matrix per unit length.
5 g=[...] S/m Conductor matrix per unit length.
6 c=[...] F/m Capacitance matrix per unit length.
7 rskin=[...] $\Omega/m \sqrt{Hz}$ Skin effect resistance matrix per unit length.
8 gdloss=[...] S/m Hz Dielectric loss conductance matrix per unit length.
9 fgdloss (Hz) Dielectric loss cut-off frequency.
10 file RLGC data file that contains the frequency dependent RLGC data or S-parameter data file.
11 freqscale=1 Frequency scale factor for frequency dependent RLGC data and S-parameter data.

Virtuoso Simulator Components and Device Models Reference

Distributed Components

2-D Field Solver parameters

- 12 `linetype=sublossline` Transmission line type.
Possible values are `microstrip`, `stripline`, `coplanar`, or `sublossline`.
- 13 `modeltype=wideband` Model type.
Possible values are `lossless`, `narrowband` or `wideband`.
- 14 `numlayer` Number of dielectric layers.
- 15 `numgnd` Number of ground planes.
- 16 `er=[...]` Relative dielectric constant.
- 17 `layerthickness=[...]` mDielectric layer thickness.
- 18 `dlosstype=tangent` Dielectric loss type. Loss value is specified with parameter, `dloss`.
Possible values are `sigma` or `tangent`.
- 19 `dloss=[...]` Dielectric layer loss. Can be in terms of dielectric conductivity or tangent loss, determined by parameter, `dlosstype`.
- 20 `linewidth=[...]` m Signal line width.
- 21 `linethickness=[...]` mSignal line thickness.
- 22 `lineheight=[...]` mSignal line height.
- 23 `linespace=[...]` m Signal line spacing.
- 24 `linesigma (S/m)` Signal line conductivity.
- 25 `gndthickness=[...]` mGround plane thickness.
- 26 `gndsigma (S/m)` Ground plane conductivity.

Virtuoso Simulator Components and Device Models Reference

Distributed Components

Rational fitting parameters

27 $f_{\max}=2.5e10$ Hz Maximum signal frequency used to determine the relevant range of rational fitting or used in the 2D field solver.

TLINE-related parameters

28 $z_0=50$ Ω Characteristic impedance of lossless line.

29 t_d (s) Time delay of a lossless line in seconds, a measure of the electrical length.

30 f (Hz) Reference frequency (used in conjunction to the normalized length to specify electrical length of line).

31 $n_l=0.25$ Normalized electrical length in wavelengths at f of a lossless line.

32 $vel=1$ Propagation velocity of the line given as a multiple of c , the speed of light in free space. ($vel \leq 1$).

TLINE conductor loss parameters

33 $corner=0$ Hz Corner frequency for skin effect, frequency where skin depth equals the conductors wall thickness.

34 $d_{cr}=0$ Ω/m DC series resistance per unit length.

35 f_c (Hz) Conductor loss measurement frequency (use with r , q_c , or $alpha_c$).

36 $seriesr=0$ Ω/m Conductor (series) resistance per unit length at f_c .

37 $alpha_c=0$ dB/m Conductor loss at f_c (low loss approximation).

38 $q_c=\infty$ Conductor loss quality factor at f_c (low loss approximation).

TLINE dielectric loss parameters

39 f_d (Hz) Dielectric loss measurement frequency (use with q_d).

40 $shuntg=0$ S/m Dielectric (shunt) conductance per unit length.

Virtuoso Simulator Components and Device Models Reference

Distributed Components

- 41 `alphad=0` dB/m Dielectric loss (low loss approximation).
- 42 `qd=∞` Dielectric loss quality factor at `fd` (low loss approximation).

Noise parameters

- 43 `trise` (C) Temperature rise from ambient.
- 44 `thermalnoise=yes` Thermal noise.
Possible values are `no` or `yes`.
- 45 `noisemodel` To use the internal thermal noise model, or the externally supplied noise data in the S-parameter data file. The default behavior is to use external data whenever it is available.
Possible values are `internal` or `external`.

Model Definition

`model modelName mtline parameter=value ...`

Model Parameters

RLGC data parameters

- 1 `r=[...]` Ω/m Resistance matrix per unit length.
- 2 `l=[...]` H/m Inductance matrix per unit length.
- 3 `g=[...]` S/m Conductor matrix per unit length.
- 4 `c=[...]` F/m Capacitance matrix per unit length.
- 5 `rskin=[...]` Ω/m $\sqrt{\text{Hz}}$ Skin effect resistance matrix per unit length.
- 6 `gdloss=[...]` S/m Hz Dielectric loss conductance matrix per unit length.
- 7 `fgdloss` (Hz) Dielectric loss cut-off frequency.

Virtuoso Simulator Components and Device Models Reference

Distributed Components

- 8 `file` RLCG data file that contains the frequency dependent RLCG data or S-parameter data file.
- 9 `freqscale=1` Frequency scale factor for frequency dependent RLCG data and S-parameter data.

2-D Field Solver parameters

- 10 `linetype=sublossline` Transmission line type.
Possible values are `microstrip`, `stripline`, `coplanar`, or `sublossline`.
- 11 `modeltype=wideband` Model type.
Possible values are `lossless`, `narrowband` or `wideband`.
- 12 `numlayer` Number of dielectric layers.
- 13 `numgnd=1` Number of ground planes.
- 14 `er=[...]` Relative dielectric constant.
- 15 `layerthickness=[...] m` Dielectric layer thickness.
- 16 `dlosstype=tangent` Dielectric loss type. Loss value is specified with parameter, `dloss`.
Possible values are `sigma` or `tangent`.
- 17 `dloss=[...]` Dielectric layer loss. Can be in terms of dielectric conductivity or tangent loss, determined by parameter, `dlosstype`.
- 18 `linewidth=[...] m` Signal line width.
- 19 `linethickness=[...] m` Signal line thickness.
- 20 `lineheight=[...] m` Signal line height.
- 21 `linespace=[...] m` Signal line spacing.
- 22 `linesigma (S/m)` Signal line conductivity.

Virtuoso Simulator Components and Device Models Reference

Distributed Components

23 `gndthickness=[...]` mGround plane thickness.

24 `gndsigma` (S/m) Ground plane conductivity.

Rational fitting parameters

25 `fmax=2.5e10` Hz Maximum signal frequency used to determine the relevant range of rational fitting or used in the 2D field solver.

TLINE-related parameters

26 `z0=50` Ω Characteristic impedance of lossless line.

27 `f` (Hz) Reference frequency (used in conjunction to the normalized length to specify electrical length of line).

28 `vel=1` Propagation velocity of the line given as a multiple of c , the speed of light in free space. ($vel \leq 1$).

TLINE conductor loss parameters

29 `corner=0` Hz Corner frequency for skin effect, frequency where skin depth equals the conductors wall thickness.

30 `dcr=0` Ω/m DC series resistance per unit length.

31 `fc` (Hz) Conductor loss measurement frequency (use with r , q_c , or α_{hc}).

32 `seriesr=0` Ω/m Conductor (series) resistance per unit length at f_c .

33 `alphac=0` dB/m Conductor loss at f_c (low loss approximation).

34 `qc= ∞` Conductor loss quality factor at f_c (low loss approximation).

TLINE dielectric loss parameters

35 `fd` (Hz) Dielectric loss measurement frequency (use with q_d).

36 `shuntg=0` S/m Dielectric (shunt) conductance per unit length.

Virtuoso Simulator Components and Device Models Reference

Distributed Components

- 37 `alphad=0` dB/m Dielectric loss (low loss approximation).
- 38 `qd=∞` Dielectric loss quality factor at `fd` (low loss approximation).

Noise parameters

- 39 `trise=0` C Default temperature rise from ambient.
- 40 `thermalnoise=yes` Thermal noise.
Possible values are `no` or `yes`.
- 41 `noisemodel` To use the internal thermal noise model, or the externally supplied noise data in the S-parameter data file. The default behavior is to use external data whenever it is available.
Possible values are `internal` or `external`.

Important note about rational fitting:

Spectre uses rational fitting algorithm to build a stable model that approximates the desired transmission line characteristics. Maximum signal frequency f_{max} is used to determine the relevant range of rational fitting. The accuracy of the mtline model is solely dependent on how well the rational approximation is over frequency range $[f_{min}, f_{max}]$.

When constant RLGC matrices are provided, 1Hz is used as f_{min} and f_{max} is defaulted to 25GHz. Three times the inverse of rise time in the input signal can be used as a good estimation of f_{max} . When RLGC data file is provided, the lowest frequency point in the data file is used as f_{min} , and the largest frequency point in the data file is used as f_{max} . User should provide sufficient data points to cover both low-frequency and high-frequency for an accurate, stable model.

Modeling frequency dependent effects:

One can model the frequency dependent RLGC matrices by providing the data file using parameter `file`. One should always try to provide accurate and sufficient data to describe the frequency dependent RLGC matrices.

In addition, the following simplified equation can be used to model skin effect with the constant RLGC matrices

$$R(f) = r + \text{sqrt}(f) * (1 + j) * r_{\text{skin}},$$

and the following equation can be used to model dielectric loss with the constant RLGC matrices

Virtuoso Simulator Components and Device Models Reference

Distributed Components

$$G(f) = g + f * gdloss,$$

where f stands for frequency, or

$$G(f) = g + f * gdloss / \sqrt{1 + (f/gdloss)^2}$$

if the fgdlloss parameter is specified to limit the dielectric loss effect at higher frequencies. User should be aware of that the equation of G(f) results in a non-physical model, and it could lead to an unstable rational model.

Parameter Index

In the following index, I refers to instance parameters, M refers to the model parameters section, O refers to the output parameters section, and OP refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of M-35 means the 35th model parameter.

alphac	I-37	fgdlloss	I-9	lineheight	M-20	qc	M-34
alphac	M-33	fgdlloss	M-7	linesigma	I-24	qd	I-42
alphad	I-41	file	I-10	linesigma	M-22	qd	M-38
alphad	M-37	file	M-8	linespace	I-23	r	I-3
c	I-6	fmax	I-27	linespace	M-21	r	M-1
c	M-4	fmax	M-25	linethickness	I-21	rskin	I-7
corner	I-33	freqscale	I-11	linethickness	M-19	rskin	M-5
corner	M-29	freqscale	M-9	linetype	I-12	seriesr	I-36
dcr	I-34	g	I-5	linetype	M-10	seriesr	M-32
dcr	M-30	g	M-3	linewidth	I-20	shuntg	I-40

Virtuoso Simulator Components and Device Models Reference

Distributed Components

dloss	I-19	gdloss	I-8	linewidth	M-18	shuntg	M-36
dloss	M-17	gdloss	M-6	m	I-2	td	I-29
dlossstype	I-18	gndsigma	I-26	modeltype	I-13	thermalnoise	I-44
dlossstype	M-16	gndsigma	M-24	modeltype	M-11	thermalnoise	M-40
er	I-16	gndthickness	I-25	nl	I-31	trise	I-43
er	M-14	gndthickness	M-23	noisemodel	I-45	trise	M-39
f	I-30	l	I-4	noisemodel	M-41	vel	I-32
f	M-27	l	M-2	numgnd	I-15	vel	M-28
fc	I-35	layerthickness	I-17	numgnd	M-13	z0	I-28
fc	M-31	layerthickness	M-15	numlayer	I-14	z0	M-26
fd	I-39	len	I-1	numlayer	M-12		
fd	M-35	lineheight	I-22	qc	I-38		

Delay Line (delay)

Sample Instance Statement

```
dl1(outp outn cntrlp cntrln) delay td=10n gain=1.5
```

Instance Definition

```
Name p n ps ns delay parameter=value ...
```


Instance Parameters

- | | | |
|---|-----------------------|----------------------|
| 1 | <code>td=0.0 s</code> | Time delay. |
| 2 | <code>gain=1</code> | Gain parameter. |
| 3 | <code>m=1</code> | Multiplicity factor. |

Operating-Point Parameters

- | | | |
|---|--------------------|-----------------|
| 1 | <code>v (V)</code> | Output voltage. |
|---|--------------------|-----------------|

Four Terminal Relay (relay)

The four-terminal relay is a voltage controlled relay tied between terminals `t1` and `t2`. The voltage between terminals `ps` and `ns` controls the relay resistance. The relay resistance varies nonlinearly between `ropen` and `rclosed`, the open relay resistance and closed relay resistance, respectively. These resistance values correspond to control voltages of `vt1` and `vt2` respectively. The four parameters, `vt1`, `vt2`, `ropen`, and `rclosed`, can be instance or model parameters.

As an alternative, you can specify the threshold voltage `vth` and a transition width `trans` rather than specifying `vt1` and `vt2`. These two parameters are then calculated from `vth` and `trans`. If all four parameters are specified, `vth` and `trans` override `vt1` and `vt2`. However, `vt1` and `vt2` values you specify on the instance override any model parameter specifications.

The final model parameter, `hysteresis`, designates a hysteresis with the on voltage shifted from `vth` by an amount `hysteresis` and the off voltage shifted by the same amount in the opposite direction. The direction of shift depends on the sign of `trans` (or the relative magnitudes of `vt1` and `vt2`): if `trans` is positive, the on voltage shifts by `+hysteresis`; if `trans` is negative (implying that the relay is "normally on"), the on-voltage shifts by `-hysteresis`.

This device is not supported within altergroup.

Operating conductance is calculated from the instance parameters as follows:

When `Vc` lies between `vt1` and `vt2`,

$$G = G_{min} + (G_{min} - G_{max}) * [2 * (Vc - vt1)^3 - 3 * (vt2 - vt1) * (Vc - vt1)^2] / (vt2 - vt1)^3$$

Otherwise, if $v_{t1} < v_{t2}$, then

$$G = G_{min} \quad \text{for } V_c < v_{t1} \text{ and}$$

$$G = G_{max} \quad \text{for } V_c > v_{t2}.$$

If $v_{t1} > v_{t2}$,

$$G = G_{min} \quad \text{for } V_c > v_{t1} \text{ and}$$

$$G = G_{max} \quad \text{for } V_c < v_{t2}.$$

where $G_{min} = 1 / r_{open}$, $G_{max} = 1 / r_{closed}$, and $V_c = V(ps) - V(ns)$.

Sample Instance Statement

```
rel1 (1 2 ps ns) my_relay ropen=1G rclosed=2
```

Sample Model Statement

```
model my_relay relay vt1=2.5 vt2=5 ropen=100M rclosed=0.1
```

Instance Definition

```
Name 1 2 ps ns ModelName parameter=value ...
```

```
Name 1 2 ps ns relay parameter=value ...
```

Instance Parameters

- | | | |
|---|----------------------------|---|
| 1 | v_{t1} (V) | Relay resistance is r_{open} at this voltage. |
| 2 | $v_{t2}=v_{t1}+1.0$ V | Relay resistance is r_{closed} at this voltage. |
| 3 | $r_{open}=\infty$ Ω | Resistance of a fully open relay. |
| 4 | $r_{closed}=1.0$ Ω | Resistance of a fully closed relay. |
| 5 | $m=1.0$ | Multiplicity factor. |
| 6 | $region=off$ | Estimated operating region. Spectre outputs number (0-1) in a rawfile.
Possible values are <code>off</code> or <code>on</code> . |

Virtuoso Simulator Components and Device Models Reference

Distributed Components

Model Definition

```
model modelName relay parameter=value ...
```

Model Parameters

- | | | |
|---|-------------------------------|---|
| 1 | <code>vt1</code> (V) | Relay resistance is <code>ropen</code> at this voltage. |
| 2 | <code>vt2=vt1+1.0</code> V | Relay resistance is <code>rclosed</code> at this voltage. |
| 3 | <code>ropen=∞</code> Ω | Resistance of a fully open relay. |
| 4 | <code>rclosed=1.0</code> Ω | Resistance of a fully closed relay. |
| 5 | <code>hysteresis=0.0</code> V | Switching Hysteresis. |
| 6 | <code>vth=0.0</code> V | Threshold Voltage. |
| 7 | <code>trans=0.0</code> V | Switch Transition Region Width. |

Operating-Point Parameters

- | | | |
|---|-------------------------|---|
| 1 | <code>region=off</code> | Estimated operating region. Spectre outputs number (0-1) in a rawfile.
Possible values are <code>off</code> or <code>on</code> . |
| 2 | <code>res</code> (Ω) | Relay resistance. |

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

`hysteresis` M-5 `region` I-6 `ropen` M-3 `vt2` I-2

m	I-5	region	OP-1	trans	M-7	vt2	M-2
rclosed	I-4	res	OP-2	vt1	I-1	vth	M-6
rclosed	M-4	ropen	I-3	vt1	M-1		

Linear Two Winding Ideal Transformer (transformer)

Winding 1 connects terminals t1 and b1, and winding 2 connects t2 and b2. The number of turns on windings 1 and 2 are given by n1 and n2, respectively, and n2 must not be zero. The absolute number of turns of each winding is not important, only the ratio of n1 to n2. Current through winding 1 is computed.

This device is not supported within altergroup.

An ideal transformer is modeled, so it acts as a transformer at DC. Thus

$$\frac{v_1}{v_2} = \frac{t_1}{t_2} = \frac{i_2}{i_1}$$

To model a physical transformer with L₁ and L₂ as the inductance of the windings and k as the coupling coefficient, add an inductor L_m = k.L₁ in parallel with winding 1 and inductors L_{e1} = L₁.(1 - k) and L_{e2} = L₂.(1 - k) in series with windings 1 and 2, respectively. The turns ratio can be computed with

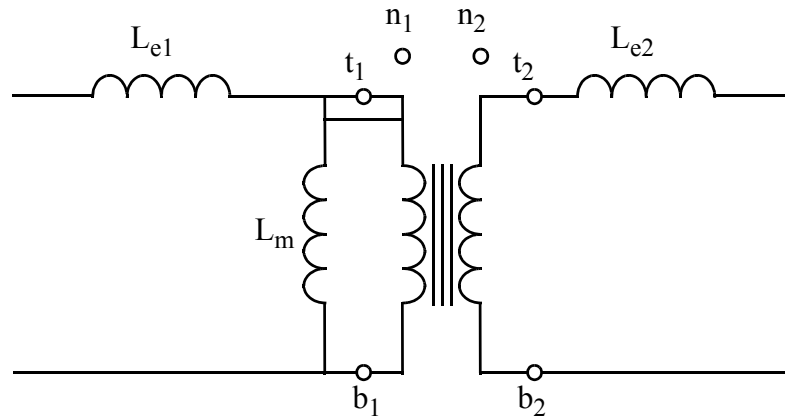
$$\frac{n_1}{n_2} = \sqrt{\frac{L_1}{L_2}}$$

k can be calculated from the L₁ (the inductance of winding 1 with

$$k = \sqrt{1 - \frac{L_s}{L_1}}$$

Virtuoso Simulator Components and Device Models Reference

Distributed Components



Instance Definition

Name `t1 b1 t2 b2 transformer` parameter=value ...

Instance Parameters

- | | | |
|---|-------------------|-------------------------------|
| 1 | <code>n1=1</code> | Number of turns on winding 1. |
| 2 | <code>n2=1</code> | Number of turns on winding 2. |
| 3 | <code>m=1</code> | Multiplicity factor. |

Virtuoso Simulator Components and Device Models Reference

Distributed Components

Other Models

This chapter describes component statements for the following models:

- High-Voltage MOSFET Model (hvmos) on page 2816
- MISN Field Effect Transistor (misnan) on page 2836
- Diffusion Resistor Model (rdiff) on page 2845

High-Voltage MOSFET Model (hvmos)

HV (High-Voltage) MOS transistor model is a deep submicron, high-voltage MOSFET model. It is based on the BSIM3v3 version 3.1. Major enhancements include current-crowding effect at high gate bias, asymmetric source-drain structure, mobility reduction, transconductance reduction under high V_{gs} at saturation region, forward and reverse mode, self-heating, and more flexible gate-dependent output characteristics. HVMOS can be used for high voltage IC design applications such as Flash memory with asymmetric LDD structures, LCD drivers, CCD, E2PROM and LDMOS applications.

Like BSIM3v3, the HVMOS transistor model also allows the binning option to achieve even higher accuracy. The binning equation is given by

$$P = P_0 + P_I / L_{eff} + P_w / W_{eff} + P_p / (L_{eff} * W_{eff})$$

Only the P_0 parameters are listed. P_I , P_w , and P_p are not shown but can be recognized. The names of P_I , P_w , and P_p are identical to that of P_0 but with a prefix of I , w , and p , respectively. HVMOS transistors require that you use a model statement.

This device is supported within altergroups.

Sample Instance Statement

```
m1 (1 2 0 0) hvmos w=1.5u l=1u ad=2.6p as=2.6p pd=6.6p ps=6.6p nrd=1.54 nrs=1.54
```

Sample Model Statement

```
model hvmos hvmos vtho=0.53 w0=2.14e-6 nlx=1.8e-7 nch=2.3e18 xj=0.22e-6 k1=0.48  
k2=-0.02 drout=1.1 rsh=10 cgso=2.4e-10 cgdo=2.4e-10
```

Instance Definition

```
Name d g s b ModelName parameter=value ...
```

Instance Parameters

- | | | |
|---|----------------------|---------------------------|
| 1 | w (m) | Channel width. |
| 2 | l (m) | Channel length. |
| 3 | as (m ²) | Area of source diffusion. |
| 4 | ad (m ²) | Area of drain diffusion. |

Virtuoso Simulator Components and Device Models Reference

Other Models

5	<code>ps (m)</code>	Perimeter of source diffusion.
6	<code>pd (m)</code>	Perimeter of drain diffusion.
7	<code>nrd (m/m)</code>	Number of squares of drain diffusion.
8	<code>nrs (m/m)</code>	Number of squares of source diffusion.
9	<code>ld (m)</code>	Length of drain diffusion region.
10	<code>ls (m)</code>	Length of source diffusion region.
11	<code>isnoisy=yes</code>	Should resistor generate noise. Possible values are <code>no</code> or <code>yes</code> .
12	<code>m=1</code>	Multiplicity factor (number of MOSFETs in parallel).
13	<code>region=triode</code>	Estimated operating region. Spectre outputs number (0-3) in a rawfile. Possible values are <code>off</code> , <code>triode</code> , <code>sat</code> , or <code>subth</code> .
14	<code>nqsmod</code>	NQS flag.
15	<code>trise</code>	Temperature rise from ambient.
16	<code>dtemp</code>	alias of <code>trise</code> .

Model Definition

```
model modelName hvmos parameter=value ...
```

Model Parameters

Device type parameters

1	<code>type=n</code>	Transistor type. Possible values are <code>n</code> or <code>p</code> .
2	<code>hvmosver=2.0</code>	HVMOS Model version selector. The available versions are 1.0, 2.0.

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Other Models

Threshold voltage parameters

3	v_{tho} (V)	Threshold voltage at zero body bias for long-channel devices. For enhancement-mode devices, $v_{tho} > 0$ for n-channel and $v_{tho} < 0$ for p-channel.
4	$k_1=0.5 \sqrt{V}$	Body-effect coefficient, default is 0.53 for $hvmosver \geq 2.0$.
5	$k_2=-0.0186$	Charge-sharing parameter.
6	$k_3=80$	Narrow width coefficient.
7	$k_{3b}=0 \text{ 1/V}$	Narrow width coefficient.
8	$w_0=2.5e-6 \text{ m}$	Narrow width coefficient.
9	$n_{lx}=1.74e-7 \text{ m}$	Lateral nonuniform doping coefficient.
10	$\gamma_1=1.0 \sqrt{V}$	Body-effect coefficient near the surface.
11	$\gamma_2=0 \sqrt{V}$	Body-effect coefficient in the bulk.
12	$v_{bx}=-3 \text{ V}$	Threshold voltage transition body voltage.
13	$v_{bm}=-3 \text{ V}$	Maximum applied body voltage.
14	$dvt_0=2.2$	First coefficient of short-channel effects.
15	$dvt_1=0.53$	Second coefficient of short-channel effects.
16	$dvt_2=-0.032 \text{ 1/V}$	Body-bias coefficient of short-channel effects.
17	$a_{0f}=1$	Forward nonuniform depletion width effect coefficient.
18	$a_{0r}=a_{0f}$	Reverse nonuniform depletion width effect coefficient.
19	$b_0=0 \text{ m}$	Bulk charge coefficient due to narrow width effect.
20	$b_1=0 \text{ m}$	Bulk charge coefficient due to narrow width effect.
21	$a_1=0$	No-saturation coefficient.

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Other Models

- 22 $a2=1$ No-saturation coefficient.
- 23 $ags=0 \text{ F/m}^2 \text{ V}$ Gate-bias dependence of Abulk.
- 24 $ketaf=-0.047 \text{ 1/V}$ Body-bias coefficient for non-uniform depletion width effect.
- 25 $ketar=ketaf \text{ 1/V}$ Reverse body-bias coefficient for non-uniform depletion width effect.

Process parameters

- 26 $nsub=6e16 \text{ cm}^{-3}$ Substrate doping concentration.
- 27 $nch=1.7e17 \text{ cm}^{-3}$ Peak channel doping concentration.
- 28 $xj=0.15e-6 \text{ m}$ Source/drain junction depth.
- 29 $lint=0 \text{ m}$ Lateral diffusion for one side.
- 30 $wint=0 \text{ m}$ Width reduction for one side.
- 31 $ll=0 \text{ m}$ Length dependence of delta L.
- 32 $lln=1$ Length exponent of delta L.
- 33 $lw=0 \text{ m}$ Width dependence of delta L.
- 34 $lwn=1$ Width exponent of delta L.
- 35 $lwl=0 \text{ m}^2$ Area dependence of delta L.
- 36 $lmin=0 \text{ m}$ The minimum channel length for which the model is still valid.
- 37 $lmax=1 \text{ m}$ The maximum channel length for which the model is still valid.
- 38 $wl=0 \text{ m}$ Length dependence of delta W.
- 39 $wln=1$ Length exponent of delta W.
- 40 $ww=0 \text{ m}$ Width dependence of delta W.
- 41 $wwn=1$ Width exponent of delta W.

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Other Models

42	$wwl=0 \text{ m}^2$	Area dependence of delta W.
43	$wmin=0 \text{ m}$	The minimum channel width for which the model is still valid.
44	$wmax=1 \text{ m}$	The maximum channel width for which the model is still valid.
45	$dwg=0 \text{ m}/\sqrt{v}$	Gate-bias dependence of channel width.
46	$dwb=0 \text{ m}/\sqrt{v}$	Body-bias dependence of channel width.
47	$tox=1.5e-8 \text{ m}$	Gate oxide thickness.
48	$xt=1.55e-7 \text{ m}$	Doping depth.
49	$rd0=0 \text{ } \Omega$	Fixed drain resistance.
50	$rs0=0 \text{ } \Omega$	Fixed source resistance.
51	$rdw=0 \text{ } \Omega \text{ } \mu\text{m}$	Width dependence of drain resistance.
52	$rsw=0 \text{ } \Omega \text{ } \mu\text{m}$	Width dependence of source resistance.
53	$rdsw=0 \text{ } \Omega \text{ } \mu\text{m}$	Width dependence of drain-source resistance.
54	$prwb=0 \text{ } 1/\sqrt{v}$	Body-effect coefficient for Rds.
55	$prwg=0 \text{ } 1/\sqrt{v}$	Gate-effect coefficient for Rds.
56	$wr=1$	Width offset for parasitic resistance.
57	$binunit=2$	Bin parameter unit selector. 1 for microns and 2 for meters.

Mobility parameters

58	$mobmod=1$	Mobility model selector.
59	$u0f=670 \text{ cm}^2/\text{V s}$	Forward low-field surface mobility at t_{nom} . Default is 250 for PMOS.
60	$u0r=u0f \text{ cm}^2/\text{V s}$	Reverse low-field surface mobility at t_{nom} .
61	$vsatf=8e4 \text{ m/s}$	Forward carrier saturation velocity at t_{nom} .

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Other Models

- 62 $dv_{satf}=0$ m/s Forward gate-bias dependence of saturation velocity.
- 63 $dv_{satbf}=0$ m/s Forward body-bias dependence of saturation velocity.
- 64 $vsatr=vsatf$ m/s Reverse carrier saturation velocity at t_{nom} .
- 65 $dv_{satr}=dv_{satf}$ m/s Reverse gate-bias dependence of saturation velocity.
- 66 $dv_{satbr}=dv_{satbf}$ m/s Reverse body-bias dependence of saturation velocity.
- 67 $u_{af}=2.25e-9$ m/v Forward first-order mobility reduction coefficient.
- 68 $u_{bf}=5.87e-19$ m^2/v^2 Forward second-order mobility reduction coefficient.
- 69 $u_{cf}=-4.65e-11$ m/v^2 Forward body-bias dependence of mobility. Default is -0.046 and unit is 1/V for $mobmod=3$.
- 70 $u_{df}=0$ m/v^2 Forward source-resistance dependence of mobility.
- 71 $u_{ar}=u_{af}$ m/v Reverse first-order mobility reduction coefficient.
- 72 $u_{br}=u_{bf}$ m^2/v^2 Reverse second-order mobility reduction coefficient.
- 73 $u_{cr}=u_{cf}$ m/v^2 Reverse body-bias dependence of mobility.
- 74 $u_{dr}=u_{df}$ m/v^2 Reverse source-resistance dependence of mobility.

Output resistance parameters

- 75 $dr_{out}=0.56$ DIBL effect on output resistance coefficient.
- 76 $p_{clmf}=1.3$ Forward channel length modulation coefficient.
- 77 $p_{clmr}=p_{clmf}$ Reverse channel length modulation coefficient.
- 78 $pdiblc1f=0.39$ Forward first coefficient of drain-induced barrier lowering.
- 79 $pdiblc1r=pdiblc1f$ Reverse first coefficient of drain-induced barrier lowering.

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Other Models

- 80 $\text{pdiblc2f}=8.6\text{e-}3$ Forward second coefficient of drain-induced barrier lowering.
- 81 $\text{pdiblc2r}=\text{pdiblc2f}$ Reverse second coefficient of drain-induced barrier lowering.
- 82 $\text{pdiblc2f}=0$ 1/V Body-effect coefficient for DIBL.
- 83 $\text{pdiblc2r}=\text{pdiblc2f}$ 1/V Reverse body-effect coefficient for DIBL.
- 84 $\text{pscbe1f}=4.24\text{e}8$ V/m First coefficient of substrate current body effect.
- 85 $\text{pscbe2f}=1\text{e-}5$ m/v Second coefficient of substrate current body effect.
- 86 $\text{pscbe3f}=0$ V/m Third coefficient of substrate current body effect.
- 87 $\text{pscbe1r}=\text{pscbe1f}$ V/m Reverse first coefficient of substrate current body effect.
- 88 $\text{pscbe2r}=\text{pscbe2f}$ m/v Reverse second coefficient of substrate current body effect.
- 89 $\text{pvag}=0$ Gate-dependence of Early voltage.
- 90 $\text{pclmgf}=0$ Forward gate dependence of $V_{a\text{clm}}$.
- 91 $\text{pclmgr}=\text{pclmgf}$ Reverse gate dependence of $V_{a\text{clm}}$.
- 92 $\text{pclmbf}=0$ Forward body dependence of $V_{a\text{clm}}$.
- 93 $\text{pclmbr}=\text{pclmbf}$ Reverse body dependence of $V_{a\text{clm}}$.
- 94 $\text{pdiblgf}=0$ Forward gate dependence of $V_{a\text{dibl}}$.
- 95 $\text{pdiblgr}=\text{pdiblgf}$ Reverse gate dependence of $V_{a\text{dibl}}$.
- 96 $\text{delta}=0.01$ V Effective drain voltage smoothing parameter.

Subthreshold parameters

- 97 $\text{cdsc}=2.4\text{e-}4$ F/m² Source/drain and channel coupling capacitance.

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Other Models

98	$cdscb=0 \text{ F/m}^2 \text{ V}$	Body-bias dependence of $cdsc$.
99	$cdscd=0 \text{ F/m}^2 \text{ V}$	Drain-bias dependence of $cdsc$.
100	$nfactor=1$	Subthreshold swing coefficient.
101	$cit=0 \text{ F}$	Interface trap parameter for subthreshold swing.
102	$voff=-0.08 \text{ V}$	Threshold voltage offset.
103	$dsub=drout$	DIBL effect in subthreshold region.
104	$eta0f=0.08$	DIBL coefficient subthreshold region.
105	$etabf=-0.07 \text{ 1/V}$	Body-bias dependence of $et0$.
106	$eta0r=eta0f$	Reverse DIBL coefficient subthreshold region.
107	$etabr=etabf \text{ 1/V}$	Body-bias dependence of $eta0r$.

Substrate current parameters

108	$alpha0=0 \text{ m/v}$	Substrate current impact ionization coefficient.
109	$alpha1=0 \text{ 1/V}$	substrate current model parameter.
110	$beta0=30 \text{ 1/V}$	Substrate current impact ionization exponent.

Parasitic resistance parameters

111	$rsh=0 \text{ } \Omega/\text{sqr}$	Drain diffusion sheet resistance.
112	$rshs=0 \text{ } \Omega/\text{sqr}$	Source diffusion sheet resistance.
113	$rs=0 \text{ } \Omega$	Source resistance.
114	$rd=0 \text{ } \Omega$	Drain resistance.
115	$lgcs=0 \text{ m}$	Gate-to-contact length of source side.
116	$lgcd=0 \text{ m}$	Gate-to-contact length of drain side.

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Other Models

117	$r_{sc}=0 \ \Omega$	Source contact resistance.
118	$r_{dc}=0 \ \Omega$	Drain contact resistance.
119	$r_{ss}=0 \ \Omega \ m$	Scalable source resistance.
120	$r_{dd}=0 \ \Omega \ m$	Scalable drain resistance.
121	$sc=\infty \ m$	Spacing between contacts.
122	$ldif=0 \ m$	Lateral diffusion beyond the gate.
123	$hdif=0 \ m$	Length of heavily doped diffusion .
124	$minr=0.1 \ \Omega$	Minimum source/drain resistance.

Junction diode model parameters

125	$j_s \ (A/m^2)$	Bulk junction reverse saturation current density.
126	$j_{sw}=0 \ A/m$	Sidewall junction reverse saturation current density.
127	$i_s=1e-14 \ A$	Bulk junction reverse saturation current.
128	$n=1$	Junction emission coefficient.
129	$n_j=1$	alias of n.
130	$dskip=yes$	Use simple piece-wise linear model for diode currents below $0.1*i_{abstol}$. Possible values are no or yes.
131	$imelt='imax' \ A$	Explosion current, default is 0.1 for hvmosver ≥ 2.0 .
132	$ijth='imax' \ A$	Junction threshold current.
133	$jmelt='jmax' \ A/m^2$	Explosion current density.

Overlap capacitance parameters

134	$c_{gso} \ (F/m)$	Gate-source overlap capacitance.
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Virtuoso Simulator Components and Device Models Reference

Other Models

135	c_{gdo} (F/m)	Gate-drain overlap capacitance.
136	c_{gbo} (F/m)	Gate-bulk overlap capacitance.
137	$meto=0$ m	Metal overlap in fringing field.
138	$c_{gsl}=0$ F/m	Gate-source overlap capacitance in LDD region.
139	$c_{gd1}=0$ F/m	Gate-drain overlap capacitance in LDD region.
140	$ckappa=0.6$	Overlap capacitance fitting parameter.
141	$deltaacc=0.1$ V	Capacitance smoothing parameter.

Junction capacitance model parameters

142	$c_{bs}=0$ F	Bulk-source zero-bias junction capacitance.
143	$c_{bd}=0$ F	Bulk-drain zero-bias junction capacitance.
144	$c_j=5e-4$ F/m ²	Zero-bias junction bottom capacitance density.
145	$m_j=1/2$	Bulk junction bottom grading coefficient.
146	$p_b=0.8$ V	Bulk junction built-in potential, default is 1.0 for $hvmosver \geq 2.0$.
147	$f_c=0.5$	Forward-bias depletion capacitance threshold.
148	$c_{jsw}=5e-10$ F/m	Zero-bias junction sidewall capacitance density.
149	$m_{jsw}=1/3$	Bulk junction sidewall grading coefficient.
150	$p_{bsw}=0.8$ V	Side-wall junction built-in potential, default is 1.0 for $hvmosver \geq 2.0$.
151	$f_{csw}=0.5$	Side-wall forward-bias depletion capacitance threshold.
152	$c_{jswg}=c_{jsw}$ F/m	Zero-bias gate-side junction capacitance density.
153	$m_{jswg}=m_{jsw}$	Gate-side junction grading coefficient.
154	$p_{bswg}=p_{bsw}$ V	Gate-side junction built-in potential.

Virtuoso Simulator Components and Device Models Reference

Other Models

Charge model selection parameters

155	capmod=2	Intrinsic charge model.
156	nqsmod=0	Non-quasi static model selector. Set to 1 to turn on nqs.
157	dwc=wint m	Delta W for capacitance model.
158	dlc=lint m	Delta L for capacitance model.
159	clc=1e-7 m	Intrinsic capacitance fitting parameter.
160	cle=0.6	Intrinsic capacitance fitting parameter.
161	cf (F/m)	Fringe capacitance parameter.
162	a0cvf=a0f	A0 for C-V calculation.
163	a0cvr=a0r	Reverse A0 for C-V calculation.
164	qgvd0f=1	Cgd fitting parameter.
165	qgvd0r=qgvd0f	Reverse Cgd fitting parameter.
166	elm=5	Elmore constant of the channel.
167	vfbcv=-1	Flat-band voltage for capmod=0.
168	acde=0.5 1/V	Exponential coefficient for finite charge thickness.
169	moin=15 1/V	Coefficient for Vgs dependent surface potential.
170	xpart=0	Drain/source channel charge partition in saturation for BSIM charge model, use 0.0 for 40/60, 0.5 for 50/50, or 1.0 for 0/100.

Default instance parameters

171	w=5e-6 m	Default channel width.
172	l=5e-6 m	Default channel length.
173	as=0 m ²	Default area of source diffusion.

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Other Models

174	$a_d=0$ m ²	Default area of drain diffusion.
175	$p_s=0$ m	Default perimeter of source diffusion.
176	$p_d=0$ m	Default perimeter of drain diffusion.
177	$n_{rd}=0$ m/m	Default number of squares of drain diffusion.
178	$n_{rs}=0$ m/m	Default number of squares of source diffusion.
179	$x_w=0$ m	Width variation due to masking and etching.
180	$x_l=0$ m	Length variation due to masking and etching.

Temperature effects parameters

181	t_{nom} (C)	Parameters measurement temperature. Default set by <code>options</code> .
182	$t_{rise}=0$ C	Temperature rise from ambient.
183	$t_{lev}=0$	DC temperature selector.
184	$t_{levc}=0$	AC temperature selector.
185	$e_g=1.12452$ V	Energy band gap.
186	$gap1=7.02e-4$ V/C	Band gap temperature coefficient.
187	$gap2=1108$ C	Band gap temperature offset.
188	$kt1=-0.11$ V	Temperature coefficient for threshold voltage.
189	$kt1l=0$ v m	Temperature coefficient for threshold voltage.
190	$kt2=0.022$	Temperature coefficient for threshold voltage.
191	$atf=3.3e4$ m/s	Temperature coefficient for v_{satf} .
192	$atr=atf$ m/s	Temperature coefficient for v_{satr} .
193	$at1f=0$ m/s	Temperature coefficient for d_{vsatf} .
194	$at1r=at1f$ m/s	Temperature coefficient for d_{vsatr} .

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Other Models

195	$ua1f=4.31e-9$ m/v	Temperature coefficient for ua_f .
196	$ub1f=-7.61e-18$ m ² /v ²	Temperature coefficient for ub_f .
197	$uc1f=-5.5e-11$ m/v ²	Temperature coefficient for uc_f . Default is -0.056 for $mobmod=3$.
198	$ud1f=0$ m/v ²	Temperature coefficient for ud_f .
199	$ua1r=ua1f$ m/v	Temperature coefficient for uar .
200	$ub1r=ub1f$ m ² /v ²	Temperature coefficient for ubr .
201	$uc1r=uc1f$ m/v ²	Temperature coefficient for ucr .
202	$ud1r=0$ m/v ²	Temperature coefficient for udr .
203	$rth=0$ Ω	Self-heating thermal resistance.
204	$rthg=0$ 1/V	Gate-effect coefficient for Rth .
205	$rthb=0$ 1/ \sqrt{v}	Body-effect coefficient for Rth .
206	$prr=0$ Ω	Temperature coefficient for Rds .
207	$trs=0$ 1/C	Temperature parameter for source resistance.
208	$trd=0$ 1/C	Temperature parameter for drain resistance.
209	$ute=-1.5$	Mobility temperature exponent.
210	$xTi=3$	Saturation current temperature exponent.
211	$ptc=0$ V/C	Surface potential temperature coefficient.
212	$tcv=0$ V/C	Threshold voltage temperature coefficient.
213	$pta=0$ V/C	Junction potential temperature coefficient.
214	$tpb=0$ V/C	Junction potential temperature coefficient.
215	$ptp=0$ V/C	Sidewall junction potential temperature coefficient.

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Other Models

216	$t_{pbsw}=0$ V/C	Sidewall junction potential temperature coefficient.
217	$c_{ta}=0$ 1/C	Junction capacitance temperature coefficient.
218	$t_{cj}=0$ 1/C	Junction capacitance temperature coefficient.
219	$c_{tp}=0$ 1/C	Sidewall junction capacitance temperature coefficient.
220	$t_{cjsw}=0$ 1/C	Sidewall junction capacitance temperature coefficient.
221	$t_{cjswg}=0$ 1/C	Temperature coefficient for c_{jswg} .
222	$t_{pbswg}=0$ V/C	Temperature coefficient for p_{bswg} .

Noise model parameters

223	$noimod=1$	Noise model selector.
224	$kf=0$	Flicker (1/f) noise coefficient.
225	$em=4.1e7$ V/m	Maximum electric field.
226	$af=1$	Flicker (1/f) noise exponent.
227	$ef=1$	Flicker (1/f) noise frequency exponent.
228	$noia=1e20$	Oxide trap density coefficient. Default is $9.9e18$ for pmos.
229	$noib=5e4$	Oxide trap density coefficient. Default is $2.4e3$ for pmos.
230	$noic=-1.4e-8$	Oxide trap density coefficient. Default is $1.4e-8$ for pmos. Default is $-1.4-12$ for $hvmosver \geq 2.0$.

Operating region warning control parameters

231	$alarm=none$	Forbidden operating region. Possible values are <i>none</i> , <i>off</i> , <i>triode</i> , <i>sat</i> , <i>subth</i> , or <i>rev</i> .
232	$imax=1$ A	Maximum allowable current, default is 0.1 for $hvmosver \geq 2.0$.
233	$jmax=1e8$ A/m ²	Maximum allowable current density.

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Other Models

234 `bvj= ∞` V Junction reverse breakdown voltage.

235 `vbox=1e9` `tox` V Oxide breakdown voltage.

Length dependent parameters (Not listed)

Width dependent parameters (Not listed)

Cross-term dependent parameters (Not listed)

The `imax` (`jmax`) parameter is used to aid convergence and prevent numerical overflow. The junction characteristics of the FET are accurately modeled for current (density) up to `imax` (`jmax`). For currents (density) above `imax` (`jmax`), the junction is modeled as a linear resistor and a warning is printed.

Output Parameters

- 1 `weff` (m) Effective channel width.
- 2 `leff` (m) Effective channel length.
- 3 `rseff` (Ω) Effective source resistance.
- 4 `rdeff` (Ω) Effective drain resistance.

Operating-Point Parameters

- 1 `type=n` Transistor type.
Possible values are `n` or `p`.
- 2 `region=triode` Estimated operating region. Spectre outputs number (0-3) in a rawfile.
Possible values are `off`, `triode`, `sat`, or `subth`.
- 3 `reversed` Reverse mode indicator.
Possible values are `no` or `yes`.
- 4 `ids` (A) Resistive drain-to-source current.
- 5 `vgs` (V) Gate-source voltage.

Virtuoso Simulator Components and Device Models Reference

Other Models

6	v_{ds} (V)	Drain-source voltage.
7	v_{bs} (V)	Bulk-source voltage.
8	v_{th} (V)	Threshold voltage.
9	v_{dsat} (V)	Drain-source saturation voltage.
10	g_m (S)	Common-source transconductance.
11	g_{ds} (S)	Common-source output conductance.
12	g_{mbs} (S)	Body-transconductance.
13	β_{eff} (A/V ²)	Effective β .
14	c_{jd} (F)	Drain-bulk junction capacitance.
15	c_{js} (F)	Source-bulk junction capacitance.
16	c_{gg} (F)	C _{gg} .
17	c_{gd} (F)	C _{gd} .
18	c_{gc} (F)	C _{gc} .
19	c_{gs} (F)	C _{gs} .
20	c_{gb} (F)	C _{gb} .
21	c_{dg} (F)	C _{dg} .
22	c_{dd} (F)	C _{dd} .
23	c_{ds} (F)	C _{ds} .
24	c_{db} (F)	C _{db} .
25	c_{sg} (F)	C _{sg} .
26	c_{sd} (F)	C _{sd} .
27	c_{ss} (F)	C _{ss} .

