

Virtuoso® Simulator Circuit Components and Device Models Manual

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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 36
- [Typographic and Syntax Conventions](#) on page 37

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 UltraSim C-Macromodel Interface](#)
- [Virtuoso UltraSim Reliability Interface](#)
- *Virtuoso UltraSim Simulator Tutorial*
- [Virtuoso UltraSim Waveform Interface](#)
- [Virtuoso UltraSim Simulator: What's New](#)
- [Virtuoso UltraSim Simulator Known Problems and Solutions](#)
- [RelXpert Reliability Simulator User Guide](#)

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

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

- *Virtuoso BSIMPro User's Manual*
- *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.

<code>literal</code>	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.
<code>argument</code>	Words in italics indicate user-defined arguments for which you must substitute a name or a value. (The characters before the underscore (<code>_</code>) in the word indicate the data types that this argument can take. Names are case sensitive.
<code> </code>	Vertical bars (OR-bars) separate possible choices for a single argument. They take precedence over any other character.
<code>[]</code>	Brackets denote optional arguments. When used with OR-bars, they enclose a list of choices. You can choose one argument from the list.
<code>{ }</code>	Braces are used with OR-bars and enclose a list of choices. You must choose one argument from the list.
<code>...</code>	Three dots (...) indicate that you can repeat the previous argument. If you use them with brackets, you can specify zero or

Virtuoso Simulator Components and Device Models Reference

Preface

— more arguments. If they are used without brackets, you must specify at least one argument, but you can specify more.

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:

- [BSIM-CMG](#) on page 2
- [Current Sources](#) on page 43
- [Voltage Sources](#) on page 75
- [Behavioral Source \(bsource\)](#) on page 97
- [Independent Resistive Source \(port\)](#) on page 103
- [Linear N Port \(nport\)](#) on page 111
- [Current Probe \(iprobe\)](#) on page 122
- [Circuit Reduced Order Model \(cktrom\)](#) on page 123
- [Analog-to-Logic Converter \(a2d\)](#) on page 125
- [device checker \(assert\)](#) on page 125
- [Logic-to-Analog Converter \(d2a\)](#) on page 127
- [Ideal Switch \(switch\)](#) on page 128
- [Ratiometric Fourier Analyzer \(fourier\)](#) on page 130
- [IBIS I/O buffer \(ibis_buffer\)](#) on page 134

BSIM-CMG

Common-Gate Multi-Gate MOSFET Model

BSIM-CMG is a SPICE compact model for modeling the electrical characteristics of common-gate MG structures, developed by UC Berkeley. The latest version is 102.0.

Overview of BSIM-CMG

BSIM-CMG, the common-gate model has two modules, three-terminal BSIMCMG-SOI module and four-terminal BSIMCMG-BULK module. 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. All the important MG transistor behaviors are captured by this model. Volume inversion is included in the solution of the Poissons equation, hence the subsequent I-V formulation automatically captures the volume inversion effect. Analysis of electro-static 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. 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, thermal/flicker/shot noise, 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.

Usage

Sample Model Statement

```
model nch bsimcmg devtype = 1.000 eot = 1.0n hfin = 30n nbody = 1E+22 phig = 4.610  
agidl = 50.00f
```

Sample Instance Statement

There are two modules in BSIM-CMG, they are selected automatically based on the terminals number of the instances. The following are examples:

Virtuoso Simulator Components and Device Models Reference

Circuit Components

```
m1 (d g s b) nch tfin=15n length=30n nf=10
m2 (d g s) nch tfin=15n length=30n nf=10
```

where, m1 will select BSIMCMG-BULK module, and m2 will select BSIMCMG-SOI module.

BSIM-CMG 102.0 Model Equations

Bias Independent Calculations

Physical Constants

Physical quantities in BSIM-CMG are in M.K.S units unless specified otherwise.

$$q = 1.6 \times 10^{-19}$$

$$\epsilon_0 = 8.8542 \times 10^{-12}$$

$$\hbar = 1.05457 \times 10^{-34}$$

$$m_e = 9.11 \times 10^{-31}$$

$$k = 1.3787 \times 10^{-23}$$

$$\epsilon_{sub} = EPSRSUB \cdot \epsilon_0$$

$$\epsilon_{ox} = EPSROX \cdot \epsilon_0$$

$$C_{ox} = \frac{3.9 \cdot \epsilon_0}{EOT}$$

$$C_{si} = \frac{\epsilon_{sub}}{TFIN}$$

$$\epsilon_{ratio} = \frac{EPSRSUB}{3.9}$$

Effective Channel Width and Length

$$\Delta L = LINT + \frac{LL}{(LENGTH + XL)^{LLN}}$$

$$\Delta L_{CV} = DLC + \frac{LLC}{(LENGTH + XL)^{LLN}}$$

$$L_{eff} = LENGTH + XL - 2\Delta L$$

$$L_{eff,CV} = LENGTH + XL - 2\Delta L_{CV}$$

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

$$W_{eff0} = 2 \cdot HFIN + 2 \cdot FECH \cdot TFIN - DELTAW$$

$$W_{eff,CV0} = 2 \cdot HFIN + 2 \cdot FECH \cdot TFIN - DELTAWCV$$

Binning Calculations

The optional binning methodology [2] is adopted in BSIM-CMG.

For a given length, each model parameter $PARAM_i$ is calculate as a function of $PARAM$, and a length dependent term, $LPARAM$:

$$PARAM_i = PARAM + \frac{1}{L_{eff}} \cdot LPARAM$$

Temperature Effects

$$E_{g,300} = BG0SUB - \frac{TBGASUB \cdot 300.15^2}{300.15 + TBGBSUB}$$

$$E_g = BG0SUB - \frac{TBGASUB \cdot T^2}{T + TBGBSUB}$$

$$n_i = NI0SUB \cdot \left(\frac{T}{300.15} \right)^{\frac{3}{2}} \cdot \exp \left(\frac{BG0SUB \cdot q}{2k \cdot 300.15} - \frac{E_g \cdot q}{2k \cdot T} \right)$$

$$N_c = NC0SUB \cdot \left(\frac{T}{300.15} \right)^{\frac{3}{2}}$$

$$\Delta V_{th,temp} = \left(KT1 + \frac{KT1L}{L_{eff}} \right) \cdot \left(\frac{T}{TNOM} - 1 \right)$$

If $MOBMOD = 0$ then

$$U0(T) = U0_i \cdot \left(\frac{T}{TNOM} \right)^{UTE_i}$$

$$UA(T) = UA_i \cdot \left(\frac{T}{TNOM} \right)^{UA1_i}$$

$$UD(T) = UD_i \cdot \left(\frac{T}{TNOM} \right)^{UD1_i}$$

$$UCS(T) = UCS_i \cdot \left(\frac{T}{TNOM} \right)^{UCSTE_i}$$

If $MOBMOD = 1$ then

$$THETAMU(T) = THETAMU_i \cdot \left(\frac{TNOM}{T} \right)^{STTHETAMU}$$

$$MUE(T) = MUE_i \cdot \left(\frac{TNOM}{T} \right)^{STMUE}$$

$$CS(T) = CS_i \cdot \left(\frac{TNOM}{T} \right)^{STCS}$$

Virtuoso Simulator Components and Device Models Reference

Circuit Components

$$THETASAT(T) = THETASAT_i \cdot \left(\frac{TNOM}{T}\right)^{STHETASAT_i}$$

$$VSAT(T) = VSAT_i \cdot (1 - AT \cdot (T - TNOM))$$

$$BETA0(T) = BETA0_i \cdot \left(\frac{T}{TNOM}\right)^{IT}$$

$$BGIDL(T) = BGIDL_i \cdot (1 + TGIDL \cdot (T - TNOM))$$

$$RDSWMIN(T) = RDSWMIN \cdot (1 + PRT \cdot (T - TNOM))$$

$$RDSW(T) = RDSW \cdot (1 + PRT \cdot (T - TNOM))$$

$$RSWMIN(T) = RSWMIN \cdot (1 + PRT \cdot (T - TNOM))$$

$$RDWMIN(T) = RDWMIN \cdot (1 + PRT \cdot (T - TNOM))$$

$$RSW(T) = RSW \cdot (1 + PRT \cdot (T - TNOM))$$

$$RDW(T) = RDW \cdot (1 + PRT \cdot (T - TNOM))$$

$$I_{gtemp} = \left(\frac{T}{TNOM}\right)^{IGT_i}$$

Body Doping and Gate Workfunction

If $PHISMOD = 1$ and $NBODY_i > 10^{23} m^{-3}$ then

$$n_{body} = 10^{23} m^{-3}$$

else

$$n_{body} = NBODY_i$$

If $NGATE_i > 0$ then

$$\Delta\Phi = \max\left(0, \frac{E_g}{2} - \frac{kT}{q} \cdot \ln\left(\frac{NGATE_i}{n_i}\right)\right)$$

else

$$\Delta\Phi = \begin{cases} PHIG_i - EASUB & \text{for NMOS,} \\ (EASUB + E_g) - PHIG_i & \text{for PMOS.} \end{cases}$$

$$\phi_B = \frac{kT}{q} \cdot \ln\left(\frac{n_{body}}{n_i}\right)$$

$$\phi_{SD} = \min\left[\frac{E_g}{2}, \frac{kT}{q} \cdot \ln\left(\frac{NSD_i}{n_i}\right)\right]$$

$$V_{fbsd} = \begin{cases} PHIG_i - (EASUB + \frac{E_g}{2} - \phi_{SD}) & \text{for NMOS,} \\ -\left[PHIG_i - (EASUB + \frac{E_g}{2} + \phi_{SD})\right] & \text{for PMOS.} \end{cases}$$

$$\gamma_0 = \frac{\sqrt{2q \epsilon_{sub} n_{body}}}{C_{ox}}$$

$$\phi_{bulk} = \frac{1}{2} \frac{qn_{body}}{\epsilon_{sub}} \left(\frac{TFIN}{2}\right)^2$$

$$\phi_{pert} = \phi_{bulk}$$

$$Q_{bulk} = \sqrt{2qn_{body}\epsilon_{sub}\phi_{pert}}$$

Poly Depletion

$$V_{poly0} = \frac{1}{2} \frac{q \cdot NGATE_i \cdot \epsilon_{sub}}{C_{ox}^2}$$

Short Channel Effects

$$V_{bi} = \frac{kT}{q} \cdot \ln\left(\frac{NSD_i \cdot n_{body}}{n_i^2}\right)$$

$$H_{eff} = \sqrt{\frac{HFIN}{8} \cdot (HFIN + 2 \cdot \epsilon_{ratio} \cdot EOT)}$$

$$\lambda = \begin{cases} \sqrt{\frac{\epsilon_{ratio}}{2} \left(1 + \frac{TFIN}{4\epsilon_{ratio}EOT}\right) TFIN \cdot EOT} & \text{if } GEOMOD = 0 \\ \frac{1}{\sqrt{\frac{\epsilon_{ratio}}{2} \left(1 + \frac{TFIN}{4\epsilon_{ratio}EOT}\right) TFIN \cdot EOT} + \frac{1}{4H_{eff}^2}} & \text{if } GEOMOD = 1 \\ \frac{0.5}{\sqrt{\frac{\epsilon_{ratio}}{2} \left(1 + \frac{TFIN}{4\epsilon_{ratio}EOT}\right) TFIN \cdot EOT} + \frac{1}{4H_{eff}^2}} & \text{if } GEOMOD = 2 \end{cases}$$

Quantum Mechanical Effects

$$m_x = 0.916 \cdot m_e$$

Constants for Surface Potential Calculation

$$r1 = \frac{2\epsilon_{sub}}{C_{ox} \cdot TFIN}$$

$$r2 = \begin{cases} 0 & \text{if } NGATE_i = 0 \\ \frac{4 \cdot kT \epsilon_{sub}}{q \cdot TFIN^2 \cdot NGATE_i} & \text{if } NGATE_i > 0 \end{cases}$$

Mobility Model

$$\mu_0 = U0(T) \times (1 - UP_i \times (L_{eff})^{-LPA_i})$$

$$\eta = \begin{cases} \frac{1}{2} \cdot ETAMOB & \text{for NMOS} \\ \frac{1}{3} \cdot ETAMOB & \text{for PMOS} \end{cases}$$

Terminal Voltages

Terminal Voltages and Vdsx 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

Vt Roll-o, DIBL, and Subthreshold Slope Degradation

$$\psi_{st} = 0.4 + PHIN_i + \Phi_B$$

$$C_{dsc} = \frac{0.5}{\cosh\left(DVT1_i \cdot \frac{L_{eff}}{\lambda}\right) - 1} \cdot (CDSC_i + CDSCD_i \cdot V_{dsx})$$

$$n = 1 + \frac{CIT_i + C_{dsc}}{(2C_{si}) \parallel C_{ox}}$$

$$\Delta V_{th,SCE} = -\frac{0.5 \cdot DVT0_i}{\cosh\left(DVT1_i \cdot \frac{L_{eff}}{\lambda}\right) - 1} \cdot (V_{bi} - \psi_{st})$$

$$\Delta V_{th,DIBL} = -\frac{0.5 \cdot ETA0_i}{\cosh\left(DSUB_i \cdot \frac{L_{eff}}{\lambda}\right) - 1} \cdot V_{dsx}$$

$$\Delta V_{th,RSCE} = K1RSCE_i \cdot \left[\sqrt{1 + \frac{LPE0_i}{L_{eff}}} - 1 \right] \cdot \sqrt{\psi_{st}}$$

$$\Delta V_{th,all} = \Delta V_{th,SCE} + \Delta V_{th,DIBL} + \Delta V_{th,RSCE} + \Delta V_{th,temp}$$

$$V_{gsfb} = \begin{cases} V_{gs} - \Delta\Phi - \Delta V_{th,all} & \text{if } PHISMOD = 0 \\ V_{gs} - \Delta\Phi - \Delta V_{th,all} - \frac{q n_{body} TFIN}{2C_{ox}} & \text{if } PHISMOD = 1 \end{cases}$$

Voltage Limiting for Accumulation

$$V_{gsfb\text{eff}} = \frac{1}{2} \left[V_{gsfb} + \Phi_B + \frac{E_g}{2} + \sqrt{\left(V_{gsfb} + \Phi_B + \frac{E_g}{2} \right)^2 + 4 \times 10^{-8}} \right] - \Phi_B - \frac{E_g}{2}$$

Surface Potential Calculation

Surface potentials at the source and drain ends are derived from the Poisson's equation with a perturbation method [3] and computed using the Householder's cubic iteration method [4] [5] [6]. Perturbation allows accurate modeling of finite body doping.

When the body is lightly-doped, a simplified surface potential algorithm can be activated by setting PHISMOD = 1 to enhance computational efficiency.

Calculations Common to the Source and Drain Surface Potentials

$$a = e^{\frac{q\phi_{\text{pert}}}{nkT}}$$

$$b = \frac{\phi_{\text{bulk}}}{(nkT/q)^2}$$

$$c = 2nkT/q$$

$$F_1 = \ln \left(\sqrt{\frac{2\epsilon_{\text{sub}}nkT}{q^2N_c} \frac{2}{TFIN}} \right)$$

Surface Potential 2-stage Analytical Approximation (PHISMOD = 0)

$$E_{0,QM} = \frac{\hbar^2 \pi^2}{2m_x \cdot TFIN^2}$$

$$V_{ch} = \begin{cases} QMFACTOR_i \cdot \frac{E_{0,QM}}{q} & \text{at source} \\ QMFACTOR_i \cdot \frac{E_{0,QM}}{q} + V_{dseff} & \text{at drain} \end{cases}$$

$$F = \frac{q(V_{gsfbeff} - \phi_{pert} - V_{ch})}{2nkT} - F_1$$

$$Z1 = Tan^{-1} \left(exp \left(F - r1 \cdot \sqrt{\frac{\phi_{bulk} \cdot \phi_{pert}}{n(kT/q)^2}} - r2 \cdot \frac{\phi_{bulk} \cdot \phi_{pert}}{n(kT/q)^2} \right) \right)$$

$$Z2 = Tan^{-1} \left(\frac{2ln(1 + e^F)}{r1 \cdot \pi \cdot e^{q\phi_{pert}/2nkT}} \right)$$

$$\beta = MIN(Z1, Z2)$$

$$T0 = (1 + \beta Tan\beta)$$

$$T2 = \sqrt{\beta^2 \left(\frac{a}{Cos^2\beta} - 1 \right) + b \cdot (\phi_{pert} - c \cdot \ln(Cos\beta))}$$

$$T3 = -2 \cdot \beta + b \cdot c \cdot Tan(\beta) + 2a \cdot \beta \cdot Sec^2(\beta) \cdot T0$$

$$T4 = -2 + 2a \cdot \beta^2 Sec^4(\beta)$$

$$+ Sec^2(\beta) (2a + b \cdot c + 8a \cdot \beta Tan(\beta) + 4a \cdot \beta^2 Tan^2(\beta))$$

$$T5 = 2T4 \cdot Tan(\beta)$$

$$+ 4 (3T0 \cdot a \cdot \beta Sec^4(\beta) + Tan(\beta) + 2T0 \cdot a \cdot Sec^2(\beta) Tan(\beta))$$

Virtuoso Simulator Components and Device Models Reference

Circuit Components

$$f_0 = \ln(\beta) - \ln(\text{Cos}(\beta)) + r_1 \cdot T_2 - F + r_2 \cdot T_2^2$$

$$f_1 = \frac{1}{\beta} + \text{Tan}(\beta) + \frac{r_1 \cdot T_3}{2T_2} + r_2 \cdot T_3$$

$$f_2 = -\frac{1}{\beta^2} + \text{Sec}^2(\beta) - \frac{r_1 \cdot T_3^2}{4T_2^3} + \frac{r_1 \cdot T_4}{2T_2} + r_2 \cdot T_4$$

$$f_3 = \frac{2}{\beta^3} + 2\text{Sec}^2(\beta)\text{Tan}(\beta) + \frac{3r_1 \cdot T_3^3}{8T_2^5} - \frac{3r_1 \cdot T_3 \cdot T_4}{4T_2^3} \\ + \frac{r_1 \cdot T_5}{2T_2} + r_2 \cdot T_5$$

$$\beta = \beta - \frac{f_0}{f_1} \cdot \left(1 + \frac{f_0 \cdot f_2}{2f_1^2} + \frac{f_0^2 \cdot (3f_2^2 - f_1 \cdot f_3)}{6f_1^4} \right)$$

Repeat (3.91) to (3.100).

$$\psi_0 = 2n \frac{kT}{q} \cdot \ln \left(\frac{2\beta}{T_{Si}} \cdot \sqrt{\frac{2\epsilon_{sub} n kT \cdot n_{body}}{q^2 n_i^2}} \right)$$

$$\begin{cases} \psi_s = \psi_0 - 2n \frac{kT}{q} \ln(\text{Cos}(\beta)) + \phi_{pert} & \text{at source} \\ \psi_d = \psi_0 - 2n \frac{kT}{q} \ln(\text{Cos}(\beta)) + \phi_{pert} + V_{dseff} & \text{at drain} \end{cases}$$

Simplified Surface Potential Approximation (PHISMOD = 1)

$$E_{0,QM} = \frac{\hbar^2 \pi^2}{2m_x \cdot TFIN^2}$$

$$V_{ch} = \begin{cases} QMFACTOR_i \cdot \frac{E_{0,QM}}{q} & \text{at source} \\ QMFACTOR_i \cdot \frac{E_{0,QM}}{q} + V_{dseff} & \text{at drain} \end{cases}$$

$$F = \frac{q(V_{gsfbeff} - V_{ch})}{2nkT} - F_1$$

$$Z1 = \text{Tan}^{-1}(\exp(F))$$

$$Z2 = \text{Tan}^{-1}\left(\frac{2\ln(1 + e^F)}{r1 \cdot \pi}\right)$$

$$\beta = \text{MIN}(Z1, Z2)$$

$$f0 = \ln(\beta) - \ln(\text{Cos}(\beta)) + r1 \cdot \beta \cdot \text{Tan}(\beta) + r2 \cdot \beta^2 \cdot \text{Tan}^2(\beta) - F$$

$$f1 = \frac{1}{\beta} + \beta \cdot \text{Sec}^2(\beta) [r1 + 2 \cdot r2 \cdot \beta \cdot \text{Tan}(\beta)] +$$

$$\text{Tan}(\beta) [1 + r1 + 2 \cdot r2 \cdot \beta \cdot \text{Tan}(\beta)]$$

$$f2 = \text{Sec}^2(\beta) \left[1 + 2 \left(r1 + r2 \cdot \beta^2 \cdot \text{Sec}^2(\beta) + r1 \cdot \beta \cdot \text{Tan}(\beta) \right. \right. \\ \left. \left. + 2 \cdot r2 \cdot \left(\beta^2 \text{Tan}^2(\beta) + 2\beta \cdot \text{Tan}(\beta) \right) \right) \right] + \frac{1}{\beta^2} [2 \cdot r2 \cdot \beta^2 \cdot \text{Tan}^2(\beta) - 1]$$

$$f3 = \frac{2}{\beta^3} + 2 \cdot \beta \cdot \text{Sec}^4(\beta) \left[r1 + 2 \cdot r2 \cdot \left(3 + 4\beta \text{Tan}(\beta) \right) \right] \\ + 2\text{Sec}^2(\beta) \text{Tan}(\beta) \cdot \left[1 + 3 \cdot r1 \right. \\ \left. + 2 \cdot r1 \cdot \beta \cdot \text{Tan}(\beta) + 2 \cdot r2 \left(3 \left(1 + 2 \cdot \beta \cdot \text{Tan}(\beta) \right) + 2 \cdot \beta^2 \cdot \text{Tan}^2(\beta) \right) \right]$$

$$\beta = \beta - \frac{f0}{f1} \cdot \left(1 + \frac{f0 \cdot f2}{2f1^2} + \frac{f0^2 \cdot (3f2^2 - f1 \cdot f3)}{6f1^4} \right)$$

Repeat (3.109) to (3.113).

$$\begin{cases} \psi_s = \frac{2nkT}{q} [\ln(\beta) - \ln(\text{cos}(\beta)) + F_1] & \text{at source} \\ \psi_d = \frac{2nkT}{q} [\ln(\beta) - \ln(\text{cos}(\beta)) + F_1] + V_{dseff} & \text{at drain} \end{cases}$$

Drain Saturation Voltage

The drain saturation voltage model is calculated after the source-side surface potential (ψ_s) has been calculated. V_{dseff} is subsequently used to compute the drain-side surface potential (ψ_d).

Electric Field Calculations

Electric Field is in *MV/cm*

$$q_{bs} = \frac{q \cdot n_{body} \cdot TFIN}{2 \cdot C_{ox}}$$

$$q_{is} = V_{gsfbeff} - \psi_s - q_{bs}$$

$$E_{effs} = 10^{-8} \cdot \left(\frac{q_{bs} + \eta \cdot q_{is}}{\epsilon_{ratio} \cdot EOT} \right)$$

Drain Saturation Voltage (V_{dsat}) Calculations

If $MOBMOD = 0$ then

$$q_{im,th} = \begin{cases} \frac{300 \times 10^{-9}}{0.5 \cdot \mu_0 C_{ox}} & \text{for NMOS} \\ \frac{80 \times 10^{-9}}{0.5 \cdot \mu_0 C_{ox}} & \text{for PMOS} \end{cases}$$

$$G_{mobs} = 1 + UA(T) \cdot (E_{effs})^{EU} + \frac{UD(T)}{\left(\frac{1}{2} \cdot \left(1 + \frac{q_{is}}{q_{im,th}}\right)\right)^{UCS(T)}}$$

If $MOBMOD = 1$ then

$$G_{mobs} = 1 + (MUE(T) \cdot E_{effs})^{THETAMU(T)} + CS(T) \cdot \left(\frac{q_{bs}}{q_{bs} + q_{is}}\right)^2$$

$$R_{ds,s} = \frac{1}{(W_{eff0})^{WR_i}} \cdot \left(RDSWMIN(T) + \frac{RDSW(T)}{1 + PRWG_i \cdot q_{is}} \right)$$

$$E_{sat} = \frac{2 \cdot VSAT(T)}{\mu_0 / G_{mobs}}$$

$$E_{satL} = E_{sat} \cdot L_{eff}$$

If $R_{ds,s} = 0$ then

$$V_{dsat} = \frac{E_{satL} \cdot KSATIV_i \cdot (V_{gsfbeff} - \psi_s + 2\frac{kT}{q})}{E_{satL} + KSATIV_i \cdot (V_{gsfbeff} - \psi_s + 2\frac{kT}{q})}$$

else

$$WVC_{ox} = W_{eff} \cdot VSAT(T) \cdot C_{ox}$$

$$T_a = 2 \cdot WVC_{ox} \cdot R_{ds,s}$$

$$T_b = KSATIV_i \cdot (V_{gsfbeff} - \psi_s + 2\frac{kT}{q}) \cdot (1 + 3 \cdot WVC_{ox} \cdot R_{ds,s}) + E_{satL}$$

$$T_c = KSATIV_i \cdot (V_{gsfbeff} - \psi_s + 2\frac{kT}{q})$$

$$\times \left(E_{satL} + T_a \cdot KSATIV_i \cdot (V_{gsfbeff} - \psi_s + 2\frac{kT}{q}) \right)$$

$$V_{dsat} = \frac{\left(T_b - \sqrt{T_b^2 - 2T_a T_c} \right)}{T_a}$$

$$V_{dseff} = \frac{V_{ds}}{\left(1 + \left(\frac{V_{ds}}{V_{dsat}} \right)^{MEX P_i} \right)^{1/MEX P_i}}$$

Poly Depletion

$$\psi_m = \frac{\psi_s + \psi_d}{2}$$

If $NGATE_i > 0$ then

$$T1 = \frac{V_{gsfbef} - \psi_m}{V_{poly0}}$$

$$T2 = T1^2 + 0.00004$$

$$T3 = \frac{T1 + \sqrt{T2}}{2}$$

$$K = \frac{1 - \sqrt{T3 + 1}}{2\sqrt{T3 + 1}} \cdot \left(1 + \frac{T1}{\sqrt{T2}}\right)$$

$$V_{polym} = V_{poly0} \cdot \left(\sqrt{T3 + 1} - 1\right)^2$$

else

$$V_{polym} = K = 0$$

Midpoint Potential and Charge

$$q_{bm} = \frac{q \cdot n_{body} \cdot TFIN}{2C_{ox}}$$

$$q_{id} = \begin{cases} V_{gsfbef} - \psi_d - \frac{q \cdot n_{body} \cdot TFIN}{2C_{ox}} & PHISMOD = 0 \\ V_{gsfbef} - \psi_d & PHISMOD = 1 \end{cases}$$

$$q_{im} = \begin{cases} V_{gsfbef} - \psi_m - q_{bm} - V_{polym} & PHISMOD = 0 \\ V_{gsfbef} - \psi_m - V_{polym} & PHISMOD = 1 \end{cases}$$

$$\Delta\psi = \psi_d - \psi_s$$

Effective Width Model

Effective Charge Thickness for Quantum Mechanical Effects

$$Q_i = C_{ox} \cdot q_{im}$$

$$T_{cen,0} = \left(\frac{21\epsilon_{sub}\hbar^2}{2qm_x Q_i} \right)^{1/3}$$

$$T_{cen} = \frac{T_{cen,0}}{\left(1 + \left(\frac{T_{cen,0}}{TFIN/3} \right)^{MEXP_i} \right)^{1/MEXP_i}}$$

Effective Width Model

If $GEOMOD = 0$ then

$$W_{eff} = W_{eff0}$$

$$W_{eff,CV} = W_{eff,CV0}$$

If $GEOMOD = 1$ then

$$W_{eff} = W_{eff0} - 4T_{cen}$$

$$W_{eff,CV} = W_{eff,CV0} - 4T_{cen}$$

If $GEOMOD = 2$ then

$$W_{eff} = W_{eff0} - 8T_{cen}$$

$$W_{eff,CV} = W_{eff,CV0} - 8T_{cen}$$

Mobility Model

The default mobility model (MOBMOD=0) is based on the BSIM4 model [7]. MOBMOD=1 is adopted from the PSP model [8].

$$E_{effm} = 10^{-8} \cdot \left(\frac{q_{bm} + \eta \cdot q_{im}}{\epsilon_{ratio} \cdot EOT} \right)$$

If *MOBMOD* = 0 then

$$G_{mob} = 1 + UA(T) \cdot (E_{effm})^{EU} + \frac{UD(T)}{\left(\frac{1}{2} \cdot \left(1 + \frac{q_{im}}{q_{im,th}} \right) \right)^{UCS(T)}}$$

If *MOBMOD* = 1 then

$$G_{mob} = 1 + (MUE(T) \cdot E_{effm})^{THETAMU(T)} + CS(T) \cdot \left(\frac{q_{bm}}{q_{bm} + q_{im}} \right)^2$$

Output Conductance

Channel Length Modulation

The channel length modulation equation of the PSP model [8] has been simplified adopted in BSIM-CMG.

$$T1 = \ln \left(\frac{1 + \frac{V_{ds} - \Delta\psi}{VP}}{1 + \frac{V_{dseff} - \Delta\psi}{VP}} \right)$$

$$dL = ALP_i \cdot T1$$

$$G_{dL} = \frac{1}{1 + dL + dL^2}$$

Output Conductance due to DIBL

The DIBL output conductance module of the BSIM4 model [7] has been simplified

adopted in BSIM-CMG.

$$\theta_{rout} = \frac{0.5 \cdot PDIBL1_i}{\cosh\left(DROUT_i \cdot \frac{L_{eff}}{\lambda}\right) - 1} + PDIBL2_i$$

$$V_{ADIBL} = \frac{q_{im} + 2kT/q}{\theta_{rout}} \cdot \left(1 - \frac{V_{dsat}}{V_{dsat} + q_{im} + 2kT/q}\right) \cdot \left(1 + PVAG_i \cdot \frac{q_{im}}{E_{sat} L_{eff}}\right)$$

$$F_{oc} = \left(1 + \frac{V_{ds} - V_{dseff}}{V_{ADIBL}}\right)$$

S/D Series Resistance and Velocity Saturation

S/D Series Resistance

BSIM-CMG offers two options to model the source/drain series resistance. The internal resistance option ($RDSMOD = 0$) adds a correction term in the I-V, whereas the external resistance option ($RDSMOD = 1$) incorporates two additional resistor elements.

If $RDSMOD = 0$ then

$$R_{ds} = \frac{1}{W_{eff} W_{Ri}} \cdot \left(RDSWMIN(T) + \frac{RDSW(T)}{1 + PRWG_i \cdot q_{im}} \right)$$

$$G_{mob,r} = G_{mob} + \mu_0 \cdot C_{ox} \cdot \frac{W_{eff}}{L_{eff}} \cdot q_{im} \cdot R_{ds}$$

$$R_{source} = 10^{-3}$$

$$R_{drain} = 10^{-3}$$

If $RDSMOD = 1$ then

$$G_{mob,r} = G_{mob} \quad ($$

$$V_{gs,eff} = \frac{1}{2} \left[V_{gs} - V_{fbsd} + \sqrt{(V_{gs} - V_{fbsd})^2 + 10^{-4}} \right] \quad ($$

$$V_{gd,eff} = \frac{1}{2} \left[V_{gd} - V_{fbsd} + \sqrt{(V_{gd} - V_{fbsd})^2 + 10^{-4}} \right] \quad ($$

$$R_{source} = 10^{-3} + \frac{1}{NF \cdot W_{eff} W_{Ri}} \cdot \left(RSWMIN(T) + \frac{RSW(T)}{1 + PRWG_i \cdot V_{gs,eff}} \right) \quad ($$

$$R_{drain} = 10^{-3} + \frac{1}{NF \cdot W_{eff} W_{Ri}} \cdot \left(RDWMIN(T) + \frac{RDW(T)}{1 + PRWG_i \cdot V_{gd,eff}} \right) \quad ($$

Current Degradation Due to Velocity Saturation

$$Z_{sat} = \begin{cases} \left(\frac{THETASAT(T) \cdot \Delta\psi}{G_{mob,r} \cdot G_{dL}} \right)^2 & \text{for NMOS} \\ \frac{\left(\frac{THETASAT(T) \cdot \Delta\psi}{G_{mob,r} \cdot G_{dL}} \right)^2}{1 + \frac{THETASAT(T) \cdot \Delta\psi}{G_{mob,r} \cdot G_{dL}}} & \text{for PMOS} \end{cases}$$

$$G_{vsat} = \frac{G_{mob,r} \cdot G_{dL}}{2} \cdot \left(1 + \sqrt{1 + 2Z_{sat}} \right)$$

Drain Current Model

Calculate Drain Current in Linear Region

$$Q_s = (V_{gsfbeff} - \psi_s) \cdot C_{ox}$$

$$Q_d = (V_{gsfbeff} - \psi_d) \cdot C_{ox}$$

$$i_{ds1} = C_{ox} \cdot \left(V_{gsfbeff} - \psi_m - V_{polym} - \frac{Q_{bulk}}{C_{ox}} + 2 \frac{kT}{q} \right) \cdot \Delta\psi$$

$$i_{ds2} = -\frac{kT}{q} \left(5 \frac{kT}{q} C_{Si} + 2Q_{bulk} \right) \cdot \ln \left(\frac{Q_s + Q_{bulk} + 5 \frac{kT}{q} C_{Si}}{Q_d + Q_{bulk} + 5 \frac{kT}{q} C_{Si}} \right)$$

$$I_{ds0} = \mu_0 \cdot \frac{W_{eff}}{L_{eff}} (i_{ds1} + i_{ds2}) \cdot \frac{F_{oc}}{G_{vsat}}$$

Capacitance Model

Intrinsic (Normalized) Charge

$$q_b = \frac{Q_{bulk}}{C_{ox}}$$

$$B = 2 \left(V_{gsfbeff} - q_b - V_{polym} + 2 \frac{kT}{q} \right)$$

$$q_g = V_{gsfbeff} - V_{polym} - \psi_m + \frac{(1 + K)^2 \Delta\psi^2}{6(B - \psi_s - \psi_d)}$$

$$q_d = \frac{V_{gsfbeff} - V_{polym} - q_b}{2} - \frac{\psi_s + 2\psi_d}{6} - \frac{K \Delta\psi}{12}$$

$$+ \frac{(1 + K)^2 \Delta\psi^2}{12(B - \psi_s - \psi_d)} + \frac{(1 + K)^3 \Delta\psi^3}{60(B - \psi_s - \psi_d)^2}$$

Terminal Charge and Parasitics

$$C_{oxe} = \frac{3.9 \cdot \epsilon_0}{EOT + T_{cen}/\epsilon_{ratio}}$$

$$Q_{g,intrinsic} = C_{oxe} \cdot W_{eff,CV} \cdot L_{eff,CV} \cdot (q_g)$$

$$Q_{d,intrinsic} = C_{oxe} \cdot W_{eff,CV} \cdot L_{eff,CV} \cdot (-q_d)$$

$$Q_{b,intrinsic} = C_{oxe} \cdot W_{eff,CV} \cdot L_{eff,CV} \cdot (-q_b)$$

$$Q_{s,intrinsic} = -Q_{g,intrinsic} - Q_{d,intrinsic} - Q_{b,intrinsic}$$

$$Q_{gs,ov} = C_{ox} \cdot W_{eff,CV} \cdot LOV_i \cdot V_{gs}$$

$$Q_{gd,ov} = C_{ox} \cdot W_{eff,CV} \cdot LOV_i \cdot V_{gd}$$

$$Q_{gs,fr} = W_{eff,CV} \cdot CF_i \cdot V_{gs}$$

$$Q_{gd,fr} = W_{eff,CV} \cdot CF_i \cdot V_{gd}$$

$$Q_g = (Q_{g,intrinsic} + Q_{gs,ov} + Q_{gd,ov} + Q_{gs,fr} + Q_{gd,fr}) \times NF$$

$$Q_d = (Q_{d,intrinsic} - Q_{gd,ov} - Q_{gd,fr}) \times NF$$

$$Q_b = (Q_{b,intrinsic}) \times NF$$

$$Q_s = (Q_{s,intrinsic} - Q_{gs,ov} - Q_{gs,fr}) \times NF$$

Impact Ionization and GIDL/GISL Model

Impact Ionization Current

$$I_{ii} = \frac{ALPHA0_i + ALPHA1_i \cdot L_{eff}}{L_{eff}} (V_{ds} - V_{dseff}) \cdot e^{\frac{BETA0(T)}{V_{ds} - V_{dseff}}} \cdot I_{ds}$$

Gate-Induced-Drain/Source-Leakage Current

GIDL/GISL is calculated only if $GIDLMOD = 1$

$$I_{gidl} = AGIDL_i \cdot W_{eff} \cdot \frac{V_{ds} - V_{gs} - EGIDL_i + V_{fbsd}}{\epsilon_{ratio} \cdot EOT}$$

$$\times \exp\left(-\frac{\epsilon_{ratio} \cdot EOT \cdot BGIDL(T)}{V_{ds} - V_{gs} - EGIDL_i + V_{fbsd}}\right) \times NF$$

$$I_{gisl} = AGIDL_i \cdot W_{eff} \cdot \frac{-V_{ds} - V_{gd} - EGIDL_i + V_{fbsd}}{\epsilon_{ratio} \cdot EOT}$$

$$\times \exp\left(-\frac{\epsilon_{ratio} \cdot EOT \cdot BGIDL(T)}{-V_{ds} - V_{gd} - EGIDL_i + V_{fbsd}}\right) \times NF$$

Gate Tunneling Current

Gate tunneling current is calculated only for $IGMOD = 1$.

Gate to Body Current

I_{gb} is calculated only for the bulk (4-terminal) module.

$$A = 3.75956 \times 10^{-7}$$

$$B = 9.82222 \times 10^{11}$$

$$V_{oxm} = V_{gsfb} - \frac{\psi_s + \psi_d}{2}$$

$$V_{gbeff} = \frac{V_{gs} + V_{gd}}{2}$$

$$V_{aux,igbinv} = NIGBINV_i \cdot \frac{kT}{q} \cdot \ln\left(1 + \exp\left(\frac{V_{oxm} - EIGBINV_i}{NIGBINV_i \cdot kT/q}\right)\right)$$

$$I_{gbinv} = \frac{W_{eff} \cdot L_{eff} \cdot A}{(EOT \cdot \frac{EPSROX}{3.9})^2} \cdot V_{gbeff} \cdot V_{aux,igbinv} \cdot I_{gtemp} \times NF \cdot$$

$$\exp(-B \cdot EOT \cdot (AIGBINV_i - BIGBINV_i \cdot V_{oxm}) \cdot (1 + CIGBINV_i \cdot V_{oxm}))$$

Gate to Channel Current

$$A = \begin{cases} 4.97232 \times 10^{-7} & \text{for NMOS} \\ 3.42536 \times 10^{-7} & \text{for PMOS} \end{cases}$$

$$B = \begin{cases} 7.45669 \times 10^{11} & \text{for NMOS} \\ 1.16645 \times 10^{12} & \text{for PMOS} \end{cases}$$

$$V_{auxs} = NIGC_i \cdot \left(V_{gsfbeff} - \psi_s - \frac{Q_{bulk}}{C_{ox}} \right)$$

$$V_{auxd} = NIGC_i \cdot \left(V_{gsfbeff} - \psi_d - \frac{Q_{bulk}}{C_{ox}} \right)$$

$$I_{gcs} = \frac{W_{eff} \cdot L_{eff} \cdot A}{\left(EOT \cdot \frac{EPSROX}{3.9} \right)^2} \cdot V_{oxm} \cdot V_{auxs} \cdot I_{gtemp} \times NF \cdot$$

$$\exp \left(-B \cdot EOT \cdot \frac{EPSROX}{3.9} \cdot (AIGC_i - BIGC_i \cdot V_{oxm}) \cdot (1 + CIGC_i \cdot V_{oxm}) \right)$$

$$I_{gcd} = \frac{W_{eff} \cdot L_{eff} \cdot A}{\left(EOT \cdot \frac{EPSROX}{3.9} \right)^2} \cdot V_{oxm} \cdot V_{auxd} \cdot I_{gtemp} \times NF \cdot$$

$$\exp \left(-B \cdot EOT \cdot \frac{EPSROX}{3.9} \cdot (AIGC_i - BIGC_i \cdot V_{oxm}) \cdot (1 + CIGC_i \cdot V_{oxm}) \right)$$

$$I_{gc} = I_{gcs} + I_{gcd}$$

Gate to Source/Drain Current

$$A = \begin{cases} 4.97232 \times 10^{-7} & \text{for NMOS} \\ 3.42536 \times 10^{-7} & \text{for PMOS} \end{cases}$$

$$B = \begin{cases} 7.45669 \times 10^{11} & \text{for NMOS} \\ 1.16645 \times 10^{12} & \text{for PMOS} \end{cases}$$

$$V'_{gs} = \sqrt{(V_{gs} - V_{fbsd})^2 + 10^{-4}}$$

$$V'_{gd} = \sqrt{(V_{gd} - V_{fbsd})^2 + 10^{-4}}$$

$$I_{gs} = \frac{W_{eff} \cdot DLCIG \cdot A}{(EOT \cdot \frac{EPSROX}{3.9} \cdot POXEDGE_i)^2} \cdot V_{gs} \cdot V'_{gs} \cdot I_{gtemp} \times NF \cdot$$

$$\exp\left(-B \cdot EOT \cdot \frac{EPSROX}{3.9} \cdot POXEDGE_i \cdot (AIGS_i - BIGS_i \cdot V'_{gs}) \cdot (1 + CIGS_i \cdot V'_{gs})\right)$$

$$I_{gd} = \frac{W_{eff} \cdot DLCIG \cdot A}{(EOT \cdot \frac{EPSROX}{3.9} \cdot POXEDGE_i)^2} \cdot V_{gd} \cdot V'_{gd} \cdot I_{gtemp} \times NF \cdot$$

$$\exp\left(-B \cdot EOT \cdot \frac{EPSROX}{3.9} \cdot POXEDGE_i \cdot (AIGS_i - BIGS_i \cdot V'_{gd}) \cdot (1 + CIGS_i \cdot V'_{gd})\right)$$

Non Quasi-static Model

Non quasi-static (NQS) model in this version is modeled through an effective intrinsic input resistance, R_{ii} [9].

$$I_{dovds} = \mu_0 C_{ox} \frac{W_{eff}}{L_{eff}} q_{im} \frac{F_{oc}}{G_{vsat}}$$

$$\frac{1}{R_{ii}} = NF \cdot XRCRG1_i \cdot \left(I_{dovds} + XRCRG2_i \cdot \frac{\mu_{eff} C_{oxe} W_{eff} kT}{q L_{eff}} \right)$$

Junction Current

Diffusion Component

Diffusion current is only calculated for the bulk (4-terminal) module.

$$I_{bs} = TFIN \cdot WDIOS \cdot ISDIF_i \cdot \exp \left[\frac{XDIF_i \cdot qE_{g,300}}{NDIODE_i \cdot kT} \left(\frac{T}{TNOM} - 1 \right) \right] \\ \cdot \left[\exp \left(\frac{qV_{bs}}{NDIODE_i \cdot kT} \right) - 1 \right] \times NF$$

$$I_{bd} = TFIN \cdot WDIOD \cdot IDDIF_i \cdot \exp \left[\frac{XDIFD_i \cdot qE_{g,300}}{NDIODED_i \cdot kT} \left(\frac{T}{TNOM} - 1 \right) \right] \\ \cdot \left[\exp \left(\frac{qV_{bd}}{NDIODED_i \cdot kT} \right) - 1 \right] \times NF$$

Generation-recombination Component

$$I_{ds,gen} = HFIN \cdot TFIN \cdot (L_{eff} - LINTIGEN) \cdot (AIGEN_i \cdot V_{ds} + BIGEN_i \cdot V_{ds}^3) \\ \cdot \exp \left[\frac{qE_{g,300}}{NTGEN_i \cdot kT} \left(\frac{T}{TNOM} - 1 \right) \right] \times NF$$

Noise Models

Noise models in BSIM-CMG are adopted from BSIM4 [7]. The following table lists the origin of each noise model:

Model in BSIM-CMG 102.0	Origin
Flicker noise model	BSIM4 Unified Model (FN)IMOD=1)
Thermal noise	BSIM4 TNOIMOD=0
FGate current shot noise	BSIM gate current noise

Flicker Noise Model

$$E_{sat,noi} = \frac{2V_{SAT_i}}{\mu_{eff}}$$

$$L_{eff,noi} = L_{eff} - 2 \cdot LINTNOI$$

$$\Delta L_{clm} = l \cdot \ln \left[\frac{1}{E_{sat,noi}} \cdot \left(\frac{V_{ds} - V_{dseff}}{l} + EM \right) \right]$$

$$N_0 = \frac{C_{ore} \cdot q_{is}}{q}$$

$$N_l = \frac{C_{ore} \cdot q_{id}}{q}$$

$$N^* = \frac{kT}{q^2} (C_{ore} + CIT)$$

$$FN1 = NOIA \cdot \ln \left(\frac{N_0 + N^*}{N_l + N^*} \right) + NOIB \cdot (N_0 - N_l) + \frac{NOIC}{2} (N_0^2 - N_l^2)$$

$$FN2 = \frac{NOIA + NOIB \cdot N_l + NOIC \cdot N_l^2}{(N_l + N^*)^2}$$

$$S_{si} = \frac{kTq^2\mu_{eff}I_{ds}}{C_{ore}L_{eff,noi}^2f^{EF} \cdot 10^{10}} \cdot FN1 + \frac{kTI_{ds}^2\Delta L_{clm}}{W_{eff} \cdot NF \cdot L_{eff,noi}^2f^{EF} \cdot 10^{10}} \cdot FN2$$

$$S_{wi} = \frac{NOIA \cdot kT \cdot I_{ds}^2}{W_{eff} \cdot NF \cdot L_{eff,noi}f^{EF} \cdot 10^{10} \cdot N^{*2}}$$

$$S_{id,flicker} = \frac{S_{wi}S_{si}}{S_{wi} + S_{si}}$$

Thermal Noise Model (TNOIMOD = 0)

$$Q_{inv} = |Q_{s,intrinsic} + Q_{d,intrinsic}|$$

$$\overline{i_d^2} = \begin{cases} NF \times \frac{4kT\Delta f}{R_{ds} + \frac{L_{eff}^2}{\mu_{eff}Q_{inv}}} \cdot NTNOI & \text{if RDSMOD} = 0 \\ NF \times \frac{4kT\Delta f}{L_{eff}^2} \cdot \mu_{eff}Q_{inv} \cdot NTNOI & \text{if RDSMOD} = 1 \end{cases}$$

Gate Current Shot Noise

Shot noise is calculated only if $IGMOD = 1$.

$$\overline{i_{gs}^2} = 2q(I_{gcs} + I_{gs})$$

$$\overline{i_{gd}^2} = 2q(I_{gcd} + I_{gd})$$

$$\overline{i_{gb}^2} = 2qI_{gbinv}$$

Simulation Outputs

Sample input decks for the BSIM-CMG model are listed as follows:

SPICE Deck	Description
idvgnmos.sp	I_d - V_{gs} characteristics for n-FETs (25 ⁰ C)
idvgpmos.sp	I_d - V_{gs} characteristics for p-FETs (25 ⁰ C)
idvdnmos.sp	I_d - V_{ds} characteristics for n-FETs (25 ⁰ C)
idvdnmos.sp	I_d - V_{ds} characteristics for p-FETs (25 ⁰ C)
idvgnmos_m55C.sp	I_d - V_{gs} characteristics for n-FETs (-55 ⁰ C)
idvgpmos_m55C.sp	I_d - V_{gs} characteristics for p-FETs (-55 ⁰ C)
idvdnmos_m55C.sp	I_d - V_{ds} characteristics for n-FETs (-55 ⁰ C)
idvdpmos_m55C.sp	I_d - V_{ds} characteristics for p-FETs (-55 ⁰ C)
idvgnmos_m100C.sp	I_d - V_{gs} characteristics for n-FETs (100 ⁰ C)
idvgpmos_m100C.sp	I_d - V_{gs} characteristics for p-FETs (100 ⁰ C)
idvdnmos_m100C.sp	I_d - V_{ds} characteristics for n-FETs (100 ⁰ C)
idvdpmos_m100C.sp	I_d - V_{ds} characteristics for p-FETs (100 ⁰ C)
ac.sp	AC simulation example
noise.sp	noise simulation example
gummel.sp	Gummel symmetry test
ringosc_17stg.sp	Ring oscillator simulation example
inverter_transient.sp	Inverter transient response example

Component Statements

This device is supported within altergroups.

Instance Definition

```
Name d g s [b] ModelName parameter=value ...
```

Instance Parameters

- 1 `exp_cr=` instance parameter: no description.
- 2 `cmi_limexp_method=` instance parameter: no description.
- 3 `cmi_compactable=` instance parameter: no description.
- 4 `m=` instance parameter: no description.
- 5 `length=` instance parameter: no description.
- 6 `tfin=` units are m.
- 7 `nf=` number of fins in parallel.

Model Definition

```
model modelName bsimcmg parameter=value ...
```

Model Parameters

- 1 `igmod=` Gate current switcher; 0=turn off, 1=turn on.
- 2 `gidlmod=` GIDL/GISL switcher; 0=turn off, 1=turn on.
- 3 `phismod=` Simplified Surface Potential Solution, 0 = turn off, 1 = turn on (lightly-doped).
- 4 `geomod=` structure selector, 0 = double gate, 1 = triple gate, 2 = quadruple gate.
- 5 `rdsmode=` S/D resistance mod switch, 0 = Internal, 1 = External.

Virtuoso Simulator Components and Device Models Reference

Circuit Components

6	mobmod=	Mobility Model selector, 0 = BSIM4-based, 1 = PSP-based.
7	devtype=	type of model, 1: ntype, 0: ptype.
8	xl=	L offset for channel length due to mask/etch effect.
9	lint=	Length reduction parameter.
10	ll=	Length reduction parameter.
11	lln=	Length reduction parameter.
12	llc=	Length reduction parameter.
13	dlc=	Delta L for C-V model.
14	eot=	effective gate dielectric thickness relative to SiO ₂ , m.
15	hfin=	fin height.
16	fech=	end-channel factor, for different orientaion/shape.
17	deltaw=	reduction of effective width due to shape of fin.
18	fechcv=	CV end-channel factor, for different orientaion/shape.
19	deltawcv=	CV reduction of effective width due to shape of fin.
20	nbody=	
21	lnbody=	
22	phig=	Gate workfunction.
23	lphig=	
24	epsrox=	Relative dielectric constant of the gate dielectric.
25	epsrsub=	Relative dielectric constant of the channel material.
26	easub=	Electron affinity of substrate.
27	ni0sub=	Intrinsic carrier constant at 300.15K.

Virtuoso Simulator Components and Device Models Reference

Circuit Components

28	bg0sub=	band gap of substrate at 300.15k, ev.
29	nc0sub=	conduction band density of states, m-3.
30	ngate=	parameter for poly gate doping.
31	lngate=	
32	nsd=	units are m-3.
33	lnsd=	
34	cit=	parameter for interface trap.
35	lcit=	
36	cdsc=	coupling capacitance between s/d and channel.
37	lcdsc=	
38	cdscd=	drain-bias sensitivity of cdsc.
39	lcdscd=	
40	dvt0=	sce coefficient.
41	ldvt0=	
42	dvt1=	sce exponent coefficient.
43	ldvt1=	
44	phin=	nonuniform vertical doping effect on surface potential, v.
45	lphin=	
46	eta0=	dibl coefficient.
47	leta0=	
48	dsub=	dibl exponent coefficient.
49	ldsub=	

Virtuoso Simulator Components and Device Models Reference

Circuit Components

50	k1rsce=	k1 for reverse short channel effect calculation (due to pocket implant).
51	lk1rsce=	
52	lpe0=	equivalent length of pocket region at zero bias.
53	llpe0=	
54	qmfactor=	prefactor for qm correction.
55	lqmfactor=	
56	vsat=	saturation velocity m/s.
57	lvsat=	
58	ksativ=	parameter for long channel vdsat.
59	lksativ=	
60	mexp=	smoothing function factor for vdsat.
61	lmexp=	
62	thetasat=	velocity saturation parameter.
63	lthetasat=	
64	u0=	shared: low-field mobility ($m^2/v-s$).
65	lu0=	
66	etamob=	effective field parameter.
67	up=	shared: mobility I coefficient (um^lpa).
68	lup=	shared.
69	lpa=	shared: mobility I power coefficient.
70	llpa=	shared.

Virtuoso Simulator Components and Device Models Reference

Circuit Components

71	ua=	mod0: mobility reduction coefficient.
72	lua=	mod0.
73	eu=	mod0: mobility reduction exponent.
74	leu=	mod0.
75	ud=	mod0: coulombic scattering parameter.
76	lud=	mod0 (experimental).
77	ucs=	mod0: coulombic scattering parameter.
78	lucs=	mod0 (experimental).
79	mue=	mod1: mobility reduction coefficient.
80	lmue=	mod1.
81	thetamu=	mod1: mobility reduction exponent.
82	cs=	mod1: coulombic scattering parameter.
83	lcs=	mod1.
84	alp=	clm prefactor.
85	lalp=	
86	vp=	clm log dependence parameter.
87	rdswwmin=	s/d extension resistance per unit width at high vgs, $\text{ohm}(\mu\text{m})^{\text{wr}}$.
88	rdsww=	zero bias s/d extension resistance per unit width, $\text{ohm}(\mu\text{m})^{\text{wr}}$.
89	lrdsw=	
90	rswmin=	source resistance for rdsmod=1.
91	rsw=	zero bias source resistance for rdsmod=1.
92	lrsw=	

Virtuoso Simulator Components and Device Models Reference

Circuit Components

93	rdwmin=	drain resistance for rdsmod=1.
94	rdw=	zero bias drain resistance for rdsmod=1.
95	lrdw=	
96	prwg=	gate bias dependence of s/d extension resistance, v-1.
97	lprwg=	
98	wr=	w dependence parameter of s/d extension resistance.
99	lwr=	
100	rgeltd=	gate electrode resistance (experimental).
101	pdibl1=	parameter for dibl effect on rout.
102	lpdibl1=	
103	pdibl2=	parameter for dibl effect on rout.
104	lpdibl2=	
105	drout=	I dependence of dibl effect on rout.
106	ldrout=	
107	pvag=	vg dependence on early voltage.
108	lpvag=	
109	aigbinv=	parameter for igb in inversion.
110	laigbinv=	
111	bigbinv=	parameter for igb in inversion.
112	lbigbinv=	
113	cigbinv=	parameter for igb in inversion.
114	lcigbinv=	

Virtuoso Simulator Components and Device Models Reference

Circuit Components

115	eigbinv=	parameter for igb in inversion.
116	leigbinv=	
117	nigbinv=	parameter for igb in inversion.
118	lnigbinv=	
119	aigc=	parameter for igc in inversion.
120	laigc=	
121	bigc=	parameter for igc in inversion.
122	lbigc=	
123	cigc=	parameter for igc in inversion.
124	lcigc=	
125	nigc=	parameter for igc in inversion.
126	lnigc=	
127	dlcig=	delta I for igs model.
128	aigs=	parameter for igs in inversion.
129	laigs=	
130	bigc=	parameter for igs in inversion.
131	lbigc=	
132	cigs=	parameter for igs in inversion.
133	lcigs=	
134	poxedge=	factor for the gate edge tox.
135	lpoxedge=	

Virtuoso Simulator Components and Device Models Reference

Circuit Components

136	agidl=	pre-exponential coeff. for gidl in mho.
137	lagidl=	
138	bgidl=	exponential coeff. for gidl in v/m.
139	lbgidl=	
140	egidl=	band bending parameter for gidl in v.
141	legidl=	
142	alpha0=	first parameter of iii, m/v.
143	lalpha0=	
144	alpha1=	I scaling parameter of iii, 1/v.
145	lalpha1=	
146	beta0=	vds dependent parameter of iii, 1/v.
147	lbeta0=	
148	lov=	overlap length for fg/s fg/d overlap (m).
149	llov=	
150	cf=	outer fringe cap (f).
151	lcf=	
152	wdios=	effective junction width at source.
153	wdiod=	effective junction width at drain.
154	isdif=	reverse saturation current (source).
155	lisdif=	
156	iddif=	reverse saturation current (drain).

Virtuoso Simulator Components and Device Models Reference

Circuit Components

157	<code>liddif=</code>	
158	<code>ndiode=</code>	diode ideality factor for source diode.
159	<code>lndiode=</code>	
160	<code>ndioded=</code>	diode ideality factor for drain diode .
161	<code>lndioded=</code>	
162	<code>lintigen=</code>	lint for thermal generation current.
163	<code>ntgen=</code>	thermal generation current parameter.
164	<code>lntgen=</code>	
165	<code>aigen=</code>	thermal generation current parameter.
166	<code>laigen=</code>	
167	<code>bigen=</code>	thermal generation current parameter.
168	<code>lbigen=</code>	
169	<code>xrcrg1=</code>	Set XRCRG1=0 to turn off NQS gate resistance.
170	<code>lxrcrg1=</code>	
171	<code>xrcrg2=</code>	
172	<code>lxrcrg2=</code>	
173	<code>ef=</code>	flicker noise frequency exponent.
174	<code>lintnoi=</code>	
175	<code>em=</code>	
176	<code>noia=</code>	
177	<code>noib=</code>	
178	<code>noic=</code>	

Virtuoso Simulator Components and Device Models Reference

Circuit Components

179	<code>ntnoi=</code>	
180	<code>tnom=</code>	temperature at which the model is extracted.
181	<code>tbgasub=</code>	bandgap temperature coefficient .
182	<code>tbgbsub=</code>	bandgap temperature coefficient .
183	<code>kt1=</code>	vth temperature coefficient (v).
184	<code>kt11=</code>	vth temperature I coefficient (m-v).
185	<code>ute=</code>	mobility temperature coefficient.
186	<code>lute=</code>	
187	<code>ua1=</code>	mobility temperature coefficient.
188	<code>lua1=</code>	
189	<code>ud1=</code>	mobility temperature coefficient.
190	<code>lud1=</code>	
191	<code>ucste=</code>	mobility temperature coefficient.
192	<code>lucste=</code>	
193	<code>stthetamu=</code>	mobility temperature coefficient.
194	<code>stmue=</code>	mobility temperature coefficient.
195	<code>stcs=</code>	mobility temperature coefficient.
196	<code>at=</code>	saturation velocity temperature.
197	<code>lat=</code>	
198	<code>stthetasat=</code>	saturation velocity temperature.
199	<code>lstthetasat=</code>	

Virtuoso Simulator Components and Device Models Reference

Circuit Components

200	<code>prt=</code>	resistance temperature dependence.
201	<code>lprt=</code>	
202	<code>iit=</code>	impact ionization temperature dependence.
203	<code>liit=</code>	
204	<code>tgidl=</code>	gidl temperature dependence.
205	<code>ltgidl=</code>	
206	<code>igt=</code>	gate current temperature dependence.
207	<code>ligt=</code>	
208	<code>xdif=</code>	temperature dependence factor for .
209	<code>lxdif=</code>	
210	<code>xdifd=</code>	temperature dependence factor for.
211	<code>lxdifd=</code>	

Output Parameters

1	<code>d</code>	node: description not provided.
2	<code>g</code>	node: description not provided.
3	<code>s</code>	node: description not provided.
4	<code>b</code>	node: description not provided.
5	<code>di</code>	node: description not provided.
6	<code>si</code>	node: description not provided.
7	<code>gi</code>	node: description not provided.
8	<code>ge</code>	node: description not provided.

Virtuoso Simulator Components and Device Models Reference

Circuit Components

Operating-Point Parameters

1	<code>exp_cr=</code>	instance parameter: no description.
2	<code>cmi_limexp_method=</code>	instance parameter: no description.
3	<code>cmi_compactable=</code>	instance parameter: no description.
4	<code>m=</code>	instance parameter: no description.
5	<code>length=</code>	
6	<code>tfin=</code>	units are m.
7	<code>nf=</code>	number of fins in parallel.
8	<code>op_ids ()</code>	Drain current.
9	<code>op_igbinv ()</code>	igb in inversion.
10	<code>op_igcs ()</code>	Gate to channel current, source.
11	<code>op_igcd ()</code>	Gate to channel current, drain.
12	<code>op_igc ()</code>	Gate to channel current.
13	<code>op_igisl ()</code>	Gate induced source leakage current.
14	<code>op_igidl ()</code>	Gate induced drain leakage current.
15	<code>op_igd ()</code>	Gate to drain current.
16	<code>op_igs ()</code>	Gate to source current.
17	<code>op_iii ()</code>	Impact Ionization current.
18	<code>op_ibs1 ()</code>	Junction Current.
19	<code>op_ibd1 ()</code>	Junction Current.
20	<code>op_idsgen ()</code>	Drain current, generation-recombination component.

Virtuoso Simulator Components and Device Models Reference

Circuit 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.

agidl M-136	igmod M-1	lnigbinv M-118	op_igbinv OP-9
aigbinv M-109	igt M-206	lnigc M-126	op_igc OP-12
aigc M-119	iit M-202	lnsd M-33	op_igcd OP-11
aigen M-165	isdif M-154	lntgen M-164	op_igcs OP-10
aigs M-128	klrsce M-50	lov M-148	op_igd OP-15
alp M-84	ksativ M-58	lpa M-69	op_igidl OP-14
alpha0 M-142	kt1 M-183	lpdibl1 M-102	op_igisl OP-13
alpha1 M-144	kt11 M-184	lpdibl2 M-104	op_igs OP-16
at M-196	lagidl M-137	lpe0 M-52	op_iii OP-17
b O-4	laigbinv M-110	lphig M-23	pdibl1 M-101
beta0 M-146	laigc M-120	lphin M-45	pdibl2 M-103
bg0sub M-28	laigen M-166	lpoxedge M-135	phig M-22
bgidl M-138	laigs M-129	lprt M-201	phin M-44
bigbinv M-111	lalp M-85	lprwg M-97	phismod M-3
bigc M-121	lalpha0 M-143	lpvag M-108	poxedge M-134
bigen M-167	lalpha1 M-145	lqmfactor M-55	prt M-200

Virtuoso Simulator Components and Device Models Reference

Circuit Components

big5 M-130	lat M-197	lrdsw M-89	prwg M-96
cdsc M-36	lbeta0 M-147	lrdw M-95	pvag M-107
cdscd M-38	lbgidl M-139	lrsw M-92	qmfactor M-54
cf M-150	lbigbinv M-112	lstthetasat M-199	rdsmod M-5
cigbinv M-113	lbigc M-122	ltgidl M-205	rdswh M-88
cigc M-123	lbigen M-168	lthetasat M-63	rdswhmin M-87
cigs M-132	lbigs M-131	lu0 M-65	rdw M-94
cit M-34	lcdsc M-37	lua M-72	rdwhmin M-93
cmi_compactable I-3	lcdscd M-39	lua1 M-188	rgeltd M-100
cmi_compactable OP-3	lcf M-151	lucs M-78	rsw M-91
cmi_limexp_method I-2	lcigbinv M-114	lucste M-192	rswmin M-90
cmi_limexp_method OP-2	lcigc M-124	lud M-76	s O-3
cs M-82	lcigs M-133	lud1 M-190	si O-6
d O-1	lcit M-35	lup M-68	stcs M-195
deltaw M-17	lcs M-83	lute M-186	stmue M-194
deltawcv M-19	ldrout M-106	lvsat M-57	stthetamu M-193
devtype M-7	ldsub M-49	lwr M-99	stthetasat M-198
di O-5	ldvt0 M-41	lxdif M-209	tbgasub M-181
dlc M-13	ldvt1 M-43	lxdifd M-211	tbgbsub M-182

Virtuoso Simulator Components and Device Models Reference

Circuit Components

dlcig	M-127	legidl	M-141	lxrcrg1	M-170	tfin	I-6
drout	M-105	leigbinv	M-116	lxrcrg2	M-172	tfin	OP-6
dsub	M-48	length	I-5	m	I-4	tgidl	M-204
dvt0	M-40	length	OP-5	m	OP-4	thetamu	M-81
dvt1	M-42	leta0	M-47	mexp	M-60	thetasat	M-62
easub	M-26	leu	M-74	mobmod	M-6	tnom	M-180
ef	M-173	liddif	M-157	mue	M-79	u0	M-64
egidl	M-140	ligt	M-207	nbody	M-20	ua	M-71
eigbinv	M-115	liit	M-203	nc0sub	M-29	ua1	M-187
em	M-175	lint	M-9	ndiode	M-158	ucs	M-77
eot	M-14	lintigen	M-162	ndioded	M-160	ucste	M-191
epsrox	M-24	lintnoi	M-174	nf	I-7	ud	M-75
epsrsub	M-25	lisdif	M-155	nf	OP-7	ud1	M-189
eta0	M-46	lklrsce	M-51	ngate	M-30	up	M-67
etamob	M-66	lksativ	M-59	ni0sub	M-27	ute	M-185
eu	M-73	ll	M-10	nigbinv	M-117	vp	M-86
exp_cr	I-1	llc	M-12	nigc	M-125	vsat	M-56
exp_cr	OP-1	lln	M-11	noia	M-176	wdiod	M-153
fech	M-16	llov	M-149	noib	M-177	wdios	M-152
fechcv	M-18	llpa	M-70	noic	M-178	wr	M-98
g	O-2	llpe0	M-53	nsd	M-32	xdif	M-208

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Circuit Components

ge	O-8	lmexp	M-61	ntgen	M-163	xdifd	M-210
geomod	M-4	lmue	M-80	ntnoi	M-179	x1	M-8
gi	O-7	lnbody	M-21	op_ibd1	OP-19	xrcrg1	M-169
gidlmod	M-2	lndiode	M-159	op_ibs1	OP-18	xrcrg2	M-171
hfin	M-15	lndioded	M-161	op_ids	OP-8		
iddif	M-156	lngate	M-31	op_idsgen	OP-20		

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 ...
```

Virtuoso Simulator Components and Device Models Reference

Circuit Components

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 <code>mprobe</code> functions the same as <code>probe</code> except that it will divide the input current by the <code>mfactor</code> .
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 <code>mprobes</code> function the same as <code>probes</code> except that they will divide the input currents by the <code>mfactor</code> .
7	<code>ports=[...]</code>	Indices of the probe ports through which the controlling currents flow. For multi-input digital gates only.
8	<code>type=cccs</code>	Type of the source. Possible values are <code>cccs</code> , <code>and</code> , <code>nand</code> , <code>or</code> , or <code>nor</code> .
9	<code>delta=0</code>	Smoothing parameter. This may lead to circuit convergency. Its value should be in the range between 0 and 0.5, both ends included. The smaller the <code>delta</code> is, the sharper the corner is.

Linear source parameters

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

Virtuoso Simulator Components and Device Models Reference

Circuit Components

PWL source parameters

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

Temperature effects parameters

- | | | |
|----|-----------------------------------|------------------------------------|
| 19 | <code>tc1=0 1/C</code> | Linear temperature coefficient. |
| 20 | <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.

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

Virtuoso Simulator Components and Device Models Reference

Circuit Components

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


Virtuoso Simulator Components and Device Models Reference

Circuit Components

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 <code>mprobe</code> functions the same as <code>probe</code> except that it will divide the input current by the <code>mfactor</code> . |
| 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 <code>mprobes</code> function the same as <code>probes</code> except that they will divide the input currents by the <code>mfactor</code> . |
| 7 | <code>ports=[...]</code> | Indices of the probe ports through which the controlling currents flow. For multi-input digital gates only. |
| 8 | <code>type=ccvs</code> | Type of the source.
Possible values are <code>ccvs</code> , <code>and</code> , <code>nand</code> , <code>or</code> , or <code>nor</code> . |
| 9 | <code>delta=0</code> | Smoothing parameter. This may lead to circuit convergency. Its value should be in the range between 0 and 0.5, both ends included. The smaller the <code>delta</code> is, the sharper the corner is. |

Linear source parameters

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

Virtuoso Simulator Components and Device Models Reference

Circuit Components

PWL source parameters

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

Temperature effects parameters

- | | | |
|----|-----------------------------------|------------------------------------|
| 19 | <code>tc1=0 1/C</code> | Linear temperature coefficient. |
| 20 | <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.

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

Virtuoso Simulator Components and Device Models Reference

Circuit Components

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-14	min	I-12	probes	I-5	tc1	I-19
delta	I-9	mprobe	I-3	pwl	I-16	tc2	I-20
file	I-15	mprobes	I-6	pwr	OP-3	td	I-11
i	OP-1	port	I-4	rm	I-10	type	I-8
m	I-1	ports	I-7	scale	I-17	v	OP-2
max	I-13	probe	I-2	stretch	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 isource parameter=value ...
```

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

Instance Parameters

1 dc=0 A DC value.

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Circuit Components

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 `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.
- 8 `period= ∞ s` Period of waveform.
- 9 `rise (s)` Rise time for pulse waveform (time for transition from `val0` to `val1`). If parameter `rise` 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 `fall (s)` Fall time for pulse waveform (time for transition from `val1` to `val0`). If parameter `fall` 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 `width= ∞ s` Pulse width (duration of `val1`).

PWL waveform parameters

- 12 `file` Name of file containing waveform.

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Circuit Components

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>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> or <code>yes</code> .
18	<code>pwlperiod (s)</code>	Period of the periodic PWL waveform.
19	<code>pwlperiodstart (s)</code>	Period start time of the periodic PWL waveform.
20	<code>twidth=pwlperiod/1000 s</code>	Transition width used when making PWL waveforms periodic.

Sinusoidal waveform parameters

21	<code>sinedc=dc A</code>	DC level for sinusoidal waveforms.
22	<code>ampl=1 A</code>	Peak amplitude of sinusoidal waveform.
23	<code>freq=0 Hz</code>	Frequency of sinusoidal waveform.
24	<code>sinephase=0 °</code>	Phase of sinusoid when <code>t=delay</code> .
25	<code>ampl2=1 A</code>	Peak amplitude of second sinusoidal waveform.
26	<code>freq2=0 Hz</code>	Frequency of second sinusoidal waveform.
27	<code>sinephase2=0 °</code>	Phase of second sinusoid when <code>t=delay</code> .
28	<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.
29	<code>fmodindex=0</code>	FM index of modulation for sinusoidal waveform.
30	<code>fmodfreq=0 Hz</code>	FM modulation frequency for sinusoidal waveform.

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Circuit Components

- 31 `fmodfiles=[...]` One or two file names: containing FM waveform for one file case, and FM I/Q signals for two files with I file first.
- 32 `ammodindex=0` AM index of modulation for sinusoidal waveform.
- 33 `ammodoffset=1` AM offset of modulation for sinusoidal waveform.
- 34 `ammodfreq=0 Hz` AM modulation frequency for sinusoidal waveform.
- 35 `ammodphase=0 °` AM phase of modulation for sinusoidal waveform.
- 36 `damp=0 1/s` Damping factor for sinusoidal waveform.
- 37 `freqvec=[...] Hz` Vector of support frequency of sinusoid channel source.
- 38 `amp1vec=[...] A` Vector of Peak amplitude_i of sinusoid channel source.
- 39 `phasevec=[...] °` Vector of Phase of sinusoid channel source.
- 40 `maxharms=[...]` Array of number of harmonics of each frequency.

Exponential waveform parameters

- 41 `td1=0 s` Rise start time for exponential wave.
- 42 `tau1 (s)` Rise time constant for exponential wave.
- 43 `td2 (s)` Fall start time for exponential wave.
- 44 `tau2 (s)` Fall time constant for exponential wave.

Pattern parameters

- 45 `data` The bit string. A string that contains a series of the four states, 1 0 m z.
- 46 `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.

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Circuit Components

47 `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.

Noise Parameters

48 `noisefile` Name of file containing excess spot noise data in the form of frequency-noise pairs.

49 `noisevec=[...]` A^2/Hz Excess spot noise as a function of frequency in the form of frequency-noise pairs.

Small signal parameters

50 `mag=0` A Small signal current.

51 `phase=0` ° Small signal phase.

52 `xfmag=1` A/A Transfer function analysis magnitude.

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

54 `pacphase=0` ° Periodic AC analysis phase.

Multiplication factor parameters

55 `m=1` Multiplicity factor.

Temperature effects parameters

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

57 `tc2=0` C⁻² Second order temperature coefficient.

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

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 $t = \text{delay}$.

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Circuit Components

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 can not 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 `(wavelength - 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 `(wavelength - 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 `(period - 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`.

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Circuit Components

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 `i` (A) Current through the source.
- 2 `v` (V) Voltage across the source.
- 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>allbrkpts</code>	I-17	<code>fmodfreq</code>	I-30	<code>period</code>	I-8	<code>tc1</code>	I-56
<code>ammodfreq</code>	I-34	<code>fmodindex</code>	I-29	<code>phase</code>	I-51	<code>tc2</code>	I-57
<code>ammodindex</code>	I-32	<code>freq</code>	I-23	<code>phasevec</code>	I-39	<code>td1</code>	I-41
<code>ammodoffset</code>	I-33	<code>freq2</code>	I-26	<code>pwlperiod</code>	I-18	<code>td2</code>	I-43
<code>ammodphase</code>	I-35	<code>freqvec</code>	I-37	<code>pwlperiodstart</code>	I-19	<code>tnom</code>	I-58

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ampl	I-22	fundname	I-3	pwr	OP-3	twidht	I-20
ampl2	I-25	fundname2	I-28	rise	I-9	type	I-2
amplvec	I-38	i	OP-1	rptstart	I-46	v	OP-2
damp	I-36	m	I-55	rpttimes	I-47	val0	I-6
data	I-45	mag	I-50	scale	I-15	val1	I-7
dc	I-1	maxharms	I-40	sinedc	I-21	wave	I-13
delay	I-4	noisefile	I-48	sinephase	I-24	width	I-11
edgetype	I-5	noisevec	I-49	sinephase2	I-27	xfmag	I-52
fall	I-10	offset	I-14	stretch	I-16		
file	I-12	pacmag	I-53	tau1	I-42		
fmodfiles	I-31	pacphase	I-54	tau2	I-44		

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 a_1, a_2, \dots, a_m , the polynomial function $F(a_0, a_1, \dots, a_m)$ 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.

Virtuoso Simulator Components and Device Models Reference

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> | Indice 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 convergency. 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 *cs* 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 convergency. 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. |

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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.**ss-Domain Linear Current Controlled Current Source (scccs)**

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

```
I1 (2 1) inductor I=15
```

```
sc1 (1 0) scccs probe=I1 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.

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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) 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

```
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.
---	--------------------	-----------------

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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.

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

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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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> , <code>or</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 convergency. 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 <code>[in1 out1 in2 out2 ...]</code> .
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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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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```
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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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

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

where the c_s are coefficients of the polynomial terms.

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 <code>mprobes</code> function the same as <code>probes</code> except that they will divide the input currents by the <code>mfactor</code> .
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 convergency. 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

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

where the c_s are coefficients of the polynomial terms.

Sample Instance Statement

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

Instance Definition

```
Name p n psl nsl ... 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 convergency. 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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Circuit Components

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 $2*(2s+1)/(4s+3)$. 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

```
e1 (1 0 control 0) svccs 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>	<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 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 convergency. 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

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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 | <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 val1=5 period=100n rise=10n fall=10n
width=40n
vpwll (1 0) vsource type=pwl wave=[1n 0 1.1n 2 1.5n 0.5 2n 3 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, 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.

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.

8 period= ∞ s Period of waveform.

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- 9 `rise (s)` Rise time for pulse waveform (time for transition from `val0` to `val1`). If parameter `rise` 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 `fall (s)` Fall time for pulse waveform (time for transition from `val1` to `val0`). If parameter `fall` 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 `width= ∞ s` Pulse width (duration of `val1`).

PWL waveform parameters

- 12 `file` Name of file containing waveform.
- 13 `wave=[...]` Vector of time/value pairs that defines waveform.
- 14 `offset=0 V` DC offset for the PWL waveform.
- 15 `scale=1` Scale factor for the PWL waveform.
- 16 `stretch=1` Scale factor for time given for the PWL waveform.
- 17 `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` or `yes`.
- 18 `pwlperiod (s)` Period of the periodic PWL waveform.
- 19 `pwlperiodstart (s)` Period start time of the periodic PWL waveform.
- 20 `twidth=pwlperiod/1000 s` Transition width used when making PWL waveforms periodic.

Sinusoidal waveform parameters

- 21 `sinedc=dc V` DC level for sinusoidal waveforms.

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22	<code>ampl=1 V</code>	Peak amplitude of sinusoidal waveform.
23	<code>freq=0 Hz</code>	Frequency of sinusoidal waveform.
24	<code>sinephase=0 °</code>	Phase of sinusoid when <code>t=delay</code> .
25	<code>ampl2=1 V</code>	Peak amplitude of second sinusoidal waveform.
26	<code>freq2=0 Hz</code>	Frequency of second sinusoidal waveform.
27	<code>sinephase2=0 °</code>	Phase of second sinusoid when <code>t=delay</code> .
28	<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.
29	<code>fmodindex=0</code>	FM index of modulation for sinusoidal waveform.
30	<code>fmodfreq=0 Hz</code>	FM modulation frequency for sinusoidal waveform.
31	<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.
32	<code>ammodindex=0</code>	AM index of modulation for sinusoidal waveform.
33	<code>ammodoffset=1</code>	AM offset of modulation for sinusoidal waveform.
34	<code>ammodfreq=0 Hz</code>	AM modulation frequency for sinusoidal waveform.
35	<code>ammodphase=0 °</code>	AM phase of modulation for sinusoidal waveform.
36	<code>damp=0 1/s</code>	Damping factor for sinusoidal waveform.
37	<code>freqvec=[...] Hz</code>	Vector of support frequency of sinusoid channel source.
38	<code>amplvec=[...] V</code>	Vector of Peak amplitude <i>i</i> of sinusoid channel source.
39	<code>phasevec=[...] °</code>	Vector of Phase of sinusoid channel source.
40	<code>maxharms=[...]</code>	Array of number of harmonics of each frequency.

Exponential waveform parameters

41	<code>td1=0 s</code>	Rise start time for exponential wave.
----	----------------------	---------------------------------------

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Circuit Components

42 `tau1 (s)` Rise time constant for exponential wave.

43 `td2 (s)` Fall start time for exponential wave.

44 `tau2 (s)` Fall time constant for exponential wave.

Pattern parameters

45 `data` The bit string. A string that contains a series of the four states, 1 0 m z.

46 `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.

47 `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.

Noise Parameters

48 `noisefile` Name of file containing excess spot noise data in the form of frequency-noise pairs.

49 `noisevec=[...] V2/Hz` Excess spot noise as a function of frequency in the form of frequency-noise pairs.

Small signal parameters

50 `mag=0 V` Small signal voltage.

51 `phase=0 °` Small signal phase.

52 `xfmag=1 V/V` Transfer function analysis magnitude.

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

54 `pacphase=0 °` Periodic AC analysis phase.

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Circuit Components

Multiplication factor parameters

55 `m=1` Multiplicity factor.

Temperature effects parameters

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

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

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

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 can not 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

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repeating, the waveform changes linearly in an interval of `twidth` from its value at (`period - 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. |

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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allbrkpts	I-17	fmodfreq	I-30	period	I-8	tc1	I-56
ammodfreq	I-34	fmodindex	I-29	phase	I-51	tc2	I-57
ammodindex	I-32	freq	I-23	phasevec	I-39	td1	I-41
ammodoffset	I-33	freq2	I-26	pwlperiod	I-18	td2	I-43
ammodphase	I-35	freqvec	I-37	pwlperiodstart	I-19	tnom	I-58
ampl	I-22	fundname	I-3	pwr	OP-3	twidth	I-20
ampl2	I-25	fundname2	I-28	rise	I-9	type	I-2
amplvec	I-38	i	OP-2	rptstart	I-46	v	OP-1
damp	I-36	m	I-55	rpttimes	I-47	val0	I-6
data	I-45	mag	I-50	scale	I-15	val1	I-7
dc	I-1	maxharms	I-40	sinedc	I-21	wave	I-13
delay	I-4	noisefile	I-48	sinephase	I-24	width	I-11
edgetype	I-5	noisevec	I-49	sinephase2	I-27	xfmag	I-52
fall	I-10	offset	I-14	stretch	I-16		
file	I-12	pacmag	I-53	taul	I-42		
fmodfiles	I-31	pacphase	I-54	tau2	I-44		

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.

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Circuit Components

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 (`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 $2 \cdot (2s+1)/(4s+3)$. 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
```

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Circuit Components

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.
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.

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Circuit Components

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.
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-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 $z = 2 - 2j$, 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

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Circuit Components

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
```

```
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	<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> .

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6	<code>polyarg=inversez</code>	Polynomial argument. Possible values are <code>z</code> or <code>inversez</code> .
7	<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> .
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

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gainfactor	I-5	polyarg	I-6	td	I-2
i	OP-1	pwr	OP-3	ts	I-1
m	I-12	sxz	I-7	tt	I-3

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.

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

Sample Instance Statement

```
name (node1 node2) bsource behav_param param_list
```

where `behav_param` can be

<code>c=simple_expr</code>	Capacitance between the nodes
<code>g=simple_expr</code>	Conductance between the nodes
<code>i=generic_expr</code>	Current through <code>bsource</code>
<code>l=simple_expr</code>	Inductance between the nodes
<code>phi=simple_expr</code>	Flux in the <code>bsource</code> device
<code>q=simple_expr</code>	Charge in <code>bsource</code> device
<code>r=simple_expr</code>	Resistance between the nodes
<code>v=generic_expr</code>	Voltage across the nodes

A `simple_expr` is defined as a spectre expression containing,

1. netlist parameters

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2. current simulation time, \$time
3. node voltages, v(a,b), where a and b are nodes in the spectre netlist or v(a), which is voltage between node a and ground
4. branch currents, i("inst_id:index"), where inst_id is an instance name given in the netlist and index is the port index. The default value for index is 0.

A generic_expr is defined as a simple_expr or ddt() or idt() of simple_expr. The param_list is param_name=value.

Multiplicity factor

m The value of m will be default to 1.

Temperature Parameters

- | | |
|---------|--|
| 1 tc1 | Linear temperature co-efficient. Valid for all behavioural elements. Default value is 0 1/C. |
| 2 tc2 | Quadratic temperature co-efficient. Valid for all behavioural elements. Default value is 0 C ⁻² |
| 3 tnom | Parameters measurement temperature. Valid for all behavioural elements. Default value is 27.0. |
| 4 trise | Temperature rise for ambient. Valid for all behavioural elements. Default value is 0.0. |

Clipping Parameters

- | | |
|-----------|---|
| 1 max_val | Maximum value of bsource expression. Valid for all behavioural elements, but generally used with i and v elements for clipping the current or voltage between the specified values. |
| 2 min_val | Minimum value of bsource expression. Valid for all behavioural elements, but generally used with i and v elements for clipping the current or voltage between the specified values. |

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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 behavioural expressions;the other parameters must be assigned constant or parametric expressions.

Instance Parameters

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

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

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$$(1-1) \quad i = ddt(q) = ddt(\text{simple_expr})$$

$$(1-2) \quad v = ddt(\text{phi}) = ddt(\text{simple_expr})$$

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

$$(1-3) \quad v = i \times r = i \times (\text{simple_expr})$$

$$(1-4) \quad i = g \times v = (\text{simple_expr}) \times v$$

$$(1-5) \quad i = c \times ddt(v) = (\text{simple_expr}) \times ddt(v)$$

$$(1-6) \quad v = l \times ddt(i) = (\text{simple_expr}) \times ddt(i)$$

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:

$$(1-7) \quad g(v) = \frac{di}{dv}$$

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:

$$(1-8) \quad g = g_s(v)$$

then the true conductance is given by:

$$(1-9) \quad g(v) = \frac{d}{dv}(g_s(v) \times v)$$

$$(1-10) \quad g(v) = g_s(v) + v \left(\frac{d}{dv} g_s v \right)$$

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:

$$(1-11) \quad i = \int g_s(v) dv$$

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.

$$(1-12) \quad \textit{white_noise} = \textit{simple_expr}$$

$$(1-13) \quad \textit{flicker_noise} = \textit{simple_expr} \quad \textit{fexp} = \textit{constant_expr}$$

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

$$(1-14) \quad \textit{noisePSD} = \frac{\textit{simple_expr}}{f^{\textit{fexp}}}$$

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:

$$(1-15) \quad \textit{white_noise} = 4 \times k \times T \times g$$

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

$$(1-16) \quad \textit{flicker_noise} = kf \times \textit{pow}((g \times V(p, n)), af) \quad \textit{fexp} = 2$$

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:

$$(1-17) \quad \textit{white_noise} = 4 \times k \times T \times r$$

$$(1-18) \quad \textit{flicker_noise} = kf \times (r \times \textit{pow}(i(\textit{inst_name}:0), af)) \quad \textit{fexp} = 2$$

Noise for elements g and r

The syntax is:

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```
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,

$$(1-19) \quad white_noise = 4 \times k \times T \times x$$

$$(1-20) \quad flicker_noise = \frac{kf \times (x \times v(p, n))^{af}}{freq^{fexp}}$$

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,

$$(1-21) \quad white_noise = 4 \times k \times T \times x$$

$$(1-22) \quad flicker_noise = \frac{kf \times (x \times I(relement))^{af}}{freq^{fexp}}$$

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.

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
```

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Circuit Components

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.

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.

8 period= ∞ s Period of waveform.

9 rise (s) Rise time for pulse waveform (time for transition from val0 to val1). If parameter rise 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 fall (s) Fall time for pulse waveform (time for transition from val1 to val0). If parameter fall 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

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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 `width=∞ s` Pulse width (duration of `vall`).

PWL waveform parameters

12 `file` Name of file containing waveform.

13 `wave=[...]` Vector of time/value pairs that defines waveform.

14 `offset=0 V` DC offset for the PWL waveform.

15 `scale=1` Scale factor for the PWL waveform.

16 `pwldbm (dBm)` Power of PWL waveform in dBm (alternative to `scale`).

17 `stretch=1` Scale factor for time given for the PWL waveform.

18 `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` or `yes`.

19 `pwlperiod (s)` Period of the periodic PWL waveform.

20 `pwlperiodstart (s)` Period start time of the periodic PWL waveform.

21 `twidth=pwlperiod/1000 s`
Transition width used when making PWL waveforms periodic.

Sinusoidal waveform parameters

22 `sinedc=dc V` DC level for sinusoidal waveforms.

23 `ampl=1 V` Peak amplitude of sinusoidal waveform.

24 `dbm (dBm)` Amplitude of sinusoidal waveform in dBm (alternative to `ampl`).

25 `freq=0 Hz` Frequency of sinusoidal waveform.

26 `sinephase=0 °` Phase of sinusoid when `t=delay`.

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Circuit Components

27	<code>amp12=1 V</code>	Peak amplitude of second sinusoidal waveform.
28	<code>dbm2 (dBm)</code>	Amplitude of second sinusoidal waveform in dBm (alternative to <code>amp12</code>).
29	<code>freq2=0 Hz</code>	Frequency of second sinusoidal waveform.
30	<code>sinephase2=0 °</code>	Phase of second sinusoid when <code>t=delay</code> .
31	<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.
32	<code>fmodindex=0</code>	FM index of modulation for sinusoidal waveform.
33	<code>fmodfreq=0 Hz</code>	FM modulation frequency for sinusoidal waveform.
34	<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.
35	<code>ammodindex=0</code>	AM index of modulation for sinusoidal waveform.
36	<code>ammodoffset=1</code>	AM offset of modulation for sinusoidal waveform.
37	<code>ammodfreq=0 Hz</code>	AM modulation frequency for sinusoidal waveform.
38	<code>ammodphase=0 °</code>	AM phase of modulation for sinusoidal waveform.
39	<code>damp=0 1/s</code>	Damping factor for sinusoidal waveform.
40	<code>freqvec=[...] Hz</code>	Vector of support frequency of sinusoid channel source.
41	<code>amp1vec=[...] V</code>	Vector of Peak amplitude <i>i</i> of sinusoid channel source.
42	<code>dbm1vec=[...] dBm</code>	Vector of Amplitude of sinusoidal waveform in dBm (alternative to <code>amp1vec</code>).
43	<code>phasevec=[...] °</code>	Vector of Phase of sinusoid channel source.
44	<code>maxharms=[...]</code>	Array of number of harmonics of each frequency.

Exponential waveform parameters

45	<code>td1=0 s</code>	Rise start time for exponential wave.
----	----------------------	---------------------------------------

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Circuit Components

46 tau1 (s) Rise time constant for exponential wave.

47 td2 (s) Fall start time for exponential wave.

48 tau2 (s) Fall time constant for exponential wave.

Pattern parameters

49 data The bit string. A string that contains a series of the four states, 1 0 m z.

50 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.

51 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.

Noise Parameters

52 noisefile Name of file containing excess spot noise data in the form of frequency-noise pairs.

53 noisevec=[...] V^2/Hz Excess spot noise as a function of frequency in the form of frequency-noise pairs.

54 noisetemp (C) Noise temperature of port. If not specified, the noise temperature is taken to be 290 K.

Port parameters

55 r=50 Ω Reference resistance.

56 x=0 Ω Reference reactance, ignored for time domain analyses.

57 lchock=0.1 H Choke inductor for network analyser.

58 lchoke=0.1 H Choke inductor for network analyser.

59 cblock=0.0001 F Blocking capacitance for network analyser.

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Circuit Components

60 `num` Port number.

61 `m=1` Multiplicity factor.

Small signal parameters

62 `mag=0 V` Small signal voltage.

63 `phase=0 °` Small signal phase.

64 `xfmag=1 V/V` Transfer function analysis magnitude.

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

66 `pacdbm (dBm)` Periodic AC analysis magnitude in dBm (alternative to `pacmag`).

67 `pacphase=0 °` Periodic AC analysis phase.

Temperature effects parameters

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

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

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

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 can not change `bit` type to other types or other types to `bit`.

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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 `(wavelength - 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 `(wavelength - 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 `(period - 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

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Circuit Components

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.

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.

allbrkpts	I-18	file	I-12	offset	I-14	stretch	I-17
ammodfreq	I-37	fmmodfiles	I-34	pacdbm	I-66	tau1	I-46
ammodindex	I-35	fmmodfreq	I-33	pacmag	I-65	tau2	I-48
ammodoffset	I-36	fmmodindex	I-32	pacphase	I-67	tc1	I-68
ammodphase	I-38	freq	I-25	period	I-8	tc2	I-69
ampl	I-23	freq2	I-29	phase	I-63	td1	I-45
ampl2	I-27	freqvec	I-40	phasevec	I-43	td2	I-47
amplvec	I-41	fundname	I-3	pwldbm	I-16	tnom	I-70
cblock	I-59	fundname2	I-31	pwlperiod	I-19	twidht	I-21

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damp	I-39	lchock	I-57	pwlperiodstart	I-20	type	I-2
data	I-49	lchoke	I-58	r	I-55	val0	I-6
dbm	I-24	m	I-61	rise	I-9	val1	I-7
dbm2	I-28	mag	I-62	rptstart	I-50	wave	I-13
dbmvec	I-42	maxharms	I-44	rpttimes	I-51	width	I-11
dc	I-1	noisefile	I-52	scale	I-15	x	I-56
delay	I-4	noisetemp	I-54	sinedc	I-22	xfmag	I-64
edgetype	I-5	noisevec	I-53	sinephase	I-26		
fall	I-10	num	I-60	sinephase2	I-30		

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.

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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 2π 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 data can cause unnecessary warning messages. Number of frequency domain samples used for FFT is `fmax/fdelta` 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.

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Circuit Components

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.

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> or <code>citi</code> . |
| 4 | <code>scale=1</code> | Frequency scale factor. |
| 5 | <code>interp=spline</code> | Method to interpolate s-parameter data.
Possible values are <code>spline</code> , <code>rational</code> or <code>linear</code> . |
| 6 | <code>matrixform=no</code> | Flag for matrix form input.
Possible values are <code>no</code> or <code>yes</code> . |

Virtuoso Simulator Components and Device Models Reference

Circuit Components

Spline/Linear interpolation parameters

- | | | |
|----|--------------------------------|---|
| 7 | <code>fmax</code> (Hz) | Maximum frequency of interest. Default is 3 times the highest frequency found in s-parameter file. |
| 8 | <code>fdelta</code> (Hz) | Frequency sampling interval. Default value is $f_{max}/1024$, or $1/t_{stop}$, whichever is smaller. |
| 9 | <code>maxn=4096</code> | Maximal order of impulse response. Cannot exceed 16384.klhu |
| 10 | <code>imptrunc=1.0e-4</code> | Impulse response truncation threshold relative to the main maximum. The tail of the impulse response below <code>imptrunc</code> will be removed. Set <code>imptrunc=0</code> to keep the tail. |
| 11 | <code>datatrunc=0.00</code> | Non-diagonal S-param data truncation threshold relative to the maximum non-diagonal element in the same row. The non-diagonal S-param data below <code>datatrunc</code> will be dropped. Set <code>datatrunc=0</code> to keep all S-param data. |
| 12 | <code>usewindow=no</code> | Use smooth data windowing function. Possible values are <code>no</code> or <code>yes</code> . |
| 13 | <code>dcextrap=constant</code> | Long delay DC extrapolation method. Possible values are <code>constant</code> , <code>unwrap</code> or <code>hpunwrap</code> . |
| 14 | <code>hfextrap=constant</code> | Long delay high-frequency extrapolation method. Possible values are <code>constant</code> or <code>linear</code> . |

Rational interpolation parameters

- | | | |
|----|--------------------------|---|
| 15 | <code>relerr=0.01</code> | Maximum relative allowed tolerance for rational interpolation errors. Deviations of the nport model from supplied s-parameter data of relative magnitude less than <code>relerr</code> are generally ignored. |
| 16 | <code>abserr=1e-4</code> | Maximum absolute allowed tolerance for rational interpolation errors. Deviations of the nport model from supplied s-parameter data of absolute magnitude less than <code>abserr</code> are generally ignored. |
| 17 | <code>romdatfile</code> | File used for storing time-domain reduced order model (ROM). |

Virtuoso Simulator Components and Device Models Reference

Circuit Components

18 `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`.

Passivity checking and enforcement parameters

19 `passivity=no` Check and enforce passivity of s parameters. Possible values are `no`, `check` or `enforce`.

20 `pabstol=1e-6` Absolute tolerance of passivity criteria.

21 `causality=no` Correct s parameter data to ensure system is causal. Possible values are `no`, `fmax` or `auto`.

Noise parameters

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

23 `thermalnoise=yes` Thermal noise. Possible values are `no` or `yes`.

24 `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`.

25 `noisecorr=real` Forces noise correlation matrix to be real. Possible values are `real` or `complex`.

Matrixform state-space model parameter

26 `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.

27 `portquantities=[...]`
A vector of integers that defines quantities of the ports. Use 0 for voltage and 1 for current.

28 `matrixfile` Matrix entry data file name.

Virtuoso Simulator Components and Device Models Reference

Circuit Components

29	<code>matrixA=[...]</code>	Nonzero entries in coefficient matrix A. Its format is [... row_i col_j value_ij ...].
30	<code>matrixB=[...]</code>	Nonzero entries in coefficient matrix B. Its format is [... row_i col_j value_ij ...].
31	<code>matrixC=[...]</code>	Nonzero entries in coefficient matrix C. Its format is [... row_i col_j value_ij ...].
32	<code>matrixD=[...]</code>	Nonzero entries in coefficient matrix D. Its format is [... row_i col_j value_ij ...].
33	<code>matrixE=[...]</code>	Nonzero entries in coefficient matrix E. Its format is [... row_i col_j value_ij ...].
34	<code>matrixK=[...]</code>	Nonzero entries in coefficient matrix K. Its format is [... row_i col_j value_ij ...].

Model Parameters

1	<code>file</code>	S-parameter data file name.
2	<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> or <code>citi</code> .
3	<code>scale=1</code>	Frequency scale factor.
4	<code>matrixform=no</code>	Flag for matrix form input. Possible values are <code>no</code> or <code>yes</code> .

Spline/Linear interpolation parameters

5	<code>fmax (Hz)</code>	Maximum frequency of interest. Default is 3 times the highest frequency provided in the s-parameter file.
6	<code>fdelta (Hz)</code>	Frequency sampling interval. Default value is <code>fmax/1024</code> , or <code>1/tstop</code> , whichever is smaller.
7	<code>maxn=4096</code>	Maximal order of impulse response.
8	<code>imptrunc=1.0e-4</code>	Relative truncation threshold for the impulse response.

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Circuit Components

- 9 `datatrunc=0.001` Relative truncation threshold for the non-diagonal S-param data.
- 10 `usewindow=no` Use smooth data windowing function. Possible values are no or yes.
- 11 `hfextrap=constant` Long delay high-frequency extrapolation method. Possible values are constant or linear.

Passivity checking and enforcement parameters

- 12 `passivity=no` Check and enforce passivity of s parameters. Possible values are no, check or enforce.
- 13 `pabstol=1e-6` Absolute tolerance of passivity criteria.
- 14 `causality=no` Correct s parameter data to ensure system is causal. Possible values are no, fmax or auto.

Noise parameters

- 15 `trise=0 C` Default temperature rise from ambient.
- 16 `thermalnoise=yes` Thermal noise. Possible values are no or yes.
- 17 `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.
- 18 `noisecorr=real` Forces noise correlation matrix to be real.. Possible values are real or complex.

Matrixform state-space model parameter

- 19 `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.
- 20 `portquantities=[...]` A vector of integers that defines quantities of the ports. Use 0 for voltage and 1 for current.

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Circuit Components

21	<code>matrixfile</code>	Matrix entry data file name.
22	<code>matrixA=[...]</code>	Nonzero entries in coefficient matrix A. Its format is [... row_i col_j value_ij ...].
23	<code>matrixB=[...]</code>	Nonzero entries in coefficient matrix B. Its format is [... row_i col_j value_ij ...].
24	<code>matrixC=[...]</code>	Nonzero entries in coefficient matrix C. Its format is [... row_i col_j value_ij ...].
25	<code>matrixD=[...]</code>	Nonzero entries in coefficient matrix D. Its format is [... row_i col_j value_ij ...].
26	<code>matrixE=[...]</code>	Nonzero entries in coefficient matrix E. Its format is [... row_i col_j value_ij ...].
27	<code>matrixK=[...]</code>	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 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`

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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:

`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

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Circuit Components

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
```

```
...
```

```
;
```

```
;matrix C, 2x3
```

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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
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

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Circuit Components

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]
```

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

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Circuit Components

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.

<code>a</code>	I-2	<code>c</code>	I-4	<code>i</code>	OP-1	<code>pwr</code>	OP-3
<code>b</code>	I-3	<code>d</code>	I-5	<code>m</code>	I-1	<code>v</code>	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>	Upperbound of the parameter to be checked.
2	<code>min=∞</code>	Lowerbound 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 ratioed 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 | <code>fund (Hz)</code> | Fundamental frequency. |
| 2 | <code>points=20 maxharm</code> | Minimum number of time points. |
| 3 | <code>harms=9</code> | Desired number of harmonics. |
| 4 | <code>active=yes</code> | Whether Fourier analysis should be performed or skipped.
Possible values are <code>no</code> or <code>yes</code> . |
| 5 | <code>order=2</code> | Order of interpolation. |
| 6 | <code>firstharm=1</code> | First harmonic computed for test (numerator) channel. |
| 7 | <code>reffirstharm=1</code> | 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.

<code>active</code> I-3	<code>harms</code> I-8	<code>points</code> I-2	<code>refnormharm</code> I-15
<code>active</code> M-4	<code>harms</code> M-3	<code>points</code> M-2	<code>refterm</code> I-6
<code>firstharm</code> I-12	<code>harmsvec</code> I-7	<code>reffirstharm</code> I-13	<code>scale</code> I-11
<code>firstharm</code> M-6	<code>normharm</code> I-14	<code>reffirstharm</code> M-7	<code>term</code> I-5
<code>fund</code> I-1	<code>order</code> I-4	<code>refharms</code> I-10	<code>where</code> I-16

fund M-1

order M-5

refharmsvect I-9

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 $V(\text{out}) < 0.5$. 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 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:

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

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

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

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

Virtuoso Simulator Components and Device Models Reference

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.

Virtuoso Simulator Components and Device Models Reference

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	
opensource	y	n	y	n	n	o	n	o	n	
ioopensource	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 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

Virtuoso Simulator Components and Device Models Reference

Circuit Components

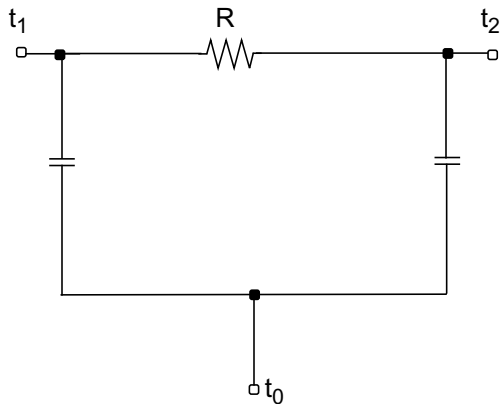
c_com_pc	I-18	gc_scal	I-25	pu_scal	I-22	vrange	M-5
c_com_pd	I-17	gndclamp	M-10	pulldown	M-8	vref	M-6
c_com_pu	I-16	interpol	I-11	pullup	M-7	vtfall1	M-17
ccomp	M-2	loadfall1	M-18	ramp	M-23	vtfall2	M-21
compatible	I-8	loadfall2	M-22	ramp_fwf	I-13	vth	M-24
corner	I-3	loadrise1	M-16	ramp_rwf	I-12	vtrise1	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
downfall	M-14	pc_scal	I-24	spd_scal	I-29	xv_pu	I-20
downrise	M-13	pd_scal	I-23	spu_scal	I-28		
enable	M-3	polarity	I-4	type	M-1		
file	I-1	polarity	M-4	upfall	M-12		

Passive Components

This chapter contains information on

- [Two Terminal Resistor](#) on page 144
- [Physical Resistor \(phy_res\)](#) on page 157
- [R2 Model \(r2\)](#) on page 166
- [Fractional Impedance/Admittance Pole \(fracpole\)](#) on page 179
- [Two Terminal Capacitor \(capacitor\)](#) on page 183
- [Interconnect Capacitance \(intcap\)](#) on page 188
- [Junction Capacitor \(juncap\)](#) on page 193
- [JUNCAP2 Model \(juncap200\)](#) on page 198
- [Junction Capacitor \(juncap_eldo\)](#) on page 203
- [Two Terminal Inductor \(inductor\)](#) on page 209
- [Mutual Inductor \(mutual_inductor\)](#) on page 212
- [Magnetic Core with Hysteresis \(core\)](#) on page 213
- [Winding for Magnetic Core \(winding\)](#) on page 218
- [Linear Inductance, Reluctance, Resistance, and Capacitance Matrix \(rlck_matrix\)](#) on page 218

Two Terminal Resistor (resistor)



Two Terminal Resistor

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

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

Otherwise,

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

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 c_k 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.

FlickerNoise Model

The flicker noise equations for the two terminal resistor are the same as the physical resistor.

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 *di* is given and is nonzero,

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

otherwise

$$C_j = \frac{\epsilon_{ox}}{thick}$$

where

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

$$\epsilon_{ox} = 3.453148e-11 \text{ F/meter}$$

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 222.

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.

If R(inst) is not given and R(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 (coeffs=[c1 c2 ...]) is specified, the resistor is nonlinear. When nonlinform is set to g, the conductance is

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

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.

Virtuoso Simulator Components and Device Models Reference

Passive Components

For AC analysis, RAC(inst) AC resistance will be used.

If RAC(inst) is not given, and RAC(model) is given,

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

otherwise,

RAC(inst) will use DC resistance.

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

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

where

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

if trise(inst) is given, and

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

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(inst) is not given and C(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:

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

Virtuoso Simulator Components and Device Models Reference

Passive Components

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)
```

Instance Definition

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

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

Instance Parameters

1	r (Ω)	Resistance.
2	l (m)	Resistor length.
3	w (m)	Resistor width.
4	m=1	Multiplicity factor.
5	scale=1	Scale factor.
6	resform	Use the resistance form for this instance. Default is yes if $r < \text{thresh}$. Possible values are no or yes.
7	tc1=0 1/C	Linear temperature coefficient(alias=lv3,tc1r).
8	tc1r=0 1/C	Alias for tc1.

Virtuoso Simulator Components and Device Models Reference

Passive Components

9	$tc2=0 \text{ C}^{-2}$	Quadratic temperature coefficient(alias=lv4,tc2r).
10	$tc2r=0 \text{ C}^{-2}$	Alias for tc2.
11	trise (C)	Temperature rise from ambient.
12	isnoisy=yes	Should resistor generate noise. Possible values are no or yes.
13	c (F)	Capacitance.
14	$tc1c=0 \text{ 1/C}$	Linear temperature coefficient of capacitor.
15	$tc2c=0 \text{ C}^{-2}$	Quadratic temperature coefficient of capacitor.
16	rac (Ω)	Default AC resistance, (alias=ac).
17	scaler	Resistance scaling factor.
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	$r=0.0 \text{ }\Omega$	Default resistance.
---	------------------------	---------------------

Virtuoso Simulator Components and Device Models Reference

Passive Components

- 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.
- 9 `etchl=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`.

Virtuoso Simulator Components and Device Models Reference

Passive Components

Noise model parameters

- 18 $k_f=0$ Flicker (1/f) noise coefficient.
- 19 $a_f=2$ Flicker (1/f) noise exponent.
- 20 $w_{dexp}=1$ Flicker (1/f) noise W exponent.
- 21 $l_{dexp}=1$ Flicker (1/f) noise L exponent.
- 22 $w_{eexp}=0$ Flicker (1/f) noise W effective exponent.
- 23 $l_{eexp}=0$ Flicker (1/f) noise L effective exponent.
- 24 $f_{exp}=1$ Flicker (1/f) noise frequency exponent.

DC-mismatch model parameters

- 25 $m_r=0.0$ Resistor mismatch dependence.
- 26 $m_{r1}=0.0$ $1/m^{m_{r1p}}$ Resistor mismatch length dependence.
- 27 $m_{r1p}=0.0$ Resistor mismatch length power dependence.
- 28 $m_{rw}=0.0$ $1/m^{m_{rwp}}$ Resistor mismatch width dependence.
- 29 $m_{rwp}=0.0$ Resistor mismatch width power dependence.
- 30 $m_{r1w1}=0.0$ $1/m^{(2 m_{r1w1p})}$
Resistor mismatch area 1 dependence.
- 31 $m_{r1w1p}=0.0$ Resistor mismatch area 1 power dependence.
- 32 $m_{r1w2}=0.0$ $1/m^{(2 m_{r1w2p})}$
Resistor mismatch area 2 dependence.
- 33 $m_{r1w2p}=0.0$ Resistor mismatch area 2 power dependence.

Wire RC parameters

- 34 $c=0$ F Default capacitance.

Virtuoso Simulator Components and Device Models Reference

Passive Components

35	$c_{j=0}$ F/m ²	Bottomwall capacitance.
36	$c_{jsw=0}$ 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.
44	$dtemp=0$ C	Alias of default temperature rise from ambient.
45	$cap=0$ F	Alias of default capacitance.
46	$dw=0$ m	Alias of width narrowing due to etching per side.
47	$dlnr=0$ m	Alias of length narrowing due to etching per side.
48	$cox=0$ F/m ²	Alias of bottomwall capacitance .
49	$capsw=0$ F/m	Alias of sidewall fringing capacitance.
50	$res=0$ 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`.

Virtuoso Simulator Components and Device Models Reference

Passive Components

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:

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

For `nonlinform=g` the conductance is

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

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

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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 r_{ac} during AC analyses, and r_{dc} 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	l_{eff} (m)	Effective resistor length.
2	w_{eff} (m)	Effective resistor width.
3	r_{eff} (Ω)	Effective resistance.
4	c_{eff} (F)	Effective capacitance.

Operating-Point Parameters

1	v (V)	Voltage at operating point.
2	i (A)	Current through the resistor.
3	r_{res} (Ω)	Resistance at op point.
4	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

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

af	M-19	i	OP-2	r	I-1	tc1c	M-40
c	I-13	isnoisy	I-12	r	M-1	tc1r	I-8
c	M-34	kf	M-18	rac	I-16	tc2	I-9
cap	I-20	l	I-2	rac	M-5	tc2	M-12
cap	M-45	l	M-6	reff	O-3	tc2c	I-15
capsw	M-49	ldexp	M-21	res	M-50	tc2c	M-41
ceff	O-4	leexp	M-23	res	OP-3	tc2r	I-10
cj	M-35	leff	O-1	resform	I-6	thick	M-37
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	tc1	I-7	weff	O-2
etch1	M-9	nonlinform	M-16	tc1	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 $t1$ and $t2$) and two diodes (tied between $t1-t0$ and $t2-t0$). 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 $t0$, 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,

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

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

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

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

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

The large-signal conductance is given by

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

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

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

The resistance as a function of temperature is given by:

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

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 $t1-t0$ and $t2-t0$. 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,

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

Otherwise,

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

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

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

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 ...
```

Instance Parameters

1	r (Ω)	Resistance.
2	c (F)	Linear capacitance.
3	l (m)	Line length.
4	w (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	$\text{tc1}=0$ 1/C	Linear temperature coefficient of resistor.
7	$\text{tc2}=0$ C^{-2}	Quadratic temperature coefficient of resistor.
8	$\text{tc1c}=0$ 1/C	Linear temperature coefficient of linear capacitor.

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- | | | |
|----|------------------------------------|--|
| 9 | <code>tc2c=0 C⁻²</code> | Quadratic temperature coefficient of linear capacitor. |
| 10 | <code>trise (C)</code> | 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 ...
```

Model Parameters

Substrate type parameters

- | | | |
|---|------------------------|---|
| 1 | <code>subtype=p</code> | Substrate type.
Possible values are <code>n</code> , <code>p</code> or <code>poly</code> . |
|---|------------------------|---|

Resistance parameters

- | | | |
|---|---------------------------|---|
| 2 | <code>r=∞ Ω</code> | Default resistance. |
| 3 | <code>rsh=∞ Ω/sqr</code> | Sheet resistance. |
| 4 | <code>minr=0.1 Ω</code> | Minimum resistance. |
| 5 | <code>coeffs=[...]</code> | Vector of polynomial conductance or resistance coefficients. |
| 6 | <code>nonlinform=g</code> | The form of the nonlinear resistance.
Possible values are <code>g</code> or <code>r</code> . |

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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.

15 `js=0 A/m2` Saturation current density.

16 `n=1` Emission coefficient.

17 `eg=1.11 V` Band gap.

18 `xti=3` Saturation current temperature exponent.

19 `imelt='imax' A` Explosion current, diode is linearized beyond this current to aid convergence.

20 `jmelt='jmelt' A/m2` Explosion current density, diode is linearized beyond this current to aid convergence.

21 `imax=1 A` Maximum current, currents above this limit generate a warning.

22 `jmax=1e8 A/m2` Maximum current density, currents above this limit generate a warning.

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23 `dskip=yes` Use simple piece-wise linear model for diode currents below $0.1 \cdot i_{abstol}$.
Possible values are `no` or `yes`.

24 `bvj= ∞ V` Junction reverse breakdown voltage.

Junction capacitance model parameters

25 `c=0 F` Default linear capacitance.

26 `cj=0 F/m2` Zero-bias junction bottom capacitance density.

27 `cjsw=0 F/m` Zero-bias junction sidewall capacitance density.

28 `mj=1/2` Junction bottom grading coefficient.

29 `mjsw=1/3` Junction sidewall grading coefficient.

30 `pb=0.8 V` Junction bottom built-in potential.

31 `pbsw=0.8 V` Junction sidewall built-in potential.

32 `fc=0.5` Junction bottom capacitor forward-bias threshold.

33 `fcsw=0.5` Junction sidewall capacitor forward-bias threshold.

34 `tt=0 s` Transit time.

Device size parameters

35 `l= ∞ 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.

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41 `scaler=1` Resistance scaling factor.

42 `scalec=1` Capacitance scaling factor.

Noise model parameters

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

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

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

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

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

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

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

DC-mismatch model parameters

50 `mr=0.0 Ω^2` Resistor mismatch dependence.

51 `mr1=0.0 Ω^2/m^{mr1p}`
Resistor mismatch length dependence.

52 `mr1p=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 `mr1w1=0.0 $\Omega^2/m^{(2 mr1w1p)}$`
Resistor mismatch area 1 dependence.

56 `mr1w1p=0.0` Resistor mismatch area 1 power dependence.

57 `mr1w2=0.0 $\Omega^2/m^{(2 mr1w2p)}$`
Resistor mismatch area 2 dependence.

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58 `mr1w2p=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.
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.

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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.

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
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

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fc	M-32	mj	M-28	res	OP-8	wdexp	M-45
fcs	M-33	mjs	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
id1	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 x1=0.2u xw=-0.05u
+ p3=0.12 q3=1.63 p2=0.014 q2=3.79
```


Equivalent Circuit

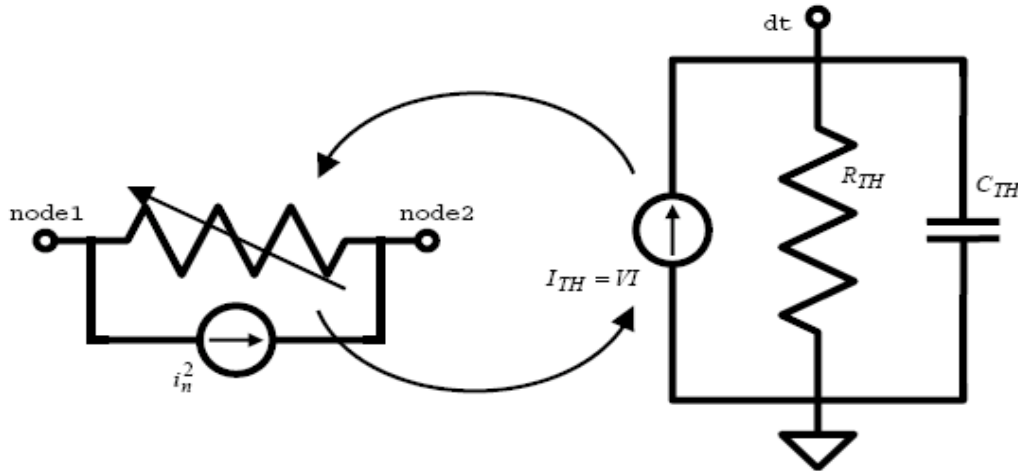


Figure 2-1 Model Equivalent Network (the thermal sub-network is optional)

Bias Dependence

If V is the voltage between the terminals node1 and node2, then the current flowing from node1 to node2 is

$$(2-1) \quad I = \frac{V}{r_{dc}}$$

the DC bias dependent resistance is

$$(2-2) \quad r_{dc} = R_0(T) \cdot rFactor$$

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

$$(2-3) \quad rFactor = 1 - p2 - p3 + p2\sqrt{1 + (q2E)^2} + p3^3\sqrt{1 + |q3E|^3}$$

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

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spreading and/or contact resistance are included in x_l). 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 167, the derivative of [Equation 2-1](#) on page 167 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

$$(2-7) T(dt)_{gTH}$$

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

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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

$$(2-9) \quad xleff = xl(c1 + c2)/2$$

(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

$$(2-10) \quad l_{um} = l \cdot scale \cdot (1 - shrink/100) \cdot 10^6$$

$$(2-11) \quad w_{um} = w \cdot scale \cdot (1 - shrink/100) \cdot 10^6$$

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 of microns. The effective electrical dimensions are

$$(2-12) \quad leff_{um} = l_{um} + xleff$$

$$(2-13) \quad weff_{um} = w_{um} + xw$$

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 t_{nom} . 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.

$$(2-14) \quad R_{0,nom} = r$$

and the effective width is calculated

$$(2-15) \quad weff_{um} = \frac{rsh}{R_{0,nom}} leff_{um}$$

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

$$(2-16) \quad R_{0,nom} = r$$

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$$(2-17) \quad l_{eff_um} = \frac{R_{0,nom}}{rsh} w_{eff_um}$$

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,

$$(2-18) \quad R_{0,nom} = rsh \frac{l_{eff_um}}{w_{eff_um}}$$

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,

$$(2-19) \quad T_{C1}^{eff} = tc1 + \frac{0.5(c1 + c2)tc1l}{l_{eff_um}} + \frac{tc1w}{w_{eff_um}}$$

$$(2-20) \quad T_{C2}^{eff} = tc2 + \frac{0.5(c1 + c2)tc2l}{l_{eff_um}} + \frac{tc2w}{w_{eff_um}}$$

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 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

$$(2-21) \quad g_{TH} = g_{th0} + g_{thp} \cdot p_um2 + g_{tha} \cdot a_um2$$

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$$(2-22) \quad c_{TH} = c_{th0} + c_{thp} \cdot p_{um2} + c_{tha} \cdot a_{um2}$$

where the area and perimeter are calculated as

$$(2-23) \quad a_{um2} = l_{um} \cdot w_{um}$$

$$(2-24) \quad p_{um} = 2l_{um} + (c1 + c2)w_{um}$$

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 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 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

$$(2-25) \quad \begin{aligned} g_{TH} &= g_{th0} + g_{thp}(2l_{um} + 2w_{um} + 4\Delta) + g_{tha}(l_{um} + \Delta)(w_{um} + \Delta) \\ &= (g_{th0} + 4g_{thp} \cdot \Delta + g_{tha} \cdot \Delta^2) + (g_{thp} + 0.5g_{tha} \cdot \Delta)p_{um} + g_{tha} \cdot a_{um2} \end{aligned}$$

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

$$(2-26) \quad R_0(T) = R_{0, nom} (1 + T_{C1}^{eff} dT + T_{C2}^{eff} dT^2)$$

where $R_{0, nom}$ 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

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Passive Components

T_{c1}^{eff} and T_{c2}^{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 170 and [Equation 2-20](#) on page 170. Smooth limiting of the resistance temperature coefficient in ([Equation 2-21](#) on page 170) 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

$$(2-27) K_{FN}(T) = kfn(1 + tc1kfn dT)$$

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 167).

The flicker noise component is DC current dependent ([Equation 2-2](#) on page 167), and scales with geometry per the physical restrictions noted in [Equation 2-3](#) on page 167.

$$(2-29) \quad i_{flicker}^2 = K_{FN}(T) \left(\frac{I}{W} \right)^{afn} \frac{1}{L} \frac{1}{f^{bfm}}$$

where f is frequency (in Hz), afn and bfm are model parameters, $K_{FN}(T)$ is the temperature dependent flicker noise coefficient ([Equation 2-27](#) on page 172), 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

$$(2-30) \quad R(E) = R_0 \left((1 - p_2 - p_3) + p_3 \sqrt[3]{1 + |q_3 E|^3} + p_2 \sqrt{1 + (q_2 E)^2} \right)$$

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

$$(2-31) \quad R(E) = R_0 (1 + p_3 (|q_3 E| - 1))$$

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

$$(2-32) \quad R(E) = R_0 (1 + 0.5 p_2 \cdot q_2^2 E^2)$$

therefore this term approximates a quadratic (second order) field dependence of resistance with a coefficient of value $0.5 p_2 \cdot q_2^2$. For high fields this component becomes

$$(2-33) \quad R(E) = R_0 (1 + p_2 (|q_2 E| - 1))$$

and it turns out that the behavior embodied in [Equation 2-32](#) on page 173 and [Equation 2-33](#) on page 173 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,

$$(2-34) \quad 0 \leq p_3 < 1$$

and

$$(2-35) \quad 0 \leq p_2 < 1 - p_3$$

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.

Virtuoso Simulator Components and Device Models Reference

Passive Components

3	<code>l=1e-6 m</code>	Resistor length.
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.

Virtuoso Simulator Components and Device Models Reference

Passive Components

10	$l_{min}=0.0 \mu\text{m}$	Minimum channel length for which the model is valid.
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	$x_w=0.0 \mu\text{m}$	width offset.
15	$x_l=0.0 \mu\text{m}$	length offset.
16	$dx_{le}=0.0 \mu\text{m}$	length delta.
17	$sw_{efgeo}=no$	Switch for electric field geometry calculation.
18	$q_3=0.0 \mu\text{m}/\text{V}$	threshold for the linear field coefficient activities.
19	$p_3=0$	coefficient for linear field.
20	$q_2=0.0 \mu\text{m}/\text{V}$	threshold for the quadratic field coefficient activities.
21	$p_2=0$	coefficient for quadratic field.
22	$k_{fn}=0$	coefficient for flicker noise.
23	$a_{fn}=2.0$	flicker noise current exponent.
24	$b_{fn}=1.0$	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.

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32	$t_{c2l}=0.0 \mu\text{m}/\text{K}^2$	tc length coefficient for resistance quadratic.
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	$g_{th0}=1.0\text{e}6 \text{ W}/\text{K}$	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	$l_{\text{eff_um}}$ (μm)	effective length in um.
6	$w_{\text{eff_um}}$ (μm)	effective width in um.
7	r_{dc} (Ω)	DC Resistance.
8	r_{ac} (Ω)	AC Resistance.
9	r_{th} (K/W)	thermal Resistance.

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Passive Components

- 10 `cth` (sW/K) thermal capacitance.
- 11 `dt_et` (C) The self-heating temperature rise.

Parameter Index

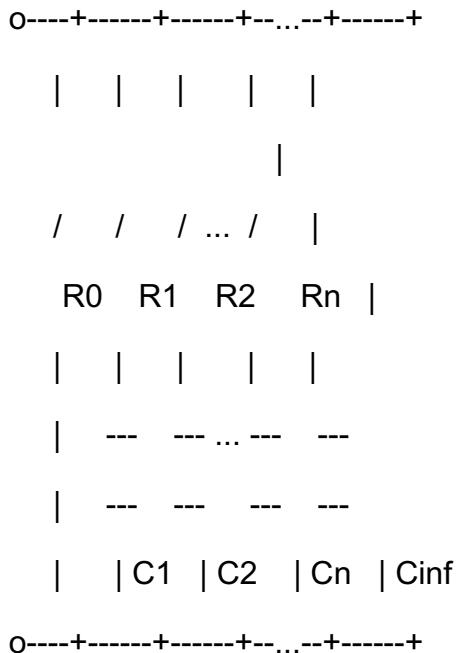
In the following index, **I** refers to instance parameters, **M** refers to the model parameters section, **O** refers to the output parameters section, and **OP** refers to the operating point parameters section. The number indicates where to look in the appropriate section to find the description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

<code>afn</code> M-23	<code>jmax</code> M-26	<code>revision</code> M-2	<code>tmax</code> M-5
<code>bfn</code> M-24	<code>kfn</code> M-22	<code>rsh</code> M-9	<code>tmaxclip</code> M-28
<code>c1</code> I-5	<code>l</code> I-3	<code>rth</code> OP-9	<code>tmin</code> M-4
<code>c1</code> M-42	<code>leff_um</code> OP-5	<code>rthresh</code> M-6	<code>tminclip</code> M-27
<code>c2</code> I-6	<code>level</code> M-7	<code>shrink</code> M-3	<code>tnom</code> M-8
<code>c2</code> M-43	<code>lmax</code> M-11	<code>sw_efgeo</code> M-17	<code>trise</code> I-7
<code>cth</code> OP-10	<code>lmin</code> M-10	<code>sw_et</code> I-9	<code>v</code> OP-1
<code>cth0</code> M-39	<code>m</code> I-1	<code>sw_fngeo</code> M-25	<code>version</code> M-1
<code>ctha</code> M-41	<code>p2</code> M-21	<code>tcl</code> I-10	<code>w</code> I-2
<code>cthp</code> M-40	<code>p3</code> M-19	<code>tcl</code> M-29	<code>weff_um</code> OP-6
<code>dt_et</code> OP-11	<code>power</code> OP-3	<code>tclkfn</code> M-35	<code>wmax</code> M-13
<code>dxle</code> M-16	<code>q2</code> M-20	<code>tcll</code> M-31	<code>wmin</code> M-12
<code>gth0</code> M-36	<code>q3</code> M-18	<code>tclw</code> M-33	<code>xl</code> M-15
<code>gtha</code> M-38	<code>r</code> I-4	<code>tc2</code> I-11	<code>xw</code> M-14

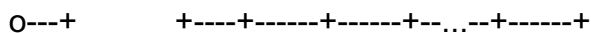
gthp M-37	r0 OP-4	tc2 M-30
i OP-2	r_ac OP-8	tc2l M-32
isnoisy I-8	r_dc OP-7	tc2w M-34

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.

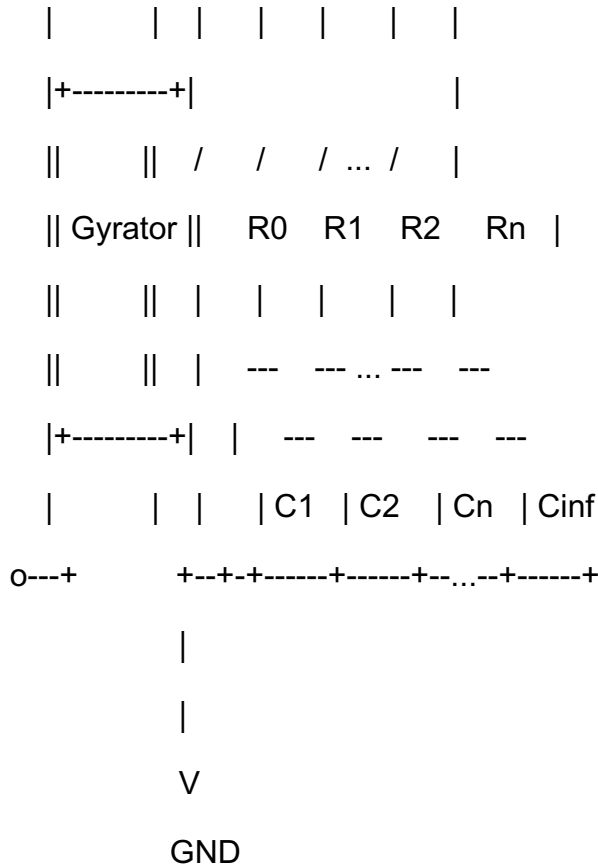


This model is converted to model a Fractional Admittance Pole by combining it with a gyrator.



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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 specifies 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 `R0` or `Cinf` 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 labelled 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 $2*\pi*\text{freq}=1$.
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 $2*\pi*\text{freq}=1$.
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.

<code>coef</code>	<code>I-3</code>	<code>f0</code>	<code>M-1</code>	<code>lumps</code>	<code>I-5</code>	<code>pwr</code>	<code>OP-3</code>
<code>coef</code>	<code>M-3</code>	<code>f1</code>	<code>I-2</code>	<code>lumps</code>	<code>M-5</code>	<code>rforce</code>	<code>I-10</code>
<code>dec</code>	<code>I-6</code>	<code>f1</code>	<code>M-2</code>	<code>m</code>	<code>I-8</code>	<code>slope</code>	<code>I-4</code>
<code>dec</code>	<code>M-6</code>	<code>i</code>	<code>OP-2</code>	<code>profile</code>	<code>I-7</code>	<code>slope</code>	<code>M-4</code>
<code>f0</code>	<code>I-1</code>	<code>ic</code>	<code>I-9</code>	<code>profile</code>	<code>M-7</code>	<code>v</code>	<code>OP-1</code>

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))
```

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	scalec	Capacitance scaling factor.

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The instance parameter `scale`, if specified, overrides the value given by the option parameter `scalem`. 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	<code>c=0 F</code>	Default capacitance.
2	<code>trise=0 C</code>	Default <code>trise</code> value for instance.
3	<code>tnom (C)</code>	Parameters measurement temperature. Default set by <code>options</code> .
4	<code>w=0 m</code>	Default capacitor width.
5	<code>l=0 m</code>	Default capacitor length.
6	<code>etch=0 m</code>	Narrowing due to side etching.
7	<code>cj=0 F/m²</code>	Bottom capacitance density.
8	<code>cjsw=0 F/m</code>	Sidewall capacitance.
9	<code>scalec=1</code>	Capacitance scaling factor.
10	<code>rforce=1 Ω</code>	Resistance used when forcing initial conditions.
11	<code>di=0</code>	Relative dielectric constant.
12	<code>thick=0 m</code>	Dielectric thickness.

Polynomial capacitor parameters

13	<code>coeffs=[...]</code>	Vector of polynomial capacitance coefficients.
14	<code>min (F)</code>	minimum Capacitance.

Virtuoso Simulator Components and Device Models Reference

Passive Components

15 `max` (F) maximum Capacitance.

Temperature effects parameters

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

17 `tc2=0` C⁻² Quadratic temperature coefficient.

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.

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>area</code> I-10	<code>di</code> M-11	<code>perim</code> I-11	<code>thick</code> M-12
<code>c</code> I-1	<code>etch</code> M-6	<code>rforce</code> M-10	<code>tnom</code> M-3
<code>c</code> M-1	<code>ic</code> I-9	<code>scale</code> I-5	<code>trise</code> I-6
<code>cap</code> OP-1	<code>l</code> I-3	<code>scalec</code> I-13	<code>trise</code> M-2
<code>ceff</code> O-3	<code>l</code> M-5	<code>scalec</code> M-9	<code>w</code> I-2
<code>cj</code> M-7	<code>leff</code> O-1	<code>tc1</code> I-7	<code>w</code> M-4

Virtuoso Simulator Components and Device Models Reference

Passive Components

cjsw	M-8	m	I-4	tc1	M-16	weff	O-2
coeffs	I-12	max	M-15	tc2	I-8		
coeffs	M-13	min	M-14	tc2	M-17		

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 Philips MOST Modelbook (Dec.96) as INTCAP model.

(c) Philips 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.

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 EL track of the reference electrode. |

Virtuoso Simulator Components and Device Models Reference

Passive Components

3	$a_{in}=0.0 \text{ m}^2$	The common area of IN track of the reference electrode.
4	$a_{ins}=0.0 \text{ m}^2$	The common area of INS track of the reference electrode.
5	$a_{ps}=0.0 \text{ m}^2$	The common area of PS track of the reference electrode.
6	$l_{bel}=0.0 \text{ m}$	The sum of periphery length of EL -segments common to node n2 downwards.
7	$l_{bin}=0.0 \text{ m}$	The sum of periphery length of IN -segments to node n2 downwards.
8	$l_{bins}=0.0 \text{ m}$	The sum of periphery length of INS -segments common to node n2 downwards.
9	$l_{bps}=0.0 \text{ m}$	The sum of periphery length of PS -segments common to node n2 downwards.
10	$l_{fbel}=0.0 \text{ m}$	The sum of periphery length-factor products EL downwards.
11	$l_{fbin}=0.0 \text{ m}$	The sum of periphery length-factor products IN downwards.
12	$l_{fbins}=0.0 \text{ m}$	The sum of periphery length-factor products INS downwards.
13	$l_{fbps}=0.0 \text{ m}$	The sum of periphery length-factor products PS downwards.
14	$l_{ftel}=0.0 \text{ m}$	The sum of periphery length-factor products EL upwards.
15	$l_{ftin}=0.0 \text{ m}$	The sum of periphery length-factor products IN upwards.
16	$l_{ftins}=0.0 \text{ m}$	The sum of periphery length-factor products INS upwards.
17	$l_{ftps}=0.0 \text{ m}$	The sum of periphery length-factor products PS upwards.
18	$l_{tel}=0.0 \text{ m}$	The sum of periphery length of EL -segments common to node n2 upwards.
19	$l_{tin}=0.0 \text{ m}$	The sum of periphery length of IN -segments common to node n2 upwards.
20	$l_{tins}=0.0 \text{ m}$	The sum of periphery length of INS -segments common to node n2 upwards.

Virtuoso Simulator Components and Device Models Reference

Passive Components

21	<code>ltps=0.0 m</code>	The sum of periphery length of PS-segments common to node n2 upwards.
22	<code>ldsel=0.0 m</code>	The sum of Li/Si quotients for EL tracks.
23	<code>ldsins=0.0 m</code>	The sum of Li/Si quotients for IN tracks.
24	<code>ldsins=0.0 m</code>	The sum of Li/Si quotients for INS tracks.
25	<code>ldsp=0.0 m</code>	The sum of Li/Si quotients for PS tracks.
26	<code>lxbinsps=0.0 m</code>	The sum of Li/Si quotients for an IN track in parallel with an PS track.
27	<code>lxbinsin=0.0 m</code>	The sum of Li/Si quotients for an INS track in parallel with an IN track.
28	<code>lxbinsps=0.0 m</code>	The sum of Li/Si quotients for an INS track in parallel with an PS track.
29	<code>lxbelps=0.0 m</code>	The sum of Li/Si quotients for an EL track in parallel with an PS track.
30	<code>lxbelin=0.0 m</code>	The sum of Li/Si quotients for an EL track in parallel with an IN track.
31	<code>lxbelins=0.0 m</code>	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 ...
```


Virtuoso Simulator Components and Device Models Reference

Passive Components

Model Parameters

1	$cbps=0.0 \text{ F/m}^2$	Bottom capacitance, PS to node n2.
2	$cebpsm=0.0 \text{ F/m}$	Edge to bottom capacitance (PS), 1.0um spacing.
3	$cebpsi=0.0 \text{ F/m}$	Edge to bottom capacitance (PS), single track.
4	$cetpsm=0.0 \text{ F/m}$	Edge to top capacitance (PS), 1.0um spacing.
5	$cetpsi=0.0 \text{ F/m}$	Edge to top capacitance (PS), single track.
6	$cbin=0.0 \text{ F/m}^2$	Bottom capacitance, IN to node n2.
7	$cebinm=0.0 \text{ F/m}$	Edge to bottom capacitance (IN), 1.0um spacing.
8	$cebini=0.0 \text{ F/m}$	Edge to bottom capacitance (IN), single track.
9	$cetinm=0.0 \text{ F/m}$	Edge to top capacitance (IN), 1.0um spacing.
10	$cetini=0.0 \text{ F/m}$	Edge to top capacitance (IN), single track.
11	$cbins=0.0 \text{ F/m}^2$	Bottom capacitance, INS to node n2.
12	$cebinsm=0.0 \text{ F/m}$	Edge to bottom capacitance (INS), 1.0um spacing.
13	$cebinsi=0.0 \text{ F/m}$	Edge to bottom capacitance (INS), single track.
14	$cetinsm=0.0 \text{ F/m}$	Edge to top capacitance (INS), 1.0um spacing.
15	$cetinsi=0.0 \text{ F/m}$	Edge to top capacitance (INS), single track.
16	$cbel=0.0 \text{ F/m}^2$	Bottom capacitance, EL to node n2.
17	$cebelm=0.0 \text{ F/m}$	Edge to bottom capacitance (EL), 1.0um spacing.
18	$cebeli=0.0 \text{ F/m}$	Edge to bottom capacitance (EL), single track.
19	$cetelm=0.0 \text{ F/m}$	Edge to top capacitance (EL), 1.0um spacing.
20	$ceteli=0.0 \text{ F/m}$	Edge to top capacitance (EL), single track.
21	$cecps=0.0 \text{ F/m}$	Lateral capacitance (PS), 1.0um spacing.

Virtuoso Simulator Components and Device Models Reference

Passive Components

- 22 `cecin=0.0 F/m` Lateral capacitance (IN), 1.0um spacing.
- 23 `cecins=0.0 F/m` Lateral capacitance (INS), 1.0um spacing.
- 24 `cecel=0.0 F/m` Lateral capacitance (EL), 1.0um spacing.

Output Parameters

- 1 `cap (F)` Total 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>ael</code> I-2	<code>cebinsm</code> M-12	<code>cetpsm</code> M-4	<code>lftin</code> I-15
<code>ain</code> I-3	<code>cebpsi</code> M-3	<code>lbel</code> I-6	<code>lftins</code> I-16
<code>ains</code> I-4	<code>cebpsm</code> M-2	<code>lbin</code> I-7	<code>lftps</code> I-17
<code>aps</code> I-5	<code>cecel</code> M-24	<code>lbins</code> I-8	<code>ltel</code> I-18
<code>cap</code> O-1	<code>cecin</code> M-22	<code>lbsps</code> I-9	<code>ltin</code> I-19
<code>cbel</code> M-16	<code>cecins</code> M-23	<code>ldsel</code> I-22	<code>ltins</code> I-20
<code>cbin</code> M-6	<code>cecps</code> M-21	<code>ldsins</code> I-23	<code>ltps</code> I-21
<code>cbins</code> M-11	<code>ceteli</code> M-20	<code>ldsins</code> I-24	<code>lxbelin</code> I-30
<code>cbps</code> M-1	<code>cetelm</code> M-19	<code>ldsps</code> I-25	<code>lxbelins</code> I-31
<code>cebeli</code> M-18	<code>cetini</code> M-10	<code>lfbel</code> I-10	<code>lxbelps</code> I-29
<code>cebelm</code> M-17	<code>cetinm</code> M-9	<code>lfbins</code> I-11	<code>lxbinsps</code> I-26

Virtuoso Simulator Components and Device Models Reference

Passive Components

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 m ²	Diffusion area.
2	ls=1e-06 m	Length of the side-wall of the diffusion area AB which is not under the gate.
3	lg=1e-06 m	Length of the side-wall of the diffusion area AB which is under the gate.
4	mult=1	Number of devices in parallel.
5	region=triode	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	m=1	Multiplicity factor.
7	area=1.0e-12 m ²	alias of ab.
8	peri=0.0 m	alias of ls.
9	pgate=0.0 m	alias of lg.
10	pj=0.0 m	alias of peri.

Virtuoso Simulator Components and Device Models Reference

Passive Components

Model Definition

model modelName juncap parameter=value ...

Model Parameters

- | | | |
|----|------------------------------|--|
| 1 | level=1 | Level of this model. |
| 2 | dta=0 K | Temperature offset of the juncap element with respect to TA. |
| 3 | tr=25 C | Temperature at which the parameters have been determined. |
| 4 | vr=0 V | Voltage at which the parameters have been determined. |
| 5 | jsgbr=0.001 Am ⁻² | Bottom saturation-current density due to electron-hole generation at V=VR. |
| 6 | jsdbr=0.001 Am ⁻² | Bottom saturation-current density due to diffusion from back contact. |
| 7 | jsgsr=0.001 Am ⁻¹ | Sidewall saturation-current density due to electron-hole generation at V=VR. |
| 8 | jsdsr=0.001 Am ⁻¹ | Sidewall saturation-current density due to diffusion from back contact. |
| 9 | jsggr=0.001 Am ⁻¹ | Gate edge saturation-current density due to diffusion from back contact. |
| 10 | jsdgr=0.001 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 V | Reverse breakdown voltage. |
| 15 | cjbr=1e-12 Fm ⁻² | Bottom junction capacitance at V=VR. |
| 16 | cjsr=1e-12 Fm ⁻¹ | Sidewall junction capacitance at V=VR. |

Virtuoso Simulator Components and Device Models Reference

Passive Components

17	$c_{jgr}=1e-12 \text{ Fm}^{-1}$	Gate edge junction capacitance at $V=V_R$.
18	$v_{dbr}=1 \text{ V}$	Diffusion voltage of the bottom junction at $T=T_R$.
19	$v_{dsr}=1 \text{ V}$	Diffusion voltage of the sidewall junction at $T=T_R$.
20	$v_{dgr}=1 \text{ V}$	Diffusion voltage of the gate edge junction at $T=T_R$.
21	$p_b=0.4$	Bottom junction grading coefficient.
22	$p_s=0.4$	Sidewall junction grading coefficient.
23	$p_g=0.4$	Gate edge junction grading coefficient.
24	$i_{max}=1e+03 \text{ A}$	Explosion current.
25	$shrink=0$	Linear shrink factor.
26	$shrink2=0$	Areal shrink factor.
27	$type=n$	Transistor gender. Possible values are n, p, npn, pnp, npnv, pnpv, npnl, or pnp1.
28	$t_{nom} \text{ (C)}$	alias of t_{nom} .
29	$t_{ref} \text{ (C)}$	alias of t_{nom} .

Output Parameters

1	$dta \text{ (K)}$	Temperature offset of the juncap element with respect to T_A .
2	$t_r \text{ (C)}$	Temperature at which the parameters have been determined.
3	$v_r \text{ (V)}$	Voltage at which the parameters have been determined.
4	$i_{s gb} \text{ (Am}^{-2}\text{)}$	Bottom saturation-current density due to electron-hole generation at $V=V_R$.
5	$i_{s db} \text{ (Am}^{-2}\text{)}$	Bottom saturation-current density due to diffusion from back contact.
6	$i_{s gs} \text{ (Am}^{-1}\text{)}$	Sidewall saturation-current density due to electron-hole generation at $V=V_R$.

Virtuoso Simulator Components and Device Models Reference

Passive Components

7	i_{sds} ($A\text{m}^{-1}$)	Sidewall saturation-current density due to diffusion from back contact.
8	i_{sgg} ($A\text{m}^{-1}$)	Gate edge saturation-current density due to electron-hole generation at $V=V_R$.
9	i_{sdg} ($A\text{m}^{-1}$)	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} ($F\text{m}^{-2}$)	Bottom junction capacitance at $V=V_R$.
14	c_{js} ($F\text{m}^{-1}$)	Sidewall junction capacitance at $V=V_R$.
15	c_{jg} ($F\text{m}^{-1}$)	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 $T=T_R$.
18	v_{dg} (V)	Diffusion voltage of the gate edge junction at $T=T_R$.
19	p_b	Bottom junction grading coefficient.
20	p_s	Sidewall junction grading coefficient.
21	i_{max} (A)	Explosion current.
22	v_{expl} (A)	Explosion voltage.
23	p_g	Gate edge junction grading coefficient.

Operating-Point Parameters

1	g (S)	Total differential conductance.
2	c (F)	Total capacitance.

Virtuoso Simulator Components and Device Models Reference

Passive Components

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
cjbr	M-15	jsdgr	M-10	ns	M-12	tref	M-29
cjg	O-15	jsdsr	M-8	ns	O-11	type	M-27
cjgr	M-17	jsgbr	M-5	pb	M-21	vb	M-14
cjs	O-14	jsggr	M-9	pb	O-19	vdb	O-16
cjsr	M-16	jsgsr	M-7	peri	I-8	vdbr	M-18
dta	M-2	level	M-1	pg	M-23	vdg	O-18
dta	O-1	lg	I-3	pg	O-23	vdgr	M-20
g	OP-1	ls	I-2	pgate	I-9	vds	O-17
imax	M-24	lx1	OP-3	pj	I-10	vdsr	M-19

Virtuoso Simulator Components and Device Models Reference

Passive Components

imax	O-21	lx3	OP-4	ps	M-22	vexpl	O-22
isdb	O-5	lx5	OP-5	ps	O-20	vr	M-4
isdg	O-9	m	I-6	region	I-5	vr	O-3
isds	O-7	mult	I-4	shrink	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 ...

Instance Parameters

1	ab=1e-12 m ²	Junction area.
2	ls=1e-06 m	STI-edge part of junction perimeter.
3	lg=1e-06 m	Gate-edge part of junction perimeter.
4	mult=1	Number of devices in parallel.
5	region=triode	Estimated DC operating region, used as a convergence aid. Possible values are off, rev, fwd, or brk.
6	m=1	Multiplicity factor.
7	area=1	alias of mult.

Virtuoso Simulator Components and Device Models Reference

Passive Components

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 n, p, npn, pnp, npnv, pnpv, npnl, or pnp1. |
| 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. |
| 8 | <code>cjorgat=1e-09 Fm⁻¹</code> | Zero-bias capacitance per unit-of-length of gate-edge component. |
| 9 | <code>vbirbot=1 V</code> | Built-in voltage at the reference temperature of bottom component. |
| 10 | <code>vbirsti=1 V</code> | Built-in voltage at the reference temperature of STI-edge component. |
| 11 | <code>vbirgat=1 V</code> | Built-in voltage at the reference temperature of gate-edge component. |
| 12 | <code>pbot=0.5</code> | Grading coefficient of bottom component. |
| 13 | <code>psti=0.5</code> | Grading coefficient of STI-edge component. |
| 14 | <code>pgat=0.5</code> | Grading coefficient of gate-edge component. |

Virtuoso Simulator Components and Device Models Reference

Passive Components

- 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.
- 23 `csrhgat=0.0001 Am-2`
Shockley-Read-Hall prefactor of gate-edge component.
- 24 `xjunsti=1e-07 m` Junction depth of STI-edge component.
- 25 `xjungat=1e-07 m` Junction depth of gate-edge component.
- 26 `ctatbot=100 Am-3` Trap-assisted tunneling prefactor of bottom component.
- 27 `ctatsti=0.0001 Am-2`
Trap-assisted tunneling prefactor of STI-edge component.
- 28 `ctatgat=0.0001 Am-2`
Trap-assisted tunneling prefactor of gate-edge component.
- 29 `mefftatbot=0.25` Effective mass (in units of m_0) for trap-assisted tunneling of bottom component.
- 30 `mefftatsti=0.25` Effective mass (in units of m_0) for trap-assisted tunneling of STI-edge component.

Virtuoso Simulator Components and Device Models Reference

Passive Components

- 31 `mefftatgat=0.25` Effective mass (in units of m_0) for trap-assisted tunneling of gate-edge component.
- 32 `cbbtbot=1e-12 AV-3` Band-to-band tunneling prefactor of bottom component.
- 33 `cbbtsti=1e-18 AV-3m` Band-to-band tunneling prefactor of STI-edge component.
- 34 `cbbtgat=1e-18 AV-3m` Band-to-band tunneling prefactor of gate-edge component.
- 35 `fbbtrbot=1e+09 Vm-1` Normalization field at the reference temperature for band-to-band tunneling of bottom component.
- 36 `fbbtrsti=1e+09 Vm-1` Normalization field at the reference temperature for band-to-band tunneling of STI-edge component.
- 37 `fbbtrgat=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.

Virtuoso Simulator Components and Device Models Reference

Passive Components

45	<code>pbrsti=4 V</code>	Breakdown onset tuning parameter of STI-edge component.
46	<code>pbrgat=4 V</code>	Breakdown onset tuning parameter of gate-edge component.
47	<code>swjunexp=0</code>	Flag for JUNCAP-express; 0=full model, 1=express model.
48	<code>vjunref=2.5</code>	Typical maximum junction voltage; usually about 2*VSUP.
49	<code>fjunq=0.03</code>	Fraction below which junction capacitance components are considered negligible.

Operating-Point Parameters

1	<code>vak (V)</code>	Voltage between anode and cathode.
2	<code>cj (F)</code>	Total source junction capacitance.
3	<code>cjbot (F)</code>	Junction capacitance (bottom component).
4	<code>cjgat (F)</code>	Junction capacitance (gate-edge component).
5	<code>cjsti (F)</code>	Junction capacitance (STI-edge component).
6	<code>ij (A)</code>	Total source junction current.
7	<code>ijbot (A)</code>	Junction current (bottom component).
8	<code>ijgat (A)</code>	Junction current (gate-edge component).
9	<code>ijsti (A)</code>	Junction current (STI-edge component).
10	<code>si (A²/Hz)</code>	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.