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Other Models

28	<code>csb</code> (F)	Csb.
29	<code>cbg</code> (F)	Cbg.
30	<code>cbd</code> (F)	Cbd.
31	<code>cbs</code> (F)	Cbs.
32	<code>cbb</code> (F)	Cbb.
33	<code>ron</code> (Ω)	On-resistance.
34	<code>id</code> (A)	Resistive drain current.
35	<code>ibulk</code> (A)	Resistive bulk current.
36	<code>pwr</code> (W)	Power at op point.
37	<code>gmoverid</code> (1/V)	Gm/Ids.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

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<code>a0cvr</code> M-163	<code>dvsatbr</code> M-66	<code>mobmod</code> M-58	<code>rth</code> M-203
<code>a0f</code> M-17	<code>dvsatf</code> M-62	<code>moin</code> M-169	<code>rthb</code> M-205
<code>a0r</code> M-18	<code>dvsatr</code> M-65	<code>n</code> M-128	<code>rthg</code> M-204
<code>a1</code> M-21	<code>dvt0</code> M-14	<code>nch</code> M-27	<code>sc</code> M-121
<code>a2</code> M-22	<code>dvt1</code> M-15	<code>nfactor</code> M-100	<code>tcj</code> M-218
<code>acde</code> M-168	<code>dvt2</code> M-16	<code>nj</code> M-129	<code>tcjsw</code> M-220

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Other Models

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ad	M-174	dwc	M-157	noia	M-228	tcv	M-212
af	M-226	dwg	M-45	noib	M-229	tlev	M-183
ags	M-23	ef	M-227	noic	M-230	tlevc	M-184
alarm	M-231	eg	M-185	noimod	M-223	tnom	M-181
alpha0	M-108	elm	M-166	nqsmod	I-14	tox	M-47
alpha1	M-109	em	M-225	nqsmod	M-156	tpb	M-214
as	I-3	eta0f	M-104	nrd	I-7	tpbsw	M-216
as	M-173	eta0r	M-106	nrd	M-177	tpbswg	M-222
at1f	M-193	etabf	M-105	nrs	I-8	trd	M-208
at1r	M-194	etabr	M-107	nrs	M-178	trise	I-15
atf	M-191	fc	M-147	nsub	M-26	trise	M-182
atr	M-192	fcsw	M-151	pb	M-146	trs	M-207
b0	M-19	gamma1	M-10	pbsw	M-150	type	M-1
b1	M-20	gamma2	M-11	pbswg	M-154	type	OP-1
beta0	M-110	gap1	M-186	pclmbf	M-92	u0f	M-59
betaeff	OP-13	gap2	M-187	pclmbr	M-93	u0r	M-60
binunit	M-57	gds	OP-11	pclmf	M-76	ua1f	M-195
bvj	M-234	gm	OP-10	pclmgf	M-90	ua1r	M-199
capmod	M-155	gmbs	OP-12	pclmgr	M-91	uaf	M-67
cbb	OP-32	gmoverid	OP-37	pclmr	M-77	uar	M-71

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Other Models

cbd	M-143	hdif	M-123	pd	I-6	ub1f	M-196
cbd	OP-30	hvmosver	M-2	pd	M-176	ub1r	M-200
cbg	OP-29	ibulk	OP-35	pdiblc1f	M-78	ubf	M-68
cbs	M-142	id	OP-34	pdiblc1r	M-79	ubr	M-72
cbs	OP-31	ids	OP-4	pdiblc2f	M-80	uc1f	M-197
cdb	OP-24	ijth	M-132	pdiblc2r	M-81	uc1r	M-201
cdd	OP-22	imax	M-232	pdiblcbf	M-82	ucf	M-69
cdg	OP-21	imelt	M-131	pdiblcbr	M-83	ucr	M-73
cds	OP-23	is	M-127	pdiblgf	M-94	ud1f	M-198
cdsc	M-97	isnoisy	I-11	pdiblgr	M-95	ud1r	M-202
cdscb	M-98	jmax	M-233	prt	M-206	udf	M-70
cdscd	M-99	jmelt	M-133	prwb	M-54	udr	M-74
cf	M-161	js	M-125	prwg	M-55	ute	M-209
cgb	OP-20	jsw	M-126	ps	I-5	vbm	M-13
cgbo	M-136	k1	M-4	ps	M-175	vbox	M-235
cgc	OP-18	k2	M-5	pscbe1f	M-84	vbs	OP-7
cgd	OP-17	k3	M-6	pscbe1r	M-87	vbx	M-12
cgdl	M-139	k3b	M-7	pscbe2f	M-85	vds	OP-6
cgdo	M-135	ketaf	M-24	pscbe2r	M-88	vdsat	OP-9
cgg	OP-16	ketar	M-25	pscbeq	M-86	vfbcv	M-167
cgs	OP-19	kf	M-224	pta	M-213	vgs	OP-5

Virtuoso Simulator Components and Device Models Reference

Other Models

cgs1	M-138	kt1	M-188	ptc	M-211	voff	M-102
cgs0	M-134	kt11	M-189	ptp	M-215	vsatf	M-61
cit	M-101	kt2	M-190	pvag	M-89	vsatr	M-64
cj	M-144	l	I-2	pwr	OP-36	vth	OP-8
cjd	OP-14	l	M-172	qgvd0f	M-164	vtho	M-3
cjs	OP-15	ld	I-9	qgvd0r	M-165	w	I-1
cjsw	M-148	ldif	M-122	rd	M-114	w	M-171
cjswg	M-152	leff	O-2	rd0	M-49	w0	M-8
ckappa	M-140	lgcd	M-116	rdc	M-118	weff	O-1
clc	M-159	lgcs	M-115	rdd	M-120	wint	M-30
cle	M-160	lint	M-29	rdeff	O-4	wl	M-38
csb	OP-28	ll	M-31	rds	M-53	wln	M-39
csd	OP-26	lln	M-32	rdw	M-51	wmax	M-44
csg	OP-25	lmax	M-37	region	I-13	wmin	M-43
css	OP-27	lmin	M-36	region	OP-2	wr	M-56
cta	M-217	ls	I-10	reversed	OP-3	ww	M-40
ctp	M-219	lw	M-33	ron	OP-33	ww1	M-42
delta	M-96	lw1	M-35	rs	M-113	wwn	M-41
deltaacc	M-141	lwn	M-34	rs0	M-50	xj	M-28
dlc	M-158	m	I-12	rsc	M-117	x1	M-180
drout	M-75	meto	M-137	rseff	O-3	xpart	M-170

dskip	M-130	minr	M-124	rsh	M-111	xt	M-48
dsub	M-103	mj	M-145	rshs	M-112	xti	M-210
dtemp	I-16	mjsw	M-149	rss	M-119	xw	M-179

MISN Field Effect Transistor (misnan)

Cadence plans to stop supporting this model and recommends that it no longer be used.

The MISN model is formulated in terms of solutions for the boundary surface potentials of the channel and has the inherent property of continuous modeling. It is an inhouse MOSFET model of NORTEL. The MISN model requires a model statement.

This device is not supported within altergroup.

This device is dynamically loaded from the shared object /vobs/spectre_dev/tools.sun4v/cmi/lib/5.0.doc/libnortel_sh.so

Sample Instance Statement:

```
mn1 (1 2 0 0) nch w=1.5u l=1u ad=2.6p as=2.6p pd=6.6p ps=6.6p
```

Sample Model Statement:

```
model nch misnan type=n cox=4.4e-6 dop=2e17 phi=-0.43 xj=0.23 scrat=1.4 mu=400  
rws=250 is=0.98e-13 cjgo=2e-13 noimdl=1
```

Instance Definition

```
Name d g s b ModelName parameter=value ...
```

Instance Parameters

- | | | |
|---|-------------------------|---------------------------|
| 1 | w=1e-5 m | Channel width. |
| 2 | l=3e-6 m | Channel length. |
| 3 | as=3e-11 m ² | Area of source diffusion. |

Virtuoso Simulator Components and Device Models Reference

Other Models

4	$ad=3e-11 \text{ m}^2$	Area of drain diffusion.
5	$ps=2.6e-5 \text{ m}$	Perimeter of source diffusion.
6	$pd=2.6e-5 \text{ m}$	Perimeter of drain diffusion.
7	$m=1$	Multiplicity factor (number of MOSFETs in parallel).
8	$region=triode$	Estimated DC operating region, used as a convergence aid. Possible values are <code>off</code> , <code>triode</code> , <code>sat</code> , or <code>subthresh</code> .

Model Definition

`model modelName misnan parameter=value ...`

Model Parameters

Intrinsic MOS parameters

1	$type=n$	Transistor gender. Possible values are <code>n</code> or <code>p</code> .
2	$cox=4.309e-7 \text{ F/cm}^2$	Gate oxide cap per unit area.
3	$dop=1.665e17 \text{ cm}^{-3}$	Substrate doping. Default = $2.58e17$ for pmos.
4	$phi=-0.55 \text{ V}$	Gate Fermi potential.
5	$qss=-5.078e-8 \text{ Coul/cm}^2$	Effective gate oxide charge per unit area. Default = $1.05e-8$ for pmos.
6	$dopldd=3.2e17 \text{ cm}^{-3}$	LDD region doping concentration. Default = $3.2e19$ for pmos.

Geometry parameters

7	$lvar=0 \text{ }\mu\text{m}$	Gate length correction.
---	------------------------------	-------------------------

Virtuoso Simulator Components and Device Models Reference

Other Models

8	$wvar=0 \mu\text{m}$	Gate width correction.
9	$dls=0.0273 \mu\text{m}$	Sideway diffusion length of source region. Default = 0.037 for pmos.
10	$dld=0.0273 \mu\text{m}$	Sideway diffusion length of drain region. Default = 0.037 for pmos.
11	$d1=0.07 \mu\text{m}$	Sideways diffusion length of S/D regions. Default = 0.04 for pmos.
12	$dw=0.032 \mu\text{m}$	Electrical channel width correction. Default = 0.018 for pmos.

Threshold voltage parameters

13	$xj=0.24 \mu\text{m}$	Source/drain-to-substrate junction depth. Default = 0.31 for pmos.
14	$scrat=1.5$	Short channel threshold voltage ratio. Default = 0.7 for pmos.
15	$scind=1.45$	Short channel threshold voltage index. Default = 1.42 for pmos.
16	$ncrat=0.17$	Narrow channel threshold voltage ratio. Default = 0.095 for pmos.
17	$athp=7.5$	Factor controlling peak magnitude effect. Default = 3.5 for pmos.
18	$athl=2e4 \text{ 1/cm}$	Factor controlling channel length dependence effect. Default = $4e4$ for pmos.
19	$athb=-1.7e-3$	Factor controlling substrate bias dependence effect. Default = $-6e-3$.

Mobility parameters

20	$\mu=577 \text{ cm}^2/\text{V s}$	Low-field carrier mobility. Default = 120 for pmos.
21	$\text{mutxp}=1.72$	Temperature coefficient for the carrier mobility. Default = 1.01 for pmos.
22	$kg=1.4e-7 \text{ cm/V}$	Gate field factor. Default = $1.685e-7$.
23	$v0=3.21e7 \text{ cm/s}$	Scattering limited velocity. Default = $2.45e7$.

Virtuoso Simulator Components and Device Models Reference

Other Models

24	$v0txp=-6.3$	Temp coefficient for scattering limited velocity. Default = -5 for pmos.
25	$find=1.25$	Field mobility index factor. Default = 1.9 for pmos.
26	$gfc=9.1e-10$	Gate voltage dependence of enhanced gate-field scattering. Default = $1.05e-10$ for pmos.
27	$gfc_m=3e-5$	Drain voltage dependence of enhanced gate-field scattering. Default = $2.3e-3$ for pmos.
28	$gfmb=1.45e-3$	Factor controlling substrate bias dependence of enhanced gate-field scattering. Default $3.3e-3$ for pmos.
29	$csf=1.06e-11$	Drain voltage dependence of coulomb scattering. Default = $1.35e-12$ for pmos.
30	$csfb=1.61e-3$	Body voltage dependence of coulomb scattering. Default = $8.5e-3$ for pmos.

Saturation parameters

31	$dprat=15$	Drain region/channel doping ration. Default = 2 for pmos.
32	$satpr=0.2$	Saturation region shaping factor. Default = 1.0 for pmos.
33	$sbd_r=0.3535534$	Primary parameter controlling the onset of saturation.
34	$sadr=5$	Secondary parameter controlling the onset of saturation.

Capacitance parameters

35	$sccf=0.25$	Inner fringing factor for the N+ S/D.
----	-------------	---------------------------------------

Extrinsic parameters

36	$rws=480 \Omega \mu m$	Source series resistance. Default = 1180 for pmos.
37	$rwd=480 \Omega \mu m$	Drain series resistance. Default = 1180 for pmos.

Virtuoso Simulator Components and Device Models Reference

Other Models

- 38 $rsd=-1 \Omega \mu m$ Drain/source series resistance. Negative value for asymmetrical devices.
- 39 $rgsh=0 \Omega \mu m$ Gate series resistance.
- 40 $wtgf=0.28 \mu m$ Width of transition from gate to field oxide under poly.
- 41 $cpts=5.7e-9 F/cm^2$ Poly-to-substrate capacitance per unit area.
- 42 $cgfrs=1e-12 F/cm$ Gate-source overlap fringing field capacitance.
- 43 $cgfrd=1e-12 F/cm$ Gate-drain overlap fringing field capacitance.
- 44 $cgfr=1.36e-12 F/cm$ Gate overlap fringing field capacitance.

Junction parameters

- 45 $is=1.02e-12 A/cm^2$ Sat current per unit area of S/D region-injection component. Default = $9.21e-13$ for pmos.
- 46 $isg=1e-20 A/cm$ Sat current per unit length of gate oxide periphery-injection component. Default = $1.17e-20$.
- 47 $isf=1e-20 A/cm$ Sat current per unit length of field oxide periphery-injection component. Default = $1.17e-20$.
- 48 $ig=1.31e-10 A/cm^2$ Sat current per unit area of S/D region-generation component. Default = $8.27e-10$.
- 49 $igg=6.99e-14 A/cm$ Sat current per unit length of gate oxide periphery-generation/recombination component. Default = $6.47e-14$.
- 50 $igf=6.99e-14 A/cm$ Sat current per unit length of field oxide periphery-generation/recombination component. Default = $6.47e-14$.
- 51 $cjo=9.39e-8 F/cm^2$ Zero bias junction capacitance per unit area. Default = $1.273e-7$ for pmos.

Virtuoso Simulator Components and Device Models Reference

Other Models

- 52 $ena=0.387$ Junction capacitance coefficient for the area component. Default = 0.472 for pmos.
- 53 $cjgo=2.085e-12$ F/cm Zero bias junction cap per unit length of gate oxide periphery. Default = 1.864e-12 for pmos.
- 54 $eng=0.322$ Junction cap coefficient for gate oxide periphery component. Default = 0.334 for pmos.
- 55 $cjfo=3.037e-12$ F/cm Zero bias junction cap per unit length of field oxide periphery. Default = 3.077e-12 for pmos.
- 56 $enf=0.322$ Junction cap coefficient for field oxide periphery component. Default = 0.334 for pmos.

Noise parameters

- 57 $noimdl=1$ Noise model selector.
- 58 $nt=1.6e10$ cm⁻² Surface trap density. Default = 4e9 for pmos.
- 59 $nttx=-4$ Surface trap density temperature coefficient.
- 60 $fidx=0.85$ Flicker noise frequency coefficient.
- 61 $beta=1$ Thermal noise proportional constant.
- 62 $sgma=3e-16$ Capture cross section. Default = 3e-15 for pmos.
- 63 $xtau=1e-8$ 1/E depth.
- 64 $wbar=1$ Barrier height for tunneling. Default = 4 for pmos.
- 65 $dept=3e-7$ Depth of trap distribution.

Operating-Point Parameters

- 1 vgs (V) Gate-source voltage.
- 2 vds (V) Drain-source voltage.

Virtuoso Simulator Components and Device Models Reference

Other Models

3	vbs (V)	Bulk-source voltage.
4	id (A)	Drain current.
5	vth (V)	Threshold voltage.
6	vdsat (V)	Drain-source saturation voltage.
7	gm (S)	Common-source transconductance.
8	gd (S)	Common-source output conductance.
9	gs (S)	Body-transconductance.
10	gmb (S)	Body transconductance.
11	gjs (S)	Drain-bulk junction conductance.
12	ibs (A)	Drain-bulk junction current.
13	gjd (S)	Source-bulk junction conductance.
14	ibd (A)	Source-bulk junction current.
15	qgg (Coul)	Gate charge.
16	qss (Coul)	Source charge.
17	qdd (Coul)	Drain charge.
18	qbb (Coul)	Bulk charge.
19	cgg (F)	Cgg.
20	cgs (F)	Cgs.
21	cgd (F)	Cgd.
22	cgb (F)	Cgb.
23	csg (F)	Csg.
24	css (F)	Css.

Virtuoso Simulator Components and Device Models Reference

Other Models

25	csd (F)	Csd.
26	csb (F)	Csb.
27	cdg (F)	Cdg.
28	cds (F)	Cds.
29	cdd (F)	Cdd.
30	cdb (F)	Cdb.
31	cbg (F)	Cbg.
32	cbs (F)	Cbs.
33	cbd (F)	Cbd.
34	cbb (F)	Cbb.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

ad	I-4	csd	OP-25	ibd	OP-14	region	I-8
as	I-3	csf	M-29	ibs	OP-12	rgsh	M-39
athb	M-19	csfb	M-30	id	OP-4	rsd	M-38
athl	M-18	csg	OP-23	ig	M-48	rwd	M-37
athp	M-17	css	OP-24	igf	M-50	rws	M-36
beta	M-61	dept	M-65	igg	M-49	sadr	M-34
cbb	OP-34	dl	M-11	is	M-45	satpr	M-32

Virtuoso Simulator Components and Device Models Reference

Other Models

cbd	OP-33	dld	M-10	isf	M-47	sldr	M-33
cbg	OP-31	dls	M-9	isg	M-46	sccf	M-35
cbs	OP-32	dop	M-3	kg	M-22	scind	M-15
cdb	OP-30	dopldd	M-6	l	I-2	scrat	M-14
cdd	OP-29	dprat	M-31	lvar	M-7	sgma	M-62
cdg	OP-27	dw	M-12	m	I-7	type	M-1
cds	OP-28	ena	M-52	mu	M-20	v0	M-23
cgb	OP-22	enf	M-56	mutxp	M-21	v0txp	M-24
cgd	OP-21	eng	M-54	ncrat	M-16	vbs	OP-3
cgfr	M-44	fidx	M-60	noimdl	M-57	vds	OP-2
cgfrd	M-43	find	M-25	nt	M-58	vdsat	OP-6
cgfrs	M-42	gd	OP-8	nttx	M-59	vgs	OP-1
cgg	OP-19	gfc	M-26	pd	I-6	vth	OP-5
cgs	OP-20	gfcm	M-27	phi	M-4	w	I-1
cjfo	M-55	gfmb	M-28	ps	I-5	wbar	M-64
cjgo	M-53	gjd	OP-13	qbb	OP-18	wtgf	M-40
cjo	M-51	gjs	OP-11	qdd	OP-17	wvar	M-8
cox	M-2	gm	OP-7	qgg	OP-15	xj	M-13
cpts	M-41	gmb	OP-10	qss	M-5	xtau	M-63
csb	OP-26	gs	OP-9	qss	OP-16		

Diffusion Resistor Model (rdiff)

The rdiff model is a diffusion resistor model, which accurately models the temperature, applied bias and back-bias dependencies of NWell, N+, and P+ resistors. It is described in the paper MODEL FOR DIFFUSION RESISTORS (NWell, N+, P+) USED IN CMOS IC DESIGNS by M.J.B.Bolt, FASELEC Process Development Group, PDG-93029, Modified 3rd May 1995.

Some extensions to that description are applied:

Appropriate model and instance parameter default values are used.

No clipping of parameters is performed. Parameter values are checked for validity. If invalid parameter values occur, the job is aborted with an error message.

For exact inverse behavior of the model in case of V_h less than V_I , the setting of $V_{bl} = \text{abs}(V_b - V_h)$ is replaced by $V_{bl} = \text{min}(\text{abs}(V_b - V_h), \text{abs}(V_b - V_I))$. Additionally, the direction of I_h is inverted in this case.

Note: In noise analysis, rdiff instances will not generate any contribution, since there are no noise sources included in the rdiff model.

(c) Philips Electronics N.V. 1993, 1995

This device is supported within altergroups.

This device is dynamically loaded from the shared object /vobs/spectre_dev/tools.lnx86/cmi/lib/5.0.doc/libphilips_sh.so

Sample Instance Statement

```
r2 (1 2 0) rdsn l=9u w=2u nb=0 m=1
```

Sample Model Statement

```
model rdsn rdiff level=1 tr=27 dta=0 rshr=2.5e3 wtol=0.22u rint=3.5u swvp=13.4u  
power=2 tcr1=1.5e-3 tcr2=1e-5 vpr=40
```

Instance Definition

```
Name h l [b] ModelName parameter=value ...
```

Virtuoso Simulator Components and Device Models Reference

Other Models

Instance Parameters

1	<code>l=1.0 scale m</code>	Drawn length of resistor. Must be greater than zero. Scale set by option <code>scale</code> .
2	<code>w=1.0 scale m</code>	Drawn width of resistor. Must be greater than zero. Scale set by option <code>scale</code> .
3	<code>nb=0.0</code>	Number of bends in the resistor. Must be greater or equal zero.
4	<code>m=1.0</code>	Multiplicity factor. Must be greater than zero.

Model Definition

```
model modelName rdiff parameter=value ...
```

Model Parameters

1	<code>level=1.0</code>	Level of this model. Must be 1.
2	<code>tr (C)</code>	Reference temperature. Default set by option <code>tnom</code> .
3	<code>tref (C)</code>	Alias of <code>tr</code> . Default set by option <code>tnom</code> .
4	<code>tnom (C)</code>	Alias of <code>tr</code> . Default set by option <code>tnom</code> .
5	<code>dta=0 K</code>	Temperature offset of the device.
6	<code>trise=0 K</code>	Alias of <code>dta</code> .
7	<code>rshr=1.0e+3 Ω/sqr</code>	Sheet resistance at reference temperature. Must be greater than zero.
8	<code>wtol=0.0 m</code>	Offset between the drawn and effective resistor width.
9	<code>tcr1=0.0 1/K</code>	Linear temperature coefficient of the resistor.
10	<code>tcr2=0.0 1/K²</code>	Quadratic temperature coefficient of the resistor.
11	<code>vpr=100.0 V</code>	Reference Pinch-off voltage.
12	<code>swvp=0.0 V/m</code>	Coefficient of the width dependence of <code>vpr</code> .

Virtuoso Simulator Components and Device Models Reference

Other Models

13	<code>power=1.5</code>	Voltage exponent. Must be greater than zero.
14	<code>vdr=1.0 V</code>	Diffusion voltage at reference temperature.
15	<code>rint=0.0 Ω m</code>	Interface resistance at reference temperature.
16	<code>tcrint1=0.0 1/K</code>	Linear temperature coefficient of the interface resistor.

Output Parameters

1	<code>vd (V)</code>	Diffusion voltage. Must be greater than zero.
2	<code>rsh (Ω/sqr)</code>	Sheet resistance. Must be greater than zero.
3	<code>vp (V)</code>	Pinch-off voltage. Must be greater than zero.
4	<code>r0 (Ω)</code>	Zero bias resistance. Must be greater than zero.

Operating-Point Parameters

1	<code>vhl (V)</code>	Absolute value of the applied bias across the resistor.
2	<code>vbl (V)</code>	Absolute value of the back-bias across the resistor.
3	<code>ih (A)</code>	DC current into the resistor.
4	<code>r (Ω)</code>	Actual resistance value.
5	<code>pwr (W)</code>	Power.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

`dta` M-5 `r` OP-4 `tcrint1` M-16 `vhl` OP-1

Virtuoso Simulator Components and Device Models Reference

Other Models

ih	OP-3	r0	O-4	tnom	M-4	vp	O-3
l	I-1	rint	M-15	tr	M-2	vpr	M-11
level	M-1	rsh	O-2	tref	M-3	w	I-2
m	I-4	rshr	M-7	trise	M-6	wtol	M-8
nb	I-3	swvp	M-12	vbl	OP-2		
power	M-13	tcr1	M-9	vd	O-1		
pwr	OP-5	tcr2	M-10	vdr	M-14		

BSIM-CMG

This chapter contains the following information about the BSIM-CMG model:

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- [BSIM-CMG Model Equations](#) on page 2852
 - [Bias Independent Calculations](#) on page 2852
 - [Terminal Voltages](#) on page 2855
 - [Short Channel Effects](#) on page 2856
 - [Surface Potential Calculation](#) on page 2857
 - [Drain Saturation Voltage](#) on page 2857
 - [Average Potential and Charge](#) on page 2860
 - [Quantum Mechanical Effects](#) on page 2861
 - [Mobility Degradation and Series Resistance](#) on page 2863
 - [Lateral Non-uniform Doping Model](#) on page 2864
 - [Body Effect Model](#) on page 2864
 - [Output Conductance](#) on page 2864
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Virtuoso Simulator Components and Device Models Reference

BSIM-CMG

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- [Junction Current and Capacitances](#) on page 2879
- [Self-heating Model](#) on page 2879
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- [Model Version Update](#) on page 2881
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Model Overview

BSIM-CMG is a SPICE compact model for modeling the electrical characteristics of common gate MG structures, developed by UC Berkeley.

Physical surface potential-based formulations are derived for both intrinsic and extrinsic models with finite body doping. The surface potentials at the source and drain ends are solved analytically with poly-depletion and quantum mechanical effects. The effect of finite body doping is captured through a perturbation approach. The analytic surface potential solution agrees with 2-D device simulation results well. If the channel doping concentration is low enough to be neglected, computational efficiency can be further improved by setting `COREMOD = 1`.

All the important MG transistor behaviors are captured by this model. Volume inversion is included in the solution of the Poisson's equation, hence the subsequent I-V formulation automatically captures the volume inversion effect. Analysis of the electrostatic potential in the body of MG MOSFETs provided the model equation for the short channel effects (SCE). The extra electrostatic control from the end-gates (top/bottom gates) (triple or quadruple-gate) is also captured in the short channel model.

Users can specify the MG structure of interest via a geometry mode selector (`GEOMOD`, `DG = 0`, `TG = 1`, `QG = 2`, `CG = 3`). Hybrid-surface-orientation mobility, corner-induced effective width reduction, and end-channel-enhanced electrostatic control are considered to address the physics of tri-gate (TG) and quadruple-gate (QG) devices.

BSIM-CMG provides the flexibility to model devices with novel materials. This includes parameters for non-silicon channel devices and High-K/ Metal-gate stack.

Other important effects, such as, mobility degradation, velocity saturation, velocity overshoot, series resistance, channel length modulation, quantum mechanical effects, gate tunneling current, gate-induced-drain-leakage, temperature effects, channel thermal noise, flicker noise, noise associated with device parasitics, and parasitic capacitance, are also incorporated in the model.

BSIM-CMG has been verified with industrial experimental data. The model is continuous and symmetric at $v_{ds} = 0$. This physics-based model is scalable and predictive over a wide range of device parameters.

BSIM-CMG Model Equations

Bias Independent Calculations

Physical constants

Physical quantities in BSIM-CMG are in M.K.S units unless specified otherwise.

$$q = 1.6 \times 10^{-19}$$

$$\epsilon_0 = 8.8542 \times 10^{-12}$$

$$h = 1.05457 \times 10^{-34}$$

$$m_e = 9.11 \times 10^{-31}$$

$$\epsilon_{sub} = EPSRSUB \cdot \epsilon_0$$

$$\epsilon_{ox} = EPSROX \cdot \epsilon_0$$

$$C_{ox} = \frac{3.9 \cdot \epsilon_0}{EOT}$$

$$C_{si} = \frac{\epsilon_{sub}}{TFIN}$$

$$\epsilon_{ratio} = \frac{EPSRSUB}{3.9}$$

Effective Channel Width, Channel Length and Fin Number

$$\Delta L = LINT + \frac{LL}{(L + XL)^{LLN}}$$

$$\Delta LCV = DLC + \frac{LLC}{(L + XL)^{LLN}}$$

$$L_{eff} = L + XL + -2\Delta L$$

$$L_{eff, CV} = L + XL + -2\Delta LCV$$

If BULKMOD=1 and CAPMOD=1 then

$$L_{eff, CV, acc} = L_{eff, CV} - DLCACC$$

If GEOMOD=0 then

$$W_{eff0} = 2 \cdot HFIN - DELTAW$$

$$W_{eff, CV0} = 2 \cdot HFIN - DELTAWCV$$

If GEOMOD=1 then

$$W_{eff0} = 2 \cdot HFIN + FECH \cdot TFIN - DELTAW$$

$$W_{eff, CV0} = 2 \cdot HFIN + FECH \cdot TFIN - DELTAWCV$$

If GEOMOD=2 then

$$W_{eff0} = 2 \cdot HFIN + 2 \cdot FECH \cdot TFIN - DELTAW$$

$$W_{eff, CV0} = 2 \cdot HFIN + 2 \cdot FECH \cdot TFIN - DELTAWCV$$

If GEOMOD=3 then

$$R = \frac{D}{2}$$

$$W_{eff0} = \pi \cdot D - DELTAW$$

$$W_{eff, CV0} = \pi \cdot D - DELTAWCV$$

$$NFIN_{total} = NFIN \times NF$$

Quantum Mechanical Effects

The following bias-independent calculations are for the threshold voltage shift and bias dependence of inversion charge centroid due to quantum mechanical confinement.

If GEOMOD=0 then

$$MT_{cen} = 1 + AQMTCEN \cdot \exp\left(-\frac{TFIN}{BQMTCEN}\right)$$

$$T_{cen0} = TFIN \cdot MT_{cen}$$

If GEOMOD=1 then

$$MT_{cen} = 1 + AQMTCEN \cdot \exp\left(-\frac{\min(HFIN, TFIN)}{BQMTCEN}\right)$$

$$T_{cen0} = \min(HFIN, TFIN) \cdot MT_{cen}$$

If GEOMOD=2 then

$$MT_{cen} = 1 + AQMTCEN \cdot \exp\left(-\frac{\min(HFIN, TFIN)}{BQMTCEN}\right)$$

$$T_{cen0} = \min(HFIN, TFIN) \cdot MT_{cen}$$

If GEOMOD=3 then

$$MTcen = 1 + AQMTCEN \cdot \exp\left(-\frac{R}{BQMTCEN}\right)$$

$$T_{cen0} = R \cdot MTcen$$

Binning Calculations

For given L and NFIN, each model parameter $PARAM_i$ is calculated as a function of PARAM, a length dependent term, LPARAM, a number of fin per finger(NFIN) dependent term, NPARAM, product L x NFIN term, and PPARAM:

$$PARAM_i = PARAM + \frac{1.0e^{-6}}{L_{eff} + DLBIN} \cdot LPARAM + \frac{1.0}{NFIN} \cdot NPARAM + \frac{1.0e^{-6}}{(L_{eff} + DLBIN) \cdot NFIN} \cdot PPARAM$$

Terminal Voltages

Terminal Voltages and V_{dsx} Calculation

$$V_{gs} = V_g - V_s$$

$$V_{gd} = V_g - V_d$$

$$V_{gb} = V_g - V_b$$

$$V_{ds} = V_d - V_s$$

$$V_{dsx} = \sqrt{v_{ds}^2 + 0.01} - 0.1$$

Short Channel Effects

Weighting Function for Forward and Reverse Mode

$$T0 = \tanh(0.6 * q * V_{ds} / kT)$$

$$Wf = 0.5 + 0.5T0$$

$$Wr = 0.5 - 0.5T0$$

Asymmetric Parameters

If ASYMMOD=1 then

$$CDSCDa = CDSCDi * Wf + CDSCDRi * Wr$$

$$ETAa = ETA0i * Wf + ETA0Ri * Wr$$

$$PDIBL1a = PDIBL1i * Wf + PDIBL1Ri * Wr$$

$$PTWGa = PTWG(T) * Wf + PTWGR(T) * Wr$$

$$VSAT1a = VSAT1(T) * Wf + VSAT1R(T) * Wr$$

$$RSDRa = RSDR(T) * Wf + RSDRR(T) * Wr$$

$$RDDRa = RDDR(T) * Wf + RDDRR(T) * Wr$$

Else

All above PARAMa=PARAM and reverse mode parameter PAPAMR are ignored.

Vt Roll-off, DIBL, and Subthreshold Slope Degradation

$$\Delta V_{th, SCE} = -\frac{0.5 \cdot DVT0_i}{\cosh\left(DVT1_i \cdot \frac{Leff}{\lambda}\right) - 1} \cdot (V_{bi} - \Psi_{st})$$

$$\Delta V_{th, DIBL} = -\frac{0.5 \cdot ETA0}{\cosh\left(DSUB_i \cdot \frac{Leff}{\lambda}\right) - 1} \cdot V_{dsx}$$

$$V_{th, RSCE} = K1RSCE_i \cdot \left[\sqrt{1 + \frac{LPE0_i}{Leff}} - 1 \right] \cdot \sqrt{\Psi_{st}}$$

$$\Delta V_{th, all} = \Delta V_{th, SCE} + \Delta V_{th, DIBL} + \Delta V_{th, RSCE} + \Delta V_{th, temp}$$

$$V_{gsfb} = V_{gs} - \Delta q\Phi - \Delta V_{th, all} - DVTHSHIFT$$

Surface Potential Calculation

Surface potentials at the source and drain ends are derived from the Poisson's equation with a perturbation method and computed using the Householder's cubic iteration method. Perturbation allows accurate modeling of finite body doping.

When the body is lightly-doped, a simplified surface potential algorithm can be activated by setting `COREMOD=1` to enhance computational efficiency.

Drain Saturation Voltage

Electric Field Calculations

Electric Field is in MV/cm

If GEOMOD is not equal to 3 then

$$E_{effs} = 10^{-8} \cdot \left(\frac{q_{bs} + \eta \cdot q_{is}}{\varepsilon_{ratio} \cdot EOT} \right)$$

Drain Saturation Voltage (V_{dsat}) Calculations

$$D_{mobs} = \begin{cases} 1 + UA(T) \cdot (E_{effs})^{EU} + \frac{UD(T)}{\left(\frac{1}{2} \cdot \left(1 + \frac{q_{is}}{q_{im, th}} \right) \right)^{UCS(T)}} & \text{BULKMOD=0} \\ 1 + (UA(T) + UC(T) \cdot V_{eseff}) \cdot (E_{effs})^{EU} + \frac{UD(T)}{\left(\frac{1}{2} \cdot \left(1 + \frac{q_{is}}{q_{im, th}} \right) \right)^{UCS(T)}} & \text{BULKMOD=1} \end{cases}$$

$$D_{mobs} = \frac{D_{mobs}}{U0MULT}$$

If RDSMOD=0 then

$$R_{ds, s} = frac1(W_{eff0}(\mu m))^{WR_i} \cdot \left(RDSWMIN(T) + \frac{RDSW(T)}{1 + PRWG_i \cdot q_{is}} \right)$$

If $R_{DSMOD}=1$ then

$$R_{ds,s} = 0$$

$$E_{sat} = \frac{2 \cdot VSAT(T)}{\mu_0(T)/D_{mobs}}$$

$$E_{satL} = E_{sat} \cdot L_{eff}$$

If $R_{ds,s}=0$ then

$$V_{dsat} = \frac{E_{satL} \cdot KSATIV_i \cdot \left(V_{gsfbeff} - \Psi_s + 2 \frac{kT}{q} \right)}{E_{satL} + KSATIV_i \cdot \left(V_{gsfbeff} - \Psi_s + 2 \frac{kT}{q} \right)}$$

Else

$$WVC_{ox} = W_{eff0} \cdot V_{SAT}(T) \cdot C_{ox}$$

$$T_a = 2 \cdot WVC_{ox} \cdot R_{ds,s}$$

$$T_b = KSATV_i \cdot (V_{gsfbeff} - \phi_s + 2kT/q) \cdot (1 + 3 \cdot WVC_{ox} \cdot R_{ds,s}) + E_{satL}$$

$$T_c = KSATV_i \cdot (V_{gsfbeff} - \phi_s + 2kT/q) \cdot (E_{satL} + T_a \cdot KSATV_i \cdot (V_{gsfbeff} - \phi_s + 2kT/q))$$

$$V_{dsat} = \frac{(T_b - \sqrt{T_b^2 - 2T_a T_c})}{T_a}$$

$$V_{dseff} = \frac{V_{ds}}{\left(1 + \left(\frac{V_{ds}}{V_{dsat}}\right)^{MEXP(T)}\right)^{1/MEXP(T)}}$$

Average Potential and Charge

$$\Delta\Psi = \Psi_d - \Psi_s$$

$$q_{ba} = q_{bs}$$

If GEOMOD is not equal to 3 then

If NGATE_i>0 then

$$T_{polyd} = \sqrt{1 + \frac{V_{gsfbeff} - \Psi_d}{V_{poly0}}} - 1$$

$$V_{polyd} = V_{poly0} \cdot T_{polyd}^2$$

else

$$V_{polyd}=0$$

$$q_{id} = \begin{cases} V_{gsfb\text{eff}}^{-\Psi_d} - q_{bm} - V_{polyd} & \text{if } COREMOD = 0 \\ V_{gsfb\text{eff}}^{-\Psi_d} - V_{polyd} & \text{if } COREMOD = 1 \end{cases}$$

$$q_{ia} = 0.5 \cdot (q_{is} + q_{id})$$

$$\Delta q_i = q_{is} - q_{id}$$

Quantum Mechanical Effects

Charge Centroid Calculation

$$T4 = \frac{q_{im} + ETAQM \cdot q_{bm}}{QM0}$$

$$T5 = 1 + T4^{ALPHAQM}$$

$$T_{cen} = \frac{T_{cen0}}{T5}$$

Effective Width Model

If GEOMOD=0 then

$$W_{eff} = W_{eff0}$$

$$W_{eff, CV} = W_{eff, CV0}$$

If GEOMOD=1 then

$$W_{eff} = W_{eff0} - 4 \cdot QMTCENIV_i \cdot T_{cen}$$

$$W_{ef, CV} = W_{eff, CV0} - 4 \cdot QMTCENCV_i \cdot T_{cen}$$

If GEOMOD=2

$$W_{eff} = W_{eff0} - 8 \cdot QMTCENIV_i \cdot T_{cen}$$

$$W_{ef, CV} = W_{eff, CV0} - 8 \cdot QMTCENCV_i \cdot T_{cen}$$

If GEOMOD=3 then

$$W_{eff} = W_{eff0} - 2\pi \cdot QMTCENIV_i \cdot T_{cen}$$

$$W_{eff, CV} = W_{eff0, CV0} - 2\pi \cdot QMTCENCV_i \cdot T_{cen}$$

Effective Oxide Thickness/Effective Capacitance

If QMTCENCV_i is not equal to 0 then

$$C_{ox, eff} = \begin{cases} \frac{3.9 \cdot \epsilon_0}{TOXP \frac{3.9}{EPSROX} + T_{cen} \frac{QMTCENCV_i}{\epsilon_{ratio}}} & GEOMOD \neq 3 \\ \frac{3.9 \cdot \epsilon_0}{R \cdot \left[\frac{1}{\epsilon_{ratio}} \ln\left(\frac{R}{R - T_{cen}}\right) + \frac{3.9}{EPSROX} \ln\left(1 + \frac{T_{exp}}{R}\right) \right]} & GEOMOD = 3 \end{cases}$$

Charge Centroid Calculation for Accumulation

$$C_{ox, acc} = \begin{cases} \frac{3.9 \cdot \epsilon_0}{TOXP \frac{3.9}{EPSROX} + \frac{T_{cen0}}{T6} \frac{QMTCENCVA_i}{\epsilon_{ratio}}} & GEOMOD \neq 3 \\ \frac{3.9 \cdot \epsilon_0}{R \cdot \left[\frac{1}{\epsilon_{ratio}} \ln\left(\frac{R}{R - T_{cen0}/T6}\right) + \frac{3.9}{EPSROX} \ln\left(1 + \frac{T_{exp}}{R}\right) \right]} & GEOMOD = 3 \end{cases}$$

If QMTCENCVi=0 then

$$C_{ox \cdot eff} = C_{ox}$$

$$C_{ox \cdot acc} = \frac{3.9 \cdot \epsilon_0}{EOTACC}$$

Mobility Degradation and Series Resistance

Mobility Degradation

$$\eta = \begin{cases} \frac{1}{2} \cdot ETAMOB_i & NMOS \\ \frac{1}{3} \cdot ETAMOB_i & PMOS \end{cases}$$

$$E_{effa} = 10^{-8} \cdot \left(\frac{q_{ba} + \eta \cdot q_{ia}}{\epsilon_{ratio} \cdot EOT} \right)$$

$$D_{mob} = \begin{cases} 1 + UA(T) \cdot (E_{effa})^{EU} + \frac{UD(T)}{\left(\frac{1}{2} \cdot \left(1 + \frac{q_{ia}}{q_{ba}} \right) \right)^{UCS(T)}} & \mathbf{BULKMOD=0} \\ 1 + (UA(T) + UC(T) \cdot V_{eseff}) \cdot (E_{effa})^{EU} + \frac{UD(T)}{\left(\frac{1}{2} \cdot \left(1 + \frac{q_{ia}}{q_{ba}} \right) \right)^{UCS(T)}} & \mathbf{BULKMOD=1} \end{cases}$$

$$D_{mob} = \frac{D_{mob}}{U0MULT}$$

Lateral Non-uniform Doping Model

$$M_{nud} = \exp\left(-\frac{K0_i}{K0SI_i \cdot q_{ia} + 2.0 \cdot \frac{nkT}{q}}\right)$$

Body Effect Model

$$V_{esx} = V_{es} - 0.5 \cdot (V_{ds} - V_{dsx})$$

$$V_{eseff} = \min(V_{esx}, 0.95 \cdot PHIBE_i)$$

$$dVth_{BE} = \sqrt{PHIBE_i - V_{eseff}} - \sqrt{PHIBE_i}$$

$$M_{ob} = \exp\left(-dVth_{BE} \frac{K1_i + K1SAT_i \cdot V_{dsx}}{K0SI_i \cdot q_{ia} + 2.0 \cdot \frac{nkT}{q}}\right)$$

Output Conductance

Channel Length Modulation

$$C_{clm} = \begin{cases} PCLM_i \cdot (1 + PCLMG_i \cdot q_{ia}) & \text{for } PCLMG > 0 \\ \frac{1}{\frac{1}{PCLM_i} - PCLMG_i \cdot q_{ia}} & \text{for } PCLMG < 0 \end{cases}$$

$$M_{clm} = 1 + \frac{1}{C_{clm}} \ln\left[1 + \frac{V_{ds} - V_{dseff}}{V_{ASAT} + E_{satL}}\right] \cdot C_{clm}$$

Output Conductance due to DBL

$$PVAG_{factor} = \begin{cases} 1 + PVAG_i \cdot \frac{q_{ia}}{E_{sat} L_{eff}} & \text{for } PVAG_i > 0 \\ \frac{1}{1 - PVAG_i \cdot \frac{q_{ia}}{E_{sat} L_{eff}}} & \text{for } PVAG_i < 0 \end{cases}$$

$$\theta_{rout} = \frac{0.5 \cdot PDIBL1_a}{\cosh\left(DROUT_i \cdot \frac{L_{eff}}{\lambda}\right) - 1} + PDIBL2_i$$

$$V_{ADIBL} = \frac{q_{ia} + 2kT/q}{\theta_{rout}} \cdot \left(1 - \frac{V_{dsat}}{V_{dsat} + q_{ia} + 2kT/q}\right) \cdot PVAG_{factor}$$

$$M_{oc} = \left(1 + \frac{V_{ds} - V_{dseff}}{V_{ADIBL}}\right) \cdot M_{clm}$$

Velocity Saturation

Current Degradation Due to Velocity Saturation

$$E_{sat1} = \frac{2 \cdot VSAT1_a \cdot D_{mob}}{\mu_0(T)}$$

$$\delta_{vsat} = DELTAVSAT_i$$

$$D_{vsat} = \frac{1 + \left(\delta_{vsat} + \left(\frac{\Delta q_i}{E_{sat1} L_{eff}} \right)^{PSAT(L)} \right)^{\frac{1}{PSAT(L)}}}{1 + (\delta_{vsat})^{\frac{1}{PSAT(L)}}} + \frac{1}{2} \cdot PTWG_a \cdot q_{ia} \cdot \Delta \phi^2$$

Non-Saturation Effect

$$T_0 = \max \left[\left[A1_i + \frac{A2_i}{q_{ia} + 2.0 \cdot \frac{nkT}{q}} \right] \cdot \Delta q_i^2, -1 \right]$$

$$N_{sat} = \frac{1 + \sqrt{1 + T_0}}{2}$$

$$D_{vsat} = D_{vsat} \cdot N_{sat}$$

Drain Current Model

$$I_{ds} = IDS0MULT \cdot \mu_0(T) \cdot C_{ox} \cdot \frac{W_{eff}}{L_{eff}} \cdot i_{ds0} \cdot \frac{M_{oc} M_{ob} M_{nud}}{D_{vsat} D_r D_{mob}} \times NFIN_{total}$$

Intrinsic Capacitance Model

Channel Length Modulation

$$M_{clm, CV} = 1 + \frac{1}{PCLMCV} \ln \left[1 + \frac{V_{ds} - V_{dseff}}{V_{dsat} + E_{satCVL}} \right] \cdot PCLMCV$$

$$I_{ds, CV} = T1 \cdot \frac{M_{clm, CV}}{D_{r, CV}}$$

Intrinsic (Normalized) Charge

$$q_b = q_{bs}$$

$$q_g = \left[q_{ia} + T0 \cdot \frac{\Delta q_i^2}{12 \cdot i_{ds, CV}} \right] \cdot \frac{1}{M_{clm, CV}} + (M_{clm, CV} - 1) \cdot q_{id}$$

$$q_d = \left[0.5 \cdot q_{ia} - \frac{\Delta q_i}{12} \cdot \left(1 - T1 \frac{\Delta q_i}{30 \cdot i_{ds, CV}} - T2 \frac{\Delta q_i^2}{1260 \cdot i_{ds, CV}^2} \right) \right] \cdot \frac{1}{M_{clm, CV}^2} + \left[M_{clm, CV} - \frac{1}{M_{clm, CV}} \right] \cdot q_{id}$$

Accumulation Charge

If GEOMOD=3 then

$$q_{0, acc} = \frac{2 \cdot kT \cdot r1_{acc}}{q}$$

Terminal Charges

For GEOMOD not equal to 3

$$q_{i, acc} = V_{gsf, beff, ac} - \frac{2kT}{q} [1n(\beta)] - 1n(\cos(\beta)) + F_{1, acc}$$

For GEOMOD=3

$$q_{i, acc} = q_{0, acc} \cdot g$$

Terminal Charges

$$Q_{g, intrinsic} = NFIN_{total} \cdot C_{ox, eff} \cdot W_{eff, CV} \cdot L_{eff, CV} \cdot (q_g)$$

$$Q_{d, intrinsic} = NFIN_{total} \cdot C_{ox, eff} \cdot W_{eff, CV} \cdot L_{eff, CV} \cdot (-q_d)$$

$$Q_{b, intrinsic} = NFIN_{total} \cdot C_{ox, eff} \cdot W_{eff, CV} \cdot L_{eff, CV} \cdot (-q_b)$$

$$Q_{s, intrinsic} = -Q_{g, intrinsic} - Q_{d, intrinsic} - Q_{b, intrinsic}$$

$$Q_{g, acc} = NFIN_{total} \cdot C_{ox, acc} \cdot W_{eff, CV0} \cdot L_{eff, CV} \cdot (-q_{i, acc})$$

$$Q_{b, acc} = NFIN_{total} \cdot C_{ox, acc} \cdot W_{eff, CV0} \cdot L_{eff, CV} \cdot (-q_{i, acc})$$

Parasitic resistances and capacitance models

BSIM-CMG models the parasitic source/drain resistance in two components: a bias dependent extension resistance and a bias independent diffusion resistance. Parasitic gate resistance is modeled as well.

RDSMOD=0 (Internal)

$$R_{source} = R_{s, geo}$$

$$R_{drain} = R_{d, geo}$$

$$R_{ds} = \frac{1}{NFIN_{total} \cdot W_{Ri}} \cdot \left(RDSWMIN(T) + \frac{RDSW(T)}{1 + PRWG_i \cdot q_{ia}} \right)$$

$$D_r = 1.0 + NFIN_{total} \cdot \mu_0(T) \cdot C_{ox} \cdot \frac{W_{eff}}{L_{eff}} \cdot \frac{i_{ds0}}{\Delta q_i} \cdot \frac{R_{ds}}{D_{vsat} \cdot D_{mob}}$$

RDSMOD=1 (External)

$$R_{source} = \frac{1}{W_{eff0} \cdot WR_i \times NFIN_{total}} \cdot \left(RSWMIN(T) + \frac{RSW(T)}{1 + PRWG_i \cdot V_{gs,eff}} \right) + R_{s,geo}$$

$$R_{drain} = \frac{1}{W_{eff0} \cdot WR_i \times NFIN_{total}} \cdot \left(RSWMIN(T) + \frac{RSW(T)}{1 + PRWG_i \cdot V_{gd,eff}} \right) + R_{d,geo}$$

$R_{s,geo}$ and $R_{d,geo}$ are the source and drain diffusion resistances, described as follows:

Sheet Resistance Model

RGEOMOD = 0 (sheet resistance model)

$$R_{s,geo} = NRS \cdot RSHS$$

$$R_{d,geo} = NRD \cdot RSHD$$

Diffusion Resistance Model for Variability Modeling

RGEOMOD=1

$$R_{s,geo} = R_{d,geo} = \frac{R_{rsd} + R_{ext}}{NF} \cdot \left[\frac{R_{GEOA} + R_{GEOB} \times TFIN + R_{GEOC} \times FPITCH}{R_{GEOD} \times LRSD + R_{GEOE} \times HEPI} \right]$$

Gate Electrode Resistance Model

$$R_{geld} = \begin{cases} \frac{RGEXT + RGFIN \cdot NFIN}{3 \cdot NF} & \text{for } NGCON = 1 \\ \frac{RGEXT + RGFIN \cdot NFIN}{12 \cdot NF} & \text{for } NGCON = 2 \end{cases}$$

Bias-dependent Overlap Capacitance Model

The bias-dependent overlap capacitance model in BSIM-CMG is adopted from BSIM4 for CGEOMOD = 0 and CGEOMOD = 2. The overlap charge is given by:

$$\frac{Q_{gs,ov}}{NFIN_{total} \cdot W_{effCV}} = CGSO \cdot V_{gs} + CGSL \cdot \left[V_{gs} - V_{fbsd} - V_{gs,overlap} - \frac{CKAPPAS}{2} X \right] \cdot \left(\sqrt{1 - \frac{4V_{gs,overlap}}{CKAPPAS}} - 1 \right)$$

$$\frac{Q_{gd,ov}}{NFIN_{total} \cdot W_{effCV}} = CGDO \cdot V_{gd} + CGDL \cdot \left[V_{gd} - V_{fbsd} - V_{gd,overlap} - \frac{CKAPPAD}{2} X \right] \cdot \left(\sqrt{1 - \frac{4V_{gd,overlap}}{CKAPPAD}} - 1 \right)$$

Substrate Parasitics

$$C_{sbox} = C_{box} \cdot ASEO + C_{box,sw} \cdot (PSEO - FPITCH \times NFIN_{total})$$

$$C_{dbox} = C_{box} \cdot ADEO + C_{box,sw} \cdot (PDEO - FPITCH \times NFIN_{total})$$

$$C_{box,sw} = CSDESW \cdot 1n \left(1 + \frac{HFIN}{EOTBOX} \right)$$

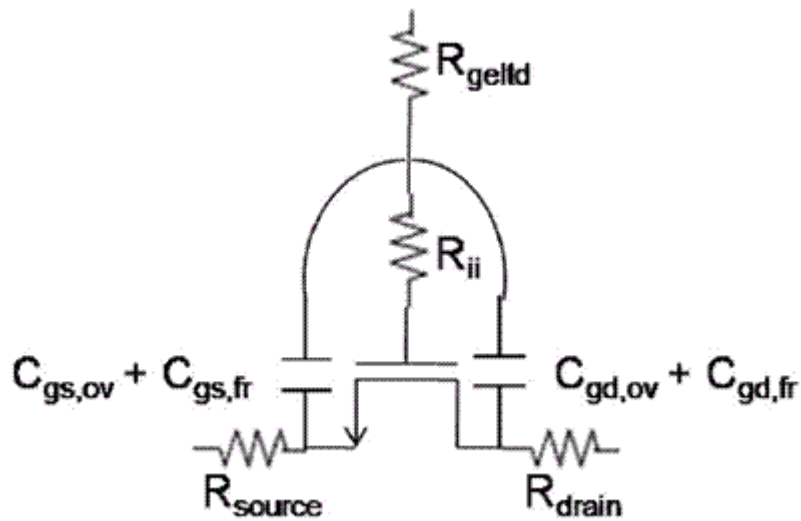
$$C_{ge,overlap,1} = (CGBO \cdot NF + NGCON + CGBN \cdot NFIN_{total}) \cdot L_{eff,CV}$$

Fringe Capacitances and Capacitance Model Selectors

CGEOMOD=0

$$C_{gs,fr} = NFIN_{total} \cdot W_{eff,CV} \cdot CFS_i$$

$$C_{gd,fr} = NFIN_{total} \cdot W_{eff,CV} \cdot CFD_i$$

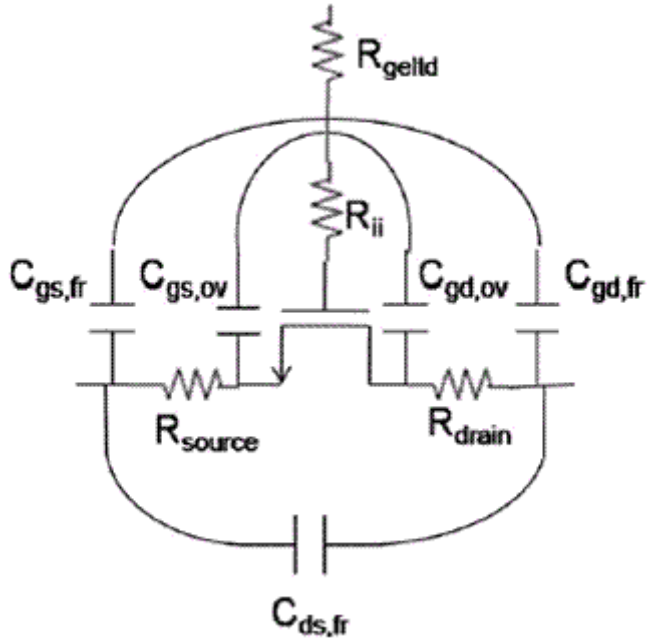


R-C network for CGEOMOD=0, NQSMOD=1, RGATEMOD=1 and RDSMOD=1.

Virtuoso Simulator Components and Device Models Reference

BSIM-CMG

If NQSMOD, RGATEMOD or RDSMOD is 0, then the corresponding resistances become 0 and the nodes collapse.



R-C network for CGEOMOD=1, NQSMOD=1, RGATEMOD=1 and RDSMOD=1.

If NQSMOD, RGATEMOD or RDSMOD is 0, then the corresponding resistances become 0 and the nodes collapse.

CGEOMOD = 1

$$C_{gs,ov} = COVS_i$$

$$C_{gd,ov} = COVD_i$$

$$C_{gs,fr} = CGSP$$

$$C_{gd,fr} = CGDP$$

$$C_{ds,fr} = CDSP$$

In CGEOMOD=2

$$C_{fr, top} = C_{fringe, 2D}(H_g, H_{rsd} \cdot LRSD) \times TFIN \times NFIN$$

$$C_{fr, side} = 2 \times C_{fringe, 2D}(W_g, T_{rsd} \cdot LRSD) \times HFIN \times NFIN$$

$$C_{corner} = \frac{\epsilon_{sp}}{LSP} \cdot [A_{corner} \times HFIN + ARSDEND + ASILIEND]$$

$$C_{fr, geo} = \frac{(C_{corner} + C_{fr, top} + CGEOE \cdot C_{fr, side}) \times NF}{[CGEOA + CGEOB \cdot TFIN + CGEOC \cdot FPITCH + CGEOD \cdot LRSD]}$$

$$C_{fr, top} = \left\{ 3.467 \times 10^{-11} \cdot \ln\left(\frac{EPSRSP \cdot 10^{-7}}{3.9 \cdot LSP}\right) + 0.942 \cdot H_{rsd} \cdot \frac{\epsilon_{sp}}{LSP} \right\} \cdot ([TFIN + (FPITCH - TFIN) \cdot CRATIO] \cdot NFIN)$$

CGEOMOD=0/1/2

$$C_{ds, fr} = CDSP$$

Impact Ionization and GIDL/GISL Model

Impact Ionization Current

I_{ij} can be switched off by setting IIMOD = 0

Case: IIMOD = 1

$$I_{ii} = \frac{ALPHA0_i + ALPHA1_i \cdot L_{eff}}{L_{eff}} (V_{ds} - V_{dseff}) \cdot e^{\frac{BETA0(T)}{V_{ds} - V_{dseff}}} \cdot Ids$$

Case: IIMOD=2

$$I_{ii} = ALPHAI_i \cdot I_{ds} \cdot \exp\left(\frac{V_{diff}}{BETAI2_i + BETAI1_i V_{diff} + BETAI0_i V_{diff}^2}\right)$$

Gate-Induced-Drain/Source-Leakage Current

GIDL/GISL are calculated only for GIDLMOD = 1

$$T0 = AGIDL_i \cdot W_{eff0} \cdot \frac{V_{ds} - V_{fgs} - EGIDL_i + V_{fbsd}}{\epsilon_{ratio} \cdot EOT} \times \exp\left(-\frac{\epsilon_{ratio} \cdot EOT \cdot BGIDL(T)}{V_{ds} - V_{gs} - EGIDL_i + V_{fbsd}}\right) \times NFIN_{total}$$

$$I_{gidl} = \begin{cases} \frac{V_{de}^3}{T0 \cdot CGIDL + V_{de}^3} & BULKMOD = 1 \\ T0 \cdot V_{ds} & BULKMOD=0 \end{cases}$$

$$T1 = AGISL_i \cdot W_{eff0} \cdot \left(\frac{-V_{ds} - V_{gd} - EGISL_i + V_{fbsd}}{\epsilon_{ratio} \cdot EOT}\right)^{PGISL_i} \times \exp\left(-\frac{\epsilon_{ratio} \cdot EOT \cdot BGIDL(T)}{-V_{ds} - V_{gd} - EGIDL_i + V_{fbsd}}\right) NFIN_{total}$$

$$I_{gisl} = \begin{cases} \frac{V_{se}^3}{T1 \cdot CGISL + V_{se}^3} & BULKMOD = 1 \\ T1 \cdot V_{ds} & BULKMOD=0 \end{cases}$$

Gate Tunneling Current

Gate to body current I_{gbinv} and I_{gbacc} is calculated only if $IGBMOD = 1$

$$I_{gbinv} = \frac{W_{eff0} \cdot L_{eff} \cdot A \cdot T_{ox, ratio} \cdot V_{ge} \cdot V_{aux, igbinv} \cdot I_{gtemp} \times NFIN_{total}}{\exp(-B \cdot TOXP \cdot (AIGBINV_i - BIGBINV_i \cdot q_{ia})) \cdot (1 + CIGBINV_i \cdot q_{ia})}$$

$$I_{gbacc} = \frac{W_{eff0} \cdot L_{eff} \cdot A \cdot T_{ox, ratio} \cdot V_{ge} \cdot V_{aux, igbacc} \cdot I_{gtemp} \times NFIN_{total}}{\exp(-B \cdot TOXP \cdot (AIGBINV_i - BIGBINV_i \cdot V_{oxacc})) \cdot (1 + CIGBINV_i \cdot V_{oxacc})}$$

Gate to channel current I_{gc} is calculated only for $IGCMOD = 1$.

$$I_{gcs0} = \frac{W_{eff0} \cdot L_{eff} \cdot A \cdot T_{ox, ratio} \cdot I_{gtemp} \times NFIN_{total} \cdot T0}{\exp(-B \cdot TOXP \cdot (AIGC_i - BIGC_i \cdot V_{oxm})) \cdot (1 + CIGC_i \cdot V_{oxm})}$$

$$I_{gcs} = I_{gcs0} \cdot \frac{PIGCD_i \cdot V_{dseffx} + \exp(PIGCD_i \cdot V_{dseffx}) - 1.0 + 1.0e - 4}{PIGCD_i^2 \cdot V_{dseffx}^2 + 2.0e - 4}$$

$$I_{gcd} = I_{gcs0} \cdot \frac{1.0 - (PIGCD_i \cdot V_{dseffx} + 1.0) + \exp(-PIGCD_i \cdot V_{dseffx}) + 1.0e - 4}{PIGCD_i^2 \cdot V_{dseffx}^2 + 2.0e - 4}$$

Gate to source/drain current I_{gs} , I_{gd} are calculated only for $IGCMOD = 1$

$$i_{gsd, mult} = I_{gtemp} \cdot \frac{W_{eff0} \cdot A}{(TOXP \cdot POXEDGE_i)^2} \left(\frac{TOXREF}{(TOXP \cdot POXEDGE_i)^2} \right)^{NTOXi}$$

$$I_{gs} = \frac{i_{gsd, mult} \cdot DLCIGS \cdot V'_{gs} \times NFIN_{total}}{\exp(-B \cdot TOXP \cdot POXEDGE_i \cdot (AIGS_i - BIGS_i \cdot V'_{gs})) \cdot (1 + CIGS_i \cdot V'_{gs})}$$

$$I_{gd} = \frac{i_{gsd, mult} \cdot DLCIGD \cdot V_{gd} \cdot V'_{gd} X_{NFIN_{total}}}{\exp(-B \cdot TOXP \cdot POXEDGE_i \cdot (AIGS_i - BIGS_i \cdot V'_{gd}) \cdot (1 + CIGS_i \cdot V'_{gd}))}$$

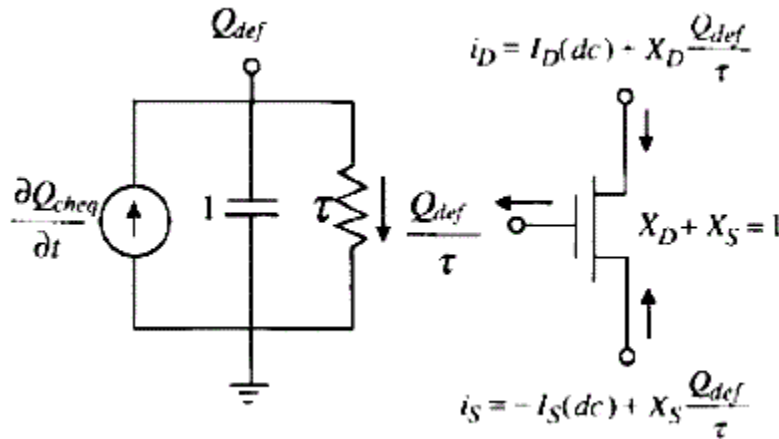
Non Quasi-static Models

This version offers three different non quasi-static (NQS) models. Each of these can be turned on/off using the NQSMOD switch. Setting NQSMOD = 0 turns off all NQS models and switches to plain quasi-static calculations.

Gate Resistance Model (NQSMOD = 1)

$$I_{dovVds} = \mu_0(T) C_{ox} \frac{W_{eff}}{L_{eff}} q_{ia} \frac{M_{oc}}{G_{vsat}}$$

$$\frac{1}{R_{ii}} = \frac{NF}{NFIN} \cdot XRCRG1_i \cdot \left(I_{dovVds} + XRCRG2 \cdot \frac{\mu_{eff} C_{oxe} W_{eff} kT}{qL_{eff}} \right)$$



R-C network for calculating deficient charge Q_{def} and the instantaneous charge, Q_{def}/τ is used in place of the quasi-static charges.

Charge Deficit Model (NQSMOD = 2)

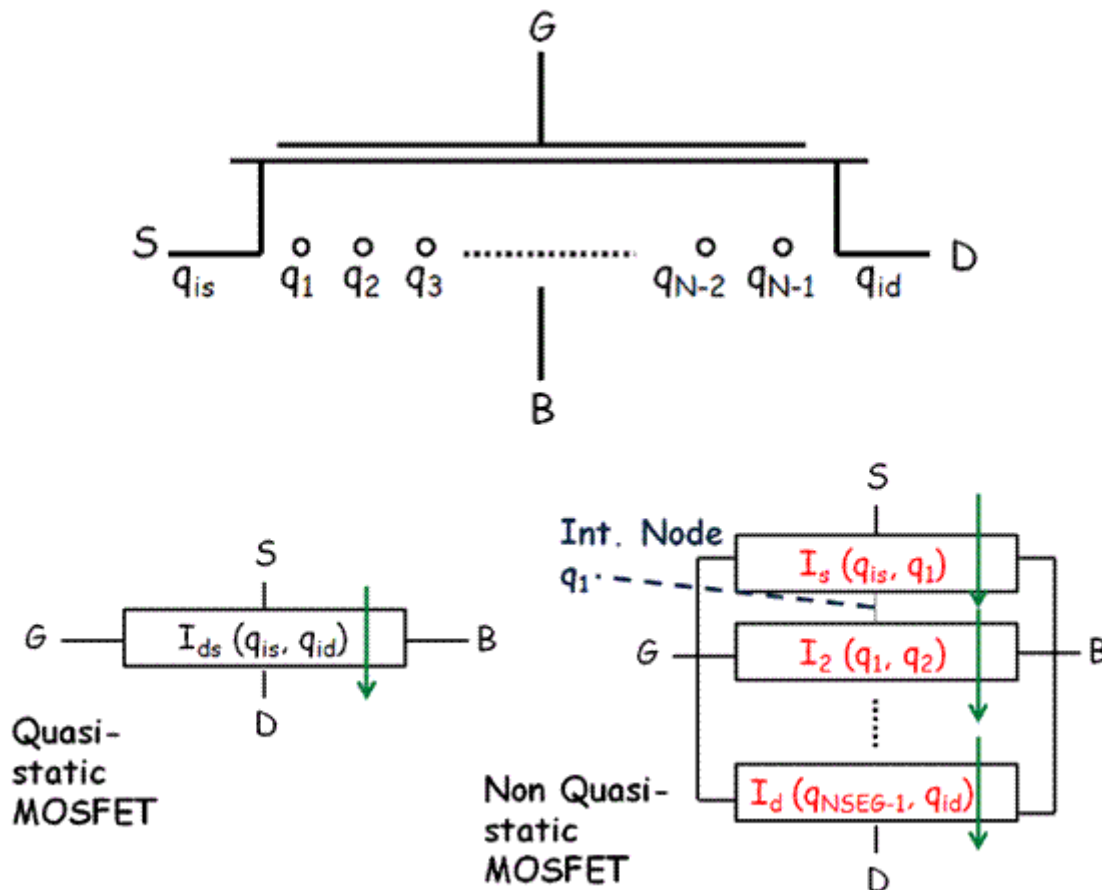
$$X_{d,part} = \frac{q_d}{q_g}$$

$$I_{dovVds} = \mu_0(T) C_{ox} \frac{W_{eff}}{L_{eff}} q_{ia} \frac{M_{oc}}{D_{vsat}}$$

$$\frac{1}{R_{ii}} = \frac{NF}{NFIN} \cdot XRCRG1_i \cdot \left(I_{dovVds} + XRCRG2 \cdot \frac{\mu_{eff} C_{oxe} W_{eff} kT}{qL_{eff}} \right)$$

$$\frac{1}{\tau} = \frac{1}{R_{ii} \cdot C_{ox} \cdot W_{eff} \cdot L_{eff}}$$

Charge Segmentation Model (NQSMOD = 3)



A N-segment charge-segmented MOSFET with N-1 internal nodes.

Note: This model is not supported for COREMOD = 1 && GEOMOD not equal to 3. That is, for double gate and likes together with the simplified surface potential solution.

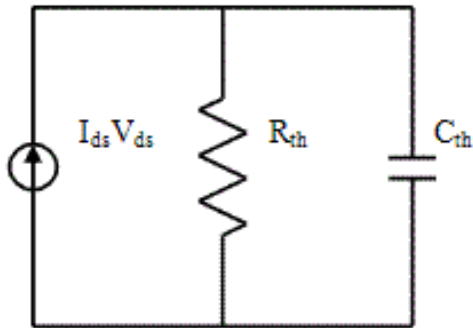
Generation-recombination Component

$$I_{ds, gen} = \frac{HFIN \cdot TFIN \cdot (L_{eff} - LINTIGEN) \cdot (AIGEN_i \cdot V_{ds} + BIGEN_i \cdot V_{ds}^3)}{\exp\left[\frac{qE_g}{NTGEN_i \cdot kT} \left(\frac{T}{TNOM} - 1\right)\right]} \times NFIN_{total}$$

Junction Current and Capacitances

The junction current and capacitances are only calculated for bulk multi-gate devices (BULKMOD = 1).

Self-heating Model



Thermal resistance and capacitance calculations:

$$\frac{1}{R_{th}} = G_{th} = \frac{WTH0 + FPITCH + NFIN_{total}}{RTH0}$$

$$C_{th} = C_{TH0} + (WTH0 + FPITCH \cdot NFIN_{total})$$

Noise Models

Noise models in BSIM-CMG are based on BSIM4. The following table lists the origin of each noise model:

Model in BSIM-CMG105.0 alpha	Origin
Flicker noise model	BSIM4 Unified Model (FNOIMOD=1)
Thermal noise	BSIM4 TNOIMOD=0
Gate current shot noise	BSIM4 gate current noise
Noise associated with parasitic resistances	BSIM4 parasitic resistance noise

Flicker Noise Model

$$S_{si} = \frac{kTq^2 \mu_{eff} I_{ds}}{C_{oxe} L_{eff, noif}^2 \cdot 10^{10}} \cdot FN1 + \frac{kTI_{ds}^2 \Delta L_{clm}}{W_{eff} \cdot NFIN_{total} \cdot L_{eff, noif}^2 \cdot 10^{10}} \cdot FN2$$

$$S_{wi} = \frac{NOIA \cdot kT \cdot I_{ds}^2}{W_{eff} \cdot NFIN_{total} \cdot L_{eff, noif}^2 \cdot 10^{10} \cdot N^{*2}}$$

$$S_{id, flicker} = \frac{S_{wi} S_{si}}{S_{wi} + S_{si}}$$

Thermal noise model (TNOIMOD = 0)

$$Q_{inv} = |Q_{s, intrinsic} + Q_{d, intrinsic}| \times NFIN_{total}$$

$$\overline{i_d^2} = \begin{cases} NTNOI \cdot \frac{4kT\Delta f}{R_{ds} + \frac{L_{eff}^2}{\mu_{eff} Q_{inv}}} & \text{if } RDSMOD = 0 \\ NTNOI \cdot \frac{4kT\Delta f}{L_{eff}^2} \cdot \mu_{eff} Q_{inv} & \text{if } RDSMOD = 1 \end{cases}$$

Gate Current Shot Noise

$$\overline{i_{gs}^2} = 2q(I_{gcs} + I_{gs})$$

$$\overline{i_{gd}^2} = 2q(I_{gcd} + I_{gd})$$

$$\overline{i_{gb}^2} = 2qI_{gbinv}$$

Resistor Noise

The noise associated with each parasitic resistors in BSIM-CMG is calculated.

If RDSMOD = 1 then

$$\overline{\frac{i_{RS}^2}{\Delta f}} = 4kT \cdot \frac{1}{R_{source}}$$

$$\overline{\frac{i_{RD}^2}{\Delta f}} = 4kT \cdot \frac{1}{R_{drain}}$$

If RGATEMOD = 1 then

$$\overline{\frac{i_{RG}^2}{\Delta f}} = 4kT \cdot \frac{1}{R_{g\text{eltd}}}$$

Model Version Update

Version 105.02 Update

- Added binning along NFIN for all the binnable parameters
- Introduced Gate-to-Substrate Bias dependent parasitic capacitance through parameters CGBL and CKAPPA (both binned)
- Introduced a second-step-junction to S-B and D-B diodes through parameters SJS, MJS2, SJSWS, MJSWS2, SJSWGS, MJSWGS2?SJD, MJD2, SJSWD, MJSWD2, SJSWGD, MJSWGD2
- Source/Drain Junction Tunneling Currents have been introduced (Refer to the BSIM4 model for equations, parameters and binning)

Version 105.03 update

- PCLMG, VASAT, ETAMOB have been added to the list of binnable parameters.
- DVTSHIFT parameter introduced as a handle to create Vth shift.

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- All older mobility models replaced with one single new mobility model. The new mobility model uses UA, EU, UD and UCS parameters from MOBMOD=0 of 105.02 release if MOBMOD=1 is used from the previous version.
- New velocity saturation (Ion degradation) model. Parameters VSAT1 (binned), DELTAVSAT replace old parameter THETASAT. This change is not backward compatible.
- RDSMOD=0 implementation changed for better accuracy.
- CLM Model modified to prevent cross-correlation of binning parameters.
- Igb accumulation component added for IGBMOD=1. Available for both BULKMOD=0 and 1.
- Vds asymmetric function changed for better higher order derivative predictivity.
- Accumulation side charge centroid incorporated for better fitting of accumulation capacitance.
- Old parameter ALPHAQM replaced by PQM for the inversion side charge centroid equation.
- Definition of TNOM changed from Kelvin to Celsius to be consistent with BSIM4/BSIMSOI.

Version 105.031 update

- Limited the exponential function in TANH(x) definition
- GIDL Current Model modified for zero current at zero bias.
- Gate Current Model modified, as follows:
 - Default values of BIGBINV, AIGBACC, BIGBACC, NIGBACC changed
 - Gate-to-Channel Current, I_{gcs}/I_{gcd}. Partition function implemented with parameter PIGCD (Binned)
 - Gate Edge Leakage I_{gs} changed
 - Gate Edge Leakage I_{gd} changed
- Removed CLM effect in Charge Model due to wrong implementation.
- Fixed discontinuity in implementation at PCLMG=0 for CLM Model

Version 105.04 update

- Inbuilt tanh() function used instead of $((\exp(x) - \exp(-x))) / (\exp(x) + \exp(-x))$
- GIDL Current Model modified. New parameter PGIDL/PGISL introduced.
- Gate Current Model modified. Equations around BSIM4 parameters NTOX (binned) and TOXREF added
- CLM Model modified.
 - Fixed discontinuity in implementation at PCLMG=0 for CLM Model
 - CLM Model for I-V Modified.
- Parameter VASAT removed. The old equation was known to cause unphysical wiggles.
- ETAMOB binning corrected and linear temperature dependence added with new parameter EMOBT
- Velocity Saturation Model for better Id,sat and Gm,sat fitting
- Parameters DELTAVSAT, DVTSHIFT and KT1 are now binned
- CGEOMOD=0 case; removed QM effects in Fringe Caps
- Drain-to-Source Fringe Cap now available for all CGEOMOD
- Introduced DLCACC parameter for accumulation region capacitance (CAPMOD=1 and BULKMOD=1)
- Velocity Saturation Model for Short Channel C-V introduced. New parameter VSATCV (binned) added
- CLM Model for C-V Modified.
 - MlcmCV factor simplified. Parameters VASATCV and PCLMGCV removed
 - Corrected the wrong implementation of in the charge equations
 - For NQSMOD=3, a simple change has been made
- Added relevant equations for Short Channel CV.
- Parameter NFIN has been converted from integer to real to enable optimization
- Gate-to-Substrate Overlap cap scalability corrected. New parameter CGBN introduced.
- Temperature Dependence for Subthreshold Swing enhanced with new parameter TSS (binned)

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- RDSMOD=1 enhanced to capture quasi-saturation / current crowding for high voltage devices. New parameters RSDR, RDDR, PRSDR, PRDDR introduced and new equations added. Temperature dependence through TRSDR and TRDDR parameters
- Asymmetric Model - ASYMMOD Switch.
 - In order to model highly asymmetric devices, seven parameters identified in the model and their reverse mode equivalents created. These parameters are: CDSCDR, ETA0R, PDIBL1R, PTWGR, VSAT1R, RSDRR, and RDDRR (Original parameters + 'R' in the end)
 - Additional parameter PRWG split into PRWGS and PRWGD for source and drain side in RDSMOD=1
- Some cosmetic changes to Impact Ionization model (especially IIMOD=1), implementing smooth functions
- Body Effect for BULKMOD=1. New parameters introduced: PHIBE, K1, K1ST, K1SAT.
- Removed nVtm in the poly-depletion correction term.
- Changed the value of q from 1.6e-19 to 1.60219e-19 (Coulombs)
- Quantum Mechanical Effects
 - Introduced new parameter QMTCENCVA (binned) to replace QMTCENCV for the accumulation region capacitance;
 - Some bug fixes done for variable 'Tcen' calculations in both inversion and accumulation region
- Introduced Non-saturation effect with new parameters A1 and A2. To be used to improve Id,sat and Gm,sat fitting.
- Lateral NUD Model introduced to create IV-CV Vth shift.

Version 106.0.0 update

BSIMCMG 106.0.0 is the first standard model for FinFETs. It is based on the version 105.031. Following are the changes from its base version:

- Used built-in hyperbolic functions instead of macros
- Added more significant digits to definition of electronic charge
- Fixed usage of parameter "CIT" in noise model

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- Clamped ϕ_{ib} and v_{bi} to positive. Current expressions can be negative with SHMOD=1 at high temperature
- Fixed some typo bugs

Version 106.1.0 update

BSIMCMG 106.1.0 is the second standard model for FinFETs. It is based on the version 105.04. Following are the changes from its base version:

- The definitions of the physical intrinsic capacitances, CEDI and CEEI have been corrected
- Gate resistance model has been corrected
- V_{fbsd} equation for poly and metal gates has been changed
- For `_BINNABLE_` parameters, the bounds are now applied to the "Effective PARAM" (PARAM_i) instead of the root term (PARAM). These include K0SI, DSUB, DVT1, PSAT, and PHIBE.
- The effects of mobility, series resistances, and velocity saturation degradation terms on C-V calculations have been commented out for now (a roll back to BSIM-CMG105.031) to investigate those terms more carefully.
- Effective Channel Length equation has been changed
- Coulomb scattering term has been changed for correct weak-inversion ID-VG slop/behavior
- Threshold voltage definition has been introduced
- Temperature dependence of gate tunneling current has been introduced
- Temperature dependence of the body effect model, lateral non-uniform doping model, and non-saturation effect model has been introduced
- The temperature effect on U0 now affects UTL
- Temperature and length dependence of the impact ionization current has been introduced
- The oxide thickness TOXG is now used in the gate tunneling current, instead of physical oxide thickness TOXP.
- The impact of series resistance on C-V model has been introduced. To enhance the fitting accuracy, a new parameter (correction factor) RCVFAC has been introduced and used in equation for RDSMOD=0.

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- To accurately capture the transition region between subthreshold and strong inversion in I-V when a forward body bias is taken into account, a new model parameter K1SI has been introduced and used in Mob.
- The value of Is (Id) at accumulation region has been clamped at the fixed value of 1.0E-15. In this version, a new model parameter IMIN has been introduced to specify this value.
- NQSMOD=3 has been disabled to perform an offline study
- A more careful examination of the C-V model derivation revealed that 1) dividing the term idscv by Dmob_cv and Dr_CV and 2) multiplying it by MclmCV were implementation mistakes. This has been corrected.
- To enhance the fitting accuracy, two new parameters DELTAVSATCV and PSATCV have been introduced in Dvsat and CV
- When the argument x is too huge, the built-in cosh(x) could cause arithmetic point error due to overflow. To protect the code, for $x > 40$, $0.5/(\cosh(x)-1)$ has been replaced by $\exp(-x)$.
- Gate-induced source and drain leakage current equations have been changed

Version 107.0.0 update

BSIMCMG 107.0.0 is the third standard model for FinFETs. It is based on the version 105.04. Following are the changes from its previous version 106.1.0:

- Lower COVS, COVD; defaults to 0 from 25pF.
- For CGEOMOD=1 only, GEO1SW=1 now enables the parameters COVS, COVD, CGSP, and CGDP to be in F per fin per gate-finger per unit channel width. The default value of the GEO1SW switch is zero.
- New NFIN scaling equations have been added for the following parameters: PHIG, CDSC, CDSCD, CDSCDR, NBODY, VSAT, VSAT1, VSAT1R, ETA0, and U0.
- The length scaling of SCE and SS has been decoupled. The new binnable parameter DVT1SS has been introduced.
- Temperature dependence of DIBL coefficient and Reverse-mode DIBL coefficient has been added. Two new parameters TETA0 and TETA0R have been introduced.
- Long channel DIBL, also called Drain-Induced Vth Shift (DITS) has been added. Two new parameters DVTP0 and DVTP1 have been added.

- The average charge weighing factor has been added through the new parameter `CHARGEWF`.
- Support for the length dependence of the `Gate` workfunction has been added. A new parameters `PHIGL` has been added.
- To be consistent with SOI, RTH and CTH equations in the self-heating sub-model have been updated.
- The initial guess for the surface potential calculation has been improved. The model is now infinitely scalable with respect to `TFIN` and `NBODY` without any clamping on `NBODY`.

Component Statements

This device is supported within altergroups.

Instance Definition

Name `d g s e` ModelName parameter=value ...

Instance Parameters

- | | | |
|---|---------------------------------|--|
| 1 | <code>m=1.0</code> | Multiplicity factor (number of FINFETs in parallel). |
| 2 | <code>l=(30 1.0e-9)</code> | Designed Gate Length. |
| 3 | <code>d=(40 1.0e-9)</code> | Diameter of the cylinder (GEOMOD=3). |
| 4 | <code>tfin=(15 1.0e-9)</code> | Body (Fin) thickness. |
| 5 | <code>fpitch=(80 1.0e-9)</code> | Fin pitch. |
| 6 | <code>nf=1</code> | Number of fingers. |
| 7 | <code>nfin=1.0</code> | Number of fins per finger. |
| 8 | <code>ngcon=1</code> | number of gate contact (1 or 2 sided). |
| 9 | <code>aseo=0</code> | Source to substrate overlap area through oxide. |

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10	adeo=0	Drain to substrate overlap area through oxide.
11	pseo=0	Perimeter of source to substrate overlap region.
12	pdeo=0	Perimeter of drain to substrate overlap region.
13	asej=0	Source junction area (BULKMOD=1).
14	adej=0	Drain junction area (BULKMOD=1).
15	psej=0	Source to substrate PN junction perimeter (BULKMOD=1).
16	pdej=0	Drain to substrate PN junction perimeter (BULKMOD=1).
17	cgsp=0.0	Constant gate-to-source fringe capacitance (CGEOMOD=1).
18	cgdp=0.0	Constant gate-to-drain fringe capacitance (CGEOMOD=1).
19	cdsp=0.0	Constant drain-to-source fringe capacitance (All CGEOMOD).
20	nrs=0.0	Number of source diffusion squares.
21	nrd=0.0	Number of drain diffusion squares.
22	lrsd=(30 1.0e-9)	Length of the source/drain.
23	rsc=0.0	Source contact resistance.
24	rdc=0.0	Drain contact resistance.
25	dtemp=0	Variability in Device Temperature.
26	trise=0	Variability in Device Temperature.
27	delvtrand=0	Variability in Vth.
28	u0mult=1	Variability in carrier mobility.
29	ids0mult=1	Variability in Drain current for misc. reasons.
30	isnoisy=1	Should device generate noise.

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Model Definition

model modelName bsimcmg parameter=value ...

Model Parameters

1	version=105.03	The available versions are 105.01, 105.02, 105.03, 105.031, 105.04, 106.0, 106.1 and 107.0..
2	binunit=1	Bin parameter unit selector. 1 for microns and 2 for meters.
3	l=(30 1.0e-9)	Designed Gate Length.
4	d=(40 1.0e-9)	Diameter of the cylinder (GEOMOD=3).
5	tfin=(15 1.0e-9)	Body (Fin) thickness.
6	fpitch=(80 1.0e-9)	Fin pitch.
7	nfin=1	Number of fins per finger.
8	ngcon=1	number of gate contact (1 or 2 sided).
9	aseo=0	Source to substrate overlap area through oxide.
10	adeo=0	Drain to substrate overlap area through oxide.
11	pseo=0	Perimeter of source to substrate overlap region.
12	pdeo=0	Perimeter of drain to substrate overlap region.
13	asej=0	Source junction area (BULKMOD=1).
14	adej=0	Drain junction area (BULKMOD=1).
15	psej=0	Source to substrate PN junction perimeter (BULKMOD=1).
16	pdej=0	Drain to substrate PN junction perimeter (BULKMOD=1).
17	cgsp=0.0	Constant gate-to-source fringe capacitance (CGEOMOD=1).
18	cgdp=0.0	Constant gate-to-drain fringe capacitance (CGEOMOD=1).

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BSIM-CMG

19	<code>cdsp=0.0</code>	Constant drain-to-source fringe capacitance (CGEOMOD=1).
20	<code>nrs=0.0</code>	Number of source diffusion squares.
21	<code>nrd=0.0</code>	Number of source diffusion squares.
22	<code>lrsd=(30 1.0e-9)</code>	Length of the source/drain.
23	<code>delvtrand=0</code>	Variability in V_{th} .
24	<code>u0mult=1</code>	Variability in carrier mobility.
25	<code>ids0mult=1</code>	Variability in Drain current for misc. reasons.
26	<code>xl=0</code>	L offset for channel length due to mask/etch effect.
27	<code>type=n</code>	Device doping type. pl0: ptype, nl1: ntype. Possible values are p and n.
28	<code>devtype=n</code>	Device doping type(the same usage as type). pl0: ptype, nl1: ntype. Possible values are p and n.
29	<code>bulkmod=0</code>	0: SOI multi-gate, 1: Bulk multi-gate.
30	<code>coremod=0</code>	0: Default surface potential algorithm, 1: Simplified (efficient) surface potential algorithm.
31	<code>geomod=1</code>	structure selector. 0: Double gate, 1: Triple gate, 2: Quadruple gate, 3: Cylindrical gate.
32	<code>mobmod=0</code>	0: BSIM4-based mobility model, 1: PSP-based mobility model.
33	<code>rdsmod=0</code>	Internal s/d resistance model, 1: External s/d resistance model.
34	<code>asymmod=0</code>	0: Asymmetry Model turned off - forward mode parameters used, 1: Asymmetry Model turned on.
35	<code>igcmmod=0</code>	0: Turn off I_{gc} , I_{gs} and I_{gd} , 1: Turn on I_{gc} , I_{gs} and I_{gd} .
36	<code>igbmod=0</code>	0: Turn off I_{gb} , 1: Turn on I_{gb} .
37	<code>gidlmod=0</code>	0: Turn off GIDL/GISL current, 1: Turn on GIDL/GISL current.

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38	<code>iimod=0</code>	0: No impact ionization current, 1: BSIM4-based model, 2: BSIMSOI-based model.
39	<code>nqsmod=0</code>	0: NQS models turned off, 1: NQS gate resistance / gi node turned on, 2: NQS charge deficit model (BSIM4) / q node turned on, 3: //NQS charge segmentation model / Nseg nodes turned on.
40	<code>shmod=0</code>	0: No self-heating, 1: Self-heating turned on.
41	<code>rgatemod=0</code>	0: Gate electrode resistance / ge node turned off, 1: Gate electrode resistance / ge node turned on.
42	<code>rgeomod=0</code>	Geometry-dependent source/drain resistance. 0: RSH-based, 1: Holistic.
43	<code>cgeomod=0</code>	Geometry dependent parasitic capacitance,model selector.
44	<code>capmod=0</code>	0: No accumulation capacitance, 1: Accumulation capacitance included. Available only for BULKMOD = 1.
45	<code>lint=0</code>	Length reduction parameter (dopant diffusion effect).
46	<code>ll=0</code>	Length reduction parameter (dopant diffusion effect).
47	<code>lln=1</code>	Length reduction parameter (dopant diffusion effect).
48	<code>dlc=0</code>	Delta L for C-V model.
49	<code>dlcacc=0</code>	Delta L for C-V model in accumulation region (CAPMOD=1, BULKMOD=1).
50	<code>dlbin=0</code>	Delta L for Binning.
51	<code>llc=0</code>	Length reduction parameter (dopant diffusion effect).
52	<code>eot=(1.0 1.0e-9)</code>	equivalent oxide thickness in meters.
53	<code>toxp=(1.2 1.0e-9)</code>	physical oxide thickness in meter.

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54	<code>eotbox=(140 1.0e-9)</code>	equivalent oxide thickness of the buried oxide (SOI FinFET) or STI (bulk FinFET) in meters.
55	<code>hfin=(30 1.0e-9)</code>	Fin height in meters.
56	<code>fech=1</code>	End-channel factor, for different orientation/shape.
57	<code>deltaw=0</code>	Change of effective width due to shape of fin/cylinder.
58	<code>fechcv=1</code>	CV end-channel factor, for different orientation/shape.
59	<code>deltawcv=0</code>	CV change of effective width due to shape of fin/cylinder.
60	<code>nbody=1e22</code>	channel (body) doping.
61	<code>nsd=2e26</code>	Source/drain active doping concentration in m ⁻³ .
62	<code>phig=4.61</code>	Gate workfunction, eV.
63	<code>epsrox=3.9</code>	Relative dielectric constant of the gate dielectric.
64	<code>epsrsub=11.9</code>	Relative dielectric constant of the channel material.
65	<code>easub=4.05</code>	Electron affinity of substrate, eV.
66	<code>ni0sub=1.1e16</code>	Intrinsic carrier constant at 300.15K, m ⁻³ .
67	<code>bg0sub=1.12</code>	Band gap of substrate at 300.15K, eV.
68	<code>nc0sub=2.86e25</code>	Conduction band density of states, m ⁻³ .
69	<code>ngate=0.0</code>	Parameter for Poly Gate Doping. For metal gate please set NGATE = 0.
70	<code>cit=0.0</code>	parameter for interface trap.
71	<code>cdsc=7e-3</code>	coupling capacitance between S/D and channel.
72	<code>cdscd=7e-3</code>	drain-bias sensitivity of CDS.
73	<code>cdscdr=7e-3</code>	Reverse-mode drain-bias sensitivity of CDSC (Experimental).

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74	dvt0=0.0	SCE exponent coefficient, after binning should be in (0:inf).
75	dvt1=0.60	SCE exponent coefficient.
76	phin=0.05	Nonuniform vertical doping effect on surface potential, V.
77	eta0=0.60	DIBL coefficient.
78	eta0r=0.60	Reverse-mode DIBL coefficient (Experimental).
79	dsub=1.06	DIBL exponent coefficient.
80	k1rsce=0.0	K1 for reverse short channel effect calculation.
81	lpe0=(5.0 1.0e-9)	Equivalent length of pocket region at zero bias.
82	dvtshift=0	Vth shift handle.
83	k0=0.0	Lateral NUD voltage parameter, V.
84	k0si=1.0	Correction factor for strong inversion, used in Mnud, after binning should be from (0:inf).
85	phibe=0.7	Body effect voltage parameter, V, after binning should be from [0.2:1.2].
86	k1=0.0	Body effect coefficient for sub-threshold region.
87	k1si=1.0	Correction factor for strong inversion, used in Mob.
88	k1sat=0.0	Correction factor for K1 in saturation (high Vds).
89	dvtb=0.60	Body effect roll-off coefficient.
90	lpeb=0.0	Lateral non-uniform doping effect on K1.
91	qmfactor=0.0	Prefactor + switch for QM Vth correction.
92	qmtceniv=0.0	Prefactor + switch for QM Width correction for IV.
93	qmtcencv=0.0	Prefactor + switch for QM Width and Toxeff correction for CV.