Virtuoso Simulator Components and Device Models Reference

Passive Components

ab	I-1	ctatsti	M-27	m	I-6	stfbbtgat	M-40
area	I-7	dta	M-4	mefftatbot	M-29	stfbbtsti	M-39
cbbtbot	M-32	fbttrbot	M-35	mefftatgat	M-31	swjunexp	M-47
cbbtgat	M-34	fbttrgat	M-37	mefftatsti	M-30	trj	M-3
cbbtsti	M-33	fbttrsti	M-36	mult	I-4	type	M-2
cj	OP-2	fjunq	M-49	pbot	M-12	vak	OP-1
cjbot	OP-3	idsatrbot	M-18	pbrbot	M-44	vbirbot	M-9
cjgat	OP-4	idsatrgat	M-20	pbrgat	M-46	vbirgat	M-11
cjorbot	M-6	idsatrsti	M-19	pbrsti	M-45	vbirsti	M-10
cjorgat	M-8	ij	OP-6	pgat	M-14	vbrbot	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
csrhgat	M-23	imax	M-5	psti	M-13	xjungat	M-25
csrhisti	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 Philips MOST

Virtuoso Simulator Components and Device Models Reference

Passive Components

Modelbook (Dec.93) as JUNCAP model. 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 modelbook 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 i_{max} 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 i_{max} . For currents above i_{max} , 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

```
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. |

Virtuoso Simulator Components and Device Models Reference

Passive Components

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` .

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.

Virtuoso Simulator Components and Device Models Reference

Passive Components

11 $i_{max}=1.0$ A Explosion current.

Temperature effects parameters

12 $dt_a=0.0$ K Temperature offset of the juncap element with respect to ambient temperature.

13 $tr_{rise}=0.0$ K Alias of dt_a .

14 tr (C) Temperature at which the parameters have been determined. Default set by option t_{nom} .

15 tr_{ref} (C) Alias of tr . Default set by option t_{nom} .

16 t_{nom} (C) Alias of tr . Default set by option t_{nom} .

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.

Virtuoso Simulator Components and Device Models Reference

Passive Components

25 `vdsr=1.0 V` Diffusion voltage of the sidewall junction at reference temperature.

26 `vdgr=1.0 V` Diffusion voltage of the gate edge junction at reference temperature.

Grading coefficient parameters

27 `pb=0.4` Bottom-junction grading coefficient.

28 `ps=0.4` Sidewall-junction grading coefficient.

29 `pg=0.4` Gate edge-junction grading coefficient.

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 `cjb (F)` Capacitance of bottom area `ab`.

2 `cjs (F)` Capacitance of locos-edge `ls`.

3 `cjg (F)` Capacitance of gate-edge `lg`.

4 `isdb (A)` Diffusion saturation-current of bottom area `ab`.

5 `isds (A)` Diffusion saturation-current of locos-edge `ls`.

6 `isdg (A)` Diffusion saturation-current of gate-edge `lg`.

7 `isgb (A)` Generation saturation-current of bottom area `ab`.

8 `isgs (A)` Generation saturation-current of locos-edge `ls`.

9 `isgg (A)` Generation saturation-current of gate-edge `lg`.

Virtuoso Simulator Components and Device Models Reference

Passive Components

10	vdb (V)	Diffusion voltage of bottom area ab.
11	vds (V)	Diffusion voltage of locos-edge ls.
12	vdg (V)	Diffusion voltage of gate-edge lg.

Operating-Point Parameters

1	v (V)	juncap bias voltage ($v = v_a - v_k$).
2	i (A)	Total resistive current from anode to cathode ($i = i_a = -i_k$).
3	gm (S)	Total differential conductance.
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

Virtuoso Simulator Components and Device Models Reference

Passive Components

<code>cjgr</code> M-19	<code>jsdbr</code> M-6	<code>pg</code> M-29	<code>vdg</code> O-12
<code>cjs</code> O-2	<code>jsdgr</code> M-10	<code>ps</code> M-28	<code>vdgr</code> M-26
<code>cjsr</code> M-18	<code>jsdsr</code> M-8	<code>pwr</code> OP-6	<code>vds</code> O-11
<code>compatible</code> M-30	<code>jsgbr</code> M-5	<code>q</code> OP-4	<code>vdsr</code> M-25
<code>dta</code> M-12	<code>jsggr</code> M-9	<code>region</code> I-5	<code>vr</code> M-23
<code>gm</code> OP-3	<code>jsgsr</code> M-7	<code>tnom</code> M-16	
<code>i</code> OP-2	<code>level</code> M-4	<code>tr</code> M-14	
<code>imax</code> M-11	<code>lg</code> I-3	<code>tref</code> 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 `trise(inst)` is given, and

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

otherwise.

Sample Instance Statement

without model:

```
l33 (0 net29) inductor l=10e-9 r=1 m=1
```

with model:

```
l33 (0 net29) ind l=10e-9 r=1 m=1
```

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

```
I33 (0 net29) inductor l=I0*(1 + v(net27, net28)*c1)
```

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= <code>lv2</code>).

Virtuoso Simulator Components and Device Models Reference

Passive Components

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 1/C</code>	Linear temperature coefficient.
9	<code>tc2=0 C⁻²</code>	Quadratic temperature coefficient.
10	<code>scalei</code>	Inductance scaling factor.

Model Definition

```
model modelName inductor parameter=value ...
```

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 <code>nodesets</code> and initial conditions.
8	<code>coeffs=[...]</code>	Vector of polynomial inductance coefficients.
9	<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.

Virtuoso Simulator Components and Device Models Reference

Passive Components

Output Parameters

1 `indef` (H) Effective inductance(alias=lv1).

Operating-Point Parameters

1 `ind` (H) Inductance at operating point.

2 `i` (A) Current at operating point(alias=lx2).

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>	<code>M-11</code>	<code>indef</code>	<code>O-1</code>	<code>r</code>	<code>I-2</code>	<code>tc1</code>	<code>M-3</code>
<code>coeffs</code>	<code>I-7</code>	<code>isnoisy</code>	<code>I-6</code>	<code>r</code>	<code>M-2</code>	<code>tc2</code>	<code>I-9</code>
<code>coeffs</code>	<code>M-8</code>	<code>kf</code>	<code>M-10</code>	<code>rforce</code>	<code>M-7</code>	<code>tc2</code>	<code>M-4</code>
<code>i</code>	<code>OP-2</code>	<code>l</code>	<code>I-1</code>	<code>scalei</code>	<code>I-10</code>	<code>tnom</code>	<code>M-6</code>
<code>ic</code>	<code>I-5</code>	<code>l</code>	<code>M-1</code>	<code>scalei</code>	<code>M-9</code>	<code>trise</code>	<code>I-4</code>
<code>ind</code>	<code>OP-1</code>	<code>m</code>	<code>I-3</code>	<code>tc1</code>	<code>I-8</code>	<code>trise</code>	<code>M-5</code>

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
ml1 mutual_inductor coupling=1 ind1=l1 ind2=l2
```

Instance Definition

Name mutual_inductor parameter=value ...

Instance Parameters

- | | | |
|---|------------|-------------------------|
| 1 | coupling=0 | Coupling coefficient. |
| 2 | k=0 | Alias to coupling. |
| 3 | ind1 | Inductor to be coupled. |
| 4 | ind2 | Inductor to be coupled. |

Operating-Point Parameters

- | | | |
|---|----------|---|
| 1 | mind (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.

Virtuoso Simulator Components and Device Models Reference

Passive Components

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
```

```
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:

$$\phi = \phi_{ir} + (\phi_{is} - \phi_{ir}) F / (F + H_a) \quad \text{for region number 1}$$

$$\phi = \phi_{is} * (F - F_c) / (F - H_b) \quad \text{for region number 2}$$

where ϕ = flux density

F = magnetomotive force

ϕ_{res} = residual flux density

ϕ_{sat} = 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
```

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 ...
```

Virtuoso Simulator Components and Device Models Reference

Passive Components

Model Parameters

1	<code>br=1 gauss</code>	Residual flux density.
2	<code>bm=1 gauss</code>	Saturation flux density.
3	<code>hc=1 oersteds</code>	Coercive magnetizing force (value of H where B equals 0).
4	<code>area=1 cm²</code>	Effective magnetic cross-sectional area of core.
5	<code>len=1 cm</code>	Effective length of magnetic path.
6	<code>id (cm)</code>	Inner diameter of toroidal core.
7	<code>od (cm)</code>	Outer diameter of toroidal core.
8	<code>gap=0.0 cm</code>	Gap length.

Initial Conditions

9	<code>b0 (gauss)</code>	Initial condition for core.
---	-------------------------	-----------------------------

Frequency Loss Parameters

10	<code>freq (Hz)</code>	Core operating frequency.
11	<code>p1_f1 (W/Kg)</code>	Core power loss at frequency f1.
12	<code>f1 (Hz)</code>	Reference frequency for power loss.
13	<code>p2_f2 (W/Kg)</code>	Core power loss at frequency f2.
14	<code>f2 (Hz)</code>	Reference frequency for power loss.
15	<code>bflux (gauss)</code>	Reference flux density.
16	<code>density (g/cm³)</code>	Core density.

Temperature Effects Parameters

17	<code>temp (C)</code>	Core operating temperature.
----	-----------------------	-----------------------------

Virtuoso Simulator Components and Device Models Reference

Passive Components

18	bm_t1 (gauss)	Saturated flux density B_m at T1.
19	br_t1 (gauss)	Residual flux density B_r at T1.
20	hc_t1 (oersteds)	Coercive force H_c at T1.
21	t1 (C)	Reference temperature.

Operating-Point Parameters

1	b (gauss)	Flux density of the core.
2	h (oersteds)	Magnetic field strength.

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</code> (Ω) | 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.

Virtuoso Simulator Components and Device Models Reference

Passive Components

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, Vp and Vn are vectors of positive and negative terminal voltages.

Capacitance equations

$$I_p = I + C_p \cdot \text{ddt}(V_p)$$

$$I_n = -I + C_n \cdot \text{ddt}(V_n)$$

where Ip and In are vectors of terminal currents, Cp, Cn are capacitance matrices for positive and negative terminals.

Sample Instance Statement

```
l33 (p1 n1 p2 n2) rlck_matrix l=[1 1 10n 1 2 -1n 2 2 5n] r=[1 1 100m 2 2 50m]
```

Instance Definition

```
Name 1 2 ... rlck_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 l=[...] H Inductance matrix.

Virtuoso Simulator Components and Device Models Reference

Passive Components

2	<code>r=[...] Ω</code>	Resistance matrix.
3	<code>k=[...] 1/H</code>	Reluctance matrix.
4	<code>c1=[...] F</code>	Capacitance matrix for positive terminals.
5	<code>c2=[...] F</code>	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>	rck matrix data file name.
8	<code>m=1</code>	Multiplicity factor.

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.

<code>c1</code>	I-4	<code>file</code>	I-7	<code>k</code>	I-3	<code>m</code>	I-8
<code>c2</code>	I-5	<code>ignore_coupling</code>	I-6	<code>l</code>	I-1	<code>r</code>	I-2

Parameters Common to All Devices

This chapter discusses the following topics:

- [Multiplication Factor \(m\)](#) on page 222
- [Scaling Factors \(scale and scalem\)](#) on page 222
- [imelt and imax](#) on page 223
- [SPICE Compatibility Flag \(compatible\)](#) on page 224

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)

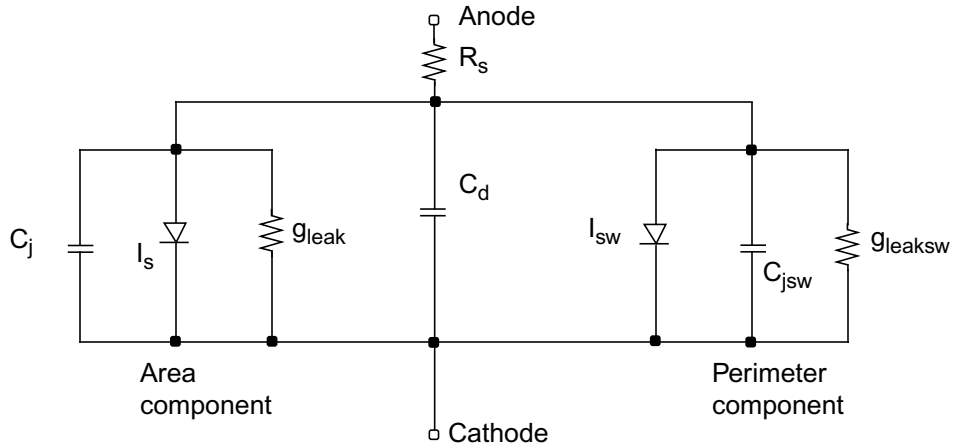
The DIODE level-1 model is based on the junction (Berkeley-spice) model and the level-2 model is based on the Fowler-Nordheim model. This chapter contains the following information about the DIODE model:

- [Level-1 Model](#) on page 228
- [Noise Model](#) on page 235
- [Level-2 Model](#) on page 237
- [Level-3 Model](#) on page 238
- [Component Statements](#) on page 238

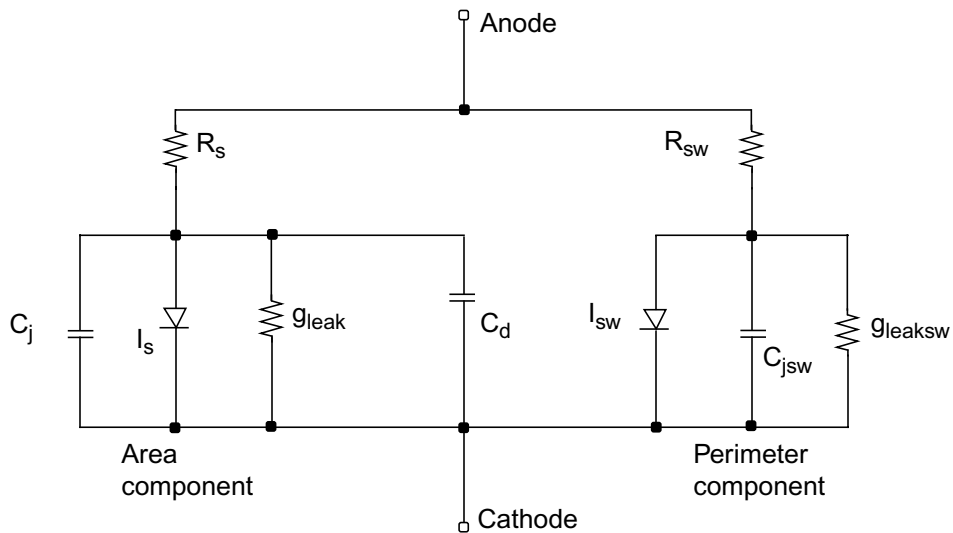
Virtuoso Simulator Components and Device Models Reference

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.

Virtuoso Simulator Components and Device Models Reference

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: `isw`, `ns`, `cjsw`, `mjsw`, `fcs`, `rs`, `gleaksw`, `ctp`, and `ptp`. If the sidewall parasitic resistance (`rs`) 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 `rs` 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 (`gleak` and `gleaksw`) in parallel with the intrinsic diodes.

DC Current

$$I_{jtot} = I_j + I_{jsw}$$

where V_t is the thermal voltage given by

$$V_t = \frac{kT}{q}$$

$$I_j = \begin{cases} is \left(e^{\frac{V}{nV_t}} - 1 \right) & \text{if } V \leq V_{Expl} \\ I_{offset} + G_{Expl}V & \text{otherwise} \end{cases}$$

$$V_{Expl} = nV_t \ln \left[1 + \frac{imelt}{is} \right]$$

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} .

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*).

$$i_{sw} = \begin{cases} i_{sw_{nom}} \left(\frac{T}{T_{nom}} \right)^{\frac{x_{ti}}{n_s}} \exp \left[\frac{eg}{V_{t,nom}} - \frac{eg}{V_t} \right] & \text{if } tlev = 0 \text{ or } 1 \\ i_{sw_{nom}} \left(\frac{T}{T_{nom}} \right)^{\frac{x_{ti}}{n_s}} \exp \left[\frac{E_g(T_{nom})}{V_{t,nom}} - \frac{E_g(T)}{V_t} \right] & \text{if } tlev = 2 \end{cases}$$

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

$$gleak = gleak_{nom} (1 + tgs * \Delta T + tgs2 * \Delta T^2)$$

$$gleaksw = gleaksw_{nom} (1 + tgs * \Delta T + tgs2 * \Delta T^2)$$

Virtuoso Simulator Components and Device Models Reference

Diode Model (diode)

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). For Level 1, the area does not have any units. For Level2 and Level 3, the unit of area is meter ² .
2	perim	Junction perimeter factor. For Level 1, the perim does not have any units. For Level2 and Level 3, the unit of perim is meter.
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 off, on or breakdown.
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.

Virtuoso Simulator Components and Device Models Reference

Diode Model (diode)

13 `isnoisy=yes` Should device generate noise.
Possible values are `no` or `yes`.

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 `level=1` Model selector. 1 = Junction ,2 = Fowler-Nordheim, 3 = Junction + additional metal and polysilicon capacitances.

2 `dcap=2` Depletion capacitance equations selector (hspice compatibility flag only).

3 `compatible=spectre` Spice compatible flag.
Possible values are `spectre`, `spice2`, `spice3`, `cdsspice`, `hspice`, `spiceplus`, `eldo`, `sspice`, or `mica`.

Process parameters

4 `etch=0 m` Narrowing due to etching per side.

5 `etchl=0 m` Length reduction due to etching per side.

6 `l=1e-6 m` Drawn length of junction.

7 `w=1e-6 m` Drawn width of junction.

Virtuoso Simulator Components and Device Models Reference

Diode Model (diode)

Junction diode parameters

8	<code>js=1e-14 A/Area</code>	Saturation current.
9	<code>is=`jsA'</code>	Alias to <code>js</code> .
10	<code>jsw=0 A/Perim</code>	Sidewall saturation current.
11	<code>isw=`jswA'</code>	Alias to <code>jsw</code> .
12	<code>isp=`jswA'</code>	Alias to <code>jsw</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>ikp=`ikA/Area'</code>	High-level injection knee current for sidewall.
17	<code>ikr=ik A/Area</code>	Reverse high-level injection knee current (hspice compatibility flag only).
18	<code>area=1</code>	Junction area factor.
19	<code>perim=0</code>	Junction perimeter factor.
20	<code>allow_scaling=no</code>	Allow scale option and instance scale parameter to affect diode instance geometry parameters. Possible values are <code>no</code> or <code>yes</code> .

Capacitive parameters

21	<code>tt=0 s</code>	Transit time.
22	<code>cd=0 F/Area</code>	Linear capacitance.
23	<code>cjo=0 F/Area</code>	Zero-bias junction capacitance.
24	<code>vj=1 V</code>	Junction potential.(For Hspice, its default value is 0.8).
25	<code>pb=`vjV'</code>	Alias to <code>vj</code> .

Virtuoso Simulator Components and Device Models Reference

Diode Model (diode)

26	$m=0.5$	Grading coefficient.
27	$c_{jsw}=0 \text{ F/Perim}$	Zero-bias sidewall junction capacitance.
28	$c_{jp}=\text{'}c_{jsw}\text{'}$	Alias to c_{jsw} .
29	$v_{jsw}=1 \text{ V}$	Sidewall junction potential.(For Hspice, its default value is v_j).
30	$php=\text{'}v_{jsw}\text{'}$	Alias of v_{jsw} .
31	$m_{jsw}=0.33$	Sidewall grading coefficient.
32	$f_c=0.5$	Forward-bias depletion capacitance threshold.
33	$f_{cs}=\text{'}f_c\text{'}$	Coefficient for forward-bias depletion sidewall capacitance .
34	$l_m=0.0 \text{ m}$	Length of metal capacitor (level=3 only).
35	$l_p=0.0 \text{ m}$	Length of polysilicon capacitor(level=3 only).
36	$w_m=0.0 \text{ m}$	Width of metal capacitor(level=3 only).
37	$w_p=0.0 \text{ m}$	Width of polysilicon capacitor(level=3 only).
38	$x_m=0.0 \text{ m}$	XM accounts for masking and etching effects(level=3 only).
39	$x_p=0.0 \text{ m}$	XP accounts for masking and etching effects(level=3 only).
40	$x_{oi}=0.0 \text{ m}$	Thickness of the polysilicon to bulk oxide. Units - nAngstrom (level=3 only).
41	$x_{om}=0.0 \text{ m}$	Thickness of the metal to bulk oxide. Units - nAngstrom (level=3 only).
42	$x_w=0.0 \text{ m}$	Accounts for masking and etching effects(level=3 only).
43	$v_{jmin}=0.1$	Lowest value for build-in junction potential.

Breakdown parameters

44	$bv=\nabla \text{ V}$	Reverse breakdown voltage. Note: $bv=0$ is not the same as $bv=\text{infinity}$.
----	-----------------------	---

Virtuoso Simulator Components and Device Models Reference

Diode Model (diode)

45	$vb = `bvV'$	Alias to bv .
46	$ibv = 0.001 \text{ A/Area}$	Current at breakdown voltage.
47	$nz = 1$	Emission coefficient for Zener diode.
48	$bvj = \nabla \text{ V}$	Voltage at which junction breakdown warning is issued.
49	$isr = 0 \text{ A/m}^2$	Recombination current parameter.
50	$ibvl = 0 \text{ A/m}^2$	Low-level reverse breakdown current.
51	$nbv = 1$	Reverse breakdown ideality factor.
52	$nbvl = 1$	Reverse breakdown ideality factor.
53	$ikf = 0 \text{ A}$	High-injection knee current.

Parasitic resistance parameters

54	$rs = 0 \text{ } \Omega$	Series resistance (/area).
55	$rsw = 0 \text{ } \Omega$	Sidewall series resistance (/perim).
56	$gleak = 0 \text{ S}$	Bottom junction leakage conductance (*area).
57	$gleaksw = 0 \text{ S}$	Sidewall junction leakage conductance (*perim).
58	$minr = 0.1 \text{ } \Omega$	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	$eg = 1.11 \text{ V}$	Band gap. Note: when not specified, the default value is temperature dependent. It is 1.11 at temp=27C.
63	$gap1 = 7.02e-4 \text{ V/C}$	Band gap temperature coefficient.

Virtuoso Simulator Components and Device Models Reference

Diode Model (diode)

64	gap2=1108 C	Band gap temperature offset.
65	x _{ti} =3	Saturation current temperature exponent.
66	tbv1=0 1/C	Linear temperature coefficient for b _v .
67	tcv=`tbv11/C'	Linear temperature coefficient for b _v .
68	tbv2=0 C ⁻²	Quadratic temperature coefficient for b _v .
69	tikf=0 1/C	IKF temperature coefficient(linear).
70	tnom (C)	Parameters measurement temperature. Default set by options.
71	trise=0 C	Temperature rise from ambient.
72	trs=0 1/C	Linear temperature coefficient for parasitic resistance.
73	trs1=0 1/C	Alias of trs.
74	tmod=tnom C	Model temperature.
75	trs2=0 C ⁻²	Quadratic temperature coefficient for parasitic resistance.
76	tgs=0 1/C	Linear temperature coefficient for leakage conductance.
77	tgs2=0 C ⁻²	Quadratic temperature coefficient for leakage conductance.
78	cta=0 1/C	Junction capacitance temperature coefficient.
79	ctp=0 1/C	Sidewall junction capacitance temperature coefficient.
80	pta=0 V/C	Junction potential temperature coefficient.
81	ptp=0 V/C	Sidewall junction potential temperature coefficient.
82	ttt1=0.0 1/C	1st order temp. coeff. for tt hspice.
83	ttt2=0.0 C ⁻²	2st order temp. coeff. for tt hspice.
84	tm1=0.0 1/C	1st order temp. coeff. for Mj hspice.
85	tm2=0.0 C ⁻²	2st order temp. coeff. for Mj hspice.

Virtuoso Simulator Components and Device Models Reference

Diode Model (diode)

Junction diode model control parameters

- 86 `jmelt=`jmeltA/Area'` Explosion current.
- 87 `imelt=`jmeltA'` Alias to `jmelt`.
- 88 `expli=`jmeltA'` Alias to `jmelt`.
- 89 `jmax=1 A/Area` Maximum allowable current.
- 90 `imax=`jmaxA'` Alias to `jmax`.
- 91 `dskip=yes` Use simple piece-wise linear model for diode currents below $0.1 \cdot i_{abstol}$. Possible values are `no` or `yes`.

Fowler-Nordheim diode parameters

- 92 `if=1e-10 A/V^nf` Forward Fowler-Nordheim current coefficient (*area).
- 93 `ir=`ifA/V^nr'` Reverse Fowler-Nordheim current coefficient (*area).
- 94 `ecrf=2.55e10 V/m` Forward critical field (For hspice compatible, the unit is V/cm, default value is $1.0e-8$).
- 95 `ecrr=`ecrfV/m'` Reverse critical field (For hspice compatible, the unit is V/cm).
- 96 `ef=`ecrfV/m'` Alias of `ecrf`.
- 97 `er=`ecrrV/m'` Alias of `ecrr`.
- 98 `nf=2` Forward voltage power.
- 99 `nr=`nf'` Reverse voltage power.
- 100 `tox=1e-8 m` Thickness of insulating layer.

TSMC Stand Alone model parameters

- 101 `rod=`rs'Ω` Alias for `Rs` (Ohmic series resistance).

Virtuoso Simulator Components and Device Models Reference

Diode Model (diode)

102	$j_{ts}=0 \text{ A/m}^2$	Bottom trap-assisted saturation current density (with Level=1 and StAlone flag=1).
103	$j_{tssw}=0 \text{ A/m}^2$	Sidewall trap-assisted saturation current density (with Level=1 and StAlone flag=1).
104	$mrs=0.4$	Fitting parameter for Rseff (with Level=1 and StAlone flag=1).
105	$n_{jts}=60$	Non-ideality factor for Jts (with Level=1 and StAlone flag=1).
106	$n_{jtssw}=60$	Non-ideality factor for Jtssw (with Level=1 and StAlone flag=1).
107	$x_{ts}=0.055$	Power dependence of Jts on temperature (with Level=1 and StAlone flag=1).
108	$x_{tssw}=0.055$	Power dependence of Jtssw on temperature (with Level=1 and StAlone flag=1).
109	$tn_{jts}=0.15$	Temperature coefficient for Njts (with Level=1 and StAlone flag=1).
110	$tn_{jtssw}=0.15$	Temperature coefficient for Njtssw (with Level=1 and StAlone flag=1).
111	$t_{rod}=0$	Temperature coefficient for Rod(Rs) (with Level=1 and StAlone flag=1).

Noise model parameters

112	$k_f=0$	Flicker noise (1/f) coefficient.
113	$a_f=1$	Flicker noise (1/f) exponent.

Shrink Parmaters

114	$shrink=1.0$	Shrink factor.
115	$shrink2=0.0$	Area shrink parameter.

Trap-assisted tunneling current parameters

116	$j_{tun}=0 \text{ A}$	Tunneling saturation current per area..
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Virtuoso Simulator Components and Device Models Reference

Diode Model (diode)

117	<code>jtunsw=0</code>	A	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..
120	<code>egtun=eg</code>	V	Parameter for tunneling current at reverse region.

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.

Output Parameters

1	<code>bveff</code>	(V)	Effective reverse breakdown voltage .
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Operating-Point Parameters

1	<code>region=on</code>		Estimated operating region. Spectre outputs number (0-2) in a rawfile. Possible values are <code>off</code> , <code>on</code> or <code>breakdown</code> .
2	<code>v</code>	(V)	Extrinsic diode voltage.
3	<code>i</code>	(A)	Resistive diode current (alias= <code>lx1</code>).
4	<code>pwr</code>	(W)	Power dissipation.
5	<code>res</code>	(Ω)	Resistance of intrinsic diode.
6	<code>resp</code>	(Ω)	Resistance of intrinsic sidewall diode.
7	<code>cap</code>	(F)	Junction capacitance.
8	<code>capp</code>	(F)	Sidewall junction capacitance.
9	<code>cd</code>	(F)	Total junction capacitance (alias= <code>lx5</code>).
10	<code>gd</code>	(S)	Equivalent conductance (alias= <code>lx2</code>).
11	<code>qd</code>	(Coul)	Charge of diode capacitor (alias= <code>lx3</code>).
12	<code>vdio</code>	(V)	Voltage, across diode (VD), excluding R_S (alias= <code>lx0</code>).

Virtuoso Simulator Components and Device Models Reference

Diode Model (diode)

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	ibv	M-46	nbv	M-51	tmod	M-74
allow_scaling	M-20	ibvl	M-50	nbvl	M-52	tnjts	M-109
area	I-1	if	M-92	nf	M-98	tnjtssw	M-110
area	M-18	ik	M-15	njts	M-105	tnom	M-70
bv	M-44	ikf	M-53	njtssw	M-106	tox	M-100
bveff	O-1	ikp	M-16	nr	M-99	trise	I-8
bvj	M-48	ikr	M-17	ns	M-14	trise	M-71
cap	OP-7	imax	M-90	ntun	M-118	trod	M-111
capp	OP-8	imelt	M-87	nz	M-47	trs	M-72
cd	M-22	ir	M-93	pb	M-25	trs1	M-73
cd	OP-9	is	M-9	perim	I-2	trs2	M-75
cjo	M-23	isnoisy	I-13	perim	M-19	tt	M-21
cjp	M-28	isp	M-12	php	M-30	ttt1	M-82
cjsw	M-27	isr	M-49	pta	M-80	ttt2	M-83
compatible	M-3	isw	M-11	ptp	M-81	v	OP-2
cta	M-78	jmax	M-89	pwr	OP-4	vb	M-45

Virtuoso Simulator Components and Device Models Reference

Diode Model (diode)

ctp M-79	jmelt M-86	qd OP-11	vdio OP-12
dcap M-2	js M-8	region I-7	vj M-24
dskip M-91	jsw M-10	region OP-1	vjmin M-43
ecrf M-94	jts M-102	res OP-5	vjsw M-29
ecrr M-95	jtssw M-103	resp OP-6	w I-4
ef M-96	jtun M-116	rod M-101	w M-7
eg M-62	jtunsw M-117	rs M-54	wm I-11
eglev M-61	kf M-112	rsw M-55	wm M-36
egtun M-120	l I-3	scale I-6	wp I-12
er M-97	l M-6	shrink M-114	wp M-37
etch M-4	level M-1	shrink2 M-115	xm M-38
etchl M-5	lm I-9	tbv1 M-66	xoi M-40
expli M-88	lm M-34	tbv2 M-68	xom M-41
fc M-32	lp I-10	tcv M-67	xp M-39
fcs M-33	lp M-35	tgs M-76	xti M-65
gap1 M-63	m I-5	tgs2 M-77	xtitun M-119
gap2 M-64	m M-26	tikf M-69	xts M-107
gd OP-10	minr M-58	tlev M-59	xtssw M-108
gleak M-56	mjsw M-31	tlevc M-60	xw M-42
gleaksw M-57	mrs M-104	tm1 M-84	
i OP-3	n M-13	tm2 M-85	

Virtuoso Simulator Components and Device Models Reference

Diode Model (diode)

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 256
- [DC Current](#) on page 256
- [Nonlinear Base Resistance](#) on page 258
- [Nonlinear Collector Resistance \(If *rcv* Is Specified\)](#) on page 258
- [Collector Leakage Current](#) on page 258
- [Substrate Leakage Current](#) on page 259
- [Charge and Capacitance](#) on page 259
- [Excess Phase](#) on page 260
- [Temperature Effect](#) on page 261
- [Noise Model](#) on page 269
- [Scaling Effects](#) on page 270
- [Device Regions](#) on page 256

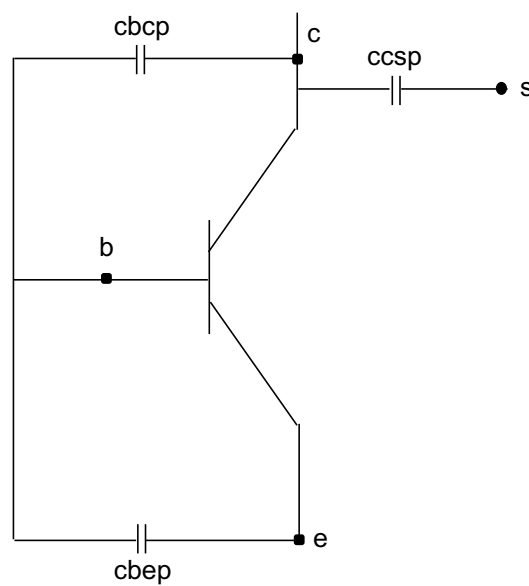
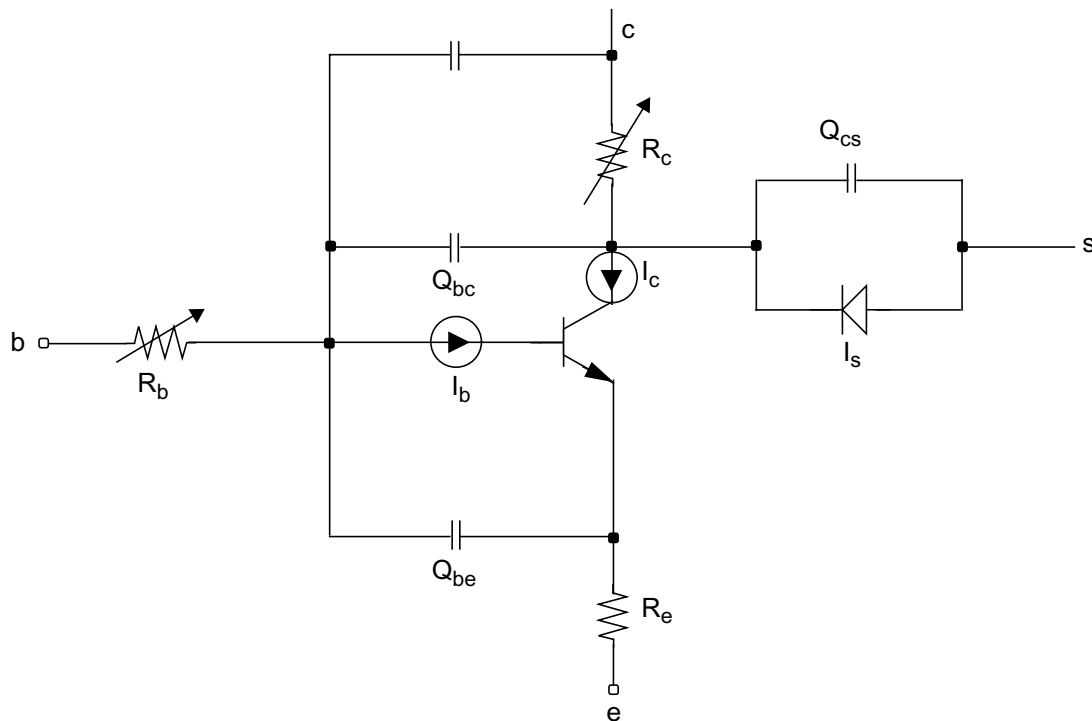
Note: When the Virtuoso® Spectre® circuit simulator option `approx` is set to `yes`, `pow()` in the junction depletion capacitance calculation and `sqrt()` in the BJT and MOSFET level 1-5 models are replaced by a spline-function approximation. For more information, see `spectre -h options`.

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:

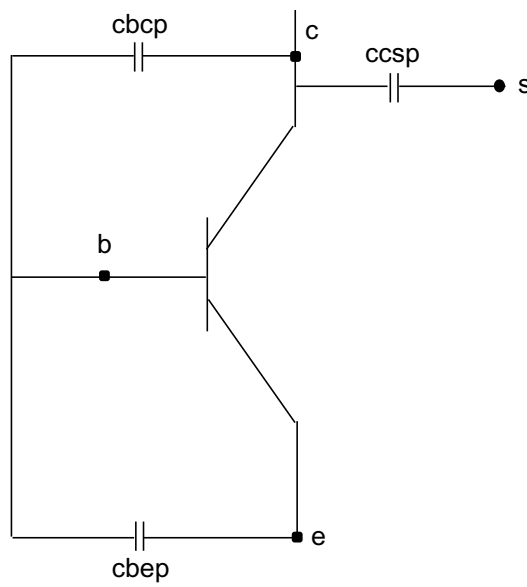
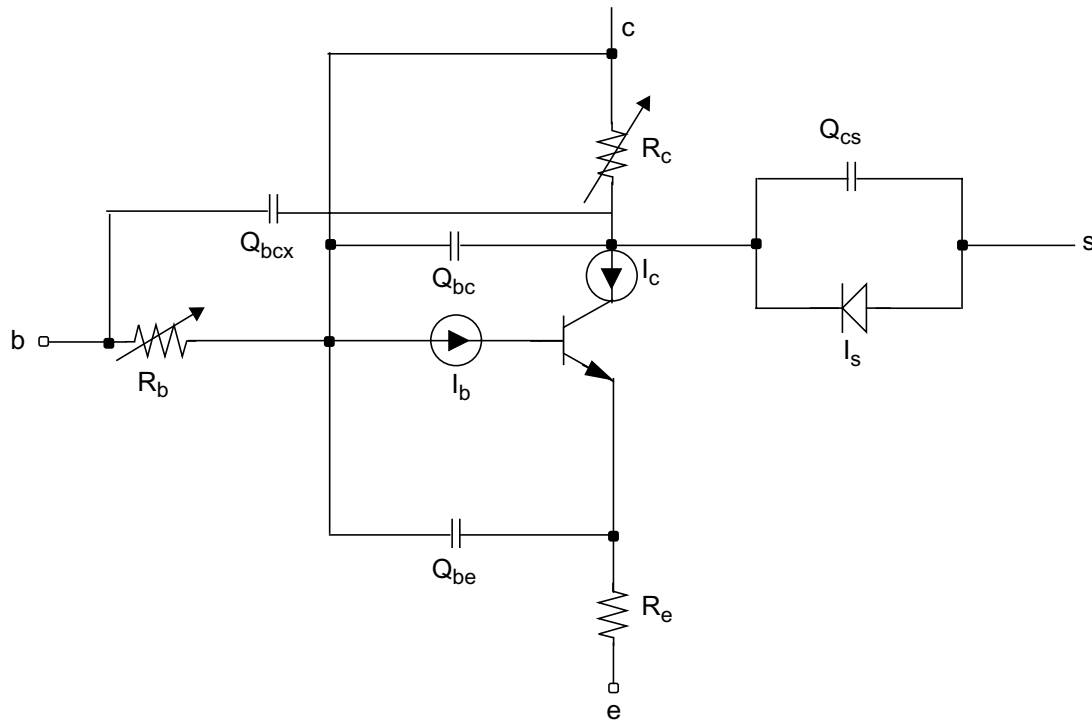
If `Cbcsplit2` or `Cbcsplit` is not specified:



Virtuoso Simulator Components and Device Models Reference

BJT Model (bjt)

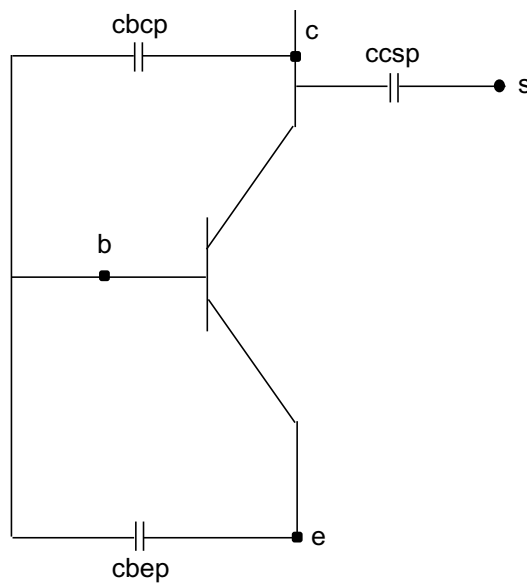
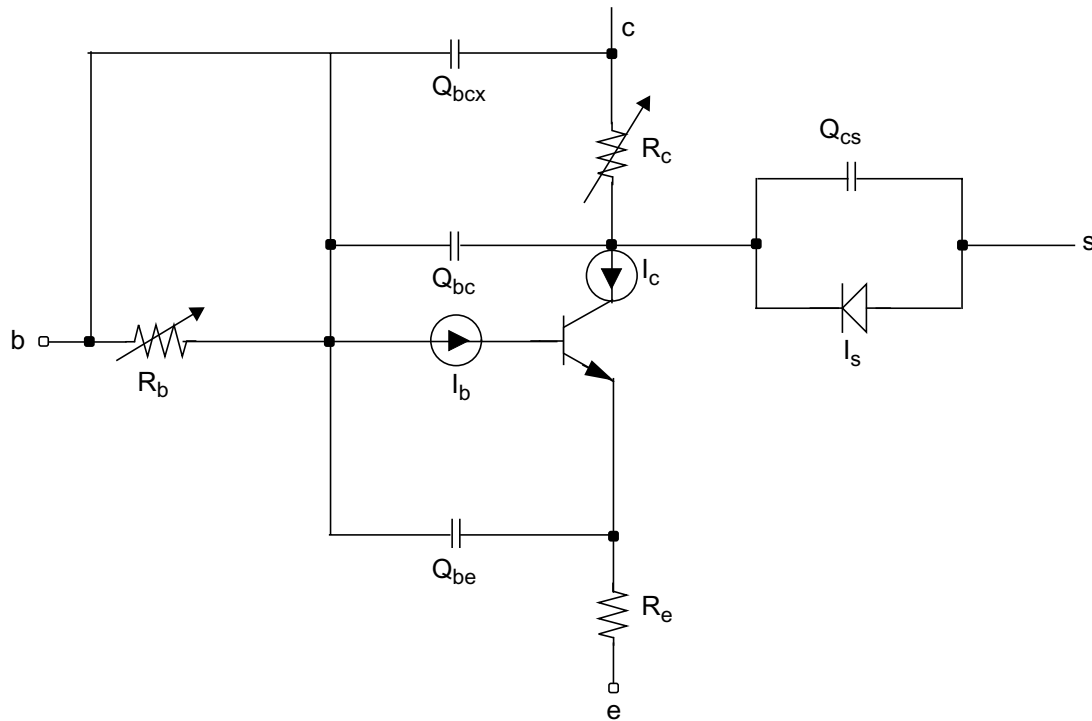
If Cbcsplit=xcjc:



Virtuoso Simulator Components and Device Models Reference

BJT Model (bjt)

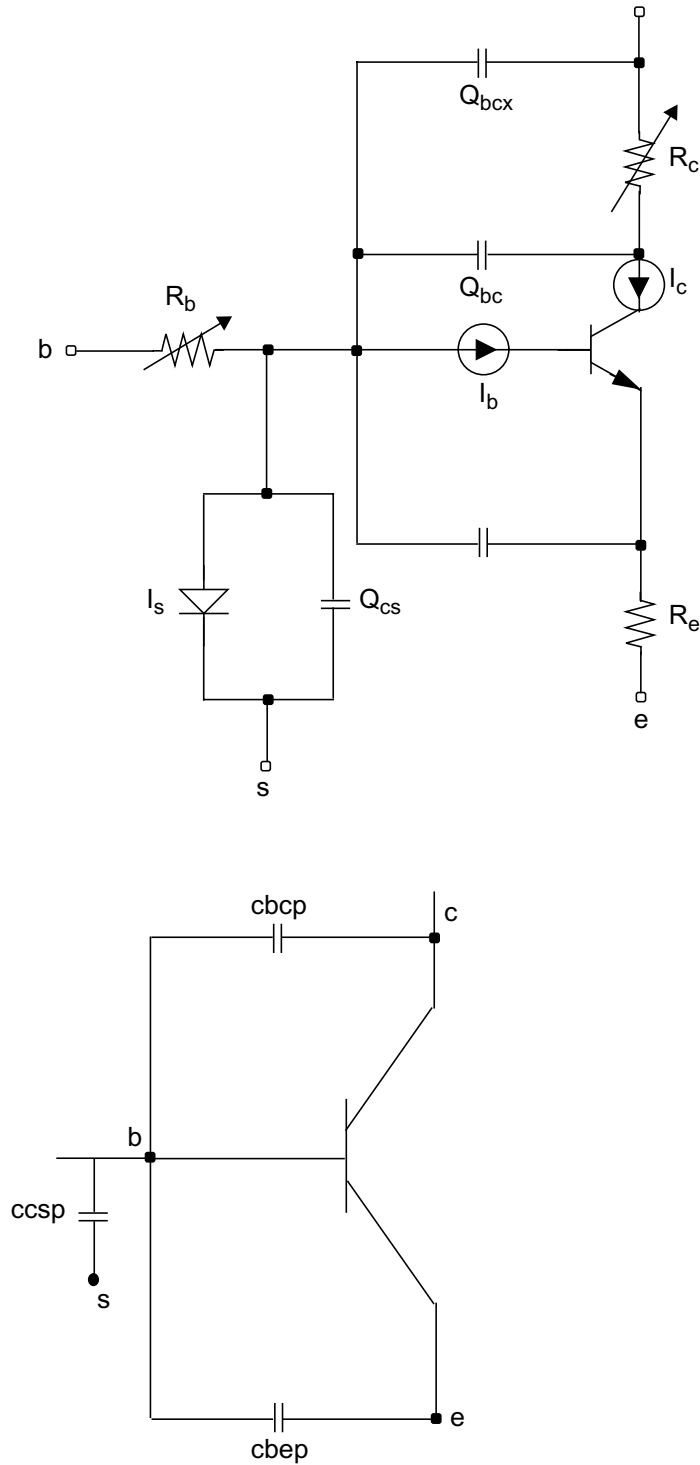
If Cbcsplit2=xcjc2



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

$$I_c = \frac{is}{Q_B} \left(e^{\frac{V_{BE}}{n_f V_t}} - e^{\frac{V_{BC}}{n_r V_t}} \right) - I_{CB}$$

$$I_b = \frac{is}{\beta_f} \left(e^{\frac{V_{BE}}{n_f V_t}} - 1 \right) + is e \left(e^{\frac{V_{BE}}{n_e V_t}} - 1 \right) + I_{CB}$$

where V_t is the thermal voltage given by

$$V_t = \frac{kT}{q}$$

$$I_{CB} = \frac{is}{\beta_r} \left(e^{\frac{V_{BC}}{n_r V_t}} - 1 \right) + isc \left(e^{\frac{V_{BC}}{n_c V_t}} - 1 \right)$$

The intact equation for QB and nkf 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 Q_B equation is:

$$Q_B = \frac{Q_1}{2}(1 + \sqrt{1 + 4Q_2})$$

$$Q_1 = \begin{cases} \frac{1}{-\frac{V_{BC}}{vaf} - \frac{V_{BE}}{var}} & \text{if neither } k_e \text{ or } k_c \text{ is specified} \\ \left(1 + \int_0^{V_{BE}} f_{c_j}(k_e, v_{j_e}, m_{j_e})dv + \int_0^{V_{BC}} f_{c_j}(k_c, v_{j_c}, m_{j_c})dv\right) & \text{otherwise} \end{cases}$$

where f_{c_j} is defined as follows:

$$f_{c_j}(C, P, M) = \begin{cases} \frac{C}{\left(1 - \frac{v}{P}\right)^M} & \text{if } v \leq fc * P \\ \frac{C}{(1 - fc)^{1+M}} \left[1 - fc(1 + M) + \frac{M}{P}v\right] & \text{otherwise} \end{cases}$$

$$Q_2 = \frac{is}{ikf} \left(e^{\frac{V_{BE}}{nfV_t}} - 1 \right) + \frac{is}{ikr} \left(e^{\frac{V_{BC}}{nrV_t}} - 1 \right)$$

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

$$\frac{cbo}{vbo} = \frac{is}{br(nrV_t)} + \frac{isc}{ncV_t} \quad .$$

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

$$Q_{be} = \frac{tf I_{Fwd}}{Q_B} \left\{ 1 + (xtf) e^{\frac{V_{BC}}{\sqrt{2}vtf}} \left[\frac{I_{Fwd}}{I_{Fwd} + itf} \right]^2 \right\} + \int_0^{V_{BE}} f_{cj} (cje, vje, mje) dv$$

where

$$I_{Fwd} = is \left(e^{\frac{V_{BE}}{nfV_t}} - 1 \right)$$

Note: If `compatible()` `spectre`, the equation is as follows

$$Q_{be} = \frac{tf I_{Fwd}}{Q_B} \left\{ 1 + (xtf) e^{\frac{V_{BC}}{1.44vtf}} \left[\frac{I_{Fwd}}{I_{Fwd} + itf} \right]^2 \right\} + \int_0^{V_{BE}} f_{cj} (cje, vje, mje) dv$$

$$Q_{bc} = tr*is \left(e^{\frac{V_{BC}}{nrV_t}} - 1 \right) + xcjc \int_0^{V_{BC}} f_{cj} (cjc, vjc, mjc) dv$$

$$Q_{bcx} = (1 - xcjc) \int_0^{V_{BCX}} f_{cj} (cjc, vjc, mjc) dv$$

$$Q_{cs} = \begin{cases} \int_0^{V_{CS}} f_{cj} (cjs, vjs, mjs) dv & \text{if } mjs \text{ is specified} \\ cjs V_{CS} & \text{otherwise} \end{cases}$$

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 $tlev=0, 1, \text{ or } 3$

$$E_{g,ref} = 1.16 - 7.02 \cdot 10^{-4} \cdot \frac{T_{nom}^2}{T_{nom} + 1108}$$

$$E_g = 1.16 - 7.02 \cdot 10^{-4} \cdot \frac{T_{nom}^2}{T + 1108}$$

$$dV_{je}dT = -\frac{E_{g,ref} + 3V_{T,nom} + (1.16 - E_{g,ref})\left(2 - \frac{T_{nom}}{T_{nom} + 1108}\right) - V_{je}}{T_{nom}}$$

$$dV_{jc}dT = -\frac{E_{g,ref} + 3V_{T,nom} + (1.16 - E_{g,ref})\left(2 - \frac{T_{nom}}{T_{nom} + 1108}\right) - V_{jc}}{T_{nom}}$$

$$dV_{js}dT = -\frac{E_{g,ref} + 3V_{T,nom} + (1.16 - E_{g,ref})\left(2 - \frac{T_{nom}}{T_{nom} + 1108}\right) - V_{js}}{T_{nom}}$$

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 $tlev=0, 1, \text{ or } 2$

$$I_{kfT} = I_{kf} \cdot (1 + t_{ikf1} \Delta T + t_{ikf2} \Delta T^2)$$

$$I_{krT} = I_{kr} \cdot (1 + t_{ikr1} \Delta T + t_{ikr2} \Delta T^2)$$

$$I_{rbT} = I_{rb} \cdot (1 + t_{irb1} \Delta T + t_{irb2} \Delta T^2)$$

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 $tlev=0, 1, \text{ or } 3$

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

$$V_{jeT} = V_{je} - t_{vje} \Delta T$$

$$C_{jcT} = C_{jc} \cdot (1 + C_{tc} \Delta T)$$

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

$$V_{jeT} = V_{je} + dV_{je} dT \Delta T$$

Virtuoso Simulator Components and Device Models Reference

BJT Model (bjt)

$$C_{jcT} = C_{jc} \cdot \left(1 - 0.5 \cdot dV_{jc} dT \frac{\Delta T}{V_{jc}}\right)$$

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

$$\overline{i_{R_B}^2} = \begin{cases} \frac{4kT}{R_B} \frac{rbnoi}{R_B} \Delta f & \text{if } rbnoi \text{ is specified} \\ \frac{4kt}{R_B} \Delta f & \text{otherwise} \end{cases}$$

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 resistor generate noise. Possible values are no or yes.

Model Definition

```
model modelName bjt parameter=value ...
```

Virtuoso Simulator Components and Device Models Reference

BJT Model (bjt)

Model Parameters

Structural parameters

- | | | |
|---|------------------------------|---|
| 1 | <code>type=npn</code> | Transistor type.
Possible values are <code>npn</code> or <code>pnp</code> . |
| 2 | <code>struct=vertical</code> | Transistor structure. For <code>pnp</code> default= <code>lateral</code> .
Possible values are <code>vertical</code> or <code>lateral</code> . |

Saturation current parameters

- | | | |
|---|-------------------------|--|
| 3 | <code>is=1e-16 A</code> | Saturation current (*area). |
| 4 | <code>ise=0 A</code> | B-E leakage saturation current. Set to $c2 * is$ if not given.
(*area). |
| 5 | <code>isc=0 A</code> | B-C leakage saturation current. Set to $c4 * is$ if not given.
(*area). |
| 6 | <code>iss=0 A</code> | Substrate leakage saturation current (*area). |
| 7 | <code>c2=0</code> | Forward leakage saturation current coefficient. |
| 8 | <code>c4=0</code> | Reverse leakage saturation current coefficient. |

B-C leakage model parameters

- | | | |
|----|-------------------------|---|
| 9 | <code>cbo=0 A</code> | Extrapolated 0-volt B-C leakage current (*area). |
| 10 | <code>gbo=0 S</code> | Slope of I_{cbo} vs. V_{bc} above V_{bo} (*area). |
| 11 | <code>vbo=0 V</code> | Slope of I_{cbo} vs. V_{bc} at $V_{bc}=0$. |
| 12 | <code>tcbo=0 1/C</code> | Temperature coefficient for <code>cbo</code> . |
| 13 | <code>tgbo=0 1/C</code> | Temperature coefficient for <code>gbo</code> . |

Emission coefficient parameters

- | | | |
|----|-------------------|-------------------------------|
| 14 | <code>nf=1</code> | Forward emission coefficient. |
|----|-------------------|-------------------------------|

Virtuoso Simulator Components and Device Models Reference

BJT Model (bjt)

15	$nr=1$	Reverse emission coefficient.
16	$ne=1.5$	B-E leakage emission coefficient.
17	$nc=2$	B-C leakage emission coefficient.
18	$ns=1$	Substrate junction emission coefficient.

Current gain parameters

19	$bf=100$ A/A	Forward current gain (beta).
20	bfm (A/A)	Forward current gain (beta).
21	$br=1$ A/A	Reverse current gain (beta).
22	brm (A/A)	Reverse current gain (beta).
23	$ikf=\infty$ A	High current corner for forward beta (*area).
24	$ik=\infty$ A	High current corner for forward beta (*area).
25	$jbf=\infty$ A	High current corner for forward beta (*area).
26	$ikr=\infty$ A	High current corner for reverse beta (*area).
27	jbr (A)	High current corner for reverse beta (*area).

Early voltage parameters

28	$vaf=\infty$ V	Forward Early voltage.
29	$va=\infty$ V	Forward Early voltage.
30	$var=\infty$ V	Reverse Early voltage.
31	$vb=\infty$ V	Reverse Early voltage.
32	$ke=0$ 1/V	B-E space-charge integral multiplier.
33	$kc=0$ 1/V	B-C space-charge integral multiplier.

Virtuoso Simulator Components and Device Models Reference

BJT Model (bjt)

Parasitic resistance parameters

34	$r_b=0 \ \Omega$	Zero-bias base resistance (/area).
35	$r_{bm}=r_b \ \Omega$	Minimum base resistance for high currents (/area).
36	$i_{rb}=\infty \ \text{A}$	Current at base resistance midpoint (*area).
37	$j_{rb} \ (\text{A})$	Current at base resistance midpoint (*area).
38	$i_{ob} \ (\text{A})$	Current at base resistance midpoint (*area).
39	$r_{bmod}=spice$	Nonlinear R_b model. Possible values are <code>spectre</code> or <code>spice</code> .
40	$r_c=0 \ \Omega$	Collector resistance (/area).
41	$r_{cv}=0 \ \Omega$	Variable collector resistance (/area).
42	$r_{cm}=0 \ \Omega$	Minimum collector resistance (/area).
43	$dope=1e15 \ \text{cm}^{-3}$	Collector background doping concentration.
44	$cex=1$	Current crowding exponent.
45	$cco=1 \ \text{A}$	Current crowding normalization constant (*area).
46	$r_e=0 \ \Omega$	Emitter resistance (/area).
47	$minr=0.1 \ \Omega$	Minimum parasitic resistance.

Junction capacitance parameters

48	$dcap=2$	Depletion capacitance model selector.
49	$c_{je}=0 \ \text{F}$	B-E zero-bias junction capacitance (*area).
50	$v_{je}=0.75 \ \text{V}$	B-E built-in junction potential.
51	$m_{je}=1/3$	B-E junction exponent.
52	$p_e=0.75 \ \text{V}$	B-E built-in junction potential.

Virtuoso Simulator Components and Device Models Reference

BJT Model (bjt)

53	$m_e=1/3$	B-E junction exponent.
54	$c_{jc}=0$ F	B-C zero-bias junction capacitance (*area).
55	$v_{jc}=0.75$ V	B-C built-in junction potential.
56	$m_{jc}=1/3$	B-C junction exponent.
57	$p_c=0.75$ V	B-C built-in junction potential.
58	$m_c=1/3$	B-C junction exponent.
59	$x_{cjc}=1$	Fraction of B-C capacitance tied to internal base node.
60	$x_{cjc2}=1$	Fraction of B-C capacitance tied to collector and fraction of B-C tied to internal node.
61	$c_{js}=0$ F	B-S zero-bias junction capacitance (*area).
62	$c_{cs}=0$ F	B-S zero-bias junction capacitance (*area).
63	c_{sub} (F)	B-S zero-bias junction capacitance (*area).
64	$v_{js}=0.75$ V	B-S built-in junction potential.
65	$m_{js}=0$	B-S junction exponent.
66	$p_s=0.75$ V	B-S built-in junction potential.
67	p_{sub} (V)	B-S built-in junction potential.
68	$m_s=0$	B-S junction exponent.
69	e_{sub}	B-S junction exponent.
70	$f_c=0.5$	Junction capacitor forward-bias threshold.
71	$c_{bcsp}=0$ F	B-C parasitic capacitance.
72	$c_{bep}=0$ F	B-E parasitic capacitance.
73	$c_{csp}=0$ F	C-S parasitic capacitance.

Virtuoso Simulator Components and Device Models Reference

BJT Model (bjt)

Transit time and excess phase parameters

74	$t_{f=0}$ s	Ideal forward transit time.
75	$t_{d=0}$ s	Intrinsic base delay time.
76	$x_{tf=0}$	Coefficient for bias dependence of t_f .
77	$v_{tf=\infty}$ V	Voltage describing V_{bc} dependence of t_f .
78	$i_{tf=0}$ A	High current parameter for effect on t_f (*area).
79	j_{tf} (A)	High current parameter for effect on t_f (*area).
80	$t_r=0$ s	Ideal reverse transit time.
81	$p_{tf=0}$ °	Excess phase at freq = $1.0/(t_f * 2 \pi)$ Hz.

Temperature effects parameters

82	t_{nom} (C)	Parameters measurement temperature. Default set by <code>options</code> .
83	t_{ref} (C)	TNOMs alias.
84	$t_{rise=0}$ C	Temperature rise from ambient.
85	$e_g=1.11$ V	Band-gap.
86	$x_{tb}=0$	Beta temperature exponent.
87	$x_{ti}=3$	Temperature exponent for effect on i_s .
88	p_t	Temperature exponent for effect on i_s .
89	$t_{rb1}=0$ 1/C	Linear temperature coefficient for the base resistor.
90	$t_{rb2}=0$ C ⁻²	Quadratic temperature coefficient for the base resistor.
91	$t_{rm1}=0$ 1/C	Linear temperature coefficient for the minimum base resistor.
92	$t_{rm2}=0$ C ⁻²	Quadratic temperature coefficient for the minimum base resistor.
93	$t_{rc1}=0$ 1/C	Linear temperature coefficient for the collector resistor.

Virtuoso Simulator Components and Device Models Reference

BJT Model (bjt)

94	$\text{trc2}=0 \text{ C}^{-2}$	Quadratic temperature coefficient for the collector resistor.
95	$\text{tre1}=0 \text{ 1/C}$	Linear temperature coefficient for the emitter resistor.
96	$\text{tre2}=0 \text{ C}^{-2}$	Quadratic temperature coefficient for the emitter resistor.
97	$\text{tlev}=0$	DC temperature selector.
98	$\text{tlevc}=0$	AC temperature selector.
99	$\text{eglev}=0$	DC temperature selector.
100	$\text{gap1}=7.02\text{e-}4 \text{ V/C}$	Band-gap temperature coefficient.
101	$\text{gap2}=1108 \text{ C}$	Band-gap temperature offset.
102	$\text{tikf1}=0 \text{ 1/C}$	Linear temperature coefficient for ikf .
103	$\text{tikf2}=0 \text{ C}^{-2}$	Quadratic temperature coefficient for ikf .
104	$\text{tikr1}=0 \text{ 1/C}$	Linear temperature coefficient for ikr .
105	$\text{tikr2}=0 \text{ C}^{-2}$	Quadratic temperature coefficient for ikr .
106	$\text{tirb1}=0 \text{ 1/C}$	Linear temperature coefficient for irb .
107	$\text{tirb2}=0 \text{ C}^{-2}$	Quadratic temperature coefficient for irb .
108	$\text{tis1}=0 \text{ 1/C}$	Linear temperature coefficient for is .
109	$\text{tis2}=0 \text{ C}^{-2}$	Quadratic temperature coefficient for is .
110	$\text{tise1}=0 \text{ 1/C}$	Linear temperature coefficient for ise .
111	$\text{tise2}=0 \text{ C}^{-2}$	Quadratic temperature coefficient for ise .
112	$\text{tisc1}=0 \text{ 1/C}$	Linear temperature coefficient for isc .
113	$\text{tisc2}=0 \text{ C}^{-2}$	Quadratic temperature coefficient for isc .
114	$\text{tiss1}=0 \text{ 1/C}$	Linear temperature coefficient for iss .
115	$\text{tiss2}=0 \text{ C}^{-2}$	Quadratic temperature coefficient for iss .

Virtuoso Simulator Components and Device Models Reference

BJT Model (bjt)

116	$t_{bf1}=0$	1/C	Linear temperature coefficient for b_f .
117	$t_{bf2}=0$	C^{-2}	Quadratic temperature coefficient for b_f .
118	$t_{br1}=0$	1/C	Linear temperature coefficient for b_r .
119	$t_{br2}=0$	C^{-2}	Quadratic temperature coefficient for b_r .
120	$t_{vaf1}=0$	1/C	Linear temperature coefficient for v_{af} .
121	$t_{vaf2}=0$	C^{-2}	Quadratic temperature coefficient for v_{af} .
122	$t_{var1}=0$	1/C	Linear temperature coefficient for v_{ar} .
123	$t_{var2}=0$	C^{-2}	Quadratic temperature coefficient for v_{ar} .
124	$t_{itf1}=0$	1/C	Linear temperature coefficient for i_{tf} .
125	$t_{itf2}=0$	C^{-2}	Quadratic temperature coefficient for i_{tf} .
126	$t_{tf1}=0$	1/C	Linear temperature coefficient for t_f .
127	$t_{tf2}=0$	C^{-2}	Quadratic temperature coefficient for t_f .
128	$t_{tr1}=0$	1/C	Linear temperature coefficient for t_r .
129	$t_{tr2}=0$	C^{-2}	Quadratic temperature coefficient for t_r .
130	$t_{nf1}=0$	1/C	Linear temperature coefficient for n_f .
131	$t_{nf2}=0$	C^{-2}	Quadratic temperature coefficient for n_f .
132	$t_{nr1}=0$	1/C	Linear temperature coefficient for n_r .
133	$t_{nr2}=0$	C^{-2}	Quadratic temperature coefficient for n_r .
134	$t_{ne1}=0$	1/C	Linear temperature coefficient for n_e .
135	$t_{ne2}=0$	C^{-2}	Quadratic temperature coefficient for n_e .
136	$t_{nc1}=0$	1/C	Linear temperature coefficient for n_c .
137	$t_{nc2}=0$	C^{-2}	Quadratic temperature coefficient for n_c .

Virtuoso Simulator Components and Device Models Reference

BJT Model (bjt)

138	$t_{ns1}=0$	1/C	Linear temperature coefficient for n_s .
139	$t_{ns2}=0$	C^{-2}	Quadratic temperature coefficient for n_s .
140	$t_{mje1}=0$	1/C	Linear temperature coefficient for m_{je} .
141	$t_{mje2}=0$	C^{-2}	Quadratic temperature coefficient for m_{je} .
142	$t_{mjc1}=0$	1/C	Linear temperature coefficient for m_{jc} .
143	$t_{mjc2}=0$	C^{-2}	Quadratic temperature coefficient for m_{jc} .
144	$t_{mjs1}=0$	1/C	Linear temperature coefficient for m_{js} .
145	$t_{mjs2}=0$	C^{-2}	Quadratic temperature coefficient for m_{js} .
146	$c_{te}=0$	1/C	Temperature coefficient for c_{je} .
147	$c_{tc}=0$	1/C	Temperature coefficient for c_{jc} .
148	$c_{ts}=0$	1/C	Temperature coefficient for c_{js} .
149	$t_{vje}=0$	V/C	Temperature coefficient for v_{je} .
150	$t_{vjc}=0$	V/C	Temperature coefficient for v_{jc} .
151	$t_{vjs}=0$	V/C	Temperature coefficient for v_{js} .
152	$t_{vtf1}=0$	1/C	Linear temperature coefficient for v_{tf} .
153	$t_{vtf2}=0$	C^{-2}	Quadratic temperature coefficient for v_{tf} .
154	$t_{xtf1}=0$	1/C	Linear temperature coefficient for x_{tf} .
155	$t_{xtf2}=0$	C^{-2}	Quadratic temperature coefficient for x_{tf} .

Junction diode model control parameters

156	$dskip=yes$		Skip junction calculations if they are reverse-saturated. Possible values are <code>no</code> or <code>yes</code> .
157	$imelt='imax'$	A	Junction explosion current (*area).

Virtuoso Simulator Components and Device Models Reference

BJT Model (bjt)

Operating region warning control parameters

158	<code>bvbe=∞ V</code>	B-E breakdown voltage.
159	<code>bvbc=∞ V</code>	B-C breakdown voltage.
160	<code>bvce=∞ V</code>	C-E breakdown voltage.
161	<code>bvsub=∞ V</code>	Substrate junction breakdown voltage.
162	<code>vbefwd=0.2 V</code>	B-E forward voltage.
163	<code>vbcfwd=0.2 V</code>	B-C forward voltage.
164	<code>vsubfwd=0.2 V</code>	Substrate junction forward voltage.
165	<code>imax=1e3 A</code>	Maximum allowable base current (*area).
166	<code>imax1=`imax' A</code>	Maximum allowable collector current (*area).
167	<code>alarm=none</code>	Forbidden operating region. Possible values are <code>none</code> , <code>off</code> , <code>fwd</code> , <code>rev</code> , or <code>sat</code> .

Noise model parameters

168	<code>kf=0</code>	Flicker (1/f) noise coefficient.
169	<code>af=1</code>	Flicker (1/f) noise exponent.
170	<code>kb=0</code>	Burst noise coefficient.
171	<code>bnoise_{fc}=1</code>	Burst noise cutoff frequency.
172	<code>rbnoi=r_b Ω</code>	Effective base noise resistance.

Compatibility model parameters

173	<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> .
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Virtuoso Simulator Components and Device Models Reference

BJT Model (bjt)

- 174 `mvt0=0.0 V` Threshold mismatch intercept.
- 175 `updatelevel=0` Model update selector. The available versions are 0, 1 .

Shrink Parmaters

`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 `type=npn` Transistor type.
Possible values are `npn` or `pnP`.
- 2 `struct=vertical` Transistor structure. For `pnP` default=`lateral`.
Possible values are `vertical` or `lateral`.
- 3 `region=fwd` Estimated operating region. Spectre outputs number (0-4) in a rawfile.
Possible values are `off`, `fwd`, `rev`, `sat`, or `breakdown`.
- 4 `vbe (V)` Base-emitter voltage (alias=`Ix0`).
- 5 `vbc (V)` Base-collector voltage (alias=`Ix1`).
- 6 `vce (V)` Collector-emitter voltage.

Virtuoso Simulator Components and Device Models Reference

BJT Model (bjt)

7	v_{sub} (V)	Substrate junction voltage (alias=lx24).
8	i_c (A)	Resistive collector current (alias=lx2).
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 (Ω)	$1/R_{beff}$ internal conductance (alias=lx16).

Virtuoso Simulator Components and Device Models Reference

BJT Model (bjt)

28	qbe	Base emitter charge (alias=lx8).
29	qbc	Base collector charge (alias=lx10).
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 (Ω)	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-169	ib	OP-9	rbmod	M-39	tns1	M-138
alarm	M-167	ic	OP-8	rbnoi	M-172	tns2	M-139
area	I-1	ik	M-24	rc	M-40	tr	M-80
areab	I-2	ikf	M-23	rc	OP-18	trb1	M-89
areac	I-3	ikr	M-26	rcm	M-42	trb2	M-90
betaac	OP-13	imax	M-165	rcv	M-41	trc1	M-93
betadc	OP-12	imax1	M-166	re	M-46	trc2	M-94
bf	M-19	imelt	M-157	re	OP-36	tre1	M-95

Virtuoso Simulator Components and Device Models Reference

BJT Model (bjt)

bfm	M-20	iob	M-38	region	I-6	tre2	M-96
bnoiseFc	M-171	irb	M-36	region	OP-3	tref	M-83
br	M-21	is	M-3	ro	OP-16	trise	I-5
brm	M-22	isc	M-5	rpi	OP-15	trise	M-84
bvbc	M-159	ise	M-4	struct	M-2	trm1	M-91
bvbe	M-158	isnoisy	I-7	struct	OP-2	trm2	M-92
bvce	M-160	iss	M-6	tbf1	M-116	ttf1	M-126
bvsub	M-161	isub	OP-10	tbf2	M-117	ttf2	M-127
c2	M-7	itf	M-78	tbr1	M-118	ttr1	M-128
c4	M-8	jbf	M-25	tbr2	M-119	ttr2	M-129
cbcp	M-71	jbr	M-27	tcbo	M-12	tvaf1	M-120
cbep	M-72	jrb	M-37	td	M-75	tvaf2	M-121
cbo	M-9	jtf	M-79	tf	M-74	tvar1	M-122
cco	M-45	kb	M-170	tgbo	M-13	tvar2	M-123
ccs	M-62	kc	M-33	tikf1	M-102	tvjc	M-150
ccsp	M-73	ke	M-32	tikf2	M-103	tvje	M-149
cex	M-44	kf	M-168	tikr1	M-104	tvjs	M-151
cjc	M-54	log_ib	OP-34	tikr2	M-105	tvtf1	M-152
cje	M-49	log_ic	OP-33	tirb1	M-106	tvtf2	M-153
cjs	M-61	m	I-4	tirb2	M-107	txtf1	M-154
cmu	OP-20	mc	M-58	tisl	M-108	txtf2	M-155

Virtuoso Simulator Components and Device Models Reference

BJT Model (bjt)

cmux	OP-21	me	M-53	tis2	M-109	type	M-1
compatible	M-173	minr	M-47	tisc1	M-112	type	OP-1
cpi	OP-19	mjc	M-56	tisc2	M-113	updatelevel	M-175
csub	M-63	mje	M-51	tise1	M-110	va	M-29
csub	OP-22	mjs	M-65	tise2	M-111	vaf	M-28
ctc	M-147	ms	M-68	tiss1	M-114	var	M-30
cte	M-146	mvt0	M-174	tiss2	M-115	vb	M-31
cts	M-148	nc	M-17	titf1	M-124	vbc	OP-5
dcap	M-48	ne	M-16	titf2	M-125	vbcfwd	M-163
dope	M-43	nf	M-14	tlev	M-97	vbe	OP-4
dskip	M-156	nr	M-15	tlevc	M-98	vbefwd	M-162
eg	M-85	ns	M-18	tmjc1	M-142	vbo	M-11
eglev	M-99	pc	M-57	tmjc2	M-143	vce	OP-6
esub	M-69	pe	M-52	tmje1	M-140	vjc	M-55
fc	M-70	ps	M-66	tmje2	M-141	vje	M-50
ft	OP-23	psub	M-67	tmjs1	M-144	vjs	M-64
g0	OP-26	pt	M-88	tmjs2	M-145	vsub	OP-7
gap1	M-100	ptf	M-81	tnc1	M-136	vsubfwd	M-164
gap2	M-101	pwr	OP-11	tnc2	M-137	vtf	M-77
gb	OP-27	qbc	OP-29	tne1	M-134	xcjc	M-59

Virtuoso Simulator Components and Device Models Reference

BJT Model (bjt)

gbo	M-10	qbe	OP-28	tne2	M-135	xcjc2	M-60
gm	OP-14	qsc	OP-30	tnf1	M-130	xtb	M-86
gmu	OP-25	rb	M-34	tnf2	M-131	xtf	M-76
gpi	OP-24	rb	OP-17	tnom	M-82	xti	M-87
grc	OP-31	rbb	OP-32	tnr1	M-132		
gre	OP-35	rbm	M-35	tnr2	M-133		

HiCUM Model (bht)

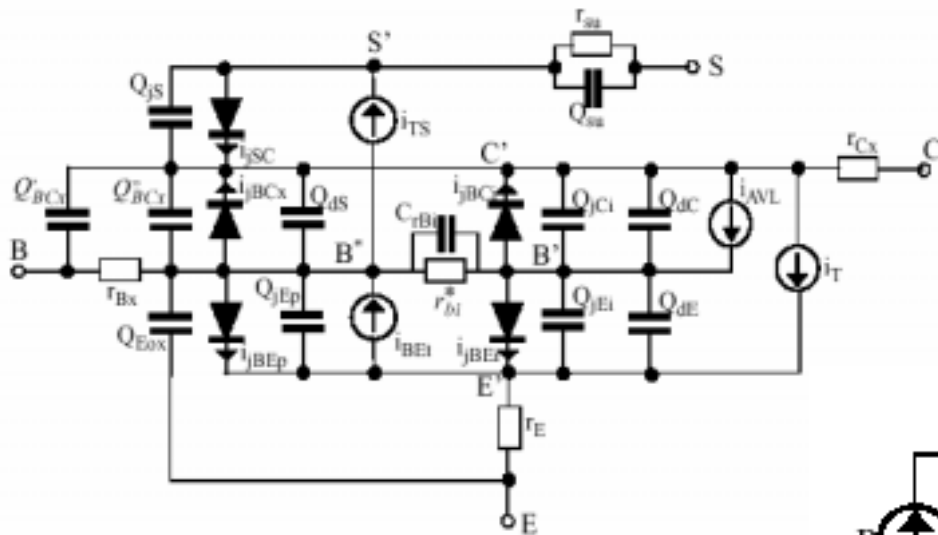
The HiCUM model was developed by Professor M. Schroter. This chapter contains the following information:

- [DC Equations](#) on page 288
- [Charge and Capacitance Equations](#) on page 291
- [Noise Model](#) on page 294
- [Temperature Effect](#) on page 295
- [Self-Heating](#) on page 297
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- [Scaling Effects](#) on page 308
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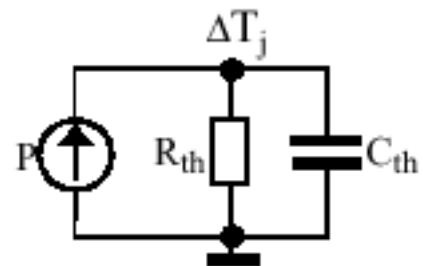
Virtuoso Simulator Components and Device Models Reference

HiCUM Model (bht)

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 modelling 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

$$i_T = i_{Tf} - i_{Tr}$$

$$i_{Tf1} = \frac{C_{10}}{Q_{p,T}} \exp\left(\frac{V_{B'E'}}{m_{cf} V_T}\right)$$

$$i_{Tf} = i_{Tf1} \left(1 + \frac{i_{Tf1}}{i_{ch}}\right)$$

Virtuoso Simulator Components and Device Models Reference
HiCUM Model (bht)

$$i_{Tr} = \frac{C_{10}}{Q_{p,T}} \exp\left(\frac{V_{B'C'}}{V_T}\right)$$

$$Q_{p,T} = \frac{Q_{p,low}}{2} + \sqrt{\left(\frac{Q_{p,low}}{2}\right)^2 + \tau_{f0} C_{10} \exp\left(\frac{V_{B'E'}}{V_T}\right) + \tau_r C_{10} \exp\left(\frac{V_{B'C'}}{V_T}\right)}$$

$$Q_{p,1} = Q_{p0} + Q_{jEi} h_{jei} + h_{jci} Q_{jci}$$

$$I_{CK} = \frac{V_{ceff}}{r_{cio}} \frac{1}{\sqrt{1 + \left(\frac{V_{ceff}}{V_{lim}}\right)^2}} \left[1 + \frac{x + \sqrt{x^2 + 10^{-3}}}{2} \right]$$

$$X = (V_{ceff} - V_{lim}) / V_{PT}$$

$$r_{cio} = \frac{w_c}{q \mu_{nc0} N_{ci} A_E f_{cs}}$$

$$V_{lim} = \frac{V_{sn}}{\mu_{nc0}} w_c$$

$$V_{PT} = \frac{q N_{ci}}{2E} w_c^2$$

$$i_{jBEi} = I_{BEis} \left[\exp\left(\frac{V_{B'E'}}{m_{BEi} V_T}\right) - 1 \right] + I_{REis} \left[\exp\left(\frac{V_{B'E'}}{m_{BEi} V_T}\right) - 1 \right]$$

$$i_{jBEp} = I_{BEps} \left[\exp\left(\frac{V_{B'E'}}{m_{BEp} V_T}\right) - 1 \right] + I_{REps} \left[\exp\left(\frac{V_{B'E'}}{m_{REp} V_T}\right) - 1 \right]$$

$$i_{jBCi} = I_{BCis} \left[\exp\left(\frac{V_{B'C'}}{m_{BCi} V_T}\right) - 1 \right]$$

Virtuoso Simulator Components and Device Models Reference
HiCUM Model (bht)

$$i_{jBCx} = I_{BCxs} \left[\exp\left(\frac{V_{B'C'}}{M_{BCx} V_T}\right) - 1 \right]$$

$$r_{Bi} = r_{Bi0} \frac{C_i}{C_i + C_{dEp}}$$

$$r_{Bi0} = r_{SBi0} \frac{b_E}{I_E n_E} g_i$$

$$C_i = C_{jEi} + C_{dEi} + C_{dci}$$

$$C_{dEp} = C_{dE}(1 - f_{Qi})$$

$$i_{AVL} = I_T \frac{f_{AVL} V_{DCi}}{C_c^{1/z_{ci}}} \exp\left(-\frac{q_{AVL}}{C_{jCi0} V_{DCi}} C_c^{(1/z_{ci} - 1)}\right)$$

$$C_c = \frac{C_{jci}(V_{B'C'})}{C_{jci0}}$$

$$i_{BEt} = I_{BEts} (-V_e) C_e^{1 - 1/z_E} \exp\left[-a_{BEt} C_e^{1/z_E - 1}\right] \quad *$$

$$I_{BEts} = 2 \frac{\sqrt{2m^* E_G} q^3 V_{DE}^2}{h^2 \epsilon_{Si}} C_{jE0}$$

$$a_{BEt} = \frac{8\pi \sqrt{2m^* E_G} E_G W_{BE0}}{3qh} \frac{1}{2V_{DE}}$$

$$C_e = \frac{C_{jE}(V)}{C_{jE0}}$$

$$i_{TS} = I_{TSf} - I_{TSr} = I_{TSS} \left[\exp\left(\frac{V_{B^*C'}}{m_{Sf} V_T}\right) - \exp\left(\frac{V_{S'C'}}{m_{Sr} V_T}\right) \right]$$

$$i_{SC} = I_{SCS} \left[\exp\left(\frac{V_{S'C'}}{m_{SC} V_T}\right) - 1 \right]$$

Charge and Capacitance Equations

$$Q_{P,T} = Q_{p0} + h_{jEi} Q_{jEi} + h_{jCi} Q_{jCi} + Q_{f,T} + Q_{r,T}$$

$$Q_{f,T} = Q_{f0} + \Delta Q_{Ef} + \Delta Q_{fh}$$

$$Q_{f0} = \tau_{f0} i_{Tf}$$

$$\Delta Q_{Ef} = \Delta \tau_{Ef} \frac{i_{Tf}}{1 + g_{\tau E}}$$

$$\Delta \tau_{Ef} = \tau_{Ef0} \left(\frac{i_{Tf}}{I_{CK}} \right)^{g_{\tau E}}$$

$$\tau_{Ef0} = \frac{1}{\beta_0} \left(\frac{W_E}{V_{Ke}} + \frac{W_E^2}{2\mu_{PE} V_T} \right)$$

$$\Delta Q_{fh} = \Delta Q_{Bf} + Q_{cf} = \tau_{hcS} i_{Tf} W^2$$

$$Q_{r,T} = \tau_r i_{Tr}$$

$$C_{jEi} = \frac{C_{jEi0}}{(1 - V_j/V_{DEi})^{2Ei}} \cdot \frac{e}{1 + e} + a_{jEi} C_{jEi0} \frac{1}{1 + e}$$

Virtuoso Simulator Components and Device Models Reference
HiCUM Model (bht)

$$e = \exp\left(\frac{V_f - V_{B'E'}}{V_T}\right)$$

$$V_j = V_f - V_T \ln[1 + e] < V_f$$

$$V_f = V_{DEi} \left[1 - a_{jEi}^{-1/(z_{Ei})} \right]$$

$$Q_{jEi} = \frac{C_{jEi0} V_{DEi}}{1 - Z_{Ei}} \left[1 - \left(1 - \frac{V_j}{V_{DEi}} \right)^{1/(z_{Ei})} \right] + a_{jEi} C_{jEi0} (V_{B'E'} - V_j)$$

$$C_{jci} = C_{jci,cl} + C_{jci,PT} + C_{jci,fb}$$

$$C_{jci,cl} = \frac{C_{jci0}}{(1 - V_{j,m}/V_{DCi})^{z_{ci}}} \cdot \frac{Q_{j,r}}{1 + e_{j,r}} \frac{e_{j,m}}{1 + e_{j,m}}$$

$$C_{jci,fb} = a_{jci} C_{jci0} \frac{1}{e_{j,r} + 1}$$

$$C_{jci,PT} = \frac{C_{jci0,r}}{(1 - V_{j,r}/V_{DCi})^{z_{ci,r}}} \cdot \frac{1}{1 + e_{j,m}}$$

$$Q_{jCi} = Q_{jCi,m} + Q_{jci,r} + a_{jci} C_{jci0} (V_{B'C'} - V_{j,r}) - Q_{jci,c}$$

$$Q_{jCi,m} = \frac{C_{jCi0} V_{DCi}}{1 - z_{Ci}} \left[1 - \left(1 - \frac{V_{j,m}}{V_{DCi}} \right)^{1 - z_{Ci}} \right]$$

$$Q_{jCi,r} = \frac{C_{jCi,r} V_{DCi}}{1 - z_{Ci,r}} \left[1 - \left(1 - \frac{V_{j,r}}{V_{DCi}} \right)^{1 - z_{Ci,r}} \right]$$

Virtuoso Simulator Components and Device Models Reference
HiCUM Model (bht)

$$Q_{jCi,c} = \frac{C_{jCi,r} V_{DCi}}{1 - z_{ci,r}} \left[1 - \left(1 - \frac{V_{j,m}}{V_{DCi}} \right)^{1 - z_{ci,r}} \right]$$

$$C_{jCi0,r} = C_{jCi0} \cdot \left(\frac{V_{DCi}}{V_{PTCi}} \right)^{(Z_{ci} - Z_{ci,r})}$$

$$C_i = C_{jEi} + C_{jCi} + C_{dE} + C_{dC}$$

$$Q_{dS} = Y_{Sf} i_{TSf}$$

$$C_{dE} = \tau_f S_{fb}$$

$$C_{dC} = \tau_r S_{rC} + \tau_f S_{fC}$$

$$C_{dS} = \tau_{Sf} S_{TSu,b}$$

$$S_{fb} = \left. \frac{dI_{Tf}}{dV_{B'E'}} \right|_{V_{B'C'}} = \frac{I_{Tf1}}{V_{Tf}} \cdot \frac{Q_{P,T} + \tau_r I_{Tr} - h_{jei} C_{jEi} V_{Tf}}{Q_{P,T} + \tau_r I_{Tr} + \tau_{fT} I_{Tf1} d_{ch}} d_{ch}$$

$$d_{Ch} = 1 + 2I_{Tf1}/I_{Ch}$$

$$S_{fC} = \left. \frac{dI_{Tf}}{dV_{C'E'}} \right|_{V_{B'E'}} = \frac{I_{Tf1}}{V_{Af}} \cdot \frac{d}{1 + d\tau_{f,T} I_{Tf1}/Q_{P,T}}$$

$$V_{Af} = \frac{Q_{P,T}}{h_{jci} C_{jCi} - \left. \frac{dQ_f}{dV_{C'E'}} \right|_{V_{B'E'}}$$

$$d = d_{ch} \frac{e}{1 + e}$$

$$e = \exp\left(\frac{V_c}{V_T} - 1\right)$$

$$S_{rc} = \left. \frac{dI_{Tr}}{dV_{C'E'}} \right|_{V_{B'E'}} = -\frac{I_{Tr}}{V_T} \cdot \frac{Q_{p,T} + (\tau_{f,T} S_{fc} - h_{jci} C_{jci}) V_T}{Q_{p,T} + \tau_r I_{Tr}}$$

$$S_{Tsu,b} = \frac{I_{TsS}}{m_{sf} V_T} \exp\left(\frac{V_{B^*C'}}{m_{sf} V_T}\right)$$

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 pectral density S_{incinb} :

$$S_{incinb} \approx -2qI_T \times (j\omega\tau_{Bf} \times alit)$$

$$\tau_{Bf} = \frac{I_T}{I_{BEi}}$$

Temperature Effect

$$r_{ci}(T) = r_{ci}(T_0) \left(\frac{T}{T_0}\right)^{\zeta_{ci}}$$

$$V_{lim}(T) = V_{lim}(T_0)(1 - \alpha_{VS}\Delta T) \left(\frac{T}{T_0}\right)^{\zeta_{ci}}$$

$$V_{C'E's}(T) = V_{C'E's}(T_0)[1 + \alpha_{CES}\Delta T]$$

$$\tau_0(T) = \tau_0(T_0)[1 + \alpha_{\tau_0}\Delta T + K_{\tau_0}\Delta T^2]$$

$$\tau_{hcs}(T) = \tau_{hcs}(T_0) \left(\frac{T}{T_0}\right)^{(\tau_{ci} - 1)}$$

$$\tau_{Ej0}(T) = \tau_{Ej}(T_0) \frac{T/T_0}{1 + \alpha_B\Delta T}$$

$$V_D(T) = V_D(T_0) \frac{T}{T_0} - V_{Gj} \left(\frac{T}{T_0} - 1\right) - 3V_T \ln\left(\frac{T}{T_0}\right)$$

$$C_{j0}(T) = C_{j0}(T_0) \left(\frac{V_D(T_0)}{V_D(T)}\right)^2$$

Virtuoso Simulator Components and Device Models Reference

HiCUM Model (bht)

$$\alpha_j(T) = \alpha_j(T_0) \frac{V_D(T)}{V_D(T_0)}$$

$$r_{Bi0}(T) = r_{Bi0}(T_0) \left(\frac{T}{T_0} \right)^{\zeta_{rBi}}$$

$$f_{AVL}(T) = f_{AVL}(T_0) \exp(\alpha_{fav} \Delta T)$$

$$q_{AVL}(T) = q_{AVL}(T_0) \exp(\alpha_{qav} \Delta T)$$

$$I_{BEtS}(T) = I_{BEtS}(T_0) \sqrt{\frac{V_G(T_0)}{V_G(T)}} \left(\frac{V_{DEp}(T)}{V_{DEp}(T_0)} \right)^2 \frac{C_{jEp0}(T)}{C_{jEp0}(T_0)}$$

$$a_{BEt}(T) = a_{BEt}(T_0) \left(\frac{V_G(T)}{V_G(T_0)} \right)^{3/2} \frac{V_{DEp}(T)}{V_{DEp}(T_0)}$$

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`,

$$I_{tss}(T) = I_{tss}(T_0) \times (T/T_0)^{3/Msf} \times \exp(VGB / (Msf \times Vt) \times (T/T_0 - 1))$$

$$TEF0(T) = TEF0(T_0) \times (T/T_0) / (0.5 \times (A + \sqrt{A \times A + le - 6}))$$

$$C_{dci} = Tr \times Src$$

where

$$A = 1.0 + Alb \times \Delta T$$

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:

$$Pwr = Vcei \times It - Vbci \times Iavl$$

If `updatelevel=2`,

$$Pwr = Pwr + (Vbp - Vb) \times \frac{(Vbp - Vb)}{Rbi} \quad \text{if } Rbi0 \text{ is given}$$

$$Pwr = Pwr + (Vbx - Vbp) \times \frac{(Vbx - Vbp)}{Rbx} \quad \text{if } Rbx \text{ is given}$$

$$Pwr = Pwr + (Vcx - Vc) \times \frac{(Vcx - Vc)}{Rcx} \quad \text{if } Rcx \text{ is given}$$

$$Pwr = Pwr + (Ve - Vex) \times \frac{(Ve - Vex)}{Re} \quad \text{if } Re \text{ is given}$$

NQS effect

Lateral NQS

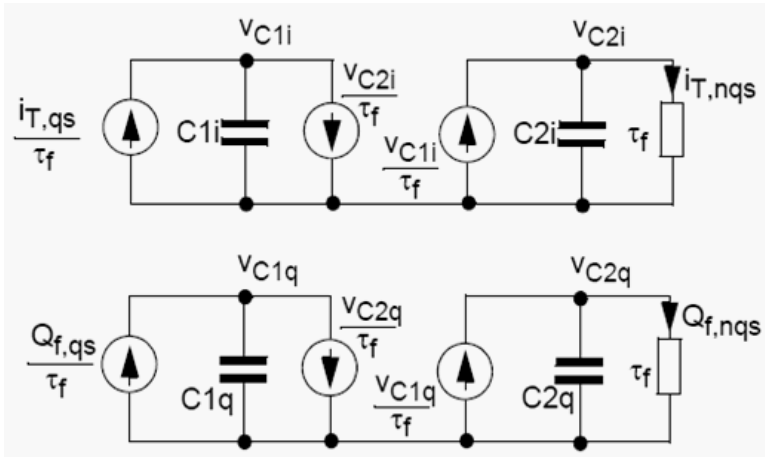
The lateral NQS effect is implemented by an adequate capacitance C_{rBi} in parallel to the resistance r_{Bi} .

$$C_{rBi} = f_{crBi} \times C_{jei} \times C_{jci} \times C_{dei} \times C_{dci}$$

$$Q_{rBi} = C_{rBi} \times V_{B \times B}$$

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_f .



$$\frac{i_{T,qs} - V_{C2i}}{\tau_f} = \frac{d \times (alit \times V_{C1i})}{dt}$$

$$\frac{V_{C1i} - V_{C2i}}{\tau_f} = \frac{d \times (alit \times V_{C2i}/3)}{dt}$$

$$i_{T,nqs} = \frac{V_{C2i}}{\tau_f}$$

$$\frac{Q_{T,qs} - V_{C2q}}{\tau_f} = \frac{d \times (alqf \times V_{C1i})}{dt}$$

$$\frac{V_{C1q} - V_{C2q}}{\tau_f} = \frac{d \times (alqf \times V_{C2q}/3)}{dt}$$

$$Q_{T,nqs} = \frac{V_{C2q}}{\tau_f}$$

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

$$n_{ie}^2(T) = n_{ie}^2(T_0) \left(\frac{T}{T_0}\right)^{m_g} \exp\left[\frac{V_{geff}(0)}{V_T} \left(\frac{T}{T_0} - 1\right)\right]$$

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

$$v_j = V_f - V_T \frac{x + \sqrt{x^2 + a_{ff}}}{2} < V_f$$

$$x = \frac{V_f - v_{BE'}}{V_T}$$

$$a_{ff} = 41n^2(2) = 1.921812$$

$$C_{jEi} = \frac{C_{jEi0}}{(1 - v_j/V_{DEi})^{z_{Ei}}} \cdot \frac{dv_j}{dv_{BE'}} + a_{jEi} C_{jEi0} \left(1 - \frac{dv_j}{dv_{BE'}} \right)$$

$$\frac{dv_j}{dv_{BE'}} = \frac{x + \sqrt{x^2 + a_{ff}}}{2\sqrt{x^2 + a_{ff}}}$$

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

$$C_{dCi} = \tau_r S_{rc}$$

$$C_{dEi}^C = \tau_f S_{fc} + \left. \frac{dQ_f}{dV_{CE}} \right|_{T_{Tf}, T}$$

$$C_{dEi}^B = \tau_r S_{rb}$$

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

$$I_{TS}(T) = I_{TSS}(T_0) \left(\frac{T}{T_0}\right)^{\zeta_{BCxT}} \exp\left[\frac{V_{gCeff}(0)}{V_T} \left(\frac{T}{T_0} - 1\right)\right]$$

$$\tau_{Sf}(T) = \tau_{Sf}(T_0) \left(\frac{T}{T_0}\right)^{(\zeta_{Cx} - 1)}$$

Scaling Effects

For scaling effects, see [Scaling Factors \(scale and scalem\)](#) on page 222.

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.

Instance Parameters

Parameters valid for both modes

- | | | |
|---|----------------------------|--|
| 1 | <code>region=</code> | Estimated operating region.
Possible values are <code>off</code> , <code> fwd</code> , <code> rev</code> , or <code> sat</code> . |
| 2 | <code>trise ()</code> | Temperature rise from ambient. |
| 3 | <code>self_heating=</code> | Control switch for self-heating. Possible values are <code>no</code> , <code>yes</code> or <code>fast</code> . <code>Fast</code> is Cadences 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> or <code>fast</code> . |
| 4 | <code>m=</code> | Multiplicity factor (number of devices in parallel). |

Parameters for structure mode

- | | | |
|---|-----------------------|--|
| 5 | <code>isnoisy=</code> | Should resistor generate noise.
Possible values are <code>no</code> or <code>yes</code> . |
|---|-----------------------|--|

Structural parameters

- | | | |
|---|--------------------|-------------------------|
| 6 | <code>area=</code> | Transistor area factor. |
|---|--------------------|-------------------------|

Model Definition

model modelName bht parameter=value ...

Model Parameters

Major mode of operation

1 mode= Mode for model parameter determination.
Possible values are `internal`.

Parameters for internal mode

Structural parameters

2 type= Transistor type.
Possible values are `npn` or `pnP`.

3 latb= Parameter for lateral scaling (Zeta_b).

4 latl= Parameter for lateral scaling (Zeta_l).

Internal transistor

5 c10= Constant for ICCR.

6 qp0= Zero-bias hole charge.

7 ich= High current correction (multidimens. ICCR).

8 hjci= B-C depletion charge weighting factor.

9 hjei= B-E depletion charge weighting factor.

10 mcf= Forward non-ideality factor of Su transfer current.

11 tsf= Transit time(forward operation).

12 hfc= Collector minority charge weighting factor.

Virtuoso Simulator Components and Device Models Reference

HiCUM Model (bht)

13	hfe=	Emitter minority charge weighting factor.
14	alit=	Factor for additional delay time of iT.
15	cjei0=	Internal zero-bias BE depletion capacitance.
16	vdei=	Internal BE built-in voltage.
17	zei=	Internal BE depletion coefficient.
18	aljei=	Maximum int. depl. cap. divided by Cjei0.
19	cjci0=	Internal zero-bias BC depletion capacitance.
20	vdci=	Internal BC built-in voltage.
21	zci=	Internal BC depletion coefficient.
22	vptci=	Punch-through voltage of internal BC junction.
23	t0=	Time constant (low current densities).
24	dt0h=	Time constant for base and BC space charge layer width modulation.
25	tbvl=	Time constant for modeling carrier jam.
26	tef0=	Neutral emitter storage time.
27	gtfe=	Current dependence factor for TEF0.
28	thcs=	Saturation time constant.
29	alhc=	Smoothing factor for base and collector transit time.
30	fthc=	Partitioning factor for base and collector portion.
31	vcse=	Internal CE saturation voltage.
32	rci0=	Low-field resistance of epitaxial collector.
33	vlim=	Limitation voltage.

Virtuoso Simulator Components and Device Models Reference

HiCUM Model (bht)

34	vpt=	Punch-through voltage.
35	tr=	Ideal reverse transit time.
36	alqf=	Factor for additional delay time of minority charge.
37	ibeis=	Internal BE saturation current.
38	mbei=	Internal BE non-ideality factor.
39	ireis=	Internal BE saturation current (recombination).
40	mrei=	Internal BE non-ideality factor (recombination).
41	ibcis=	Internal BC saturation current.
42	mbci=	Internal BC non-ideality factor.
43	favl=	Avalanche current factor.
44	qavl=	Exponent factor for Avalanche current.
45	rbi0=	Internal base resistance at zero-bias.
46	fdqr0=	Correction factor for modulation.
47	fgeo=	Geometry factor for current crowding.
48	fqi=	Ratio of internal to total minority charge.
49	fcrbi=	Ratio of h.f. shunt to total internal capacitance.

Peripheral elements

50	cjep0=	Peripheral zero-bias BE depletion capacitance.
51	vdep=	Peripheral BE built-in voltage.
52	zep=	Peripheral BE depletion coefficient.
53	aljep=	Maximum per. depl. cap. divided by Cjep0.
54	ibeps=	Peripheral BE saturation current.

Virtuoso Simulator Components and Device Models Reference

HiCUM Model (bht)

55	<code>mbep=</code>	Peripheral BE non-ideality factor.
56	<code>ireps=</code>	Periph. BE saturation current (recomb.).
57	<code>mrep=</code>	Periph. BE non-ideality factor (recomb.).

External elements

58	<code>cjcx0=</code>	External zero-bias BC depletion capacitance.
59	<code>vdcx=</code>	External BC built-in voltage.
60	<code>zcx=</code>	External BC depletion coefficient.
61	<code>vptcx=</code>	Punch-through voltage of external BC junction.
62	<code>ccox=</code>	BC overlap capacitance.
63	<code>fbcx=</code>	Partitioning factor for <code>Cjcx</code> and <code>Ccox</code> over <code>rBx</code> .
64	<code>ibcxS=</code>	External BC saturation current.
65	<code>mbcx=</code>	External BC non-ideality factor.
66	<code>ceox=</code>	Emitter oxide (overlap) capacitance.
67	<code>rbx=</code>	External base series resistance.
68	<code>re=</code>	Emitter series resistance.
69	<code>rcx=</code>	External collector series resistance.

Substrate transistor

70	<code>cjs0=</code>	Zero-bias CS depletion capacitance.
71	<code>vds=</code>	CS built-in voltage.
72	<code>zs=</code>	CS depletion coefficient.
73	<code>vpts=</code>	Punch-through voltage of CS junction.

Virtuoso Simulator Components and Device Models Reference

HiCUM Model (bht)

74	<code>rsu=</code>	Substrate resistance.
75	<code>csu=</code>	Substrate coupling capacitance.
76	<code>iscs=</code>	CS diode saturation current.
77	<code>msc=</code>	CS diode non-ideality factor.
78	<code>itss=</code>	Transfer saturation current of Su transistor.
79	<code>msf=</code>	Forward non-ideality factor of Su transfer current.
80	<code>msr=</code>	Reverse non-ideality factor of Su transfer current.
81	<code>ibets=</code>	BE tunneling saturation current.
82	<code>abet=</code>	BE tunneling factor.

Noise parameters

83	<code>kf=</code>	Flicker noise factor.
84	<code>af=</code>	Flicker noise exponent factor.
85	<code>krbi=</code>	Noise factor for internal base resistance.

Temperature effect parameters

86	<code>tnom ()</code>	Parameters measurement temperature. Default set by options.
87	<code>vgb=</code>	Bandgap-voltage.
88	<code>alb=</code>	Rel. temperature coeff. of current gain.
89	<code>alfav=</code>	Temperature coefficient for FAVL.
90	<code>alqav=</code>	Temperature coefficient for QAVL.
91	<code>zetaci=</code>	Temper. coeff. (mobility) for epi-collector.
92	<code>alvs=</code>	Rel. temperature coeff. of satur. drift velocity.

Virtuoso Simulator Components and Device Models Reference

HiCUM Model (bht)

93	<code>alces=</code>	Rel. temperature coeff. of VCEs.
94	<code>zetarbi=</code>	Temper. coeff. (mobility) for int. base res.
95	<code>zetarbx=</code>	Temper. coeff. (mobility) for ext. base res.
96	<code>zetarcx=</code>	Temper. coeff. (mobility) for ext. collector res.
97	<code>zetare=</code>	Temper. coeff. (mobility) for emitter res.
98	<code>alt0=</code>	Frist-order temper. coeff. of temperature T0.
99	<code>kt0=</code>	Second-order temper. coeff. of temperature T0.
100	<code>rth=</code>	Thermal resistance for self-heating.
101	<code>cth=</code>	Thermal capacitance for self-heating.
102	<code>debug=</code>	Debug.
103	<code>version=</code>	Model version selector. The available versions are 1.0, 2.1, 2.20, 2.21 ,2.22and 2.23.

Operating region warning control parameters

104	<code>updatelevel=</code>	Model update selector. The available versions are 0, 1 ,2 and 3.
105	<code>minr=</code>	Minimum resistance.
106	<code>imax=</code>	Maximum current.
107	<code>tmax=</code>	Maximum device temperature.
108	<code>tmin=</code>	Minimum resistance.
109	<code>alarm=</code>	Forbidden operating region. Possible values are none, off, fwd, rev, or sat.
110	<code>mvt0=</code>	Threshold mismatch intercept.

Virtuoso Simulator Components and Device Models Reference

HiCUM Model (bht)

Formally released Hicum 2.2 new parameters

111	$v_{gc} =$	eff. collector bandgap voltage.
112	$v_{ge} =$	eff. emitter bandgap voltage.
113	$v_{gs} =$	eff. substrate bandgap voltage.
114	$z_{etact} =$	Exponent coefficient in transfer current temperature dependence.
115	$z_{etabet} =$	Exponent coefficient in B-E junction current temperature dependence.
116	$t_{bhrec} =$	Base current recombination time constant at B-C barrier for high forward injection.
117	$t_{unode} =$	Specifies the base node connection for the tunneling current, possible values are 0 and 1, 1 signifies perimeter node.
118	$c_{bepar} =$	Total parasitic B-E capacitance.
119	$f_{bepar} =$	Partitioning factor of parasitic B-E cap.
120	$f_{1vg} =$	Coefficient K1 in T-dependent band-gap equation.
121	$f_{2vg} =$	Coefficient K2 in T-dependent band-gap equation.
122	$c_{fbe} =$	Flag for determining where to tag the flicker noise source, possible values are -1 and -2.
123	$z_{etacx} =$	Temperature exponent of mobility in substrate transistor transit time.
124	$c_{bcpar} =$	Total parasitic B-C capacitance.
125	$f_{bcpar} =$	Partitioning factor of parasitic B-C cap.
126	$a_{jei} =$	Ratio of maximum to zero-bias value of internal B-E capacitance.
127	$a_{jep} =$	Ratio of maximum to zero-bias value of peripheral B-E capacitance.

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128	ahc=	Smoothing factor for current dependence of base and collector transit time.
129	flsh=	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.
130	flcomp=	Flag for compatibility with v2.1 model (0=v2.1).
131	flnqs=	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.

Output Parameters

1	debug	Debug variable.
---	-------	-----------------

Operating-Point Parameters

1	temp ()	Temperature.
2	ic ()	Collector current.
3	ib ()	Base current.
4	vbei ()	Internal base-emitter voltage.
5	qjei ()	Internal base-emitter space charge.
6	cjei ()	Internal base-emitter depletion capacitance.
7	vbep ()	Peripheral base-emitter voltage.
8	qjep ()	Peripheral base-emitter space charge.
9	cjep ()	Peripheral base-emitter depletion capacitance.
10	vbci ()	Internal base-collector voltage.
11	qjci ()	Internal base-collector space charge.
12	cjci ()	Internal base-collector depletion capacitance.

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13	vbc _p ()	Vbc _p .
14	qjc _p ()	Qjc _p .
15	cjc _p ()	Cjc _p .
16	vbc _x ()	Vbc _x .
17	qjc _x ()	Qjc _x .
18	cjc _x ()	Cjc _x .
19	vsc ()	Vsc.
20	qjs ()	Substrate space charge.
21	cjs ()	Substrate capacitance.
22	qdsu ()	Substrate diffusion charge.
23	cdsu ()	Substrate diffusion capacitance.
24	vcei ()	Internal collector emitter voltage.
25	tf ()	Transit Time.
26	qf ()	Minority charge.
27	qdei ()	Internal base-emitter diffusion charge.
28	cdei ()	Internal base-emitter diffusion capacitance.
29	qdc _i ()	Internal base-collector diffusion charge.
30	cd _{ci} ()	Internal base-collector diffusion capacitance.
31	qp ()	Hole charge.
32	it ()	Transfer current.
33	itf ()	Transfer current.
34	itr ()	Transfer current.

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35	<code>ibet</code> ()	Tunneling current.
36	<code>gm</code> ()	Common-emitter transconductance.
37	<code>si</code> ()	Common emitter output conductance.
38	<code>sfb</code>	Sfb variable.
39	<code>srb</code>	Srb variable.
40	<code>sfc</code>	Sfc variable.
41	<code>src</code>	Src variable.
42	<code>rbi</code> ()	Internal base resistance.
43	<code>rbx</code> ()	External base resistance.
44	<code>rcx</code> ()	External collector resistance.
45	<code>re</code> ()	Re variable.
46	<code>rsu</code> ()	External collector resistance.
47	<code>is</code> ()	Substrate current.
48	<code>ft</code> ()	Unity small-signal current-gain frequency.
49	<code>pwr</code> ()	Power dissipation.
50	<code>iavl</code> ()	<code>lavl</code> .
51	<code>ibei</code> ()	<code>lbei</code> .
52	<code>ibci</code> ()	<code>lbci</code> .
53	<code>ibep</code> ()	<code>lbep</code> .
54	<code>ijbcx</code> ()	<code>ljbcx</code> .
55	<code>ijsc</code> ()	<code>ljsc</code> .
56	<code>ie</code> ()	<code>le</code> .

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57	<code>cbe</code> ()	Cbe.
58	<code>cbc</code> ()	Cbc.
59	<code>betar</code> ()	betar.
60	<code>beta</code> ()	beta.
61	<code>betadc</code> ()	betadc, the alias is beta.
62	<code>gmavl</code> ()	Transconductance for avalanche current.
63	<code>gms</code> ()	Transconductance of the parasitic substrate PNP.
64	<code>rpii</code> ()	Intrinsic input resistance.
65	<code>rpix</code> ()	Extrinsic input resistance.
66	<code>rmui</code> ()	Intrinsic feedback resistance.
67	<code>rmux</code> ()	Extrinsic feedback resistance.
68	<code>rmus</code> ()	Intrinsic substrate feedback resistance.
69	<code>ro</code> ()	Output resistance.
70	<code>ros</code> ()	Output resistance for the parasitic substrate PNP.
71	<code>cpii</code> ()	Total intrinsic BE capacitance.
72	<code>cpix</code> ()	Total extrinsic BE capacitance.
73	<code>cmui</code> ()	Total intrinsic BC capacitance.
74	<code>cmux</code> ()	Total extrinsic BC capacitance.
75	<code>ccs</code> ()	CS junction capacitance.
76	<code>crbi</code> ()	Shunt capacitance across RBI.
77	<code>vef</code> ()	Effective Forward Early voltage.
78	<code>ver</code> ()	Effective Inverse Early voltage.

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HiCUM Model (bht)

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-82	flvg	M-120	m	I-4	t0	M-23
af	M-84	f2vg	M-121	mbci	M-42	tbhrec	M-116
ahc	M-128	fav1	M-43	mbcx	M-65	tbvl	M-25
ajei	M-126	fbc	M-63	mbei	M-38	tef0	M-26
ajep	M-127	fbcpar	M-125	mbep	M-55	temp	OP-1
alarm	M-109	fbepar	M-119	mcf	M-10	tf	OP-25
alb	M-88	fcrbi	M-49	minr	M-105	thcs	M-28
alces	M-93	fdqr0	M-46	mode	M-1	tmax	M-107
alfav	M-89	fgeo	M-47	mrei	M-40	tmin	M-108
alhc	M-29	flcomp	M-130	mrep	M-57	tnom	M-86
alit	M-14	flnqs	M-131	msc	M-77	tr	M-35
aljei	M-18	flsh	M-129	msf	M-79	trise	I-2
aljep	M-53	fqi	M-48	msr	M-80	tsf	M-11
alqav	M-90	ft	OP-48	mvt0	M-110	tunode	M-117
alqf	M-36	fthc	M-30	pwr	OP-49	type	M-2
alt0	M-98	gm	OP-36	qavl	M-44	updatelevel	M-104
alvs	M-92	gmavl	OP-62	qdc1	OP-29	vbci	OP-10

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area	I-6	gms	OP-63	qdei	OP-27	vbcp	OP-13
beta	OP-60	gtfe	M-27	qdsu	OP-22	vbcx	OP-16
betadc	OP-61	hfc	M-12	qf	OP-26	vbei	OP-4
betar	OP-59	hfe	M-13	qjci	OP-11	vbep	OP-7
c10	M-5	hjci	M-8	qjcp	OP-14	vcei	OP-24
cbc	OP-58	hjei	M-9	qjcx	OP-17	vcex	M-31
cbcpar	M-124	iavl	OP-50	qjei	OP-5	vdci	M-20
cbe	OP-57	ib	OP-3	qjep	OP-8	vdcx	M-59
cbepar	M-118	ibci	OP-52	qjs	OP-20	vdei	M-16
ccox	M-62	ibcis	M-41	qp	OP-31	vdep	M-51
ccs	OP-75	ibcxs	M-64	qp0	M-6	vds	M-71
cdci	OP-30	ibei	OP-51	rbi	OP-42	vef	OP-77
cdei	OP-28	ibeis	M-37	rbi0	M-45	ver	OP-78
cdsu	OP-23	ibep	OP-53	rbx	M-67	version	M-103
ceox	M-66	ibeps	M-54	rbx	OP-43	vgb	M-87
cfbe	M-122	ibet	OP-35	rci0	M-32	vgc	M-111
cjci	OP-12	ibets	M-81	rcx	M-69	vge	M-112
cjci0	M-19	ic	OP-2	rcx	OP-44	vgs	M-113
cjcp	OP-15	ich	M-7	re	M-68	vlim	M-33
cjcx	OP-18	ie	OP-56	re	OP-45	vpt	M-34
cjcx0	M-58	ijbcx	OP-54	region	I-1	vptci	M-22

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cjei	OP-6	ijsc	OP-55	rmui	OP-66	vptcx	M-61
cjei0	M-15	imax	M-106	rmus	OP-68	vpts	M-73
cjep	OP-9	ireis	M-39	rmux	OP-67	vsc	OP-19
cjep0	M-50	ireps	M-56	ro	OP-69	zci	M-21
cjs	OP-21	is	OP-47	ros	OP-70	zcx	M-60
cjs0	M-70	iscs	M-76	rpii	OP-64	zei	M-17
cmui	OP-73	isnoisy	I-5	rpix	OP-65	zep	M-52
cmux	OP-74	it	OP-32	rsu	M-74	zetabet	M-115
cpii	OP-71	itf	OP-33	rsu	OP-46	zetaci	M-91
cpix	OP-72	itr	OP-34	rth	M-100	zetact	M-114
crbi	OP-76	itss	M-78	self_heating	I-3	zetacx	M-123
csu	M-75	kf	M-83	sfb	OP-38	zetarbi	M-94
cth	M-101	krbi	M-85	sfc	OP-40	zetarbx	M-95
debug	M-102	kt0	M-99	si	OP-37	zetarcx	M-96
debug	O-1	latb	M-3	srb	OP-39	zetare	M-97
dt0h	M-24	latl	M-4	src	OP-41	zs	M-72

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 1.20, and all of previous versions are supported with setting model parameter VERSION.

Compared to the previous L0 version, this new version contains some code related changes:

- 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 a void divide-by-zero.

This chapter contains the following information about the BHT0 model:

- [Equivalent Circuit](#) on page 325
- [Charge formulation of the internal transistor](#) on page 326
- [Derivation of the simplified transfer current equation](#) on page 327
- [Static base current components](#) on page 329
- [Depletion charges and capacitances](#) on page 329
- [Minority charges and capacitances](#) on page 329
- [Series Resistance](#) on page 331
- [Temperature Dependence](#) on page 331
- [Noise Model](#) on page 333

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HiCUM Level-0 Model (bht0)

- [Charge Storage Elements](#) on page 335
- [Series Resistance](#) on page 335
- [Temperature Effects](#) on page 336
- [Component Statements](#) on page 338

Equivalent Circuit

Figure 7-1 Large signal equivalent circuit of the simplified HiCUM version, HiCUM/L0

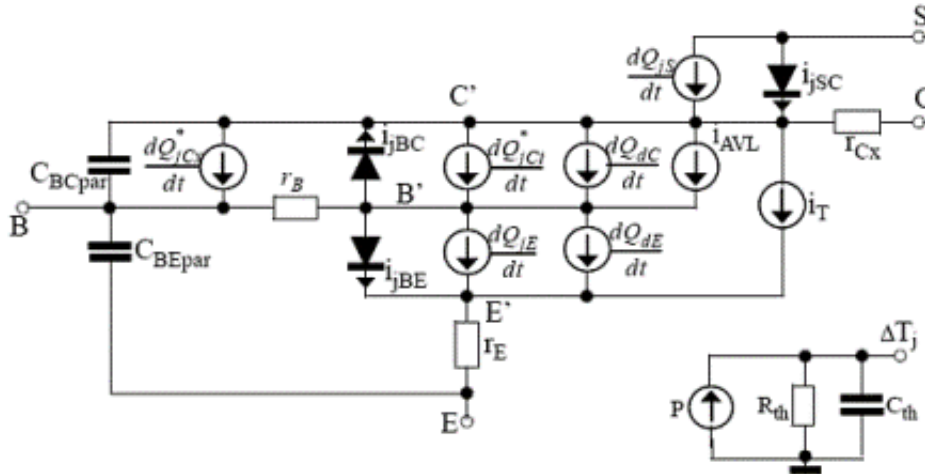


Figure 7-2 Small signal equivalent circuit of HiCUM/L0

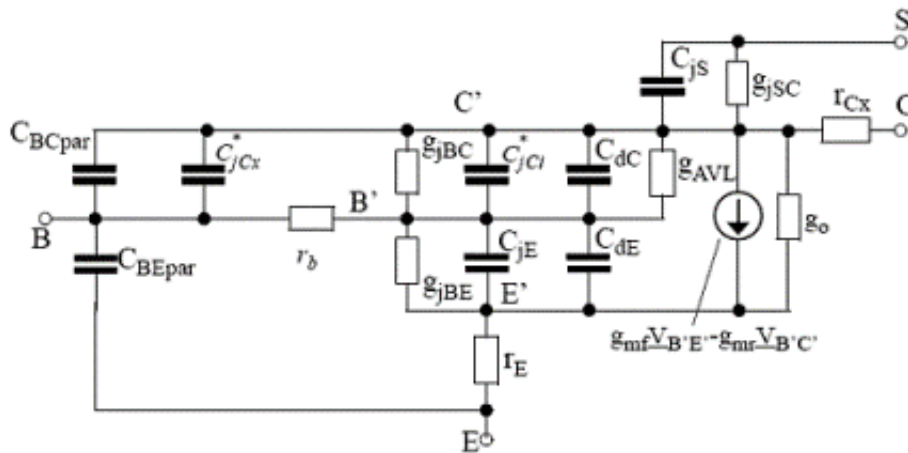
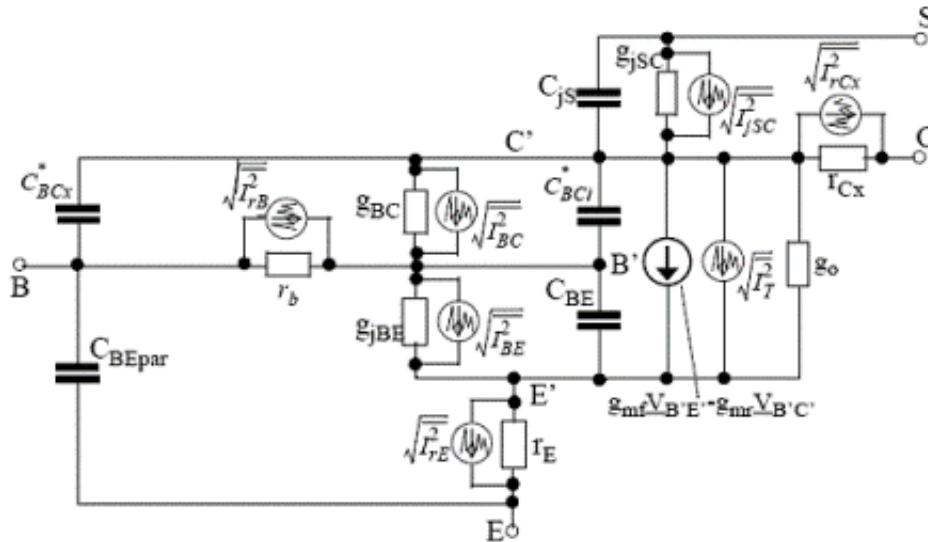


Figure 7-3 Small signal noise equivalent circuit of HICUM/L0 showing the noise sources with their RMS values used in a circuit simulator



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

$$\tau = \tau_{f0}(v_{B'C'}) + \Delta\tau_f(i_{Tf} v_{C'E'}) ,$$

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.

$$\Delta\tau_f = \left[\tau_{hcs} w^2 \left(1 + \frac{2I_{CK}}{i_{Tf} \sqrt{\left(1 - \frac{I_{CK}}{i_{Tf}}\right)^2 + a_{hc}}} \right) + \tau_{fE0} \left(\frac{i_{Tf}}{I_{CK}} \right)^{g_{\tau E}} \right] .$$

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:

$$Q_{p,I} = Q_{p0} + h_{je1} Q_{jE1} + h_{jcl} Q_{jC1} = Q_{p0} + h_{je1} (Q_{jE1,op} + \Delta Q_{jE1}) + h_{jcl} Q_{jC1}.$$

$$Q_{p0}^* = Q_{p0} + h_{je1} Q_{jE1,op}.$$

$$\frac{Q_{p,I}}{Q_{p0}^*} = 1 + \frac{h_{je1} \Delta Q_{jE1}}{Q_{p0}^*} + \frac{h_{jcl} Q_{jC1}}{Q_{p0}^*} + \frac{Q_{f,I}}{Q_{p0}^*} + \frac{Q_{r,I}}{Q_{p0}^*}$$

The resulting transfer current expression reads

$$i_{Tf} = \frac{\tilde{I}_S}{Q_{p,I}/Q_{p0}^*} \exp\left(\frac{V_{BE}}{V_T}\right),$$

with a modified saturation current

$$\tilde{I}_S = c_{10} / Q_{p0}^*.$$

The forward transfer current equation can be written in a more familiar form:

$$i_{Tf} = \frac{\tilde{I}_S}{1 + \frac{h_{jcl} Q_{jC1}}{Q_{p0}^*} + \frac{Q_{f,I}}{Q_{p0}^*} + \frac{Q_{r,I}}{Q_{p0}^*}} \exp\left(\frac{V_{BE}}{m_{Cf} V_T}\right).$$

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 $V_{B'E',op}$ 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:

$$V_{Ef} = \frac{Q_{p0}^*}{h_{jci}C_{jCi0}}.$$

The critical (or knee) current of the D.C. forward transfer curve is defined as:

$$I_{Qf} = Q_{p0}^*/\tau_{r0}(V_{B'C'} = 0)$$

$$I_{Qr} = Q_{p0}^*/\tau_f$$

Quadratic equation for normalized charge:

$$q_{p,I} = \underbrace{1 + \frac{q_{jci}}{V_{Ef}}}_{q_j} + \underbrace{\left(\frac{i_{Tf}}{I_{Qf}} + \frac{i_{Tr}}{I_{Qr}} \right)}_{q_m} \cdot \frac{1}{q_{p,I}}.$$

The final formulaiton for the HICUM/L0 transfer current components:

$$\boxed{i_{Tf} = \frac{i_{Tfn}}{1 + \frac{\Delta q_{fn}}{q_{p,I}}}} \quad \text{and} \quad \boxed{i_{Tr} = \frac{i_{Trn}}{1 + \frac{\Delta q_{fn}}{q_{p,I}}}}$$

The total transfer current in HICUM/L0 reads:

$$i_T = i_{Tf} - i_{Tr}$$

Static base current components

$$i_{jBE} = I_{BES} \left[\exp\left(\frac{v_{BE}}{m_{BE}V_T}\right) - 1 \right] + I_{RES} \left[\exp\left(\frac{v_{BE}}{m_{RE}V_T}\right) - 1 \right],$$

$$i_{jBC} = I_{jBCS} \left[\exp\left(\frac{v_{BC}}{m_{BC}V_T}\right) - 1 \right]$$

$$i_{AVL} = k_{AVL} \frac{i_{Tf}}{C_c^{1/z_{ci}}} \exp\left(-e_{AVL} C_c^{\left(\frac{1}{z_{ci}} - 1\right)}\right)$$

$$i_{jSC} = I_{SCS} \left[\exp\left(\frac{v_{SC}}{m_{SC}V_T}\right) - 1 \right]$$

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:

$$\tau_f(v_{CE}, i_{Tf}) = \tau_f(v_{BC}) + \Delta\tau_f(v_{CE}, i_{Tf})$$

Low curent densities

The transit time reads:

$$\tau_{f0}(v_{BC'}) = \tau_0 + \Delta\tau_{0h}(c-1) + \tau_{Bfvi} \left(\frac{1}{c} - 1 \right)$$

The respective forward minority charge is given by:

$$Q_{f0} = \tau_{f0} i_{Tf}$$

Medium and high curent 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.:

$$I_{CK} = \frac{v_{ceff}}{r_{Cf0}} \frac{1}{\sqrt{1 + \left(\frac{v_{ceff}}{V_{lim}} \right)^2}} \left[1 + \frac{x + \sqrt{x^2 + 10^{-3}}}{2} \right]$$

$$v_{ceff} = V_T \left[1 + \frac{1}{2} \left\{ u_{vc} + \sqrt{u_{vc}^2 + 1.921812} \right\} \right]$$

$$\Delta Q_{fh} = \tau_{hcs} i_{Tf} w^2$$

Series Resistance

Internal base resistance

$$r_{Bi} = r_i \psi(\eta)$$

$$\psi(\eta) = \frac{\ln(1 + \eta)}{\eta}$$

$$\eta = f_{geo} \frac{r_i I_{BE}}{V_T}$$

$$r_i = \frac{r_{Bi0}}{f_{Qz}}$$

$$f_{Qz} = \frac{1}{2} \left\{ Q_z + \sqrt{Q_z^2 + 0.01} \right\}$$

$$Q_z = \left(1 + \frac{q_{jE}}{V_{r0E}} + \frac{q_{jCl}}{V_{r0C}} + \frac{I_{Tf}}{I_{Qf}} + \frac{I_{Tr}}{I_{Qr}} \right)$$

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

$$V_g(T_0) = k_2 + V_g(0)$$

$$I_S^*(T) = I_S^*(T_0) \left(\frac{T}{T_0}\right)^{\zeta_{scr}} \exp\left[\frac{V_{Gb}}{V_T(T)} \left(\frac{T}{T_0} - 1\right)\right]$$

$$I_{BES}(T) = I_{BES}(T_0) \left(\frac{T}{T_0}\right)^{\zeta_{BET}} \exp\left[\frac{V_{Gb}}{V_T(T)} \left(\frac{T}{T_0} - 1\right)\right]$$

$$I_{RES}(T) = I_{RES}(T_0) \left(\frac{T}{T_0}\right)^{m_r/2} \exp\left[\frac{V_{Gb}}{V_T(T)} \left(\frac{T}{T_0} - 1\right)\right]$$

$$I_{BCS}(T) = I_{BCS}(T_0) \left(\frac{T}{T_0}\right)^{\zeta_{BCI}} \exp\left[\frac{V_{Gbx}}{V_T(T)} \left(\frac{T}{T_0} - 1\right)\right]$$

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 $\zeta_{scr} = m_g - 1.5$

$$C_{j0}(T) = C_{j0}(T_0) \left(\frac{V_D(T_0)}{V_D(T)}\right)^z$$

$$V_{Dj}(T_0) = 2V_{T0} \ln \left[\exp\left(\frac{V_D(T_0)}{2V_{T0}}\right) - \exp\left(-\frac{V_D(T_0)}{2V_{T0}}\right) \right]$$

$$V_{Dj}(T) = V_{Dj}(T_0) \left(\frac{T}{T_0}\right) + V_g \left(1 - \frac{T}{T_0}\right) - m_g V_{T0} \ln\left(\frac{T}{T_0}\right)$$

$$V_D(T) = V_{Df}(T) + 2V_T \ln \left(\frac{1 + \sqrt{1 + 4 \exp\left(-\frac{V_{Df}(T)}{V_T}\right)}}{2} \right)$$

$$\tau_0(T) = \tau_0(T_0)[1 + a_{lt0}(T - T_0) + k_{t0}(T - T_0)^2]$$

$$r_{Cf0}(T) = r_{Cf0}(T_0) \left(\frac{T}{T_0}\right)^{\zeta_{cf}}$$

$$V_{CEs}(T) = V_{CEs}(T_0)[1 + (T - T_0)\alpha_{CEs}]$$

$$r_{Cx}(T) = r_{Cx}(T_0) \left(\frac{T}{T_0}\right)^{\zeta_{rcx}}$$

$$r_{Bx}(T) = r_{Bx}(T_0) \left(\frac{T}{T_0}\right)^{\zeta_{rbx}}$$

$$r_{Bf0}(T) = r_{Bf0}(T_0) \left(\frac{T}{T_0}\right)^{\zeta_{rbf}}$$

$$r_E(T) = r_E(T_0) \left(\frac{T}{T_0}\right)^{\zeta_{re}}$$

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

$$i_T = c_{10} \cdot \frac{\exp(V_{B'E'}/V_T) - \exp(V_{B'C'}/V_T)}{Q_{p0} + h_{jei}Q_{jei} + h_{jci}Q_{jci} + Q_{fT} + Q_{rT}}$$

$$i_{Tf} = \frac{I^*_S}{1 + \frac{h_{jci}Q_{jci}}{Q_{p0}} + \frac{Q_{fT}}{Q_{p0}} + \frac{Q_{rT}}{Q_{p0}}} \cdot \exp\left(\frac{v_{B'E'}}{m_{Cf}V_T}\right)$$

$$I^*_S = (c_{10}/Q^*_{p0}) \exp((h_{jei}C_{jei,op}v_{B'E',op})/Q^*_{p0})$$

$$V_{Ef} = \frac{Q^*_{p0}}{h_{jci}C_{jci0}}$$

$$I_{Qf} = Q^*_{p0}/\tau_{f0}(v_{B'C'} = 0)$$

$$I_{Qr} = Q^*_{p0}/\tau_f$$

$$q_{pT} = \frac{1 + q_{jCi}/V_{Ef}}{q_j} + \frac{i_{Tfl}/I_{Qf} + i_{Trl}/I_{Qr}}{q_m/q_{pT}}$$

$$i_{Trl} = \frac{I^*_s}{q_{pT}} \exp\left(\frac{v_{B'C'}}{m_{Cr}V_T}\right)$$

$$\frac{Q_{fT} - \tau_{f0}i_{Tfl}}{Q^*_{p0}} \cong \Delta q_{fh} = \left(w^2 + t_{fh}I_{CK}\right) \frac{i_{Tfl}}{I_{Qfh}}$$

$$i_T = \frac{i_{Tfl} - i_{Trl}}{1 + \Delta q_{fh}/q_{pT}}$$

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.

$$\Delta\tau_f = \tau_{hcs}w^2 \left(1 + \frac{2l_{CK}}{i_{Tf}\sqrt{(1-l_{CK}/i_{Tf})^2 + a_{hc}}}\right) + \tau_{fE0} \left(\frac{i_{Tf}}{I_{CK}}\right)^{s_{\tau fE}}$$

$$Q_f = ((Q_{f0} + dQ_{ef}) + dQ_{fh})$$

$$Q_r = \tau_r i_{Tr}$$

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

$$q_{tt0} = T_{dev}/T_{nom}$$

$$I_s(t) = I_S * \exp(ZETACT * \ln(q_{tt0}) + VGB/VT * (q_{tt0} - 1))$$

$$I_{bes}(t) = IBES * \exp(ZETABET * \ln(q_{tt0}) + VGE/VT * (q_{tt0} - 1))$$

$$I_{res}(t) = IRES * \exp(ZETABET * \ln(q_{tt0}) + v_{gbe}/VT * (q_{tt0} - 1))$$

$$I_{bcs}(t) = IBCS * \exp(ZETABCI * \ln(q_{tt0}) + VGC/VT * (q_{tt0} - 1))$$

$$I_{scs}(t) = ISCS * \exp(ZETASCT * \ln(q_{tt0}) + VGS/VT * (q_{tt0} - 1))$$

$$vd_{j0} = 2 * VT * \ln(\exp(0.5 * vd/VT) - \exp(-0.5 * vd/VT))$$

$$vd_{jt} = vd_{j0} * q_{tt0} + v_g * (1 - q_{tt0}) - m_g * VT * \ln(q_{tt0})$$

$$vd_t = vd_{jt} + 2 * VT * \ln(0.5 * (1 + \sqrt{1 + 4 * \exp(-vd_{jt}/VT)}))$$

where v_g can be replaced with v_{gbe} , v_{gbc} , or v_{gsc}

$$C_{je0}(t) = CJE0 * \exp(ZE * \ln(VDE/vd_t))$$

$$C_{jci0}(t) = CJCI0 * \exp(ZCI * \ln(VDCI/vd_t))$$

$$C_{jcx0}(t) = CJCX0 * \exp(ZCX * \ln(VDCX/vd_t))$$

Virtuoso Simulator Components and Device Models Reference

HiCUM Level-0 Model (bht0)

$$Cjs0(t) = CJS0 * \exp(ZS * \ln(VDS/vd_t))$$

$$Rci0(t) = RCI0 * \exp(ZETACI * \ln(qtt0))$$

$$Vlim(t) = VLIM * \exp((ZETACI - avs) * \ln(qtt0))$$

$$Vces(t) = VCES * (1 + ALCES * dt)$$

$$T0(t) = T0 * (1 + ALT0 * dt + KT0 * dT * dT)$$

$$Thcs(t) = THCS * \exp((ZETACI - 1) * \ln_qtt0)$$

$$zetatef = ZETABET - ZETACT - 0.5$$

$$dvg = VGB - VGE$$

$$Tef0(t) = TEF0 * \exp(ZETATEF * \ln(qtt0) - dvg/VT * (qtt0 - 1))$$

$$Rbx(t) = RBX * \exp(ZETARBX * \ln(qtt0))$$

$$Rcx(t) = RCX * \exp(ZETARCX * \ln(qtt0))$$

$$rbi0(t) = RBI0 * \exp(ZETARBI * \ln(qtt0))$$

$$Re(t) = RE * \exp(ZETARE * \ln(qtt0))$$

$$Eavl(t) = EAVL * \exp(ALEAV * dT) \quad /$$

$$Kavl(t) = KAVL * \exp(ALKAV * dT)$$

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.

Component Statements

The device is supported within altergroups.

Instance Definition

```
Name c b e s [tnode] ModelName parameter=value ...
```

Instance Parameters

- | | | |
|---|-----------------------|-------------------------------------|
| 1 | exp_cr=80.0 | instance parameter: no description. |
| 2 | cmi_limexp_method=1.0 | instance parameter: no description. |
| 3 | cmi_compactable=1.0 | instance parameter: no description. |
| 4 | m=1.0 | instance parameter: no description. |

Virtuoso Simulator Components and Device Models Reference

HiCUM Level-0 Model (bht0)

5 dt=0.0 K Temperature change for particular transistor.

Model Definition

```
model modelName bht0 parameter=value ...
```

Model Parameters

1	is=1.0e-16 A	(Modified) saturation current.
2	mcf=1.00	Non-ideality coefficient of forward collector current.
3	mcr=1.00	Non-ideality coefficient of reverse collector current.
4	vef=1.0e6 V	forward Early voltage (normalization volt.).
5	ver=1.0e6 V	reverse Early voltage (normalization volt.).
6	iqf=1.0e6 A	forward d.c. high-injection toll-off current.
7	fiqf=0	flag for turning on base related critical current.
8	iqr=1.0e6 A	inverse d.c. high-injection roll-off current.
9	iqfh=1.0e6 A	high-injection correction current.
10	tfh=0.0	high-injection correction factor.
11	ahcx=0	Smoothing factor for the d.c. injection width.
12	ibes=1e-18 A	BE saturation current.
13	mbe=1.0	BE non-ideality factor.
14	ires=0.0 A	BE recombination saturation current.
15	mre=2.0	BE recombination non-ideality factor.
16	ibcs=0.0 A	BC saturation current.
17	mbc=1.0	BC non-ideality factor.
18	cje0=1.0e-20 F	Zero-bias BE depletion capacitance.

Virtuoso Simulator Components and Device Models Reference

HiCUM Level-0 Model (bht0)

19	vde=0.9 V	BE built-in voltage.
20	ze=0.5	BE exponent factor.
21	aje=2.5	Ratio of maximum to zero-bias value.
22	vdedc=0.9 V	BE charge built-in voltage for d.c. transfer current.
23	zedc=0.5	charge BE exponent factor for d.c. transfer current.
24	ajedc=2.5	BE capacitance ratio Ratio maximum to zero-bias value for d.c. transfer current.
25	t0=0.0 s	low current transit time at $V_{bici}=0$.
26	dt0h=0.0	model parameter: no description.
27	tbvl=0.0 s	SCR width modulation contribution.
28	tef0=0.0 s	Storage time in neutral emitter.
29	gte=1.0	Exponent factor for emitter transit time.
30	thcs=0.0 s	Saturation time at high current densities.
31	ahc=0.1	Smoothing factor for current dependence.
32	tr=0.0 s	Storage time at inverse operation.
33	rci0=150 Ohm	Low-field collector resistance under emitter.
34	vlim=0.5 V	Voltage dividing ohmic and satur.region.
35	vpt=100 V	Punch-through voltage.
36	vces=0.1 V	Saturation voltage.
37	cjci0=1.0e-20 F	Total zero-bias BC depletion capacitance.
38	vdci=0.7 V	BC built-in voltage.
39	zci=0.333	BC exponent factor.

Virtuoso Simulator Components and Device Models Reference

HiCUM Level-0 Model (bht0)

40	vptci=100 V	Punch-through voltage of BC junction.
41	cjcx0=1.0e-20 F	Zero-bias external BC depletion capacitance.
42	vdcx=0.7 V	External BC built-in voltage.
43	zcx=0.333	External BC exponent factor.
44	vptcx=100 V	Punch-through voltage.
45	fbc=1.0	Split factor = C_{jci0}/C_{jc0} .
46	rbi0=0.0 Ohm	Internal base resistance at zero-bias.
47	vr0e=2.5 V	forward Early voltage (normalization volt.).
48	vr0c=1.0e6 V	forward Early voltage (normalization volt.).
49	fgeo=0.656	Geometry factor.
50	rbx=0.0 Ohm	External base series resistance.
51	rcx=0.0 Ohm	Emitter series resistance.
52	re=0.0 Ohm	External collector series resistance.
53	itss=0.0 A	Substrate transistor transfer saturation current.
54	msf=1.0	Substrate transistor transfer current non-ideality factor.
55	iscs=0.0 A	SC saturation current.
56	msc=1.0	SC non-ideality factor.
57	cjs0=1.0e-20 F	Zero-bias SC depletion capacitance.
58	vds=0.3 V	SC built-in voltage.
59	zs=0.3	External SC exponent factor.
60	vpts=100 V	SC punch-through voltage.
61	cbcpar=0.0 F	Collector-base isolation (overlap) capacitance.

Virtuoso Simulator Components and Device Models Reference
HiCUM Level-0 Model (bht0)

62	cbepar=0.0 F	Emitter-base oxide capacitance.
63	eavl=0.0	Exponent factor.
64	kavl=0.0	Prefactor.
65	kf=0.0 M ^(1-AF)	flicker noise coefficient.
66	af=2.0	flicker noise exponent factor.
67	vgb=1.2 V	Bandgap-voltage.
68	vge=1.17 V	Effective emitter bandgap-voltage.
69	vgc=1.17 V	Effective collector bandgap-voltage.
70	vgs=1.17 V	Effective substrate bandgap-voltage.
71	f1vg=(-1.02377e-4) V/K	Coefficient K1 in T-dependent bandgap equation.
72	f2vg=4.3215e-4 V/K	Coefficient K2 in T-dependent bandgap equation.
73	alt0=0.0 1/K	First-order TC of tf0.
74	kt0=0.0 1/K ²	Second-order TC of tf0.
75	zetact=3.0	Exponent coefficient in transfer current temperature dependence.
76	zetabet=3.5	Exponent coefficient in BE junction current temperature dependence.
77	zetaci=0.0	TC of epi-collector diffusivity.
78	alvs=0.0 1/K	Relative TC of satur.drift velocity.
79	alces=0.0 1/K	Relative TC of vces.
80	zetarbi=0.0	TC of internal base resistance.
81	zetarbx=0.0	TC of external base resistance.

Virtuoso Simulator Components and Device Models Reference

HiCUM Level-0 Model (bht0)

82	zetarcx=0.0	TC of external collector resistance.
83	zetare=0.0	TC of emitter resistances.
84	zetiqlf=0.0	TC of iqlf.
85	alkav=0.0 1/K	TC of avalanche prefactor.
86	aleav=0.0 1/K	TC of avalanche exponential factor.
87	zetarth=0.0	Exponent factor for temperature dependent thermal resistance.
88	flsh=0	Flag for self-heating calculation.
89	rth=0.0 K/W	Thermal resistance.
90	cth=0.0 Ws/K	Thermal capacitance.
91	nnp=1	model type flag for npn.
92	ppn=0	model type flag for pnp.
93	tnom=27 C	Temperature for which parameters are valid.
94	version=1.2	Model version selector, possible value is 1.0, 1.11, 1.12 and 1.2.

Output Parameters

1	c	external collector node.
2	b	external base node.
3	e	external emitter node.
4	s	external substrate node.
5	tnode	local temperature rise node.
6	ci	internal collector node.
7	bi	internal base node.
8	ei	internal emitter node.

Virtuoso Simulator Components and Device Models Reference

HiCUM Level-0 Model (bht0)

Operating Point Parameters

1	exp_cr=80.0	instance parameter: no description.
2	cmi_limexp_method=1.0	instance parameter: no description.
3	cmi_compactable=1.0	instance parameter: no description.
4	m=1.0	instance parameter: no description.
5	dt=0.0 K	Temperature change for particular transistor.
6	qjci (C)	B-C internal junction charge.
7	qjei (C)	B-E internal junction charge.
8	cjei (F)	B-E internal junction capacitance.
9	it (A)	Transfer Current.
10	ijbc (A)	Base-collector diode current.
11	iavl (A)	Avalanche current.
12	ijsc (A)	Substrate-collector diode current.
13	leei (A)	Current through external to internal emitter node.
14	lcci (A)	Current through external to internal collector node.
15	lbbi (A)	Current through external to internal base node.
16	lbici (A)	Base-collector diode current minus the avalanche current.
17	ijbe (A)	Base-emitter diode 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

Virtuoso Simulator Components and Device Models Reference

HiCUM Level-0 Model (bht0)

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.

Ibbi	OP-15	dt	OP-5	m	I-4	vde	M-19
Ibici	OP-16	dt0h	M-26	m	OP-4	vdedc	M-22
Icci	OP-14	e	O-3	mbc	M-17	vds	M-58
Ieei	OP-13	eavl	M-63	mbe	M-13	vef	M-4
af	M-66	ei	O-8	mcf	M-2	ver	M-5
ahc	M-31	exp_cr	I-1	mcr	M-3	version	M-94
ahcx	M-11	exp_cr	OP-1	mre	M-15	vgb	M-67
aje	M-21	flvg	M-71	msc	M-56	vgc	M-69
ajedc	M-24	f2vg	M-72	msf	M-54	vge	M-68
alces	M-79	fbc	M-45	npn	M-91	vgs	M-70
aleav	M-86	fgeo	M-49	pnp	M-92	vlim	M-34
alkav	M-85	fiqf	M-7	qjci	OP-6	vpt	M-35
alt0	M-73	flsh	M-88	qjei	OP-7	vptci	M-40
alvs	M-78	gte	M-29	rbi0	M-46	vptcx	M-44
b	O-2	iavl	OP-11	rbx	M-50	vpts	M-60
bi	O-7	ibcs	M-16	rci0	M-33	vr0c	M-48
c	O-1	ibes	M-12	rcx	M-51	vr0e	M-47
cbcpa	M-61	ijbc	OP-10	re	M-52	zci	M-39

Virtuoso Simulator Components and Device Models Reference

HiCUM Level-0 Model (bht0)

cbepar	M-62	ijbe	OP-17	rth	M-89	zcx	M-43
ci	O-6	ijsc	OP-12	s	O-4	ze	M-20
cjci0	M-37	iqf	M-6	t0	M-25	zedc	M-23
cjcx0	M-41	iqfh	M-9	tbvl	M-27	zetabet	M-76
cje0	M-18	iqr	M-8	tef0	M-28	zetaci	M-77
cjei	OP-8	ires	M-14	tfh	M-10	zetact	M-75
cjs0	M-57	is	M-1	thcs	M-30	zetarbi	M-80
cmi_compactable I-3		iscs	M-55	tnode	O-5	zetarbx	M-81
cmi_compactable OP-3		it	OP-9	tnom	M-93	zetarcx	M-82
cmi_limexp_method I-2		itss	M-53	tr	M-32	zetare	M-83
cmi_limexp_method OP-2		kavl	M-64	vcas	M-36	zetarh	M-87
cth	M-90	kf	M-65	vdci	M-38	zetiql	M-84
dt	I-5	kt0	M-74	vdcx	M-42	zs	M-59

Mextram Models (bjt504, bjt504t, bjtd504, and bjtd504t)

This chapter describes the component statements for the models listed below. See Philips_Models for more information on these models.

- [Compact Bipolar-Transistor Model \(bjt504\)](#) on page 348
- [Compact Bipolar-Transistor Model \(bjt504\)](#) on page 348
- [Compact Bipolar-Transistor Model \(bjtd504\)](#) on page 378
- [Compact Bipolar-Transistor Model \(bjt504\)](#) on page 348

Compact Bipolar-Transistor Model (bjt504)

Instance Definition

Name c b e s 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 bjt504 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 modelling of reverse current gain. |
| 5 | exphi=1 | Flag for the distributed high-frequency effects in transient. |
| 6 | exavl=0 | Flag for extended modelling 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. |

Virtuoso Simulator Components and Device Models Reference

Mextram Models (bjt504, bjt504t, bjtd504, and bjtd504t)

10	$v_{ef}=44$ V	Forward Early voltage.
11	$b_f=215$	Ideal forward current gain.
12	$i_{bf}=2.7e-15$ A	Saturation current of the non-ideal forward base current.
13	$m_{lf}=2$	Non ideality factor of the non-ideal forward base current.
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	$s_{fh}=0.3$	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	$a_{xi}=0.3$	Smoothness parameter for the onset of quasi-saturation.
30	$c_{je}=7.3e-14$ F	Zero-bias emitter-base depletion capacitance.

Virtuoso Simulator Components and Device Models Reference

Mextram Models (bjt504, bjt504t, bjtd504, and bjtd504t)

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	$deg=0$ 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.

Virtuoso Simulator Components and Device Models Reference

Mextram Models (bjt504, bjt504t, bjtd504, and bjtd504t)

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>iss=4.8e-17 A</code>	Base-substrate saturation current.
67	<code>iks=0.00025 A</code>	Base-substrate high injection knee current.
68	<code>cjs=3.15e-13 F</code>	Zero-bias collector-substrate depletion capacitance.
69	<code>vds=0.62 V</code>	Collector-substrate diffusion voltage.
70	<code>ps=0.34</code>	Collector-substrate grading coefficient.
71	<code>vgs=1.2 V</code>	Band-gap voltage of the substrate.

Virtuoso Simulator Components and Device Models Reference

Mextram Models (bjt504, bjt504t, bjtd504, and bjtd504t)

72	<code>as=1.58</code>	For a closed buried layer: $A_s=A_c$: for an open buried layer: $A_s=A_{epi}$.
73	<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> .
74	<code>imax=1.0 A</code>	Explosion current.
75	<code>tnom (deg. C)</code>	alias of <code>tnom</code> .
76	<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 modelling of reverse current gain.
4	<code>exphi</code>	Flag for the distributed high-frequency effects in transient.
5	<code>exavl</code>	Flag for extended modelling 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

Mextram Models (bjt504, bjt504t, bjtd504, and bjtd504t)

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

Mextram Models (bjt504, bjt504t, bjtd504, and bjtd504t)

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	aepe	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

Mextram Models (bjt504, bjt504t, bjtd504, and bjtd504t)

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: $A_s=A_{epi}$.

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.

Virtuoso Simulator Components and Device Models Reference

Mextram Models (bjt504, bjt504t, bjtd504, and bjtd504t)

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.
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.

Virtuoso Simulator Components and Device Models Reference

Mextram Models (bjt504, bjt504t, bjtd504, and bjtd504t)

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	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.

Virtuoso Simulator Components and Device Models Reference

Mextram Models (bjt504, bjt504t, bjtd504, and bjtd504t)

49	grbv _x (1/Ω)	Early-effect on base resistance.
50	grbv _y (1/Ω)	Early-effect on base resistance.
51	grbv _z (1/Ω)	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	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.
58	C _{bez} (F)	Early effect on b-e diffusion charge.
59	C _{bcx} (F)	Early effect on b-c diffusion charge.
60	C _{bcy} (F)	Capacitance floor b-c junction.
61	C _{bcz} (F)	Capacitance floor b-c junction.
62	C _{bcex} (F)	Capacitance extrinsic b-c junction.
63	XC _{bcex} (F)	Capacitance extrinsic b-c junction.
64	C _{b1b2} (F)	Capacitance AC current crowding.
65	C _{b1b2x} (F)	Cross-capacitance AC current crowding .
66	C _{b1b2y} (F)	Cross-capacitance AC current crowding.
67	C _{b1b2z} (F)	Cross-capacitance AC current crowding.
68	g _m (1/Ω)	Transconductance.
69	beta	Current amplification.
70	g _{out} (1/Ω)	Output conductance.

Virtuoso Simulator Components and Device Models Reference

Mextram Models (bjt504, bjt504t, bjtd504, and bjtd504t)

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	XI_{sub} (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	xg_S ($1/\Omega$)	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.

Virtuoso Simulator Components and Device Models Reference

Mextram Models (bjt504, bjt504t, bjtd504, and bjtd504t)

BetaDC	OP-3	XIsub	OP-82	gSf	OP-87	rcc	O-24
Cb1b2	OP-64	XQex	OP-33	gm	OP-68	rcv	M-26
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	grbvx	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

Virtuoso Simulator Components and Device Models Reference

Mextram Models (bjt504, bjt504t, bjtd504, and bjtd504t)

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
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

Virtuoso Simulator Components and Device Models Reference

Mextram Models (bjt504, bjt504t, bjtd504, and bjtd504t)

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
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 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 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 modelling of reverse current gain. |
| 5 | exphi=1 | Flag for the distributed high-frequency effects in transient. |
| 6 | exavl=0 | Flag for extended modelling of avalanche currents. |

Virtuoso Simulator Components and Device Models Reference

Mextram Models (bjt504, bjt504t, bjtd504, and bjtd504t)

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	$xibi=0$	Part of ideal base current that belongS to the sidewall.
15	$bri=7$	Ideal reverse current gain.
16	$ibr=1e-15$ A	Saturation current of the non-ideal reverse base current.
17	$vlr=0.2$ V	Cross-over voltage of the non-ideal reverse base current.
18	$xext=0.63$	Part of I_{ex} , Q_{tex} , Q_{ex} and I_{sub} that depends on V_{bc1} instead of V_{b1c1} .
19	$wavl=1.1e-06$ m	Epilayer thickness used in weak-avalanche model.
20	$vavl=3$ V	Voltage determining curvature of avalanche current.
21	$sfh=0.3$	Current spreading factor of avalanche model (when EXAVL=1).
22	$re=5$ Ω	Emitter resistance.
23	$rbc=23$ Ω	Constant part of the base resistance.
24	$rbv=18$ Ω	Zero-bias value of the variable part of the base resistance.
25	$rcc=12$ Ω	Constant part of collector resistance.
26	$rcv=150$ Ω	Resistance of the un-modulated epilayer.
27	$scrcv=1.25e+03$ Ω	Space charge resistance of the epilayer.

Virtuoso Simulator Components and Device Models Reference

Mextram Models (bjt504, bjt504t, bjtd504, and bjtd504t)

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.
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.

Virtuoso Simulator Components and Device Models Reference

Mextram Models (bjt504, bjt504t, bjtd504, and bjtd504t)

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>iss=4.8e-17 A</code>	Base-substrate saturation current.
67	<code>iks=0.00025 A</code>	Base-substrate high injection knee current.
68	<code>cjs=3.15e-13 F</code>	Zero-bias collector-substrate depletion capacitance.

Virtuoso Simulator Components and Device Models Reference

Mextram Models (bjt504, bjt504t, bjtd504, and bjtd504t)

69	<code>vds=0.62 V</code>	Collector-substrate diffusion voltage.
70	<code>ps=0.34</code>	Collector-substrate grading coefficient.
71	<code>vgs=1.2 V</code>	Band-gap voltage of the substrate.
72	<code>as=1.58</code>	For a closed buried layer: $A_s=A_c$: for an open buried layer: $A_s=A_{epi}$.
73	<code>rth=300 K/W</code>	Thermal resistance.
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 modelling of reverse current gain.
4	<code>exphi</code>	Flag for the distributed high-frequency effects in transient.
5	<code>exavl</code>	Flag for extended modelling 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

Mextram Models (bjt504, bjt504t, bjtd504, and bjtd504t)

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	x_{ibi}	Part of ideal base current that belongS to the sidewall.
14	b_{ri}	Ideal reverse current gain.
15	i_{br} (A)	Saturation current of the non-ideal reverse base current.
16	v_{lr} (V)	Cross-over voltage of the non-ideal reverse base current.
17	x_{ext}	Part of I_{ex} , Q_{tex} , Q_{ex} and I_{sub} that depends on V_{bc1} instead of V_{b1c1} .
18	w_{avl} (M)	Epilayer thickness used in weak-avalanche model.
19	v_{avl} (V)	Voltage determining curvature of avalanche current.
20	s_{fh}	Current spreading factor of avalanche model (when $EXAVL=1$).
21	r_e (Ω)	Emitter resistance.
22	r_{bc} (Ω)	Constant part of the base resistance.
23	r_{bv} (Ω)	Zero-bias value of the variable part of the base resistance.
24	r_{cc} (Ω)	Constant part of collector resistance.
25	r_{cv} (Ω)	Resistance of the un-modulated epilayer.
26	s_{rcv} (Ω)	Space charge resistance of the epilayer.
27	i_{hc} (A)	Critical current for velocity saturation in the epilayer.
28	axi	Smoothness parameter for the onset of quasi-saturation.
29	c_{je} (F)	Zero-bias emitter-base depletion capacitance.

Virtuoso Simulator Components and Device Models Reference

Mextram Models (bjt504, bjt504t, bjtd504, and bjtd504t)

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.
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.

Virtuoso Simulator Components and Device Models Reference

Mextram Models (bjt504, bjt504t, bjtd504, and bjtd504t)

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.
60	<code>dvgte (V)</code>	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 (A)</code>	Base-substrate saturation current.
66	<code>iks (A)</code>	Base-substrate high injection knee current.
67	<code>cjs (F)</code>	Zero-bias collector-substrate depletion capacitance.
68	<code>vds (V)</code>	Collector-substrate diffusion voltage.
69	<code>ps</code>	Collector-substrate grading coefficient.
70	<code>vgs (V)</code>	Band-gap voltage of the substrate.

Virtuoso Simulator Components and Device Models Reference

Mextram Models (bjt504, bjt504t, bjtd504, and bjtd504t)

71	as	For a closed buried layer: $A_s=A_c$, for an open buried layer: $A_s=A_{epi}$.
72	rth (K/W)	Thermal resistance.
73	cth (J/K)	Thermal capacitance.
74	ath	Temperature coefficient of the thermal resistance.

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.
9	In (A)	Main current.
10	Ic1c2 (A)	Epilayer current.
11	Ib1b2 (A)	Pinched-base current.
12	Ib1 (A)	Ideal forward base current.
13	SIb1 (A)	Ideal side-wall base current.
14	Ib2 (A)	Non-ideal forward base current.
15	Ib3 (A)	Non-ideal reverse base current.
16	Iex (A)	Extrinsic reverse base current.

Virtuoso Simulator Components and Device Models Reference

Mextram Models (bjt504, bjt504t, bjtd504, and bjtd504t)

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 ($1/\Omega$)	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.

Virtuoso Simulator Components and Device Models Reference

Mextram Models (bjt504, bjt504t, bjtd504, and bjtd504t)

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	$gmuex$ ($1/\Omega$)	Conductance extrinsic b-c junction.
45	$Xgmuex$ ($1/\Omega$)	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.

Virtuoso Simulator Components and Device Models Reference

Mextram Models (bjt504, bjt504t, bjtd504, and bjtd504t)

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.
80	TK (K)	Actual temperature.
81	Isub (A)	Substrate current.
82	XIsub (A)	Substrate current.

Virtuoso Simulator Components and Device Models Reference

Mextram Models (bjt504, bjt504t, bjtd504, and bjtd504t)

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	xg_S ($1/\Omega$)	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.

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	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-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

Virtuoso Simulator Components and Device Models Reference

Mextram Models (bjt504, bjt504t, bjtd504, and bjtd504t)

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
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
Iclc2	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

Virtuoso Simulator Components and Device Models Reference

Mextram Models (bjt504, bjt504t, bjtd504, and bjtd504t)

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	cth	M-74	level	M-1	vgj	O-59
Qts	OP-84	cth	O-73	m	I-3	vgs	M-71
RB	OP-72	dais	M-52	mc	M-39	vgs	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

Virtuoso Simulator Components and Device Models Reference

Mextram Models (bjt504, bjt504t, bjtd504, and bjtd504t)

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
Vele	OP-8	exmod	O-3	rbv	M-24	xrec	M-48
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.

Virtuoso Simulator Components and Device Models Reference

Mextram Models (bjt504, bjt504t, bjtd504, and bjtd504t)

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 modelling of reverse current gain.
5	exphi=1	Flag for the distributed high-frequency effects in transient.
6	exavl=0	Flag for extended modelling 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	xibi=0	Part of ideal base current that belongs to the sidewall.
15	bri=7	Ideal reverse current gain.
16	ibr=1e-15 A	Saturation current of the non-ideal reverse base current.
17	vlr=0.2 V	Cross-over voltage of the non-ideal reverse base current.
18	xext=0.63	Part of I_{ex} , Q_{tex} , Q_{ex} and I_{sub} that depends on V_{bc1} instead of V_{b1c1} .

Virtuoso Simulator Components and Device Models Reference

Mextram Models (bjt504, bjt504t, bjtd504, and bjtd504t)

19	wavl=1.1e-06 m	Epilayer thickness used in weak-avalanche model.
20	vavl=3 V	Voltage determining curvature of avalanche current.
21	sfh=0.3	Current spreading factor of avalanche model (when EXAVL=1).
22	re=5 Ω	Emitter resistance.
23	rbc=23 Ω	Constant part of the base resistance.
24	rbv=18 Ω	Zero-bias value of the variable part of the base resistance.
25	rcc=12 Ω	Constant part of collector resistance.
26	rcv=150 Ω	Resistance of the un-modulated epilayer.
27	srcrv=1.25e+03 Ω	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 Cjc.

Virtuoso Simulator Components and Device Models Reference

Mextram Models (bjt504, bjt504t, bjtd504, and bjtd504t)

39	<code>mc=0.5</code>	Coefficient for the current modulation of the collector-base depletion capacitance.
40	<code>xcjc=0.032</code>	Fraction of the collector-base depletion capacitance under the emitter.
41	<code>cbco=0</code>	Collector-base overlap capacitance.
42	<code>mtau=1</code>	Non-ideality factor of the emitter stored charge.
43	<code>taue=2e-12 s</code>	Minimum transit time of stored emitter charge.
44	<code>taub=4.2e-12 s</code>	Transit time of stored base charge.
45	<code>tepi=4.1e-11 s</code>	Transit time of stored epilayer charge.
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.

Virtuoso Simulator Components and Device Models Reference

Mextram Models (bjt504, bjt504t, bjtd504, and bjtd504t)

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 n, p, npn, pnp, npnv, pnpv, npnl, or pnp1.
67	<code>imax=1.0 A</code>	Explosion current.
68	<code>tnom (deg. C)</code>	alias of tnom.
69	<code>tr (deg. C)</code>	alias of tnom.

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 modelling of reverse current gain.
4	<code>exphi</code>	Flag for the distributed high-frequency effects in transient.
5	<code>exavl</code>	Flag for extended modelling 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.

Virtuoso Simulator Components and Device Models Reference

Mextram Models (bjt504, bjt504t, bjtd504, and bjtd504t)

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.
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.

Virtuoso Simulator Components and Device Models Reference

Mextram Models (bjt504, bjt504t, bjtd504, and bjtd504t)

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.
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.

Virtuoso Simulator Components and Device Models Reference

Mextram Models (bjt504, bjt504t, bjtd504, and bjtd504t)

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.
56	dvgbr (V)	Bandgap voltage difference of reverse current gain.
57	vgb (V)	Bandgap voltage of the base.
58	vgc (V)	Bandgap voltage of the collector.
59	vgj (V)	Bandgap voltage recombination emitter-base junction.
60	dvgte (V)	Bandgap voltage difference of emitter stored charge.
61	af	Exponent of the Flicker-noise.
62	kf	Flicker-noise coefficient of the ideal base current.
63	kfn	Flicker-noise coefficient of the non-ideal base current.
64	kavl	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 Ic/Ib.
4	Vb2e1 (V)	Internal base-emitter bias.
5	Vb2c2 (V)	Internal base-collector bias.
6	Vb2c1 (V)	Internal base-collector bias including epilayer.

Virtuoso Simulator Components and Device Models Reference

Mextram Models (bjt504, bjt504t, bjtd504, and bjtd504t)

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.
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.

Virtuoso Simulator Components and Device Models Reference

Mextram Models (bjt504, bjt504t, bjtd504, and bjtd504t)

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	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.

Virtuoso Simulator Components and Device Models Reference

Mextram Models (bjt504, bjt504t, bjtd504, and bjtd504t)

51	grbvz (1/Ω)	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.
68	gm (1/Ω)	Transconductance.
69	beta	Current amplification.
70	gout (1/Ω)	Output conductance.
71	gmμ (1/Ω)	Feedback transconductance.
72	RB (Ω)	Base resistance.

Virtuoso Simulator Components and Device Models Reference

Mextram Models (bjt504, bjt504t, bjtd504, and bjtd504t)

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.
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	XIex	OP-17	gmu	OP-71	re	M-22
Cblb2	OP-64	XQex	OP-33	gmux	OP-44	re	O-21
Cblb2x	OP-65	XQtex	OP-31	gmux	OP-41	region	I-2
Cblb2y	OP-66	Xgmux	OP-45	gmuy	OP-42	scrcv	M-27
Cblb2z	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

Virtuoso Simulator Components and Device Models Reference

Mextram Models (bjt504, bjt504t, bjtd504, and bjtd504t)

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
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

Virtuoso Simulator Components and Device Models Reference

Mextram Models (bjt504, bjt504t, bjtd504, and bjtd504t)

Qblb2	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
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

Virtuoso Simulator Components and Device Models Reference

Mextram Models (bjt504, bjt504t, bjtd504, and bjtd504t)

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 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 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 ...
```

Virtuoso Simulator Components and Device Models Reference

Mextram Models (bjt504, bjt504t, bjtd504, and bjtd504t)

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 modelling of reverse current gain.
5	exphi=1	Flag for the distributed high-frequency effects in transient.
6	exavl=0	Flag for extended modelling 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	xibi=0	Part of ideal base current that belongs to the sidewall.
15	bri=7	Ideal reverse current gain.
16	ibr=1e-15 A	Saturation current of the non-ideal reverse base current.
17	vlr=0.2 V	Cross-over voltage of the non-ideal reverse base current.
18	xext=0.63	Part of I_{ex} , Q_{tex} , Q_{ex} and I_{sub} that depends on V_{bc1} instead of V_{b1c1} .
19	wavl=1.1e-06 m	Epilayer thickness used in weak-avalanche model.
20	vavl=3 V	Voltage determining curvature of avalanche current.