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94	<code>qmtcencva=0.0</code>	Prefactor + switch for QM Width and Toxeff correction for CV (accumulation region).
95	<code>aqmtcen=0.0</code>	Parameter for Geometric dependence of Tcen on R/TFIN/HFIN.
96	<code>bqmtcen=12.0e-9</code>	Parameter for Geometric dependence of Tcen on R/TFIN/HFIN.
97	<code>etaqm=0.54</code>	Bulk charge coefficient for Tcen.
98	<code>qm0=1.00e-3</code>	Knee-Point for Tcen in inversion (Charge normalized to Cox).
99	<code>pqm=0.66</code>	Slope of normalized Tcen in inversion.
100	<code>qm0acc=1.00e-3</code>	Knee-Point for Tcen in accumulation (Charge normalized to Cox).
101	<code>pqmacc=0.66</code>	Slope of normalized Tcen in accumulation.
102	<code>alphaqm=0.66</code>	Slope of normalized Tcen in strong inversion/accumulation.
103	<code>vsat=85000</code>	Saturation Velocity m/s.
104	<code>avsat=0.0</code>	Length dependence of VSAT.
105	<code>bvsat=100.0e-9</code>	Length dependence of VSAT.
106	<code>vsat1=85000</code>	Velocity Saturation parameter for I_on degradation - forward mode.
107	<code>vsat1r=85000</code>	Velocity Saturation parameter for I_on degradation - reverse mode.
108	<code>avsat1=0.0</code>	
109	<code>bvsat1=100.0e-9</code>	
110	<code>deltavsat=1.0</code>	
111	<code>psat=2.0</code>	Velocity saturation exponent for C-V.
112	<code>apsat=0.0</code>	
113	<code>bpsat=1.0</code>	

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114	<code>ksativ=1.0</code>	parameter for long channel Vdsat.
115	<code>vsatcv=85000</code>	Velocity Saturation parameter for CV.
116	<code>avsatcv=0.0</code>	
117	<code>bvsatcv=100.0e-9</code>	
118	<code>mexp=4</code>	Smoothing function factor for Vdsat.
119	<code>amexp=0.0</code>	Length dependence of MEXP.
120	<code>bmexp=1.0</code>	Length dependence of MEXP.
121	<code>ptwg=0.0</code>	Gmsat degradation parameter - forward mode.
122	<code>ptwgr=0.0</code>	Gmsat degradation parameter - reverse mode.
123	<code>aptwg=0.0</code>	Length dependence of PTWG.
124	<code>bptwg=100.0e-9</code>	Length dependence of PTWG.
125	<code>thetasat=2.0</code>	Velocity saturation parameter.
126	<code>athetasat=0.0</code>	Length dependence of THETASAT.
127	<code>bthetasat=100.0e-9</code>	Length dependence of THETASAT.
128	<code>u0=0.03</code>	Shared: low-field mobility ($m^2/V\cdot s$).
129	<code>etamob=2.0</code>	Effective field parameter.
130	<code>up=0</code>	Shared: Mobility L coefficient (um^LPA).
131	<code>lpa=1.0</code>	Shared: Mobility L power coefficient.
132	<code>ua=0.3</code>	MOD0: Mobility reduction coefficient.
133	<code>aua=0.0</code>	MOD0: Length dependence of UA.
134	<code>bua=100.0e-9</code>	Length dependence of UA.

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135	$uc=0.0$	Body effect for mobility degradation parameter - BULKMOD=1.
136	$eu=2.5$	MOD0: Mobility reduction exponent.
137	$aeu=0.0$	
138	$beu=100.0e-9$	
139	$ud=0.0$	MOD0: Coulomb scattering parameter.
140	$aud=0.0$	MOD0: Length dependence of UD.
141	$bud=50.0e-9$	Length dependence of UD.
142	$ucs=1.0$	MOD0: Coulomb scattering parameter.
143	$mue=1.2$	MOD1: Mobility reduction coefficient.
144	$thetamu=1.0$	MOD1: Mobility reduction exponent.
145	$athetamu=0.0$	MOD1: Length dependence of THETAMU.
146	$bthetamu=100.0e-9$	Length dependence of THETAMU.
147	$cs=0$	MOD1: Coulomb scattering parameter.
148	$acs=0.0$	MOD1: Length dependence of CS.
149	$bcs=50.0e-9$	Length dependence of CS.
150	$pclm=0.013$	CLM prefactor.
151	$apclm=0.0$	Length dependence of PCLM.
152	$bpclm=100.0e-9$	Length dependence of PCLM.
153	$pclmg=0.0$	CLM prefactor gate voltage dependence.
154	$vasat=0.2$	CLM log dependence parameter.
155	$pclmcv=0.013$	CLM parameter for Short Channel CV.

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156	<code>pclmgcv=0.0</code>	CLM prefactor gate voltage dependence.
157	<code>vasatcv=0.2</code>	CLM log dependence parameter.
158	<code>a1=0.0</code>	Non-saturation effect parameter for strong inversion region.
159	<code>a2=0.0</code>	Non-saturation effect parameter for moderate inversion region.
160	<code>rdswmin=0.0</code>	S/D extension resistance per unit width at high V_{gs} , $\text{ohm}(\mu\text{m})^{WR}$.
161	<code>rdsw=100.0</code>	zero bias S/D extension resistance per unit width, $\text{ohm}(\mu\text{m})^{WR}$.
162	<code>ardsw=0.0</code>	Geometrical scaling of RDSW.
163	<code>brdsw=100.0e-9</code>	Geometrical scaling of RDSW.
164	<code>rswmin=0.0</code>	Source Resistance for RDSMOD=1.
165	<code>rsw=50.0</code>	zero bias Source Resistance for RDSMOD=1.
166	<code>arsw=0.0</code>	Geometrical scaling of RSW.
167	<code>brsw=100.0e-9</code>	Geometrical scaling of RSW.
168	<code>rdwmin=0.0</code>	Drain Resistance for RDSMOD=1.
169	<code>rdw=50.0</code>	zero bias Drain Resistance for RDSMOD=1.
170	<code>ardw=0.0</code>	Geometrical scaling of RDW.
171	<code>brdw=100.0e-9</code>	Geometrical scaling of RDW.
172	<code>prwg=0</code>	gate bias dependence of S/D extension resistance, V-1.
173	<code>rsdr=0.0</code>	Source side drift resistance parameter - forward mode.
174	<code>rsdrr=0.0</code>	Source side drift resistance parameter - reverse mode.
175	<code>rddr=0.0</code>	Drain side drift resistance parameter - forward mode.
176	<code>rddrr=0.0</code>	Drain side drift resistance parameter - reverse mode.

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177	<code>prsd=1.0</code>	Source side quasi-saturation parameter.
178	<code>prdd=1.0</code>	Drain side quasi-saturation parameter.
179	<code>prwgs=0.0</code>	Gate bias dependence of source extension resistance, Units:V ⁻¹ .
180	<code>prwgd=0.0</code>	Gate bias dependence of drain extension resistance, Units:V ⁻¹ .
181	<code>wr=1.0</code>	W dependence parameter of S/D extension resistance.
182	<code>trsd=0.0</code>	
183	<code>trdd=0.0</code>	
184	<code>rgext=0.0</code>	Effective gate electrode external resistance.
185	<code>rgfin=1.0e-3</code>	Effective gate electrode per finger per fin resistance.
186	<code>rshs=0.0</code>	Source-side sheet resistance.
187	<code>rshd=0.0</code>	Drain-side sheet resistance.
188	<code>hepi=(10.0 1.0e-9)</code>	Height of the raised source/drain on top of the fin.
189	<code>tsili=(10.0 1.0e-9)</code>	Thickness of the silicide on top of the raised source/drain.
190	<code>rhoc=1.0e-12</code>	Contact resistivity at the silicon/silicide interface.
191	<code>rhorsd=1.0</code>	Average resistivity of silicon in the raised source/drain region.
192	<code>rhoext=1.0</code>	Average resistivity of silicon in the fin extension region.
193	<code>cratio=0.5</code>	Ratio of the corner area filled with silicon to the total corner area.
194	<code>deltaprsd=0.0</code>	Change in silicon/silicide interface length due to non-rectangular epi.
195	<code>sdterm=0</code>	Indicator fo whether the source/drain are terminated with silicide.
196	<code>lsp=(6 1.0e-9)</code>	Thickness of the gate sidewall spacer.

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197	$ldg=5.0e-9$	Lateral diffusion gradient in the fin extension region.
198	$epsrsp=3.9$	Relative dielectric constant of the spacer.
199	$tgate=(30.0\ 1.0e-9)$	Gate height on top of the hard mask.
200	$tmask=(30.0\ 1.0e-9)$	Height of hard mask on top of the fin.
201	$asiliend=0.0$	Extra silicide cross sectional area at the two ends of the FinFET.
202	$arsdend=0.0$	Extra raised source/drain cross sectional area at the two ends of the FinFET.
203	$prsdend=0.0$	Extra silicon/silicide interface perimeter at the two ends of the FinFET.
204	$nsde=2e25$	Source/drain active doping concentration at Leff edge.
205	$rgeoa=1.0$	Fitting parameter for RGEOMOD=1.
206	$rgeob=0.0$	Fitting parameter for RGEOMOD=1.
207	$rgeoc=0.0$	Fitting parameter for RGEOMOD=1.
208	$rgeod=0.0$	Fitting parameter for RGEOMOD=1.
209	$rgeoe=0.0$	Fitting parameter for RGEOMOD=1.
210	$cgeoa=1.0$	Fitting parameter for CGEOMOD=2.
211	$cgeob=0.0$	Fitting parameter for CGEOMOD=2.
212	$cgeoc=0.0$	Fitting parameter for CGEOMOD=2.
213	$cgeod=0.0$	Fitting parameter for CGEOMOD=2.
214	$cgeoe=1.0$	Fitting parameter for CGEOMOD=2.
215	$pdibl1=1.30$	DIBL Output Conductance parameter - forward mode.
216	$pdibl1r=1.30$	DIBL Output Conductance parameter - reverse mode.

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217	$p_{dibl2}=2.0e-4$	DIBL Output Conductance parameter.
218	$drout=1.06$	L dependence of DIBL effect on R_{out} .
219	$pvag=1.0$	V_g dependence on early voltage.
220	$a_{igbinv}=1.11e-2$	parameter for I_{gb} in inversion.
221	$b_{igbinv}=9.49e-4$	parameter for I_{gb} in inversion.
222	$c_{igbinv}=6.00e-3$	parameter for I_{gb} in inversion.
223	$e_{igbinv}=1.1$	parameter for I_{gb} in inversion.
224	$n_{igbinv}=3.0$	parameter for I_{gb} in inversion.
225	$a_{igbacc}=1.36e-2$	parameter for I_{gb} in accumulation.
226	$b_{igbacc}=1.71e-3$	parameter for I_{gb} in accumulation.
227	$c_{igbacc}=7.5e-2$	parameter for I_{gb} in accumulation.
228	$n_{igbacc}=1.0$	parameter for I_{gb} in accumulation.
229	$a_{igc}=1.36e-2$	parameter for I_{gc} in inversion.
230	$b_{igc}=1.71e-3$	parameter for I_{gc} in inversion.
231	$c_{igc}=0.075$	parameter for I_{gc} in inversion.
232	$n_{igc}=1.0$	parameter for I_{gc} in inversion.
233	$p_{igcd}=1.0$	parameter for I_{gc} partition.
234	$dlcigs=0$	Delta L for I_{gs} model.
235	$a_{igs}=1.36e-2$	parameter for I_{gs} in inversion.
236	$b_{igs}=1.71e-3$	parameter for I_{gs} in inversion.
237	$c_{igs}=0.075$	parameter for I_{gs} in inversion.
238	$dlcigd=0$	Delta L for I_{gd} model.

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239	$aigd=1.36e-2$	parameter for I_{gd} in inversion.
240	$bigd=1.71e-3$	parameter for I_{gd} in inversion.
241	$cigd=0.075$	parameter for I_{gd} in inversion.
242	$toxref=(1.2 \ 1.0e-9)$	Target tox value [m].
243	$ntox=1.0$	Exponent for Tox ratio.
244	$poxedge=1.0$	Factor for the gate edge Tox.
245	$agisl=(6.055 \ 1.0e-12)$	pre-exponential coeff. for GISL in mho.
246	$bgisl=0.3e9$	exponential coeff. for GISL in V/m.
247	$cgisl=0.5$	parameter for body-effect of GISL in V^3 .
248	$egisl=0.2$	band bending parameter for GISL in V.
249	$pgisl=1.0$	parameter for body-bias effect on GISL.
250	$agidl=(6.055 \ 1.0e-12)$	pre-exponential coeff. for GIDL in mho.
251	$bgidl=0.3e9$	exponential coeff. for GIDL in V/m.
252	$cgidl=0.5$	parameter for body-effect of GIDL in V^3 .
253	$egidl=0.2$	band bending parameter for GIDL in V.
254	$pgidl=1.0$	parameter for body-bias effect on GIDL.
255	$alpha0=0.0$	first parameter of I_{ii} , m/V.
256	$alpha1=0.0$	L scaling parameter of I_{ii} , 1/V.
257	$beta0=0.0$	V_{ds} dependent parameter of I_{ii} , 1/V.
258	$alphaii=0.0$	Pre-exponential Constant of I_{ii} .

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259	<code>betaii0=0.0</code>	Vds dependent parameter of lii, 1/V.
260	<code>betaii1=0.0</code>	Vds dependent parameter of lii.
261	<code>betaii2=0.1</code>	Vds dependent parameter of lii, V.
262	<code>esatii=1.0e7</code>	Saturation channel E-Field for lii, V/m.
263	<code>lii=0.5E-9</code>	Channel length dependent parameter of lii, V-m.
264	<code>sii0=0.5</code>	Vgs dependent parameter of lii, 1/V.
265	<code>sii1=0.1</code>	1st Vgs dependent parameter of lii, 1/V.
266	<code>sii2=0.0</code>	2nd Vgs dependent parameter of lii.
267	<code>siid=0.0</code>	3rd Vds dependent parameter of lii, 1/V.
268	<code>eotacc=(1.0 1.0e-9)</code>	equivalent oxide thickness for accumulation region in meters.
269	<code>delvfbacc=0.0</code>	Change in Flatband Voltage; Vfb_accumulation-Vfb_inversion.
270	<code>cfs=2.5e-11</code>	Outer Fringe Cap (source side).
271	<code>dfd=2.5e-11</code>	Outer Fringe Cap (drain side).
272	<code>covs=2.5e-11</code>	Constant g/s overlap capacitance.
273	<code>covd=2.5e-11</code>	Constant g/d overlap capacitance.
274	<code>cgso=0.0</code>	Non LDD region source-gate overlap capacitance per unit channel width.
275	<code>cgdo=0.0</code>	Non LDD region drain-gate overlap capacitance per unit channel width.
276	<code>cgsl=0.0</code>	Overlap capacitance between gate and lightly-doped source region(for GEOMOD = 0, 2).
277	<code>cgdl=0.0</code>	Overlap capacitance between gate and lightly-doped drain region(for GEOMOD = 0, 2).

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278	$ckappas=0.6$	Coefficient of bias-dependent overlap capacitance for the source side(for CGEOMOD = 0, 2).
279	$ckappad=0.6$	Coefficient of bias-dependent overlap capacitance for the drain side(for CGEOMOD = 0, 2).
280	$cgbo=0.0$	Gate to substrate overlap cap per unit channel length per finger per NGCON.
281	$cgbn=0.0$	Gate to substrate overlap cap per unit channel length per fin per finger.
282	$cgb1=0.0$	Bias dependent component of Gate to substrate overlap cap per unit channel length per fin per finger.
283	$ckappab=0.6$	Coefficient for gate to substrate bias-dependent overlap capacitance(for BULKMOD = 1).
284	$csdesw=0.0$	Coefficient for source/drain to substrate sidewall cap.
285	$cjs=5.0e-4$	Unit area source-side junction capacitance at zero bias.
286	$cjd=5.0e-4$	Unit area drain-side junction capacitance at zero bias.
287	$cjsws=5.0e-10$	Unit length source-side sidewall junction capacitance at zero bias.
288	$cjswd=5.0e-10$	Unit length drain-side sidewall junction capacitance at zero bias.
289	$cjswgs=0.0$	Unit length source-side gate sidewall junction capacitance at zero bias.
290	$cjswgd=0.0$	Unit length drain-side gate sidewall junction capacitance at zero bias.
291	$pbs=1.0$	Source-side bulk junction built-in potential.
292	$pbd=1.0$	Drain-side bulk junction built-in potential.
293	$pbsws=1.0$	Built-in potential for Source-side sidewall junction capacitance.
294	$pbswd=1.0$	Built-in potential for Drain-side sidewall junction capacitance.

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295	$pbswgs=1.0$	Built-in potential for Source-side gate sidewall junction capacitance.
296	$pbswg\bar{d}=1.0$	Built-in potential for Drain-side gate sidewall junction capacitance.
297	$mjs=0.5$	Source bottom junction capacitance grading coefficient.
298	$mjd=0.5$	Drain bottom junction capacitance grading coefficient.
299	$mjsws=0.33$	Source sidewall junction capacitance grading coefficient.
300	$mjsw\bar{d}=0.33$	Drain sidewall junction capacitance grading coefficient.
301	$mjswgs=0.33$	Source-side gate sidewall junction capacitance grading coefficient.
302	$mjswg\bar{d}=0.33$	Drain-side gate sidewall junction capacitance grading coefficient.
303	$sjs=0.0$	Constant for source-side two-step second junction capacitance.
304	$sjd=0.0$	Constant for drain-side two-step second junction capacitance.
305	$sjsws=0.0$	Constant for sidewall two-step second junction capacitance(source-side).
306	$sjsw\bar{d}=0.0$	Constant for sidewall two-step second junction capacitance(drain-side).
307	$sjswgs=0.0$	Constant for gate sidewall two-step second junction capacitance(source-side).
308	$sjswg\bar{d}=0.0$	Constant for gate sidewall two-step second junction capacitance(drain-side).
309	$mjs2=0.125$	Source bottom two-step second junction capacitance grading coefficient.
310	$mjd2=0.125$	Drain bottom two-step second junction capacitance grading coefficient.
311	$mjsws2=0.083$	Isolation-edge sidewall two-step second junction capacitance grading coefficient(source-side).

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312	$mj_{swd2}=0.083$	Isolation-edge sidewall two-step second junction capacitance grading coefficient(drain-side).
313	$mj_{swgs2}=0.083$	Gate-edge sidewall two-step second junction capacitance grading coefficient(source-side).
314	$mj_{swgd2}=0.083$	Gate-edge sidewall two-step second junction capacitance grading coefficient(drain-side).
315	$j_{ss}=1.0e-4$	Bottom source junction reverse saturation current density.
316	$j_{sd}=1.0e-4$	Bottom drain junction reverse saturation current density.
317	$j_{sws}=0.0$	Unit length reverse saturation current for sidewall source junction.
318	$j_{swd}=0.0$	Unit length reverse saturation current for sidewall drain junction.
319	$j_{swgs}=0.0$	Unit length reverse saturation current for gate-edge sidewall source junction.
320	$j_{swgd}=0.0$	Unit length reverse saturation current for gate-edge sidewall drain junction.
321	$n_{js}=1.0$	Source junction emission coefficient.
322	$n_{jd}=1.0$	Drain junction emission coefficient.
323	$ij_{thsfwd}=0.1$	Forward source diode breakdown limiting current.
324	$ij_{thdfwd}=0.1$	Forward drain diode breakdown limiting current.
325	$ij_{thsrev}=0.1$	Reverse source diode breakdown limiting current.
326	$ij_{thdrev}=0.1$	Reverse drain diode breakdown limiting current.
327	$b_{vs}=10.0$	Source diode breakdown voltage.
328	$b_{vd}=10.0$	Drain diode breakdown voltage.
329	$x_{jbvs}=1.0$	Fitting parameter for source diode breakdown current.
330	$x_{jbvd}=1.0$	Fitting parameter for drain diode breakdown current.

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331	$j_{tss}=0.0$	Bottom source junction trap-assisted saturation current density.
332	$j_{t\bar{s}d}=0.0$	Bottom drain junction trap-assisted saturation current density.
333	$j_{tssws}=0.0$	Unit length trap-assisted saturation current for isolation-edge source side-wall junction.
334	$j_{tssw\bar{d}}=0.0$	Unit length trap-assisted saturation current for isolation-edge drain side-wall junction.
335	$j_{tsswgs}=0.0$	Unit length trap-assisted saturation current for gate-edge source sidewall junction.
336	$j_{tsswgd}=0.0$	Unit length trap-assisted saturation current for gate-edge drain sidewall junction.
337	$j_{tw\text{eff}}=0.0$	Trap-assisted tunneling current width dependence.
338	$n_{jts}=20.0$	Non-ideality factor for JTSS.
339	$n_{jt\bar{s}d}=20.0$	Non-ideality factor for JTSD.
340	$n_{jtssw}=20.0$	Non-ideality factor for JTSSWS.
341	$n_{jtssw\bar{d}}=20.0$	Non-ideality factor for JTSSWD.
342	$n_{jtsswgs}=20.0$	Non-ideality factor for JTSSWGS.
343	$n_{jtsswgd}=20.0$	Non-ideality factor for JTSSWGD.
344	$v_{tss}=10.0$	Bottom source junction trap-assisted current voltage dependent parameter.
345	$v_{t\bar{s}d}=10.0$	Bottom drain junction trap-assisted current voltage dependent parameter.
346	$v_{tssws}=10.0$	Unit length trap-assisted current voltage dependent parameter for isolation-edge source sidewall junction.
347	$v_{tssw\bar{d}}=10.0$	Unit length trap-assisted current voltage dependent parameter for isolation-edge drain sidewall junction.

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348	<code>vtsswgs=10.0</code>	Unit length trap-assisted current voltage dependent parameter for gate-edge source sidewll junction.
349	<code>vtsswgd=10.0</code>	Unit length trap-assisted current voltage dependent parameter for gate-edge drain sidewll junction.
350	<code>lintigen=0</code>	Lint for Thermal Generation Current.
351	<code>ntgen=1.0</code>	Thermal Generation Current Parameter.
352	<code>aigen=0</code>	Thermal Generation Current Parameter.
353	<code>bigen=0</code>	Thermal Generation Current Parameter.
354	<code>xrcrg1=12.0</code>	Parameter for non quasi-static gate resistance NQSMOD = 1 and NQSMOD = 2.
355	<code>xrcrg2=1.0</code>	Parameter for non quasi-static gate resistance NQSMOD = 1 and NQSMOD = 2.
356	<code>nseg=4</code>	Number of segments for NQSMOD=3 (3,5 & 10 supported).
357	<code>ef=1.0</code>	Flicker Noise frequency exponent.
358	<code>em=4.1e7</code>	Flicker noise parameter.
359	<code>noia=6.250e+39</code>	Flicker noise parameter.
360	<code>noib=3.125e+24</code>	Flicker noise parameter.
361	<code>noic=8.750e+07</code>	Flicker noise parameter.
362	<code>ntnoi=1.0</code>	Thermal noise parameter.
363	<code>tnom=27.0</code>	Temperature at which the model is extracted (Kelvin).
364	<code>tbgasub=7.02e-4</code>	Bandgap Temperature Coefficient(eV / degrees).
365	<code>tbgbsub=1108.0</code>	Bandgap Temperature Coefficient(degrees).
366	<code>kt1=0.0</code>	Vth Temperature Coefficient (V).
367	<code>kt1l=0.0</code>	Vth Temperature L Coefficient (m-V).

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368	$t_{ss}=0.0$	SSwing Temperature Coefficient (/ degrees).
369	$u_{te}=0.0$	Mobility Temperature Coefficient.
370	$u_{t1}=(-1.5e-3)$	Mobility Temperature Coefficient.
371	$emob_{t}=0.0$	
372	$u_{a1}=1.032e-3$	Mobility Temperature Coefficient.
373	$u_{c1}=0.056e-9$	
374	$u_{d1}=0.0$	Mobility Temperature Coefficient.
375	$u_{cste}=(-4.775e-3)$	Mobility Temperature Coefficient.
376	$st_{thetamu}=1.5$	Mobility Temperature Coefficient.
377	$stmue=0.0$	Mobility Temperature Coefficient.
378	$stcs=0.0$	Mobility Temperature Coefficient.
379	$at=(-1.56e-3)$	Saturation Velocity Temperature Coefficient.
380	$tmexp=0.0$	Temperature coefficient for V_{dseff} .
381	$ptwgt=0.004$	Temperature dependence of PTWG.
382	$st_{thetasat}=0.0217$	Saturation Velocity Temperature Coefficient.
383	$prt=0.001$	Series Resistance Temperature Coefficient.
384	$iit=(-0.5)$	Impact Ionization Temperature Dependence, IIMOD=1.
385	$tii=0.0$	Impact Ionization Temperature Dependence, IIMOD=2.
386	$tgidl=(-0.003)$	GIDL/GISL Temperature Dependence.
387	$igt=2.5$	Gate Current Temperature Dependence.
388	$tcj=0.0$	Temperature coefficient for CJS/CJD.

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389	$t_{cjsw}=0.0$	Temperature coefficient for CJSWS/CJSWD.
390	$t_{cjswg}=0.0$	Temperature coefficient for CJSWGS/CJSWGD.
391	$t_{pb}=0.0$	Temperature coefficient for PBS/PBD.
392	$t_{pbsw}=0.0$	Temperature coefficient for PBSWS/PBSW.
393	$t_{pbswg}=0.0$	Temperature coefficient for PBSWGS/PBSWGD.
394	$x_{tis}=3.0$	Source junction current temperature exponent.
395	$x_{tid}=3.0$	Drain junction current temperature exponent.
396	$x_{tss}=0.02$	Power dependence of JTSS on temperature.
397	$x_{tstd}=0.02$	Power dependence of JTSD on temperature.
398	$x_{tssws}=0.02$	Power dependence of JTSSWS on temperature.
399	$x_{tsswd}=0.02$	Power dependence of JTSSWG on temperature.
400	$x_{tsswgs}=0.02$	Power dependence of JTSSWGS on temperature.
401	$x_{tsswgd}=0.02$	Power dependence of JTSSWGD on temperature.
402	$t_{njts}=0.0$	Temperature coefficient for NJTS.
403	$t_{njtstd}=0.0$	Temperature coefficient for NJTSD.
404	$t_{njtssw}=0.0$	Temperature coefficient for NJTSSW.
405	$t_{njtsswd}=0.0$	Temperature coefficient for NJTSSWD.
406	$t_{njtsswg}=0.0$	Temperature coefficient for NJTSSWG.
407	$t_{njtsswgd}=0.0$	Temperature coefficient for NJTSSWGD.
408	$r_{th0}=0.01$	Thermal resistance for self-heating calculation.
409	$c_{th0}=1.0E-05$	Thermal capacitance for self-heating calculation.
410	$w_{th0}=0.0$	Width-dependence coefficient for self-heating calculation.

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411	<code>toxg=(1.2 1.0e-9)</code>	oxide thickness for gate current model in meters.
412	<code>k01=0.0</code>	Temperature dependence of lateral NUD voltage parameter, V.
413	<code>k0si1=0.0</code>	Temperature dependence of K0SI, 1/K.
414	<code>k1si1=0.0</code>	Temperature dependence of K1SI, 1/K.
415	<code>k11=0.0</code>	Temperature dependence of K1.
416	<code>k1sat1=0.0</code>	Temperature dependence of K1SAT1.
417	<code>rcvfac=1.0</code>	Series resistance correction factor for CV.
418	<code>a11=0.0</code>	Temperature dependence of A1.
419	<code>a21=0.0</code>	Temperature dependence of A2.
420	<code>aigbinv1=0</code>	parameter for Igb in inversion.
421	<code>aigbacc1=0</code>	parameter for Igb in accumulation.
422	<code>aigc1=0</code>	parameter for Igc in inversion.
423	<code>aigs1=0</code>	parameter for Igs in inversion.
424	<code>aigd1=0</code>	parameter for Igd in inversion.
425	<code>alpha01=0.0</code>	Temperature dependence of ALPHA0, m/V/degrees.
426	<code>alpha11=0.0</code>	Temperature dependence ALPHA1, 1/V/degree.
427	<code>alphaii0=0.0</code>	first parameter of Iii for IIMOD=2, m/V.
428	<code>alphaii01=0.0</code>	Temperature dependence of ALPHAII0, m/V/degrees.
429	<code>alphaii1=0.0</code>	L scaling parameter of Iii for IIMOD=2, 1/V.
430	<code>alphaii11=0.0</code>	Temperature dependence of ALPHAII1, 1/V/degrees.
431	<code>imin=1.0E-15</code>	Parameter for Vgs Clamping for inversion region calc. in accumulation.

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432	deltavsatcv=1.0	
433	psatcv=2.0	Velocity saturation exponent for C-V.
434	apsatcv=0.0	
435	bpsatcv=1.0	
436	cgeo1sw=0	For CGEOMOD=1 only, this switch enables the parameters COVS, COVD, CGSP, and CGDP to be in F per fin, per gate-finger, per unit channel width.
437	nbodyn1=0	NFIN dependence of channel (body) doping.
438	nbodyn2=1.0e5	NFIN dependence of channel (body) doping.
439	phigl=0	Length dependence of Gate workfunction, eV/m.
440	phign1=0	NFIN dependence of Gate workfunction.
441	phign2=1.0e5	NFIN dependence of Gate workfunction.
442	cdscn1=0	NFIN dependence of CDSC.
443	cdscn2=1.0e5	NFIN dependence of CDSC.
444	cdscdn1=0	NFIN dependence of CDSCD.
445	cdscdn2=1.0e5	NFIN dependence of CDSCD.
446	cdscdrn1=0	NFIN dependence of CDSCD.
447	cdscdrn2=1.0e-5	NFIN dependence of CDSCD.
448	dvt1ss=0.60	Subthreshold Swing exponent coefficient, after binning should be in (0:inf).
449	eta0n1=0	NFIN dependence of ETA0.
450	eta0n2=1.0e5	NFIN dependence of ETA0.
451	teta0=0.0	Temperature dependence of DIBL coefficient, 1/K.

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452	<code>teta0r=0.0</code>	Temperature dependence of Reverse-mode DIBL coefficient, 1/K.
453	<code>dvtp0=0</code>	Coefficient for Drain-Induced Vth Shift (DITS).
454	<code>dvtp1=0</code>	DITS exponent coefficient.
455	<code>vsatn1=0</code>	NFIN dependence of VSAT.
456	<code>vsatn2=1.0e5</code>	NFIN dependence of VSAT.
457	<code>vsat1n1=0</code>	NFIN dependence of VSAT1.
458	<code>vsat1n2=1.0e-5</code>	NFIN dependence of VSAT1.
459	<code>vsat1rn1=0</code>	NFIN dependence of VSAT1R.
460	<code>vsat1rn2=1.0e-5</code>	NFIN dependence of VSAT1R.
461	<code>mexpr=4</code>	
462	<code>amexpr=0.0</code>	
463	<code>bmexpr=1.0</code>	
464	<code>tmexpr=0.0</code>	
465	<code>u0n1=0</code>	NFIN dependence of U0.
466	<code>u0n2=1.0e5</code>	NFIN dependence of U0.
467	<code>chargewf=0</code>	Average Channel Charge Weighting Factor, +1:source-side, 0:middle, -1:drain-side.
468	<code>minr=0.001 Ω</code>	
469	<code>compatible=spectre</code>	compatible parameters. Possible values are <code>spectre</code> , <code>spice2</code> , <code>spice3</code> , <code>cdsspice</code> , <code>hspice</code> , <code>spiceplus</code> , <code>eldo</code> , <code>sspice</code> , and <code>mica</code> .
470	<code>vthmod=0</code>	Vth output selector. 'std' outputs model equation Vth. 'vthcc' outputs constant current Vth, and may impact simulation

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	performance. The default value is taken from the options parameter 'vthmod'. Possible values are <code>std</code> and <code>vthcc</code> .
471 <code>ivth=0.0</code>	Vth current parameter. The default value is taken from the options parameter 'ivthn' or 'ivthp', depending on the type of the model.
472 <code>ivthw=0.0</code>	Width offset for constant current Vth. The default value is taken from the options parameter 'ivthw'.
473 <code>ivthl=0.0</code>	Length offset for constant current Vth. The default value is taken from the options parameter 'ivthl'.
474 <code>ivth_vdsmin=0.05</code>	Minimum Vds in constant current Vth calculating. The default value is taken from the options parameter 'ivth_vdsmin'.
475 <code>ffnoiflag=0</code>	
476 <code>lnbody=0</code>	Length dependence of nbody.
477 <code>nnbody=0</code>	NFIN dependence of nbody.
478 <code>pnbody=0</code>	Cross-term dependence of nbody.
479 <code>lphig=0</code>	Length dependence of phig.
480 <code>nphig=0</code>	NFIN dependence of phig.
481 <code>pphig=0</code>	Cross-term dependence of phig.
482 <code>lngate=0</code>	Length dependence of ngate.
483 <code>nngate=0</code>	NFIN dependence of ngate.
484 <code>pngate=0</code>	Cross-term dependence of ngate.
485 <code>lcit=0</code>	Length dependence of cit.
486 <code>ncit=0</code>	NFIN dependence of cit.
487 <code>pcit=0</code>	Cross-term dependence of cit.

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488	l _{cdsc} =0	Length dependence of cdsc.
489	n _{cdsc} =0	NFIN dependence of cdsc.
490	p _{cdsc} =0	Cross-term dependence of cdsc.
491	l _{cdscd} =0	Length dependence of cdscd.
492	n _{cdscd} =0	NFIN dependence of cdscd.
493	p _{cdscd} =0	Cross-term dependence of cdscd.
494	l _{cdscdr} =0	Length dependence of cdscdr.
495	n _{cdscdr} =0	NFIN dependence of cdscdr.
496	p _{cdscdr} =0	Cross-term dependence of cdscdr.
497	l _{dvt0} =0	Length dependence of dvt0.
498	n _{dvt0} =0	NFIN dependence of dvt0.
499	p _{dvt0} =0	Cross-term dependence of dvt0.
500	l _{dvt1} =0	Length dependence of dvt1.
501	n _{dvt1} =0	NFIN dependence of dvt1.
502	p _{dvt1} =0	Cross-term dependence of dvt1.
503	l _{dvt1ss} =0	Length dependence of dvt1ss.
504	n _{dvt1ss} =0	NFIN dependence of dvt1ss.
505	p _{dvt1ss} =0	Cross-term dependence of dvt1ss.
506	l _{phin} =0	Length dependence of phin.
507	n _{phin} =0	NFIN dependence of phin.
508	p _{phin} =0	Cross-term dependence of phin.
509	l _{eta0} =0	Length dependence of eta0.

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510	neta0=0	NFIN dependence of eta0.
511	peta0=0	Cross-term dependence of eta0.
512	leta0r=0	Length dependence of eta0r.
513	neta0r=0	NFIN dependence of eta0r.
514	peta0r=0	Cross-term dependence of eta0r.
515	ldsub=0	Length dependence of dsub.
516	ndsub=0	NFIN dependence of dsub.
517	pdsb=0	Cross-term dependence of dsub.
518	lk1rsce=0	Length dependence of lk1rsce.
519	nk1rsce=0	NFIN dependence of lk1rsce.
520	pk1rsce=0	Cross-term dependence of lk1rsce.
521	lpe0=0	Length dependence of lpe0.
522	npe0=0	NFIN dependence of lpe0.
523	ppe0=0	Cross-term dependence of lpe0.
524	ldvtshift=0	Length dependence of dvtshift.
525	ndvtshift=0	NFIN dependence of dvtshift.
526	pdvtshift=0	Cross-term dependence of dvtshift.
527	lphibe=0	Length dependence of phibe.
528	nphibe=0	NFIN dependence of phibe.
529	pphibe=0	Cross-term dependence of phibe.
530	lk0=0	Length dependence of k0.
531	nk0=0	NFIN dependence of k0.

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532	$pk0=0$	Cross-term dependence of $k0$.
533	$lk0si=0$	Length dependence of $k0si$.
534	$nk0si=0$	NFIN dependence of $k0si$.
535	$pk0si=0$	Cross-term dependence of $k0si$.
536	$lk1=0$	Length dependence of $k1$.
537	$nk1=0$	NFIN dependence of $k1$.
538	$pk1=0$	Cross-term dependence of $k1$.
539	$lk1si=0$	Length dependence of $k1si$.
540	$nk1si=0$	NFIN dependence of $k1si$.
541	$pk1si=0$	Cross-term dependence of $k1si$.
542	$lk1sat=0$	Length dependence of $k1sat$.
543	$nk1sat=0$	NFIN dependence of $k1sat$.
544	$pk1sat=0$	Cross-term dependence of $k1sat$.
545	$ldvtb=0$	Length dependence of $dvtb$.
546	$ndvtb=0$	NFIN dependence of $dvtb$.
547	$pdvtb=0$	Cross-term dependence of $dvtb$.
548	$llpeb=0$	Length dependence of $lpeb$.
549	$nlpeb=0$	NFIN dependence of $lpeb$.
550	$plpeb=0$	Cross-term dependence of $lpeb$.
551	$lqmfactor=0.0$	Length dependence of $qmfactor$.
552	$nqmfactor=0.0$	NFIN dependence of $qmfactor$.
553	$pqmfactor=0.0$	Cross-term dependence of $qmfactor$.

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554	<code>lqmtceniv=0.0</code>	Length dependence of <code>qmtceniv</code> .
555	<code>nqmtceniv=0.0</code>	NFIN dependence of <code>qmtceniv</code> .
556	<code>pqmtceniv=0.0</code>	Cross-term dependence of <code>qmtceniv</code> .
557	<code>lqmtcencv=0.0</code>	Length dependence of <code>qmtcencv</code> .
558	<code>nqmtcencv=0.0</code>	NFIN dependence of <code>qmtcencv</code> .
559	<code>pqmtcencv=0.0</code>	Cross-term dependence of <code>qmtcencv</code> .
560	<code>lqmtcencva=0.0</code>	Length dependence of <code>qmtcencva</code> .
561	<code>nqmtcencva=0.0</code>	NFIN dependence of <code>qmtcencva</code> .
562	<code>pqmtcencva=0.0</code>	Cross-term dependence of <code>qmtcencva</code> .
563	<code>lvsat=0</code>	Length dependence of <code>vsat</code> .
564	<code>nvsat=0</code>	NFIN dependence of <code>vsat</code> .
565	<code>pvsat=0</code>	Cross-term dependence of <code>vsat</code> .
566	<code>lvsat1=0</code>	Length dependence of <code>vsat1</code> .
567	<code>nvsat1=0</code>	NFIN dependence of <code>vsat1</code> .
568	<code>pvsat1=0</code>	Cross-term dependence of <code>vsat1</code> .
569	<code>lvsat1r=0</code>	Length dependence of <code>vsat1r</code> .
570	<code>nvsat1r=0</code>	NFIN dependence of <code>vsat1r</code> .
571	<code>pvsat1r=0</code>	Cross-term dependence of <code>vsat1r</code> .
572	<code>lpsat=0</code>	Length dependence of <code>psat</code> .
573	<code>npsat=0</code>	NFIN dependence of <code>psat</code> .
574	<code>ppsats=0</code>	Cross-term dependence of <code>psat</code> .
575	<code>ldeltavsat=0</code>	Length dependence of <code>deltavsat</code> .

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576	<code>ndeltavsat=0</code>	NFIN dependence of <code>ndetavsat</code> .
577	<code>pdeltavsat=0</code>	Cross-term dependence of <code>deltavsat</code> .
578	<code>lksativ=0</code>	Length dependence of <code>ksativ</code> .
579	<code>nksativ=0</code>	NFIN dependence of <code>ksativ</code> .
580	<code>pksativ=0</code>	Cross-term dependence of <code>ksativ</code> .
581	<code>lvsatcv=0</code>	Length dependence of <code>vsatcv</code> .
582	<code>nvsatcv=0</code>	NFIN dependence of <code>vsatcv</code> .
583	<code>pvsatcv=0</code>	Cross-term dependence of <code>vsatcv</code> .
584	<code>lmexp=0</code>	Length dependence of <code>mexp</code> .
585	<code>nmexp=0</code>	NFIN dependence of <code>mexp</code> .
586	<code>pmexp=0</code>	Cross-term dependence of <code>mexp</code> .
587	<code>lmexpr=0</code>	Length dependence of <code>mexpr</code> .
588	<code>nmexpr=0</code>	NFIN dependence of <code>mexpr</code> .
589	<code>pmexpr=0</code>	NFIN dependence of <code>mexpr</code> .
590	<code>lptwg=0.0</code>	Length dependence of <code>ptwg</code> .
591	<code>nptwg=0.0</code>	NFIN dependence of <code>ptwg</code> .
592	<code>pptwg=0.0</code>	Cross-term dependence of <code>ptwg</code> .
593	<code>lptwgr=0.0</code>	Length dependence of <code>ptwgr</code> .
594	<code>nptwgr=0.0</code>	NFIN dependence of <code>ptwgr</code> .
595	<code>pptwgr=0.0</code>	Cross-term dependence of <code>ptwgr</code> .
596	<code>lthetasat=0</code>	Length dependence of <code>thetasat</code> .
597	<code>nthetasat=0</code>	NFIN dependence of <code>thetasat</code> .

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598	$p_{\text{thetasat}}=0$	Cross-term dependence of thetasat .
599	$l_{u0}=0$	Length dependence of $u0$.
600	$n_{u0}=0$	NFIN dependence of $u0$.
601	$p_{u0}=0$	Cross-term dependence of $u0$.
602	$l_{\text{etamob}}=0$	Length dependence of etamob .
603	$n_{\text{etamob}}=0$	NFIN dependence of etamob .
604	$p_{\text{etamob}}=0$	Cross-term dependence of etamob .
605	$l_{up}=0$	Length dependence of up .
606	$n_{up}=0$	NFIN dependence of up .
607	$p_{up}=0$	Cross-term dependence of up .
608	$l_{ua}=0$	Length dependence of ua .
609	$n_{ua}=0$	NFIN dependence of ua .
610	$p_{ua}=0$	Cross-term dependence of ua .
611	$l_{uc}=0$	Length dependence of uc .
612	$n_{uc}=0$	NFIN dependence of uc .
613	$p_{uc}=0$	Cross-term dependence of uc .
614	$l_{eu}=0$	Length dependence of eu .
615	$n_{eu}=0$	NFIN dependence of eu .
616	$p_{eu}=0$	Cross-term dependence of eu .
617	$l_{ud}=0$	Length dependence of ud .
618	$n_{ud}=0$	NFIN dependence of ud .
619	$p_{ud}=0$	Cross-term dependence of ud .

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620	lucs=0	Length dependence of ucs.
621	nucs=0	NFIN dependence of ucs.
622	pucs=0	Cross-term dependence of ucs.
623	lmue=0	Length dependence of mue.
624	nmue=0	NFIN dependence of mue.
625	pmue=0	Cross-term dependence of mue.
626	lcs=0	Length dependence of cs.
627	ncs=0	NFIN dependence of cs.
628	pcs=0	Cross-term dependence of cs.
629	lpclm=0	Length dependence of pclm.
630	npclm=0	NFIN dependence of pclm.
631	ppclm=0	Cross-term dependence of pclm.
632	lpclmg=0	Length dependence of pclmg.
633	npclmg=0	Length dependence of nclmg.
634	ppclmg=0	Length dependence of pclmg.
635	lvasat=0	Length dependence of lvasat.
636	nvasat=0	Length dependence of nvasat.
637	pvasat=0	Length dependence of pvasat.
638	lpclmcv=0	Length dependence of pclmcv.
639	npclmcv=0	NFIN dependence of pclmcv.
640	ppclmcv=0	Cross-term dependence of pclmcv.
641	la1=0	Length dependence of a1.

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642	na1=0	NFIN dependence of a1.
643	pa1=0	Cross-term dependence of a1.
644	la2=0	Length dependence of a2.
645	na2=0	NFIN dependence of a2.
646	pa2=0	Cross-term dependence of a2.
647	lrdsw=0	Length dependence of rdsw.
648	nrdsw=0	NFIN dependence of rdsw.
649	prdsw=0	Cross-term dependence of rdsw.
650	lrsw=0.0	Length dependence of rsw.
651	nrsw=0.0	NFIN dependence of rsw.
652	prsw=0.0	Cross-term dependence of rsw.
653	lrdw=0.0	Length dependence of rdw.
654	nrdw=0.0	NFIN dependence of rdw.
655	prdw=0.0	Cross-term dependence of rdw.
656	lprwg=0	Length dependence of prwg.
657	nprwg=0	NFIN dependence of prwg.
658	pprwg=0	Cross-term dependence of prwg.
659	lprwgs=0	Length dependence of prwgs.
660	nprwgs=0	NFIN dependence of prwgs.
661	pprwgs=0	Cross-term dependence of prwgs.
662	lprwgd=0	NFIN dependence of prwgd.
663	nprwgd=0	NFIN dependence of prwgd.

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664	<code>pprwgd=0</code>	Cross-term dependence of <code>prwgd</code> .
665	<code>lwr=0</code>	Length dependence of <code>wr</code> .
666	<code>nwr=0</code>	NFIN dependence of <code>wr</code> .
667	<code>pwr=0</code>	Cross-term dependence of <code>wr</code> .
668	<code>lpdibl1=0</code>	Length dependence of <code>pdibl1</code> .
669	<code>npdibl1=0</code>	NFIN dependence of <code>pdibl1</code> .
670	<code>ppdibl1=0</code>	Cross-term dependence of <code>pdibl1</code> .
671	<code>lpdibl1r=0</code>	Length dependence of <code>pdibl1r</code> .
672	<code>npdibl1r=0</code>	NFIN dependence of <code>pdibl1r</code> .
673	<code>ppdibl1r=0</code>	Cross-term dependence of <code>pdibl1r</code> .
674	<code>lpdibl2=0</code>	Length dependence of <code>pdibl2</code> .
675	<code>npdibl2=0</code>	NFIN dependence of <code>pdibl2</code> .
676	<code>ppdibl2=0</code>	Cross-term dependence of <code>pdibl2</code> .
677	<code>ldrout=0</code>	Length dependence of <code>dROUT</code> .
678	<code>ndrout=0</code>	NFIN dependence of <code>dROUT</code> .
679	<code>pdrout=0</code>	Cross-term dependence of <code>dROUT</code> .
680	<code>lpvag=0</code>	Length dependence of <code>pvag</code> .
681	<code>npvag=0</code>	NFIN dependence of <code>pvag</code> .
682	<code>ppvag=0</code>	Cross-term dependence of <code>pvag</code> .
683	<code>laigbinv=0</code>	Length dependence of <code>aigbinv</code> .
684	<code>naigbinv=0</code>	NFIN dependence of <code>aigbinv</code> .
685	<code>paigbinv=0</code>	Cross-term dependence of <code>aigbinv</code> .

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686	lbigbinv=0	Length dependence of bigbinv.
687	nbigbinv=0	NFIN dependence of bigbinv.
688	pbigbinv=0	Cross-term dependence of bigbinv.
689	lcigbinv=0	Length dependence of cigbinv.
690	ncigbinv=0	NFIN dependence of cigbinv.
691	pcigbinv=0	Cross-term dependence of cigbinv.
692	leigbinv=0	Length dependence of eigbinv.
693	neigbinv=0	NFIN dependence of eigbinv.
694	peigbinv=0	Cross-term dependence of eigbinv.
695	lnigbinv=0	Length dependence of nigbinv.
696	nnigbinv=0	NFIN dependence of nigbinv.
697	pnigbinv=0	Cross-term dependence of nigbinv.
698	laigbacc=0	Length dependence of laigbacc.
699	naigbacc=0	Length dependence of naigbacc.
700	paigbacc=0	Length dependence of paigbacc.
701	lbigbacc=0	Length dependence of lbigbacc.
702	nbigbacc=0	Length dependence of nbigbacc.
703	pbigbacc=0	Length dependence of pbigbacc.
704	lcigbacc=0	Length dependence of lcigbacc.
705	ncigbacc=0	Length dependence of ncigbacc.
706	pcigbacc=0	Length dependence of pcigbacc.
707	lnigbacc=0	Length dependence of lnigbacc.

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708	<code>nnigbacc=0</code>	Length dependence of <code>nnigbacc</code> .
709	<code>pnigbacc=0</code>	Length dependence of <code>pnigbacc</code> .
710	<code>laigc=0</code>	Length dependence of <code>aigc</code> .
711	<code>naigc=0</code>	NFIN dependence of <code>aigc</code> .
712	<code>paigc=0</code>	Cross-term dependence of <code>aigc</code> .
713	<code>lbigc=0</code>	Length dependence of <code>bigc</code> .
714	<code>nbigc=0</code>	NFIN dependence of <code>bigc</code> .
715	<code>pbigc=0</code>	Cross-term dependence of <code>bigc</code> .
716	<code>lcigc=0</code>	Length dependence of <code>cigc</code> .
717	<code>ncigc=0</code>	NFIN dependence of <code>cigc</code> .
718	<code>pcigc=0</code>	Cross-term dependence of <code>cigc</code> .
719	<code>lnigc=0</code>	Length dependence of <code>nigc</code> .
720	<code>nnigc=0</code>	NFIN dependence of <code>nigc</code> .
721	<code>pnigc=0</code>	Cross-term dependence of <code>nigc</code> .
722	<code>lpigcd=0</code>	Length dependence of <code>pigcd</code> .
723	<code>npigcd=0</code>	NFIN dependence of <code>pigcd</code> .
724	<code>ppigcd=0</code>	Cross-term dependence of <code>pigcd</code> .
725	<code>laigs=0</code>	Length dependence of <code>aigs</code> .
726	<code>naigs=0</code>	NFIN dependence of <code>aigs</code> .
727	<code>paigs=0</code>	Cross-term dependence of <code>aigs</code> .
728	<code>lbiggs=0</code>	Length dependence of <code>biggs</code> .
729	<code>nbiggs=0</code>	NFIN dependence of <code>biggs</code> .

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730	pbig _s =0	Cross-term dependence of big _s .
731	lcig _s =0	Length dependence of cig _s .
732	ncig _s =0	NFIN dependence of cig _s .
733	pcig _s =0	Cross-term dependence of cig _s .
734	laigd=0	Length dependence of aigd.
735	naigd=0	NFIN dependence of aigd.
736	paigd=0	Cross-term dependence of aigd.
737	lbigd=0	Length dependence of bigd.
738	nbigd=0	NFIN dependence of bigd.
739	pbigd=0	Cross-term dependence of bigd.
740	lcigd=0	Length dependence of cigd.
741	ncigd=0	NFIN dependence of cigd.
742	pcigd=0	Cross-term dependence of cigd.
743	lntox=0	Length dependence of ntox.
744	nntox=0	Length dependence of ntox.
745	pntox=0	Length dependence of ntox.
746	lpoxedge=0	Length dependence of poxedge.
747	npoxedge=0	NFIN dependence of poxedge.
748	ppoxedge=0	Cross-term dependence of poxedge.
749	lagidl=0	Length dependence of agidl.
750	nagidl=0	NFIN dependence of agidl.
751	pagidl=0	Cross-term dependence of agidl.

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BSIM-CMG

752	lbgidl=0	Length dependence of bgidl.
753	nbgidl=0	NFIN dependence of bgidl.
754	pbgidl=0	Cross-term dependence of bgidl.
755	legidl=0	Length dependence of egidl.
756	negidl=0	NFIN dependence of egidl.
757	pegidl=0	Cross-term dependence of egidl.
758	lcgidl=0	Length dependence of cgidl.
759	ncgidl=0	NFIN dependence of cgidl.
760	pcgidl=0	Cross-term dependence of cgidl.
761	lpgidl=0	Length dependence of pgidl.
762	npgidl=0	Length dependence of pgidl.
763	ppgidl=0	Length dependence of pgidl.
764	lagisl=0	Length dependence of agisl.
765	nagisl=0	NFIN dependence of agisl.
766	pagisl=0	Cross-term dependence of agisl.
767	lbgisl=0	Length dependence of bgisl.
768	nbgisl=0	NFIN dependence of bgisl.
769	pbgisl=0	Cross-term dependence of bgisl.
770	legisl=0	Length dependence of egisl.
771	negisl=0	NFIN dependence of egisl.
772	pegisl=0	Cross-term dependence of egisl.
773	lcgisl=0	Length dependence of cgisl.

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BSIM-CMG

774	<code>ncgisl=0</code>	NFIN dependence of <code>cgisl</code> .
775	<code>pcgisl=0</code>	Cross-term dependence of <code>cgisl</code> .
776	<code>lpgisl=0</code>	Length dependence of <code>pgisl</code> .
777	<code>npgisl=0</code>	Length dependence of <code>pgisl</code> .
778	<code>ppgisl=0</code>	Length dependence of <code>pgisl</code> .
779	<code>lalpha0=0.0</code>	Length dependence of <code>alpha0</code> .
780	<code>nalpha0=0.0</code>	NFIN dependence of <code>alpha0</code> .
781	<code>palpha0=0.0</code>	Cross-term dependence of <code>alpha0</code> .
782	<code>lalpha1=0.0</code>	Length dependence of <code>alpha1</code> .
783	<code>nalpha1=0.0</code>	NFIN dependence of <code>alpha1</code> .
784	<code>palpha1=0.0</code>	Cross-term dependence of <code>alpha1</code> .
785	<code>lbeta0=0.0</code>	Length dependence of <code>beta0</code> .
786	<code>nbeta0=0.0</code>	NFIN dependence of <code>beta0</code> .
787	<code>pbeta0=0.0</code>	Cross-term dependence of <code>beta0</code> .
788	<code>lalphaii=0.0</code>	Length dependence of <code>alphaii</code> .
789	<code>nalphaii=0.0</code>	NFIN dependence of <code>alphaii</code> .
790	<code>palphaii=0.0</code>	Cross-term dependence of <code>alphaii</code> .
791	<code>lbetaii0=0.0</code>	Length dependence of <code>betaii0</code> .
792	<code>nbetaii0=0.0</code>	NFIN dependence of <code>betaii0</code> .
793	<code>pbetaii0=0.0</code>	Cross-term dependence of <code>betaii0</code> .
794	<code>lbetaii1=0.0</code>	Length dependence of <code>betaii1</code> .
795	<code>nbetaii1=0.0</code>	NFIN dependence of <code>betaii1</code> .

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796	<code>pbetaii1=0.0</code>	Cross-term dependence of <code>betaii1</code> .
797	<code>lbetaii2=0.0</code>	Length dependence of <code>betaii2</code> .
798	<code>nbetaii2=0.0</code>	NFIN dependence of <code>betaii2</code> .
799	<code>pbetaii2=0.0</code>	Cross-term dependence of <code>betaii2</code> .
800	<code>lesatii=0.0</code>	Length dependence of <code>esatii</code> .
801	<code>nesatii=0.0</code>	NFIN dependence of <code>esatii</code> .
802	<code>pesatii=0.0</code>	Cross-term dependence of <code>esatii</code> .
803	<code>llii=0.0</code>	Length dependence of <code>lii</code> .
804	<code>nlii=0.0</code>	NFIN dependence of <code>lii</code> .
805	<code>plii=0.0</code>	Cross-term dependence of <code>lii</code> .
806	<code>lsiio=0.0</code>	Length dependence of <code>sii0</code> .
807	<code>nsii0=0.0</code>	NFIN dependence of <code>sii0</code> .
808	<code>psii0=0.0</code>	Cross-term dependence of <code>sii0</code> .
809	<code>lsiil=0.0</code>	Length dependence of <code>sii1</code> .
810	<code>nsiil=0.0</code>	NFIN dependence of <code>sii1</code> .
811	<code>psii1=0.0</code>	Cross-term dependence of <code>sii1</code> .
812	<code>lsiil2=0.0</code>	Length dependence of <code>sii2</code> .
813	<code>nsiil2=0.0</code>	NFIN dependence of <code>sii2</code> .
814	<code>psii2=0.0</code>	Cross-term dependence of <code>sii2</code> .
815	<code>lsiid=0.0</code>	Length dependence of <code>siid</code> .
816	<code>nsiid=0.0</code>	NFIN dependence of <code>siid</code> .
817	<code>psiid=0.0</code>	Cross-term dependence of <code>siid</code> .

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818	lcfs=0.0	Length dependence of cfs.
819	ncfs=0.0	NFIN dependence of cfs.
820	pcfs=0.0	Cross-term dependence of cfs.
821	lcfcd=0.0	Length dependence of cfd.
822	ncfd=0.0	NFIN dependence of cfd.
823	pcfcd=0.0	Cross-term dependence of cfd.
824	lcovs=0.0	Length dependence of.
825	ncovs=0.0	NFIN dependence of.
826	pcovs=0.0	Cross-term dependence of.
827	lcovd=0.0	Length dependence of covd.
828	ncovd=0.0	NFIN dependence of covd.
829	pcovd=0.0	Cross-term dependence of covd.
830	lcgsl=0.0	Length dependence of cgsl.
831	ncgsl=0.0	NFIN dependence of cgsl.
832	pcgsl=0.0	Cross-term dependence of cgsl.
833	lcgdl=0.0	Length dependence of cgdl.
834	ncgdl=0.0	NFIN dependence of cgdl.
835	pcgdl=0.0	Cross-term dependence of cgdl.
836	lckappas=0.0	Length dependence of ckappas.
837	nckappas=0.0	NFIN dependence of ckappas.
838	pckappas=0.0	Cross-term dependence of ckappas.
839	lckappad=0.0	Length dependence of ckappad.

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840	<code>nckappad=0.0</code>	NFIN dependence of <code>ckappad</code> .
841	<code>pckappad=0.0</code>	Cross-term dependence of <code>ckappad</code> .
842	<code>lcgbl=0.0</code>	Length dependence of <code>cgbl</code> .
843	<code>ncgbl=0.0</code>	NFIN dependence of <code>cgbl</code> .
844	<code>pcgbl=0.0</code>	Cross-term dependence of <code>cgbl</code> .
845	<code>lckappab=0.0</code>	Length dependence of <code>ckappab</code> .
846	<code>nckappab=0.0</code>	NFIN dependence of <code>ckappab</code> .
847	<code>pckappab=0.0</code>	Cross-term dependence of <code>ckappab</code> .
848	<code>lntgen=0</code>	Length dependence of <code>ntgen</code> .
849	<code>nntgen=0</code>	NFIN dependence of <code>ntgen</code> .
850	<code>pntgen=0</code>	Cross-term dependence of <code>ntgen</code> .
851	<code>laigen=0</code>	Length dependence of <code>aigen</code> .
852	<code>naigen=0</code>	NFIN dependence of <code>aigen</code> .
853	<code>paigen=0</code>	Cross-term dependence of <code>aigen</code> .
854	<code>lbigen=0</code>	Length dependence of <code>bigen</code> .
855	<code>nbigen=0</code>	NFIN dependence of <code>bigen</code> .
856	<code>pbigen=0</code>	Cross-term dependence of <code>bigen</code> .
857	<code>lxrcrg1=0.0</code>	Length dependence of <code>xrcrg1</code> .
858	<code>nxrcrg1=0.0</code>	NFIN dependence of <code>xrcrg1</code> .
859	<code>pxrcrg1=0.0</code>	Cross-term dependence of <code>xrcrg1</code> .
860	<code>lxrcrg2=0.0</code>	Length dependence of <code>xrcrg2</code> .
861	<code>nxrcrg2=0.0</code>	NFIN dependence of <code>xrcrg2</code> .

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862	<code>pxrcrg2=0.0</code>	Cross-term dependence of <code>xrcrg2</code> .
863	<code>lintnoi=0.0</code>	Length dependence of <code>intnoi</code> .
864	<code>lute=0.0</code>	Length dependence of <code>ute</code> .
865	<code>nute=0.0</code>	NFIN dependence of <code>ute</code> .
866	<code>pute=0.0</code>	Cross-term dependence of <code>ute</code> .
867	<code>lutl=0.0</code>	Length dependence of <code>utl</code> .
868	<code>nutl=0.0</code>	NFIN dependence of <code>utl</code> .
869	<code>putl=0.0</code>	Cross-term dependence of <code>utl</code> .
870	<code>lemobt=0</code>	Length dependence of <code>emobt</code> .
871	<code>nemobt=0</code>	NFIN dependence of <code>emobt</code> .
872	<code>pemobt=0</code>	Cross-term dependence of <code>emobt</code> .
873	<code>lua1=0.0</code>	Length dependence of <code>ua1</code> .
874	<code>nua1=0.0</code>	NFIN dependence of <code>ua1</code> .
875	<code>pua1=0.0</code>	Cross-term dependence of <code>ua1</code> .
876	<code>luc1=0.0</code>	Length dependence of <code>uc1</code> .
877	<code>nuc1=0.0</code>	NFIN dependence of <code>uc1</code> .
878	<code>puc1=0.0</code>	Cross-term dependence of <code>uc1</code> .
879	<code>lud1=0.0</code>	Length dependence of <code>ud1</code> .
880	<code>nud1=0.0</code>	NFIN dependence of <code>ud1</code> .
881	<code>pud1=0.0</code>	Cross-term dependence of <code>ud1</code> .
882	<code>lucste=0.0</code>	Length dependence of <code>ucste</code> .
883	<code>nucste=0.0</code>	NFIN dependence of <code>ucste</code> .

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884	<code>pucste=0.0</code>	Cross-term dependence of <code>ucste</code> .
885	<code>lptwgt=0</code>	Length dependence of <code>ptwgt</code> .
886	<code>nptwgt=0</code>	NFIN dependence of <code>ptwgt</code> .
887	<code>pptwgt=0</code>	Cross-term dependence of <code>ptwgt</code> .
888	<code>lat=0</code>	Length dependence of <code>at</code> .
889	<code>nat=0</code>	NFIN dependence of <code>at</code> .
890	<code>pat=0</code>	Cross-term dependence of <code>at</code> .
891	<code>lstthetasat=0</code>	Length dependence of <code>stthetasat</code> .
892	<code>nstthetasat=0</code>	NFIN dependence of <code>stthetasat</code> .
893	<code>pstthetasat=0</code>	Cross-term dependence of <code>stthetasat</code> .
894	<code>lprt=0</code>	Length dependence of <code>prt</code> .
895	<code>nprt=0</code>	NFIN dependence of <code>prt</code> .
896	<code>pprt=0</code>	Cross-term dependence of <code>prt</code> .
897	<code>lkt1=0</code>	Length dependence of <code>kt1</code> .
898	<code>nkt1=0</code>	NFIN dependence of <code>kt1</code> .
899	<code>pkt1=0</code>	Cross-term dependence of <code>kt1</code> .
900	<code>ltss=0</code>	Length dependence of <code>tss</code> .
901	<code>ntss=0</code>	NFIN dependence of <code>tss</code> .
902	<code>ptss=0</code>	Cross-term dependence of <code>tss</code> .
903	<code>liit=0</code>	Length dependence of <code>iit</code> .
904	<code>niit=0</code>	NFIN dependence of <code>iit</code> .
905	<code>piit=0</code>	Cross-term dependence of <code>iit</code> .

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906	ltii=0.0	Length dependence of tii.
907	ntii=0.0	NFIN dependence of tii.
908	ptii=0.0	Cross-term dependence of tii.
909	ltgidl=0	Length dependence of tgidl.
910	ntgidl=0	NFIN dependence of tgidl.
911	ptgidl=0	Cross-term dependence of tgidl.
912	ligt=0	Length dependence of igt.
913	nigt=0	NFIN dependence of igt.
914	pigt=0	Cross-term dependence of igt.
915	lk01=0	Length dependence of k01.
916	nk01=0	NFIN dependence of k01.
917	pk01=0	Cross-term dependence of k01.
918	lk0si1=0	Length dependence of k0si1.
919	nk0si1=0	NFIN dependence of k0si1.
920	pk0si1=0	Cross-term dependence of k0si1.
921	lk1si1=0	Length dependence of k1si1.
922	nk1si1=0	NFIN dependence of k1si1.
923	pk1si1=0	Cross-term dependence of k1si1.
924	lk11=0	Length dependence of k11.
925	nk11=0	NFIN dependence of k11.
926	pk11=0	Cross-term dependence of k11.
927	lk1sat1=0	Length dependence of k1sat1.

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928	<code>nk1sat1=0</code>	NFIN dependence of <code>k1sat1</code> .
929	<code>pk1sat1=0</code>	Cross-term dependence of <code>k1sat1</code> .
930	<code>la11=0</code>	Length dependence of <code>a11</code> .
931	<code>na11=0</code>	NFIN dependence of <code>a11</code> .
932	<code>pa11=0</code>	Cross-term dependence of <code>a11</code> .
933	<code>la21=0</code>	Length dependence of <code>a21</code> .
934	<code>na21=0</code>	NFIN dependence of <code>a21</code> .
935	<code>pa21=0</code>	Cross-term dependence of <code>a21</code> .
936	<code>laigbinv1=0</code>	Length dependence of <code>aigbinv1</code> .
937	<code>naigbinv1=0</code>	NFIN dependence of <code>aigbinv1</code> .
938	<code>paigbinv1=0</code>	Cross-term dependence of <code>aigbinv1</code> .
939	<code>laigbacc1=0</code>	Length dependence of <code>aigbacc1</code> .
940	<code>naigbacc1=0</code>	NFIN dependence of <code>aigbacc1</code> .
941	<code>paigbacc1=0</code>	Cross-term dependence of <code>aigbacc1</code> .
942	<code>laigc1=0</code>	Length dependence of <code>aigc1</code> .
943	<code>naigc1=0</code>	NFIN dependence of <code>aigc1</code> .
944	<code>paigc1=0</code>	Cross-term dependence of <code>aigc1</code> .
945	<code>laigs1=0</code>	Length dependence of <code>aigs1</code> .
946	<code>naigs1=0</code>	NFIN dependence of <code>aigs1</code> .
947	<code>paigs1=0</code>	Cross-term dependence of <code>aigs1</code> .
948	<code>laigd1=0.0</code>	Length dependence of <code>aigd1</code> .
949	<code>naigd1=0.0</code>	NFIN dependence of <code>aigd1</code> .

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950	$\text{paigd1}=0.0$	Cross-term dependence of aigd1 .
951	$\text{lalphaii0}=0.0$	Length dependence of alphaii0 .
952	$\text{nalpha}=0.0$	NFIN dependence of alphaii0 .
953	$\text{palphaii0}=0.0$	Cross-term dependence of alphaii0 .
954	$\text{lalphaii1}=0.0$	Length dependence of alphaii1 .
955	$\text{nalphaii1}=0.0$	NFIN dependence of alphaii1 .
956	$\text{palphaii1}=0.0$	Cross-term dependence of alphaii1 .
957	$\text{lpsatcv}=0$	Length dependence of psatcv .
958	$\text{npsatcv}=0$	NFIN dependence of psatcv .
959	$\text{ppsatcv}=0$	Cross-term dependence of psatcv .
960	$\text{ldeltavsatcv}=0$	Length dependence of deltavsatcv .
961	$\text{ndeltavsatcv}=0$	NFIN dependence of deltavsatcv .
962	$\text{pdeltavsatcv}=0$	Cross-term dependence of deltavsatcv .
963	$\text{mvtwl}=0.0 \text{ V m}$	Threshold mismatch area dependence.
964	$\text{mvtwl2}=0.0 \text{ V m}^{1.5}$	Threshold mismatch area square dependence.
965	$\text{mvt0}=0.0 \text{ V}$	Threshold mismatch intercept.
966	$\text{mbewl}=0.0 \text{ m}$	Beta mismatch area dependence.
967	$\text{mbe0}=0.0$	Beta mismatch intercept.
968	$\text{mismatchmod}=0$	Select mismatch mode. The available modes are 0, 1, 2 and 3.
969	$\text{mismatchdist}=0.0$	Mismatch Distance.
970	$\text{lmin}=0.0 \text{ m}$	Minimum channel length for which the model is valid.

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971	<code>lmax=1.0 m</code>	Maximum channel length for which the model is valid.
972	<code>nfinmin=1</code>	Minimum number of fins per finger.
973	<code>nfinmax=100000</code>	Maximum number of fins per finger.

Output Parameters

1	<code>w_{eff}</code>	Effective channel width.
2	<code>l_{eff}</code>	Effective channel length.
3	<code>w_{effcv}</code>	Effective channel width for C-V.
4	<code>l_{effcv}</code>	Effective channel length for C-V.
5	<code>_age_is_shared</code>	NULL.
6	<code>tempeff (C)</code>	Effective temperature for a single device.
7	<code>temp_sh (C)</code>	Effective temperature including selfheating temperature.

Operating-Point Parameters

1	<code>linearity_factor</code>	
2	<code>i_{ds} (A)</code>	Intrinsic drain current (electrical).
3	<code>g_m</code>	Transconductance.
4	<code>g_{ds}</code>	Output conductance.
5	<code>g_{mbs}</code>	Body transconductance.
6	<code>r_{out} (Ω)</code>	Output resistance.
7	<code>v_{gs} (V)</code>	VGS.
8	<code>v_{gd} (V)</code>	VGD.

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9	<code>vds</code> (V)	VDS.
10	<code>ves</code> (V)	VES.
11	<code>vth</code> (V)	Threshold voltage.
12	<code>vgt</code> (V)	Effective gate drive voltage.
13	<code>vfb</code> (V)	Flatband voltage.
14	<code>beta</code>	Drain current prefactor per fin per finger.
15	<code>vdssat</code> (V)	Drain-Source saturation voltage.
16	<code>pwr</code> (W)	Power at op point.
17	<code>ideff</code> (A)	Total drain current (physical).
18	<code>iseff</code> (A)	Total source current (physical).
19	<code>igtot</code> (A)	Total gate current.
20	<code>isub</code> (A)	Substrate current.
21	<code>idsgen</code> (A)	Generation-Recombination Current (Physical).
22	<code>iii</code> (A)	Impact ionization current.
23	<code>igidl</code> (A)	GIDL current (physical).
24	<code>igisl</code> (A)	GISL current (physical).
25	<code>ijsb</code> (A)	Source-Body junction current (physical).
26	<code>ijdb</code> (A)	Drain-Body junction current (physical).
27	<code>igs</code> (A)	IGS.
28	<code>igd</code> (A)	IGD.
29	<code>igcs</code> (A)	IGCS.
30	<code>igcd</code> (A)	IGCD.

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31	igbs (A)	IBGS.
32	igbd (A)	IBGD.
33	igbacc (A)	IGBACC.
34	igbinv (A)	IGBINV.
35	qgi (C)	Intrinsic gate charge.
36	qdi (C)	Intrinsic drain charge.
37	qsi (C)	Intrinsic source charge.
38	qbi (C)	Intrinsic body charge.
39	qg (C)	Total gate charge.
40	qd (C)	Total drain charge.
41	qs (C)	Total source charge.
42	qb (C)	Total bulk charge.
43	cggi (F)	Intrinsic gate capacitance.
44	cgsi (F)	Intrinsic gate-to-source capacitance.
45	cgdi (F)	Intrinsic gate-to-drain capacitance.
46	cgei (F)	Intrinsic gate-to-bulk capacitance.
47	cdgi (F)	Intrinsic drain-to-gate capacitance.
48	cddi (F)	Intrinsic drain capacitance.
49	cdsi (F)	Intrinsic drain-to-source capacitance.
50	cdei (F)	Intrinsic drain-to-bulk capacitance.
51	csgi (F)	Intrinsic source-to-gate capacitance.
52	csdi (F)	Intrinsic source-to-drain capacitance.

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53	<code>cssi</code> (F)	Intrinsic source capacitance.
54	<code>csei</code> (F)	Intrinsic source-to-bulk capacitance.
55	<code>cegi</code> (F)	Intrinsic bulk-to-gate capacitance.
56	<code>cedi</code> (F)	Intrinsic bulk-to-drain capacitance.
57	<code>cesi</code> (F)	Intrinsic bulk-to-drain capacitance.
58	<code>ceei</code> (F)	Intrinsic bulk capacitance.
59	<code>cgg</code> (F)	Total gate capacitance.
60	<code>cgs</code> (F)	Total gate-to-source capacitance.
61	<code>cgd</code> (F)	Total gate-to-drain capacitance.
62	<code>cge</code> (F)	Total gate-to-bulk capacitance.
63	<code>cdg</code> (F)	Total drain-to-gate capacitance.
64	<code> added</code> (F)	Total drain capacitance.
65	<code>cds</code> (F)	Total drain-to-source capacitance.
66	<code>cde</code> (F)	Total drain-to-bulk capacitance.
67	<code>csg</code> (F)	Total source-to-gate capacitance.
68	<code> added</code> (F)	Total source-to-drain capacitance.
69	<code>css</code> (F)	Total source capacitance.
70	<code>cse</code> (F)	Total source-to-bulk capacitance.
71	<code>ceg</code> (F)	Total bulk-to-gate capacitance.
72	<code>ced</code> (F)	Total bulk-to-drain capacitance.
73	<code>ces</code> (F)	Total bulk-to-drain capacitance.
74	<code>cee</code> (F)	Total bulk capacitance.

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75	<code>cgsext</code> (F)	Gate-Source overlap + outer fringing capacitance.
76	<code>cgdext</code> (F)	Gate-Drain overlap + outer fringing capacitance.
77	<code>cgbov</code> (F)	Gate-Body overlap capacitance.
78	<code>cjst</code> (F)	Total of junction capacitance and source/drain-body overlap capacitance.
79	<code>cjdt</code> (F)	Total of junction capacitance and source/drain-body overlap capacitance.
80	<code>rsgeo</code>	External bias independent source resistance.
81	<code>rdgeo</code>	External bias independent drain resistance.
82	<code>cfgeo</code> (C)	Geometric parasitic cap for <code>cgeomod=1</code> .
83	<code>para_rs</code> (R)	Parasitic source resistance.
84	<code>para_rd</code> (R)	Parasitic drain resistance.
85	<code>para_rg</code> (R)	Parasitic gate electrode resistance.
86	<code>para_csbox</code> (c)	Parasitic coupled capacitance between source and substrate.
87	<code>para_cdbox</code> (c)	Parasitic coupled capacitance between drain and substrate.
88	<code>para_cgbox</code> (c)	Parasitic coupled capacitance between gate and substrate.
89	<code>para_qgs_ov</code> (c)	Parasitic overlap capacitance between gate and source.
90	<code>para_qgd_ov</code> (c)	Parasitic overlap capacitance between gate and drain.
91	<code>para_qgs_fr</code> (c)	Parasitic fringe capacitance between gate and source.
92	<code>para_qgd_fr</code> (c)	Parasitic fringe capacitance between gate and drain.

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93	<code>para_qds_fr</code> (c)	Parasitice fringe capacitance between source and drain.
94	<code>didsdvg</code>	DIDSDVG.
95	<code>didsdvs</code>	DIDSDVS.
96	<code>didsdvd</code>	DIDSDVD.
97	<code>digsdvg</code>	DIGSDVG.
98	<code>digsdvs</code>	DIGSDVS.
99	<code>digsdvd</code>	DIGSDVD.
100	<code>digddvg</code>	DIGDDVG.
101	<code>digddvs</code>	DIGDDVS.
102	<code>digddvd</code>	DIGDDVD.
103	<code>diiidvg</code>	DIIDVG.
104	<code>diiidvs</code>	DIIDVS.
105	<code>diiidvd</code>	DIIDVD.
106	<code>digidldvg</code>	DIGIDLVDG.
107	<code>digidldvs</code>	DIGIDLVS.
108	<code>digidldvd</code>	DIGILDVD.
109	<code>digislvg</code>	DIGISLVDG.
110	<code>digislvs</code>	DIGISLVS.
111	<code>digislvd</code>	DIGISLVD.
112	<code>cgt</code> (F)	CGT.
113	<code>cst</code> (F)	CST.

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114	<code>cdt</code> (F)	CDT.
115	<code>didsdvth</code>	DIDSDVTH.
116	<code>digsdvth</code>	DIGSDVTH.
117	<code>digddvth</code>	DIGDDVTH.
118	<code>diiidvth</code>	DI IIDVTH.
119	<code>digidldvth</code>	DIGIDL DVTH.
120	<code>digisldvth</code>	DIGISL DVTH.
121	<code>dithdvth</code>	DITH DVTH.
122	<code>ith</code> (A)	ITH.
123	<code>dithdvg</code>	DITH DVG.
124	<code>dithdvs</code>	DITH DVS.
125	<code>dithdvd</code>	DITH DVD.
126	<code>lpoly</code>	LPOLY.
127	<code>reversed</code>	REVERSED. Possible values are <code>no</code> and <code>yes</code> .
128	<code>vgst</code> (V)	Gate-source voltage.
129	<code>vgdt</code> (V)	Gate-drain voltage.
130	<code>vdet</code> (V)	Drain-bulk voltage.
131	<code>vget</code> (V)	Gate-bulk voltage.
132	<code>vdst</code> (V)	Drain-source voltage.
133	<code>vest</code> (V)	Bulk-source voltage.
134	<code>_age_vs</code> (V)	The source terminal voltage.

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Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

<u>age_is_shared</u> O-5	ids0mult M-25	naigs1 M-946	peu M-616
<u>age_vs</u> OP-134	idsgen OP-21	nalpha M-952	pgidl M-254
a1 M-158	igbacc OP-33	nalpha0 M-780	pgisl M-249
a11 M-418	igbd OP-32	nalpha1 M-783	phibe M-85
a2 M-159	igbinv OP-34	nalphaii M-789	phig M-62
a21 M-419	igbmod M-36	nalphaii1 M-955	phigl M-439
acs M-148	igbs OP-31	nat M-889	phign1 M-440
adej I-14	igcd OP-30	nbeta0 M-786	phign2 M-441
adej M-14	igcmmod M-35	nbetaii0 M-792	phin M-76
adeo I-10	igcs OP-29	nbetaii1 M-795	pigcd M-233
adeo M-10	igd OP-28	nbetaii2 M-798	pigt M-914
aeu M-137	igidl OP-23	nbgidl M-753	piit M-905
agidl M-250	igisl OP-24	nbgis1 M-768	pk0 M-532
agisl M-245	igs OP-27	nbigbacc M-702	pk01 M-917
aigbacc M-225	igt M-387	nbigbinv M-687	pk0si M-535
aigbaccl M-421	igtot OP-19	nbigc M-714	pk0si1 M-920
aigbinv M-220	iii OP-22	nbigd M-738	pk1 M-538

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aigbinv1 M-420	iimod M-38	nbigen M-855	pk11 M-926
aigc M-229	iit M-384	nbig5 M-729	pk1rsce M-520
aigc1 M-422	ijdb OP-26	nbody M-60	pk1sat M-544
aigd M-239	ijsb OP-25	nbodyn1 M-437	pk1sat1 M-929
aigdl M-424	ijthdfwd M-324	nbodyn2 M-438	pk1si M-541
aigen M-352	ijthdrev M-326	nc0sub M-68	pk1si1 M-923
aigs M-235	ijthsfwd M-323	ncdsc M-489	pk1sativ M-580
aigs1 M-423	ijthsrev M-325	ncdscd M-492	pkt1 M-899
alpha0 M-255	imin M-431	ncdscdr M-495	plii M-805
alpha01 M-425	iseff OP-18	ncfd M-822	plpe0 M-523
alpha1 M-256	isnoisy I-30	ncfs M-819	plpeb M-550
alpha11 M-426	isub OP-20	ncgbl M-843	pmexp M-586
alphaii M-258	ith OP-122	ncgdl M-834	pmexpr M-589
alphaii0 M-427	ivth M-471	ncgidl M-759	pmue M-625
alphaii01 M-428	ivth_vdsmin M-474	ncgis1 M-774	pnbody M-478
alphaii1 M-429	ivth1 M-473	ncgs1 M-831	pngate M-484
alphaii11 M-430	ivthw M-472	ncigbacc M-705	pnigbacc M-709
alphaqm M-102	jsd M-316	ncigbinv M-690	pnigbinv M-697
amexp M-119	jss M-315	ncigc M-717	pnigc M-721
amexpr M-462	jswd M-318	ncigd M-741	pntgen M-850
apclm M-151	jswgd M-320	ncigs M-732	pntox M-745

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apsat M-112	jswgs M-319	ncit M-486	poxedge M-244
apsatcv M-434	jsws M-317	nckappab M-846	ppclm M-631
aptwg M-123	jtsd M-332	nckappad M-840	ppclm cv M-640
aqmtcen M-95	jtss M-331	nckappas M-837	ppclmg M-634
ardsw M-162	jtsswd M-334	ncovd M-828	ppdibl1 M-670
ardw M-170	jtsswgd M-336	ncovs M-825	ppdibl1r M-673
arsdend M-202	jtsswgs M-335	ncs M-627	ppdibl2 M-676
arsw M-166	jtssws M-333	ndeltavsat M-576	ppgidl M-763
asej I-13	jtweff M-337	ndeltavsatcv M-961	ppgis1 M-778
asej M-13	k0 M-83	ndrout M-678	pphibe M-529
aseo I-9	k01 M-412	ndsub M-516	pphig M-481
aseo M-9	k0si M-84	ndvt0 M-498	pphin M-508
asiliend M-201	k0si1 M-413	ndvt1 M-501	ppigcd M-724
asymmod M-34	k1 M-86	ndvt1ss M-504	ppoxedge M-748
at M-379	k11 M-415	ndvtb M-546	pprt M-896
athetamu M-145	k1rsce M-80	ndvtshift M-525	pprwg M-658
athetasat M-126	k1sat M-88	negidl M-756	pprwgd M-664
aua M-133	k1sat1 M-416	negisl M-771	pprwgs M-661
aud M-140	k1si M-87	neigbinv M-693	ppsat M-574
avsat M-104	k1si1 M-414	nemobt M-871	ppsatcv M-959
avsat1 M-108	ksativ M-114	nesatii M-801	pptwg M-592

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avsatcv M-116	kt1 M-366	neta0 M-510	pptwgr M-595
bcs M-149	kt11 M-367	neta0r M-513	pptwgt M-887
beta OP-14	l I-2	netamob M-603	ppvag M-682
beta0 M-257	l M-3	neu M-615	pqm M-99
betaii0 M-259	la1 M-641	nf I-6	pqmacc M-101
betaii1 M-260	la11 M-930	nfin I-7	pqmfactor M-553
betaii2 M-261	la2 M-644	nfin M-7	pqmtcencv M-559
beu M-138	la21 M-933	nfinmax M-973	pqmtcencva M-562
bg0sub M-67	lagidl M-749	nfinmin M-972	pqmtceniv M-556
bgidl M-251	lagisl M-764	ngate M-69	prddr M-178
bgisl M-246	laigbacc M-698	ngcon I-8	prdswh M-649
bigbacc M-226	laigbaccl M-939	ngcon M-8	prdw M-655
bigbinv M-221	laigbinv M-683	ni0sub M-66	prsdend M-203
bigc M-230	laigbinv1 M-936	nigbacc M-228	prsdrr M-177
bigd M-240	laigc M-710	nigbinv M-224	prsw M-652
bigen M-353	laigc1 M-942	nigc M-232	prr M-383
bigsh M-236	laigd M-734	nigt M-913	prwg M-172
binunit M-2	laigd1 M-948	niit M-904	prwgd M-180
bmexp M-120	laigen M-851	njd M-322	prwgs M-179
bmexpr M-463	laigs M-725	njs M-321	psat M-111
bpclm M-152	laigs1 M-945	njts M-338	psatcv M-433

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bpsat	M-113	lalpha0	M-779	njtsd	M-339	psej	I-15
bpsatcv	M-435	lalpha1	M-782	njtssw	M-340	psej	M-15
bptwg	M-124	lalphaii	M-788	njtsswd	M-341	pseo	I-11
bqmtcen	M-96	lalphaii0	M-951	njtsswg	M-342	pseo	M-11
brdsw	M-163	lalphaii1	M-954	njtsswgd	M-343	psii0	M-808
brdw	M-171	lat	M-888	nk0	M-531	psii1	M-811
brsw	M-167	lbeta0	M-785	nk01	M-916	psii2	M-814
bthetamu	M-146	lbetaii0	M-791	nk0si	M-534	psiid	M-817
bthetasat	M-127	lbetaii1	M-794	nk0sil	M-919	pstthetasat	M-893
bua	M-134	lbetaii2	M-797	nk1	M-537	ptgidl	M-911
bud	M-141	lbgidl	M-752	nk11	M-925	pthetasat	M-598
bulkmod	M-29	lbgisl	M-767	nk1rsce	M-519	ptii	M-908
bvd	M-328	lbigbacc	M-701	nk1sat	M-543	ptss	M-902
bvs	M-327	lbigbinv	M-686	nk1sat1	M-928	ptwg	M-121
bvsat	M-105	lbigc	M-713	nk1si	M-540	ptwgr	M-122
bvsat1	M-109	lbigd	M-737	nk1sil	M-922	ptwgt	M-381
bvsatcv	M-117	lbigen	M-854	nksativ	M-579	pu0	M-601
capmod	M-44	lbigc	M-728	nkt1	M-898	pua	M-610
cdd	OP-64	lcdsc	M-488	nlii	M-804	pua1	M-875
cddi	OP-48	lcdscd	M-491	nlpe0	M-522	puc	M-613
cde	OP-66	lcdscdr	M-494	nlpeb	M-549	puc1	M-878

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cdei	OP-50	lcfd	M-821	nmexp	M-585	pucs	M-622
cdg	OP-63	lcfs	M-818	nmexpr	M-588	pucste	M-884
cdgi	OP-47	lcgbl	M-842	nmue	M-624	pud	M-619
cds	OP-65	lcgdl	M-833	nnbody	M-477	pud1	M-881
cdsc	M-71	lcgidl	M-758	nngate	M-483	pup	M-607
cdscd	M-72	lcgis1	M-773	nnighbacc	M-708	pute	M-866
cdscdn1	M-444	lcgs1	M-830	nnighbinv	M-696	put1	M-869
cdscdn2	M-445	lcighbacc	M-704	nnigc	M-720	pvag	M-219
cdscdr	M-73	lcighbinv	M-689	nntgen	M-849	pvasat	M-637
cdscdrn1	M-446	lcigc	M-716	nntox	M-744	pvsat	M-565
cdscdrn2	M-447	lcigd	M-740	noia	M-359	pvsat1	M-568
cdscn1	M-442	lcigs	M-731	noib	M-360	pvsat1r	M-571
cdscn2	M-443	lcit	M-485	noic	M-361	pvsatcv	M-583
cdsi	OP-49	lckappab	M-845	npclm	M-630	pwr	M-667
cdsp	I-19	lckappad	M-839	npclmcv	M-639	pwr	OP-16
cdsp	M-19	lckappas	M-836	npclmg	M-633	pxrcrg1	M-859
cdt	OP-114	lcovd	M-827	npdibl1	M-669	pxrcrg2	M-862
ced	OP-72	lcovs	M-824	npdibl1r	M-672	qb	OP-42
cedi	OP-56	lcs	M-626	npdibl2	M-675	qbi	OP-38
cee	OP-74	ldeltavsat	M-575	npgidl	M-762	qd	OP-40
ceei	OP-58	ldeltavsatcv	M-960	npgis1	M-777	qdi	OP-36

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ceg OP-71	ldg M-197	nphibe M-528	qg OP-39
cegi OP-55	ldrout M-677	nphig M-480	qgi OP-35
ces OP-73	ldsub M-515	nphin M-507	qm0 M-98
cesi OP-57	ldvt0 M-497	npigcd M-723	qm0acc M-100
cf d M-271	ldvt1 M-500	npoxedge M-747	qmfactor M-91
cfgeo OP-82	ldvt1ss M-503	np rt M-895	qmtcencv M-93
cfs M-270	ldvtb M-545	nprwg M-657	qmtcencva M-94
cgbl M-282	ldvtshift M-524	nprwgd M-663	qmtceniv M-92
cgbn M-281	leff O-2	nprwgs M-660	qs OP-41
cgbo M-280	leffcv O-4	npsat M-573	qsi OP-37
cgbov OP-77	legidl M-755	npsatcv M-958	rcvfac M-417
cgd OP-61	legisl M-770	nptwg M-591	rdc I-24
cgdext OP-76	leigbinv M-692	nptwgr M-594	rddr M-175
cgdi OP-45	lemobt M-870	nptwgt M-886	rddrr M-176
cgdl M-277	lesatii M-800	npvag M-681	rdgeo OP-81
cgdo M-275	leta0 M-509	nqmfactor M-552	rdsmod M-33
cgdp I-18	leta0r M-512	nqmtcencv M-558	rdsw M-161
cgdp M-18	letamob M-602	nqmtcencva M-561	rdswmin M-160
cge OP-62	leu M-614	nqmtceniv M-555	rdw M-169
cgei OP-46	ligt M-912	nqsmod M-39	rdwmin M-168
cgeolsw M-436	lii M-263	nrd I-21	reversed OP-127

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cgeoa	M-210	liit	M-903	nrd	M-21	rgatemod	M-41
cgeob	M-211	linearity_factor	OP-1	nrds	M-648	rgeoa	M-205
cgeoc	M-212	lint	M-45	nrdw	M-654	rgeob	M-206
cgeod	M-213	lintigen	M-350	nrs	I-20	rgeoc	M-207
cgeoe	M-214	lintnoi	M-863	nrs	M-20	rgeod	M-208
cgeomod	M-43	lk0	M-530	nrs	M-651	rgeoe	M-209
cgg	OP-59	lk01	M-915	nsd	M-61	rgeomod	M-42
cggi	OP-43	lk0si	M-533	nsde	M-204	rgext	M-184
cgidl	M-252	lk0si1	M-918	nseg	M-356	rgfin	M-185
cgisl	M-247	lk1	M-536	nsii0	M-807	rhoc	M-190
cgs	OP-60	lk11	M-924	nsii1	M-810	rhoext	M-192
cgsext	OP-75	lk1rsce	M-518	nsii2	M-813	rhorsd	M-191
cgsi	OP-44	lk1sat	M-542	nsiid	M-816	rout	OP-6
cgs1	M-276	lk1sat1	M-927	nstthetasat	M-892	rsc	I-23
cgso	M-274	lk1si	M-539	ntgen	M-351	rsdr	M-173
cgsp	I-17	lk1si1	M-921	ntgidl	M-910	rsdrr	M-174
cgsp	M-17	lksativ	M-578	nthetasat	M-597	rsgeo	OP-80
cgt	OP-112	lkt1	M-897	ntii	M-907	rshd	M-187
chargewf	M-467	ll	M-46	ntnoi	M-362	rshs	M-186
cigbacc	M-227	llc	M-51	ntox	M-243	rsw	M-165
cigbinv	M-222	llii	M-803	ntss	M-901	rswmin	M-164

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cigc M-231	lln M-47	nu0 M-600	rth0 M-408
cigd M-241	llpe0 M-521	nua M-609	sdterm M-195
cigs M-237	llpeb M-548	nua1 M-874	shmod M-40
cit M-70	lmax M-971	nuc M-612	sii0 M-264
cjd M-286	lmexp M-584	nucl M-877	sii1 M-265
cjdt OP-79	lmexpr M-587	nucs M-621	sii2 M-266
cjs M-285	lmin M-970	nucste M-883	siid M-267
cjst OP-78	lmue M-623	nud M-618	sjd M-304
cjswd M-288	lnbody M-476	nud1 M-880	sjs M-303
cjswgd M-290	lngate M-482	nup M-606	sjswd M-306
cjswgs M-289	lnigbacc M-707	nute M-865	sjswgd M-308
cjsws M-287	lnigbinv M-695	nut1 M-868	sjswgs M-307
ckappab M-283	lnigc M-719	nvasat M-636	sjsws M-305
ckappad M-279	lntgen M-848	nvsat M-564	stcs M-378
ckappas M-278	lntox M-743	nvsat1 M-567	stmue M-377
compatible M-469	lpa M-131	nvsat1r M-570	stthetamu M-376
coremod M-30	lpclm M-629	nvsatcv M-582	stthetasat M-382
covd M-273	lpclmcv M-638	nwr M-666	tbgasub M-364
covs M-272	lpclmg M-632	nxrcrg1 M-858	tbgbsub M-365
cratio M-193	lpdibl1 M-668	nxrcrg2 M-861	tcj M-388
cs M-147	lpdibl1r M-671	pal M-643	tcjsw M-389