Virtuoso Simulator Components and Device Models Reference

Mextram Models (bjt504, bjt504t, bjtd504, and bjtd504t)

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.
33	<code>xcje=0.4</code>	Fraction of the emitter-base depletion capacitance that belongs to the sidewall.
34	<code>cbeo=0</code>	Emitter-base overlap capacitance.
35	<code>cjc=7.8e-14 F</code>	Zero-bias collector-base depletion capacitance.
36	<code>vdc=0.68 V</code>	Collector-base diffusion voltage.
37	<code>pc=0.5</code>	Collector-base grading coefficient.
38	<code>xp=0.35</code>	Constant part of Cjc.
39	<code>mc=0.5</code>	Coefficient for the current modulation of the collector-base depletion capacitance.
40	<code>xcjc=0.032</code>	Fraction of the collector-base depletion capacitance under the emitter.

Virtuoso Simulator Components and Device Models Reference

Mextram Models (bjt504, bjt504t, bjtd504, and bjtd504t)

41	<code>cbco=0</code>	Collector-base overlap capacitance.
42	<code>mtau=1</code>	Non-ideality factor of the emitter stored charge.
43	<code>taue=2e-12 s</code>	Minimum transit time of stored emitter charge.
44	<code>taub=4.2e-12 s</code>	Transit time of stored base charge.
45	<code>tepi=4.1e-11 s</code>	Transit time of stored epilayer charge.
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.

Virtuoso Simulator Components and Device Models Reference

Mextram Models (bjt504, bjt504t, bjtd504, and bjtd504t)

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>rth=300 K/W</code>	Thermal resistance.
67	<code>cth=3e-09 J/K</code>	Thermal capacitance.
68	<code>ath=0</code>	Temperature coefficient of the thermal resistance.
69	<code>type=n</code>	Transistor gender. Possible values are n, p, npn, pnp, npnv, pnpv, npnl, or pnp1.
70	<code>imax=1.0 A</code>	Explosion current.
71	<code>tnom (deg. C)</code>	alias of <code>tnom</code> .
72	<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 modelling of reverse current gain.
4	<code>exphi</code>	Flag for the distributed high-frequency effects in transient.
5	<code>exavl</code>	Flag for extended modelling 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.

Virtuoso Simulator Components and Device Models Reference

Mextram Models (bjt504, bjt504t, bjtd504, and bjtd504t)

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.
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.

Virtuoso Simulator Components and Device Models Reference

Mextram Models (bjt504, bjt504t, bjtd504, and bjtd504t)

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.
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.

Virtuoso Simulator Components and Device Models Reference

Mextram Models (bjt504, bjt504t, bjtd504, and bjtd504t)

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.
56	dvgbr (V)	Bandgap voltage difference of reverse current gain.
57	vgb (V)	Bandgap voltage of the base.
58	vgc (V)	Bandgap voltage of the collector.
59	vgj (V)	Bandgap voltage recombination emitter-base junction.
60	dvgte (V)	Bandgap voltage difference of emitter stored charge.
61	af	Exponent of the Flicker-noise.
62	kf	Flicker-noise coefficient of the ideal base current.
63	kfn	Flicker-noise coefficient of the non-ideal base current.
64	kavl	Switch for white noise contribution due to avalanche.
65	rth (K/W)	Thermal resistance.
66	cth (J/K)	Thermal capacitance.
67	ath	Temperature coefficient of the thermal resistance.

Operating-Point Parameters

1	Ic (A)	External DC collector current.
2	Ib (A)	External DC base current.
3	BetaDC	External DC current gain Ic/Ib.

Virtuoso Simulator Components and Device Models Reference

Mextram Models (bjt504, bjt504t, bjtd504, and bjtd504t)

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.
24	$S Q_{te}$ (C)	Sidewall base-emitter depletion charge.
25	Q_{be} (C)	Base-emitter diffusion charge.

Virtuoso Simulator Components and Device Models Reference

Mextram Models (bjt504, bjt504t, bjtd504, and bjtd504t)

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.
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.

Virtuoso Simulator Components and Device Models Reference

Mextram Models (bjt504, bjt504t, bjtd504, and bjtd504t)

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.
68	gm ($1/\Omega$)	Transconductance.
69	beta	Current amplification.

Virtuoso Simulator Components and Device Models Reference

Mextram Models (bjt504, bjt504t, bjtd504, and bjtd504t)

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.

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_{aDC}	OP-3	X_{Qex}	OP-33	f_T	OP-75	r_{cv}	O-25
C_{b1b2}	OP-64	X_{Qtex}	OP-31	g_m	OP-68	r_e	M-22
C_{b1b2x}	OP-65	X_{gmuex}	OP-45	g_{mu}	OP-71	r_e	O-21
C_{b1b2y}	OP-66	X_{iWepi}	OP-77	g_{mux}	OP-44	region	I-2
C_{b1b2z}	OP-67	ab	M-51	g_{mux}	OP-41	r_{th}	M-66

Virtuoso Simulator Components and Device Models Reference

Mextram Models (bjt504, bjt504t, bjtd504, and bjtd504t)

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
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

Virtuoso Simulator Components and Device Models Reference

Mextram Models (bjt504, bjt504t, bjtd504, and bjtd504t)

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
Qblb2	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
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
Sibl	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

Virtuoso Simulator Components and Device Models Reference

Mextram Models (bjt504, bjt504t, bjtd504, and bjtd504t)

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		

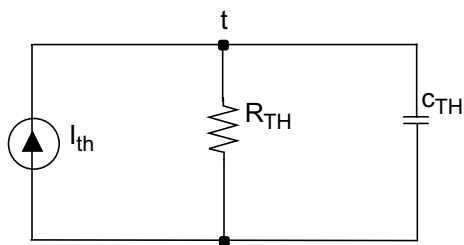
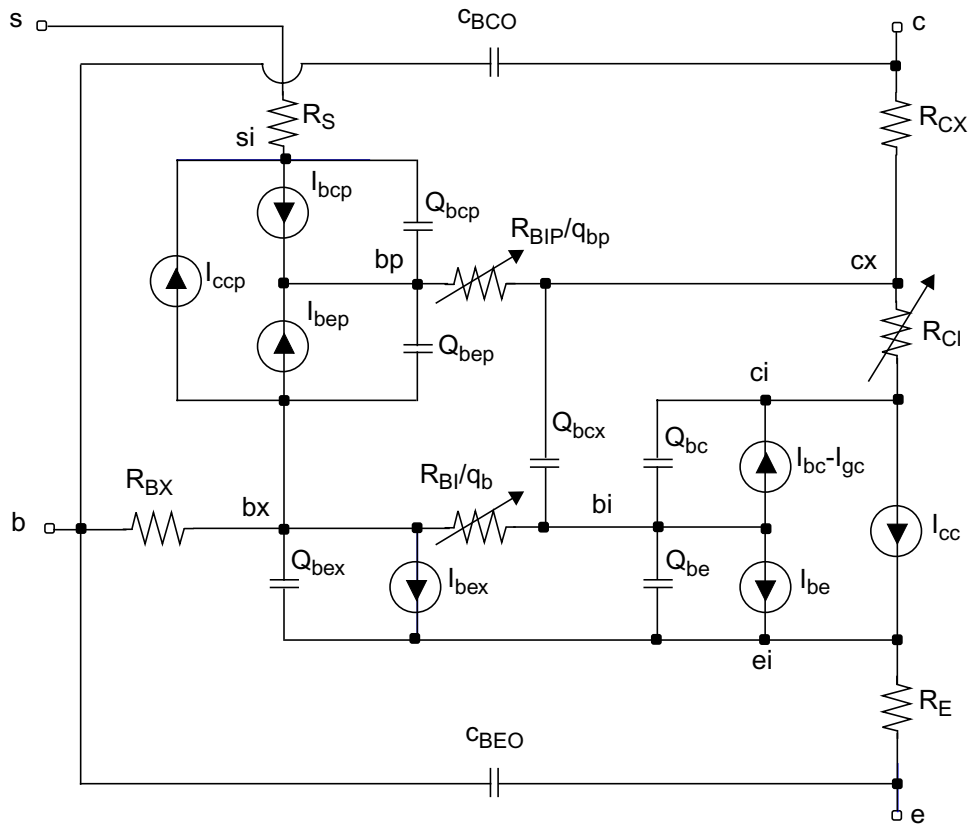
VBIC Model (vbic)

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:

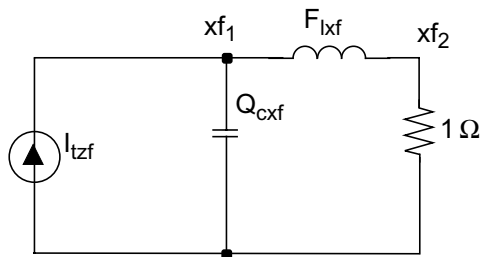
- [VBIC 1.1](#) on page 409
 - [DC Current](#) on page 409
 - [Charge Equations](#) on page 411
 - [Excess Phase](#) on page 414
 - [Small Signal Parameters](#) on page 414
 - [Temperature Equations](#) on page 416
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- [VBIC 1.2](#) on page 420
 - [DC Current](#) on page 420
 - [Charge Equations](#) on page 422
 - [Temperature Equations](#) on page 424
- [Scaling Effects](#) on page 425
- [Component Statements](#) on page 425

Virtuoso Simulator Components and Device Models Reference

VBIC Model (vbic)



Thermal network



Excess phase network

VBIC 1.1

DC Current

$$I_{cc} = \frac{I_{tf} - I_{tr}}{Q_b}$$

$$I_{tf} = I_s (e^{V_{bei}/N_f V_{tm}} - 1)$$

$$I_{tr} = I_s (e^{V_{bei}/N_r V_{tm}} - 1)$$

$$Q_b = \frac{1}{2} \left(Q_1 + \sqrt{Q_1^2 + 4Q_2} \right)$$

$$Q_1 = \frac{1}{\sqrt{2}} \left(\left(0.9999 + \frac{Q'_{je}}{V_{er}} + \frac{Q'_{jc}}{V_{ef}} \right)^2 + 10^{-8} \right) + \frac{1}{2} \left(0.9999 + \frac{Q'_{je}}{V_{er}} + \frac{Q'_{jc}}{V_{ef}} \right) + 10^{-4}$$

$$Q'_{je} = \frac{Q_{je}}{C_{je}}$$

$$Q'_{jc} = \frac{Q_{jc}}{C_{jc}}$$

$$Q_2 = \frac{I_{tf}}{I_{kf}} + \frac{I_{tr}}{I_{kr}}$$

$$I_{be} = W_{be} \left[I_{bei} (e^{V_{bei}/N_{ei} V_{tm}} - 1) + I_{ben} (e^{V_{bei}/N_{en} V_{tm}} - 1) \right]$$

$$I_{bex} = (1 - W_{be}) \left[I_{bei} (e^{V_{bex}/N_{ei} V_{tm}} - 1) + I_{ben} (e^{V_{bex}/N_{en} V_{tm}} - 1) \right]$$

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)

$$I_{rci} = \frac{V_{rci} + V_{tm}[K_{bci} - K_{bcx} - \ln(R_{kpi})]}{R_{ci}\sqrt{1 + (D_{erf})^2}}$$

$$D_{erf} = \frac{V_{rci} + V_{tm} [K_{bci} - K_{bcx} - \ln(R_{kp1})]}{V_o + \frac{\sqrt{V_{rci}^2 + 0.01}}{2H_{rcf}}}$$

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.

$$R_{kp1} = \frac{K_{bci} + 1}{K_{bcx} + 1}$$

$$V_{bcx} = V_{bci} - V_{rci}$$

Charge Equations

$$Q_{be} = W_{be} Q_{je} + T_{ff} I_{tf}$$

$$T_{ff} = \left\{ \begin{array}{l} T_f (1 + Q_{tf} Q_1) \left[1 + X_{tf} e^{V_{bci}/(1.44 V_{tf})} \frac{\left(\frac{I_{tf}(\text{current})}{I_{tf}(\text{model parameter})} \right)^2}{\left(1 + \frac{I_{tf}}{I_{tf}} \right)^2} \right] \\ T_f (1 + Q_{tf} Q_1) \end{array} \right\} \begin{array}{l} \text{if } I_{tf}(\text{model parameter}) > 0 \\ \text{otherwise} \end{array}$$

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 409.

$$Q_{bc} = T_r I_{tr} + Q_{jc} + Q_{co} K_{bci}$$

$$Q_{bex} = (1 - W_{be}) Q_{jex}$$

$$Q_{bcx} = Q_{co} K_{bcx}$$

$$Q_{bep} = T_r I_{tfp} + Q_{jep}$$

$$Q_{bcp} = Q_{jcp}$$

$$Q_{je} = Q_j(C_{je}, P_e, M_e, A_{je}, V_{bei})$$

$$Q_{jc} = Q_j(C_{jc}, P_c, M_c, A_{jc}, V_{bci})$$

$$Q_{jex} = Q_j(C_{je}, P_e, M_e, A_{je}, V_{bex})$$

$$Q_{jep} = Q_j(C_{jep}, P_c, M_c, A_{jc}, V_{bep})$$

$$Q_{jcp} = Q_j(C_{jcp}, P_s, M_s, A_{js}, V_{bcp})$$

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)

$$Q_j = -\frac{C_j P \left(1 - \frac{V_I}{P}\right) \left(1 - \frac{V_I}{P}\right)^{-M}}{1 - M} - Q_0 + \frac{C_j (V - V_I + V_{I0})}{(1 - F_c)^M}$$

$$Q_0 = -\frac{C_j P \left(1 - \frac{V_{I0}}{P}\right)^{1-M}}{1 - M}$$

$$V_{I0} = \frac{1}{2}(D_{v0} - M_{v0}) + P F_c$$

$$D_{v0} = -P F_c$$

$$M_{v0} = \sqrt{D_{v0}^2 + A_j}$$

If $A_j \leq 0$, $Q_j(C_j, P, M, A_j, V)$ is calculated as

$$Q_j = \left\{ \begin{array}{l} C_j P \left[\frac{1 - \left(1 - \frac{V}{P}\right)^{1-M}}{1 - M} \right] \\ \frac{[1 - F_c (1 + M)] (V - F_c P) + \frac{M (V^2 - F_c^2 P^2)}{2P}}{(1 - F_c)^{M+1}} + \frac{P}{1 - M} \left[1 - \frac{1}{(1 - F_c)^{M-1}} \right] \end{array} \right. \begin{array}{l} \text{If} \\ V \leq F_c P \\ \\ \text{other} \\ \text{wise} \end{array}$$

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

$$\phi(s) = \frac{3\omega_0^2}{s^2 + 3\omega_0 s + 3\omega_0^2}$$

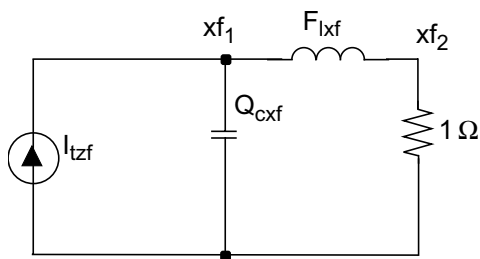
where

$$\omega_0 = \frac{1}{td}$$

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,

$$F_t = \frac{g_m}{2\pi(c_{pi} + g_m \cdot tf + cb_{cx} + cmu(g_m R_{ci} + 1))}$$

where

$$R_{ci} = \frac{dI_{rci}}{dV_{rci}}$$

and tf is the model parameter.

If R_{ci} is not given,

Virtuoso Simulator Components and Device Models Reference

VBIC Model (vbic)

$$F_t = \frac{g_m}{2\pi(c_{pi} + c_{bcx} + c_{mu})}$$

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)

$$C_{jc} = C_{jcnom} \left(\frac{P_{cnom}}{P_c} \right)^{M_c}$$

$$C_{jep} = C_{jepnom} \left(\frac{P_{cnom}}{P_c} \right)^{M_c}$$

$$C_{jcp} = C_{jcpnom} \left(\frac{P_{snom}}{P_s} \right)^{M_s}$$

$$P_e = A_e + 2V_{tm} \ln \left[\frac{1}{2} \left(1 + \sqrt{1 + 4e^{-A_e/V_{tm}}} \right) \right]$$

$$A_e = 2V_{tm} \ln \left(e^{PE_{nom}/2V_{tm}} - e^{-PE_{nom}/2V_{tm}} \right) R_t - 3V_{tm} \ln(R_t) - E_{aie}(R_t - 1)$$

$$P_c = A_c + 2V_{tm} \ln \left[\frac{1}{2} \left(1 + \sqrt{1 + 4e^{-A_c/V_{tm}}} \right) \right]$$

$$A_c = 2V_{tm} \ln \left(e^{PC_{nom}/2V_{tm}} - e^{-PC_{nom}/2V_{tm}} \right) R_t - 3V_{tm} \ln(R_t) - E_{aic}(R_t - 1)$$

$$P_s = A_s + 2V_{tm} \ln \left[\frac{1}{2} \left(1 + \sqrt{1 + 4e^{-A_s/V_{tm}}} \right) \right]$$

$$A_s = 2V_{tm} \ln \left(e^{PS_{nom}/2V_{tm}} - e^{-PS_{nom}/2V_{tm}} \right) R_t - 3V_{tm} \ln(R_t) - E_{ais}(R_t - 1)$$

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)

$$\overline{i_{Ibe}^2} \approx 2 q I_{be} + \frac{K_{fn} I_{be}^{A_{fn}}}{f^{B_{fn}}} \Delta f$$

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:

$$\overline{i_{Rbep}^2} = 2 q I_{bep} + \frac{K_{fn} I_{bep}^{A_{fn}}}{f B_{fn}}$$

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 ($V_{be} > 0$)

$$I_{bei} = I_{bei}(T) \left(e^{V_{bei}/(N_{en} \cdot V_{tm})} - 1 \right)$$

Virtuoso Simulator Components and Device Models Reference
VBIC Model (vbic)

$$I_{ben} = I_{ben(T)} \left(e^{V_{bei}/(N_{en} \cdot V_{tm})} - 1 \right)$$

$$I_{bbe} = I_{bbe(T)_{nom}} \cdot \left(e^{(-V_{bbe}(T) - V_{bei})/(N_{bbe}(T) \cdot V_{tm})} - E_{bbe}(T) \right)$$

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);
  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

$$T1 = \frac{1}{2} \left(V - F_c P - \sqrt{(V - F_c P)^2 + 4A_j^2} \right) + F_c P$$

}

If ($A_{jc} > 0$)

If $(V_{rt} > 0) \wedge (A_{rt} > 0)$

Virtuoso Simulator Components and Device Models Reference

VBIC Model (vbic)

then

$$dv0 = -(F_c \cdot P)$$

$$vn0 = \frac{V_{rt} + dv0}{V_{rt} - dv0}$$

$$v_{nl0} = \frac{2 \cdot vn0}{\sqrt{(vn0 - 1)^2 + 4 \cdot A_j^2} + \sqrt{(vn0 + 1)^2 + 4 \cdot A_{rt}^2}}$$

$$v_{l0} = \frac{1}{2} \cdot (v_{nl0} \cdot (V_{rt} - dv0) - V_{rt} - dv0)$$

$$Q_{l0} = P \cdot \frac{\left(1 - \left(1 - \frac{V_{l0}}{P}\right)^{1-M}\right)}{1-M}$$

$$vn = \frac{2 \cdot V + V_{rt} + dv0}{V_{rt} - dv0}$$

$$vnl = \frac{2 \cdot vn}{\sqrt{(vn - 1)^2 + 4 \cdot A \cdot A} + \sqrt{(vn + 1)^2 + 4 \cdot A_{rt} \cdot A_{rt}}}$$

$$vl = \frac{1}{2} \cdot (vnl \cdot (V_{rt} - dv0) - V_{rt} - dv0)$$

$$Q_{jc0} = P \cdot \frac{\left(1 - \left(1 - \frac{vl}{P}\right)^{1-M}\right)}{1-M}$$

$$sel = \frac{1}{2} \cdot (vnl + 1)$$

$$crt = \left(1 + \frac{V_{rt}}{P}\right)^{-M}$$

$$cl = (1 - sel) \cdot crt + sel \cdot cmx$$

$$Q_l = (V - vl + vl0) \cdot cl$$

Virtuoso Simulator Components and Device Models Reference

VBIC Model (vbic)

$$Q_{jc} = Q_l + Q_{jc0} - Q_{l0}$$

else

$$vl = \frac{1}{2} \cdot \left(V - F_c \cdot P - \sqrt{(V - (F_c \cdot P))^2 + 4 \cdot A \cdot A} \right) + F_c \cdot P$$

$$v_{l0} = -\frac{1}{2} \cdot \left(-F_c \cdot P + \sqrt{(F_c \cdot P)^2 + 4 \cdot A \cdot A} \right)$$

$$Q_{j0} = -P \cdot \frac{\left(1 - \frac{v_{l0}}{P}\right)^{1-M}}{1-M}$$

$$Q_{l0} = -P \cdot \frac{\left(1 - \frac{vl}{P}\right)^{1-M}}{1-M}$$

$$Q_{jc} = Q_{l0} + (1 - F_c)^{-M} \cdot (V - vl + v_{l0}) - Q_{j0}$$

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 222.

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 `hrctf=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 $r_{bi}=0 \Omega$ Intrinsic base resistance (/area).
- 35 $r_{bx}=0 \Omega$ Extrinsic base resistance (/area).
- 36 $r_e=0 \Omega$ Emitter resistance (/area).
- 37 $r_s=0 \Omega$ Substrate resistance (/area).
- 38 $r_{bp}=0 \Omega$ Parasitic base resistance (/area).
- 39 $r_{cx}=0 \Omega$ Extrinsic collector resistance (/area).
- 40 $r_{ci}=0 \Omega$ Intrinsic collector resistance (/area).
- 41 $minr=0.01 \Omega$ Minimum parasitic resistance.

Junction capacitance parameters

- 42 $c_{je}=0 F$ B-E zero-bias capacitance (*area).
- 43 $p_e=0.75 V$ B-E built-in potential.
- 44 $m_e=0.33$ B-E grading coefficient.
- 45 $a_{je}=-0.5$ B-E capacitance smoothing factor.
- 46 $f_c=0.9$ Forward-bias depletion capacitance limit.
- 47 $c_{beo}=0 F$ Extrinsic B-E overlap capacitance (*area).
- 48 $c_{jc}=0 F$ B-C zero-bias capacitance (*area).
- 49 $c_{jep}=0 F$ 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>	$\exp(-VBBE/(NBBE*Vtv))t$.

Shrink Parmaters

`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	vce (V)	Collector-emitter voltage.
6	vcs (V)	Collector-substrate voltage.
7	temp (C)	Device temperature.
8	ith (A)	Thermal source.
9	ic (A)	Intrinsic DC collector current. ($I_{cc} - I_{bc} + I_{gc}$).
10	ib (A)	Intrinsic DC base current. ($I_{be} + I_{bc} - I_{gc}$).
11	icc (A)	C-E current.
12	ibe (A)	Intrinsic B-E junction current.
13	ibc (A)	Intrinsic B-C junction current.
14	ibex (A)	BX-E junction current.
15	igc (A)	Breakdown current.
16	iccp (A)	Parasitic transport C-E current.
17	ibep (A)	Parasitic transport B-E current.
18	ibcp (A)	Parasitic transport B-C current.
19	betadc (A/A)	Ratio of external collector current to external base current. (I_{c_ext}/I_{b_ext}).
20	gm (S)	Intrinsic small-signal transconductance. ($g_m = dI_{cc_dVbe} + dI_{cc_dVbc}$).
21	gpi (S)	Intrinsic small-signal input conductance. ($g_{pi} = dI_{be_dVbe}$).
22	go (S)	Intrinsic small-signal output conductance. ($g_o = -dI_{cc_dVbc}$).
23	gmu (S)	Intrinsic small-signal Collector-Base conductance. ($g_{mu} = dI_{bc_dVbc}$).
24	cpi (F)	Intrinsic small-signal B-E capacitance. Same as cje.

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	eais	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)

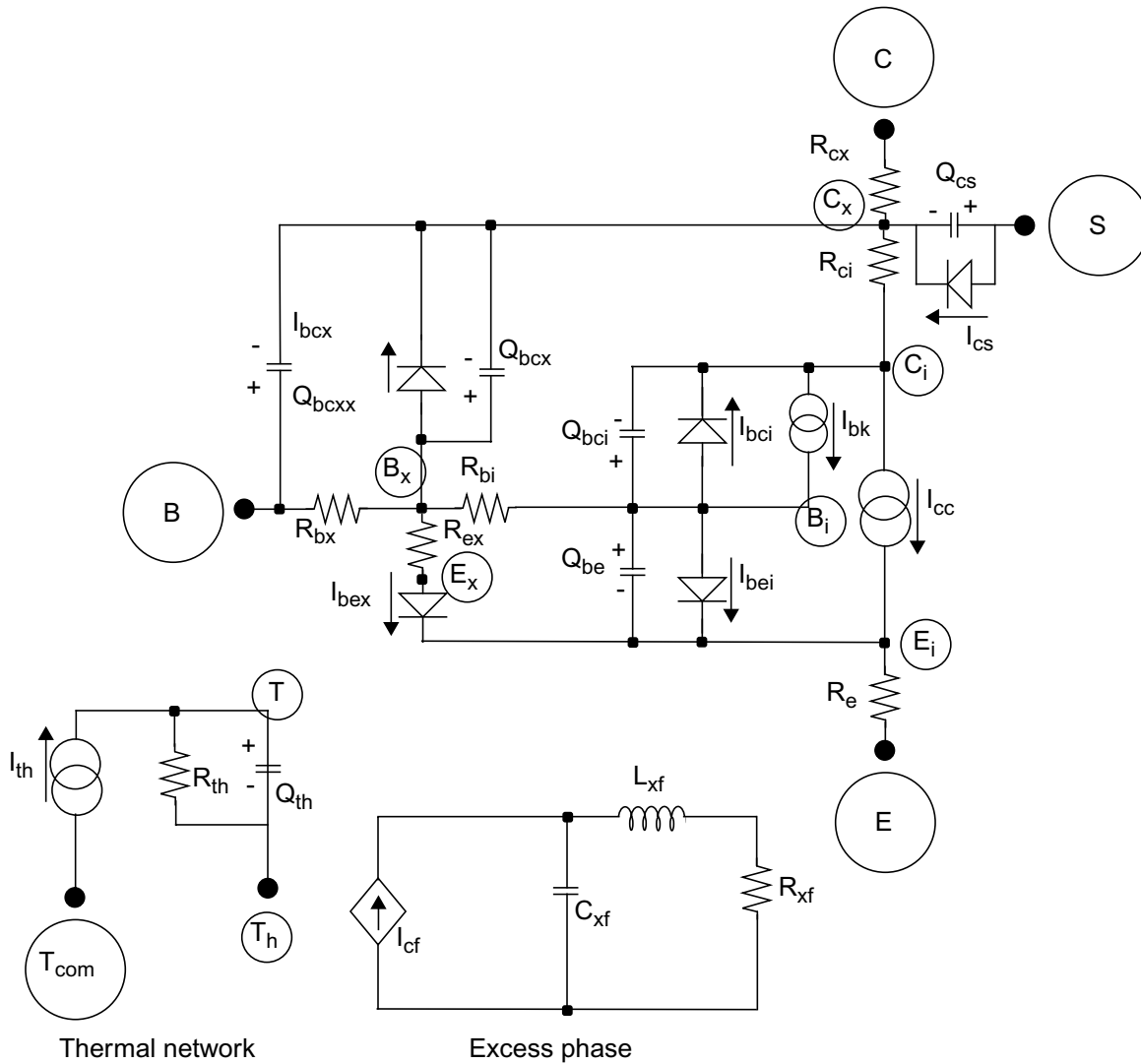
The Hetero-junction Bipolar Transistor (HBT) model was developed by UCSD as part of the ARPA High Speed Circuit Design Program. The model has four external electrical nodes, one thermal node, and up to nine internals depending on the version of the model you specify.

This chapter contains the following information for the HBT model:

- [DC Current](#) on page 442
- [Junction Capacitance](#) on page 444
- [Total Charge](#) on page 445
- [Thermal Current Equations](#) on page 448
- [Temperature Equations](#) on page 448
- [Scaling Effects](#) on page 451
- [Component Statements](#) on page 451

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)

$$C_{jch} = \begin{cases} C_{jc} \left((1 - I_o)^{M_{jc}} \right) & \text{If } I_o < 1 \\ -C_{jc} \left((I_o - 1)^{M_{jc}} \right) & \text{otherwise} \end{cases}$$

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 $C_{jch} \leq C_{min}(1 - F_c)^{M_{jc}}$,

$$Q_{bcf} = C_{cmin} \left(V_{bc} - V_{min1} - \frac{V_{jc} - V_{min1}}{1 - M_{jc}} \right) + \frac{C_{jch}(M_{jc})(V_{bc} - F_c(V_{jc}))V_{Rc}}{2(1 - F_c)^{M_{jc}}}$$

Thermal Current Equations

$$I_{th} = I_{cc}(V_{ce}) + I_{be}(V_{be}) + I_{bex}(V_{bex}) + I_{bcx}(V_{bcx}) + (I_{bc} - I_{bk})(V_{bc} - I_{cs})(V_{cs}) \\ + \frac{V_{bbx}^2}{R_{bx}} + \frac{V_{bex}^2}{R_{ex}} + \frac{V_{bxbi}^2}{R_{bi}} + \frac{V_{eei}^2}{R_e} + \frac{V_{ccx}^2}{R_{cx}} + \frac{V_{cxi}^2}{R_{ci}}$$

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)

$$R_{cx} = R_{cxnom} \left(R_{t_{op}}^{X_{rc}} \right)$$

$$R_{ci} = R_{cinom} \left(R_{t_{op}}^{X_{rc}} \right)$$

$$R_{bx} = R_{bxnom} \left(R_{t_{op}}^{X_{rb}} \right)$$

$$R_{bi} = R_{binom} \left(R_{t_{op}}^{X_{rb}} \right)$$

$$R_e = R_{enom} \left(R_{t_{op}}^{X_{re}} \right)$$

$$R_{ex} = R_{exnom} \left(R_{t_{op}}^{X_{rex}} \right)$$

$$I_s = I_{snom} \left(R_{td}^{X_{ti}} \right) \left(e^{E_g(R_{td}-1)/V_{tm}} \right)$$

$$I_{sa} = I_{sanom} \left(R_{td}^{X_{ti}} \right) \left(e^{(E_g + E_{aa})(R_{td}-1)/V_{tm}} \right)$$

$$I_{sb} = I_{sbnom} \left(R_{td}^{X_{ti}} \right) \left(e^{(E_g + E_{ab})(R_{td}-1)/V_{tm}} \right)$$

$$B_f = B_{fnom} \left(R_{td}^{X_{tb}} \right)$$

$$B_r = B_{rnom} \left(R_{td}^{X_{tb}} \right)$$

$$I_{se} = I_{senom} \left(R_{td}^{(X_{ti}/N_e - X_{tb})} \right) \left(e^{(E_g + E_{ae})/N_e(V_{tm}) - (E_g + E_{ae})/N_{enom}(V_{tmnom})} \right)$$

Virtuoso Simulator Components and Device Models Reference

HBT Model (hbt)

$$N_e = N_{enom} + T_{ne}(\Delta T)$$

$$I_{sc} = I_{scnom} \left(R_{td}^{(X_{ti}/N_c - X_{tb})} \right) \left(e^{(E_g + E_{ac})/N_c(V_{tm}) - (E_g + E_{ac})/N_{cnom}(V_{tmnom})} \right)$$

$$N_c = N_{cnom} + T_{nc}(\Delta T)$$

$$I_{sex} = I_{sexnom} \left(R_{td}^{X_{ti}/N_{ex} - X_{tb}} \right) \left(e^{(E_g + E_{ax})/N_{ex}(V_{tm}) - (E_g + E_{ax})/N_{exnom}(V_{tmnom})} \right)$$

$$N_{ex} = N_{exnom} + T_{nex}(\Delta T)$$

$$V_j = V_{jnom} - T_{vj}(T_{op} - Tnom)$$

$$C_j = C_{jnom} \left(\frac{V_{jnom}}{V_j} \right)^{M_j}$$

$$I_{tc} = I_{tcnom} \left(R_{td}^{X_{ticc}} \right)$$

$$I_{tc2} = I_{tc2nom} \left(R_{td}^{X_{ticc2}} \right)$$

$$T_{krk} = T_{krknom} \left(R_{top}^{X_{tikrk}} \right)$$

$$V_{krk} = V_{krknom} \left(R_{top}^{X_{rvkrk}} \right)$$

$$I_{krk} = I_{krknom} \left(R_{top}^{X_{tikrk}} \right)$$

Scaling Effects

For scaling effects, see [Scaling Factors \(scale and scalem\)](#) on page 222.

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>nbc=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	<code>x_{ti}=2</code>	Exponent for <code>i_s</code> temperature dependence.
74	<code>x_{tb}=2</code>	Exponent for beta temperature dependence.
75	<code>t_{ne}=0</code>	Coefficient for <code>n_e</code> temperature dependence.
76	<code>t_{nc}=0</code>	Coefficient for <code>n_c</code> temperature dependence.
77	<code>t_{nex}=0</code>	Coefficient for <code>n_{ex}</code> temperature dependence.
78	<code>e_{ae}=0 V</code>	Activation energy for <code>i_{sa}</code> temperature dependence.
79	<code>e_{ac}=0 V</code>	Activation energy for <code>i_{sb}</code> temperature dependence.
80	<code>e_{aa}=0 V</code>	Activation energy for <code>i_{se}</code> temperature dependence.
81	<code>e_{ab}=0 V</code>	Activation energy for <code>i_{sc}</code> temperature dependence.
82	<code>e_{ax}=0 V</code>	Activation energy for <code>i_{sx}</code> temperature dependence.
83	<code>x_{re}=0</code>	Exponent for <code>r_e</code> temperature dependence.
84	<code>x_{rex}=0</code>	Exponent for <code>r_{ex}</code> temperature dependence.
85	<code>x_{rb}=0</code>	Exponent for <code>r_b</code> temperature dependence.
86	<code>x_{rc}=0</code>	Exponent for <code>r_c</code> temperature dependence.
87	<code>t_{vje}=0 V/C</code>	Coefficient for <code>v_{je}</code> temperature dependence.
88	<code>t_{vjc}=0 V/C</code>	Coefficient for <code>v_{jc}</code> temperature dependence.
89	<code>t_{vjcx}=0 V/C</code>	Coefficient for <code>v_{jc}x</code> temperature dependence.
90	<code>t_{vjs}=0 V/C</code>	Coefficient for <code>v_{js}</code> temperature dependence.
91	<code>x_{t_{itc}}=0</code>	Exponent for <code>i_{tc}</code> temperature dependence.
92	<code>x_{t_{itc2}}=0</code>	Exponent for <code>i_{tc2}</code> temperature dependence.
93	<code>x_{t_{tf}}=0</code>	Exponent for <code>t_f</code> temperature dependence.
94	<code>x_{t_{krk}}=0</code>	Exponent for <code>t_{krk}</code> 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)

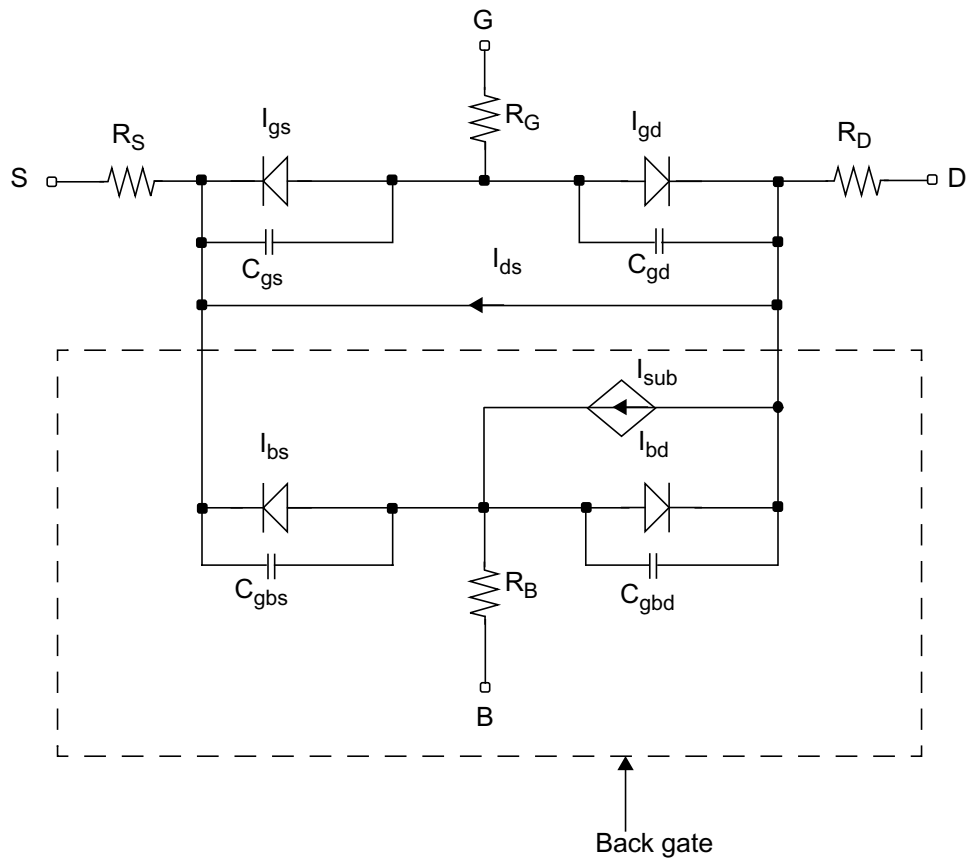
JFET Model (jfet)

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 464
- [Drain Current for the Triode Region](#) on page 465
- [Drain Current for the Saturation Region](#) on page 465
- [Gate Junction Currents](#) on page 466
- [Gate Junction Capacitance](#) on page 467
- [Temperature Effect](#) on page 467
- [Noise Model](#) on page 470
- [Scaling Effects](#) on page 471
- [Component Statements](#) on page 471

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 $V_{DS} \leq V_{GST}$.

$$I_{DS} = \begin{cases} beta(2V_{GST} - V_{DS})V_{DS}(1 + \lambda V_{DS}) & level = 1 \\ betaV_{GST}^{np} \tanh\left(\frac{alphaV_{DS}}{V_{GST}}\right)(1 + \lambda V_{DS}) & level = 2 \\ \beta_4 V_{GST}^{np} \tanh\left(\frac{alphaV_{DS}}{V_{GST}}\right)(1 + \lambda V_{DS}) & level = 3 \end{cases}$$

where

$$\beta_4 = beta\left(\frac{vto + vtop}{V_{to4} + vtop}\right)$$

$$\lambda = lambda(1 + lambda1V_{GST})$$

Drain Current for the Saturation Region

Note: These equations apply when $V_{GST} \geq 0$ and $V_{DS} \geq V_{GST}$.

Virtuoso Simulator Components and Device Models Reference

JFET Model (jfet)

$$I_{DS} = \begin{cases} \beta V_{GST}^2 (1 + \lambda V_{DS}) & \text{level} = 1 \\ \beta V_{GST}^{np} \tanh\left(\frac{\alpha V_{DS}}{V_{GST}}\right) (1 + \lambda V_{DS}) & \text{level} = 2 \\ \beta_4 V_{GST}^{np} \tanh\left(\frac{\alpha V_{DS}}{V_{GST}}\right) (1 + \lambda V_{DS}) & \text{level} = 3 \end{cases}$$

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 13, "Common MOSFET Equations."](#)

Gate Junction Currents

$$I_{GS(GD)} = \begin{cases} i_s \left(e^{\frac{V_{gs(gd)}}{nV_t}} - 1 \right) & \text{if } V_{gs(gd)} \leq V_{Expl} \\ I_{offset} + G_{Expl} V_{gs(gd)} & \text{otherwise} \end{cases}$$

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

$$C_{GS(GD)}(V_{GS(GD)}) = \begin{cases} \frac{cgs(cgd)}{\left[1 - \frac{V_{gs(gd)}}{pb}\right]^{mj}} & \text{if } V_{GS(GD)} \leq fc*pb \\ \frac{cgs(cgd)}{(1-fc)^{mj}} \left[1 + \frac{mj(V_{gs(gd)} - pb*fc)}{pb(1-fc)} \right] & \text{otherwise} \end{cases}$$

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)

$$C_{gd} = cgd_{nom} \left\{ 1 + mj \left[0.0004(T - Tnom) + \frac{(pb_{nom} - pb)}{pb_{nom}} \right] \right\}$$

Junction Potential

$$pb = pb_{nom} \left(\frac{T}{Tnom} \right) - 3V_t \ln \left[\frac{T}{Tnom} \right] - E_{g,nom} \left(\frac{T}{Tnom} \right) + E_g$$

Transconductance Temperature

$$Beta = Beta \times \left(\frac{T}{Tnom + bto} \right)^{bte}$$

$$Lambda = Lambda \times \left(\frac{T}{Tnom + lto} \right)^{lte}$$

$$Lambda1 = Lambda1 \times \left(\frac{T}{Tnom + lto} \right)^{lte}$$

Gate Junction Current

$$is = is_{nom} \left(\frac{T}{Tnom} \right)^{xti} \exp \left[\frac{E_{g,nom}}{V_{t,nom}} - \frac{E_g}{V_t} \right]$$

where, if SPICE-compatibility is required (set by the options),

$$E_g = 1.16 - \frac{7.02 \times 10^{-4} T^2}{1108 + T}$$

$$E_{g,nom} = 1.16 - \frac{7.02 \times 10^{-4} Tnom^2}{1108 + Tnom}$$

otherwise,

Virtuoso Simulator Components and Device Models Reference

JFET Model (jfet)

$$E_g = 1.17 - \frac{4.73 \times 10^{-4} T^2}{636 + T}$$

$$E_{g, nom} = 1.17 - \frac{4.73 \times 10^{-4} T_{nom}^2}{636 + T_{nom}}$$

For equations on parameters `tlev`, `tlevc`, `gap1`, and `gap2`, see [Chapter 13, “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

$$\text{tempfactor} = 1.0 + \text{delta}T \times (tc1 \times \text{delta}T + tc2)$$

$$R_{geff} = \text{tempfactor} \times R_g$$

$$R_{deff} = \text{tempfactor} \times R_d$$

$$R_{seff} = \text{tempfactor} \times R_s$$

$$R_{beff} = \text{tempfactor} \times R_b$$

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> area= w/l , <code>acm=1</code> area= $w.l$.

`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>	I_d 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 481
- [Lateral PNP Transistor \(bjt301\)](#) on page 484
- [Lateral PNP Transistor \(bjt500\)](#) on page 492
- [Lateral PNP Transistor \(bjt500t\)](#) on page 504
- [Vertical NPN/PNP Transistor \(bjt503\)](#) on page 516
- [Compact Bipolar-Transistor Model \(bjt504\)](#) on page 527
- [Compact Bipolar-Transistor Model \(bjt504t\)](#) on page 532
- [Compact Bipolar-Transistor Model \(bjtd3500\)](#) on page 537
- [Compact Bipolar-Transistor Model \(bjtd3500t\)](#) on page 553
- [Long Channel JFET/MOSFET Model \(mos30\)](#) on page 569
- [MOS Model 40, Level 40 \(mos40t\)](#) on page 573
- [Long Channel JFET/MOSFET Model \(mos3002\)](#) on page 579
- [Compact MOS-Transistor Model \(mos705\)](#) on page 583
- [Compact MOS-Transistor Model \(mos902\)](#) on page 594
- [Compact MOS-Transistor Model \(mos903\)](#) on page 606
- [Compact MOS-Transistor Distortion Model \(mos1100\)](#) on page 630
- [Compact MOS-Transistor Distortion Model \(mos1100e\)](#) on page 642
- [MOS Model 11, Level 1101 \(mos11010\)](#) on page 651
- [MOS Model 11, Level 1101 \(mos11010t\)](#) on page 664
- [MOS Model 11, Level 1101 \(mos11011\)](#) on page 677

Virtuoso Simulator Components and Device Models Reference

Philips Models

- [MOS Model 11, Level 1101 \(mos11011t\)](#) on page 696
- [MOS Model 11, Level 1101 \(mos1101e\)](#) on page 715
- [MOS Model 11, Level 1101 \(mos1101et\)](#) on page 726
- [MOS Model 11, Level 1102 \(mos11020\)](#) on page 737
- [MOS Model 11, Level 1102 \(mos11020t\)](#) on page 750
- [MOS Model 11, Level 1102 \(mos11021\)](#) on page 764
- [MOS Model 11, Level 1102 \(mos11021t\)](#) on page 783
- [MOS Model 11, Level 1102 \(mos1102e\)](#) on page 803
- [MOS Model 11, Level 1102 \(mos1102et\)](#) on page 814
- [Lateral Double-diffused MOS Model \(MOS Model Level 2001\) \(mos2001\)](#) on page 826
- [Lateral Double-diffused MOS Model \(MOS Model Level 2001\) \(mos2001e\)](#) on page 836
- [Lateral Double-diffused MOS Model \(MOS Model Level 2001\) \(mos2001et\)](#) on page 845
- [Lateral Double-diffused MOS Model \(MOS Model Level 2001\) \(mos2001t\)](#) on page 855
- [Lateral Double-diffused MOS Model \(MOS Model Level 2002\) \(mos2002\)](#) on page 865
- [Lateral Double-diffused MOS Model \(MOS Model Level 2002\) \(mos2002e\)](#) on page 876
- [Lateral Double-diffused MOS Model \(MOS Model Level 2002\) \(mos2002et\)](#) on page 886
- [Lateral Double-diffused MOS Model \(MOS Model Level 2002\) \(mos2002t\)](#) on page 897
- [MOS Model 31, Level 3100 \(mos3100\)](#) on page 908
- [MOS Model 31, Level 3100 \(mos3100t\)](#) on page 914

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 modelbook 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`.

Virtuoso Simulator Components and Device Models Reference

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>k_f=0.0</code>	Flickernoise coefficient.
20	<code>a_f=1.0</code>	Flickernoise exponent.
21	<code>d_{ta}=0.0 K</code>	Difference between device temperature and ambient temperature.
22	<code>t_{rise} (K)</code>	Alias of <code>d_{ta}</code> .
23	<code>i_{max}=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>p_{wr} (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 modelbook 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 pnpl. |
| 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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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 .

Virtuoso Simulator Components and Device Models Reference

Philips Models

41	<code>ptbf=0.0</code>	Power for temperature dependence of <code>bf</code> .
42	<code>ptbr=0.0</code>	Power for temperature dependence of <code>br</code> .
43	<code>ptrc=0.0</code>	Power for temperature dependence of <code>rc</code> .
44	<code>ptrb=0.0</code>	Power for temperature dependence of <code>rbc</code> and <code>rbv</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 (A)</code>	Saturation current.
2	<code>iole (A)</code>	Non-ideal forward base saturation current.
3	<code>iolc (A)</code>	Non-ideal reverse base saturation current.
4	<code>bft (A/A)</code>	Ideal forward common-emitter current gain (beta).
5	<code>brt (A/A)</code>	Ideal reverse common-collector current gain (beta).
6	<code>rct (Ω)</code>	Collector resistance.
7	<code>rbct (Ω)</code>	Constant part of base resistance.
8	<code>rbvt (Ω)</code>	Variable part of base resistance.
9	<code>taubt (s)</code>	Forward transit time related to neutral base.
10	<code>cjet (F)</code>	Zero bias emitter-base depletion capacitance.
11	<code>vdet (V)</code>	Emitter-base diffusion voltage.

Virtuoso Simulator Components and Device Models Reference

Philips Models

12	t_{aurt} (s)	Ideal reverse transit time.
13	c_{jct} (F)	Zero bias collector-base depletion capacitance.
14	v_{dct} (V)	Collector-base diffusion voltage.
15	c_{jst} (F)	Zero bias substrate junction depletion capacitance.
16	v_{dst} (V)	Substrate junction diffusion voltage.

Operating-Point Parameters

1	i_b (A)	Base current.
2	i_c (A)	Collector current.
3	i_e (A)	Emitter current.
4	i_{sub} (A)	Substrate current.
5	v_{be} (V)	Base-emitter voltage.
6	v_{bc} (V)	Base-collector voltage.
7	v_{ce} (V)	Collector-emitter voltage.
8	v_{subj} (V)	Substrate voltage.
9	β_{tadc} (A/A)	Ratio of DC collector current to DC Base current.
10	r_b (Ω)	Base resistance at operating point.
11	r_c (Ω)	Collector resistance at operating point.
12	r_e (Ω)	Emitter resistance at operating point.
13	i_{cb} (A)	Collector-Base current.
14	i_{eb} (A)	Emitter-Base current.
15	i_{csub} (A)	Collector-Substrate current.
16	i_{esub} (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 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 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 . |

Virtuoso Simulator Components and Device Models Reference

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 .

Virtuoso Simulator Components and Device Models Reference

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>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>	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>npn</code> , <code>npnv</code> , <code>pnpv</code> , <code>npnl</code> , or <code>pnpl</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` Flicker noise 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

eaf1	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
ear1	M-14	ise	OP-11	snbn	O-52	vlr	M-12
ear1	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 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 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>eaf1=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>v1r=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>ear1=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 <code>rbc</code> .
24	<code>rbcv=10 Ω</code>	Variable part of the base resistance <code>rbc</code> .
25	<code>rbec=10 Ω</code>	Constant part of the base resistance <code>rbe</code> .
26	<code>rbev=50 Ω</code>	Variable part of the base resistance <code>rbe</code> .

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>vgbs=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>pnp</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	<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>	Flicker noise coefficient.
57	<code>af</code>	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	gf1 (S)	Forward conductance, lateral path.
31	gr1 (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	vgcb	M-47
cmul	OP-48	ip	OP-16	region	I-2	vgcb	O-44

Virtuoso Simulator Components and Device Models Reference

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

Virtuoso Simulator Components and Device Models Reference

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	$ef_i=0.7$	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.

Virtuoso Simulator Components and Device Models Reference

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	$dt_a = 0.0$ K	Difference of the device temperature to the ambient temperature.
44	$t_{rise} = 0.0$ K	Alias of dt_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.

Virtuoso Simulator Components and Device Models Reference

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 mextram.
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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

22	ik_{st} (A)	Knee current of the substrate.
23	cj_{st} (F)	Zero bias collector-substrate depletion capacitance.
24	vd_{st} (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	v_{be} (V)	Base-emitter voltage.
6	v_{bc} (V)	Base-collector voltage.
7	v_{ce} (V)	Collector-emitter voltage.
8	v_{sc} (V)	Substrate voltage.
9	r_e (Ω)	Constant emitter resistance.
10	r_{cc} (Ω)	Constant collector resistance.
11	r_{bc} (Ω)	Constant part of base resistance.
12	β_{adc} (A/A)	DC current gain.
13	pwr (W)	Power.
14	V_{b1e1} (V)	Internal voltage.
15	V_{b2e1} (V)	Internal voltage.
16	V_{b2c1} (V)	Internal voltage.
17	V_{b2c2} (V)	Internal voltage.
18	V_{b1b2} (V)	Internal voltage.

Virtuoso Simulator Components and Device Models Reference

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: $dI_{b1}/dV_{b2e1} + dI_{b2}/dV_{b2e1}$.

Virtuoso Simulator Components and Device Models Reference

Philips Models

40	<code>sgpi</code> (S)	Conductance sidewall base-emitter junction: $dIb1S/dVb1e1$.
41	<code>gmux</code> (S)	Dependence avalanche multiplication on internal b-e junction: $-dIavl/dVb2e1$.
42	<code>gmu</code> (S)	Dependence avalanche multiplication on internal b-c junction: $-dIavl/dVb2c2$.
43	<code>gmuz</code> (S)	Dependence avalanche multiplication on external b-c junction: $-dIavl/dVb2c1$.
44	<code>grbv</code> (S)	$dIb1b2/dVb1b2$.
45	<code>grbvX</code> (S)	Emitter Early-effect on $Ib1b2$: $dIb1b2/dVb2e1$.
46	<code>grbvY</code> (S)	Internal collector Early-effect on $Ib1b2$: $dIb1b2/dVb2c2$.
47	<code>grbvZ</code> (S)	External collector Early effect on $Ib1b2$: $dIb1b2/dVb2c1$.
48	<code>gmueX</code> (S)	Conductance floor extrinsic b-c junction: $dIlex/dVb1c1 + dIsub/dVb1c1 + dIb3/dVb1c1$.
49	<code>xgmueX</code> (S)	Conductance sidewall extrinsic b-c junction: $dXIlex/dVbc1 + dXIsub/dVbc1$.
50	<code>gsub</code> (S)	Conductance s-c junction: $dIsub/dVsc1$.
51	<code>gpnP</code> (S)	Transconductance floor extrinsic PNP transistor: $dIsub/dVb1c1$.
52	<code>xgpnP</code> (S)	Transconductance sidewall extrinsic PNP transistor: $dXIsub/dVbc1$.
53	<code>cbex</code> (F)	Capacitance floor b-e junction: $dQte/dVb2e1 + dQbe/dVb2e1 + dQn/dVb2e1$.
54	<code>cbey</code> (F)	Internal collector Early-effect on Qbe : $dQbe/dVb2c2$.
55	<code>cbeyZ</code> (F)	External collector Early-effect on Qbe : $dQbe/dVb2c1$.
56	<code>scte</code> (F)	Dependence of $QteS$ on internal b-e junction: $dQteS/dVb2e1$.
57	<code>cbcx</code> (F)	Emitter Early-effect on Qbc : $dQbc/dVb2e1$.

Virtuoso Simulator Components and Device Models Reference

Philips Models

58	<i>cbcy</i> (F)	Capacitance intrinsic b-c junction: $dQ_{tc}/dV_{b2c2} + dQ_{bc}/dV_{b2c2} + dQ_{epi}/dV_{b2c2}$.
59	<i>cbcz</i> (F)	Collector Early-effect on Q_{tc} : $dQ_{tc}/dV_{b2c1} + dQ_{bc}/dV_{b2c1} + dQ_{epi}/dV_{b2c1}$.
60	<i>cb1b2</i> (F)	Capacitance AC current crowding: $dQ_{b1b2}/dV_{b1b2} = C_b$.
61	<i>cb1b2x</i> (F)	Dependence of Q_{b1b2} on internal b-e junction voltage: dQ_{b1b2}/dV_{b2e1} .
62	<i>cbce_x</i> (F)	Capacitance floor extrinsic b-c junction: $dQ_{tex}/dV_{b1c1} + dQ_{ex}/dV_{b1c1}$.
63	<i>xcbce_x</i> (F)	Capacitance sidewall extrinsic b-c junction: $dXQ_{tex}/dV_{bc1} + dXQ_{ex}/dV_{bc1}$.
64	<i>cts</i> (F)	Capacitance s-c junction: $dQ_{tex}/dV_{b1c1} + dQ_{ex}/dV_{b1c1}$.
65	<i>cbe</i> (F)	C_{be} .
66	<i>cbc</i> (F)	C_{bc} .
67	<i>csc</i> (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.

<i>Vb1b2</i>	OP-18	<i>dta</i>	M-43	<i>ikst</i>	O-22	<i>sfh</i>	M-24
<i>Vb1c1</i>	OP-19	<i>efi</i>	M-19	<i>ikt</i>	O-5	<i>sgpi</i>	OP-40
<i>Vb1e1</i>	OP-14	<i>er</i>	M-51	<i>imax</i>	M-66	<i>taune</i>	M-28
<i>Vb2c1</i>	OP-16	<i>eta</i>	M-17	<i>in</i>	OP-21	<i>taunet</i>	O-14

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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

Virtuoso Simulator Components and Device Models Reference

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)

This device is supported within altergroups.

This device is dynamically loaded from the shared object `/vobs/spectre_dev/tools.sun4v/cmi/lib/4.0.doc/libphilips_sh.so`

Instance Definition

Name `c b e s` `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> , <code>subth</code> , <code>rev</code> , <code>fwd</code> , or <code>brk</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

Output Parameters

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. |

Virtuoso Simulator Components and Device Models Reference

Philips Models

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.
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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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	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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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.
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	β	Current amplification.
70	$gout$ ($1/\Omega$)	Output conductance.
71	gmu ($1/\Omega$)	Feedback transconductance.
72	RB (Ω)	Base resistance.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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.
80	TK (K)	Actual temperature.
81	Isub (A)	Substrate current.
82	XIsub (A)	Substrate current.
83	Isf (A)	Substrate failure current.
84	Qts (C)	Collector-substrate depletion charge.
85	gS (1/Ω)	Conductance parasitic PNP transistor.
86	XgS (1/Ω)	Conductance parasitic PNP transistor.
87	gSf (1/Ω)	
88	Cts (C)	Capacitance s-c junction:.

Compact Bipolar-Transistor Model (bjt504t)

This device is dynamically loaded from the shared object /vobs/spectre_dev/tools.sun4v/cmi/lib/4.0.doc/libphilips_sh.so

Instance Definition

```
Name c b e s 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> , <code>subth</code> , <code>rev</code> , <code>fwd</code> , or <code>brk</code> .
3	<code>m=1</code>	Multiplicity factor.
4	<code>area=1</code>	alias of <code>mult</code> .

Model Definition

```
model modelName bjt504t parameter=value ...
```

Model Parameters

Output Parameters

Operating-Point Parameters

1	<code>Ic (A)</code>	External DC collector current.
2	<code>Ib (A)</code>	External DC base current.
3	<code>BetaDC</code>	External DC current gain I_c/I_b .
4	<code>Vb2e1 (V)</code>	Internal base-emitter bias.
5	<code>Vb2c2 (V)</code>	Internal base-collector bias.
6	<code>Vb2c1 (V)</code>	Internal base-collector bias including epilayer.
7	<code>Vb1c1 (V)</code>	External base-collector bias without contact resistances.
8	<code>Ve1e (V)</code>	Bias over emitter resistance.
9	<code>In (A)</code>	Main current.
10	<code>Ic1c2 (A)</code>	Epilayer current.

Virtuoso Simulator Components and Device Models Reference

Philips Models

11	I_{b1b2} (A)	Pinched-base current.
12	I_{b1} (A)	Ideal forward base current.
13	SI_{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	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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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	X_{gmuex} ($1/\Omega$)	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:.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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.
75	fT (Hz)	Good approximation for cut-off frequency.
76	Iqs (A)	Current at onset of quasi-saturation.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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.
81	$Isub$ (A)	Substrate current.
82	$XIsub$ (A)	Substrate current.
83	$Issf$ (A)	Substrate failure current.
84	Qts (C)	Collector-substrate depletion charge.
85	gS ($1/\Omega$)	Conductance parasitic PNP transistor.
86	XgS ($1/\Omega$)	Conductance parasitic PNP transistor.
87	gSf ($1/\Omega$)	
88	Cts (C)	Capacitance s-c junction:.

Compact Bipolar-Transistor Model (bjtd3500)

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 c b e 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=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 bjtd3500 parameter=value ...
```

Model Parameters

1	<code>level=3.5e+03</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 modelling 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 modelling 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>mhf=1</code>	Non ideality factor of the non-ideal forward base current.
15	<code>mlr=2</code>	Non ideality factor of the non-ideal reverse base current.

Virtuoso Simulator Components and Device Models Reference

Philips Models

16	<code>mhr=1</code>	Non ideality factor of the ideal reverse base current.
17	<code>mf=1</code>	Non ideality factor of main current.
18	<code>xibi=0</code>	Part of ideal base current that belongS to the sidewall.
19	<code>bri=7</code>	Ideal reverse current gain.
20	<code>ibr=1e-15 A</code>	Saturation current of the non-ideal reverse base current.
21	<code>vlr=0.2 V</code>	Cross-over voltage of the non-ideal reverse base current.
22	<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} .
23	<code>wavl=1.1e-06 m</code>	Epilayer thickness used in weak-avalanche model.
24	<code>vavl=3 V</code>	Voltage determining curvature of avalanche current.
25	<code>sfh=0.3</code>	Current spreading factor of avalanche model (when EXAVL=1).
26	<code>re=5 Ω</code>	Emitter resistance.
27	<code>rbc=23 Ω</code>	Constant part of the base resistance.
28	<code>rbv=18 Ω</code>	Zero-bias value of the variable part of the base resistance.
29	<code>rcc=12 Ω</code>	Constant part of collector resistance.
30	<code>rcv=150 Ω</code>	Resistance of the un-modulated epilayer.
31	<code>scrcv=1.25e+03 Ω</code>	Space charge resistance of the epilayer.
32	<code>ihc=0.004 A</code>	Critical current for velocity saturation in the epilayer.
33	<code>axi=0.3</code>	Smoothness parameter for the onset of quasi-saturation.
34	<code>cje=7.3e-14 F</code>	Zero-bias emitter-base depletion capacitance.
35	<code>vde=0.95 V</code>	Emitter-base diffusion voltage.
36	<code>pe=0.4</code>	Emitter-base grading coefficient.

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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 behaviour of Qtc.
54	$alfaw=0$	Smooth switch for reachthrough modelling.
55	$sw=0.1$	Smoothness parameter for reachthrough modelling.
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>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> .
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 modelling of reverse current gain.
4	<code>exphi</code>	Flag for the distributed high-frequency effects in transient.
5	<code>exavl</code>	Flag for extended modelling 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>mhf</code>	Non ideality factor of the ideal forward base current.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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.
26	rbc (Ω)	Constant part of the base resistance.
27	rbv (Ω)	Zero-bias value of the variable part of the base resistance.
28	rcc (Ω)	Constant part of collector resistance.
29	rcv (Ω)	Resistance of the un-modulated epilayer.
30	scrcv (Ω)	Space charge resistance of the epilayer.
31	ihc (A)	Critical current for velocity saturation in the epilayer.
32	axi	Smoothness parameter for the onset of quasi-saturation.
33	cje (F)	Zero-bias emitter-base depletion capacitance.
34	vde (V)	Emitter-base diffusion voltage.

Virtuoso Simulator Components and Device Models Reference

Philips Models

35	pe	Emitter-base grading coefficient.
36	xcje	Fraction of the emitter-base depletion capacitance that belongs to the sidewall.
37	cbeo	Emitter-base overlap capacitance.
38	cjc (F)	Zero-bias collector-base depletion capacitance.
39	vdc (V)	Collector-base diffusion voltage.
40	pc	Collector-base grading coefficient.
41	xp	Constant part of Cjc.
42	mc	Coefficient for the current modulation of the collector-base depletion capacitance.
43	xcjc	Fraction of the collector-base depletion capacitance under the emitter.
44	cbco	Collector-base overlap capacitance.
45	vos (V)	Voltage describing overshoot.
46	isat (A)	Saturation current.
47	repi (Ω)	Ohmic resistance epilayer.
48	rdmin	Minimum relative collector doping.
49	sbn	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 behaviour of Qtc.
53	alfaw	Smooth switch for reachthrough modelling.
54	sw	Smoothness parameter for reachthrough modelling.

Virtuoso Simulator Components and Device Models Reference

Philips Models

55	<code>mtau</code>	Non-ideality factor of the emitter stored charge.
56	<code>taue (s)</code>	Minimum transit time of stored emitter charge.
57	<code>taub (s)</code>	Transit time of stored base charge.
58	<code>tepi (s)</code>	Transit time of stored epilayer charge.
59	<code>taur (s)</code>	Transit time of reverse extrinsic stored base charge.
60	<code>deg (eV)</code>	Bandgap difference over the base.
61	<code>xrec</code>	Pre-factor of the recombination part of I_{b1} .
62	<code>aqbo</code>	Temperature coefficient of the zero-bias base charge.
63	<code>ae</code>	Temperature coefficient of the resistivity of the emitter.
64	<code>ab</code>	Temperature coefficient of the resistivity of the base.
65	<code>dais</code>	Parameter for fine tuning of temperature dependence of collector-emitter saturation current.
66	<code>aepi</code>	Temperature coefficient of the resistivity of the epilayer.
67	<code>aex</code>	Temperature coefficient of the resistivity of the extrinsic base.
68	<code>ac</code>	Temperature coefficient of the resistivity of the buried layer.
69	<code>aisat</code>	Temperature coefficient of the saturation current.
70	<code>dvgbf (V)</code>	Bandgap voltage difference of forward current gain.
71	<code>dvgbr (V)</code>	Bandgap voltage difference of reverse current gain.
72	<code>vgb (V)</code>	Bandgap voltage of the base.
73	<code>vgc (V)</code>	Bandgap voltage of the collector.
74	<code>vgj (V)</code>	Bandgap voltage recombination emitter-base junction.
75	<code>dvgte (V)</code>	Bandgap voltage difference of emitter stored charge.

Virtuoso Simulator Components and Device Models Reference

Philips Models

76	a_f	Exponent of the Flicker-noise.
77	k_f	Flicker-noise coefficient of the ideal base current.
78	k_{fn}	Flicker-noise coefficient of the non-ideal base current.
79	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	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.

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Philips Models

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.
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.

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Philips Models

40	gpiz (1/Ω)	Early effect on recombination base current.
41	gmux (1/Ω)	Early effect on avalanche current limiting.
42	gmuy (1/Ω)	Conductance of avalanche current.
43	gmuz (1/Ω)	Conductance of avalanche current.
44	gmue _x (1/Ω)	Conductance extrinsic b-c junction.
45	Xgmue _x (1/Ω)	Conductance extrinsic b-c junction.
46	grcv _y (1/Ω)	Conductance of the epilayer current.
47	grcv _z (1/Ω)	Conductance of the epilayer current.
48	Rbv (Ω)	Conductance of the epilayer current.
49	grbv _x (1/Ω)	Early-effect on base resistance.
50	grbv _y (1/Ω)	Early-effect on base resistance.
51	grbv _z (1/Ω)	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	Cbc _x (F)	Early effect on b-c diffusion charge.
60	Cbc _y (F)	Capacitance floor b-c junction.
61	Cbc _z (F)	Capacitance floor b-c junction.

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62	C_{bcex} (F)	Capacitance extrinsic b-c junction.
63	XC_{bcex} (F)	Capacitance extrinsic b-c junction.
64	C_{b1b2} (F)	Capacitance AC current crowding.
65	C_{b1b2x} (F)	Cross-capacitance AC current crowding .
66	C_{b1b2y} (F)	Cross-capacitance AC current crowding.
67	C_{b1b2z} (F)	Cross-capacitance AC current crowding.
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.

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.

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	sbjn	M-50
Cbcx	OP-59	aex	O-67	gy	OP-35	sbjn	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
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

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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
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

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Philips Models

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
SIbl	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
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	gmux	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
Xgmux	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 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 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 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. |

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Philips Models

4	<code>exmod=1</code>	Flag for extended modelling 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 modelling 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>mhf=1</code>	Non ideality factor of the non-ideal forward base current.
15	<code>mlr=2</code>	Non ideality factor of the non-ideal reverse base current.
16	<code>mhr=1</code>	Non ideality factor of the ideal reverse base current.
17	<code>mf=1</code>	Non ideality factor of main current.
18	<code>xibi=0</code>	Part of ideal base current that belongs to the sidewall.
19	<code>bri=7</code>	Ideal reverse current gain.
20	<code>ibr=1e-15 A</code>	Saturation current of the non-ideal reverse base current.
21	<code>vlr=0.2 V</code>	Cross-over voltage of the non-ideal reverse base current.
22	<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} .
23	<code>wavl=1.1e-06 m</code>	Epilayer thickness used in weak-avalanche model.
24	<code>vavl=3 V</code>	Voltage determining curvature of avalanche current.

Virtuoso Simulator Components and Device Models Reference

Philips Models

25	$sfh=0.3$	Current spreading factor of avalanche model (when EXAVL=1).
26	$re=5 \Omega$	Emitter resistance.
27	$rbc=23 \Omega$	Constant part of the base resistance.
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 Cjc.
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.

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Philips Models

45	<code>cbco=0</code>	Collector-base overlap capacitance.
46	<code>vos=0.04 V</code>	Voltage describing overshoot.
47	<code>isat=0.067 A</code>	Saturation current.
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 behaviour of Qtc.
54	<code>alfaw=0</code>	Smooth switch for reachthrough modelling.
55	<code>sw=0.1</code>	Smoothness parameter for reachthrough modelling.
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.

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Philips Models

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.
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>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 modelling 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>pnv</code> , <code>npnv</code> , <code>pnpv</code> , <code>npnl</code> , or <code>pnpl</code> .

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Philips Models

87 `imax=1.0 A` Explosion current.

88 `tnom (deg. C)` alias of `tnom`.

89 `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 modelling of reverse current gain.

4 `exphi` Flag for the distributed high-frequency effects in transient.

5 `exavl` Flag for extended modelling 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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

18	<code>bri</code>	Ideal reverse current gain.
19	<code>ibr</code> (A)	Saturation current of the non-ideal reverse base current.
20	<code>vlr</code> (V)	Cross-over voltage of the non-ideal reverse base current.
21	<code>xext</code>	Part of I_{ex} , Q_{tex} , Q_{ex} and I_{sub} that depends on V_{bc1} instead of V_{b1c1} .
22	<code>wavl</code> (M)	Epilayer thickness used in weak-avalanche model.
23	<code>vavl</code> (V)	Voltage determining curvature of avalanche current.
24	<code>sfh</code>	Current spreading factor of avalanche model (when $EXAVL=1$).
25	<code>re</code> (Ω)	Emitter resistance.
26	<code>rbc</code> (Ω)	Constant part of the base resistance.
27	<code>rbv</code> (Ω)	Zero-bias value of the variable part of the base resistance.
28	<code>rcc</code> (Ω)	Constant part of collector resistance.
29	<code>rcv</code> (Ω)	Resistance of the un-modulated epilayer.
30	<code>srcrv</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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

39	vdc (V)	Collector-base diffusion voltage.
40	pc	Collector-base grading coefficient.
41	xp	Constant part of Cjc.
42	mc	Coefficient for the current modulation of the collector-base depletion capacitance.
43	xcjc	Fraction of the collector-base depletion capacitance under the emitter.
44	cbco	Collector-base overlap capacitance.
45	vos (V)	Voltage describing overshoot.
46	isat (A)	Saturation current.
47	repi (Ω)	Ohmic resistance epilayer.
48	rdmin	Minimum relative collector doping.
49	sbn	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 behaviour of Qtc.
53	alfaw	Smooth switch for reachthrough modelling.
54	sw	Smoothness parameter for reachthrough modelling.
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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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.
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	kavl	Switch for white noise contribution due to avalanche.
80	rth (K/W)	Thermal resistance.

Virtuoso Simulator Components and Device Models Reference

Philips Models

81	c_{th} (J/K)	Thermal capacitance.
82	a_{th}	Temperature coefficient of the thermal resistance.
83	dt_{max} (K)	Maximal dynamic temperature increase.
84	exr_{th}	Flag for extended modelling of non-linear 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.
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.

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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/Ω)	Forward transconductance.
35	g _y (1/Ω)	Reverse transconductance.
36	g _z (1/Ω)	Reverse transconductance.
37	Sg _{pi} (1/Ω)	Conductance sidewall b-e junction.
38	gp _{ix} (1/Ω)	Conductance floor b-e junction.
39	gp _{iy} (1/Ω)	Early effect on recombination base current.

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Philips Models

40	gpiz (1/Ω)	Early effect on recombination base current.
41	gmux (1/Ω)	Early effect on avalanche current limiting.
42	gmuy (1/Ω)	Conductance of avalanche current.
43	gmuz (1/Ω)	Conductance of avalanche current.
44	gmux (1/Ω)	Conductance extrinsic b-c junction.
45	Xgmux (1/Ω)	Conductance extrinsic b-c junction.
46	grcvy (1/Ω)	Conductance of the epilayer current.
47	grcvz (1/Ω)	Conductance of the epilayer current.
48	Rbv (Ω)	Conductance of the epilayer current.
49	grbvz (1/Ω)	Early-effect on base resistance.
50	grbvy (1/Ω)	Early-effect on base resistance.
51	grbvz (1/Ω)	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.

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62	C_{bcex} (F)	Capacitance extrinsic b-c junction.
63	XC_{bcex} (F)	Capacitance extrinsic b-c junction.
64	C_{b1b2} (F)	Capacitance AC current crowding.
65	C_{b1b2x} (F)	Cross-capacitance AC current crowding .
66	C_{b1b2y} (F)	Cross-capacitance AC current crowding.
67	C_{b1b2z} (F)	Cross-capacitance AC current crowding.
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.

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.

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
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

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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
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

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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
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	expfi	M-5	rbc	M-27	xcje	O-36
XCbceX	OP-63	expfi	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
XgmueX	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	gmueX	OP-44	rcv	O-29	xrec	M-62

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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, EP MOS 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.

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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 ...
```

Virtuoso Simulator Components and Device Models Reference

Philips Models

Instance Parameters

1	<code>mult=1</code>	Number of devices in parallel.
2	<code>area=1</code>	Alias of <code>mult</code> .
3	<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> .
4	<code>m=1</code>	Multiplicity factor.

Model Definition

```
model modelName mos30 parameter=value ...
```

Model Parameters

1	<code>type=n</code>	Transistor gender. Possible values are <code>n</code> or <code>p</code> .
2	<code>ron=1.0 Ω</code>	Ohmic resistance at zero bias.
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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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>tréf (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>r_{ont} (Ω)</code>	Ohmic resistance at zero bias.
2	<code>r_{sat} (Ω)</code>	Space charge resistance at zero bias.
3	<code>v_{satt} (V)</code>	Critical drain-source voltage for hot carriers.
4	<code>v_{subt} (V)</code>	Substrate diffusion voltage.
5	<code>c_{gate} (F)</code>	Gate capacitance at zero bias.
6	<code>c_{subt} (F)</code>	Substrate capacitance at zero bias.

Operating-Point Parameters

1	<code>pwr (W)</code>	Power.
2	<code>ids (A)</code>	Total current including velocity saturation.
3	<code>q_b (Coul)</code>	Substrate charge.
4	<code>q_g (Coul)</code>	Gate charge.

Virtuoso Simulator Components and Device Models Reference

Philips Models

5	qds (Coul)	Space charge in the channel.
6	$gdsd$ (S)	Conductance ($d i_{ds} / d v_d$).
7	$gdsg$ (S)	Conductance ($d i_{ds} / d v_g$).
8	$gdss$ (S)	Conductance ($d i_{ds} / d v_s$).
9	$gdsb$ (S)	Conductance ($d i_{ds} / d v_b$).
10	cbd (F)	Capacitance ($d q_b / d v_d$).
11	cbg (F)	Capacitance ($d q_b / d v_g$).
12	cbs (F)	Capacitance ($d q_b / d v_s$).
13	cbb (F)	Capacitance ($d q_b / d v_b$).
14	cgd (F)	Capacitance ($d q_g / d v_d$).
15	cgg (F)	Capacitance ($d q_g / d v_g$).
16	cgs (F)	Capacitance ($d q_g / d v_s$).
17	cgb (F)	Capacitance ($d q_g / d v_b$).
18	$cdsd$ (F)	Capacitance ($d q_{ds} / d v_d$).
19	$cdsg$ (F)	Capacitance ($d q_{ds} / d v_g$).
20	$cdss$ (F)	Capacitance ($d q_{ds} / d v_s$).
21	$cdsb$ (F)	Capacitance ($d q_{ds} / d v_b$).

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

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	qjb	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
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 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

Virtuoso Simulator Components and Device Models Reference

Philips Models

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. |
| 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 | tbox=-1 m^{-3} | Box oxide thickness. |
| 10 | cgate=0 F | Gate capacitance at zero bias. |
| 11 | cbox=0 F | Wafer capacitance. |

Virtuoso Simulator Components and Device Models Reference

Philips Models

12	<code>tausc=0 s</code>	Space charge transit time of the channel.
13	<code>ach=0</code>	Temperature coefficient resistivity of the channel.
14	<code>achmod=0</code>	Parameter to switch to extended temperature scaling.
15	<code>achron=0</code>	Temperature coefficient of ohmic resistance at zero bias.
16	<code>achvsat=0</code>	Temperature coefficient of critical drain-source voltage for hot carriers.
17	<code>achrsat=0</code>	Temperature coefficient of space charge resistance at zero bias.
18	<code>tref=25 C</code>	Reference temperature.
19	<code>dta=0 K</code>	Temperature offset of the device.
20	<code>rth=300 K/W</code>	Thermal resistance.
21	<code>cth=3e-09 J/K</code>	Thermal capacitance.
22	<code>ath=0</code>	Temperature coefficient of the thermal resistance.
23	<code>type=n</code>	Transistor gender. Possible values are n, p, npn, pnp, npnv, pnpv, npnl, or pnp1.
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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

6	t_{ox} (m)	Gate oxide thickness.
7	d_{ch} (m^{-3})	Doping level channel.
8	t_{box} (m^{-3})	Box oxide thickness.
9	c_{gate} (F)	Gate capacitance at zero bias.
10	c_{box} (F)	Wafer capacitance.
11	t_{ausc} (s)	Space charge transit time of the channel.
12	r_{th} (K/W)	Thermal resistance.
13	c_{th} (J/K)	Thermal capacitance.
14	a_{th}	Temperature coefficient of the thermal resistance.

Operating-Point Parameters

1	i_{ds} (A)	Drain source current.
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.
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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

13	cgb (F)	Gate charge dependence on bulk voltage.
14	q _b (C)	Bulk charge.
15	cbd (F)	Bulk charge dependence on drain voltage.
16	cbg (F)	Bulk charge dependence on gate voltage.
17	cbs (F)	Bulk charge dependence on substrate voltage.
18	ccb (F)	Bulk charge dependence on bulk voltage.
19	q _d (C)	Drain charge.
20	cdd (F)	Drain charge dependence on drain voltage (dQ _d /dV _d).
21	cdg (F)	Drain charge dependence on gate voltage (-dQ _d /dV _g).
22	cds (F)	Drain charge dependence on source voltage (-dQ _d /dV _s).
23	cdb (F)	Drain charge dependence on bulk voltage (-dQ _d /dV _b).
24	q _s (C)	Source charge.
25	csd (F)	Source charge dependence on drain voltage (-dQ _s /dV _d).
26	cs _g (F)	Source charge dependence on gate voltage (-dQ _s /dV _g).
27	css (F)	Source charge dependence on source voltage (dQ _s /dV _s).
28	csb (F)	Source charge dependence on bulk voltage (-dQ _s /dV _b).
29	u	Transistor gain.
30	r _{out} (Ω)	Small-signal output resistance.
31	v _{early} (V)	Equivalent early voltage.
32	i _{ohm} (A)	Drain source current excluding velocity saturation.
33	i _{hc} (A)	Critical current for velocity saturation.
34	P _{diss} (W)	Dissipation.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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	cgate	M-10	imax	M-24	tausc	O-11
TK	OP-35	cgate	O-9	iohm	OP-32	tbox	M-9
ach	M-13	cgb	OP-13	level	M-1	tbox	O-8
achmod	M-14	cgd	OP-10	m	I-3	tnom	M-25
achron	M-15	cgg	OP-11	mult	I-1	tox	M-7
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	qb	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

Virtuoso Simulator Components and Device Models Reference

Philips Models

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 ...
```

Virtuoso Simulator Components and Device Models Reference

Philips Models

Instance Parameters

1	<code>mult=1</code>	Number of devices in parallel.
2	<code>area=1</code>	Alias of <code>mult</code> .
3	<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> .
4	<code>m=1</code>	Multiplicity factor.

Model Definition

```
model modelName mos3002 parameter=value ...
```

Model Parameters

1	<code>type=n</code>	Transistor gender. Possible values are <code>n</code> or <code>p</code> .
2	<code>ron=1.0 Ω</code>	Ohmic resistance at zero bias.
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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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.
2	<code>rsat (Ω)</code>	Space charge resistance at zero bias.
3	<code>vsatt (V)</code>	Critical drain-source voltage for hot carriers.
4	<code>vsubt (V)</code>	Substrate diffusion voltage.
5	<code>cgate (F)</code>	Gate capacitance at zero bias.
6	<code>csubt (F)</code>	Substrate capacitance at zero bias.

Operating-Point Parameters

1	<code>pwr (W)</code>	Power.
2	<code>ids (A)</code>	Total current including velocity saturation.
3	<code>qb (Coul)</code>	Substrate charge.
4	<code>qg (Coul)</code>	Gate charge.

Virtuoso Simulator Components and Device Models Reference

Philips Models

5	qds (Coul)	Space charge in the channel.
6	$gdsd$ (S)	Conductance ($d\ i_{ds} / d\ v_d$).
7	$gdsg$ (S)	Conductance ($d\ i_{ds} / d\ v_g$).
8	$gdss$ (S)	Conductance ($d\ i_{ds} / d\ v_s$).
9	$gdsb$ (S)	Conductance ($d\ i_{ds} / d\ v_b$).
10	cbd (F)	Capacitance ($d\ q_b / d\ v_d$).
11	cbg (F)	Capacitance ($d\ q_b / d\ v_g$).
12	cbs (F)	Capacitance ($d\ q_b / d\ v_s$).
13	cbb (F)	Capacitance ($d\ q_b / d\ v_b$).
14	cgd (F)	Capacitance ($d\ q_g / d\ v_d$).
15	cgg (F)	Capacitance ($d\ q_g / d\ v_g$).
16	cgs (F)	Capacitance ($d\ q_g / d\ v_s$).
17	cgb (F)	Capacitance ($d\ q_g / d\ v_b$).
18	$cdsd$ (F)	Capacitance ($d\ q_{ds} / d\ v_d$).
19	$cdsg$ (F)	Capacitance ($d\ q_{ds} / d\ v_g$).
20	$cdss$ (F)	Capacitance ($d\ q_{ds} / d\ v_s$).
21	$cdsb$ (F)	Capacitance ($d\ q_{ds} / d\ v_b$).

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

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	qjb	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
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		

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.

(c) Philips Electronics N.V. 1993, 1994

In extension to the modelbook 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.

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

Sample Instance Statement:

```
mnl (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. |
| 2 | ln=1.0 scale m | Drawn channel length in the lay-out of the actual transistor. Scale set by option scale. |
| 3 | w=1.0 scale m | Alias for wn. |
| 4 | l=1.0 scale m | Alias for ln. |
| 5 | mult=1 | Number of devices in parallel. |
| 6 | area=1 | Alias of mult. |
| 7 | region=triode | Estimated DC operating region, used as a convergence aid. Possible values are off, triode, sat, or subth. |
| 8 | m=1 | Multiplicity factor. |

Model Definition

```
model modelName mos705 parameter=value ...
```

Virtuoso Simulator Components and Device Models Reference

Philips Models

Model Parameters

1	<code>type=n</code>	Transistor gender. Possible values are n or p.
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>	$The1$ of the reference transistor.
8	<code>th2n=0 1/\sqrt{V}</code>	$The2$ of the reference transistor.
9	<code>th3n=0 1/V</code>	$The3$ of the reference transistor at the reference temperature.
10	<code>gamman=0</code>	Γ_m of the reference transistor.
11	<code>shiftn=0 $V^{(1-n)}$</code>	S_h of the reference transistor.
12	<code>nn=0</code>	N of the reference transistor.
13	<code>pn=0 1/V</code>	P of the reference transistor.
14	<code>ava=0</code>	A of the reference transistor.
15	<code>avb=1 V</code>	B of the reference transistor.
16	<code>avc=0</code>	C of the reference transistor.
17	<code>wref=100u m</code>	Effective width of the reference transistor.
18	<code>wtol=0 m</code>	Difference between drawn and effective gate width.
19	<code>dvtn=0 V m</code>	Narrow-width factor of the threshold voltage at v_{sbref} .
20	<code>dkon=0 \sqrt{V} m</code>	Narrow-width factor of k_0 .

Virtuoso Simulator Components and Device Models Reference

Philips Models

21	$dkn=0 \sqrt{V} \text{ m}$	Narrow-width factor of k .
22	$dvsbxn=0 \text{ V m}$	Narrow-width factor of v_{sbx} .
23	$dde1vx=0 \text{ Vm}$	Narrow-width factor of $dvsbx$.
24	$betan=20u \text{ A/V}^2$	Gain factor of a infinite-square transistor at the reference temperature.
25	$dth1n=0 \text{ m/V}$	Narrow-width factor of th_{e1} .
26	$dth2n=0 \text{ m}/\sqrt{V}$	Narrow-width factor of th_{e2} .
27	$dth3n=0 \text{ m/V}$	Narrow-width factor of th_{e3} .
28	$dgamn=0 \text{ m}$	Narrow-width factor of gam .
29	$dava=0 \text{ m}$	Narrow-width factor of a .
30	$davb=0 \text{ V m}$	Narrow-width factor of b .
31	$davc=0 \text{ m}$	Narrow-width factor of c .
32	$lref=100u \text{ m}$	Effective length of the reference transistor.
33	$ltol=0 \text{ m}$	Difference between drawn and actual gate polysilicon length.
34	$gvtn=0 \text{ V m}$	Short-channel factor of the threshold voltage at v_{sbref} .
35	$gkon=0 \sqrt{V} \text{ m}$	Short-channel factor of k_o .
36	$gkn=0 \sqrt{V} \text{ m}$	Short-channel factor of k .
37	$gvsbxn=0 \text{ V m}$	Short-channel factor of v_{sbx} .
38	$gde1vx=0 \text{ V m}$	Short-channel factor of $dvsbx$.
39	$gth1n=0 \text{ m/V}$	Short-channel factor of th_{e1} .
40	$gth2n=0 \text{ m}/\sqrt{V}$	Short-channel factor of th_{e2} .
41	$gth3n=0 \text{ m/V}$	Short-channel factor of th_{e3} .

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42	$ggamn=0$ m	Short-channel factor of g_{am} .
43	$gshift=0$ $V^{(1-n)}$ m^2	Short-channel factor of s_h .
44	$gnn=0$ m	Short-channel factor of n .
45	$gpn=0$ m/V	Short-channel factor of p .
46	$gava=0$ m	Short-channel factor of a .
47	$gavb=0$ V m	Short-channel factor of b .
48	$gavc=0$ m	Short-channel factor of c .
49	$lap=0$ m	Half of the effective channel-length reduction due to lateral diffusion.
50	$vsbref=0$ V	Source to bulk reference voltage for parameter determination.
51	$phi=600m$ V	Diffusion potential at the reference temperature.
52	$tcvt=-1m$ V/K	Temperature coefficient of v_{t0} .
53	$tbetan=1.5$	Power temperature coefficient of bet .
54	$tth3n=0$ $1/(V\ K)$	Temperature coefficient of t_{he3} .
55	$tgth3n=0$ $m/(V\ K)$	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	$subthn=0$	Weak-inversion factor.
58	$vtr=0$ V	Depletion-MOS-transistor-transition voltage.
59	$ratio=0$	Depletion-MOS-transistor-gain ratio.
60	$vfb=0$ V	Flat-band voltage.
61	$tox=100n$ m	Gate-oxide thickness.

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62	$c_{ol}=0$ F/m	Gate/drain or gate/source overlap capacitance per unit length.
63	$f_{noise}=0$ $m^2 V^2$	Flicker-noise factor.
64	$t_{noise}=0$	Thermal-noise factor.

Temperature parameters

65	t_r (C)	Reference temperature. Default set by option t_{nom} .
66	t_{ref} (C)	Alias of t_r . Default set by option t_{nom} .
67	t_{nom} (C)	Alias of t_r . Default set by option t_{nom} .
68	$d_{ta}=0$ K	Deviation between the temperature of the transistor and the temperature of the circuit.
69	$t_{rise}=0$ K	Alias of d_{ta} .

Output Parameters

1	w_{eff} (V)	Effective channel width of the actual transistor.
2	l_{eff} (V)	Effective channel length of the actual transistor.
3	t_{wophif} (V)	Diffusion potential.
4	β_{et} (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	d_{vsbx} (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	t_{he1} (1/V)	Gate-bias-controlled transverse-field mobility reduction factor.

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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	gam	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	me (\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	cox (F)	Gate capacitance.
23	$cgso$ (F)	Gate/source-overlap capacitance.
24	$cgdo$ (F)	Gate/drain-overlap capacitance.
25	$vtre$ (V)	Depletion MOS transistor transition voltage.
26	$ratio$	Depletion MOS transistor gain ratio.
27	$vfbe$ (V)	Flat band voltage.
28	$vtemp$ (V)	kT/q at actual device temperature.
29	$gnoise$ (V^2)	Coefficient of the flicker noise for the actual transistor.
30	$unoise$ (J)	Coefficient of the thermal noise for the actual transistor.

Operating-Point Parameters

1	ide (A)	Drain current.
2	ige (A)	Gate current.

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3	i_{se} (A)	Source current.
4	i_{be} (A)	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)	Drain-source current.
9	i_{db} (A)	Drain-bulk current.
10	i_{sb} (A)	Source-bulk current.
11	pwr (W)	Power.
12	v_{ts} (V)	V_{to} including back-bias effects.
13	v_{gt} (V)	Effective gate drive including back-bias and drain effects.
14	v_{dss} (V)	Saturation voltage at actual bias.
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 ($- d q_g / d v_s$).

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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	u	Transistor gain (gm/gds).
35	rout (Ω)	Small signal output resistance (1/gds).
36	vearly (V)	Equivalent Early voltage ($ I_d /gds$).
37	keff (\sqrt{V})	Describes body effect at actual bias.
38	befeff (S/V)	Effective beta at actual bias in the simple MOS model.
39	fug (Hz)	Unity gain frequency at actual bias ($gm/(2*\pi*cox)$).
40	sqrtsw (V/\sqrt{Hz})	Input-referred RMS white noise voltage (\sqrt{sth}/gm).
41	sqrtfff (V/\sqrt{Hz})	Input-referred RMS 1/f noise voltage at 1kHz ($\sqrt{gnoise/1000}$).
42	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

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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
beff	OP-38	dvtm	M-19	lap	M-49	trise	M-69
bet	O-4	fknee	OP-42	leff	O-2	tth3n	M-54
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

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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
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	thel	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 modelbook 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
```

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 thelr=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.

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 `vtor=0.8 V` Threshold voltage at zero back-bias.

10 `stvt0=0.01 V/K` Coefficient of the temperature dependence of `vt0`.

11 `slvt0=0.5e-6 V m` Coefficient of the length dependence of `vt0`.

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- 12 $sl2vto=0$ V m² Second coefficient of the length dependence of v_{to} .
- 13 $swvto=5e-6$ V m Coefficient of the width dependence of v_{to} .
- 14 $kor=0.5$ \sqrt{V} Low-backbias body factor.
- 15 $slko=1e-6$ \sqrt{V} m Coefficient of the length dependence of k_o .
- 16 $swko=10e-6$ \sqrt{V} m Coefficient of the width dependence of k_o .
- 17 $kr=0.1$ \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.
- 21 $vsbxr=0.9$ V Transition voltage for the dual-k-factor model.
- 22 $slvsbx=0.5e-6$ V m Coefficient of the length dependence of $vsbx$.
- 23 $swvsbx=5e-6$ V m Coefficient of the width dependence of $vsbx$.
- 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 $thelr=0.05$ 1/V Coefficient of the mobility reduction due to the gate-induced field.
- 27 $stthelr=3e-3$ 1/(V K) Coefficient of the temperature dependence of $thel$.
- 28 $slthelr=50e-9$ m/V Coefficient of the length dependence of $thel$.

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- 29 $slthe1=5e-9 \text{ m}/(\text{V K})$ Coefficient of the temperature dependence of $slthe1$.
- 30 $swthe1=1e-6 \text{ m}/\text{V}$ Coefficient of the width dependence of $the1$.
- 31 $fthe1=0$ Coefficient describing the width dependence of $the1$ for $w < wdog$.
- 32 $the2r=17e-3 \text{ 1}/\sqrt{\text{V}}$ Coefficient of the mobility reduction due to the back-bias.
- 33 $stthe2r=0.1e-3 \text{ 1}/(\sqrt{\text{V K}})$ Coefficient of the temperature dependence of $the2$.
- 34 $slthe2r=5e-9 \text{ m}/\sqrt{\text{V}}$ Coefficient of the length dependence of $the2$.
- 35 $slthe2=0.5e-9 \text{ m}/(\sqrt{\text{V K}})$ Coefficient of the temperature dependence of $slthe2$.
- 36 $swthe2=0.1e-6 \text{ m}/\sqrt{\text{V}}$ Coefficient of the width dependence of $the2$.
- 37 $the3r=37e-3 \text{ 1}/\text{V}$ Coefficient of the mobility reduction due to the lateral field.
- 38 $stthe3r=0.1e-3 \text{ 1}/(\text{V K})$ Coefficient of the temperature dependence of $the3$.
- 39 $slthe3r=5e-9 \text{ m}/\text{V}$ Coefficient of the length dependence of $the3$.
- 40 $slthe3=0.5e-9 \text{ m}/(\text{V K})$ Coefficient of the temperature dependence of $slthe3$.
- 41 $swthe3=0.1e-6 \text{ m}/\text{V}$ Coefficient of the width dependence of $the3$.

Drain-feedback parameters

- 42 $gam1r=40e-3 \text{ V}^{(1-etads)}$ Coefficient for the drain induced threshold shift for large gate drive.
- 43 $slgam1=0.1e-6 \text{ V}^{(1-etads)} \text{ m}$ Coefficient of the length dependence of $gam1$.

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- 44 $swgam1=1e-6 V^{(1-etads)} m$ Coefficient of the width dependence of $gam1$.
- 45 $etadsr=0.6$ Exponent of the vds dependence of $gam1$.
- 46 $alpr=4e-3$ Factor of the channel-length modulation.
- 47 $etaalp=0.5$ Exponent of the length dependence of alp .
- 48 $slalp=0.14e-3 m^{etaalp}$ Coefficient of the length dependence of alp .
- 49 $swalp=0.1e-6 m$ Coefficient of the width dependence of alp .
- 50 $vpr=0.25 V$ Characteristic voltage of the channel-length modulation.

Sub-threshold parameters

- 51 $gamoor=1.1e-3$ Coefficient for the drain induced threshold shift at zero gate drive.
- 52 $slgamoo=10e-15 m^2$ 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 $stmo=0.01 1/K$ 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 $slzet1=0.14e-6 m^{etazet}$ Coefficient of the length dependence of $zet1$.
- 61 $vsbtr=99 V$ Limiting voltage of the vsb dependence of m and $gamoo$.

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62 $slvsbt=10e-6$ V m Coefficient of the length dependence of $vsbt$.

Weak-avalanche parameters

63 $a1r=22$ Factor of the weak-avalanche current.

64 $sta1=0.1$ 1/K Coefficient of the temperature dependence of $a1$.

65 $sla1=10e-6$ m Coefficient of the length dependence of $a1$.

66 $swa1=0.1e-3$ m Coefficient of the width dependence of $a1$.

67 $a2r=33$ V Exponent of the weak-avalanche current.

68 $sla2=10e-6$ V m Coefficient of the length dependence of $a2$.

69 $swa2=0.1e-3$ V m Coefficient of the width dependence of $a2$.

70 $a3r=0.6$ Factor of the drain-source voltage above which weak-avalanche occurs.

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 $tnom$.

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78	<code>tref</code> (C)	Alias of <code>tr</code> . Default set by option <code>tnom</code> .
79	<code>tnom</code> (C)	Alias of <code>tr</code> . Default set by option <code>tnom</code> .
80	<code>dta=0</code> K	Temperature offset of the device.
81	<code>trise=0</code> K	Alias of <code>dta</code> .

Output Parameters

1	<code>le</code> (m)	Effective channel length.
2	<code>we</code> (m)	Effective channel width.
3	<code>vto</code> (V)	Threshold voltage at zero back-bias.
4	<code>ko</code> (\sqrt{V})	Low-backbias body factor.
5	<code>k</code> (\sqrt{V})	High-backbias body factor.
6	<code>phib</code> (V)	Surface potential at strong inversion.
7	<code>vsbx</code> (V)	Transition voltage for the dual- k -factor model.
8	<code>bet</code> (A/V ²)	Gain factor (* mult).
9	<code>the1</code> (1/V)	Coefficient of the mobility reduction due to the gate-induced field.
10	<code>the2</code> (1/ \sqrt{V})	Coefficient of the mobility reduction due to the back-bias.
11	<code>the3</code> (1/V)	Coefficient of the mobility reduction due to the lateral field.
12	<code>gam1</code> (V ^(1-etads))	Coefficient for the drain induced threshold shift for large gate drive.
13	<code>etads</code>	Exponent of the <code>vds</code> dependence of <code>gam1</code> .
14	<code>alp</code>	Factor of the channel-length modulation.
15	<code>vp</code> (V)	Characteristic voltage of the channel-length modulation.
16	<code>gamoo</code>	Coefficient for the drain induced threshold shift at zero gate drive.

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17	etagam	Exponent of the back-bias dependence of γ_{amo} .
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 v_{sb} dependence of m and γ_{amo} .
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).
27	cgdo (F)	Gate-drain overlap capacitance (* mult).
28	cgso (F)	Gate-source overlap capacitance (* mult).
29	nt (J)	Coefficient of the thermal noise.
30	nf (V ²)	Coefficient of the flicker noise (/ 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.

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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_{t0} 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 ($d i_{ds} / d v_{gs}$).
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 ($- d q_s / d v_d$).

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29	<code>csg</code> (F)	Capacitance (- d qs / d vg).
30	<code>css</code> (F)	Capacitance (d qs / d vs).
31	<code>csb</code> (F)	Capacitance (- d qs / d vb).
32	<code>cbd</code> (F)	Capacitance (- d qb / d vd).
33	<code>cbg</code> (F)	Capacitance (- d qb / d vg).
34	<code>cbs</code> (F)	Capacitance (- d qb / d vs).
35	<code>cbb</code> (F)	Capacitance (d qb / d vb).
36	<code>u</code>	Transistor gain (gm/gds).
37	<code>rout</code> (Ω)	Small signal output resistance (1/gds).
38	<code>vearly</code> (V)	Equivalent Early voltage ($ id /gds$).
39	<code>keff</code> (\sqrt{V})	Describes body effect at actual bias.
40	<code>beff</code> (S/V)	Effective beta at actual bias in the simple MOS model ($2* ids /vgt^2$).
41	<code>fug</code> (Hz)	Unity gain frequency at actual bias ($gm/(2*pi*cin)$).
42	<code>sqrtsw</code> (V/\sqrt{Hz})	Input-referred RMS white noise voltage (\sqrt{sth}/gm).
43	<code>sqrtfff</code> (V/\sqrt{Hz})	Input-referred RMS 1/f noise voltage at 1kHz ($\sqrt{nf/1000}$).
44	<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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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
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

Virtuoso Simulator Components and Device Models Reference

Philips Models

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
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 modelbook 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

```
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 thelr=0.67 stthelr=-1.76e-3 etaalp=0 slalp=0 alpr=0.01
```

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 mos903 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.

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.

Threshold-voltage parameters

8 `vtor=0.8 V` Threshold voltage at zero back-bias.

9 `stvt0=0.01 V/K` Coefficient of the temperature dependence of v_{t0} .

10 `slvt0=0.5e-6 V m` Coefficient of the length dependence of v_{t0} .

11 `sl2vt0=0 V m2` Second coefficient of the length dependence of v_{t0} .

12 `swvt0=5e-6 V m` Coefficient of the width dependence of v_{t0} .

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 13 $k_{or}=0.5 \sqrt{V}$ Low-backbias body factor.
- 14 $slk_o=1e-6 \sqrt{V} \text{ m}$ Coefficient of the length dependence of k_o .
- 15 $swk_o=10e-6 \sqrt{V} \text{ m}$ Coefficient of the width dependence of k_o .
- 16 $k_r=0.1 \sqrt{V}$ High-backbias body factor.
- 17 $slk=0.5e-6 \sqrt{V} \text{ m}$ Coefficient of the length dependence of k .
- 18 $swk=5e-6 \sqrt{V} \text{ m}$ Coefficient of the width dependence of k .
- 19 $\phi_{ibr}=0.65 \text{ V}$ Surface potential at strong inversion.
- 20 $v_{sbxr}=0.9 \text{ V}$ Transition voltage for the dual-k-factor model.
- 21 $slv_{sbx}=0.5e-6 \text{ V m}$ Coefficient of the length dependence of v_{sbx} .
- 22 $swv_{sbx}=5e-6 \text{ V m}$ Coefficient of the width dependence of v_{sbx} .

Channel-current parameters

- 23 $\beta_{etsq}=0.1e-3 \text{ A/V}^2$ Gain factor for an infinite square transistor.
- 24 $\epsilon_{tabet}=0.5$ Exponent of the temperature dependence of the gain factor.
- 25 $thelr=0.05 \text{ 1/V}$ Coefficient of the mobility reduction due to the gate-induced field.
- 26 $stthelr=3e-3 \text{ 1/(V K)}$ Coefficient of the temperature dependence of $thel$.
- 27 $slthelr=50e-9 \text{ m/V}$ Coefficient of the length dependence of $thel$.
- 28 $stlthel=5e-9 \text{ m/(V K)}$ Coefficient of the temperature dependence of $slthel$.
- 29 $swthel=1e-6 \text{ m/V}$ Coefficient of the width dependence of $thel$.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 30 $w_{dog}=0$ m Characteristic drawn gate width, below which dogboning appears.
- 31 $f_{the1}=0$ Coefficient describing the width dependence of t_{he1} for $w < w_{dog}$.
- 32 $t_{he2r}=17e-3$ $1/\sqrt{V}$ Coefficient of the mobility reduction due to the back-bias.
- 33 $st_{the2r}=0.1e-3$ $1/(\sqrt{V} \text{ K})$ Coefficient of the temperature dependence of t_{he2} .
- 34 $sl_{the2r}=5e-9$ m/ \sqrt{V} Coefficient of the length dependence of t_{he2} .
- 35 $st_{lthe2}=0.5e-9$ m/ $(\sqrt{V} \text{ K})$ Coefficient of the temperature dependence of sl_{the2} .
- 36 $sw_{the2}=0.1e-6$ m/ \sqrt{V} Coefficient of the width dependence of t_{he2} .
- 37 $t_{he3r}=37e-3$ $1/V$ Coefficient of the mobility reduction due to the lateral field.
- 38 $st_{the3r}=0.1e-3$ $1/(V \text{ K})$ Coefficient of the temperature dependence of t_{he3} .
- 39 $sl_{the3r}=5e-9$ m/V Coefficient of the length dependence of t_{he3} .
- 40 $st_{lthe3}=0.5e-9$ m/(V K) Coefficient of the temperature dependence of sl_{the3} .
- 41 $sw_{the3}=0.1e-6$ m/V Coefficient of the width dependence of t_{he3} .

Drain-feedback parameters

- 42 $gam1r=40e-3$ $V^{(1-etads)}$ Coefficient for the drain induced threshold shift for large gate drive.
- 43 $slgam1=0.1e-6$ $V^{(1-etads)}$ m Coefficient of the length dependence of $gam1$.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 44 $swgam1=1e-6 V^{(1-etads)} m$ Coefficient of the width dependence of $gam1$.
- 45 $etadsr=0.6$ Exponent of the vds dependence of $gam1$.
- 46 $alpr=4e-3$ Factor of the channel-length modulation.
- 47 $etaalp=0.5$ Exponent of the length dependence of alp .
- 48 $slalp=0.14e-3 m^{etaalp}$ Coefficient of the length dependence of alp .
- 49 $swalp=0.1e-6 m$ Coefficient of the width dependence of alp .
- 50 $vpr=0.25 V$ Characteristic voltage of the channel-length modulation.

Sub-threshold parameters

- 51 $gamoor=1.1e-3$ Coefficient for the drain induced threshold shift at zero gate drive.
- 52 $slgamoo=10e-15 m^2$ 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 $stmo=0.01 1/K$ 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 $slzet1=0.14e-6 m^{etazet}$ Coefficient of the length dependence of $zet1$.
- 61 $vsbtr=99 V$ Limiting voltage of the vsb dependence of m and $gamoo$.

Virtuoso Simulator Components and Device Models Reference

Philips Models

62 $slvsbt=10e-6$ V m Coefficient of the length dependence of $vsbt$.

Weak-avalanche parameters

63 $a1r=22$ Factor of the weak-avalanche current.

64 $sta1=0.1$ 1/K Coefficient of the temperature dependence of $a1$.

65 $sla1=10e-6$ m Coefficient of the length dependence of $a1$.

66 $swa1=0.1e-3$ m Coefficient of the width dependence of $a1$.

67 $a2r=33$ V Exponent of the weak-avalanche current.

68 $sla2=10e-6$ V m Coefficient of the length dependence of $a2$.

69 $swa2=0.1e-3$ V m Coefficient of the width dependence of $a2$.

70 $a3r=0.6$ Factor of the drain-source voltage above which weak-avalanche occurs.

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 $nfmod=0.0$ Switch that selects either old or new flicker noise model.

77 $nfr=16e-12$ V² Flicker noise coefficient of the reference transistor (for $nfmod=1$).

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 78 $n_{far}=7.15e+22$ $1/(V\ m^4)$
First coefficient of the flicker noise coefficient of the reference transistor (for $n_{mod}=1$).
- 79 $n_{fbr}=2.16e+7$ $1/(V\ m^2)$
Second coefficient of the flicker noise coefficient of the reference transistor (for $n_{mod}=1$).
- 80 $n_{fcr}=0.0$ $1/V$
Third coefficient of the flicker noise coefficient of the reference transistor (for $n_{mod}=1$).

Temperature parameters

- 81 t_r (C)
Reference temperature. Default set by option t_{nom} .
- 82 t_{ref} (C)
Alias of t_r . Default set by option t_{nom} .
- 83 $dta=0$ K
Temperature offset of the device.
- 84 $t_{rise}=0$ K
Alias of dta .

Other parameters

- 85 $th3mod=1$
Flag for θ_3 clipping.

Compatibility model parameters

- 86 $compatible=spectre$
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 l_e (m)
Effective channel length.
- 2 w_e (m)
Effective channel width.
- 3 v_{to} (V)
Threshold voltage at zero back-bias.

Virtuoso Simulator Components and Device Models Reference

Philips Models

4	k_o (\sqrt{V})	Low-backbias body factor.
5	k (\sqrt{V})	High-backbias body factor.
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 ($V^{(1-\text{etads})}$)	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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

25	a3	Factor of the drain-source voltage above which weak-avalanche occurs.
26	cox (F)	Gate-to-channel capacitance (* mult).
27	cgdo (F)	Gate-drain overlap capacitance (* mult).
28	cgso (F)	Gate-source overlap capacitance (* mult).
29	nt (J)	Coefficient of the thermal noise.
30	nf (V ²)	Coefficient of the flicker noise (/ mult) (nfmod = 0).
31	nfa (1/(V m ⁴))	First coefficient of the flicker noise of the actual transistor (nfmod = 1).
32	nfb (1/(V m ²))	Second coefficient of the flicker noise of the actual transistor (nfmod = 1).
33	nfc (1/V)	Second coefficient of the flicker noise of the actual transistor (nfmod = 1).
34	tox (m)	Thickness of gate oxide layer.

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-source current.
9	idb (A)	Resistive drain-bulk current.

Virtuoso Simulator Components and Device Models Reference

Philips Models

10	i_{sb} (A)	Resistive source-bulk current.
11	i_{avl} (A)	Substrate current.
12	pwr (W)	Power.
13	v_{t1} (V)	v_{t0} 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 ($d i_{ds} / d v_{gs}$).
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 ($- d q_s / d v_b$).

Virtuoso Simulator Components and Device Models Reference

Philips Models

32	cbd (F)	Capacitance (- d qb / d vd).
33	cbg (F)	Capacitance (- d qb / d vg).
34	cbs (F)	Capacitance (- d qb / d vs).
35	cbb (F)	Capacitance (d qb / d vb).
36	u	Transistor gain (gm/gds).
37	rout (Ω)	Small signal output resistance (1/gds).
38	vearly (V)	Equivalent Early voltage ($ id /gds$).
39	keff (\sqrt{V})	Describes body effect at actual bias.
40	beff (S/V)	Effective beta at actual bias in the simple MOS model ($2* ids /vgt^2$).
41	fug (Hz)	Unity gain frequency at actual bias ($gm/(2*pi*cin)$).
42	sqrtsw (V/ \sqrt{Hz})	Input-referred RMS white noise voltage (\sqrt{sth}/gm).
43	sqrtfff (V/ \sqrt{Hz})	Input-referred RMS 1/f noise voltage at 1kHz ($\sqrt{nf/1000}$).
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 fknee OP-44 phib O-6 swthe3 M-41

Virtuoso Simulator Components and Device Models Reference

Philips Models

a1r	M-63	fthel	M-31	phibr	M-19	swvsbx	M-22
a2	O-24	fug	OP-41	phit	O-20	swvto	M-12
a2r	M-67	gam1	O-12	pwr	OP-12	th3mod	M-85
a3	O-25	gam1r	M-42	region	I-5	thel	O-9
a3r	M-70	gamoo	O-16	rout	OP-37	thelr	M-25
alp	O-14	gamoor	M-51	sl2vto	M-11	the2	O-10
alpr	M-46	gds	OP-19	slal	M-65	the2r	M-32
area	I-4	gm	OP-17	sla2	M-68	the3	O-11
beff	OP-40	gmb	OP-18	sla3	M-71	the3r	M-37
bet	O-8	iavl	OP-11	slalp	M-48	tox	M-73
betsq	M-23	ibe	OP-4	slgam1	M-43	tox	O-34
cbb	OP-35	idb	OP-9	slgamoo	M-52	tr	M-81
cbd	OP-32	ide	OP-1	slk	M-17	tref	M-82
cbg	OP-33	ids	OP-8	slko	M-14	trise	M-84
cbs	OP-34	ige	OP-2	slmo	M-56	type	M-1
cdb	OP-23	isb	OP-10	slthelr	M-27	u	OP-36
cdd	OP-20	ise	OP-3	slthe2r	M-34	vds	OP-5
cdg	OP-21	k	O-5	slthe3r	M-39	vdss1	OP-15
cds	OP-22	keff	OP-39	slvsbt	M-62	vearly	OP-38
cgb	OP-27	ko	O-4	slvsbx	M-21	vgs	OP-6
cgd	OP-24	kor	M-13	slvto	M-10	vgt2	OP-14

Virtuoso Simulator Components and Device Models Reference

Philips Models

cgdo	O-27	kr	M-16	slzet1	M-60	vp	O-15
cgg	OP-25	l	I-2	sqrtsff	OP-43	vpr	M-50
cgs	OP-26	lap	M-5	sqrtsfw	OP-42	vsat	OP-16
cgso	O-28	le	O-1	stal	M-64	vsb	OP-7
col	M-74	ler	M-2	stlthe1	M-28	vsbt	O-22
compatible	M-86	lvar	M-4	stlthe2	M-35	vsbtr	M-61
cox	O-26	m	I-6	stlthe3	M-40	vsbx	O-7
csb	OP-31	mo	O-18	stmo	M-55	vsbxr	M-20
csd	OP-28	mor	M-54	stthe1r	M-26	vt1	OP-13
csg	OP-29	mult	I-3	stthe2r	M-33	vto	O-3
css	OP-30	nf	O-30	stthe3r	M-38	vtor	M-8
dta	M-83	nfa	O-31	stvto	M-9	w	I-1
etaalp	M-47	nfar	M-78	swal	M-66	wdog	M-30
etabet	M-24	nfb	O-32	swa2	M-69	we	O-2
etads	O-13	nfbr	M-79	swa3	M-72	wer	M-3
etadsr	M-45	nfc	O-33	swalp	M-49	wot	M-7
etagam	O-17	nfcrc	M-80	swgam1	M-44	wvar	M-6
etagamr	M-53	nfmod	M-76	swk	M-18	zet1	O-21
etam	O-19	nfr	M-77	swko	M-15	zet1r	M-58
etamr	M-57	nt	O-29	swthe1	M-29		
etazet	M-59	ntr	M-75	swthe2	M-36		

Virtuoso Simulator Components and Device Models Reference

Philips Models

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. |

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`.

12 `swvfb=4.400e-09 V m`
Coefficient of the width dependency of `vfbr`.

Virtuoso Simulator Components and Device Models Reference

Philips Models

13 $k_{or}=368.0e-03 \sqrt{V}$ Body effect coefficient for the reference transistor.

14 $slk_o=-8.240e-09 \sqrt{V} \text{ m}$ Coefficient of the length dependence of k_o .

15 $sl2k_o=-2.260e-15 \sqrt{V} \text{ m}^2$ Second coefficient of the length dependence of k_o .

16 $swk_o=5.86e-09 \sqrt{V} \text{ m}$ Coefficient of the width dependence of k_o .

17 $\phi_{ibr}=0.6 \text{ V}$ Surface potential at strong inversion.

Channel-current parameters

18 $\beta_{tsq}=370.9e-06 \text{ A/V}^2$ Gain factor for an infinite square transistor.

19 $\eta_{\beta} = 1.6$ Exponent of the temperature dependence of the gain factor.

20 $\theta_{srr}=16.10e-3 \text{ 1/V}^2$ Mobility degradation parameter due to surface roughness scattering.

21 $\sigma_{\theta_{srr}}=0.0 \text{ 1/(V}^2 \text{ K)}$ Coefficient of the temperature dependence of θ_{srr} .

22 $\sigma_{\theta_{srr}}=0.0 \text{ 1/(V}^2 \text{ m)}$ Coefficient of the width dependence of θ_{srr} .

23 $\theta_{phr}=0.055 \text{ 1/V}$ Mobility degradation parameter due to phonon scattering.

24 $\sigma_{\theta_{ph}}=0.0 \text{ 1/(V K)}$ Coefficient of the temperature dependence of θ_{ph} .

25 $\sigma_{\theta_{ph}}=0.0 \text{ 1/(V m)}$ Coefficient of the width dependence of θ_{ph} .

26 $\eta_{\text{amobr}}=1.6$ Effective field parameter for dependence on depletion charge.

27 $\sigma_{\eta_{\text{amobr}}}=0.0 \text{ 1/m}$ Coefficient of the width dependence of η_{amobr} .

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Philips Models

- 28 $t_{\text{thersq}}=0.155 \text{ 1/V}$ Coefficient of gate voltage independent part of series resistance.
- 29 $sw_{\text{ther}}=0.0 \text{ 1/(V m)}$
Coefficient of the width dependence of t_{ther} .
- 30 $t_{\text{ther1}}=0.0 \text{ V}$ Numerator of gate voltage independent part of series resistance.
- 31 $t_{\text{ther2}}=1.0 \text{ V}$ Denominator of gate voltage independent part of series resistance.
- 32 $t_{\text{thenr}}=0.480 \text{ 1/V}$ Velocity saturation parameter due to optical phonon scattering.
- 33 $st_{\text{then}}=0.0 \text{ 1/(V K)}$
Coefficient of the temperature dependence of t_{hen} .
- 34 $sw_{\text{then}}=0.0 \text{ 1/(V m)}$
Coefficient of the width dependence of t_{hen} .
- 35 $t_{\text{hepr}}=0.0 \text{ 1/V}$ Velocity saturation parameter due to acoustic phonon scattering.
- 36 $st_{\text{thep}}=0.0 \text{ 1/(V K)}$
Coefficient of the temperature dependence of t_{hep} .
- 37 $sw_{\text{thep}}=0.0 \text{ 1/(V m)}$
Coefficient of the width dependence of t_{hep} .
- 38 $g_{\text{thep}}=1.0$ Velocity saturation factor due to acoustic phonon scattering.
- 39 $t_{\text{hethr}}=3.227\text{e-}3 \text{ 1/V}^3$
Coefficient of self-heating.
- 40 $sl_{\text{theth}}=2.460\text{e-}9 \text{ 1/(V}^3 \text{ m)}$
Coefficient of the length dependence of t_{heth} .
- 41 $sw_{\text{theth}}=0.0 \text{ 1/(V}^3 \text{ m)}$
Coefficient of the width dependence of t_{heth} .

Sub-threshold parameters

- 42 $sd_{\text{iblo}}=2.030\text{e-}03 \text{ 1/}\sqrt{\text{V}}$
Drain-induced barrier lowering parameter.

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Philips Models

- 43 $sdiblexp=1.340$ Exponent of the length dependence of $sdibl$.
- 44 $dphi=0.800$ V Parameter for short-channel subthreshold behaviour.

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.
- 57 $sla2=1.00e-06$ V m Coefficient of the length dependence of $a2$.
- 58 $swa2=2.00e-06$ V m Coefficient of the width dependence of $a2$.

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Philips Models

59 $a3r=0.650$ Factor of the drain-source voltage above which weak-avalanche occurs.

60 $sla3=-550.0e-06$ m Coefficient of the length dependence of $a3$.

61 $swa3=0.0$ m Coefficient of the width dependence of $a3$.

Charge parameters

62 $tox=4.5e-09$ m Thickness of the oxide layer.

63 $col=320e-12$ F/m Gate overlap capacitance per unit channel width.

Temperature parameters

64 tr (C) Reference temperature. Default set by option $tnom$.

65 $tref$ (C) Alias of tr . Default set by option $tnom$.

66 $tnom$ (C) Alias of tr . Default set by option $tnom$.

67 $dta=0.0$ K Temperature offset of the device.

68 $trise=0.0$ K Alias of dta .

Output Parameters

1 le (m) Effective channel length.

2 we (m) Effective channel width.

3 vfb (V) Flat-band voltage.

4 ko (\sqrt{V}) Body effect coefficient.

5 $phib$ (V) Surface potential at strong inversion.

6 bet (A/V^2) Gain factor.

7 $thesr$ ($1/V^2$) Mobility degradation parameter due to surface roughness scattering.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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/√V)	Drain-induced barrier lowering parameter.
18	dphi (V)	Parameter for short-channel subthreshold behaviour.
19	ssf (1/√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.
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).

Virtuoso Simulator Components and Device Models Reference

Philips Models

29 c_{gso} (F) Gate-source overlap capacitance (* 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 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_{to} (V) Threshold voltage at zero back-bias.

14 v_{ts} (V) V_{ts} .

15 v_{gt} (V) Effective gate drive including backbias and drain effects.

16 v_{dss} (V) Saturation voltage at actual bias.

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 ($d i_{ds} / d v_{ds}$).

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Philips Models

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 ($1/g_{ds}$).
39	v_{early} (V)	Equivalent Early voltage ($ i_d /g_{ds}$).
40	k_{eff} (\sqrt{V})	Describes body effect at actual bias.
41	b_{eff} (S/V)	Effective beta at actual bias in the simple MOS model ($2* i_{ds} /v_{gt}^2$).

Virtuoso Simulator Components and Device Models Reference

Philips Models

42 fug (Hz) Unity gain frequency at actual bias ($gm/(2\pi \cdot cin)$).

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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a1r	M-52	fug	OP-42	sl2vfb	M-11	ther1	O-11
a2	O-25	gds	OP-20	sla1	M-54	ther2	O-12
a2r	M-56	gm	OP-18	sla2	M-57	ther2	M-31
a3	O-26	gmb	OP-19	sla3	M-60	thersq	M-28
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area	I-4	ibe	OP-4	ssf	O-19	thethr	M-39
beff	OP-41	idb	OP-9	ssfsq	M-45	tnom	M-66
bet	O-6	ide	OP-1	stal	M-53	tox	M-62
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cbb	OP-36	ige	OP-2	stthep	M-36	tref	M-65
cbd	OP-33	isb	OP-10	sttheph	M-24	trise	M-68
cbg	OP-34	ise	OP-3	stthesr	M-21	type	M-1
cbs	OP-35	keff	OP-40	stvfb	M-9	u	OP-37

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Philips Models

cdb	OP-24	ko	O-4	swal	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
cgb	OP-28	le	O-1	swetamob	M-27	vfbr	M-8
cgd	OP-25	ler	M-2	swko	M-16	vgs	OP-6
cgdo	O-28	lvar	M-4	swssf	M-46	vgt	OP-15
cgg	OP-26	m	I-6	swthen	M-34	vp	O-21
cgs	OP-27	mexp	O-22	swthep	M-37	vp	M-49
cgso	O-29	mexpl	M-51	swtheph	M-25	vsat	OP-17
col	M-63	mexpo	M-50	swther	M-29	vsb	OP-7
cox	O-27	mult	I-3	swthesr	M-22	vto	OP-13
csb	OP-32	phib	O-5	swtheth	M-41	vts	OP-14
csd	OP-29	phibr	M-17	swvfb	M-12	w	I-1
csg	OP-30	phit	O-23	then	O-13	we	O-2
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etamob	O-9	sdiblo	M-42	ther	O-10		

Compact MOS-Transistor Distortion Model (mos1100)

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 mos1100 parameter=value ...

Model Parameters

1	<code>level=1.1e+03</code>	MOS Level.
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.

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Philips Models

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>slko=0 \sqrt{V} m</code>	Coefficient of the length dependence of <code>ko</code> .
13	<code>sl2ko=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>slphib=0 Vm</code>	Coefficient of the length dependence of <code>phib</code> .
18	<code>sl2phib=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.
21	<code>etabet=1.3(n)/0.5(p)</code>	Exponent of the temperature dependence of the gain factor.
22	<code>fbet1=0</code>	Relative mobility decrease due to first lateral profile.
23	<code>lp1=8e-07 m</code>	Characteristic length of first lateral profile.
24	<code>fbet2=0</code>	Relative mobility decrease due to second lateral profile.
25	<code>lp2=8e-07 m</code>	Characteristic length of second lateral profile.

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Philips Models

- 26 $thesrr=0.4(n)/0.73(p) \text{ 1/V}$
Coefficient of the mobility reduction due to surface roughness scattering.
- 27 $swthesr=0 \text{ m}$ Coefficient of the width dependence of thesr.
- 28 $thephr=0.0129(n)/0.001(p) \text{ 1/V}$
Coefficient of the mobility reduction due to phonon scattering.
- 29 $etaph=1.75$ Exponent of the temperature dependence of theph.
- 30 $swtheph=0 \text{ m}$ Coefficient of the width dependence of theph.
- 31 $etamobr=1.4(n)/3(p)$
Effective field parameter for dependence on depletion/inversion charge.
- 32 $stetamob=0 \text{ 1/K}$ Coefficient of the temperature dependence of etamob.
- 33 $swetamob=0 \text{ m}$ 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 $therr=0.155(n)/0.08(p) \text{ 1/V}$
Coefficient of the series resistance.
- 37 $etar=0.95(n)/0.4(p)$
Exponent of the temperature dependence of ther.
- 38 $swther=0 \text{ m}$ Coefficient of the width dependence of ther.
- 39 $ther1=0 \text{ V}$ Numerator of gate voltage dependent part of series resistance.
- 40 $ther2=1 \text{ V}$ Denominator of gate voltage dependent part of series resistance.
- 41 $thesatr=0.5(n)/0.2(p) \text{ 1/V}$
Velocity saturation parameter due to optical/acoustic phonon scattering.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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.
56	$alpr=0.01$	Factor of the channel length modulation.
57	$slalp=1$	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.

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Philips Models

61	$l_{min}=1.5e-07$ m	Minimum effective channel length in technology, used for calculation of smoothing factor m .
62	$a_{1r}=6$	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	$a_{2r}=38$ 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	$a_{3r}=1$	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	$igacccr=0$ 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.
76	$vfbov=0$ V	Flat-band voltage for the Source/Drain overlap extensions.
77	$kov=2.5$ \sqrt{V}	Body-effect factor for the Source/Drain overlap extensions.
78	$igovr=0$ A/V ²	Gain factor for Source/Drain overlap gate tunnelling current.
79	$tox=3.2e-09$ m	Thickness of gate oxide layer.
80	$col=3.2e-10$ F/m	Gate overlap capacitance per unit channel width.

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81	<code>gatenoise=0</code>	Flag for in/exclusion of induced gate thermal noise.
82	<code>ntr=1.66e-20 J</code>	Coefficient of the thermal noise.
83	<code>nfar=1.57e+22(n)/3.83e+23(p) 1/(Vm⁴)</code>	First coefficient of the flicker noise.
84	<code>nfbr=4.75e+08(n)/1.02e+08(p) 1/(Vm²)</code>	Second coefficient of the flicker noise.
85	<code>nfcr=0(n)/7.3e-09(p) 1/V</code>	Third coefficient of the flicker noise.
86	<code>dta=0 K</code>	Temperature offset of the device.
87	<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> .
88	<code>imax=1.0 A</code>	Explosion current.
89	<code>tnom (C)</code>	alias of <code>tnom</code> .
90	<code>tref (C)</code>	alias of <code>tnom</code> .

Output Parameters

1	<code>vfb (V)</code>	Flat-band voltage for the actual transistor.
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>theqh ($1/V$)</code>	Mobility degradation parameter due to phonon scattering.
8	<code>etamob</code>	Effective field parameter for dependence on depletion charge.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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.
25	iginv (A/V ²)	Gain factor for intrinsic gate tunnelling current in inversion.
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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

29	v_{fbov} (V)	Flat-band voltage for the Source/Drain overlap extensions.
30	k_{ov} (\sqrt{V})	Body-effect factor for the Source/Drain overlap extensions.
31	i_{gov} (A/V ²)	Gain factor for Source/Drain overlap tunnelling current.
32	c_{ox} (F)	Oxide capacitance for the intrinsic channel (* mult).
33	c_{gdo} (F)	Oxide capacitance for the gate-drain overlap (* mult).
34	c_{gso} (F)	Oxide capacitance for the gate-source overlap (* mult).
35	$gatenoise$	Flag for in/exclusion of induced gate thermal noise.
36	n_t (J)	Thermal noise coefficient.
37	n_{fa} (1/(Vm ⁴))	First coefficient of the flicker noise.
38	n_{fb} (1/(Vm ²))	Second coefficient of the flicker noise.
39	n_{fc} (1/V)	Third coefficient of the flicker noise.
40	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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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 ($- d q_s / d v_b$).
30	c_{bd} (F)	Capacitance ($- d q_b / d v_d$).

Virtuoso Simulator Components and Device Models Reference

Philips Models

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 ($ 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	$sqrtsfw$ (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 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	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
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

Virtuoso Simulator Components and Device Models Reference

Philips Models

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	stal	M-63	vgs	OP-7
cgso	O-34	ler	M-2	stetamob	M-32	vgt	OP-12
cgsol	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
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

Virtuoso Simulator Components and Device Models Reference

Philips Models

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 `off`, `triode`, `sat`, or `subth`.
- 3 `m=1` Multiplicity factor.
- 4 `area=1` alias of `mult`.

Model Definition

```
model modelName mos1100e parameter=value ...
```

Model Parameters

- 1 `level=1.1e+03` MOS Level.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 2 $v_{fb} = -1.05 \text{ V}$ Flat-band voltage for the actual transistor.
- 3 $k_o = 0.5 \sqrt{\text{V}}$ Body-effect factor.
- 4 $k_{pinv} = 0 \text{ 1}/\sqrt{\text{V}}$ Inverse of body-effect factor of the poly-silicon gate.
- 5 $\phi_{ib} = 0.95 \text{ V}$ Surface potential at the onset of strong inversion.
- 6 $\beta_{et} = 0.00192(n)/0.000381(p) \text{ A/V}^2$
Gain factor.
- 7 $\theta_{esr} = 0.356(n)/0.73(p) \text{ 1/V}$
Mobility degradation parameter due to surface roughness scattering.
- 8 $\theta_{eph} = 0.0129(n)/0.001(p) \text{ 1/V}$
Mobility degradation parameter due to phonon scattering.
- 9 $\epsilon_{tamob} = 1.4(n)/3(p)$
Effective field parameter for dependence on depletion charge.
- 10 $\nu = 2$ Exponent of field dependence of mobility model.
- 11 $\theta_{er} = 0.0812(n)/0.079(p) \text{ 1/V}$
Coefficient of series resistance.
- 12 $\theta_{er1} = 0 \text{ V}$ Numerator of gate voltage dependent part of series resistance.
- 13 $\theta_{er2} = 1 \text{ V}$ Denominator of gate voltage dependent part of series resistance.
- 14 $\theta_{esat} = 0.251(n)/0.173(p) \text{ 1/V}$
Velocity saturation parameter due to optical/acoustic phonon scattering.
- 15 $\theta_{eth} = 1e-05(n)/0(p) \text{ 1/V}^3$
Coefficient of self-heating.
- 16 $s_{dibl} = 0.000853(n)/3.55e-05(p) \text{ 1}/\sqrt{\text{V}}$
Drain-induced barrier lowering parameter.
- 17 $m_o = 0 \text{ V}$ Parameter for (short-channel) subthreshold slope.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 18 $ssf=0.012(n)/0.01(p) \text{ } 1/\sqrt{V}$
Static-feedback parameter.
- 19 $alp=0.025$
Factor of channel length modulation.
- 20 $vp=0.05 \text{ } V$
Characteristic voltage of channel-length modulation.
- 21 $mexp=5$
Smoothing factor.
- 22 $phit=0.0266 \text{ } V$
Thermal voltage at the actual temperature.
- 23 $a1=6.02(n)/6.86(p)$
Factor of the weak-avalanche current.
- 24 $a2=38(n)/57.3(p) \text{ } V$
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 $iginv=0 \text{ } A/V^2$
Gain factor for intrinsic gate tunnelling current in inversion.
- 27 $binv=48(n)/87.5(p) \text{ } A/V^2$
Probability factor for intrinsic gate tunnelling current in inversion.
- 28 $igacc=0 \text{ } A/V^2$
Gain factor for intrinsic gate tunnelling current in accumulation.
- 29 $bacc=48 \text{ } V$
Probability factor for intrinsic gate tunnelling current in accumulation.
- 30 $vfbov=0 \text{ } V$
Flat-band voltage for the Source/Drain overlap extensions.
- 31 $kov=2.5 \text{ } \sqrt{V}$
Body-effect factor for the Source/Drain overlap extensions.
- 32 $igov=0 \text{ } A/V^2$
Gain factor for Source/Drain overlap tunnelling current.
- 33 $cox=2.98e-14(n)/2.72e-14(p) \text{ } F$
Oxide capacitance for the intrinsic channel (* mult).
- 34 $cgdo=6.39e-15(n)/6.36e-15(p) \text{ } F$
Oxide capacitance for the gate-drain overlap (* mult).

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 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 $nfa=8.32e+22(n)/1.9e+22(p)$ $1/(Vm^4)$
First coefficient of the flicker noise.
- 39 $nfb=2.51e+07(n)/5.04e+06(p)$ $1/(Vm^2)$
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/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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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/√V)	Drain-induced barrier lowering parameter.
16	mo (V)	Parameter for (short-channel) subthreshold slope.
17	ssf (1/√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.
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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

30	k_{ov} (\sqrt{V})	Body-effect factor for the Source/Drain overlap extensions.
31	i_{gov} (A/V^2)	Gain factor for Source/Drain overlap tunnelling current.
32	c_{ox} (F)	Oxide capacitance for the intrinsic channel (* mult).
33	c_{gdo} (F)	Oxide capacitance for the gate-drain overlap (* mult).
34	c_{gso} (F)	Oxide capacitance for the gate-source overlap (* mult).
35	$gatenoise$	Flag for in/exclusion of induced gate thermal noise.
36	n_t (J)	Thermal noise coefficient.
37	n_{fa} ($1/(V_m^4)$)	First coefficient of the flicker noise.
38	n_{fb} ($1/(V_m^2)$)	Second coefficient of the flicker noise.
39	n_{fc} ($1/V$)	Third coefficient of the flicker noise.
40	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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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 ($- d q_s / d v_b$).
30	c_{bd} (F)	Capacitance ($- d q_b / d v_d$).
31	c_{bg} (F)	Capacitance ($- d q_b / d v_g$).

Virtuoso Simulator Components and Device Models Reference

Philips Models

32	<code>cbs</code> (F)	Capacitance (- d qb / d vs).
33	<code>cbb</code> (F)	Capacitance (d qb / d vb).
34	<code>cgd01</code> (F)	Gate-drain overlap capacitance of the actual transistor.
35	<code>cgs01</code> (F)	Gate-source overlap capacitance of the actual transistor.
36	<code>u</code>	Transistor gain (gm/gds).
37	<code>rout</code> (Ω)	Small-signal output resistance (1/gds).
38	<code>vearly</code> (V)	Equivalent Early voltage ($ id /gds$).
39	<code>keff</code> (\sqrt{V})	Body effect parameter.
40	<code>bef</code> (A/V^2)	Gain factor.
41	<code>fug</code> (Hz)	Unity gain frequency at actual bias ($gm/(2*\pi*cin)$).
42	<code>sqrtsw</code> (V/\sqrt{Hz})	Input-referred RMS white noise voltage density.
43	<code>sqrtfff</code> (V/\sqrt{Hz})	Input-referred RMS white noise voltage density at 1 kHz.
44	<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.

a1	M-23	<code>cgs01</code>	OP-35	<code>kpinv</code>	M-4	<code>ther</code>	M-11
a1	O-22	<code>cox</code>	M-33	<code>kpinv</code>	O-3	<code>ther</code>	O-10

Virtuoso Simulator Components and Device Models Reference

Philips Models

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	vearly	OP-38
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

Virtuoso Simulator Components and Device Models Reference

Philips Models

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 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 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 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.
11	<code>sl2ko=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 $stetamob=0 \text{ 1/K}$ 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 $therr=0.155(n)/0.08(p) \text{ 1/V}$ 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 $ther1=0 \text{ V}$ Numerator of gate voltage dependent part of series resistance.
- 41 $ther2=1 \text{ V}$ Denominator of gate voltage dependent part of series resistance.
- 42 $thesatr=0.5(n)/0.2(p) \text{ 1/V}$ 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 $thethr=0.001(n)/0.0005(p) \text{ 1/V}^3$ Coefficient of self-heating.
- 48 $thethexp=1$ Exponent of the length dependence of THETH.

Virtuoso Simulator Components and Device Models Reference

Philips Models

49	swtheth=0	Coefficient of the width dependence of THETH.
50	sdiblo=0.0001 $1/\sqrt{V}$	Drain-induced barrier lowering parameter.
51	sdiblexp=1.35	Exponent of the length dependence of SDIBL.
52	mo=0	Parameter for short-channel subthreshold slope.
53	mor=0	Parameter for short-channel subthreshold slope per unit length.
54	moexp=1.34	Exponent of the length dependence of MO.
55	ssfr=0.00625 $1/\sqrt{V}$	Static feedback parameter.
56	slssf=1	Coefficient of the length dependence of SSF.
57	swssf=0	Coefficient of the width dependence of SSF.
58	alpr=0.01	Factor of the channel length modulation.
59	slalp=1	Coefficient of the length dependence of ALP.
60	alpexp=1	Exponent of the length dependence of ALP.
61	swalp=0	Coefficient of the width dependence of ALP.
62	vp=0.05 V	Characteristic voltage of channel-length modulation.
63	lmin=1.5e-07 m	Minimum effective channel length in technology, used for calculation of smoothing factor m.
64	alr=6	Factor of the weak-avalanche current.
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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

69	$s_{la2}=0$	Coefficient of the length dependence of A2.
70	$s_{wa2}=0$	Coefficient of the width dependence of A2.
71	$a_{3r}=1$	Factor of the drain-source voltage above which weak-avalanche occurs.
72	$s_{la3}=0$	Coefficient of the length dependence of A3.
73	$s_{wa3}=0$	Coefficient of the width dependence of A3.
74	$i_{ginvr}=0 \text{ A/V}^2$	Gain factor for intrinsic gate tunnelling current in inversion.
75	$b_{inv}=48(n)/87.5(p) \text{ V}$	Probability factor for intrinsic gate tunnelling current in inversion.
76	$i_{gaccr}=0 \text{ A/V}^2$	Gain factor for intrinsic gate tunnelling current in accumulation.
77	$b_{acc}=48 \text{ V}$	Probability factor for intrinsic gate tunnelling current in accumulation.
78	$v_{fbov}=0 \text{ V}$	Flat-band voltage for the Source/Drain overlap extensions.
79	$k_{ov}=2.5 \sqrt{V}$	Body-effect factor for the Source/Drain overlap extensions.
80	$i_{govr}=0 \text{ A/V}^2$	Gain factor for Source/Drain overlap gate tunnelling current.
81	$a_{gidlr}=0 \text{ A/V}^3$	Gain factor for gate-induced leakage current.
82	$b_{gidl}=41 \text{ V}$	Probability factor for gate-induced drain leakage current at reference temperature.
83	$stb_{gidl}=-0.000364 \text{ V/K}$	Coefficient of the temperature dependence of BGIDL.
84	$c_{gidl}=0$	Factor for the lateral field dependence of the gate-induced leakage current.
85	$t_{ox}=3.2e-09 \text{ m}$	Thickness of gate oxide layer.
86	$c_{ol}=3.2e-16 \text{ F}$	Gate overlap capacitance for a channel width of 1 μm .
87	$g_{atnoise}=0$	Flag for in/exclusion of induced gate thermal noise.