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csd	OP-68	lpdibl2	M-674	pa11	M-932	tcjswg	M-390
csdesw	M-284	lpe0	M-81	pa2	M-646	temp_sh	O-7
csdi	OP-52	lpeb	M-90	pa21	M-935	tempeff	O-6
cse	OP-70	lpgidl	M-761	pagidl	M-751	teta0	M-451
csei	OP-54	lpgisl	M-776	pagisl	M-766	teta0r	M-452
csg	OP-67	lphibe	M-527	paigbacc	M-700	tfin	I-4
csgi	OP-51	lphig	M-479	paigbaccl	M-941	tfin	M-5
css	OP-69	lphin	M-506	paigbinv	M-685	tgate	M-199
cssi	OP-53	lpigcd	M-722	paigbinv1	M-938	tgidl	M-386
cst	OP-113	lpoly	OP-126	paigc	M-712	thetamu	M-144
cth0	M-409	lpoxedge	M-746	paigcl	M-944	thetasat	M-125
d	I-3	lprt	M-894	paigd	M-736	tii	M-385
d	M-4	lprwg	M-656	paigdl	M-950	tmask	M-200
deltaprsd	M-194	lprwgd	M-662	paigen	M-853	tmexp	M-380
deltavsat	M-110	lprwgs	M-659	paigs	M-727	tmexpr	M-464
deltavsatcv	M-432	lpsat	M-572	paigs1	M-947	tnjts	M-402
deltaw	M-57	lpsatcv	M-957	palpha0	M-781	tnjtssd	M-403
deltawcv	M-59	lptwg	M-590	palpha1	M-784	tnjtssw	M-404
delvfbacc	M-269	lptwgr	M-593	palphaii	M-790	tnjtsswd	M-405
delvtrand	I-27	lptwgt	M-885	palphaii0	M-953	tnjtsswg	M-406
delvtrand	M-23	lpvag	M-680	palphaii1	M-956	tnjtsswgd	M-407

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devtype	M-28	lqmfactor	M-551	para_cdbox	OP-87	tnom	M-363
didsdvd	OP-96	lqmtcencv	M-557	para_cgbox	OP-88	toxg	M-411
didsdvg	OP-94	lqmtcencva	M-560	para_csbox	OP-86	toxp	M-53
didsdvs	OP-95	lqmtceniv	M-554	para_qds_fr 93	OP-	toxref	M-242
didsdvth	OP-115	lrdsw	M-647	para_qgd_fr 92	OP-	tpb	M-391
digddvd	OP-102	lrdw	M-653	para_qgd_ov 90	OP-	tpbsw	M-392
digddvg	OP-100	lrsd	I-22	para_qgs_fr 91	OP-	tpbswg	M-393
digddvs	OP-101	lrsd	M-22	para_qgs_ov 89	OP-	trddr	M-183
digddvth	OP-117	lrsw	M-650	para_rd	OP-84	trise	I-26
digidldvd	OP-108	lsii0	M-806	para_rg	OP-85	trsdrr	M-182
digidldvg	OP-106	lsii1	M-809	para_rs	OP-83	tsili	M-189
digidldvs	OP-107	lsii2	M-812	pat	M-890	tss	M-368
digidldvth	OP- 119	lsiid	M-815	pbd	M-292	type	M-27
digisldvd	OP-111	lsp	M-196	pbeta0	M-787	u0	M-128
digisldvg	OP-109	lstthetasat	M- 891	pbetai0	M-793	u0mult	I-28
digisldvs	OP-110	ltgidl	M-909	pbetai1	M-796	u0mult	M-24
digisldvth	OP- 120	lthetasat	M-596	pbetai2	M-799	u0n1	M-465
digsdvd	OP-99	ltii	M-906	pbgidl	M-754	u0n2	M-466
digsdvg	OP-97	ltss	M-900	pbgisl	M-769	ua	M-132

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digsdvs	OP-98	lu0	M-599	pbigbacc	M-703	ua1	M-372
digsdvth	OP-116	lua	M-608	pbigbinv	M-688	uc	M-135
diidvd	OP-105	lua1	M-873	pbigc	M-715	uc1	M-373
diidvg	OP-103	luc	M-611	pbigd	M-739	ucs	M-142
diidvs	OP-104	luc1	M-876	pbigen	M-856	ucste	M-375
diidvth	OP-118	lucs	M-620	pbiggs	M-730	ud	M-139
dithdvd	OP-125	lucste	M-882	pbs	M-291	ud1	M-374
dithdvg	OP-123	lud	M-617	pbswd	M-294	up	M-130
dithdvs	OP-124	lud1	M-879	pbswgd	M-296	ute	M-369
dithdvth	OP-121	lup	M-605	pbswgs	M-295	ut1	M-370
dlbin	M-50	lute	M-864	pbsws	M-293	vasat	M-154
dlc	M-48	lut1	M-867	pcdsc	M-490	vasatcv	M-157
dlcacc	M-49	lvasat	M-635	pcdscd	M-493	vdet	OP-130
dlcigd	M-238	lvsat	M-563	pcdscdr	M-496	vds	OP-9
dlcigs	M-234	lvsat1	M-566	pcfd	M-823	vdssat	OP-15
drout	M-218	lvsat1r	M-569	pcfs	M-820	vdst	OP-132
dsub	M-79	lvsatcv	M-581	pcgbl	M-844	version	M-1
dtemp	I-25	lwr	M-665	pcgdl	M-835	ves	OP-10
dvt0	M-74	lxrcrg1	M-857	pcgidl	M-760	vest	OP-133
dvt1	M-75	lxrcrg2	M-860	pcgis1	M-775	vfb	OP-13
dvt1ss	M-448	m	I-1	pcgs1	M-832	vgd	OP-8

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dvtb	M-89	mbe0	M-967	pcighbacc	M-706	vgdt	OP-129
dvtp0	M-453	mbewl	M-966	pcigbinv	M-691	vget	OP-131
dvtpl	M-454	mexp	M-118	pcigc	M-718	vgs	OP-7
dvtshift	M-82	mexpr	M-461	pcigd	M-742	vgst	OP-128
easub	M-65	minr	M-468	pcigs	M-733	vgt	OP-12
ef	M-357	mismatchdist	M-969	pcit	M-487	vsat	M-103
egidl	M-253	mismatchmod	M-968	pckappab	M-847	vsatl	M-106
egisl	M-248	mjd	M-298	pckappad	M-841	vsatl1n1	M-457
eigbinv	M-223	mjd2	M-310	pckappas	M-838	vsatl1n2	M-458
em	M-358	mjs	M-297	pclm	M-150	vsatl1r	M-107
emobt	M-371	mjs2	M-309	pclmcv	M-155	vsatl1rn1	M-459
eot	M-52	mjswd	M-300	pclmg	M-153	vsatl1rn2	M-460
eotacc	M-268	mjswd2	M-312	pclmgcv	M-156	vsatcv	M-115
eotbox	M-54	mjswgd	M-302	pcovd	M-829	vsatn1	M-455
epsrox	M-63	mjswgd2	M-314	pcovs	M-826	vsatn2	M-456
epsrsp	M-198	mjswgs	M-301	pcs	M-628	vth	OP-11
epsrsub	M-64	mjswgs2	M-313	pdej	I-16	vthmod	M-470
esatii	M-262	mjsws	M-299	pdej	M-16	vtssd	M-345
eta0	M-77	mjsws2	M-311	pdeltavsat	M-577	vtss	M-344
eta0n1	M-449	mobmod	M-32	pdeltavsatcv	M-962	vtsswd	M-347

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BSIM-CMG

eta0n2	M-450	mue	M-143	pdeo	I-12	vtsswgd	M-349
eta0r	M-78	mvt0	M-965	pdeo	M-12	vtsswgs	M-348
etamob	M-129	mvtw1	M-963	pdibl1	M-215	vtssws	M-346
etaqm	M-97	mvtw12	M-964	pdibl1r	M-216	weff	O-1
eu	M-136	na1	M-642	pdibl2	M-217	weffcv	O-3
fech	M-56	na11	M-931	pdROUT	M-679	wr	M-181

BSIM-IMG

BSIM-IMG is a SPICE compact model for modeling the electrical characteristics of common gate MG structures, developed by UC Berkeley. The latest version is 101.0.

The BSIM-IMG models the independent double-gate structure as a four terminal device, containing the source(s), drain(d), front gate(fg), and back gate(bg) terminals. The two gates (fg, bg) are allowed to have different workfunctions ($\Delta\phi_1, \Delta\phi_2$) and dielectric thicknesses (T_{ox1}, T_{ox2}). They can also be biased separately at different voltages.

This chapter contains the following information about the BSIM-IMG model:

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 - [Bias Independent Calculations](#) on page 2960
 - [Terminal Voltages and Pre-Conditioning](#) on page 2962
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BSIM-IMG

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Model Overview

Physical surface-potential-based formulations are derived in both intrinsic and extrinsic models of BSIM-IMG. Surface potentials and integrated charge densities at the source and drain ends are obtained by solving the Poisson's equation in a fully-depleted, lightly doped body and calculating with efficient analytical approximations. Since the surface potential equation is derived based on Poisson's equation, the model captures volume inversion effects very well and shows excellent scalability compared with 2D device simulation.

To meet the requirements of future devices, new parameters have been included to model devices consisting of novel materials. This includes parameters for non-silicon channel devices and High-K gate insulators.

The back-gate of a planar double-gate SOI FET is often used for tuning device threshold voltage (V_{TH}). Therefore, the effect of back-gate on V_{TH} must also be addressed by the model. V_{TH} varies with back-gate voltage. When V_{bg} is low, they follow a linear relationship. At large V_{bg} , however, the back-gate effect slows down as a result of back surface accumulation.

Other important effects, such as short channel effects, mobility degradation, velocity saturation, velocity overshoot, series resistance, channel length modulation, quantum mechanical effects, gate tunneling current, gate-induced-drain-leakage, and parasitic capacitance are also incorporated in the model.

The model is continuous and symmetric at $V_{ds}=0$. This physics-based model is scalable and predictive over a wide range of device parameters.

BSIM-IMG Model Equations

Bias Independent Calculations

Physical Constants

Physical quantities in BSIM-IMG are in M.K.S units, unless specified otherwise.

$$q = 1.6 \times 10^{-19}$$

$$\epsilon_0 = 8.8542 \times 10^{-12}$$

$$k = 1.3787 \times 10^{-23}$$

$$\epsilon_{si} = EPSRSUB \cdot \epsilon_0$$

$$\epsilon_{ox1} = EPSROX1 \cdot \epsilon_0$$

$$\epsilon_{ox2} = EPSROX2 \cdot \epsilon_0$$

$$C_{ox1} = \frac{39 \cdot \epsilon_0}{EOT1}$$

$$C_{ox2} = \frac{39 \cdot \epsilon_0}{EOT2}$$

$$C_{si} = \frac{\epsilon_{si}}{TSI}$$

$$\epsilon_{ratio} = \frac{EPSRSUB}{3.9}$$

$$V_{tm} = \frac{kT}{q}$$

$$V_{gfb2n} = -1.2$$

Effective Channel Width, Channel Length

$$\Delta L = LINT + \frac{LL}{(L + XL) \cdot LLN}$$

$$\Delta LCV = DLC + \frac{LLC}{(L + XL) \cdot LLN}$$

$$L_{eff} = L + XL - 2\Delta L$$

$$L_{eff, CV} = L + XL - 2\Delta LCV$$

$$W_{eff} = W$$

$$W_{eff, CV} = W$$

Binning Calculations

$$PARAM_i = PARAM + \frac{1}{L_{eff}} \cdot LPARAM + \frac{1}{W_{eff}} \cdot WPARAM + \frac{1}{L_{eff} \cdot W_{eff}} \cdot PPARAM$$

Front and Back Gate Workfunction Calculation

$$\Phi_{ref} = \begin{cases} EASUB & \text{for } NMOS \\ EASUB + E_g & \text{for } PMOS \end{cases}$$

$$\Delta\Phi_1 = devsign \cdot (PHIG1_i - \Phi_{ref})$$

$$\Delta\Phi_2 = devsign \cdot (PHIG2_i - \Phi_{ref})$$

$$\Phi_{sd} = EASUB + \frac{E_g}{2} - devsign \cdot \min\left[\frac{E_g}{2}, \frac{kT}{q} \cdot \ln\left(\frac{NSD}{ni}\right)\right]$$

$$V_{fbSD} = devsign \cdot (PHIG1_i - \Phi_{sd})$$

Terminal Voltages and Pre-Conditioning

Terminal Voltages and V_{dsx} Calculation

$$V_{fgs} = V_{fg} - V_s$$

$$V_{fgd} = V_{fg} - V_d$$

$$V_{bgs} = V_{bg} - V_s$$

$$V_{bgd} = V_{bg} - V_d$$

$$V_{ds} = V_d - V_s$$

$$V_{gfb1} = V_{fgs} - \Delta\Phi_1$$

$$V_{gfb2} = V_{bgs} - \Delta\Phi_2$$

$$V_{dsx} = \sqrt{V_{ds}^2 + 0.01} - 0.1$$

Back Gate Biasing Effect

$$K_{vbg} = KBG0 - \frac{0.5 \cdot KBG1}{\cosh\left(DBG \cdot \frac{Leff}{\lambda}\right)}$$

$$K_{vbg}^* = KBG2 + \frac{1}{2} \left[K_{vbg} - KBG2 + \sqrt{(K_{vbg} - KBG2)^2 + 0.0001} \right]$$

$$V_{gfb2eff} = V_{gfb2n} - \text{symmetryfactor}$$

$$\gamma_0 = -\frac{C_{ox2} \cdot C_{si}}{(C_{ox2} + C_{si}) \cdot C_{ox1}}$$

$$\Delta V_{th, vbg} = \gamma_0 \cdot K_{vbg}^* \cdot (V_{gfb2} - V_{gfb2eff})$$

Short Channel Effects

Vt Roll-off

$$\Delta V_{th, SCE} = -\frac{0.5 \cdot DVT0_i}{\cosh\left(DVT1 \cdot \frac{Leff}{\lambda}\right) - 1} \cdot (V_{bi} - \Phi_{st})$$

Drain Induced Barrier Lowering (DIBL)

$$\Delta V_{th, DIBL} = -\frac{0.5 \cdot ETA0_i}{\cosh\left(DSUB \cdot \frac{Leff}{\lambda}\right) - 1} \cdot V_{dsx}$$

Vt Roll on/off at moderate channel lengths

$$V_{th, RSCE} = K1RSCE \left[\sqrt{1 + \frac{LPE0}{Leff}} - 1 \right] \cdot \sqrt{\Psi_{st}}$$

Vt Roll on/off at moderate channel lengths and high V_{ds}

$$\Delta V_{th, DSC} = -\frac{DSC0}{DSC1 + L_{eff}} \cdot V_{dsx}$$

Body Doping Effects

Body Doping Effect

$$\Delta V_{g, NBODY} = -\frac{q \cdot NBODY \cdot TS1}{C_{ox1}} \left[1 - \frac{0.5 \cdot TSI}{TSI + \epsilon_{ratio} \cdot EOT2} \right]$$

Drain Saturation Voltage

The drain saturation voltage model is calculated after the source-side surface potential (ϕ_s) has been calculated. V_{dseff} is subsequently used to compute the drain-side surface potential (ϕ_d).

Electric Field Calculations

$$q_{is} = \frac{Q_{tots}}{C_{ox1}}$$

$$q_{bs} = \frac{q \cdot NBODY \cdot TSI}{C_{ox1}}$$

$$T_2 = \eta_{\mu} q_{is} + q_{bs} + E_{bs} \cdot \frac{\epsilon_{si}}{C_{ox1}}$$

$$T_3 = \frac{1}{2} \left(T_2 + \sqrt{T_2^2 + 0.001} \right)$$

$$E_{effs} = 10^{-8} \cdot \frac{C_{ox1}}{\epsilon_{si}} \cdot T_3$$

Calculate the Drain Saturation Voltage

$$D_{mobs} = 1 + (UA(T) + UC(T) \cdot V_{bgs}) \cdot (E_{effs})^{EU} + \frac{UD(T)}{\left(\frac{1}{2} \left(1 + \frac{q_{is}}{q_{ia, th}} \right) \right) UCS(T)}$$

$$E_{sat} = \frac{2 \cdot VSAT}{\mu_o D_{mobs}}$$

If $D_{rs}=0$, then

$$V_{dsat} = \frac{E_{sat} L_{eff} \cdot \left(\frac{Q_{tots}}{C_{ox1} + C_{ox2}} \right)}{E_{sat} L_{eff} + \frac{Q_{tots}}{C_{ox1} + C_{ox2}}}$$

If D_{rs} is not equal to 0, then

$$T_6 = K_{SATIV} \cdot \left(\frac{Q_{tots}}{C_{ox1} + C_{ox2}} + 2V_t \right)$$

$$a = 2W \cdot V_{SAT} \cdot C_{ox1} \cdot G_{rs}$$

$$b = T_6 + E_{sat} L_{eff} + 3T_6 W_{eff} \cdot V_{SAT} \cdot C_{ox1} \cdot G_{rs}$$

$$c = T_6 \cdot [E_{sat} L_{eff} + T_6 \cdot a]$$

$$V_{dsat} = \frac{b - \sqrt{b^2 - 2ac}}{a}$$

Calculate Average Field, Potential, and Charge

Average Field, Potential, and Charge

$$\phi_m = \frac{\phi_{fs} + \phi_{fd}}{2}$$

$$q_{ia} = \frac{Q_{tots} + Q_{totd}}{2C_{ox1}}$$

$$q_{ba} = \frac{qN_A \cdot TSI}{C_{ox1}}$$

$$E_{ba} = \frac{E_{bs} + E_{bd}}{2}$$

$$\Delta\phi = \phi_{fd} - \phi_{fs}$$

$$\Delta q_i = \frac{Q_{tots} - Q_{totd}}{C_{ox1}}$$

Mobility Degradation

The mobility model is based on the BSIM4 model.

$$\eta = \begin{cases} \frac{1}{2} \cdot ETAMOB & \text{for } NMOS \\ \frac{1}{2} \cdot ETAMOB & \text{for } PMOS \end{cases}$$

$$T_2 = \eta_{\mu} q_{ia} + q_{ba} + E_{ba} \cdot \frac{\epsilon_{si}}{C_{ox1}}$$

$$T_3 = \frac{1}{2} \left(T_2 + \sqrt{T_2^2 + 0.001} \right)$$

$$E_{effm} = 10^{-8} \cdot \frac{C_{ox1}}{\epsilon_{si}} \cdot T_3$$

$$D_{mob0} = 1 + (UA(T) + UC(T) \cdot V_{bgs}) \cdot (E_{effm})^{EU} + \frac{UD(T)}{\left(\frac{1}{2} \left(1 + \frac{q_{ia}}{q_{ia,th}} \right) \right) UCS(T)}$$

$$D_{mob} = \frac{D_{mob0}}{U0MULT}$$

Output Conductance

Channel Length Modulation

$$C_{clm} = \begin{cases} PCLM \cdot (1 + PCLMG \cdot q_{im}) & \text{for } PCLMG > 0 \\ PCLM \div (1 - PCLMG \cdot q_{im}) & \text{for } PCLMG < 0 \end{cases}$$

$$M_{clm} = 1 + \frac{1}{C_{clm}} \ln \left[1 + \frac{V_{ds} - V_{dseff}}{V_{ASAT}} \right] \cdot C_{clm}$$

Output Conductance due to DIBL

$$PVAG_{factor} = \begin{cases} 1 + PVAG_i \cdot \frac{q_{ia}}{E_{sat} L_{eff}} & \text{for } PVAG_i > 0 \\ \frac{1}{1 - PVAG_i \cdot \frac{q_{ia}}{E_{sat} L_{eff}}} & \text{for } PVAG_i < 0 \end{cases}$$

$$\theta_{rout} = \frac{0.5 \cdot PDIBL1_i}{\cosh\left(DROUT_i \cdot \frac{L_{eff}}{\lambda}\right) - 1} + PDIBL2_i$$

$$V_{ADIBL} = \frac{q_{im} + 2kT/q}{\theta_{rout}} \cdot \left(1 - \frac{V_{dsat}}{V_{dsat} + q_{ia} + 2kT/q} \right) \cdot PVAG_{factor}$$

$$M_{oc} = \left(1 + \frac{V_{ds} - V_{dseff}}{V_{ADIBL}} \right) \cdot M_{clm}$$

M_{oc} is multiplied to I_{ds} in the `_nal` drain current expression.

Velocity Saturation

Current Degradation Due to Velocity Saturation

The following formulation models the current degradation factor due to velocity saturation in the linear region. It is adopted from the BSIM5 model.

$$E_{sat1} = \frac{2 \cdot VSAT1(T)}{\mu_{eff}}$$

$$\delta_{vsat} = DELTAVSAT$$

$$T_0 = 0.8 + VSATB \cdot V_{bgx}$$

$$X_{sat} = 0.2 + \frac{\left[T_0 + \sqrt{T_0^2 + 0.01} \right]}{2}$$

$$D_{vsat} = \frac{1 + \sqrt{\delta_{vsat} + \left(\frac{\Delta q_i}{E_{sat1} L_{eff}} \cdot X_{sat} \right)^2}}{1 + \sqrt{\delta_{vsat}}} + \frac{1}{2} \cdot PTWG(T) \cdot q_{ia} \cdot \Delta q_i^2$$

Drain Current Model

$$I_{ds0} = \mu_0 \cdot C_{ox1} \cdot \frac{W_{eff}}{L_{eff}} \cdot i_{ds0} \cdot \frac{M_{oc}}{D_{mob} \cdot D_r \cdot D_{vsat}}$$

C-V Model

Channel Length Modulation

$$C_{clm, CV} = \begin{cases} PCLMCV \cdot (1 + PCLMGCV \cdot q_{im}) & \text{for } PCLMGCV > 0 \\ \frac{PCLMCV}{1 - PCLMGCV \cdot q_{im}} & \text{for } PCLMGCV < 0 \end{cases}$$

$$M_{clm, CV} = 1 + \frac{1}{C_{clm, CV}} n_1 + \left[\frac{V_{ds} - V_{dseff}}{VASAT} \cdot C_{clm, CV} \right]$$

Assign Variables

$$Q_{fg} = \frac{1}{M_{clm, CV}} \cdot C_{ox1} \cdot W_{eff} \cdot L_{eff} \cdot (q_{fg})$$

$$Q_{bg} = \frac{1}{M_{clm, CV}} \cdot C_{ox1} \cdot W_{eff} \cdot L_{eff} \cdot (q_{bg})$$

$$Q_d = \frac{1}{M_{clm, CV}} \cdot C_{ox1} \cdot W_{eff} \cdot L_{eff} \cdot (-q_{d1} - q_{d2})$$

Parasitic Resistance and Capacitance Models

BSIM-IMG models the parasitic source/drain resistance in two components, a bias dependent extension resistance, and a bias independent diffusion resistance.

The parasitic capacitance model in BSIM-MG includes a bias-independent outer fringe capacitance, a bias-dependent inner fringe capacitance, a bias-dependent overlap capacitance, and substrate capacitances.

Bias-dependent Extension Resistance

RDSMOD=0 (Internal)

$$R_{ds} = \frac{1}{NF \cdot W_{eff}} \cdot \left(RDSWMIN(T) + \frac{RDSW(T)}{1 + PRWG_i \cdot q_{ia}} \right)$$

RDSMOD=1 (External)

$$R_{source} = \frac{1}{W_{eff0} \cdot NF} \cdot \left(RSWMIN(T) + \frac{RSW(T)}{1 + PRWG_i \cdot V_{gs, eff}} \right) + R_{s, geo}$$

$$R_{drain} = \frac{1}{W_{eff0} \cdot NF} \cdot \left(RDWMIN(T) + \frac{RDW(T)}{1 + PRWG_i \cdot V_{gd, eff}} \right) + R_{d, geo}$$

Bias-independent Diffusion Resistance

$$R_{s, geo} = NRD \cdot RSHS$$

$$R_{d, geo} = NRD \cdot RSHD$$

Overlap Capacitance Model

$$Q_{fgs, ov} = W_{eff, CV} \cdot LOVS_i \cdot C_{ox1} \cdot C_{(ge, s)} + W_{eff, CV} \cdot CGSL$$

$$\left\{ V_{fgs, noswap} - V_{fbsd} - V_{fgs, ov} - \frac{1}{2} \cdot CKAPPAS \cdot \left[\left(\sqrt{1 - \frac{4V_{gs, overlap}}{CKAPPAS}} - 1 \right) \right] \right\} \cdot devsign$$

$$Q_{fgd, ov} = W_{eff, CV} \cdot LOVD_i \cdot C_{ox1} \cdot V_{(ge, d)} + W_{eff, CV} \cdot CGDL$$

$$\left\{ V_{fgd, noswap} - V_{fbsd} - V_{fgd, ov} - \frac{1}{2} \cdot CKAPPAS \cdot \left[\left(\sqrt{1 - \frac{4V_{gd, overlap}}{CKAPPAD}} - 1 \right) \right] \right\} \cdot devsign$$

Outer Fringe Capacitances

$$Q_{fgs, of} = W_{eff, CV} \cdot CFS \cdot V_{(ge, s)}$$

$$Q_{fgd, of} = W_{eff, CV} \cdot CFD \cdot V_{(ge, d)}$$

Inner Fringe Capacitance

$$C_{if, factor} = ETACIF \cdot W_{eff, CV} \cdot \frac{2\epsilon_{si}}{\pi}$$

$$1n \left[\frac{\epsilon_{ratio} \cdot EOT1 + TSI + \sqrt{L_{un}^2 + TSI^2 + 2\epsilon_{ratio} \cdot EOT1 \cdot TSI}}{L_{un} + \epsilon_{ratio} \cdot EOT1} \right]$$

$$Q_{fgs, if} = devsign \cdot C_{if, factor} \cdot \left(\psi_{fs} - 0.0 - \frac{1}{2}E_g \right)$$

$$Q_{fgd, if} = devsign \cdot C_{if, factor} \cdot \left(\psi_{fd} - V_{ds} - \frac{1}{2}E_g \right)$$

Source/drain to Substrate Capacitances

$$C_{sdbgswo} = CSDBGSW \cdot 1n \left(1 + \frac{TSI}{EOT2} \right)$$

$$Q_{sbg} = [C_{ox2} \cdot AS + (PS - W) \cdot C_{sdbgswo}] \cdot V(s, bg)$$

$$Q_{dbg} = [C_{ox2} \cdot AD + (PD - W) \cdot C_{sdbgswo}] \cdot V(d, bg)$$

Impact Ionization and GIDL/GISL Model

Impact Ionization Current

$$I_{ii} = \frac{ALPHA0_i + ALPHA1_i \cdot L_{eff}}{L_{eff}} (V_{ds} - V_{dseff}) \cdot e^{\frac{-BETA0}{V_{ds} - V_{dseff}}} \cdot I_{ds}$$

Gate-Induced-Drain/Source-Leakage Current

$$I_{gidl} = AGIDL \cdot W_{eff} \cdot \frac{V_{ds} - V_{fgs} - EGIDL + V_{fbsd}}{\epsilon_{ratio} \cdot EOT1} \times \exp\left(\frac{\epsilon_{ratio} \cdot EOT1 \cdot BGIDL(T)}{V_{ds} - V_{fgs} - EGIDL + V_{fbsd}}\right)$$

$$I_{gisl} = AGIDL \cdot W_{eff} \cdot \frac{-V_{ds} - V_{fgd} - EGIDL + V_{fbsd}}{\epsilon_{ratio} \cdot EOT1} \times \exp\left(\frac{\epsilon_{ratio} \cdot EOT1 \cdot BGIDL(T)}{-V_{ds} - V_{fgd} - EGIDL + V_{fbsd}}\right)$$

Gate Tunneling Current

Gate to channel current (I_{gc})

$$I_{gcs} = \frac{W_{eff} \cdot L_{eff} \cdot A}{\left(\frac{EOT1 \cdot EPSROX}{3.9}\right)^2} \cdot V'_{fgs} \cdot V_{auxs} \cdot \exp\left(-B \cdot \frac{EOT1 \cdot EPSROX}{3.9} \cdot (AIGC - BIGC \cdot V_{oxm})\right) \cdot (1 + CIGC \cdot V_{oxm})$$

$$I_{gcd} = \frac{W_{eff} \cdot L_{eff} \cdot A}{\left(\frac{EOT1 \cdot EPSROX}{3.9}\right)^2} \cdot V'_{fgd} \cdot V_{auxd} \cdot \exp\left(-B \cdot \frac{EOT1 \cdot EPSROX}{3.9} \cdot (AIGC - BIGC \cdot V_{oxm})\right) \cdot (1 + CIGC \cdot V_{oxm})$$

$$I_{gc} = I_{gcs} + I_{gcd}$$

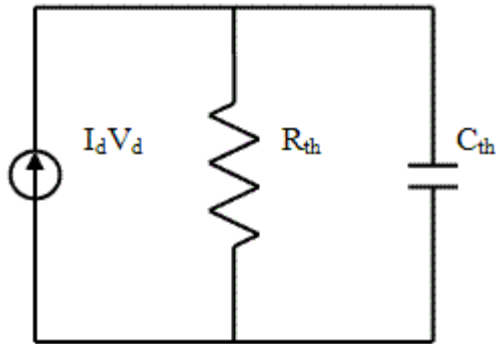
Gate to source/drain current (I_{gs} , I_{gd})

$$I_{gs} = \frac{W_{eff} \cdot DLCIG \cdot A}{\left(EOT \cdot \frac{EPSROX}{3.9} \cdot POXEDGE_i\right)^2} \cdot V_{fgs} \cdot V'_{fgs} \cdot \exp\left(-B \cdot EOT \cdot \frac{EPSROX}{3.9} \cdot POXEDGE_i \cdot (AIGS_i - BIGS_i \cdot V'_{fgs}) \cdot (1 + CIGS_i \cdot V'_{fgs})\right)$$

$$I_{gd} = \frac{W_{eff} \cdot DLCIG \cdot A}{\left(EOT \cdot \frac{EPSROX}{3.9} \cdot POXEDGE_i\right)^2} \cdot V_{fgd} \cdot V'_{fgd} \cdot \exp\left(-B \cdot EOT \cdot \frac{EPSROX}{3.9} \cdot POXEDGE_i \cdot (AIGS_i - BIGS_i \cdot V'_{fgd}) \cdot (1 + CIGS_i \cdot V'_{fgd})\right)$$

Self Heating Model

Figure 46-1 R-C network for self-heating calculation



Thermal resistance and capacitance calculations

$$\frac{1}{R_{th}} = G_{th} = \frac{WTH0 + W_{eff} \cdot NF}{RTH0}$$

$$C_{th} = CTH0 \cdot (WTH0 + W_{eff} \cdot NF)$$

Component Statements

Sample Model Statement

```
Model nch bsimimg devtype=1 gidlmod=1 igmod=1 rdsmod=1 nobody=1e22
```

Sample Instance Statement

```
m1 (d fg s bg) nchl=30n w=1u nf=4
```

Instance Definition

```
Name d fg s bg ModelName parameter=value ...
```

Instance Parameters

- 1 exp_cr=80.0 instance parameter
- 2 cmi_limexp_method=1.0 instance parameter
- 3 cmi_compactable=1.0 instance parameter
- 4 m=1.0 Multiplicity factor.
- 5 l=(30 1.0e-9) Designed Gate Length.
- 6 w=(1 1.0e-6) Designed Gate Width.
- 7 nf=1 Number of fingers.

Virtuoso Simulator Components and Device Models Reference

BSIM-IMG

8	as=0.0	Source area in m ² .
9	ad=0.0	Drain area in m ² .
10	ps=0.0	Source perimeter in m.
11	pd=0.0	Drain perimeter in m.
12	nrs=0.0	Number of source diffusion square.
13	nrd=0.0	Number of source diffusion squares.
14	xl=0	L offset for channel length due to mask/etch effect.
15	delvtrand=0	Variability in V _{th} .
16	u0mult=1	Variability in carrier mobility.
17	ids0mult=1	Variability in Drain current for misc. reasons.

Model Definition

model modelName bsimimg parameter=value ...

Model Parameters

1	devtype=1	Device doping type. 0: ptype, 1: ntype.
2	rdsmod=0	0: Internal s/d resistance model; 1: External s/d resistance model.
3	gidlmod=0	0: Turn off GIDL/GISL current; 1: Turn on GIDL/GISL current.
4	igmod=0	Gate current switcher; 0=turn off, 1=turn on.
5	lint=0	Length reduction parameter.
6	rgatmod=0	0: Gate electrode resistance / ge node turned off, 1: Gate electrode resistance / ge node turned on.
7	nqsmod=0	0: NQS models turned off, 1: NQS gate resistance / gi node turned on.

Virtuoso Simulator Components and Device Models Reference

BSIM-IMG

8	shmod=0	0: No self-heating, 1: Self-heating turned on.
9	ll=0	Length reduction parameter.
10	lln=1	Length reduction parameter.
11	llc=0	Length reduction parameter.
12	d1c=0	Delta L for C-V model.
13	eot1=(1.0 1.0e-9)	Equivalent front gate dielectric thickness relative to SiO ₂ , (m).
14	eot2=(140 1.0e-9)	Equivalent back gate dielectric thickness relative to SiO ₂ , (m).
15	tsi=(8.0 1.0e-9)	Body thickness (m).
16	nbody=1e22	channel (body) doping.
17	nsd=2e26	Source/drain active doping concentration in m ⁻³ .
18	nbg=6.0e22	Back gate (or substrate) doping (positive means same as body, vice versa.).
19	easub=4.05	Electron affinity of substrate, eV.
20	ni0sub=1.1e16	Intrinsic carrier constant at 300.15K, m ⁻³ .
21	bg0sub=1.12	Band gap of substrate at 300.15K, eV.
22	nc0sub=2.86e25	Conduction band density of states, m ⁻³ .
23	phig1=4.61	Front Gate Workfunction, eV.
24	phig2=5.17	Back Gate Workfunction, eV.
25	epsrsub=11.9	Relative dielectric constant of the channel material.
26	epsrox1=3.9	Relative dielectric constant of the front gate dielectric.
27	epsrox2=3.9	Relative dielectric constant of the back gate dielectric.

Virtuoso Simulator Components and Device Models Reference

BSIM-IMG

28	<code>ascl=0.0</code>	
29	<code>bscl=0.0</code>	
30	<code>cit=0</code>	parameter for interface trap.
31	<code>cdsc=0.14</code>	coupling capacitance between S/D and channel.
32	<code>cdscd=0.14</code>	drain-bias sensitivity of CDSC.
33	<code>dvt0=19.20</code>	SCE coefficient.
34	<code>dvt1=0.45</code>	SCE exponent coefficient.
35	<code>phin=0.045</code>	Nonuniform vertical doping effect on surface potential, V.
36	<code>eta0=2.00</code>	DIBL coefficient 1.
37	<code>dsub=0.375</code>	DIBL coefficient 2.
38	<code>k1rsce=(-0.32)</code>	Vt Roll-off at moderate Lg.
39	<code>lpe0=8.2e-9</code>	Vt Roll-off at moderate Lg.
40	<code>dsc0=0.0</code>	
41	<code>dsc1=1.00e-9</code>	
42	<code>vsat=85000</code>	
43	<code>avsat=0.0</code>	
44	<code>bvsat=100.0e-9</code>	
45	<code>vsat1=85000</code>	
46	<code>avsat1=0.0</code>	
47	<code>bvsat1=100.0e-9</code>	
48	<code>deltavsat=1.0</code>	
49	<code>ksativ=1.0</code>	

Virtuoso Simulator Components and Device Models Reference

BSIM-IMG

50 mexp=4
51 amexp=0.0
52 bmexp=1.0
53 ptwg=0.0
54 aptwg=0.0
55 bptwg=100.0e-9
56 at=(-1.56e-3)
57 tmexp=0.0
58 ptwgt=0.004
59 ptwgb=0.0
60 vsatb=0.0
61 u0=0.03
62 etamob=2.0
63 up=0
64 lpa=1.0
65 ua=0.3
66 aua=0.0
67 bua=100.0e-9
68 eu=2.5
69 aeu=0.0
70 beu=100.0e-9
71 uc=0

Virtuoso Simulator Components and Device Models Reference

BSIM-IMG

72 ud=0.0

73 aud=0.0

74 bud=50.0e-9

75 ucs=1.0

76 ute=0.0

77 utl=(-1.5e-3)

78 ua1=1.032e-3

79 ud1=0.0

80 ucste=(-4.775e-3)

81 rdswmin=0.0

82 rdsw=100.0

83 ards=0.0

84 brds=100.0e-9

85 rswmin=0.0

86 rsw=50.0

87 arsw=0.0

88 brsw=100.0e-9

89 rdwmin=0.0

90 rdw=50.0

91 ardw=0.0

92 brdw=100.0e-9

Virtuoso Simulator Components and Device Models Reference

BSIM-IMG

93	prwg=0	
94	prwb=0	
95	wr=1.0	
96	p _{rt} =0.001	
97	p _{dibl1} =1.30	
98	p _{dibl2} =2.0e-4	
99	d _{rout} =1.06	
100	p _{vag} =1.0	
101	p _{clm} =0.013	
102	a _{pclm} =0.0	
103	b _{pclm} =100.0e-9	
104	p _{clmg} =0.0	
105	v _{asat} =0.2	
106	p _{clm_{cv}} =0.013	
107	p _{clmg_{cv}} =0.0	
108	v _{asat_{cv}} =0.2	
109	r _{shs} =0.0	Source-side sheet resistance.
110	r _{shd} =0.0	Drain-side sheet resistance.
111	a _{igc} =1.36e-2	parameter for I _{gc} in inversion.
112	b _{igc} =1.71e-3	parameter for I _{gc} in inversion.
113	c _{igc} =0.075	parameter for I _{gc} in inversion.
114	n _{igc} =1.0	parameter for I _{gc} in inversion.

Virtuoso Simulator Components and Device Models Reference

BSIM-IMG

115	<code>vthigc=0.3</code>	parameter for I_{gc} in inversion.
116	<code>aigs=1.36e-2</code>	parameter for I_{gs} , I_{gd} .
117	<code>big=1.71e-3</code>	parameter for I_{gs} , I_{gd} .
118	<code>cigs=0.075</code>	parameter for I_{gs} , I_{gd} .
119	<code>poxedge=1</code>	Factor for the gate edge T_{ox} .
120	<code>dlcig=0</code>	Delta L for I_{gs}/I_{gd} model.
121	<code>agidl=6.055e-12</code>	pre-exponential coeff. for GIDL in mho.
122	<code>bgidl=3.0e8</code>	exponential coeff. for GIDL in V/m.
123	<code>egidl=0.2</code>	band bending parameter for GIDL in V.
124	<code>alpha0=0.0</code>	first parameter of I_{ii} , m/V.
125	<code>alpha1=0.0</code>	L scaling parameter of I_{ii} , 1/V.
126	<code>beta0=0.0</code>	V_{ds} dependent parameter of I_{ii} , 1/V.
127	<code>lovs=0.0</code>	Overlap length for fg/s fg/d overlap (m).
128	<code>lovd=0.0</code>	Overlap length for fg/s fg/d overlap (m).
129	<code>cfs=0.0</code>	Outer Fringe Cap (F).
130	<code>dfd=0.0</code>	Outer Fringe Cap (F).
131	<code>cgs1=0.0</code>	
132	<code>cgdl=0.0</code>	
133	<code>ckappas=0.6</code>	
134	<code>ckappad=0.6</code>	
135	<code>etacif=1.0</code>	
136	<code>csdbgs=0.0</code>	Source/drain sidewall fringing capacitance per unit length.

Virtuoso Simulator Components and Device Models Reference

BSIM-IMG

137	$kg_0=1.0$	Length dependence of body factor.
138	$kg_1=0.0$	Length dependence of body factor.
139	$kg_2=(-1.0)$	Length dependence of body factor.
140	$dbg=0.12$	Length dependence of body factor.
141	$t_{nom}=27.0$	Temperature at which the model is extracted (Celcius).
142	$t_{bgasub}=7.02e-4$	Bandgap Temperature Coefficient (eV / degrees).
143	$t_{bgbsub}=1108.0$	Bandgap Temperature Coefficient (degrees).
144	$kt_1=0.0$	Vth Temperature Coefficient (V).
145	$kt_{11}=0.0$	Vth Temperature L Coefficient (m-V).
146	$kt_2=0.0$	Vth Temperature Vbg Coefficient (V).
147	$kt_3=0.0$	Vth Temperature Vds Coefficient (V).
148	$iit=(-0.5)$	Impact Ionization Temperature Dependence.
149	$t_{gidl}=(-0.003)$	GIDL/GISL Temperature Dependence.
150	$igt=2.5$	Gate Current Temperature Dependence.
151	$r_{th0}=0.01$	Thermal resistance.
152	$c_{th0}=1.0E-05$	Thermal capacitance.
153	$w_{th0}=0.0$	Width dependence coefficient for Rth and Cth.
154	$rdkeep=0$	
155	$rskeep=0$	
156	$lrdsw=0.0$	
157	$wrdsw=0.0$	
158	$prdsw=0.0$	

Virtuoso Simulator Components and Device Models Reference

BSIM-IMG

159 lrdw=0.0

160 wrdw=0.0

161 prdw=0.0

162 lrsw=0.0

163 wrsw=0.0

164 prsw=0.0

165 lprwg=0.0

166 wprwg=0.0

167 pprwg=0.0

168 lprwb=0.0

169 wprwb=0.0

170 pprwb=0.0

171 lwr=0.0

172 wwr=0.0

173 pwr=0.0

174 lphig1=0.0

175 wphig1=0.0

176 pphig1=0.0

177 lphig2=0.0

178 wphig2=0.0

179 pphig2=0.0

180 lnsd=0.0

Virtuoso Simulator Components and Device Models Reference

BSIM-IMG

181 wnsd=0.0

182 pnsd=0.0

183 lnbody=0.0

184 wnbody=0.0

185 pnbody=0.0

186 lcit=0.0

187 wcit=0.0

188 pcit=0.0

189 lcdsc=0.0

190 wcdsc=0.0

191 pcdsc=0.0

192 lcdscd=0.0

193 wcdscd=0.0

194 pcdscd=0.0

195 ldvt0=0.0

196 wdvt0=0.0

197 pdvt0=0.0

198 ldvt1=0.0

199 wdvt1=0.0

200 pdvt1=0.0

201 lphin=0.0

202 wphin=0.0

Virtuoso Simulator Components and Device Models Reference

BSIM-IMG

203 pphin=0.0

204 leta0=0.0

205 weta0=0.0

206 peta0=0.0

207 ldsb=0.0

208 wdsb=0.0

209 pdsb=0.0

210 lk1rsce=0.0

211 wk1rsce=0.0

212 pk1rsce=0.0

213 llpe0=0.0

214 wlpe0=0.0

215 plpe0=0.0

216 lmexp=0.0

217 wmexp=0.0

218 pmexp=0.0

219 lptwg=0.0

220 wptwg=0.0

221 pptwg=0.0

222 lptwgt=0.0

223 wptwgt=0.0

224 pptwgt=0.0

Virtuoso Simulator Components and Device Models Reference

BSIM-IMG

225 lu0=0.0

226 wu0=0.0

227 pu0=0.0

228 lua=0.0

229 wua=0.0

230 pua=0.0

231 luc=0.0

232 wuc=0.0

233 puc=0.0

234 lud=0.0

235 wud=0.0

236 pud=0.0

237 lucs=0.0

238 wucs=0.0

239 pucs=0.0

240 leu=0.0

241 weu=0.0

242 peu=0.0

243 lutl=0.0

244 wutl=0.0

245 putl=0.0

246 lute=0.0

Virtuoso Simulator Components and Device Models Reference

BSIM-IMG

247 wute=0.0

248 pute=0.0

249 lua1=0.0

250 wua1=0.0

251 pua1=0.0

252 lud1=0.0

253 wud1=0.0

254 pud1=0.0

255 lucste=0.0

256 wucste=0.0

257 pucste=0.0

258 lat=0.0

259 wat=0.0

260 pat=0.0

261 lpvt=0.0

262 wpvt=0.0

263 ppvt=0.0

264 liit=0.0

265 wiit=0.0

266 piit=0.0

267 ltgidl=0.0

268 wtgidl=0.0

Virtuoso Simulator Components and Device Models Reference

BSIM-IMG

269 ptgidl=0.0

270 ligt=0.0

271 wigt=0.0

272 pigt=0.0

273 lpclm=0.0

274 wpclm=0.0

275 ppclm=0.0

276 lpclmcv=0.0

277 wpclmcv=0.0

278 ppclmcv=0.0

279 ldrout=0.0

280 wdrout=0.0

281 pdrout=0.0

282 lpdibl1=0.0

283 wpdibl1=0.0

284 ppdibl1=0.0

285 lpdibl2=0.0

286 wpdibl2=0.0

287 ppdibl2=0.0

288 lpvag=0.0

289 wpvag=0.0

290 ppvag=0.0

Virtuoso Simulator Components and Device Models Reference

BSIM-IMG

291 lalpha0=0.0

292 walpha0=0.0

293 palpha0=0.0

294 lalpha1=0.0

295 walpha1=0.0

296 palpha1=0.0

297 lbeta0=0.0

298 wbeta0=0.0

299 pbeta0=0.0

300 laigc=0.0

301 waigc=0.0

302 paigc=0.0

303 lbigc=0.0

304 wbigc=0.0

305 pbigc=0.0

306 lcigc=0.0

307 wcigc=0.0

308 pcigc=0.0

309 lnigc=0.0

310 wnigc=0.0

311 pnigc=0.0

312 lagidl=0.0

Virtuoso Simulator Components and Device Models Reference

BSIM-IMG

313 wagidl=0.0

314 pagidl=0.0

315 lbgidl=0.0

316 wbgidl=0.0

317 pbgidl=0.0

318 legidl=0.0

319 wegidl=0.0

320 pegidl=0.0

321 laigs=0.0

322 waigs=0.0

323 paigs=0.0

324 lbiggs=0.0

325 wbiggs=0.0

326 pbiggs=0.0

327 lcigs=0.0

328 wcigs=0.0

329 pcigs=0.0

330 lpoxedge=0.0

331 wpoxedge=0.0

332 ppoxedge=0.0

333 llovs=0.0

334 wlovs=0.0

Virtuoso Simulator Components and Device Models Reference

BSIM-IMG

335 plovs=0.0

336 llovd=0.0

337 wlovd=0.0

338 plovd=0.0

339 lcfs=0.0

340 wcfs=0.0

341 pcfs=0.0

342 lcfd=0.0

343 wcfd=0.0

344 pcfd=0.0

345 lvsat=0.0

346 wvsat=0.0

347 pvsat=0.0

348 lvsat1=0.0

349 wvsat1=0.0

350 pvsat1=0.0

351 lksativ=0.0

352 wksativ=0.0

353 pksativ=0.0

354 lup=0.0

355 wup=0.0

356 pup=0.0

Output Parameters

- 1 d
- 2 fg
- 3 s
- 4 bg
- 5 di
- 6 si
- 7 ge
- 8 gi
- 9 t

Operating-Point Parameters

- 1 exp_cr=80.0 instance parameter
- 2 cmi_limexp_method=1.0 instance parameter
- 3 cmi_compactable=1.0 instance parameter
- 4 m=1.0 Multiplicity factor.
- 5 l=(30 1.0e-9) Designed Gate Length.
- 6 w=(1 1.0e-6) Designed Gate Width.
- 7 nf=1 Number of fingers.
- 8 as=0.0 Source area in m².
- 9 ad=0.0 Drain area in m².
- 10 ps=0.0 Source perimeter in m.

Virtuoso Simulator Components and Device Models Reference

BSIM-IMG

11	pd=0.0	Drain perimeter in m.
12	nrs=0.0	Number of source diffusion square.
13	nrd=0.0	Number of source diffusion squares.
14	xl=0	L offset for channel length due to mask/etch effect.
15	delvtrand=0	Variability in Vth.
16	u0mult=1	Variability in carrier mobility.
17	ids0mult=1	Variability in Drain current for misc. reasons.
18	op_ids (A)	
19	op_qfg (C)	
20	op_qbg (C)	
21	op_qd (C)	
22	op_qs (C)	
23	op_ueff	
24	op_cfgd (F)	
25	op_cfgfg (F)	
26	op_cfgs (F)	
27	op_cfgbg (F)	
28	op_cbgd (F)	
29	op_cbgfg (F)	
30	op_cbgs (F)	
31	op_cbgbg (F)	
32	op_cdd (F)	

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33 op_cdfg (F)

34 op_cds (F)

35 op_cdbg (F)

Parameter Index

In the following index, I refers to instance parameters, M refers to the model parameters section, O refers to the output parameters section, and OP refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of M-35 means the 35th model parameter.

ad	I-9	lagidl	M-312	op_qd	OP-21	s	O-3
ad	OP-9	laigc	M-300	op_qfg	OP-19	shmod	M-8
aeu	M-69	laigs	M-321	op_qs	OP-22	si	O-6
agidl	M-121	lalpha0	M-291	op_ueff	OP-23	t	O-9
aigc	M-111	lalpha1	M-294	pagidl	M-314	tbgasub	M-142
aigs	M-116	lat	M-258	paigc	M-302	tbgbsub	M-143
alpha0	M-124	lbeta0	M-297	paigs	M-323	tgidl	M-149
alpha1	M-125	lbgidl	M-315	palpha0	M-293	tmexp	M-57
amexp	M-51	lbigc	M-303	palpha1	M-296	tnom	M-141
apclm	M-102	lbigc	M-324	pat	M-260	tsi	M-15
aptwg	M-54	lcdsc	M-189	pbeta0	M-299	u0	M-61
ardsw	M-83	lcdscd	M-192	pbgidl	M-317	u0mult	I-16
ardw	M-91	lcfid	M-342	pbigc	M-305	u0mult	OP-16
arsw	M-87	lcfs	M-339	pbigc	M-326	ua	M-65

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as	I-8	lcigc	M-306	pcdsc	M-191	ua1	M-78
as	OP-8	lcigs	M-327	pcdscd	M-194	uc	M-71
ascl	M-28	lcit	M-186	pcfd	M-344	ucs	M-75
at	M-56	ldrout	M-279	pcfs	M-341	ucste	M-80
aua	M-66	ldsub	M-207	pcigc	M-308	ud	M-72
aud	M-73	ldvt0	M-195	pcigs	M-329	ud1	M-79
avsat	M-43	ldvt1	M-198	pcit	M-188	up	M-63
avsat1	M-46	legidl	M-318	pclm	M-101	ute	M-76
beta0	M-126	leta0	M-204	pclmcv	M-106	ut1	M-77
beu	M-70	leu	M-240	pclmg	M-104	vasat	M-105
bg	O-4	ligt	M-270	pclmgcv	M-107	vasatcv	M-108
bg0sub	M-21	liit	M-264	pd	I-11	vsat	M-42
bgidl	M-122	lint	M-5	pd	OP-11	vsat1	M-45
bigc	M-112	lk1rsce	M-210	pdibl1	M-97	vsatb	M-60
bigc	M-117	lksativ	M-351	pdibl2	M-98	vthigc	M-115
bmexp	M-52	ll	M-9	pdrou	M-281	w	I-6
bpc1m	M-103	llc	M-11	pdsu	M-209	w	OP-6
bptwg	M-55	lln	M-10	pdvt0	M-197	wagidl	M-313
brdsw	M-84	llovd	M-336	pdvt1	M-200	waigc	M-301
brdw	M-92	llovs	M-333	pegidl	M-320	waigs	M-322
brsw	M-88	llpe0	M-213	peta0	M-206	walpha0	M-292

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bocl M-29	lmexp M-216	peu M-242	walphal M-295
bua M-67	lnbody M-183	phig1 M-23	wat M-259
bud M-74	lnigc M-309	phig2 M-24	wbeta0 M-298
bvsat M-44	lnsd M-180	phin M-35	wbgidl M-316
bvsat1 M-47	lovd M-128	pigt M-272	wbigc M-304
cdsc M-31	lovs M-127	piit M-266	wbigs M-325
cdscd M-32	lpa M-64	pklrsc M-212	wcdsc M-190
cfcl M-130	lpclm M-273	pkrsativ M-353	wcdscd M-193
cfs M-129	lpclmclv M-276	plovd M-338	wcfd M-343
cgdl M-132	lpdibl1 M-282	plovs M-335	wcfs M-340
cgs1 M-131	lpdibl2 M-285	plpe0 M-215	wcigc M-307
cigc M-113	lpe0 M-39	pmexp M-218	wcigs M-328
cigs M-118	lphig1 M-174	pnbody M-185	wcit M-187
cit M-30	lphig2 M-177	pnigc M-311	wdrout M-280
ckappad M-134	lphin M-201	pnsd M-182	wdsub M-208
ckappas M-133	lpoxedge M-330	poxedge M-119	wdvt0 M-196
cmi_compactable I-3	lpprt M-261	ppclm M-275	wdvt1 M-199
cmi_compactable OP-3	lprwb M-168	ppclmclv M-278	wegidl M-319
cmi_limexp_method I-2	lprwg M-165	ppdibl1 M-284	weta0 M-205

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cmi_limexp_method OP-2	lptwg M-219	ppdibl2 M-287	weu M-241
csdbgs M-136	lptwgt M-222	pphig1 M-176	wigt M-271
cth0 M-152	lpvag M-288	pphig2 M-179	wiit M-265
d O-1	lrdsw M-156	pphin M-203	wklrsce M-211
dbg M-140	lrdw M-159	ppoxedge M-332	wksativ M-352
deltavsat M-48	lrs M-162	pprt M-263	wlovd M-337
delvtrand I-15	ltgidl M-267	pprwb M-170	wlovs M-334
delvtrand OP-15	lu0 M-225	pprwg M-167	wlpe0 M-214
devtype M-1	lua M-228	pptwg M-221	wmexp M-217
di O-5	lua1 M-249	pptwgt M-224	wnbody M-184
dlc M-12	luc M-231	ppvag M-290	wnigc M-310
dlcig M-120	lucs M-237	prds M-158	wnsd M-181
drout M-99	lucste M-255	prdw M-161	wpclm M-274
dsc0 M-40	lud M-234	prsw M-164	wpclmcv M-277
dsc1 M-41	lud1 M-252	prt M-96	wpdibl1 M-283
dsub M-37	lup M-354	prwb M-94	wpdibl2 M-286
dvt0 M-33	lute M-246	prwg M-93	wphig1 M-175
dvt1 M-34	lut1 M-243	ps I-10	wphig2 M-178
easub M-19	lvsat M-345	ps OP-10	wphin M-202
egidl M-123	lvsat1 M-348	ptgidl M-269	wpoxedge M-331

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eot1	M-13	lwr	M-171	ptwg	M-53	wprt	M-262
eot2	M-14	m	I-4	ptwgb	M-59	wprwb	M-169
epsrox1	M-26	m	OP-4	ptwgt	M-58	wprwg	M-166
epsrox2	M-27	mexp	M-50	pu0	M-227	wptwg	M-220
epsrsub	M-25	nbg	M-18	pua	M-230	wptwgt	M-223
eta0	M-36	nbody	M-16	pua1	M-251	wpvag	M-289
etacif	M-135	nc0sub	M-22	puc	M-233	wr	M-95
etamob	M-62	nf	I-7	pucs	M-239	wrdsw	M-157
eu	M-68	nf	OP-7	pucste	M-257	wrdw	M-160
exp_cr	I-1	ni0sub	M-20	pud	M-236	wrs	M-163
exp_cr	OP-1	nigc	M-114	pud1	M-254	wtgid1	M-268
fg	O-2	nqsmod	M-7	pup	M-356	wth0	M-153
ge	O-7	nrd	I-13	pute	M-248	wu0	M-226
gi	O-8	nrd	OP-13	put1	M-245	wua	M-229
gidlmod	M-3	nrs	I-12	pvag	M-100	wua1	M-250
ids0mult	I-17	nrs	OP-12	pvsat	M-347	wuc	M-232
ids0mult	OP-17	nsd	M-17	pvsat1	M-350	wucs	M-238
igmod	M-4	op_cbgbg	OP-31	pwr	M-173	wucste	M-256
igt	M-150	op_cbgd	OP-28	rdkeep	M-154	wud	M-235
iit	M-148	op_cbgfg	OP-29	rdsmod	M-2	wud1	M-253
klrsce	M-38	op_cbgs	OP-30	rdsw	M-82	wup	M-355

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kgb0	M-137	op_cdbg	OP-35	rdswmin	M-81	wute	M-247
kgb1	M-138	op_cdd	OP-32	rdw	M-90	wutl	M-244
kgb2	M-139	op_cdfg	OP-33	rdwmin	M-89	wvsat	M-346
ksativ	M-49	op_cds	OP-34	rgatemod	M-6	wvsatl	M-349
kt1	M-144	op_cfgbg	OP-27	rshd	M-110	wwr	M-172
kt1l	M-145	op_cfgd	OP-24	rshs	M-109	xl	I-14
kt2	M-146	op_cfgfg	OP-25	rskeep	M-155	xl	OP-14
kt3	M-147	op_cfgs	OP-26	rsw	M-86		
l	I-5	op_ids	OP-18	rswmin	M-85		
l	OP-5	op_qbg	OP-20	rth0	M-151		

Angelov Model

The Angelov model is an empirical equation-based large signal model that is used for III-V field effect transistors, such as HEMT and MESFET. An enhancement version of Angelov model, which was developed by L.S. Liu, J.G. Ma, and G.I. Ng is also integrated into this model, which improves both model accuracy and convergence. The enhancement version is called as MA (modified Angelov) model, which can be turned on with model parameter `ma_mod=1`.

This chapter contains the following information for the Angelov model:

- [Ma Model Equation](#) on page 3004
- [Component Statements](#) on page 3004

Ma Model Equation

To activate the Ma model, you need to set the value of the `ma_model` model parameter to 1.

There are two I_{ds} equations in the Ma model referred to as `idsmod=0` and `idsmod=1`.

$$I_{ds} = I_{ds1} \cdot I_{ds2}$$

$$I_{ds2} = \tanh(\alpha V_{ds})(1 + \lambda V_{ds})$$

For `idsmod=0` (with Gm compression and $l_{sat} \approx 2I_{pk}$).

$$I_{ds1} = I_{pk}[1 + \tanh(\Psi_1)]$$

$$\Psi_1 = P_1 \cdot V_{gsp} + P_{21} \cdot V_{eff_{p1}}^2 + P_{31} \cdot V_{eff_{p1}}^3 + P_{22} \cdot V_{eff_{p2}}^2 + P_{32} \cdot V_{eff_{p2}}^3$$

For `idsmod=1` (with Gm compression and $l_{sat} \neq 2I_{pk}$)

$$I_{ds1} = I_{pk}[1 + \tanh(ph_1)] + I_{pk}' \tanh(ph_2)$$

$$I_{pk}' = I_{pk}$$

$$ph_1 = P_1 \cdot V_{eff_{p1}} + P_2 \cdot V_{eff_{p1}}^2 + P_3 \cdot V_{eff_{p1}}^3$$

$$ph_2 = P_1' \cdot V_{eff_{p2}} + P_{22} \cdot V_{eff_{p2}}^2 + P_{32} \cdot V_{eff_{p2}}^3$$

$$P_1' = P_1 \cdot I_{pk} / I_{pk}'$$

Component Statements

This device is supported within altergroups.

Virtuoso Simulator Components and Device Models Reference

Angelov Model

Sample Instance Statement

```
pch (1234) pchmod m=1 trise=20
```

Sample Model Statement

```
model pchmod angelov idsmod=1 igmod=1 ij=25.92e-9 ipk0=12.17e-3 kf=0.0 klf=0.0  
lambda1=1e-3 lambda=71.08e-3 ld=76.3e-12 rc=10.0e3 rcin=100e3 rcmin=1.0 rd=4.122  
rg=74.35 rgd=32.54 ri=144.7 rs=6.2 rth=1.09e3 selft=1 tau=1.0e-12 td1=100e-3 td=25  
tg=25 tmn=1.0 tnom=25 vjg=374.1e-3 vkn=800.0e-3
```

Instance Definition

```
Name d g s [t] ModelName parameter=value ...
```

Instance Parameters

1	m=1.0	Multiplicity factor.
2	w=1e-6 m	Gate width, unused but reserved.
3	ng=1	Gate fingers, unused but reserved.
4	mode=1	Unused but reserved.
5	noise=1	Unused but reserved.
6	trise=0.0 C	Difference sim. temp and device temp.
7	temp=27 C	Device temp only used if Trise is zero.

Model Definition

```
model modelName angelov parameter=value ...
```

Model Parameters

1	type=n	Channel type parameter, n=NFET p=PFET. Possible values are n or p.
2	noimod=1	Unused but reserved.
3	selft=0	Flag for self-heating.

Virtuoso Simulator Components and Device Models Reference

Angelov Model

4	<code>idsmod=0</code>	Ids Current Model [0:3].
5	<code>igmod=0</code>	Select gate diode model [0:1].
6	<code>capmod=2</code>	Select cap model [0:2].
7	<code>ipk0=0.05 A</code>	Current for max. transconductance Ipk.
8	<code>vpk=(-0.2) V</code>	Gate voltage Vpk for max transconductance.
9	<code>dvpks=0.2 V</code>	Delta gate voltage at peak gm.
10	<code>p1=1.0 1/V</code>	Polynomial coeff P1 for channel current.
11	<code>p2=0.0 1/V²</code>	Polynomial coeff P2 for channel current.
12	<code>p3=0.0 1/V³</code>	Polynomial coeff P3 for channel current.
13	<code>alphar=0.1 1/V</code>	Saturation parameter alpha_r.
14	<code>alphas=1.0 1/V</code>	Saturation parameter alpha.
15	<code>vkn=0.8 V</code>	Knee voltage.
16	<code>lambda=0.0</code>	Channel length modulation parameter.
17	<code>lambda1=0.0</code>	Channel length modulation parameter.
18	<code>lvlg=0.0</code>	Coeff for channel length modulation parameter
19	<code>b1=0.0</code>	Unsaturated coeff B1 for P1.
20	<code>b2=3.0 1/V</code>	Saturated coeff B2 for P1.
21	<code>lsb0=0.0</code>	Soft breakdown model parameter.
22	<code>vtr=20.0 V</code>	Soft breakdown model parameter.
23	<code>vsb2=0.0 V</code>	Surface breakdown model parameter.
24	<code>cds=0 F</code>	Zero-bias D-S junction capacitance.

Virtuoso Simulator Components and Device Models Reference

Angelov Model

25	$cgs_{pi}=0.0$ F	Gate-source pinch-off capacitance.
26	$cgs_0=0.0$ F	Gate-source capacitance parameter.
27	$cgd_{pi}=0.0$ F	Gate-drain pinch-off capacitance.
28	$cgd_{pe}=0$ F	External G-D Capacitor.
29	$cgd_0=0.0$ F	Gate-drain capacitance parameter Cgdo.
30	$p_{10}=0.0$	Polynomial coeff P10 for capacitance.
31	$p_{11}=1.0$	Polynomial coeff P11 for capacitance.
32	$p_{20}=0.0$	Polynomial coeff P20 for capacitance.
33	$p_{21}=0.2$	Polynomial coeff P21 for capacitance.
34	$p_{30}=0.0$	Polynomial coeff P30 for capacitance.
35	$p_{31}=0.2$	Polynomial coeff P31 for capacitance.
36	$p_{40}=0.0$	Polynomial coeff P40 for capacitance.
37	$p_{41}=1.0$	Polynomial coeff P41 for capacitance.
38	$p_{111}=0.0$	Polynomial coeff P400 for capacitance.
39	$ij=0.00005$ A	Gate fwd saturation current.
40	$pg=15.0$	Gate current parameter.
41	$ne=1.4$	Gate p-n emission coeff.
42	$v_{jg}=0.7$ V	Gate current parm.
43	$rg=0.0$ Ohm	Gate ohmic resistance.
44	$rd=0.0$ Ohm	Drain ohmic resistance.
45	$ri=0.0$ Ohm	Input resistance.
46	$rs=0.0$ Ohm	Source ohmic resistance.

Virtuoso Simulator Components and Device Models Reference

Angelov Model

47	$rgd=0$	Ohm	Gate resistance.
48	$ld=0$	H	Drain ohmic inductance.
49	$ls=0$	H	Source ohmic inductance.
50	$lg=0$	H	Gate ohmic inductance.
51	$tau=0$	s	Device delay.
52	$rcmin=1.0e3$	Ohm	Min value of R_c .
53	$rc=10.0e3$	Ohm	R for freq dep output cond.
54	$crf=0.0$	F	C for freq dep output cond.
55	$rcin=100.0e3$	Ohm	R for freq dep input cond.
56	$crfin=0.0$	F	C for freq dep input cond.
57	$rth=0.0$	Ohm	Thermal resistance.
58	$cth=0.0$	F	Thermal capacitance.
59	$tcipk0=0.0$	A/K	Linear temp coef T_{pk} for I_{pk} .
60	$tcp1=0.0$	A/K	Linear temp coef T_{pk} for I_{pk} .
61	$tccgs0=0.0$		Linear temp coef C_{gs0} parm.
62	$tccgd0=0.0$		Linear temp coef C_{gd0} parm.
63	$tclsb0=0.0$		Linear temp coef L_{sb0} parm.
64	$tcrc=0.0$		Linear temp coef R_c parm.
65	$tccrf=0.0$		Linear temp coef C_{rf} parm.
66	$noiser=0.5$		Gate noise coeff.
67	$noisep=1.0$		Gate noise coeff.
68	$noisec=0.9$		Gate-drain noise coeff.

Virtuoso Simulator Components and Device Models Reference

Angelov Model

69	<code>fnc=0.0 Hz</code>	Noise corner freq.
70	<code>kf=0.0</code>	Flicker noise coeff.
71	<code>af=1.0</code>	Flicker noise exponent.
72	<code>ffe=1.0</code>	Flicker noise parameter.
73	<code>tg=25.0 C</code>	Equiv temp.
74	<code>td=25.0 C</code>	Equiv temp.
75	<code>td1=0.1 C</code>	Equiv temp.
76	<code>tmn=1.0</code>	noise fitting coeff.
77	<code>k1f=1.0e14</code>	Flicker noise exponent.
78	<code>fgr=60.0e3 Hz</code>	G-R freq corner.
79	<code>np=0.3</code>	flicker noise freq exp.
80	<code>lw=0.1 mm</code>	effective gate noise width.
81	<code>tnom=27 C</code>	param meas T.
82	<code>ma_mod=0</code>	Flag to turn on Ma model.

Operating-Point Parameters

1	<code>m=1.0</code>	Multiplicity factor.
2	<code>w=1e-6 m</code>	Gate width, unused but reserved.
3	<code>ng=1</code>	Gate fingers, unused but reserved.
4	<code>mode=1</code>	Unused but reserved.
5	<code>noise=1</code>	Unused but reserved.
6	<code>trise=0.0 C</code>	Difference sim. temp and device temp.
7	<code>temp=27 C</code>	Device temp only used if Trise is zero.

Virtuoso Simulator Components and Device Models Reference

Angelov Model

8	ids (A)	Ids.
9	igs (A)	Igs.
10	igd (A)	Igd.
11	qgd (F)	Qgd.
12	qgs (F)	Qgs.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

af	M-71	kf	M-70	p10	M-30	tccgs0	M-61
alphar	M-13	klf	M-77	p11	M-31	tccrf	M-65
alphas	M-14	lambda	M-16	p111	M-38	tcipk0	M-59
b1	M-19	lambda1	M-17	p2	M-11	tclsb0	M-63
b2	M-20	ld	M-48	p20	M-32	tcp1	M-60
capmod	M-6	lg	M-50	p21	M-33	tcrc	M-64
cds	M-24	ls	M-49	p3	M-12	td	M-74
cgd0	M-29	lsb0	M-21	p30	M-34	td1	M-75
cgdpe	M-28	lvg	M-18	p31	M-35	temp	I-7
cgdpi	M-27	lw	M-80	p40	M-36	temp	OP-7
cgs0	M-26	m	I-1	p41	M-37	tg	M-73
cgspi	M-25	m	OP-1	pg	M-40	tmn	M-76

Virtuoso Simulator Components and Device Models Reference

Angelov Model

crf	M-54	ma_mod	M-82	qgd	OP-11	tnom	M-81
crfin	M-56	mode	I-4	qgs	OP-12	trise	I-6
cth	M-58	mode	OP-4	rc	M-53	trise	OP-6
dvpks	M-9	ne	M-41	rcin	M-55	type	M-1
ffe	M-72	ng	I-3	rcmin	M-52	vjg	M-42
fgr	M-78	ng	OP-3	rd	M-44	vkn	M-15
fnc	M-69	noimod	M-2	rg	M-43	vpks	M-8
ids	OP-8	noise	I-5	rgd	M-47	vsb2	M-23
idsmod	M-4	noise	OP-5	ri	M-45	vtr	M-22
igd	OP-10	noisec	M-68	rs	M-46	w	I-2
igmod	M-5	noisep	M-67	rth	M-57	w	OP-2
igs	OP-9	noiser	M-66	selft	M-3		
ij	M-39	np	M-79	tau	M-51		
ipk0	M-7	p1	M-10	tccgd0	M-62		

Virtuoso Simulator Components and Device Models Reference

Angelov Model

DIODE_CMC Model

The `DIODE_CMC` model is based on Juncap2 200.3.3 from NXP Semiconductors. It is mainly used to model those diodes that are formed with MOSFETs. Those MOSFETs have source, drain, or well-to-bulk junctions. Geometrically, `DIODE_CMC` has capacitances and currents of bottom, gate edge, and STI edge contributions.

This chapter contains the following information for the `DIODE_CMC` model:

- [Model Version and Development](#) on page 3013
- [Model Equations](#) on page 3013
- [Component Statements](#) on page 3024

Model Version and Development

The current available version for `DIODE_CMC` is version 1.0.0.

Model Equations

Junction Charge

$$C_{jo} = CJOR \cdot \left(\frac{VBIR}{V_{bi}} \right)^P$$

$$V_j = hyp5(V_{AK}; V_{F,min}, V_{ch})$$

$$Q'_j = \left\{ \frac{C_{j0} \cdot V_{bi}}{1 - P} \cdot \left[1 - \left(1 - \frac{V_j}{V_{bi}} \right)^{1 - P} \right] + a \cdot C_{j0} \cdot (V_{AK} - V_j) \right\}$$

Ideal Current

$$M_{ID} = \left\{ \begin{array}{ll} \exp\left(\frac{V_{AK}}{n \cdot \phi_{TD}}\right) & \text{if } V_{AK} < V_{max} \\ \left(1 + \frac{V_{AK} - V_{MAX}}{n \cdot \phi_{TD}}\right) \cdot \exp\left(\frac{V_{MAX}}{\phi_{TD}}\right) & \text{if } V_{AK} \geq V_{max} \end{array} \right\}$$

$$I_D = (M_{ID} - 1) \cdot I_{DSAT}$$

Shockley-Read-Hall current

$$Z_{inv} = \left\{ \begin{array}{ll} \sqrt{\exp\left(\frac{V_{AK}}{\phi_{TD}}\right)} & \text{if } V_{AK} < V_{max} \\ \sqrt{\left(1 + \frac{V_{AK} - V_{MAX}}{\phi_{TD}}\right) \cdot \exp\left(\frac{V_{MAX}}{\phi_{TD}}\right)} & \text{if } V_{AK} \geq V_{max} \end{array} \right\}$$

$$Z = \frac{1}{Z_{inv}}$$

$$\Psi^* = \left\{ \begin{array}{ll} \phi_{TD} \cdot \ln[z + 2 + \sqrt{(z+1) \cdot (z+3)}] & \text{if } V_{AK} > 0 \\ -\frac{V_{AK}}{2} + \phi_{TD} \cdot \ln[1 + 2 \cdot z_{inv} + \sqrt{(1+z_{inv}) \cdot (1+3 \cdot z_{inv})}] & \text{if } V_{AK} \leq 0 \end{array} \right\}$$

$$V_{j, lim} = V_{bi, min} - 2 \cdot \Psi^*$$

$$V_{j, SRH} = \text{hyp2}(V_{AK}; V_{j, lim}, \phi_{TD})$$

$$\Delta w_{SRH} = \left(\frac{w_{SRH, step}^2 \cdot \ln w_{SRH, step}}{1 - w_{SRH, step}} + w_{SRH, step} \right) \cdot (1 - 2 \cdot P)$$

$$w_{SRH} = w_{SRH, step} + \Delta w_{SRH}$$

Virtuoso Simulator Components and Device Models Reference

DIODE_CMC Model

$$W_{dep} = \frac{XJUN \cdot \epsilon_{Si}}{CJOR} \cdot \left(\frac{V_{bi} - V_{j, SRH}}{VBIR} \right)^P$$

$$I_{SRH} = CSRH \cdot F_{TD} \cdot (z_{inv} - 1) \cdot w_{SRH} \cdot W_{dep}$$

Trap-Assisted Tunneling Current

$$F_{max} = \frac{V_{bi} - V_{j,SRH}}{W_{dep} \cdot (1 - P)}$$

$$m_{eff} = MEFFTAT \cdot m_0$$

$$\Delta E = \max\left(\frac{\phi_{GD}}{2}, \phi_{TD}\right)$$

$$a_{TAT} = \frac{\Delta E}{\phi_{TD}}$$

$$b_{TAT} = \sqrt{\frac{32 \cdot m_{eff} \cdot q \cdot \Delta E^3}{3 \cdot h \cdot F_{max}}}$$

$$u'_{max} = \left(\frac{2 \cdot a_{TAT}}{3 \cdot b_{TAT}}\right)^2$$

$$u_{max} = \sqrt{\frac{u'^2_{max}}{u'^2_{max} + 1}}$$

$$w_{\Gamma} = \left(1 + b_{TAT} \cdot u_{max}^{\frac{3}{2}}\right)^{\frac{P}{P-1}}$$

$$w_{TAT} = \frac{w_{SRH} \cdot w_{\Gamma}}{w_{SRH} + w_{\Gamma}}$$

$$k_{TAT} = \sqrt{\frac{3 \cdot b_{TAT}}{8 \cdot \sqrt{u_{max}}}}$$

$$l_{TAT} = \frac{4 \cdot a_{TAT}}{3 \cdot b_{TAT}} \cdot \sqrt{u_{max}} - u_{max}$$

$$m_{TAT} = \frac{2 \cdot a_{TAT}^2}{3 \cdot b_{TAT}} \cdot \sqrt{u_{max}} - a_{TAT} \cdot u_{max} + \frac{b_{TAT}}{2} u_{max}^{3/2}$$

$$erfcapprox(y) = \left\{ \begin{array}{l} \begin{array}{l} \frac{1}{1 + p_{erfc} \cdot y} \quad \text{if } y > 0 \\ \frac{1}{1 - p_{erfc} \cdot y} \quad \text{if } y \leq 0 \end{array} \\ \\ erfcapprox^+ = \left(a_{erfc} \cdot t_{erfc} + b_{erfc} \cdot t_{erfc}^2 + c_{erfc} \cdot t_{erfc}^3 \right) \cdot \exp(-y^2) \\ \\ erfcapprox(y) = \left\{ \begin{array}{l} erfcapprox^+ \quad \text{if } y > 0 \\ 2 - erfcapprox^+ \quad \text{if } y \leq 0 \end{array} \right\} \end{array} \right.$$

$$\Gamma_{max} = \frac{a_{TAT} \cdot \exp(m_{TAT}) \cdot erfcapprox[k_{TAT} \cdot (l_{TAT} - 1)] \cdot \sqrt{\pi}}{2 \cdot k_{TAT}}$$

$$\Gamma_{TAT} = CTAT \cdot F_{TD} \cdot (z_{inv} - 1) \cdot \Gamma_{max} \cdot w_{TAT} \cdot W_{dep}$$

Band-to-band tunneling current

$$V_{BBT,lim} = \min(VBIRBOT, VBIRSTI, VBIRGAT) - \Delta V_{bi}$$

$$V_{BBT} = \text{hyp}_2(V_{AK}, V_{BBT,lim}, \phi_{TR})$$

$$W_{dep,r} = \frac{XJUN \cdot \epsilon_{Si}}{CJOR} \cdot \left(\frac{VBIR - V_{BBT}}{VBIR} \right)$$

$$F_{max,r} = \frac{VBIR - V_{BBT}}{W_{dep,r} \cdot (1 - P)}$$

$$F_{BBT} = FBBTR \cdot [1 + STFBBT \cdot (T_{KD} - T_{KR})]$$

$$I_{BBT} = CBBT \cdot V_{AK} \cdot F_{max,r}^2 \cdot \exp\left(-\frac{F_{BBT}}{F_{max,r}}\right)$$

Avalanche and Breakdown

$$V_{av} = \text{hyp}_2(V_{AK}; 0, \epsilon_{av})$$

$$f_{stop} = \frac{1}{1 - \alpha_{av} \cdot \frac{PBR}{VBR}}$$

$$s_f = -f_{stop}^2 \cdot \alpha_{av} \cdot \frac{PBR - 1}{VBR}$$

$$f_{breakdown} = \begin{cases} \frac{1}{1 - \left| \frac{-V_{av}}{VBR} \right|^{PBR}} & \text{if } V_{av} > -\alpha_{av} \cdot VBR \\ f_{stop} + (V_{av} + \alpha_{av} \cdot VBR) \cdot s_f & \text{if } V_{av} \leq -\alpha_{av} \cdot VBR \end{cases}$$

Total Current

$$I_j = (I_D + I_{SRH} + I_{TAT} + I_{BBT}) \cdot f_{breakdown}$$

Thermal Voltage

$$T_{KR} = T_0 + TRJ$$

$$T_{KD} = \max(T_0 + temp + subckt_trise + TRISE + DTA, T_0 + T_{min})$$

$$\phi_{TR} = \frac{k_B \cdot T_{KR}}{q}$$

$$\phi_{TD} = \frac{k_B \cdot T_{KD}}{q}$$

Band Gap

$$\Delta\phi_{GR} = -\frac{7.02e-4 \cdot T_{KR}^2}{1108.0 + T_{KR}}$$

$$\phi_{GR,bot} = PHIGBOT + \Delta\phi_{GR}$$

$$\phi_{GR,sti} = PHIGSTI + \Delta\phi_{GR}$$

$$\phi_{GR,gat} = PHIGGAT + \Delta\phi_{GR}$$

$$\Delta\phi_{GD} = -\frac{7.02e-4 \cdot T_{KD}^2}{1108.0 + T_{KD}}$$

$$\phi_{GD,bot} = PHIGBOT + \Delta\phi_{GD}$$

$$\phi_{GD,sti} = PHIGSTI + \Delta\phi_{GD}$$

$$\phi_{GD,gat} = PHIGGAT + \Delta\phi_{GD}$$

Intrinsic Carrier Concentration

$$F_{TD, bot} = \left(\frac{T_{KD}}{T_{KR}} \right)^{XTI/2.0} \cdot \exp \left(\frac{\phi_{GR, bot}}{2 \cdot \phi_{TR}} - \frac{\phi_{GD, bot}}{2 \cdot \phi_{TD}} \right)$$

$$F_{TD, sti} = \left(\frac{T_{KD}}{T_{KR}} \right)^{XTI/2.0} \cdot \exp \left(\frac{\phi_{GR, sti}}{2 \cdot \phi_{TR}} - \frac{\phi_{GD, sti}}{2 \cdot \phi_{TD}} \right)$$

$$F_{TD, gat} = \left(\frac{T_{KD}}{T_{KR}} \right)^{XTI/2.0} \cdot \exp \left(\frac{\phi_{GR, gat}}{2 \cdot \phi_{TR}} - \frac{\phi_{GD, gat}}{2 \cdot \phi_{TD}} \right)$$

Saturation Current Density

$$I_{DSAT, bot} = IDSATRBOT \cdot F_{TD, bot}^2$$

$$I_{DSAT, sti} = IDSATRSTI \cdot F_{TD, sti}^2$$

$$I_{DSAT, gat} = IDSATRGAT \cdot F_{TD, gat}^2$$

Determination of Vmax

$$V_{max, bot} = \begin{cases} V_{max, large} & \text{if } I_{DSAT, bot} \cdot AB = 0 \\ \phi_{TD} \cdot \ln \left(\frac{IMAX}{I_{DSAT, bot} \cdot AB} + 1 \right) & \text{if } I_{DSAT, bot} \cdot AB \neq 0 \end{cases}$$

$$V_{max, sti} = \begin{cases} V_{max, large} & \text{if } I_{DSAT, sti} \cdot LS = 0 \\ \phi_{TD} \cdot \ln\left(\frac{IMAX}{I_{DSAT, sti} \cdot LS} + 1\right) & \text{if } I_{DSAT, sti} \cdot LS \neq 0 \end{cases}$$

$$V_{max, gat} = \begin{cases} V_{max, large} & \text{if } I_{DSAT, gat} \cdot LG = 0 \\ \phi_{TD} \cdot \ln\left(\frac{IMAX}{I_{DSAT, gat} \cdot LG} + 1\right) & \text{if } I_{DSAT, gat} \cdot LG \neq 0 \end{cases}$$

$$V_{max} = \min(V_{max, bot}, V_{max, sti}, V_{max, gat})$$

Built-In Voltages

$$U_{bi, bot} = VBIRBOT \cdot \frac{T_{KD}}{T_{KR}} - 2 \cdot \phi_{TD} \cdot \ln F_{TD, bot}$$

$$V_{bi, bot} = U_{bi, bot} + \phi_{TD} \cdot \ln\left[1 + \exp\left(\frac{V_{bi, low} - U_{bi, bot}}{\phi_{TD}}\right)\right]$$

$$U_{bi, sti} = VBIRSTI \cdot \frac{T_{KD}}{T_{KR}} - 2 \cdot \phi_{TD} \cdot \ln F_{TD, sti}$$

$$V_{bi, sti} = U_{bi, sti} + \phi_{TD} \cdot \ln \left[1 + \exp \left(\frac{V_{bi, low} - U_{bi, sti}}{\phi_{TD}} \right) \right]$$

$$U_{bi, gat} = VBIRGAT \cdot \frac{T_{KD}}{T_{KR}} - 2 \cdot \phi_{TD} \cdot \ln F_{TD, gat}$$

$$V_{bi, gat} = U_{bi, gat} + \phi_{TD} \cdot \ln \left[1 + \exp \left(\frac{V_{bi, low} - U_{bi, gat}}{\phi_{TD}} \right) \right]$$

Determination of VF, min and Vch

$$V_{bi, min} = \min(V_{bi, bot}, V_{bi, sti}, V_{bi, gat})$$

$$V_{F, min} = \begin{cases} V_{bi, min} \cdot (1 - a^{-1/(PBOT)}) & \text{if } V_{bi, min} = V_{bi, bot} \\ V_{bi, min} \cdot (1 - a^{-1/(PSTI)}) & \text{if } V_{bi, min} = V_{bi, sti} \\ V_{bi, min} \cdot (1 - a^{-1/(PGAT)}) & \text{if } V_{bi, min} = V_{bi, gat} \end{cases}$$

$$V_{ch} = \varepsilon_{ch} \cdot V_{bi, min}$$

Voltage Difference VAK

$$V_{AK} = TYPE \cdot (V_A - V_K)$$

Final Junction Current

$$I_j = TYPE \cdot MULT \cdot (AB \cdot I_{j, bot} + LS \cdot I_{j, sti} + LG \cdot I_{j, gat})$$

Auxiliary Equations

$$hyp_1(x; \varepsilon) = \frac{1}{2} \cdot \left(x + \sqrt{x^2 + 4 \cdot \varepsilon^2} \right)$$

$$hyp_2(x; x_0, \varepsilon) = x - hyp_1(x - x_0, \varepsilon)$$

$$hyp_5(x; x_0, \varepsilon) = x_0 - hyp_1\left(x_0 - x - \frac{\varepsilon^2}{x_0}; \varepsilon\right)$$

Component Statements

This device is supported within altergroups

Instance Definition

Name a k ModelName parameter=value ...

Instance Parameters

- | | | |
|---|-------------------------|--------------------------------------|
| 1 | ab=1E-12 m ² | Junction area. |
| 2 | area=1E-12 | Junction area. |
| 3 | ls=1e-6 m | STI-edge part of junction perimeter. |
| 4 | pj=1e-6 | STI-edge part of junction perimeter. |

Virtuoso Simulator Components and Device Models Reference

DIODE_CMC Model

5	<code>perim=1e-6</code>	STI-edge part of junction perimeter.
6	<code>lg=0 m</code>	Gate-edge part of junction perimeter.
7	<code>mult=1</code>	Number of devices in parallel.
8	<code>m=1</code>	Number of devices in parallel.
9	<code>trise=0.0</code>	Temperature rise from the ambient.
10	<code>diode_region=1.0</code>	
11	<code>region=on</code>	Estimated operating region. Spectre outputs number (0-2) in a rawfile. Possible values are <code>off</code> , <code>on</code> , and <code>breakdown</code> .

Model Definition

```
model modelName diode_cmc parameter=value ...
```

Model Parameters

1	<code>level=1002</code>	Model level must be 1002.
2	<code>version=1</code>	Model version.
3	<code>subversion=0</code>	Model subversion.
4	<code>revision=0</code>	Model revision.
5	<code>type=n</code>	Type parameter, n reflects n-type, p reflects p-type. Possible values are <code>n</code> and <code>p</code> .
6	<code>dta=0 C</code>	Temperature offset with respect to ambient temperature.
7	<code>imax=1000 A</code>	Maximum current up to which forward current behaves exponentially.
8	<code>trj=21 C</code>	Reference temperature.
9	<code>cjorbot=1E-3 Fm⁻²</code>	Zero-bias capacitance per unit-of-area of bottom component.

Virtuoso Simulator Components and Device Models Reference

DIODE_CMC Model

- 10 `cjorsti=1E-9 Fm^-1` Zero-bias capacitance per unit-of-length of STI-edge component.
- 11 `cjorgat=1E-9 Fm^-1` Zero-bias capacitance per unit-of-length of gate-edge component.
- 12 `vbirbot=1 V` Built-in voltage at the reference temperature of bottom component.
- 13 `vbirsti=1 V` Built-in voltage at the reference temperature of STI-edge component.
- 14 `vbirgat=1 V` Built-in voltage at the reference temperature of gate-edge component.
- 15 `pbot=0.5` Grading coefficient of bottom component.
- 16 `pssti=0.5` Grading coefficient of STI-edge component.
- 17 `pgat=0.5` Grading coefficient of gate-edge component.
- 18 `phigbot=1.16 V` Zero-temperature bandgap voltage of bottom component.
- 19 `phigsti=1.16 V` Zero-temperature bandgap voltage of STI-edge component.
- 20 `phiggat=1.16 V` Zero-temperature bandgap voltage of gate-edge component.
- 21 `idsatrbot=1E-12 Am^-2` Saturation current density at the reference temperature of bottom component.
- 22 `idsatrsti=1E-18 Am^-1` Saturation current density at the reference temperature of STI-edge component.
- 23 `idsatrgat=1E-18 Am^-1` Saturation current density at the reference temperature of gate-edge component.
- 24 `csrbot=1E2 Am^-3` Shockley-Read-Hall prefactor of bottom component.

Virtuoso Simulator Components and Device Models Reference

DIODE_CMC Model

- 25 $csrhisti=1E-4 \text{ Am}^{-2}$ Shockley-Read-Hall prefactor of STI-edge component.
- 26 $csrhgat=1E-4 \text{ Am}^{-2}$ Shockley-Read-Hall prefactor of gate-edge component.
- 27 $xjunsti=100E-9 \text{ m}$ Junction depth of STI-edge component.
- 28 $xjungat=100E-9 \text{ m}$ Junction depth of gate-edge component.
- 29 $ctatbot=1E2 \text{ Am}^{-3}$ Trap-assisted tunneling prefactor of bottom component.
- 30 $ctatsti=1E-4 \text{ Am}^{-2}$ Trap-assisted tunneling prefactor of STI-edge component.
- 31 $ctatgat=1E-4 \text{ Am}^{-2}$ Trap-assisted tunneling prefactor of gate-edge component.
- 32 $mefftatbot=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of bottom component.
- 33 $mefftatsti=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of STI-edge component.
- 34 $mefftatgat=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of gate-edge component.
- 35 $cbbtbot=1E-12 \text{ AV}^{-3}$ Band-to-band tunneling prefactor of bottom component.
- 36 $cbbtsti=1E-18 \text{ AV}^{-3}_m$ Band-to-band tunneling prefactor of STI-edge component.
- 37 $cbbtgat=1E-18 \text{ AV}^{-3}_m$ Band-to-band tunneling prefactor of gate-edge component.
- 38 $fbbtrbot=1E9 \text{ Vm}^{-1}$ Normalization field at the reference temperature for band-to-band tunneling of bottom component.
- 39 $fbbtrsti=1E9 \text{ Vm}^{-1}$ Normalization field at the reference temperature for band-to-band tunneling of STI-edge component.

Virtuoso Simulator Components and Device Models Reference

DIODE_CMC Model

- 40 `fbttrgat=1E9 Vm-1` Normalization field at the reference temperature for band-to-band tunneling of gate-edge component.
- 41 `stfbbtbot=(-1E-3) K-1` Temperature scaling parameter for band-to-band tunneling of bottom component.
- 42 `stfbbtsti=(-1E-3) K-1` Temperature scaling parameter for band-to-band tunneling of STI-edge component.
- 43 `stfbbtgat=(-1E-3) K-1` Temperature scaling parameter for band-to-band tunneling of gate-edge component.
- 44 `vbrbot=10 V` Breakdown voltage of bottom component.
- 45 `vbrsti=10 V` Breakdown voltage of STI-edge component.
- 46 `vbrgat=10 V` Breakdown voltage of gate-edge component.
- 47 `pbrbot=4 V` Breakdown onset tuning parameter of bottom component.
- 48 `pbrsti=4 V` Breakdown onset tuning parameter of STI-edge component.
- 49 `pbrgat=4 V` Breakdown onset tuning parameter of gate-edge component.
- 50 `rsbot=0.0 VA-1m2` Series resistance per unit-of-area of bottom component.
- 51 `rssti=0.0 VA-1m` Series resistance per unit-of-length of STI-edge component.
- 52 `rsgat=0.0 VA-1m` Series resistance per unit-of-length of gate-edge component.
- 53 `rscom=0.0 ohm` Common series resistance, no scaling .
- 54 `strs=0` Temperature scaling parameter for series resistance.
- 55 `kf=0` KF parameter for flicker noise.
- 56 `af=1.0` AF parameter for flicker noise.

Virtuoso Simulator Components and Device Models Reference

DIODE_CMC Model

57	<code>tt=0</code>	s	Transit time.
58	<code>stvbrbot1=0</code>	1/K	Temp. co of breakdown voltage bottom component.
59	<code>stvbrbot2=0</code>	1/K ²	Temp. co of breakdown voltage bottom component.
60	<code>stvbrsti1=0</code>	1/K	Temp. co of breakdown voltage STI-edge component.
61	<code>stvbrsti2=0</code>	1/K ²	Temp. co of breakdown voltage STI-edge component.
62	<code>stvbrgat1=0</code>	1/K	Temp. co of breakdown voltage gate-edge component.
63	<code>stvbrgat2=0</code>	1/K ²	Temp. co of breakdown voltage gate-edge component.
64	<code>nfabot=1.0</code>		ideality factor bottom component.
65	<code>nfasti=1.0</code>		ideality factor STI-edge component.
66	<code>nfagat=1.0</code>		ideality factor gate-edge component.
67	<code>abmin=0.0</code>	m ²	minimum allowed junction area.
68	<code>abmax=1.0</code>	m ²	maximum allowed junction area.
69	<code>lsmin=0.0</code>	m	minimum allowed junction STI-edge.
70	<code>lsmax=1.0</code>	m	maximum allowed junction STI-edge.
71	<code>lgmin=0.0</code>	m	minimum allowed junction gate-edge.
72	<code>lgmax=1.0</code>	m	maximum allowed junction gate-edge.
73	<code>tempmin=(-55)</code>	C	minimum allowed junction temp.
74	<code>tempmax=155</code>	C	maximum allowed junction temp.
75	<code>vfmax=0.0</code>	V	maximum allowed forward junction bias.
76	<code>vrmax=0.0</code>	V	maximum allowed reverse junction bias.
77	<code>pt=3</code>		Temp. co of saturation current.
78	<code>xti=3</code>		Temp. co of saturation current.