Virtuoso Simulator Components and Device Models Reference

Philips Models

88	$nt=1.62e-20$ J	Thermal noise coefficient.
89	$nfar=1.57e+23(n)/3.83e+24(p)$ $1/(Vm^4)$	First coefficient of the flicker noise for a channel area of 1 um^2 .
90	$nfbr=4.75e+09(n)/1.02e+09(p)$ $1/(Vm^2)$	Second coefficient of the flicker noise for a channel area of 1 um^2 .
91	$nfcr=0(n)/7.3e-08(p)$ $1/V$	Third coefficient of the flicker noise for a channel area of 1 um^2 .
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 pnp1.
94	$imax=1.0$ A	Explosion current.
95	$tnom$ (C)	alias of $tnom$.
96	$tref$ (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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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/√V)	Drain-induced barrier lowering parameter.
16	mo	Parameter for (short-channel) subthreshold slope.
17	ssf (1/√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 (√V)	Body-effect factor for the Source/Drain overlap extensions.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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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Philips Models

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 ($d q_s / d v_s$).

Virtuoso Simulator Components and Device Models Reference

Philips Models

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 ($ i_d /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

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	O-21	etamobr	M-32	nfa	O-39	swthesat	M-46
alr	M-64	etaph	M-30	nfcr	M-91	swthesr	M-28
a2	O-22	etar	M-38	nfb	O-40	swtheth	M-49
a2r	M-68	etasat	M-43	nfc	O-41	theph	O-7
a3	O-23	etasr	M-27	nfar	M-89	theph	M-29
a3r	M-71	fbet1	M-22	nfb	O-40	ther	O-10
agidl	O-31	fbet2	M-24	nfc	O-41	ther1	M-40
agidlr	M-81	fknee	OP-46	nt	M-88	ther1	O-11
alp	O-18	fug	OP-43	nt	O-38	ther2	M-41
alpexp	M-60	gatenoise	M-87	nu	M-35	ther2	O-12
alpr	M-58	gatenoise	O-37	nu	O-9	therr	M-37
area	I-6	gds	OP-17	nuexp	M-36	thesat	O-13
bacc	M-77	gm	OP-15	phib	O-4	thesatexp	M-45
bacc	O-27	gmb	OP-16	phibr	M-14	thesatr	M-42
beff	OP-42	iavl	OP-2	region	I-4	thesr	O-6
bet	O-5	ids	OP-1	rout	OP-39	thesrr	M-26
betsq	M-19	igacc	O-26	sdibl	O-15	theth	O-14
bgidl	M-82	igaccr	M-76	sdiblexp	M-51	thethexp	M-48
bgidl	O-32	igb	OP-5	sdiblo	M-50	thethr	M-47
		sl2ko	M-11				

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Philips Models

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
cgdo	O-35	kpinv	M-13	ssf	O-17	vfbov	M-78
cgdol	OP-34	kpinv	O-3	ssfr	M-55	vfbov	O-28
cgg	OP-23	l	I-1	stal	M-65	vgs	OP-7
cgidl	M-84	lap	M-3	stbgidl	M-83	vgt	OP-12
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
cgsol	OP-35	lp1	M-23	swa1	M-67	vsb	OP-8
col	M-86	lp2	M-25	swa2	M-70	vth	OP-11

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cox	O-34	lvar	M-2	swa3	M-73	vto	OP-9
csb	OP-29	m	I-5	swalp	M-61	vtb	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
css	OP-28	moexp	M-54	swphib	M-18	wot	M-5
dta	M-92	moo	M-52	swssf	M-57	wvar	M-4
etabetr	M-20	mor	M-53	swtheph	M-31		
etamob	O-8	mult	I-3	swther	M-39		

MOS Model 11, Level 1101 (mos11010t)

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 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..
- 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 mos11010t parameter=value ...
```

Model Parameters

1 `level=1.1e+04` Transistor Level.

2 `lvar=0 m` Difference between the actual and the programmed poly-silicon gate length.

3 `lap=4e-08 m` Effective channel length reduction per side.

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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 16 $sl_{\text{phib}}=0$ Coefficient of the length dependence of PHIB.
- 17 $sl_{2\text{phib}}=0$ Second coefficient of the length dependence of PHIB.
- 18 $sw_{\text{phib}}=0$ Coefficient of the width dependence of PHIB.
- 19 $\text{betsq}=0.000371(n)/0.000115(p) \text{ A/V}^2$
Gain factor for an infinite square transistor.
- 20 $\text{etabetr}=1.3(n)/0.5(p)$
Exponent of the temperature dependence of the gain factor.
- 21 $s_{\text{letabet}}=0$ Coefficient of length dependence of ETABETR.
- 22 $\text{fbet1}=0$ Relative mobility decrease due to first lateral profile.
- 23 $lp1=8e-07 \text{ m}$ Characteristic length of first lateral profile.
- 24 $\text{fbet2}=0$ Relative mobility decrease due to second lateral profile.
- 25 $lp2=8e-07 \text{ m}$ Characteristic length of second lateral profile.
- 26 $\text{thesrr}=0.4(n)/0.73(p) \text{ 1/V}$
Coefficient of the mobility reduction due to surface roughness scattering.
- 27 $\text{etasr}=0.65(n)/0.5(p)$
Exponent of the temperature dependence of THESR.
- 28 $sw_{\text{thesr}}=0$ Coefficient of the width dependence of THESR.
- 29 $\text{thephr}=0.0129(n)/0.001(p) \text{ 1/V}$
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 $sw_{\text{theph}}=0$ Coefficient of the width dependence of THEPH.
- 32 $\text{etamobr}=1.4(n)/3(p)$
Effective field parameter for dependence on depletion/inversion charge.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 33 $stetamob=0 \text{ 1/K}$ 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 $therr=0.155(n)/0.08(p) \text{ 1/V}$ 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 $ther1=0 \text{ V}$ Numerator of gate voltage dependent part of series resistance.
- 41 $ther2=1 \text{ V}$ Denominator of gate voltage dependent part of series resistance.
- 42 $thesatr=0.5(n)/0.2(p) \text{ 1/V}$ 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 $thethr=0.001(n)/0.0005(p) \text{ 1/V}^3$ Coefficient of self-heating.
- 48 $thethexp=1$ Exponent of the length dependence of THETH.
- 49 $swtheth=0$ Coefficient of the width dependence of THETH.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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>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</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.
69	<code>sla2=0</code>		Coefficient of the length dependence of A2.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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	$iginvr=0 \text{ A/V}^2$	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	$kov=2.5 \sqrt{\text{V}}$	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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 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 μm^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 μm^2 .
- 91 $n_{fcr}=0(n)/7.3e-08(p) \ 1/V$
Third coefficient of the flicker noise for a channel area of 1 μm^2 .
- 92 $d_{ta}=0 \ K$ Temperature offset of the device.
- 93 $r_{th}=300 \ K/W$ Thermal resistance.
- 94 $c_{th}=3e-09 \ J/K$ Thermal capacitance.
- 95 $a_{th}=0$ Temperature coefficient of the thermal resistance.
- 96 $type=n$ Transistor gender.
Possible values are n, p, npn, pnp, npnv, pnpv, npnl, or pnp1.
- 97 $i_{max}=1.0 \ A$ Explosion current.
- 98 $t_{nom} \ (C)$ alias of t_{nom} .
- 99 $t_{ref} \ (C)$ 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 $\phi_{ib} \ (V)$ Surface potential at the onset of strong inversion.
- 5 $\beta_{et} \ (A/V^2)$ 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	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/√V)	Drain-induced barrier lowering parameter.
16	mo	Parameter for (short-channel) subthreshold slope.
17	ssf (1/√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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

28	v_{fbov} (V)	Flat-band voltage for the Source/Drain overlap extensions.
29	k_{ov} (\sqrt{V})	Body-effect factor for the Source/Drain overlap extensions.
30	ig_{ov} (A/V ²)	Gain factor for Source/Drain overlap tunnelling current.
31	ag_{idl} (A/V ³)	Gain factor for gate-induced leakage current.
32	bg_{idl} (V)	Probability factor for gate-induced drain leakage current at reference temperature.
33	cg_{idl}	Factor for the lateral field dependence of the gate-induced leakage current.
34	cox (F)	Oxide capacitance for the intrinsic channel (* mult).
35	cg_{do} (F)	Oxide capacitance for the gate-drain overlap (* mult).
36	cg_{so} (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.
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.
43	r_{th} (K/W)	Thermal resistance.
44	c_{th} (J/K)	Thermal capacitance.

Operating-Point Parameters

1	ids (A)	Drain current, excl. avalanche and tunnel currents.
2	i_{avl} (A)	Substrate current due to weak-avalanche.
3	igs (A)	Gate-to-source current due to direct tunnelling.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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 ($d q_g / d v_g$).
24	c_{gs} (F)	Capacitance ($- d q_g / d v_s$).

Virtuoso Simulator Components and Device Models Reference

Philips Models

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 ($ 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	$sqrtsfw$ (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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

46	<code>fknee</code> (Hz)	Cross-over frequency above which white noise is dominant.
47	<code>Pdiss</code> (W)	Dissipation.
48	<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-47	<code>dta</code>	M-92	<code>mult</code>	I-3	<code>swther</code>	M-39
<code>TK</code>	OP-48	<code>etabetr</code>	M-20	<code>nfa</code>	O-39	<code>swthesat</code>	M-46
<code>a1</code>	O-21	<code>etamob</code>	O-8	<code>nfcr</code>	M-89	<code>swthesr</code>	M-28
<code>a1r</code>	M-64	<code>etamobr</code>	M-32	<code>nfb</code>	O-40	<code>swtheth</code>	M-49
<code>a2</code>	O-22	<code>etaph</code>	M-30	<code>nfbr</code>	M-90	<code>theph</code>	O-7
<code>a2r</code>	M-68	<code>etar</code>	M-38	<code>nfc</code>	O-41	<code>thephr</code>	M-29
<code>a3</code>	O-23	<code>etasat</code>	M-43	<code>nfcr</code>	M-91	<code>ther</code>	O-10
<code>a3r</code>	M-71	<code>etasr</code>	M-27	<code>nt</code>	M-88	<code>ther1</code>	M-40
<code>agidl</code>	O-31	<code>fbet1</code>	M-22	<code>nt</code>	O-38	<code>ther1</code>	O-11
<code>agidlr</code>	M-81	<code>fbet2</code>	M-24	<code>nu</code>	M-35	<code>ther2</code>	M-41
<code>alp</code>	O-18	<code>fknee</code>	OP-46	<code>nu</code>	O-9	<code>ther2</code>	O-12
<code>alpexp</code>	M-60	<code>fug</code>	OP-43	<code>nuexp</code>	M-36	<code>therr</code>	M-37
<code>alpr</code>	M-58	<code>gatenoise</code>	M-87	<code>phib</code>	O-4	<code>thesat</code>	O-13

Virtuoso Simulator Components and Device Models Reference

Philips Models

area	I-6	gatenoise	O-37	phibr	M-14	thesatexp	M-45
ath	M-95	gds	OP-17	region	I-4	thesatr	M-42
bacc	M-77	gm	OP-15	rout	OP-39	thesr	O-6
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	slal	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
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

Virtuoso Simulator Components and Device Models Reference

Philips Models

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 ...

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 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.
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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

11	$v_{fb} = -1.05 \text{ V}$	Flat-band voltage at reference temperature.
12	$p_{oko} = 0.5 \sqrt{V}$	Coefficient for the geometry independent part of KO.
13	$p_{lko} = 0 \sqrt{V}$	Coefficient for the length dependence of KO.
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	$k_{pinv} = 0 \text{ 1}/\sqrt{V}$	Inverse of body-effect factor of the poly-silicon gate.
17	$p_{ophib} = 0.95 \text{ V}$	Coefficient for the geometric independent part of PHIB.
18	$p_{lphib} = 0 \text{ V}$	Coefficient for the length dependence of PHIB.
19	$p_{wphib} = 0 \text{ V}$	Coefficient for the width dependence of PHIB.
20	$p_{lwphib} = 0 \text{ V}$	Coefficient for the length times width dependence of PHIB.
21	$p_{obet} = 0.00192(n) / 0.000381(p) \text{ A}/V^2$	Coefficient for the geometry independent part of BET.
22	$p_{lbet} = 0 \text{ A}/V^2$	Coefficient for the length dependence of BET.
23	$p_{wbet} = 0 \text{ A}/V^2$	Coefficient for the width dependence of BET.
24	$p_{lwbet} = 0 \text{ A}/V^2$	Coefficient for the width over length dependence of BET.
25	$p_{othesr} = 0.356(n) / 0.73(p) \text{ 1}/V$	Coefficient of the geometry independent part of THESR.
26	$p_{lthesr} = 0 \text{ 1}/V$	Coefficient of the length dependence of THESR.
27	$p_{wthesr} = 0 \text{ 1}/V$	Coefficient of the width dependence of THESR.
28	$p_{lwthesr} = 0 \text{ 1}/V$	Coefficient of the length times width dependence of THESR.
29	$p_{otheph} = 0.0129(n) / 0.001(p) \text{ 1}/V$	Coefficient of the geometry independent part of THEPH.
30	$p_{ltheph} = 0 \text{ 1}/V$	Coefficient of the length dependence of THEPH.

Virtuoso Simulator Components and Device Models Reference

Philips Models

31	$p_{wtheph}=0 \text{ 1/V}$	Coefficient of the width dependence of THEPH.
32	$pl_{wtheph}=0 \text{ 1/V}$	Coefficient of the length times width dependence of THEPH.
33	$po_{etamob}=1.4(n)/3(p)$	Coefficient of the geometry independent part of ETAMOB.
34	$pletamob=0$	Coefficient of the length dependence of ETAMOB.
35	$pw_{etamob}=0$	Coefficient of the width dependence of ETAMOB.
36	$plw_{etamob}=0$	Coefficient of the length times width dependence of ETAMOB.
37	$po_{ther}=0.0812(n)/0.079(p) \text{ 1/V}$	Coefficient of the geometry independent part of THER.
38	$pl_{ther}=0 \text{ 1/V}$	Coefficient of the length dependence of THER.
39	$pw_{ther}=0 \text{ 1/V}$	Coefficient of the width dependence of THER.
40	$plw_{ther}=0 \text{ 1/V}$	Coefficient of the length times width dependence of THER.
41	$ther1=0 \text{ V}$	Numerator of gate voltage dependent part of series resistance.
42	$ther2=1 \text{ V}$	Denominator of gate voltage dependent part of series resistance.
43	$po_{thesat}=0.251(n)/0.173(p) \text{ 1/V}$	Coefficient of the geometry independent part of THESAT.
44	$pl_{thesat}=0 \text{ 1/V}$	Coefficient of the length dependence of THESAT.
45	$pw_{thesat}=0 \text{ 1/V}$	Coefficient of the width dependence of THESAT.
46	$plw_{thesat}=0 \text{ 1/V}$	Coefficient of the length times width dependence of THESAT.
47	$po_{theth}=1e-05(n)/0(p) \text{ 1/V}^3$	Coefficient of the geometry independent part of THETH.
48	$pl_{theth}=0 \text{ 1/V}^3$	Coefficient of the length dependence of THETH.
49	$pw_{theth}=0 \text{ 1/V}^3$	Coefficient of the width dependence of THETH.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 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 $pwm=0$ 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 $pwsf=0 \ 1/\sqrt{V}$ 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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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	$p_{oa2}=38(n)/57.3(p) \quad v$	Coefficient of the geometry independent part of A2.
77	$p_{la2}=0 \quad v$	Coefficient of the length dependence of A2.
78	$p_{wa2}=0 \quad v$	Coefficient of the width dependence of A2.
79	$p_{lwa2}=0 \quad v$	Coefficient of the length times width dependence of A2.
80	$p_{oa3}=0.641(n)/0.425(p)$	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	$p_{oiginv}=0 \quad A/V^2$	Coefficient of the geometry independent part of IGINV.
85	$p_{liginv}=0 \quad A/V^2$	Coefficient of the length dependence of IGINV.
86	$p_{wiginv}=0 \quad A/V^2$	Coefficient of the width dependence of IGINV.
87	$p_{lwiginv}=0 \quad A/V^2$	Coefficient of the length times width dependence of IGINV.
88	$p_{obinv}=48(n)/87.5(p) \quad v$	Coefficient of the geometry independent part of BINV.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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.
104	$pwigov=0$	A/V^2	Coefficient of the width dependence of IGOV.
105	$plwigov=0$	A/V^2	Coefficient of the length times width dependence of IGOV.
106	$poagidl=0$	A/V^3	Coefficient of the geometry independent part of AGIDL.
107	$plagidl=0$	A/V^3	Coefficient of the length dependence of AGIDL.
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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

111	<code>plbgidl=0</code>	V	Coefficient of the length dependence of BGIDL.
112	<code>pwbgidl=0</code>	V	Coefficient of the width dependence of BGIDL.
113	<code>plwbgidl=0</code>	V	Coefficient of the length times width dependence of BGIDL.
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</code>	m	Thickness of gate oxide layer.
119	<code>poccox=2.98e-14(n)/2.72e-14(p)</code>	F	Coefficient of the geometry independent part of COX.
120	<code>plcox=0</code>	F	Coefficient of the length dependence of COX.
121	<code>pwccox=0</code>	F	Coefficient of the width dependence of COX.
122	<code>plwcox=0</code>	F	Coefficient of the length times width dependence of COX.
123	<code>pocgdo=6.39e-15(n)/6.36e-15(p)</code>	F	Coefficient of the geometry independent part of CGDO.
124	<code>plcgdo=0</code>	F	Coefficient of the length dependence of CGDO.
125	<code>pwcgdo=0</code>	F	Coefficient of the width dependence of CGDO.
126	<code>plwcgdo=0</code>	F	Coefficient of the length time width dependence of CGDO.
127	<code>pocgso=6.39e-15(n)/6.36e-15(p)</code>	F	Coefficient of the geometry independent part of CGSO.
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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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.
134	<code>plnfa=0 1/V m⁴</code>	Coefficient of the length dependence of NFA.
135	<code>pwnfa=0 1/V m⁴</code>	Coefficient of the width dependence of NFA.
136	<code>plwnfa=0 1/V m⁴</code>	Coefficient of the length times width dependence of NFA.
137	<code>ponfb=2.51e+07(n)/5.04e+06(p) 1/V m²</code>	Coefficient of the geometry independent part of NFB.
138	<code>plnfb=0 1/V m²</code>	Coefficient of the length dependence of NFB.
139	<code>pwnfb=0 1/V m²</code>	Coefficient of the width dependence of NFB.
140	<code>plwnfb=0 1/V m²</code>	Coefficient of the length times width dependence of NFB.
141	<code>ponfc=0(n)/3.63e-10(p) 1/V</code>	Coefficient of the geometry independent part of NFC.
142	<code>plnfc=0 1/V</code>	Coefficient of the length dependence of NFC.
143	<code>pwnfc=0 1/V</code>	Coefficient of the width dependence of NFC.
144	<code>plwnfc=0 1/V</code>	Coefficient of the length times width dependence of NFC.
145	<code>potvfb=0.0005 V/K</code>	Coefficient of the geometry independent part of STVFB.
146	<code>pltvfb=0 V/K</code>	Coefficient of the length dependence of STVFB.
147	<code>pwtvfb=0 V/K</code>	Coefficient of the width dependence of STVFB.
148	<code>plwtvfb=0 V/K</code>	Coefficient of the length times width dependence of STVFB.
149	<code>potphib=-0.00085 V/K</code>	Coefficient of the geometry independent part of STPHIB.
150	<code>pltphib=0 V/K</code>	Coefficient of the length dependence of STPHIB.

Virtuoso Simulator Components and Device Models Reference

Philips Models

151	$pwtphib=0 \text{ V/K}$	Coefficient of the width dependence of STPHIB.
152	$plwtphib=0 \text{ V/K}$	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	$potetamob=0 \text{ 1/K}$	Coefficient of the geometry independent part of STETAMOB.
166	$pltetamob=0 \text{ 1/K}$	Coefficient of the length dependence of STETAMOB.
167	$pwtetamob=0 \text{ 1/K}$	Coefficient of the width dependence of STETAMOB.
168	$plwtetamob=0 \text{ 1/K}$	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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

171	$pltnuexp=0$	Coefficient of the length dependence of NUEXP.
172	$pwtnuexp=0$	Coefficient of the width dependence of NUEXP.
173	$plwtnuexp=0$	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	$pota1=0 \text{ 1/K}$	Coefficient of the geometry independent part of STA1.
183	$plta1=0 \text{ 1/K}$	Coefficient of the length dependence of STA1.
184	$pwtal=0 \text{ 1/K}$	Coefficient of the width dependence of STA1.
185	$plwta1=0 \text{ 1/K}$	Coefficient of the length times width dependence of STA1.
186	$potbgidl=-0.000364 \text{ V/K}$	Coefficient of the geometry independent part of STBGIDL.
187	$pltbgidl=0 \text{ V/K}$	Coefficient of the length dependence of STBGIDL.
188	$pwtbgidl=0 \text{ V/K}$	Coefficient of the width dependence of STBGIDL.
189	$plwtbgidl=0 \text{ V/K}$	Coefficient of the length times width dependence of STBGIDL.
190	$dta=0 \text{ K}$	Temperature offset of the device.

Virtuoso Simulator Components and Device Models Reference

Philips Models

191	<code>type=n</code>	Transistor gender. Possible values are n, p, npn, pnp, npnv, pnpv, npnl, or pnp1.
192	<code>imax=1.0 A</code>	Explosion current.
193	<code>tnom (C)</code>	alias of <code>tnom</code> .
194	<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	<code>mo</code>	Parameter for (short-channel) subthreshold slope.
17	<code>ssf</code> ($1/\sqrt{V}$)	Static-feedback parameter.
18	<code>alp</code>	Factor of channel length modulation.
19	<code>vp</code> (V)	Characteristic voltage of channel-length modulation.
20	<code>mexp</code>	Smoothing factor.
21	<code>a1</code>	Factor of the weak-avalanche current.
22	<code>a2</code> (V)	Exponent of the weak-avalanche current.
23	<code>a3</code>	Factor of the drain-source voltage above which weak-avalanche occurs.
24	<code>iginv</code> (A/V^2)	Gain factor for intrinsic gate tunnelling current in inversion.
25	<code>binv</code> (V)	Probability factor for intrinsic gate tunnelling current in inversion.
26	<code>igacc</code> (A/V^2)	Gain factor for intrinsic gate tunnelling current in accumulation.
27	<code>bacc</code> (V)	Probability factor for intrinsic gate tunnelling current in accumulation.
28	<code>vfbov</code> (V)	Flat-band voltage for the Source/Drain overlap extensions.
29	<code>kov</code> (\sqrt{V})	Body-effect factor for the Source/Drain overlap extensions.
30	<code>igov</code> (A/V^2)	Gain factor for Source/Drain overlap tunnelling current.
31	<code>agidl</code> (A/V^3)	Gain factor for gate-induced leakage current.
32	<code>bgidl</code> (V)	Probability factor for gate-induced drain leakage current at reference temperature.
33	<code>cgidl</code>	Factor for the lateral field dependence of the gate-induced leakage current.
34	<code>cox</code> (F)	Oxide capacitance for the intrinsic channel (* mult).
35	<code>cgdo</code> (F)	Oxide capacitance for the gate-drain overlap (* mult).

Virtuoso Simulator Components and Device Models Reference

Philips Models

36	c_{gso} (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.
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	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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

14	$vsat$ (V)	Saturation limit.
15	gm (A/V)	Transconductance ($d\ i_{ds} / d\ v_{gs}$).
16	gmb (A/V)	Substrate-transconductance ($d\ i_{ds} / d\ v_{bs}$).
17	gds (A/V)	Output conductance ($d\ i_{ds} / d\ v_{ds}$).
18	cdd (F)	Capacitance ($d\ q_d / d\ v_d$).
19	cdg (F)	Capacitance ($- d\ q_d / d\ v_g$).
20	cds (F)	Capacitance ($- d\ q_d / d\ v_s$).
21	cdb (F)	Capacitance ($- d\ q_d / d\ v_b$).
22	cgd (F)	Capacitance ($- d\ q_g / d\ v_d$).
23	cgg (F)	Capacitance ($d\ q_g / d\ v_g$).
24	cgs (F)	Capacitance ($- d\ q_g / d\ v_s$).
25	cgb (F)	Capacitance ($- d\ q_g / d\ v_b$).
26	csd (F)	Capacitance ($- d\ q_s / d\ v_d$).
27	csg (F)	Capacitance ($- d\ q_s / d\ v_g$).
28	css (F)	Capacitance ($d\ q_s / d\ v_s$).
29	csb (F)	Capacitance ($- d\ q_s / d\ v_b$).
30	cbd (F)	Capacitance ($- d\ q_b / d\ v_d$).
31	cbg (F)	Capacitance ($- d\ q_b / d\ v_g$).
32	cbs (F)	Capacitance ($- d\ q_b / d\ v_s$).
33	cbb (F)	Capacitance ($d\ q_b / d\ v_b$).
34	$cgdo1$ (F)	Gate-drain overlap capacitance of the actual transistor.
35	$cgsol$ (F)	Gate-source overlap capacitance of the actual transistor.

Virtuoso Simulator Components and Device Models Reference

Philips Models

36	<code>w_{eff}</code> (m)	Effective channel width for geometrical models.
37	<code>l_{eff}</code> (m)	Effective channel length for geometrical models.
38	<code>u</code>	Transistor gain (gm/gds).
39	<code>r_{out}</code> (Ω)	Small-signal output resistance (1/gds).
40	<code>v_{early}</code> (V)	Equivalent Early voltage ($ i_d /g_{ds}$).
41	<code>k_{eff}</code> (\sqrt{V})	Body effect parameter.
42	<code>b_{eff}</code> (A/V ²)	Gain factor.
43	<code>f_{ug}</code> (Hz)	Unity gain frequency at actual bias ($g_m/(2\pi C_{in})$).
44	<code>sqrtsfw</code> (V/ $\sqrt{\text{Hz}}$)	Input-referred RMS white noise voltage density.
45	<code>sqrtsff</code> (V/ $\sqrt{\text{Hz}}$)	Input-referred RMS white noise voltage density at 1 kHz.
46	<code>f_{knee}</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.

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<code>a2</code>	O-22	<code>nu</code>	M-169	<code>plwtbgidl</code>	M-189	<code>pwiginv</code>	M-86
<code>a3</code>	O-23	<code>nu</code>	O-9	<code>plwtetabet</code>	M-156	<code>pwigov</code>	M-104
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Virtuoso Simulator Components and Device Models Reference

Philips Models

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cbg	OP-31	plcgdo	M-124	plwtuexp	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	poal	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
cgb	OP-25	pliginv	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

Virtuoso Simulator Components and Device Models Reference

Philips Models

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cgso	O-36	plnfc	M-142	pocgidl	M-114	pwtphib	M-151
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csg	OP-27	pltbgidl	M-187	poiginv	M-84	sqrtsff	OP-45
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gds	OP-17	plther	M-38	pophib	M-17	ther2	O-12
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

Virtuoso Simulator Components and Device Models Reference

Philips Models

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	pwal	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
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

Virtuoso Simulator Components and Device Models Reference

Philips Models

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 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 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..
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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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.
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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

19	$p_{w\text{phib}}=0 \text{ V}$	Coefficient for the width dependence of PHIB.
20	$p_{lw\text{phib}}=0 \text{ V}$	Coefficient for the length times width dependence of PHIB.
21	$p_{ob\text{et}}=0.00192(n)/0.000381(p) \text{ A/V}^2$	Coefficient for the geometry independent part of BET.
22	$p_{l\text{bet}}=0 \text{ A/V}^2$	Coefficient for the length dependence of BET.
23	$p_{w\text{bet}}=0 \text{ A/V}^2$	Coefficient for the width dependence of BET.
24	$p_{lw\text{bet}}=0 \text{ A/V}^2$	Coefficient for the width over length dependence of BET.
25	$p_{oth\text{esr}}=0.356(n)/0.73(p) \text{ 1/V}$	Coefficient of the geometry independent part of THESR.
26	$p_{l\text{thesr}}=0 \text{ 1/V}$	Coefficient of the length dependence of THESR.
27	$p_{w\text{thesr}}=0 \text{ 1/V}$	Coefficient of the width dependence of THESR.
28	$p_{lw\text{thesr}}=0 \text{ 1/V}$	Coefficient of the length times width dependence of THESR.
29	$p_{oth\text{eph}}=0.0129(n)/0.001(p) \text{ 1/V}$	Coefficient of the geometry independent part of THEPH.
30	$p_{l\text{theph}}=0 \text{ 1/V}$	Coefficient of the length dependence of THEPH.
31	$p_{w\text{theph}}=0 \text{ 1/V}$	Coefficient of the width dependence of THEPH.
32	$p_{lw\text{theph}}=0 \text{ 1/V}$	Coefficient of the length times width dependence of THEPH.
33	$p_{o\text{etamob}}=1.4(n)/3(p)$	Coefficient of the geometry independent part of ETAMOB.
34	$p_{l\text{etamob}}=0$	Coefficient of the length dependence of ETAMOB.
35	$p_{w\text{etamob}}=0$	Coefficient of the width dependence of ETAMOB.
36	$p_{lw\text{etamob}}=0$	Coefficient of the length times width dependence of ETAMOB.
37	$p_{oth\text{er}}=0.0812(n)/0.079(p) \text{ 1/V}$	Coefficient of the geometry independent part of THER.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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.
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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

56	$p_{lmo}=0$	Coefficient of the length dependence of MO.
57	$p_{wmo}=0$	Coefficient of the width dependence of MO.
58	$p_{lwmo}=0$	Coefficient of the length times width dependence of MO.
59	$p_{ossf}=0.012(n)/0.01(p) \ 1/\sqrt{V}$	Coefficient of the geometry independent part of SSF.
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	$p_{oalp}=0.025$	Coefficient of the geometry independent part of ALP.
64	$p_{lalp}=0$	Coefficient of the length dependence of ALP.
65	$p_{walp}=0$	Coefficient of the width dependence of ALP.
66	$p_{lwalp}=0$	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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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.
83	$plwa3=0$	Coefficient of the length times width dependence of A3.
84	$poiginv=0 \text{ A/V}^2$	Coefficient of the geometry independent part of IGINV.
85	$pliginv=0 \text{ A/V}^2$	Coefficient of the length dependence of IGINV.
86	$pwiginv=0 \text{ A/V}^2$	Coefficient of the width dependence of IGINV.
87	$plwiginv=0 \text{ A/V}^2$	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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

96	<code>pobacc=48</code>	V	Coefficient of the geometry independent part of BACC.
97	<code>plbacc=0</code>	V	Coefficient of the length dependence of BACC.
98	<code>pwbacc=0</code>	V	Coefficient of the width dependence of BACC.
99	<code>plwbacc=0</code>	V	Coefficient of the length times width dependence of BACC.
100	<code>vfbov=0</code>	V	Flat-band voltage for the Source/Drain overlap extensions.
101	<code>kov=2.5</code>	\sqrt{V}	Body-effect factor for the Source/Drain overlap extensions.
102	<code>poigov=0</code>	A/V^2	Coefficient of the geometry independent part of IGOV.
103	<code>pligov=0</code>	A/V^2	Coefficient of the length dependence of IGOV.
104	<code>pwigov=0</code>	A/V^2	Coefficient of the width dependence of IGOV.
105	<code>plwigov=0</code>	A/V^2	Coefficient of the length times width dependence of IGOV.
106	<code>poagidl=0</code>	A/V^3	Coefficient of the geometry independent part of AGIDL.
107	<code>plagidl=0</code>	A/V^3	Coefficient of the length dependence of AGIDL.
108	<code>pwagidl=0</code>	A/V^3	Coefficient of the width dependence of AGIDL.
109	<code>plwagidl=0</code>	A/V^3	Coefficient of the length times width dependence of AGIDL.
110	<code>pobgidl=41</code>	V	Coefficient of the geometry independent part of BGIDL.
111	<code>plbgidl=0</code>	V	Coefficient of the length dependence of BGIDL.
112	<code>pwbgidl=0</code>	V	Coefficient of the width dependence of BGIDL.
113	<code>plwbgidl=0</code>	V	Coefficient of the length times width dependence of BGIDL.
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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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.
122	$p_{lwcox}=0$	F	Coefficient of the length times width dependence of COX.
123	$p_{ocgdo}=6.39e-15(n)/6.36e-15(p)$	F	Coefficient of the geometry independent part of CGDO.
124	$p_{lcgdo}=0$	F	Coefficient of the length dependence of CGDO.
125	$p_{wcgdo}=0$	F	Coefficient of the width dependence of CGDO.
126	$p_{lwcgdo}=0$	F	Coefficient of the length time width dependence of CGDO.
127	$p_{ocgso}=6.39e-15(n)/6.36e-15(p)$	F	Coefficient of the geometry independent part of CGSO.
128	$p_{lcgso}=0$	F	Coefficient of the length dependence of CGSO.
129	$p_{wcgso}=0$	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	$n_t=1.62e-20$	J	Thermal noise coefficient.
133	$p_{onfa}=8.32e+22(n)/1.9e+22(p)$	$1/V$ 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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

137	$\text{ponfb}=2.51\text{e}+07(\text{n})/5.04\text{e}+06(\text{p})$	$1/\text{V m}^2$	Coefficient of the geometry independent part of NFB.
138	$\text{plnfb}=0$	$1/\text{V m}^2$	Coefficient of the length dependence of NFB.
139	$\text{pwnfb}=0$	$1/\text{V m}^2$	Coefficient of the width dependence of NFB.
140	$\text{plwnfb}=0$	$1/\text{V m}^2$	Coefficient of the length times width dependence of NFB.
141	$\text{ponfc}=0(\text{n})/3.63\text{e}-10(\text{p})$	$1/\text{V}$	Coefficient of the geometry independent part of NFC.
142	$\text{plnfc}=0$	$1/\text{V}$	Coefficient of the length dependence of NFC.
143	$\text{pwnfc}=0$	$1/\text{V}$	Coefficient of the width dependence of NFC.
144	$\text{plwnfc}=0$	$1/\text{V}$	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	$\text{potetabet}=1.3(\text{n})/0.5(\text{p})$		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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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.
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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

177	<code>plwtetar=0</code>	Coefficient of the length times width dependence of ETAR.
178	<code>potetasat=1.04(n)/0.86(p)</code>	Coefficient of the geometry independent part of ETASAT.
179	<code>pltetasat=0</code>	Coefficient of the length dependence of ETASAT.
180	<code>pwtetasat=0</code>	Coefficient of the width dependence of ETASAT.
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>pwtal=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>rth=300 K/W</code>	Thermal resistance.
192	<code>cth=3e-09 J/K</code>	Thermal capacitance.
193	<code>ath=0</code>	Temperature coefficient of the thermal resistance.
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 tnom.

Virtuoso Simulator Components and Device Models Reference

Philips Models

197 `tref` (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.
10	<code>ther</code> ($1/V$)	Coefficient of series resistance.
11	<code>ther1</code> (V)	Numerator of gate voltage dependent part of series resistance.
12	<code>ther2</code> (V)	Denominator of gate voltage dependent part of series resistance.
13	<code>thesat</code> ($1/V$)	Velocity saturation parameter due to optical/acoustic phonon scattering.
14	<code>theth</code> ($1/V^3$)	Coefficient of self-heating.
15	<code>sdibl</code> ($1/\sqrt{V}$)	Drain-induced barrier lowering parameter.
16	<code>mo</code>	Parameter for (short-channel) subthreshold slope.
17	<code>ssf</code> ($1/\sqrt{V}$)	Static-feedback parameter.
18	<code>alp</code>	Factor of channel length modulation.

Virtuoso Simulator Components and Device Models Reference

Philips Models

19	v_p (V)	Characteristic voltage of channel-length modulation.
20	m_{exp}	Smoothing factor.
21	a_1	Factor of the weak-avalanche current.
22	a_2 (V)	Exponent of the weak-avalanche current.
23	a_3	Factor of the drain-source voltage above which weak-avalanche occurs.
24	ig_{inv} (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	ig_{acc} (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	v_{fbov} (V)	Flat-band voltage for the Source/Drain overlap extensions.
29	k_{ov} (\sqrt{V})	Body-effect factor for the Source/Drain overlap extensions.
30	ig_{ov} (A/V ²)	Gain factor for Source/Drain overlap tunnelling current.
31	ag_{idl} (A/V ³)	Gain factor for gate-induced leakage current.
32	bg_{idl} (V)	Probability factor for gate-induced drain leakage current at reference temperature.
33	cg_{idl}	Factor for the lateral field dependence of the gate-induced leakage current.
34	c_{ox} (F)	Oxide capacitance for the intrinsic channel (* mult).
35	c_{gdo} (F)	Oxide capacitance for the gate-drain overlap (* mult).
36	c_{gso} (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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

39	nfa ($1/(V_m^4)$)	First coefficient of the flicker noise.
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.
43	rth (K/W)	Thermal resistance.
44	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.
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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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 ($- d q_b / d v_s$).
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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

37	<code>leff</code> (m)	Effective channel length for geometrical models.
38	<code>u</code>	Transistor gain (gm/gds).
39	<code>rout</code> (Ω)	Small-signal output resistance (1/gds).
40	<code>vearly</code> (V)	Equivalent Early voltage ($ id /gds$).
41	<code>keff</code> (\sqrt{V})	Body effect parameter.
42	<code>beff</code> (A/V^2)	Gain factor.
43	<code>fug</code> (Hz)	Unity gain frequency at actual bias ($gm/(2*\pi*cin)$).
44	<code>sqrtsw</code> (V/\sqrt{Hz})	Input-referred RMS white noise voltage density.
45	<code>sqrtfff</code> (V/\sqrt{Hz})	Input-referred RMS white noise voltage density at 1 kHz.
46	<code>fknee</code> (Hz)	Cross-over frequency above which white noise is dominant.
47	<code>Pdiss</code> (W)	Dissipation.
48	<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-47	<code>nfb</code>	O-40	<code>plwssf</code>	M-62	<code>pwiginv</code>	M-86
<code>TK</code>	OP-48	<code>nfc</code>	O-41	<code>plwtal</code>	M-185	<code>pwigov</code>	M-104
<code>a1</code>	O-21	<code>nt</code>	M-132	<code>plwtbgidl</code>	M-189	<code>pwko</code>	M-14

Virtuoso Simulator Components and Device Models Reference

Philips Models

a2	O-22	nt	O-38	plwtetabet	M-156	pwmexp	M-70
a3	O-23	nu	M-169	plwtetamob	M-168	pwm0	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	pwszf	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	poal	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
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

Virtuoso Simulator Components and Device Models Reference

Philips Models

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	sqrtssf OP-45
csd OP-26	pltal 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
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

Virtuoso Simulator Components and Device Models Reference

Philips Models

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
l	I-1	plwetamob	M-36	pwagidl	M-108	vsat	OP-14
lap	M-3	plwigacc	M-95	plwalp	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

Virtuoso Simulator Components and Device Models Reference

Philips Models

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 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 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 mos1101e parameter=value ...

Model Parameters

- | | | |
|----|--|---|
| 1 | <code>level=1.1e+03</code> | Transistor Level. |
| 2 | <code>tr=21 C</code> | Reference temperature. |
| 3 | <code>vfb=-1.05 V</code> | Flat-band voltage at reference temperature. |
| 4 | <code>stvfb=0.0005 V/K</code> | Coefficient of temperature dependence of VFB. |
| 5 | <code>ko=0.5 \sqrt{V}</code> | Body-effect factor. |
| 6 | <code>kpinv=0 $1/\sqrt{V}$</code> | Inverse of body-effect factor of the poly-silicon gate. |
| 7 | <code>phib=0.95 V</code> | Surface potential at the onset of strong inversion. |
| 8 | <code>stphib=-0.00085 V/K</code> | Coefficient of the temperature dependency of PHIB. |
| 9 | <code>bet=0.00192(n)/0.000381(p) A/V^2</code> | Gain factor. |
| 10 | <code>etabet=1.3(n)/0.5(p)</code> | Exponent of the temperature dependence of the gain factor. |
| 11 | <code>thesr=0.356(n)/0.73(p) $1/V$</code> | Mobility degradation parameter due to surface roughness scattering. |
| 12 | <code>etasr=0.65(n)/0.5(p)</code> | Exponent of the temperature dependence of THESR. |
| 13 | <code>theph=0.0129(n)/0.001(p) $1/V$</code> | Mobility degradation parameter due to phonon scattering. |
| 14 | <code>etaph=1.35(n)/3.75(p)</code> | Exponent of the temperature dependence of THEPH. |

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 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.
- 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 $sdibl=0.000853(n)/3.55e-05(p) \text{ 1/}\sqrt{V}$ Drain-induced barrier lowering parameter.
- 27 $mo=0$ Parameter for (short-channel) subthreshold slope.
- 28 $ssf=0.012(n)/0.01(p) \text{ 1/}\sqrt{V}$ Static-feedback parameter.
- 29 $alp=0.025$ Factor of channel length modulation.
- 30 $vp=0.05 \text{ V}$ Characteristic voltage of channel-length modulation.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 31 $m_{exp}=5$ Smoothing factor.
- 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 $ig_{inv}=0 \text{ A/V}^2$ 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 $ig_{acc}=0 \text{ A/V}^2$ Gain factor for intrinsic gate tunnelling current in accumulation.
- 39 $b_{acc}=48 \text{ V}$ Probability factor for intrinsic gate tunnelling current in accumulation.
- 40 $vf_{bov}=0 \text{ V}$ Flat-band voltage for the Source/Drain overlap extensions.
- 41 $kov=2.5 \sqrt{\text{V}}$ Body-effect factor for the Source/Drain overlap extensions.
- 42 $ig_{ov}=0 \text{ A/V}^2$ 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	$nfa=8.32e+22(n)/1.9e+22(p)$ $1/(Vm^4)$	First coefficient of the flicker noise.
53	$nfb=2.51e+07(n)/5.04e+06(p)$ $1/(Vm^2)$	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	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.

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.

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	u	Transistor gain (gm/gds).
37	r_{out} (Ω)	Small-signal output resistance (1/gds).
38	v_{early} (V)	Equivalent Early voltage ($ i_d /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	$sqrt_{sfw}$ (V/ \sqrt{Hz})	Input-referred RMS white noise voltage density.
43	$sqrt_{sff}$ (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.

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	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
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

Virtuoso Simulator Components and Device Models Reference

Philips Models

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
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 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 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 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. |

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 5 $k_o=0.5 \sqrt{V}$ Body-effect factor.
- 6 $k_{pinv}=0 \ 1/\sqrt{V}$ 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.
- 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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 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/V³ 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/V² Gain factor for intrinsic gate tunnelling current in inversion.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 37 $\text{binv}=48(n)/87.5(p)$ V
Probability factor for intrinsic gate tunnelling current in inversion.
- 38 $\text{igacc}=0$ A/V²
Gain factor for intrinsic gate tunnelling current in accumulation.
- 39 $\text{bacc}=48$ V
Probability factor for intrinsic gate tunnelling current in accumulation.
- 40 $\text{vfbov}=0$ V
Flat-band voltage for the Source/Drain overlap extensions.
- 41 $\text{kov}=2.5$ \sqrt{V}
Body-effect factor for the Source/Drain overlap extensions.
- 42 $\text{igov}=0$ A/V²
Gain factor for Source/Drain overlap tunnelling current.
- 43 $\text{agidl}=0$ A/V³
Gain factor for gate-induced leakage current.
- 44 $\text{bgidl}=41$ V
Probability factor for gate-induced drain leakage current at reference temperature.
- 45 $\text{stbgidl}=-0.000364$ V/K
Coefficient of the temperature dependence of BGIDL.
- 46 $\text{cgidl}=0$
Factor for the lateral field dependence of the gate-induced leakage current.
- 47 $\text{cox}=2.98e-14(n)/2.72e-14(p)$ F
Oxide capacitance for the intrinsic channel (* mult).
- 48 $\text{cgdo}=6.39e-15(n)/6.36e-15(p)$ F
Oxide capacitance for the gate-drain overlap (* mult).
- 49 $\text{cgso}=6.39e-15(n)/6.36e-15(p)$ F
Oxide capacitance for the gate-source overlap (* mult).
- 50 $\text{gatenoise}=0$
Flag for in/exclusion of induced gate thermal noise.
- 51 $\text{nt}=1.62e-20$ J
Thermal noise coefficient.
- 52 $\text{nfa}=8.32e+22(n)/1.9e+22(p)$ 1/(Vm⁴)
First coefficient of the flicker noise.
- 53 $\text{nfb}=2.51e+07(n)/5.04e+06(p)$ 1/(Vm²)
Second coefficient of the flicker noise.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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.
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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

10	<code>ther</code> ($1/V$)	Coefficient of series resistance.
11	<code>ther1</code> (V)	Numerator of gate voltage dependent part of series resistance.
12	<code>ther2</code> (V)	Denominator of gate voltage dependent part of series resistance.
13	<code>thesat</code> ($1/V$)	Velocity saturation parameter due to optical/acoustic phonon scattering.
14	<code>theth</code> ($1/V^3$)	Coefficient of self-heating.
15	<code>sdibl</code> ($1/\sqrt{V}$)	Drain-induced barrier lowering parameter.
16	<code>mo</code>	Parameter for (short-channel) subthreshold slope.
17	<code>ssf</code> ($1/\sqrt{V}$)	Static-feedback parameter.
18	<code>alp</code>	Factor of channel length modulation.
19	<code>vp</code> (V)	Characteristic voltage of channel-length modulation.
20	<code>mexp</code>	Smoothing factor.
21	<code>a1</code>	Factor of the weak-avalanche current.
22	<code>a2</code> (V)	Exponent of the weak-avalanche current.
23	<code>a3</code>	Factor of the drain-source voltage above which weak-avalanche occurs.
24	<code>iginv</code> (A/V^2)	Gain factor for intrinsic gate tunnelling current in inversion.
25	<code>binv</code> (V)	Probability factor for intrinsic gate tunnelling current in inversion.
26	<code>igacc</code> (A/V^2)	Gain factor for intrinsic gate tunnelling current in accumulation.
27	<code>bacc</code> (V)	Probability factor for intrinsic gate tunnelling current in accumulation.
28	<code>vfbov</code> (V)	Flat-band voltage for the Source/Drain overlap extensions.
29	<code>kov</code> (\sqrt{V})	Body-effect factor for the Source/Drain overlap extensions.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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.
43	rth (K/W)	Thermal resistance.
44	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.

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.
45	P_{diss} (W)	Dissipation.
46	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-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
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

Virtuoso Simulator Components and Device Models Reference

Philips Models

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
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

Virtuoso Simulator Components and Device Models Reference

Philips Models

<code>cgidl</code>	M-46	<code>imax</code>	M-61	<code>stetamob</code>	M-16
<code>cgidl</code>	O-33	<code>keff</code>	OP-39	<code>stphib</code>	M-8
<code>cgs</code>	OP-24	<code>ko</code>	M-5	<code>stvfb</code>	M-4

MOS Model 11, Level 1102 (mos11020)

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 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 mos11020 parameter=value ...
```

Virtuoso Simulator Components and Device Models Reference

Philips Models

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.
11	<code>sl2ko=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.
15	<code>stphib=-0.00085 V/K</code>	Coefficient of the temperature dependency of PHIB.
16	<code>slphib=0</code>	Coefficient of the length dependence of PHIB.
17	<code>sl2phib=0</code>	Second coefficient of the length dependence of PHIB.
18	<code>swphib=0</code>	Coefficient of the width dependence of PHIB.
19	<code>betsq=0.000371(n)/0.000115(p) A/V^2</code>	Gain factor for an infinite square transistor.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 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.
- 29 $thephr=0.0129(n)/0.001(p) 1/V$ 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.
- 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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 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.
- 49 $swtheth=0$
Coefficient of the width dependence of THETH.
- 50 $sdiblo=0.0001 \ 1/\sqrt{V}$
Drain-induced barrier lowering parameter.
- 51 $sdiblexp=1.35$
Exponent of the length dependence of SDIBL.
- 52 $mo=0$
Parameter for short-channel subthreshold slope.
- 53 $mor=0$
Parameter for short-channel subthreshold slope per unit length.
- 54 $moexp=1.34$
Exponent of the length dependence of MO.

Virtuoso Simulator Components and Device Models Reference

Philips Models

55	$ssfr=0.00625 \text{ 1}/\sqrt{V}$	Static feedback parameter.
56	$slssf=1$	Coefficient of the length dependence of SSF.
57	$swssf=0$	Coefficient of the width dependence of SSF.
58	$alpr=0.01$	Factor of the channel length modulation.
59	$slalp=1$	Coefficient of the length dependence of ALP.
60	$alpexp=1$	Exponent of the length dependence of ALP.
61	$swalp=0$	Coefficient of the width dependence of ALP.
62	$vp=0.05 \text{ V}$	Characteristic voltage of channel-length modulation.
63	$lmin=1.5e-07 \text{ m}$	Minimum effective channel length in technology, used for calculation of smoothing factor m .
64	$a1r=6$	Factor of the weak-avalanche current.
65	$sta1=0 \text{ 1}/K$	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	$a2r=38 \text{ V}$	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	$iginvr=0 \text{ A}/V^2$	Gain factor for intrinsic gate tunnelling current in inversion.

Virtuoso Simulator Components and Device Models Reference

Philips Models

75	$b_{inv}=48(n)/87.5(p)$ 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	$b_{acc}=48$ V	Probability factor for intrinsic gate tunnelling current in accumulation.
78	$vfbov=0$ V	Flat-band voltage for the Source/Drain overlap extensions.
79	$k_{ov}=2.5$ \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.
84	$cgidl=0$	Factor for the lateral field dependence of the gate-induced leakage current.
85	$tox=3.2e-09$ m	Thickness of gate oxide layer.
86	$col=3.2e-16$ F	Gate overlap capacitance for a channel width of 1 μ m.
87	$gatenoise=0$	Flag for in/exclusion of induced gate thermal noise.
88	$nt=1.62e-20$ J	Thermal noise coefficient.
89	$n_{far}=1.57e+23(n)/3.83e+24(p)$ 1/(V μ m ⁴)	First coefficient of the flicker noise for a channel area of 1 μ m ² .
90	$n_{fbr}=4.75e+09(n)/1.02e+09(p)$ 1/(V μ m ²)	Second coefficient of the flicker noise for a channel area of 1 μ 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 μ m ² .

Virtuoso Simulator Components and Device Models Reference

Philips Models

92	<code>dta=0 K</code>	Temperature offset of the device.
93	<code>csr=0</code>	Factor of the Coulomb scattering.
94	<code>slcs=0</code>	Coefficient of the length dependence of CS.
95	<code>csexp=1</code>	Exponent of the length dependence of CS.
96	<code>swcs=0</code>	Coefficient of the width dependence of CS.
97	<code>etacs=0</code>	Exponent of the temperature dependence of CS.
98	<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> .
99	<code>imax=1.0 A</code>	Explosion current.
100	<code>mbeo=0.0</code>	DCmatch parameter.
101	<code>mvto=0.0</code>	DCmatch parameter.
102	<code>tnom (C)</code>	alias of <code>tnom</code> .
103	<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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

9	<code>nu</code>	Exponent of field dependence of mobility model.
10	<code>cs</code>	Coefficient of Coulomb scattering.
11	<code>ther (1/V)</code>	Coefficient of series resistance.
12	<code>ther1 (V)</code>	Numerator of gate voltage dependent part of series resistance.
13	<code>ther2 (V)</code>	Denominator of gate voltage dependent part of series resistance.
14	<code>thesat (1/V)</code>	Velocity saturation parameter due to optical/acoustic phonon scattering.
15	<code>theth (1/V³)</code>	Coefficient of self-heating.
16	<code>sdibl (1/√V)</code>	Drain-induced barrier lowering parameter.
17	<code>mo</code>	Parameter for (short-channel) subthreshold slope.
18	<code>ssf (1/√V)</code>	Static-feedback parameter.
19	<code>alp</code>	Factor of channel length modulation.
20	<code>vp (V)</code>	Characteristic voltage of channel-length modulation.
21	<code>mexp</code>	Smoothing factor.
22	<code>a1</code>	Factor of the weak-avalanche current.
23	<code>a2 (V)</code>	Exponent of the weak-avalanche current.
24	<code>a3</code>	Factor of the drain-source voltage above which weak-avalanche occurs.
25	<code>iginv (A/V²)</code>	Gain factor for intrinsic gate tunnelling current in inversion.
26	<code>binv (V)</code>	Probability factor for intrinsic gate tunnelling current in inversion.
27	<code>igacc (A/V²)</code>	Gain factor for intrinsic gate tunnelling current in accumulation.
28	<code>bacc (V)</code>	Probability factor for intrinsic gate tunnelling current in accumulation.

Virtuoso Simulator Components and Device Models Reference

Philips Models

29	v_{fbov} (V)	Flat-band voltage for the Source/Drain overlap extensions.
30	k_{ov} (\sqrt{V})	Body-effect factor for the Source/Drain overlap extensions.
31	i_{gov} (A/V^2)	Gain factor for Source/Drain overlap tunnelling current.
32	a_{gidl} (A/V^3)	Gain factor for gate-induced leakage current.
33	b_{gidl} (V)	Probability factor for gate-induced drain leakage current at reference temperature.
34	c_{gidl}	Factor for the lateral field dependence of the gate-induced leakage current.
35	c_{ox} (F)	Oxide capacitance for the intrinsic channel (* mult).
36	c_{gdo} (F)	Oxide capacitance for the gate-drain overlap (* mult).
37	c_{gso} (F)	Oxide capacitance for the gate-source overlap (* mult).
38	$g_{atnoise}$	Flag for in/exclusion of induced gate thermal noise.
39	n_t (J)	Thermal noise coefficient.
40	n_{fa} ($1/(V_m^4)$)	First coefficient of the flicker noise.
41	n_{fb} ($1/(V_m^2)$)	Second coefficient of the flicker noise.
42	n_{fc} ($1/V$)	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.

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 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 ($ 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	$sqrtsfw$ (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	etacs	M-97	mult	I-3	swtheph	M-31
a1r	M-64	etamob	O-8	mvto	M-101	swther	M-39
a2	O-23	etamobr	M-32	nfa	O-40	swthesat	M-46
a2r	M-68	etaph	M-30	nfarc	M-89	swthesr	M-28
a3	O-24	etar	M-38	nfb	O-41	swtheth	M-49
a3r	M-71	etasat	M-43	nfbr	M-90	theph	O-7
agidl	O-32	etasr	M-27	nfc	O-42	thephr	M-29
agidlr	M-81	fbet1	M-22	nfcrc	M-91	ther	O-11
alp	O-19	fbet2	M-24	nt	M-88	ther1	M-40
alpexp	M-60	fknee	OP-46	nt	O-39	ther1	O-12
alpr	M-58	fug	OP-43	nu	M-35	ther2	M-41
area	I-6	gatenoise	M-87	nu	O-9	ther2	O-13
bacc	M-77	gatenoise	O-38	nuexp	M-36	therr	M-37
bacc	O-28	gds	OP-17	phib	O-4	thesat	O-14
beff	OP-42	gm	OP-15	phibr	M-14	thesatexp	M-45
bet	O-5	gmb	OP-16	region	I-4	thesatr	M-42

Virtuoso Simulator Components and Device Models Reference

Philips Models

betsq M-19	iavl OP-2	rout OP-39	thesr O-6
bgidl M-82	ids OP-1	sdibl O-16	thesrr M-26
bgidl O-33	igacc O-27	sdiblexp M-51	theth O-15
binv M-75	igaccr M-76	sdiblo M-50	thethexp M-48
binv O-26	igb OP-5	sl2ko M-11	thethr M-47
cbb OP-33	igd OP-4	sl2phib M-17	tnom M-102
cbd OP-30	iginv O-25	slal M-66	tox M-85
cbg OP-31	iginvr M-74	sla2 M-69	tox O-43
cbs OP-32	igov O-31	sla3 M-72	tr M-6
cdb OP-21	igovr M-80	slalp M-59	tref M-103
cdd OP-18	igs OP-3	slcs M-94	type M-98
cdg OP-19	imax M-99	sletabet M-21	u OP-38
cds OP-20	keff OP-41	slko M-10	vds OP-6
cgb OP-25	ko O-2	slphib M-16	vdss OP-13
cgd OP-22	kor M-9	slssf M-56	vearly OP-40
cgdo O-36	kov M-79	slthesat M-44	vfb M-7
cgdol OP-34	kov O-30	sqrtsff OP-45	vfb O-1
cgg OP-23	kpinv M-13	sqrtsfw OP-44	vfbov M-78
cgidl M-84	kpinv O-3	ssf O-18	vfbov O-29
cgidl O-34	l I-1	ssfr M-55	vgs OP-7
cgs OP-24	lap M-3	stal M-65	vgt OP-12

Virtuoso Simulator Components and Device Models Reference

Philips Models

cgso	O-37	leff	OP-37	stbgidl	M-83	vp	M-62
cgso1	OP-35	level	M-1	stetamob	M-33	vp	O-20
col	M-86	lmin	M-63	stphib	M-15	vsat	OP-14
cox	O-35	lp1	M-23	stvfb	M-8	vsb	OP-8
cs	O-10	lp2	M-25	swa1	M-67	vth	OP-11
csb	OP-29	lvar	M-2	swa2	M-70	vto	OP-9
csd	OP-26	m	I-5	swa3	M-73	vts	OP-10
csexp	M-95	mbeo	M-100	swalp	M-61	w	I-2
csg	OP-27	mexp	O-21	swcs	M-96	weff	OP-36
csr	M-93	mo	O-17	swetamob	M-34	wot	M-5
css	OP-28	moexp	M-54	swko	M-12	wvar	M-4
dta	M-92	moo	M-52	swphib	M-18		
etabetr	M-20	mor	M-53	swssf	M-57		

MOS Model 11, Level 1102 (mos11020t)

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 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 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.
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 $\text{thephr}=0.0129(n)/0.001(p) \text{ 1/V}$
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 $\text{stetamob}=0 \text{ 1/K}$
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 $\text{therr}=0.155(n)/0.08(p) \text{ 1/V}$
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 $\text{ther1}=0 \text{ V}$
Numerator of gate voltage dependent part of series resistance.
- 41 $\text{ther2}=1 \text{ V}$
Denominator of gate voltage dependent part of series resistance.
- 42 $\text{thesatr}=0.5(n)/0.2(p) \text{ 1/V}$
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 <i>m</i> .
64	<code>alr=6</code>	Factor of the weak-avalanche current.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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.
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</code>	A/V^2	Gain factor for intrinsic gate tunnelling current in inversion.
75	<code>binv=48(n)/87.5(p)</code>	V	Probability factor for intrinsic gate tunnelling current in inversion.
76	<code>igaccr=0</code>	A/V^2	Gain factor for intrinsic gate tunnelling current in accumulation.
77	<code>bacc=48</code>	V	Probability factor for intrinsic gate tunnelling current in accumulation.
78	<code>vfbov=0</code>	V	Flat-band voltage for the Source/Drain overlap extensions.
79	<code>kov=2.5</code>	\sqrt{V}	Body-effect factor for the Source/Drain overlap extensions.
80	<code>igovr=0</code>	A/V^2	Gain factor for Source/Drain overlap gate tunnelling current.
81	<code>agidlr=0</code>	A/V^3	Gain factor for gate-induced leakage current.
82	<code>bgidl=41</code>	V	Probability factor for gate-induced drain leakage current at reference temperature.
83	<code>stbgidl=-0.000364</code>	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>csr=0</code>	Factor of the Coulomb scattering.
94	<code>slcs=0</code>	Coefficient of the length dependence of CS.
95	<code>csexp=1</code>	Exponent of the length dependence of CS.
96	<code>swcs=0</code>	Coefficient of the width dependence of CS.
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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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.
11	<code>ther ($1/V$)</code>	Coefficient of series resistance.
12	<code>ther1 (V)</code>	Numerator of gate voltage dependent part of series resistance.
13	<code>ther2 (V)</code>	Denominator of gate voltage dependent part of series resistance.
14	<code>thesat ($1/V$)</code>	Velocity saturation parameter due to optical/acoustic phonon scattering.
15	<code>theth ($1/V^3$)</code>	Coefficient of self-heating.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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.
34	$cgidl$	Factor for the lateral field dependence of the gate-induced leakage current.
35	cox (F)	Oxide capacitance for the intrinsic channel (* mult).

Virtuoso Simulator Components and Device Models Reference

Philips Models

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.
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	vtb (V)	Threshold voltage including back-bias effects.
11	vth (V)	Threshold voltage including back-bias and drain-bias effects.

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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_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	$sqrtsfw$ (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	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
alr	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
alpr	M-58	fknee	OP-46	nu	O-9	ther2	O-13
area	I-6	fug	OP-43	nuexp	M-36	therr	M-37
ath	M-100	gatenoise	M-87	phib	O-4	thesat	O-14
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
bet	O-5	gmb	OP-16	rth	M-98	thesrr	M-26
betsq	M-19	iavl	OP-2	rth	O-44	theth	O-15

Virtuoso Simulator Components and Device Models Reference

Philips Models

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
binv O-26	igb OP-5	sl2ko M-11	tox M-85
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
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	stal M-65	vp O-20
cgso O-37	leff OP-37	stbgidl M-83	vsat OP-14

Virtuoso Simulator Components and Device Models Reference

Philips Models

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	swal	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 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 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..

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 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.
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.

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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	$p_{ltheph}=0 1/V$	Coefficient of the length dependence of THEPH.
31	$p_{wthepth}=0 1/V$	Coefficient of the width dependence of THEPH.
32	$p_{lwtheph}=0 1/V$	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.

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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	$kov=2.5 \sqrt{\text{V}}$	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.

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Philips Models

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.
128	$plcgso=0$ F	Coefficient of the length dependence of CGSO.
129	$pwcgso=0$ F	Coefficient of the width dependence of CGSO.
130	$plwcgso=0$ 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	$ponfa=8.32e+22(n)/1.9e+22(p)$ $1/V$ m ⁴	Coefficient of the geometry independent part of NFA.

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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.

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Philips Models

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.
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	$pwtnuexp=0$	Coefficient of the width dependence of NUEXP.
173	$plwtnuexp=0$	Coefficient of the length times width dependence of NUEXP.

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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	$\text{pocs}=0$	Coefficient of the geometry independent part of CS.
192	$\text{plcs}=0$	Coefficient of the length dependence of CS.
193	$\text{pwcs}=0$	Coefficient of the width dependence of CS.

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Philips Models

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 A</code>	Explosion current.
201	<code>mbeo=0.0</code>	DCmatch parameter.
202	<code>mvto=0.0</code>	DCmatch parameter.
203	<code>tnom (C)</code>	alias of <code>tnom</code> .
204	<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.

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Philips Models

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/√V)	Drain-induced barrier lowering parameter.
17	mo	Parameter for (short-channel) subthreshold slope.
18	ssf (1/√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.

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30	k_{ov} (\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	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.

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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 ($- d q_s / d v_d$).
27	c_{sg} (F)	Capacitance ($- d q_s / d v_g$).

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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 ($ 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	$sqrtsfw$ (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.

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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.

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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	pwal	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 3.0.2

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	<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.
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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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.
26	<code>plthesr=0 $1/V$</code>	Coefficient of the length dependence of THESR.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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.
45	$pwthesat=0 \ 1/V$	Coefficient of the width dependence of THESAT.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 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.
- 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 $pwm=0$ 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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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.
83	$plwa3=0$	Coefficient of the length times width dependence of A3.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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.
104	$pwigov=0 \ A/V^2$	Coefficient of the width dependence of IGOV.

Virtuoso Simulator Components and Device Models Reference

Philips Models

105	$plwigov=0$	A/V^2	Coefficient of the length times width dependence of IGOV.
106	$poagidl=0$	A/V^3	Coefficient of the geometry independent part of AGIDL.
107	$plagidl=0$	A/V^3	Coefficient of the length dependence of AGIDL.
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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

126	$p_{lwcgdo}=0$	F	Coefficient of the length time width dependence of CGDO.
127	$p_{ocgso}=6.39e-15(n)/6.36e-15(p)$	F	Coefficient of the geometry independent part of CGSO.
128	$p_{lcgso}=0$	F	Coefficient of the length dependence of CGSO.
129	$p_{wcgso}=0$	F	Coefficient of the width dependence of CGSO.
130	$p_{lwcgso}=0$	F	Coefficient of the length times width dependence of CGSO.
131	$g_{atenoise}=0$		Flag for in/exclusion of induced gate thermal noise.
132	$n_t=1.62e-20$	J	Thermal noise coefficient.
133	$p_{onfa}=8.32e+22(n)/1.9e+22(p)$	$1/V \text{ m}^4$	Coefficient of the geometry independent part of NFA.
134	$p_{lnfa}=0$	$1/V \text{ m}^4$	Coefficient of the length dependence of NFA.
135	$p_{wnfa}=0$	$1/V \text{ m}^4$	Coefficient of the width dependence of NFA.
136	$p_{lwnfa}=0$	$1/V \text{ m}^4$	Coefficient of the length times width dependence of NFA.
137	$p_{onfb}=2.51e+07(n)/5.04e+06(p)$	$1/V \text{ m}^2$	Coefficient of the geometry independent part of NFB.
138	$p_{lnfb}=0$	$1/V \text{ m}^2$	Coefficient of the length dependence of NFB.
139	$p_{wnfb}=0$	$1/V \text{ m}^2$	Coefficient of the width dependence of NFB.
140	$p_{lwnfb}=0$	$1/V \text{ m}^2$	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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

146	$pltvfb=0$ V/K	Coefficient of the length dependence of STVFB.
147	$pwtvfb=0$ V/K	Coefficient of the width dependence of STVFB.
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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

166	$pltetamob=0 \ 1/K$	Coefficient of the length dependence of STETAMOB.
167	$pwtetamob=0 \ 1/K$	Coefficient of the width dependence of STETAMOB.
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	$pwtneuexp=0$	Coefficient of the width dependence of NUEXP.
173	$plwtneuexp=0$	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	$pota1=0 \ 1/K$	Coefficient of the geometry independent part of STA1.
183	$plta1=0 \ 1/K$	Coefficient of the length dependence of STA1.
184	$pwtal=0 \ 1/K$	Coefficient of the width dependence of STA1.
185	$plwta1=0 \ 1/K$	Coefficient of the length times width dependence of STA1.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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.
202	<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>pnpv</code> , <code>nnp1</code> , or <code>pnnp1</code> .
203	<code>imax=1.0 A</code>	Explosion current.
204	<code>mbeo=0.0</code>	DCmatch parameter.
205	<code>mvto=0.0</code>	DCmatch parameter.
206	<code>tnom (C)</code>	alias of <code>tnom</code> .

Virtuoso Simulator Components and Device Models Reference

Philips Models

207 `tref` (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.
10	<code>cs</code>	Coefficient of Coulomb scattering.
11	<code>ther</code> ($1/V$)	Coefficient of series resistance.
12	<code>ther1</code> (V)	Numerator of gate voltage dependent part of series resistance.
13	<code>ther2</code> (V)	Denominator of gate voltage dependent part of series resistance.
14	<code>thesat</code> ($1/V$)	Velocity saturation parameter due to optical/acoustic phonon scattering.
15	<code>theth</code> ($1/V^3$)	Coefficient of self-heating.
16	<code>sdibl</code> ($1/\sqrt{V}$)	Drain-induced barrier lowering parameter.
17	<code>mo</code>	Parameter for (short-channel) subthreshold slope.
18	<code>ssf</code> ($1/\sqrt{V}$)	Static-feedback parameter.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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.
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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

39	n_t (J)	Thermal noise coefficient.
40	n_{fa} ($1/(V_m^4)$)	First coefficient of the flicker noise.
41	n_{fb} ($1/(V_m^2)$)	Second coefficient of the flicker noise.
42	n_{fc} ($1/V$)	Third coefficient of the flicker noise.
43	t_{ox} (m)	Thickness of gate oxide layer.
44	r_{th} (K/W)	Thermal resistance.
45	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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

14	$vsat$ (V)	Saturation limit.
15	gm (A/V)	Transconductance ($d\ i_{ds} / d\ v_{gs}$).
16	gmb (A/V)	Substrate-transconductance ($d\ i_{ds} / d\ v_{bs}$).
17	gds (A/V)	Output conductance ($d\ i_{ds} / d\ v_{ds}$).
18	cdd (F)	Capacitance ($d\ q_d / d\ v_d$).
19	cdg (F)	Capacitance ($- d\ q_d / d\ v_g$).
20	cds (F)	Capacitance ($- d\ q_d / d\ v_s$).
21	cdb (F)	Capacitance ($- d\ q_d / d\ v_b$).
22	cgd (F)	Capacitance ($- d\ q_g / d\ v_d$).
23	cgg (F)	Capacitance ($d\ q_g / d\ v_g$).
24	cgs (F)	Capacitance ($- d\ q_g / d\ v_s$).
25	cgb (F)	Capacitance ($- d\ q_g / d\ v_b$).
26	csd (F)	Capacitance ($- d\ q_s / d\ v_d$).
27	csg (F)	Capacitance ($- d\ q_s / d\ v_g$).
28	css (F)	Capacitance ($d\ q_s / d\ v_s$).
29	csb (F)	Capacitance ($- d\ q_s / d\ v_b$).
30	cbd (F)	Capacitance ($- d\ q_b / d\ v_d$).
31	cbg (F)	Capacitance ($- d\ q_b / d\ v_g$).
32	cbs (F)	Capacitance ($- d\ q_b / d\ v_s$).
33	cbb (F)	Capacitance ($d\ q_b / d\ v_b$).
34	$cgdo1$ (F)	Gate-drain overlap capacitance of the actual transistor.
35	$cgsol$ (F)	Gate-source overlap capacitance of the actual transistor.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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 ($ 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	$sqrtsfw$ (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	nfb	O-41	$plwssf$	M-62	$pwigacc$	M-94
T_K	OP-48	nfc	O-42	$plwtal$	M-185	$pwiginv$	M-86

Virtuoso Simulator Components and Device Models Reference

Philips Models

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	pwsdibl	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
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	plwtheph	M-31
cgb	OP-25	pligacc	M-93	poalp	M-63	plwther	M-39

Virtuoso Simulator Components and Device Models Reference

Philips Models

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	pwtnuexp	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	pltal	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
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

Virtuoso Simulator Components and Device Models Reference

Philips Models

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
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

Virtuoso Simulator Components and Device Models Reference

Philips Models

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.

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 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.
- 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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 13 $\text{theph}=0.0129(n)/0.001(p) \text{ 1/V}$
Mobility degradation parameter due to phonon scattering.
- 14 $\text{etaph}=1.35(n)/3.75(p)$
Exponent of the temperature dependence of THEPH.
- 15 $\text{etamob}=1.4(n)/3(p)$
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 $\text{nuexp}=5.25(n)/3.23(p)$
Exponent of the temperature dependence of parameter NU.
- 19 $\text{ther}=0.0812(n)/0.079(p) \text{ 1/V}$
Coefficient of series resistance.
- 20 $\text{etar}=0.95(n)/0.4(p)$
Exponent of the temperature dependence of THER.
- 21 $\text{ther1}=0 \text{ V}$
Numerator of gate voltage dependent part of series resistance.
- 22 $\text{ther2}=1 \text{ V}$
Denominator of gate voltage dependent part of series resistance.
- 23 $\text{thesat}=0.251(n)/0.173(p) \text{ 1/V}$
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 $\text{theth}=1e-05(n)/0(p) \text{ 1/V}^3$
Coefficient of self-heating.
- 26 $\text{sdibl}=0.000853(n)/3.55e-05(p) \text{ 1/}\sqrt{\text{V}}$
Drain-induced barrier lowering parameter.
- 27 $\text{mo}=0$
Parameter for (short-channel) subthreshold slope.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 28 $ssf=0.012(n)/0.01(p) \text{ } 1/\sqrt{V}$
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.
- 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.

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)` $1/(V\text{m}^4)$
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 `cs=0`
Coefficient of Coulomb scattering.
- 58 `etacs=0`
Exponent of the temperature dependence of CS.
- 59 `type=n`
Transistor gender.
Possible values are n, p, npn, pnp, npnv, pnpv, npnl, or pnp1.
- 60 `imax=1.0` A
Explosion current.
- 61 `mbe=0.0`
DCmatch parameter.

Virtuoso Simulator Components and Device Models Reference

Philips Models

62 `mvt=0.0` DCmatch parameter.

63 `tnom (C)` alias of `tnom`.

64 `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.

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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

17	<code>mo</code>	Parameter for (short-channel) subthreshold slope.
18	<code>ssf</code> ($1/\sqrt{V}$)	Static-feedback parameter.
19	<code>alp</code>	Factor of channel length modulation.
20	<code>vp</code> (V)	Characteristic voltage of channel-length modulation.
21	<code>mexp</code>	Smoothing factor.
22	<code>a1</code>	Factor of the weak-avalanche current.
23	<code>a2</code> (V)	Exponent of the weak-avalanche current.
24	<code>a3</code>	Factor of the drain-source voltage above which weak-avalanche occurs.
25	<code>iginv</code> (A/V^2)	Gain factor for intrinsic gate tunnelling current in inversion.
26	<code>binv</code> (V)	Probability factor for intrinsic gate tunnelling current in inversion.
27	<code>igacc</code> (A/V^2)	Gain factor for intrinsic gate tunnelling current in accumulation.
28	<code>bacc</code> (V)	Probability factor for intrinsic gate tunnelling current in accumulation.
29	<code>vfbov</code> (V)	Flat-band voltage for the Source/Drain overlap extensions.
30	<code>kov</code> (\sqrt{V})	Body-effect factor for the Source/Drain overlap extensions.
31	<code>igov</code> (A/V^2)	Gain factor for Source/Drain overlap tunnelling current.
32	<code>agidl</code> (A/V^3)	Gain factor for gate-induced leakage current.
33	<code>bgidl</code> (V)	Probability factor for gate-induced drain leakage current at reference temperature.
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).

Virtuoso Simulator Components and Device Models Reference

Philips Models

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.

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>vtS</code> (V)	Threshold voltage including back-bias effects.
11	<code>vth</code> (V)	Threshold voltage including back-bias and drain-bias effects.
12	<code>vgt</code> (V)	Effective gate drive voltage including back-bias and drain voltage effects.
13	<code>vdss</code> (V)	Drain saturation voltage at actual bias.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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 ($- d q_b / d v_s$).
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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

36	u	Transistor gain (gm/gds).
37	rout (Ω)	Small-signal output resistance (1/gds).
38	vearly (V)	Equivalent Early voltage ($ i_d /g_{ds}$).
39	keff (\sqrt{V})	Body effect parameter.
40	beff (A/V^2)	Gain factor.
41	fug (Hz)	Unity gain frequency at actual bias ($g_m/(2\pi C_{in})$).
42	sqrtsw (V/\sqrt{Hz})	Input-referred RMS white noise voltage density.
43	sqrtfff (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.

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	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

Virtuoso Simulator Components and Device Models Reference

Philips Models

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
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

Virtuoso Simulator Components and Device Models Reference

Philips Models

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 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 d g s b dt 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 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.
- 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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 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.
- 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 $sdibl=0.000853(n)/3.55e-05(p) \text{ 1/}\sqrt{\text{V}}$
Drain-induced barrier lowering parameter.
- 27 $mo=0$
Parameter for (short-channel) subthreshold slope.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 28 $ssf=0.012(n)/0.01(p) \text{ } 1/\sqrt{V}$
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.
- 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.

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 $nfa=8.32e+22(n)/1.9e+22(p)$ $1/(Vm^4)$
First coefficient of the flicker noise.
- 53 $nfb=2.51e+07(n)/5.04e+06(p)$ $1/(Vm^2)$
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 $cs=0$
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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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	tnom (C)	alias of tnom.
67	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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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/√V)	Drain-induced barrier lowering parameter.
17	mo	Parameter for (short-channel) subthreshold slope.
18	ssf (1/√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 (√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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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.

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 ($ i_d /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	$sqrt_{sfw}$ (V/\sqrt{Hz})	Input-referred RMS white noise voltage density.
43	$sqrt_{sff}$ (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.
45	P_{diss} (W)	Dissipation.
46	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-45	cgso	O-37	ko	M-5	stphib	M-8
TK	OP-46	cgsol	OP-35	ko	O-2	stvfb	M-4
a1	M-32	cox	M-47	kov	M-41	theph	M-13
a1	O-22	cox	O-35	kov	O-30	theph	O-7
a2	M-34	cs	M-57	kpinv	M-6	ther	M-19
a2	O-23	cs	O-10	kpinv	O-3	ther	O-11
a3	M-35	csb	OP-29	level	M-1	ther1	M-21
a3	O-24	csd	OP-26	m	I-3	ther1	O-12
agidl	M-43	csg	OP-27	mbe	M-64	ther2	M-22
agidl	O-32	css	OP-28	mexp	M-31	ther2	O-13
alp	M-29	cth	M-60	mexp	O-21	thesat	M-23
alp	O-19	cth	O-45	mo	M-27	thesat	O-14
area	I-4	dta	M-56	mo	O-17	thesr	M-11
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

Virtuoso Simulator Components and Device Models Reference

Philips Models

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
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 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 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. |
| 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. |

Virtuoso Simulator Components and Device Models Reference

Philips Models

4	$t_{ref}=25 \text{ deg. C}$	Reference temperature.
5	$v_{fb}=-1 \text{ V}$	Flatband voltage of the channel region, at reference temperature.
6	$stv_{fb}=0 \text{ V/K}$	Temperature scaling coefficient for VFB.
7	$v_{fbd}=-0.1 \text{ V}$	Flatband voltage of the drift region, at reference temperature.
8	$stv_{fbd}=0 \text{ V/K}$	Temperature scaling coefficient for the flatband voltage of the drift region.
9	$k_{or}=1.6 \text{ V}^{(1/2)}$	Body factor of the channel region of an infinitely wide transistor.
10	$sw_{ko}=0$	Width scaling coefficient for KO.
11	$k_{odr}=1 \text{ V}^{-1/2}$	Body factor of the drift region of an infinitely wide transistor.
12	$sw_{kod}=0$	Width scaling coefficient for the body factor of the drift region.
13	$\phi_{hib}=0.86 \text{ V}$	Surface potential at the onset of strong inversion in the channel region, at reference temperature.
14	$st\phi_{hib}=-0.0012 \text{ V/K}$	Temperature scaling coefficient for PHIB.
15	$\phi_{hibd}=0.78 \text{ V}$	Surface potential at the onset of strong inversion in the drift region, at reference temperature.
16	$st\phi_{hibd}=-0.0012 \text{ V/K}$	Temperature scaling coefficient for PHIBD.
17	$\beta_{etw}=7e-05 \text{ A/V}^2$	Gain factor of a channel region of 1 μm wide, at reference temperature.
18	$e_{tabet}=1.6$	Temperature scaling exponent for BET.
19	$\beta_{etaccw}=7e-05 \text{ A/V}^{-2}$	Gain factor of drift region of 1 μm wide, at reference temperature.
20	$e_{tabetacc}=1.5$	Temperature scaling exponent for BETACC.

Virtuoso Simulator Components and Device Models Reference

Philips Models

21	$rdw=4e+03 \ \Omega$	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.
35	$sdibl=0.001 \text{ V}^{(-1/2)}$	Factor for drain-induced barrier lowering.
36	$msdibl=3$	Exponent for the drain-induced barrier lowering dependence on the backgate bias.
37	$mo=0 \text{ V}$	Parameter for the (short-channel) sub-threshold slope.

Virtuoso Simulator Components and Device Models Reference

Philips Models

38	$ssf=1e-12 \text{ V}^{-1/2}$	Factor for static feedback.
39	$a1r=15$	Factor of weak avalanche current of an infinitely wide transistor, at reference temperature.
40	$sta1=0 \text{ K}^{-1}$	Temperature scaling coefficient for A1.
41	$swa1=0$	Width scaling coefficient for A1.
42	$a2=73 \text{ V}$	Exponent of weak avalanche current.
43	$a3=0.8$	Factor of the drain-source voltage above which weak avalanche occurs.
44	$coxw=7.5e-16 \text{ F}$	Oxide capacitance for an intrinsic channel region of 1um wide.
45	$coxdw=7.5e-16 \text{ F}$	Oxide capacitance for an intrinsic drift region of 1um wide.
46	$cgdow=0 \text{ F}$	Gate-to-drain overlap capacitance for a drift region of 1 um wide.
47	$cgsow=0 \text{ F}$	Gate-to-source overlap capacitance for a channel region of 1 um wide.
48	$nt=1.65e-20 \text{ J}$	Coefficient of thermal noise, at reference temperature.
49	$nfaw=1.4e+25 \text{ V}^{-1} \text{ m}^{-4}$	First coefficient of flicker noise for a channel region of 1 um wide.
50	$nfbw=2e+08 \text{ V}^{-1} \text{ m}^{-2}$	Second coefficient of flicker noise for a channel region of 1 um wide.
51	$nfCW=0 \text{ V}^{-1}$	Third coefficient of flicker noise for a channel region of 1 um 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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

55 $i_{max}=1.0$ A Explosion current.

56 t_{nom} (deg. C) alias of t_{nom} .

57 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_{hib} (V) Surface potential at the onset of strong inversion in the channel region, at reference temperature.

6 ϕ_{hibd} (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_{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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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	$coxd$ (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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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 ($d q_d / d v_d$).
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 ($- d q_d / d v_b$).

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Philips Models

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 ($ id /gds$).
38	b_{eff} (A/V^2)	Gain factor.
39	f_{ug} (Hz)	Unity gain frequency at actual bias ($gm/(2*\pi*cin)$).
40	g_{mos} (A/V)	Transconductance of channel region.
41	$sqrtsfw$ ($V/Hz^{1/2}$)	Input-referred RMS white noise voltage density.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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.

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>csd</code> OP-25	<code>nfbw</code> M-50	<code>the2r</code> M-27
<code>alr</code> M-39	<code>csg</code> OP-26	<code>nfc</code> O-32	<code>the3</code> O-14
<code>a2</code> M-42	<code>css</code> OP-27	<code>nfcw</code> M-51	<code>the3r</code> M-29
<code>a2</code> O-23	<code>dta</code> M-53	<code>nt</code> M-48	<code>tnom</code> M-56
<code>a3</code> M-43	<code>etabet</code> M-18	<code>nt</code> O-29	<code>tox</code> M-52
<code>a3</code> O-24	<code>etabetacc</code> M-20	<code>phib</code> M-13	<code>tox</code> O-33
<code>alp</code> M-33	<code>etard</code> M-22	<code>phib</code> O-5	<code>tr</code> M-57
<code>alp</code> O-16	<code>etathe3</code> M-30	<code>phibd</code> M-15	<code>tref</code> M-4
<code>area</code> I-6	<code>fknee</code> OP-43	<code>phibd</code> O-6	<code>type</code> M-54
<code>beff</code> OP-38	<code>fug</code> OP-39	<code>rd</code> O-9	<code>u</code> OP-35
<code>bet</code> O-7	<code>gds</code> OP-16	<code>rdw</code> M-21	<code>vdiseff</code> OP-11
<code>betacc</code> O-8	<code>gm</code> OP-14	<code>region</code> I-4	<code>vdissat</code> OP-12
<code>betaccw</code> M-19	<code>gmb</code> OP-15	<code>rout</code> OP-36	<code>vds</code> OP-3

Virtuoso Simulator Components and Device Models Reference

Philips Models

betw	M-17	gmms	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	swthe1	M-25	vts	OP-7
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	thelacc	M-26	wdvar	M-3
coxdw	M-45	nfa	O-30	thelacc	O-12	weff	OP-33
coxw	M-44	nfaw	M-49	thelr	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 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 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 mos2001e parameter=value ...
```

Model Parameters

- | | | |
|---|----------------|------------------------|
| 1 | level=2e+03 | Must be 2001. |
| 2 | tref=25 deg. C | Reference temperature. |

Virtuoso Simulator Components and Device Models Reference

Philips Models

3	$v_{fb} = -1 \text{ V}$	Flatband voltage of the channel region, at reference temperature.
4	$stv_{fb} = 0 \text{ V/K}$	Temperature scaling coefficient for VFB.
5	$v_{fbd} = -0.1 \text{ V}$	Flatband voltage of the drift region, at reference temperature.
6	$stv_{fbd} = 0 \text{ V/K}$	Temperature scaling coefficient for the flatband voltage of the drift region.
7	$k_o = 1.6 \text{ V}^{(1/2)}$	Body factor of the channel region.
8	$k_{od} = 1 \text{ V}^{-1/2}$	Body factor of the drift region.
9	$\phi_{ib} = 0.86 \text{ V}$	Surface potential at the onset of strong inversion in the channel region, at reference temperature.
10	$st\phi_{ib} = -0.0012 \text{ V/K}$	Temperature scaling coefficient for PHIB.
11	$\phi_{ibd} = 0.78 \text{ V}$	Surface potential at the onset of strong inversion in the drift region, at reference temperature.
12	$st\phi_{ibd} = -0.0012 \text{ V/K}$	Temperature scaling coefficient for PHIBD.
13	$\beta = 0.0014 \text{ A/V}^2$	Gain factor of the channel region, at reference temperature.
14	$e_{\beta} = 1.6$	Temperature scaling exponent for BET.
15	$\beta_{acc} = 0.0014 \text{ A/V}^{-2}$	Gain factor for accumulation in the drift region, at reference temperature.
16	$e_{\beta_{acc}} = 1.5$	Temperature scaling exponent for BETACC.
17	$r_d = 200 \text{ } \Omega$	On-resistance of the drift region, at reference temperature.
18	$e_{r_d} = 1.5$	Temperature scaling exponent for RD.
19	$\lambda_{md} = 0.2$	Quotient of the depletion layer thickness to the effective thickness of the drift region at $V_{SB} = 0 \text{ V}$.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 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.
- 29 $msdibl=3$ Exponent for the drain-induced barrier lowering dependence on the backgate bias.
- 30 $mo=0 \text{ V}$ Parameter for the (short-channel) sub-threshold slope.
- 31 $ssf=1e-12 \text{ V}^{(-1/2)}$ Factor for static feedback.
- 32 $a1=15$ Factor of weak avalanche current, at reference temperature.
- 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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

37	$\text{cox}d=1.5e-14 \text{ F}$	Oxide capacitance for the intrinsic drift region.
38	$\text{cgdo}=0 \text{ F}$	Gate-to-drain overlap capacitance.
39	$\text{cgso}=0 \text{ F}$	Gate-to-source overlap capacitance.
40	$\text{nt}=1.65e-20 \text{ J}$	Coefficient of thermal noise, at reference temperature.
41	$\text{nfa}=7e+23 \text{ V}^{-1} \text{ m}^{-4}$	First coefficient of flicker noise.
42	$\text{nfb}=1e+07 \text{ V}^{-1} \text{ m}^{-2}$	Second coefficient of flicker noise.
43	$\text{nfc}=0 \text{ V}^{-1}$	Third coefficient of flicker noise.
44	$\text{tox}=3.8e-08 \text{ m}$	Thickness of the oxide above the channel region.
45	$\text{dta}=0 \text{ K}$	Temperature offset to the ambient temperature.
46	$\text{type}=\text{n}$	Transistor gender. Possible values are n, p, npn, pnp, npnv, pnpv, npnl, or pnp1.
47	$\text{imax}=1.0 \text{ A}$	Explosion current.
48	tnom (deg. C)	alias of tnom.
49	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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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 $V_{\text{SB}} = 0$ 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 ($\text{V}^{-1/2}$)	Mobility reduction coefficient for $V_{\text{SB}} > 0$ 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 ($\text{V}^{-1/2}$)	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 ($\text{V}^{-1/2}$)	Factor for static feedback.
22	a1	Factor of weak avalanche current, at reference temperature.
23	a2 (V)	Exponent of weak avalanche current.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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.
6	vto (V)	Zero-bias threshold voltage.
7	vt s (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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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 ($- d\ q_s / d\ v_g$).
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 ($d\ q_b / d\ v_b$).

Virtuoso Simulator Components and Device Models Reference

Philips Models

33	<code>u</code>	Transistor gain (gm/gds).
34	<code>rout</code> (Ω)	Small-signal output resistance (1/gds).
35	<code>vearly</code> (V)	Equivalent Early voltage ($ id /gds$).
36	<code>beff</code> (A/V^2)	Gain factor.
37	<code>fug</code> (Hz)	Unity gain frequency at actual bias ($gm/(2*\pi*cin)$).
38	<code>gmмос</code> (A/V)	Transconductance of channel region.
39	<code>sqrtsw</code> ($V/Hz^{1/2}$)	Input-referred RMS white noise voltage density.
40	<code>sqrtfff</code> ($V/Hz^{1/2}$)	Input-referred RMS white noise voltage density at 1 kHz.
41	<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.

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

Virtuoso Simulator Components and Device Models Reference

Philips Models

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	vdiseff	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
cdg	OP-18	ko	M-7	sdibl	O-18	vfbд	M-5
cds	OP-19	ko	O-3	sqrtsff	OP-40	vfbд	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

Virtuoso Simulator Components and Device Models Reference

Philips Models

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	vtg	OP-7
cox	O-25	mo	O-20	thel	O-11		

Lateral Double-diffused MOS Model (MOS Model Level 2001) (mos2001et)

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 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 mos2001et parameter=value ...
```

Virtuoso Simulator Components and Device Models Reference

Philips Models

Model Parameters

- | | | |
|----|----------------------------------|---|
| 1 | $level=2e+03$ | Must be 2001. |
| 2 | $tref=25 \text{ deg. C}$ | Reference temperature. |
| 3 | $vfb=-1 \text{ V}$ | Flatband voltage of the channel region, at reference temperature. |
| 4 | $stvfb=0 \text{ V/K}$ | Temperature scaling coefficient for VFB. |
| 5 | $vfbd=-0.1 \text{ V}$ | Flatband voltage of the drift region, at reference temperature. |
| 6 | $stvfbd=0 \text{ V/K}$ | Temperature scaling coefficient for the flatband voltage of the drift region. |
| 7 | $ko=1.6 \text{ V}^{(1/2)}$ | Body factor of the channel region. |
| 8 | $kod=1 \text{ V}^{-1/2}$ | Body factor of the drift region. |
| 9 | $phib=0.86 \text{ V}$ | Surface potential at the onset of strong inversion in the channel region, at reference temperature. |
| 10 | $stphib=-0.0012 \text{ V/K}$ | Temperature scaling coefficient for PHIB. |
| 11 | $phibd=0.78 \text{ V}$ | Surface potential at the onset of strong inversion in the drift region, at reference temperature. |
| 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. |

Virtuoso Simulator Components and Device Models Reference

Philips Models

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	$the1=0.09 \text{ V}^{-1}$	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.
29	$msdibl=3$	Exponent for the drain-induced barrier lowering dependence on the backgate bias.
30	$mo=0 \text{ V}$	Parameter for the (short-channel) sub-threshold slope.
31	$ssf=1e-12 \text{ V}^{(-1/2)}$	Factor for static feedback.
32	$a1=15$	Factor of weak avalanche current, at reference temperature.
33	$sta1=0 \text{ K}^{-1}$	Temperature scaling coefficient for A1.
34	$a2=73 \text{ V}$	Exponent of weak avalanche current.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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	$cox=1.5e-14$ 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.
48	$ath=0$	Temperature coefficient of the thermal resistance.
49	$type=n$	Transistor gender. Possible values are n, p, npn, pnp, npnv, pnpv, npnl, or pnp1.
50	$imax=1.0$ A	Explosion current.
51	$tnom$ (deg. C)	alias of $tnom$.
52	tr (deg. C)	alias of $tnom$.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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.
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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

17	v_p (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	m_o (V)	Parameter for the (short-channel) sub-threshold slope.
21	ssf ($V^{-1/2}$)	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	cox (F)	Oxide capacitance for the intrinsic channel region.
26	$coxd$ (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.
34	rth (K/W)	Thermal resistance.
35	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	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.
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 ($d q_d / d v_d$).
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 ($d q_g / d v_g$).

Virtuoso Simulator Components and Device Models Reference

Philips Models

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	u	Transistor gain (gm/gds).
34	rout (Ω)	Small-signal output resistance (1/gds).
35	vearly (V)	Equivalent Early voltage ($ i_d /gds$).
36	beff (A/V^2)	Gain factor.
37	fug (Hz)	Unity gain frequency at actual bias ($gm/(2*\pi*cin)$).
38	gm _{mos} (A/V)	Transconductance of channel region.
39	sqrtsfw ($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.
41	fknee (Hz)	Cross-over frequency above which white noise is dominant.
42	P _{diss} (W)	Dissipation.
43	TK (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.

Pdiss	OP-42	cox	O-25	mo	O-20	the1	O-11
TK	OP-43	coxd	M-37	msdibl	M-29	the1acc	M-21
a1	M-32	coxd	O-26	msdibl	O-19	the1acc	O-12
a1	O-22	csb	OP-28	mult	I-1	the2	M-22
a2	M-34	csd	OP-25	nfa	M-41	the2	O-13
a2	O-23	csg	OP-26	nfa	O-30	the3	M-23
a3	M-35	css	OP-27	nfb	M-42	the3	O-14
a3	O-24	cth	M-47	nfb	O-31	tnom	M-51
alp	M-26	cth	O-35	nfc	M-43	tox	M-44
alp	O-16	dta	M-45	nfc	O-32	tox	O-33
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

Virtuoso Simulator Components and Device Models Reference

Philips Models

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
cgso	M-39	mexp	M-25	stvfb	M-4	vts	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 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 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 ...
```

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. |

Virtuoso Simulator Components and Device Models Reference

Philips Models

4	$t_{ref}=25 \text{ deg. C}$	Reference temperature.
5	$v_{fb}=-1 \text{ V}$	Flatband voltage of the channel region, at reference temperature.
6	$stv_{fb}=0 \text{ V/K}$	Temperature scaling coefficient for VFB.
7	$v_{fbd}=-0.1 \text{ V}$	Flatband voltage of the drift region, at reference temperature.
8	$stv_{fbd}=0 \text{ V/K}$	Temperature scaling coefficient for the flatband voltage of the drift region.
9	$k_{or}=1.6 \text{ V}^{(1/2)}$	Body factor of the channel region of an infinitely wide transistor.
10	$sw_{ko}=0$	Width scaling coefficient for KO.
11	$k_{odr}=1 \text{ V}^{-1/2}$	Body factor of the drift region of an infinitely wide transistor.
12	$sw_{kod}=0$	Width scaling coefficient for the body factor of the drift region.
13	$\phi_{ib}=0.86 \text{ V}$	Surface potential at the onset of strong inversion in the channel region, at reference temperature.
14	$st\phi_{ib}=-0.0012 \text{ V/K}$	Temperature scaling coefficient for PHIB.
15	$\phi_{ibd}=0.78 \text{ V}$	Surface potential at the onset of strong inversion in the drift region, at reference temperature.
16	$st\phi_{ibd}=-0.0012 \text{ V/K}$	Temperature scaling coefficient for PHIBD.
17	$\beta_{etw}=7e-05 \text{ A/V}^2$	Gain factor of a channel region of 1 μm wide, at reference temperature.
18	$e_{tabet}=1.6$	Temperature scaling exponent for BET.
19	$\beta_{etaccw}=7e-05 \text{ A/V}^{-2}$	Gain factor of drift region of 1 μm wide, at reference temperature.
20	$e_{tabetacc}=1.5$	Temperature scaling exponent for BETACC.

Virtuoso Simulator Components and Device Models Reference

Philips Models

21	$rdw=4e+03 \ \Omega$	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.
35	$sdibl=0.001 \text{ V}^{(-1/2)}$	Factor for drain-induced barrier lowering.
36	$msdibl=3$	Exponent for the drain-induced barrier lowering dependence on the backgate bias.
37	$mo=0 \text{ V}$	Parameter for the (short-channel) sub-threshold slope.

Virtuoso Simulator Components and Device Models Reference

Philips Models

38	$ssf=1e-12 \text{ V}^{-1/2}$	Factor for static feedback.
39	$a1r=15$	Factor of weak avalanche current of an infinitely wide transistor, at reference temperature.
40	$sta1=0 \text{ K}^{-1}$	Temperature scaling coefficient for A1.
41	$swa1=0$	Width scaling coefficient for A1.
42	$a2=73 \text{ V}$	Exponent of weak avalanche current.
43	$a3=0.8$	Factor of the drain-source voltage above which weak avalanche occurs.
44	$coxw=7.5e-16 \text{ F}$	Oxide capacitance for an intrinsic channel region of 1um wide.
45	$coxdw=7.5e-16 \text{ F}$	Oxide capacitance for an intrinsic drift region of 1um wide.
46	$cgdow=0 \text{ F}$	Gate-to-drain overlap capacitance for a drift region of 1 um wide.
47	$cgsow=0 \text{ F}$	Gate-to-source overlap capacitance for a channel region of 1 um wide.
48	$nt=1.65e-20 \text{ J}$	Coefficient of thermal noise, at reference temperature.
49	$nfaw=1.4e+25 \text{ V}^{-1} \text{ m}^{-4}$	First coefficient of flicker noise for a channel region of 1 um wide.
50	$nfbw=2e+08 \text{ V}^{-1} \text{ m}^{-2}$	Second coefficient of flicker noise for a channel region of 1 um wide.
51	$nfCW=0 \text{ V}^{-1}$	Third coefficient of flicker noise for a channel region of 1 um 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	$rth=300 \text{ K/W}$	Thermal resistance.
55	$cth=3e-09 \text{ J/K}$	Thermal capacitance.

Virtuoso Simulator Components and Device Models Reference

Philips Models

56	<code>ath=0</code>	Temperature coefficient of the thermal resistance.
57	<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> .
58	<code>imax=1.0 A</code>	Explosion current.
59	<code>tnom (deg. C)</code>	alias of <code>tnom</code> .
60	<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	coxdr (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 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 ($ i_d /g_{ds}$).
38	b_{eff} (A/V ²)	Gain factor.
39	f_{ug} (Hz)	Unity gain frequency at actual bias ($g_m/(2*\pi*c_{in})$).

Virtuoso Simulator Components and Device Models Reference

Philips Models

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
<code>a2</code>	M-42	<code>cth</code>	M-55	<code>nt</code>	M-48	<code>tnom</code>	M-59
<code>a2</code>	O-23	<code>cth</code>	O-35	<code>nt</code>	O-29	<code>tox</code>	M-52
<code>a3</code>	M-43	<code>dta</code>	M-53	<code>phib</code>	M-13	<code>tox</code>	O-33
<code>a3</code>	O-24	<code>etabet</code>	M-18	<code>phib</code>	O-5	<code>tr</code>	M-60
<code>alp</code>	M-33	<code>etabetacc</code>	M-20	<code>phibd</code>	M-15	<code>tref</code>	M-4

Virtuoso Simulator Components and Device Models Reference

Philips Models

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	gmmos	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
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

Virtuoso Simulator Components and Device Models Reference

Philips Models

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 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 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 mos2002 parameter=value ...
```

Model Parameters

1 `level=2e+03` Must be 2002.

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 $V_{\text{SB}} = 0 \text{ V}$.
- 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 $V_{\text{SB}} > 0$ 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>the3dr=0 V⁻¹</code>	Mobility reduction coefficient in a channel region of an infinitely wide transistor due to velocity saturation.
34	<code>etathe3d=1</code>	Temperature scaling exponent for THE3D.
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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

49	<code>sta1dr=0</code> K^{-1}	Temperature scaling coefficient for A1DR.
50	<code>swa1dr=0</code>	Width scaling coefficient for A1DR.
51	<code>a2dr=73</code> V	Exponent of drift weak avalanche current.
52	<code>a3dr=0.8</code>	Factor of the drain-source voltage above which drift weak avalanche occurs.
53	<code>coxw=7.5e-16</code> F	Oxide capacitance for an intrinsic channel region of 1um wide.
54	<code>coxdw=7.5e-16</code> F	Oxide capacitance for an intrinsic drift region of 1um wide.
55	<code>cgdow=0</code> F	Gate-to-drain overlap capacitance for a drift region of 1 um wide.
56	<code>cgsow=0</code> F	Gate-to-source overlap capacitance for a channel region of 1 um wide.
57	<code>nt=1.65e-20</code> J	Coefficient of thermal noise, at reference temperature.
58	<code>nfaw=1.4e+25</code> $\text{V}^{-1} \text{m}^{-4}$	First coefficient of flicker noise for a channel region of 1 um wide.
59	<code>nfbw=2e+08</code> $\text{V}^{-1} \text{m}^{-2}$	Second coefficient of flicker noise for a channel region of 1 um wide.
60	<code>nfaw=0</code> V^{-1}	Third coefficient of flicker noise for a channel region of 1 um wide.
61	<code>tox=3.8e-08</code> m	Thickness of the oxide above the channel region.
62	<code>dtta=0</code> K	Temperature offset to the ambient temperature.
63	<code>type=n</code>	Transistor gender. Possible values are n, p, npn, pnp, npnv, pnpv, npnl, or pnp1.
64	<code>imax=1.0</code> A	Explosion current.
65	<code>tnom</code> (deg. C)	alias of tnom.
66	<code>tr</code> (deg. C)	alias of tnom.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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.
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	θ_{e3d} (V^{-1})	Mobility reduction coefficient in the drift region due to the horizontal electrical field caused by velocity saturation.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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.
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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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.
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)	Saturation voltage of channel region at actual bias.
13	$vddisat$ (V)	Saturation voltage of drift region at actual bias.
14	gm (A/V)	Transconductance ($d\,ids / d\,vgs$).
15	gmb (A/V)	Substrate-transconductance ($d\,ids / d\,vbs$).
16	gds (A/V)	Output conductance ($d\,ids / d\,vds$).

Virtuoso Simulator Components and Device Models Reference

Philips Models

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.
35	u	Transistor gain (gm/gds).
36	r_{out} (Ω)	Small-signal output resistance (1/gds).
37	v_{early} (V)	Equivalent Early voltage ($ i_d /gds$).
38	β_{eff} (A/V ²)	Gain factor.

Virtuoso Simulator Components and Device Models Reference

Philips Models

39	fug (Hz)	Unity gain frequency at actual bias ($gm/(2\pi\cdot cin)$).
40	gm _{mos} (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.

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
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

Virtuoso Simulator Components and Device Models Reference

Philips Models

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	gmmos	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
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

Virtuoso Simulator Components and Device Models Reference

Philips Models

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	thelacc	M-26	wvar	M-2
coxd	O-32	mult	I-3	thelacc	O-12		
coxdw	M-54	nfa	O-36	the1r	M-24		

Lateral Double-diffused MOS Model (MOS Model Level 2002) (mos2002e)

This is SiMKit 3.0.

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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

4 `area=1` alias of mult.

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. |
| 12 | <code>stphibd=-0.0012 V/K</code> | Temperature scaling coefficient for PHIBD. |
| 13 | <code>bet=0.0014 A/V²</code> | Gain factor of the channel region, at reference temperature. |
| 14 | <code>etabet=1.6</code> | Temperature scaling exponent for BET. |

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 15 $\text{betacc}=0.0014 \text{ A/V}^{-2}$ Gain factor for accumulation in the drift region, at reference temperature.
- 16 $\text{etabetacc}=1.5$ Temperature scaling exponent for BETACC.
- 17 $\text{rd}=200 \text{ } \Omega$ On-resistance of the drift region, at reference temperature.
- 18 $\text{etard}=1.5$ Temperature scaling exponent for RD.
- 19 $\text{lamd}=0.2$ Quotient of the depletion layer thickness to the effective thickness of the drift region at $V_{SB} = 0 \text{ V}$.
- 20 $\text{the1}=0.09 \text{ V}^{-1}$ Mobility reduction coefficient in the channel region due to vertical electrical field caused by strong inversion.
- 21 $\text{the1acc}=0.02 \text{ V}^{-1}$ Mobility reduction coefficient in the drift region due to the vertical electrical field caused by accumulation.
- 22 $\text{the2}=0.03 \text{ V}^{(-1/2)}$ Mobility reduction coefficient for $V_{SB} > 0$ in the channel region due to the vertical electrical field caused by depletion.
- 23 $\text{the3}=0.4 \text{ V}^{-1}$ Mobility reduction coefficient in the channel region due to the horizontal electrical field caused by velocity saturation.
- 24 $\text{etathe3}=1$ Temperature scaling exponent for THE3.
- 25 $\text{mexp}=2$ Smoothing factor for transition from linear to saturation regime.
- 26 $\text{the3d}=0 \text{ V}^{-1}$ Mobility reduction coefficient in the drift region due to the horizontal electrical field caused by velocity saturation.
- 27 $\text{etathe3d}=1$ Temperature scaling exponent for THE3D.
- 28 $\text{mexpd}=2$ Smoothing factor for transition from linear to quasi-saturation regime.
- 29 $\text{alp}=0.002$ Factor for channel length modulation.
- 30 $\text{vp}=0.05 \text{ V}$ Characteristic voltage of channel length modulation.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 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.
- 44 $coxd=1.5e-14 \text{ F}$ Oxide capacitance for the intrinsic drift region.
- 45 $cgdo=0 \text{ F}$ Gate-to-drain overlap capacitance.
- 46 $cgso=0 \text{ F}$ Gate-to-source overlap capacitance.
- 47 $nt=1.65e-20 \text{ J}$ Coefficient of thermal noise, at reference temperature.
- 48 $nfa=7e+23 \text{ V}^{-1} \text{ m}^{-4}$ First coefficient of flicker noise.

Virtuoso Simulator Components and Device Models Reference

Philips Models

49	$nfb=1e+07 \text{ V}^{-1} \text{ m}^{-2}$	Second coefficient of flicker noise.
50	$nfc=0 \text{ V}^{-1}$	Third coefficient of flicker noise.
51	$tox=3.8e-08 \text{ m}$	Thickness of the oxide above the channel region.
52	$dta=0 \text{ K}$	Temperature offset to the ambient temperature.
53	$type=n$	Transistor gender. Possible values are n, p, npn, pnp, npnv, pnpv, npnl, or pnp1.
54	$imax=1.0 \text{ A}$	Explosion current.
55	$tnom \text{ (deg. C)}$	alias of tnom.
56	$tr \text{ (deg. C)}$	alias of tnom.

Output Parameters

1	$vfb \text{ (V)}$	Flatband voltage of the channel region, at reference temperature.
2	$vibd \text{ (V)}$	Flatband voltage of the drift region.
3	$ko \text{ (V}^{1/2}\text{)}$	Body factor of the channel region.
4	$kod \text{ (V}^{1/2}\text{)}$	Body factor of the drift region.
5	$phib \text{ (V)}$	Surface potential at the onset of strong inversion in the channel region, at reference temperature.
6	$phibd \text{ (V)}$	Surface potential at the onset of strong inversion in the drift region, at reference temperature.
7	$bet \text{ (A/V}^2\text{)}$	Gain factor of the channel region, at reference temperature.
8	$betacc \text{ (A/V}^2\text{)}$	Gain factor for accumulation in the drift region, at reference temperature.
9	$rd \text{ (}\Omega\text{)}$	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	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.
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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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 _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.
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.
5	vsb (V)	Source-bulk voltage.
6	vto (V)	Zero-bias threshold voltage.
7	vts (V)	Threshold voltage including back-bias effects.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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 ($- d\ q_s / d\ v_d$).
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 ($- d\ q_s / d\ v_b$).

Virtuoso Simulator Components and Device Models Reference

Philips Models

29	cbd (F)	Capacitance (- d qb / d vd).
30	cbg (F)	Capacitance (- d qb / d vg).
31	cbs (F)	Capacitance (- d qb / d vs).
32	cbb (F)	Capacitance (d qb / d vb).
33	u	Transistor gain (gm/gds).
34	rout (Ω)	Small-signal output resistance (1/gds).
35	vearly (V)	Equivalent Early voltage ($ id /gds$).
36	beff (A/V^2)	Gain factor.
37	fug (Hz)	Unity gain frequency at actual bias ($gm/(2*\pi*cin)$).
38	gmmos (A/V)	Transconductance of channel region.
39	sqrtsw (V/Hz ^{1/2})	Input-referred RMS white noise voltage density.
40	sqrtfff (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.

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.

alch M-35	cgso O-34	mexpd M-28	the1 M-20
alch O-25	cox M-43	mexpd O-18	the1 O-11

Virtuoso Simulator Components and Device Models Reference

Philips Models

a1dr	M-39	cox	O-31	mo	M-33	thelacc	M-21
a1dr	O-28	coxd	M-44	mo	O-23	thelacc	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
cbb	OP-32	gmb	OP-15	rd	O-9	vds	OP-3
cbd	OP-29	gmmos	OP-38	region	I-2	vearly	OP-35
cbg	OP-30	iavl	OP-2	rout	OP-34	vfb	M-3

Virtuoso Simulator Components and Device Models Reference

Philips Models

cbs	OP-31	ids	OP-1	sdibl	M-31	vfb	O-1
cdb	OP-20	imax	M-54	sdibl	O-21	vfbd	M-5
cdd	OP-17	ko	M-7	sqrtsff	OP-40	vfbd	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	lamd	M-19	stalch	M-36	vp	O-20
cgdo	M-45	lamd	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	stvfbd	M-6	vts	OP-7

Lateral Double-diffused MOS Model (MOS Model Level 2002) (mos2002et)

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 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 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. |
| 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	$coxd=1.5e-14 \text{ F}$	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	$rth=300$ K/W	Thermal resistance.
54	$cth=3e-09$ J/K	Thermal capacitance.
55	$ath=0$	Temperature coefficient of the thermal resistance.
56	$type=n$	Transistor gender. Possible values are n, p, npn, pnp, npnv, pnpv, npnl, or pnp1.
57	$imax=1.0$ 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	$vibd$ (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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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.
21	sdibl (V ^{-1/2})	Factor for drain-induced barrier lowering.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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	coxdr (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	cth (J/K)	Thermal capacitance.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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 ($- d q_d / d v_s$).
20	c_{db} (F)	Capacitance ($- d q_d / d v_b$).

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Philips Models

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	u	Transistor gain (gm/gds).
34	r_{out} (Ω)	Small-signal output resistance ($1/gds$).
35	v_{early} (V)	Equivalent Early voltage ($ id /gds$).
36	b_{eff} (A/V^2)	Gain factor.
37	f_{ug} (Hz)	Unity gain frequency at actual bias ($gm/(2*\pi*cin)$).
38	g_{mmos} (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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

- 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	$coxd$	M-44	mo	O-23	$the1acc$	O-12
$a1dr$	O-28	$coxd$	O-32	$msdibl$	M-32	$the2$	M-22
$a2ch$	M-37	csb	OP-28	$msdibl$	O-22	$the2$	O-13
$a2ch$	O-26	csd	OP-25	$mult$	I-1	$the3$	M-23
$a2dr$	M-41	csg	OP-26	nfa	M-48	$the3$	O-14
$a2dr$	O-29	css	OP-27	nfa	O-36	$the3d$	M-26
$a3ch$	M-38	cth	M-54	nfb	M-49	$the3d$	O-16
$a3ch$	O-27	cth	O-41	nfb	O-37	$tnom$	M-58
$a3dr$	M-42	dta	M-52	nfc	M-50	tox	M-51
$a3dr$	O-30	$etabet$	M-14	nfc	O-38	tox	O-39

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Philips Models

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
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 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 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	$level=2e+03$	Must be 2002.
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.
15	$phibd=0.78$ V	Surface potential at the onset of strong inversion in the drift region, at reference temperature.
16	$stphibd=-0.0012$ V/K	Temperature scaling coefficient for PHIBD.
17	$betw=7e-05$ A/V ²	Gain factor of a channel region of 1 μ m wide, at reference temperature.

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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	$rdw=4e+03 \ \Omega$	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>a1dr=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.

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Philips Models

53	$\text{coxw}=7.5\text{e-}16 \text{ F}$	Oxide capacitance for an intrinsic channel region of 1um wide.
54	$\text{coxdw}=7.5\text{e-}16 \text{ F}$	Oxide capacitance for an intrinsic drift region of 1um wide.
55	$\text{cgdow}=0 \text{ F}$	Gate-to-drain overlap capacitance for a drift region of 1 um wide.
56	$\text{cgsow}=0 \text{ F}$	Gate-to-source overlap capacitance for a channel region of 1 um wide.
57	$\text{nt}=1.65\text{e-}20 \text{ J}$	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	$\text{nfcw}=0 \text{ V}^{-1}$	Third coefficient of flicker noise for a channel region of 1 um wide.
61	$\text{tox}=3.8\text{e-}08 \text{ m}$	Thickness of the oxide above the channel region.
62	$\text{dta}=0 \text{ K}$	Temperature offset to the ambient temperature.
63	$\text{rth}=300 \text{ K/W}$	Thermal resistance.
64	$\text{cth}=3\text{e-}09 \text{ J/K}$	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	$\text{imax}=1.0 \text{ A}$	Explosion current.
68	tnom (deg. C)	alias of tnom.
69	tr (deg. C)	alias of tnom.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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.
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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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.
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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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	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	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)	Saturation voltage of channel region at actual bias.
13	$vddisat$ (V)	Saturation voltage of drift region at actual bias.
14	gm (A/V)	Transconductance ($d\,ids / d\,vgs$).

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Philips Models

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_{deff} (m)	Effective drift region width for geometrical model.
35	u	Transistor gain (g_m/g_{ds}).
36	r_{out} (Ω)	Small-signal output resistance ($1/g_{ds}$).

Virtuoso Simulator Components and Device Models Reference

Philips Models

37	vearly (V)	Equivalent Early voltage ($ i_d /g_{ds}$).
38	beff (A/V ²)	Gain factor.
39	fug (Hz)	Unity gain frequency at actual bias ($g_m/(2\pi\cdot c_{in})$).
40	gm _{mos} (A/V)	Transconductance of channel region.
41	sqrt _{tsfw} (V/Hz ^{1/2})	Input-referred RMS white noise voltage density.
42	sqrt _{tsff} (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	P _{diss} (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.

P _{diss}	OP-44	cox _{dw}	M-54	nfa	O-36	the _{1r}	M-24
TK	OP-45	cox _w	M-53	nfaw	M-58	the ₂	O-13
a _{lch}	O-25	cs _b	OP-28	nfb	O-37	the _{2r}	M-27
a _{lchr}	M-43	cs _d	OP-25	nfbw	M-59	the ₃	O-14
a _{ldr}	O-28	cs _g	OP-26	nfc	O-38	the _{3d}	O-16
a _{ldrr}	M-48	cs _s	OP-27	nfcw	M-60	the _{3dr}	M-33

Virtuoso Simulator Components and Device Models Reference

Philips Models

a2ch	M-46	cth	M-64	nt	M-57	the3r	M-29
a2ch	O-26	cth	O-41	nt	O-35	tnom	M-68
a2dr	M-51	dta	M-62	phib	M-13	tox	M-61
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	gmмос	OP-40	sqrtsff	OP-42	vfb	O-1
betaccw	M-19	iavl	OP-2	sqrtsfw	OP-41	vfbд	M-7
betw	M-17	ids	OP-1	ssf	M-42	vfbд	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

Virtuoso Simulator Components and Device Models Reference

Philips Models

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
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 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 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 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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

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>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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

9	v_{subt} (V)	Substrate diffusion voltage.
10	c_{gate} (F)	Gate capacitance at zero bias.
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 ($di_{\text{ds}}/dV_{\text{g}}$).
7	g_{mb} (A/V)	Bulk transconductance ($di_{\text{ds}}/dV_{\text{b}}$).
8	g_{ds} (A/V)	Output conductance ($di_{\text{ds}}/dV_{\text{d}}$).
9	q_{g} (C)	Gate charge.
10	c_{gd} (F)	Gate charge dependence on drain voltage ($-dQ_{\text{g}}/dV_{\text{d}}$).
11	c_{gg} (F)	Gate charge dependence on gate voltage ($dQ_{\text{g}}/dV_{\text{g}}$).
12	c_{gs} (F)	Gate charge dependence on source voltage ($-dQ_{\text{g}}/dV_{\text{s}}$).
13	c_{gb} (F)	Gate charge dependence on bulk voltage ($-dQ_{\text{g}}/dV_{\text{b}}$).
14	q_{b} (C)	Bulk charge.
15	c_{bd} (F)	Bulk charge dependence on drain voltage ($-dQ_{\text{b}}/dV_{\text{d}}$).
16	c_{bg} (F)	Bulk charge dependence on gate voltage ($-dQ_{\text{b}}/dV_{\text{g}}$).
17	c_{bs} (F)	Bulk charge dependence on source voltage ($-dQ_{\text{b}}/dV_{\text{s}}$).

Virtuoso Simulator Components and Device Models Reference

Philips Models

18	c_{bb} (F)	Bulk charge dependence on bulk voltage (dQ_b/dV_b).
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.
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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

ach	M-15	cgs	OP-12	level	M-1	tox	O-6
achmod	M-16	csb	OP-28	m	I-3	tr	M-25
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	qb	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 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 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. |

Virtuoso Simulator Components and Device Models Reference

Philips Models

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.
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.

Virtuoso Simulator Components and Device Models Reference

Philips Models

28 `tr` (deg. C) alias of `tnom`.

Output Parameters

1 `ront` (Ω) Ohmic resistance at zero bias.

2 `rsatt` (Ω) Space charge resistance at zero bias.

3 `vsatt` (V) Critical drain-source voltage for hot carriers.

4 `psat` Velocity saturation coefficient.

5 `vp` (V) Pinch off voltage at zero gate and substrate voltages.

6 `tox` (m) Gate oxide thickness.

7 `dch` (m^{-3}) Doping level channel.

8 `dsub` (m^{-3}) Doping level substrate.

9 `vsubt` (V) Substrate diffusion voltage.

10 `cgate` (F) Gate capacitance at zero bias.

11 `csubt` (F) Substrate capacitance at zero bias.

12 `tausc` (s) Space charge transit time of the channel.

13 `rth` (K/W) Thermal resistance.

14 `cth` (J/K) Thermal capacitance.

Operating-Point Parameters

1 `ids` (A) Drain source current (including velocity saturation).

2 `vds` (V) Drain source voltage.

3 `vgs` (V) Gate source voltage.

4 `vbs` (V) Bulk source voltage.

Virtuoso Simulator Components and Device Models Reference

Philips Models

5	v_p (V)	Channel pinch off voltage.
6	g_m (A/V)	Transconductance (dl_{ds}/dV_g).
7	g_{mb} (A/V)	Bulk transconductance (dl_{ds}/dV_b).
8	g_{ds} (A/V)	Output conductance (dl_{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.
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 ($-dQ_s/dV_g$).

Virtuoso Simulator Components and Device Models Reference

Philips Models

27	<code>css</code> (F)	Source charge dependence on source voltage (dQ_s/dV_s).
28	<code>csb</code> (F)	Source charge dependence on bulk voltage ($-dQ_s/dV_b$).
29	<code>u</code>	Transistor gain (g_m/g_{ds}).
30	<code>rout</code> (Ω)	Small signal output resistance ($1/g_{ds}$).
31	<code>vearly</code> (V)	Equivalent early voltage ($ I_{ds} /g_{ds}$).
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>cgg</code> OP-11	<code>iohm</code> OP-32	<code>tox</code> M-7
<code>TK</code> OP-35	<code>cgs</code> OP-12	<code>level</code> M-1	<code>tox</code> O-6
<code>ach</code> M-15	<code>csb</code> OP-28	<code>m</code> I-3	<code>tr</code> M-28
<code>achmod</code> M-16	<code>csd</code> OP-25	<code>mult</code> I-1	<code>tref</code> M-20
<code>achron</code> M-17	<code>csg</code> OP-26	<code>psat</code> M-5	<code>type</code> M-25
<code>achrsat</code> M-19	<code>css</code> OP-27	<code>psat</code> O-4	<code>u</code> OP-29
<code>achvsat</code> M-18	<code>csub</code> M-13	<code>q_b</code> OP-14	<code>v_{bs}</code> OP-4

Virtuoso Simulator Components and Device Models Reference

Philips Models

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
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		

Virtuoso Simulator Components and Device Models Reference

Philips Models

Common MOSFET Equations

This chapter discusses the following topics:

- [Parameters Common to BSIM1 and BSIM2 Models](#) on page 922
- [Drain and Source Parasitic Resistance](#) on page 927
- [Parameters Common to Levels 1-3 Only](#) on page 922
- [Source/Drain Bulk Junction Models](#) on page 924
- [Temperature Effect on Model Parameters](#) on page 930
- [Noise Model](#) on page 936

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.

Note: 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

$$W_{scaled} = w \times scale + xw \times scalem$$

$$W_{eff} = \begin{cases} w \times scale + xw \times scalem - 2wd \times scalem & \text{Level 1-3} \\ w \times scale + xw \times scalem - dw \times scalem & \text{BSIM 1-2} \end{cases}$$

$$L_{eff} = \begin{cases} l \times scale + xl \times scalem - 2ld \times scalem & \text{Level 1-3} \\ l \times scale + xl \times scalem - ld \times scalem & \text{BSIM 1-2} \end{cases}$$

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

$$vto = V_{FB} + phi + gamma \sqrt{phi}$$

where

$$V_{FB} = \phi_{MS} - \frac{q(nss)}{C_{ox}}$$

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} .

$$\phi_{MS} = \begin{cases} -0.5(E_g + phi) & \text{if } tpg = 1 \\ 0.5(E_g - phi) & \text{if } tpg = -1 \\ -0.05 - 0.5(E_g + phi) & \text{if } tpg = 0 \end{cases}$$

Virtuoso Simulator Components and Device Models Reference

Common MOSFET Equations

E_g is the energy gap whose equation is given later.

- If vto is specified, V_{FB} is calculated from

$$V_{FB} = vto - phi - gamma\sqrt{phi}$$

- If you do not give phi and $nsub$ is specified, phi is calculated from

$$phi = 2V_t \ln\left[\frac{nsub}{n_i}\right]$$

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

$$gamma = \frac{\sqrt{2q\epsilon_{si}nsub}}{C_{ox}}$$

- 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.
 - If you do not give kp and uo is specified, kp is calculated from $kp = uo * C_{ox}$.
 - If neither kp nor uo is given, their default values are used.

In SPICE, if you give kp but not uo , uo is not calculated from kp . The default value of uo (600) is used. If you specify both kp and uo , SPICE does not check the consistency between them. In the Spectre circuit simulator, kp and uo 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 uo 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 uo , but Spectre calculates uo 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`, `cdsspice`, or `spiceplus`) in the `.options` card, and the Spectre simulator does not force uo to be consistent with kp . In SPICE, V_{DSAT} is a function of ($uo/vmax$) rather than uo alone. Therefore, you can still make uo 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 $u0$ 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

$$I_{BS(BD)} = \begin{cases} is \left(e^{\frac{V_{BS(BD)}}{V_t}} - 1 \right) & \text{if } V_{BS(BD)} \leq V_{Expl} \\ I_{offset} + G_{Expl} V_{BS(BD)} & \text{otherwise} \end{cases}$$

where

$$V_{Expl} = V_t \ln \left[1 + \frac{imax}{is} \right]$$

is the forward explosion voltage,

$$G_{Expl} = V_t(imax + is)$$

is the conductance at V_{Expl} , and

$$I_{offset} = imax - V_{Expl} G_{Expl}$$

is the linear extrapolated current at $V_{BS(BD)} = 0$ from V_{Expl} .

Bulk-Junction Bottom (Sidewall) Capacitance

$$C_{BS(BD)} = \begin{cases} \frac{cbs(cbd)}{\left(1 - \frac{V_{BS(BD)}}{pb}\right)^{mj}} & \text{if } V_{BS(BD)} \leq fc \times pb \\ \frac{cbs(cbd)}{(1-fc)^{mj}} \left[1 + \frac{mj(V_{BS(BD)} - pb*fc)}{pb(1-fc)} \right] & \text{otherwise} \end{cases}$$

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:

$$\text{Drain area} = \begin{cases} ad & \text{if } ad \text{ is given} \\ 2hdif*scalem*W_{scaled} & \text{if } hdif \text{ is given} \\ W_{eff}*ld & \text{if } ld \text{ is given} \\ W_{eff}*ldd & \text{if } ldd \text{ is given} \\ 0 & \text{otherwise} \end{cases}$$

$$\text{Source area} = \begin{cases} as & \text{if } as \text{ is given} \\ 2hdif*scalem*W_{scaled} & \text{if } hdif \text{ is given} \\ W_{eff}*ls & \text{if } ls \text{ is given} \\ W_{eff}*lds & \text{if } lds \text{ is given} \\ 0 & \text{otherwise} \end{cases}$$

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 Perimeters

The drain and source perimeters are calculated in the order shown in the following equations:

$$\text{Drain perimeter} = \begin{cases} p_d & \text{if } p_d \text{ is given} \\ 4hdif * scalem + 2W_{scaled} & \text{if } hdif \text{ is given} \\ W_{eff} + 2ld & \text{if } ld \text{ is given} \\ W_{eff} + 2l_{dd} & \text{if } l_{dd} \text{ is given} \\ 0 & \text{otherwise} \end{cases}$$

$$\text{Source perimeter} = \begin{cases} p_s & \text{if } p_s \text{ is given} \\ 4hdif * scalem + 2W_{scaled} & \text{if } hdif \text{ is given} \\ W_{eff} + 2ls & \text{if } ls \text{ is given} \\ W_{eff} + 2lds & \text{if } lds \text{ is given} \\ 0 & \text{otherwise} \end{cases}$$

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 Squares

The number of drain and source squares is calculated in the order shown in the following equations:

$$\text{Number of drain squares} = \begin{cases} nrd & \text{if } nrd \text{ is given} \\ hdif / W_{scaled} & \text{if } hdif \text{ is given} \\ lgcd / W_{eff} & \text{if } lgcd \text{ is given} \\ 0 & \text{otherwise} \end{cases}$$

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$$\text{Number of source squares} = \begin{cases} nrs & \text{if } nrs \text{ is given} \\ hdif/W_{scaled} & \text{if } hdif \text{ is given} \\ lgcs/W_{eff} & \text{if } lgcs \text{ is given} \\ 0 & \text{otherwise} \end{cases}$$

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.

$$\text{Drain saturation current} = \begin{cases} i_s & \text{if } i_s \text{ is given} \\ j_s * ad & \text{otherwise} \end{cases}$$

$$\text{Source saturation current} = \begin{cases} i_s & \text{if } i_s \text{ is given} \\ j_s * as & \text{otherwise} \end{cases}$$

Junction Capacitance

cbs (cbd) always overrides cj . If you do not give cbs (cbd) and cj is specified, cbs (cbd) is calculated from cj and the source (drain) area.

$$\text{Drain capacitance} = \begin{cases} cbd & \text{if } cbd \text{ is specified} \\ cj * ad & \text{otherwise} \end{cases}$$

$$\text{Source capacitance} = \begin{cases} cbs & \text{if } cbs \text{ is specified} \\ cj * as & \text{otherwise} \end{cases}$$

Drain and Source Parasitic Resistance

For MSOFET models except EKV,

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Common MOSFET Equations

$$\text{Drain Resistance} = \begin{cases} nrd*rsh + \frac{rdc}{N_{SC}} + \frac{rd(ld + ldif)scalem}{W_{scaled}} & \text{if } ldif \text{ is given} \\ nrd*rsh + \frac{rdc}{N_{SC}} + rd + \frac{rdd}{W_{eff}} & \text{otherwise} \end{cases}$$

$$\text{Source Resistance} = \begin{cases} nrs*rsh + \frac{rsc}{N_{SC}} + \frac{rs(ld + ldif)scalem}{W_{scaled}} & \text{if } ldif \text{ is given} \\ nrs*rsh + \frac{rsc}{N_{SC}} + rs + \frac{rss}{W_{eff}} & \text{otherwise} \end{cases}$$

$$N_{SC} = \begin{cases} 1 & \text{if } sc \text{ is infinity or negative (default)} \\ W_{eff} & \text{if } sc = 0 \\ \text{MAX}\left[\text{INT}\left(\frac{W_{eff}}{sc}\right), 1\right] & \text{otherwise} \end{cases}$$

For EKV,

$$\text{Drain Resistance} = \begin{cases} nrd*rsh + \frac{rdc}{W_{eff}} + \frac{rd(ld + ldif)scalem}{W_{scaled}} & \text{if } ldif \text{ is given} \\ nrd*rsh + \frac{rdc}{W_{eff}} + rd + \frac{rdd}{Width} & \text{otherwise} \end{cases}$$

$$\text{Source Resistance} = \begin{cases} nrs*rsh + \frac{rsc}{W_{eff}} + \frac{rs(ld + ldif)scalem}{W_{scaled}} & \text{if } ldif \text{ is given} \\ nrs*rsh + \frac{rsc}{W_{eff}} + rs + \frac{rdd}{Width} & \text{otherwise} \end{cases}$$

The diffusion resistance depends on the value you specify for the `maxrsd` parameter.

- If the parasitic resistance is more than the `maxrsd` value, the diffusion resistance is calculated as described above.

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Common MOSFET Equations

- If the parasitic resistance is less than the `maxrsd` value, the resistor is removed and the correction is added to the current as compensation. The correction is calculated as follows:

$$I'_{ds} = \frac{I_{ds}}{(1 + r_{ddiff} \cdot g_{ds} + r_{sdiff} \cdot (g_{ds} + g_m + g_{mbs}))}$$

where

$$g_{ds} = \frac{dI_{ds}}{dV_{ds}}$$

$$g_m = \frac{dI_{ds}}{dV_{gs}}$$

$$g_{mbs} = \frac{dI_{ds}}{dV_{bs}}$$

For more information on the `maxrsd` parameter, see `spectre -h bsim4`.

Overlap Capacitance

$$C_{gd} = \begin{cases} cgdo/scalem * W_{eff} & \text{if } cgdo \text{ is given} \\ W_{scaled}(ld + meto)scalem * C_{ox} & \text{if } meto \text{ is given} \end{cases}$$

$$C_{gs} = \begin{cases} cgso/scalem * W_{eff} & \text{if } cgso \text{ is given} \\ W_{scaled}(ld + meto)scalem * C_{ox} & \text{if } meto \text{ is given} \end{cases}$$

$$C_{gb} = \begin{cases} cgbo/scalem * L_{eff} & \text{if } cgbo \text{ is given} \\ 2L_{eff}(ld + meto)scalem * C_{ox} & \text{if } meto \text{ is given} \end{cases}$$

where

$$C_{ox} = \frac{\epsilon_{ox}}{tox * scalem}$$

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

$$T = trise + T_{ambient}$$

where $T_{ambient}$ is the global temperature set by the simulator.

Mobility and Transconductance Parameters

$$u_o = u_{o_{nom}} \left(\frac{T}{T_{nom}} \right)^{ute}$$

$$k_p = k_{p_{nom}} \left(\frac{T}{T_{nom}} \right)^{ute}$$

where *ute* is the exponent parameter. Default value of *ute* is -1.5.

Energy Band Gap

$$E_g(T) = \begin{cases} e^{g - \frac{gap1 * T^2}{T + gap2}} & \text{if } tlev = 2 \\ \left(1.17 - \frac{4.73 \times 10^{-4} T^2}{T + 636} \right) & \text{if } tlev = 0 \text{ or } 1 \\ & \text{and } compatible = spectre \\ \left(1.16 - \frac{7.02 \times 10^{-4} T^2}{T + 1108} \right) & \text{otherwise} \end{cases}$$

Surface Potential

$$\phi(T) = \begin{cases} \phi_{nom}\left(\frac{T}{Tnom}\right) - \Delta\phi & \text{if } tlevc = 0 \\ \phi_{nom} - ptc\Delta T & \text{if } tlevc = 1 \text{ or } 2 \\ \phi_{nom} - \frac{d\phi}{dT}\Delta T & \text{if } tlevc = 3 \end{cases}$$

where

$$\Delta\phi = V_t(T) \left\{ 3 \ln \left[\frac{T}{Tnom} \right] + \frac{E_{g,nom}}{V_{t,nom}} - \frac{E_g(T)}{V_t(T)} \right\}$$

$$E_{g,nom} = E_g(Tnom)$$

$$V_{t,nom} = \frac{k(Tnom)}{q}$$

$$\Delta T = T - Tnom$$

$$n_i = 1.45 \times 10^{10} \left(\frac{T}{300} \right)^{1.5} \exp \left[\frac{1.12}{0.0516} - \frac{E_g(T)}{2V_t(T)} \right]$$

$$\frac{d\phi}{dT} = \begin{cases} \frac{-\left[\Delta E_{phi} + (1.16 - E_{g,nom}) * \left(2 - \frac{Tnom}{Tnom + 1108} \right) \right]}{Tnom} & \text{if } tlev = 0, 1 \\ \frac{-\left[\Delta E_{phi} + (eg - E_{g,nom}) * \left(2 - \frac{Tnom}{Tnom + gap2} \right) \right]}{Tnom} & \text{if } tlev = 2 \end{cases}$$

where

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Common MOSFET Equations

$$\Delta E_{phi} = E_{g,nom} + 3V_{t,nom} - phi_{nom}$$

Built-in Voltage of Source/Drain Junctions

If $tlevc = 0$,

$$pb(T) = pb_{nom} \left(\frac{T}{Tnom} \right) - \Delta\phi$$

$$pbsw(T) = pbsw_{nom} \left(\frac{T}{Tnom} \right) - \Delta\phi$$

If $tlevc = 1,2$,

$$pb(T) = pb_{nom} - pta\Delta T$$

$$pbsw(T) = pbsw_{nom} - ptp\Delta T$$

If $tlevc = 3$,

$$pb(T) = pb_{nom} + \left(\frac{d\phi_B}{dT} \right) \Delta T$$

$$pbsw(T) = pbsw_{nom} + \left(\frac{d\phi_{sw}}{dT} \right) \Delta T$$

where

$$\frac{d\phi_B}{dT} = \begin{cases} \frac{-\left[\Delta E_{PB} + (1.16 - E_{g,nom}) * \left(2 - \frac{Tnom}{Tnom + 1108} \right) \right]}{Tnom} & \text{if } tlev = 0, 1 \\ \frac{-\left[\Delta E_{PB} + (eg - E_{g,nom}) * \left(2 - \frac{Tnom}{Tnom + gap2} \right) \right]}{Tnom} & \text{if } tlev = 2 \end{cases}$$

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Common MOSFET Equations

$$\frac{d\phi_{BSW}}{dT} = \begin{cases} -\frac{[\Delta E_{PBSW} + (1.16 - E_{g,nom}) * (2 - \frac{Tnom}{Tnom + 1108})]}{Tnom} & \text{if } tlev = 0, 1 \\ -\frac{[\Delta E_{PBSW} + (eg - E_{g,nom}) * (2 - \frac{Tnom}{Tnom + gap2})]}{Tnom} & \text{if } tlev = 2 \end{cases}$$

where

$$\Delta E_{PB} = E_{g,nom} + 3V_{t,nom} - pb_{nom}$$

$$\Delta E_{PBSW} = E_{g,nom} + 3V_{t,nom} - pbsw_{nom}$$

Junction Leakage Currents

$$is(T) = is_{nom} e^{Fact/n}$$

$$js(T) = js_{nom} e^{Fact/n}$$

where

$$Fact = \frac{E_{g,nom}}{V_{t,nom}} - \frac{E_g(T)}{V_t} + xti \ln \left[\frac{T}{Tnom} \right]$$

Junction Capacitances

If $tlevc = 0$

$$cbd(T) = cbd_{nom} \left[1 + mj \left(0.0004\Delta T - \frac{pb(T)}{pb_{nom}} + 1 \right) \right]$$

$$cbs(T) = cbs_{nom} \left[1 + mj \left(0.0004\Delta T - \frac{pb(T)}{pb_{nom}} + 1 \right) \right]$$

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Common MOSFET Equations

$$c_j(T) = c_{j_{nom}} \left[1 + m_j \left(0.0004 \Delta T - \frac{pb(T)}{pb_{nom}} + 1 \right) \right]$$

$$c_{jsw}(T) = c_{jsw_{nom}} \left[1 + m_{jsw} \left(0.0004 \Delta T - \frac{pb_{sw}(T)}{pb_{sw_{nom}}} + 1 \right) \right]$$

If $tlevc = 1$

$$cbd(T) = cbd_{nom} (1 + cta \Delta T)$$

$$cbs(T) = cbs_{nom} (1 + cta \Delta T)$$

$$c_j(T) = c_{j_{nom}} (1 + cta \Delta T)$$

$$c_{jsw}(T) = c_{jsw_{nom}} (1 + ctp \Delta T)$$

If $tlevc = 2$,

$$cbd(T) = cbd_{nom} \left(\frac{pb_{nom}}{pb(T)} \right)^{m_j}$$

$$cbs(T) = cbs_{nom} \left(\frac{pb_{nom}}{pb(T)} \right)^{m_j}$$

$$c_j(T) = c_{j_{nom}} \left(\frac{pb_{nom}}{pb(T)} \right)^{m_j}$$

$$c_{jsw}(T) = c_{jsw_{nom}} \left(\frac{pb_{sw_{nom}}}{pb_{sw}(T)} \right)^{m_{jsw}}$$

If $tlevc = 3$,

$$cbd(T) = cbd_{nom} \left[1 - 0.5 \left(\frac{d\phi_B}{dT} \right) \left(\frac{\Delta T}{pb_{nom}} \right) \right]$$

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Common MOSFET Equations

$$cbs(T) = cbs_{nom} \left[1 - 0.5 \left(\frac{d\phi_B}{dT} \right) \left(\frac{\Delta T}{pb_{nom}} \right) \right]$$

$$cj(T) = cj_{nom} \left[1 - 0.5 \left(\frac{d\phi_B}{dT} \right) \left(\frac{\Delta T}{pb_{nom}} \right) \right]$$

$$cjsw(T) = cjsw_{nom} \left[1 - 0.5 \left(\frac{d\phi_{SW}}{dT} \right) \left(\frac{\Delta T}{pbsw_{nom}} \right) \right]$$

Channel Length Modulation

$$\lambda(T) = \lambda_{nom} (1 + \lambda_{ex} \Delta T)$$

$$\kappa(T) = \kappa_{nom} (1 + \lambda_{ex} \Delta T)$$

Threshold Voltage

If $tlev = 0$,

$$V_{bi}(T) = vto_{nom} - \gamma \sqrt{\phi_{nom}} + \frac{\phi(T) - \phi_{nom}}{2} + \frac{E_{g,nom} - E_g(T)}{2}$$

$$vto(T) = V_{bi}(T) + \gamma \sqrt{\phi(T)}$$

If $tlev = 1$,

$$vto(T) = vto_{nom} - tcv \Delta T$$

Note: tcv is negative.

$$V_{bi}(T) = vto(T) - \gamma \sqrt{\phi(T)}$$

If $tlev = 2$,

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Common MOSFET Equations

$$v_{to}(T) = v_{to_{nom}} + \left(1 + \frac{\gamma}{2\sqrt{\phi_{i_{nom}}}}\right) \frac{d\phi}{dT} \Delta T$$

$$V_{bi}(T) = v_{to}(T) - \gamma \sqrt{\phi_{i}(T)}$$

Drain and Source Parasitic Resistance

$$r_d(T) = r_{d_{nom}}(1 + tr_d \Delta T)$$

$$r_s(T) = r_{s_{nom}}(1 + tr_s \Delta T)$$

Critical Field

$$u_{crit}(T) = u_{crit_{nom}} \left(\frac{T}{T_{nom}}\right)^{flex}$$

Noise Model

This section contains model equations for the noise model.

Drain Resistance Thermal Noise

$$\overline{i_{R_d}^2} = \frac{4kT}{R_d} \Delta f$$

Source Resistance Thermal Noise

$$\overline{i_{R_s}^2} = \frac{4kT}{R_s} \Delta f$$

Channel Thermal and Flicker Noise

$$\overline{i_{DS}^2} = \overline{i_{n, thermal}^2} + \frac{kf I_{DS}^{af} \Delta f}{C_{ox} W_{eff} L_{eff} f^{ef}}$$

where

$$\overline{i_{n, thermal}^2} = \frac{8kT(g_m + g_{mb} + g_{ds})\Delta f}{3} \left[\frac{3}{2} - \frac{V_{DS}}{2V_{DSAT}} \right]$$

$$V'_{DS} = \text{MIN}(V_{DS}, V_{DSAT})$$

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.

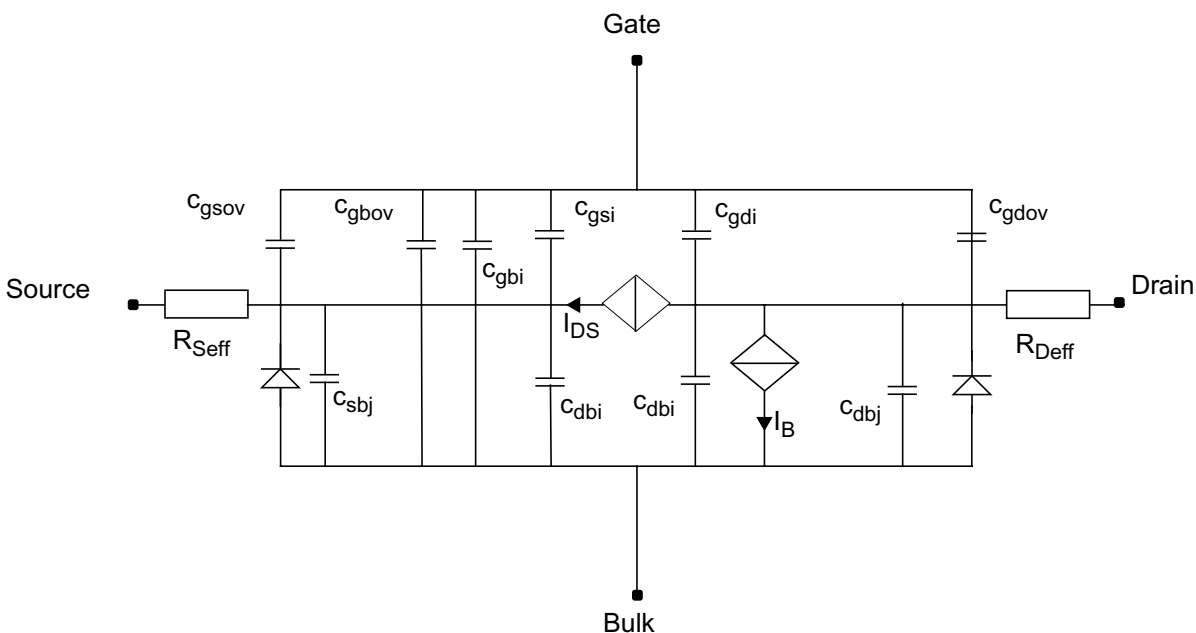
Virtuoso Simulator Components and Device Models Reference

Common MOSFET Equations

MOS Capacitance Model

This chapter contains model equations for the MOS capacitance model, including the following:

- [Modified Meyer Model](#) on page 940
- [Yang-Chatterjee Model](#) on page 944
- [BSIM Charge Model with 0/100 Partitioning \(xpart=1\)](#) on page 947
- [BSIM Charge Model with 40/60 Partitioning \(xpart=0\)](#) on page 947
- [BSIM Charge Model with 50/50 Partitioning \(xpart=0.5\)](#) on page 951
- [Scaling Effects](#) on page 954



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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 $V_{DS} \geq V_{DSAT}$.

$$C_{gg} = \frac{2}{3} C_o$$

$$C_{gb} = \frac{1}{3} C_o \frac{dV_{TH}}{dV_{BS}}$$

$$C_{gs} = -(C_{gg} + C_{gb})$$

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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 $V_{GS} \leq V_{TH}$.

$$C_{gg} = C_{bb} = \frac{C_o \gamma}{2 \sqrt{\left(\frac{\gamma}{2}\right)^2 + V_{GS} - V_{BS} - V_{FB}}}$$

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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

$$C_{dd} = \frac{\alpha_x}{4} C_o \left[2 \left(\frac{1}{3Fac^2} + \frac{2V_{DS}}{3Fac^3} \right) \left(8V_{DSAT}^2 - 6V_{DSAT}V_{DS} + \frac{6}{5}V_{DS}^2 \right) \right. \\ \left. + \frac{V_{DS} \left(\frac{12}{5}V_{DS} - 6V_{DSAT} \right)}{2Fac^2} \right]$$

$$C_{ds} = -(C_{dg} + C_{dd} + C_{ds})$$

$$C_{sg} = -(C_{gg} + C_{dg} + C_{bg})$$

$$C_{sd} = -(C_{gd} + C_{dd} + C_{bd})$$

$$C_{sb} = -(C_{gb} + C_{db} + C_{bb})$$

$$C_{ss} = -(C_{gs} + C_{ds} + C_{bs})$$

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 222.

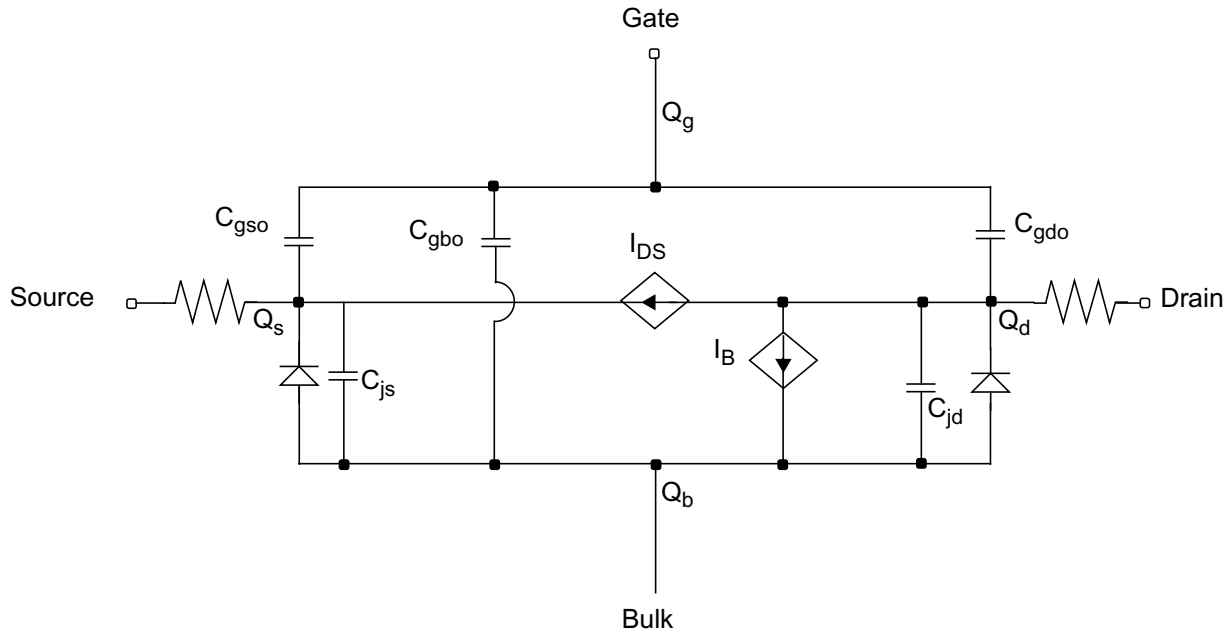
MOS Level-1 Model (mos1)

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 956
- [Threshold Voltage](#) on page 956
- [Drain Saturation Voltage](#) on page 957
- [Drain Current for the Subthreshold Region](#) on page 957
- [Drain Current for the Triode Region](#) on page 957
- [Drain Current for the Saturation Region](#) on page 958
- [Drain Saturation Voltage \(Modified Level-1 Model\)](#) on page 958
- [Drain Current for the Triode Region \(Modified Level-1 Model\)](#) on page 959
- [Drain Current for the Saturation Region \(Modified Level-1 Model\)](#) on page 959
- [Substrate Current](#) on page 959
- [Scaling Effects](#) on page 960
- [Component Statements](#) on page 960

Virtuoso Simulator Components and Device Models Reference

MOS Level-1 Model (mos1)



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 $V_{GS} > V_{ON}$ 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

$$\beta = \frac{kp * W_{eff}}{L_{eff}}$$

Drain Current for the Saturation Region

Note: This equation applies when $V_{GS} > V_{ON}$ and $V_{DS} > V_{DSAT}$.

$$I_{DS} = \frac{\beta V_{GST}^2}{2} (1 + \lambda * V_{DS})$$

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, *theta* and *vmax*, into the Level-1 model. The meanings of *theta* and *vmax* 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 *theta* or *vmax* (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

$$K = \frac{1 + V_c + \sqrt{1 + 2V_c}}{2}$$

$$V_c = \frac{V_{GST} u_0}{vmax * L_{eff}}$$

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

$$E_c = \frac{v_{max}}{u_0}$$

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.

$$I_{DB} = \begin{cases} I_{DS} A_i (V_{DS} - V_{DSAT}) e^{-B_i / (V_{DS} - V_{DSAT})} & \text{if } V_{DS} \leq V_{DSAT} \\ 0 & \text{otherwise} \end{cases}$$

where

$$A_i = aio + \frac{laio \times 10^{-6}}{L_{eff}} + \frac{waio \times 10^{-6}}{W_{eff}}$$

$$B_i = bio + \frac{l_{bio} \times 10^{-6}}{L_{eff}} + \frac{w_{bio} \times 10^{-6}}{W_{eff}}$$

Scaling Effects

For scaling effects, see [Scaling Factors \(scale and scalem\)](#) on page 222.

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.
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.

Virtuoso Simulator Components and Device Models Reference

MOS Level-1 Model (mos1)

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>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> .
---	---------------------	--

Drain current model parameters

2	<code>vto=0 V</code>	Threshold voltage at zero body bias.
3	<code>kp=2.0718e-5 A/V²</code>	Transconductance parameter.
4	<code>lambda=0 1/V</code>	Channel length modulation parameter.
5	<code>phi=0.7 V</code>	Surface potential at strong inversion.

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6	$\gamma=0 \text{ } \sqrt{\text{V}}$	Body-effect parameter.
7	$\mu_0=600 \text{ cm}^2/\text{V s}$	Carrier surface mobility.
8	$v_{\text{max}}=\infty \text{ m/s}$	Carrier saturation velocity.
9	$\theta=0 \text{ 1/V}$	Mobility modulation coefficient.

Process parameters

10	$n_{\text{sub}}=1.13\text{e}16 \text{ cm}^{-3}$	Channel doping concentration.
11	$n_{\text{ss}}=0 \text{ cm}^{-2}$	Surface state density.
12	$n_{\text{fs}}=0 \text{ cm}^{-2}$	Fast surface state density.
13	$t_{\text{pg}}=+1$	Type of gate (+1 = opposite of substate, -1 = same as substate, 0 = aluminum).
14	$l_{\text{d}}=0 \text{ m}$	Lateral diffusion.
15	$w_{\text{d}}=0 \text{ m}$	Field-oxide encroachment.
16	$x_{\text{w}}=0 \text{ m}$	Width variation due to masking and etching.
17	$x_{\text{l}}=0 \text{ m}$	Length variation due to masking and etching.
18	$t_{\text{ox}}=1\text{e}-7 \text{ m}$	Gate oxide thickness.

Impact ionization parameters

19	$a_{\text{i}0}=0 \text{ 1/V}$	Impact ionization current coefficient.
20	$l_{\text{ai}0}=0 \text{ } \mu\text{m/V}$	Length sensitivity of $a_{\text{i}0}$.
21	$w_{\text{ai}0}=0 \text{ } \mu\text{m/V}$	Width sensitivity of $a_{\text{i}0}$.
22	$b_{\text{i}0}=0 \text{ V}$	Impact ionization current exponent.
23	$l_{\text{bi}0}=0 \text{ } \mu\text{m V}$	Length sensitivity of $b_{\text{i}0}$.

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24 $w_{bi0}=0 \mu\text{m}$ V Width sensitivity of $bi0$.

Overlap capacitance parameters

25 $c_{gso}=0 \text{ F/m}$ Gate-source overlap capacitance.

26 $c_{gdo}=0 \text{ F/m}$ Gate-drain overlap capacitance.

27 $c_{gbo}=0 \text{ F/m}$ Gate-bulk overlap capacitance.

28 $meto=0 \text{ m}$ Metal overlap in fringing field.

Charge model selection parameters

29 $capmod=bsim$ Intrinsic charge model.
Possible values are `none`, `meyer`, `yang`, or `bsim`.

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 $r_s=0 \Omega$ Source resistance.

33 $r_d=0 \Omega$ Drain resistance.

34 $r_{ss}=0 \Omega \text{ m}$ Scalable source resistance.

35 $r_{dd}=0 \Omega \text{ m}$ Scalable drain resistance.

36 $r_{sh}=0 \Omega/\text{sqr}$ Source/drain diffusion sheet resistance.

37 $r_{sc}=0 \Omega$ Source contact resistance.

38 $r_{dc}=0 \Omega$ Drain contact resistance.

39 $minr=0.1 \Omega$ Minimum source/drain resistance.

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40	ldif=0 m	Lateral diffusion beyond the gate.
41	hdif=0 m	Length of heavily doped diffusion.
42	lgcs=0 m	Gate-to-contact length of source side.
43	lgcd=0 m	Gate-to-contact length of drain side.
44	sc= ∞ m	Spacing between contacts.

Junction diode model parameters

45	js (A/m ²)	Bulk junction reverse saturation current density.
46	is=1e-14 A	Bulk junction reverse saturation current.
47	n=1	Junction emission coefficient.
48	dskip=yes	Use simple piece-wise linear model for diode currents below 0.1*iabstol. Possible values are no or yes.
49	imelt=`imax' A	Explosion current, diode is linearized beyond this current to aid convergence.
50	jmelt=`jmax' A/m ²	Explosion current density, diode is linearized beyond this current to aid convergence.

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.

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57	$c_{jsw}=0$ F/m	Zero-bias junction sidewall capacitance density.
58	$m_{jsw}=1/3$	Bulk junction sidewall grading coefficient.
59	$p_{bsw}=0.8$ V	Side-wall junction built-in potential.
60	$f_{csw}=0.5$	Side-wall forward-bias depletion capacitance threshold.

Operating region warning control parameters

61	$alarm=none$	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> .
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	$bv_j=\infty$ V	Junction reverse breakdown voltage.
65	$vbox=1e9$ t_{ox} V	Oxide breakdown voltage.

Temperature effects parameters

66	t_{nom} (C)	Parameters measurement temperature. Default set by <i>options</i> .
67	$t_{rise}=0$ C	Temperature rise from ambient.
68	$u_{to}=0$ C	Mobility temperature offset.
69	$u_{te}=-1.5$	Mobility temperature exponent.
70	$t_{lev}=0$	DC temperature selector.
71	$t_{levc}=0$	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.

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75	<code>flex=0</code>	Temperature exponent for <code>ucrit</code> .
76	<code>lamex=0 1/C</code>	Temperature parameter for <code>lambda</code> and <code>kappa</code> .
77	<code>trs=0 1/C</code>	Temperature parameter for source resistance.
78	<code>trd=0 1/C</code>	Temperature parameter for drain resistance.
79	<code>x_{ti}=3</code>	Saturation current temperature exponent.
80	<code>ptc=0 V/C</code>	Surface potential temperature coefficient.
81	<code>tcv=0 V/C</code>	Threshold voltage temperature coefficient.
82	<code>pta=0 V/C</code>	Junction potential temperature coefficient.
83	<code>ptp=0 V/C</code>	Sidewall junction potential temperature coefficient.
84	<code>cta=0 1/C</code>	Junction capacitance temperature coefficient.
85	<code>ctp=0 1/C</code>	Sidewall junction capacitance temperature coefficient.

Default instance parameters

86	<code>w=3e-6 m</code>	Default channel width.
87	<code>l=3e-6 m</code>	Default channel length.
88	<code>as=0 m²</code>	Default area of source diffusion.
89	<code>ad=0 m²</code>	Default area of drain diffusion.
90	<code>ps=0 m</code>	Default perimeter of source diffusion.
91	<code>pd=0 m</code>	Default perimeter of drain diffusion.
92	<code>nrd=0 m/m</code>	Default number of squares of drain diffusion.
93	<code>nrs=0 m/m</code>	Default number of squares of source diffusion.
94	<code>l_{dd}=0 m</code>	Default length of drain diffusion region.
95	<code>l_{ds}=0 m</code>	Default length of source diffusion region.

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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 m</code>	Channel width at which noise parameters were extracted.

Auto Model Selector parameters

101	<code>wmax=1.0 m</code>	Maximum channel width for which the model is valid.
102	<code>wmin=0.0 m</code>	Minimum channel width for which the model is valid.
103	<code>lmax=1.0 m</code>	Maximum channel length for which the model is valid.
104	<code>lmin=0.0 m</code>	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> .
106	<code>degradation=no</code>	Hot-electron degradation flag. Possible values are <code>no</code> or <code>yes</code> .
107	<code>dvthc=1 V</code>	Degradation coefficient for threshold voltage.
108	<code>dvthe=1</code>	Degradation exponent for threshold voltage.
109	<code>duoc=1 S</code>	Degradation coefficient for transconductance.
110	<code>duoe=1</code>	Degradation exponent for transconductance.
111	<code>crivth=0.1 V</code>	Maximum allowable threshold voltage shift.
112	<code>criuo=10%</code>	Maximum allowable normalized mobility change.

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MOS Level-1 Model (mos1)

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 m</code>	Nominal device width in degradation calculation.
116	<code>lnom=1e-6 m</code>	Nominal device length in degradation calculation.
117	<code>vbsn=0 V</code>	Substrate voltage in degradation calculation.
118	<code>vdsni=0.1 V</code>	Drain voltage in I_{ds} degradation calculation.
119	<code>vgsni=5 V</code>	Gate voltage in I_{ds} degradation calculation.
120	<code>vdsng=0.1 V</code>	Drain voltage in G_m degradation calculation.
121	<code>vgsng=5 V</code>	Gate voltage in G_m degradation calculation.

Spectre stress parameters

122	<code>esat=1.1e7 V/m</code>	Critical field in V_{dsat} calculation.
123	<code>esatg=2.5e6 1/m</code>	Gate voltage dependence of $esat$.
124	<code>vpg=-0.25</code>	Gate voltage modifier.
125	<code>vpb=-0.13</code>	Gate voltage modifier.
126	<code>subc1=2.24e-5</code>	Substrate current coefficient.
127	<code>subc2=-0.1e-5 1/V</code>	Substrate current coefficient.
128	<code>sube=6.4</code>	Substrate current exponent.
129	<code>strc=1</code>	Stress coefficient.
130	<code>stre=1</code>	Stress exponent.

BERT stress parameters

131	<code>h0=1</code>	Aging coefficient.
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MOS Level-1 Model (mos1)

132	$hgd=0$	$1/V$	Bias dependence of h_0 .
133	$m_0=1$		Aging exponent.
134	$mgd=0$	$1/V$	Bias dependence of m_0 .
135	$ecrit_0=1.1e5$	V/cm	Critical electric field.
136	$lecrit_0=0$	μm	Length dependence of $ecrit_0$.
137	$wecrit_0=0$	μm	Width dependence of $ecrit_0$.
138	$ecritg=0$	$1/cm$	Gate voltage dependence of $ecrit_0$.
139	$lecritg=0$	$\mu m/cm$	Length dependence of $ecritg$.
140	$wecritg=0$	$\mu m/cm$	Width dependence of $ecritg$.
141	$ecritb=0$	$1/cm$	Substrate voltage dependence of $ecrit_0$.
142	$lecritb=0$	$\mu m/cm$	Length dependence of $ecritb$.
143	$wecritb=0$	$\mu m/cm$	Width dependence of $ecritb$.
144	$lc_0=1$		Substrate current coefficient.
145	$llc_0=0$	μm	Length dependence of lc_0 .
146	$wlc_0=0$	μm	Width dependence of lc_0 .
147	$lc_1=1$		Substrate current coefficient.
148	$llc_1=0$	μm	Length dependence of lc_1 .
149	$wlc_1=0$	μm	Width dependence of lc_1 .
150	$lc_2=1$		Substrate current coefficient.
151	$llc_2=0$	μm	Length dependence of lc_2 .
152	$wlc_2=0$	μm	Width dependence of lc_2 .
153	$lc_3=1$		Substrate current coefficient.

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154	$l_{c3}=0 \mu\text{m}$	Length dependence of l_{c3} .
155	$w_{l_{c3}}=0 \mu\text{m}$	Width dependence of l_{c3} .
156	$l_{c4}=1$	Substrate current coefficient.
157	$l_{l_{c4}}=0 \mu\text{m}$	Length dependence of l_{c4} .
158	$w_{l_{c4}}=0 \mu\text{m}$	Width dependence of l_{c4} .
159	$l_{c5}=1$	Substrate current coefficient.
160	$l_{l_{c5}}=0 \mu\text{m}$	Length dependence of l_{c5} .
161	$w_{l_{c5}}=0 \mu\text{m}$	Width dependence of l_{c5} .
162	$l_{c6}=1$	Substrate current coefficient.
163	$l_{l_{c6}}=0 \mu\text{m}$	Length dependence of l_{c6} .
164	$w_{l_{c6}}=0 \mu\text{m}$	Width dependence of l_{c6} .
165	$l_{c7}=1$	Substrate current coefficient.
166	$l_{l_{c7}}=0 \mu\text{m}$	Length dependence of l_{c7} .
167	$w_{l_{c7}}=0 \mu\text{m}$	Width dependence of l_{c7} .

Shrink Parmaters

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

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MOS Level-1 Model (mos1)

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 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.

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MOS Level-1 Model (mos1)

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.

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.

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6	vgs (V)	Gate-source voltage.
7	vds (V)	Drain-source voltage.
8	vbs (V)	Bulk-source voltage.
9	vth (V)	Threshold voltage.
10	vdsat (V)	Drain-source saturation voltage.
11	gm (S)	Common-source transconductance.
12	gds (S)	Common-source output conductance.
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.

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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.

ad	I-4	gap2	M-74	llc7	M-166	tlev	M-70
ad	M-89	gds	OP-12	lmax	M-103	tlevc	M-71
adef	O-6	gm	OP-11	lmin	M-104	tnom	M-66
af	M-98	gmbs	OP-13	lnom	M-116	tox	M-18
age	OP-28	gmoverid	OP-25	ls	I-10	tpg	M-13
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
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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
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

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degradation 106	M-	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
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

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MOS Level-1 Model (mos1)

gap1 M-73

llc6 M-163

theta M-9

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MOS Level-1 Model (mos1)

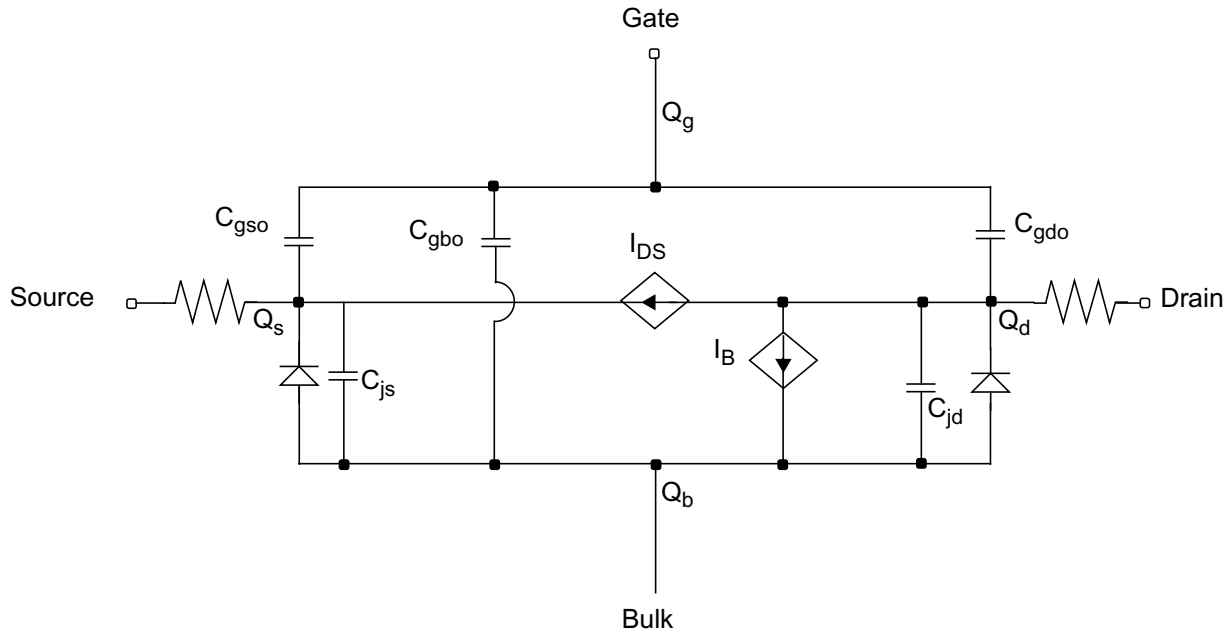
MOS Level-2 Model (mos2)

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 980
- [Threshold Voltage](#) on page 980
- [Drain Saturation Voltage](#) on page 981
- [Drain Current for the Subthreshold Region](#) on page 982
- [Drain Current for the Triode Region](#) on page 983
- [Drain Current for the Saturation Region](#) on page 984
- [Substrate Current](#) on page 984
- [Scaling Effects](#) on page 985
- [Component Statements](#) table on page 985

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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

$$V_{TH} = V_{BI} + \gamma_s \sqrt{\phi_{hi} - V_{BS}} + (\eta - 1)(\phi_{hi} - V_{BS})$$

where

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$$V_{BI} = v_{to} - \gamma \sqrt{\phi_i}$$

$$\gamma_s = \gamma (1 - \alpha_S - \alpha_D)$$

$$\alpha_S = \frac{x_j}{2L_{eff}} \left[\sqrt{1 + \frac{2W_S}{x_j}} - 1 \right]$$

$$\alpha_D = \frac{x_j}{2L_{eff}} \left[\sqrt{1 + \frac{2W_D}{x_j}} - 1 \right]$$

$$W_S = X_D \sqrt{\phi_i - V_{BS}}$$

$$W_D = X_D \sqrt{\phi_i - V_{BS} + V_{DS}}$$

$$X_D = \begin{cases} \sqrt{\frac{2\epsilon_{si}}{q * (n_{sub})}} & \text{if } v_{max} \text{ is not specified} \\ \sqrt{\frac{2\epsilon_{si}}{q * n_{eff} * n_{sub}}} & \text{otherwise} \end{cases}$$

$$\eta = 1 + \frac{\Delta \pi \epsilon_{si}}{4C_{ox} W_{eff}}$$

If x_j or n_{sub} is zero, the short-channel effects on threshold voltage are not evaluated (that is, $\gamma_s = \gamma$).

Drain Saturation Voltage

If v_{max} is not specified, V_{DSAT} is determined by the pinchoff condition and is given by

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$$V_{DSAT} = \frac{V_{GS} - V_{BIN}}{\eta} + \frac{1}{2} \left(\frac{\gamma_s}{\eta} \right)^2 (1 - Fac)$$

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 $V_{DS} \leq V_{DSAT}$.

$$I_{DS} = \beta \left\{ \left(V_{GS} - V_{BIN} - \frac{\eta V_{DS}}{2} \right) V_{DS} - \frac{2}{3} \gamma_s [(\phi_i - V_{BS} + V_{DS})^{3/2} - (\phi_i - V_{BS})^{3/2}] \right\}$$

where

$$\beta = \frac{\mu_{eff} C_{ox} W_{eff}}{L_{eff} - \Delta L}$$

$$\mu_{eff} = u_0 \left[\frac{u_{crit} \epsilon_{si}}{C_{ox} (V_{GS} - V_{TH} - u_{tra} * V_{DS})} \right]^{u_{exp}}$$

SPICE does not implement the *utra* effect. Also, if $(V_{GS} - V_{TH}) \leq (u_{crit} \epsilon_{si} / C_{ox})$, μ_{eff} is clipped to u_0 . 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:

$$\beta = \frac{\mu_{eff} C_{ox} W_{eff}}{L_{eff}} \left(\frac{L_{eff}}{W_B}\right)^2 \left(\frac{2W_B}{L_{eff}} + \frac{\Delta L}{L_{eff}} - 1\right)$$

where

$$W_B = X_D \sqrt{\rho b}$$

Drain Current for the Saturation Region

Note: This equation applies when $V_{GS} \geq V_{ON}$ and $V_{DS} \geq V_{DSAT}$.

$$I_{DS} = \beta \left\{ \left(V_{GS} - V_{BIN} - \frac{\eta V_{DSAT}}{2} \right) V_{DSAT} - \frac{2}{3} \gamma_s \left[(\phi_i - V_{BS} + V_{DSAT})^{3/2} - (\phi_i - V_{BS})^{3/2} \right] \right\}$$

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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$$I_{DB} = \begin{cases} I_{DS} A_i (V_{DS} - V_{DSAT}) e^{-B_i / (V_{DS} - V_{DSAT})} & \text{if } V_{DS} \leq V_{DSAT} \\ 0 & \text{otherwise} \end{cases}$$

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 222.

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 ultra=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
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Sample Model Statement

```
model nch2 mos2 type=n vto=0.66 lambda=0.018 gamma=0.6 nsub=0.213e16 kp=0.978e-4  
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```

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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 ...

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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.

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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 substate, -1 = same as substate, 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	$met_o=0 \text{ m}$	Metal overlap in fringing field.

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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.

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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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68	<code>imax=1 A</code>	Maximum current, currents above this limit generate a warning.
69	<code>jmax=1e8 A/m²</code>	Maximum current density, currents above this limit generate a warning.
70	<code>bvj=∞ V</code>	Junction reverse breakdown voltage.
71	<code>vbox=1e9 tox V</code>	Oxide breakdown voltage.

Temperature effects parameters

72	<code>tnom (C)</code>	Parameters measurement temperature. Default set by <code>options</code> .
73	<code>trise=0 C</code>	Temperature rise from ambient.
74	<code>uto=0 C</code>	Mobility temperature offset.
75	<code>ute=-1.5</code>	Mobility temperature exponent.
76	<code>tlev=0</code>	DC temperature selector.
77	<code>tlevc=0</code>	AC temperature selector.
78	<code>eg=1.12452 V</code>	Energy band gap.
79	<code>gap1=7.02e-4 V/C</code>	Band gap temperature coefficient.
80	<code>gap2=1108 C</code>	Band gap temperature offset.
81	<code>flex=0</code>	Temperature exponent for <code>ucrit</code> .
82	<code>lamex=0 1/C</code>	Temperature parameter for <code>lambda</code> and <code>kappa</code> .
83	<code>trs=0 1/C</code>	Temperature parameter for source resistance.
84	<code>trd=0 1/C</code>	Temperature parameter for drain resistance.
85	<code>x_{ti}=3</code>	Saturation current temperature exponent.
86	<code>ptc=0 V/C</code>	Surface potential temperature coefficient.
87	<code>t_{cv}=0 V/C</code>	Threshold voltage temperature coefficient.

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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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Auto Model Selector parameters

107	wmax=1.0 m	Maximum channel width for which the model is valid.
108	wmin=0.0 m	Minimum channel width for which the model is valid.
109	lmax=1.0 m	Maximum channel length for which the model is valid.
110	lmin=0.0 m	Minimum channel length for which the model is valid.

Degradation parameters

111	degramod=spectre	Degradation model selector. Possible values are spectre or bert.
112	degradation=no	Hot-electron degradation flag. Possible values are no or yes.
113	dvthc=1 V	Degradation coefficient for threshold voltage.
114	dvthe=1	Degradation exponent for threshold voltage.
115	duoc=1 S	Degradation coefficient for transconductance.
116	duoe=1	Degradation exponent for transconductance.
117	crivth=0.1 V	Maximum allowable threshold voltage shift.
118	criuo=10%	Maximum allowable normalized mobility change.
119	crigm=10%	Maximum allowable normalized transconductance change.
120	criids=10%	Maximum allowable normalized drain current change.
121	wnom=5e-6 m	Nominal device width in degradation calculation.
122	lnom=1e-6 m	Nominal device length in degradation calculation.
123	vbsn=0 V	Substrate voltage in degradation calculation.
124	vdsni=0.1 V	Drain voltage in I_{ds} degradation calculation.
125	vgsni=5 V	Gate voltage in I_{ds} degradation calculation.

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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 $h_{gd}=0$ 1/V Bias dependence of h_0 .

139 $m_0=1$ Aging exponent.

140 $m_{gd}=0$ 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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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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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 Parmaters

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

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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

Virtuoso Simulator Components and Device Models Reference

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

Virtuoso Simulator Components and Device Models Reference

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	xl	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		

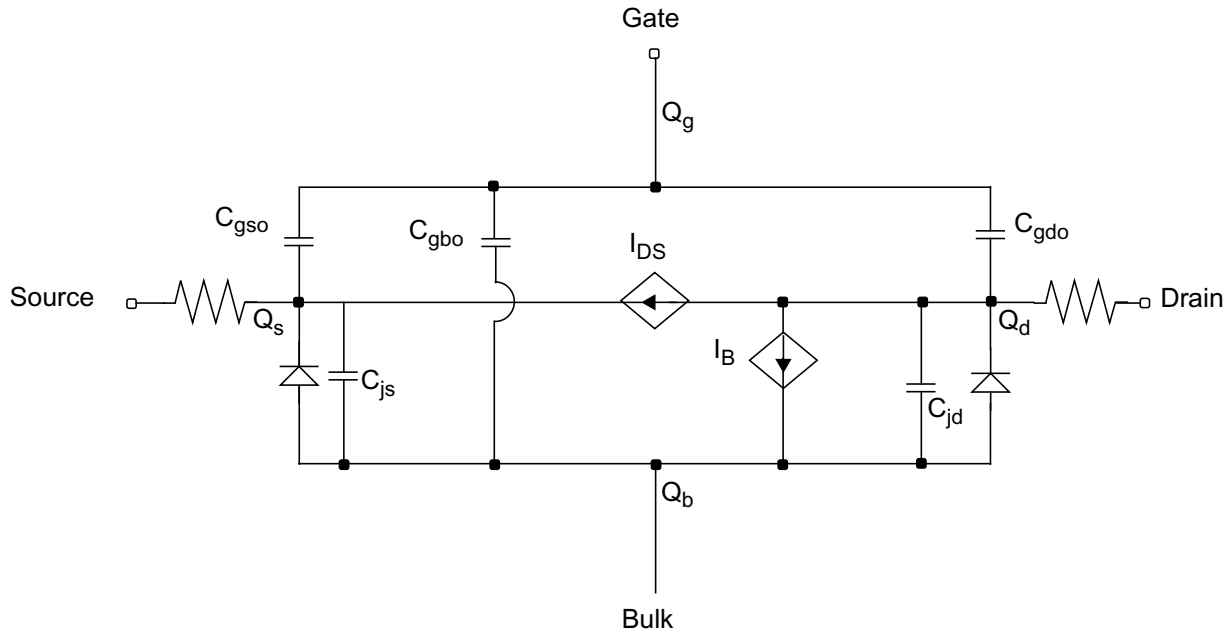
MOS Level-3 Model (mos3)

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 1004
- [Threshold Voltage](#) on page 1004
- [Drain Saturation Voltage](#) on page 1005
- [Drain Current for the Subthreshold Region](#) on page 1006
- [Drain Current for the Triode Region](#) on page 1007
- [Drain Current for the Saturation Region](#) on page 1007
- [Substrate Current](#) on page 1008
- [Scaling Effects](#) on page 1008
- [Component Statements](#) table on page 1008

Virtuoso Simulator Components and Device Models Reference

MOS Level-3 Model (mos3)



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

$$V_{BI} = v_{to} - \gamma \sqrt{\phi_i}$$

$$\sigma = \frac{8.15 \times 10^{-22} \text{ eta}}{C_{ox} L_{eff}^3}$$

$$F_S = 1 - \frac{x_j}{L_{eff}} \left\{ \left(\frac{ld}{x_j} + \frac{W_C}{x_j} \right) \sqrt{1 - \left(\frac{W_p}{1 + W_p} \right)^2} - \frac{ld}{x_j} \right\}$$

$$W_p = \frac{X_D}{x_j} \sqrt{\phi_i - V_{BS}}$$

$$X_D = \sqrt{\frac{2\epsilon_{si}}{q * n_{sub}}}$$

$$\frac{W_c}{x_j} = 0.0631353 + 0.8013292 W_p - 0.01110777 W_p^2$$

$$F_N = \frac{\text{delta} * \pi * \epsilon_{si}}{2 C_{ox} W_{eff}}$$

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

$$V_{GST} = V_{GS} - V_{TH}$$

$$F_B = \frac{\gamma_s F_S}{4\sqrt{\phi - V_{BS}}} + F_N$$

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

$$n = 1 + \frac{C_{FS} + C_D}{C_{ox}}$$

$$C_{FS} = q(nfs)$$

$$C_D = \left[\frac{\gamma_s}{2\sqrt{\phi - V_{BS}}} - \frac{d\gamma_s}{dV_{BS}} \sqrt{\phi - V_{BS} + F_N} \right] C_{ox}$$

$$I_{DS} = I_{DS, ON} e^{(V_{GS} - V_{ON})/nV_t}$$

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 $\Delta L < L_{eff}/2$, 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

$$A_i = aio + \frac{l_{aio} \times 10^{-6}}{L_{eff}} + \frac{w_{aio} \times 10^{-6}}{W_{eff}}$$

$$B_i = bio + \frac{l_{bio} \times 10^{-6}}{L_{eff}} + \frac{w_{bio} \times 10^{-6}}{W_{eff}}$$

Scaling Effects

For scaling effects, see [Scaling Factors \(scale and scalem\)](#) on page 222.

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 substate, -1 = same as substate, 0 = aluminum).
16	$t_{ox}=1e-7 \text{ m}$	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 $c_{gdo}=0$ F/m Gate-drain overlap capacitance.
- 30 $c_{gbo}=0$ 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, e.g. use 0.4 for 40/60, 0.5 for 50/50, 0 for 0/100.

Parasitic resistance parameters

- 35 $r_s=0$ Ω Source resistance.
- 36 $r_d=0$ Ω Drain resistance.
- 37 $r_{sh}=0$ Ω/sqr Source/drain diffusion sheet resistance.
- 38 $r_{ss}=0$ Ω m Scalable source resistance.
- 39 $r_{dd}=0$ Ω m Scalable drain resistance.
- 40 $r_{sc}=0$ Ω Source contact resistance.
- 41 $r_{dc}=0$ 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	flex=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 Parmaters

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>rdeff</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>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.

Virtuoso Simulator Components and Device Models Reference

MOS Level-3 Model (mos3)

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.
13	<code>gmbs</code> (S)	Body-transconductance.
14	<code>gameff</code> (\sqrt{V})	Effective body effect coefficient.
15	<code>betaeff</code> (A/V ²)	Effective beta.
16	<code>cbd</code> (F)	Drain-bulk junction capacitance.
17	<code>cbs</code> (F)	Source-bulk junction capacitance.
18	<code>cgs</code> (F)	Gate-source capacitance.
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 Vdsat.

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)

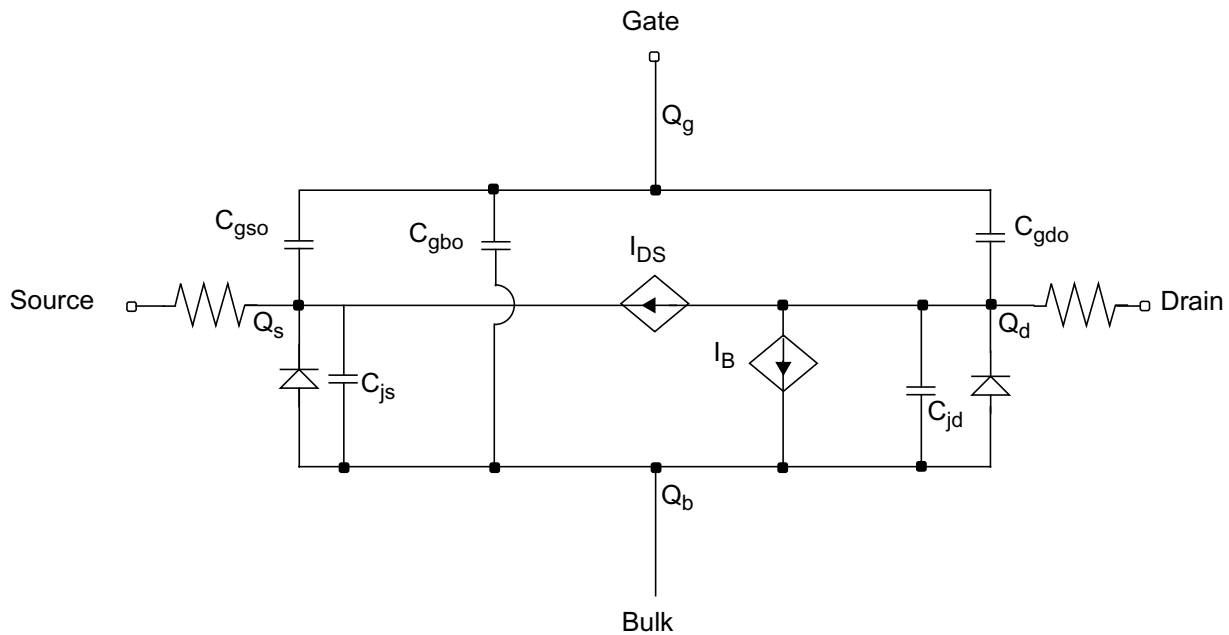
BSIM1 Level-4 Model (bsim1)

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 1029
- [Drain Current Model](#) on page 1030
- [Scaling Effects](#) on page 1033
- [Component Statements](#) on page 1033

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 222.

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	$lvfb=0$	$V \mu m$	Length dependence of vfb .
4	$wvfb=0$	$V \mu m$	Width dependence of vfb .
5	$pvfb=0$	$V \mu m$	Width-length dependence of vfb .
6	$phi0=0.75$	V	Surface potential.
7	$lphi=0$	$V \mu m$	Length dependence of phi .
8	$wphi=0$	$V \mu m$	Width dependence of phi .
9	$pphi=0$	$V \mu m$	Width-length dependence of phi .
10	$k1=0.7$	\sqrt{V}	Body-effect coefficient.
11	$lk1=0$	$\sqrt{V} \mu m$	Length dependence of $k1$.
12	$wk1=0$	$\sqrt{V} \mu m$	Width dependence of $k1$.
13	$pk1=0$	$\sqrt{V} \mu m$	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.
19	$leta=0$	μm	Length dependence of eta .
20	$weta=0$	μm	Width dependence of eta .
21	$peta=0$	μm	Width-length dependence of eta .
22	$x2e=0$	$1/V$	Body-bias dependence of eta .
23	$lx2e=0$	$\mu m/V$	Length dependence of $x2e$.
24	$wx2e=0$	$\mu m/V$	Width dependence of $x2e$.

Virtuoso Simulator Components and Device Models Reference
BSIM1 Level-4 Model (bsim1)

- 25 $px2e=0$ $\mu\text{m}/\text{V}$ Width-length dependence of $x2e$.
- 26 $x3e=0$ $1/\text{V}$ Drain-bias dependence of eta .
- 27 $lx3e=0$ $\mu\text{m}/\text{V}$ Length dependence of $x3e$.
- 28 $wx3e=0$ $\mu\text{m}/\text{V}$ Width dependence of $x3e$.
- 29 $px3e=0$ $\mu\text{m}/\text{V}$ Width-length dependence of $x3e$.

Mobility parameters

- 30 $muz=400$ $\text{cm}^2/\text{V s}$ Low-field mobility.
- 31 $lmuz=0$ $\text{cm}^2/\text{V s}$ Length dependence of muz .
- 32 $wmuz=0$ $\text{cm}^2/\text{V s}$ Width dependence of muz .
- 33 $pmuz=0$ $\text{cm}^2/\text{V s}$ Width-length dependence of muz .
- 34 $x2mz=0$ $\text{cm}^2/\text{V}^2 \text{ s}$ Body-bias dependence of muz .
- 35 $lx2mz=0$ $\text{cm}^2 \mu\text{m}/\text{V}^2 \text{ s}$
Length dependence of $x2mz$.
- 36 $wx2mz=0$ $\text{cm}^2 \mu\text{m}/\text{V}^2 \text{ s}$
Width dependence of $x2mz$.
- 37 $px2mz=0$ $\text{cm}^2 \mu\text{m}/\text{V}^2 \text{ s}$
Width-length dependence of $x2mz$.
- 38 $mus=450$ $\text{cm}^2/\text{V s}$ Mobility in the saturation region.
- 39 $lmus=0$ $\text{cm}^2 \mu\text{m}/\text{V s}$
Length dependence of mus .
- 40 $wmus=0$ $\text{cm}^2 \mu\text{m}/\text{V s}$
Width dependence of mus .
- 41 $pmus=0$ $\text{cm}^2 \mu\text{m}/\text{V s}$
Width-length dependence of mus .
- 42 $x2ms=0$ $\text{cm}^2/\text{V}^2 \text{ s}$ 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 mus .
- 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> .
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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=`imax`` A Explosion current, diode is linearized beyond this current to aid convergence.
- 135 `jmelt=`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*`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	$v_{pg}=-0.25$	Gate voltage modifier.
193	$v_{pb}=-0.13$	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>adef</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	<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.
13	<code>gds</code> (S)	Common-source output conductance.
14	<code>gmbs</code> (S)	Body-transconductance.
15	<code>cbd</code> (F)	Drain-bulk junction capacitance.
16	<code>cbs</code> (F)	Source-bulk junction capacitance.
17	<code>cgs</code> (F)	Gate-source capacitance.
18	<code>cgd</code> (F)	Gate-drain capacitance.
19	<code>cgb</code> (F)	Gate-bulk capacitance.
20	<code>ron</code> (Ω)	ON-resistance.
21	<code>id</code> (A)	Resistive drain current.
22	<code>ibulk</code> (A)	Resistive bulk current.
23	<code>pwr</code> (W)	Power at op point.
24	<code>gmoverid</code> (1/V)	Gm/Ids.
25	<code>isub</code> (A)	Substrate current.
26	<code>stress</code>	Hot-electron stress.
27	<code>age</code> (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	pul	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

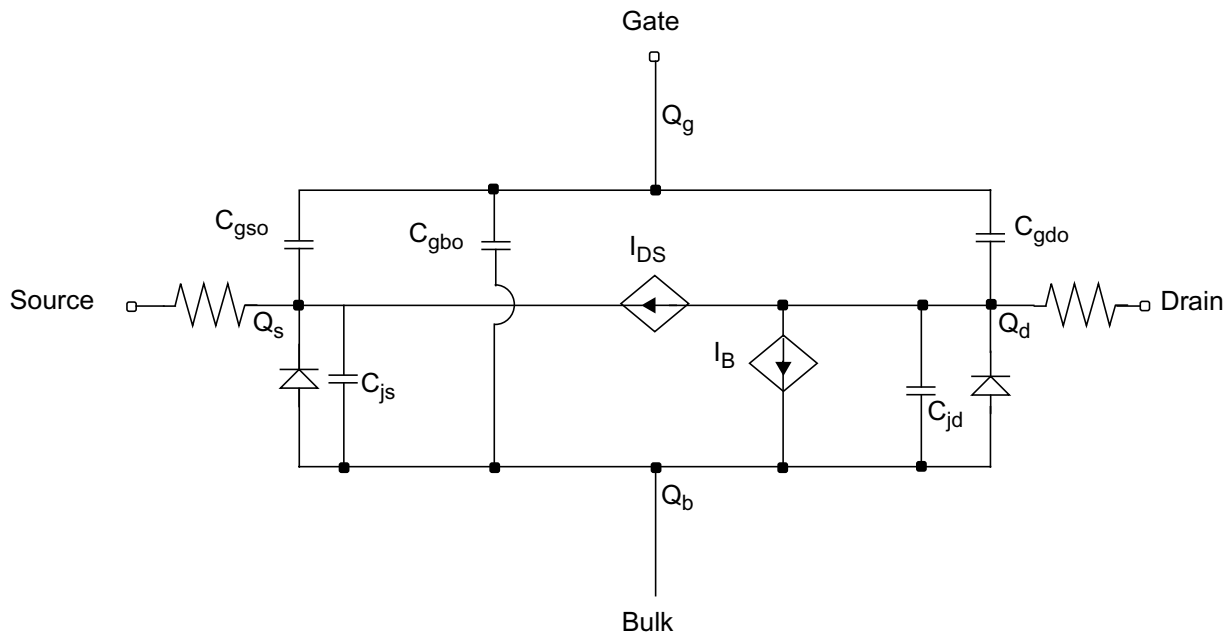
BSIM2 Level-5 Model (bsim2)

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 1058
- [Drain Current Model](#) on page 1058
- [Scaling Effects](#) on page 1062
- [Component Statements](#) on page 1062

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 semiempirical 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	$d1$	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 $V_{GST} \leq V_{glow}$.

$$I_{subth} = \beta V_t^2 e^{V_{offset} + V_{GST}/nV_t} [1 - e^{-V_{DS}/V_t}]$$

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 $V_{DS} \leq V_{SAT}$.

$$I_{DS} = \frac{\beta_0 \left(V_{GST} - \frac{a}{2} V_{DS} \right) V_{DS}}{[1 + U_a V_{GST} + U_b V_{GST}^2 + U_{1S} V_{DS}]}$$

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 222.

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	<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> (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 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 μ m` Length dependence of `vfb`.

4 `wvfb=0 V μ m` Width dependence of `vfb`.

5 `pvfb=0 V μ m` Width-length dependence of `vfb`.

6 `phi0=0.75 V` Surface potential.

7 `lphi=0 V μ m` Length dependence of `phi`.

8 `wphi=0 V μ m` Width dependence of `phi`.

9 `pphi=0 V μ m` Width-length dependence of `phi`.

10 `k1=0.7 \sqrt{V}` Body-effect coefficient.

11 `lk1=0 \sqrt{V} μ m` Length dependence of `k1`.

12 `wk1=0 \sqrt{V} μ m` Width dependence of `k1`.

13 `pk1=0 \sqrt{V} μ m` Width-length dependence of `k1`.

14 `k2=0` Charge-sharing parameter.

15 `lk2=0 μ m` Length dependence of `k2`.

16 `wk2=0 μ m` Width dependence of `k2`.

17 `pk2=0 μ m` 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 | $\eta ab=0$ $1/\text{V}$ | Body-bias dependence of $\eta a0$. |
| 23 | $l\eta ab=0$ $\mu\text{m}/\text{V}$ | Length dependence of ηab . |
| 24 | $w\eta ab=0$ $\mu\text{m}/\text{V}$ | Width dependence of ηab . |
| 25 | $p\eta ab=0$ $\mu\text{m}/\text{V}$ | Width-length dependence of ηab . |

Mobility parameters

- | | | |
|----|--|--------------------------------------|
| 26 | $\mu 0=400$ $\text{cm}^2/\text{V s}$ | Low-field mobility. |
| 27 | $l\mu 0=0$ $\text{cm}^2/\text{V s}$ | Length dependence of $\mu 0$. |
| 28 | $w\mu 0=0$ $\text{cm}^2/\text{V s}$ | Width dependence of $\mu 0$. |
| 29 | $p\mu 0=0$ $\text{cm}^2/\text{V s}$ | Width-length dependence of $\mu 0$. |
| 30 | $\mu 0b=0$ $\text{cm}^2/\text{V}^2 \text{ s}$ | Body-bias dependence of μz . |
| 31 | $l\mu 0b=0$ $\text{cm}^2 \mu\text{m}/\text{V}^2 \text{ s}$ | Length dependence of $x2mz$. |
| 32 | $w\mu 0b=0$ $\text{cm}^2 \mu\text{m}/\text{V}^2 \text{ s}$ | Width dependence of $x2mz$. |
| 33 | $p\mu 0b=0$ $\text{cm}^2 \mu\text{m}/\text{V}^2 \text{ s}$ | Width-length dependence of $x2mz$. |
| 34 | $\mu s0=450$ $\text{cm}^2/\text{V s}$ | Mobility in the saturation region. |
| 35 | $l\mu s0=0$ $\text{cm}^2 \mu\text{m}/\text{V s}$ | Length dependence of $\mu s0$. |
| 36 | $w\mu s0=0$ $\text{cm}^2 \mu\text{m}/\text{V s}$ | Width dependence of $\mu s0$. |

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BSIM2 Level-5 Model (bsim2)

37	$p_{\mu s0}=0$	$\text{cm}^2 \mu\text{m}/\text{V} \text{ s}$	Width-length dependence of μ_{s0} .
38	$\mu_{sb}=0$	$\text{cm}^2/\text{V}^2 \text{ s}$	Body-bias dependence of μ_{s0} .
39	$l_{\mu sb}=0$	$\text{cm}^2 \mu\text{m}/\text{V}^2 \text{ s}$	Length dependence of μ_{s0} .
40	$w_{\mu sb}=0$	$\text{cm}^2 \mu\text{m}/\text{V}^2 \text{ s}$	Length dependence of μ_{s0} .
41	$p_{\mu sb}=0$	$\text{cm}^2 \mu\text{m}/\text{V}^2 \text{ s}$	Length dependence of μ_{s0} .
42	$\mu_{20}=1$		Empirical channel length modulation parameter.
43	$l_{\mu 20}=0$	μm	Length dependence of μ_{20} .
44	$w_{\mu 20}=0$	μm	Width dependence of μ_{20} .
45	$p_{\mu 20}=0$	μm	Width-length dependence of μ_{20} .
46	$\mu_{2b}=0$	$1/\text{V}$	Body-bias dependence of μ_{20} .
47	$l_{\mu 2b}=0$	$\mu\text{m}/\text{V}$	Length dependence of μ_{2b} .
48	$w_{\mu 2b}=0$	$\mu\text{m}/\text{V}$	Width dependence of μ_{2b} .
49	$p_{\mu 2b}=0$	$\mu\text{m}/\text{V}$	Width-length dependence of μ_{2b} .
50	$\mu_{2g}=0$	$1/\text{V}$	Gate-bias dependence of μ_{20} .
51	$l_{\mu 2g}=0$	$\mu\text{m}/\text{V}$	Length dependence of μ_{2g} .
52	$w_{\mu 2g}=0$	$\mu\text{m}/\text{V}$	Width dependence of μ_{2g} .
53	$p_{\mu 2g}=0$	$\mu\text{m}/\text{V}$	Width-length dependence of μ_{2g} .
54	$\mu_{30}=5$	$\text{cm}^2/\text{V}^2 \text{ s}$	Empirical output resistance parameter.
55	$l_{\mu 30}=0$	$\text{cm}^2 \mu\text{m}/\text{V}^2 \text{ s}$	Length dependence of μ_{30} .

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BSIM2 Level-5 Model (bsim2)

- 56 $w\mu_{30}=0$ $\text{cm}^2 \mu\text{m}/\text{V}^2 \text{ s}$ Width dependence of μ_{30} .
- 57 $p\mu_{30}=0$ $\text{cm}^2 \mu\text{m}/\text{V}^2 \text{ s}$ Width-length dependence of μ_{30} .
- 58 $\mu_{3b}=0$ $\text{cm}^2/\text{V}^3 \text{ s}$ Body-bias dependence of μ_{30} .
- 59 $l\mu_{3b}=0$ $\text{cm}^2 \mu\text{m}/\text{V}^3 \text{ s}$ Length dependence of μ_{3b} .
- 60 $w\mu_{3b}=0$ $\text{cm}^2 \mu\text{m}/\text{V}^3 \text{ s}$ Width dependence of μ_{3b} .
- 61 $p\mu_{3b}=0$ $\text{cm}^2 \mu\text{m}/\text{V}^3 \text{ s}$ Width-length dependence of μ_{3b} .
- 62 $\mu_{3g}=0$ $\text{cm}^2/\text{V}^3 \text{ s}$ Gate-bias dependence of μ_{30} .
- 63 $l\mu_{3g}=0$ $\text{cm}^2 \mu\text{m}/\text{V}^3 \text{ s}$ Length dependence of μ_{3g} .
- 64 $w\mu_{3g}=0$ $\text{cm}^2 \mu\text{m}/\text{V}^3 \text{ s}$ Width dependence of μ_{3g} .
- 65 $p\mu_{3g}=0$ $\text{cm}^2 \mu\text{m}/\text{V}^3 \text{ s}$ Width-length dependence of μ_{3g} .
- 66 $\mu_{40}=0$ $\text{cm}^2/\text{V}^3 \text{ s}$ Empirical output resistance parameter.
- 67 $l\mu_{40}=0$ $\text{cm}^2 \mu\text{m}/\text{V}^3 \text{ s}$ Length dependence of μ_{40} .
- 68 $w\mu_{40}=0$ $\text{cm}^2 \mu\text{m}/\text{V}^3 \text{ s}$ Width dependence of μ_{40} .
- 69 $p\mu_{40}=0$ $\text{cm}^2 \mu\text{m}/\text{V}^3 \text{ s}$ Width-length dependence of μ_{40} .
- 70 $\mu_{4b}=0$ $\text{cm}^2/\text{V}^3 \text{ s}$ Empirical output resistance parameter.
- 71 $l\mu_{4b}=0$ $\text{cm}^2 \mu\text{m}/\text{V}^3 \text{ s}$ 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 $u_{l0=0} \text{ } 1/V$ 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 $vghigh$.
149	$wvghigh=0$	$V \mu m$	Width dependence of $vghigh$.
150	$pvghigh=0$	$V \mu m$	Width-length dependence of $vghigh$.

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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	t_{emp} (C)	Parameters measurement temperature. Default set by options.
162	$t_{rise} = 0$ C	Temperature rise from ambient.
163	$t_{empmod} = 432$	Temperature model selector.
164	$version = 432$	Version selector.
165	$u_{to} = 0$ C	Mobility temperature offset.
166	$u_{te} = -1.5$	Mobility temperature exponent.
167	$t_{lev} = 0$	DC temperature selector.
168	$t_{levc} = 0$	AC temperature selector.
169	$p_{tc} = 0$ V/C	Surface potential temperature coefficient.

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BSIM2 Level-5 Model (bsim2)

170	$eg=1.12452$	V	Energy band gap.
171	$gap1=7.02e-4$	V/C ²	Band gap temperature coefficient.
172	$gap2=1108$	K	Band gap temperature offset.
173	$trs=0$	1/C	Temperature coefficient for source resistance.
174	$trd=0$	1/C	Temperature coefficient for drain resistance.
175	$x_{ti}=3$		Saturation current temperature exponent.

Overlap capacitance parameters

176	$cgso=0$	F/m	Gate-source overlap capacitance.
177	$cgdo=0$	F/m	Gate-drain overlap capacitance.
178	$cgbo=0$	F/m	Gate-bulk overlap capacitance.
179	$meto=0$	m	Metal overlap in fringing field.

Charge model selection parameters

180	$capmod=bsim$		Intrinsic charge model. Possible values are <code>none</code> , <code>meyer</code> , <code>yang</code> , or <code>bsim</code> .
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	$rs=0$	Ω	Source resistance.
184	$rd=0$	Ω	Drain resistance.
185	$rsh=0$	Ω/sqr	Source/drain diffusion sheet resistance.

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BSIM2 Level-5 Model (bsim2)

186	$r_{sc}=0$	Ω	Source contact resistance.
187	$r_{dc}=0$	Ω	Drain contact resistance.
188	$r_{ss}=0$	Ω m	Scalable source resistance.
189	$r_{dd}=0$	Ω m	Scalable drain resistance.
190	$minr=0.1$	Ω	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 <i>no</i> or <i>yes</i> .
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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BSIM2 Level-5 Model (bsim2)

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	$a_s=0$ m ²	Area of source diffusion.
224	$a_d=0$ m ²	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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BSIM2 Level-5 Model (bsim2)

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} .

Virtuoso Simulator Components and Device Models Reference

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	wulb	M-100
isnoisy	I-15	mu20	M-42	temp	M-161	wuld	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

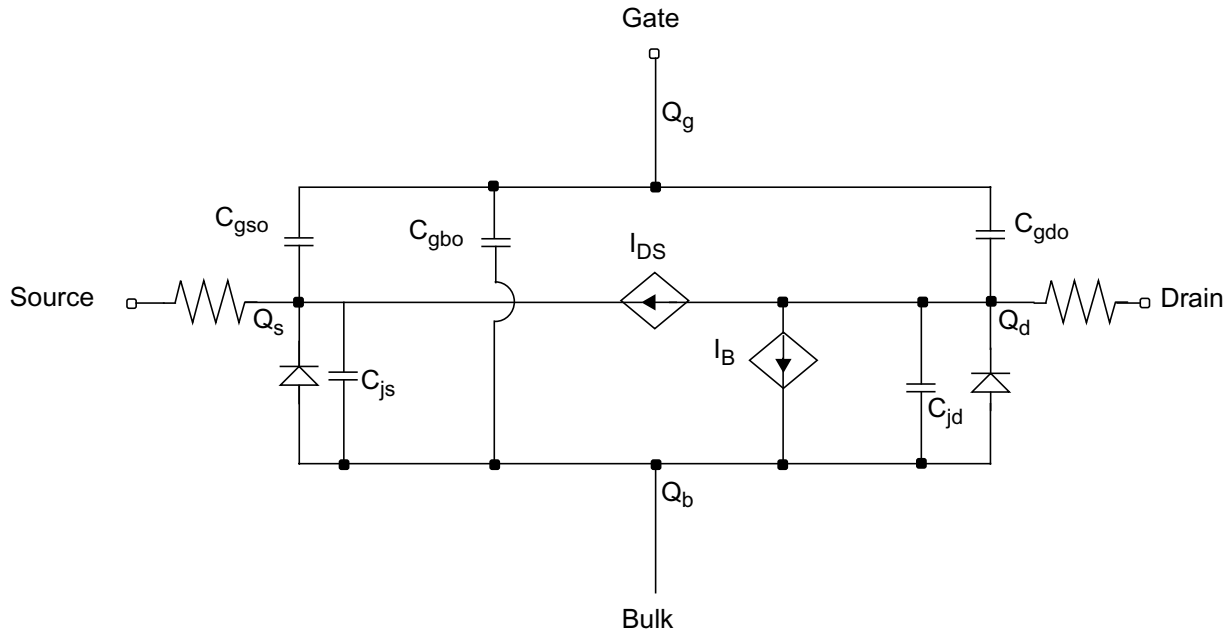
BSIM2 Level-5 Model (bsim2)

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	xl	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 1090
- [Subthreshold Current](#) on page 1091
- [Drain Saturation Voltage](#) on page 1093
- [Drain Current for the Triode Region](#) on page 1094
- [Drain Current for the Saturation Region](#) on page 1095
- [Default Model Parameter Value Calculation](#) on page 1096
- [Scaling Effects](#) on page 1099
- [New Features in BSIM3 Version 3.2.4](#) on page 1099
- [Component Statements](#) on page 1099



Threshold Voltage

$$V_{TH} = vtho + k1(\sqrt{phi - V_{BS}} - \sqrt{phi}) - k2 * V_{BS} - \Delta V_{TH} +$$

$$k1 \left[\sqrt{1 + \frac{nlx}{L_{eff}} \sqrt{\frac{phi}{phi - V_{BS}}}} - 1 \right] \sqrt{phi} + \frac{k3 * tox * phi}{W_{eff} + w0} + (kt1 + kt2 V_{BS}) \left(\frac{T}{tnom} - 1 \right)$$

where

$$\Delta V_{TH} = \theta(vbi - phi)$$

$$\theta = dvt0 * \theta_0$$

$$\theta_0 = e^{-dvt1 * L_{eff} / 2l_0} + 2e^{-dvt1 * L_{eff} / l_0}$$

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

$$I_{subth} = \frac{I_{exp} I_{limit}}{I_{exp} + I_{limit}} (1 - e^{-V_{DS}/V_{tm}})$$

where

$$I_{limit} = 4.5\beta_0 V_{tm}^2$$

$$I_{exp} = \beta_{subth} V_{tm}^2 e^{(V'_{GST}/nV_{tm})}$$

$$V'_{GST} = V_{GST} - v_{off} + V_{dibl}$$

$$V_{dibl} = (\eta_{a0} + \eta_{ab} * V_{BS}) * \theta_d * V_{DS}$$

Virtuoso Simulator Components and Device Models Reference
BSIM3v2 Level-10 Model (bsim3)

$$\theta_d = pdibl1[e^{-droul*L_{eff}/2l_{00}} + 2e^{-droul*L_{eff}/l_{00}}]$$

$$l_{00} = \sqrt{\frac{\epsilon_{si}toxX_{dep0}}{\epsilon_{ox}}}$$

$$X_{dep0} = \sqrt{\frac{2\epsilon_{si}phi}{q* npeak}}$$

$$V_{GST} = V_{GS} - V_{TH}$$

$$\beta_{subth} = \frac{uoC_{d0}W_{eff}}{L_{eff}}$$

$$n = 1 + \frac{C_d}{C_{ox}}nfactor + \frac{(cdsc + cdsc1*V_{BS})}{C_{ox}}\theta_0 + \frac{C_{it}}{C_{ox}}$$

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

$$R_{ds} = rds0 + \frac{rds0 * 10^{-6}}{W_{eff}}$$

$$E_{SAT} = \frac{2vsat}{\mu_{eff}}$$

$$\mu_{eff} = \frac{uo}{U_{vert}}$$

$$U_{vert} = 1 + ua \left(\frac{V_{GS} + V_{TH}}{tox} \right) + ub \left(\frac{V_{GS} + V_{TH}}{tox} \right)^2 + uc * V_{BS}$$

If $keta = 0$,

$$A_{bulk} = 1 + \frac{k1*a0*L_{eff}}{2(L_{eff} + 2\sqrt{xjX_{dep}})\sqrt{phi} - V_{BS}}$$

otherwise,

$$A_{bulk} = \left(1 + \frac{k1*a0*L_{eff}}{2(L_{eff} + 2\sqrt{xjX_{dep}})\sqrt{phi}} \right) \frac{1}{1 + keta*V_{BS}/L_{eff}}$$

$$C_A = A_{bulk}^2 R_{vcw}$$

$$C_B = V_{GST} + A_{bulk} E_{SAT} L_{eff} + 3A_{bulk} R_{vcw} V_{GST}$$

$$C_C = E_{SAT} L_{eff} V_{GST} + 2R_{vcw} V_{GST}^2$$

$$R_{vcw} = V_{SAT} * R_{ds} C_{ox} W_{eff}$$

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 13, "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)

$$k2 = \frac{(\text{gamma}2 - \text{gamma}1)(\sqrt{\text{phi}} - v_{bx} - \sqrt{\text{phi}})}{2\sqrt{\text{phi}}(\sqrt{\text{phi}} - v_{bm} - \sqrt{\text{phi}}) + v_{bm}}$$

- 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

$$v_{fb} = v_{tho} - \text{phi} - k1\sqrt{\text{phi}} + k2*\text{phi}$$

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

$$V_{bx} = \text{phi} - \frac{q*n_{peak}*x_t^2}{2\epsilon_{si}}$$

- 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

$$V_{ghigh} = n0V_{tm} \left[\ln \left(\frac{10C_{ox}}{C_d} \right) + 3 \right]$$

where

$$C_d = \sqrt{\frac{q\epsilon_{si}n_{peak}}{2\phi}}$$

- If V_{glow} is not given, it is calculated from

$$V_{glow} = v_{off} + n0V_{tm} \ln \left(\frac{C_{ox}}{10C_d} \right) - \theta * v_{dd}$$

- 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 222.

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 `lit1 (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 $n_{sub}=2e15$ cm^{-3} Substrate doping concentration.
- 27 $n_{peak}=1.7e17$ cm^{-3} Peak channel doping concentration.
- 28 n_{gate} (cm^{-3}) Poly-gate doping concentration.
- 29 $x_j=0.15e-6$ m Source/drain junction depth.
- 30 $d_l=0$ m Lateral diffusion for one side.
- 31 $d_w=0$ m Width reduction for one side.
- 32 $t_{ox}=1.5e-8$ m Gate oxide thickness.
- 33 $v_{dd}=5$ V Maximum drain voltage.
- 34 $x_t=1.55e-7$ m Doping depth.
- 35 $l_{dd}=0$ m Total length of lightly doped drain region.
- 36 $r_{ds0}=0$ Ω Total drain-source resistance.
- 37 $r_{dsw}=0$ 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.

Virtuoso Simulator Components and Device Models Reference

BSIM3v2 Level-10 Model (bsim3)

56	$v_{\text{ghigh}}=0.12 \text{ V}$	Upper bound of transition region.
57	$v_{\text{glow}}=-0.12 \text{ V}$	Lower bound of transition region.
58	$c_{\text{dsc}}=2.4\text{e-}4 \text{ F/m}^2$	Source/drain and channel coupling capacitance.
59	$c_{\text{dscb}}=0 \text{ F/m}^2 \text{ V}$	Body-bias dependence of c_{dsc} .
60	$n_{\text{factor}}=1$	Subthreshold swing coefficient.
61	$c_{\text{it}}=0 \text{ F}$	Interface trap parameter for subthreshold swing.
62	$v_{\text{off}}=-0.11 \text{ V}$	Threshold voltage offset.
63	$d_{\text{sub}}=d_{\text{rout}}$	DIBL effect in subthreshold region.
64	$\eta_{\text{a0}}=0.08$	DIBL coefficient subthreshold region.
65	$\eta_{\text{ab}}=-0.07 \text{ 1/V}$	Body-bias dependence of η_{a0} .

Parasitic resistance parameters

66	$r_{\text{sh}}=0 \text{ } \Omega/\text{sqr}$	Source/drain diffusion sheet resistance.
67	$r_{\text{s}}=0 \text{ } \Omega$	Source resistance.
68	$r_{\text{d}}=0 \text{ } \Omega$	Drain resistance.
69	$l_{\text{gcs}}=0 \text{ m}$	Gate-to-contact length of source side.
70	$l_{\text{gcd}}=0 \text{ m}$	Gate-to-contact length of drain side.
71	$r_{\text{sc}}=0 \text{ } \Omega$	Source contact resistance.
72	$r_{\text{dc}}=0 \text{ } \Omega$	Drain contact resistance.
73	$r_{\text{ss}}=0 \text{ } \Omega \text{ m}$	Scalable source resistance.
74	$r_{\text{dd}}=0 \text{ } \Omega \text{ m}$	Scalable drain resistance.
75	$s_{\text{c}}=\infty \text{ m}$	Spacing between contacts.
76	$l_{\text{dif}}=0 \text{ m}$	Lateral diffusion beyond the gate.

Virtuoso Simulator Components and Device Models Reference

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/m^2) 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/m^2 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/m^2 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 $as=0$ m² Default area of source diffusion.
- 105 $ad=0$ m² Default area of drain diffusion.
- 106 $ps=0$ m Default perimeter of source diffusion.
- 107 $pd=0$ 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

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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/I _{ds} .

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

Virtuoso Simulator Components and Device Models Reference

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		

Virtuoso Simulator Components and Device Models Reference
BSIM3v2 Level-10 Model (bsim3)

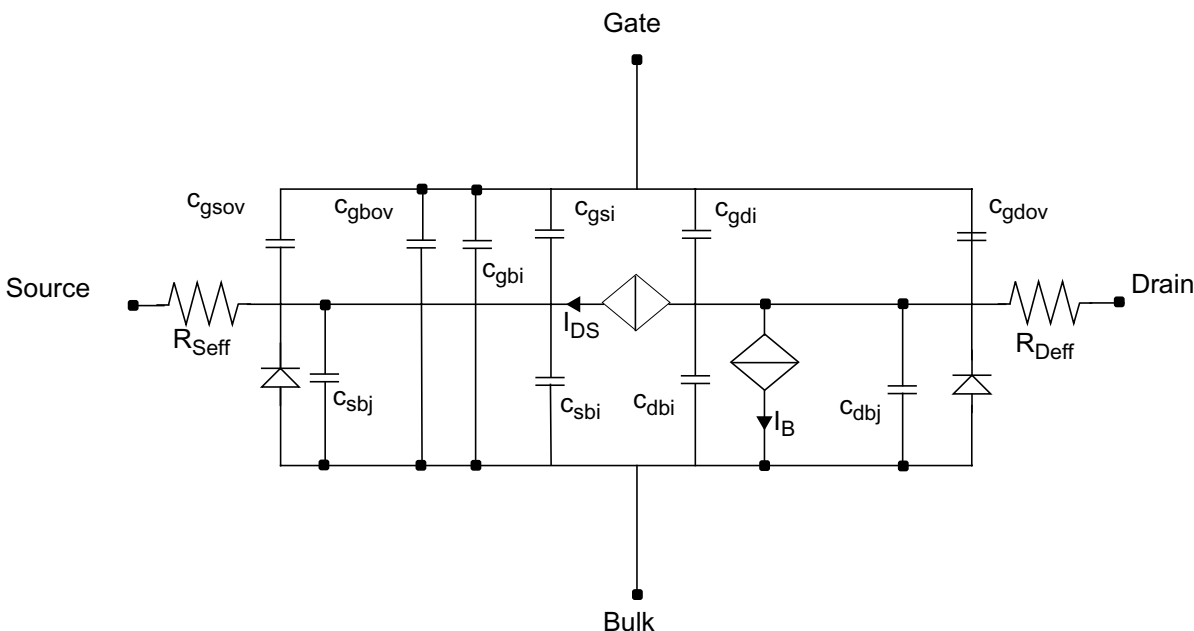
BSIM3v3 Level-11 Model (bsim3v3)

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. This chapter the following information for the BSIM3 model version 3.1, 3.2, 3.2.1, and 3.2.2:

- [Spectre-Specific Parameters](#) on page 1118
- [I-V Model](#) on page 1123
- [Capacitance Model](#) on page 1130
- [Nonquasi-static \(NQS\) Model](#) on page 1149
- [SPICE3 Junction Diode Model](#) on page 1150
- [Flicker Noise](#) on page 1150
- [Channel Thermal Noise](#) on page 1152
- [Default Model Parameter Value Calculation](#) on page 1153
- [Gate Leak Currents](#) on page 1155
- [LOD Model](#) on page 1159
- [Differences between BSIM3v3 Subversions](#) on page 1162
- [Parameter Differences between BSIM3v3 Levels](#) on page 1164
- [Scaling Effects](#) on page 1166
- [Component Statements](#) on page 1167
- [Binning Parameters](#) on page 1200

Virtuoso Simulator Components and Device Models Reference

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.

Virtuoso Simulator Components and Device Models Reference

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 <code>diomod=1</code> (default value), the Spectre junction model is used. The equations are described in Chapter 13, "Common MOSFET Equations" . If <code>diomod=0</code> , 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 $0.1 \cdot i_{abstol}$.
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:

Virtuoso Simulator Components and Device Models Reference
BSIM3v3 Level-11 Model (bsim3v3)

$$\text{Drain area} = \begin{cases} ad & \text{if } ad \text{ is given} \\ 2hdif * scalem * W_{scaled} & \text{if } hdif \text{ is given} \\ W_{eff} * ld & \text{if } ld \text{ is given} \\ 0 & \text{otherwise} \end{cases}$$

$$\text{Source area} = \begin{cases} ds & \text{if } ds \text{ is given} \\ 2hdif * scalem * W_{scaled} & \text{if } hdif \text{ is given} \\ W_{eff} * ls & \text{if } ls \text{ is given} \\ 0 & \text{otherwise} \end{cases}$$

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 Perimeters

The drain and source perimeters are calculated in the order shown in the following equations:

$$\text{Drain perimeter} = \begin{cases} pd & \text{if } pd \text{ is given} \\ 4hdif * scalem + 2W_{scaled} & \text{if } hdif \text{ is given} \\ W_{eff} + 2ld & \text{if } ld \text{ is given} \\ 0 & \text{otherwise} \end{cases}$$

$$\text{Source perimeter} = \begin{cases} p_s & \text{if } p_s \text{ is given} \\ 4hdif * scalem + 2W_{scaled} & \text{if } hdif \text{ is given} \\ W_{eff} + 2ls & \text{if } ls \text{ is given} \\ 0 & \text{otherwise} \end{cases}$$

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} .

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

$$l_t = \sqrt{\epsilon_{si} X_{dep} / C_{ox}} (1 + D_{vt2} V_{bseff})$$

$$l_{tw} = \sqrt{\epsilon_{si} X_{dep} / C_{ox}} (1 + D_{vt2w} V_{bseff})$$

$$l_{to} = \sqrt{\epsilon_{si} X_{dep0} / C_{ox}}$$

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$$X_{dep} = \sqrt{\frac{2\epsilon_{si}(\Phi_s - V_{bseff})}{qN_{ch}}}$$

$$X_{dep0} = \sqrt{\frac{2\epsilon_{si}\Phi_s}{qN_{ch}}}$$

$$V_{bseff} = V_{bc} + 0.5 \left[V_{bs} - V_{bc} - \delta_1 + \sqrt{(V_{bs} - V_{bc} - \delta_1)^2 - 4\delta_1 V_{bc}} \right]$$

($\delta_1 = 0.001$)

$$V_{bc} = 0.9 \left(\Phi_s - \frac{K_1^2}{4K_2} \right)$$

$$V_{bi} = V_t \times \ln \left[\frac{N_{ch} N_{DS}}{n_i^2} \right]$$

$$N_{DS} = 10^{20}, V_t = \frac{kT}{q}, \text{ the thermal voltage}$$

Effective Vgs-Vthc

$$V_{gsteff} = \frac{2nv_t \ln \left[1 + \exp \left(\frac{V_{gs} - V_{th}}{2nv_t} \right) \right]}{1 + 2nC_{ox} \sqrt{\frac{2\Phi_s}{q\epsilon_{si}N_{ch}}} \exp \left(-\frac{V_{gs} - V_{th} - 2V_{off}}{2nv_t} \right)}$$

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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 $\lambda = 1$,

$$V_{DSAT} = \frac{E_{sat}L_{eff}(V_{gsteff} + 2v_t)}{A_{bulk}E_{sat}L_{eff} + (V_{gsteff} + 2v_t)}$$

$$A_{bulk} = \left(1 + \frac{K_1}{2\sqrt{\Phi_s - V_{bseff}}}\left\{\frac{A_o L_{eff}}{L_{eff} + 2\sqrt{X_j X_{dep}}}\left[1 - A_{gs} V_{gsteff}\right.\right.\right. \\ \left.\left.\left.\left(\frac{L_{eff}}{L_{eff} + 2\sqrt{X_j X_{dep}}}\right)^2\right] \frac{B_o}{W_{eff} f^{\beta} B_1}\right\}\right) \frac{1}{1 + K_{eta} V_{bseff}}$$

$$E_{sat} = \frac{2v_{sat}}{\mu_{eff}}$$

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

$$I_{DS} = \frac{I_{dso}(V_{dseff})}{1 + \frac{R_{ds} I_{dso}(V_{dseff})}{V_{dseff}}} \left(1 + \frac{V_{ds} - V_{dseff}}{V_a} \right) \left(1 + \frac{V_{ds} - V_{dseff}}{V_{ascbe}} \right)$$

$$I_{dso} = I_{dso} = \frac{W_{eff} \mu_{eff} C_{ox} V_{gsteff} \left(1 - A_{bulk} \frac{V_{dseff}}{2(V_{gsteff} + 2v_t)} \right) V_{dseff}}{L_{eff} [1 + V_{dseff}/(E_{sat} L_{eff})]}$$

$$V_a = V_{asat} + \left(1 + \frac{P_{vag} V_{gsteff}}{E_{sat} L_{eff}} \right) \left(\frac{1}{V_{aclm}} + \frac{1}{V_{adiblc}} \right)^{-1}$$

$$V_{aclm} = \frac{A_{bulk} E_{sat} L_{eff} + V_{gsteff}}{P_{clm} A_{bulk} E_{sat} L_{itl}} (V_{ds} - V_{dseff})$$

$$V_{adiblc} = \frac{(V_{gsteff} + 2v_t)}{\theta_{rout} (1 + P_{diblc} V_{bseff})} \left(1 - \frac{A_{bulk} V_{dsat}}{A_{bulk} V_{dsat} + V_{gsteff} + 2v_t} \right)$$

$$\theta_{rout} = P_{diblc1} \left[\exp\left(-D_{rout} \frac{L_{eff}}{2l_{t0}}\right) + 2 \exp\left(-D_{rout} \frac{L_{eff}}{l_{t0}}\right) \right] + P_{diblc2}$$

$$\frac{1}{V_{ascbe}} = \frac{P_{scbe2}}{L_{eff}} \exp\left(\frac{-P_{scbe1} L_{itl}}{V_{ds} - V_{dseff}}\right)$$

$$V_{asat} = \frac{E_{sat} L_{eff} + V_{dsat} + 2R_{ds} v_{sat} C_{ox} W_{eff} V_{gsteff} \left[1 - \frac{A_{bulk} V_{dsat}}{2(V_{gsteff} + 2v_t)} \right]}{2/\lambda - 1 + R_{ds} v_{sat} C_{ox} W_{eff} A_{bulk}}$$

$$L_{itl} = \sqrt{\frac{\epsilon_{si} T_{ox} X_j}{\epsilon_{ox}}}$$

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

$$V_{poly} = \frac{1}{2} X_{poly} E_{poly} = \frac{q N_{gate} X_{poly}^2}{2 \epsilon_{si}}$$

$$\epsilon_{ox} E_{ox} = \epsilon_{si} E_{poly} = \sqrt{2q \epsilon_{si} N_{gate} V_{poly}}$$

$$V_{gs} - V_{fb} - \Phi_s = V_{poly} + V_{ox}$$

$$a(V_{gs} - V_{fb} - \Phi_s - V_{poly})^2 - V_{poly} = 0$$

$$a = \frac{\epsilon_{ox}^2}{2q\epsilon_{si}N_{gate}T_{ox}^2}$$

$$V_{gs_eff} = V_{fb} + \Phi_s + \frac{q\epsilon_{si}N_{gate}T_{ox}^2}{\epsilon_{ox}^2} \left(\sqrt{1 + \frac{2\epsilon_{ox}^2(V_{gs} - V_{FB} - \Phi_s)}{q\epsilon_{si}N_{gate}T_{ox}^2}} - 1 \right)$$

Effective Channel Length and Width

$$L_{eff} = L_{drawn} - 2dL$$

where

$$L_{drawn} = L(given) \times scale + xl \times scalem$$

$$W_{eff} = W_{drawn} - 2dW$$

$$W_{eff}' = W_{drawn} - 2dW'$$

$$dW = dW' + dW_g V_{gsteff} + dW_b (\sqrt{\Phi_s - V_{bseff}} - \sqrt{\Phi_s})$$

$$dW' = W_{int} + \frac{W_l}{L^{L_{ln}}} + \frac{W_w}{W^{L_{wn}}} + \frac{W_{wl}}{L^{L_{ln}} W^{L_{wn}}}$$

$$dL = L_{int} + \frac{L_l}{L^{L_{ln}}} + \frac{L_w}{W^{L_{wn}}} + \frac{L_{wl}}{L^{L_{ln}} W^{L_{wn}}}$$

$$W_{effc} = W_{drawn} - dWC$$

Drain/Source Resistance

$$R_{ds} = \frac{R_{dsw}[1 + P_{rwg}V_{gsteff} + P_{rwb}(\sqrt{\Phi_s - V_{bseff}} - \sqrt{\Phi_s})]}{(10^6 W_{eff'})^{Wr}}$$

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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$$\delta L_{eff} = D_{lc} + \frac{L_{lc}}{L_{ln}} + \frac{L_{wc}}{W_{wn}} + \frac{L_{wlc}}{L_{ln}W_{wn}}$$

$$W_{active} = W_{drawn} - 2\delta W_{eff}$$

$$\delta W_{eff} = D_{wc} + \frac{W_{lc}}{L_{ln}} + \frac{W_{wc}}{W_{wn}} + \frac{W_{wlc}}{L_{ln}W_{wn}}$$

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)

$$OverlapC_{gs} = \begin{cases} C_{gso} & \text{if } cgso \text{ is given} \\ (dlc + meto) \times C_{ox} - C_{gsl} & \text{if } dlc \text{ is given and } dlc > 0 \\ 0.6 \times X_j \times C_{ox} & \text{otherwise} \end{cases}$$

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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,

$$Q_{overlap, d} = \left[C_{gdo} V_{gd} + C_{gdl} \left\{ V_{gd} - V_{gd, overlap} + \frac{C_{kappa}}{2} \left(-1 + \sqrt{1 + \frac{4V_{gd, overlap}}{C_{kappa}}} \right) \right\} \right] W_{active}$$

$$V_{gd, overlap} = \frac{1}{2} \left\{ (V_{gd} + \delta_1) - \sqrt{(V_{gd} + \delta_1)^2 + 4\delta_1} \right\} \quad \text{where } \delta_1 = 0.02$$

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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$$Q_{inv} = -W_{active}L_{active}C_{ox} \left(V_{gs} - V_{th} - \frac{A_{bulk}' \times V_{ds}}{2} + \frac{A_{bulk}'^2 V_{ds}^2}{12 \left(V_{gs} - V_{th} + \frac{A_{bulk}'}{2} V_{ds} \right)} \right)$$

$$Q_b = W_{active}L_{active}C_{ox} \left[V_{fbcv} - V_{th} + \Phi_s + \frac{(1 - A_{bulk}')V_{ds}}{2} - \frac{(1 - A_{bulk}')A_{bulk}'V_{ds}^2}{12 \left(V_{gs} - V_{th} - \frac{A_{bulk}'}{2} V_{ds} \right)} \right]$$

$$Q_s = Q_d = 0.5Q_{inv}$$

$$0.5Q_{inv} = -W_{active}L_{active}C_{ox} \left[V_{gs} - V_{th} - \frac{A_{bulk}'}{2} V_{ds} + \frac{A_{bulk}'^2 V_{ds}^2}{12 \left(V_{gs} - V_{th} - \frac{A_{bulk}'}{2} V_{ds} \right)} \right]$$

otherwise,

$$Q_g = W_{active}L_{active}C_{ox} \left(V_{gs} - V_{fbcv} - \Phi_s - \frac{V_{dsat}}{3} \right)$$

$$Q_s = Q_d = -\frac{1}{3}W_{active}L_{active}C_{ox}(V_{gs} - V_{th})$$

$$Q_b = -W_{active}L_{active}C_{ox} \left(V_{fbcv} + \Phi_s - V_{th} + \frac{(1 - A_{bulk}')V_{dsat}}{3} \right)$$

40160 Channel-Charge Partition

If $V_{ds} < V_{dsat}$,

$$Q_g = C_{ox}W_{active}L_{active} \left[V_{gs} - V_{fbcv} - \Phi_s - \frac{V_{ds}}{2} + \frac{A_{bulk}'V_{ds}^2}{12 \left(V_{gs} - V_{th} - \frac{A_{bulk}'}{2} V_{ds} \right)} \right]$$

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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 $V_{ds} < V_{dsat}$,

$$Q_g = C_{ox} W_{active} L_{active} \left[V_{gs} - V_{fbcv} - \Phi_s - \frac{V_{ds}}{2} + \frac{A_{bulk}' V_{ds}^2}{12 \Delta \left(V_{gs} - V_{th} - \frac{A_{bulk}'}{2} V_{ds} \right)} \right]$$

$$Q_{inv} = -W_{active} L_{active} C_{ox} \left[V_{gs} - V_{th} - \frac{A_{bulk}' V_{ds}}{2} + \frac{A_{bulk}'^2 V_{ds}^2}{12 \left(V_{gs} - V_{th} - \frac{A_{bulk}'}{2} V_{ds} \right)} \right]$$

$$Q_b = W_{active} L_{active} C_{ox} \left[V_{fbcv} - V_{th} + \Phi_s + \frac{(1 - A_{bulk}') V_{ds}}{2} - \frac{(1 - A_{bulk}') A_{bulk}' V_{ds}^2}{12 \left(V_{gs} - V_{th} - \frac{A_{bulk}'}{2} V_{ds} \right)} \right]$$

$$Q_d = -W_{active} L_{active} C_{ox} \left[\frac{V_{gs} - V_{th}}{2} + \frac{A_{bulk}' V_{ds}}{4} - \frac{(A_{bulk}' V_{ds})^2}{24 \left(V_{gs} - V_{th} - \frac{A_{bulk}'}{2} V_{ds} \right)} \right]$$

$$Q_s = -(Q_g + Q_b + Q_d)$$

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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BSIM3v3 Level-11 Model (bsim3v3)

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

$$Q_{g1} = W_{active} L_{active} C_{ox} \frac{K_1^2}{2} \left(-1 + \sqrt{1 + \frac{4(V_{gs} - V_{FB} - V_{gsteffcv} - V_{bs})}{K_1^2}} \right)$$

$$Q_{b1} = -Q_{g1}$$

$$V_{fb} = \begin{cases} V_{th} - \Phi_s - K_1 \sqrt{\Phi_s} & \text{if version} \leq 3.1 \text{ and version} = 3.2.1 \\ V_{th}(V_{bs} = 0) - \Phi_s - K_1 \sqrt{\Phi_s} & \text{if version} = 3.2 \text{ and version} = 3.2.2 \end{cases}$$

$$V_{dsat, cv} = \frac{V_{gsteffcv}}{A_{bulk}'}$$

$$A_{bulk}' = \begin{cases} A_{bulk0} \left(1 + \left(\frac{C_{lc}}{L_{eff}} \right)^{C_{le}} \right) & \text{if version} \leq 3.1 \\ A_{bulk0} \left(1 + \left(\frac{C_{lc}}{L_{active}} \right)^{C_{le}} \right) & \text{if version} > 3.1 \end{cases}$$

$$A_{bulk0} = \left(1 + \frac{K_1}{2\sqrt{\Phi_s - V_{bseff}}} \left\{ \frac{A_0 L_{eff}}{L_{eff} + 2\sqrt{X_j X_{dep}}} + \frac{B_o}{W_{eff}' + B_1} \right\} \right) \frac{1}{1 + K_{eta} V_{bseff}}$$

$$V_{gsteffcv} = n \times N_{off} \times V_t \ln \left[1 + \exp \left(\frac{V_{gs} - V_{th} - V_{offcv}}{n \times N_{off} \times V_t} \right) \right]$$

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

$$Q_s = -W_{active} L_{active} C_{ox} \left(\frac{V_{gsteffcv}}{2} + \frac{A_{bulk}' V_{ds}}{4} - \frac{(A_{bulk}' V_{ds})^2}{24 \left(V_{gsteffcv} - \frac{A_{bulk}'}{2} V_{ds} \right)} \right)$$

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$$Q_d = -(Q_g + Q_b + Q_s)$$

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

$$Q_s = -W_{active} L_{active} C_{ox} \left(\frac{2V_{gstefcv}}{3} \right)$$

$$Q_d = -(Q_g + Q_b + Q_s)$$

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 $V_4 = V_{dsat, cv} - V_{ds} - \delta_4$; $\delta_4 = 0.02$

$$Q_{inv} = -W_{active} L_{active} C_{ox} \left(\left(V_{gsteffcv} - \frac{A_{bulk}'}{2} V_{cveff} \right) + \frac{A_{bulk}'^2 V_{cveff}^2}{12 \left(V_{gsteffcv} - \frac{A_{bulk}'}{2} V_{cveff} \right)} \right)$$

$$\delta Q_{sub} = W_{active} L_{active} C_{ox} \left(\frac{1 - A_{bulk}'}{2} V_{cveff} - \frac{(1 - A_{bulk}') A_{bulk}' V_{cveff}^2}{12 \left(V_{gsteffcv} - \frac{A_{bulk}'}{2} V_{cveff} \right)} \right)$$

50150 Charge Partition

$$Q_s = Q_d = 0.5 Q_{inv} =$$

$$(-1) \frac{W_{active} L_{active} C_{ox}}{2} \left(V_{gsteffcv} - \frac{A_{bulk}'}{2} V_{cveff} + \frac{A_{bulk}'^2 V_{cveff}^2}{12 \left(V_{gsteffcv} - \frac{A_{bulk}'}{2} V_{cveff} \right)} \right)$$

40160 Channel-Charge Partition

$$Q_s = \left(-\frac{W_{active} L_{active} C_{ox}}{2 \left(V_{gsteffcv} - \frac{A_{bulk}'}{2} V_{cveff} \right)^2} \right) \left(V_{gsteffcv}^3 - \frac{4}{3} V_{gsteffcv}^2 (A_{bulk}' V_{cveff}) \right. \\ \left. + \frac{2}{3} V_{gsteffcv} (A_{bulk}' V_{cveff})^2 - \frac{2}{15} (A_{bulk}' V_{cveff})^3 \right)$$

$$Q_d = \left(-\frac{W_{active} L_{active} C_{ox}}{2 \left(V_{gsteffcv} - \frac{A_{bulk}' V_{cveff}}{2} \right)^2} \right) \left(V_{gsteffcv}^3 - \frac{5}{3} V_{gsteffcv}^2 (A_{bulk}' V_{cveff}) + \right. \\ \left. V_{gsteffcv} (A_{bulk}' V_{cveff})^2 - \frac{1}{5} (A_{bulk}' V_{cveff})^3 \right)$$

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.

$$Q_g = -(Q_{inv} + Q_{acc} + Q_{sub0} + \delta Q_{sub})$$

$$Q_b = Q_{acc} + Q_{sub0} + \delta Q_{sub}$$

$$Q_{inv} = Q_d + Q_s$$

$$V_{FBeff} = V_{fb} - 0.5 \left(V_3 + \sqrt{V_3^2 + 4\delta_3 V_{fb}} \right)$$

where

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$$V_3 = V_{fb} - V_{gb} - \delta_3$$

$$\delta_3 = 0.02$$

$$V_{fb} = V_{th}(V_{bs} = 0) - \phi_s - K_1 \sqrt{\phi_s}$$

$$Q_{acc} = -W_{active} L_{active} C_{oxeff} (V_{fb} - V_{fb})$$

$$C_{oxeff} = \frac{C_{ox} C_{cen}}{C_{ox} + C_{cen}}$$

$$C_{ox} = \frac{E_{ox}}{t_{ox} - dt_{oxcv}}$$

$$C_{cen} = \frac{\epsilon_{si}}{T_{cen}}$$

$$T_{cen} = L_{deb} - 0.5 \times \left(T_3 + \sqrt{T_3^2 + 4 \times 10^{-3} L_{deb} T_{ox}} \right)$$

$$T_3 = L_{deb} \left\{ 1 - \exp \left[\frac{A_{cde} \times (V_{gs} - V_{bseff} - V_{fb})}{10^8 T_{ox}} \right] \right\} - 10^{-3} T_{ox}$$

$$Q_{sub} = -W_{active} L_{active} C_{oxeff} K_1 \left[\sqrt{\frac{K_1^2}{4} + V_{gs} - V_{fb} - V_{bseff} - V_{gsteffcv}} - \frac{K_1}{2} \right]$$

$$V_{gsteffcv} = nN_{off} V_t \ln \left[1 + \exp \left(\frac{V_{gs} - V_{th} - V_{offcv}}{nN_{off} V_t} \right) \right]$$

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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)

$$C_{(s,d,g,b),g} = \frac{\partial Q_{s,d,g,b}}{\partial V_{gsteffcv}} \frac{\partial V_{gsteffcv}}{\partial V_{gt}}$$

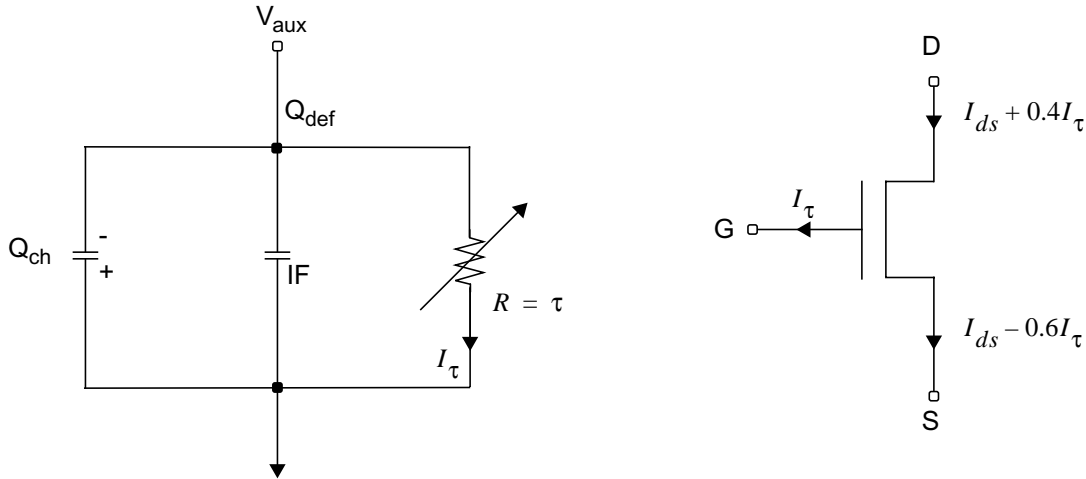
$$C_{(s,d,g,b),s} = -\frac{\partial Q_{s,d,g,b}}{\partial V_{ds}} + \frac{\partial Q_{s,d,g,b}}{\partial V_{gsteffcv}} \frac{\partial V_{gsteffcv}}{\partial V_{gt}} \left(\frac{\partial V_{th}}{\partial V_{ds}} + \frac{\partial V_{th}}{\partial V_{bs}} \right)$$

$$C_{(s,d,g,b),d} = \frac{\partial Q_{s,d,g,b}}{\partial V_{ds}} - \frac{\partial Q_{s,d,g,b}}{\partial (V_{gsteffcv})} \frac{\partial V_{gsteffcv}}{\partial V_{gt}} \frac{\partial V_{th}}{\partial V_{ds}}$$

$$C_{(s,d,g,b),b} = \frac{\partial Q_{s,d,g,b}}{\partial V_{bs}} - \frac{\partial Q_{s,d,g,b}}{\partial V_{gsteffcv}} \frac{\partial V_{gsteffcv}}{\partial V_{gt}} \frac{\partial V_{th}}{\partial V_{bs}}$$

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:

$$Q_{ch} = Q_{eq} - Q_{def}$$

$$g_\tau = \frac{1}{\tau} = \frac{1}{\tau_{drift}} + \frac{1}{\tau_{diff}}$$

$$\tau_{drift} = \frac{C_{ox} W_{eff} L_{eff}^3}{\mu_{eff} \epsilon |Q_{eq} - \alpha Q_{def}|} \approx \frac{\zeta}{|Q_{eq}|}$$

where

$\epsilon \equiv$ 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 [Chapter 13, “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.

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

$$FlickerNoise = \frac{K_f I_{ds}^{A_f}}{C_{ox} L_{eff}^2 f^{E_f}} \times (wnoi)/(weff)$$

otherwise

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BSIM3v3 Level-11 Model (bsim3v3)

$$FlickerNo = \frac{K_f I_{ds}^{A_f}}{C_{ox} L_{eff}^2 f^{E_f}}$$

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

$$N_l = \begin{cases} C_{ox} \left(\frac{V_{gs} - V_{th} - V_{ds}}{q} \right) & \text{if version} < 3.2.4 \\ \left(C_{OX} \cdot V_{gsteff} \cdot \left(1 - \frac{A_{bulk} V_{dseff}}{V_{gsteff} + 2V_t} \right) \right) / q & \text{if version} \geq 3.2.4 \end{cases}$$

$$V_{ds} = MIN(V_{ds}, V_{dsat})$$

ΔL_{CLM} refers to channel length reduction due to *CLM* and is given by

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$$\Delta L_{clm} = \begin{cases} L_{itl} \times \log \left(\frac{V_{ds} - V_{dsat} + E_m}{E_{sat}} \right) & \text{if } V_{DS} > V_{DSAT} \\ 0 & \text{otherwise} \end{cases}$$

$$E_{sat} = \frac{2 \times V_{sat}}{U_{eff}}$$

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

$$\overline{i_D^2} = \frac{8kT}{3} (g_m + g_{ds} + g_{mb})$$

For `noimod=2` and `4`,

$$\bar{i}_d = \frac{4kTu_{eff}}{L_{eff}^2 + u_{eff}|Q_{inv}| \cdot R_{ds}} |Q_{inv}| \quad \text{if version} = 3.2.4$$

$$\bar{i}_d = \left(\frac{4kTu_{eff}}{L_{eff}^2} \cdot |Q_{inv}| \right) \quad \text{if version} > \text{ or } < 3.2.4$$

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 1134.

Default Model Parameter Value Calculation

- If v_{tho} is not given, it is calculated from

$$v_{tho} = v_{fb} + \phi_{hi} + k1\sqrt{\phi_{hi}}$$

- If ϕ_{hi} is not given, it is calculated from

$$\phi_{hi} = 2V_{tm} \ln\left(\frac{n_{ch}}{n_i}\right)$$

where V_{tm} is the thermal voltage given by

$$V_{tm} = \frac{kT}{q}$$

$$n_i = 1.45 \times 10^{10} \left(\frac{T}{300}\right)^{1.5} \exp\left(21.5565981 - \frac{E_g(T)}{2V_{tm}}\right)$$

where $E_g(T)$ is the energy band gap at temperature T . The equation for E_g is shown in [Chapter 13, “Common MOSFET Equations”](#).

- If $k1$ is not given, it is calculated from

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$$k1 = \text{gamma}2 - 2k2\sqrt{\text{phi} - vbm}$$

- 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

$$V_{bx} = \text{phi} - \frac{q*nch*xl^2}{2\epsilon_{si}}$$

- If $cgso$ is not given, dlc is given, and $dlc > 0$

$$cgso = (dlc + meto) \times cox - cgsl$$

otherwise

$$cgso = 0.6 \times xj \times cox$$

- If $cgdo$ not given, dlc given, and $dlc > 0$

$$cgdo = (dlc + meto) \times cox - cgdl$$

otherwise

$$cgdo = 0.6 \times xj \times cox$$

Gate Leak Currents

This section describes the parameters and equations for gate leak currents.

Instance Parameters

Parameter	Description
$A_{forward}$	Forward gate leakage current coefficient. Default value is 0.0.
$A_{reverse}$	Reverse gate leakage current coefficient. Default value is 0.0.

If $A_{forward}$ and $A_{reverse}$ are both 0.0, gate leak current is also 0.0.

Model Parameters

Parameter	Description
$B_{forward}$	Forward gate leakage current coefficient in $\text{pow}()$. Default value is 0.0.
$B_{reverse}$	Reverse gate leakage current coefficient in $\text{pow}()$. Default value is 0.0.
$C_{forward}$	Forward gate leakage current coefficient in $\text{exp}()$. Default value is 0.0.
$C_{reverse}$	Reverse gate leakage current coefficient in $\text{exp}()$. Default value is 0.0.
T_{cc}	Gate leakage current temperature coefficient. Default value is 0.0.

Leak current between Gate and Drain

If $V_{gd} > 0$

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BSIM3v3 Level-11 Model (bsim3v3)

$$I_{gd} = A_{forward} \times (1.0 + T_{cc} \times (Temp - T_{nom})) \times pow(V_{gd}, B_{forward}) \times \exp(C_{forward} \times V_{gd})$$

If $V_{gd} < 0$

$$I_{gd} = -A_{reverse} \times (1.0 + T_{cc} \times (Temp - T_{nom})) \times pow(-V_{gd}, B_{reverse}) \times \exp(C_{reverse} \times V_{gd})$$

If $V_{gd} = 0$

$I_{gd} = 0.0$

Leak current between Gate and Source

- If $I_{gcModel} = 0$ and $I_{gbModel} = 0$,

If $V_{gs} > 0$

$$I_{gs} = A_{forward} \times (1.0 + T_{cc} \times (Temp - T_{nom})) \times pow(V_{gs}, B_{forward}) \times \exp(C_{forward} \times V_{gs})$$

If $V_{gs} < 0$

$$I_{gs} = -A_{reverse} \times (1.0 + T_{cc} \times (Temp - T_{nom})) \times pow(-V_{gs}, B_{reverse}) \times \exp(C_{reverse} \times V_{gs})$$

If $V_{gs} = 0$

$I_{gs} = 0.0$

- 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 $I_{gcMod} = 1$

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BSIM3v3 Level-11 Model (bsim3v3)

$$V_{aux} = N_{igc} \cdot vt \cdot \log\left(1 + \exp\left(\frac{V_{gse} - V_{th0}}{N_{igc} \cdot vt}\right)\right)$$

For $I_{gcmod}=2$

$$V_{aux} = N_{igc} \cdot vt \cdot \log\left(1 + \exp\left(\frac{V_{gse} - V_{th}}{N_{igc} \cdot vt}\right)\right)$$

$$T_{oxratio} = \left(\frac{T_{oxref}}{T_{oxe}}\right)^{N_{tox}} \frac{1}{T_{oxe}^2}$$

$$V_{oxdepinv} = K1_{ox} \sqrt{\phi_s} + V_{gsteff}$$

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

I_{gs} represents the gate tunneling current between the gate and source diffusion region, while I_{gd} represents the gate tunneling current between the gate and the drain diffusion region.

$$I_{gs} = W_{eff} D_{lcig} \cdot A_{echvb} \cdot T_{oxratioedge} V_{gs} V_{gs}' \exp(-B_{echvb} \cdot T_{oxe} \cdot P_{oxedge} \cdot (A_{igsd} - B_{igsd} \cdot V_{gs}'))$$

$$I_{gd} = W_{eff} D_{lcig} \cdot A_{echvb} \cdot T_{oxratioedge} V_{gd} V_{gd}' \exp(-B_{echvb} \cdot T_{oxe} \cdot P_{oxedge} \cdot (A_{igsd} - B_{igsd} \cdot V_{gd}'))$$

where

$$T_{oxratioedge} = \left(\frac{T_{oxref}}{T_{oxe} P_{oxedge}}\right) \frac{1}{(T_{oxe} P_{oxedge})^2}$$

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BSIM3v3 Level-11 Model (bsim3v3)

Igb

$$I_{gb} = I_{gbacc} + I_{gbinv}$$

I_{gbacc} is determined by ECB (Electronic tunneling from Conduction band) and is significant in accumulation and given by:

$$I_{gbacc} = W_{eff} L_{eff} A_{echve} \cdot T_{oxratio} V_{gb} V_{aux} \cdot \exp(-Bechvb \cdot Toxe(Aigbacc - Bigbacc \cdot V_{oxacc})(1 + Cigbac \cdot V_{oxacc}))$$

Where

$$V_{oxacc} = V_{fbsb} - V_{fbeff}$$

$$V_{fbsb} = V_{th} \Big|_{V_{bs} = V_{ds} = 0q} - \phi_s - K1 \sqrt{\phi_s}$$

$$V_{aux} = Nigbacc \cdot vt \cdot \log\left(1 + \exp\left(\frac{V_{gb} - V_{fbsb}}{Nigbacc \cdot vt}\right)\right)$$

I_{gbinv} is determined by EVB (Electron tunneling from valence band) and is significant in inversion and given by:

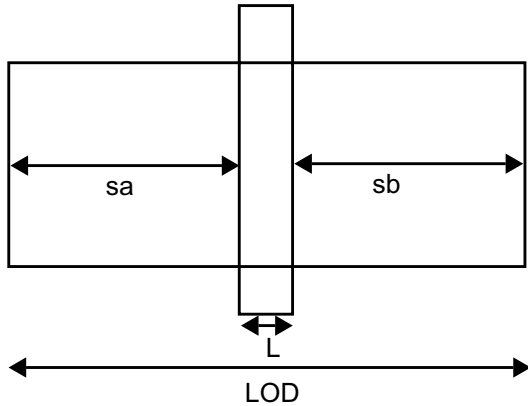
$$I_{gbinv} = W_{eff} L_{eff} A_{echve} \cdot T_{oxratio} V_{gb} V_{aux} \cdot \exp(-Bechvb \cdot Toxe(Aigbinv - Bigbinv \cdot V_{oxdepinv})(1 + Cigbinv \cdot V_{oxdepinv}))$$

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 .



$$\rho_{\mu_{eff}} = \frac{ku0}{Kstress_u0} \cdot (Inv_sa + Inv_sb)$$

$$Inv_sa = \frac{1}{SA + 0.5 \cdot L_{drawn}}$$

$$Inv_sb = \frac{1}{SB + 0.5 \cdot L_{drawn}}$$

$$Kstress_u0 = \left(1 + \frac{LKU0}{(L_{drawn} + XL)^{LLODKU0}} + \frac{WKU0}{(W_{drawn} + XW + WLOD)^{WLODKU0}} + \frac{PKU0}{(L_{drawn} + XL)^{LLODKU0} \cdot (W_{drawn} + XW + WLOD)^{WLODKU0}} \right) \times \left(1 + TKU0 \cdot \left(\frac{Temperature}{TNOM} - 1 \right) \right)$$

For irregular LOD device,

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$$\frac{1}{SA_{eff} + 0.5 \cdot L_{drawn}} = \sum_{i=1}^n \frac{SW_i}{W_{drawn}} \cdot \frac{1}{sa_i + 0.5 \cdot L_{drawn}}$$

$$\frac{1}{SB_{eff} + 0.5 \cdot L_{drawn}} = \sum_{i=1}^n \frac{SW_i}{W_{drawn}} \cdot \frac{1}{sb_i + 0.5 \cdot L_{drawn}}$$

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} .

$$K_{stress_vth0} = 1 + \frac{LKVTH0}{(L_{drawn} + XL)^{LLODKVTH}} + \frac{WKVTH0}{(W_{drawn} + XW + WLOD)^{WLODKVTH}}$$

$$+ \frac{PKVTH0}{(L_{drawn} + XL)^{LLODKVTH} \cdot (W_{drawn} + XW + WLOD)^{WLODKVTH}}$$

$$VTH0 = VTH0_{original} + \frac{KVTH0}{K_{stress_vth0}} \cdot (Inv_sa + Inv_sb - Inv_sa_{ref} - Inv_sb_{ref})$$

$$K2 = K2_{original} + \frac{STK2}{K_{stress_vth0}^{LODK2}} \cdot (Inv_sa + Inv_sb - Inv_sa_{ref} - Inv_sb_{ref})$$

$$ETA0 = ETA0_{original} + \frac{STETA0}{K_{stress_vth0}^{LODETO}} \cdot (Inv_sa + Inv_sb - Inv_sa_{ref} - Inv_sb_{ref})$$

Well Proximity Effect

$$Vth0 = Vth0_{org} + KVth0we \cdot (Sca + Web \cdot Scb + Wec \cdot Scc)$$

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$$K2 = K2_{org} + K2we \cdot (Sca + Web \cdot Scb + Wec \cdot Scc)$$

$$\mu_{eff} = \mu_{eff,org} \cdot (1 + Ku0we \cdot (Sca + Web \cdot Scb + Wec \cdot Scc))$$

SC is defined as the distance to a single we;; 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:

$$Sca = \frac{Scref^2}{W_{drawn}} \left(\frac{1}{Sc} - \frac{1}{Sc + W_{drawn}} \right)$$

$$Scb = \frac{1}{W_{drawn} Scref} \left(\begin{array}{l} \frac{Scref Sc \cdot \exp\left(-10 \frac{Sc}{Scref}\right) + \frac{Scref^2}{400} \exp\left(-10 \frac{Sc}{Scref}\right)}{10} \\ - \frac{Scref (Sc + W_{drawn}) \exp\left(-10 \frac{Sc + W_{drawn}}{Scref}\right)}{10} \\ - \frac{Scref^2}{400} \exp\left(-10 \frac{Sc + W_{drawn}}{Scref}\right) \end{array} \right)$$

$$Scc = \frac{1}{W_{drawn} Scref} \left(\begin{array}{l} \frac{Scref Sc \cdot \exp\left(-20 \frac{Sc}{Scref}\right) + \frac{Scref^2}{400} \exp\left(-20 \frac{Sc}{Scref}\right)}{20} \\ - \frac{Scref (Sc + W_{drawn}) \exp\left(-20 \frac{Sc + W_{drawn}}{Scref}\right)}{20} \\ - \frac{Scref^2}{400} \exp\left(-20 \frac{Sc + W_{drawn}}{Scref}\right) \end{array} \right)$$

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

$$V_{fb} = \begin{cases} V_{th} - \Phi_s - K_1 \sqrt{\Phi_s} & \text{if version } \leq 3.1 \text{ and version } = 3.2.1 \\ V_{th}(V_{bs} = 0) - \Phi_s - K_1 \sqrt{\Phi_s} & \text{if version } = 3.2 \text{ and version } = 3.2.2 \end{cases}$$

$$A_{bulk}' = \begin{cases} A_{bulk0} \left(1 + \left(\frac{C_{lc}}{L_{eff}} \right)^{C_{le}} \right) & \text{if version } \leq 3.1 \\ A_{bulk0} \left(1 + \left(\frac{C_{lc}}{L_{active}} \right)^{C_{le}} \right) & \text{if version } > 3.1 \end{cases}$$

capmod=2

$$V_{fb} = \begin{cases} V_{th} - \Phi_s - K_1 \sqrt{\Phi_s} & \text{if version } \leq 3.1 \text{ or version } = 3.2.1 \\ V_{th}(V_{bs} = 0) - \Phi_s - K_1 \sqrt{\Phi_s} & \text{otherwise} \end{cases}$$

$$A_{bulk}' = \begin{cases} A_{bulk0} \left(1 + \left(\frac{C_{lc}}{L_{eff}} \right)^{C_{le}} \right) & \text{if version } \leq 3.1 \\ A_{bulk0} \left(1 + \left(\frac{C_{lc}}{L_{active}} \right)^{C_{le}} \right) & \text{if version } > 3.1 \end{cases}$$

When **The equations are**

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

$$N_l = \begin{cases} C_{ox} \left(\frac{V_{gs} - V_{th} - V_{ds}}{q} \right) & \text{if version } < 3.2.4 \\ \left(C_{OX} \cdot V_{gsteff} \cdot \left(1 - \frac{A_{bulk} V_{dseff}}{V_{gsteff} + 2V_t} \right) \right) / q_0 & \text{if version } \geq 3.2.4 \end{cases}$$

3. Channel Thermal Noise

$$\overline{i_d^2} = \frac{4kTu_{eff}}{L_{eff}^2 + u_{eff} |Q_{inv}| \cdot R_{ds}} |Q_{inv}| \quad \text{if version } = 3.2.4$$

$$\overline{i_d^2} = \left(\frac{4kTu_{eff}}{L_{eff}^2} \cdot |Q_{inv}| \right) \quad \text{if version } < \text{ or } > 3.2.4$$

4. If vto is not given

$$vto = \begin{cases} -1.0 + Phi + K1 \times SqrtPhi + Delvto & \text{if version } \leq 3.1 \\ Vfb + Phi + K1 \times SqrtPhi + Delvto & \text{if version } > 3.1 \end{cases}$$

5. Overlap Capacitance

□ If OverlapCgs < 0

For BSIM3v3 version < 3.1

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$$OverlapCgs = 1.0e - 7 \times T_{ox}$$

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

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

Parameter Name	Default Value for each Level	Description
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.
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

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

Parameter Name	Default Value for each Level	Description
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

$$w = w \times scale$$

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 kl=0.823562
```

Instance Definition

```
Name d g s b ModelName parameter=value ...
```

Instance Parameters

- | | | |
|---|--------|--------------------------------|
| 1 | w () | Channel width. |
| 2 | l () | Channel length. |
| 3 | as () | Area of source diffusion. |
| 4 | ad () | Area of drain diffusion. |
| 5 | ps () | Perimeter of source diffusion. |
| 6 | pd () | Perimeter of drain diffusion. |

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

7	<code>nrd ()</code>	Number of squares of drain diffusion.
8	<code>nrs ()</code>	Number of squares of source diffusion.
9	<code>m=</code>	Multiplicity factor (number of MOSFETs in parallel).
10	<code>region=</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> .
11	<code>nqsmod</code>	NQS flag.
12	<code>acnqsmod</code>	AC NQS flag.
13	<code>isnoisy=</code>	Should device generate noise. Possible values are <code>no</code> or <code>yes</code> .
14	<code>trise</code>	Temperature rise from ambient.
15	<code>aforward=</code>	Forward gate leakage current coefficient.
16	<code>areverse=</code>	Reverse gate leakage current coefficient.
17	<code>delvto=</code>	shift in zero-bias threshold voltage <code>vth0</code> .
18	<code>mulmu0=</code>	mobility multiplier.
19	<code>mulu0=</code>	mobility multiplier.
20	<code>delk1=</code>	shift in body bias coefficient <code>k1</code> .
21	<code>delnfct=</code>	shift in subthreshold swing factor <code>nfactor</code> .
22	<code>geo=</code>	Geometry selector.
23	<code>rdc=</code>	Drain contact resistance.
24	<code>rsc=</code>	Source contact resistance.
25	<code>sa=</code>	Distance between OD edge to poly of one side.
26	<code>sb=</code>	Distance between OD edge to poly of the other side.

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

27	<code>stimod</code>	LOD stress effect model selector.
28	<code>sca=</code>	Integral of the first distribution function for scattered well dopant.
29	<code>sca=</code>	Integral of the second distribution function for scattered well dopant.
30	<code>scc=</code>	Integral of the third distribution function for scattered well dopant.
31	<code>sc=</code>	Distance to a single well edge .

Model Definition

`model modelName bsim3v3 parameter=value ...`

Model Parameters

Model Parameters

Device type parameters

1	<code>type=</code>	Transistor type. Possible values are n or p.
---	--------------------	---

Threshold voltage parameters

2	<code>vtho ()</code>	Threshold voltage at zero body bias for long-channel devices. For enhancement-mode devices, $vtho > 0$ for n-channel and $vth < 0$ for p-channel. Default value is calculated from other model parameters.
3	<code>vfb=</code>	Flat-band voltage.
4	<code>k1=</code>	Body-effect coefficient.
5	<code>k2=</code>	Charge-sharing parameter.
6	<code>k3=</code>	Narrow width coefficient.
7	<code>k3b=</code>	Narrow width coefficient.

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

8	w0=	Narrow width coefficient.
9	n1x=	Lateral nonuniform doping coefficient.
10	gamma1 ()	Body-effect coefficient near the surface.
11	gamma2 ()	Body-effect coefficient in the bulk.
12	vbx ()	Threshold voltage transition body voltage.
13	vbm=	Maximum applied body voltage.
14	dvt0=	First coefficient of short-channel effects.
15	dvt1=	Second coefficient of short-channel effects.
16	dvt2=	Body-bias coefficient of short-channel effects.
17	dvt0w=	First coefficient of narrow-width effects.
18	dvt1w=	Second coefficient of narrow-width effects.
19	dvt2w=	Body-bias coefficient of narrow-width effects.
20	a0=	Nonuniform depletion width effect coefficient.
21	b0=	Bulk charge coefficient due to narrow width effect.
22	b1=	Bulk charge coefficient due to narrow width effect.
23	a1=	No-saturation coefficient.
24	a2=	No-saturation coefficient.
25	ags=	Gate-bias dependence of A_{bulk} .
26	keta=	Body-bias coefficient for non-uniform depletion width effect.
27	vfbflag=	49 Vfb selector.

Process parameters

28	nsub=	Substrate doping concentration.
----	-------	---------------------------------

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

29	nch=	Peak channel doping concentration.
30	ngate=	Poly-gate doping concentration.
31	xj=	Source/drain junction depth.
32	lint=	Lateral diffusion for one side.
33	wint=	Width reduction for one side.
34	ll=	Length dependence of delta L.
35	lln=	Length exponent of delta L.
36	lw=	Width dependence of delta L.
37	lwn=	Width exponent of delta L.
38	lwl=	Area dependence of delta L.
39	wl=	Length dependence of delta W.
40	wln=	Length exponent of delta W.
41	ww=	Width dependence of delta W.
42	wwn=	Width exponent of delta W.
43	wwl=	Area dependence of delta W.
44	dwg=	Gate-bias dependence of channel width.
45	dwb=	Body-bias dependence of channel width.
46	tox=	Gate oxide thickness.
47	dtoxcv=	Delta oxide thickness.
48	toxm=	Tox at which parameters were extracted.
49	toxe=	Electrical gate equivalent oxide thickness.
50	xt=	Doping depth.

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

51	<code>rdsw=</code>	Width dependence of drain-source resistance.
52	<code>prwb=</code>	Body-effect coefficient for Rds.
53	<code>prwg=</code>	Gate-effect coefficient for Rds.
54	<code>wr=</code>	Width offset for parasitic resistance.
55	<code>binunit=</code>	Bin parameter unit selector. 1 for microns and 2 for meters.
56	<code>binflag=</code>	49 binning factor.
57	<code>lref=</code>	49 binning length factor.
58	<code>wref=</code>	49 binning width factor.

Mobility parameters

59	<code>mobmod=</code>	Mobility model selector.
60	<code>u0=</code>	Low-field surface mobility at t_{nom} . Default is 250 for PMOS Mobility can also be specified in M2/Vs..
61	<code>vsat=</code>	Carrier saturation velocity at t_{nom} .
62	<code>ua=</code>	First-order mobility reduction coefficient.
63	<code>ub=</code>	Second-order mobility reduction coefficient.
64	<code>uc=</code>	Body-bias dependence of mobility. Default is -0.046 and unit is 1/ V for <code>mobmod=3</code> .

Output resistance parameters

65	<code>drout=</code>	DIBL effect on output resistance coefficient.
66	<code>pclm=</code>	Channel length modulation coefficient.
67	<code>pdiblc1=</code>	First coefficient of drain-induced barrier lowering.

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

68	<code>pdiblc2=</code>	Second coefficient of drain-induced barrier lowering.
69	<code>pdiblcb=</code>	Body-effect coefficient for DIBL.
70	<code>pscbe1=</code>	First coefficient of substrate current body effect.
71	<code>pscbe2=</code>	Second coefficient of substrate current body effect.
72	<code>pvag=</code>	Gate dependence of Early voltage.
73	<code>delta=</code>	Effective drain voltage smoothing parameter.

Subthreshold parameters

74	<code>cdsc=</code>	Source/drain and channel coupling capacitance.
75	<code>cdscb=</code>	Body-bias dependence of <code>cdsc</code> .
76	<code>cdscd=</code>	Drain-bias dependence of <code>cdsc</code> .
77	<code>nfactor=</code>	Subthreshold swing coefficient.
78	<code>cit=</code>	Interface trap parameter for subthreshold swing.
79	<code>voff=</code>	Threshold voltage offset.
80	<code>dsub=</code>	DIBL effect in subthreshold region.
81	<code>eta0=</code>	DIBL coefficient subthreshold region.
82	<code>etab=</code>	Body-bias dependence of <code>et0</code> .

Substrate current parameters

83	<code>alpha0=</code>	Substrate current impact ionization coefficient.
84	<code>alpha1=</code>	Substrate current impact ionization coefficient.
85	<code>beta0=</code>	Substrate current impact ionization exponent.

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

Parasitic resistance parameters

86	rsh=	Source/drain diffusion sheet resistance.
87	rs=	Source resistance.
88	rd=	Drain resistance.
89	lgcs=	Gate-to-contact length of source side.
90	lgcd=	Gate-to-contact length of drain side.
91	rsc=	Source contact resistance.
92	rdc=	Drain contact resistance.
93	rss=	Scalable source resistance.
94	rdd=	Scalable drain resistance.
95	sc=	Spacing between contacts.
96	ldif=	Lateral diffusion beyond the gate.
97	hdif=	Length of heavily doped diffusion.
98	minr=	Minimum source/drain resistance.

Junction diode model parameters

99	js ()	Bulk junction reverse saturation current density.
100	jsw=	Sidewall junction reverse saturation current density.
101	jssw=	Alias of jsw.
102	is=	Bulk junction reverse saturation current.
103	n=	Junction emission coefficient.
104	nj=	Junction emission coefficient.

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

105	<code>dskip=</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> .
106	<code>imelt=</code>	Explosion current.
107	<code>ijth ()</code>	Alias to <code>imelt</code> .
108	<code>jmelt=</code>	Explosion current density.
109	<code>vnds=</code>	Reverse diode current transition point.
110	<code>nds=</code>	Reverse bias slope coefficient.
111	<code>tt=</code>	Transit time.

Overlap capacitance parameters

112	<code>cgso ()</code>	Gate-source overlap capacitance.
113	<code>cgdo ()</code>	Gate-drain overlap capacitance.
114	<code>cgbo=</code>	Gate-bulk overlap capacitance. The default value is 0 if <code>version=3.0</code> .
115	<code>meto=</code>	Metal overlap in fringing field.
116	<code>cgsl=</code>	Gate-source overlap capacitance in LDD region.
117	<code>cgdl=</code>	Gate-drain overlap capacitance in LDD region.
118	<code>ckappa=</code>	Overlap capacitance fitting parameter.

Junction capacitance model parameters

119	<code>cbs=</code>	Bulk-source zero-bias junction capacitance.
120	<code>cbd=</code>	Bulk-drain zero-bias junction capacitance.
121	<code>cj=</code>	Zero-bias junction bottom capacitance density.

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

122	m_j =	Bulk junction bottom grading coefficient.
123	p_b =	Bulk junction built-in potential.
124	f_c =	Forward-bias depletion capacitance threshold.
125	c_{jsw} =	Zero-bias junction sidewall capacitance density.
126	m_{jsw} =	Bulk junction sidewall grading coefficient.
127	p_{bsw} =	Side-wall junction built-in potential.
128	c_{jswg} =	Zero-bias gate-side junction capacitance density.
129	m_{jswg} =	Gate-side junction grading coefficient.
130	p_{bswg} =	Gate-side junction built-in potential.
131	f_{csw} =	Side-wall forward-bias depletion capacitance threshold.

Charge model selection parameters

132	$capmod$ =	Intrinsic charge model.
133	$nqsmod$ =	Non-quasi static model selector. Set to 1 to turn on nqs.
134	$acnqsmod$ =	AC Non-quasi static model selector. Set to 1 to turn on nqs.
135	dwc =	Delta W for capacitance model.
136	dlc =	Delta L for capacitance model.
137	clc =	Intrinsic capacitance fitting parameter.
138	cle =	Intrinsic capacitance fitting parameter.
139	cf ()	Fringe capacitance parameter.
140	elm =	Elmore constant of the channel.
141	$vfbcv$ =	Flat-band voltage for $capmod=0$.
142	$acde$ =	CV parameter.

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

143	<code>moin=</code>	CV parameter.
144	<code>noff=</code>	Transition parameter.
145	<code>voffcv=</code>	Transition parameter.
146	<code>xpart=</code>	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.
147	<code>llc=</code>	Length dependence of delta L for CV.
148	<code>lwc=</code>	Width dependence of delta L for CV.
149	<code>lwlc=</code>	Area dependence of delta L for CV.
150	<code>wlc=</code>	Length dependence of delta W for CV.
151	<code>wwc=</code>	Width dependence of delta W for CV.
152	<code>wwlc=</code>	Area dependence of delta W for CV.
153	<code>wmlt=</code>	Width shrink reduction factor.
154	<code>lmlt=</code>	Length shrink reduction factor.

Default for instance parameters

155	<code>w=</code>	Default channel width.
156	<code>l=</code>	Default channel length.
157	<code>as=</code>	Default area of source diffusion.
158	<code>ad=</code>	Default area of drain diffusion.
159	<code>ps=</code>	Default perimeter of source diffusion.
160	<code>pd=</code>	Default perimeter of drain diffusion.
161	<code>nrd=</code>	Default number of squares of drain diffusion.

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

162	<code>nrs=</code>	Default number of squares of source diffusion.
163	<code>version=</code>	Model version selector. The available versions are 3.1, 3.2, 3.21, 3.22, 3.23, 3.24 and 3.3.
164	<code>paramchk=</code>	Model parameter checking selector.
165	<code>fullreinit=</code>	Model parameter full reinit selector.
166	<code>level=</code>	BSIM3v3 model selector. The available level are 11, 49 and 53.
167	<code>acm=</code>	BSIM3v3 area calculation method selector.
168	<code>geo=</code>	geometry selector.
169	<code>calcacm=</code>	49 geometry factor.

Temperature effects parameters

170	<code>tnom ()</code>	Parameters measurement temperature. Default set by <code>options</code> .
171	<code>trise=</code>	Temperature rise from ambient.
172	<code>tlev=</code>	DC temperature selector.
173	<code>tlevc=</code>	AC temperature selector.
174	<code>eg=</code>	Energy band gap.
175	<code>gap1=</code>	Band gap temperature coefficient.
176	<code>gap2=</code>	Band gap temperature offset.
177	<code>eglev=</code>	DC temperature selector.
178	<code>diomod=</code>	a flag to select junction model. <code>diomod=1</code> junction model described in Common MOSFET Equations section will be used. <code>diomod=0</code> Berkeley junction model is used. <code>diomod=100</code> TSMC special diode model .
179	<code>kt1=</code>	Temperature coefficient for threshold voltage.
180	<code>kt11=</code>	Temperature coefficient for threshold voltage.

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

181	kt2=	Temperature coefficient for threshold voltage.
182	at=	Temperature coefficient for v_{sat} .
183	ua1=	Temperature coefficient for u_a .
184	ub1=	Temperature coefficient for u_b .
185	uc1=	Temperature coefficient for u_c . Default is -0.056 for mobmod=3.
186	prt=	Temperature coefficient for R_{ds} .
187	trs=	Temperature parameter for source resistance.
188	trd=	Temperature parameter for drain resistance.
189	ute=	Mobility temperature exponent.
190	x _{ti} =	Saturation current temperature exponent.
191	pta=	Junction potential temperature coefficient.
192	tpb=	Temperature coefficient for p_b .
193	ptp=	Sidewall junction potential temperature coefficient.
194	tpbsw=	Temperature coefficient for p_{bsw} .
195	tpbswg=	Temperature coefficient for p_{bswg} .
196	cta=	Junction capacitance temperature coefficient.
197	tcj=	Temperature coefficient for c_j .
198	ctp=	Sidewall junction capacitance temperature coefficient.
199	tcjsw=	Temperature coefficient for c_{jsw} .
200	tcjswg=	Temperature coefficient for c_{jswg} .

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

Noise model parameters

201	noimod=	Noise model selector.
202	kf=	Flicker (1/f) noise coefficient.
203	af=	Flicker (1/f) noise exponent.
204	ef=	Flicker (1/f) noise frequency exponent.
205	noia=	Oxide trap density coefficient. Default is 9.9e18 for pmos.
206	noib=	Oxide trap density coefficient. Default is 2.4e3 for pmos.
207	noic=	Oxide trap density coefficient. Default is 1.4e-12 for pmos.
208	noid=	flicker noise subthreshold-above threshold transition coefficient.
209	wnoi=	Channel width at which noise parameters were extracted.
210	em=	Maximum electric field.
211	flkmod=	Flicker noise model (0 for Ids based model, 1 for gm based model).
212	gamma=	Thermal noise coefficient.
213	nlev=	49 noise selector.
214	gdsnoi=	Channel thermal noise coefficient for 49 noise.
215	lintnoi=	Lint offset for noise calculation.

Gate-Induced drain leakage parameters

216	agidl=	Pre-exponential coefficient for GIDL.
217	bgidl=	Exponential coefficient for GIDL.
218	cgidl=	Parameter for body-bias effect on GIDL.
219	egidl=	Fitting parameter for band bending for GIDL.

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

220	agisl=	Pre-exponential coefficient for GISL.
221	bgisl=	Exponential coefficient for GISL.
222	cgisl=	Parameter for body-bias effect on GISL.
223	egisl=	Fitting parameter for band bending for GISL.

Gate leak current parameters

224	bforward=	Forward gate leakage current coefficient in pow().
225	breverse=	Reverse gate leakage current coefficient in pow().
226	cforward=	Forward gate leakage current coefficient in exp().
227	creverse=	Reverse gate leakage current coefficient in exp().
228	tcc=	Gate leakage current temperature coefficient.
229	aigbinv=	Parameter for I_{gb} in inversion.
230	bigbinv=	Parameter for I_{gb} in inversion.
231	cigbinv=	Parameter for I_{gb} in inversion.
232	eigbinv=	Parameter for I_{gb} in inversion.
233	nigbinv=	Parameter for I_{gb} in inversion.
234	aigbacc=	Parameter for I_{gb} in accumulation.
235	bigbacc=	Parameter for I_{gb} in accumulation.
236	cigbacc=	Parameter for I_{gb} in accumulation.
237	nigbacc=	Parameter for I_{gb} in accumulation.

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

238	aigsd=	Parameter for Igs and Igd.
239	bigsd=	Parameter for Igs and Igd.
240	cigsd=	Parameter for Igs and Igd.
241	aigc=	Parameter for Igcs and Igcd.
242	bigc=	Parameter for Igcs and Igcd.
243	cigc=	Parameter for Igcs and Igcd.
244	nigc=	Parameter for Igcs, Igcd, Igs and Igd.
245	pigcd=	Vds dependence of Igcs and Igcd.
246	dlcig=	Source/drain overlap length for Igs and Igd.
247	ntox=	Exponent for the gate oxide ratio.
248	toxref=	Nominal gate oxide thickness for gate dielectric tunneling current model only.
249	poxedge=	Factor for the gate oxide thickness in source/drain overlap regions.
250	igcmod=	Gate-to-channel and gate-to-source, gate-to-drain tunneling model selector.
251	igbmod=	Gate-to-substrate tunneling model selector.

Auto Model Selector parameters

252	wmax=	Maximum channel width for which the model is valid.
253	wmin=	Minimum channel width for which the model is valid.

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

254 `lmax=` Maximum channel length for which the model is valid.

255 `lmin=` Minimum channel length for which the model is valid.

Operating region warning control parameters

256 `alarm=` Forbidden operating region.
Possible values are `none`, `off`, `triode`, `sat`, `subth`, or `rev`.

257 `imax=` Maximum allowable current.

258 `jmax=` Maximum allowable current density.

259 `bvj=` Junction reverse breakdown voltage.

260 `vbox=` Oxide breakdown voltage.

261 `warn=` Parameter to turn warnings on and off.
Possible values are `off` or `on`.

262 `apwarn=` Warning message flag.

Length dependent parameters

263 `xl=` Length variation due to masking and etching.

264 `xlref=` Length variation due to masking and etching.

265 `lagidl=` Length dependence of `agidl`.

266 `lbgidl=` Length dependence of `bgidl`.

267 `lcgidl=` Length dependence of `cgidl`.

268 `legidl=` Length dependence of `egidl`.

Width dependent parameters

269 `xw=` Width variation due to masking and etching.

270 `xwref=` Width variation due to masking and etching.

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

271 `wagidl=` Width dependence of `agidl`.

272 `wbgidl=` Width dependence of `bgidl`.

273 `wcgidl=` Width dependence of `cgidl`.

274 `wegidl=` Width dependence of `egidl`.

Cross-term dependent parameters (Not listed)

275 `pagidl=` Cross-term dependence of `agidl`.

276 `pbgidl=` Cross-term dependence of `bgidl`.

277 `pcgidl=` Cross-term dependence of `cgidl`.

278 `pegidl=` Cross-term dependence of `egidl`.

DC-mismatch dependent parameters

279 `mvtwl=` Threshold mismatch area dependence.

280 `mvtwl2=` Threshold mismatch area square dependence.

281 `mvt0=` Threshold mismatch intercept.

282 `mbewl=` Beta mismatch area dependence.

283 `mbe0=` Beta mismatch intercept.

284 `mismatchmod=` select Mismatch mode. The available modes are 0, 1, 2 and 3.

285 `mismatchdist=` Mismatch Distance.

Mos Table Model parameters

286 `mos_method=` Table model enable.
Possible values are `s` or `a`.

287 `mos_vres=` Voltage increment for table model grid.

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BSIM3v3 Level-11 Model (bsim3v3)

LOD model parameters

288	<code>stimod=</code>	LOD stress effect model selector. 0 for no LOD, 1 for UCB LOD.
289	<code>sa0=</code>	reference distance between od edge to poly of one side.
290	<code>saref ()</code>	Alias to Sa0.
291	<code>sb0=</code>	reference distance between od edge to poly of the other side.
292	<code>sbref ()</code>	Alias to sb0.
293	<code>wlod=</code>	length parameter for stress effect.
294	<code>ku0=</code>	mobility degradation/enhancement coefficient for stress effect.
295	<code>kvsat=</code>	saturation velocity degradation/enhancement parameter for stress effect.
296	<code>kvth0=</code>	threshold shift parameter for stress effect.
297	<code>tku0=</code>	temperature coefficient of ku0.
298	<code>llodku0=</code>	length parameter for u0 stress effect.
299	<code>wlodku0=</code>	width parameter for u0 stress effect.
300	<code>llodvth=</code>	length parameter for vth stress effect.
301	<code>wlodvth=</code>	width parameter for vth stress effect.
302	<code>lku0=</code>	length dependence of ku0.
303	<code>wku0=</code>	width dependence of ku0.
304	<code>pku0=</code>	cross-term dependence of ku0.
305	<code>lkvth0=</code>	length dependence of kvth0.
306	<code>wkvth0=</code>	width dependence of kvth0.

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307	<code>pkvth0=</code>	cross-term dependence of <code>kvth0</code> .
308	<code>stk2=</code>	<code>k2</code> shift factor related to <code>vth0</code> change.
309	<code>lodk2=</code>	<code>k2</code> shift modification factor for stress effect.
310	<code>steta0=</code>	<code>eta0</code> shift factor related to <code>vth0</code> change.
311	<code>lodeta0=</code>	<code>eta0</code> shift modification factor for stress effect.
312	<code>wpemod=</code>	Flag for WPE model (WPEMOD=1 to activate this model) .
313	<code>web=</code>	Coefficient for SCB.
314	<code>wec=</code>	Coefficient for SCC.
315	<code>kvth0we=</code>	Threshold shift factor for well proximity effect .
316	<code>k2we=</code>	<code>K2</code> shift factor for well proximity effect.
317	<code>lkvth0we=</code>	Length dependence of <code>kvth0we</code> .
318	<code>wkvth0we=</code>	Width dependence of <code>kvth0we</code> .
319	<code>pkvth0we=</code>	Cross-term dependence of <code>kvth0we</code> .
320	<code>lk2we=</code>	Length dependence of <code>k2we</code> .
321	<code>wk2we=</code>	Width dependence of <code>k2we</code> .
322	<code>pk2we=</code>	Cross-term dependence of <code>k2we</code> .
323	<code>ku0we=</code>	Mobility degradation factor for well proximity effect .
324	<code>lku0we=</code>	Length dependence of <code>ku0we</code> .
325	<code>wku0we=</code>	Width dependence of <code>ku0we</code> .
326	<code>pku0we=</code>	Cross-term dependence of <code>ku0we</code> .
327	<code>scref=</code>	Reference distance to calculate SCA, SCB and SCC .

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TSMC junction diode model parameters

328	<code>jtss=</code>	Source bottom trap-assisted saturation current density.
329	<code>jtstd=</code>	Drain bottom trap-assisted saturation current density.
330	<code>jtssws=</code>	Source isolation-edge sidewall trap-assisted saturation current density.
331	<code>jtsswd=</code>	Drain isolation-edge sidewall trap-assisted saturation current density.
332	<code>jtsswgs=</code>	Source Gate-edge isolation-edge sidewall trap-assisted saturation current density.
333	<code>jtsswgd=</code>	Drain isolation-edge sidewall trap-assisted saturation current density.
334	<code>njts=</code>	Non-ideality factor for <code>Jtss</code> and <code>Jtstd</code> .
335	<code>njtssw=</code>	Non-ideality factor for <code>Jtssws</code> and <code>Jtsswd</code> .
336	<code>njtsswg=</code>	Non-ideality factor for <code>Jtsswgs</code> and <code>Jtsswgd</code> .
337	<code>mnr=</code>	Fitting parameter for resistance induced non-ideality factor.
338	<code>bnr=</code>	Fitting parameter for resistance induced non-ideality factor.
339	<code>cnr=</code>	Fitting parameter for resistance induced non-ideality factor.
340	<code>dnr=</code>	Fitting parameter for resistance induced non-ideality factor.
341	<code>xtss=</code>	Power dependence of <code>Jtss</code> on temperature.
342	<code>xtstd=</code>	Power dependence of <code>Jtstd</code> on temperature.
343	<code>xtssws=</code>	Power dependence of <code>Jtssws</code> on temperature.
344	<code>xtsswd=</code>	Power dependence of <code>Jtsswd</code> on temperature.
345	<code>xtsswgs=</code>	Power dependence of <code>Jtsswgs</code> on temperature.
346	<code>xtsswgd=</code>	Power dependence of <code>Jtsswgd</code> on temperature.

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347	<code>tnjts=</code>	Temperature coefficient for NJTS.
348	<code>tnjtssw=</code>	Temperature coefficient for njtssw.
349	<code>tnjtsswg=</code>	Temperature coefficient for njtsswg.
350	<code>tmnr=</code>	Temperature coefficient for mnr.
351	<code>tcnr=</code>	Temperature coefficient for cnr.
352	<code>tdnr=</code>	Temperature coefficient for dnr.
353	<code>jsswg=</code>	Sidewall-gate junction reverse saturation current density.
354	<code>xjbv=</code>	Fitting parameter for diodes breakdown.
355	<code>ijthrev=</code>	Reverse maximum allowable current.
356	<code>nrfwd=</code>	Nominal value of Nr for forward linearization.

Shrink Parmaters

357	<code>shrink=</code>	linear shrink parameter.
358	<code>shrink2=</code>	area shrink parameter.
359	<code>msgskip=</code>	Skip some warning message customer requested. Possible values are <code>off</code> or <code>on</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

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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.