Virtuoso Simulator Components and Device Models Reference

DIODE_CMC Model

79	<code>scalee=1.0</code>	Scale parameter.
80	<code>shrink=0</code>	Scale parameter.
81	<code>swjunexp=0.0</code>	Flag for JUNCAP-express; 0=full model, 1=express model.
82	<code>vjunref=2.5</code>	Typical maximum junction voltage; usually about 2*VSUP.
83	<code>fjunq=0.03</code>	Fraction below which junction capacitance components are considered negligible.

Output Parameters

1	<code>tempeff (C)</code>	Effective temperature for a single device.
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Operating-Point Parameters

1	<code>diode_region=1.0</code>	
2	<code>region=on</code>	Estimated operating region. Spectre outputs number (0-2) in a rawfile. Possible values are <code>off</code> , <code>on</code> , and <code>breakdown</code> .
3	<code>vak (V)</code>	Voltage between anode and cathode excluding the series resistor.
4	<code>cj (F)</code>	Total source junction capacitance.
5	<code>cjbot (F)</code>	Junction capacitance (bottom component).
6	<code>cjgat (F)</code>	Junction capacitance (gate-edge component).
7	<code>cjsti (F)</code>	Junction capacitance (STI-edge component).
8	<code>ij (A)</code>	Total source junction current.
9	<code>ijbot (A)</code>	Junction current (bottom component).
10	<code>ijgat (A)</code>	Junction current (gate-edge component).
11	<code>ijsti (A)</code>	Junction current (STI-edge component).

Virtuoso Simulator Components and Device Models Reference

DIODE_CMC Model

12	si (A^2/Hz)	Total junction current noise spectral density.
13	vrs (V)	Voltage across series resistor.
14	sf (A^2/Hz)	Total junction flicker noise spectral density.
15	sr (A^2/Hz)	Total series resistor thermal noise spectral density.
16	$rseries$ (V/A)	Series resistor.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

ab	I-1	$idsatrbot$	M-21	$perim$	I-5	$stvbrgat2$	M-63
$abmax$	M-68	$idsatrgat$	M-23	$pgat$	M-17	$stvbrsti1$	M-60
$abmin$	M-67	$idsatrsti$	M-22	$phigbot$	M-18	$stvbrsti2$	M-61
af	M-56	ij	OP-8	$phiggat$	M-20	$subversion$	M-3
$area$	I-2	$ijbot$	OP-9	$phigsti$	M-19	$swjunexp$	M-81
$cbbtbot$	M-35	$ijgat$	OP-10	pj	I-4	$tempeff$	O-1
$cbbtgat$	M-37	$ijsti$	OP-11	$psti$	M-16	$tempmax$	M-74
$cbbtsti$	M-36	$imax$	M-7	pt	M-77	$tempmin$	M-73
cj	OP-4	kf	M-55	$region$	I-11	$trise$	I-9
$cjbot$	OP-5	$level$	M-1	$region$	OP-2	trj	M-8
$cjgat$	OP-6	lg	I-6	$revision$	M-4	tt	M-57

Virtuoso Simulator Components and Device Models Reference

DIODE_CMC Model

cjorbot	M-9	lgmax	M-72	rsbot	M-50	type	M-5
cjorgat	M-11	lgmin	M-71	rscom	M-53	vak	OP-3
cjorsti	M-10	ls	I-3	rseries	OP-16	vbirbot	M-12
cjsti	OP-7	lsmax	M-70	rsgat	M-52	vbirgat	M-14
csrbot	M-24	lsmin	M-69	rssti	M-51	vbirsti	M-13
csrhgat	M-26	m	I-8	scalee	M-79	vbrbot	M-44
csrhsti	M-25	mefftatbot	M-32	sf	OP-14	vbrgat	M-46
ctatbot	M-29	mefftatgat	M-34	shrink	M-80	vbrsti	M-45
ctatgat	M-31	mefftatsti	M-33	si	OP-12	version	M-2
ctatsti	M-30	mult	I-7	sr	OP-15	vfmax	M-75
diode_region	I-10	nfabot	M-64	stfbbtbot	M-41	vjunref	M-82
diode_region	OP-1	nfagat	M-66	stfbbtgat	M-43	vrmax	M-76
dta	M-6	nfasti	M-65	stfbbtsti	M-42	vrs	OP-13
fbbotrbot	M-38	pbot	M-15	strs	M-54	xjungat	M-28
fbbotrgat	M-40	pbrbot	M-47	stvbrbot1	M-58	xjunsti	M-27
fbbotrsti	M-39	pbrgat	M-49	stvbrbot2	M-59	xti	M-78
fjunq	M-83	pbrsti	M-48	stvbrgat1	M-62		

JFET100 Model

JFET100 is a new model developed by TSMC.

Instance Definition

Name d g s e ModelName parameter=value ...

Instance Parameters

1	<code>l=1.0e-6</code>	Drawn Length.
2	<code>w=1.0e-6</code>	Drawn Width.
3	<code>nf=1.0</code>	Number of finger.
4	<code>as=1.0e-12</code>	Source diffusion area.
5	<code>ad=as</code>	Drain diffusion area.
6	<code>ps=1.0e-6</code>	Source diffusion perimeter.
7	<code>pd=ps</code>	Drain diffusion perimeter.
8	<code>nrs=1.0</code>	Number of squares of drain diffusion for resistance calculations.
9	<code>nrd=nrs</code>	Number of squares of source diffusion for resistance calculations.
10	<code>lgs=1.0e-6</code>	Space of source to gate open.
11	<code>lgd=lgs</code>	Space of drain to gate open.
12	<code>dtemp=0</code>	Temperature offset.

Virtuoso Simulator Components and Device Models Reference

JFET100 Model

- 13 `trise=0` Temperature offset.
- 14 `m=1` number of devices in parallel.

Model Definition

`model modelName jfet100 parameter=value ...`

Model Parameters

- 1 `level=100` Level no. of the JFET model.
- 2 `version=0.2` version no. of the JFET model.
- 3 `type=1` Device type: `ntype(1)`, `ptype(-1)`.
Possible values are `p` and `n`.
- 4 `shmod=0` Self-heating mode: `off(0)`, `on(1)`.
- 5 `capmod=1` Capacitance mode: single depletion capacitor model(0), double depletion capacitor model(1).
- 6 `cdsmode=0` Capacitance mode: constant cds capacitor model(0), single-step cds capacitor model(1).
- 7 `resmod=0` Resistance mode: without internal drain resistance(0), with internal drain resistance(1).
- 8 `betatempmod=1` Temperature dependence mode of BETA.
- 9 `tlevc=1` Temperature dependence mode of capacitance .
- 10 `tlev=1` Temperature dependence mode of bandgap evaluation.
- 11 `xl=0.0` Length offset.
- 12 `dlc=0.0` Length offset in CV evaluation.
- 13 `xw=0.0` Width offset.
- 14 `dwc=0.0` Width offset in CV evaluation.
- 15 `rg=0.0` Gate resistance.

Virtuoso Simulator Components and Device Models Reference

JFET100 Model

16	<code>rs=0.0</code>	Source resistance.
17	<code>rd=_mpv(RS)</code>	Drain resistance.
18	<code>rdis=0.0</code>	The resistance in series with the gate-source diode.
19	<code>rdid=_mpv(RDIS)</code>	The resistance in series with the gate-drain diode.
20	<code>tnom=25.0</code>	
21	<code>eg=1.16</code>	Energy bandgap for the gate-drain and gate-source diode for TLEV=2.
22	<code>gap1=7.02e-4</code>	First bandgap correction factor for TLEV=2.
23	<code>gap2=1108</code>	Second bandgap correction factor for TLEV=2.
24	<code>shconst=5.0</code>	Temperature smoothing constant.
25	<code>ifwdlimit=0.01</code>	Limiting current for the forward gate-drain and gate-source diode per Weff.
26	<code>iss=1.0e-14</code>	Saturation current of the gate-source diode per unit area.
27	<code>nsf=5.0</code>	Emission coefficient of the gate-source diode.
28	<code>its=1.0e-14</code>	Tunneling saturation current of the gate-source diode per unit area.
29	<code>nts=10.0</code>	Tunneling emission coefficient of the gate-source diode.
30	<code>vts=10.0</code>	Trap-assisted voltage dependent parameter of the gate-source diode.
31	<code>offsets=0.0</code>	Offset voltage in evaluating tunneling current of the gate-source diode.
32	<code>isd=_mpv(ISS)</code>	Saturation current of the gate-drain diode per unit area.
33	<code>ndf=_mpv(NSF)</code>	Emission coefficient of the gate-drain diode.
34	<code>itd=_mpv(ITS)</code>	Tunneling saturation current of the gate-drain diode per unit area.

Virtuoso Simulator Components and Device Models Reference

JFET100 Model

35	<code>ntd=_mpv(NTS)</code>	Tunneling emission coefficient of the gate-drain diode.
36	<code>vt d=_mpv(VTS)</code>	Trap-assisted voltage dependent parameter of the gate-drain diode.
37	<code>offsetd=_mpv(OFFSETS)</code>	Offset voltage in evaluating tunneling current of the gate-drain diode.
38	<code>alpha=2.0</code>	Saturation factor.
39	<code>beta=1.0e-4</code>	Transconductance parameter.
40	<code>delta=0.0</code>	Ids feedback parameter.
41	<code>gamds=0.0</code>	Drain induced threshold voltage lowering coefficient.
42	<code>lambda=0.0</code>	Channel length modulation parameter.
43	<code>k1=0.0</code>	Threshold voltage sensitivity to body bias.
44	<code>nd=0.0</code>	Drain subthreshold factor.
45	<code>ng=0.0</code>	Gate subthreshold factor.
46	<code>mstar=0.5</code>	Fitting factor for moderate inversion condition.
47	<code>subconst=100.0e-3</code>	Fitting factor for the subthreshold swing.
48	<code>ucrit=0.0</code>	Critical field for mobility degradation.
49	<code>vgexp=2.0</code>	Gate voltage exponent.
50	<code>vto=(-2.0)</code>	Threshold voltage.
51	<code>voff=0.0</code>	Offset voltage in subthreshold region.
52	<code>satexp=3.0</code>	Drain voltage exponent.
53	<code>cvto=0.0</code>	Threshold voltage for CV model.
54	<code>calpha=4.0e-2</code>	Saturation factor for CV model.

Virtuoso Simulator Components and Device Models Reference

JFET100 Model

55	<code>cgamds=0.0</code>	Drain induced threshold voltage lowering coefficient for CV model.
56	<code>ck1=0.0</code>	Body bias dependence factor for CV model.
57	<code>cgs=0.0</code>	Zero-bias gate-source junction capacitance.
58	<code>cgd=0.0</code>	Zero-bias gate-drain junction capacitance.
59	<code>mjs=0.5</code>	Grading coefficient for gate-source diode.
60	<code>mjd=_mpv(MJS)</code>	Grading coefficient for gate-drain diode.
61	<code>cgd1=0.0</code>	Zero-bias gate-drain junction capacitance for the second depletion capacitance (only for CAPMOD=1).
62	<code>cgs1=0.0</code>	Zero-bias gate-source junction capacitance for the second depletion capacitance (only for CAPMOD=1).
63	<code>mjs1=0.2</code>	Grading coefficient for the second depletion gate-source diode (only for CAPMOD=1).
64	<code>mjd1=_mpv(MJS1)</code>	Grading coefficient for the second depletion gate-drain diode (only for CAPMOD=1).
65	<code>pb=0.8</code>	Gate junction potential.
66	<code>fc=0.9</code>	Coefficient for forward-bias depletion capacitance formulas.
67	<code>cvtD=0.0</code>	Second threshold voltage for CV model.
68	<code>calphad=4.0e-2</code>	Second Saturation factor for CV model.
69	<code>covs=0.0</code>	Overlap capacitance between gate and source.
70	<code>covd=_mpv(COVS)</code>	Overlap capacitance between gate and drain.
71	<code>cvtDs=0.0</code>	First switching voltage for the step like drain-source capacitance (only for CDSMOD=1).
72	<code>cvtDs1=0.0</code>	Second switching voltage for the step like drain-source capacitance (only for CDSMOD=1).

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73	<code>cvt_{ds2}=0.0</code>	Third switching voltage for the step like drain-source capacitance (only for CDSMOD=1).
74	<code>calph_{ads}=4.0e-2</code>	First saturation factor for drain-source capacitance (only for CDSMOD=1).
75	<code>calph_{ads1}=4.0e-2</code>	Second saturation factor for drain-source capacitance (only for CDSMOD=1).
76	<code>calph_{ads2}=4.0e-2</code>	Third saturation factor for drain-source capacitance (only for CDSMOD=1).
77	<code>mj_{ds}=0.5</code>	Grading coefficient for the first drain-source capacitance (only for CDSMOD=1).
78	<code>mj_{ds1}=_mpv (MJDS)</code>	Grading coefficient for the second drain-source capacitance (only for CDSMOD=1).
79	<code>mj_{ds2}=_mpv (MJDS1)</code>	Grading coefficient for the third drain-source capacitance (only for CDSMOD=1).
80	<code>mj_{ds3}=_mpv (MJDS2)</code>	Grading coefficient for the fourth drain-source capacitance (only for CDSMOD=1).
81	<code>cap_{ds}=0.0</code>	Capacitance between drain and source.
82	<code>cap_{ds1}=0.0</code>	Zero-bias drain-source capacitance for the second capacitance (only for CDSMOD=1).
83	<code>cap_{ds2}=0.0</code>	Zero-bias drain-source capacitance for the third capacitance (only for CDSMOD=1).
84	<code>cap_{ds3}=0.0</code>	Zero-bias drain-source capacitance for the fourth capacitance (only for CDSMOD=1).
85	<code>pb_{ds}=0.8</code>	First Drain-source junction potential (only for CDSMOD=1).
86	<code>pb_{ds1}=0.8</code>	Second Drain-source junction potential (only for CDSMOD=1).
87	<code>pb_{ds2}=0.8</code>	Third Drain-source junction potential (only for CDSMOD=1).

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88	<code>fcds=0.9</code>	Coefficient for forward-bias drain-source capacitance formulas (only for CDSMOD=1).
89	<code>capsb=0.0</code>	Capacitance between source and body.
90	<code>capdb=0.0</code>	Capacitance between drain and body.
91	<code>capgb=0.0</code>	Capacitance between gate and body.
92	<code>xtis=0.0</code>	Junction current temperature exponent for gate-source diode.
93	<code>xtid=_mpv(XTIS)</code>	Junction current temperature exponent for gate-drain diode.
94	<code>xts=0.0</code>	Power dependence of ITS.
95	<code>tnts=0.0</code>	Temperature coefficient of NTS.
96	<code>xtid=_mpv(XTS)</code>	Power dependence of ITD.
97	<code>tntd=_mpv(TNTS)</code>	Temperature coefficient of NTD.
98	<code>tvto=0.0</code>	Temperature coefficient of VTO.
99	<code>tvooff=0.0</code>	Temperature coefficient of VOFF.
100	<code>tgamds=0.0</code>	Temperature coefficient of GAMDS.
101	<code>tdelta=0.0</code>	Temperature coefficient of DELTA.
102	<code>trg1=0.0</code>	First order temperature coefficient of RG.
103	<code>trs1=0.0</code>	First order temperature coefficient of RS.
104	<code>trd1=_mpv(TRS1)</code>	First order temperature coefficient of RD.
105	<code>trg2=0.0</code>	Second order temperature coefficient of RG.
106	<code>trs2=0.0</code>	Second order temperature coefficient of RS.
107	<code>trd2=_mpv(TRS2)</code>	Second order temperature coefficient of RD.
108	<code>trdis1=0.0</code>	First order temperature coefficient of RDIS.

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109	<code>trdid1=_mpv(TRDIS1)</code>	First order temperature coefficient of RDID.
110	<code>trdis2=0.0</code>	Second order temperature coefficient of RDIS.
111	<code>trdid2=_mpv(TRDIS2)</code>	Second order temperature coefficient of RDIS.
112	<code>ctd=0.0</code>	Temperature coefficient of CGD (TLEVC=1).
113	<code>cts=_mpv(CTD)</code>	Temperature coefficient of CGS (TLEVC=1).
114	<code>tpb=0.0</code>	Temperature coefficient of PB (TLEVC=1, 2).
115	<code>tfbex=1.0</code>	Temperature factor for BEX.
116	<code>bex1=0.0</code>	First order temperature coefficient of mobility exponent.
117	<code>bex2=0.0</code>	Second order temperature coefficient of mobility exponent.
118	<code>tfvgexp=1.0</code>	Temperature factor for VGEXP.
119	<code>vgexpt1=0.0</code>	First order temperature coefficient of gate voltage exponent.
120	<code>vgexpt2=0.0</code>	Second order temperature coefficient of gate voltage exponent.
121	<code>tcvto=0.0</code>	Temperature coefficient of CVTO.
122	<code>tcgamds=0.0</code>	Temperature coefficient of CGAMDS.
123	<code>tcvt ds=0.0</code>	Temperature coefficient of CVTDS (CDSMOD=1).
124	<code>ct ds=0.0</code>	Temperature coefficient of CAPDS and CAPDS1 (CDSMOD=1).
125	<code>tcvtd=0.0</code>	
126	<code>tpb ds=0.0</code>	Temperature coefficient of PBDS (CDSMOD=1)).
127	<code>trdv1=0.0</code>	First order temperature coefficient of RDV.
128	<code>trdv2=0.0</code>	Second order temperature coefficient of RDV.
129	<code>trdvg1=0.0</code>	First order temperature coefficient of RDVG.

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130	<code>tvdeff1=0.0</code>	First order temperature coefficient of VDEFF.
131	<code>tvdmr1=0.0</code>	First order temperature coefficient of VDMR.
132	<code>kf=0.0</code>	Flicker noise coefficient.
133	<code>af=1.0</code>	Flicker noise exponent.
134	<code>ef=1.0</code>	Flicker noise frequency exponent.
135	<code>gdsnoi=1.0</code>	Channel noise coefficient.
136	<code>rth0=0.01</code>	Thermal resistance.
137	<code>cth0=1.0E-05</code>	Thermal capacitance.
138	<code>shlimit=(-1.0)</code>	Limit of temperature change due to self heating; if it is negative, there is no limit. .
139	<code>wth0=0.0</code>	Minimum width for thermal.
140	<code>ls=2.5e-6</code>	Length of ohmic open at source side.
141	<code>ld=_mpv(LS)</code>	Length of ohmic open at drain side.
142	<code>lfp=1.0e-6</code>	Source side field plate.
143	<code>pfp=1.0e-6</code>	Gate side field plate.
144	<code>rdv=0.0</code>	Voltage dependent RD coefficient.
145	<code>rdvg=0.2</code>	Gate-bias dependent RD parameter .
146	<code>vdeff=1.0</code>	Drain-bias exponent RD parameter.
147	<code>vdmr=500</code>	Drain-bias dependent RD parameter.
148	<code>liss=0.0</code>	length dependence of iss.
149	<code>wiss=0.0</code>	width dependence of iss.
150	<code>piss=0.0</code>	cross-term dependence of iss.

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151	l _{nsf} =0.0	length dependence of nsf.
152	w _{nsf} =0.0	width dependence of nsf.
153	p _{nsf} =0.0	cross-term dependence of nsf.
154	l _{x_ti_s} =0.0	length dependence of x _t i _s .
155	w _{x_ti_s} =0.0	width dependence of x _t i _s .
156	p _{x_ti_s} =0.0	cross-term dependence of x _t i _s .
157	l _{i_ts} =0.0	length dependence of i _t s.
158	w _{i_ts} =0.0	width dependence of i _t s.
159	p _{i_ts} =0.0	cross-term dependence of i _t s.
160	l _{n_ts} =0.0	length dependence of n _t s.
161	w _{n_ts} =0.0	width dependence of n _t s.
162	p _{n_ts} =0.0	cross-term dependence of n _t s.
163	l _{x_ts} =0.0	length dependence of x _t s.
164	w _{x_ts} =0.0	width dependence of x _t s.
165	p _{x_ts} =0.0	cross-term dependence of x _t s.
166	l _{v_ts} =0.0	length dependence of v _t s.
167	w _{v_ts} =0.0	width dependence of v _t s.
168	p _{v_ts} =0.0	cross-term dependence of v _t s.
169	l _{n_tn_ts} =0.0	length dependence of n _t n _t s.
170	w _{n_tn_ts} =0.0	width dependence of n _t n _t s.
171	p _{n_tn_ts} =0.0	cross-term dependence of n _t n _t s.
172	l _{i_sd} =0.0	length dependence of i _s d.

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173	<code>wisd=0.0</code>	width dependence of <code>isd</code> .
174	<code>pisd=0.0</code>	cross-term dependence of <code>isd</code> .
175	<code>lndf=0.0</code>	length dependence of <code>ndf</code> .
176	<code>wndf=0.0</code>	width dependence of <code>ndf</code> .
177	<code>pndf=0.0</code>	cross-term dependence of <code>ndf</code> .
178	<code>lxtid=0.0</code>	length dependence of <code>xtid</code> .
179	<code>wxtid=0.0</code>	width dependence of <code>xtid</code> .
180	<code>pxtid=0.0</code>	cross-term dependence of <code>xtid</code> .
181	<code>litd=0.0</code>	length dependence of <code>itd</code> .
182	<code>witd=0.0</code>	width dependence of <code>itd</code> .
183	<code>pitd=0.0</code>	cross-term dependence of <code>itd</code> .
184	<code>lntd=0.0</code>	length dependence of <code>ntd</code> .
185	<code>wntd=0.0</code>	width dependence of <code>ntd</code> .
186	<code>pntd=0.0</code>	cross-term dependence of <code>ntd</code> .
187	<code>lxtd=0.0</code>	length dependence of <code>xtd</code> .
188	<code>wxtd=0.0</code>	width dependence of <code>xtd</code> .
189	<code>pxtd=0.0</code>	cross-term dependence of <code>xtd</code> .
190	<code>lvtd=0.0</code>	length dependence of <code>vtd</code> .
191	<code>wvtd=0.0</code>	width dependence of <code>vtd</code> .
192	<code>pvtd=0.0</code>	cross-term dependence of <code>vtd</code> .
193	<code>ltntd=0.0</code>	length dependence of <code>tntd</code> .
194	<code>wtntd=0.0</code>	width dependence of <code>tntd</code> .

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195	<code>ptntd=0.0</code>	cross-term dependence of <code>tntd</code> .
196	<code>lalpha=0.0</code>	length dependence of <code>alpha</code> .
197	<code>walpha=0.0</code>	width dependence of <code>alpha</code> .
198	<code>palpha=0.0</code>	cross-term dependence of <code>alpha</code> .
199	<code>lbeta=0.0</code>	length dependence of <code>beta</code> .
200	<code>wbeta=0.0</code>	width dependence of <code>beta</code> .
201	<code>pbeta=0.0</code>	cross-term dependence of <code>beta</code> .
202	<code>ldelta=0.0</code>	length dependence of <code>delta</code> .
203	<code>wdelta=0.0</code>	width dependence of <code>delta</code> .
204	<code>pdelta=0.0</code>	cross-term dependence of <code>delta</code> .
205	<code>lgamds=0.0</code>	length dependence of <code>gamds</code> .
206	<code>wgamds=0.0</code>	width dependence of <code>gamds</code> .
207	<code>pgamds=0.0</code>	cross-term dependence of <code>gamds</code> .
208	<code>llambda=0.0</code>	length dependence of <code>lambda</code> .
209	<code>wlambda=0.0</code>	width dependence of <code>lambda</code> .
210	<code>plambda=0.0</code>	cross-term dependence of <code>lambda</code> .
211	<code>lk1=0.0</code>	length dependence of <code>k1</code> .
212	<code>wk1=0.0</code>	width dependence of <code>k1</code> .
213	<code>pk1=0.0</code>	cross-term dependence of <code>k1</code> .
214	<code>lnd=0.0</code>	length dependence of <code>nd</code> .
215	<code>wnd=0.0</code>	width dependence of <code>nd</code> .
216	<code>pnd=0.0</code>	cross-term dependence of <code>nd</code> .

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JFET100 Model

217	lng=0.0	length dependence of ng.
218	wng=0.0	width dependence of ng.
219	png=0.0	cross-term dependence of ng.
220	lmstar=0.0	length dependence of mstar.
221	wmstar=0.0	width dependence of mstar.
222	pmstar=0.0	cross-term dependence of mstar.
223	lsatexp=0.0	length dependence of satexp.
224	wsatexp=0.0	width dependence of satexp.
225	psatexp=0.0	cross-term dependence of satexp.
226	lucrit=0.0	length dependence of ucrit.
227	wucrit=0.0	width dependence of ucrit.
228	pucrit=0.0	cross-term dependence of ucrit.
229	lvgexp=0.0	length dependence of vgexp.
230	wvgexp=0.0	width dependence of vgexp.
231	pvgexp=0.0	cross-term dependence of vgexp.
232	lvto=0.0	length dependence of vto.
233	wvto=0.0	width dependence of vto.
234	pvtto=0.0	cross-term dependence of vto.
235	lvoff=0.0	length dependence of voff.
236	wvoff=0.0	width dependence of voff.
237	pvoff=0.0	cross-term dependence of voff.
238	lrs=0.0	length dependence of rs.

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239	wrs=0.0	width dependence of rs.
240	prs=0.0	cross-term dependence of rs.
241	lrd=0.0	length dependence of rd.
242	wrd=0.0	width dependence of rd.
243	prd=0.0	cross-term dependence of rd.
244	lrg=0.0	length dependence of rg.
245	wrg=0.0	width dependence of rg.
246	prg=0.0	cross-term dependence of rg.
247	lrdis=0.0	length dependence of rdis.
248	wrdis=0.0	width dependence of rdis.
249	prdis=0.0	cross-term dependence of rdis.
250	lrdid=0.0	length dependence of rdid.
251	wrdid=0.0	width dependence of rdid.
252	prdid=0.0	cross-term dependence of rdid.
253	lrdv=0.0	length dependence of rdv.
254	wrdv=0.0	width dependence of rdv.
255	prdv=0.0	cross-term dependence of rdv.
256	lrdvg=0.0	length dependence of rdvg.
257	wrdvg=0.0	width dependence of rdvg.
258	prdvg=0.0	cross-term dependence of rdvg.
259	lvdeff=0.0	length dependence of vdeff.
260	wvdeff=0.0	width dependence of vdeff.

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261	<code>pvdeff=0.0</code>	cross-term dependence of <code>vdeff</code> .
262	<code>lvdmr=0.0</code>	length dependence of <code>vdmr</code> .
263	<code>wvdmr=0.0</code>	width dependence of <code>vdmr</code> .
264	<code>pvdmr=0.0</code>	cross-term dependence of <code>vdmr</code> .
265	<code>ltrdv1=0.0</code>	length dependence of <code>trdv1</code> .
266	<code>wtrdv1=0.0</code>	width dependence of <code>trdv1</code> .
267	<code>ptrdv1=0.0</code>	cross-term dependence of <code>trdv1</code> .
268	<code>ltrdv2=0.0</code>	length dependence of <code>trdv2</code> .
269	<code>wtrdv2=0.0</code>	width dependence of <code>trdv2</code> .
270	<code>ptrdv2=0.0</code>	cross-term dependence of <code>trdv2</code> .
271	<code>ltrdvg1=0.0</code>	length dependence of <code>trdvg1</code> .
272	<code>wtrdvg1=0.0</code>	width dependence of <code>trdvg1</code> .
273	<code>ptrdvg1=0.0</code>	cross-term dependence of <code>trdvg1</code> .
274	<code>ltrdvg2=0.0</code>	length dependence of <code>trdvg2</code> .
275	<code>wtrdvg2=0.0</code>	width dependence of <code>trdvg2</code> .
276	<code>ptrdvg2=0.0</code>	cross-term dependence of <code>trdvg2</code> .
277	<code>ltvdeff1=0.0</code>	length dependence of <code>tvdeff1</code> .
278	<code>wtvdeff1=0.0</code>	width dependence of <code>tvdeff1</code> .
279	<code>ptvdeff1=0.0</code>	cross-term dependence of <code>tvdeff1</code> .
280	<code>ltvdeff2=0.0</code>	length dependence of <code>tvdeff2</code> .
281	<code>wtvdeff2=0.0</code>	width dependence of <code>tvdeff2</code> .
282	<code>ptvdeff2=0.0</code>	cross-term dependence of <code>tvdeff2</code> .

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283	l _{tvdmr1} =0.0	length dependence of tvdmr1.
284	w _{tvdmr1} =0.0	width dependence of tvdmr1.
285	p _{tvdmr1} =0.0	cross-term dependence of tvdmr1.
286	l _{tvdmr2} =0.0	length dependence of tvdmr2.
287	w _{tvdmr2} =0.0	width dependence of tvdmr2.
288	p _{tvdmr2} =0.0	cross-term dependence of tvdmr2.
289	l _{cvto} =0.0	length dependence of cvto.
290	w _{cvto} =0.0	width dependence of cvto.
291	p _{cvto} =0.0	cross-term dependence of cvto.
292	l _{calpha} =0.0	length dependence of calpha.
293	w _{calpha} =0.0	width dependence of calpha.
294	p _{calpha} =0.0	cross-term dependence of calpha.
295	l _{cgamds} =0.0	length dependence of cgamds.
296	w _{cgamds} =0.0	width dependence of cgamds.
297	p _{cgamds} =0.0	cross-term dependence of cgamds.
298	l _{cvtds} =0.0	length dependence of cvtds.
299	w _{cvtds} =0.0	width dependence of cvtds.
300	p _{cvtds} =0.0	cross-term dependence of cvtds.
301	l _{cvtds1} =0.0	length dependence of cvtds1.
302	w _{cvtds1} =0.0	width dependence of cvtds1.
303	p _{cvtds1} =0.0	cross-term dependence of cvtds1.
304	l _{cvtds2} =0.0	length dependence of cvtds2.

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305	wcvt _{ds2} =0.0	width dependence of cvt _{ds2} .
306	pcvt _{ds2} =0.0	cross-term dependence of cvt _{ds2} .
307	lcalph _{ads} =0.0	length dependence of calph _{ads} .
308	wcalph _{ads} =0.0	width dependence of calph _{ads} .
309	pcalph _{ads} =0.0	cross-term dependence of calph _{ads} .
310	lcalph _{ads1} =0.0	length dependence of calph _{ads1} .
311	wcalph _{ads1} =0.0	width dependence of calph _{ads1} .
312	pcalph _{ads1} =0.0	cross-term dependence of calph _{ads1} .
313	lcalph _{ads2} =0.0	length dependence of calph _{ads2} .
314	wcalph _{ads2} =0.0	width dependence of calph _{ads2} .
315	pcalph _{ads2} =0.0	cross-term dependence of calph _{ads2} .
316	lcalph _{ad} =0.0	length dependence of calph _{ad} .
317	wcalph _{ad} =0.0	width dependence of calph _{ad} .
318	pcalph _{ad} =0.0	cross-term dependence of calph _{ad} .
319	ltgam _{ds} =0.0	length dependence of tgam _{ds} .
320	wtgam _{ds} =0.0	width dependence of tgam _{ds} .
321	ptgam _{ds} =0.0	cross-term dependence of tgam _{ds} .
322	ltv _{to} =0.0	length dependence of tv _{to} .
323	wtv _{to} =0.0	width dependence of tv _{to} .
324	ptv _{to} =0.0	cross-term dependence of tv _{to} .
325	ltv _{off} =0.0	length dependence of tv _{off} .
326	wtv _{off} =0.0	width dependence of tv _{off} .

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327	<code>ptvoff=0.0</code>	cross-term dependence of <code>tvoff</code> .
328	<code>lck1=0.0</code>	length dependence of <code>ck1</code> .
329	<code>wck1=0.0</code>	width dependence of <code>ck1</code> .
330	<code>pck1=0.0</code>	cross-term dependence of <code>ck1</code> .
331	<code>ltcgamds=0.0</code>	length dependence of <code>tcgamds</code> .
332	<code>wtcgamds=0.0</code>	width dependence of <code>tcgamds</code> .
333	<code>ptcgamds=0.0</code>	cross-term dependence of <code>tcgamds</code> .
334	<code>ltcvto=0.0</code>	length dependence of <code>tcvto</code> .
335	<code>wtcvto=0.0</code>	width dependence of <code>tcvto</code> .
336	<code>ptcvto=0.0</code>	cross-term dependence of <code>tcvto</code> .
337	<code>ltcvtd=0.0</code>	length dependence of <code>tcvtd</code> .
338	<code>wtcvtd=0.0</code>	width dependence of <code>tcvtd</code> .
339	<code>ptcvtd=0.0</code>	cross-term dependence of <code>tcvtd</code> .
340	<code>ltcvtds=0.0</code>	length dependence of <code>tcvtds</code> .
341	<code>wtcvtds=0.0</code>	width dependence of <code>tcvtds</code> .
342	<code>ptcvtds=0.0</code>	cross-term dependence of <code>tcvtds</code> .
343	<code>ltrg1=0.0</code>	length dependence of <code>trg1</code> .
344	<code>wtrg1=0.0</code>	width dependence of <code>trg1</code> .
345	<code>ptrg1=0.0</code>	cross-term dependence of <code>trg1</code> .
346	<code>ltrg2=0.0</code>	length dependence of <code>trg2</code> .
347	<code>wtrg2=0.0</code>	width dependence of <code>trg2</code> .
348	<code>ptrg2=0.0</code>	cross-term dependence of <code>trg2</code> .

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349	ltrs1=0.0	length dependence of trs1.
350	wtrs1=0.0	width dependence of trs1.
351	ptrs1=0.0	cross-term dependence of trs1.
352	ltrs2=0.0	length dependence of trs2.
353	wtrs2=0.0	width dependence of trs2.
354	ptrs2=0.0	cross-term dependence of trs2.
355	ltrd1=0.0	length dependence of trd1.
356	wtrd1=0.0	width dependence of trd1.
357	ptrd1=0.0	cross-term dependence of trd1.
358	ltrd2=0.0	length dependence of trd2.
359	wtrd2=0.0	width dependence of trd2.
360	ptrd2=0.0	cross-term dependence of trd2.
361	ltrdis1=0.0	length dependence of trdis1.
362	wtrdis1=0.0	width dependence of trdis1.
363	ptrdis1=0.0	cross-term dependence of trdis1.
364	ltrdis2=0.0	length dependence of trdis2.
365	wtrdis2=0.0	width dependence of trdis2.
366	ptrdis2=0.0	cross-term dependence of trdis2.
367	ltrdid1=0.0	length dependence of trdid1.
368	wtrdid1=0.0	width dependence of trdid1.
369	ptrdid1=0.0	cross-term dependence of trdid1.
370	ltrdid2=0.0	length dependence of trdid2.

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371	wtrdid2=0.0	width dependence of trdid2.
372	ptrdid2=0.0	cross-term dependence of trdid2.
373	ltpb=0.0	length dependence of tpb.
374	wtpb=0.0	width dependence of tpb.
375	ptpb=0.0	cross-term dependence of tpb.
376	ltpbds=0.0	length dependence of tpbds.
377	wtpbds=0.0	width dependence of tpbds.
378	ptpbds=0.0	cross-term dependence of tpbds.
379	lbex1=0.0	length dependence of bex1.
380	wbex1=0.0	width dependence of bex1.
381	pbex1=0.0	cross-term dependence of bex1.
382	lbex2=0.0	length dependence of bex2.
383	wbex2=0.0	width dependence of bex2.
384	pbex2=0.0	cross-term dependence of bex2.
385	ltdelta=0.0	length dependence of tdelta.
386	wtdelta=0.0	width dependence of tdelta.
387	ptdelta=0.0	cross-term dependence of tdelta.
388	lvgecpt1=0.0	length dependence of vgecpt1.
389	wvgecpt1=0.0	width dependence of vgecpt1.
390	pvgecpt1=0.0	cross-term dependence of vgecpt1.
391	lvgecpt2=0.0	length dependence of vgecpt2.
392	wvgecpt2=0.0	width dependence of vgecpt2.

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- 393 $p_{vgexpt2}=0.0$ cross-term dependence of vg_{expt2} .
- 394 $l_{rth0}=0.0$ length dependence of r_{th0} .
- 395 $w_{rth0}=0.0$ width dependence of r_{th0} .
- 396 $p_{rth0}=0.0$ cross-term dependence of r_{th0} .
- 397 $l_{cth0}=0.0$ length dependence of c_{th0} .
- 398 $w_{cth0}=0.0$ width dependence of c_{th0} .
- 399 $p_{cth0}=0.0$ cross-term dependence of c_{th0} .
- 400 $vds_max=><Font<FTagsm$
symbol><FLockedNo>><CharBullet><Font<FTag><FLo
ckedNo>><Font<FTagl
literals><FLockedNo>><String V
Maximum allowed voltage cross source and drain.
- 401 $vgd_max=><Font<FTagsm$
symbol><FLockedNo>><CharBullet><Font<FTag><FLo
ckedNo>><Font<FTagl
literals><FLockedNo>><String V
Maximum allowed voltage cross gate and drain.
- 402 $vgs_max=><Font<FTagsm$
symbol><FLockedNo>><CharBullet><Font<FTag><FLo
ckedNo>><Font<FTagl
literals><FLockedNo>><String V
Maximum allowed voltage cross gate and source/bulk.
- 403 $vbd_max=><Font<FTagsm$
symbol><FLockedNo>><CharBullet><Font<FTag><FLo
ckedNo>><Font<FTagl
literals><FLockedNo>><String V
Maximum allowed voltage cross source/drain and bulk.
- 404 $vbs_max=vbd_max$ V Maximum allowed voltage cross source and bulk.
- 405 $vgb_max=><Font<FTagsm$
symbol><FLockedNo>><CharBullet><Font<FTag><FLo
ckedNo>><Font<FTagl

Virtuoso Simulator Components and Device Models Reference

JFET100 Model

literals><FLockedNo>><String V
Maximum allowed voltage cross gate and bulk.

- 406 `vgdr_max=vgd_max` V
Maximum allowed reverse voltage cross gate and drain.
- 407 `vgdr_max=vgd_max` V
Maximum allowed reverse voltage cross gate and drain.
- 408 `vgbr_max=vgb_max` V
Maximum allowed reverse voltage cross gate and bulk.
- 409 `vbsr_max=vbs_max` V
Maximum allowed reverse voltage cross source and bulk.
- 410 `vbdr_max=vbd_max` V
Maximum allowed reverse voltage cross source/drain and bulk.
- 411 `wmax=1.0` m
Maximum channel width for which the model is valid.
- 412 `wmin=0.0` m
Minimum channel width for which the model is valid.
- 413 `lmax=1.0` m
Maximum channel length for which the model is valid.
- 414 `lmin=0.0` m
Minimum channel length for which the model is valid.

Output Parameters

- 1 `weff` effective channel width.
- 2 `leff` effective channel length.
- 3 `weffcv` effective channel width for CV.
- 4 `leffcv` effective channel length for CV.
- 5 `meff` Effective multiplicity factor (m-factor).

Operating-Point Parameters

- 1 `devtempr` device temperature.

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2	i_{ds} (A)	Channel Current.
3	i_{gs} (A)	Gate-to-source Current.
4	i_{gd} (A)	Gate-to-drain Current.
5	v_{gs} (V)	Voltage difference between the terminals of the gate-source diode for IV evaluation.
6	v_{gd} (V)	Voltage difference between the terminals of the gate-drain diode for IV evaluation.
7	v_{gscv} (V)	Voltage difference between the terminals of the gate-source diode for CV evaluation.
8	v_{gdcv} (V)	Voltage difference between the terminals of the gate-drain diode for CV evaluation.
9	v_{th} (V)	Threshold voltage.
10	g_m	transconductance.
11	g_{ds}	conductance.
12	c_{gd} (C)	intrinsic gate-to-drain capacitance.
13	c_{gs} (C)	intrinsic gate-to-drain capacitance.

Parameter Index

In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

ad	I-5	lrdvg	M-256	prdv	M-255	vgdcv	OP-8
af	M-133	lrg	M-244	prdvg	M-258	vgdr_max	M-406

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alpha	M-38	lrs	M-238	prg	M-246	vgexp	M-49
as	I-4	lrth0	M-394	prs	M-240	vgexpt1	M-119
beta	M-39	ls	M-140	prth0	M-396	vgexpt2	M-120
betatempmod	M-8	lsatexp	M-223	ps	I-6	vgs	OP-5
bex1	M-116	ltcgamds	M-331	psatexp	M-225	vgs_max	M-402
bex2	M-117	ltcvtd	M-337	ptcgamds	M-333	vgscv	OP-7
calpha	M-54	ltcvtds	M-340	ptcvtd	M-339	vgsr_max	M-407
calphad	M-68	ltcvto	M-334	ptcvtds	M-342	voff	M-51
calphads	M-74	ltdelta	M-385	ptcvto	M-336	vtd	M-36
calphads1	M-75	ltgamds	M-319	ptdelta	M-387	vth	OP-9
calphads2	M-76	ltntd	M-193	ptgamds	M-321	vto	M-50
capdb	M-90	ltnts	M-169	ptntd	M-195	vts	M-30
capds	M-81	ltpb	M-373	ptnts	M-171	w	I-2
capds1	M-82	ltpbds	M-376	ptpb	M-375	walpha	M-197
capds2	M-83	ltrd1	M-355	ptpbds	M-378	wbeta	M-200
capds3	M-84	ltrd2	M-358	ptrd1	M-357	wbex1	M-380
capgb	M-91	ltrdid1	M-367	ptrd2	M-360	wbex2	M-383
capmod	M-5	ltrdid2	M-370	ptrdid1	M-369	wcalpha	M-293
capsb	M-89	ltrdis1	M-361	ptrdid2	M-372	wcalphad	M-317
cdsmod	M-6	ltrdis2	M-364	ptrdis1	M-363	wcalphads	M-308
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cgd1	M-61	ltrdvg2	M-274	ptrdvg1	M-273	wck1	M-329
cgs	M-57	ltrg1	M-343	ptrdvg2	M-276	wcth0	M-398
cgs	OP-13	ltrg2	M-346	ptrg1	M-345	wcvtds	M-299
cgs1	M-62	ltrs1	M-349	ptrg2	M-348	wcvtds1	M-302
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covd	M-70	ltvdeff1	M-277	ptrs2	M-354	wcvto	M-290
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cvtds1	M-72	lvdmr	M-262	pvdeff	M-261	wits	M-158
cvtds2	M-73	lvgexp	M-229	pvdmr	M-264	wk1	M-212
cvto	M-53	lvgexpt1	M-388	pvgexp	M-231	wlambda	M-209
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eg	M-21	lxteid	M-178	pvtoid	M-189	wnsf	M-152
fc	M-66	lxteis	M-154	pvtoid	M-180	wntd	M-185
fcds	M-88	lxts	M-163	pvtoid	M-156	wnts	M-161
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gap2	M-23	mjd	M-60	rdid	M-19	wrdis	M-248
gds	OP-11	mjd1	M-64	rdis	M-18	wrdv	M-254
gdsnoi	M-135	mjds	M-77	rdv	M-144	wrdvg	M-257
gm	OP-10	mjds1	M-78	rdvg	M-145	wrg	M-245
ids	OP-2	mjds2	M-79	resmod	M-7	wrs	M-239
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igd	OP-4	mjs	M-59	rs	M-16	wsatexp	M-224
igs	OP-3	mjs1	M-63	rth0	M-136	wtcgamds	M-332
isd	M-32	mstar	M-46	satexp	M-52	wtcvtd	M-338
iss	M-26	nd	M-44	shconst	M-24	wtcvtds	M-341
itd	M-34	ndf	M-33	shlimit	M-138	wtcvto	M-335
its	M-28	nf	I-3	shmod	M-4	wtdelta	M-386
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lalpha	M-196	nsf	M-27	tcvtds	M-123	wtnts	M-170
lambda	M-42	ntd	M-35	tcvto	M-121	wtpb	M-374
lbeta	M-199	nts	M-29	tdelta	M-101	wtpbds	M-377
lbex1	M-379	offsetd	M-37	tfbex	M-115	wtrd1	M-356
lbex2	M-382	offsets	M-31	tfvgexp	M-118	wtrd2	M-359
lcalpha	M-292	palpha	M-198	tgamds	M-100	wtrdid1	M-368
lcalphad	M-316	pb	M-65	tlev	M-10	wtrdid2	M-371
lcalphads	M-307	pbds	M-85	tlevc	M-9	wtrdis1	M-362
lcalphads1	M-310	pbds1	M-86	tnom	M-20	wtrdis2	M-365
lcalphads2	M-313	pbds2	M-87	tntd	M-97	wtrdv1	M-266
lcgamds	M-295	pbeta	M-201	tnts	M-95	wtrdv2	M-269
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lcvtds2	M-304	pcalphads	M-309	trdid1	M-109	wtrs1	M-350
lcvto	M-289	pcalphads1	M-312	trdid2	M-111	wtrs2	M-353
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lgamds	M-205	pcvtds2	M-306	trg2	M-105	wucrit	M-227
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lgs	I-10	pd	I-7	trs1	M-103	wvdmr	M-263
lisd	M-172	pdelta	M-204	trs2	M-106	wvgexp	M-230
liss	M-148	ppf	M-143	tvdeff1	M-130	wvgexpt1	M-389
litd	M-181	pgamds	M-207	tvdmr1	M-131	wvgexpt2	M-392
lits	M-157	pisd	M-174	tvoff	M-99	wvoff	M-236
lk1	M-211	piss	M-150	tvto	M-98	wvtd	M-191
llambda	M-208	pitd	M-183	type	M-3	wvto	M-233
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lmstar	M-220	plambda	M-210	vbd_max	M-410	wxtid	M-179
lnd	M-214	pmstar	M-222	vbs_max	M-404	wxtis	M-155
lndf	M-175	pnd	M-216	vbsr_max	M-409	wxts	M-164
lng	M-217	pndf	M-177	vdeff	M-146	x1	M-11
lnsf	M-151	png	M-219	vdmr	M-147	xtd	M-96
lntd	M-184	pnsf	M-153	vds_max	M-400	xtid	M-93

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lrddid	M-250	prd	M-243	vgbr_max	M-408	xw	M-13
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