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

```
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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BSIM3v3 Level-11 Model (bsim3v3)

Output Parameters

1	<code>w_{eff} ()</code>	Effective channel width (alias=lv2).
2	<code>l_{eff} ()</code>	Effective channel length (alias=lv1).
3	<code>r_{seff} ()</code>	Effective source resistance (alias=lv17).
4	<code>r_{deff} ()</code>	Effective drain resistance (alias=lv16).
5	<code>a_{seff} ()</code>	Effective source area (alias=lv4).
6	<code>a_{deff} ()</code>	Effective drain area (alias=lv3).
7	<code>p_{seff} ()</code>	Effective source perimeter (alias=lv12).
8	<code>p_{deff} ()</code>	Effective drain perimeter (alias=lv11).

Operating-Point Parameters

1	<code>type=</code>	Transistor type. Possible values are <code>n</code> or <code>p</code> .
2	<code>region=</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>	Resistive drain-to-source current (alias=lx4).
5	<code>isub ()</code>	substrate current (alias=lx50).
6	<code>vgs ()</code>	Gate-source voltage.
7	<code>vds ()</code>	Drain-source voltage (alias=lx3).
8	<code>vbs ()</code>	Bulk-source voltage.
9	<code>vgb ()</code>	gate-bulk voltage.
10	<code>vdb ()</code>	Drain-bulk voltage.

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BSIM3v3 Level-11 Model (bsim3v3)

11	<code>v_{gd}</code> ()	Gate-Drain voltage.
12	<code>v_{th}</code> ()	Threshold voltage (alias=lv9).
13	<code>v_{dsat}</code> ()	Drain-source saturation voltage (alias=lv10).
14	<code>v_{fb_{eff}}</code> ()	V _{fb} effective (alias=lv26).
15	<code>g_m</code> ()	Common-source transconductance (alias=lx7).
16	<code>g_{ds}</code> ()	Common-source output conductance (alias=lx8).
17	<code>g_{mbs}</code> ()	Body-transconductance (alias=lx9).
18	<code>beta_{eff}</code> ()	Effective beta.
19	<code>c_{jd}</code> ()	Drain-bulk junction capacitance (alias=lx29).
20	<code>c_{js}</code> ()	Source-bulk junction capacitance (alias=lx28).
21	<code>q_b</code> ()	total bulk charge (alias=lx12).
22	<code>q_g</code> ()	Total gate charge (alias=lx14).
23	<code>q_d</code> ()	Total drain charge (alias=lx16).
24	<code>q_{bd}</code> ()	Drain-bulk charge (alias=lx24).
25	<code>q_{bs}</code> ()	Source-bulk charge (alias=lx26).
26	<code>c_{gg}</code> ()	dQ _g _dV _g (alias=lx18).
27	<code>c_{gd}</code> ()	dQ _g _dV _d (alias=lx19).
28	<code>c_{gs}</code> ()	dQ _g _dV _s (alias=lx20).
29	<code>c_{gb}</code> ()	dQ _g _dV _{bk} .
30	<code>c_{dg}</code> ()	dQ _d _dV _g (alias=lx32).
31	<code>c_{dd}</code> ()	dQ _d _dV _d (alias=lx33).
32	<code>c_{ds}</code> ()	dQ _d _dV _s (alias=lx34).

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33	<code>cdb ()</code>	<code>dQd_dVb</code> .
34	<code>csg ()</code>	<code>dQs_dVg</code> .
35	<code>csd ()</code>	<code>dQs_dVd</code> .
36	<code>css ()</code>	<code>dQs_dVs</code> .
37	<code>csb ()</code>	<code>dQs_dVb</code> .
38	<code>cbg ()</code>	<code>dQb_dVg</code> (alias= <code>lx21</code>).
39	<code>cbd ()</code>	<code>dQb_dVd</code> (Intrinsic part of <code>Cbd</code>) (alias= <code>lx22</code>).
40	<code>cbs ()</code>	<code>dQb_dVs</code> (Intrinsic part of <code>Cbs</code>) (alias= <code>lx23</code>).
41	<code>cbb ()</code>	<code>dQb_dVb</code> .
42	<code>ron ()</code>	On-resistance.
43	<code>id ()</code>	Resistive drain current (alias= <code>i1</code>).
44	<code>is ()</code>	Resistive source current (alias= <code>i3</code>).
45	<code>ibulk ()</code>	Resistive bulk current (alias= <code>i4</code>).
46	<code>ibs ()</code>	Source-bulk diode current (alias= <code>lx5</code>).
47	<code>ibd ()</code>	Drain-bulk diode current (alias= <code>lx6</code>).
48	<code>pwr ()</code>	Power at op point.
49	<code>gmoverid ()</code>	<code>Gm/Ids</code> .
50	<code>cgsov1 ()</code>	Gate-source overlap and fringing capacitance (alias= <code>lv36</code>).
51	<code>cgdov1 ()</code>	Gate-drain overlap and fringing capacitance (alias= <code>lv37</code>).
52	<code>cgbov1 ()</code>	Gate-bulk overlap capacitance (alias= <code>lv38</code>).
53	<code>i1 ()</code>	Alias for <code>id</code> .
54	<code>i3 ()</code>	Alias of Resistive source current.

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55	<code>i4</code> ()	Alias of Resistive bulk current.
56	<code>gbd</code> ()	Conductance of the drain diode (alias=lx10).
57	<code>gbs</code> ()	Conductance of the source diode (alias=lx11).
58	<code>vgsteff</code> ()	effective vgs.
59	<code>qinv</code> ()	inversion charge.
60	<code>igd</code> ()	Gate-to-drain leakage current.
61	<code>igs</code> ()	Gate-to-source leakage current.
62	<code>igb</code> ()	Gate-to-bulk tunneling current.
63	<code>igcs</code> ()	Gate-to-channel (source side) tunneling current.
64	<code>igcd</code> ()	Gate-to-channel (drain side) tunneling current.
65	<code>igidl</code> ()	Gate-induced drain leakage current.
66	<code>igisl</code> ()	Gate-induced source leakage current.
67	<code>qgi</code> ()	Intrinsic Gate charge.
68	<code>qsi</code> ()	Intrinsic Source charge.
69	<code>qdi</code> ()	Intrinsic Drain charge.
70	<code>qbi</code> ()	Intrinsic Bulk charge.
71	<code>cddb</code> ()	Intrinsic drain capacitance.
72	<code>cssb</code> ()	Intrinsic source capacitance.
73	<code>cgg</code> ()	Intrinsic gate capacitance.
74	<code>cgsb</code> ()	Intrinsic gate-to-source capacitance.
75	<code>cgdb</code> ()	Intrinsic gate-to-drain capacitance.
76	<code>cbdb</code> ()	Intrinsic bulk-to-drain capacitance.

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- 77 `cbsbi` () Intrinsic bulk-to-source capacitance.
- 78 `qsarco` () Total Source charge (Charge Conservation: $QS = -(QG + QD + QB)$).

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>a0</code> M-20	<code>dvt2</code> M-16	<code>lwn</code> M-37	<code>sc</code> M-95
<code>a1</code> M-23	<code>dvt2w</code> M-19	<code>m</code> I-9	<code>sca</code> I-28
<code>a2</code> M-24	<code>dwb</code> M-45	<code>mbe0</code> M-283	<code>scb</code> I-29
<code>acde</code> M-142	<code>dwc</code> M-135	<code>mbewl</code> M-282	<code>scc</code> I-30
<code>acm</code> M-167	<code>dwg</code> M-44	<code>meto</code> M-115	<code>scref</code> M-327
<code>acnqsmo</code> I-12	<code>ef</code> M-204	<code>minr</code> M-98	<code>shrink</code> M-357
<code>acnqsmo</code> M-134	<code>eg</code> M-174	<code>mismatchdist</code> M-285	<code>shrink2</code> M-358
<code>ad</code> I-4	<code>egidl</code> M-219	<code>mismatchmod</code> M-284	<code>steta0</code> M-310
<code>ad</code> M-158	<code>egisl</code> M-223	<code>mj</code> M-122	<code>stimod</code> I-27
<code>adef</code> O-6	<code>eglev</code> M-177	<code>mjsw</code> M-126	<code>stimod</code> M-288
<code>af</code> M-203	<code>eigbinv</code> M-232	<code>mjswg</code> M-129	<code>stk2</code> M-308
<code>aforward</code> I-15	<code>elm</code> M-140	<code>mnr</code> M-337	<code>tcc</code> M-228
<code>agidl</code> M-216	<code>em</code> M-210	<code>mobmod</code> M-59	<code>tcj</code> M-197

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ags M-25	etab M-82	mos_method M-286	tcjswg M-200
aigbacc M-234	fc M-124	mos_vres M-287	tcnr M-351
aigbinv M-229	fcs w M-131	msgskip M-359	tdnr M-352
aigc M-241	flkmod M-211	mulmu0 I-18	tku0 M-297
aigsd M-238	fullreinit M-165	mulu0 I-19	tlev M-172
alarm M-256	gamma M-212	mvt0 M-281	tlevc M-173
alpha0 M-83	gamma1 M-10	mvtw1 M-279	tmnr M-350
alpha1 M-84	gamma2 M-11	mvtw12 M-280	tnjts M-347
apwarn M-262	gap1 M-175	n M-103	tnjtssw M-348
areverse I-16	gap2 M-176	nch M-29	tnjtsswg M-349
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as M-157	gbs OP-57	nfactor M-77	tox M-46
aseff O-5	gds OP-16	ngate M-30	toxe M-49
at M-182	gdsnoi M-214	nigbacc M-237	toxm M-48
b0 M-21	geo I-22	nigbinv M-233	toxref M-248
b1 M-22	geo M-168	nigc M-244	tpb M-192
beta0 M-85	gm OP-15	nj M-104	tpbsw M-194
betaeff OP-18	gmbs OP-17	njts M-334	tpbswg M-195
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bgidl M-217	hdif M-97	njtsswg M-336	trise I-14

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bgisl M-221	i1 OP-53	nlev M-213	trise M-171
bigbacc M-235	i3 OP-54	nlx M-9	trs M-187
bigbinv M-230	i4 OP-55	noff M-144	tt M-111
bigc M-242	ibd OP-47	noia M-205	type M-1
bigsd M-239	ibs OP-46	noib M-206	type OP-1
binflag M-56	ibulk OP-45	noic M-207	u0 M-60
binunit M-55	id OP-43	noid M-208	ua M-62
bnr M-338	ids OP-4	noimod M-201	ua1 M-183
breverse M-225	igb OP-62	nqsmod I-11	ub M-63
bvj M-259	igbmod M-251	nqsmod M-133	ub1 M-184
calcacm M-169	igcd OP-64	nrd I-7	uc M-64
capmod M-132	igcmmod M-250	nrd M-161	uc1 M-185
cbb OP-41	igcs OP-63	nrfwd M-356	ute M-189
cbd M-120	igd OP-60	nrs I-8	vbm M-13
cbd OP-39	igid1 OP-65	nrs M-162	vbox M-260
cbdbi OP-76	igisl OP-66	nsub M-28	vbs OP-8
cbg OP-38	igs OP-61	ntox M-247	vbv M-12
cbs M-119	ijth M-107	pagidl M-275	vdb OP-10
cbs OP-40	ijthrev M-355	paramchk M-164	vds OP-7
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cddbi	OP-71	is	OP-44	pbswg	M-130	vfbcv	M-141
cdg	OP-30	isnoisy	I-13	pcgidl	M-277	vfbeff	OP-14
cds	OP-32	isub	OP-5	pclm	M-66	vfbflag	M-27
cdsc	M-74	jmax	M-258	pd	I-6	vgb	OP-9
cdscb	M-75	jmelt	M-108	pd	M-160	vgd	OP-11
cdscd	M-76	js	M-99	pdeff	O-8	vgs	OP-6
cf	M-139	jssw	M-101	pdiblc1	M-67	vgsteff	OP-58
cforward	M-226	jsswg	M-353	pdiblc2	M-68	vnds	M-109
cgb	OP-29	jsw	M-100	pdiblcb	M-69	voff	M-79
cgbo	M-114	jtsd	M-329	pegidl	M-278	voffcv	M-145
cgbovl	OP-52	jtss	M-328	pigcd	M-245	vsat	M-61
cgd	OP-27	jtsswd	M-331	pk2we	M-322	vth	OP-12
cgdbi	OP-75	jtsswgd	M-333	pku0	M-304	vtho	M-2
cgdl	M-117	jtsswgs	M-332	pku0we	M-326	w	I-1
cgdo	M-113	jtssws	M-330	pkvth0	M-307	w	M-155
cgdovl	OP-51	k1	M-4	pkvth0we	M-319	w0	M-8
cgg	OP-26	k2	M-5	poxedge	M-249	wagidl	M-271
cggbi	OP-73	k2we	M-316	prt	M-186	warn	M-261
cgidl	M-218	k3	M-6	prwb	M-52	wbgidl	M-272
cgisl	M-222	k3b	M-7	prwg	M-53	wcgidl	M-273

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cgs	OP-28	keta	M-26	ps	I-5	web	M-313
cgsbi	OP-74	kf	M-202	ps	M-159	wec	M-314
cgs1	M-116	kt1	M-179	pscbe1	M-70	weff	O-1
cgso	M-112	kt11	M-180	pscbe2	M-71	wegidl	M-274
cgsov1	OP-50	kt2	M-181	pseff	O-7	wint	M-33
cigbacc	M-236	ku0	M-294	pta	M-191	wk2we	M-321
cigbinv	M-231	ku0we	M-323	ptp	M-193	wku0	M-303
cigc	M-243	kvsat	M-295	pvag	M-72	wku0we	M-325
cigsd	M-240	kvth0	M-296	pwr	OP-48	wkvth0	M-306
cit	M-78	kvth0we	M-315	qj	OP-21	wkvth0we	M-318
cj	M-121	l	I-2	qjd	OP-24	wl	M-39
cjd	OP-19	l	M-156	qbi	OP-70	wlc	M-150
cjs	OP-20	lagidl	M-265	qbs	OP-25	wln	M-40
cjsw	M-125	lbgidl	M-266	qd	OP-23	wlod	M-293
cjswg	M-128	lcgidl	M-267	qdi	OP-69	wlodku0	M-299
ckappa	M-118	ldif	M-96	qg	OP-22	wlodvth	M-301
clc	M-137	leff	O-2	qgi	OP-67	wmax	M-252
cle	M-138	legidl	M-268	qinv	OP-59	wmin	M-253
cnr	M-339	level	M-166	qsi	OP-68	wmlt	M-153
creverse	M-227	lgcd	M-90	qsrco	OP-78	wnoi	M-209
csb	OP-37	lgcs	M-89	rd	M-88	wpemod	M-312

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

csd	OP-35	lint	M-32	rdc	I-23	wr	M-54
csg	OP-34	lintnoi	M-215	rdc	M-92	wref	M-58
css	OP-36	lk2we	M-320	rdd	M-94	ww	M-41
cssbi	OP-72	lku0	M-302	rdeff	O-4	wwc	M-151
cta	M-196	lku0we	M-324	rdsw	M-51	wwl	M-43
ctp	M-198	lkvth0	M-305	region	I-10	wwlc	M-152
delk1	I-20	lkvth0we	M-317	region	OP-2	wnn	M-42
delnfct	I-21	ll	M-34	reversed	OP-3	xj	M-31
delta	M-73	llc	M-147	ron	OP-42	xjbv	M-354
delvto	I-17	lln	M-35	rs	M-87	xl	M-263
diomod	M-178	llodku0	M-298	rsc	I-24	xlref	M-264
dlc	M-136	llodvth	M-300	rsc	M-91	xpart	M-146
dlcig	M-246	lmax	M-254	rseff	O-3	xt	M-50
dnr	M-340	lmin	M-255	rsh	M-86	xti	M-190
droun	M-65	lmlt	M-154	rss	M-93	xtsd	M-342
dskip	M-105	lodeta0	M-311	sa	I-25	xtss	M-341
dsub	M-80	lodk2	M-309	sa0	M-289	xtsswd	M-344
dtoxcv	M-47	lref	M-57	saref	M-290	xtsswgd	M-346
dvt0	M-14	lw	M-36	sb	I-26	xtsswgs	M-345
dvt0w	M-17	lwc	M-148	sb0	M-291	xtssws	M-343
dvt1	M-15	lw1	M-38	sbref	M-292	xw	M-269

dvt1w M-18

lwlc M-149

sc I-31

xwref M-270

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 21-1 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
PK2	K2 length and width sensitivity
LDVT0	DVT0 length sensitivity
WDVT0	DVT0 width sensitivity
PDVT0	DVT0 length and width sensitivity

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

Parameter Name	Description
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
PNSUB	NSUB length and width sensitivity
LNCH	NCH length sensitivity
WNCH	NCH width sensitivity
PNCH	NCH length and width sensitivity

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

Parameter Name	Description
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
PPCLM	PCLM length and width sensitivity
LPDIBLC1	PDIBLC1 length sensitivity
WPDIBLC1	PDIBLC1 width sensitivity
PPDIBLC1	PDIBLC1 length and width sensitivity

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

Parameter Name	Description
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
PPRT	PRT length and width sensitivity
LAGS	AGS length sensitivity
WAGS	AGS width sensitivity
PAGS	AGS length and width sensitivity

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

Parameter Name	Description
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
PNFACTOR	NFACTOR length and width sensitivity
LCIT	CIT length sensitivity
WCIT	CIT width sensitivity
PCIT	CIT length and width sensitivity

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

Parameter Name	Description
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
PK3	K3 length and width sensitivity
LK3B	K3B length sensitivity
WK3B	K3B width sensitivity
PK3B	K3B length and width sensitivity

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

Parameter Name	Description
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
PDELTA	DELTA length and width sensitivity
LB0	B0 length sensitivity
WB0	B0 width sensitivity
PB0	B0 length and width sensitivity

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

Parameter Name	Description
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
PDWC	DWC length and width sensitivity
LDLC	DLC length sensitivity
WDLC	DLC width sensitivity
PDLC	DLC length and width sensitivity

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

Parameter Name	Description
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
PMOIN	MOIN length and width sensitivity
LNOFF	NOFF length sensitivity
WNOFF	NOFF width sensitivity
PNOFF	NOFF length and width sensitivity

Virtuoso Simulator Components and Device Models Reference

BSIM3v3 Level-11 Model (bsim3v3)

Parameter Name	Description
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
PXT	XT length and width sensitivity

Virtuoso Simulator Components and Device Models Reference
BSIM3v3 Level-11 Model (bsim3v3)

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:

- [Instance](#) on page 1213
 - [Instance syntax](#) on page 1213
- [Model](#) on page 1213
 - [Model syntax](#) on page 1213
 - [Auto Model Selection](#) on page 1214
- [Equivalent Circuit](#) on page 1215
- [Device Regions](#) on page 1215
- [Global Control Options](#) on page 1216
- [Model Version Update](#) on page 1217
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Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

- [Model Equations](#) on page 1220
 - [Effective Oxide Thickness, Channel Length and Channel Width](#) on page 1220
 - [Threshold Voltage Model](#) on page 1223
 - [Channel Charge and Subthreshold Swing Models](#) on page 1224
 - [Gate Direct Tunneling Current Model](#) on page 1224
 - [Drain Current Model](#) on page 1226
 - [Body Current Model](#) on page 1229
 - [Capacitance Model](#) on page 1230
 - [Overlap Capacitance Models](#) on page 1239
 - [High Speed/RF Models](#) on page 1239
 - [Noise Models](#) on page 1245
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 - [Stress Effects Models](#) on page 1260
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 - [TMIBSIM4 Model \(tmibsim4\)](#) on page 1263
- [Models and Equations in Version Updates](#) on page 1263
- [Component Statements](#) on page 1275

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 1275.

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 al=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  
drout=0.56pdiblc2=9.84e-6 psobel=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 ucl=-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 1275.

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

$$P = P_0 + P_l / L_{eff} + P_w / W_{eff} + P_p / (L_{eff} * W_{eff})$$

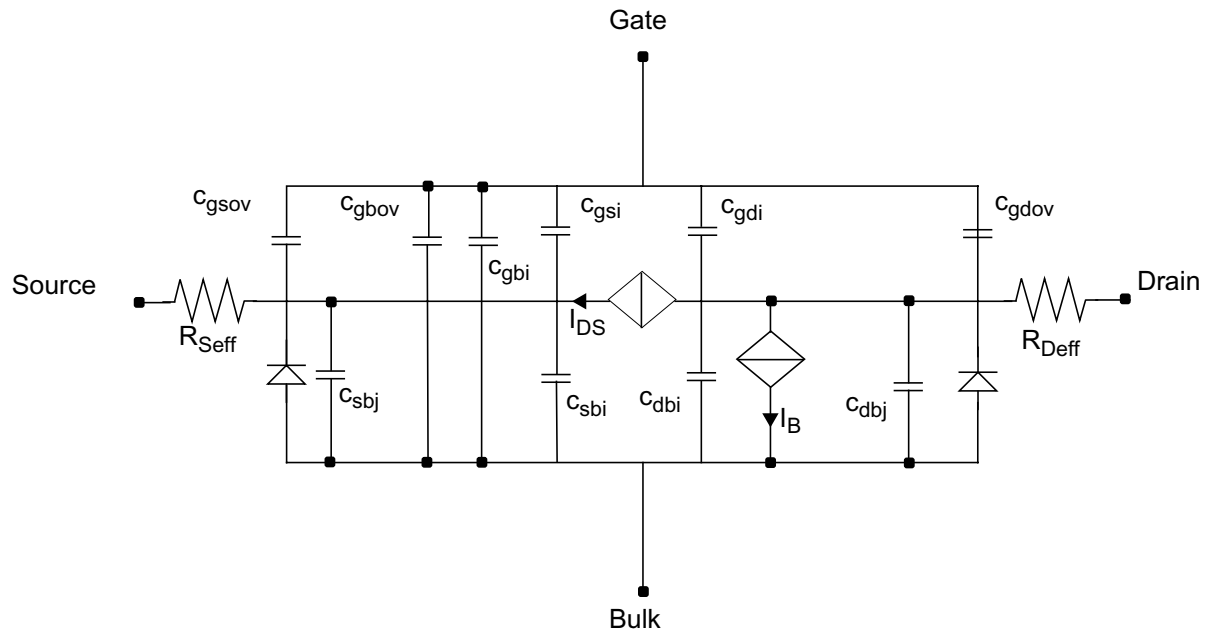
The names of P_l , P_w , and P_p are identical to that of P_0 but with a prefix of l, w, and p, respectively.

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:



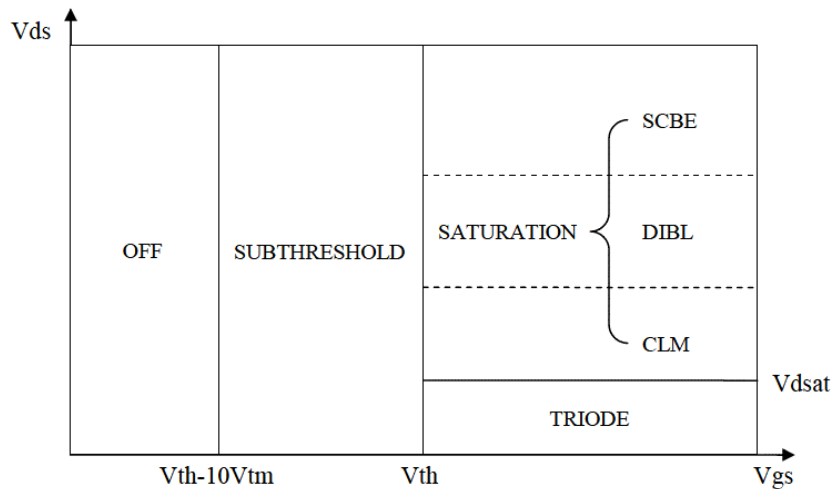
Device Regions

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 split 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).

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

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.

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 Coulombic 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 Coulombic 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 `ourceSatCurrent=0.0` when `Aseff` and `Pseff` are zero. Turn off drain side diode by setting `DrainSatCurrent=0.0` when `Adeff` and `Pdeff` are zero.

Model Equations

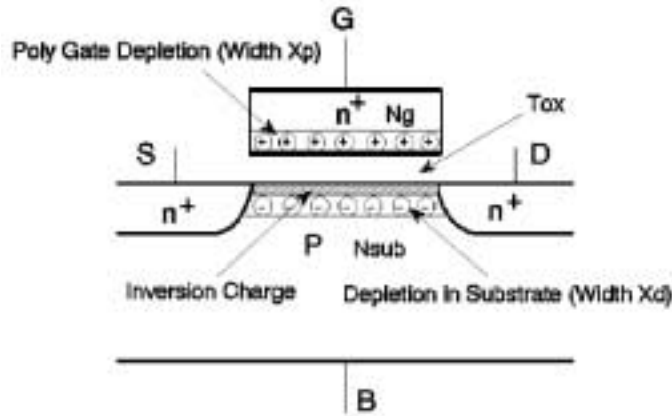
Effective Oxide Thickness, Channel Length and Channel Width

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 $mtrlmod=0$

$$V_{gse} = V_{FB} + \Phi_s + \frac{q\epsilon_{si}NGATE \cdot T_{oxe}^2}{EPSROX^2} \left(\sqrt{1 + \frac{2EPSROX^2(V_{gs} - V_{FB} - \Phi_s)}{q\epsilon_{si}NGATE \cdot T_{oxe}^2}} - 1 \right)$$

For $mtrlmod=1$ (the non-silicon channel or high- k gate insulator)

$$V_{gse} = V_{FB} + \Phi_s + \frac{q\epsilon_{gate}NGATE}{C_{oxe}^2} \left(\sqrt{1 + \frac{2 \cdot C_{oxe}^2(V_{gs} - V_{FB} - \Phi_s)}{q\epsilon_{gate}NGATE}} - 1 \right)$$

Effective Channel Length and Width

$$L_{eff} = L_{drawn} + XL - 2dL$$

$$W_{eff} = \frac{W_{drawn}}{NF} + XW - 2dW$$

$$W_{eff}' = \frac{W_{drawn}}{NF} + XW - 2dW'$$

$$dW = dW' + DWG \cdot V_{gsteff} + DWB(\sqrt{\Phi_s - V_{bseff}} - \sqrt{\Phi_s})$$

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$$dW' = WINT + \frac{WL}{L^{WLN}} + \frac{WW}{W^{WWN}} + \frac{WWL}{L^{WLN}W^{WWN}}$$

$$dL = LINT + \frac{LL}{L^{LLN}} + \frac{LW}{W^{LWN}} + \frac{LWL}{L^{LLN}W^{LWN}}$$

$WINT$ 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.

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

$$L_{active} = L_{drawn} + XL - 2dL$$

$$W_{active} = \frac{W_{drawn}}{NF} + XW - 2dW$$

$$dL = DLC + \frac{LLC}{L^{LLN}} + \frac{LWC}{W^{LWN}} + \frac{LWLC}{L^{LLN}W^{LWN}}$$

$$dW = DWC + \frac{WLC}{L^{WLN}} + \frac{WWC}{W^{WWN}} + \frac{WWLC}{L^{WLN}W^{WWN}}$$

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

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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 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:

$$W_{effcj} = \frac{W_{drawn}}{NF} - 2 \cdot \left(DWJ + \frac{WLC}{L_{WLN}} + \frac{WWC}{W_{WWN}} + \frac{WWLC}{L_{WLN} W_{WWN}} \right)$$

Threshold Voltage Model

Considering non-uniform doping, short-channel effect, DIBL effect, and narrow-width effect, the complete V_{th} model is:

$$\begin{aligned} V_{th} = & VTH0 + (K_{10x} \cdot \sqrt{\Phi_s - V_{bseff}} - K1 \cdot \sqrt{\Phi_s}) \sqrt{1 + \frac{LPEB}{L_{eff}}} - K_{2ox} \cdot V_{bseff} \\ & + K_{1ox} \left(\sqrt{1 + \frac{LPE0}{L_{eff}}} - 1 \right) \sqrt{\Phi_s} + (K3 + K3B \cdot V_{bseff}) \frac{TOXE}{W_{eff} + W0} \Phi_s \\ & - 0.5 \cdot \left[\frac{DVT0W}{\cosh(DVT1W \cdot \frac{L_{eff} \cdot W_{eff}}{l_{tw}}) - 1} + \frac{DVT0}{\cosh(DVT1 \cdot \frac{L_{eff}}{l_t}) - 1} \right] (V_{bi} - \Phi_s) \\ & - \frac{0.5}{\cosh(DSUB \cdot \frac{L_{eff}}{l_{t0}}) - 1} (ETA0 + ETAB \cdot V_{bseff}) \cdot V_{ds} \\ & - nv_t \cdot \ln \left(\frac{L_{eff}}{L_{eff} + DVTP0 \cdot [1 + \exp(-DVTP1 \cdot V_{ds})]} \right) \end{aligned}$$

Channel Charge and Subthreshold Swing Models

A unified expression for channel charge from subthreshold to strong inversion regions is

$$Q_{ch}(y) = C_{oxeff} \cdot V_{gseff} \cdot \left(1 - \frac{V_F(y)}{V_b}\right)$$

The drain current equation in the subthreshold region can be expressed as

$$I_{ds} = I_0 \left[1 - \exp\left(-\frac{V_{ds}}{v_t}\right)\right] \cdot \exp\left(\frac{V_{gs} - V_{th} - V'_{off}}{nv_t}\right)$$

where

$$I_0 = \mu \frac{W}{L} \sqrt{\frac{q\epsilon_{si}NDEP}{2\Phi_s}} v_t^2$$

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.

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

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$V_{t_{nom}} (=kT_{nom}/q)$ when $t_{empmod} = 2$. The gate tunneling current components are expressed as following:

$$I_{gb} = I_{gbacc} + I_{gbinv}$$

$$= W_{eff} L_{eff} \cdot A \cdot T_{oxRatio} \cdot V_{gb} \cdot V_{aux}$$

$$\cdot [\exp(-B \cdot TOXE (AIGBACC - BIGBACC \cdot V_{oxacc}) \cdot (1 + CIGBACC \cdot V_{oxacc}))$$

$$+ \exp(-B \cdot TOXE (AIGBINV - BIGBINV \cdot V_{oxdepinv}) \cdot (1 + CIGBINV \cdot V_{oxdepinv}))]$$

$$I_{gs} = W_{eff} \cdot DLCIG \cdot A \cdot T_{oxRatioEdge} \cdot V_{gs} \cdot V_{gs}'$$

$$\cdot \exp[-B \cdot TOXE \cdot POXEDGE \cdot (AIGS - BIGS \cdot V_{gs}') \cdot (1 + CIGS \cdot V_{gs}')]]$$

$$I_{gd} = W_{eff} \cdot DLCIGD \cdot A \cdot T_{oxRatioEdge} \cdot V_{gd} \cdot V_{gd}'$$

$$\cdot \exp[-B \cdot TOXE \cdot POXEDGE \cdot (AIGD - BIGD \cdot V_{gd}') \cdot (1 + CIGD \cdot V_{gd}')]]$$

$$I_{gc} = I_{gcs} + I_{gcd}$$

where

$$I_{gcs} = I_{gc0} \cdot \frac{PIGCD \cdot V_{dseff} + \exp(-PIGCD \cdot V_{dseff}) - 1 + 1.0e-4}{PIGCD^2 \cdot V_{dseff}^2 + 2.0e-4}$$

$$I_{gcd} = I_{gc0} \cdot \frac{1 - (PIGCD \cdot V_{dseff} + 1) \cdot \exp(-PIGCD \cdot V_{dseff}) + 1.0e-4}{PIGCD^2 \cdot V_{dseff}^2 + 2.0e-4}$$

$$I_{gc0} = W_{eff} L_{eff} \cdot A \cdot T_{oxRatio} \cdot V_{gse} \cdot V_{aux}$$

$$\cdot \exp[-B \cdot TOXE (AIGC - BIGC \cdot V_{oxdepinv}) (1 + CIGC \cdot V_{oxdepinv})]$$

Drain Current Model

Bulk Charge Effect

The bulk charge effect caused by non-zero V_{ds} is modeled as

$$A_{bulk} = \left[1 + F_doping \cdot \left[\frac{A0 \cdot L_{eff}}{L_{eff} + 2\sqrt{XJ \cdot X_{dep}}} \cdot \left(1 - AGS \cdot V_{gsteff} \left(\frac{L_{eff}}{L_{eff} + 2\sqrt{XJ \cdot X_{dep}}} \right)^2 \right) + \frac{B0}{W'_{eff} + B1} \right] \right] \cdot \frac{1}{1 + KETA \cdot V_{bseff}}$$

$$F_doping = \frac{\sqrt{1 + LPEB / L_{eff}} \cdot K_{1ox}}{2\sqrt{\Phi_s - V_{bseff}}} + K_{2ox} - K_{3B} \frac{TOXE}{W'_{eff} + W0} \Phi_s$$

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

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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:

$$mobmod = 0$$

$$\mu_{eff} = \frac{U0 \cdot f(L_{eff})}{1 + (UA + UC \cdot V_{bseff})E_{eff} + UB \cdot E_{eff}^2 + UD \left(\frac{V_{th} \cdot EOT}{V_{gsteff} + 2\sqrt{V_{th}^2 + 0.0001}} \right)^2}$$

$$mobmod = 1$$

$$\mu_{eff} = \frac{U0 \cdot f(L_{eff})}{1 + (UA \cdot E_{eff} + UB \cdot E_{eff}^2)(1 + UC \cdot V_{bseff}) + UD \left(\frac{V_{th} \cdot EOT}{V_{gsteff} + 2\sqrt{V_{th}^2 + 0.0001}} \right)^2}$$

$$mobmod = 2$$

$$\mu_{eff} = \frac{U0 \cdot f(L_{eff})}{1 + (UA + UC \cdot V_{bseff}) \left[\frac{V_{gsteff} + C_0 \cdot (V_{THO} - V_{FB} - \Phi_s)}{TOXE} \right]^{EU} + UD \left(\frac{V_{th} \cdot TOXE}{V_{gsteff} + 2\sqrt{V_{th}^2 + 0.0001}} \right)^2}$$

$mobmod = 3$, for high k/metal gate structure (introduced by BSIM4.6.2):

$$\mu_{eff} = \frac{U0 \cdot f(L_{eff})}{1 + (UA + UC \cdot V_{bseff}) \left[\frac{V_{gsteff} + C_0 \cdot (V_{THO} - V_{FB} - \Phi_s)}{6 \cdot TOXE} \right]^{EU} + \frac{UD}{0.5[1 + V_{gsteff} / V_{gsteff, vth}]^{UCS}}}$$

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

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dominates in a specific region. The channel current equation for both linear and saturation regions is:

$$I_{ds} = \frac{I_{ds0}NF}{1 + \frac{R_{ds}I_{ds0}}{V_{dseff}}} \left[1 + \frac{1}{C_{clm}} \ln\left(\frac{V_A}{V_{Asat}}\right) \right] \left(1 + \frac{V_{ds} - V_{dseff}}{V_{ADIBL}} \right) \left(1 + \frac{V_{ds} - V_{dseff}}{V_{ASCBE}} \right) \left(1 + \frac{V_{ds} - V_{dseff}}{V_{ADITS}} \right)$$

where NF is the number of device fingers, and Early voltage

$$V_A = V_{Asat} + V_{ACLM}$$

The Early voltage at $V_{ds} = V_{dsat}$ is

$$V_{Asat} = \frac{E_{sat}L_{eff} + V_{dsat} + 2R_{ds}vsatC_{oxe}W_{eff}V_{gsteff}}{R_{ds}vsatC_{oxe}W_{eff}A_{bulk} - 1 + \frac{2}{\lambda}} \left[1 - \frac{A_{bulk}V_{dsat}}{2(V_{gsteff} + 2v_t)} \right]$$

The Early voltage due to CLM effect is

$$V_{ACLM} = C_{clm} (V_{ds} - V_{dsat})$$

where

$$C_{clm} = \frac{F}{PCLM} \left(1 + PVAG \frac{V_{gsteff}}{E_{sat}L_{eff}} \right) \left(1 + \frac{R_{ds}I_{ds0}}{V_{dseff}} \right) \left(L_{eff} + \frac{V_{sat}}{E_{sat}} \right) \frac{1}{litl}$$

The Early voltage due to DIBL effect is

$$V_{ADIBL} = \frac{V_{gsteff} + 2v_t}{\theta_{rout}(1 + PDIBLCB \cdot V_{bseff})} \left(1 - \frac{A_{bulk}V_{dsat}}{A_{bulk}V_{dsat} + V_{gseff} + 2v_t} \right) \left(1 + PVAG \frac{V_{gsteff}}{E_{sat}L_{eff}} \right)$$

The Early voltage due to SCBE effect is

$$V_{ASCBE} = \frac{L_{eff}}{PSCBE2} \exp\left(\frac{PSCBE1 \cdot litl}{V_{ds} - V_{dsat}}\right)$$

The Early voltage due to Drain-Induced Threshold Shift (DITS) by pocket implant is

$$V_{ADITS} = \frac{F}{PDITS} \left[1 + (1 + PDITSL \cdot L_{eff}) \exp(PDITSD \cdot V_{ds}) \right]$$

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:

$$I_{DS} = \frac{I_{DS,HD}}{[1 + (v_{sHD} / v_{sBT})^{2MM}]^{1/2MM}}$$

where the current including the velocity overshoot effect is:

$$I_{DS,HD} = \frac{I_{DS} \left(1 + \frac{V_{dseff}}{L_{eff} E_{sat}}\right)}{1 + \frac{V_{dseff}}{L_{eff} E_{sat}^{OV}}}$$

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:

$$I_{sub} = \frac{A_i}{B_i} I_{ds} (V_{ds} - V_{dsat}) \exp\left(-\frac{B_i \cdot litl}{V_{ds} - V_{dsat}}\right)$$

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

$$I_{ii} = \frac{ALPHA0 + ALPHA1 \cdot L_{eff}}{L_{eff}} (V_{ds} - V_{dseff}) \exp\left(\frac{BETA0}{V_{ds} - V_{dseff}}\right) \cdot \frac{I_{ds}}{1 + \frac{V_{ds} - V_{dseff}}{V_{ASCBE}}}$$

I_{GIDL} and I_{GISL} Model

mtrmod=0

$$I_{GIDL} = AGIDL \cdot W_{effCJ} \cdot NF \cdot \frac{V_{ds} - V_{gse} - EGIDL}{3T_{oxe}} \cdot \exp\left(-\frac{3T_{oxe} \cdot BGIDL}{V_{ds} - V_{gse} - EGIDL}\right) \cdot \frac{V_{db}^3}{CGIDL + V_{db}^3}$$

$$I_{GISL} = AGISL \cdot W_{effCJ} \cdot NF \cdot \frac{-V_{ds} - V_{gde} - EGISL}{3T_{oxe}} \cdot \exp\left(-\frac{3T_{oxe} \cdot BGISL}{-V_{ds} - V_{gde} - EGISL}\right) \cdot \frac{V_{sb}^3}{CGISL + V_{sb}^3}$$

mtrmod=1

$$I_{GIDL} = AGIDL \cdot W_{effCJ} \cdot NF \cdot \frac{V_{ds} - V_{gse} - EGIDL + V_{fbsd}}{EOT \cdot \frac{EPSRSUB}{3.9}}$$

$$\cdot \exp\left(-\frac{EOT \cdot \frac{EPSRSUB}{3.9} \cdot BGIDL}{V_{ds} - V_{gse} - EGIDL + V_{fbsd}}\right) \cdot \frac{V_{db}^3}{CGIDL + V_{db}^3}$$

$$I_{GISL} = AGISL \cdot W_{effCJ} \cdot NF \cdot \frac{-V_{ds} - V_{gde} - EGISL + V_{fbsd}}{EOT \cdot \frac{EPSRSUB}{3.9}}$$

$$\cdot \exp\left(-\frac{EOT \cdot \frac{EPSRSUB}{3.9} \cdot BGISL}{-V_{ds} - V_{gde} - EGISL + V_{fbsd}}\right) \cdot \frac{V_{sb}^3}{CGISL + V_{sb}^3}$$

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 cupmod 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:

$$Q_g = -(Q_{sub} + Q_{inv} + Q_{acc})$$

$$Q_b = Q_{acc} + Q_{sub}$$

$$Q_{inv} = Q_s + Q_d$$

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:

$$C_{ij} = \frac{\partial Q_i}{\partial V_j}$$

where i and j denote the transistor terminals. C_{ij} satisfies

$$\sum_i C_{ij} = \sum_j C_{ij} = 0$$

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

$$Q_g = W_{active} L_{active} C_{oxe} (V_{gs} - V_{bs} - VFBCV)$$

$$Q_{sub} = -Q_g$$

$$Q_{inv} = 0$$

Subthreshold region

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$$Q_{sub0} = -W_{active}L_{active}C_{oxe} \frac{K_{1ox}^2}{2} \left(-1 + \sqrt{1 + \frac{4(V_{gs} - VFBCV - V_{bs})}{K_{1ox}^2}} \right)$$

$$Q_g = -Q_{sub0}$$

$$Q_{inv} = 0$$

Strong inversion

$$V_{dsat, cv} = \frac{V_{gs} - V_{th}}{A_{bulk}'}$$

$$A_{bulk}' = A_{bulk} \left(1 + \left(\frac{CLC}{L_{eff}} \right)^{CLE} \right)$$

$$V_{TH} = VFBCV + \Phi_s + K_{1ox} \sqrt{\Phi_s - V_{bseff}}$$

Linear Region

$$Q_g = C_{oxe} W_{active} L_{active} \left[V_{gs} - VFBCV - \Phi_s - \frac{V_{ds}}{2} + \frac{A_{bulk}' \times V_{ds}^2}{12 \left(V_{gs} - V_{th} - \frac{A_{bulk}' V_{ds}}{2} \right)} \right]$$

$$Q_b = C_{oxe} W_{active} L_{active} \left[VFBCV - V_{th} - \Phi_s + \frac{(1 - A_{bulk}') V_{ds}}{2} - \frac{(1 - A_{bulk}') A_{bulk}' V_{ds}^2}{12 \left(V_{gs} - V_{th} - \frac{A_{bulk}' V_{ds}}{2} \right)} \right]$$

50/50 Charge Partition

$$Q_{inv} = -C_{oxe} W_{active} L_{active} \left(V_{gs} - V_{th} - \Phi_s - \frac{A_{bulk}' V_{ds}}{2} + \frac{A_{bulk}'^2 V_{ds}^2}{12 \left(V_{gs} - V_{th} - \frac{A_{bulk}' V_{ds}}{2} \right)} \right)$$

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$$Q_s = Q_d = 0.5Q_{inv}$$

40/60 Channel-Charge Partition

$$Q_d = -C_{oxe} W_{active} L_{active}$$

$$\left(\frac{V_{gs} - V_{th}}{2} - \frac{A_{bulk}' V_{ds}}{2} + \frac{A_{bulk}' V_{ds} \left[\frac{(V_{gs} - V_{th})^2}{6} - \frac{A_{bulk}' V_{ds} (V_{gs} - V_{th})}{8} + \frac{(A_{bulk}' V_{ds})^2}{40} \right]}{12 \left(V_{gs} - V_{th} - \frac{A_{bulk}' V_{ds}}{2} \right)^2} \right)$$

$$Q_s = -(Q_g + Q_b + Q_d)$$

0/100 Partitioning

$$Q_d = -C_{oxe} W_{active} L_{active} \left(\frac{V_{gs} - V_{th}}{2} + \frac{A_{bulk}' V_{ds}}{4} - \frac{(A_{bulk}' V_{ds})^2}{24} \right)$$

$$Q_s = -(Q_g + Q_b + Q_d)$$

Saturation Region

$$Q_g = C_{oxe} W_{active} L_{active} \left(V_{gs} - VFBCV - \Phi_s - \frac{V_{dsat}}{3} \right)$$

$$Q_b = -C_{oxe} W_{active} L_{active} \left(VFBCV + \Phi_s - V_{th} + \frac{(1 - A_{bulk}') V_{dsat}}{3} \right)$$

50/50 Partitioning

$$Q_s = Q_d = -\frac{1}{3} C_{oxe} W_{active} L_{active} (V_{gs} - V_{th})$$

40/60 Partitioning

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$$Q_d = -\frac{4}{15}C_{oxe}W_{active}L_{active}(V_{gs} - V_{th})$$

$$Q_s = -(Q_g + Q_b + Q_d)$$

0/100 Channel-Charge Partition

$$Q_d = 0$$

$$Q_s = -(Q_g + Q_b)$$

For capmod=1

$$Q_g = -(Q_{inv} + Q_{acc} + Q_{sub0} + \delta Q_{sub})$$

$$Q_b = -(Q_{acc} + Q_{sub0} + \delta Q_{sub})$$

$$Q_{inv} = Q_s + Q_d$$

$$Q_{acc} = -W_{active}L_{active}C_{oxe} \cdot (V_{FBeff} - V_{fbzb})$$

$$Q_{sub0} = -W_{active}L_{active}C_{oxe} \cdot \frac{K_{1ox}^2}{2} \cdot \left[-1 + \sqrt{1 + \frac{4(V_{gse} - V_{FBeff} - V_{gsteff} - V_{bseff})}{K_{1ox}^2}} \right]$$

$$V_{dsat, cv} = \frac{V_{gsteffcv}}{A_{bulk}'}$$

$$Q_{inv} = -W_{active}L_{active}C_{oxe} \cdot \left[V_{gsteff, cv} - \frac{1}{2}A_{bulk}'V_{cveff} + \frac{A_{bulk}'^2V_{cveff}^2}{12 \cdot \left(V_{gsteff, cv} - \frac{A_{bulk}'V_{cveff}}{2} \right)} \right]$$

$$\delta Q_{sub} = W_{active}L_{active}C_{oxe} \cdot \left[\frac{1 - A_{bulk}'}{2}V_{cveff} - \frac{(1 - A_{bulk}') \cdot A_{bulk}'V_{cveff}^2}{12 \cdot \left(V_{gsteff, cv} - \frac{A_{bulk}'V_{cveff}}{2} \right)} \right]$$

Virtuoso Simulator Components and Device Models Reference
BSIM4 Level-14 Model (bsim4)

50/50 Charge Partition

$$Q_S = Q_D = -\frac{W_{active}L_{active}C_{oxe}}{2} \left[V_{gsteff,cv} - \frac{1}{2}A_{bulk}'V_{cveff} + \frac{A_{bulk}'^2V_{cveff}^2}{12 \cdot \left(V_{gsteff,cv} - \frac{A_{bulk}'V_{cveff}}{2} \right)} \right]$$

40/60 Channel-Charge Partition

$$Q_S = -\frac{W_{active}L_{active}C_{oxe}}{2 \left(V_{gsteff,cv} - \frac{A_{bulk}'V_{cveff}}{2} \right)^2} \left[V_{gsteff,cv}^3 - \frac{4}{3}V_{gsteff,cv}^2 A_{bulk}'V_{cveff} + \frac{2}{3}V_{gsteff,cv}(A_{bulk}'V_{cveff})^2 - \frac{2}{15}(A_{bulk}'V_{cveff})^3 \right]$$

$$Q_D = -\frac{W_{active}L_{active}C_{oxe}}{2 \left(V_{gsteff,cv} - \frac{A_{bulk}'V_{cveff}}{2} \right)^2} \left[V_{gsteff,cv}^3 - \frac{5}{3}V_{gsteff,cv}^2 A_{bulk}'V_{cveff} + V_{gsteff,cv}(A_{bulk}'V_{cveff})^2 - \frac{1}{5}(A_{bulk}'V_{cveff})^3 \right]$$

0/100 Charge Partition

$$Q_S = -\frac{W_{active}L_{active}C_{oxe}}{2} \cdot \left(V_{gsteff,cv} + \frac{1}{2}A_{bulk}'V_{cveff} - \frac{A_{bulk}'^2V_{cveff}^2}{12 \cdot \left(V_{gsteff,cv} - \frac{A_{bulk}'V_{cveff}}{2} \right)} \right)$$

$$Q_D = -\frac{W_{active}L_{active}C_{oxe}}{2} \cdot \left[V_{gsteff,cv} - \frac{3}{2}A_{bulk}'V_{cveff} + \frac{A_{bulk}'^2V_{cveff}^2}{4 \cdot \left(V_{gsteff,cv} - \frac{A_{bulk}'V_{cveff}}{2} \right)} \right]$$

For capmod = 2

$$Q_{acc} = W_{active}L_{active}C_{oxeff} \cdot V_{gbacc}$$

Virtuoso Simulator Components and Device Models Reference
BSIM4 Level-14 Model (bsim4)

$$V_{gbacc} = \frac{1}{2} \cdot \left[V_0 + \sqrt{V_0^2 + 0.08V_{fbzb}} \right]$$

$$V_0 = V_{fbzb} + V_{bseff} - V_{gs} - 0.02$$

$$V_{cveff} = V_{dsat} - \frac{1}{2} \cdot \left(V_1 + \sqrt{V_1^2 + 0.08V_{dsat}} \right)$$

$$V_1 = V_{dsat} - V_{ds} - 0.02$$

$$V_{dsat} = \frac{\langle V_{gsteff, cv} - \Phi_{\delta} \rangle_{eff}}{A_{bulk}'}$$

When updatelevel=1, a smooth function is applied when calculating $(V_{gsteff, cv} - \Psi_{\delta, eff})$ to improve convergence behavior of the model.

$$\Phi_{\delta} = \Phi_s - 2\Phi_B = v_t \ln \left(\frac{V_{gsteffCV} \cdot (V_{gsteffCV} + 2K_{1ox} \sqrt{2\Phi_B})}{MOIN \cdot K_{1ox}^2 v_t} \right)$$

$$Q_{sub0} = -W_{active} L_{active} C_{oxeff} \cdot \frac{K_{1ox}^2}{2} \left[-1 + \sqrt{1 + \frac{4(V_{gse} - V_{FBeff} - V_{bseffs} - V_{gsteff, cv})}{K_{1ox}^2}} \right]$$

$$Q_{inv} = -W_{active} L_{active} C_{oxeff} \cdot \left[\langle V_{gsteff, cv} - \Phi_{\delta} \rangle_{eff} - \frac{1}{2} A_{bulk}' V_{cveff} + \frac{A_{bulk}'^2 V_{cveff}^2}{12 \cdot \left(\langle V_{gsteff, cv} - \Phi_{\delta} \rangle_{eff} - \frac{A_{bulk}' V_{cveff}}{2} \right)} \right]$$

$$\delta Q_{sub} = -W_{active} L_{active} C_{oxeff} \cdot \left[\frac{1 - A_{bulk}'}{2} V_{cveff} - \frac{(1 - A_{bulk}') \cdot A_{bulk}' V_{cveff}^2}{12 \cdot \left(\langle V_{gsteff, cv} - \Phi_{\delta} \rangle_{eff} - \frac{A_{bulk}' V_{cveff}}{2} \right)} \right]$$

Virtuoso Simulator Components and Device Models Reference
BSIM4 Level-14 Model (bsim4)

50/50 Partitioning

$$Q_S = Q_D = -\frac{W_{active}L_{active}C_{oxeff}}{2}$$

$$\left[\langle V_{gsteff, cv - \phi\delta} \rangle_{eff} - \frac{1}{2}A_{bulk}'V_{cveff} + \frac{A_{bulk}'^2V_{cveff}^2}{12 \cdot \left(\langle V_{gsteff, cv - \phi\delta} \rangle_{eff} - \frac{A_{bulk}'V_{cveff}}{2} \right)} \right]$$

40/60 Partitioning

$$Q_S = -\frac{W_{active}L_{active}C_{oxeff}}{2 \left(\langle V_{gsteff, cv - \phi\delta} \rangle_{eff} - \frac{A_{bulk}'V_{cveff}}{2} \right)^2}$$

$$\left[\langle V_{gsteff, cv - \phi\delta} \rangle_{eff}^3 - \frac{4}{3} \langle V_{gsteff, cv - \phi\delta} \rangle_{eff}^2 A_{bulk}'V_{cveff} + \right.$$

$$\left. \frac{2}{3} \langle V_{gsteff, cv - \phi\delta} \rangle_{eff} (A_{bulk}'V_{cveff})^2 - \frac{2}{15} (A_{bulk}'V_{cveff})^3 \right]$$

$$Q_D = -\frac{W_{active}L_{active}C_{oxeff}}{2 \left(\langle V_{gsteff, cv - \phi\delta} \rangle_{eff} - \frac{A_{bulk}'V_{cveff}}{2} \right)^2}$$

$$\left[\langle V_{gsteff, cv - \phi\delta} \rangle_{eff}^3 - \frac{5}{3} \langle V_{gsteff, cv - \phi\delta} \rangle_{eff}^2 A_{bulk}'V_{cveff} + \langle V_{gsteff, cv - \phi\delta} \rangle_{eff} (A_{bulk}'V_{cveff})^2 \right.$$

$$\left. - \frac{1}{5} (A_{bulk}'V_{cveff})^3 \right]$$

0/100 Partitioning

Virtuoso Simulator Components and Device Models Reference
BSIM4 Level-14 Model (bsim4)

$$Q_S = -\frac{W_{active} L_{active} C_{oxeff}}{2} \cdot \left[(V_{gsteff, cv} - \Phi_{\delta})_{eff} + \frac{1}{2} A_{bulk} V_{cveff} - \frac{A_{bulk} V_{cveff}^2}{12 \cdot \left((V_{gsteff, cv} - \Phi_{\delta})_{eff} - \frac{A_{bulk} V_{cveff}}{2} \right)} \right]$$

$$Q_D = -\frac{W_{active} L_{active} C_{oxeff}}{2} \cdot \left[(V_{gsteff, cv} - \Phi_{\delta})_{eff} - \frac{3}{2} A_{bulk} V_{cveff} - \frac{A_{bulk} V_{cveff}^2}{4 \cdot \left((V_{gsteff, cv} - \Phi_{\delta})_{eff} - \frac{A_{bulk} V_{cveff}}{2} \right)} \right]$$

When `updatelevel=0`,

$$\langle V_{gsteff, cv} - \Phi_{\delta} \rangle_{eff} = V_{gsteff, cv} - \Phi_{\delta}$$

When `updatelevel=1`, or `version=4.5`,

$$\langle V_{gsteff, cv} - \Phi_{\delta} \rangle_{eff} = 0.5 \cdot \left[(V_{gsteff, cv} - \Phi_{\delta} - 0.0001) + \sqrt{(V_{gsteff, cv} - \Phi_{\delta} - 0.0001)^2 + V_{gsteff, cv} \cdot 0.0004} \right]$$

Intrinsic Capacitances (with Body Bias and DIBL)

$$C_{(s, d, g, b), g} = \frac{\partial Q_{s, d, g, b}}{\partial V_{gsteffcv}} \frac{\partial V_{gsteffcv}}{\partial V_{gt}}$$

$$C_{(s, d, g, b), s} = -\frac{\partial Q_{s, d, g, b}}{\partial V_{ds}} + \frac{\partial Q_{s, d, g, b}}{\partial V_{gsteffcv}} \frac{\partial V_{gsteffcv}}{\partial V_{gt}} \left(\frac{\partial V_{th}}{\partial V_{ds}} + \frac{\partial V_{th}}{\partial V_{bs}} \right)$$

$$C_{(s, d, g, b), d} = \frac{\partial Q_{s, d, g, b}}{\partial V_{ds}} - \frac{\partial Q_{s, d, g, b}}{\partial (V_{gsteffcv})} \frac{\partial V_{gsteffcv}}{\partial V_{gt}} \frac{\partial V_{th}}{\partial V_{ds}}$$

$$C_{(s,d,g,b),b} = \frac{\partial Q_{s,d,g,b}}{\partial V_{bs}} - \frac{\partial Q_{s,d,g,b}}{\partial V_{gsteffcv}} \frac{\partial V_{gsteffcv}}{\partial V_{gt}} \frac{\partial V_{th}}{\partial V_{bs}}$$

Overlap Capacitance Models

capmod=0, Bias-independent overlap capacitance model

$$Q_{overlap,s} = W_{active} \cdot CGSO \cdot V_{gs}$$

$$Q_{overlap,d} = W_{active} \cdot CGDO \cdot V_{gd}$$

$$Q_{overlap,b} = L_{active} \cdot CGBO \cdot V_{gb}$$

capmod= 1 and 2, Bias-dependent overlap capacitance model

$$\frac{Q_{overlap,s}}{W_{active}} = CGSO \cdot V_{gs} + CGSL \left(V_{gs} - V_{gs,overlap} - \frac{CKAPPAS}{2} \left(-1 + \sqrt{1 - \frac{4V_{gs,overlap}}{CKAPPAS}} \right) \right)$$

$$\frac{Q_{overlap,d}}{W_{active}} = CGDO \cdot V_{gd} + CGDL \left(V_{gd} - V_{gd,overlap} - \frac{CKAPPAD}{2} \left(-1 + \sqrt{1 - \frac{4V_{gd,overlap}}{CKAPPAD}} \right) \right)$$

$$Q_{overlap,g} = -(Q_{overlap,d} + Q_{overlap,s} + CGBO \cdot L_{active} \cdot V_{gb})$$

where

$$V_{gs,overlap} = \frac{V_{gs} + \delta_1 - \sqrt{(V_{gs} + \delta_1)^2 + 4\delta_1}}{2},$$

$$V_{gd,overlap} = \frac{V_{gd} + \delta_1 - \sqrt{(V_{gd} + \delta_1)^2 + 4\delta_1}}{2}, \delta_1 = 0.02V$$

High Speed/RF Models

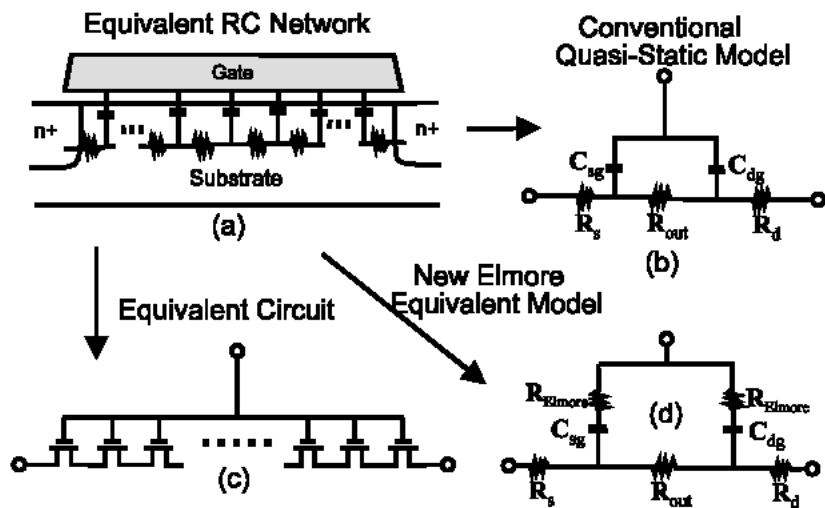
Charge-deficit Nonquasi-static (NQS) Model

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) dependent and the transcapacitances and transconductances (such as G_m) for AC analysis can therefore be expressed as functions for $j\omega\tau$.

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

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.



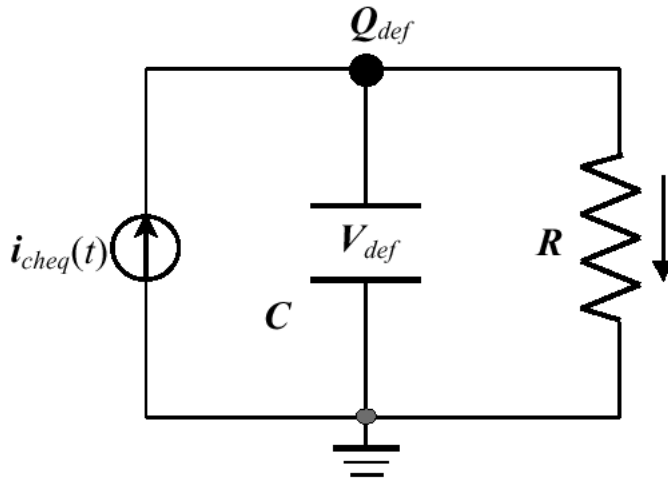
The Transient Model

The transient charge-deficit NQS model can be turned on by setting ***trnqsMod*** = 1 and off by setting ***trnqsMod*** = 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:

Virtuoso Simulator Components and Device Models Reference
BSIM4 Level-14 Model (bsim4)

$$Q_{def}(t) = V_{def} \times C_{fact}$$



Considering both the transport and charging component, the total current related to the terminals D, G, and S can be written as:

$$i_{D, G, S}(t) = I_{D, G, S}(DC) + \frac{\partial Q_{d, g, s}(t)}{\partial t}$$

Based on the relaxation time approach, the terminal charge and corresponding charging current are modeled by

$$Q_{def}(t) = Q_{cheq}(t) - Q_{ch}(t)$$

and

$$\frac{\partial Q_{def}(t)}{\partial t} = \frac{\partial Q_{cheq}(t)}{\partial t} - \frac{Q_{def}(t)}{\tau}$$

$$\frac{\partial Q_{d, g, s}(t)}{\partial t} = D, G, S_{xpart} \frac{Q_{def}(t)}{\tau}$$

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

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

$$\frac{1}{R_{ii}} = XRCRG1 \cdot \left(\frac{I_{ds}}{V_{dseff}} + XRCRG2 \cdot \frac{W_{eff} \mu_{eff} C_{oxeff} k_B T}{q L_{eff}} \right)$$

where C_{oxeff} is the effective gate dielectric capacitance calculated from the DC model.

Note: R_{ii} 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:

$$\Delta Q_{ch}(t) = \frac{\Delta Q_{cheq}(t)}{1 + j\omega\tau}$$

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:

$$G_m = \frac{G_{m0}}{1 + \omega^2 \tau^2} + j \left(-\frac{G_{m0} \cdot \omega\tau}{1 + \omega^2 \tau^2} \right)$$

and

$$C_{dg} = \frac{C_{dg0}}{1 + \omega^2 \tau^2} + j \left(-\frac{C_{dg0} \cdot \omega\tau}{1 + \omega^2 \tau^2} \right)$$

The quantities above with sub "0" are known from OP (Operating Point) analysis.

Gate Electrode Electrode and Intrinsic-Input Resistance (IIR) Model

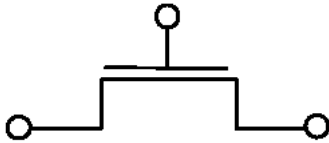
BSIM4 provides four options for modeling gate electrode resistance (bias-independent) and intrinsic-input resistance (IIR, bias-dependent). The IIR model considers the relaxation-time effect due to the distributive RC nature of the channel region, and therefore describes the first-order non-quasi-static effect. Thus, the IIR model should not be used together with the

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

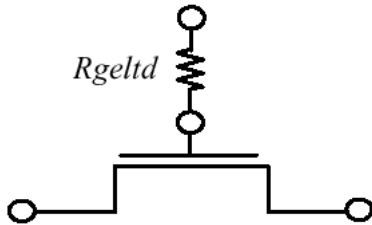
charge-deficit NQS model. The model selector ***rgateMod*** is used to choose different options.

rgateMod = 0 (zero-resistance)



In this case, no gate resistance is generated.

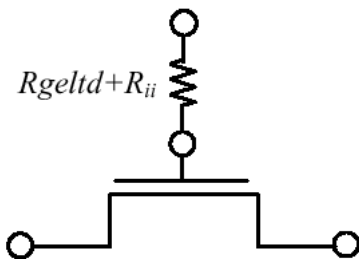
rgateMod = 1 (constant-resistance)



In this case, only the electrode gate resistance (bias-dependent) is generated by adding an internal gate node. R_{geltd} is given by

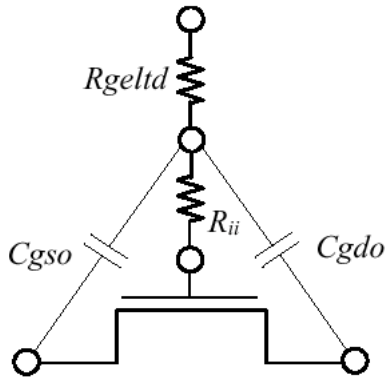
$$R_{geltd} = \frac{RSHG \cdot \left(XGW + \frac{W_{effc}}{3 \cdot NGCON} \right)}{NGCON \cdot (L_{drawn} - XGL) \cdot NF}$$

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_{ii} . 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)

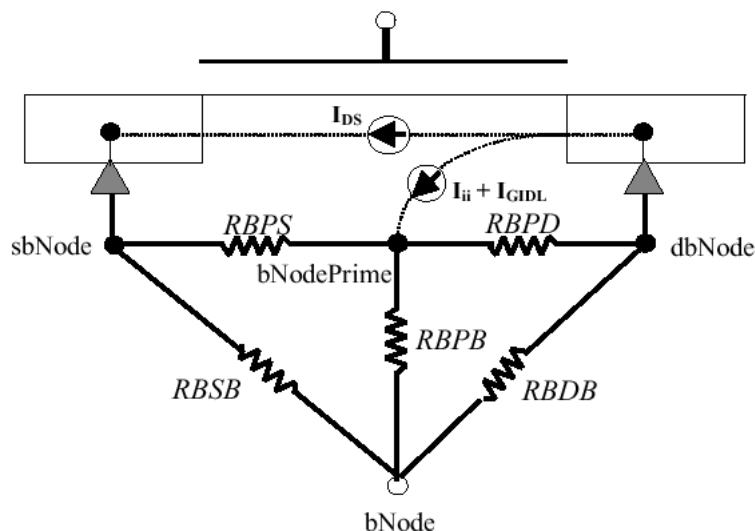
All five resistances in the substrate network as shown schematically below are present simultaneously.

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

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:

$$S_{id}(f) = \frac{KF \cdot I_{ds}^{AF}}{C_{oxe} L_{eff}^2 f^{EF}}$$

fnoiMod = 1 (unified model)

The total flicker noise density is

$$S_{id}(f) = \frac{S_{id,inv}(f) \cdot S_{id,subvt}(f)}{S_{id,inv}(f) + S_{id,subvt}(f)}$$

The noise density in the inversion region is:

$$S_{id,inv}(f) = \frac{k_B T q^2 \mu_{eff} I_{ds}}{C_{ox} (L_{eff} - 2 \cdot LINTNOI)^2 A_{bulk} f^{EF} \cdot 10^{10}} \cdot \left(NOIA \cdot \log\left(\frac{N_0 + N^*}{N_l + N^*}\right) + NOIB \cdot (N_0 - N_l) + \frac{NOIC}{2} (N_0^2 - N_l^2) \right) + \frac{k_B T I_{ds}^2 \Delta L_{clm}}{W_{eff} \cdot (L_{eff} - 2 \cdot LINTNOI)^2 f^{EF} \cdot 10^{10}} \cdot \frac{NOIA + NOIB \cdot N_l + NOIC \cdot N_l^2}{(N_l + N^*)^2}$$

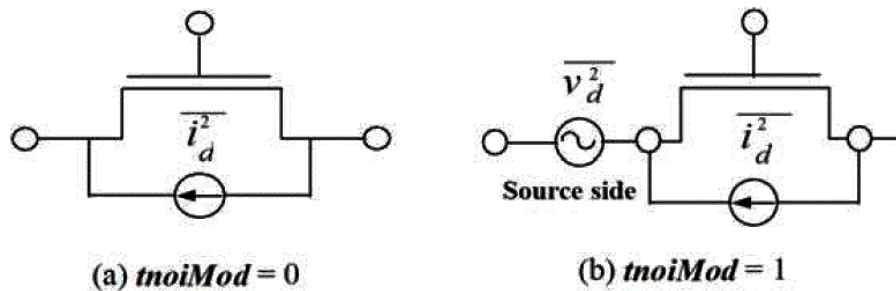
lintnoi is an offset to the length reduction parameter (*lint*) for flicker noise, which is introduced by BSIM4.4.

The noise density in the subthreshold region is:

$$S_{id,subvt}(f) = \frac{NOIA \cdot k_B T \cdot I_{ds}^2}{W_{eff} L_{eff} f^{EF} N^{*2} \cdot 10^{10}}$$

Channel Thermal Noise

BSIM4 provides two channel thermal noise models: charge-based model (default model) and the holistic model. They can be selected by *tnoimod*. The schematic for BSIM4 channel thermal noise modeling is shown as following:



***tnoimod* = 0 (charge-based)**

Chargebased model is similar to that used in BSIM3v3.2. The noise current is given by:

$$\overline{i_D^2} = \frac{4k_B T \Delta f}{R_{ds}(V) + \frac{L_{eff}^2}{\mu_{eff} |Q_{inv}|}} \cdot NTNOI$$

where

$$Q_{inv} = W_{active} L_{active} C_{oxeff} \cdot NF \cdot \left[V_{gsteff} - \frac{A_{bulk} V_{dseff}}{2} + \frac{A_{bulk}^2 V_{dseff}^2}{12 \cdot \left(V_{gsteff} - \frac{A_{bulk} V_{dseff}}{2} \right)} \right]$$

***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

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

$$\overline{v_d^2} = 4k_B T \cdot \theta_{toi}^2 \cdot \frac{V_{dseff} \Delta f}{I_{ds}}$$

The noise current source put in the channel region with gate and body amplification is given by:

$$\overline{i_d^2} = 4k_B T \frac{V_{dseff} \Delta f}{I_{ds}} [G_{ds} + \beta_{toi} \cdot (G_m + G_{mbs})]^2 - \overline{v_d^2} \cdot (G_m + G_{ds} + G_{mbs})^2 \quad \text{if}$$

where

$$\theta_{toi} = RNOIB \cdot \left[1 + TNOIB \cdot L_{eff} \cdot \left(\frac{V_{gsteff}}{E_{sat} L_{eff}} \right)^2 \right]$$

$$\beta_{toi} = RNOIA \cdot \left[1 + TNOIA \cdot L_{eff} \cdot \left(\frac{V_{gsteff}}{E_{sat} L_{eff}} \right)^2 \right]$$

Asymmetric MOS Junction Diode Models

Junction Diode IV Model

In BSIM4, there are three junction diode IV models. When the IV model selector **diMod** 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 **diMod** 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 **diMod** = 1 and *XJBVS*, *XJBVD*, *BVS*, and *BVD* parameters all have no effect. When **diMod** is set to 2 ("resistance-and-breakdown"), BSIM4 models the diode breakdown with current limiting in both forward and reverse operations. In general, setting **diMod** to 1 produces fast convergence.

Source/Body Junction Diode

diMod - 0 (resistance-free)

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

$$I_{bs} = I_{sbs} \left[\exp \left(\frac{qV_{bs}}{NJS \cdot k_B TNOM} \right) - 1 \right] \cdot f_{breakdown} + V_{bs} \cdot G_{min}$$

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}).

$$I_{sbs} = A_{seff} J_{ss}(T) + R_{seff} J_{ssws}(T) + W_{effej} \cdot NF \cdot J_{sswgs}(T)$$

where

$$f_{breakdown} = 1 + XJBVS \cdot \exp \left(\frac{q \cdot (BVS + V_{bs})}{NJS \cdot k_B TNOM} \right)$$

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.

$$I_{bs} = I_{sbs} \left[\exp \left(\frac{qV_{bs}}{NJS \cdot k_B TNOM} \right) - 1 \right] + V_{bs} \cdot G_{min}$$

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.

$$I_{bs} = I_{sbs} \left[\exp \left(\frac{qV_{bs}}{NJS \cdot k_B TNOM} \right) - 1 \right] \cdot f_{breakdown} + V_{bs} \cdot G_{min}$$

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)

$$I_{bd} = I_{sbd} \left[\exp\left(\frac{qV_{bd}}{NJD \cdot k_B TNOM}\right) - 1 \right] \cdot f_{breakdown} + V_{bd} \cdot G_{min}$$

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}),

$$I_{sbd} = A_{deff} J_{sd}(T) + P_{deff} J_{sswd}(T) + W_{effcj} \cdot NF \cdot J_{sswgd}(T)$$

where

$$f_{breakdown} = 1 + XJBVD \cdot \exp\left(-\frac{q \cdot (BVD + V_{bd})}{NJD \cdot k_B TNOM}\right)$$

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.

$$I_{bd} = I_{sbd} \left[\exp\left(\frac{qV_{bd}}{NJD \cdot k_B TNOM}\right) - 1 \right] + V_{bd} \cdot G_{min}$$

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.

$$I_{bd} = I_{sbd} \left[\exp\left(\frac{qV_{bd}}{NJD \cdot k_B TNOM}\right) - 1 \right] \cdot f_{breakdown} + V_{bd} \cdot G_{min}$$

For **dioMod** = 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:

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

$$I_{bs_total} = I_{bs}$$

$$-W_{effcj} \cdot NF \cdot J_{tsswgs}(T) \cdot \left[\exp\left(\frac{-V_{bs}}{NJTSSWG(T) \cdot Vtm0} \cdot \frac{VTSSWGS}{VTSSWGS - V_{bs}}\right) - 1 \right]$$

$$-P_{s, deff} J_{tssws}(T) \left[\exp\left(\frac{-V_{bs}}{NJTSSW(T) \cdot Vtm0} \cdot \frac{VTSSWS}{VTSSWS - V_{bs}}\right) - 1 \right]$$

$$-A_{s, deff} J_{tss}(T) \left[\exp\left(\frac{-V_{bs}}{NJTS(T) \cdot Vtm0} \cdot \frac{VTSS}{VTSS - V_{bs}}\right) - 1 \right] + g_{min} \cdot V_{bs}$$

$$I_{bd_total} = I_{bd}$$

$$-W_{effcj} \cdot NF \cdot J_{tsswgd}(T) \cdot \left[\exp\left(\frac{-V_{bd}}{NJTSSWGD(T) \cdot Vtm0} \cdot \frac{VTSSWGD}{VTSSWGD - V_{bd}}\right) - 1 \right]$$

$$-P_{s, deff} J_{tsswd}(T) \left[\exp\left(\frac{-V_{bd}}{NJTSSWD(T) \cdot Vtm0} \cdot \frac{VTSSWD}{VTSSWD - V_{bd}}\right) - 1 \right]$$

$$-A_{d, deff} J_{tsd}(T) \left[\exp\left(\frac{-V_{bd}}{NJTSD(T) \cdot Vtm0} \cdot \frac{VTSD}{VTSD - V_{bd}}\right) - 1 \right] + g_{min} \cdot V_{bd}$$

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

$$C_{bs} = A_{seff} C_{jbs} + P_{seff} C_{jbsws} + W_{effcj} \cdot NF \cdot C_{jbswgs}$$

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

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 $V_{bs} < 0$

$$C_{jbs} = CJS(T) \cdot \left(1 - \frac{V_{bs}}{PBS(T)}\right)^{-MJS}$$

otherwise

$$C_{jbs} = CJS(T) \cdot \left(1 + MJS \cdot \frac{V_{bs}}{PBS(T)}\right)$$

C_{jbsws}

if $V_{bs} < 0$

$$C_{jbsws} = CJSWS(T) \cdot \left(1 - \frac{V_{bs}}{PBSWS(T)}\right)^{-MJSWS}$$

otherwise

$$C_{jbsws} = CJSWS(T) \cdot \left(1 + MJSWS \cdot \frac{V_{bs}}{PBSWS(T)}\right)$$

C_{jbswgs}

if $V_{bs} < 0$

$$C_{jbswgs} = CJSWGS(T) \cdot \left(1 - \frac{V_{bs}}{PBSWGS(T)}\right)^{-MJSWGS}$$

otherwise

Virtuoso Simulator Components and Device Models Reference
BSIM4 Level-14 Model (bsim4)

$$C_{jbswgs} = CJSWGS(T) \cdot \left(1 + MJSWGS \cdot \frac{V_{bs}}{PBSWGS(T)} \right)$$

Drain/Body Junction Diode

$$C_{bd} = A_{deff} C_{jbd} + P_{deff} C_{jbswd} + W_{effcj} \cdot NF \cdot C_{jbswgd}$$

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 $V_{bd} < 0$

$$C_{jbd} = CJD(T) \cdot \left(1 - \frac{V_{bd}}{PBD(T)} \right)^{-MJD}$$

otherwise

$$C_{jbd} = CJD(T) \cdot \left(1 + MJD \cdot \frac{V_{bd}}{PBD(T)} \right)$$

C_{jbsdsw}

if $V_{bd} < 0$

$$C_{jbsdsw} = CJSWD(T) \cdot \left(1 - \frac{V_{bd}}{PBSWD(T)} \right)^{-MJSWD}$$

otherwise

$$C_{jbsdsw} = CJSWD(T) \cdot \left(1 + MJSWD \cdot \frac{V_{bd}}{PBSWD(T)} \right)$$

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

C_{jbdswg}

if $V_{bd} < 0$

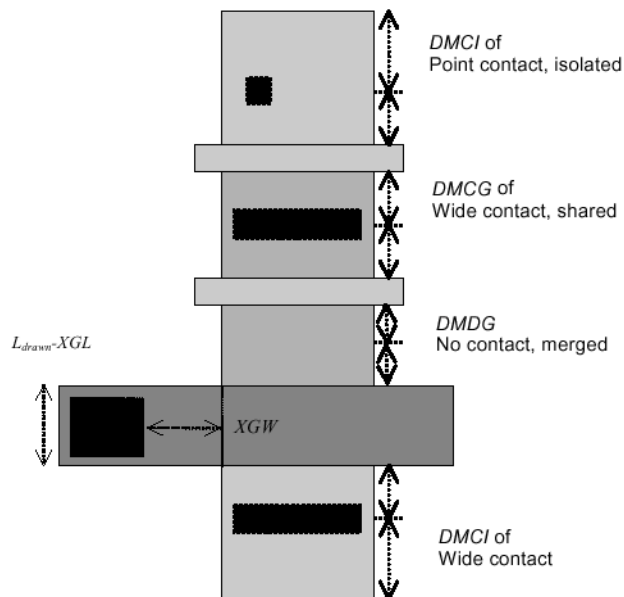
$$C_{jbdswgd} = C_{JSWGD}(T) \cdot \left(1 - \frac{V_{bd}}{P_{BSWGD}(T)}\right)^{-M_{JSWGD}}$$

otherwise

$$C_{jbdswgd} = C_{JSWGD}(T) \cdot \left(1 + M_{JSWGD} \cdot \frac{V_{bd}}{P_{BSWGD}(T)}\right)$$

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:

Virtuoso Simulator Components and Device Models Reference
BSIM4 Level-14 Model (bsim4)

If (PS is given)

if ($perMod = 0$)

$$P_{seff} = PS$$

else

$$P_{seff} = PS - W_{effcj} \cdot NF$$

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>
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>

Virtuoso Simulator Components and Device Models Reference
BSIM4 Level-14 Model (bsim4)

<i>geoMod</i>	End source	End drain	Note
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:

$$V_{th}(T) = V_{th}(TNOM) + \left(KT1 + \frac{KT1L}{L_{eff}} + KT2 \cdot V_{bseff} \right) \cdot \left(\frac{T}{TNOM} - 1 \right)$$

$$V_{fb}(T) = V_{fb}(TNOM) - KT1 \cdot \left(\frac{T}{TNOM} - 1 \right)$$

$$VOFF(T) = VOFF(TNOM) \cdot [1 + TVOFF \cdot (T - TNOM)]$$

$$VFBSDOFF(T) = VFBSDOFF(TNOM) \cdot [1 + TVFBSDOFF \cdot (T - TNOM)]$$

Temperature Dependence of Mobility

$$U0(T) = U0(TNOM) \cdot (T/TNOM)^{UTE}$$

$$UA(T) = UA(TNOM) + UA1 \cdot (T/TNOM - 1)$$

$$UB(T) = UB(TNOM) + UB1 \cdot (T/TNOM - 1)$$

$$UC(T) = UC(TNOM) + UC1 \cdot (T/TNOM - 1)$$

Temperature Dependence of Saturation Velocity

$$v_{sat}(T) = VSAT(TNOM) - AT \cdot (T/TNOM - 1)$$

Temperature Dependence of LDD Resistance

rdsMod = 0 (internal source/drain LDD resistance)

$$RDSW(T) = RDSW(TNOM) + PRT \cdot \left(\frac{T}{TNOM} - 1 \right)$$

$$RDSWMIN(T) = RDSWMIN(TNOM) + PRT \cdot \left(\frac{T}{TNOM} - 1 \right)$$

rdsMod = 1 (external source/drain LDD resistance)

$$RDW(T) = RDW(TNOM) + PRT \cdot \left(\frac{T}{TNOM} - 1 \right)$$

$$RDWMIN(T) = RDWMIN(TNOM) + PRT \cdot \left(\frac{T}{TNOM} - 1 \right)$$

$$RSW(T) = RSW(TNOM) + PRT \cdot \left(\frac{T}{TNOM} - 1 \right)$$

$$RSWMIN(T) = RSWMIN(TNOM) + PRT \cdot \left(\frac{T}{TNOM} - 1 \right)$$

Temperature Dependence of Junction Diode IV

Side Source Diode 0

$$I_{sbs} = A_{seff} J_{ss}(T) + P_{seff} J_{ssws}(T) + W_{effej} \cdot NF \cdot J_{sswgs}(T)$$

where

Virtuoso Simulator Components and Device Models Reference
BSIM4 Level-14 Model (bsim4)

$$J_{ss}(T) = JSS(TNOM) \cdot \exp\left(\frac{\frac{E_g(TNOM)}{v_t(TNOM)} - \frac{E_g(T)}{v_t(T)} + XTIS \cdot \ln\left(\frac{T}{TNOM}\right)}{NJS}\right)$$

$$J_{ssws}(T) = JSSWS(TNOM) \cdot \exp\left(\frac{\frac{E_g(TNOM)}{v_t(TNOM)} - \frac{E_g(T)}{v_t(T)} + XTIS \cdot \ln\left(\frac{T}{TNOM}\right)}{NJS}\right)$$

$$J_{sswgs}(T) = JSSWGS(TNOM) \cdot \left(\sqrt{\frac{JTWEFF}{W_{effci}}} + 1.0\right) \exp\left(\frac{\frac{E_g(Tnom)}{V_t(Tnom)} - \frac{E_g(T)}{V_t(T)} + XTIS \cdot \ln\left(\frac{T}{Tnom}\right)}{NJS}\right)$$

where

$$E_g(TNOM) = 1.16 - \frac{7.02 \times 10^{-4} TNOM^2}{TNOM + 1108}$$

$$E_g(T) = 1.16 - \frac{7.02 \times 10^{-4} T^2}{T + 1108}$$

$$n_i = 1.45e10 \cdot \frac{TNOM}{300.15} \cdot \sqrt{\frac{TNOM}{300.15}} \cdot \exp\left[21.5565981 - \frac{qE_g(TNOM)}{2 \cdot k_B T}\right]$$

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

$$CJS(T) = CJS(TNOM) \cdot [1 + TCJ \cdot (T - TNOM)]$$

Virtuoso Simulator Components and Device Models Reference
BSIM4 Level-14 Model (bsim4)

$$CJSWS(T) = CJSWS(TNOM) + TCJSW \cdot (T - TNOM)$$

$$CJSWGS(T) = CJSWGS(TNOM) \cdot [1 + TCJSWG \cdot (T - TNOM)]$$

The temperature dependences of the built-in potentials on the source side are modeled by

$$PBS(T) = PBS(TNOM) - TPB \cdot (T - TNOM)$$

$$PBSWS(T) = PBSWS(TNOM) - TPBSW \cdot (T - TNOM)$$

$$PBSWGS(T) = PBSWGS(TNOM) - TPBSWG \cdot (T - TNOM)$$

Temperature Dependence of Junction Diode IV

$$J_{tsswgs,d}(T) = J_{tsswgs,d}(TNOM) \cdot \exp\left[\frac{-E_g(TNOM)}{k_B T} \cdot X_{tsswgs,d} \cdot \left(1 - \frac{T}{TNOM}\right)\right]$$

$$J_{tssws,d}(T) = J_{tssws,d}(TNOM) \cdot \exp\left[\frac{-E_g(TNOM)}{k_B T} \cdot X_{tssws,d} \cdot \left(1 - \frac{T}{TNOM}\right)\right]$$

$$J_{tss,d}(T) = J_{tss,d}(TNOM) \cdot \exp\left[\frac{-E_g(TNOM)}{k_B T} \cdot X_{tss,d} \cdot \left(1 - \frac{T}{TNOM}\right)\right]$$

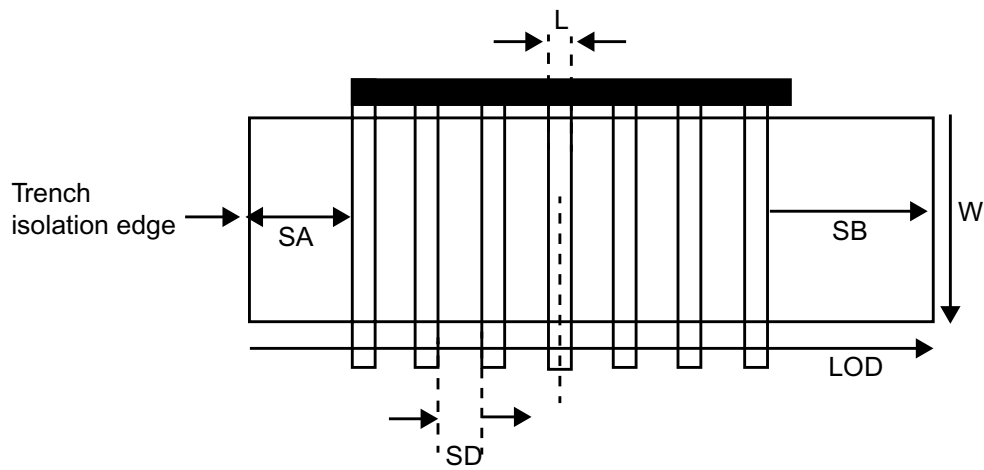
$$NJTSSWG(T) = NJTSSWG(TNOM) \cdot \left[1 + TNJTSSWG\left(\frac{T}{TNOM} - 1\right)\right]$$

$$NJTSSW(T) = NJTSSW(TNOM) \cdot \left[1 + TNJTSSW\left(\frac{T}{TNOM} - 1\right)\right]$$

$$NJTS(T) = NJTS(TNOM) \cdot \left[1 + TNTJS\left(\frac{T}{TNOM} - 1\right)\right]$$

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.



Virtuoso Simulator Components and Device Models Reference
BSIM4 Level-14 Model (bsim4)

$$\mu_{eff} = \frac{1 + \rho_{\mu_{eff}}(SA, SB)}{1 + \rho_{\mu_{eff}}(SA_{ref}, SB_{ref})} \mu_{eff0}$$

$$v_{sattemp} = \frac{1 + KVSAT \cdot \rho_{\mu_{eff}}(SA, SB)}{1 + KVSAT \cdot \rho_{\mu_{eff}}(SA_{ref}, SB_{ref})} v_{sattemp0}$$

$$VTH0 = VTH0_{original} + \frac{KVTH0}{Kstress_vth0} \cdot (Inv_sa + Inv_sb - Inv_sa_{ref} - Inv_sb_{ref})$$

$$K2 = K2_{original} + \frac{STK2}{Kstress_vth0 LODK2} \cdot (Inv_sa + Inv_sb - Inv_sa_{ref} - Inv_sb_{ref})$$

$$ETA0 = ETA0_{original} + \frac{STETA0}{Kstress_vth0 LOETA0} \cdot (Inv_sa + Inv_sb - Inv_sa_{ref} - Inv_sb_{ref})$$

where

$$\rho_{\mu_{eff}} = \frac{KU0}{Kstress_mu0} \cdot (Inv_sa + Inv_sb)$$

$$K_{stress_mu0} = \left(1 + \frac{LKU0}{(L_{drawn} + XL)^{LLODKU0}} + \frac{WKU0}{(W_{drawn} + XW + WLOD)^{WLODKU0}} \right) + \frac{PKU0}{(L_{drawn} + XL)^{LLODKU0} \cdot (W_{drawn} + XW + WLOD)^{WLODKU0}}$$

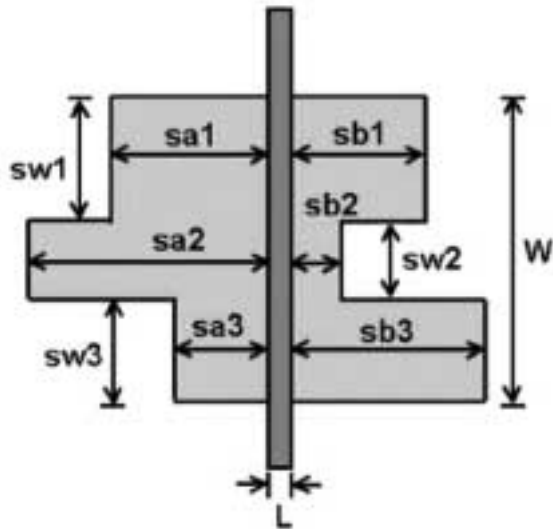
$$\cdot \left(1 + TKU0 \cdot \left(\frac{Temperature}{TNOM} - 1 \right) \right)$$

$$K_{stress_vth0} = \left(1 + \frac{LKVTH0}{(L_{drawn} + XL)^{LLODKVTH}} + \frac{WKVTH0}{(W_{drawn} + XW + WLOD)^{WLODKVTH}} \right) + \frac{PKVTH0}{(L_{drawn} + XL)^{LLODKVTH} \cdot (W_{drawn} + XW + WLOD)^{WLODKVTH}}$$

$$\cdot \left(1 + TKU0 \cdot \left(\frac{Temperature}{TNOM} - 1 \right) \right)$$

$$Inv_sa = \frac{1}{NF} \sum_{i=0}^{NF-1} \frac{1}{SA + 0.5 \cdot L_{drawn} + i \cdot (SD + L_{drawn})}$$

$$Inv_sb = \frac{1}{NF} \sum_{i=0}^{NF-1} \frac{1}{SB + 0.5 \cdot L_{drawn} + i \cdot (SD + L_{drawn})}$$



For irregular LOD device like above figure, more instance parameters (sw_i , sa_i and sb_i) are needed. Then,

$$Inv_sa = \sum_{i=1}^n \frac{sw_i}{W_{drawn}} \cdot \frac{1}{sa_i + 0.5 \cdot L_{drawn}}$$

$$Inv_sb = \sum_{i=1}^n \frac{sw_i}{W_{drawn}} \cdot \frac{1}{sb_i + 0.5 \cdot L_{drawn}}$$

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:

$$V_{th0} = V_{th0,org} + KV_{TH0WE} \cdot (SCA + WEB \cdot SCB + WEC \cdot SCC)$$

$$\mu_{eff} = \mu_{eff,org} \cdot (1 + KU_{0WE} \cdot (SCA + WEB \cdot SCB + WEC \cdot SCC))$$

$$K2 = K2_{org} + K2_{WE} \cdot (SCA + WEB \cdot SCB + WEC \cdot SCC)$$

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

$$\begin{aligned}
 I_{bs,d} = & I_{sbs,d} \left[\exp\left(\frac{qV_{bs,d}}{NJS,D \cdot k_B T}\right) - 1 \right] \cdot f_{breakdown} \\
 & - W_{effc_j} \cdot NF \cdot J_{tsswgs,d}(T) \cdot \left[\exp\left(\frac{-V_{bs,d}}{NJTSSWG(T) \cdot V_{tm0}} \cdot \frac{VTSSWGS,D}{VTSSWGS,D - V_{bs,d}}\right) - 1 \right] \\
 & - P_{s,deff} J_{tssws,d}(T) \left[\exp\left(\frac{-V_{bs,d}}{NJTSSW(T) \cdot V_{tm0}} \cdot \frac{VTSSWS,D}{VTSSWS,D - V_{bs,d}}\right) - 1 \right] \\
 & - A_{s,deff} J_{tss,d}(T) \left[\exp\left(\frac{-V_{bs,d}}{NJTS(T) \cdot V_{tm0}} \cdot \frac{VTSS,D}{VTSS,D - V_{bs,d}}\right) - 1 \right] \\
 & + V_{bs,d} \cdot G_{min}
 \end{aligned}$$

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.

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

$$V_{fbsd} = k_B T / q \log(NGATE/NSD) + VFBSDOFF$$

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:

$$S_{id,inv}(f) = \frac{k_B T q^2 \mu_{eff} I_{ds}}{C_{oxe} (L_{eff} + LINTNOI)^2 A_{bulk} f^{ef}} \left(NOIA \cdot \log\left(\frac{N_0 + N^*}{N_l + N^*}\right) + NOIB \cdot (N_o - N_l) \right) + \frac{NOIC}{2} (N_0^2 - N_l^2) + \frac{k_B (T I_{ds}^2 \Delta L_{clm})}{W_{eff} \cdot (L_{eff} + LINTNOI)^2 f^{ef} \cdot 10^{10}} \cdot \frac{NOIA + NOIB \cdot N_l + NOIC \cdot N_l^2}{(N_l + N^*)^2}$$

New Temperature Model

$$J_{tsswgs,d}(T) = J_{tsswgs,d}(TNOM) \cdot \exp\left[\frac{-Eg(TNOM)}{k_B T} \cdot X_{tsswgs,d} \cdot \left(1 - \frac{T}{TNOM}\right)\right]$$

$$J_{tssws,d}(T) = J_{tssws,d}(TNOM) \cdot \exp\left[\frac{-Eg(TNOM)}{k_B T} \cdot X_{tssws,d} \cdot \left(1 - \frac{T}{TNOM}\right)\right]$$

$$J_{tss,d}(T) = J_{tss,d}(TNOM) \cdot \exp\left[\frac{-Eg(TNOM)}{k_B T} \cdot X_{tss,d} \cdot \left(1 - \frac{T}{TNOM}\right)\right]$$

$$NJTSSWG(T) = NJTSSWG(TNOM) \cdot \left[1 + TNJTSSWG\left(\frac{T}{TNOM} - 1\right)\right]$$

$$NJTSSW(T) = NJTSSW(TNOM) \cdot \left[1 + TNJTSSW\left(\frac{T}{TNOM} - 1\right)\right]$$

$$NJTS(T) = NJTS(TNOM) \cdot \left[1 + TNTJS\left(\frac{T}{TNOM} - 1\right)\right]$$

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 zerobias 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

mobMod=0

$$\mu_{eff} = \frac{U0 \cdot f(L_{eff})}{1 + (UA + UCV_{bseff}) \left(\frac{V_{gsteff} + 2V_{th}}{TOXE} \right) + UB \left(\frac{V_{gsteff} + 2V_{th}}{TOXE} \right)^2 + UD \left(\frac{V_{th} \cdot TOXE}{V_{gsteff} + 2\sqrt{V_{th} + 0.0001}} \right)^2}$$

mobMod=1

$$\mu_{eff} = \frac{U0 \cdot f(L_{eff})}{1 + \left[UA \left(\frac{V_{gsteff} + 2V_{th}}{TOXE} \right) + UB \left(\frac{V_{gsteff} + 2V_{th}}{TOXE} \right)^2 \right] (1 + UC \cdot V_{bseff}) + UD \left(\frac{V_{th} \cdot TOXE}{V_{gsteff} + 2\sqrt{V_{th} + 0.0001}} \right)^2}$$

Virtuoso Simulator Components and Device Models Reference
BSIM4 Level-14 Model (bsim4)

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.

$$f(L_{eff}) = 1 - UP \cdot e^{-L_{eff}/(LP)}$$

Scalable Substrate Resistance Model

$$R_X = R_{X_HORT} \parallel R_{X_VERT} \quad \text{where } R_{X_H(V)} = R_0 L^a W^b NF$$

Temperature Dependence for VOFF, VFBSDOFF

$$VOFF(T) = VOFF(TNOM) \cdot [1 + TVOFF \cdot (T - TNOM)]$$

$$VFBSDOFF(T) = VFBSDOFF(TNOM) \cdot [1 + TVFBSDOFF \cdot (T - TNOM)]$$

New Temperature Mode (TempMod = 2)

Share the same temperature equations as for TempMod=1 with the following modifications:

From

$$\Delta V_{th}(DITS) = -n v_t \cdot \ln \left(\frac{L_{eff}}{L_{eff} + DVTP0 \cdot (1 + e^{-DVPT1 \cdot V_{ds}})} \right)$$

To

$$\Delta V_{th}(DITS) = -n v_{tnom} \cdot \ln \left(\frac{L_{eff}}{L_{eff} + DVTP0 \cdot (1 + e^{-DVPT1 \cdot V_{ds}})} \right)$$

Vfbzb(T)

$$V_{fbzb}(T) = V_{fbzb}(TNOM) - KT1 \cdot \left(\frac{T}{TNOM} - 1 \right)$$

Igate(T)

T is replaced by TNOM

DELVTO: An Instance Parameter

if vth0 is given:

$$V_{th0} = V_{th0} + DELVTO$$

if vth0 is not given,

$$V_{fb} = V_{fb} + DELVTO$$

$$V_{th0} = V_{fb} + \Phi + k1 \times \sqrt{k1}$$

Well-Proximity Effect Modeling

Instance parameters: SCA, SCB, SCC, SC

Model parameters: WEB, WEC, KVTH0WE, K2WE, KU0WE, SCREF, WPEMOD

Model equations:

$$V_{th0} = V_{th0}_{org} + KVTH0WE \cdot (SCA + WEB \cdot SCB + WEC \cdot SCC)$$

$$K2 = K2_{ORG} + K2WE \cdot (SCA + WEB \cdot SCB + WEC \cdot SCC)$$

$$\mu_{eff} = \mu_{eff,org} \cdot (1 + KU0WE \cdot (SCA + WEB \cdot SCB + WEC \cdot SCC))$$

Gate Current Vbs Dependence

$$I_{gc0} = W_{eff} L_{eff} \cdot A \cdot T_{oxRatio} \cdot V_{gse} \cdot V_{aux} \cdot \exp[-B \cdot TOXE(AIGC - BIGC \cdot V_{OXDEPINV}) \cdot (1 + CIGC \cdot v_{oxdepinv})]$$

For IGCMOD=1

$$V_{aux} = NIGC \cdot v_t \cdot \log \left(1 + \exp \left(\frac{V_{gse} - VTH_0}{NIGC \cdot v_t} \right) \right)$$

For IGCMOD=2

$$V_{aux} = NIGC \cdot v_t \cdot \log \left(1 + \exp \left(\frac{V_{gse} - VTH_bsim4}{NIGC \cdot v_t} \right) \right)$$

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 trapassisted 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

$$\mu_{eff} = \frac{U0 \cdot f(L_{eff})}{1 + (UA + UC V_{bseff}) \left(\frac{V_{gsteff} + 2V_{th}}{TOXE} \right) + UB \left(\frac{V_{gsteff} + 2V_{th}}{TOXE} \right)^2 + UD \left(\frac{V_{th} \cdot TOXE}{V_{gsteff} + 2\sqrt{V_{th}^2 + 0.00001}} \right)^2}$$

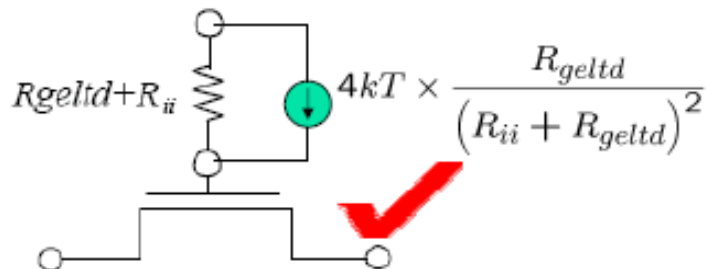
mobMod=1

$$\mu_{eff} = \frac{U0 \cdot f(L_{eff})}{1 + \left[UA \left(\frac{V_{gsteff} + 2V_{th}}{TOXE} \right) + UB \left(\frac{V_{gsteff} + 2V_{th}}{TOXE} \right)^2 \right] (1 + UC \cdot V_{bseff}) + UD \left(\frac{V_{th} \cdot TOXE}{V_{gsteff} + 2\sqrt{V_{th}^2 + 0.00001}} \right)^2}$$

mobMod=2

$$\mu_{eff} = \frac{U0}{1 + (UA + UC \cdot V_{bseff}) \left[\frac{V_{gsteff} + C_0 \cdot (V_{THO} - V_{FB} - \Phi_s)}{TOXE} \right]^{EU} + UD \left(\frac{V_{th} \cdot TOXE}{V_{gsteff} + 2\sqrt{V_{th}^2 + 0.00001}} \right)^2}$$

Improvement to NOIMOD = 2



BSIM4 Version 6.1

C-V Model

A new $V_{gsteffCV}$ definition is introduced in the C-V model to improve threshold fitting. Six new parameters have been added: CVCHARGEMOD, MINVCV, LMINVCV, WMINVCV, WMINVCV, PMINVCV, and VOFFCVL.

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.

$$E_{g0} = BG0SUB - \frac{TBGASUB \times Tnom^2}{Tnom + TBGBSUB}$$

$$E_{g(300.15)} = BG0SUB - \frac{TBGASUB \times 300.15^2}{300.15 + TBGBSUB}$$

$$n_i = NI0SUB \times \left(\frac{Tnom}{300.15} \right)^{3/2} \cdot e^{-\frac{E_{g(300.15K)} - E_{g0}}{2V_t}}$$

$$E_g = BG0SUB - \frac{TBGASUB \times Temp^2}{Temp + TBGBSUB}$$

Introduces two new parameters for charge centroid for non-silicon channel materials in both I-V and C-V models.

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

$$X_{dc} = \frac{ADOS \times 1.9 \times 10^{-9}}{1 + \left(\frac{V_{gsteff} + (V_{TH0} - V_{FB} - \phi_s)}{2t_{oxp}} \right)^{0.7 \times BDOS}}$$

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.

$$T_{oxp} = EOT - \frac{3.9}{EPSRSUB} \cdot X_{dc} |_{V_{gs} = VDDEOT, V_{ds} = V_{bs} = 0}$$

Non-poly-Si gate Material

Poly depletion is calculated using the following equation:

$$V_{gse} = V_{FB} + \Phi_s + \frac{q\epsilon_{gate}NGATE}{c_{oxe}^2} \left(\sqrt{1 + \frac{2c_{oxe}^2(V_{gs} - V_{FB} - \Phi_s)}{q\epsilon_{gate}NGATE}} - 1 \right)$$

where

$$\epsilon_{gate} = EPSRGATE \cdot EPS0 \quad \text{for MTRLMOD=1}$$

$$\epsilon_{gate} = EPSSI \quad \text{for MTRLMOD=0}$$

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 $JTWEFF$ is added to describe the TAT current width dependence.

Change in Equation for Temperature Dependence of Junction Diode IV

Side Source Diode 0

$$I_{sbs} = A_{seff} J_{ss}(T) + P_{seff} J_{ssws}(T) + W_{effcj} \cdot NF \cdot J_{sswgs}(T)$$

where

$$J_{ss}(T) = JSS(TNOM) \cdot \exp\left(\frac{\frac{E_g(TNOM)}{v_t(TNOM)} - \frac{E_g(T)}{v_t(T)} + XTIS \cdot \ln\left(\frac{T}{TNOM}\right)}{NJS}\right)$$

$$J_{ssws}(T) = JSSWS(TNOM) \cdot \exp\left(\frac{\frac{E_g(TNOM)}{v_t(TNOM)} - \frac{E_g(T)}{v_t(T)} + XTIS \cdot \ln\left(\frac{T}{TNOM}\right)}{NJS}\right)$$

$$J_{sswgs}(T) = JSSWGS(TNOM) \times \left(\sqrt{\frac{JTWEFF}{W_{effci}}} + 1.0\right) \exp\left(\frac{\frac{E_g(Tnom)}{V_t(Tnom)} - \frac{E_g(T)}{V_t(T)} + XTIS \cdot \ln\left(\frac{T}{Tnom}\right)}{NJS}\right)$$

where

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

$$E_g(TNOM) = 1.16 - \frac{7.02 \times 10^{-4} TNOM^2}{TNOM + 1108}$$

$$E_g(T) = 1.16 - \frac{7.02 \times 10^{-4} T^2}{T + 1108}$$

$$n_i = 1.45e10 \cdot \frac{TNOM}{300.15} \cdot \sqrt{\frac{TNOM}{300.15}} \cdot \exp\left[21.5565981 - \frac{qE_g(TNOM)}{2 \cdot k_B T}\right]$$

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:

$$UCS(T) = UCS(TNOM) \cdot \left(\frac{T}{TNOM}\right)^{UCSTE}$$

New Mobility Model for High K Material

A new mobility model `mobMod=3` is added to enhance the modeling of coulombic 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 R_S and R_D are the same as in tempMod=2.

Note the following:

- For tempMod=1, tempMod=2 and tempMod=3:

$$U_0(T) = U_0(TNOM) \cdot \left(\frac{T}{TNOM}\right)^{UTE}$$

and

$$UCS(T) = UCS(TNOM) \cdot \left(\frac{T}{TNOM}\right)^{UCSTE}$$

- However, when tempMod=3:

$$U_A(T) = U_A(TNOM) \cdot \left(\frac{T}{TNOM}\right)^{UA1}$$

$$U_B(T) = U_B(TNOM) \cdot \left(\frac{T}{TNOM}\right)^{UB1}$$

$$U_C(T) = U_C(TNOM) \cdot \left(\frac{T}{TNOM}\right)^{UC1}$$

$$U_D(T) = U_D(TNOM) \cdot \left(\frac{T}{TNOM}\right)^{UD1}$$

Component Statements

This device is supported within altergroups.

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

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	Number of squares of drain diffusion.
8	nrs	Number of squares of source diffusion.
9	rdc=0.0 Ohm	Drain contact resistance.
10	rsc=0.0 Ohm	Source contact resistance.
11	sa=0.0 m	Distance between OD edge to poly from one side.
12	sb=0.0 m	Distance between OD edge to poly from the other side.
13	sd=0.0 m	Distance between neighbour fingers.
14	sa1=0.0 m	Distance between OD edge to poly from one side 1.
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.

Virtuoso Simulator Components and Device Models Reference
BSIM4 Level-14 Model (bsim4)

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.
37	sw4=0.0 m	Width of SA4/SB4.
38	sw5=0.0 m	Width of SA5/SB5.
39	sw6=0.0 m	Width of SA6/SB6.
40	sw7=0.0 m	Width of SA7/SB7.
41	sw8=0.0 m	Width of SA8/SB8.
42	sw9=0.0 m	Width of SA9/SB9.

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

43	sw10=0.0 m	Width of SA10/SB10.
44	isnoisy=yes	Should device generate noise. Possible values are no or yes.
45	m=1	Multiplicity factor (number of MOSFETs in parallel).
46	region=triode	Estimated operating region. Spectre outputs the number (0-4) in a rawfile. Possible values are off, triode, sat, subth, or breakdown.
47	trnqsmod	Transient NQS model selector.
48	acnqsmod	AC small-signal NQS model selector.
49	trise	Temperature rise from ambient.
50	dtemp	Alias for trise.
51	rgatemod	Gate resistance model selector.
52	rbodymod	Substrate resistance network model selector.
53	geomod	Geometry dependent parasitics model selector.
54	stimod	LOD stress effect model selector.
55	rgeomod	Diffusion resistance and contact model selector.
56	rbpb (Ohm)	Resistance connected between bNode' and bNode.
57	rbpd (Ohm)	Resistance connected between bNode' and dbNode.
58	rbps (Ohm)	Resistance connected between bNode' and sbNode.
59	rbdb (Ohm)	Resistance connected between dbNode and bNode.
60	rbsb (Ohm)	Resistance connected between sbNode and bNode.
61	nf	Number of device fingers.

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

62	min	Whether to minimize the number of drain or source diffusions for evennumber fingered device. Set to 0 to minimize.
63	delvto=0.0 V	Shift in zero-bias threshold voltage vth0.
64	mulmu0=1.0	Mobility multiplier, alias of mulu0.
65	mulvsat=1.0	Vsat multiplier.
66	mulu0=1.0	Mobility multiplier.
67	delk1=0.0 sqrt(V)	Shift in body bias coefficient k1.
68	delnft=0.0	Shift in subthreshold swing factor nfactor.
69	deleta0=0.0	Shift in DIBL coefficient subthreshold region.
70	sca=0.0	Integral of the first distribution function for scattered well dopant.
71	scb=0.0	Integral of the second distribution function for scattered well dopant.
72	scc=0.0	Integral of the third distribution function for scattered well dopant.
73	sc=0.0 m	Distance to a single well edge.
74	xgw=0.0 m	Distance from the gate contact to the channel edge.
75	ngcon=1.0	Number of gate contacts.

Model Parameters

Device type parameters

1	type=n	Transistor type. Possible values are n or p.
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Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

Model Selectors & Controller

2	level=14	Model level selector for spice compatibility.
3	version=4.21	Model version selector. The available versions are 4.21, 4.30, 4.40, 4.50, 4.60, 4.61, 4.62, 4.63, 4.64, and 4.65.
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	rdsmod=0	Bias-dependent source/drain resistance model selector.
10	igcmmod=0	Gate-to-channel tunneling model selector.
11	igbmod=0	Gate-to-substrate tunneling model selector.
12	capmod=2	Capacitance model selector.
13	rgatemod=0	Gate resistance model selector.
14	rbodymod=0	Substrate resistance network model selector.
15	trnqsmmod=0	Transient Non-quasi static model selector. Set to 1 to turn on nqs.
16	acnqsmmod=0	Ac Non-quasi static model selector. Set to 1 to turn on nqs.
17	fnoimod=1	Flicker noise model selector.
18	tnoimod=0	Thermal noise model selector.
19	diomod=1	Source/Drain junction diode IV model selector.
20	tempmod=0	Temperature model selector. 0 for original model and 1 for new format.
21	permod=1	Perimeter model selector.

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

22	geomod=0	Geometry dependent parasitics model selector.
23	stimod=0	LOD stress effect model selector. 0 for Berkeley LOD, 1 & 2 for TSMC LOD.
24	wpemod=0	Flag for WPE model (WPEMOD=1 to activate this model).
25	rgeomod=0	Diffusion resistance and contact model selector. It served as the default value of instance rgeomod.
26	flkmod=0	Flicker Noise Model.
27	fullreinit=0	Model parameter full reinit selector.
28	updatelevel=0	Model update selector. Available versions are 0, 1 and 2.
29	eglev=0	DC temperature selector.
30	minr=0.001 Ohm	Minimum source/drain resistance.

Process parameters

31	epsrox=3.9	Gate dielectric constant.
32	epsrgate=11.7	Dielectric constant of gate relative to vacuum.
33	epsrsub=11.7	Dielectric constant of substrate relative to vacuum.
34	eot=1.5e-9 m	Equivalent gate oxide thickness in meters.
35	toxe=3.0e-9 m	Electrical gate equivalent oxide thickness.
36	toxp=`toxe' m	Physical gate equivalent oxide thickness.
37	toxm=`toxe' m	Toxe at which parameters were extracted.
38	dtox=0.0 m	Difference between electrical and physical gate oxide thickness.
39	xj=0.15e-6 m	Source/drain junction depth.
40	gamma1 (sqrt(V))	Body-effect coefficient near the surface.
41	gamma2 (sqrt(V))	Body-effect coefficient in the bulk.

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

42	$ndep=1.7e17 \text{ cm}^{-3}$	Channel doping concentration at depletion edge for zero body bias.
43	$nsub=6.0e16 \text{ cm}^{-3}$	Substrate doping concentration.
44	$ngate=0.0 \text{ cm}^{-3}$	Poly Si gate doping concentration.
45	$nsd=1.0e20 \text{ cm}^{-3}$	Source-drain doping concentration.
46	$vbx \text{ (V)}$	Vbs at which the depletion region width equals XT.
47	$xt=1.55e-7 \text{ m}$	Doping depth.
48	$rsh=0.0 \text{ Ohm/sqr}$	Source/drain sheet resistance.
49	$rshg=0.1 \text{ Ohm/sqr}$	Gate electrode sheet resistance.
50	$lint=0.0 \text{ m}$	Lateral diffusion for one side.
51	$wint=0.0 \text{ m}$	Width reduction for one side.
52	$wl=0.0 \text{ m}^{wln}$	Length dependence of delta W.
53	$wln=1.0$	Length exponent of delta W.
54	$ww=0.0 \text{ m}^{wwn}$	Width dependence of delta W.
55	$wwn=1.0$	Width exponent of delta W.
56	$wwl=0.0 \text{ m}^{(wwn+wln)}$	Area dependence of delta W.
57	$ll=0.0 \text{ m}^{lln}$	Length dependence of delta L.
58	$lln=1.0$	Length exponent of delta L.
59	$lw=0.0 \text{ m}^{lwn}$	Width dependence of delta L.
60	$lwn=1.0$	Width exponent of delta L.

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

- 61 $lwl=0.0 \text{ m}^{(l_{ln}+l_{wn})}$ Area dependence of delta L.
- 62 $dwg=0.0 \text{ m/V}$ Gate-bias dependence of channel width.
- 63 $dwb=0.0 \text{ m/sqrt(V)}$ Body-bias dependence of channel width.

Threshold voltage parameters

- 64 $vtho=0.7(\text{nmos}) / -0.7(\text{pmos}) \text{ V}$ Threshold voltage at $V_{bs}=0$ for long-channel devices. Alias of $vth0$.
- 65 $vfb=-1.0 \text{ V}$ Flat-band voltage.
- 66 $vddeot=1.5(\text{nmos}) / -1.5(\text{pmos}) \text{ V}$ Voltage for extraction of Equivalent gate oxide thickness.
- 67 $\phi_{in}=0.0 \text{ V}$ Non-uniform vertical doping effect on surface potential.
- 68 $k1=0.53 \text{ sqrt(V)}$ First-order body bias coefficient.
- 69 $k2=-0.0186$ Second-order body bias coefficient.
- 70 $k3=80.0$ Narrow width coefficient.
- 71 $k3b=0.0 \text{ 1/V}$ Body effect coefficient of $K3$.
- 72 $w0=2.5e-6 \text{ m}$ Narrow width coefficient.
- 73 $lpe0=1.74e-7 \text{ m}$ Lateral non-uniform doping at $V_{bs}=0$.
- 74 $lpeb=0.0 \text{ m}$ Lateral non-uniform doping effect on $K1$.
- 75 $vbm=-3.0 \text{ V}$ Maximum applied body voltage in V_{TH0} calculation.
- 76 $dvt0=2.2$ First coefficient of short-channel effects.
- 77 $dvt1=0.53$ Second coefficient of short-channel effects.
- 78 $dvt2=-0.032 \text{ 1/V}$ Body-bias coefficient of short-channel effects.

Virtuoso Simulator Components and Device Models Reference
BSIM4 Level-14 Model (bsim4)

79	dvtp0=0.0 m	First coefficient of drain-induced Vth shift for long-channel pocket devices.
80	dvtp1=0.0 1/V	Second coefficient of drain-induced Vth shift for long-channel pocket devices.
81	dvt0w=0.0	First coefficient of narrow-width effects.
82	dvt1w=5.3e6 1/m	Second coefficient of narrow-width effects.
83	dvt2w=-0.032 1/V	Body-bias coefficient of narrow-width effects.
84	a0=1.0	Nonuniform depletion width effect coefficient.
85	ags=0.0 1/V	Gate-bias dependence of Abulk.
86	b0=0.0 m	Bulk charge coefficient due to narrow width effect.
87	b1=0.0 m	Bulk charge coefficient due to narrow width effect.
88	keta=-0.047 1/V	Body-bias coefficient for non-uniform depletion width effect.
89	a1=0.0 1/V	First non-saturation effect parameter.
90	a2=1.0	Second non-saturation factor.
91	phig=4.05 eV	The gate work function.
92	ni0sub=1.45e10 cm ⁻³	Intrinsic carrier concentration at T=300.15K.
93	bg0sub=1.16 eV	Band-gap of substrate at T=0K.
94	tbgasub=7.02e-4 V/K	First parameter of band-gap change due to temperature.
95	tbgbsub=1108.0 K	Second parameter of bandgap change due to temperature.
96	ados=1.0	Charge centroid parameter.
97	bdos=1.0	Charge centroid parameter.
98	tempeot=300.15 C	Temperature for extraction of EOT.

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

- 99 $l_{\text{effeot}}=1 \text{ m}$ Effective length for extraction of EOT.
- 100 $w_{\text{effeot}}=10 \text{ m}$ Effective width for extraction of EOT.

Mobility parameters

- 101 $\mu_0=670(\text{nmos}) / 250(\text{pmos}) \text{ cm}^2/\text{V}\cdot\text{s}$
 Low-field surface mobility at t_{nom} .
- 102 $u_a=1.0\text{e-}9(\text{mobmod}=0,1) / 1.0\text{e-}15 (\text{mobmod}=2) \text{ m/V}$
 First-order mobility reduction coefficient.
- 103 $u_b=1.0\text{e-}19 \text{ m}^2/\text{V}^2$
 Second-order mobility reduction coefficient.
- 104 $u_c=-0.0465 \text{ 1/V} (\text{mobmod}=1) / -0.0465\text{e-}9 \text{ m/V}^2 (\text{mobmod}=0,2)$
 Body-bias dependence of mobility.
- 105 $u_d=1.0\text{e}14 \text{ /m}^2$ Coulomb scattering factor of mobility.
- 106 $u_p=0.0$ Channel length linear factor of mobility.
- 107 $l_p=1.0\text{e-}8 \text{ m}$ Channel length exponential factor of mobility.
- 108 $u_e=1.67(\text{nmos}) / 1.0(\text{pmos})$
 Exponent for mobility degradation of $\text{mobmod}=2$.
- 109 $v_{\text{sat}}=8.0\text{e}4 \text{ m/s}$ Carrier saturation velocity at t_{nom} .
- 110 $\lambda=0.0$ Velocity overshoot coefficient.
- 111 $v_{\text{tl}}=2.0\text{e}5 \text{ m/s}$ Thermal velocity.
- 112 $l_c=5.0\text{e-}9 \text{ m}$ Velocity back scattering coefficient.
- 113 $x_n=3.0$ Velocity back scattering coefficient.
- 114 $e_{\text{asub}}=4.05 \text{ eV}$ Electron affinity of substrate.
- 115 $u_{\text{cs}}=1.67(\text{nmos}) / 1.0(\text{pmos})$
 Colombic scattering exponent.

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BSIM4 Level-14 Model (bsim4)

116 ucste=-4.775e-3 Temperature coefficient of colombic mobility.

Subthreshold parameters

117 voff=-0.08 V Threshold voltage offset.

118 tvoff=0.0 V Temperature parameter for voff.

119 ltvoff=0.0 V Length dependence of tvoff.

120 wtvoff=0.0 V Width dependence of tvoff.

121 ptvoff=0.0 V Cross-term dependence of tvoff.

122 voffl=0.0 mV Channel-length dependence of Voff.

123 minv=0.0 Vgsteff fitting parameter for moderate inversion condition.

124 nfactor=1.0 Subthreshold swing coefficient.

125 eta0=0.08 DIBL coefficient subthreshold region.

126 etab=-0.07 1/V Body-bias dependence of et0.

127 dsub='drout' DIBL effect in subthreshold region.

128 cit=0.0 F/m² Interface trap parameter for subthreshold swing.

129 cdsc=2.4e-4 F/m² Source/drain and channel coupling capacitance.

130 cdscb=0.0 F/m²*V Body-bias dependence of cdsc.

131 cdscd=0.0 F/m²*V Drain-bias dependence of cdsc.

Output resistance parameters

132 pclm=1.3 Channel length modulation coefficient.

133 pdiblc1=0.39 First coefficient of drain-induced barrier lowering.

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BSIM4 Level-14 Model (bsim4)

134	pdiblc2=8.6e-3	Second coefficient of drain-induced barrier lowering.
135	pdiblcb=0.0 1/V	Body-effect coefficient for DIBL.
136	drout=0.56	DIBL effect on output resistance coefficient.
137	pscbe1=4.24e8 V/m	First coefficient of substrate current body effect.
138	pscbe2=1e-5 m/V	Second coefficient of substrate current body effect.
139	fprout=0.0 V/sqrt(m)	Effect of pocket implant on Rout degradation.
140	pvag=0.0	Gate dependence of Early voltage.
141	delta=0.01 V	Effective drain voltage smoothing parameter.
142	pdits=0.0 1/V	Effect of pocket implant on Rout degradation.
143	pditsl=0.0 1/m	Channel-length dependence of drain-induced Vth shift on Rout.
144	pditsd=0.0 1/V	Vds dependence of drain-induced Vth shift on Rout.

Bias-dependent Rds parameters

145	rdsw=200.0 Ohm*um^wr	Zero bias LDD resistance per unit width for RDSMOD=0.
146	rdswmin=0.0 Ohm*um^wr	LDD resistance per unit width at high Vgs and zero Vbs for RDSMOD=0.
147	rdw=100.0 Ohm*um^wr	Zero bias LDD resistance per unit width for RDSMOD=1.
148	rdwmin=0.0 Ohm*um^wr	LDD resistance per unit width at high Vgs and zero Vbs for RDSMOD=1.
149	rsw=100.0 Ohm*um^wr	Zero bias LDD resistance per unit width for RDSMOD=1.

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BSIM4 Level-14 Model (bsim4)

- 150 rswmin=0.0 Ohm*um^{wr}
LDD resistance per unit width at high Vgs and zero Vbs for RDSMOD=1.
- 151 prwg=1 1/V
Gate-effect coefficient for Rds.
- 152 prwb=0.0 1/sqrt(V)
Body-effect coefficient for Rds.
- 153 wr=1.0
Width offset for parasitic resistance.

Substrate current parameters

- 154 alpha0=0.0 A*m/V
Substrate current impact ionization coefficient.
- 155 alpha1=0.0 A/V
Substrate current impact ionization coefficient.
- 156 beta0=30.0 1/V
Substrate current impact ionization exponent.

Gate-Induced drain leakage parameters

- 157 agidl=0.0 1/Ohm
Pre-exponential coefficient for GIDL.
- 158 bgidl=2.3e9 V/m
Exponential coefficient for GIDL.
- 159 cgidl=0.5 V³
Parameter for body-bias effect on GIDL.
- 160 egidl=0.8 V
Fitting parameter for band bending for GIDL.
- 161 agisl=agidl 1/Ohm
Pre-exponential coefficient for GISL (bsim4.6).
- 162 bgisl=bgidl V/m
Exponential coefficient for GISL (bsim4.6).
- 163 cgisl=cgidl V³
Parameter for body-bias effect on GISL (bsim4.6).
- 164 egisl=egidl V
Fitting parameter for band bending for GISL (bsim4.6).

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BSIM4 Level-14 Model (bsim4)

Gate Tunneling parameters

- 165 $aigbacc=0.43 \sqrt{F/g} * s/m$
Parameter for I_{gb} in accumulation.
- 166 $bigbacc=0.054 \sqrt{F/g} * s/(m * V)$
Parameter for I_{gb} in accumulation.
- 167 $cigbacc=0.075 \text{ 1/V}$
Parameter for I_{gb} in accumulation.
- 168 $nigbacc=1.0$ Parameter for I_{gb} in accumulation.
- 169 $aigbinv=0.35 \sqrt{F/g} * s/m$
Parameter for I_{gb} in inversion.
- 170 $bigbinv=0.03 \sqrt{F/g} * s/(m * V)$
Parameter for I_{gb} in inversion.
- 171 $cigbinv=0.006 \text{ 1/V}$
Parameter for I_{gb} in inversion.
- 172 $eigbinv=1.1 \text{ V}$ Parameter for I_{gb} in inversion.
- 173 $nigbinv=3.0$ Parameter for I_{gb} in inversion.
- 174 $aigc=0.43(\text{nmos}) / 0.31(\text{pmos}) \sqrt{F/g} * s/m$
Parameter for I_{gcs} and I_{gcd} .
- 175 $bigc=0.054(\text{nmos}) / 0.024(\text{pmos}) \sqrt{F/g} * s/(m * V)$
Parameter for I_{gcs} and I_{gcd} .
- 176 $cigc=0.075(\text{nmos}) / 0.03(\text{pmos}) \text{ 1/V}$
Parameter for I_{gcs} and I_{gcd} .
- 177 $aigsd=0.43(\text{nmos}) / 0.31(\text{pmos}) \sqrt{F/g} * s/m$
Parameter for I_{gs} and I_{gd} .
- 178 $bigsd=0.054(\text{nmos}) / 0.024(\text{pmos}) \sqrt{F/g} * s/(m * V)$
Parameter for I_{gs} and I_{gd} .
- 179 $cigsd=0.075(\text{nmos}) / 0.03(\text{pmos}) \text{ 1/V}$
Parameter for I_{gs} and I_{gd} .

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BSIM4 Level-14 Model (bsim4)

180	$aigs=1.36e-2(\text{nmos}) / 9.80e-3(\text{pmos}) \sqrt{F/g} * s/m$ Parameter for Igs (bsim4.6).	
181	$big_s=1.71e-3(\text{nmos}) / 7.59e-4(\text{pmos}) \sqrt{F/g} * s/(m * V)$ Parameter for Igs (bsim4.6).	
182	$cigs=0.075(\text{nmos}) / 0.03(\text{pmos}) 1/V$ Parameter for Igs (bsim4.6).	
183	$aigd=1.36e-2(\text{nmos}) / 9.80e-3(\text{pmos}) \sqrt{F/g} * s/m$ Parameter for Igd (bsim4.6).	
184	$big_d=1.71e-3(\text{nmos}) / 7.59e-4(\text{pmos}) \sqrt{F/g} * s/(m * V)$ Parameter for Igd (bsim4.6).	
185	$cigd=0.075(\text{nmos}) / 0.03(\text{pmos}) 1/V$ Parameter for Igd (bsim4.6).	
186	$dlcig='Lint'$ m	Source overlap length for Igs.
187	$dlcigd=dlcig$ m	drain overlap length for Igd (bsim4.6).
188	$nigc=1.0$	Parameter for Igc_s, Igc_d, Igs and Igd.
189	$poxedge=1.0$	Factor for the gate oxide thickness in source/drain overlap regions.
190	$pigcd=1.0$	Vds dependence of Igc_s and Igc_d.
191	$ntox=1.0$	Exponent for the gate oxide ratio.
192	$toxref=3.0e-9$ m	Nominal gate oxide thickness for gate dielectric tunneling current model only.
193	$vfbsdoff=0.0$ V	S/D flatband voltage offset.
194	$tvfbsdoff=0.0$ V	Temperature parameter for vfbsdoff.
195	$ltvfbsdoff=0.0$ V	Length dependence of tvfbsdoff.
196	$wtvfbsdoff=0.0$ V	Width dependence of tvfbsdoff.
197	$ptvfbsdoff=0.0$ V	Cross-term dependence of tvfbsdoff.

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

Overlap capacitance parameters

198	cgso (F/m)	Non LDD region source-gate overlap capacitance per unit channel width.
199	cgdo (F/m)	Non LDD region drain-gate overlap capacitance per unit channel width.
200	cgbo=2*Dwc*Coxe F/m	Non LDD region drain-gate overlap capacitance per unit channel width.
201	meto=0.0 m	Metal overlap in fringing field.
202	cgs1=0.0 F/m	Overlap capacitance between gate and lightly-doped source region.
203	cgd1=0.0 F/m	Overlap capacitance between gate and lightly-doped drain region.
204	ckappas=0.6 V	Coefficient of bias-dependent overlap capacitance for the source side.
205	ckappad=`ckappas' V	Coefficient of bias-dependent overlap capacitance for the source side.

Charge model selection parameters

206	xpart=0.0	Charge partition number. Use 0.0 for 40/60, 0.5 for 50/50, and 1.0 for 0/100.
207	cf (F/m)	Fringing field capacitance (alias=lx91).
208	clc=1e-7 m	Constant term for the short channel model.
209	cle=0.6	Exponential term for the short channel model.
210	dlc=`lint' m	Delta L for capacitance model.
211	dwc=`wint' m	Delta W for capacitance model.
212	vfbcv=-1.0	Flat-band voltage for capmod=0.

Virtuoso Simulator Components and Device Models Reference
BSIM4 Level-14 Model (bsim4)

213	noff=1.0	Transition parameter.
214	voffcv=0.0 V	CV parameter in VgsteffCV for weak to strong inversion.
215	minvcv=0.0	Fitting parameter for moderate inversion condition.
216	voffcvl=0.0 V*m	Exponential coefficient for charge thickness in CAPMOD=2 for accumulation and depletion regions.
218	moin=15.0	Exponential coefficient for charge thickness for accumulation and depletion regions.
219	llc=`ll' m^lln	Length dependence of delta L for CV.
220	lwc=`lw' m^lwn	Width dependence of delta L for CV.
221	lwc=`lw' m^(lln+lwn)	Area dependence of delta L for CV.
222	wlc=`wl' m^wln	Length dependence of delta W for CV.
223	wwc=`ww' m^wwn	Width dependence of delta W for CV.
224	wwlc=`ww' m^(wwn+wln)	Area dependence of delta W for CV.

Parasitic resistance parameters

225	dmcg=0.0 m	Distance from S/D contact center to the gate edge.
226	dmci=`dmcg' m	Distance from S/D contact center to the isolation edge in the channel-length direction.
227	dmdg=0.0 m	Distance from S/D contact center to the gate edge.
228	dmcgt=0.0 m	DMCG of test structures.
229	dwj=`dwc' m	Offset of the S/D junction width.
230	xgw=0.0 m	Distance from the gate contact to the channel edge.
231	xgl=0.0 m	Offset of gate length due to variations in patterning.

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BSIM4 Level-14 Model (bsim4)

232	xl=0.0 m	Length variation due to masking and etching.
233	xw=0.0 m	Width variation due to masking and etching.
234	ngcon=1.0	Number of gate contacts.
235	nf=1	Number of device fingers. It served as the default value of instance nf.
236	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.

Junction diode model parameters

237	ijthsrev=0.1 A	Source diode limiting current in reverse bias region.
238	ijthdrev=`ijthsrev' A	Drain diode limiting current in reverse bias region.
239	ijthsfwd=0.1 A	Source diode limiting current in forward bias region.
240	ijthdfwd=`ijthsfwd' A	Drain diode limiting current in forward bias region.
241	xjbvs=1.0	Fitting parameter for bulk-source diode breakdown.
242	xjbvd=`xjbvs'	Fitting parameter for bulk-drain diode breakdown.
243	bv=10.0 V	Diode breakdown voltage. Alias of bvs.
244	bvs=10.0 V	Source diode breakdown voltage.
245	bvd=`bvs' V	Drain diode breakdown voltage.
246	is=1.0e-14 A	Bulk junction reverse saturation current.
247	js=1.0e-4 A/m ²	Bottom junction reverse saturation current density. Alias of jss.
248	jss=1.0e-4 A/m ²	Source bottom junction reverse saturation current density.

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BSIM4 Level-14 Model (bsim4)

249	jsd=`jss' A/m ²	Drain bottom junction reverse saturation current density.
250	jsws=0.0 A/m	Isolation-edge sidewall source junction reverse saturation current density.
251	jswd=`jsws' A/m	Isolation-edge sidewall drain junction reverse saturation current density.
252	jswgs=0.0 A/m	Gate-edge sidewall source junction reverse saturation current density.
253	jswgd=`jswgs' A/m	Gate-edge sidewall drain junction reverse saturation current density.
254	jtss=0.0 A/m ²	Source bottom trap-assisted saturation current density.
255	jtsd=`jtss' A/m ²	Drain bottom trap-assisted saturation current density.
256	jtssws=0.0 A/m	Source isolation-edge sidewall trap-assisted saturation current density.
257	jtsswd=`jtssws' A/m	Drain isolation-edge sidewall trap-assisted saturation current density.
258	jtsswgs=0.0 A/m	Source Gate-edge isolation-edge sidewall trap-assisted saturation current density.
259	jtsswgd=`jtsswgs' A/m	Drain isolation-edge sidewall trap-assisted saturation current density.
260	njts=20.0	Non-ideality factor for jtss. For TSMC diode model, default=60.0.
261	njtssw=20.0	on-ideality factor for jtssws. For TSMC diode model, default=60.0.
262	njtsswg=20	Non-ideality factor for jtsswgs. For TSMC diode model, default=60.0.
263	njtsd=njts	Non-ideality factor for jtsd (bsim4.6).

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BSIM4 Level-14 Model (bsim4)

264	<code>njtsswd=njtssw</code>	Non-ideality factor for <code>jtsswd</code> (bsim4.6).
265	<code>njtsswgd=njtsswg</code>	Non-ideality factor for <code>jtsswgd</code> (bsim4.6).
266	<code>xtss=0.02</code>	Power dependence of <code>jtss</code> on temperature.
267	<code>xtsd=`xtss'</code>	Power dependence of <code>jtssd</code> on temperature.
268	<code>xtssws=0.02</code>	Power dependence of <code>jtssws</code> on temperature.
269	<code>xtsswd=`xtssws'</code>	Power dependence of <code>jtsswd</code> on temperature.
270	<code>xtsswgs=0.02</code>	Power dependence of <code>jtsswgs</code> on temperature.
271	<code>xtsswgd=`xtsswgs'</code>	Power dependence of <code>jtsswgd</code> on temperature.
272	<code>vtss=10.0 V</code>	Source bottom trap-assisted voltage dependent parameter.
273	<code>vtssd=`vtss' V</code>	Drain bottom trap-assisted voltage dependent parameter.
274	<code>vtssws=10.0 V</code>	Source STI sidewall trap-assisted voltage dependent parameter.
275	<code>vtsswd=`vtssws' V</code>	Drain STI sidewall trap-assisted voltage dependent parameter.
276	<code>vtsswgs=10.0 V</code>	Source gate-edge sidewall trap-assisted voltage dependent parameter.
277	<code>vtsswgd=`vtsswgs' V</code>	Drain gate-edge sidewall trap-assisted voltage dependent parameter.
278	<code>tnjts=0.0</code>	Temperature coefficient for <code>njts</code> .
279	<code>tnjtssw=0.0</code>	Temperature coefficient for <code>njtssw</code> .
280	<code>tnjtsswg=0.0</code>	Temperature coefficient for <code>njtsswg</code> .
281	<code>tnjtssd=tnjts</code>	Temperature coefficient for <code>njtssd</code> (bsim4.6).
282	<code>tnjtsswd=tnjtssw</code>	Temperature coefficient for <code>njtsswd</code> (bsim4.6).
283	<code>tnjtsswgd=tnjtsswg</code>	Temperature coefficient for <code>njtsswgd</code> (bsim4.6).

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BSIM4 Level-14 Model (bsim4)

284	dskip=yes	Use simple piece-wise linear model for diode currents below $0.1 \cdot i_{abstol}$. Possible values are no or yes.
285	imelt=`imax' A	Explosion current.
286	jmelt=`jmax' A/m ²	Explosion current density.
287	jtweff=0.0 m	TAT current width dependance.

TSMC junction diode model parameters

288	mnr=21.0	Fitting parameter for resistance induced non-ideality factor.
289	bnr=0.0	Fitting parameter for resistance induced non-ideality factor.
290	cnr=0.0 1/V*m	Fitting parameter for resistance induced non-ideality factor.
291	dnr=0.0 1/V	Fitting parameter for resistance induced non-ideality factor.
292	tmnr=0.0	Temperature coefficient for mnr.
293	tcnr=0.0	Temperature coefficient for cnr.
294	tdnr=0.0	Temperature coefficient for dnr.
295	nrfwd=1.0 A/m ²	Source bottom trap-assisted saturation current density.
296	jsswg=0.0	Sidewall-gate junction reverse saturation current density.

Junction capacitance model parameters

297	cj=5e-4 F/m ²	Zero bias bottom junction capacitance per unit area. Alias of cjs.
298	cjs=5.0e-4 F/m ²	Zero bias source bottom junction capacitance per unit area.
299	cjd=`cjs' F/m ²	Zero bias drain bottom junction capacitance per unit area.
300	mj=1/2	Bottom junction capacitance grading coefficient. Alias of mjs.
301	mjs=1/2	Source bottom junction capacitance grading coefficient.
302	mjd=`mjs'	Drain bottom junction capacitance grading coefficient.

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BSIM4 Level-14 Model (bsim4)

303	pb=1.0 V	Bottom junction built-in potential. Alias of pbs.
304	pbs=1.0 V	Source bottom junction built-in potential.
305	pbd=`pbs' V	Drain bottom junction built-in potential.
306	fc=0.5	Forward-bias depletion capacitance threshold.
307	cjsw=5e-10 F/m	Sidewall junction capacitance per unit periphery. Alias of cjsws.
308	cjsws=5.0e-10 F/m	Source sidewall junction capacitance per unit periphery.
309	cjswd=`cjsws' F/m	Drain sidewall junction capacitance per unit periphery.
310	mjsw=0.33	Isolation-edge sidewall junction capacitance grading coefficient. Alias of mjsws.
311	mjsws=0.33	Isolation-edge sidewall source junction capacitance grading coefficient.
312	mjswd=`mjsws'	Isolation-edge sidewall drain junction capacitance grading coefficient.
313	pbsw=1.0 V	Isolation-edge sidewall junction built-in potential. Alias of pbsws.
314	pbsws=1.0 V	Isolation-edge sidewall source junction built-in potential.
315	pbswd=`pbsws' V	Isolation-edge sidewall drain junction built-in potential.
316	cjswg=`cjsw' F/m	Gate-side junction capacitance per unit width. Alias of cjswgs.
317	cjswgs=`cjsws' F/m	Gate-side source junction capacitance per unit width.
318	cjswgd=`cjswgs' F/m	Gate-side source junction capacitance per unit width.
319	mjswg=`mjsw'	Gate-edge sidewall junction grading coefficient. Alias of mjswgs.
320	mjswgs=`mjsws'	Gate-edge sidewall source junction grading coefficient.
321	mjswgd=`mjswgs'	Gate-edge sidewall junction grading coefficient.
322	pbswg=`pbsw' V	Gate-edge sidewall junction built-in potential. Alias of pbswgs.

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BSIM4 Level-14 Model (bsim4)

- 323 pbswgs=`pbsws' V Gate-edge sidewall source junction built-in potential.
- 324 pbswgd=`pbswgs' V Gate-edge sidewall drain junction built-in potential.
- 325 fcsw=0.5 Side-wall forward-bias depletion capacitance threshold.

Temperature effects parameters

- 326 tnom (C) Parameters measurement temperature. Default set by options.
- 327 trise=0.0 C Temperature rise from ambient, alias of dtemp. It served as the default value of instance trise.
- 328 ute=-1.5 Mobility temperature exponent.
- 329 kt1=-0.11 V Temperature coefficient for threshold voltage.
- 330 kt1l=0.0 V*m Channel length dependence of the temperature coefficient for threshold voltage.
- 331 kt2=0.022 Body-bias coefficient of Vth temperature effect.
- 332 ua1=1.0e-9 m/V Temperature coefficient for ua. When tempmod=1, units should be 1/C.
- 333 ub1=-1.0e-18 m²/V² Temperature coefficient for ub. When tempmod=1, units should be 1/C.
- 334 uc1=-0.056 1/V (mobmod=1) / -5.6e-11 m/V²(modmod=0,2) Temperature coefficient for uc. When tempmod=1, units should be 1/C.
- 335 ud1=0.0 /m² Temperature coefficient of ud.
- 336 at=3.3e4 m/s Temperature coefficient for vsat. When tempmod=1, units should be 1/C.
- 337 prt=0.0 Ohm*m Temperature coefficient for Rds. If tempmod=1, units of the parameter equals 1/C.
- 338 tlev=0 DC temperature selector.
- 339 tlevc=0 AC temperature selector.

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BSIM4 Level-14 Model (bsim4)

340	eg=1.124519231 V	Energy band gap.
341	gap1=7.02e-4 V/C	Band gap temperature coefficient.
342	gap2=1108 C	Band gap temperature offset.
343	n=1.0	junction emission coefficient. Alias of njs.
344	njs=1.0	Bulk-Source junction emission coefficient.
345	njd=`njs'	Bulk-Drain junction emission coefficient.
346	xti=3	Saturation current temperature exponent. Alias of xtis.
347	xtis=3.0	Bulk-Source junction saturation current temperature exponent.
348	xtid=`xtis'	Bulk-Drain junction saturation current temperature exponent.
349	pta=0.0 V/C	Temperature coefficient for pb. Alias of tpb.
350	tpb=0.0 V/C	Temperature coefficient for pb.
351	ptp=0.0 V/C	Temperature coefficient for pbsw. Alias of tpbsw.
352	tpbsw=0.0 V/C	Temperature coefficient for pbsw.
353	tpbswg=0.0 V/C	Temperature coefficient for pbswg.
354	cta=0.0 1/C	Temperature coefficient for cj. Alias of tcj.
355	tcj=0.0 1/C	Temperature coefficient for cj.
356	ctp=0.0 1/C	Temperature coefficient for cjsw. Alias of tcjsw.
357	tcjsw=0.0 1/C	Temperature coefficient for cjsw.
358	tcjswg=0.0 1/C	Temperature coefficient for cjswg.

LOD model parameters

359	saref=1.0e-6 m	Reference distance between od edge to poly of one side.
360	sbref=1.0e-6 m	Reference distance between od edge to poly of the other side.

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BSIM4 Level-14 Model (bsim4)

361	sl=2.0e-6 m	Character length along length for stress effect.
362	lsl=0.0	Length dependence of sl.
363	wsl=0.0	Width dependence of sl.
364	psl=0.0	Cross-term dependence of sl.
365	sw=2.0e-6 m	Character length along width for stress effect.
366	lsw=0.0	Length dependence of sw.
367	wsw=0.0	Width dependence of sw.
368	psw=0.0	Cross-term dependence of sw.
369	sk0=0.0	First coefficient of stress effect.
370	lsk0=0.0	Length dependence of sk0.
371	wsk0=0.0	Width dependence of sk0.
372	psk0=0.0	Cross-term dependence of sk0.
373	sk1=0.0 m	Length coefficient of stress effect.
374	lsk1=0.0	Length dependence of sk1.
375	wsk1=0.0	Width dependence of sk1.
376	psk1=0.0	Cross-term dependence of sk1.
377	sk2=0.0 m	Width coefficient of stress effect.
378	lsk2=0.0	Length dependence of sk2.
379	wsk2=0.0	Width dependence of sk2.
380	psk2=0.0	Cross-term dependence of sk2.
381	k=0.0	Ratio of velocity/mobility changes for stress.
382	lk=0.0	Length dependence of k.

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BSIM4 Level-14 Model (bsim4)

383	wk=0.0	Width dependence of k.
384	pk=0.0	Cross-term dependence of k.
385	wlod=0.0 m	Length parameter for stress effect.
386	ku0=0.0 m	Mobility degradation/enhancement coefficient for stress effect.
387	kvsat=0.0 m	Saturation velocity degradation/enhancement parameter for stress effect.
388	tku0=0.0	Temperature coefficient of ku0.
389	llodku0=0.0	Length parameter for u0 stress effect.
390	wlodku0=0.0	Width parameter for u0 stress effect.
391	kvth0=0.0 V*m	Threshold shift parameter for stress effect.
392	llodvth=0.0	Length parameter for vth stress effect.
393	wlodvth=0.0	Width parameter for vth stress effect.
394	stk2=0.0 m	k2 shift factor related to vth0 change.
395	lodk2=1.0	k2 shift modification factor for stress effect.
396	steta0=0.0 m	eta0 shift factor related to vth0 change.
397	lodeta0=1.0	eta0 shift modification factor for stress effect.

WPE model parameters

398	web=0.0	Coefficient for SCB.
399	wec=0.0	Coefficient for SCC.
400	kvth0we=0.0 V	Threshold shift factor for well proximity effect.
401	k2we=0.0	K2 shift factor for well proximity effect.
402	ku0we=0.0	Mobility degradation factor for well proximity effect.

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

403 scref=1.0e-6 m Reference distance to calculate SCA, SCB and SCC.

Noise model parameters

404 noia=6.25e41(nmos) / 6.188e40(pmos) s^(1-EF)/(eV*m²)
Flicker noise parameter A.

405 noib=3.125e26(nmos) / 1.5e25(pmos) s^(1-EF)/eV
Flicker noise parameter C.

406 noic=8.75e9 s^(1-EF)*m²/eV
Flicker noise parameter C.

407 em=4.1e7 V/m Saturation field.

408 af=1.0 Flicker noise exponent.

409 ef=1.0 Flicker noise frequency exponent.

410 kf=0.0 A^(2-EF)*s^(1-EF)*F
Flicker noise coefficient.

411 lintnoi=0.0 m Lint offset for noise calculation.

412 wnoi=1.0e-5 m Channel width at which noise parameters were extracted.

413 ntnoi=1.0 Noise factor for short-channel devices for TNOIMOD=0 only.

414 tnoia=1.5 Coefficient of channel-length dependence of total channel thermal noise.

415 tnoib=3.5 Coefficient of channel-length dependence of total channel thermal noise.

416 rnoia=0.577 Thermal noise coefficient.

417 rnoib=0.5164 Thermal noise coefficient.

Substrate Network parameters

418 xrcrg1=12.0 Parameter for distributed channel-resistance effect for both intrinsic-input resistance and charge-deficit NQS models.

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

419	xrcrg2=1.0	Parameter to account for the excess channel diffusion resistance for both intrinsic-input resistance and charge-deficit NQS models.
420	rbpb=50.0 Ohm	Resistance connected between bNode' and bNode.
421	rbpbx0=100.0 Ohm	Body resistance RBPBX scaling.
422	rbpbxl=0.0	Body resistance RBPBX L scaling.
423	rbpbxw=0.0	Body resistance RBPBX W scaling.
424	rbpbxf=0.0	Body resistance RBPBX NF scaling.
425	rbpby0=100.0 Ohm	Body resistance RBPBY scaling.
426	rbpbyl=0.0	Body resistance RBPBY L scaling.
427	rbpbyw=0.0	Body resistance RBPBY W scaling.
428	rbpbyf=0.0	Body resistance RBPBY NF scaling.
429	rbpd=50.0 Ohm	Resistance connected between bNode' and dbNode.
430	rbpd0=50.0 Ohm	Body resistance RBPD scaling.
431	rbpdl=0.0	Body resistance RBPD L scaling.
432	rbpdw=0.0	Body resistance RBPD W scaling.
433	rbpdf=0.0	Body resistance RBPD NF scaling.
434	rbps=50.0 Ohm	Resistance connected between bNode' and sbNode.
435	rbps0=50.0 Ohm	Body resistance RBPS scaling.
436	rbpsl=0.0	Body resistance RBPS L scaling.
437	rbpsw=0.0	Body resistance RBPS W scaling.
438	rbpsf=0.0	Body resistance RBPS NF scaling.
439	rbdb=50.0 Ohm	Resistance connected between dbNode and bNode.

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

440	rbsb=50.0 Ohm	Resistance connected between sbNode and bNode.
441	rbsbx0=100.0 Ohm	Body resistance RBSBX scaling.
442	rbsby0=100.0 Ohm	Body resistance RSBY scaling.
443	rdbbx0=100.0 Ohm	Body resistance RBDBX scaling.
444	rdbby0=100.0 Ohm	Body resistance RBDBY scaling.
445	rbsdbxl=0.0	Body resistance RBSDBX L scaling.
446	rbsdbxw=0.0	Body resistance RBSDBX W scaling.
447	rbsdbxnf=0.0	Body resistance RBSDBX NF scaling.
448	rbsdbyl=0.0	Body resistance RBSDBY L scaling.
449	rbsdbyw=0.0	Body resistance RBSDBY W scaling.
450	rbsdbynf=0.0	Body resistance RBSDBY NF scaling.
451	gmin=1.0e-12 1/Ohm	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

452	w=5e-6 m	Default channel width.
453	l=5e-6 m	Default channel length.
454	as (m ²)	Default area of source diffusion.
455	ad (m ²)	Default area of drain diffusion.
456	ps (m)	Default perimeter of source diffusion.
457	pd (m)	Default perimeter of drain diffusion.
458	nrd	Default number of squares of drain diffusion.
459	nrs	Default number of squares of source diffusion.

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

460 rdc=0.0 Ohm Default drain contact resistance.

461 rsc=0.0 Ohm Default source contact resistance.

Auto Model Selector parameters

462 wmax=1.0 m Maximum channel width for which the model is valid.

463 wmin=0.0 m Minimum channel width for which the model is valid.

464 lmax=1.0 m Maximum channel length for which the model is valid.

465 lmin=0.0 m Minimum channel length for which the model is valid.

Operating region warning control parameters

466 alarm=none Forbidden operating region. Possible values are none, off, triode, sat, subth, or rev.

467 imax=1.0 A Maximum allowable junction current.

468 jmax=1.0e8 A/m² Maximum allowable junction current density.

469 bvj=infinity V Voltage at which junction breakdown warning is issued.

470 vbox=3e9*toxe V Oxide breakdown voltage.

471 warn=on Parameter to turn warnings on and off. Possible values are off or on.

Length dependent parameters

472 lvtho=0.0 V Length dependence of vtho.

473 lvth0 Length dependence of vth0.

474 lvfb=0.0 Length dependence of vfb.

475 lk1=0.0 sqrt(V) Length dependence of k1.

476 lk2=0.0 Length dependence of k2.

Virtuoso Simulator Components and Device Models Reference
BSIM4 Level-14 Model (bsim4)

477	lk3=0.0	Length dependence of k3.
478	lk3b=0.0 1/V	Length dependence of k3b.
479	lw0=0.0 m	Length dependence of w0.
480	lgamma1=0.0 sqrt(V)	Length dependence of gamma1.
481	lgamma2=0.0 sqrt(V)	Length dependence of gamma2.
482	lvbx=0.0 V	Length dependence of vbx.
483	lvbm=0.0 V	Length dependence of vbm.
484	ldvt0=0.0	Length dependence of dvt0.
485	ldvt1=0.0	Length dependence of dvt1.
486	ldvt2=0.0 1/V	Length dependence of dvt2.
487	ldvt0w=0.0	Length dependence of dvt0w.
488	ldvt1w=0.0	Length dependence of dvt1w.
489	ldvt2w=0.0	Length dependence of dvt2w.
490	la0=0.0	Length dependence of a0.
491	lb0=0.0 m	Length dependence of b0.
492	lb1=0.0 m	Length dependence of b1.
493	la1=0.0	Length dependence of a1.
494	la2=0.0	Length dependence of a2.
495	lags=0.0 F/m ² *V	Length dependence of ags.
496	lketa=0.0 1/V	Length dependence of keta.
497	Insub=0.0 cm ⁻³	Length dependence of nsub.

Virtuoso Simulator Components and Device Models Reference
BSIM4 Level-14 Model (bsim4)

498	$\text{Ingate}=0.0 \text{ cm}^{-3}$	Length dependence of n_{gate} .
499	$\text{lxj}=0.0 \text{ m}$	Length dependence of x_j .
500	$\text{ldwg}=0.0 \text{ m/V}$	Length dependence of d_{wg} .
501	$\text{ldwb}=0.0 \text{ m}/\sqrt{\text{V}}$	Length dependence of d_{wb} .
502	$\text{lxt}=0.0 \text{ m}$	Length dependence of x_t .
503	$\text{lrds w}=0.0 \text{ Ohm}\cdot\mu\text{m}$	Length dependence of r_{dsw} .
504	$\text{lprwb}=0.0 \text{ 1}/\sqrt{\text{V}}$	Length dependence of p_{rwb} .
505	$\text{lprwg}=0.0 \text{ 1/V}$	Length dependence of p_{rwg} .
506	$\text{lwr}=0.0$	Length dependence of w_r .
507	$\text{lu0}=0.0 \text{ cm}^2/\text{V}\cdot\text{s}$	Length dependence of u_0 .
508	$\text{lvsat}=0.0 \text{ m/s}$	Length dependence of v_{sat} .
509	$\text{lua}=0.0 \text{ m/V}$	Length dependence of u_a .
510	$\text{lub}=0.0 \text{ m}^2/\text{V}^2$	Length dependence of u_b .
511	$\text{luc}=0.0 \text{ m}/\text{V}^2$	Length dependence of u_c .
512	$\text{lud}=0.0 \text{ /m}^2$	Length dependence of u_d .
513	$\text{lup}=0.0$	Length dependence of u_p .
514	$\text{llp}=0.0 \text{ m}$	Length dependence of l_p .
515	$\text{ldrout}=0.0$	Length dependence of d_{rout} .
516	$\text{lpclm}=0.0$	Length dependence of p_{clm} .
517	$\text{lpdiblc1}=0.0$	Length dependence of p_{diblc1} .
518	$\text{lpdiblc2}=0.0$	Length dependence of p_{diblc2} .

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

519	$lpdiblcb=0.0$ 1/V	Length dependence of $pdiblcd$.
520	$lpscbe1=0.0$ V/m	Length dependence of $pscbe1$.
521	$lpscbe2=0.0$ m/V	Length dependence of $pscbe2$.
522	$lpvag=0.0$	Length dependence of $pvag$.
523	$ldelta=0.0$ V	Length dependence of $delta$.
524	$lcdsc=0.0$ F/m ²	Length dependence of $cdsc$.
525	$lcdscb=0.0$ F/m ² *V	Length dependence of $cdscb$.
526	$lcdscd=0.0$ F/m ² *V	Length dependence of $cdscd$.
527	$lnfactor=0.0$	Length dependence of $nfactor$.
528	$lcit=0.0$ F	Length dependence of cit .
529	$lvoff=0.0$ V	Length dependence of $voff$.
530	$ldsub=0.0$	Length dependence of $dsub$.
531	$leta0=0.0$	Length dependence of $eta0$.
532	$letab=0.0$ 1/V	Length dependence of $etab$.
533	$lalpha0=0.0$ m/V	Length dependence of $alpha0$.
534	$lalpha1=0.0$ m/V	Length dependence of $alpha1$.
535	$lbeta0=0.0$ 1/V	Length dependence of $beta0$.
536	$lcgsl=0.0$ F/m	Length dependence of $cgsl$.
537	$lcgdl=0.0$ F/m	Length dependence of $cgdl$.
538	$lclc=0.0$ m	Length dependence of clc .
539	$lcle=0.0$	Length dependence of cle .

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

540	lcf=0.0 F/m	Length dependence of cf.
541	lvfbcv=0.0	Length dependence of vfbcv.
542	lacde=0.0	Length dependence of acde.
543	lmoin=0.0	Length dependence of moin.
544	lnoff=0.0	Length dependence of noff.
545	lvoffcv=0.0	Length dependence of voffcv.
546	lminvcv=0.0	Length dependence of minvcv.
547	lkt1=0.0 V	Length dependence of kt1.
548	lkt1l=0 V*m	Length dependence of kt1l.
549	lkt2=0.0	Length dependence of kt2.
550	lat=0.0 m/s	Length dependence of at.
551	lua1=0.0 m/V	Length dependence of ua1.
552	lub1=0.0 m ² /V ²	Length dependence of ub1.
553	luc1=0.0 m/V ²	Length dependence of uc1.
554	lud1=0.0 /m ²	Length dependence of ud1.
555	lprt=0.0 Ohm	Length dependence of prt.
556	lute=0.0	Length dependence of ute.
557	lndep=0.0	Length dependence of ndep.
558	lnsd=0.0	Length dependence of nsd.
559	lphin=0.0	Length dependence of phin.
560	llpe0=0.0	Length dependence of lpe0.
561	llpeb=0.0	Length dependence of lpeb.

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

562	ldvtp0=0.0	Length dependence of dvtp0.
563	ldvtp1=0.0	Length dependence of dvtp1.
564	leu=0.0	Length dependence of eu.
565	lminv=0.0	Length dependence of minv.
566	lfprout=0.0	Length dependence of fprout.
567	lpdits=0.0	Length dependence of pdits.
568	lpditsd=0.0	Length dependence of pditsd.
569	lrdw=0.0	Length dependence of rdw.
570	lrsw=0.0	Length dependence of rsw.
571	lagidl=0.0	Length dependence of agidl.
572	lbgidl=0.0	Length dependence of bgidl.
573	lcgidl=0.0	Length dependence of cgidl.
574	legidl=0.0	Length dependence of egidl.
575	laigbacc=0.0	Length dependence of aigbacc.
576	lbigbacc=0.0	Length dependence of bigbacc.
577	lcigbacc=0.0	Length dependence of cigbacc.
578	lnigbacc=0.0	Length dependence of nigbacc.
579	laigbinv=0.0	Length dependence of aigbinv.
580	lbigbinv=0.0	Length dependence of bigbinv.
581	lcigbinv=0.0	Length dependence of cigbinv.
582	leigbinv=0.0	Length dependence of eigbinv.
583	lnigbinv=0.0	Length dependence of nigbinv.

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

584	laigc=0.0	Length dependence of aigc.
585	lbigc=0.0	Length dependence of bigc.
586	lcigc=0.0	Length dependence of cigc.
587	laigsd=0.0	Length dependence of aigsd.
588	lbigsd=0.0	Length dependence of bigsd.
589	lcigsd=0.0	Length dependence of cigsd.
590	lnigc=0.0	Length dependence of nigc.
591	lpoxedge=0.0	Length dependence of poxedge.
592	lpigcd=0.0	Length dependence of pigcd.
593	Intox=0.0	Length dependence of ntox.
594	lckappas=0.0	Length dependence of ckappas.
595	lckappad=0.0	Length dependence of ckappad.
596	lxrcrg1=0.0	Length dependence of xrcrg1.
597	lxrcrg2=0.0	Length dependence of xrcrg2.
598	lvfbsdoff=0.0	Length dependence of vfbsoff.
599	llambda=0.0	Length dependence of lambda.
600	lvtl=0.0	Length dependence of vtl.
601	lxn=0.0	Length dependence of xn.
602	lkvth0we=0.0 V	Length dependence of kvth0we.
603	lk2we=0.0	Length dependence of k2we.
604	lku0we=0.0	Length dependence of ku0we.

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

- 605 $l_{ku0}=0.0 \text{ m}$ Length dependence of k_{u0} .
- 606 $l_{kvth0}=0.0 \text{ V} \cdot \text{m}$ Length dependence of k_{vth0} .
- 607 $l_{ucs}=0.0$ Length dependence of u_{cs} .
- 608 $l_{ucste}=0.0$ Length dependence of u_{cste} .

Width dependent parameters

- 609 $w_{vth0}=0.0 \text{ V}$ Width dependence of v_{th0} .
- 610 w_{vth0} Width dependence of v_{th0} .
- 611 $w_{vfb}=0.0$ Width dependence of v_{fb} .
- 612 $w_{k1}=0.0 \text{ sqrt}(V)$ Width dependence of k_1 .
- 613 $w_{k2}=0.0$ Width dependence of k_2 .
- 614 $w_{k3}=0.0$ Width dependence of k_3 .
- 615 $w_{k3b}=0.0 \text{ 1/V}$ Width dependence of k_{3b} .
- 616 $w_{w0}=0.0 \text{ m}$ Width dependence of w_0 .
- 617 $w_{\gamma1}=0.0 \text{ sqrt}(V)$ Width dependence of γ_1 .
- 618 $w_{\gamma2}=0.0 \text{ sqrt}(V)$ Width dependence of γ_2 .
- 619 $w_{vbx}=0.0 \text{ V}$ Width dependence of v_{bx} .
- 620 $w_{vbm}=0.0 \text{ V}$ Width dependence of v_{bm} .
- 621 $w_{dvt0}=0.0$ Width dependence of d_{vt0} .
- 622 $w_{dvt1}=0.0$ Width dependence of d_{vt1} .
- 623 $w_{dvt2}=0.0 \text{ 1/V}$ Width dependence of d_{vt2} .

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

624	$w_{dvt0w}=0.0$	Width dependence of $dvt0w$.
625	$w_{dvt1w}=0.0$	Width dependence of $dvt1w$.
626	$w_{dvt2w}=0.0$	Width dependence of $dvt2w$.
627	$wa0=0.0$	Width dependence of $a0$.
628	$wb0=0.0$ m	Width dependence of $b0$.
629	$wb1=0.0$ m	Width dependence of $b1$.
630	$wa1=0.0$	Width dependence of $a1$.
631	$wa2=0.0$	Width dependence of $a2$.
632	$wags=0.0$ F/m ² *V	Width dependence of ags .
633	$wketa=0.0$ 1/V	Width dependence of $keta$.
634	$w_{nsub}=0.0$ cm ⁻³	Width dependence of $nsub$.
635	$w_{ngate}=0.0$ cm ⁻³	Width dependence of $ngate$.
636	$w_{xj}=0.0$ m	Width dependence of xj .
637	$w_{dwdg}=0.0$ m/V	Width dependence of $dwdg$.
638	$w_{dwb}=0.0$ m/sqrt(V)	Width dependence of dwb .
639	$w_{xt}=0.0$ m	Width dependence of xt .
640	$w_{rdsw}=0.0$ Ohm*um	Width dependence of $rdsw$.
641	$w_{prwb}=0.0$ 1/sqrt(V)	Width dependence of $prwb$.
642	$w_{prwg}=0.0$ 1/V	Width dependence of $prwg$.
643	$w_{wr}=0.0$	Width dependence of wr .
644	$w_{u0}=0.0$ cm ² /V*s	Width dependence of $u0$.

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

645	wvsat=0.0 m/s	Width dependence of vsat.
646	wua=0.0 m/V	Width dependence of ua.
647	wub=0.0 m ² /V ²	Width dependence of ub.
648	wuc=0.0 m/V ²	Width dependence of uc.
649	wud=0.0 /m ²	Width dependence of ud.
650	wup=0.0	Width dependence of up.
651	wlp=0.0 m	Width dependence of lp.
652	wdrout=0.0	Width dependence of drout.
653	wpclm=0.0	Width dependence of pclm.
654	wpdiblc1=0.0	Width dependence of pdiblc1.
655	wpdiblc2=0.0	Width dependence of pdiblc2.
656	wpdiblcb=0.0 1/V	Width dependence of pdiblcb.
657	wpscbe1=0.0 V/m	Width dependence of pscbe1.
658	wpscbe2=0.0 m/V	Width dependence of pscbe2.
659	wpvag=0.0	Width dependence of pvag.
660	wdelta=0.0 V	Width dependence of delta.
661	wcdsc=0.0 F/m ²	Width dependence of cdsc.
662	wcdscb=0.0 F/m ² *V	Width dependence of cdsb.
663	wcdscd=0.0 F/m ² *V	Width dependence of cdsd.
664	wnfactor=0.0	Width dependence of nfactor.
665	wcit=0.0 F	Width dependence of cit.

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

666	wvoff=0.0 V	Width dependence of voff.
667	wdsub=0.0	Width dependence of dsub.
668	weta0=0.0	Width dependence of eta0.
669	wetab=0.0 1/V	Width dependence of etab.
670	walpha0=0.0 m/V	Width dependence of alpha0.
671	walpha1=0.0 m/V	Width dependence of alpha1.
672	wbeta0=0.0 1/V	Width dependence of beta0.
673	wcgsl=0.0 F/m	Width dependence of cgsl.
674	wcgdl=0.0 F/m	Width dependence of cgdl.
675	wclc=0.0 m	Width dependence of clc.
676	wcle=0.0	Width dependence of cle.
677	wcf=0.0 F/m	Width dependence of cf.
678	wvfbcv=0.0	Width dependence of vfbcv.
679	wacde=0.0	Width dependence of acde.
680	wmoin=0.0	Width dependence of moin.
681	wnoff=0.0	Width dependence of noff.
682	wvoffcv=0.0	Width dependence of voffcv.
683	wminvcv=0.0	Width dependence of minvcv.
684	wkt1=0.0 V	Width dependence of kt1.
685	wkt1l=0 V*m	Width dependence of kt1l.
686	wkt2=0.0	Width dependence of kt2.
687	wat=0.0 m/s	Width dependence of at.

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

688	wua1=0.0 m/V	Width dependence of ua1.
689	wub1=0.0 m ² /V ²	Width dependence of ub1.
690	wuc1=0.0 m/V ²	Width dependence of uc1.
691	wud1=0.0 /m ²	Width dependence of ud1.
692	wprt=0.0 Ohm	Width dependence of prt.
693	wute=0.0	Width dependence of ute.
694	wndep=0.0	Width dependence of ndep.
695	wnsd=0.0	Width dependence of nsd.
696	wphin=0.0	Width dependence of phin.
697	wlpe0=0.0	Width dependence of lpe0.
698	wlpeb=0.0	Width dependence of lpeb.
699	wdvtp0=0.0	Width dependence of dvtp0.
700	wdvtp1=0.0	Width dependence of dvtp1.
701	weu=0.0	Width dependence of eu.
702	wminv=0.0	Width dependence of minv.
703	wfprout=0.0	Width dependence of fprout.
704	wpdits=0.0	Width dependence of pdits.
705	wpditsd=0.0	Width dependence of pditsd.
706	wrdw=0.0	Width dependence of rdw.
707	wrsw=0.0	Width dependence of rsw.
708	wagidl=0.0	Width dependence of agidl.
709	wbgidl=0.0	Width dependence of bgidl.

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

710	wcgidl=0.0	Width dependence of cgidl.
711	wegidl=0.0	Width dependence of egidl.
712	waigbacc=0.0	Width dependence of aigbacc.
713	wbigbacc=0.0	Width dependence of bigbacc.
714	wcigbacc=0.0	Width dependence of cigbacc.
715	wnigbacc=0.0	Width dependence of nigbacc.
716	waigbinv=0.0	Width dependence of aigbinv.
717	wbigbinv=0.0	Width dependence of bigbinv.
718	wcigbinv=0.0	Width dependence of cigbinv.
719	weigbinv=0.0	Width dependence of eigbinv.
720	wnigbinv=0.0	Width dependence of nigbinv.
721	waigc=0.0	Width dependence of aigc.
722	wbigc=0.0	Width dependence of bigc.
723	wcigc=0.0	Width dependence of cigc.
724	waigsd=0.0	Width dependence of aigsd.
725	wbigsd=0.0	Width dependence of bigsd.
726	wcigsd=0.0	Width dependence of cigsd.
727	wnigc=0.0	Width dependence of nigc.
728	wpoxedg=0.0	Width dependence of poxedg.
729	wpigcd=0.0	Width dependence of pigcd.
730	wntox=0.0	Width dependence of ntox.
731	wckappas=0.0	Width dependence of ckappas.

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

732	wckappad=0.0	Width dependence of ckappad.
733	wxrcrg1=0.0	Width dependence of xrcrg1.
734	wxrcrg2=0.0	Width dependence of xrcrg2.
735	wvbsdoff=0.0	Width dependence of vbsdoff.
736	wlambda=0.0	Width dependence of lambda.
737	wvtl=0.0	Width dependence of vtl.
738	wxn=0.0	Width dependence of xn.
739	wkvth0we=0.0 V	idth dependence of kvth0we.
740	wk2we=0.0	Width dependence of k2we.
741	wku0we=0.0	Width dependence of ku0we.
742	wku0=0.0 m ^{wlodku0}	Width dependence of ku0.
743	wkvth0=0.0 V*m ^{wlodku0}	Width dependence of kvth0.
744	wucs=0.0	Width dependence of ucs.
745	wucste=0.0	Width dependence of ucste.

Cross-term dependent parameters

746	pvtho=0.0 V	Cross-term dependence of vtho.
747	pvth0	Cross-term dependence of vth0.
748	pvfb=0.0	Cross-term dependence of vfb.
749	pk1=0.0 sqrt(V)	Cross-term dependence of k1.
750	pk2=0.0	Cross-term dependence of k2.
751	pk3=0.0	Cross-term dependence of k3.

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

752	pk3b=0.0 1/V	C	Cross-term dependence of k3b.
753	pw0=0.0 m		Cross-term dependence of w0.
754	pgamma1=0.0 sqrt(V)		Cross-term dependence of gamma1.
755	pgamma2=0.0 sqrt(V)		Cross-term dependence of gamma2.
756	pvbX=0.0 V		Cross-term dependence of vbX.
757	pvbM=0.0 V		Cross-term dependence of vbM.
758	pdvt0=0.0		Cross-term dependence of dvt0.
759	pdvt1=0.0		Cross-term dependence of dvt1.
760	pdvt2=0.0 1/V		Cross-term dependence of dvt2.
761	pdvt0w=0.0		Cross-term dependence of dvt0w.
762	pdvt1w=0.0		Cross-term dependence of dvt1w.
763	pdvt2w=0.0		Cross-term dependence of dvt2w.
764	pa0=0.0		Cross-term dependence of a0.
765	pb0=0.0 m		Cross-term dependence of b0.
766	pb1=0.0 m		Cross-term dependence of b1.
767	pa1=0.0		Cross-term dependence of a1.
768	pa2=0.0		Cross-term dependence of a2.
769	pags=0.0 F/m ² *V		Cross-term dependence of ags.
770	pketa=0.0 1/V		Cross-term dependence of keta.
771	pnsb=0.0 cm ⁻³		Cross-term dependence of nsb.
772	pngate=0.0 cm ⁻³		Cross-term dependence of ngate.

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

773	$pxj=0.0$ m	Cross-term dependence of xj .
774	$pdwg=0.0$ m/V	Cross-term dependence of dwg .
775	$pdwb=0.0$ m/sqrt(V)	Cross-term dependence of dwb .
776	$pxt=0.0$ m	Cross-term dependence of xt .
777	$prdsw=0.0$ Ohm* μ m	Cross-term dependence of $rdsw$.
778	$pprwb=0.0$ 1/sqrt(V)	Cross-term dependence of $prwb$.
779	$pprwg=0.0$ 1/V	Cross-term dependence of $prwg$.
780	$pwr=0.0$	Cross-term dependence of wr .
781	$pu0=0.0$ cm ² /V*s	Cross-term dependence of $u0$.
782	$pvsat=0.0$ m/s	Cross-term dependence of $vsat$.
783	$pua=0.0$ m/V	Cross-term dependence of ua .
784	$pub=0.0$ m ² /V ²	Cross-term dependence of ub .
785	$puc=0.0$ m/V ²	Cross-term dependence of uc .
786	$pud=0.0$ /m ²	Cross-term dependence of ud .
787	$pup=0.0$	Cross-term dependence of up .
788	$plp=0.0$ m	Cross-term dependence of lp .
789	$pdrout=0.0$	Cross-term dependence of $drou$.
790	$ppclm=0.0$	Cross-term dependence of $pclm$.
791	$ppdiblc1=0.0$	Cross-term dependence of $pdiblc1$.
792	$ppdiblc2=0.0$	Cross-term dependence of $pdiblc2$.
793	$ppdiblcb=0.0$ 1/V	Cross-term dependence of $pdiblcd$.

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

794	ppscbe1=0.0 V/m	Cross-term dependence of pscbe1.
795	ppscbe2=0.0 m/V	Cross-term dependence of pscbe2.
796	ppvag=0.0	Cross-term dependence of pvag.
797	pdelta=0.0 V	Cross-term dependence of delta.
798	pcdsc=0.0 F/m ²	Cross-term dependence of cdsc.
799	pcdscb=0.0 F/m ² *V	Cross-term dependence of cdsb.
800	pcdscd=0.0 F/m ² *V	Cross-term dependence of cdsd.
801	pnfactor=0.0	Cross-term dependence of nfactor.
802	pcit=0.0 F	Cross-term dependence of cit.
803	pvoff=0.0 V	Cross-term dependence of voff.
804	pdsb=0.0	Cross-term dependence of dsb.
805	peta0=0.0	Cross-term dependence of eta0.
806	petab=0.0 1/V	Cross-term dependence of etab.
807	palpha0=0.0 m/V	Cross-term dependence of alpha0.
808	palpha1=0.0 m/V	Cross-term dependence of alpha1.
809	pbeta0=0.0 1/V	Cross-term dependence of beta0.
810	pcgsl=0.0 F/m	Cross-term dependence of cgsl.
811	pcgdl=0.0 F/m	Cross-term dependence of cgdl.
812	pclc=0.0 m	Cross-term dependence of clc.
813	pclc=0.0	Cross-term dependence of cle.
814	pcf=0.0 F/m	Cross-term dependence of cf.

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

815	pvfbcv=0.0	Cross-term dependence of vfbcv.
816	pacde=0.0	Cross-term dependence of acde.
817	pmoin=0.0	Cross-term dependence of moin.
818	pnoff=0.0	Cross-term dependence of noff.
819	pvoffcv=0.0	Cross-term dependence of voffcv.
820	pminvcv=0.0	Cross-term dependence of minvcv.
821	pkt1=0.0 V	Cross-term dependence of kt1.
822	pkt1l=0 V*m	Cross-term dependence of kt1l.
823	pkt2=0.0	Cross-term dependence of kt2.
824	pat=0.0 m/s	Cross-term dependence of at.
825	pua1=0.0 m/V	Cross-term dependence of ua1.
826	pub1=0.0 m ² /V ²	Cross-term dependence of ub1.
827	puc1=0.0 m/V ²	Cross-term dependence of uc1.
828	pud1=0.0 /m ²	Cross-term dependence of ud1.
829	pprt=0.0 Ohm	Cross-term dependence of prt.
830	pute=0.0	Cross-term dependence of ute.
831	pndep=0.0	Cross-term dependence of ndep.
832	pnsd=0.0	Cross-term dependence of nsd.
833	pphin=0.0	Cross-term dependence of phin.
834	plpe0=0.0	Cross-term dependence of lpe0.
835	plpeb=0.0	Cross-term dependence of lpeb.
836	pdvtp0=0.0	Cross-term dependence of dvtp0.

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

837	pdvtp1=0.0	Cross-term dependence of dvtp1.
838	peu=0.0	Cross-term dependence of eu.
839	pminv=0.0	Cross-term dependence of minv.
840	pfprout=0.0	Cross-term dependence of fprout.
841	ppdits=0.0	Cross-term dependence of pdits.
842	ppditsd=0.0	Cross-term dependence of pditsd.
843	prdw=0.0	Cross-term dependence of rdw.
844	prsw=0.0	Cross-term dependence of rsw.
845	pagidl=0.0	Cross-term dependence of agidl.
846	pbgidl=0.0	Cross-term dependence of bgidl.
847	pcgidl=0.0	Cross-term dependence of cgidl.
848	pegidl=0.0	Cross-term dependence of egidl.
849	paigbacc=0.0	Cross-term dependence of aigbacc.
850	pbigbacc=0.0	Cross-term dependence of bigbacc.
851	pcigbacc=0.0	Cross-term dependence of cigbacc.
852	pnigbacc=0.0	Cross-term dependence of nigbacc.
853	paigbinv=0.0	Cross-term dependence of aigbinv.
854	pbigbinv=0.0	Cross-term dependence of bigbinv.
855	pcigbinv=0.0	Cross-term dependence of cigbinv.
856	peigbinv=0.0	Cross-term dependence of eigbinv.
857	pnigbinv=0.0	Cross-term dependence of nigbinv.
858	paigc=0.0	Cross-term dependence of aigc.

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

859	pbigc=0.0	Cross-term dependence of bigc.
860	pcigc=0.0	Cross-term dependence of cigc.
861	paigsd=0.0	Cross-term dependence of aigsd.
862	pbigsd=0.0	Cross-term dependence of bigsd.
863	pcigsd=0.0	Cross-term dependence of cigsd.
864	pnigc=0.0	Cross-term dependence of nigc.
865	ppoxedge=0.0	Cross-term dependence of poxedge.
866	ppigcd=0.0	Cross-term dependence of pigcd.
867	pntox=0.0	Cross-term dependence of ntox.
868	pckappas=0.0	Cross-term dependence of ckappas.
869	pckappad=0.0	Cross-term dependence of ckappad.
870	pxrcrg1=0.0	Cross-term dependence of xrcrg1.
871	pxrcrg2=0.0	Cross-term dependence of xrcrg2.
872	pvfbsdoff=0.0	Cross-term dependence of Vfbsdoff.
873	plambda=0.0	Cross-term dependence of lambda.
874	pvtl=0.0	Cross-term dependence of vtl.
875	pxn=0.0	Cross-term dependence of xn.
876	pkvth0we=0.0 V	Cross-term dependence of kvth0we.
877	pk2we=0.0	Cross-term dependence of k2we.
878	pku0we=0.0	Cross-term dependence of ku0we.
879	pku0=0.0 $m^{(llodku0+wlo dku0)}$	Cross-term dependence of ku0.

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

- 880 `pkvth0=0.0 V*m^(llodku0+wlodku0)` Cross-term dependence of kvth0.
- 881 `pucs=0.0` Cross-term dependence of ucs.
- 882 `pucste=0.0` Cross-term dependence of ucste.

DC-mismatch dependent parameters

- 883 `mvtwl=0.0 V*m` Threshold mismatch area dependence.
- 884 `mvtwl2=0.0 V*m^1.5` Threshold mismatch area square dependence.
- 885 `mvt0=0.0 V` Threshold mismatch intercept.
- 886 `mbewl=0.0 m` Beta mismatch area dependence.
- 887 `mbe0=0.0` Beta mismatch intercept.
- 888 `mismatchmod=0` Select Mismatch mode.
- 889 `mismatchdist=0 m` Mismatch Distance.

Mos Table Model parameters

- 890 `mos_method=a` Table model enable. Possible values are s or a.
- 891 `mos_vres=0.05` Voltage increment for table model grid.

Compatibility model parameters

- 892 `compatible=spectre`
Encourage device equations to be compatible with a foreignsimulator. This option does not affect input syntax. Possible values are spectre, spice2, spice3, cdsspice, hspice, spiceplus, eldo, sspice, or mica.

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

Shrink Parmaters

- 893 shrink=0 Linear shrink parameter.
- 894 shrink2=0 Area shrink parameter.

Output Parameters

- 1 weff (m) Effective channel width (alias=lx62).
- 2 leff (m) Effective channel length (alias=lx63).
- 3 weffcv (m) Effective channel width for CV (alias=lx64).
- 4 leffcv (m) Effective channel length for CV (alias=lx65).
- 5 vfbds (V) Flat band Voltage between the gate and Drain/source diffusions (alias=lx75).
- 6 rgbi (Ohm) Gate bias-independent resistance.

Operating-Point Parameters

- 1 region=triode Estimated operating region. Spectre outputs the number (0-4) in a rawfile. Possible values are off, triode, sat, subth, or breakdown.
- 2 reversed Reverse mode indicator. Possible values are no or 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 (alias=lv9).
- 8 vdsat (V) Drain-source saturation voltage (alias=lv10).
- 9 gm (S) Common-source transconductance (alias=lx7).

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

10	gds (S)	Common-source output conductance (alias=lx8).
11	gmbs (S)	Body-transconductance (alias=lx9).
12	betaeff (A/V ²)	Effective beta (alias LV21).
13	cjd (F)	Drain-bulk junction capacitance (alias=lx29).
14	cjs (F)	Source-bulk junction capacitance (alias=lx28).
15	cgg (F)	Total gate capacitance, including intrinsic, overlap and fringing components (alias=lx82).
16	cgd (F)	Total gate-to-drain capacitance, including intrinsic, overlap, and fringing components (alias=lx83).
17	cgs (F)	Total gate-to-source capacitance, including intrinsic, overlap, and fringing components (alias=lx84).
18	cgb (F)	Total gate-to-bulk capacitance, including intrinsic and overlap components.
19	cdg (F)	Total drain-to-gate capacitance, including intrinsic, overlap, and fringing components (alias=lx87).
20	cdd (F)	Drain capacitance, including intrinsic, overlap, and fringing components.
21	cds (F)	Total drain-to-source capacitance (alias=lx86).
22	cdb (F)	Intrinsic drain-to-bulk capacitance.
23	csg (F)	Total source-to-gate capacitance, including intrinsic, overlap, and fringing components.
24	csd (F)	Total source-to-drain capacitance.
25	css (F)	Source capacitance, including intrinsic, overlap, and fringing components.
26	csb (F)	Intrinsic source-to-bulk capacitance.

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

27	cbg (F)	Total bulk-to-gate capacitance, including intrinsic nd overlap components (alias=lx88).
28	cbd (F)	Intrinsic bulk-to-drain capacitance.
29	cbs (F)	Intrinsic bulk-to-source capacitance.
30	cbb (F)	Bulk capacitance, including intrinsic and overlap components.
31	covlgs (F/m)	Gate-source overlap and fringing capacitances (alias=lv36).
32	covlgd (F/m)	Gate-drain overlap and fringing capacitances (alias=lv37).
33	covlgb (F/m)	Gate-bulk overlap capacitances (alias=lv38).
34	cggbo (F)	CGGBO = dQg/dVg intrinsic gate capacitance (alias=lx18).
35	cgdbo (F)	CGDBO = $-dQg/dVd$ intrinsic gate-to-drain capacitance (alias=lx19).
36	cgsbo (F)	CGSBO = $-dQg/dVs$ intrinsic gate-to-source capacitance (alias=lx20).
37	cbgbo (F)	CBGBO = $-dQb/dVg$ intrinsic bulk-to-gate capacitance (alias=lx21).
38	cbdbo (F)	CBDBO = $-dQb/dVd$ intrinsic bulk-to-drain capacitance (alias=lx22).
39	cbsbo (F)	CBSBO = $-dQb/dVs$ intrinsic bulk-to-source capacitance (alias=lx23).
40	cdgbo (F)	CDGBO = $-dQd/dVg$ intrinsic drain-to-gate capacitance (alias=lx32).
41	cddbo (F)	CDDBO = dQd/dVd intrinsic drain capacitance (alias=lx33).
42	cdsbo (F)	CDSBO = $-dQd/dVs$ intrinsic drain-to-source capacitance (alias=lx34).
43	ron (Ohm)	On-resistance.
44	id (A)	Resistive drain current.

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

45	ibulk (A)	Resistive bulk current.
46	pwr (W)	Power at op point.
47	gmoverid (1/V)	Gm/Ids.
48	rdeff (Ohm)	Effective drain resistance.
49	rseff (Ohm)	Effective source resistance.
50	rgbd (Ohm)	Gate bias-dependent resistance.
51	igidl (A)	Gate-induced drain leakage current (alias=Ix70).
52	igisl (A)	Gate-induced source leakage current.
53	igdt (A)	Gate Dielectric tunneling current (alias=Ix71).
54	igd (A)	Gate-to-drain tunneling current (alias=Ix39).
55	igs (A)	Gate-to-source tunneling current (alias=Ix38).
56	igb (A)	Gate-to-bulk tunneling current (alias=Ix66).
57	igbacc (A)	Gate-to-bulk tunneling current determined by ECB (alias=Ix73).
58	igbinv (A)	Gate-to-bulk tunneling current determined by EVB (alias=Ix74).
59	igcs (A)	Gate-to-channel (source side) tunneling current (alias=Ix67).
60	igcd (A)	Gate-to-channel (drain side) tunneling current (alias=Ix68).
61	gbs (S)	Bulk-source diode conductance (alias=Ix11).
62	gbd (S)	Bulk-drain diode conductance (alias=Ix10).

Parameter Index

In the following index, \mathbb{I} refers to instance parameters, \mathbb{M} refers to the model parameters section, \mathbb{O} refers to the output parameters section, and \mathbb{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 $\mathbb{M}-35$ means the 35th model parameter.

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

a0	M-84	lcdscd	M-526	pd	M-457	tnjts	M-278
a1	M-89	lcf	M-540	pdelta	M-797	tnjtsd	M-281
a2	M-90	lcgdl	M-537	pdiblc1	M-133	tnjtssw	M-279
acde	M-217	lcgidl	M-573	pdiblc2	M-134	tnjtsswd	M-282
acnqsmod	I-48	lcgsl	M-536	pdiblc3	M-135	tnjtsswg	M-280
acnqsmod	M-16	lcigbacc	M-577	pdits	M-142	tnjtsswgd	M-283
ad	I-4	lcigbinv	M-581	pditsd	M-144	tnoia	M-414
ad	M-455	lcigc	M-586	pditsl	M-143	tnoib	M-415
ados	M-96	lcigsd	M-589	pdROUT	M-789	tnoimod	M-18
af	M-408	lcit	M-528	pdsub	M-804	tnom	M-326
agidl	M-157	lckappad	M-595	pdvt0	M-758	toxe	M-35
agisl	M-161	lckappas	M-594	pdvt0w	M-761	toxM	M-37
ags	M-85	lclc	M-538	pdvt1	M-759	toxP	M-36
aigbacc	M-165	lcle	M-539	pdvt1w	M-762	toxref	M-192
aigbinv	M-169	ldelta	M-523	pdvt2	M-760	tpb	M-350
aigc	M-174	ldrout	M-515	pdvt2w	M-763	tpbsw	M-352
aigd	M-183	ldsub	M-530	pdvtp0	M-836	tpbswg	M-353
aigs	M-180	ldvt0	M-484	pdvtp1	M-837	trise	I-49
aigsd	M-177	ldvt0w	M-487	pdwb	M-775	trise	M-327
alarm	M-466	ldvt1	M-485	pdwg	M-774	trnqsmod	I-47

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

alpha0	M-154	ldvt1w	M-488	pegidl	M-848	trnqsmod	M-15
alpha1	M-155	ldvt2	M-486	peigbinv	M-856	tvfbsdoff	M-194
as	I-3	ldvt2w	M-489	permod	M-21	tvoff	M-118
as	M-454	ldvtp0	M-562	peta0	M-805	type	M-1
at	M-336	ldvtp1	M-563	petab	M-806	u0	M-101
b0	M-86	ldwb	M-501	peu	M-838	ua	M-102
b1	M-87	ldwg	M-500	pfprout	M-840	ua1	M-332
bdos	M-97	leff	O-2	pgamma1	M-754	ub	M-103
beta0	M-156	leffcv	O-4	pgamma2	M-755	ub1	M-333
betaeff	OP-12	leffeot	M-99	phig	M-91	uc	M-104
bg0sub	M-93	legidl	M-574	phin	M-67	uc1	M-334
bgidl	M-158	leigbinv	M-582	pigcd	M-190	ucs	M-115
bgisl	M-162	leta0	M-531	pk	M-384	ucste	M-116
bigbacc	M-166	letab	M-532	pk1	M-749	ud	M-105
bigbinv	M-170	leu	M-564	pk2	M-750	ud1	M-335
bigc	M-175	level	M-2	pk2we	M-877	up	M-106
bigd	M-184	lfprout	M-566	pk3	M-751	updatelevel	M-28
biggs	M-181	lgamma1	M-480	pk3b	M-752	ute	M-328
bigsd	M-178	lgamma2	M-481	pketa	M-770	vbm	M-75
binunit	M-4	lint	M-50	pkt1	M-821	vbox	M-470
bnr	M-289	lintnoi	M-411	pkt11	M-822	vbs	OP-6

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

bv	M-243	lk	M-382	pkt2	M-823	vbx	M-46
bvd	M-245	lk1	M-475	pku0	M-879	vddeot	M-66
bvj	M-469	lk2	M-476	pku0we	M-878	vds	OP-5
bvs	M-244	lk2we	M-603	pkvth0	M-880	vdsat	OP-8
capmod	M-12	lk3	M-477	pkvth0we	M-876	version	M-3
cbb	OP-30	lk3b	M-478	plambda	M-873	vfb	M-65
cbd	OP-28	lketa	M-496	plp	M-788	vfbcv	M-212
cbdbo	OP-38	lkt1	M-547	plpe0	M-834	vfbsd	O-5
cbg	OP-27	lkt11	M-548	plpeb	M-835	vfbsdoff	M-193
cbgbo	OP-37	lkt2	M-549	pminv	M-839	vgs	OP-4
cbs	OP-29	lku0	M-605	pminvcv	M-820	voff	M-117
cbsbo	OP-39	lku0we	M-604	pmoin	M-817	voffcv	M-214
cdb	OP-22	lkvth0	M-606	pndep	M-831	voffcvl	M-216
cdd	OP-20	lkvth0we	M-602	pnfactor	M-801	voffl	M-122
cddbbo	OP-41	ll	M-57	pngate	M-772	vsat	M-109
cdg	OP-19	llambda	M-599	pnigbacc	M-852	vth	OP-7
cdgbo	OP-40	llc	M-219	pnigbinv	M-857	vtho	M-64
cds	OP-21	lln	M-58	pnigc	M-864	vtl	M-111
cdsbo	OP-42	llodku0	M-389	pnoff	M-818	vtsd	M-273
cdsc	M-129	llodvth	M-392	pnsd	M-832	vtss	M-272
cdscb	M-130	llp	M-514	pnsb	M-771	vtsswd	M-275

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

cdscd M-131	llpe0 M-560	pntox M-867	vtsswgd M-277
cf M-207	llpeb M-561	poxedge M-189	vtsswgs M-276
cgb OP-18	lmax M-464	ppclm M-790	vtssws M-274
cgbo M-200	lmin M-465	ppdiblc1 M-791	w I-1
cgd OP-16	lminv M-565	ppdiblc2 M-792	w M-452
cgdbo OP-35	lminvcv M-546	ppdiblc3 M-793	w0 M-72
cgdl M-203	lmoin M-543	ppdits M-841	wa0 M-627
cgdo M-199	lndep M-557	ppditsd M-842	wa1 M-630
cgg OP-15	lnfactor M-527	pphin M-833	wa2 M-631
cggbo OP-34	lngate M-498	ppigcd M-866	wacde M-679
cgidl M-159	lnigbacc M-578	ppoxedge M-865	wagidl M-708
cgisl M-163	lnigbinv M-583	pprt M-829	wags M-632
cgs OP-17	lnigc M-590	pprwb M-778	waigbacc M-712
cgsbo OP-36	lnoff M-544	pprwg M-779	waigbinv M-716
cgs1 M-202	lnsd M-558	ppscbe1 M-794	waigc M-721
cgso M-198	lnsub M-497	ppscbe2 M-795	waigsd M-724
cigbacc M-167	lntox M-593	ppvag M-796	walpha0 M-670
cigbinv M-171	lodeta0 M-397	prdswh M-777	walpha1 M-671
cigc M-176	lodk2 M-395	prdw M-843	warn M-471
cigd M-185	lp M-107	prsw M-844	wat M-687
cigs M-182	lpclm M-516	prt M-337	wb0 M-628

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

cigsd M-179	lpdiblc1 M-517	prwb M-152	wbl M-629
cit M-128	lpdiblc2 M-518	prwg M-151	wbeta0 M-672
cj M-297	lpdiblc3 M-519	ps I-5	wbgidl M-709
cjd M-299	lpdits M-567	ps M-456	wbigbacc M-713
cjd OP-13	lpditsd M-568	pscbe1 M-137	wbigbinv M-717
cjs M-298	lpe0 M-73	pscbe2 M-138	wbigc M-722
cjs OP-14	lpeb M-74	psk0 M-372	wbigsd M-725
cjsw M-307	lphin M-559	psk1 M-376	wcdsc M-661
cjswd M-309	lpigcd M-592	psk2 M-380	wcdscb M-662
cjswg M-316	lpoxedge M-591	psl M-364	wcdscd M-663
cjswgd M-318	lprt M-555	psw M-368	wcf M-677
cjswgs M-317	lprwb M-504	pta M-349	wcgdl M-674
cjsws M-308	lprwg M-505	ptp M-351	wcgidl M-710
ckappad M-205	lpscbe1 M-520	ptvfbsdoff M-197	wcgsl M-673
ckappas M-204	lpscbe2 M-521	ptvoff M-121	wcigbacc M-714
clc M-208	lpvag M-522	pu0 M-781	wcigbinv M-718
cle M-209	lrdsw M-503	pua M-783	wcigc M-723
cnr M-290	lrdw M-569	pua1 M-825	wcigsd M-726
compatible M-892	lrsd M-570	pub M-784	wcit M-665
covlgb OP-33	lsk0 M-370	pub1 M-826	wckappad M-732
covlgd OP-32	lsk1 M-374	puc M-785	wckappas M-731

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

covlgs	OP-31	lsk2	M-378	puc1	M-827	wclc	M-675
csb	OP-26	lsl	M-362	pucs	M-881	wcle	M-676
csd	OP-24	lsw	M-366	pucste	M-882	wdelta	M-660
csg	OP-23	ltvfbsdoff	M-195	pud	M-786	wdrout	M-652
css	OP-25	ltvoff	M-119	pud1	M-828	wdsub	M-667
cta	M-354	lu0	M-507	pup	M-787	wdvt0	M-621
ctp	M-356	lua	M-509	pute	M-830	wdvt0w	M-624
cvchargemod	M-7	lua1	M-551	pvag	M-140	wdvt1	M-622
deleta0	I-70	lub	M-510	pvbm	M-757	wdvt1w	M-625
delk1	I-68	lub1	M-552	pvbv	M-756	wdvt2	M-623
delnfct	I-69	luc	M-511	pvfb	M-748	wdvt2w	M-626
delta	M-141	luc1	M-553	pvfbcv	M-815	wdvtp0	M-699
delvto	I-63	lucs	M-607	pvfbsdoff	M-872	wdvtp1	M-700
diomod	M-19	lucste	M-608	pvoff	M-803	wdwb	M-638
dlc	M-210	lud	M-512	pvoffcv	M-819	wdwg	M-637
dlcig	M-186	lud1	M-554	pvsat	M-782	web	M-398
dlcigd	M-187	lup	M-513	pvth0	M-747	wec	M-399
dmcg	M-225	lute	M-556	pvtho	M-746	weff	O-1
dmcgt	M-228	lvbm	M-483	pvt1	M-874	weffcv	O-3
dmci	M-226	lvbx	M-482	pw0	M-753	weffeot	M-100
dmdg	M-227	lvfb	M-474	pwr	M-780	wegidl	M-711

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

dnr	M-291	lvfbcv	M-541	pwr	OP-46	weigbinv	M-719
drout	M-136	lvfbsdoff	M-598	pxj	M-773	weta0	M-668
dskip	M-284	lvoff	M-529	pxn	M-875	wetab	M-669
dsub	M-127	lvoffcv	M-545	pxrcrg1	M-870	weu	M-701
dtemp	I-50	lvsat	M-508	pxrcrg2	M-871	wfprout	M-703
dtox	M-38	lvth0	M-473	pxt	M-776	wgamma1	M-617
dvt0	M-76	lvtho	M-472	rbdb	I-59	wgamma2	M-618
dvt0w	M-81	lvtl	M-600	rbdb	M-439	wint	M-51
dvt1	M-77	lw	M-59	rbdbx0	M-443	wk	M-383
dvt1w	M-82	lw0	M-479	rbdby0	M-444	wk1	M-612
dvt2	M-78	lwc	M-220	rbodymod	I-52	wk2	M-613
dvt2w	M-83	lwl	M-61	rbodymod	M-14	wk2we	M-740
dvtp0	M-79	lwlc	M-221	rbpb	I-56	wk3	M-614
dvtp1	M-80	lwn	M-60	rbpb	M-420	wk3b	M-615
dwb	M-63	lwr	M-506	rbpbx0	M-421	wketa	M-633
dwc	M-211	lxj	M-499	rbpbx1	M-422	wkt1	M-684
dwg	M-62	lxn	M-601	rbpbxnf	M-424	wkt11	M-685
dwj	M-229	lxrcrg1	M-596	rbpbxw	M-423	wkt2	M-686
easub	M-114	lxrcrg2	M-597	rbpby0	M-425	wku0	M-742
ef	M-409	lxt	M-502	rbpby1	M-426	wku0we	M-741
eg	M-340	m	I-45	rbpbynf	M-428	wkvth0	M-743

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

egidl	M-160	mbe0	M-887	rbpbyw	M-427	wkvth0we	M-739
egisl	M-164	mbewl	M-886	rbpd	I-57	wl	M-52
eglev	M-29	meto	M-201	rbpd	M-429	wlambd	M-736
eigbinv	M-172	min	I-62	rbpd0	M-430	wlc	M-222
em	M-407	min	M-236	rbpd1	M-431	wln	M-53
eot	M-34	minr	M-30	rbpdf	M-433	wlod	M-385
epsrgate	M-32	minv	M-123	rbpdw	M-432	wlodku0	M-390
epsrox	M-31	minvcv	M-215	rbps	I-58	wlodvth	M-393
epsrsub	M-33	mismatchdist	M-889	rbps	M-434	wlp	M-651
eta0	M-125	mismatchmod	M-888	rbps0	M-435	wlpe0	M-697
etab	M-126	mj	M-300	rbps1	M-436	wlpeb	M-698
eu	M-108	mjd	M-302	rbpsnf	M-438	wmax	M-462
fc	M-306	mjs	M-301	rbpsw	M-437	wmin	M-463
fcsw	M-325	mjsw	M-310	rbsb	I-60	wminv	M-702
flkmod	M-26	mjswd	M-312	rbsb	M-440	wminvcv	M-683
fnoimod	M-17	mjswg	M-319	rbsbx0	M-441	wmoin	M-680
fprout	M-139	mjswgd	M-321	rbsby0	M-442	wndep	M-694
fullreinit	M-27	mjswgs	M-320	rbsdbx1	M-445	wnfactor	M-664
gamma1	M-40	mjsws	M-311	rbsdbxnf	M-447	wngate	M-635
gamma2	M-41	mnr	M-288	rbsdbxw	M-446	wnigbacc	M-715

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

gap1	M-341	mobmod	M-6	rbsdbyl	M-448	wnigbinv	M-720
gap2	M-342	moin	M-218	rbsdbynf	M-450	wnigc	M-727
gbd	OP-62	mos_method	M-890	rbsdbyw	M-449	wnoff	M-681
gbmin	M-451	mos_vres	M-891	rdc	I-9	wnoi	M-412
gbs	OP-61	mtrlmod	M-8	rdc	M-460	wnsd	M-695
gds	OP-10	mulid0	I-67	rdeff	OP-48	wnsub	M-634
geomod	I-53	mulmu0	I-64	rdsmod	M-9	wntox	M-730
geomod	M-22	mulu0	I-66	rdsw	M-145	wpclm	M-653
gm	OP-9	mulvsat	I-65	rdswmin	M-146	wpdiblc1	M-654
gmbs	OP-11	mvt0	M-885	rdw	M-147	wpdiblc2	M-655
gmoverid	OP-47	mvtwl	M-883	rdwmin	M-148	wpdiblcb	M-656
ibulk	OP-45	mvtwl2	M-884	region	I-46	wpdits	M-704
id	OP-44	n	M-343	region	OP-1	wpditsd	M-705
ids	OP-3	ndep	M-42	reversed	OP-2	wpemod	M-24
igb	OP-56	nf	I-61	rgatemod	I-51	wphin	M-696
igbacc	OP-57	nf	M-235	rgatemod	M-13	wpigcd	M-729
igbinv	OP-58	nfactor	M-124	rgbd	OP-50	wpoxedge	M-728
igbmod	M-11	ngate	M-44	rgbi	O-6	wprt	M-692
igcd	OP-60	ngcon	I-76	rgeomod	I-55	wprwb	M-641
igcmmod	M-10	ngcon	M-234	rgeomod	M-25	wprwg	M-642
igcs	OP-59	ni0sub	M-92	rnoia	M-416	wpscbe1	M-657

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

igd OP-54	nigbacc M-168	rnoib M-417	wpscbe2 M-658
igdt OP-53	nigbinv M-173	ron OP-43	wpvag M-659
igidl OP-51	nigc M-188	rsc I-10	wr M-153
igisl OP-52	njd M-345	rsc M-461	wrdsw M-640
igs OP-55	njs M-344	rseff OP-49	wrdw M-706
ijthdfwd M-240	njts M-260	rsh M-48	wrsw M-707
ijthdrev M-238	njtsd M-263	rshg M-49	wsk0 M-371
ijthsfwd M-239	njtssw M-261	rsw M-149	wsk1 M-375
ijthsrev M-237	njtsswd M-264	rswmin M-150	wsk2 M-379
imax M-467	njtsswg M-262	sa I-11	wsl M-363
imelt M-285	njtsswgd M-265	sa1 I-14	wsw M-367
is M-246	noff M-213	sa10 I-23	wtvfbsdoff M-196
isnoisy I-44	noia M-404	sa2 I-15	wtvoff M-120
jmax M-468	noib M-405	sa3 I-16	wu0 M-644
jmelt M-286	noic M-406	sa4 I-17	wua M-646
js M-247	nrd I-7	sa5 I-18	wua1 M-688
jsd M-249	nrd M-458	sa6 I-19	wub M-647
jss M-248	nrfwd M-295	sa7 I-20	wub1 M-689
jsswg M-296	nrs I-8	sa8 I-21	wuc M-648
jswd M-251	nrs M-459	sa9 I-22	wuc1 M-690
jswgd M-253	nsd M-45	saref M-359	wucs M-744

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

jswgs M-252	nsub M-43	sb I-12	wucste M-745
jsws M-250	ntnoi M-413	sb1 I-24	wud M-649
jtsd M-255	ntox M-191	sb10 I-33	wud1 M-691
jtss M-254	pa0 M-764	sb2 I-25	wup M-650
jtsswd M-257	pa1 M-767	sb3 I-26	wute M-693
jtsswgd M-259	pa2 M-768	sb4 I-27	wvbm M-620
jtsswgs M-258	pacde M-816	sb5 I-28	wvbx M-619
jtssws M-256	pagidl M-845	sb6 I-29	wvfb M-611
jtweff M-287	pags M-769	sb7 I-30	wvfbcv M-678
k M-381	paigbacc M-849	sb8 I-31	wvfbsdoff M-735
k1 M-68	paigbinv M-853	sb9 I-32	wvoff M-666
k2 M-69	paigc M-858	sbref M-360	wvoffcv M-682
k2we M-401	paigsd M-861	sc I-74	wvsat M-645
k3 M-70	palph0 M-807	sca I-71	wvth0 M-610
k3b M-71	palph1 M-808	scb I-72	wvtho M-609
keta M-88	paramchk M-5	scc I-73	wvt1 M-737
kf M-410	pat M-824	scref M-403	ww M-54
kt1 M-329	pb M-303	sd I-13	ww0 M-616
kt1l M-330	pb0 M-765	shrink M-893	wwc M-223
kt2 M-331	pb1 M-766	shrink2 M-894	wwl M-56
ku0 M-386	pbd M-305	sk0 M-369	wwlc M-224

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

ku0we	M-402	pbeta0	M-809	sk1	M-373	wnn	M-55
kvsat	M-387	pbgidl	M-846	sk2	M-377	wwr	M-643
kvth0	M-391	pbigbacc	M-850	sl	M-361	wxj	M-636
kvth0we	M-400	pbigbinv	M-854	steta0	M-396	wxn	M-738
l	I-2	pbigc	M-859	stimod	I-54	wxrcrg1	M-733
l	M-453	pbigsd	M-862	stimod	M-23	wxrcrg2	M-734
la0	M-490	pbs	M-304	stk2	M-394	wxt	M-639
la1	M-493	pbsw	M-313	sw	M-365	xgl	M-231
la2	M-494	pbswd	M-315	sw1	I-34	xgw	I-75
lacde	M-542	pbswg	M-322	sw10	I-43	xgw	M-230
lagidl	M-571	pbswgd	M-324	sw2	I-35	xj	M-39
lags	M-495	pbswgs	M-323	sw3	I-36	xjbvd	M-242
laigbacc	M-575	pbsws	M-314	sw4	I-37	xjbvs	M-241
laigbinv	M-579	pcdsc	M-798	sw5	I-38	xl	M-232
laigc	M-584	pcdscb	M-799	sw6	I-39	xn	M-113
laigsd	M-587	pcdscd	M-800	sw7	I-40	xpart	M-206
lalpha0	M-533	pcf	M-814	sw8	I-41	xrcrg1	M-418
lalpha1	M-534	pcgdl	M-811	sw9	I-42	xrcrg2	M-419
lambda	M-110	pcgidl	M-847	tbgasub	M-94	xt	M-47
lat	M-550	pcgsl	M-810	tbgbsub	M-95	xti	M-346
lb0	M-491	pcigbacc	M-851	tcj	M-355	xtid	M-348

Virtuoso Simulator Components and Device Models Reference

BSIM4 Level-14 Model (bsim4)

lbl M-492	pcigbinv M-855	tcjsw M-357	xtis M-347
lbeta0 M-535	pcigc M-860	tcjswg M-358	xtsd M-267
lbgidl M-572	pcigsd M-863	tcnr M-293	xtss M-266
lbigbacc M-576	pcit M-802	tdnr M-294	xtsswd M-269
lbigbinv M-580	pckappad M-869	tempeot M-98	xtsswgd M-271
lbigc M-585	pckappas M-868	tempmod M-20	xtsswgs M-270
lbigsd M-588	pclc M-812	tku0 M-388	xtssws M-268
lc M-112	pcle M-813	tlev M-338	xw M-233
lcdsc M-524	pclm M-132	tlevc M-339	
lcdscb M-525	pd I-6	tmnr M-292	

PSP Model (psp)

The PSP102 model is a compact MOSFET model intended for digital, analog and RF designs. PSP is jointly developed by NXP Semiconductors Research and Arizona State University. It 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 deepsubmicron bulk CMOS technologies. The JUNCAP2 source/drain junction model is an integrated part of PSP102.

PSP 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.

This chapter contains the following information about the PSP model:

- [Model Usage](#) on page 1345
 - [Instance syntax](#) on page 1345
 - [Model syntax](#) on page 1345
- [Model History and Development](#) on page 1346
- [Reference](#) on page 1350
 - [Reference](#) on page 1350
 - [Model Equations](#) on page 1366
- [Component Statements](#) on page 1395
- [PSP MOSFET Model \(psp103\)](#) on page 1609
- [Geometry dependence and other effects](#) on page 1609
 - [Geometrical scaling rules](#) on page 1610
 - [Binning Equations](#) on page 1618

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

- ❑ [Parasitic Resistances](#) on page 1628
- ❑ [Stress effects](#) on page 1629
 - [Layout effects for multi-finger devices](#) on page 1630
 - [Layout effects for regular shapes](#) on page 1630
 - [Parameter Modifications](#) on page 1631
- ❑ [Well proximity effects](#) on page 1632
 - [Parameters for pre-layout simulation](#) on page 1632
 - [Calculation of parameter modifications](#) on page 1633
- ❑ [Asymmetric junctions](#) on page 1634

Model Usage

Instance syntax

PSP102 instance have 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. Five versions are supported, which are 102.2, 102.2.1, 102.3, 102.3.2 and 102.3.3.
2. There are 7 master names, which are psp102, psp1020, psp1021, psp102e, pspnqs1020, pspnqs1021, 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 below:

```
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)
```

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

pspnqs102e psp102(binmod=0 geomod=0 swnqs!=0)

Sample Model Statement

```
model psp102_mod psp102 type=n
+tr = 25 swigate = 0
+binmod=0 geomod=1 swnqs=9 swgidl = 1 swjuncap = 3
```

Example: PSP102.1

```
model psp102_mod psp1021 type=n version=102.1
+tr = 25 swigate = 0
+binmod=0 geomod=1 swnqs=9 swgidl = 1 swjuncap = 3
```

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
```

Example: PSP103.0

```
model psp102_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 psp102_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

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
3. 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.
 - ❑ 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)

1. PSP102.0 is supported in MMSIM6.1.1 in Dec 2006
2. 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)

1. PSP102.1 is supported in MMSIM6.2 in June 2007

2. 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

1. VerilogA code for PSP102.2 is released in Oct 2007

2. 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.
- ❑ Extend the stress model to support NF.
- ❑ Add substrate resistance network and external gate resistance.
- ❑ Add 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 (SiMKit3.0.2)

1. Implemented in MMSIM7.0.1 in June 2008

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

2. 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)

1. Implemented in MMSIM7.1.0 in Dec 2008

2. 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)

1. Implemented in MMSIM7.1.1 in June 2009

2. Changes:

- ❑ Fixed bug in JUNCAP2-model, involving FJUNQ-based selection-criterion in JUNCAPexpress charge model.
- ❑ Some minor implementation changes.

PSP102.3.3 (SiMKit3.3)

1. Implemented in MMSIM7.2 in Dec 2009. Since MMSIM7.2, version control and master name “psp102” are supported.

2. Changes:

- ❑ Added value of gate resistance to OP-output
- ❑ Minor bug fix in conditional for SP-calculation of overlap areas.

Reference

Structure

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.

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 1352. 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.

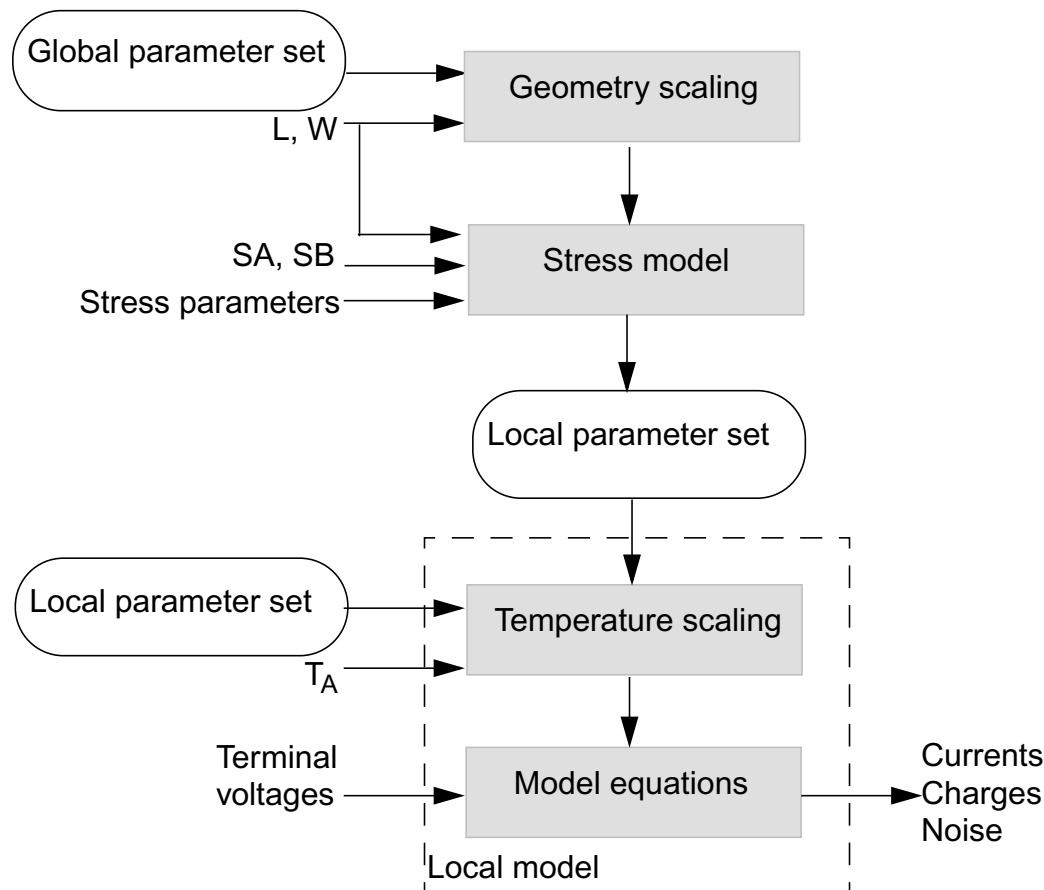


Figure 23-1 Schematic Overview of the PSP Model Structure

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 1358 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.

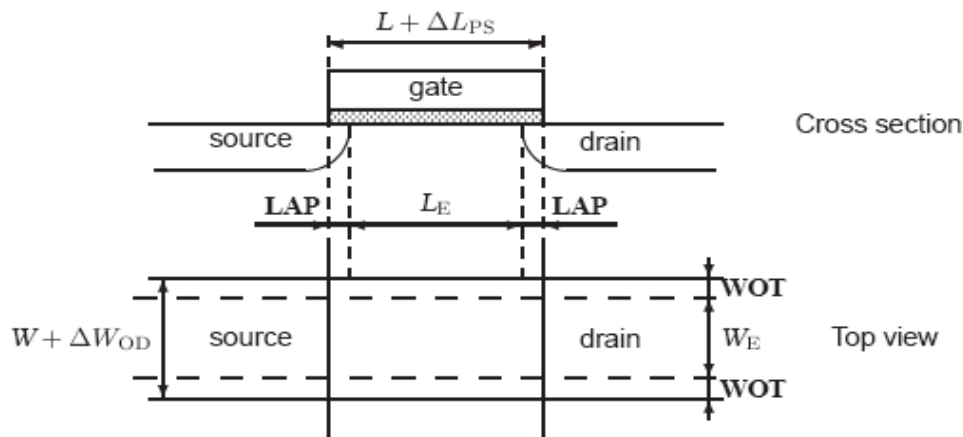


Figure 23-2 Dimensions of a MOS Transistor

Calculation of geometry-dependent parameters using physical scaling rules

Calculation of Process Parameters

$$VFB = VFB0 \cdot \left(1 + VFBL \cdot \frac{L_{EN}}{L_E}\right) \cdot \left(1 + VFBW \cdot \frac{W_{EN}}{W_E}\right) \cdot \left(1 + VFBLW \cdot \frac{W_{EN} \cdot L_{EN}}{W_E \cdot L_E}\right)$$

$$STVFB = STVFB0 \cdot \left(1 + STVFBL \cdot \frac{L_{EN}}{L_E}\right) \cdot \left(1 + STVFBW \cdot \frac{W_{EN}}{W_E}\right) \cdot \left(1 + STVFBLW \cdot \frac{W_{EN} \cdot L_{EN}}{W_E \cdot L_E}\right)$$

$$NSUB0e = NSUB0 \cdot \text{MAX}\left(\left[1 + NSUB0W \cdot \frac{W_{EN}}{W_E} \cdot \ln\left(1 + \frac{W_E}{WSEG}\right)\right], 10^{-3}\right)$$

$$NPCKe = NPCK \cdot \text{MAX}\left(\left[1 + NPCK \cdot \frac{W_{EN}}{W_E} \cdot \ln\left(1 + \frac{W_E}{WSEGP}\right)\right], 10^{-3}\right)$$

$$LPCKe = LPCK \cdot \text{MAX}\left(\left[1 + LPCKW \cdot \frac{W_{EN}}{W_E} \cdot \ln\left(1 + \frac{W_E}{WSEGP}\right)\right], 10^{-3}\right)$$

$$a = 7.5 \cdot 10^{10}$$

$$b = \sqrt{NSUB0e + 0.5 \cdot NPVCKe} - \sqrt{NSUB0e}$$

$$NP = NP0 \cdot \left(1 + NPL \cdot \frac{L_{EN}}{L_E}\right)$$

Virtuoso Simulator Components and Device Models Reference
PSP Model (psp)

$$NSUB = \begin{cases} NSUB0e + NPCKe \cdot \left[2 - \frac{L_E}{LPCKe} \right] & \text{for } L_E < LPCKe \\ NSUB0e + NPCKe \cdot \frac{LPCKe}{L_E} & \text{for } LPCKe \leq L_E \leq LPCKe \\ \left[\sqrt{NSUB0e} + a \cdot \ln \left(1 + 2 \cdot \frac{LPCKe}{L_E} \cdot \left[\exp \left(\frac{b}{a} \right) - 1 \right] \right) \right]^2 & \text{for } L_E > 2 \cdot LPCKe \end{cases}$$

$$CT = \left(CT0 + CTL \cdot \left[\frac{L_{EN}}{L_E} \right]^{CTLEXP} \right) \cdot \left(1 + CTW \cdot \frac{W_{EN}}{W_E} \right)$$

Calculation of Lateral Gradient Factor Parameters

$$F0 = 1 - F0L1 \cdot \frac{L_{EN}}{L_E} - F0L2 \cdot \left[\frac{L_{EN}}{L_E} \right]^2$$

$$AF = \left(AF0 + AFL \cdot \left[\frac{L_{EN}}{L_E} \right]^{AFLEXP} \right) \cdot \left(1 + AFW \cdot \frac{W_{EN}}{W_E} \right)$$

$$BF = BFL \cdot \left[\frac{L_{EN}}{L_E} \right]^2$$

$$CF = CFL \cdot \left[\frac{L_{EN}}{L_E} \right]^{CFLEXP} \cdot \left(1 + CFW \cdot \frac{W_{EN}}{W_E} \right)$$

Calculation of Mobility Parameters

$$FBETle = FBET1 \cdot \left(1 + FBET1W \cdot \frac{W_{EN}}{W_E} \right)$$

$$LPle = LP1 \cdot \text{MAX} \left(\left[1 + LP1W \cdot \frac{W_{EN}}{W_E} \right], 10^{-3} \right)$$

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

$$G_{P,E} = 1 + FBETle \cdot \frac{LPle}{L_E} \cdot \left[1 - \exp\left(-\frac{L_E}{LPle}\right) \right] + FBET2 \cdot \frac{LP2}{L_E} \cdot \left[1 - \exp\left(-\frac{L_E}{LP2}\right) \right]$$

$$G_{W,E} = 1 + BETW1 \cdot \frac{W_{EN}}{W_E} + BETW2 \cdot \frac{W_{EN}}{W_E} \cdot \ln\left(1 + \frac{W_E}{WBET}\right)$$

$$BETN = \frac{U0}{G_{P,E}} \cdot \frac{W_E}{L_E} \cdot G_{W,E}$$

$$STBET = STBET0 \cdot \left(1 + STBETL \cdot \frac{L_{EN}}{L_E} \right) \cdot \left(1 + STBETW \cdot \frac{W_{EN}}{W_E} \right) \\ \cdot \left(1 + STBETLW \cdot \frac{W_{EN} \cdot L_{EN}}{W_E \cdot L_E} \right)$$

$$MUE = MUE0 \cdot \left[1 + MUEW \cdot \frac{W_{EN}}{W_E} \right]$$

$$XCOR = XCOR0 \cdot \left(1 + XCORL \cdot \frac{L_{EN}}{L_E} \right) \cdot \left(1 + XCORW \cdot \frac{W_{EN}}{LW_E} \right) \\ \cdot \left(1 + XCORLW \cdot \frac{W_{EN} \cdot L_{EN}}{W_E \cdot L_E} \right)$$

$$CS = CS0 \cdot \left[1 + CSW \cdot \frac{W_{EN}}{W_E} \right]$$

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

$$COX = \epsilon_{OX} \cdot \frac{W_E \cdot L_E}{TOX}$$

$$CGOV = \epsilon_{OX} \cdot \frac{W_E \cdot LOV}{TOXOV}$$

$$CGBOV = CGBOVL \cdot \frac{L + \Delta L_{PS}}{L_{EN}}$$

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

$$IFK = IFKW \cdot \frac{W_E}{W_{EN}}$$

$$CFR = CFRW \cdot \frac{W + \Delta W_{OD}}{W_{EN}}$$

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

$$Inv_{sa} = \frac{1}{SA + 0.5 \cdot L}$$

$$Inv_{sb} = \frac{1}{SB + 0.5 \cdot L}$$

$$Inv_{sa_{ref}} = \frac{1}{SAREF + 0.5 \cdot L}$$

$$Inv_sb_{ref} = \frac{1}{SBREF + 0.5 \cdot L}$$

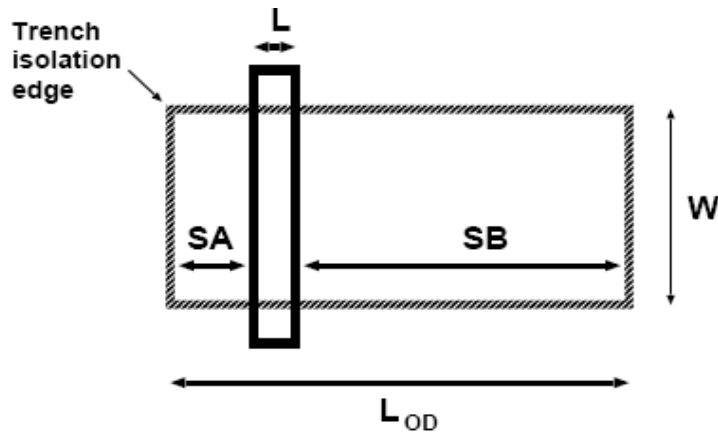


Figure 23-3 Typical layout of a MOSFET. Note that $L_{OD} = SA + SB + L$, where OD is gate oxide definition

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.

$$\frac{1}{SAEFF + 0.5 \cdot L} = \sum_{i=1}^n \frac{SW_i}{W} \cdot \frac{1}{SA_i + 0.5 \cdot L}$$

$$\frac{1}{SABFF + 0.5 \cdot L} = \sum_{i=1}^n \frac{SW_i}{W} \cdot \frac{1}{SAB + 0.5 \cdot L}$$

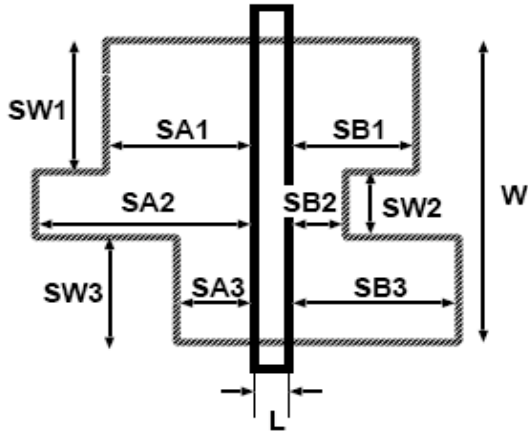


Figure 23-4 A typical layout of MOS devices with more instance parameters (SW_i, SA_i and SB_i) in addition to the traditional L and W)

Calculation of Parameter Modifications

Mobility-Related Equations

$$K_{stress_u0} = \left(1 + \frac{LKU0}{(L + \Delta L_{PS})^{LLODKU0}} + \frac{WKU0}{(W + \Delta W_{OD} + WLOD)^{WLODKU0}} + \frac{PKU0}{(L + \Delta L_{PS})^{LLODKU0} \cdot (W + \Delta W_{OD} + WLOD)^{WLODKU0}} \right) \cdot \left(1 + TKU0 \cdot \left(\frac{T_{KD}}{T_{KR}} - 1 \right) \right)$$

$$\rho\beta = \frac{KU0}{K_{stress_u0}} \cdot (Inv_sa + Inv_sb)$$

$$\rho\beta_{ref} = \frac{KU0}{K_{stress_u0}} \cdot (Inv_sa_{ref} + Inv_sb_{ref})$$

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

$$BETN = \frac{1 + \rho\beta}{1 + \rho\beta_{ref}} \cdot BETN_{ref}$$

$$THESAT = \frac{1 + \rho\beta}{1 + \rho\beta_{ref}} + \frac{1 + KVSAT \cdot \rho\beta_{ref}}{1 + KVSAT \cdot \rho\beta} \cdot THESAT_{ref}$$

Threshold-Voltage-Related Equations

$$Kstress_vth0 = 1 + \frac{LKVTH0}{(L + \Delta L_{PS})^{LLODKVTH}} + \frac{WKVTH0}{(W + \Delta W_{OD} + WLOD)^{WLODKVTH}}$$

$$+ \frac{PKU0}{(L + \Delta L_{PS})^{LLODVTH} \cdot (W + \Delta W_{OD} + WLOD)^{WLODVTH}}$$

$$\Delta Inv_s = Inv_sa + Inv_sb - Inv_sa_{ref} - Inv_sb_{ref}$$

$$VFB = VFB_{ref} + KVTH0 \cdot \frac{\Delta Inv_s}{Kstress_vth0}$$

$$AF = AF_{ref} + STK2 \cdot \frac{\Delta Inv_s}{Kstress_vth0^{LODK2}}$$

$$CF = CF_{ref} + STETA0 \cdot \frac{\Delta Inv_s}{Kstress_vth0^{LODETA0}}$$

PSP Model

Calculation of Internal Parameters (including Temperature Scaling)

Calculation of Transistor Temperature

$$T_{KR} = T_0 + TR$$

$$T_{KD} = T_0 + T_A + DTA$$

$$\Delta T = T_{KD} - T_{KR}$$

Virtuoso Simulator Components and Device Models Reference
PSP Model (psp)

$$\phi_T = \frac{k_B \cdot T_{KD}}{q}$$

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

$$\beta = \text{BETN} \cdot C_{ox} \cdot (T_{KR}/T_{KD})^{STBET}$$

$$\theta_{\mu} = \text{THEMU} \cdot (T_{KR}/T_{KD})^{STTHEMU}$$

$$\mu_E = \text{MUE} \cdot (T_{KR}/T_{KD})^{STMUE}$$

$$X_{cor} = \text{XCOR} \cdot (T_{KR}/T_{KD})^{STXCOR}$$

$$C_S = \text{CS} \cdot (T_{KR}/T_{KD})^{STCS}$$

$$E_{eff0} = 10^{-8} \cdot C_{ox}/\epsilon_{Si}$$

$$\eta_{\mu} = \begin{cases} 1/2 & \text{for NMOS} \\ 1/3 & \text{for PMOS} \end{cases}$$

Calculation of Series Resistance Parameters

$$R_s = \text{RS} \cdot (T_{KR}/T_{KD})^{STRS}$$

$$\theta_R = 2 \cdot \beta \cdot R_s$$

Calculation of Velocity Saturation Parameter

$$\theta_{sat} = \text{A2} \cdot (T_{KR}/T_{KD})^{STTHESAT}$$

Calculation of Impact-Ionization Parameter

$$\alpha_2 = A2 \cdot (T_{KD}/T_{KR})^{STA2}$$

Calculation of Gate Current Parameters

$$I_{GINV} = IGINV \cdot (T_{KD}/T_{KR})^{STIG}$$

$$I_{GOV} = A2IGOV \cdot (T_{KD}/T_{KR})^{STIG}$$

$$B = \frac{4}{3} \cdot \frac{TOX}{h} \cdot \sqrt{2 \cdot q \cdot m_0 \cdot CHIB} = 6.830909 \cdot 10^9 \cdot TOX \cdot \sqrt{CHIB}$$

$$B_{ov} = B \cdot (TOXOV)/(TOX)$$

$$GC_q = \begin{cases} -0.99 \cdot \frac{GC2}{2 \cdot GC3} & \text{if } GC3 < 0 \\ 0 & \text{if } GC3 \geq 0 \end{cases}$$

$$\alpha_b = \frac{E_g/q + \phi_B}{2}$$

$$D_{ch} = GC0 \cdot \phi^*_T$$

$$D_{ov} = GC0 \cdot \phi_T$$

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

$$x_1 = 1.25$$

$$x_{g1} = \chi_1 + G_{ov} \cdot \sqrt{\exp(-\chi_1) + \chi_1 - 1}$$

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

$$D_{nsub} = DNSUB \cdot \text{MAXA}(0, V_{GS} + V_{SB} - V_{NSUB}, NSLP)$$

$$G = G_0 \cdot \sqrt{1 + D_{nsub}}$$

Lateral Gradient Factor

$$V_{dsx} = \sqrt{V_{DS}^2 + 0.010.01}$$

Virtuoso Simulator Components and Device Models Reference
PSP Model (psp)

$$V_{sbx} = V^*_{SB} + \frac{V_{DS} - V_{dsx}}{2}$$

$$V_{sbx1} = \text{MAXA}(V_{sbx}, 0, 10^{-4})$$

$$F_{DIBL} = CF \cdot V_{dsx} \cdot (1 + CF \cdot V_{dsx}) \cdot (1 + CFB \cdot V_{sbx})$$

$$f_0 = \frac{F0}{1 + AF \cdot V_{sbx} + B_f \cdot V_{sbx1} + F_{DIBL}} + 0.01$$

$$B_t = (f_0 - 0.01) \cdot B_f \cdot \phi^*_X$$

$$\tilde{x}_0 = \frac{\phi_B + V_{sbx}}{\phi^*_T}$$

$$x_{gc} = \text{MAXA}(\chi_g, 0, 50)$$

$$x_{subf} = \frac{\chi_{gc}^2}{\chi_{gc} + \frac{G^2 \times f_0}{2} + G \cdot \sqrt{B_t \cdot \chi_{gc}^2 + f_0 \cdot \chi_{gc} + \left(\frac{G \cdot f_0}{2}\right)^2}}$$

$$\eta_f = \text{MINA}(\chi_{subf}, \tilde{x}_0 + 3, 5)$$

$$a_f = (\chi_{gc} - \eta_f)^2 - G^2 \cdot \eta_f \cdot (f_0 + B_t \cdot \eta_f)$$

$$c_f = 2 \cdot (\chi_{gc} - \eta_f) + G^2 \cdot (f_0 + 2 \cdot B_t \cdot \eta_f)$$

$$\tau = \tilde{x}_0 - \eta_f + \ln(a_f / G^2)$$

$$x_f = \sigma\left(\frac{a_f}{1 - B_t \cdot G^2}, \frac{c_f}{1 - B_t \cdot G^2}, \tau, \eta_f\right)$$

$$f = f_0 + B_t \cdot \chi_f$$

Surface Potential at Source Side and Related Variables

$$G_f = G \cdot \sqrt{f}$$

$$\xi = 1 + G_f / (\sqrt{2})$$

$$x_{ns} = \frac{\phi_B + V^*_{SB}}{\phi^*_T}$$

$$\Delta_{ns} = \exp(-\chi_{ns}) / f$$

$$x_{mrg} = 10^{-5} \cdot \xi$$

$$\begin{array}{l}
 \text{if } x_g < -x_{mrg} \\
 \left\{ \begin{array}{l}
 y_g = -x_g \\
 z = 1.25 \cdot y_g / \xi \\
 \eta = \left[z + 10 - \sqrt{(z-6)^2 + 64} \right] / 2 \\
 a = (y_g - \eta)^2 + G_f^2 \cdot (\eta + 1) \\
 c = 2 \cdot (y_g - \eta) - G_f^2 \\
 \tau = -\eta + \ln(a / G_f^2) \\
 y_0 = \sigma_1(a, c, \tau, \eta) \\
 \Delta_0 = EXP(y_0) \\
 p = 2 \cdot (y_g - y_0) + G_f^2 \cdot [\Delta_0 - 1 + \Delta_{ns} \cdot (1 - \chi'(y_0) - 1/\Delta_0)] \\
 q = (y_g - y_0)^2 + G_f^2 \cdot [y_0 - \Delta_0 + 1 + \Delta_{ns} \cdot (1 + \chi(y_0) - 1/\Delta_0 - 2 \cdot y_0)] \\
 x_s = -y_0 - \frac{2 \cdot q}{p + \sqrt{p^2 - 2 \cdot q \cdot \left\{ 2 - G_f^2 \cdot [\Delta_0 + \Delta_{ns} \cdot (1/\Delta_0 - x^n(y_0))] \right\}}}
 \end{array} \right.
 \end{array}$$

$$\text{if } |x_g| \leq x_{mrg} \quad \left\{ x_s = \frac{x_g}{\xi}, \left[1 + G_f \cdot x_g \cdot \frac{1 - \Delta_{ns}}{\xi^2 \cdot 6 \cdot \sqrt{2}} \right] \right.$$

Virtuoso Simulator Components and Device Models Reference
PSP Model (psp)

$$\text{if } x_g > x_{mrg} = \left\{ \begin{array}{l}
 \hat{x}_{g1} = x_1 + G_f \cdot \sqrt{\exp(-x_1) + x_1 - 1} \\
 \bar{x} = \frac{x_g}{\xi} \cdot [1 + x_g \cdot (\xi \cdot x_1 - \hat{x}_{g1}) / x_{g1}^2] \\
 x_0 = x_g + G_f^2 / 2 - G_f \cdot \sqrt{x_g + G_f^2 / 4 - 1 + \exp(-\bar{x})} \\
 b_x = x_{ns} + 0.5 + 2.5 \cdot f \\
 \eta = \text{MINA}(x_0, b_x, 5) - (b_x - \sqrt{b_x^2 + 5}) / 2 \\
 a = (x_g - \eta)^2 - G_f^2 \cdot [\exp(-\eta) + \eta - 1 - \Delta_{ns} - (\eta + 1 + \chi(\eta))] \\
 b = 1 - G_f^2 \cdot [\exp(-\eta) - \Delta_{ns} \cdot x^n(\eta)] \\
 c = 2 \cdot (x_g - n) + G_f^2 \cdot [1 - \exp(-\eta) - \Delta_{ns} \cdot (1 + x'(\eta))] \\
 \tau = x_{ns} - \eta + \ln(a / G^2) \\
 y_0 = a_2(a, b, c, \tau, \eta) \\
 \Delta_0 = \exp(y_0) \\
 p = 2 \cdot (x_g - y_0) + G_f^2 \cdot [1 - 1 / \Delta_0 + \Delta_{ns} \cdot (\Delta_0 - 1 - (y_0))] \\
 x_s = \frac{2 \cdot q}{p + \sqrt{p^2 - 2 \cdot q \cdot \left\{ 2 - G_f^2 \cdot [1 / \Delta_0 + \Delta_{ns} \cdot (\Delta_0 - x^n(y_0))] \right\}}}
 \end{array} \right.$$

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 $x_g > 0$.

$$q_{is} = \frac{G_f^2 \cdot \phi^*_T \cdot D_s}{x_{gs} + G_f \cdot \sqrt{P_s}}$$

$$\alpha_s = 1 + \frac{G_f \cdot (1 - E_s)}{2 \cdot \sqrt{P_s}}$$

$$q_{bs} = \phi^*_T \cdot G_f \cdot \sqrt{P_s}$$

$$\rho_s = \theta_R \cdot \frac{1 + RSB \cdot V_{sbx}}{1 + RSG \cdot q_{is}} \cdot q_{is}$$

$$\mu_x = \frac{1 + X_{cor} \cdot V_{sbx}}{1 + 0.2 \cdot X_{cor} \cdot V_{sbx}}$$

$$E_{effs,s} = E_{eff0} \cdot (q_{bs} + \eta_\mu \cdot q_{is})$$

$$G_{mob,s} = \frac{1 + (\mu_E \cdot E_{eff,s})^{\theta_\mu} + C_S \cdot \left(\frac{q_{bs}}{q_{is} + q_{bs}} \right)^2 + \rho_s}{\mu_x}$$

$$w_{sat,s} = \frac{100 \cdot q_{is} \cdot (1 + THESATB \cdot V_{sbx})}{100 + q_{is} \cdot (1 + THESATB \cdot V_{sbx})}$$

$$\theta^*_{sat,s} = \frac{\theta_{sat,s}}{G_{mob,s}} \cdot (1 + THESATG \cdot w_{sat,s})$$

$$\phi_\infty = q_{is} / \alpha_s + \phi^*_T$$

Virtuoso Simulator Components and Device Models Reference
PSP Model (psp)

$$y_{sat} = \begin{cases} \theta^*_{sat,s} \cdot \phi_{\infty}/(\sqrt{2}) & \text{for NMOS} \\ \frac{\theta^*_{sat,s} \cdot \phi_{\infty}/(\sqrt{2})}{\sqrt{1 + \theta^*_{sat,s} \cdot \phi_{\infty}/(\sqrt{2})}} & \text{for PMOS} \end{cases}$$

$$\phi_2 = \frac{\phi^*_T \cdot G_f^2 \cdot D_s \cdot SO}{a_{sat} + \sqrt{a_{sat}^2 - G_f^2 \cdot D_s \cdot SO}}$$

$$\phi_{sat} = \frac{2 \cdot \phi_0 \cdot \phi_2}{\phi_0 + \phi_2 + \sqrt{(\phi_0 + \phi_2)^2 - 3.96 \cdot \phi_0 \cdot \phi_2}}$$

$$V_{dsat} = \phi_{sat} - \phi^*_T \cdot \ln \left[1 + \frac{\phi_{sat} \cdot (\phi_{sat} - 2 \cdot a_{sat} \cdot \phi^*_T)}{G_f^2 \cdot D_s \cdot \phi_T^{*2}} \right]$$

$$V_{dse} = \frac{V_{DS}}{[1 + (V_{DS}/V_{dsat})^{AX}]^{1/(AX)}}$$

Surface Potential at Drain Side and Related Variables

$$x_{nd} = \frac{\phi_B + V_{SB}^* + V_{dse}}{\phi_T^*}$$

$$k_{ds} = \exp(-V_{dse}/\phi_T^*)$$

$$\text{if } x_g \leq x_{mrg} \quad \left\{ x_d = \frac{x_g}{\xi} \cdot \left[1 + G_f \cdot x_g \cdot \frac{1 - \Delta_{nd}}{\xi^2 \cdot 6 \cdot \sqrt{2}} \right] \right.$$

Virtuoso Simulator Components and Device Models Reference
PSP Model (psp)

$$\text{if } x_g > x_{mrg} \left\{ \begin{array}{l}
 b_x = x_{nd} + 0.5 + 2.5 \cdot f \\
 \eta = \text{MINA}(x_0, b_x, 5) - \left(b_x - \sqrt{b_x^2 + 5} \right) / 2 \\
 a = (x_g - \eta)^2 - G_f^2 \cdot [\exp(-\eta) + \eta - 1 - \Delta_{nd} \cdot (\eta + 1 + x(\eta))] \\
 b = 1 - G_f^2 / 2 \cdot [\exp(-\eta) - \Delta_{nd} \cdot x^n(\eta)] \\
 c = 2 \cdot (x_g - \eta) + G_f^2 \cdot [1 - \exp(-\eta) - \Delta_{nd} \cdot (1 + x'(\eta))] \\
 \tau = x_{nd} - \eta + \ln \langle a / G^2 \rangle \\
 y_0 = \sigma_2(a, b, c, \tau, \eta) \\
 \Delta_0 = \exp(y_0) \\
 p = 2 \cdot (x_g - y_0) + G_f^2 \cdot [1 - 1/\Delta_0 + \Delta_{nd} \cdot (\Delta_0 - 1 - x'(y_0))] \\
 q = (x_g - y_0)^2 - G_f^2 \cdot [y_0 + 1/\Delta_0 - 1 + \Delta_{nd} \cdot (\Delta_0 - y_0 - 1 - x'(y_0))] \\
 x_d = y_0 + \frac{2 \cdot q}{p + \sqrt{p^2 - 2 \cdot q \cdot \left\{ 2 - G_f^2 \cdot [1/\Delta_0 + \Delta_{nd} \cdot (\Delta_0 - x^n(y_0))] \right\}}}
 \end{array} \right.$$

$$x_{ds} = x_d - x_s$$

$$\text{if } x_{ds} < 10^{-10} \left\{ \begin{array}{l}
 p = 2 \cdot x_{gs} + G_f^2 \cdot [1 - E_s + \Delta_{nd} \cdot (1/E_s - 1 - x'(x_s))] \\
 q = G_f^2 \cdot (1 - k_{ds}) \cdot D_s \\
 \xi = 1 - G_f^2 \cdot [E_s + \Delta_{nd} (1/E_s - x^n(x_s))] \\
 x_{ds} = \frac{2 \cdot q}{p + \sqrt{p^2 - 4 \cdot \xi \cdot q}} \\
 x_d = x_s + x_{ds}
 \end{array} \right.$$

$$E_d = \exp(-x_d)$$

$$D_d = (1/E_d - x_d - 1 - (x_d)) \cdot \Delta_{nd}$$

$$\Delta\Psi = \phi_T^* \cdot x_{ds}$$

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

$$\Psi_{sd} = \phi_T^* \cdot x_d$$

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 $\eta_p = 1$).

$$x_m^{(0)} = x_m, D_m^{(0)} = D_m, E_m^{(0)} = E_m, \Delta\psi^{(0)} = \Delta\psi$$

$$d_0 = 1 - E_m^{(0)} + 2 \cdot X_{gm}/G_f^2$$

$$\eta_p = 1/(\sqrt{1 + k_p \cdot x_{gm}})$$

$$x_{pm} = k_p \cdot \left[\frac{\eta_p \cdot x_{gm}}{1 + \eta_p} \right] \cdot \frac{D_m^{(0)}}{D_m^{(0)} + P_m}$$

$$p = 2 \cdot (x_{gm} - x_{pm}) + G_f^2 \cdot (1 - E_m^{(0)} + D_m^{(0)})$$

$$q = x_{pm} \cdot (x_{pm} - 2 \cdot x_{gm})$$

$$\xi_p = 1 - G_f^2/2 \cdot (E_m^{(0)} + D_m^{(0)})$$

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

$$u_p = \frac{p \cdot q}{p^2 - \xi_p \cdot q}$$

$$x_m = x_m^{(0)} + u_p$$

$$E_m = E_m^{(0)} \cdot \exp(-u_p)$$

$$D_m = D_m^{(0)} \cdot \exp(-u_p)$$

$$P_m = x_m - 1 + E_m$$

$$x_{gm} = G_f \cdot \sqrt{D_m + P_m}$$

$$\Delta\psi = \Delta\psi^{(0)} \cdot \frac{\exp(u_p) \cdot [\bar{D} + d_0]}{1 - E_m + 2 \cdot x_{gm} \cdot \eta_p / G_f^2 + \exp(u_p) \cdot \bar{D}}$$

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 $x_g > 0$.

$$a^*_2 = a_2 \cdot [1 + A4 \cdot (\sqrt{V^*_{SB} + \phi_B} - \sqrt{\phi_B})]$$

$$\Delta V_{sat} = V_{DS} - A3 \cdot \Delta\psi$$

$$M_{av1} = \begin{cases} 0 & \text{for } \Delta V_{sat} \leq 0 \\ A1 \cdot \Delta V_{sat} \cdot \exp(\Delta\psi) & \text{for } \Delta V_{sat} > 0 \end{cases}$$

$$I_{av1} = M_{av1} \cdot I_{DS}$$

Surface Potential in Gate Overlap Regions

$$x_{ov}(x_g) = \begin{cases} \text{if } x_g < -x_{mrgov} & \left\{ \begin{array}{l} y_g = -x_g \\ z = x_1 \cdot y_g / \xi_{ov} \\ \eta = [z + 10 - \sqrt{(z-6)^2 + 64}] / 2 \\ a = (y_g - \eta)^2 + G_{ov}^2 \cdot (\eta + 1) \\ c = 2 \cdot (y_g - \eta) - G_{ov}^2 \\ \tau = -\eta + \ln(a / G_{ov}^2) \\ y_0 = \sigma_1(a, c, \tau, \eta) \\ \Delta_0 = \exp(y_0) \\ p = 2 \cdot (y_g - y_0) + G_{ov}^2 \cdot (\Delta_0 - 1) \\ q = (y_g - y_0)^2 + G_{ov}^2 \cdot (y_0 - \Delta_0 + 1) \\ x_{ov} = \frac{2 \cdot q}{p + \sqrt{p^2 - 2 \cdot q \cdot (2 - G_{ov}^2 \cdot \Delta_0)}} \end{array} \right. \\ \text{if } |x_g| < x_{mrgov} & \{ x_{ov} = x_g / \xi_{ov} \end{cases}$$

Virtuoso Simulator Components and Device Models Reference
PSP Model (psp)

$$x_{ov}(x_g) = \begin{cases} \left. \begin{array}{l} \text{if } x_g < -x_{mrgov} \\ \\ \\ \\ \\ \text{if } |x_g| < x_{mrgov} \\ \\ \\ \text{if } x_g > x_{mrgov} \end{array} \right\} \begin{cases} \begin{array}{l} y_g = -x_g \\ z = x_1 \cdot y_g / \xi_{ov} \\ \eta = [z + 10 - \sqrt{(z-6)^2 + 64}] / 2 \\ a = (y_g - \eta)^2 + G_{ov}^2 \cdot (\eta + 1) \\ c = 2 \cdot (y_g - \eta) - G_{ov}^2 \\ \tau = -\eta + \ln(a / G_{ov}^2) \\ y_0 = \sigma_1(a, c, \tau, \eta) \\ \Delta_0 = \exp(y_0) \\ p = 2 \cdot (y_g - y_0) + G_{ov}^2 \cdot (\Delta_0 - 1) \\ q = (y_g - y_0)^2 + G_{ov}^2 \cdot (y_0 - \Delta_0 + 1) \\ x_{ov} = \frac{2 \cdot q}{p + \sqrt{p^2 - 2 \cdot q \cdot (2 - G_{ov}^2 \cdot \Delta_0)}} \end{array} \\ \{x_{ov} = x_g / \xi_{ov}\} \\ \begin{array}{l} \bar{x} = x_g / \xi_{ov} \cdot [1 + x_g \cdot (\xi_{ov} \cdot x_1 - x_{g1}) / x_{g1}^2] \\ w = 1 - \exp(-\bar{x}) \\ x_0 = x_g + G_{ov}^2 / 2 - G_{ov} \cdot \sqrt{x_g + G_{ov}^2 / 4 - w} \\ p = 2 \cdot (x_g - x_0) + G_{ov}^2 \cdot (1 + \Delta_0) \\ q = (x_g - x_0)^2 - G_{ov}^2 \cdot (x_0 + \Delta_0 - 1) \\ x_{ov} = x_0 + \frac{2 \cdot q}{p + \sqrt{p^2 - 2 \cdot q \cdot (2 - G_{ov}^2 \cdot \Delta_0)}} \end{array} \end{cases}
 \end{cases}$$

$$\Psi_{sov} = -\phi_T \cdot x_{ov} \left(-\frac{V_{GS}}{\phi_T} \right)$$

$$\Psi_{dov} = -\phi_T \cdot x_{ov} \left(-\frac{V_{GS} - V_{DS}}{\phi_T} \right)$$

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

$$V_{ov0} = V_{GS} - \Psi_{sov}$$

$$V_{ovL} = V_{GS} - V_{DS} - \Psi_{dov}$$

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:

$$I_{GOV}(V_{GX}, \Psi_{ov}, V_{ov}) = \left\{ \begin{array}{l} V_{ov}^* = \sqrt{V_{ov}^2 + 10^{-6}} \\ \Psi_{tov} = MINA(0, V_{ov} + D_{ov}, 0.01) \\ z_g = \begin{cases} MINA\left(\frac{V_{ov}^*}{CHIB}, GC_Q, 10^{-6}\right) & \text{for } GC3 < 0 \\ \frac{V_{ov}^*}{CHIB} & \text{for } GC3 \geq 0 \end{cases} \\ \Delta_{Siov} = \exp\left(\frac{3.0 \cdot \phi_T + \Psi_{ov} + \Psi_{tov}}{\phi_T}\right) \\ F_{Sov} = \ln\left[\frac{1 + \Delta_{Siov}}{1 + \Delta_{Siov} \cdot \exp(-V_{GX}/\phi_T)}\right] \\ I_{GOV} = I_{GOV} \cdot F_{Sov} \cdot \exp\left(B_{ov} \cdot \left[-\frac{3}{2} + z_g \cdot (GC2 + GC3 \cdot z_g)\right]\right) \end{array} \right.$$

$$I_{GSov} = I_{GOV}(V_{GS}, \Psi_{sov}, V_{ov0})$$

$$I_{GDov} = I_{GOV}(V_{GS} - V_{DS}, \Psi_{dov}, V_{ovL})$$

Gate-Channel Current

$$V_m = V_{SB}^* + \phi_T^* \cdot \left[x_m - x_s - \ln\left(\frac{1 + \exp(V_{dse}/\phi_T^*)}{2}\right) \right]$$

Virtuoso Simulator Components and Device Models Reference
PSP Model (psp)

$$\Psi_T = \text{MINA}(0, V_{oxm} + D_{ch}, 0.01)$$

$$V^*_{oxm} = \sqrt{V_{oxm}^2 + 10^{-6}}$$

$$z_g = \begin{cases} \text{MINA}\left(\frac{V^*_{oxm}}{CHIB}, GC_Q, 10^{-6}\right) & \text{for } GC3 < 0 \\ \frac{V^*_{oxm}}{CHIB} & \text{for } GC3 \geq 0 \end{cases}$$

$$\Delta_{Si} = \exp\left(x_m - \frac{\alpha_b + V_m - \Psi_t}{\phi^*_T}\right)$$

$$F_S = \ln \left[\frac{1 + \Delta_{Si}}{1 + \Delta_{Si} \cdot \exp\left(-\frac{V_{HS} + V_{SB} - V_m}{\phi^*_T}\right)} \right]$$

$$I_{GCO} = I_{GINV} \cdot F_S \cdot \exp\left(B \cdot \left[-\frac{3}{2} + z_g \cdot (GC2 + GC3 \cdot z_g)\right]\right)$$

$$\text{if } x_g > 0 \quad \left\{ \begin{array}{l} u_0 = CHIB/[B \cdot (GC2 + 2 \cdot GC3 \cdot z_g)] \\ x = \Delta\Psi/(2 \cdot u_0) \\ b = u_0/H \\ B_b = b \cdot (1 - b)/2 \\ A_g = 1/2 - 3 \cdot B_g \\ p_{gc} = (1 - b) \cdot \frac{\sinh(x)}{x} + b \cdot \cosh(x) \\ p_{gd} = \frac{p_{gc}}{2} - B_g \cdot \sinh(x) - A_g \cdot \frac{\sinh(x)}{x} \cdot \left[\coth(x) - \frac{1}{x}\right] \end{array} \right.$$

$$\text{if } x_g \leq 0 \quad \left\{ \begin{array}{l} p_{gc} = 1 \\ p_{gd} = 1/2 \end{array} \right.$$

$$S_g = \frac{1}{2} \cdot \left(1 + \frac{x_g}{\sqrt{x^2 + 10^{-6}}} \right)$$

$$I_{GC} = I_{GCO} \cdot p_{gc} \cdot S_g$$

$$I_{GCD} = I_{GCO} \cdot p_{gd} \cdot S_g$$

$$I_{GSD} = I_{GC} - I_{GCD}$$

$$I_{GB} = I_{GCO} \cdot p_{gc} \cdot (1 - S_g)$$

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

$$I_D = I_{DS} + I_{avl} - I_{GDOV} - I_{GCD} + I_{gidl}$$

$$I_S = -I_{DS} - I_{GSov} - I_{GCS} + I_{gisl}$$

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

$$I_G = I_{GC} + I_{GB} + I_{GDov} + I_{GSov}$$

$$I_B = -I_{avl} - I_{GB} - I_{gidl} - I_{gisl}$$

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

$$Q_{bov} = CGBOV \cdot (V_{GS} - V_{SB})$$

Inner fringe charge correction

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

$$\Delta Q_S = IFK \cdot (1 + IFC \cdot V_{SB}^*) \cdot \sqrt{\text{MAXA}(IFVBI + V_{SB}^* - \Psi_{s_s}, 0, 10^{-3})}$$

$$\Delta Q_D = IFK \cdot (1 + IFC \cdot V_{DB}^*) \cdot \sqrt{\text{MAXA}(IFVBI + V_{DB}^* - \Psi_{s_d}, 0, 10^{-3})}$$

$$\Delta Q_G = -\Delta Q_S - \Delta Q_D$$

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 $x_g > 0$. In these equations f_{op} represents the operation frequency of the transistor and $j = -1^{1/2}$.

$$N^* = \frac{C_{ox}}{q} \cdot \alpha_m \cdot \phi_T$$

$$N_m^* = \frac{C_{ox}}{q} \cdot q_m^*$$

$$\Delta N = \frac{C_{ox}}{q} \cdot \alpha_m \cdot \Delta \Psi$$

Virtuoso Simulator Components and Device Models Reference
PSP Model (psp)

$$S_{fl} = \frac{q \cdot \phi_T^2 \cdot \beta \cdot I_{DS}}{f_{op} \cdot C_{ox} \cdot G_{vsat} \cdot N^*} \cdot \left[(NFA - NFB \cdot N^* + NFC \cdot N^{*2}) \cdot \ln \left(\frac{N_m^* + \Delta N / 2}{N_m^* - \Delta N / 2} \right) + (NFB + NFC \cdot N_m^* - 2 \cdot N^*) \cdot \Delta N \right]$$

$$H_0 = \frac{q^*_{im}}{\alpha_m}$$

$$t_1 = \frac{q_{im}}{q^*_{im}}$$

$$t_2 = \left(\frac{\Delta \Psi}{2 \cdot H_0} \right)^2$$

$$R = \frac{H_0}{H} - 1$$

$$l_c = 1 - 12 \cdot t_2 \cdot R$$

$$g_{ideal} = \frac{\beta \cdot q^*_{im}}{G_{vsat}} \cdot F_{\Delta L}$$

$$C_{Geff} = \left(\frac{G_{vsat}}{G_{mob} \cdot G_{\Delta L}} \right)^2 \cdot COX \cdot \eta_p$$

$$m_{id} = \frac{g_{ideal}}{l_c^2} \cdot [t_1 + 12 \cdot t_2 - 24 \cdot (1 + t_1) \cdot t_2 \cdot R]$$

$$S_{id} = N_T \cdot m_{id}$$

$$m_{ig} = \frac{1}{l_c^2 \cdot g_{ideal}} \cdot \left[\frac{t_1}{12} - t_2 \cdot \left(t_1 + \frac{1}{5} - 12 \cdot t_2 \right) - \frac{8}{5} \cdot t_2 \cdot (t_1 + 1 - 12 \cdot t_2) \cdot R \right]$$

$$S_{ig} = N_T \cdot \frac{(2 \cdot \pi \cdot f_{op} \cdot C_{Geff})^2 \cdot m_{ig}}{1 + (2 \cdot \pi \cdot f_{op} \cdot C_{Geff} \cdot m_{ig})^2}$$

$$m_{igid} = \frac{\sqrt{t_2}}{t_c^2} \cdot \left[1 - 12 \cdot t_2 - \left(t_1 + \frac{96}{5} \cdot t_2 - 12 \cdot t_1 \cdot t_2 \right) \cdot R \right]$$

$$S_{igid} = N_T \cdot \frac{2 \cdot \pi \cdot j \cdot f_{op} \cdot C_{Geff} \cdot m_{igid}}{1 + 2 \cdot \pi \cdot j \cdot f_{op} \cdot C_{Geff} \cdot m_{ig}}$$

Gate Current Shot Noise

$$S_{igs} = 2 \cdot q \cdot (I_{GCS} + I_{GSov})$$

$$S_{igd} = 2 \cdot q \cdot (I_{GCD} + I_{GDov})$$

Avalanche Current Shot Noise

$$S_{avl} = 2 \cdot q \cdot (1 + M_{avl}) \cdot I_{avl}$$

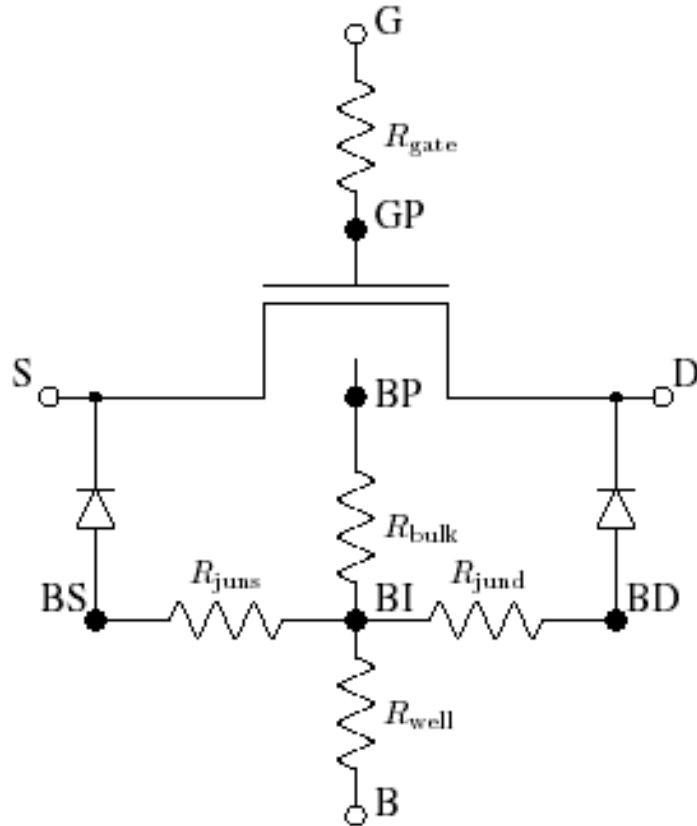
Non-Quasi-Static (NQS) RF Model

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.

$$MUNQS = MUNQSO$$

$$RG = RGO$$

$$RBULK = RBULKO$$

$$RWELL = RWELLO$$

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

$$RJUNS = RJUNSO$$

$$RJUND = RJUNDO$$

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

$$\left. \begin{aligned} p &= 2 + v_{i-1}/2 \\ v_i &= -1/(2 \cdot p) \\ A_{i,i-1} &= 1/h \\ A_{i,i} &= -2/h \\ A_{i,i+1} &= 1/h \end{aligned} \right\} \text{for } i = 1 \dots (n-1)$$

$$A_{i,j} = \frac{1}{p} \cdot (3 \cdot A_{i,j}/h - A_{i-1,j/2}) \quad \left. \right\} \text{for } j = 0 \dots n$$

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:

$$q_b(x) = -\text{sgn}(x) \cdot G_p \cdot \sqrt{\exp(-x) + x - 1}$$

$$q'_b(x) = \frac{G_p^2 \cdot [1 - \exp(-x)]}{2 \cdot q_b(x)}$$

$$q''_b(x) = q'_b(x) - \frac{q'_b(x)^2 - G_p^2/2}{q_b(x)}$$

Virtuoso Simulator Components and Device Models Reference
PSP Model (psp)

$$H(x_g) = \begin{cases} \left. \begin{array}{l} \text{if } x_g < -p_{mrg} \\ \left\{ \begin{array}{l} y_g = -x_g \\ z = 1.25 \cdot y_g / a_p \\ \eta = [z + 10 - \sqrt{(z-6)^2 + 64}] / 2 \\ a = (y_g - \eta)^2 + G_P^2 \cdot (\eta + 1) \\ c = 2 \cdot (y_g - \eta) - G_P^2 \\ r = -\eta + \ln(a / G_P^2) \\ y_0 = \sigma_1(a, c, \tau, \eta) \\ \Delta_0 = \exp(y_0) \\ \xi = 1 - G_P^2 \cdot \Delta_0 / 2 \\ p = 2 \cdot (y_g - y_0) + G_P^2 \cdot (\Delta_0 - 1) \\ q = (y_g - y_0)^2 + G_P^2 \cdot (y_0 - \Delta_0 + 1) \\ H = -y_0 - \frac{2 \cdot q}{p + \sqrt{p^2 - 4 \cdot q \cdot \xi}} \end{array} \right\} \\ \\ \text{if } |x_g| \leq -p_{mrg} \\ \left\{ H = \frac{x_g}{a_p} \right\} \\ \\ \text{if } x_g > x_{mrg} \\ \left\{ \begin{array}{l} \hat{x}_{g1} = x_1 + G \cdot \sqrt{\exp(-x_1) + x_1 - 1} \\ \bar{x} = \frac{x_g}{a_p} \cdot [1 + x_g \cdot (x_g + a_p / \hat{x}_{g1} - 1) / \hat{x}_{g1}] \\ x_0 = x_g + G_P^2 / 2 - G_P \cdot \sqrt{x_g + G_P^2 / 4 - 1 + \exp(-\bar{x})} \\ \Delta_0 = \exp(-x_0) \\ \xi = 1 - G_P^2 \cdot \Delta_0 / 2 \\ p = 2 \cdot (x_g - x_0) + G_P^2 \cdot (1 - \Delta_0) \\ q = (x_g - x_0)^2 - G_P^2 \cdot (x_0 + \Delta_0 - 1) \\ H = x_0 + \frac{2 \cdot q}{p + \sqrt{p^2 - 4 \cdot q \cdot \xi}} \end{array} \right\} \end{array} \right.
 \end{cases}$$

$$X(x_g, q_{inv}) = H(x_g + q_{inv} / p_d)$$

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

Auxiliary Functions

$$q(x) = -p_d \cdot (x_g - x) - q_b(x)$$

$$\psi(q, q_{x1}) = \frac{q}{q_{x1}} - 1$$

$$\phi(q, q_{x1}, q_{x2}) = \left(1 - \frac{q \cdot q_{x2}}{2 q_{x1}}\right) / q_{x1}$$

Normalized right-hand-side of continuity equation

$$f(x_g, q, q', q'') = \left\{ \begin{array}{l} x_z = X(x_g, q) \\ q_{x1} = \frac{\partial q}{\partial x}(x_z) = p_d - q'_b(x_z) \\ q_{x2} = \frac{\partial^2 q}{\partial x^2}(x_z) = q''_b(x_z) \\ f_0 = \psi(q, q_{z1}) \cdot q'' + \phi(q, q_{z1}, q_{z2}) \cdot q'^2 \\ x_{y1} = \frac{\partial x_z}{\partial y} = (q') / q_{x1} \\ z_{sat} = \begin{cases} (\theta_{sat}^* \cdot \phi_T^* \cdot x_{y1})^2 \\ \frac{(\theta_{sat}^* \cdot \phi_T^* \cdot x_{y1})^2}{1 + \theta_{sat}^* \cdot \Delta\psi} \end{cases} \\ \varsigma = \sqrt{1 + 2 \cdot z_{sat}} \\ F_{vsat} = 2 / (1 + \varsigma) \\ f = F_{vsat} \cdot \left[f_0 - F_{vsat} \cdot \frac{z_{sat}}{\varsigma} \cdot \psi(q, q_{x1}) \cdot (q'' + x_{y1}^2 \cdot q''_b(x_z)) \right] \end{array} \right.$$

$$T_{norm} = \frac{MUNQS \cdot \phi_T^* \cdot \beta}{C_{OX}^{qm} \cdot G_{mob} \cdot G_{\Delta L}}$$

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

$$S_0 = \sum_{i=1}^{n-1} q_i$$

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

$$S_2 = \sum_{i=1}^{n-1} q''_i$$

$$q_I^{NQS} = \int_0^1 q(y) dy = h \cdot S_0 + \frac{h}{2} \cdot (u_0 + u_n) - \frac{h^3}{12} \cdot S_2$$

$$U_0 = \sum_{i=1}^{n-1} i \cdot q_i$$

$$U_2 = \sum_{i=1}^{n-1} i \cdot q''_i$$

$$q_D^{NQS} = \int_0^1 q(y) dy = h^2 \cdot U_0 + \frac{h^2}{6} \cdot [q_0 + (3n-1)u_n] - \frac{h^4}{12} \cdot U_2$$

$$q_S^{NQS} = q_I^{NQS} - q_D^{NQS}$$

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

Common parameters

delvto=0.0	V Threshold voltage shift parameter.
factuo=1.0	Zero-field mobility pre-factor.
absource=1E-12 m^2	Bottom area of source junction.
lssource=1E-6 m	STI-edge length of source junction.
lgsource=1E-6 m	Gate-edge length of source junction.
abdrain=1E-12 m^2	Bottom area of drain junction.
lsdrain=1E-6 m	STI-edge length of drain junction.
lgdrain=1E-6 m	Gate-edge length of drain junction.
as=1E-12 m^2	Bottom area of source junction.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

ps=1E-6 m	Perimeter of source junction.
ad=1E-12 m ²	Bottom area of drain junction.
pd=1E-6 m	Perimeter of drain junction.
mult=1.0	Number of devices in parallel.
trise=0.0 K	Temperature rise from ambient.
isnoisy=yes	Should device generate noise. Possible values are no or yes.
m=1.0	Alias of mult.

Global model and bin model

l=10e-6 m	Design length.
w=10e-6 m	Design width.
sa=0.0 m	Distance between OD-edge and poly from one side.
sb=0.0 m	Distance between OD-edge and poly from other side.
sd=0.0 m	Distance between neighbouring fingers.
sca=0.0	Integral of the first distribution function for scattered well dopants.
scb=0.0	Integral of the second distribution function for scattered well dopants.
scc=0.0	Integral of the third distribution function for scattered well dopants.
sc=0.0 m	Distance between OD-edge and nearest well edge.
nf=1.0	Number of fingers.
ngcon=1.0	Number of gate contacts.
xgw=1.0E-7 m	Distance from the gate contact to the channel edge.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

Model Definition

```
model modelName psp102 parameter=value ...
```

Model Parameters

Common parameter

Special model parameters, some are also simulator global variables

- | | |
|-------------|--|
| 1 level=102 | Model level. |
| 2 type=n | Channel type parameter, n=NMOS p=PMOS. Possible values are n or p. |
| 3 tr=21.0 | C nominal (reference) temperature. |

Switch parameters that turn models or effects on or off

- | | |
|--------------------|---|
| 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 | model version selector. |
| 12 nqsscale=1.0e-4 | |
| 13 geomod=1 | 1 for geometrical model and 0 for electrical model. |
| 14 binmod=0 | 1 for bin model and 0 for non-bin model. |

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

Local model

Process parameters

- 15 $v_{fb} = (-1.0) \text{ V}$ Flatband voltage at TR.
- 16 $stv_{fb} = 5.0e-4 \text{ V/K}$ Temperature dependence of VFB.
- 17 $t_{ox} = 2.0e-09 \text{ m}$ Gate oxide thickness.
- 18 $\epsilon_{srox} = 3.9$ Relative permittivity of gate dielectric.
- 19 $n_{eff} = 5.0e+23 \text{ m}^{-3}$ Effective substrate doping.
- 20 $v_{nsub} = 0.0 \text{ V}$ Effective doping bias-dependence parameter.
- 21 $n_{slp} = 0.05 \text{ V}$ Effective doping bias-dependence parameter.
- 22 $d_{nsub} = 0.0 \text{ V}^{-1}$ Effective doping bias-dependence parameter.
- 23 $d_{phib} = 0.0 \text{ V}$ Offset parameter for PHIB.
- 24 $n_p = 1.0e+26 \text{ m}^{-3}$ Gate poly-silicon doping.
- 25 $ct = 0.0$ Interface states factor.
- 26 $t_{oxov} = 2.0e-09 \text{ m}$ Overlap oxide thickness.
- 27 $t_{oxovd} = 2.0e-09 \text{ m}$ Overlap oxide thickness for drain side.
- 28 $n_{ov} = 5.0e+25 \text{ m}^{-3}$ Effective doping of overlap region.
- 29 $n_{ovd} = 5.0e+25 \text{ m}^{-3}$ Effective doping of overlap region for drain side.

DIBL parameters

- 30 $cf = 0.0$ DIBL-parameter.
- 31 $cfb = 0.0 \text{ V}^{-1}$ Back bias dependence of CF.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

Mobility parameters

32	$\text{betn}=7\text{e-}2 \text{ m}^2/\text{V}/\text{s}$	Channel aspect ratio times zero-field mobility.
33	$\text{stbet}=1.0$	Temperature dependence of BETN.
34	$\text{mue}=0.5 \text{ m}/\text{V}$	Mobility reduction coefficient at TR.
35	$\text{stmue}=0.0$	Temperature dependence of MUE.
36	$\text{themu}=1.5$	Mobility reduction exponent at TR.
37	$\text{stthemu}=1.5$	Temperature dependence of THEMU.
38	$\text{cs}=0.0$	Coulomb scattering parameter at TR.
39	$\text{stcs}=0.0$	Temperature dependence of CS.
40	$\text{xcor}=0.0 \text{ V}^{-1}$	Non-universality factor.
41	$\text{stxcor}=0.0$	Temperature dependence of XCOR.
42	$\text{feta}=1.0$	Effective field parameter.

Series-resistance parameters (for resistance modeling as part of intrinsic mobility reduction)

43	$\text{rs}=30$	Ohm Series resistance at TR.
44	$\text{strs}=1.0$	Temperature dependence of RS.
45	$\text{rsb}=0.0 \text{ V}^{-1}$	Back-bias dependence of series resistance.
46	$\text{rsg}=0.0 \text{ V}^{-1}$	Gate-bias dependence of series resistance.

Velocity saturation parameters

47	$\text{thesat}=1.0 \text{ V}^{-1}$	Velocity saturation parameter at TR.
48	$\text{stthesat}=1.0$	Temperature dependence of THESAT.
49	$\text{thesatb}=0.0 \text{ V}^{-1}$	Back-bias dependence of velocity saturation.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

50 `thesatg=0.0 V-1` Gate-bias dependence of velocity saturation.

Saturation voltage parameters

51 `ax=3.0` Linear/saturation transition factor.

Channel length modulation (CLM) parameters

52 `alp=0.01` CLM pre-factor.

53 `alp1=0.00 V` CLM enhancement factor above threshold.

54 `alp2=0.00 V-1` CLM enhancement factor below threshold.

55 `vp=0.05 V` CLM logarithm dependence factor.

Impact ionization (II) parameters

56 `a1=1.0` Impact-ionization pre-factor.

57 `a2=10.0 V` Impact-ionization exponent at TR.

58 `sta2=0.0 V` Temperature dependence of A2.

59 `a3=1.0` Saturation-voltage dependence of impact-ionization.

60 `a4=0.0 V-0.5` Back-bias dependence of impact-ionization.

Gate current parameters

61 `gco=0.0` Gate tunnelling energy adjustment.

62 `iginv=0.0 A` Gate channel current pre-factor.

63 `igov=0.0 A` Gate overlap current pre-factor.

64 `igovd=0.0 A` Gate overlap current pre-factor for drain side.

65 `stig=2.0` Temperature dependence of IGINV and IGOV.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

- 66 $gc2=0.375$ Gate current slope factor.
- 67 $gc3=0.063$ Gate current curvature factor.
- 68 $chib=3.1\text{ V}$ Tunnelling barrier height.

Gate Induced Drain/Source Leakage (GIDL) parameters

- 69 $agidl=0.0\text{ A/V}^3$ GIDL pre-factor.
- 70 $agidld=0.0\text{ A/V}^3$ GIDL pre-factor for drain side.
- 71 $bgidl=41.0\text{ V}$ GIDL probability factor at TR.
- 72 $bgidld=41.0\text{ V}$ GIDL probability factor at TR for drain side.
- 73 $stbgidl=0.0\text{ V/K}$ Temperature dependence of BGIDL.
- 74 $stbgidld=0.0\text{ V/K}$ Temperature dependence of BGIDL for drain side.
- 75 $cgidl=0.0$ Back-bias dependence of GIDL.
- 76 $cgidld=0.0$ Back-bias dependence of GIDL for drain side.

Charge model parameters

- 77 $cox=1.0e-14\text{ F}$ Oxide capacitance for intrinsic channel.
- 78 $cgov=1.0e-15\text{ F}$ Oxide capacitance for gate-drain/source overlap.
- 79 $cgovd=1.0e-$ 5 F Oxide capacitance for gate-drain overlap.
- 80 $cgbov=0.0\text{ F}$ Oxide capacitance for gate-bulk overlap.
- 81 $cfr=0.0\text{ F}$ Outer fringe capacitance.
- 82 $cfrd=0.0\text{ F}$ Outer fringe capacitance for drain side.

Noise parameters

- 83 $fnt=1.0$ Thermal noise coefficient.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

- 84 $nfa=8.0e+22 \text{ V}^{-1}/\text{m}^4$ First coefficient of flicker noise.
- 85 $nfb=3.0e+07 \text{ V}^{-1}/\text{m}^2$ Second coefficient of flicker noise.
- 86 $nfc=0.0 \text{ V}^{-1}$ Third coefficient of flicker noise.
- 87 $ef=1.0$ Flicker noise frequency exponent.

NQS parameters only for local model

- 88 $munqs=1.0$ Relative mobility for NQS modelling.
- 89 $rg=0.0 \text{ Ohm}$ Gate resistance.
- 90 $rbulk=0.0 \text{ Ohm}$ Bulk resistance between node BP and BI.
- 91 $rwell=0.0 \text{ Ohm}$ Well resistance between node BI and B.
- 92 $rjuns=0.0 \text{ Ohm}$ Source-side bulk resistance between node BI and BS.
- 93 $rjund=0.0 \text{ Ohm}$ Drain-side bulk resistance between node BI and BD.

Global model

Process Parameters

- 94 $lvaro=0.0 \text{ m}$ Geom. independent difference between actual and programmed gate length.
- 95 $lvarl=0.0$ Length dependence of LVAR.
- 96 $lvarw=0.0$ Width dependence of LVAR.
- 97 $lap=0.0 \text{ m}$ Effective channel length reduction per side.
- 98 $wvaro=0.0 \text{ m}$ Geom. independent difference between actual and programmed field-oxide opening.
- 99 $wvarl=0.0$ Length dependence of WVAR.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

100	wvarw=0.0	Width dependence of WVAR.
101	wot=0.0 m	Effective channel width reduction per side.
102	dlq=0.0 m	Effective channel length reduction for CV.
103	dwq=0.0 m	Effective channel width reduction for CV.
104	vfbo=(-1.0)	V Geometry-independent flat-band voltage at TR.
105	vfb1=0.0	Length dependence of flat-band voltage.
106	vfbw=0.0	Width dependence of flat-band voltage.
107	vfb1w=0.0	Area dependence of flat-band voltage.
108	stvfbo=5e-4 V/K	Geometry-independent temperature dependence of VFB.
109	stvfbl=0.0	Length dependence of temperature dependence of VFB.
110	stvfbw=0.0	Width dependence of temperature dependence of VFB.
111	stvfblw=0.0	Area dependence of temperature dependence of VFB.
112	tox0=2e-9 m	Gate oxide thickness.
113	epsrox0=3.9	Relative permittivity of gate dielectric.
114	nsub0=3e23 m ⁻³	Geometry independent substrate doping.
115	nsubw=0.0	Width dependence of background doping NSUBO due to segregation.
116	wseg=1e-8 m	Char. length of segregation of background doping NSUBO.
117	npck=1e24 m ⁻³	Pocket doping level.
118	npckw=0.0	Width dependence of pocket doping NPCK due to segregation.
119	wsegp=1e-8 m	Char. length of segregation of pocket doping NPCK.
120	lpck=1e-8 m	Char. length of lateral doping profile.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

121	lpckw=0.0	Width dependence of char. length of lateral doping profile.
122	foll=0.0	First length dependence coefficient for short channel body effect.
123	foll2=0.0	Second length dependence coefficient for short channel body effect.
124	vnsubo=0.0 V	Effective doping bias-dependence parameter.
125	nslpo=0.05 V	Effective doping bias-dependence parameter.
126	dnsubo=0.0 V ⁻¹	Effective doping bias-dependence parameter.
127	dphibo=0.0 V	Geometry independent offset of PHIB.
128	dphibl=0.0 V	Length dependence offset of PHIB.
129	dphiblexp=1.0	Exponent for length dependence of offset of PHIB.
130	dphibw=0.0	Width dependence of offset of PHIB.
131	dphiblhw=0.0	Area dependence of offset of PHIB.
132	npo=1e26 m ⁻³	Geometry-independent gate poly-silicon doping.
133	npl=0.0	Length dependence of gate poly-silicon doping.
134	cto=0.0	Geometry-independent interface states factor.
135	ctl=0.0	Length dependence of interface states factor.
136	ctlexp=1.0	Exponent for length dependence of interface states factor.
137	ctw=0.0	Width dependence of interface states factor.
138	ctlhw=0.0	Area dependence of interface states factor.
139	toxovo=2e-9 m	Overlap oxide thickness.
140	toxovdo=2e-9 m	Overlap oxide thickness for drain side.
141	lov=0 m	Overlap length for gate/drain and gate/source overlap capacitance.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

- 142 `lovd=0 m` Overlap length for gate/drain overlap capacitance.
- 143 `novo=5e25 m-3` Effective doping of overlap region.
- 144 `novdo=5e25 m-3` Effective doping of overlap region for drain side.

DIBL Parameters

- 145 `cfl=0.0` Length dependence of DIBL-parameter.
- 146 `cflexp=2.0` Exponent for length dependence of CF.
- 147 `cfw=0.0` Width dependence of CF.
- 148 `cfbo=0.0 V-1` Back-bias dependence of CF.

Mobility Parameters

- 149 `uo=5e-2 m2/V/s` Zero-field mobility at TR.
- 150 `fbet1=0.0` Relative mobility decrease due to first lateral profile.
- 151 `fbet1w=0.0` Width dependence of relative mobility decrease due to first lateral profile.
- 152 `lp1=1e-8 m` Mobility-related characteristic length of first lateral profile.
- 153 `lp1w=0.0` Width dependence of mobility-related characteristic length of first lateral profile.
- 154 `fbet2=0.0` Relative mobility decrease due to second lateral profile.
- 155 `lp2=1e-8 m` Mobility-related characteristic length of second lateral profile.
- 156 `betw1=0.0` First higher-order width scaling coefficient of BETN.
- 157 `betw2=0.0` Second higher-order width scaling coefficient of BETN.
- 158 `wbet=1e-9 m` Characteristic width for width scaling of BETN.
- 159 `stbeto=1.0` Geometry independent temperature dependence of BETN.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

160	stbetl=0.0	Length dependence of temperature dependence of BETN.
161	stbetw=0.0	Width dependence of temperature dependence of BETN.
162	stbetlw=0.0	Area dependence of temperature dependence of BETN.
163	mueo=0.5 m/V	Geometry independent mobility reduction coefficient at TR.
164	muew=0.0	Width dependence of mobility reduction coefficient at TR.
165	stmueo=0.0	Temperature dependence of MUE.
166	themuo=1.5	Mobility reduction exponent at TR.
167	stthemuo=1.5	Temperature dependence of THEMU.
168	cso=0.0	Geometry independent coulomb scattering parameter at TR.
169	cs1=0.0	Length dependence of CS.
170	cs1exp=0.0	Exponent for length dependence of CS.
171	csw=0.0	Width dependence of CS.
172	cslw=0.0	Area dependence of CS.
173	stcso=0.0	Temperature dependence of CS.
174	xcoro=0.0 V^{-1}	Geometry independent non-universality parameter.
175	xcor1=0.0	Length dependence of non-universality parameter.
176	xcorw=0.0	Width dependence of non-universality parameter.
177	xcorlw=0.0	Area dependence of non-universality parameter.
178	stxcoro=0.0	Temperature dependence of XCOR.
179	fetao=1.0	Effective field parameter.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

Series Resistance

180	<code>rsw1=2.5e3</code>	Ohm Source/drain series resistance for 1 um wide channel at TR.
181	<code>rsw2=0.0</code>	Higher-order width scaling of RS.
182	<code>strso=1.0</code>	Temperature dependence of RS.
183	<code>rsbo=0.0 V⁻¹</code>	Back-bias dependence of series resistance.
184	<code>rsgo=0.0 V⁻¹</code>	Gate-bias dependence of series resistance.

Velocity Saturation

185	<code>thesato=0.0 V⁻¹</code>	Geometry independent velocity saturation parameter at TR.
186	<code>thesatl=0.05 V⁻¹</code>	Length dependence of THESAT.
187	<code>thesatlexp=1.0</code>	Exponent for length dependence of THESAT.
188	<code>thesatw=0.0</code>	Width dependence of velocity saturation parameter.
189	<code>thesatlw=0.0</code>	Area dependence of velocity saturation parameter.
190	<code>stthesato=1.0</code>	Geometry independent temperature dependence of THESAT.
191	<code>stthesatl=0.0</code>	Length dependence of temperature dependence of THESAT.
192	<code>stthesatw=0.0</code>	Width dependence of temperature dependence of THESAT.
193	<code>stthesatlw=0.0</code>	Area dependence of temperature dependence of THESAT.
194	<code>thesatbo=0.0 V⁻¹</code>	

Back-bias dependence of velocity saturation.

195	<code>thesatgo=0.0 V⁻¹</code>	Gate-bias dependence of velocity saturation
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Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

Saturation Voltage

- 196 axo=18 Geometry independent linear/saturation transition factor.
- 197 axl=0.4 Length dependence of AX.

Channel Length Modulation

- 198 alp1=5e-4 Length dependence of ALP.
- 199 alp1exp=1.0 Exponent for length dependence of ALP.
- 200 alp1w=0.0 Width dependence of ALP.
- 201 alp1l1=0.0 V Length dependence of CLM enhancement factor above threshold.
- 202 alp1l1exp=0.5 Exponent for length dependence of ALP1.
- 203 alp1l2=0.0 Second_order length dependence of ALP1.
- 204 alp1w=0.0 Width dependence of ALP1.
- 205 alp2l1=0.0 V⁻¹ Length dependence of CLM enhancement factor below threshold.
- 206 alp2l1exp=0.5 Exponent for length dependence of ALP2.
- 207 alp2l2=0.0 Second_order length dependence of ALP2.
- 208 alp2w=0.0 Width dependence of ALP2.
- 209 vpo=0.05 V CLM logarithmic dependence parameter.

Weak-avalanche parameters

- 210 a1o=1.0 Geometry independent impact-ionization pre-factor.
- 211 a1l=0.0 Length dependence of A1.
- 212 a1w=0.0 Width dependence of A1.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

213	a2o=10 V	Impact-ionization exponent at TR.
214	sta2o=0.0 V	Temperature dependence of A2.
215	a3o=1.0	Geometry independent saturation-voltage dependence of I _l .
216	a3l=0.0	Length dependence of A3.
217	a3w=0.0	Width dependence of A3.
218	a4o=0.0 V ^{-0.5}	Geometry independent back-bias dependence of I _l .
219	a4l=0.0	Length dependence of A4.
220	a4w=0.0	Width dependence of A4.

Gate current parameters

221	gcoo=0.0	Gate tunnelling energy adjustment.
222	iginvlw=0.0 A	Gate channel current pre-factor for 1 um ² channel area.
223	igovw=0.0 A	Gate overlap current pre-factor for 1 um wide channel.
224	igovdw=0.0 A	Gate overlap current pre-factor for 1 um wide channel for drain side.
225	stigo=2.0	Temperature dependence of IGINV and IGOV.
226	gc2o=0.375	Gate current slope factor.
227	gc3o=0.063	Gate current curvature factor.
228	chibo=3.1 V	tunnelling barrier height.

Gate-induced drain leakage parameters

229	agidlw=0.0 A/V ³	Width dependence of GIDL pre-factor.
230	agidldw=0.0 A/V ³	Width dependence of GIDL pre-factor for drain side.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

- 231 `bgidlo=41 V` GIDL probability factor at TR.
- 232 `bgidldo=41 V` GIDL probability factor at TR for drain side.
- 233 `stbgidlo=0.0 V/K`
Temperature dependence of BGIDL.
- 234 `stbgidldo=0.0 V/K`
Temperature dependence of BGIDL for drain side.
- 235 `cgidlo=0.0` Back-bias dependence of GIDL.
- 236 `cgidldo=0.0` Back-bias dependence of GIDL for drain side.

Charge Model Parameters

- 237 `cgbovl=0.0 F` Oxide capacitance for gate-bulk overlap for 1 um long channel.
- 238 `cfrw=0.0 F` Outer fringe capacitance for 1 um wide channel.
- 239 `cfrdw=0.0 F` Outer fringe capacitance for 1 um wide channel for drain side.

Noise Model Parameters

- 240 `fnto=1.0` Thermal noise coefficient.
- 241 `nfalw=8e22 V-1/m4`
First coefficient of flicker noise for 1 um² channel area.
- 242 `nfblw=3e7 V-1/m2`
Second coefficient of flicker noise for 1 um² channel area.
- 243 `nfclw=0.0 V-1` Third coefficient of flicker noise for 1 um² channel area.
- 244 `efo=1.0` Flicker noise frequency exponent.
- 245 `lintnoi=0.0 m` Length offset for flicker noise.
- 246 `alpnoi=2.0` Exponent for length offset for flicker noise.

Other Parameters

247 `dt_a=0 K` Temperature offset w.r.t. ambient circuit temperature.

Well proximity effect Parameters

248 `kvthoweo=0` Geometrical independent threshold shift parameter.
249 `kvthowel=0` Length dependent threshold shift parameter.
250 `kvthowew=0` Width dependent threshold shift parameter.
251 `kvthowelw=0` Area dependent threshold shift parameter.
252 `kuoweo=0` Geometrical independent mobility degradation factor.
253 `kuowel=0` Length dependent mobility degradation factor.
254 `kuowew=0` Width dependent mobility degradation factor.
255 `kuowelw=0` Area dependent mobility degradation factor.

Bin model and Global model

NQS parameters

256 `munqso=1.0` Relative mobility for NQS modelling.

Parasitic resistance parameters

257 `rgo=0.0 Ohm` Gate resistance.
258 `rbulko=0.0 Ohm` Bulk resistance between node BP and BI.
259 `rwelllo=0.0 Ohm` Well resistance between node BI and B.
260 `rjunso=0.0 Ohm` Source-side bulk resistance between node BI and BS.
261 `rjundo=0.0 Ohm` Drain-side bulk resistance between node BI and BD.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

- 262 `rint=0.0 Ohm/Sqr` Contact resistance between silicide and poly.
- 263 `rvpoly=0.0 Ohm/Sqr` Vertical poly resistance.
- 264 `rshg=0.0 Ohm/Sqr` Gate electrode diffusion sheet resistance.
- 265 `dlsil=0.0 m` Silicide extension over the physical gate length.

Stress Model Parameters

- 266 `saref=1.0e-6 m` Reference distance between OD-edge and poly from one side.
- 267 `sbref=1.0e-6 m` Reference distance between OD-edge and poly from other side.
- 268 `wlod=0 m` Width parameter.
- 269 `kuo=0 m` Mobility degradation/enhancement coefficient.
- 270 `kvsat=0 m` Saturation velocity degradation/enhancement coefficient.
- 271 `tkuo=0` Temperature dependence of KUO.
- 272 `lkuo=0 mLLODKUO` Length dependence of KUO.
- 273 `wkuo=0 mWLODKUO` Width dependence of KUO.
- 274 `pkuo=0 m(LLODKUO+WLODKUO)` Cross-term dependence of KUO.
- 275 `llodkuo=0` Length parameter for UO stress effect.
- 276 `wlodkuo=0` Width parameter for UO stress effect.
- 277 `kvtho=0 Vm` Threshold shift parameter.
- 278 `lkvtho=0 mLLODVTH` Length dependence of KVTHO.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

279	wkvtho=0 m ^{WLODVTH}	Width dependence of KVTHO.
280	pkvtho=0 m ^(LLODVTH+WLODVTH)	Cross-term dependence of KVTHO.
281	llodvth=0	Length parameter for VTH-stress effect.
282	wlodvth=0	Width parameter for VTH-stress effect.
283	stetao=0	m eta0 shift factor related to VTHO change.
284	lodetao=1.0	meta0 shift modification factor for stress effect.

Well proximity effect Parameters

285	scref=10e-6 m	Distance between OD-edge and well edge of a reference device.
286	web=0	Coefficient for SCB.
287	wec=0	Coefficient for SCC.

JUNCAP Parameters

288	imax=1000 A	Maximum current up to which forward current behaves exponentially.
289	trj=21	C reference temperature.
290	cjorbot=1E-3 Fm ⁻²	Zero-bias capacitance per unit-of-area of bottom component for sourcebulk junction.
291	cjorsti=1E-9 Fm ⁻¹	Zero-bias capacitance per unit-of-length of STI-edge component for source-bulk junction.
292	cjorgat=1E-9 Fm ⁻¹	Zero-bias capacitance per unit-of-length of gate-edge component for source-bulk junction.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

293	<code>vbirbot=1 V</code>	Built-in voltage at the reference temperature of bottom component for source-bulk junction.
294	<code>vbirsti=1 V</code>	Built-in voltage at the reference temperature of STI-edge component for source-bulk junction.
295	<code>vbirgat=1 V</code>	Built-in voltage at the reference temperature of gate-edge component for source-bulk junction.
296	<code>pbot=0.5</code>	Grading coefficient of bottom component for source-bulk junction.
297	<code>psti=0.5</code>	Grading coefficient of STI-edge component for source-bulk junction.
298	<code>pgat=0.5</code>	Grading coefficient of gate-edge component for source-bulk junction.
299	<code>phigbot=1.16 V</code>	Zero-temperature bandgap voltage of bottom component for source-bulk junction.
300	<code>phigsti=1.16 V</code>	Zero-temperature bandgap voltage of STI-edge component for source-bulk junction.
301	<code>phiggat=1.16 V</code>	Zero-temperature bandgap voltage of gate-edge component for source-bulk junction.
302	<code>idsatrbot=1E-12</code>	Am^{-2} Saturation current density at the reference temperature of bottom component for source-bulk junction.
303	<code>idsatrsti=1E-18</code>	Am^{-1} Saturation current density at the reference temperature of STI-edge component for source-bulk junction.
304	<code>idsatrgat=1E-18</code>	Am^{-1} Saturation current density at the reference temperature of gate-edge component for source-bulk junction.
305	<code>csrbot=1E2</code>	Am^{-3} Shockley-Read-Hall prefactor of bottom component for source-bulk junction.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

- 306 `csrhisti=1E-4 Am-2`
Shockley-Read-Hall prefactor of STI-edge component for source-bulk junction.
- 307 `csrhgat=1E-4 Am-2`
Shockley-Read-Hall prefactor of gate-edge component for source-bulk junction.
- 308 `xjunsti=100E-9 m` Junction depth of STI-edge component for source-bulk junction.
- 309 `xjungat=100E-9 m` Junction depth of gate-edge component for source-bulk junction.
- 310 `ctatbot=1E2 Am-3`
Trap-assisted tunneling prefactor of bottom component for source-bulk junction.
- 311 `ctatsti=1E-4 Am-2`
Trap-assisted tunneling prefactor of STI-edge component for source-bulk junction.
- 312 `ctatgat=1E-4 Am-2`
Trap-assisted tunneling prefactor of gate-edge component for sourcebulk junction.
- 313 `mefftatbot=0.25` Effective mass (in units of m_0) for trap-assisted tunneling of bottom component for source-bulk junction.
- 314 `mefftatsti=0.25` Effective mass (in units of m_0) for trap-assisted tunneling of STIedge component for source-bulk junction.
- 315 `mefftatgat=0.25` Effective mass (in units of m_0) for trap-assisted tunneling of gate-edge component for source-bulk junction.
- 316 `cbbtbot=1E-12 AV-3`
Band-to-band tunneling prefactor of bottom component for source-bulk junction.
- 317 `cbbtsti=1E-18 AV-3m`
Band-to-band tunneling prefactor of STI-edge component for sourcebulk junction.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

- 318 `cbbtgat=1E-18 AV-3m`
Band-to-band tunneling prefactor of gate-edge component for sourcebulk junction.
- 319 `fbbtbot=1E9 Vm-1`
Normalization field at the reference temperature for band-to-band tunneling of bottom component for source-bulk junction.
- 320 `fbbtsti=1E9 Vm-1`
Normalization field at the reference temperature for band-to-band tunneling of STI-edge component for source-bulk junction.
- 321 `fbbtgat=1E9 Vm-1`
Normalization field at the reference temperature for band-to-band tunneling of gate-edge component for source-bulk junction.
- 322 `stfbbtbot=(-1E-3) K-1`
Temperature scaling parameter for band-to-band tunneling of bottom component for source-bulk junction.
- 323 `stfbbtsti=(-1E-3) K-1`
Temperature scaling parameter for band-to-band tunneling of STI-edge component for source-bulk junction.
- 324 `stfbbtgat=(-1E-3) K-1`
Temperature scaling parameter for band-to-band tunneling of gate-edge component for source-bulk junction.
- 325 `vbrbot=10 V`
Breakdown voltage of bottom component for source-bulk junction.
- 326 `vbrsti=10 V`
Breakdown voltage of STI-edge component for source-bulk junction.
- 327 `vbrgat=10 V`
Breakdown voltage of gate-edge component for source-bulk junction.
- 328 `pbrbot=4 V`
Breakdown onset tuning parameter of bottom component for source-bulk junction.
- 329 `pbrsti=4 V`
Breakdown onset tuning parameter of STI-edge component for source-bulk junction.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

- 330 pbrgat=4 V Breakdown onset tuning parameter of gate-edge component for source-bulk junction.
- 331 cJORbotd=1E-3 Fm⁻² Zero-bias capacitance per unit-of-area of bottom component for drainbulk junction.
- 332 cJORstid=1E-9 Fm⁻¹ Zero-bias capacitance per unit-of-length of STI-edge component for drain-bulk junction.
- 333 cJORGatd=1E-9 Fm⁻¹ Zero-bias capacitance per unit-of-length of gate-edge component for drain-bulk junction.
- 334 vbirbotd=1 V Built-in voltage at the reference temperature of bottom component for drain-bulk junction.
- 335 vbirstid=1 V Built-in voltage at the reference temperature of STI-edge component for drain-bulk junction.
- 336 vbirgatd=1 V Built-in voltage at the reference temperature of gate-edge component for drain-bulk junction.
- 337 pbotd=0.5 Grading coefficient of bottom component for drain-bulk junction.
338 pstid=0.5 Grading coefficient of STI-edge component for drain-bulk junction.
- 339 pgatd=0.5 Grading coefficient of gate-edge component for drain-bulk junction.
- 340 phigbotd=1.16 V Zero-temperature bandgap voltage of bottom component for drain-bulk junction.
- 341 phigstid=1.16 V Zero-temperature bandgap voltage of STI-edge component for drain-bulk junction.
- 342 phiggatd=1.16 V Zero-temperature bandgap voltage of gate-edge component for drain-bulk junction.
- 343 idsatrbotd=1E-12 Am⁻² Saturation current density at the reference temperature of bottom component for drain-bulk junction.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

- 344 `idsatrstid=1E-18` Am^{-1}
Saturation current density at the reference temperature of STI-edge component for drain-bulk junction.
- 345 `idsatrgatd=1E-18` Am^{-1}
Saturation current density at the reference temperature of gate-edge component for drain-bulk junction.
- 346 `csrbotd=1E2` Am^{-3}
Shockley-Read-Hall prefactor of bottom component for drain-bulk junction.
- 347 `csrhostid=1E-4` Am^{-2}
Shockley-Read-Hall prefactor of STI-edge component for drain-bulk junction.
- 348 `csrhatd=1E-4` Am^{-2}
Shockley-Read-Hall prefactor of gate-edge component for drain-bulk junction.
- 349 `xjunstid=100E-9` m
Junction depth of STI-edge component for drain-bulk junction.
- 350 `xjungatd=100E-9` m
Junction depth of gate-edge component for drain-bulk junction.
- 351 `ctatbotd=1E2` Am^{-3}
Trap-assisted tunneling prefactor of bottom component for drain-bulk junction.
- 352 `ctatstid=1E-4` Am^{-2}
Trap-assisted tunneling prefactor of STI-edge component for drain-bulk junction.
- 353 `ctatgatd=1E-4` Am^{-2}
Trap-assisted tunneling prefactor of gate-edge component for drain-bulk junction.
- 354 `mefftatbotd=0.25`
Effective mass (in units of m_0) for trap-assisted tunneling of bottom component for drain-bulk junction.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

- 355 `mefftatstid=0.25`
Effective mass (in units of m_0) for trap-assisted tunneling of STI-edge component for drain-bulk junction.
- 356 `mefftatgatd=0.25`
Effective mass (in units of m_0) for trap-assisted tunneling of gate-edge component for drain-bulk junction.
- 357 `cbbtbotd=1E-12 AV-3`
Band-to-band tunneling prefactor of bottom component for drain-bulk junction.
- 358 `cbbtstid=1E-18 AV-3m`
Band-to-band tunneling prefactor of STI-edge component for drain-bulk junction.
- 359 `cbbtgatd=1E-18 AV-3m`
Band-to-band tunneling prefactor of gate-edge component for drain-bulk junction.
- 360 `fbbtrbotd=1E9 Vm-1`
Normalization field at the reference temperature for band-to-band tunneling of bottom component for drain-bulk junction.
- 361 `fbbtrstid=1E9 Vm-1`
Normalization field at the reference temperature for band-to-band tunneling of STI-edge component for drain-bulk junction.
- 362 `fbbtrgatd=1E9 Vm-1`
Normalization field at the reference temperature for band-to-band tunneling of gate-edge component for drain-bulk junction.
- 363 `stfbbtbotd=(-1E-3) K-1`
Temperature scaling parameter for band-to-band tunneling of bottom component for drain-bulk junction.
- 364 `stfbbtstid=(-1E-3) K-1`
Temperature scaling parameter for band-to-band tunneling of STI-edge component for drain-bulk junction.
- 365 `stfbbtgatd=(-1E-3) K-1`
Temperature scaling parameter for band-to-band tunneling of gate-edge component for drain-bulk junction.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

366	vbrbotd=10 V	Breakdown voltage of bottom component for drain-bulk junction.
367	vbrstid=10 V	Breakdown voltage of STI-edge component for drain-bulk junction.
368	vbrgatd=10 V	Breakdown voltage of gate-edge component for drain-bulk junction.
369	pbrbotd=4 V	Breakdown onset tuning parameter of bottom component for drain-bulk junction.
370	pbrstid=4 V	Breakdown onset tuning parameter of STI-edge component for drain-bulk junction.
371	pbrgatd=4 V	Breakdown onset tuning parameter of gate-edge component for drain-bulk junction.
372	swjunexp=0.0	Flag for JUNCAP-express; 0=full model, 1=express model.
373	vjunref=2.5	Typical maximum source-bulk junction voltage; usually about 2*VSUP.
374	fjunq=0.03	Fraction below which source-bulk junction capacitance components are considered negligible.
375	vjunrefd=2.5	Typical maximum drain-bulk junction voltage; usually about 2*VSUP.
376	fjunqd=0.03	Fraction below which drain-bulk junction capacitance components are considered negligible.

Bin model

377	povfb=(-1) V	Coefficient for the geometry independent part of VFB.
378	plvfb=0.0 V	Coefficient for the length dependence of VFB.
379	pwvfb=0.0 V	Coefficient for the width dependence of VFB.
380	plwvfb=0.0 V	Coefficient for the length times width dependence of VFB.
381	postvfb=0.0005 V/K	Coefficient for the geometry independent part of STVFB.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

382	<code>plstvfb=0.0</code>	V/K	Coefficient for the length dependence of STVFB.
383	<code>pwstvfb=0.0</code>	V/K	Coefficient for the width dependence of STVFB.
384	<code>plwstvfb=0.0</code>	V/K	Coefficient for the length times width dependence of STVFB.
385	<code>potox=2E-09</code>	m	Coefficient for the geometry independent part of TOX.
386	<code>poepsrox=3.9</code>		Coefficient for the geometry independent part of EPSOX.
387	<code>poneff=5E+23</code>	m^{-3}	Coefficient for the geometry independent part of NEFF.
388	<code>plneff=0.0</code>	m^{-3}	Coefficient for the length dependence of NEFF.
389	<code>pwneff=0.0</code>	m^{-3}	Coefficient for the width dependence of NEFF.
390	<code>plwneff=0.0</code>	m^{-3}	Coefficient for the length times width dependence of NEFF.
391	<code>povnsb=0</code>	V	Coefficient for the geometry independent part of VNSUB.
392	<code>ponslps=0.05</code>	V	Coefficient for the geometry independent part of NSLP.
393	<code>podnsb=0</code>	V^{-1}	Coefficient for the geometry independent part of DNSUB.
394	<code>podphib=0</code>	V	Coefficient for the geometry independent part of DPHIB.
395	<code>pldphib=0.0</code>	V	Coefficient for the length dependence of DPHIB.
396	<code>pwdphib=0.0</code>	V	Coefficient for the width dependence of DPHIB.
397	<code>plwdphib=0.0</code>	V	Coefficient for the length times width dependence of DPHIB.
398	<code>ponp=1E+26</code>	m^{-3}	Coefficient for the geometry independent part of NP.
399	<code>plnp=0.0</code>	m^{-3}	Coefficient for the length dependence of NP.
400	<code>pwnp=0.0</code>	m^{-3}	Coefficient for the width dependence of NP.
401	<code>plwnp=0.0</code>	m^{-3}	Coefficient for the length times width dependence of NP.
402	<code>poct=0</code>		Coefficient for the geometry independent part of CT.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

403	$plct=0.0$	Coefficient for the length dependence of CT.
404	$pwct=0.0$	Coefficient for the width dependence of CT.
405	$plwct=0.0$	Coefficient for the length times width dependence of CT.
406	$potoxov=2E-09$ m	Coefficient for the geometry independent part of TOXOV.
407	$potoxovd=2E-09$ m	Coefficient for the geometry independent part of TOXOV for drain side.
408	$ponov=5E+25$ m ⁻³	Coefficient for the geometry independent part of NOV.
409	$plnov=0.0$ m ⁻³	Coefficient for the length dependence of NOV.
410	$pwnov=0.0$ m ⁻³	Coefficient for the width dependence of NOV.
411	$plwnov=0.0$ m ⁻³	Coefficient for the length times width dependence of NOV.
412	$ponovd=5E+25$ m ⁻³	Coefficient for the geometry independent part of NOV for drain side.
413	$plnovd=0.0$ m ⁻³	Coefficient for the length dependence of NOV for drain side.
414	$pwnovd=0.0$ m ⁻³	Coefficient for the width dependence of NOV for drain side.
415	$plwnovd=0.0$ m ⁻³	Coefficient for the length times width dependence of NOV for drain side.
416	$pocf=0$	Coefficient for the geometry independent part of CF.
417	$plcf=0.0$	Coefficient for the length dependence of CF.
418	$pwcf=0.0$	Coefficient for the width dependence of CF.
419	$plwcf=0.0$	Coefficient for the length times width dependence of CF.
420	$pocfb=0$ V ⁻¹	Coefficient for the geometry independent part of CFB.
421	$pobetn=0.07$ m ² /V/s	Coefficient for the geometry independent part of BETN.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

422	<code>plbetn=0.0</code>	$m^2/V/s$	Coefficient for the length dependence of BETN.
423	<code>pwbetn=0.0</code>	$m^2/V/s$	Coefficient for the width dependence of BETN.
424	<code>plwbetn=0.0</code>	$m^2/V/s$	Coefficient for the length times width dependence of BETN.
425	<code>postbet=1</code>		Coefficient for the geometry independent part of STBET.
426	<code>plstbet=0.0</code>		Coefficient for the length dependence of STBET.
427	<code>pwstbet=0.0</code>		Coefficient for the width dependence of STBET.
428	<code>plwstbet=0.0</code>		Coefficient for the length times width dependence of STBET.
429	<code>pomue=0.5</code>	m/V	Coefficient for the geometry independent part of MUE.
430	<code>plmue=0.0</code>	m/V	Coefficient for the length dependence of MUE.
431	<code>pwmue=0.0</code>	m/V	Coefficient for the width dependence of MUE.
432	<code>plwmue=0.0</code>	m/V	Coefficient for the length times width dependence of MUE.
433	<code>postmue=0</code>		Coefficient for the geometry independent part of STMUE.
434	<code>pothemu=1.5</code>		Coefficient for the geometry independent part of THEMU.
435	<code>postthemu=1.5</code>		Coefficient for the geometry independent part of STTHEMU.
436	<code>pocs=0</code>		Coefficient for the geometry independent part of CS.
437	<code>plcs=0.0</code>		Coefficient for the length dependence of CS.
438	<code>pwcs=0.0</code>		Coefficient for the width dependence of CS.
439	<code>plwcs=0.0</code>		Coefficient for the length times width dependence of CS.
440	<code>postcs=0</code>		Coefficient for the geometry independent part of STCS.
441	<code>poxcor=0</code>	V^{-1}	Coefficient for the geometry independent part of XCOR.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

442	<code>plxcor=0.0 V⁻¹</code>	Coefficient for the length dependence of XCOR.
443	<code>pwxcor=0.0 V⁻¹</code>	Coefficient for the width dependence of XCOR.
444	<code>plwxcor=0.0 V⁻¹</code>	Coefficient for the length times width dependence of XCOR.
445	<code>postxcor=0</code>	Coefficient for the geometry independent part of STXCOR.
446	<code>pofeta=1</code>	Coefficient for the geometry independent part of FETA.
447	<code>pors=30 Ohm</code>	Coefficient for the geometry independent part of RS.
448	<code>plrs=0.0 Ohm</code>	Coefficient for the length dependence of RS.
449	<code>pwr=0.0 Ohm</code>	Coefficient for the width dependence of RS.
450	<code>plwr=0.0 Ohm</code>	Coefficient for the length times width dependence of RS.
451	<code>postrs=1</code>	Coefficient for the geometry independent part of STRS.
452	<code>porsb=0 V⁻¹</code>	Coefficient for the geometry independent part of RSB.
453	<code>porsg=0 V⁻¹</code>	Coefficient for the geometry independent part of RSG.
454	<code>pothesat=1 V⁻¹</code>	Coefficient for the geometry independent part of THESAT.
455	<code>plthesat=0.0 V⁻¹</code>	Coefficient for the length dependence of THESAT.
456	<code>pwthesat=0.0 V⁻¹</code>	Coefficient for the width dependence of THESAT.
457	<code>plwthesat=0.0 V⁻¹</code>	Coefficient for the length times width dependence of THESAT.
458	<code>postthesat=1</code>	Coefficient for the geometry independent part of STTHESAT.
459	<code>plstthesat=0.0</code>	Coefficient for the length dependence of STTHESAT.
460	<code>pwstthesat=0.0</code>	Coefficient for the width dependence of STTHESAT.
461	<code>plwstthesat=0.0</code>	Coefficient for the length times width dependence of STTHESAT.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

- 462 `pothesatb=0` V^{-1} Coefficient for the geometry independent part of THESATB.
- 463 `plthesatb=0.0` V^{-1}
Coefficient for the length dependence of THESATB.
- 464 `pwthesatb=0.0` V^{-1}
Coefficient for the width dependence of THESATB.
- 465 `plwthesatb=0.0` V^{-1}
Coefficient for the length times width dependence of THESATB.
- 466 `pothesatg=0` V^{-1} Coefficient for the geometry independent part of THESATG.
- 467 `plthesatg=0.0` V^{-1}
Coefficient for the length dependence of THESATG.
- 468 `pwthesatg=0.0` V^{-1}
Coefficient for the width dependence of THESATG.
- 469 `plwthesatg=0.0` V^{-1}
Coefficient for the length times width dependence of THESATG.
- 470 `poax=3` Coefficient for the geometry independent part of AX.
- 471 `plax=0.0` Coefficient for the length dependence of AX.
- 472 `pwax=0.0` Coefficient for the width dependence of AX.
- 473 `plwax=0.0` Coefficient for the length times width dependence of AX.
- 474 `poalp=0.01` Coefficient for the geometry independent part of ALP.
- 475 `plalp=0.0` Coefficient for the length dependence of ALP.
- 476 `pwalp=0.0` Coefficient for the width dependence of ALP.
- 477 `plwalp=0.0` Coefficient for the length times width dependence of ALP.
- 478 `poalp1=0` V Coefficient for the geometry independent part of ALP1.
- 479 `plalp1=0.0` V Coefficient for the length dependence of ALP1.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

480	$pwalp1=0.0$	V	Coefficient for the width dependence of ALP1.
481	$plwalp1=0.0$	V	Coefficient for the length times width dependence of ALP1.
482	$poalp2=0$	V^{-1}	Coefficient for the geometry independent part of ALP2.
483	$plalp2=0.0$	V^{-1}	Coefficient for the length dependence of ALP2.
484	$pwalp2=0.0$	V^{-1}	Coefficient for the width dependence of ALP2.
485	$plwalp2=0.0$	V^{-1}	Coefficient for the length times width dependence of ALP2.
486	$povp=0.05$	V	Coefficient for the geometry independent part of VP.
487	$poa1=1$		Coefficient for the geometry independent part of A1.
488	$pla1=0.0$		Coefficient for the length dependence of A1.
489	$pwa1=0.0$		Coefficient for the width dependence of A1.
490	$plwa1=0.0$		Coefficient for the length times width dependence of A1.
491	$poa2=10$	V	Coefficient for the geometry independent part of A2.
492	$posta2=0$	V	Coefficient for the geometry independent part of STA2.
493	$poa3=1$		Coefficient for the geometry independent part of A3.
494	$pla3=0.0$		Coefficient for the length dependence of A3.
495	$pwa3=0.0$		Coefficient for the width dependence of A3.
496	$plwa3=0.0$		Coefficient for the length times width dependence of A3.
497	$poa4=0$	$V^{-0.5}$	Coefficient for the geometry independent part of A4.
498	$pla4=0.0$	$V^{-0.5}$	Coefficient for the length dependence of A4.
499	$pwa4=0.0$	$V^{-0.5}$	Coefficient for the width dependence of A4.
500	$plwa4=0.0$	$V^{-0.5}$	Coefficient for the length times width dependence of A4.
501	$pogco=0$		Coefficient for the geometry independent part of GCO.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

502	poiginv=0 A	Coefficient for the geometry independent part of IGINV.
503	pliginv=0.0 A	Coefficient for the length dependence of IGINV.
504	pwiginv=0.0 A	Coefficient for the width dependence of IGINV.
505	plwiginv=0.0 A	Coefficient for the length times width dependence of IGINV.
506	poigov=0 A	Coefficient for the geometry independent part of IGOV.
507	pligov=0.0 A	Coefficient for the length dependence of IGOV.
508	pwigov=0.0 A	Coefficient for the width dependence of IGOV.
509	plwigov=0.0 A	Coefficient for the length times width dependence of IGOV.
510	poigovd=0 A	Coefficient for the geometry independent part of IGOV for drain side.
511	pligovd=0.0 A	Coefficient for the length dependence of IGOV for drain side.
512	pwigovd=0.0 A	Coefficient for the width dependence of IGOV for drain side.
513	plwigovd=0.0 A	Coefficient for the length times width dependence of IGOV for drain side.
514	postig=2	Coefficient for the geometry independent part of STIG.
515	pogc2=0.375	Coefficient for the geometry independent part of GC2.
516	pogc3=0.063	Coefficient for the geometry independent part of GC3.
517	pochib=3.1 V	Coefficient for the geometry independent part of CHIB.
518	poagidl=0 A/V ³	Coefficient for the geometry independent part of AGIDL.
519	plagidl=0.0 A/V ³	Coefficient for the length dependence of AGIDL.
520	pwagidl=0.0 A/V ³	Coefficient for the width dependence of AGIDL.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

521	<code>plwagidl=0.0</code>	A/V^3	Coefficient for the length times width dependence of AGIDL.
522	<code>poagidld=0</code>	A/V^3	Coefficient for the geometry independent part of AGIDL for drain side.
523	<code>plagidld=0.0</code>	A/V^3	Coefficient for the length dependence of AGIDL for drain side.
524	<code>pwagidld=0.0</code>	A/V^3	Coefficient for the width dependence of AGIDL for drain side.
525	<code>plwagidld=0.0</code>	A/V^3	Coefficient for the length times width dependence of AGIDL for drain side.
526	<code>pobgidl=41</code>	V	Coefficient for the geometry independent part of BGIDL.
527	<code>pobgidld=41</code>	V	Coefficient for the geometry independent part of BGIDL for drain side.
528	<code>postbgidl=0</code>	V/K	Coefficient for the geometry independent part of STBGIDL.
529	<code>postbgidld=0</code>	V/K	Coefficient for the geometry independent part of STBGIDL for drain side.
530	<code>pocgidl=0</code>		Coefficient for the geometry independent part of CGIDL.
531	<code>pocgidld=0</code>		Coefficient for the geometry independent part of CGIDL for drain side.
532	<code>pocox=1E-14</code>	F	Coefficient for the geometry independent part of COX.
533	<code>plcox=0.0</code>	F	Coefficient for the length dependence of COX.
534	<code>pwcox=0.0</code>	F	Coefficient for the width dependence of COX.
535	<code>plwcox=0.0</code>	F	Coefficient for the length times width dependence of COX.
536	<code>pocgov=1E-15</code>	F	Coefficient for the geometry independent part of CGOV.
537	<code>plcgov=0.0</code>	F	Coefficient for the length dependence of CGOV.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

538	<code>pwcgov=0.0 F</code>	Coefficient for the width dependence of CGOV.
539	<code>plwcgov=0.0 F</code>	Coefficient for the length times width dependence of CGOV.
540	<code>pocgovd=1E-15 F</code>	Coefficient for the geometry independent part of CGOV for drain side.
541	<code>plcgovd=0.0 F</code>	Coefficient for the length dependence of CGOV for drain side.
542	<code>pwcgovd=0.0 F</code>	Coefficient for the width dependence of CGOV for drain side.
543	<code>plwcgovd=0.0 F</code>	Coefficient for the length times width dependence of CGOV for drain side.
544	<code>pocgbov=0 F</code>	Coefficient for the geometry independent part of CGBOV.
545	<code>plcgbov=0.0 F</code>	Coefficient for the length dependence of CGBOV.
546	<code>pwcgbov=0.0 F</code>	Coefficient for the width dependence of CGBOV.
547	<code>plwcbobv=0.0 F</code>	Coefficient for the length times width dependence of CGBOV.
548	<code>pocfr=0 F</code>	Coefficient for the geometry independent part of CFR.
549	<code>plcfr=0.0 F</code>	Coefficient for the length dependence of CFR.
550	<code>pwcfr=0.0 F</code>	Coefficient for the width dependence of CFR.
551	<code>plwcfr=0.0 F</code>	Coefficient for the length times width dependence of CFR.
552	<code>pocfrd=0 F</code>	Coefficient for the geometry independent part of CFR for drain side.
553	<code>plcfrd=0.0 F</code>	Coefficient for the length dependence of CFR for drain side.
554	<code>pwcfrd=0.0 F</code>	Coefficient for the width dependence of CFR for drain side.
555	<code>plwcfrd=0.0 F</code>	Coefficient for the length times width dependence of CFR for drain side.
556	<code>pofnt=1</code>	Coefficient for the geometry independent part of FNT.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

557	$\text{ponfa}=8\text{E}+22 \text{ V}^{-1}/\text{m}^4$	Coefficient for the geometry independent part of NFA.
558	$\text{plnfa}=0.0 \text{ V}^{-1}/\text{m}^4$	Coefficient for the length dependence of NFA.
559	$\text{pwnfa}=0.0 \text{ V}^{-1}/\text{m}^4$	Coefficient for the width dependence of NFA.
560	$\text{plwnfa}=0.0 \text{ V}^{-1}/\text{m}^4$	Coefficient for the length times width dependence of NFA.
561	$\text{ponfb}=3\text{E}+07 \text{ V}^{-1}/\text{m}^2$	Coefficient for the geometry independent part of NFB.
562	$\text{plnfb}=0.0 \text{ V}^{-1}/\text{m}^2$	Coefficient for the length dependence of NFB.
563	$\text{pwnfb}=0.0 \text{ V}^{-1}/\text{m}^2$	Coefficient for the width dependence of NFB.
564	$\text{plwnfb}=0.0 \text{ V}^{-1}/\text{m}^2$	Coefficient for the length times width dependence of NFB.
565	$\text{ponfc}=0 \text{ V}^{-1}$	Coefficient for the geometry independent part of NFC.
566	$\text{plnfc}=0.0 \text{ V}^{-1}$	Coefficient for the length dependence of NFC.
567	$\text{pwnfc}=0.0 \text{ V}^{-1}$	Coefficient for the width dependence of NFC.
568	$\text{plwnfc}=0.0 \text{ V}^{-1}$	Coefficient for the length times width dependence of NFC.
569	$\text{poef}=1.0$	Coefficient for the flicker noise frequency exponent.
570	$\text{pokvthowe}=0$	Coefficient for the geometry independent part of KVTHOWE.
571	$\text{plkvthowe}=0$	Coefficient for the length dependence part of KVTHOWE.
572	$\text{pwkvthowe}=0$	Coefficient for the width dependence part of KVTHOWE.
573	$\text{plwkvthowe}=0$	Coefficient for the length times width dependence part of KVTHOWE.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

574	pokuowe=0	Coefficient for the geometry independent part of KUOWE.
575	plkuowe=0	Coefficient for the length dependence part of KUOWE.
576	pwkuowe=0	Coefficient for the width dependence part of KUOWE.
577	plwkuowe=0	Coefficient for the length times width dependence part of KUOWE.
578	lmin=0 m	Dummy parameter to label binning set.
579	lmax=1.0 m	Dummy parameter to label binning set.
580	wmin=0 m	Dummy parameter to label binning set.
581	wmax=1.0 m	Dummy parameter to label binning set.

Common parameters

582	w=10e-6 m	Default width.
583	l=10e-6 m	Default length.
584	nf=1	Number of fingers, It served as the default value of instance nf.

Local model

585	mvt=0.0	DCmatch parameter.
587	mbe=0.0	DCmatch parameter.

Global model and Bin model

586	mvto=0.0	DCmatch parameter
588	mbeo=0.0	DCmatch parameter.

Operating-Point Parameters

1	ctype	Flag for channel type.
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Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

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).
21	<code>ijssti (A)</code>	Source junction current (STI-edge component).
22	<code>ijd (A)</code>	Total drain junction current.

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PSP Model (psp)

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>	Intrinsic gate charge.
27	<code>qd</code>	Intrinsic drain charge.
28	<code>qb</code>	Intrinsic bulk charge.
29	<code>qs</code>	Intrinsic source charge.
30	<code>qgs_ov</code>	Overlap charge for gate-source.
31	<code>qgd_ov</code>	Overlap charge for gate-drain.
32	<code>qfgs</code>	Total outerFringe + overlap for gate-source.
33	<code>qfgd</code>	Total outerFringe + overlap for gate-drain.
34	<code>qgb_ov</code>	Gate-bulk overlap charge.
35	<code>qjun_s</code>	Junction charge on source side.
36	<code>qjun_d</code>	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.
43	<code>vgt</code> (V)	Effective gate drive voltage including back bias and drain bias effects.

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PSP Model (psp)

44	v_{dss} (V)	Drain saturation voltage at actual bias.
45	v_{sat} (V)	Saturation limit.
46	g_m (1/Ohm)	Transconductance.
47	g_{mb} (1/Ohm)	Substrate transconductance.
48	g_{ds} (1/Ohm)	Output conductance.
49	g_{js} (1/Ohm)	Source junction conductance.
50	g_{jd} (1/Ohm)	Drain junction conductance.
51	c_{dd} (F)	Drain capacitance.
52	c_{dg} (F)	Drain-gate capacitance.
53	c_{ds} (F)	Drain-source capacitance.
54	c_{db} (F)	Drain-bulk capacitance.
55	c_{gd} (F)	Gate-drain capacitance.
56	c_{gg} (F)	Gate capacitance.
57	c_{gs} (F)	Gate-source capacitance.
58	c_{gb} (F)	Gate-bulk capacitance.
59	c_{sd} (F)	Source-drain capacitance.
60	c_{sg} (F)	Source-gate capacitance.
61	c_{ss} (F)	Source capacitance.
62	c_{sb} (F)	Source-bulk capacitance.
63	c_{bd} (F)	Bulk-drain capacitance.
64	c_{bg} (F)	Bulk-gate capacitance.
65	c_{bs} (F)	Bulk-source capacitance.

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PSP Model (psp)

66	cbb (F)	Bulk capacitance.
67	cgsol (F)	Total gate-source overlap capacitance.
68	cgdol (F)	Total gate-drain overlap capacitance.
69	cjs (F)	Total source junction capacitance.
70	cjsbot (F)	Source junction capacitance (bottom component).
71	cjsgat (F)	Source junction capacitance (gate-edge component).
72	cjssti (F)	Source junction capacitance (STI-edge component).
73	cjd (F)	Total drain junction capacitance.
74	cjdbot (F)	Drain junction capacitance (bottom component).
75	cjdgat (F)	Drain junction capacitance (gate-edge component).
76	cjdsti (F)	Drain junction capacitance (STI-edge component).
77	weff (m)	Effective channel width for geometrical models.
78	leff (m)	Effective channel length for geometrical models.
79	lpoly (m)	
80	u	Transistor gain.
81	rout (Ohm)	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.
85	rg (Ohm)	Gate resistance.
86	sfl (A/Hz)	Flicker noise current density at 1 Hz.

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PSP Model (psp)

87	<code>sqrtsff</code> (V/sqrt(Hz))	Input-referred RMS white noise voltage density at 1 kHz.
88	<code>sqrtsfw</code> (V/sqrt(Hz))	Input-referred RMS white noise voltage density.
89	<code>sid</code> (A ² /Hz)	White noise current density.
90	<code>sig</code> (A ² /Hz)	Induced gate noise current density at 1 Hz.
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>m=1.0</code>	Alias of mult.
99	<code>lv2</code> (m)	alias of weff.
100	<code>lv1</code> (m)	alias of leff.
101	<code>lx4</code> (A)	alias of ids.
102	<code>lx3</code> (V)	alias of vds.
103	<code>lx2</code> (V)	alias of vgs.
104	<code>lv9</code> (V)	alias of vth.
105	<code>lx7</code> (1/Ohm)	alias of gm.
106	<code>lx8</code> (1/Ohm)	alias of gds.
107	<code>lx9</code> (1/Ohm)	alias of gmb.

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PSP Model (psp)

108	lx33	(F)	alias of cdd.
109	lx32	(F)	alias of cdg.
110	lx34	(F)	alias of cds.
111	lx19	(F)	alias of cgd.
112	lx18	(F)	alias of cgg.
113	lx20	(F)	alias of cgs.
114	lx22	(F)	alias of cbd.
115	lx21	(F)	alias of cbg.
116	lx23	(F)	alias of cbs.
117	lv10	(V)	alias of vdss.
118	lx5	(A)	alias of ijs.
119	lx6	(A)	alias of ijd.
120	lx28	(F)	alias of cjs.
121	lx29	(F)	alias of cjd.
122	lx38	(A)	alias of igs.
123	lx39	(A)	alias of igd.
124	lx66	(A)	alias of igb.
125	lx67	(A)	alias of igcs.
126	lx68	(A)	alias of igcd.
127	lx110	(A)	alias of igisl.
128	lx47	(A)	alias of igidl.
129	lx60	(F)	alias of csd.

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PSP Model (psp)

130	lx59 (F)	alias of csg.
131	lx58 (F)	alias of css.
132	lx12 (Coul)	alias of Qb.
133	lx14 (Coul)	alias of Qg.
134	lx16 (Coul)	alias of Qd.
135	lx83 (F)	alias of cgd including overlap cap.
136	lx84 (F)	alias of cgs including overlap cap.
137	table_ids (A)	For table model.
138	table_vth (V)	For table model.
139	table_qg (Coul)	For table model.
140	table_qd (Coul)	For table model.
141	table_qb (Coul)	For table model.
142	table_id (A)	For table model.
143	table_isub (A)	For table model.
144	table_ibs (A)	For table model.
145	table_ibd (A)	For table model.
146	table_igd (A)	For table model.
147	table_igb (A)	For table model.
148	table_igs (A)	For table model.
149	table_gds (1/Ohm)	For table model.
150	table_gm (1/Ohm)	For table model.

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PSP Model (psp)

- 151 `table_gmbs` (1/Ohm) For table model.
- 152 `table_qbs` (Coul) For table model.
- 153 `table_qbd` (Coul) For table model.
- 154 `table_vdsat` (V) For table model.
- 155 `table_leff` (m) For table model.
- 156 `table_weff` (m) For table model.
- 157 `table_aseff` (m²) For table model.
- 158 `table_adeff` (m²) For table model.
- 159 `table_pseff` (m) For table model.
- 160 `table_pdeff` (m) 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.

<code>a1</code>	M-57	<code>igcd</code>	OP-14	<code>plnov</code>	M-410	<code>rjunso</code>	M-261
<code>all</code>	M-212	<code>igcs</code>	OP-13	<code>plnovd</code>	M-414	<code>rout</code>	OP-81
<code>alo</code>	M-211	<code>igd</code>	OP-11	<code>plnp</code>	M-400	<code>rs</code>	M-44
<code>alw</code>	M-213	<code>ige</code>	OP-4	<code>plrs</code>	M-449	<code>rsb</code>	M-46

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PSP Model (psp)

a2	M-58	igidl	OP-17	plstbet	M-427	rsbo	M-184
a2o	M-214	iginv	M-63	plstthesat	M-460	rsg	M-47
a3	M-60	iginvlw	M-223	plstvfb	M-383	rsgo	M-185
a3l	M-217	igisl	OP-16	plthesat	M-456	rshg	M-265
a3o	M-216	igov	M-64	plthesatb	M-464	rsw1	M-181
a3w	M-218	igovd	M-65	plthesatg	M-468	rsw2	M-182
a4	M-61	igovdw	M-225	plvfb	M-379	rvpoly	M-264
a4l	M-220	igovw	M-224	plwa1	M-491	rwell	M-92
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alp	M-53	imax	M-289	plwcf	M-420	scref	M-286
alp1	M-54	isb	OP-9	plwcfrr	M-552	sd	I-5
alp111	M-202	ise	OP-3	plwcfrrd	M-556	sdi	OP-97
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PSP Model (psp)

alpllexp	M-203	jw	I-22	plwcgov	M-540	sfl	OP-86
alp1w	M-205	kuo	M-270	plwcgovd	M-544	siavl	OP-95
alp2	M-55	kuowel	M-254	plwcox	M-536	sid	OP-89
alp2l1	M-206	kuowelw	M-256	plwcs	M-440	sig	OP-90
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PSP Model (psp)

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PSP Model (psp)

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cjorgatd	M-334	lx68	OP-126	ponfb	M-562	table_qb	OP-141
cjorsti	M-292	lx7	OP-105	ponfc	M-566	table_qbd	OP-153
cjorstid	M-333	lx8	OP-106	ponov	M-409	table_qbs	OP-152
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cjsbot	OP-70	lx84	OP-136	ponp	M-399	table_qg	OP-139
cjsgat	OP-71	lx9	OP-107	ponslp	M-393	table_vdsat	OP-154
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csrbotd	M-347	mue	M-35	postthemu	M-436	thesatlw	M-190
csrbotd	M-347	mue	M-35	postthemu	M-436	thesatlw	M-190
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PSP Model (psp)

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PSP Model (psp)

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ef M-88	pbotd M-338	pwcgovd M-543	vfb1 M-106
efo M-245	pbrbot M-329	pwcox M-535	vfb1w M-108
epsrox M-19	pbrbotd M-370	pwcs M-439	vfb0 M-105
epsroxo M-114	pbrgat M-331	pwct M-405	vfbw M-107
factuo I-11	pbrgatd M-372	pwdphib M-397	vgs OP-38
fbbttrbot M-320	pbrsti M-330	pwiginv M-505	vgt OP-43
fbbttrbotd M-361	pbrstid M-371	pwigov M-509	vjunref M-374
fbbttrgat M-322	pd I-21	pwigovd M-513	vjunrefd M-376
fbbttrgatd M-363	pgat M-299	pwkuowe M-577	vnsub M-21
fbbttrsti M-321	pgatd M-340	pwkvthowe M-573	vnsubo M-125
fbbttrstid M-362	phigbot M-300	pwmue M-432	vp M-56
fbet1 M-151	phigbotd M-341	pwneff M-390	vpo M-210
fbet1w M-152	phiggat M-302	pwnfa M-560	vsat OP-45
fbet2 M-155	phiggatd M-343	pwnfb M-564	vsb OP-39
feta M-43	phigsti M-301	pwnfc M-568	vth OP-42
fetao M-180	phigstid M-342	pwnov M-411	vto OP-40
fjunq M-375	pkuo M-275	pwnovd M-415	vts OP-41
fjunqd M-377	pkvtho M-281	pwnp M-401	w I-2
fknee OP-92	pla1 M-489	pwrs M-450	w M-583
fnt M-84	pla3 M-495	pwstbet M-428	wbet M-159

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

fnto	M-241	pla4	M-499	pwstthesat	M-461	web	M-287
fol1	M-123	plagidl	M-520	pwstvfb	M-384	wec	M-288
fol2	M-124	plagidd	M-524	pwthesat	M-457	weff	OP-77
fug	OP-84	plalp	M-476	pwthesatb	M-465	wkuo	M-274
gc2	M-67	plalp1	M-480	pwthesatg	M-469	wkvtho	M-280
gc2o	M-227	plalp2	M-484	pwvfb	M-380	wlod	M-269
gc3	M-68	plax	M-472	pwxcor	M-444	wlodkuo	M-277
gc3o	M-228	plbetn	M-423	qjb	OP-28	wlodvth	M-283
gco	M-62	plcf	M-418	qd	OP-27	wmax	M-582
gcoo	M-222	plcfr	M-550	qfgd	OP-33	wmin	M-581
gds	OP-48	plcfrd	M-554	qfgs	OP-32	wot	M-102
geomod	M-13	plcgbov	M-546	qg	OP-26	wseg	M-117
gjd	OP-50	plcgov	M-538	qgb_ov	OP-34	wsegp	M-120
gjs	OP-49	plcgovd	M-542	qgd_ov	OP-31	wvarl	M-100
gm	OP-46	plcox	M-534	qgs_ov	OP-30	wvaro	M-99
gmb	OP-47	plcs	M-438	qjun_d	OP-36	wvarw	M-101
iavl	OP-15	plct	M-404	qjun_s	OP-35	xcor	M-41
ibe	OP-6	pldphib	M-396	qmc	M-10	xcorl	M-176
idb	OP-8	pliginv	M-504	qs	OP-29	xcorlw	M-178
ide	OP-5	pligov	M-508	rbulk	M-91	xcoro	M-175
ids	OP-7	pligovd	M-512	rbulko	M-259	xcorw	M-177

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

idsatrbot	M-303	plkuowe	M-576	rg	M-90	xgw	I-26
idsatrbotd	M-344	plkvthowe	M-572	rg	OP-85	xjungat	M-310
idsatrgat	M-305	plmue	M-431	rgo	M-258	xjungatd	M-351
idsatrgatd	M-346	plneff	M-389	rint	M-263	xjunsti	M-309
idsatrsti	M-304	plnfa	M-559	rjund	M-94	xjunstid	M-350
idsatrstid	M-345	plnfb	M-563	rjundo	M-262		
igb	OP-12	plnfc	M-567	rjuns	M-93		

PSP MOSFET Model (psp1020)

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

Name (d g s b) ModelName <parameter=value> ...

Instance Parameters

1	l=1e-05 m	Design length.
2	w=1e-05 m	Design width.
3	sa=0 m	Distance between OD-edge and poly from one side.
4	sb=0 m	Distance between OD-edge and poly from other side.
5	sd=0 m	Distance between neighbouring fingers.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

6	sca=0	Integral of the first distribution function for scattered well dopants.
7	scb=0	Integral of the second distribution function for scattered well dopants.
8	scc=0	Integral of the third distribution function for scattered well dopants.
9	sc=0 m	Distance between OD-edge and nearest well edge.
10	delvto=0 V	Threshold voltage shift parameter.
11	factuo=1	Zero-field mobility pre-factor.
12	absource=1e-12 m ²	Bottom area of source junction.
13	lssource=1e-06 m	STI-edge length of source junction.
14	lgsource=1e-06 m	Gate-edge length of source junction.
15	abdRAIN=1e-12 m ²	Bottom area of drain junction.
16	lsdRAIN=1e-06 m	STI-edge length of drain junction.
17	lgdRAIN=1e-06 m	Gate-edge length of drain junction.
18	as=1e-12 m ²	Bottom area of source junction.
19	ps=1e-06 m	Perimeter of source junction.
20	ad=1e-12 m ²	Bottom area of drain junction.
21	pd=1e-06 m	Perimeter of drain junction.
22	mult=1	Number of devices in parallel.
23	nf=1	Number of fingers.
24	ngcon=1	Number of gate contacts.
25	xgw=1e-07 m	Distance from the gate contact to the channel edge.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

26	<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> , <code>subth</code> , <code>rev</code> , <code>fwd</code> , or <code>brk</code> .
27	<code>m=1</code>	Multiplicity factor.
28	<code>trise=0</code>	Temperature rise from ambient.
29	<code>area=1</code>	alias of <code>mult</code> .

Model Definition

```
model modelName psp1020 parameter=value ...
```

Model Parameters

1	<code>level=1.02e+03</code>	Model level.
2	<code>type=n</code>	Channel type parameter, +1=NMOS -1=PMOS. 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>pnp1</code> .
3	<code>tr=21 C</code>	nominal (reference) temperature.
4	<code>swigate=0</code>	Flag for gate current, 0=turn off IG.
5	<code>swimpact=0</code>	Flag for impact ionization current, 0=turn off II.
6	<code>swgidl=0</code>	Flag for GIDL current, 0=turn off IGIDL.
7	<code>swjuncap=0</code>	Flag for juncap, 0=turn off juncap.
8	<code>swjunasym=0</code>	Flag for asymmetric junctions; 0=symmetric, 1=asymmetric.
9	<code>qmc=1</code>	Quantum-mechanical correction factor.
10	<code>lvaro=0 m</code>	Geometry independent difference between actual and programmed poly-silicon gate length.
11	<code>lvarl=0</code>	Length dependence of difference between actual and programmed poly-silicon gate length.
12	<code>lvarw=0</code>	Width dependence of LVAR.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

13	$lap=0$ m	Effective channel length reduction per side due to lateral diffusion of source/drain dopant ions.
14	$wvaro=0$ m	Geometry independent difference between actual and programmed field-oxide opening.
15	$wvarl=0$	Length dependence of WVAR.
16	$wvarw=0$	Width dependence of difference between actual and programmed field-oxide opening.
17	$wot=0$ m	Effective reduction of channel width per side due to lateral diffusion of channel-stop dopant ions.
18	$dlq=0$ m	Effective channel length reduction for CV.
19	$dwq=0$ m	Effective channel width reduction for CV.
20	$vfbo=-1$ V	Geometry-independent flat-band voltage at TR.
21	$vfbl=0$	Length dependence of flat-band voltage.
22	$vfbw=0$	Width dependence of flat-band voltage.
23	$vfblw=0$	Area dependence of flat-band voltage.
24	$stvfbo=0.0005$ V/K	Geometry-independent temperature dependence of VFB.
25	$stvfbl=0$	Length dependence of temperature dependence of VFB.
26	$stvfbw=0$	Width dependence of temperature dependence of VFB.
27	$stvfblw=0$	Area dependence of temperature dependence of VFB.
28	$toxoxo=2e-09$ m	Gate oxide thickness.
29	$epsroxoxo=3.9$	Relative permittivity of gate dielectric.
30	$nsubo=3e+23$ m ⁻³	Geometry independent substrate doping.
31	$nsubw=0$	Width dependence of background doping NSUBO due to segregation.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

32	$wseg=1e-08$ m	Char. length of segregation of background doping NSUBO.
33	$npck=1e+24$ m ⁻³	Pocket doping level.
34	$npckw=0$	Width dependence of pocket doping NPCK due to segregation.
35	$wsegp=1e-08$ m	Char. length of segregation of pocket doping NPCK.
36	$lpck=1e-08$ m	Char. length of lateral doping profile.
37	$lpckw=0$	Width dependence of char. length of lateral doping profile.
38	$fol1=0$	First length dependence coefficient for short channel body effect.
39	$fol2=0$	Second length dependence coefficient for short channel body effect.
40	$vnsubo=0$ V	Effective doping bias-dependence parameter.
41	$nslpo=0.05$ V	Effective doping bias-dependence parameter.
42	$dnsubo=0$ V ⁻¹	Effective doping bias-dependence parameter.
43	$dphibo=0$ V	Geometry independent offset of PHIB.
44	$dphibl=0$ V	Length dependence offset of PHIB.
45	$dphiblexp=1$	Exponent for length dependence of offset of PHIB.
46	$dphibw=0$	Width dependence of offset of PHIB.
47	$dphiblw=0$	Area dependence of offset of PHIB.
48	$npo=1e+26$ m ⁻³	Geometry-independent gate poly-silicon doping.
49	$npl=0$	Length dependence of gate poly-silicon doping.
50	$cto=0$	Geometry-independent interface states factor.
51	$ctl=0$	Length dependence of interface states factor.
52	$ctlexp=1$	Exponent for length dependence of interface states factor.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

53	$ctw=0$	Width dependence of interface states factor.
54	$ctlw=0$	Area dependence of interface states factor.
55	$toxovo=2e-09$ m	Overlap oxide thickness.
56	$toxovdo=2e-09$ m	Overlap oxide thickness for drain side.
57	$lov=0$ m	Overlap length for gate/drain and gate/source overlap capacitance.
58	$lovd=0$ m	Overlap length for gate/drain overlap capacitance.
59	$novo=5e+25$ m ⁻³	Effective doping of overlap region.
60	$novdo=5e+25$ m ⁻³	Effective doping of overlap region for drain side.
61	$cf1=0$ V ⁻¹	Length dependence of DIBL-parameter.
62	$cf1exp=2$	Exponent for length dependence of CF.
63	$cfw=0$	Width dependence of CF.
64	$cfbo=0$ V ⁻¹	Back-bias dependence of CF.
65	$uo=0.05$ m ² /V/s	Zero-field mobility at TR.
66	$fbet1=0$	Relative mobility decrease due to first lateral profile.
67	$fbet1w=0$	Width dependence of relative mobility decrease due to first lateral profile.
68	$lp1=1e-08$ m	Mobility-related characteristic length of first lateral profile.
69	$lp1w=0$	Width dependence of mobility-related characteristic length of first lateral profile.
70	$fbet2=0$	Relative mobility decrease due to second lateral profile.
71	$lp2=1e-08$ m	Mobility-related characteristic length of second lateral profile.
72	$betw1=0$	First higher-order width scaling coefficient of BETN.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

73	<code>betw2=0</code>	Second higher-order width scaling coefficient of BETN.
74	<code>wbet=1e-09 m</code>	Characteristic width for width scaling of BETN.
75	<code>stbeto=1</code>	Geometry independent temperature dependence of BETN.
76	<code>stbetl=0</code>	Length dependence of temperature dependence of BETN.
77	<code>stbetw=0</code>	Width dependence of temperature dependence of BETN.
78	<code>stbetlw=0</code>	Area dependence of temperature dependence of BETN.
79	<code>mueo=0.5 m/V</code>	Geometry independent mobility reduction coefficient at TR.
80	<code>muew=0</code>	Width dependence of mobility reduction coefficient at TR.
81	<code>stmueo=0</code>	Temperature dependence of MUE.
82	<code>themuo=1.5</code>	Mobility reduction exponent at TR.
83	<code>stthemuo=1.5</code>	Temperature dependence of THEMU.
84	<code>cso=0</code>	Geometry independent coulomb scattering parameter at TR.
85	<code>csl=0</code>	Length dependence of CS.
86	<code>cslexp=0</code>	Exponent for length dependence of CS.
87	<code>csw=0</code>	Width dependence of CS.
88	<code>cslw=0</code>	Area dependence of CS.
89	<code>stcso=0</code>	Temperature dependence of CS.
90	<code>xcoro=0 V¹</code>	Geometry independent non-universality parameter.
91	<code>xcorl=0</code>	Length dependence of non-universality parameter.
92	<code>xcorw=0</code>	Width dependence of non-universality parameter.
93	<code>xcorlw=0</code>	Area dependence of non-universality parameter.
94	<code>stxcoro=0</code>	Temperature dependence of XCOR.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

95	$f_{etao}=1$	Effective field parameter.
96	$r_{sw1}=2.5e+03 \Omega$	Source/drain series resistance for 1 um wide channel at TR.
97	$r_{sw2}=0$	Higher-order width scaling of RS.
98	$strso=1$	Temperature dependence of RS.
99	$rsbo=0 \text{ V}^{-1}$	Back-bias dependence of series resistance.
100	$rsgo=0 \text{ V}^{-1}$	Gate-bias dependence of series resistance.
101	$thesato=0 \text{ V}^{-1}$	Geometry independent velocity saturation parameter at TR.
102	$thesatl=0.05 \text{ V}^{-1}$	Length dependence of THESAT.
103	$thesatlexp=1$	Exponent for length dependence of THESAT.
104	$thesatw=0$	Width dependence of velocity saturation parameter.
105	$thesatlw=0$	Area dependence of velocity saturation parameter.
106	$stthesato=1$	Geometry independent temperature dependence of THESAT.
107	$stthesatl=0$	Length dependence of temperature dependence of THESAT.
108	$stthesatw=0$	Width dependence of temperature dependence of THESAT.
109	$stthesatlw=0$	Area dependence of temperature dependence of THESAT.
110	$thesatbo=0 \text{ V}^{-1}$	Back-bias dependence of velocity saturation.
111	$thesatgo=0 \text{ V}^{-1}$	Gate-bias dependence of velocity saturation.
112	$axo=18$	Geometry independent linear/saturation transition factor.
113	$axl=0.4$	Length dependence of AX.
114	$alpl=0.0005$	Length dependence of ALP.
115	$alplexp=1$	Exponent for length dependence of ALP.
116	$alpw=0$	Width dependence of ALP.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

117	$\text{alp1l1}=0$ V	Length dependence of CLM enhancement factor above threshold.
118	$\text{alp1lexp}=0.5$	Exponent for length dependence of ALP1.
119	$\text{alp1l2}=0$	Second_order length dependence of ALP1.
120	$\text{alp1w}=0$	Width dependence of ALP1.
121	$\text{alp2l1}=0$ V ¹	Length dependence of CLM enhancement factor below threshold.
122	$\text{alp2lexp}=0.5$	Exponent for length dependence of ALP2.
123	$\text{alp2l2}=0$	Second_order length dependence of ALP2.
124	$\text{alp2w}=0$	Width dependence of ALP2.
125	$\text{vpo}=0.05$ V	CLM logarithmic dependence parameter.
126	$\text{a1o}=1$	Geometry independent impact-ionization pre-factor.
127	$\text{a1l}=0$	Length dependence of A1.
128	$\text{a1w}=0$	Width dependence of A1.
129	$\text{a2o}=10$ V	Impact-ionization exponent at TR.
130	$\text{sta2o}=0$ V	Temperature dependence of A2.
131	$\text{a3o}=1$	Geometry independent saturation-voltage dependence of II.
132	$\text{a3l}=0$	Length dependence of A3.
133	$\text{a3w}=0$	Width dependence of A3.
134	$\text{a4o}=0$ V ^{0.5}	Geometry independent back-bias dependence of II.
135	$\text{a4l}=0$	Length dependence of A4.
136	$\text{a4w}=0$	Width dependence of A4.
137	$\text{gcoo}=0$	Gate tunnelling energy adjustment.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

138	<code>iginv1w=0</code>	A	Gate channel current pre-factor for 1 μm^2 channel area.
139	<code>igovw=0</code>	A	Gate overlap current pre-factor for 1 μm wide channel.
140	<code>igovdw=0</code>	A	Gate overlap current pre-factor for 1 μm wide channel for drain side.
141	<code>stigo=2</code>		Temperature dependence of IGINV and IGOV.
142	<code>gc2o=0.375</code>		Gate current slope factor.
143	<code>gc3o=0.063</code>		Gate current curvature factor.
144	<code>chibo=3.1</code>	V	Tunnelling barrier height.
145	<code>agidlw=0</code>	A/V^3	Width dependence of GIDL pre-factor.
146	<code>agidldw=0</code>	A/V^3	Width dependence of GIDL pre-factor for drain side.
147	<code>bgidlo=41</code>	V	GIDL probability factor at TR.
148	<code>bgidldo=41</code>	V	GIDL probability factor at TR for drain side.
149	<code>stbgidlo=0</code>	V/K	Temperature dependence of BGIDL.
150	<code>stbgidldo=0</code>	V/K	Temperature dependence of BGIDL for drain side.
151	<code>cgidlo=0</code>		Back-bias dependence of GIDL.
152	<code>cgidldo=0</code>		Back-bias dependence of GIDL for drain side.
153	<code>cgbov1=0</code>	F	Oxide capacitance for gate-bulk overlap for 1 μm long channel.
154	<code>cfrw=0</code>	F	Outer fringe capacitance for 1 μm wide channel.
155	<code>cfrdw=0</code>	F	Outer fringe capacitance for 1 μm wide channel for drain side.
156	<code>fnto=1</code>		Thermal noise coefficient.
157	<code>nfalw=8e+22</code>	V^1/m^4	First coefficient of flicker noise for 1 μm^2 channel area.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

158	$nfb1w=3e+07 \text{ V}^{-1}/\text{m}^2$	Second coefficient of flicker noise for 1 μm^2 channel area.
159	$nfclw=0 \text{ V}^{-1}$	Third coefficient of flicker noise for 1 μm^2 channel area.
160	$efo=1$	Flicker noise frequency exponent.
161	$lintnoi=0 \text{ m}$	Length offset for flicker noise.
162	$alpnoi=2$	Exponent for length offset for flicker noise.
163	$dta=0 \text{ K}$	Temperature offset w.r.t. ambient temperature.
164	$kvthoweo=0$	Geometrical independent threshold shift parameter.
165	$kvthowel=0$	Length dependent threshold shift parameter.
166	$kvthowew=0$	Width dependent threshold shift parameter.
167	$kvthowelw=0$	Area dependent threshold shift parameter.
168	$kuoweo=0$	Geometrical independent mobility degradation factor.
169	$kuowel=0$	Length dependent mobility degradation factor.
170	$kuowew=0$	Width dependent mobility degradation factor.
171	$kuowelw=0$	Area dependent mobility degradation factor.
172	$rgo=0 \text{ } \Omega$	Gate resistance.
173	$rbulko=0 \text{ } \Omega$	Bulk resistance between node BP and BI.
174	$rwello=0 \text{ } \Omega$	Well resistance between node BI and B.
175	$rjunso=0 \text{ } \Omega$	Source-side bulk resistance between node BI and BS.
176	$rjundo=0 \text{ } \Omega$	Drain-side bulk resistance between node BI and BD.
177	$rint=0 \text{ } \Omega/\text{Sqr}$	Contact resistance between silicide and poly.
178	$rvpoly=0 \text{ } \Omega/\text{Sqr}$	Vertical poly resistance.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

179	$rshg=0 \ \Omega/Sqr$	Gate electrode diffusion sheet resistance.
180	$dlsil=0 \ m$	Silicide extension over the physical gate length.
181	$saref=1e-06 \ m$	Reference distance between OD-edge and poly from one side.
182	$sbref=1e-06 \ m$	Reference distance between OD-edge and poly from other side.
183	$wlod=0 \ m$	Width parameter.
184	$kuo=0 \ m$	Mobility degradation/enhancement coefficient.
185	$kvsat=0 \ m$	Saturation velocity degradation/enhancement coefficient.
186	$tkuo=0$	Temperature dependence of KUO.
187	$lkuo=0 \ m^{LLODKUO}$	Length dependence of KUO.
188	$wkuo=0 \ m^{WLODKUO}$	Width dependence of KUO.
189	$pkuo=0 \ m^{(LLODKUO+WLODKUO)}$	Cross-term dependence of KUO.
190	$llodkuo=0$	Length parameter for UO stress effect.
191	$wlodkuo=0$	Width parameter for UO stress effect.
192	$kvtho=0 \ Vm$	Threshold shift parameter.
193	$lkvtho=0 \ m^{LLODVTH}$	Length dependence of KVTHO.
194	$wkvtho=0 \ m^{WLODVTH}$	Width dependence of KVTHO.
195	$pkvtho=0 \ m^{(LLODVTH+WLODVTH)}$	Cross-term dependence of KVTHO.
196	$llodvth=0$	Length parameter for VTH-stress effect.
197	$wlodvth=0$	Width parameter for VTH-stress effect.
198	$stetao=0 \ m$	eta0 shift factor related to VTHO change.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

199	<code>lodetao=1</code>	<code>eta0</code> shift modification factor for stress effect.
200	<code>scref=1e-05 m</code>	Distance between OD-edge and well edge of a reference device.
201	<code>web=0</code>	Coefficient for SCB.
202	<code>wec=0</code>	Coefficient for SCC.
203	<code>trj=21 C</code>	reference temperature.
204	<code>imax=1e+03 A</code>	Maximum current up to which forward current behaves exponentially.
205	<code>cjorbot=0.001 Fm⁻²</code>	Zero-bias capacitance per unit-of-area of bottom component for source-bulk junction.
206	<code>cjorsti=1e-09 Fm⁻¹</code>	Zero-bias capacitance per unit-of-length of STI-edge component for source-bulk junction.
207	<code>cjorgat=1e-09 Fm⁻¹</code>	Zero-bias capacitance per unit-of-length of gate-edge component for source-bulk junction.
208	<code>vbirbot=1 V</code>	Built-in voltage at the reference temperature of bottom component for source-bulk junction.
209	<code>vbirsti=1 V</code>	Built-in voltage at the reference temperature of STI-edge component for source-bulk junction.
210	<code>vbirgat=1 V</code>	Built-in voltage at the reference temperature of gate-edge component for source-bulk junction.
211	<code>pbot=0.5</code>	Grading coefficient of bottom component for source-bulk junction.
212	<code>psti=0.5</code>	Grading coefficient of STI-edge component for source-bulk junction.
213	<code>pgat=0.5</code>	Grading coefficient of gate-edge component for source-bulk junction.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

- 214 `phigbot=1.16` V Zero-temperature bandgap voltage of bottom component for source-bulk junction.
- 215 `phigsti=1.16` V Zero-temperature bandgap voltage of STI-edge component for source-bulk junction.
- 216 `phiggat=1.16` V Zero-temperature bandgap voltage of gate-edge component for source-bulk junction.
- 217 `idsatrbot=1e-12` Am^{-2} Saturation current density at the reference temperature of bottom component for source-bulk junction.
- 218 `idsatrsti=1e-18` Am^{-1} Saturation current density at the reference temperature of STI-edge component for source-bulk junction.
- 219 `idsatrgat=1e-18` Am^{-1} Saturation current density at the reference temperature of gate-edge component for source-bulk junction.
- 220 `csrbot=100` Am^{-3} Shockley-Read-Hall prefactor of bottom component for source-bulk junction.
- 221 `csrhisti=0.0001` Am^{-2} Shockley-Read-Hall prefactor of STI-edge component for source-bulk junction.
- 222 `csrhgat=0.0001` Am^{-2} Shockley-Read-Hall prefactor of gate-edge component for source-bulk junction.
- 223 `xjunsti=1e-07` m Junction depth of STI-edge component for source-bulk junction.
- 224 `xjngat=1e-07` m Junction depth of gate-edge component for source-bulk junction.
- 225 `ctatbot=100` Am^{-3} Trap-assisted tunneling prefactor of bottom component for source-bulk junction.
- 226 `ctatsti=0.0001` Am^{-2} Trap-assisted tunneling prefactor of STI-edge component for source-bulk junction.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

- 227 $ctatgat=0.0001 \text{ Am}^{-2}$ Trap-assisted tunneling prefactor of gate-edge component for source-bulk junction.
- 228 $mefftatbot=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of bottom component for source-bulk junction.
- 229 $mefftatsti=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of STI-edge component for source-bulk junction.
- 230 $mefftatgat=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of gate-edge component for source-bulk junction.
- 231 $cbbtbot=1e-12 \text{ AV}^{-3}$ Band-to-band tunneling prefactor of bottom component for source-bulk junction.
- 232 $cbbtsti=1e-18 \text{ AV}^{-3}_m$ Band-to-band tunneling prefactor of STI-edge component for source-bulk junction.
- 233 $cbbtgat=1e-18 \text{ AV}^{-3}_m$ Band-to-band tunneling prefactor of gate-edge component for source-bulk junction.
- 234 $fbbtbot=1e+09 \text{ Vm}^{-1}$ Normalization field at the reference temperature for band-to-band tunneling of bottom component for source-bulk junction.
- 235 $fbbtsti=1e+09 \text{ Vm}^{-1}$ Normalization field at the reference temperature for band-to-band tunneling of STI-edge component for source-bulk junction.
- 236 $fbbtgat=1e+09 \text{ Vm}^{-1}$ Normalization field at the reference temperature for band-to-band tunneling of gate-edge component for source-bulk junction.
- 237 $stfbbtbot=-0.001 \text{ K}^{-1}$ Temperature scaling parameter for band-to-band tunneling of bottom component for source-bulk junction.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

238	<code>stfbbtsti=-0.001</code>	K^{-1}	Temperature scaling parameter for band-to-band tunneling of STI-edge component for source-bulk junction.
239	<code>stfbbtgat=-0.001</code>	K^{-1}	Temperature scaling parameter for band-to-band tunneling of gate-edge component for source-bulk junction.
240	<code>vbrbot=10</code>	V	Breakdown voltage of bottom component for source-bulk junction.
241	<code>vbrsti=10</code>	V	Breakdown voltage of STI-edge component for source-bulk junction.
242	<code>vbrgat=10</code>	V	Breakdown voltage of gate-edge component for source-bulk junction.
243	<code>pbrbot=4</code>	V	Breakdown onset tuning parameter of bottom component for source-bulk junction.
244	<code>pbrsti=4</code>	V	Breakdown onset tuning parameter of STI-edge component for source-bulk junction.
245	<code>pbrgat=4</code>	V	Breakdown onset tuning parameter of gate-edge component for source-bulk junction.
246	<code>cjorbotd=0.001</code>	Fm^{-2}	Zero-bias capacitance per unit-of-area of bottom component for drain-bulk junction.
247	<code>cjorstid=1e-09</code>	Fm^{-1}	Zero-bias capacitance per unit-of-length of STI-edge component for drain-bulk junction.
248	<code>cjorgatd=1e-09</code>	Fm^{-1}	Zero-bias capacitance per unit-of-length of gate-edge component for drain-bulk junction.
249	<code>vbirbotd=1</code>	V	Built-in voltage at the reference temperature of bottom component for drain-bulk junction.
250	<code>vbirstid=1</code>	V	Built-in voltage at the reference temperature of STI-edge component for drain-bulk junction.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

251	<code>vbirgatd=1 V</code>	Built-in voltage at the reference temperature of gate-edge component for drain-bulk junction.
252	<code>pbotd=0.5</code>	Grading coefficient of bottom component for drain-bulk junction.
253	<code>pstid=0.5</code>	Grading coefficient of STI-edge component for drain-bulk junction.
254	<code>pgatd=0.5</code>	Grading coefficient of gate-edge component for drain-bulk junction.
255	<code>phigbotd=1.16 V</code>	Zero-temperature bandgap voltage of bottom component for drain-bulk junction.
256	<code>phigstid=1.16 V</code>	Zero-temperature bandgap voltage of STI-edge component for drain-bulk junction.
257	<code>phiggatd=1.16 V</code>	Zero-temperature bandgap voltage of gate-edge component for drain-bulk junction.
258	<code>idsatrbotd=1e-12</code>	Am^{-2} Saturation current density at the reference temperature of bottom component for drain-bulk junction.
259	<code>idsatrstid=1e-18</code>	Am^{-1} Saturation current density at the reference temperature of STI-edge component for drain-bulk junction.
260	<code>idsatrgatd=1e-18</code>	Am^{-1} Saturation current density at the reference temperature of gate-edge component for drain-bulk junction.
261	<code>csrhhbotd=100</code>	Am^{-3} Shockley-Read-Hall prefactor of bottom component for drain-bulk junction.
262	<code>csrhistid=0.0001</code>	Am^{-2} Shockley-Read-Hall prefactor of STI-edge component for drain-bulk junction.
263	<code>csrhhgatd=0.0001</code>	Am^{-2} Shockley-Read-Hall prefactor of gate-edge component for drain-bulk junction.
264	<code>xjunstid=1e-07 m</code>	Junction depth of STI-edge component for drain-bulk junction.
265	<code>xjungatd=1e-07 m</code>	Junction depth of gate-edge component for drain-bulk junction.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

- 266 `ctatbotd=100` Am^{-3} Trap-assisted tunneling prefactor of bottom component for drain-bulk junction.
- 267 `ctatstid=0.0001` Am^{-2} Trap-assisted tunneling prefactor of STI-edge component for drain-bulk junction.
- 268 `ctatgatd=0.0001` Am^{-2} Trap-assisted tunneling prefactor of gate-edge component for drain-bulk junction.
- 269 `mefftatbotd=0.25` Effective mass (in units of m_0) for trap-assisted tunneling of bottom component for drain-bulk junction.
- 270 `mefftatstid=0.25` Effective mass (in units of m_0) for trap-assisted tunneling of STI-edge component for drain-bulk junction.
- 271 `mefftatgatd=0.25` Effective mass (in units of m_0) for trap-assisted tunneling of gate-edge component for drain-bulk junction.
- 272 `cbbtbotd=1e-12` AV^3 Band-to-band tunneling prefactor of bottom component for drain-bulk junction.
- 273 `cbbtstid=1e-18` AV^{-3}m Band-to-band tunneling prefactor of STI-edge component for drain-bulk junction.
- 274 `cbbtgatd=1e-18` AV^{-3}m Band-to-band tunneling prefactor of gate-edge component for drain-bulk junction.
- 275 `fbbtrbotd=1e+09` Vm^{-1} Normalization field at the reference temperature for band-to-band tunneling of bottom component for drain-bulk junction.
- 276 `fbbtrstid=1e+09` Vm^{-1} Normalization field at the reference temperature for band-to-band tunneling of STI-edge component for drain-bulk junction.
- 277 `fbbtrgatd=1e+09` Vm^{-1} Normalization field at the reference temperature for band-to-band tunneling of gate-edge component for drain-bulk junction.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

278	<code>stfbbtbotd=-0.001</code>	K^{-1}	Temperature scaling parameter for band-to-band tunneling of bottom component for drain-bulk junction.
279	<code>stfbbtstid=-0.001</code>	K^{-1}	Temperature scaling parameter for band-to-band tunneling of STI-edge component for drain-bulk junction.
280	<code>stfbbtgatd=-0.001</code>	K^{-1}	Temperature scaling parameter for band-to-band tunneling of gate-edge component for drain-bulk junction.
281	<code>vbrbotd=10</code>	V	Breakdown voltage of bottom component for drain-bulk junction.
282	<code>vbrstid=10</code>	V	Breakdown voltage of STI-edge component for drain-bulk junction.
283	<code>vbrgatd=10</code>	V	Breakdown voltage of gate-edge component for drain-bulk junction.
284	<code>pbrbotd=4</code>	V	Breakdown onset tuning parameter of bottom component for drain-bulk junction.
285	<code>pbrstid=4</code>	V	Breakdown onset tuning parameter of STI-edge component for drain-bulk junction.
286	<code>pbrgatd=4</code>	V	Breakdown onset tuning parameter of gate-edge component for drain-bulk junction.
287	<code>swjunexp=0</code>		Flag for JUNCAP-express; 0=full model, 1=express model.
288	<code>vjunref=2.5</code>		Typical maximum junction voltage; usually about 2*VSUP.
289	<code>fjunq=0.03</code>		Fraction below which junction capacitance components are considered negligible.
290	<code>vjunrefd=2.5</code>		Typical maximum drain-bulk junction voltage; usually about 2*VSUP.
291	<code>fjunqd=0.03</code>		Fraction below which drain-bulk junction capacitance components are considered negligible.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

292 `mbeo=0.0` DCmatch parameter.

293 `mvto=0.0` DCmatch parameter.

294 `tnom (C)` alias of `tnom`.

295 `tref (C)` alias of `tnom`.

Operating-Point Parameters

1 `ctype` Flag for channel type.

2 `sdint` Flag for source-drain interchange.

3 `weff (m)` Effective channel width for geometrical models.

4 `leff (m)` Effective channel length for geometrical models.

5 `ise (A)` Total source current.

6 `ige (A)` Total gate current.

7 `ide (A)` Total drain current.

8 `ibe (A)` Total bulk current.

9 `ids (A)` Drain current, excl. avalanche, tunnel, GISL, GIDL, and junction currents.

10 `idb (A)` Drain to bulk current.

11 `isb (A)` Source to bulk current.

12 `igs (A)` Gate-source tunneling current.

13 `igd (A)` Gate-drain tunneling current.

14 `igb (A)` Gate-bulk tunneling current.

15 `igcs (A)` Gate-channel tunneling current (source component).

16 `igcd (A)` Gate-channel tunneling current (drain component).

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

17	iavl (A)	Substrate current due to weak avalanche.
18	igisl (A)	Gate-induced source leakage current.
19	igidl (A)	Gate-induced drain leakage current.
20	ijs (A)	Total source junction current.
21	ijsbot (A)	Source junction current (bottom component).
22	ijsgat (A)	Source junction current (gate-edge component).
23	ijssti (A)	Source junction current (STI-edge component).
24	ijd (A)	Total drain junction current.
25	ijdbot (A)	Drain junction current (bottom component).
26	ijdgat (A)	Drain junction current (gate-edge component).
27	ijdsti (A)	Drain junction current (STI-edge component).
28	vds (V)	Drain-source voltage.
29	vgs (V)	Gate-source voltage.
30	vsb (V)	Source-bulk voltage.
31	vto (V)	Zero-bias threshold voltage.
32	vts (V)	Threshold voltage including back bias effects.
33	vth (V)	Threshold voltage including back bias and drain bias effects.
34	vgt (V)	Effective gate drive voltage including back bias and drain bias effects.
35	vdss (V)	Drain saturation voltage at actual bias.
36	vsat (V)	Saturation limit.
37	gm (1/Ω)	Transconductance.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

38	g_{mb} ($1/\Omega$)	Substrate transconductance.
39	g_{ds} ($1/\Omega$)	Output conductance.
40	g_{js} ($1/\Omega$)	Source junction conductance.
41	g_{jd} ($1/\Omega$)	Drain junction conductance.
42	c_{dd} (F)	Drain capacitance.
43	c_{dg} (F)	Drain-gate capacitance.
44	c_{ds} (F)	Drain-source capacitance.
45	c_{db} (F)	Drain-bulk capacitance.
46	c_{gd} (F)	Gate-drain capacitance.
47	c_{gg} (F)	Gate capacitance.
48	c_{gs} (F)	Gate-source capacitance.
49	c_{gb} (F)	Gate-bulk capacitance.
50	c_{sd} (F)	Source-drain capacitance.
51	c_{sg} (F)	Source-gate capacitance.
52	c_{ss} (F)	Source capacitance.
53	c_{sb} (F)	Source-bulk capacitance.
54	c_{bd} (F)	Bulk-drain capacitance.
55	c_{bg} (F)	Bulk-gate capacitance.
56	c_{bs} (F)	Bulk-source capacitance.
57	c_{bb} (F)	Bulk capacitance.
58	c_{gsol} (F)	Total gate-source overlap capacitance.
59	c_{gdol} (F)	Total gate-drain overlap capacitance.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

60	<code>cjs</code> (F)	Total source junction capacitance.
61	<code>cjsbot</code> (F)	Source junction capacitance (bottom component).
62	<code>cjsgat</code> (F)	Source junction capacitance (gate-edge component).
63	<code>cjssti</code> (F)	Source junction capacitance (STI-edge component).
64	<code>cjd</code> (F)	Total drain junction capacitance.
65	<code>cjdbot</code> (F)	Drain junction capacitance (bottom component).
66	<code>cjdgat</code> (F)	Drain junction capacitance (gate-edge component).
67	<code>cjdsti</code> (F)	Drain junction capacitance (STI-edge component).
68	<code>u</code>	Transistor gain.
69	<code>rout</code> (Ω)	Small-signal output resistance.
70	<code>vearly</code> (V)	Equivalent Early voltage.
71	<code>bef</code> (A/V^2)	Gain factor.
72	<code>fug</code> (Hz)	Unity gain frequency at actual bias.
73	<code>sfl</code> (A/Hz)	Flicker noise current density at 1 Hz.
74	<code>sqrtsff</code> ($V/\sqrt{\text{Hz}}$)	Input-referred RMS white noise voltage density at 1 kHz.
75	<code>sqrtsfw</code> ($V/\sqrt{\text{Hz}}$)	Input-referred RMS white noise voltage density.
76	<code>sid</code> (A^2/Hz)	White noise current density.
77	<code>sig</code> (A^2/Hz)	Induced gate noise current density at 1 Hz.
78	<code>cigid</code>	Imaginary part of correlation coefficient between Sig and Sid.
79	<code>fknee</code> (Hz)	Cross-over frequency above which white noise is dominant.
80	<code>sig</code> (A^2/Hz)	Gate-source current noise spectral density.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

81	sigd (A ² /Hz)	Gate-drain current noise spectral density.
82	siavl (A ² /Hz)	Impact ionization current noise spectral density.
83	ssi (A ² /Hz)	Total source junction current noise spectral density.
84	sdi (A ² /Hz)	Total drain junction current noise spectral density.
85	lv2 (m)	alias of weff.
86	lv1 (m)	alias of leff.
87	lx4 (A)	alias of ids.
88	lx3 (V)	alias of vds.
89	lx2 (V)	alias of vgs.
90	lv9 (V)	alias of vth.
91	lx7 (1/Ω)	alias of gm.
92	lx8 (1/Ω)	alias of gds.
93	lx9 (1/Ω)	alias of gmb.
94	lx33 (F)	alias of cdd.
95	lx32 (F)	alias of cdg.
96	lx34 (F)	alias of cds.
97	lx19 (F)	alias of cgd.
98	lx18 (F)	alias of cgg.
99	lx20 (F)	alias of cgs.
100	lx22 (F)	alias of cbd.
101	lx21 (F)	alias of cbg.
102	lx23 (F)	alias of cbs.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

103	lv10 (V)	alias of vdss.
104	lx5 (A)	alias of ijs.
105	lx6 (A)	alias of ijd.
106	lx28 (F)	alias of cjs.
107	lx29 (F)	alias of cjd.
108	table_ids (A)	Current.
109	table_vth (V)	Threshold voltage including back-bias and drain-bias effects.
110	table_qg (Coul)	Charge at g node.
111	table_qd (Coul)	Charge at d node.
112	table_qb (Coul)	Charge at b node.
113	table_id (A)	Current.
114	table_isub (A)	Current.
115	table_ibs (A)	Current.
116	table_ibd (A)	Current.
117	table_igd (A)	Current.
118	table_igb (A)	Current.
119	table_igs (A)	Current.
120	table_gds (1/Ω)	conductance.
121	table_gm (1/Ω)	transconductance.
122	table_gmbs (A)	transconductance.
123	table_qbs (Coul)	charge.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

124	<code>table_qbd</code>	(Coul)	charge.
125	<code>table_vdsat</code>	(V)	saturation voltage.
126	<code>table_leff</code>	(m)	Effective channel length.
127	<code>table_weff</code>	(m)	Effective channel width.
128	<code>table_aseff</code>	(m ²)	Bottom area of source junction.
129	<code>table_adeff</code>	(m ²)	Bottom area of drain junction.
130	<code>table_pseff</code>	(m)	Perimeter of source junction.
131	<code>table_pdeff</code>	(m)	Perimeter of drain junction.

PSP MOSFET Model (psp1021)

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 `d g s b` ModelName parameter=value ...

Instance Parameters

1	<code>l=1e-05</code>	m	Design length.
2	<code>w=1e-05</code>	m	Design width.
3	<code>sa=0</code>	m	Distance between OD-edge and poly from one side.
4	<code>sb=0</code>	m	Distance between OD-edge and poly from other side.
5	<code>sd=0</code>	m	Distance between neighbouring fingers.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

6	sca=0	Integral of the first distribution function for scattered well dopants.
7	scb=0	Integral of the second distribution function for scattered well dopants.
8	scc=0	Integral of the third distribution function for scattered well dopants.
9	sc=0 m	Distance between OD-edge and nearest well edge.
10	delvto=0 V	Threshold voltage shift parameter.
11	factuo=1	Zero-field mobility pre-factor.
12	absource=1e-12 m ²	Bottom area of source junction.
13	lssource=1e-06 m	STI-edge length of source junction.
14	lgsource=1e-06 m	Gate-edge length of source junction.
15	abdRAIN=1e-12 m ²	Bottom area of drain junction.
16	lsdRAIN=1e-06 m	STI-edge length of drain junction.
17	lgdRAIN=1e-06 m	Gate-edge length of drain junction.
18	as=1e-12 m ²	Bottom area of source junction.
19	ps=1e-06 m	Perimeter of source junction.
20	ad=1e-12 m ²	Bottom area of drain junction.
21	pd=1e-06 m	Perimeter of drain junction.
22	mult=1	Number of devices in parallel.
23	nf=1	Number of fingers.
24	ngcon=1	Number of gate contacts.
25	xgw=1e-07 m	Distance from the gate contact to the channel edge.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

26	<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> , <code>subth</code> , <code>rev</code> , <code>fwd</code> , or <code>brk</code> .
27	<code>m=1</code>	Multiplicity factor.
28	<code>trise=0</code>	Temperature rise from ambient.
29	<code>area=1</code>	alias of <code>mult</code> .

Model Definition

```
model modelName psp1021 parameter=value ...
```

Model Parameters

1	<code>level=1.02e+03</code>	Model level.
2	<code>type=n</code>	Channel type parameter, +1=NMOS -1=PMOS. 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> .
3	<code>tr=21 C</code>	nominal (reference) temperature.
4	<code>swigate=0</code>	Flag for gate current, 0=turn off IG.
5	<code>swimpact=0</code>	Flag for impact ionization current, 0=turn off II.
6	<code>swgidl=0</code>	Flag for GIDL current, 0=turn off IGIDL.
7	<code>swjuncap=0</code>	Flag for juncap, 0=turn off juncap.
8	<code>swjunasym=0</code>	Flag for asymmetric junctions; 0=symmetric, 1=asymmetric.
9	<code>qmc=1</code>	Quantum-mechanical correction factor.
10	<code>lvaro=0 m</code>	Geometry independent difference between actual and programmed poly-silicon gate length.
11	<code>lvarl=0</code>	Length dependence of difference between actual and programmed poly-silicon gate length.
12	<code>lap=0 m</code>	Effective channel length reduction per side due to lateral diffusion of source/drain dopant ions.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

13	$wvaro=0$ m	Geometry independent difference between actual and programmed field-oxide opening.
14	$wvarw=0$	Width dependence of difference between actual and programmed field-oxide opening.
15	$wot=0$ m	Effective reduction of channel width per side due to lateral diffusion of channel-stop dopant ions.
16	$dlq=0$ m	Effective channel length reduction for CV.
17	$dwq=0$ m	Effective channel width reduction for CV.
18	$povfb=-1$ V	Coefficient for the geometry independent part of VFB.
19	$plvfb=0$ V	Coefficient for the length dependence of VFB.
10	$pwvfb=0$ V	Coefficient for the width dependence of VFB.
21	$plwvfb=0$ V	Coefficient for the length times width dependence of VFB.
22	$postvfb=0.0005$ V/K	Coefficient for the geometry independent part of STVFB.
23	$plstvfb=0$ V/K	Coefficient for the length dependence of STVFB.
24	$pwstvfb=0$ V/K	Coefficient for the width dependence of STVFB.
25	$plwstvfb=0$ V/K	Coefficient for the length times width dependence of STVFB.
26	$potox=2e-09$ m	Coefficient for the geometry independent part of TOX.
27	$poepsrox=3.9$	Coefficient for the geometry independent part of EPSOX.
28	$poneff=5e+23$ m ⁻³	Coefficient for the geometry independent part of NEFF.
29	$plneff=0$ m ⁻³	Coefficient for the length dependence of NEFF.
30	$pwneff=0$ m ⁻³	Coefficient for the width dependence of NEFF.
31	$plwneff=0$ m ⁻³	Coefficient for the length times width dependence of NEFF.
32	$povnsb=0$ V	Coefficient for the geometry independent part of VNSUB.

Virtuoso Simulator Components and Device Models Reference
PSP Model (psp)

33	$p_{onslp}=0.05 \text{ V}$	Coefficient for the geometry independent part of NSLP.
34	$p_{odnsub}=0 \text{ V}^{-1}$	Coefficient for the geometry independent part of DNSUB.
35	$p_{odphib}=0 \text{ V}$	Coefficient for the geometry independent part of DPHIB.
36	$p_{ldphib}=0 \text{ V}$	Coefficient for the length dependence of DPHIB.
37	$p_{wdphib}=0 \text{ V}$	Coefficient for the width dependence of DPHIB.
38	$p_{lwdphib}=0 \text{ V}$	Coefficient for the length times width dependence of DPHIB.
39	$p_{onp}=1e+26 \text{ m}^{-3}$	Coefficient for the geometry independent part of NP.
40	$p_{lnp}=0 \text{ m}^{-3}$	Coefficient for the length dependence of NP.
41	$p_{wnp}=0 \text{ m}^{-3}$	Coefficient for the width dependence of NP.
42	$p_{lwnp}=0 \text{ m}^{-3}$	Coefficient for the length times width dependence of NP.
43	$p_{oct}=0$	Coefficient for the geometry independent part of CT.
44	$p_{lct}=0$	Coefficient for the length dependence of CT.
45	$p_{wct}=0$	Coefficient for the width dependence of CT.
46	$p_{lwct}=0$	Coefficient for the length times width dependence of CT.
47	$p_{otoxov}=2e-09 \text{ m}$	Coefficient for the geometry independent part of TOXOV.
48	$p_{otoxovd}=2e-09 \text{ m}$	Coefficient for the geometry independent part of TOXOV for drain side.
49	$p_{onov}=5e+25 \text{ m}^{-3}$	Coefficient for the geometry independent part of NOV.
50	$p_{lnov}=0 \text{ m}^{-3}$	Coefficient for the length dependence of NOV.
51	$p_{wnov}=0 \text{ m}^{-3}$	Coefficient for the width dependence of NOV.
52	$p_{lwnov}=0 \text{ m}^{-3}$	Coefficient for the length times width dependence of NOV.
53	$p_{onovd}=5e+25 \text{ m}^{-3}$	Coefficient for the geometry independent part of NOV for drain side.

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PSP Model (psp)

54	$p_{lnovd}=0 \text{ m}^{-3}$	Coefficient for the length dependence of NOV for drain side.
55	$p_{wnovd}=0 \text{ m}^{-3}$	Coefficient for the width dependence of NOV for drain side.
56	$p_{lwnovd}=0 \text{ m}^{-3}$	Coefficient for the length times width dependence of NOV for drain side.
57	$p_{ocf}=0 \text{ V}^{-1}$	Coefficient for the geometry independent part of CF.
58	$p_{lcf}=0 \text{ V}^{-1}$	Coefficient for the length dependence of CF.
59	$p_{wcf}=0 \text{ V}^{-1}$	Coefficient for the width dependence of CF.
60	$p_{lwcf}=0 \text{ V}^{-1}$	Coefficient for the length times width dependence of CF.
61	$p_{ocfb}=0 \text{ V}^{-1}$	Coefficient for the geometry independent part of CFB.
62	$p_{obetn}=0.07 \text{ m}^2/\text{V}/\text{s}$	Coefficient for the geometry independent part of BETN.
63	$p_{lbetn}=0 \text{ m}^2/\text{V}/\text{s}$	Coefficient for the length dependence of BETN.
64	$p_{wbetn}=0 \text{ m}^2/\text{V}/\text{s}$	Coefficient for the width dependence of BETN.
65	$p_{lwbetn}=0 \text{ m}^2/\text{V}/\text{s}$	Coefficient for the length times width dependence of BETN.
66	$p_{ostbet}=1$	Coefficient for the geometry independent part of STBET.
67	$p_{lstbet}=0$	Coefficient for the length dependence of STBET.
68	$p_{wstbet}=0$	Coefficient for the width dependence of STBET.
69	$p_{lwestbet}=0$	Coefficient for the length times width dependence of STBET.
70	$p_{omue}=0.5 \text{ m}/\text{V}$	Coefficient for the geometry independent part of MUE.
71	$p_{lmue}=0 \text{ m}/\text{V}$	Coefficient for the length dependence of MUE.
72	$p_{wmue}=0 \text{ m}/\text{V}$	Coefficient for the width dependence of MUE.
73	$p_{lwmue}=0 \text{ m}/\text{V}$	Coefficient for the length times width dependence of MUE.
74	$p_{ostmue}=0$	Coefficient for the geometry independent part of STMUE.

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PSP Model (psp)

75	<code>pothemu=1.5</code>	Coefficient for the geometry independent part of THEMU.
76	<code>postthemu=1.5</code>	Coefficient for the geometry independent part of STTHEMU.
77	<code>pocs=0</code>	Coefficient for the geometry independent part of CS.
78	<code>plcs=0</code>	Coefficient for the length dependence of CS.
79	<code>pwcs=0</code>	Coefficient for the width dependence of CS.
80	<code>plwcs=0</code>	Coefficient for the length times width dependence of CS.
81	<code>postcs=0</code>	Coefficient for the geometry independent part of STCS.
82	<code>poxcor=0 V⁻¹</code>	Coefficient for the geometry independent part of XCOR.
83	<code>plxcor=0 V⁻¹</code>	Coefficient for the length dependence of XCOR.
84	<code>pwxcor=0 V⁻¹</code>	Coefficient for the width dependence of XCOR.
85	<code>plwxcor=0 V⁻¹</code>	Coefficient for the length times width dependence of XCOR.
86	<code>postxcor=0</code>	Coefficient for the geometry independent part of STXCOR.
87	<code>pofeta=1</code>	Coefficient for the geometry independent part of FETA.
88	<code>pors=30 Ω</code>	Coefficient for the geometry independent part of RS.
89	<code>plrs=0 Ω</code>	Coefficient for the length dependence of RS.
90	<code>pwr=0 Ω</code>	Coefficient for the width dependence of RS.
91	<code>plwrs=0 Ω</code>	Coefficient for the length times width dependence of RS.
92	<code>postrs=1</code>	Coefficient for the geometry independent part of STRS.
93	<code>porsb=0 V⁻¹</code>	Coefficient for the geometry independent part of RSB.
94	<code>porsg=0 V⁻¹</code>	Coefficient for the geometry independent part of RSG.
95	<code>pothesat=1 V⁻¹</code>	Coefficient for the geometry independent part of THESAT.
96	<code>plthesat=0 V⁻¹</code>	Coefficient for the length dependence of THESAT.

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PSP Model (psp)

97	$p_{wthesat}=0 \ V^{-1}$	Coefficient for the width dependence of THESAT.
98	$p_{lwthesat}=0 \ V^{-1}$	Coefficient for the length times width dependence of THESAT.
99	$p_{ostthesat}=1$	Coefficient for the geometry independent part of STTHESAT.
100	$p_{lstthesat}=0$	Coefficient for the length dependence of STTHESAT.
101	$p_{wstthesat}=0$	Coefficient for the width dependence of STTHESAT.
102	$p_{lwstthesat}=0$	Coefficient for the length times width dependence of STTHESAT.
103	$p_{othesatb}=0 \ V^{-1}$	Coefficient for the geometry independent part of THESATB.
104	$p_{lthesatb}=0 \ V^{-1}$	Coefficient for the length dependence of THESATB.
105	$p_{wthesatb}=0 \ V^{-1}$	Coefficient for the width dependence of THESATB.
106	$p_{lwthesatb}=0 \ V^{-1}$	Coefficient for the length times width dependence of THESATB.
107	$p_{othesatg}=0 \ V^{-1}$	Coefficient for the geometry independent part of THESATG.
108	$p_{lthesatg}=0 \ V^{-1}$	Coefficient for the length dependence of THESATG.
109	$p_{wthesatg}=0 \ V^{-1}$	Coefficient for the width dependence of THESATG.
110	$p_{lwthesatg}=0 \ V^{-1}$	Coefficient for the length times width dependence of THESATG.
111	$p_{oax}=3$	Coefficient for the geometry independent part of AX.
112	$p_{lax}=0$	Coefficient for the length dependence of AX.
113	$p_{wax}=0$	Coefficient for the width dependence of AX.
114	$p_{lwax}=0$	Coefficient for the length times width dependence of AX.
115	$p_{oalp}=0.01$	Coefficient for the geometry independent part of ALP.
116	$p_{lalp}=0$	Coefficient for the length dependence of ALP.
117	$p_{walp}=0$	Coefficient for the width dependence of ALP.
118	$p_{lwalp}=0$	Coefficient for the length times width dependence of ALP.

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PSP Model (psp)

119	$poalp1=0$	V	Coefficient for the geometry independent part of ALP1.
120	$plalp1=0$	V	Coefficient for the length dependence of ALP1.
121	$pwalp1=0$	V	Coefficient for the width dependence of ALP1.
122	$plwalp1=0$	V	Coefficient for the length times width dependence of ALP1.
123	$poalp2=0$	V^{-1}	Coefficient for the geometry independent part of ALP2.
124	$plalp2=0$	V^{-1}	Coefficient for the length dependence of ALP2.
125	$pwalp2=0$	V^{-1}	Coefficient for the width dependence of ALP2.
126	$plwalp2=0$	V^{-1}	Coefficient for the length times width dependence of ALP2.
127	$povp=0.05$	V	Coefficient for the geometry independent part of VP.
128	$poa1=1$		Coefficient for the geometry independent part of A1.
129	$pla1=0$		Coefficient for the length dependence of A1.
130	$pwa1=0$		Coefficient for the width dependence of A1.
131	$plwa1=0$		Coefficient for the length times width dependence of A1.
132	$poa2=10$	V	Coefficient for the geometry independent part of A2.
132	$posta2=0$	V	Coefficient for the geometry independent part of STA2.
133	$poa3=1$		Coefficient for the geometry independent part of A3.
134	$pla3=0$		Coefficient for the length dependence of A3.
136	$pwa3=0$		Coefficient for the width dependence of A3.
137	$plwa3=0$		Coefficient for the length times width dependence of A3.
138	$poa4=0$	$V^{-0.5}$	Coefficient for the geometry independent part of A4.
139	$pla4=0$	$V^{-0.5}$	Coefficient for the length dependence of A4.
140	$pwa4=0$	$V^{-0.5}$	Coefficient for the width dependence of A4.

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PSP Model (psp)

141	$p_{lwa4}=0$	$V^{-0.5}$	Coefficient for the length times width dependence of A4.
142	$p_{ogco}=0$		Coefficient for the geometry independent part of GCO.
143	$p_{oiginv}=0$	A	Coefficient for the geometry independent part of IGINV.
144	$p_{liginv}=0$	A	Coefficient for the length dependence of IGINV.
145	$p_{wiginv}=0$	A	Coefficient for the width dependence of IGINV.
146	$p_{lwiginv}=0$	A	Coefficient for the length times width dependence of IGINV.
147	$p_{oigov}=0$	A	Coefficient for the geometry independent part of IGOV.
148	$p_{ligov}=0$	A	Coefficient for the length dependence of IGOV.
149	$p_{wigov}=0$	A	Coefficient for the width dependence of IGOV.
150	$p_{lwigov}=0$	A	Coefficient for the length times width dependence of IGOV.
151	$p_{oigovd}=0$	A	Coefficient for the geometry independent part of IGOV for drain side.
152	$p_{ligovd}=0$	A	Coefficient for the length dependence of IGOV for drain side.
153	$p_{wigovd}=0$	A	Coefficient for the width dependence of IGOV for drain side.
154	$p_{lwigovd}=0$	A	Coefficient for the length times width dependence of IGOV for drain side.
155	$p_{ostig}=2$		Coefficient for the geometry independent part of STIG.
156	$p_{ogc2}=0.375$		Coefficient for the geometry independent part of GC2.
157	$p_{ogc3}=0.063$		Coefficient for the geometry independent part of GC3.
158	$p_{ochib}=3.1$	V	Coefficient for the geometry independent part of CHIB.
159	$p_{oagidl}=0$	A/V^3	Coefficient for the geometry independent part of AGIDL.
160	$p_{lagidl}=0$	A/V^3	Coefficient for the length dependence of AGIDL.
161	$p_{wagidl}=0$	A/V^3	Coefficient for the width dependence of AGIDL.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

162	$plwagidl=0$	A/V^3	Coefficient for the length times width dependence of AGIDL.
163	$poagidld=0$	A/V^3	Coefficient for the geometry independent part of AGIDL for drain side.
164	$plagidld=0$	A/V^3	Coefficient for the length dependence of AGIDL for drain side.
165	$pwagidld=0$	A/V^3	Coefficient for the width dependence of AGIDL for drain side.
166	$plwagidld=0$	A/V^3	Coefficient for the length times width dependence of AGIDL for drain side.
167	$pobgidl=41$	V	Coefficient for the geometry independent part of BGIDL.
168	$pobgidld=41$	V	Coefficient for the geometry independent part of BGIDL for drain side.
169	$postbgidl=0$	V/K	Coefficient for the geometry independent part of STBGIDL.
170	$postbgidld=0$	V/K	Coefficient for the geometry independent part of STBGIDL for drain
171	$pocgidl=0$		Coefficient for the geometry independent part of CGIDL.
172	$pocgidld=0$		Coefficient for the geometry independent part of CGIDL for drain side.
173	$pocox=1e-14$	F	Coefficient for the geometry independent part of COX.
174	$plcox=0$	F	Coefficient for the length dependence of COX.
175	$pwcox=0$	F	Coefficient for the width dependence of COX.
176	$plwcox=0$	F	Coefficient for the length times width dependence of COX.
177	$pocgov=1e-15$	F	Coefficient for the geometry independent part of CGOV.
178	$plcgov=0$	F	Coefficient for the length dependence of CGOV.
179	$pwcgov=0$	F	Coefficient for the width dependence of CGOV.
180	$plwcgov=0$	F	Coefficient for the length times width dependence of CGOV.

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PSP Model (psp)

181	<code>pocgovd=1e-15</code>	F	Coefficient for the geometry independent part of CGOV for drain side.
182	<code>plcgovd=0</code>	F	Coefficient for the length dependence of CGOV for drain side.
183	<code>pwcgovd=0</code>	F	Coefficient for the width dependence of CGOV for drain side.
184	<code>plwcgovd=0</code>	F	Coefficient for the length times width dependence of CGOV for drainside.
185	<code>pocgbov=0</code>	F	Coefficient for the geometry independent part of CGBOV.
186	<code>plcgbov=0</code>	F	Coefficient for the length dependence of CGBOV.
187	<code>pwcgbov=0</code>	F	Coefficient for the width dependence of CGBOV.
188	<code>plwcbgv=0</code>	F	Coefficient for the length times width dependence of CGBOV.
189	<code>pocfr=0</code>	F	Coefficient for the geometry independent part of CFR.
190	<code>plcfr=0</code>	F	Coefficient for the length dependence of CFR.
191	<code>pwcfr=0</code>	F	Coefficient for the width dependence of CFR.
192	<code>plwcf=0</code>	F	Coefficient for the length times width dependence of CFR.
193	<code>pocfrd=0</code>	F	Coefficient for the geometry independent part of CFR for drain side.
194	<code>plcfrd=0</code>	F	Coefficient for the length dependence of CFR for drain side.
195	<code>pwcf=0</code>	F	Coefficient for the width dependence of CFR for drain side.
196	<code>plwcf=0</code>	F	Coefficient for the length times width dependence of CFR for drainside.
197	<code>pofnt=1</code>		Coefficient for the geometry independent part of FNT.
198	<code>ponfa=8e+22</code>	V^{-1}/m^4	Coefficient for the geometry independent part of NFA.
199	<code>plnfa=0</code>	V^{-1}/m^4	Coefficient for the length dependence of NFA.

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PSP Model (psp)

200	$pwnfa=0 \text{ V}^{-1}/\text{m}^4$	Coefficient for the width dependence of NFA.
201	$plwnfa=0 \text{ V}^{-1}/\text{m}^4$	Coefficient for the length times width dependence of NFA.
202	$ponfb=3e+07 \text{ V}^{-1}/\text{m}^2$	Coefficient for the geometry independent part of NFB.
203	$plnfb=0 \text{ V}^{-1}/\text{m}^2$	Coefficient for the length dependence of NFB.
204	$pwnfb=0 \text{ V}^{-1}/\text{m}^2$	Coefficient for the width dependence of NFB.
205	$plwnfb=0 \text{ V}^{-1}/\text{m}^2$	Coefficient for the length times width dependence of NFB.
206	$ponfc=0 \text{ V}^{-1}$	Coefficient for the geometry independent part of NFC.
207	$plnfc=0 \text{ V}^{-1}$	Coefficient for the length dependence of NFC.
208	$pwnfc=0 \text{ V}^{-1}$	Coefficient for the width dependence of NFC.
209	$plwnfc=0 \text{ V}^{-1}$	Coefficient for the length times width dependence of NFC.
210	$poef=1$	Coefficient for the flicker noise frequency exponent.
211	$dta=0 \text{ K}$	Temperature offset w.r.t. ambient temperature.
212	$pokvthowe=0$	Coefficient for the geometry independent part of KVTHOWE.
213	$plkvthowe=0$	Coefficient for the length dependence part of KVTHOWE.
214	$pwkvthowe=0$	Coefficient for the width dependence part of KVTHOWE.
215	$plwkvthowe=0$	Coefficient for the length times width dependence part of KVTHOWE.
216	$pokuowe=0$	Coefficient for the geometry independent part of KUOWE.
217	$plkuowe=0$	Coefficient for the length dependence part of KUOWE.
218	$pwkuowe=0$	Coefficient for the width dependence part of KUOWE.
219	$plwkuowe=0$	Coefficient for the length times width dependence part of KUOWE.

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PSP Model (psp)

220	$l_{min}=0$ m	Dummy parameter to label binning set.
221	$l_{max}=1$ m	Dummy parameter to label binning set.
222	$w_{min}=0$ m	Dummy parameter to label binning set.
223	$w_{max}=1$ m	Dummy parameter to label binning set.
224	$r_{go}=0$ Ω	Gate resistance.
225	$r_{bulko}=0$ Ω	Bulk resistance between node BP and BI.
226	$r_{wello}=0$ Ω	Well resistance between node BI and B.
227	$r_{junso}=0$ Ω	Source-side bulk resistance between node BI and BS.
228	$r_{jundo}=0$ Ω	Drain-side bulk resistance between node BI and BD.
229	$r_{int}=0$ Ω/Sqr	Contact resistance between silicide and poly.
230	$r_{vpoly}=0$ Ω/Sqr	Vertical poly resistance.
231	$r_{shg}=0$ Ω/Sqr	Gate electrode diffusion sheet resistance.
232	$d_{lsil}=0$ m	Silicide extension over the physical gate length.
233	$s_{aref}=1e-06$ m	Reference distance between OD-edge and poly from one side.
234	$s_{bref}=1e-06$ m	Reference distance between OD-edge and poly from other side.
235	$w_{lod}=0$ m	Width parameter.
236	$k_{uo}=0$ m	Mobility degradation/enhancement coefficient.
237	$k_{vsat}=0$ m	Saturation velocity degradation/enhancement coefficient.
238	$t_{kuo}=0$	Temperature dependence of KUO.
239	$l_{kuo}=0$ m ^{LLODKUO}	Length dependence of KUO.
240	$w_{kuo}=0$ m ^{WLODKUO}	Width dependence of KUO.

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PSP Model (psp)

241	$p_{kuo}=0 \text{ m}^{(LLODKUO+WLODKUO)}$	Cross-term dependence of KUO.
242	$l_{lodkuo}=0$	Length parameter for UO stress effect.
243	$w_{lodkuo}=0$	Width parameter for UO stress effect.
244	$k_{vtho}=0 \text{ V}_m$	Threshold shift parameter.
245	$l_{kvtho}=0 \text{ m}^{LLODVTH}$	Length dependence of KVTHO.
246	$w_{kvtho}=0 \text{ m}^{WLODVTH}$	Width dependence of KVTHO.
247	$p_{kvtho}=0 \text{ m}^{(LLODVTH+WLODVTH)}$	Cross-term dependence of KVTHO.
248	$l_{lodvth}=0$	Length parameter for VTH-stress effect.
249	$w_{lodvth}=0$	Width parameter for VTH-stress effect.
250	$s_{etao}=0 \text{ m}$	η_0 shift factor related to VTHO change.
251	$l_{odetao}=1$	η_0 shift modification factor for stress effect.
252	$s_{cref}=1e-05 \text{ m}$	Distance between OD-edge and well edge of a reference device.
253	$w_{eb}=0$	Coefficient for SCB.
254	$w_{ec}=0$	Coefficient for SCC.
255	$t_{rj}=21 \text{ C}$	reference temperature.
256	$i_{max}=1e+03 \text{ A}$	Maximum current up to which forward current behaves exponentially.
257	$c_{jorbot}=0.001 \text{ Fm}^{-2}$	Zero-bias capacitance per unit-of-area of bottom component.
258	$c_{jorsti}=1e-09 \text{ Fm}^{-1}$	Zero-bias capacitance per unit-of-length of STI-edge component.

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PSP Model (psp)

259	$cjorgat=1e-09$	Fm^{-1}	Zero-bias capacitance per unit-of-length of gate-edge component.
260	$vbirbot=1$	V	Built-in voltage at the reference temperature of bottom component.
261	$vbirsti=1$	V	Built-in voltage at the reference temperature of STI-edge component.
262	$vbirgat=1$	V	Built-in voltage at the reference temperature of gate-edge component.
263	$pbot=0.5$		Grading coefficient of bottom component.
264	$psti=0.5$		Grading coefficient of STI-edge component.
265	$pgat=0.5$		Grading coefficient of gate-edge component.
266	$phigbot=1.16$	V	Zero-temperature bandgap voltage of bottom component.
267	$phigsti=1.16$	V	Zero-temperature bandgap voltage of STI-edge component.
268	$phiggat=1.16$	V	Zero-temperature bandgap voltage of gate-edge component.
269	$idsatrbot=1e-12$	Am^{-2}	Saturation current density at the reference temperature of bottom component.
270	$idsatrsti=1e-18$	Am^{-1}	Saturation current density at the reference temperature of STI-edge component.
271	$idsatrgat=1e-18$	Am^{-1}	Saturation current density at the reference temperature of gate-edge component.
272	$csrhibot=100$	Am^{-3}	Shockley-Read-Hall prefactor of bottom component.
273	$csrhisti=0.0001$	Am^{-2}	Shockley-Read-Hall prefactor of STI-edge component.

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PSP Model (psp)

- 274 $\text{csrhtagat}=0.0001 \text{ Am}^{-2}$ Shockley-Read-Hall prefactor of gate-edge component.
- 275 $\text{xjunsti}=1\text{e-}07 \text{ m}$ Junction depth of STI-edge component.
- 276 $\text{xjngat}=1\text{e-}07 \text{ m}$ Junction depth of gate-edge component.
- 277 $\text{ctatbot}=100 \text{ Am}^{-3}$ Trap-assisted tunneling prefactor of bottom component.
- 278 $\text{ctatsti}=0.0001 \text{ Am}^{-2}$ Trap-assisted tunneling prefactor of STI-edge component.
- 279 $\text{ctatgat}=0.0001 \text{ Am}^{-2}$ Trap-assisted tunneling prefactor of gate-edge component.
- 280 $\text{mefftatbot}=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of bottom component.
- 281 $\text{mefftatsti}=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of STI-edge component.
- 282 $\text{mefftatgat}=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of gate-edge component.
- 283 $\text{cbbtbot}=1\text{e-}12 \text{ AV}^{-3}$ Band-to-band tunneling prefactor of bottom component.
- 284 $\text{cbbtsti}=1\text{e-}18 \text{ AV}^{-3}_m$ Band-to-band tunneling prefactor of STI-edge component.
- 285 $\text{cbbtgat}=1\text{e-}18 \text{ AV}^{-3}_m$ Band-to-band tunneling prefactor of gate-edge component.
- 286 $\text{fbbtrbot}=1\text{e+}09 \text{ Vm}^{-1}$ Normalization field at the reference temperature for band-to-band tunneling of bottom component.
- 287 $\text{fbbtrsti}=1\text{e+}09 \text{ Vm}^{-1}$ Normalization field at the reference temperature for band-to-band tunneling of STI-edge component.

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PSP Model (psp)

288	<code>fbttrgat=1e+09</code>	V m^{-1}	Normalization field at the reference temperature for band-to-band tunneling of gate-edge component.
289	<code>stfbbtbot=-0.001</code>	K^{-1}	Temperature scaling parameter for band-to-band tunneling of bottom component.
290	<code>stfbbtsti=-0.001</code>	K^{-1}	Temperature scaling parameter for band-to-band tunneling of STI-edge component.
291	<code>stfbbtgat=-0.001</code>	K^{-1}	Temperature scaling parameter for band-to-band tunneling of gate-edge component.
292	<code>vbrbot=10</code>	V	Breakdown voltage of bottom component.
293	<code>vbrsti=10</code>	V	Breakdown voltage of STI-edge component.
294	<code>vbrgat=10</code>	V	Breakdown voltage of gate-edge component.
295	<code>pbrbot=4</code>	V	Breakdown onset tuning parameter of bottom component.
296	<code>pbrsti=4</code>	V	Breakdown onset tuning parameter of STI-edge component.
297	<code>pbrgat=4</code>	V	Breakdown onset tuning parameter of gate-edge component.
298	<code>cjorbotd=0.001</code>	F m^{-2}	Zero-bias capacitance per unit-of-area of bottom component for drain-bulk junction.
299	<code>cjorstid=1e-09</code>	F m^{-1}	Zero-bias capacitance per unit-of-length of STI-edge component for drain-bulk junction.
300	<code>cjorgatd=1e-09</code>	F m^{-1}	Zero-bias capacitance per unit-of-length of gate-edge component for drain-bulk junction.
301	<code>vbirbotd=1</code>	V	Built-in voltage at the reference temperature of bottom component for drain-bulk junction.

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PSP Model (psp)

302	<code>vbirstid=1</code>	V	Built-in voltage at the reference temperature of STI-edge component for drain-bulk junction.
303	<code>vbirgatd=1</code>	V	Built-in voltage at the reference temperature of gate-edge component for drain-bulk junction.
304	<code>pbotd=0.5</code>		Grading coefficient of bottom component for drain-bulk junction.
305	<code>pstid=0.5</code>		Grading coefficient of STI-edge component for drain-bulk junction.
306	<code>pgatd=0.5</code>		Grading coefficient of gate-edge component for drain-bulk junction.
307	<code>phigbotd=1.16</code>	V	Zero-temperature bandgap voltage of bottom component for drain-bulk junction.
308	<code>phigstid=1.16</code>	V	Zero-temperature bandgap voltage of STI-edge component for drain-bulk junction.
309	<code>phiggatd=1.16</code>	V	Zero-temperature bandgap voltage of gate-edge component for drain-bulk junction.
310	<code>idsatrbotd=1e-12</code>	Am^{-2}	Saturation current density at the reference temperature of bottom component for drain-bulk junction.
311	<code>idsatrstid=1e-18</code>	Am^{-1}	Saturation current density at the reference temperature of STI-edge component for drain-bulk junction.
312	<code>idsatrgatd=1e-18</code>	Am^{-1}	Saturation current density at the reference temperature of gate-edge component for drain-bulk junction.
313	<code>csrhibotd=100</code>	Am^{-3}	Shockley-Read-Hall prefactor of bottom component for drain-bulk junction.
314	<code>csrhistid=0.0001</code>	Am^{-2}	Shockley-Read-Hall prefactor of STI-edge component for drain-bulk junction.
315	<code>csrhgatd=0.0001</code>	Am^{-2}	Shockley-Read-Hall prefactor of gate-edge component for drain-bulk junction.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

- 316 `xjunstid=1e-07` m Junction depth of STI-edge component for drain-bulk junction.
- 317 `xjungatd=1e-07` m Junction depth of gate-edge component for drain-bulk junction.
- 318 `ctatbotd=100` Am^{-3} Trap-assisted tunneling prefactor of bottom component for drain-bulk junction.
- 319 `ctatstid=0.0001` Am^{-2} Trap-assisted tunneling prefactor of STI-edge component for drain-bulk junction.
- 320 `ctatgatd=0.0001` Am^{-2} Trap-assisted tunneling prefactor of gate-edge component for drain-bulk junction.
- 321 `mefftatbotd=0.25` Effective mass (in units of m_0) for trap-assisted tunneling of bottom component for drain-bulk junction.
- 322 `mefftatstid=0.25` Effective mass (in units of m_0) for trap-assisted tunneling of STI-edge component for drain-bulk junction.
- 323 `mefftatgatd=0.25` Effective mass (in units of m_0) for trap-assisted tunneling of gate-edge component for drain-bulk junction.
- 324 `cbbtbotd=1e-12` AV^3 Band-to-band tunneling prefactor of bottom component for drain-bulk junction.
- 325 `cbbtstid=1e-18` AV^{-3}m Band-to-band tunneling prefactor of STI-edge component for drain-bulk junction.
- 326 `cbbtgatd=1e-18` AV^{-3}m Band-to-band tunneling prefactor of gate-edge component for drain-bulk junction.
- 327 `fbbtrbotd=1e+09` Vm^{-1} Normalization field at the reference temperature for band-to-band tunneling of bottom component for drain-bulk junction.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

- 328 `fbbtrstid=1e+09` V m^{-1}
Normalization field at the reference temperature for band-to-band tunneling of STI-edge component for drain-bulk junction.
- 329 `fbbtrgatd=1e+09` V m^{-1}
Normalization field at the reference temperature for band-to-band tunneling of gate-edge component for drain-bulk junction.
- 330 `stfbbtbotd=-0.001` K^{-1}
Temperature scaling parameter for band-to-band tunneling of bottom component for drain-bulk junction.
- 331 `stfbbtstid=-0.001` K^{-1}
Temperature scaling parameter for band-to-band tunneling of STI-edge component for drain-bulk junction.
- 332 `stfbbtgatd=-0.001` K^{-1}
Temperature scaling parameter for band-to-band tunneling of gate-edge component for drain-bulk junction.
- 333 `vbrbotd=10` V
Breakdown voltage of bottom component for drain-bulk junction.
- 334 `vbrstid=10` V
Breakdown voltage of STI-edge component for drain-bulk junction.
- 335 `vbrgatd=10` V
Breakdown voltage of gate-edge component for drain-bulk junction.
- 336 `pbrbotd=4` V
Breakdown onset tuning parameter of bottom component for drain-bulk junction.
- 337 `pbrstid=4` V
Breakdown onset tuning parameter of STI-edge component for drain-bulk junction.
- 338 `pbrgatd=4` V
Breakdown onset tuning parameter of gate-edge component for drain-bulk junction.
- 339 `swjunexp=0`
Flag for JUNCAP-express; 0=full model, 1=express model.
- 340 `vjunref=2.5`
Typical maximum junction voltage; usually about $2 \cdot \text{VSUP}$.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

341	$f_{junq}=0.03$	Fraction below which junction capacitance components are considered negligible.
342	$v_{junrefd}=2.5$	Typical maximum drain-bulk junction voltage; usually about $2*VSUP$.
343	$f_{junqd}=0.03$	Fraction below which drain-bulk junction capacitance components are considered negligible.
344	$m_{beo}=0.0$	DCmatch parameter.
345	$m_{vto}=0.0$	DCmatch parameter.
346	t_{nom} (C)	alias of t_{nom} .
347	t_{ref} (C)	alias of t_{nom} .

Output Parameters

1	β_{etn} (A/V ²)	Gain factor.
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Operating-Point Parameters

1	$ctype$	Flag for channel type.
2	$sdint$	Flag for source-drain interchange.
3	w_{eff} (m)	Effective channel width for geometrical models.
4	l_{eff} (m)	Effective channel length for geometrical models.
5	i_{se} (A)	Total source current.
6	i_{ge} (A)	Total gate current.
7	i_{de} (A)	Total drain current.
8	i_{be} (A)	Total bulk current.
9	i_{ds} (A)	Drain current, excl. avalanche, tunnel, GISL, GIDL, and junction currents.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

10	i_{db} (A)	Drain to bulk current.
11	i_{sb} (A)	Source to bulk current.
12	i_{gs} (A)	Gate-source tunneling current.
13	i_{gd} (A)	Gate-drain tunneling current.
14	i_{gb} (A)	Gate-bulk tunneling current.
15	i_{gcs} (A)	Gate-channel tunneling current (source component).
16	i_{gcd} (A)	Gate-channel tunneling current (drain component).
17	i_{avl} (A)	Substrate current due to weak avalanche.
18	i_{gisl} (A)	Gate-induced source leakage current.
19	i_{gidl} (A)	Gate-induced drain leakage current.
20	i_{js} (A)	Total source junction current.
21	i_{jsbot} (A)	Source junction current (bottom component).
22	i_{jsgat} (A)	Source junction current (gate-edge component).
23	i_{jssti} (A)	Source junction current (STI-edge component).
24	i_{jd} (A)	Total drain junction current.
25	i_{jdbot} (A)	Drain junction current (bottom component).
26	i_{jdgat} (A)	Drain junction current (gate-edge component).
27	i_{jdsti} (A)	Drain junction current (STI-edge component).
28	v_{ds} (V)	Drain-source voltage.
29	v_{gs} (V)	Gate-source voltage.
30	v_{sb} (V)	Source-bulk voltage.
31	v_{to} (V)	Zero-bias threshold voltage.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

32	v_{ts} (V)	Threshold voltage including back bias effects.
33	v_{th} (V)	Threshold voltage including back bias and drain bias effects.
34	v_{gt} (V)	Effective gate drive voltage including back bias and drain bias effects.
35	v_{dss} (V)	Drain saturation voltage at actual bias.
36	v_{sat} (V)	Saturation limit.
37	g_m ($1/\Omega$)	Transconductance.
38	g_{mb} ($1/\Omega$)	Substrate transconductance.
39	g_{ds} ($1/\Omega$)	Output conductance.
40	g_{js} ($1/\Omega$)	Source junction conductance.
41	g_{jd} ($1/\Omega$)	Drain junction conductance.
42	c_{dd} (F)	Drain capacitance.
43	c_{dg} (F)	Drain-gate capacitance.
44	c_{ds} (F)	Drain-source capacitance.
45	c_{db} (F)	Drain-bulk capacitance.
46	c_{gd} (F)	Gate-drain capacitance.
47	c_{gg} (F)	Gate capacitance.
48	c_{gs} (F)	Gate-source capacitance.
49	c_{gb} (F)	Gate-bulk capacitance.
50	c_{sd} (F)	Source-drain capacitance.
51	c_{sg} (F)	Source-gate capacitance.
52	c_{ss} (F)	Source capacitance.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

53	csb (F)	Source-bulk capacitance.
54	cbd (F)	Bulk-drain capacitance.
55	cbg (F)	Bulk-gate capacitance.
56	cbs (F)	Bulk-source capacitance.
57	cbb (F)	Bulk capacitance.
58	cgsol (F)	Total gate-source overlap capacitance.
59	cgdol (F)	Total gate-drain overlap capacitance.
60	cjs (F)	Total source junction capacitance.
61	cjsbot (F)	Source junction capacitance (bottom component).
62	cjsgat (F)	Source junction capacitance (gate-edge component).
63	cjssti (F)	Source junction capacitance (STI-edge component).
64	cjd (F)	Total drain junction capacitance.
65	cjdbot (F)	Drain junction capacitance (bottom component).
66	cjdgat (F)	Drain junction capacitance (gate-edge component).
67	cjdsti (F)	Drain junction capacitance (STI-edge component).
68	u	Transistor gain.
69	rout (Ω)	Small-signal output resistance.
70	vearly (V)	Equivalent Early voltage.
71	beff (A/V^2)	Gain factor.
72	fug (Hz)	Unity gain frequency at actual bias.
73	sfl (A/Hz)	Flicker noise current density at 1 Hz.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

74	<code>sqrtsff</code> (V/ $\sqrt{\text{Hz}}$)	Input-referred RMS white noise voltage density at 1 kHz.
75	<code>sqrtsfw</code> (V/ $\sqrt{\text{Hz}}$)	Input-referred RMS white noise voltage density.
76	<code>sid</code> (A^2/Hz)	White noise current density.
77	<code>sig</code> (A^2/Hz)	Induced gate noise current density at 1 Hz.
78	<code>cigid</code>	Imaginary part of correlation coefficient between Sig and Sid.
79	<code>fknee</code> (Hz)	Cross-over frequency above which white noise is dominant.
80	<code>sigs</code> (A^2/Hz)	Gate-source current noise spectral density.
81	<code>sigd</code> (A^2/Hz)	Gate-drain current noise spectral density.
82	<code>siavl</code> (A^2/Hz)	Impact ionization current noise spectral density.
83	<code>ssi</code> (A^2/Hz)	Total source junction current noise spectral density.
84	<code>sdi</code> (A^2/Hz)	Total drain junction current noise spectral density.
85	<code>table_ids</code> (A)	Current.
86	<code>table_vth</code> (V)	Threshold voltage including back-bias and drain-bias effects.
87	<code>table_qg</code> (Coul)	Charge at g node.
88	<code>table_qd</code> (Coul)	Charge at d node.
89	<code>table_qb</code> (Coul)	Charge at b node.
90	<code>table_id</code> (A)	Current.
91	<code>table_isub</code> (A)	Current.
92	<code>table_ibs</code> (A)	Current.
93	<code>table_ibd</code> (A)	Current.
94	<code>table_igd</code> (A)	Current.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

95	table_igb (A)	Current.
96	table_igs (A)	Current.
97	table_gds ($1/\Omega$)	conductance.
98	table_gm ($1/\Omega$)	transconductance.
99	table_gmbs (A)	transconductance.
100	table_qbs (Coul)	charge.
101	table_qbd (Coul)	charge.
102	table_vdsat (V)	saturation voltage.
103	table_leff (m)	Effective channel length.
104	table_weff (m)	Effective channel width.
105	table_aseff (m^2)	Bottom area of source junction.
106	table_adeff (m^2)	Bottom area of drain junction.
107	table_pseff (m)	Perimeter of source junction.
108	table_pdeff (m)	Perimeter of drain junction.
109	lv2 (m)	alias of weff.
110	lv1 (m)	alias of leff.
111	lx4 (A)	alias of ids.
112	lx3 (V)	alias of vds.
113	lx2 (V)	alias of vgs.
114	lv9 (V)	alias of vth.
115	lx7 ($1/\Omega$)	alias of gm.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

116	1x8 (1/Ω)	alias of gds.
117	1x9 (1/Ω)	alias of gmb.
118	1x33 (F)	alias of cdd.
119	1x32 (F)	alias of cdg.
120	1x34 (F)	alias of cds.
121	1x19 (F)	alias of cgd.
122	1x18 (F)	alias of cgg.
123	1x20 (F)	alias of cgs.
124	1x22 (F)	alias of cbd.
125	1x21 (F)	alias of cbg.
126	1x23 (F)	alias of cbs.
127	1v10 (V)	alias of vdss.
128	1x5 (A)	alias of ijs.
129	1x6 (A)	alias of ijd.
130	1x28 (F)	alias of cjs.
131	1x29 (F)	alias of cjd.

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

PSP Model (psp)

abdrain	I-15	lgsource	I-14	plwstvfb	M-24	pwnfc	M-183
absource	I-12	lkuo	M-213	plwthesat	M-92	pwnov	M-49
ad	I-20	lkvtho	M-219	plwthesatb	M-100	pwnp	M-40
area	I-28	llodkuo	M-216	plwthesatg	M-104	pwr	M-84
as	I-18	llodvth	M-222	plwvfb	M-20	pwstbet	M-62
beff	OP-71	lmax	M-195	plwxcor	M-79	pwstthesat	M-95
betn	O-1	lmin	M-194	plxcor	M-77	pwstvfb	M-23
cbb	OP-57	lodetao	M-225	poa1	M-122	pwthesat	M-91
cbbtbot	M-257	lsdrain	I-16	poa2	M-126	pwthesatb	M-99
cbbtgat	M-259	lssource	I-13	poa3	M-128	pwthesatg	M-103
cbbtsti	M-258	lvar1	M-10	poa4	M-132	pwvfb	M-19
cbd	OP-54	lvaro	M-9	poagidl	M-149	pwxcor	M-78
cbg	OP-55	m	I-27	poalp	M-109	qmc	M-8
cbs	OP-56	mbeo	M-275	poalp1	M-113	rbulko	M-199
cdb	OP-45	mefftatbot	M-254	poalp2	M-117	region	I-26
cdd	OP-42	mefftatgat	M-256	poax	M-105	rgo	M-198
cdg	OP-43	mefftatsti	M-255	pobetn	M-56	rint	M-203
cds	OP-44	mult	I-22	pobgidl	M-153	rjundo	M-202
cgb	OP-49	mvto	M-276	pocf	M-51	rjunso	M-201
cgd	OP-46	nf	I-23	pocfb	M-55	rout	OP-69

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

cgdol	OP-59	ngcon	I-24	pocfr	M-168	rshg	M-205
cgg	OP-47	pbot	M-237	pocgbov	M-164	rvpoly	M-204
cgs	OP-48	pbrbot	M-269	pocgidl	M-155	rwello	M-200
cgsol	OP-58	pbrgat	M-271	pocgov	M-160	sa	I-3
cigid	OP-78	pbrsti	M-270	pochib	M-148	saref	M-207
cjd	OP-64	pd	I-21	pocox	M-156	sb	I-4
cjdbot	OP-65	pgat	M-239	pocs	M-71	sbref	M-208
cjdgat	OP-66	phigbot	M-240	poct	M-42	sc	I-9
cjdsti	OP-67	phiggat	M-242	podnsub	M-33	sca	I-6
cjorbot	M-231	phigsti	M-241	podphib	M-34	scb	I-7
cjorgat	M-233	pkuo	M-215	poepsrox	M-26	scc	I-8
cjorsti	M-232	pkvtho	M-221	pofeta	M-81	scref	M-226
cjs	OP-60	pla1	M-123	pofnt	M-172	sd	I-5
cjsbot	OP-61	pla3	M-129	pogc2	M-146	sdi	OP-84
cjsgat	OP-62	pla4	M-133	pogc3	M-147	sdint	OP-2
cjssti	OP-63	plagidl	M-150	pogco	M-136	sfl	OP-73
csb	OP-53	plalp	M-110	poiginv	M-137	siavl	OP-82
csd	OP-50	plalp1	M-114	poigov	M-141	sid	OP-76
csg	OP-51	plalp2	M-118	pokuowe	M-190	sig	OP-77
csrhbot	M-246	plax	M-106	pokvthowe	M-186	sigd	OP-81
csrhgat	M-248	plbetn	M-57	pomue	M-64	sigs	OP-80

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

csrhsti	M-247	plcf	M-52	poneff	M-27	sqrtsff	OP-74
css	OP-52	plcfr	M-169	ponfa	M-173	sqrtsfw	OP-75
ctatbot	M-251	plcgbv	M-165	ponfb	M-177	ssi	OP-83
ctatgat	M-253	plcgov	M-161	ponfc	M-181	stetao	M-224
ctatsti	M-252	plcox	M-157	ponov	M-47	stfbbtbot	M-263
ctype	OP-1	plcs	M-72	ponp	M-38	stfbbtgat	M-265
delvto	I-10	plct	M-43	ponslp	M-32	stfbbtsti	M-264
dlq	M-15	pldphib	M-35	pors	M-82	swgidl	M-6
dlsil	M-206	pliginv	M-138	porsb	M-87	swigate	M-4
dta	M-185	pligov	M-142	porsg	M-88	swimpact	M-5
dwq	M-16	plkuowe	M-191	posta2	M-127	swjuncap	M-7
factuo	I-11	plkvthowe	M-187	postbet	M-60	swjunexp	M-272
fbbtrbot	M-260	plmue	M-65	postbgidl	M-154	table_ids	OP-85
fbbtrgat	M-262	plneff	M-28	postcs	M-75	table_qb	OP-89
fbbtrsti	M-261	plnfa	M-174	postig	M-145	table_qd	OP-88
fjunq	M-274	plnfb	M-178	postmue	M-68	table_qg	OP-87
fknee	OP-79	plnfc	M-182	postrs	M-86	table_vth	OP-86
fug	OP-72	plnov	M-48	postthemu	M-70	tkuo	M-212
gds	OP-39	plnp	M-39	postthesat	M-93	tnom	M-277
gjd	OP-41	plrs	M-83	postvfb	M-21	tr	M-3
gjs	OP-40	plstbet	M-61	postxcor	M-80	tref	M-278

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PSP Model (psp)

gm	OP-37	plstthesat	M-94	pothemu	M-69	trj	M-229
gmb	OP-38	plstvfb	M-22	pothesat	M-89	type	M-2
iavl	OP-17	plthesat	M-90	pothesatb	M-97	u	OP-68
ibe	OP-8	plthesatb	M-98	pothesatg	M-101	vbirbot	M-234
idb	OP-10	plthesatg	M-102	potox	M-25	vbirgat	M-236
ide	OP-7	plvfb	M-18	potoxov	M-46	vbirsti	M-235
ids	OP-9	plwa1	M-125	povfb	M-17	vbrbot	M-266
idsatrbot	M-243	plwa3	M-131	povnsub	M-31	vbrgat	M-268
idsatrgat	M-245	plwa4	M-135	povp	M-121	vbrsti	M-267
idsatrsti	M-244	plwagidl	M-152	poxcor	M-76	vds	OP-28
igb	OP-14	plwalp	M-112	ps	I-19	vdss	OP-35
igcd	OP-16	plwalp1	M-116	pssti	M-238	vearly	OP-70
igcs	OP-15	plwalp2	M-120	pwal	M-124	vgs	OP-29
igd	OP-13	plwax	M-108	pwa3	M-130	vgt	OP-34
ige	OP-6	plwbetn	M-59	pwa4	M-134	vjunref	M-273
igidl	OP-19	plwcf	M-54	pwagidl	M-151	vsat	OP-36
igisl	OP-18	plwcfr	M-171	pwalp	M-111	vsb	OP-30
igs	OP-12	plwcgbov	M-167	pwalp1	M-115	vth	OP-33
ijd	OP-24	plwcgov	M-163	pwalp2	M-119	vto	OP-31
ijdbot	OP-25	plwcox	M-159	pwax	M-107	vts	OP-32
ijdgat	OP-26	plwcs	M-74	pwbetn	M-58	w	I-2

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

ijdsti	OP-27	plwct	M-45	pwcfc	M-53	web	M-227
ijs	OP-20	plwdphib	M-37	pwcfr	M-170	wec	M-228
ijsbot	OP-21	plwiginv	M-140	pwcgbov	M-166	weff	OP-3
ijsgat	OP-22	plwigov	M-144	pwcgov	M-162	wkuo	M-214
ijssti	OP-23	plwkuowe	M-193	pwcox	M-158	wkvtho	M-220
imax	M-230	plwkvthowe	M-189	pwcs	M-73	wlod	M-209
isb	OP-11	plwmue	M-67	pwct	M-44	wlodkuo	M-217
ise	OP-5	plwneff	M-30	pwdphib	M-36	wlodvth	M-223
kuo	M-210	plwnfa	M-176	pwiginv	M-139	wmax	M-197
kvsat	M-211	plwnfb	M-180	pwigov	M-143	wmin	M-196
kvtho	M-218	plwnfc	M-184	pwkuowe	M-192	wot	M-14
l	I-1	plwnov	M-50	pwkvthowe	M-188	wvaro	M-12
lap	M-11	plwnp	M-41	pwmue	M-66	wvarw	M-13
leff	OP-4	plwrs	M-85	pwneff	M-29	xgw	I-25
level	M-1	plwstbet	M-63	pwnfa	M-175	xjungat	M-250
lgdrain	I-17	plwstthesat	M-96	pwnfb	M-179	xjunsti	M-249

PSP local MOSFET Model (psp102e)

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

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

Instance Definition

Name d g s b ModelName parameter=value ...

Instance Parameters

- | | | |
|----|-------------------------------|--|
| 1 | delvto=0 V | Threshold voltage shift parameter. |
| 2 | factuo=1 | Zero-field mobility pre-factor. |
| 3 | absource=1e-12 m ² | Bottom area of source junction. |
| 4 | lssource=1e-06 m | STI-edge length of source junction. |
| 5 | lgsource=1e-06 m | Gate-edge length of source junction. |
| 6 | abdrain=1e-12 m ² | Bottom area of drain junction. |
| 7 | lsdrain=1e-06 m | STI-edge length of drain junction. |
| 8 | lgdrain=1e-06 m | Gate-edge length of drain junction. |
| 9 | as=1e-12 m ² | Bottom area of source junction. |
| 10 | ps=1e-06 m | Perimeter of source junction. |
| 11 | ad=1e-12 m ² | Bottom area of drain junction. |
| 12 | pd=1e-06 m | Perimeter of drain junction. |
| 13 | jw=1e-06 m | Gate-edge length of source/drain junction. |
| 14 | mult=1 | Number of devices in parallel. |
| 15 | region=triode | Estimated DC operating region, used as a convergence aid. Possible values are off, triode, sat, subth, rev, fwd, or brk. |
| 16 | m=1 | Multiplicity factor. |
| 17 | trise=0 | Temperature rise from ambient. |
| 18 | area=1 | alias of mult. |

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

Model Definition

```
model modelName psp102e parameter=value ...
```

Model Parameters

1	level=102	Model level.
2	type=n	Channel type parameter, +1=NMOS -1=PMOS. Possible values are n, p, npn, pnp, npnv, pnpv, npnl, or pnp1.
3	tr=21 C	nominal (reference) temperature.
4	swigate=0	Flag for gate current, 0=turn off IG.
5	swimpact=0	Flag for impact ionization current, 0=turn off II.
6	swgidl=0	Flag for GIDL current, 0=turn off IGIDL.
7	swjuncap=0	Flag for juncap, 0=turn off juncap.
8	swjunasym=0	Flag for asymmetric junctions; 0=symmetric, 1=asymmetric.
9	qmc=1	Quantum-mechanical correction factor.
10	vfb=-1 V	Flatband voltage at TR.
11	stvfb=0.0005 V/K	Temperature dependence of VFB.
12	tox=2e-09 m	Gate oxide thickness.
13	epsrox=3.9	Relative permittivity of gate dielectric.
14	neff=5e+23 m ⁻³	Effective substrate doping.
15	vnsb=0 V	Effective doping bias-dependence parameter.
16	ns1p=0.05 V	Effective doping bias-dependence parameter.
17	dnsb=0 V ¹	Effective doping bias-dependence parameter.
18	dphib=0 V	Offset parameter for PHIB.
19	np=1e+26 m ⁻³	Gate poly-silicon doping.

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PSP Model (psp)

20	$ct=0$	Interface states factor.
21	$toxov=2e-09$ m	Overlap oxide thickness.
22	$toxovd=2e-09$ m	Overlap oxide thickness for drain side.
23	$nov=5e+25$ m ⁻³	Effective doping of overlap region.
24	$novd=5e+25$ m ⁻³	Effective doping of overlap region for drain side.
25	$cf=0$ V ⁻¹	DIBL-parameter.
26	$cfb=0$ V ⁻¹	Back bias dependence of CF.
27	$betn=0.07$ m ² /V/s	Channel aspect ratio times zero-field mobility.
28	$stbet=1$	Temperature dependence of BETN.
29	$mue=0.5$ m/V	Mobility reduction coefficient at TR.
30	$stmue=0$	Temperature dependence of MUE.
31	$themu=1.5$	Mobility reduction exponent at TR.
32	$stthemu=1.5$	Temperature dependence of THEMU.
33	$cs=0$	Coulomb scattering parameter at TR.
34	$stcs=0$	Temperature dependence of CS.
35	$xcor=0$ V ⁻¹	Non-universality factor.
36	$stxcor=0$	Temperature dependence of XCOR.
37	$feta=1$	Effective field parameter.
38	$rs=30$ Ω	Series resistance at TR.
39	$strs=1$	Temperature dependence of RS.
40	$rsb=0$ V ⁻¹	Back-bias dependence of series resistance.
41	$rsg=0$ V ⁻¹	Gate-bias dependence of series resistance.

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PSP Model (psp)

42	$\text{thesat}=1 \text{ V}^{-1}$	Velocity saturation parameter at TR.
43	$\text{stthesat}=1$	Temperature dependence of THESAT.
44	$\text{thesatb}=0 \text{ V}^{-1}$	Back-bias dependence of velocity saturation.
45	$\text{thesatg}=0 \text{ V}^{-1}$	Gate-bias dependence of velocity saturation.
46	$\text{ax}=3$	Linear/saturation transition factor.
47	$\text{alp}=0.01$	CLM pre-factor.
48	$\text{alp1}=0 \text{ V}$	CLM enhancement factor above threshold.
49	$\text{alp2}=0 \text{ V}^{-1}$	CLM enhancement factor below threshold.
50	$\text{vp}=0.05 \text{ V}$	CLM logarithm dependence factor.
51	$\text{a1}=1$	Impact-ionization pre-factor.
52	$\text{a2}=10 \text{ V}$	Impact-ionization exponent at TR.
53	$\text{sta2}=0 \text{ V}$	Temperature dependence of A2.
54	$\text{a3}=1$	Saturation-voltage dependence of impact-ionization.
55	$\text{a4}=0 \text{ V}^{-0.5}$	Back-bias dependence of impact-ionization.
56	$\text{gco}=0$	Gate tunnelling energy adjustment.
57	$\text{iginv}=0 \text{ A}$	Gate channel current pre-factor.
58	$\text{igov}=0 \text{ A}$	Gate overlap current pre-factor.
59	$\text{igovd}=0 \text{ A}$	Gate overlap current pre-factor for drain side.
60	$\text{stig}=2$	Temperature dependence of IGINV and IGOV.
61	$\text{gc2}=0.375$	Gate current slope factor.
62	$\text{gc3}=0.063$	Gate current curvature factor.
63	$\text{chib}=3.1 \text{ V}$	Tunnelling barrier height.

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PSP Model (psp)

64	$agidl=0$	A/V ³	GIDL pre-factor.
65	$agidld=0$	A/V ³	GIDL pre-factor for drain side.
66	$bgidl=41$	V	GIDL probability factor at TR.
67	$bgidld=41$	V	GIDL probability factor at TR for drain side.
68	$stbgidl=0$	V/K	Temperature dependence of BGIDL.
69	$stbgidld=0$	V/K	Temperature dependence of BGIDL for drain side.
70	$cgidl=0$		Back-bias dependence of GIDL.
71	$cgidld=0$		Back-bias dependence of GIDL for drain side.
72	$cox=1e-14$	F	Oxide capacitance for intrinsic channel.
73	$cgov=1e-15$	F	Oxide capacitance for gate-drain/source overlap.
74	$cgovd=1e-15$	F	Oxide capacitance for gate-drain overlap.
75	$cgbov=0$	F	Oxide capacitance for gate-bulk overlap.
76	$cfr=0$	F	Outer fringe capacitance.
77	$cfrd=0$	F	Outer fringe capacitance for drain side.
78	$fnt=1$		Thermal noise coefficient.
79	$nfa=8e+22$	V ⁻¹ /m ⁴	First coefficient of flicker noise.
80	$nfb=3e+07$	V ¹ /m ²	Second coefficient of flicker noise.
81	$nfc=0$	V ⁻¹	Third coefficient of flicker noise.
82	$ef=1$		Flicker noise frequency exponent.
83	$rg=0$	Ω	Gate resistance.
84	$rbulk=0$	Ω	Bulk resistance between node BP and BI.
85	$rwell=0$	Ω	Well resistance between node BI and B.

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PSP Model (psp)

86	<code>rjuns=0</code>	Ω	Source-side bulk resistance between node BI and BS.
87	<code>rjund=0</code>	Ω	Drain-side bulk resistance between node BI and BD.
88	<code>trj=21</code>	C	reference temperature.
89	<code>imax=1e+03</code>	A	Maximum current up to which forward current behaves exponentially.
90	<code>cjorbot=0.001</code>	Fm^{-2}	Zero-bias capacitance per unit-of-area of bottom component for source-bulk junction.
91	<code>cjorsti=1e-09</code>	Fm^{-1}	Zero-bias capacitance per unit-of-length of STI-edge component for source-bulk junction.
92	<code>cjorgat=1e-09</code>	Fm^{-1}	Zero-bias capacitance per unit-of-length of gate-edge component for source-bulk junction.
93	<code>vbirbot=1</code>	V	Built-in voltage at the reference temperature of bottom component for source-bulk junction.
94	<code>vbirsti=1</code>	V	Built-in voltage at the reference temperature of STI-edge component for source-bulk junction.
95	<code>vbirgat=1</code>	V	Built-in voltage at the reference temperature of gate-edge component for source-bulk junction.
96	<code>pbot=0.5</code>		Grading coefficient of bottom component for source-bulk junction.
97	<code>psti=0.5</code>		Grading coefficient of STI-edge component for source-bulk junction.
98	<code>pgat=0.5</code>		Grading coefficient of gate-edge component for source-bulk junction.
99	<code>phigbot=1.16</code>	V	Zero-temperature bandgap voltage of bottom component for source-bulk junction.

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PSP Model (psp)

- 100 `phigsti=1.16` V Zero-temperature bandgap voltage of STI-edge component for source-bulk junction.
- 101 `phiggat=1.16` V Zero-temperature bandgap voltage of gate-edge component for source-bulk junction.
- 102 `idsatrbot=1e-12` Am^{-2} Saturation current density at the reference temperature of bottom component for source-bulk junction.
- 103 `idsatrsti=1e-18` Am^{-1} Saturation current density at the reference temperature of STI-edge component for source-bulk junction.
- 104 `idsatrgat=1e-18` Am^{-1} Saturation current density at the reference temperature of gate-edge component for source-bulk junction.
- 105 `csrbot=100` Am^{-3} Shockley-Read-Hall prefactor of bottom component for source-bulk junction.
- 106 `csrhisti=0.0001` Am^{-2} Shockley-Read-Hall prefactor of STI-edge component for source-bulk junction.
- 107 `csrhgat=0.0001` Am^{-2} Shockley-Read-Hall prefactor of gate-edge component for source-bulk junction.
- 108 `xjunsti=1e-07` m Junction depth of STI-edge component for source-bulk junction.
- 109 `xjungat=1e-07` m Junction depth of gate-edge component for source-bulk junction.
- 110 `ctatbot=100` Am^{-3} Trap-assisted tunneling prefactor of bottom component for source-bulk junction.
- 111 `ctatsti=0.0001` Am^{-2} Trap-assisted tunneling prefactor of STI-edge component for source-bulk junction.

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PSP Model (psp)

- 112 $ctatgat=0.0001 \text{ Am}^{-2}$ Trap-assisted tunneling prefactor of gate-edge component for source-bulk junction.
- 113 $mefftatbot=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of bottom component for source-bulk junction.
- 114 $mefftatsti=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of STI-edge component for source-bulk junction.
- 115 $mefftatgat=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of gate-edge component for source-bulk junction.
- 116 $cbbtbot=1e-12 \text{ AV}^{-3}$ Band-to-band tunneling prefactor of bottom component for source-bulk junction.
- 117 $cbbtsti=1e-18 \text{ AV}^{-3}_m$ Band-to-band tunneling prefactor of STI-edge component for source-bulk junction.
- 118 $cbbtgat=1e-18 \text{ AV}^{-3}_m$ Band-to-band tunneling prefactor of gate-edge component for source-bulk junction.
- 119 $fbbtrbot=1e+09 \text{ V}_m^{-1}$ Normalization field at the reference temperature for band-to-band tunneling of bottom component for source-bulk junction.
- 120 $fbbtrsti=1e+09 \text{ V}_m^{-1}$ Normalization field at the reference temperature for band-to-band tunneling of STI-edge component for source-bulk junction.
- 121 $fbbtrgat=1e+09 \text{ V}_m^{-1}$ Normalization field at the reference temperature for band-to-band tunneling of gate-edge component for source-bulk junction.
- 122 $stfbbtbot=-0.001 \text{ K}^{-1}$ Temperature scaling parameter for band-to-band tunneling of bottom component for source-bulk junction.

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PSP Model (psp)

123	<code>stfbbtsti=-0.001</code>	K^{-1}	Temperature scaling parameter for band-to-band tunneling of STI-edge component for source-bulk junction.
124	<code>stfbbtgat=-0.001</code>	K^{-1}	Temperature scaling parameter for band-to-band tunneling of gate-edge component for source-bulk junction.
125	<code>vbrbot=10</code>	V	Breakdown voltage of bottom component for source-bulk junction.
126	<code>vbrsti=10</code>	V	Breakdown voltage of STI-edge component for source-bulk junction.
127	<code>vbrgat=10</code>	V	Breakdown voltage of gate-edge component for source-bulk junction.
128	<code>pbrbot=4</code>	V	Breakdown onset tuning parameter of bottom component for source-bulk junction.
129	<code>pbrsti=4</code>	V	Breakdown onset tuning parameter of STI-edge component for source-bulk junction.
130	<code>pbrgat=4</code>	V	Breakdown onset tuning parameter of gate-edge component for source-bulk junction.
131	<code>cjorbotd=0.001</code>	Fm^{-2}	Zero-bias capacitance per unit-of-area of bottom component for drain-bulk junction.
132	<code>cjorstid=1e-09</code>	Fm^{-1}	Zero-bias capacitance per unit-of-length of STI-edge component for drain-bulk junction.
133	<code>cjorgatd=1e-09</code>	Fm^{-1}	Zero-bias capacitance per unit-of-length of gate-edge component for drain-bulk junction.
134	<code>vbirbotd=1</code>	V	Built-in voltage at the reference temperature of bottom component for drain-bulk junction.
135	<code>vbirstid=1</code>	V	Built-in voltage at the reference temperature of STI-edge component for drain-bulk junction.

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PSP Model (psp)

136	<code>vbirgatd=1</code>	V	Built-in voltage at the reference temperature of gate-edge component for drain-bulk junction.
137	<code>pbotd=0.5</code>		Grading coefficient of bottom component for drain-bulk junction.
138	<code>pstid=0.5</code>		Grading coefficient of STI-edge component for drain-bulk junction.
139	<code>pgatd=0.5</code>		Grading coefficient of gate-edge component for drain-bulk junction.
140	<code>phigbotd=1.16</code>	V	Zero-temperature bandgap voltage of bottom component for drain-bulk junction.
141	<code>phigstid=1.16</code>	V	Zero-temperature bandgap voltage of STI-edge component for drain-bulk junction.
142	<code>phiggatd=1.16</code>	V	Zero-temperature bandgap voltage of gate-edge component for drain-bulk junction.
143	<code>idsatrbotd=1e-12</code>	Am^{-2}	Saturation current density at the reference temperature of bottom component for drain-bulk junction.
144	<code>idsatrstid=1e-18</code>	Am^{-1}	Saturation current density at the reference temperature of STI-edge component for drain-bulk junction.
145	<code>idsatrgatd=1e-18</code>	Am^{-1}	Saturation current density at the reference temperature of gate-edge component for drain-bulk junction.
146	<code>csrhhbotd=100</code>	Am^{-3}	Shockley-Read-Hall prefactor of bottom component for drain-bulk junction.
147	<code>csrhstid=0.0001</code>	Am^{-2}	Shockley-Read-Hall prefactor of STI-edge component for drain-bulk junction.
148	<code>csrhgatd=0.0001</code>	Am^{-2}	Shockley-Read-Hall prefactor of gate-edge component for drain-bulk junction.
149	<code>xjunstid=1e-07</code>	m	Junction depth of STI-edge component for drain-bulk junction.
150	<code>xjungatd=1e-07</code>	m	Junction depth of gate-edge component for drain-bulk junction.

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PSP Model (psp)

- 151 `ctatbotd=100` Am^{-3} Trap-assisted tunneling prefactor of bottom component for drain-bulk junction.
- 152 `ctatstid=0.0001` Am^{-2} Trap-assisted tunneling prefactor of STI-edge component for drain-bulk junction.
- 153 `ctatgatd=0.0001` Am^{-2} Trap-assisted tunneling prefactor of gate-edge component for drain-bulk junction.
- 154 `mefftatbotd=0.25` Effective mass (in units of m_0) for trap-assisted tunneling of bottom component for drain-bulk junction.
- 155 `mefftatstid=0.25` Effective mass (in units of m_0) for trap-assisted tunneling of STI-edge component for drain-bulk junction.
- 156 `mefftatgatd=0.25` Effective mass (in units of m_0) for trap-assisted tunneling of gate-edge component for drain-bulk junction.
- 157 `cbbtbotd=1e-12` AV^3 Band-to-band tunneling prefactor of bottom component for drain-bulk junction.
- 158 `cbbtstid=1e-18` $\text{AV}^{-3}m$ Band-to-band tunneling prefactor of STI-edge component for drain-bulk junction.
- 159 `cbbtgatd=1e-18` $\text{AV}^{-3}m$ Band-to-band tunneling prefactor of gate-edge component for drain-bulk junction.
- 160 `fbbtrbotd=1e+09` Vm^{-1} Normalization field at the reference temperature for band-to-band tunneling of bottom component for drain-bulk junction.
- 161 `fbbtrstid=1e+09` Vm^{-1} Normalization field at the reference temperature for band-to-band tunneling of STI-edge component for drain-bulk junction.
- 162 `fbbtrgatd=1e+09` 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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PSP Model (psp)

163	$stfbbtbotd=-0.001 \text{ K}^{-1}$	Temperature scaling parameter for band-to-band tunneling of bottom component for drain-bulk junction.
164	$stfbbtstid=-0.001 \text{ K}^{-1}$	Temperature scaling parameter for band-to-band tunneling of STI-edge component for drain-bulk junction.
165	$stfbbtgatd=-0.001 \text{ K}^{-1}$	Temperature scaling parameter for band-to-band tunneling of gate-edge component for drain-bulk junction.
166	$vbrbotd=10 \text{ V}$	Breakdown voltage of bottom component for drain-bulk junction.
167	$vbrstid=10 \text{ V}$	Breakdown voltage of STI-edge component for drain-bulk junction.
168	$vbrgatd=10 \text{ V}$	Breakdown voltage of gate-edge component for drain-bulk junction.
169	$pbrbotd=4 \text{ V}$	Breakdown onset tuning parameter of bottom component for drain-bulk junction.
170	$pbrstid=4 \text{ V}$	Breakdown onset tuning parameter of STI-edge component for drain-bulk junction.
171	$pbrgatd=4 \text{ V}$	Breakdown onset tuning parameter of gate-edge component for drain-bulk junction.
172	$swjunexp=0$	Flag for JUNCAP-express; 0=full model, 1=express model.
173	$vjunref=2.5$	Typical maximum junction voltage; usually about $2*VSUP$.
174	$fjunq=0.03$	Fraction below which junction capacitance components are considered negligible.
175	$vjunrefd=2.5$	Typical maximum drain-bulk junction voltage; usually about $2*VSUP$.
176	$fjunqd=0.03$	Fraction below which drain-bulk junction capacitance components are considered negligible.

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PSP Model (psp)

177	<code>dta=0 K</code>	Temperature offset w.r.t. ambient temperature.
178	<code>mbe=0.0</code>	DCmatch parameter.
179	<code>mvt=0.0</code>	DCmatch parameter.
180	<code>tnom (C)</code>	alias of <code>tnom</code> .
181	<code>tref (C)</code>	alias of <code>tnom</code> .

Operating-Point Parameters

1	<code>ctype</code>	Flag for channel type.
2	<code>sdint</code>	Flag for source-drain interchange.
3	<code>weff (m)</code>	Effective channel width for geometrical models.
4	<code>leff (m)</code>	Effective channel length for geometrical models.
5	<code>ise (A)</code>	Total source current.
6	<code>ige (A)</code>	Total gate current.
7	<code>ide (A)</code>	Total drain current.
8	<code>ibe (A)</code>	Total bulk current.
9	<code>ids (A)</code>	Drain current, excl. avalanche, tunnel, GISL, GIDL, and junction currents.
10	<code>idb (A)</code>	Drain to bulk current.
11	<code>isb (A)</code>	Source to bulk current.
12	<code>igs (A)</code>	Gate-source tunneling current.
13	<code>igd (A)</code>	Gate-drain tunneling current.
14	<code>igb (A)</code>	Gate-bulk tunneling current.
15	<code>igcs (A)</code>	Gate-channel tunneling current (source component).

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PSP Model (psp)

16	<code>igcd</code> (A)	Gate-channel tunneling current (drain component).
17	<code>iavl</code> (A)	Substrate current due to weak avalanche.
18	<code>igisl</code> (A)	Gate-induced source leakage current.
19	<code>igidl</code> (A)	Gate-induced drain leakage current.
20	<code>ijs</code> (A)	Total source junction current.
21	<code>ijsbot</code> (A)	Source junction current (bottom component).
22	<code>ijsgat</code> (A)	Source junction current (gate-edge component).
23	<code>ijssti</code> (A)	Source junction current (STI-edge component).
24	<code>ijd</code> (A)	Total drain junction current.
25	<code>ijdbot</code> (A)	Drain junction current (bottom component).
26	<code>ijdgat</code> (A)	Drain junction current (gate-edge component).
27	<code>ijdsti</code> (A)	Drain junction current (STI-edge component).
28	<code>vds</code> (V)	Drain-source voltage.
29	<code>vgs</code> (V)	Gate-source voltage.
30	<code>vsb</code> (V)	Source-bulk voltage.
31	<code>vto</code> (V)	Zero-bias threshold voltage.
32	<code>vtS</code> (V)	Threshold voltage including back bias effects.
33	<code>vth</code> (V)	Threshold voltage including back bias and drain bias effects.
34	<code>vgt</code> (V)	Effective gate drive voltage including back bias and drain bias effects.
35	<code>vdss</code> (V)	Drain saturation voltage at actual bias.
36	<code>vsat</code> (V)	Saturation limit.

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PSP Model (psp)

37	g_m ($1/\Omega$)	Transconductance.
38	g_{mb} ($1/\Omega$)	Substrate transconductance.
39	g_{ds} ($1/\Omega$)	Output conductance.
40	g_{js} ($1/\Omega$)	Source junction conductance.
41	g_{jd} ($1/\Omega$)	Drain junction conductance.
42	c_{dd} (F)	Drain capacitance.
43	c_{dg} (F)	Drain-gate capacitance.
44	c_{ds} (F)	Drain-source capacitance.
45	c_{db} (F)	Drain-bulk capacitance.
46	c_{gd} (F)	Gate-drain capacitance.
47	c_{gg} (F)	Gate capacitance.
48	c_{gs} (F)	Gate-source capacitance.
49	c_{gb} (F)	Gate-bulk capacitance.
50	c_{sd} (F)	Source-drain capacitance.
51	c_{sg} (F)	Source-gate capacitance.
52	c_{ss} (F)	Source capacitance.
53	c_{sb} (F)	Source-bulk capacitance.
54	c_{bd} (F)	Bulk-drain capacitance.
55	c_{bg} (F)	Bulk-gate capacitance.
56	c_{bs} (F)	Bulk-source capacitance.
57	c_{bb} (F)	Bulk capacitance.
58	c_{gsol} (F)	Total gate-source overlap capacitance.

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PSP Model (psp)

59	<code>cgdol</code> (F)	Total gate-drain overlap capacitance.
60	<code>cjs</code> (F)	Total source junction capacitance.
61	<code>cjsbot</code> (F)	Source junction capacitance (bottom component).
62	<code>cjsgat</code> (F)	Source junction capacitance (gate-edge component).
63	<code>cjssti</code> (F)	Source junction capacitance (STI-edge component).
64	<code>cjd</code> (F)	Total drain junction capacitance.
65	<code>cjdbot</code> (F)	Drain junction capacitance (bottom component).
66	<code>cjdgat</code> (F)	Drain junction capacitance (gate-edge component).
67	<code>cjdsti</code> (F)	Drain junction capacitance (STI-edge component).
68	<code>u</code>	Transistor gain.
69	<code>rout</code> (Ω)	Small-signal output resistance.
70	<code>vearly</code> (V)	Equivalent Early voltage.
71	<code>beff</code> (A/V^2)	Gain factor.
72	<code>fug</code> (Hz)	Unity gain frequency at actual bias.
73	<code>sfl</code> (A/Hz)	Flicker noise current density at 1 Hz.
74	<code>sqrtsff</code> ($V/\sqrt{\text{Hz}}$)	Input-referred RMS white noise voltage density at 1 kHz.
75	<code>sqrtsfw</code> ($V/\sqrt{\text{Hz}}$)	Input-referred RMS white noise voltage density.
76	<code>sid</code> (A^2/Hz)	White noise current density.
77	<code>sig</code> (A^2/Hz)	Induced gate noise current density at 1 Hz.
78	<code>cigid</code>	Imaginary part of correlation coefficient between Sig and Sid.
79	<code>fknee</code> (Hz)	Cross-over frequency above which white noise is dominant.

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PSP Model (psp)

80	sig_s (A^2/Hz)	Gate-source current noise spectral density.
81	sig_d (A^2/Hz)	Gate-drain current noise spectral density.
82	siavl (A^2/Hz)	Impact ionization current noise spectral density.
83	ssi (A^2/Hz)	Total source junction current noise spectral density.
84	sdi (A^2/Hz)	Total drain junction current noise spectral density.
85	lv_2 (m)	alias of weff .
86	lv_1 (m)	alias of leff .
87	lx_4 (A)	alias of ids .
88	lx_3 (V)	alias of vds .
89	lx_2 (V)	alias of vgs .
90	lv_9 (V)	alias of vth .
91	lx_7 (1/Ohm)	alias of gm .
92	lx_8 (1/Ohm)	alias of gds .
93	lx_9 (1/Ohm)	alias of gmb .
94	lx_{33} (F)	alias of cdd .
95	lx_{32} (F)	alias of cdg .
96	lx_{34} (F)	alias of cbs .
97	lx_{19} (F)	alias of cgd .
98	lx_{18} (F)	alias of cgg .
99	lx_{20} (F)	alias of cgs .
100	lx_{22} (F)	alias of cbd .
101	lx_{21} (F)	alias of cbg .

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PSP Model (psp)

102	lx23 (F)	alias of cbs.
103	lv10 (V)	alias of vdss.
104	lx5 (A)	alias of ijs.
105	lx6 (A)	alias of ijd.
106	lx28 (F)	alias of cjs.
107	lx29 (F)	alias of cjd.
108	table_ids (A)	Current.
109	table_vth (V)	Threshold voltage including back-bias and drain-bias effects.
110	table_qg (Coul)	Charge at g node.
111	table_qd (Coul)	Charge at d node.
112	table_qb (Coul)	Charge at b node.
113	table_id (A)	Current.
114	table_isub (A)	Current.
115	table_ibs (A)	Current.
116	table_ibd (A)	Current.
117	table_igd (A)	Current.
118	table_igb (A)	Current.
119	table_igs (A)	Current.
120	table_gds (1/Ω)	conductance.
121	table_gm (1/Ω)	transconductance.
122	table_gmbs (A)	transconductance.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

- 123 `table_qbs` (Coul) charge.
- 124 `table_qbd` (Coul) charge.
- 125 `table_vdsat` (V) saturation voltage.
- 126 `table_aseff` (m²) Bottom area of source junction.
- 127 `table_adeff` (m²) Bottom area of drain junction.
- 128 `table_pseff` (m) Perimeter of source junction.
- 120 `table_pdeff` (m) Perimeter of drain 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.

<code>a1</code>	M-48	<code>csrhgat</code>	M-96	<code>jw</code>	I-13	<code>stfbbtbot</code>	M-111
<code>a2</code>	M-49	<code>csrhisti</code>	M-95	<code>leff</code>	OP-4	<code>stfbbtgat</code>	M-113
<code>a3</code>	M-51	<code>css</code>	OP-52	<code>level</code>	M-1	<code>stfbbtsti</code>	M-112
<code>a4</code>	M-52	<code>ct</code>	M-19	<code>lgdrain</code>	I-8	<code>stig</code>	M-56
<code>abdrain</code>	I-6	<code>ctatbot</code>	M-99	<code>lgsource</code>	I-5	<code>stmue</code>	M-27
<code>absource</code>	I-3	<code>ctatgat</code>	M-101	<code>lsdrain</code>	I-7	<code>strs</code>	M-36
<code>ad</code>	I-11	<code>ctatsti</code>	M-100	<code>lssource</code>	I-4	<code>stthemu</code>	M-29
<code>agidl</code>	M-60	<code>ctype</code>	OP-1	<code>m</code>	I-16	<code>stthesat</code>	M-40
<code>alp</code>	M-44	<code>delvto</code>	I-1	<code>mbe</code>	M-124	<code>stvfb</code>	M-10

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

alp1	M-45	dnsub	M-16	mefftatbot	M-102	stxcor	M-33
alp2	M-46	dphib	M-17	mefftatgat	M-104	swgidl	M-6
area	I-17	dta	M-123	mefftatsti	M-103	swigate	M-4
as	I-9	epsrox	M-12	mue	M-26	swimpact	M-5
ax	M-43	factuo	I-2	mult	I-14	swjuncap	M-7
beff	OP-71	fbtrbot	M-108	mvt	M-125	swjunexp	M-120
betn	M-24	fbtrgat	M-110	neff	M-13	table_ids	OP-85
bgidl	M-61	fbtrsti	M-109	nfa	M-69	table_qb	OP-89
cbb	OP-57	feta	M-34	nfb	M-70	table_qd	OP-88
cbbtbot	M-105	fjunq	M-122	nfc	M-71	table_qg	OP-87
cbbtgat	M-107	fknee	OP-79	nov	M-21	table_vth	OP-86
cbbtsti	M-106	fnt	M-68	np	M-18	themu	M-28
cbd	OP-54	fug	OP-72	nslp	M-15	thesat	M-39
cbg	OP-55	gc2	M-57	pbot	M-85	thesatb	M-41
cbs	OP-56	gc3	M-58	pbrbot	M-117	thesatg	M-42
cdb	OP-45	gco	M-53	pbrgat	M-119	tnom	M-126
cdd	OP-42	gds	OP-39	pbrsti	M-118	tox	M-11
cdg	OP-43	gjd	OP-41	pd	I-12	toxov	M-20
cds	OP-44	gjs	OP-40	pgat	M-87	tr	M-3
cf	M-22	gm	OP-37	phigbot	M-88	tref	M-127
cfb	M-23	gmb	OP-38	phiggat	M-90	trj	M-77

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

cfr M-67	iavl OP-17	phigsti M-89	type M-2
cgb OP-49	ibe OP-8	ps I-10	u OP-68
cgbov M-66	idb OP-10	psti M-86	vbirbot M-82
cgd OP-46	ide OP-7	qmc M-8	vbirgat M-84
cgdol OP-59	ids OP-9	rbulk M-73	vbirsti M-83
cgg OP-47	idsatrbot M-91	region I-15	vbrbot M-114
cgidl M-63	idsatrgat M-93	rg M-72	vbrgat M-116
cgov M-65	idsatrsti M-92	rjund M-76	vbrsti M-115
cgs OP-48	igb OP-14	rjuns M-75	vds OP-28
cgsol OP-58	igcd OP-16	rout OP-69	vdss OP-35
chib M-59	igcs OP-15	rs M-35	vearly OP-70
cigid OP-78	igd OP-13	rsb M-37	vfb M-9
cjd OP-64	ige OP-6	rsg M-38	vgs OP-29
cjdbot OP-65	igidl OP-19	rwell M-74	vgt OP-34
cjdgat OP-66	iginv M-54	sdi OP-84	vjunref M-121
cjdsti OP-67	igisl OP-18	sdint OP-2	vnsb M-14
cjorbot M-79	igov M-55	sfl OP-73	vp M-47
cjorgat M-81	igs OP-12	siavl OP-82	vsat OP-36
cjorsti M-80	ijd OP-24	sid OP-76	vsb OP-30
cjs OP-60	ijdbot OP-25	sig OP-77	vth OP-33
cjsbot OP-61	ijdgat OP-26	sigd OP-81	vto OP-31

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

cjsgat	OP-62	ijdsti	OP-27	sig	OP-80	vts	OP-32
cjssti	OP-63	ijs	OP-20	sqrtsff	OP-74	weff	OP-3
cox	M-64	ijsbot	OP-21	sqrtsfw	OP-75	xcor	M-32
cs	M-30	ijsgat	OP-22	ssi	OP-83	xjungat	M-98
csb	OP-53	ijssti	OP-23	sta2	M-50	xjunsti	M-97
csd	OP-50	imax	M-78	stbet	M-25		
csg	OP-51	isb	OP-11	stbgidl	M-62		
csrbot	M-94	ise	OP-5	stcs	M-31		

PSP NQS MOSFET Model (pspnqs1020)

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 d g s b ModelName parameter=value ...

Instance Parameters

- 1 l=1e-05 m Design length.
- 2 w=1e-05 m Design width.
- 3 sa=0 m Distance between OD-edge and poly from one side.
- 4 sb=0 m Distance between OD-edge and poly from other side.
- 5 sd=0 m Distance between neighbouring fingers.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

6	<code>sca=0</code>	Integral of the first distribution function for scattered well dopants.
7	<code>scb=0</code>	Integral of the second distribution function for scattered well dopants.
8	<code>scc=0</code>	Integral of the third distribution function for scattered well dopants.
9	<code>sc=0 m</code>	Distance between OD-edge and nearest well edge.
10	<code>delvto=0 V</code>	Threshold voltage shift parameter.
11	<code>factuo=1</code>	Zero-field mobility pre-factor.
12	<code>absource=1e-12 m²</code>	Bottom area of source junction.
13	<code>lssource=1e-06 m</code>	STI-edge length of source junction.
14	<code>lgsource=1e-06 m</code>	Gate-edge length of source junction.
15	<code>abdRAIN=1e-12 m²</code>	Bottom area of drain junction.
16	<code>lsdRAIN=1e-06 m</code>	STI-edge length of drain junction.
17	<code>lgdRAIN=1e-06 m</code>	Gate-edge length of drain junction.
18	<code>as=1e-12 m²</code>	Bottom area of source junction.
19	<code>ps=1e-06 m</code>	Perimeter of source junction.
20	<code>ad=1e-12 m²</code>	Bottom area of drain junction.
21	<code>pd=1e-06 m</code>	Perimeter of drain junction.
22	<code>mult=1</code>	Number of devices in parallel.
23	<code>nf=1</code>	Number of fingers.
24	<code>ngcon=1</code>	Number of gate contacts.
25	<code>xgw=1e-07 m</code>	Distance from the gate contact to the channel edge.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

26	<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> , <code>subth</code> , <code>rev</code> , <code>fwd</code> , or <code>brk</code> .
27	<code>m=1</code>	Multiplicity factor.
28	<code>trise=0</code>	Temperature rise from ambient.
29	<code>area=1</code>	alias of <code>mult</code> .

Model Definition

```
model modelName pspnqs1020 parameter=value ...
```

Model Parameters

1	<code>level=1.02e+03</code>	Model level.
2	<code>type=n</code>	Channel type parameter, +1=NMOS -1=PMOS. 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>pnp1</code> .
3	<code>tr=21 C</code>	nominal (reference) temperature.
4	<code>swigate=0</code>	Flag for gate current, 0=turn off IG.
5	<code>swimpact=0</code>	Flag for impact ionization current, 0=turn off II.
6	<code>swgidl=0</code>	Flag for GIDL current, 0=turn off IGIDL.
7	<code>swjuncap=0</code>	Flag for juncap, 0=turn off juncap.
8	<code>swjunasym=0</code>	Flag for asymmetric junctions; 0=symmetric, 1=asymmetric.
9	<code>qmc=1</code>	Quantum-mechanical correction factor.
10	<code>lvaro=0 m</code>	Geometry independent difference between actual and programmed poly-silicon gate length.
11	<code>lvarl=0</code>	Length dependence of difference between actual and programmed poly-silicon gate length.
12	<code>lvarw=0</code>	Width dependence of LVAR.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

13	$lap=0$ m	Effective channel length reduction per side due to lateral diffusion of source/drain dopant ions.
14	$wvaro=0$ m	Geometry independent difference between actual and programmed field-oxide opening.
15	$wvarl=0$	Length dependence of WVAR.
16	$wvarw=0$	Width dependence of difference between actual and programmed field-oxide opening.
17	$wot=0$ m	Effective reduction of channel width per side due to lateral diffusion of channel-stop dopant ions.
18	$dlq=0$ m	Effective channel length reduction for CV.
19	$dwq=0$ m	Effective channel width reduction for CV.
20	$vfbo=-1$ V	Geometry-independent flat-band voltage at TR.
21	$vfbl=0$	Length dependence of flat-band voltage.
22	$vfbw=0$	Width dependence of flat-band voltage.
23	$vfblw=0$	Area dependence of flat-band voltage.
24	$stvfbo=0.0005$ V/K	Geometry-independent temperature dependence of VFB.
25	$stvfbl=0$	Length dependence of temperature dependence of VFB.
26	$stvfbw=0$	Width dependence of temperature dependence of VFB.
27	$stvfblw=0$	Area dependence of temperature dependence of VFB.
28	$toxoxo=2e-09$ m	Gate oxide thickness.
29	$epsroxoxo=3.9$	Relative permittivity of gate dielectric.
30	$nsubo=3e+23$ m ⁻³	Geometry independent substrate doping.
31	$nsubw=0$	Width dependence of background doping NSUBO due to segregation.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

32	$wseg=1e-08$ m	Char. length of segregation of background doping NSUBO.
33	$npck=1e+24$ m ⁻³	Pocket doping level.
34	$npckw=0$	Width dependence of pocket doping NPCK due to segregation.
35	$wsegp=1e-08$ m	Char. length of segregation of pocket doping NPCK.
36	$lpck=1e-08$ m	Char. length of lateral doping profile.
37	$lpckw=0$	Width dependence of char. length of lateral doping profile.
38	$foll=0$	First length dependence coefficient for short channel body effect.
39	$foll2=0$	Second length dependence coefficient for short channel body effect.
40	$vnsubo=0$ V	Effective doping bias-dependence parameter.
41	$nslpo=0.05$ V	Effective doping bias-dependence parameter.
42	$dnsubo=0$ V ⁻¹	Effective doping bias-dependence parameter.
43	$dphibo=0$ V	Geometry independent offset of PHIB.
44	$dphibl=0$ V	Length dependence offset of PHIB.
45	$dphiblexp=1$	Exponent for length dependence of offset of PHIB.
46	$dphibw=0$	Width dependence of offset of PHIB.
47	$dphiblw=0$	Area dependence of offset of PHIB.
48	$npo=1e+26$ m ⁻³	Geometry-independent gate poly-silicon doping.
49	$npl=0$	Length dependence of gate poly-silicon doping.
50	$cto=0$	Geometry-independent interface states factor.
51	$ctl=0$	Length dependence of interface states factor.
52	$ctlexp=1$	Exponent for length dependence of interface states factor.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

53	$ctw=0$	Width dependence of interface states factor.
54	$ctlw=0$	Area dependence of interface states factor.
55	$toxovo=2e-09$ m	Overlap oxide thickness.
56	$toxovdo=2e-09$ m	Overlap oxide thickness for drain side.
57	$lov=0$ m	Overlap length for gate/drain and gate/source overlap capacitance.
58	$lovd=0$ m	Overlap length for gate/drain overlap capacitance.
59	$novo=5e+25$ m ⁻³	Effective doping of overlap region.
60	$novdo=5e+25$ m ⁻³	Effective doping of overlap region for drain side.
61	$cf1=0$ V ⁻¹	Length dependence of DIBL-parameter.
62	$cf1exp=2$	Exponent for length dependence of CF.
63	$cfw=0$	Width dependence of CF.
64	$cfbo=0$ V ⁻¹	Back-bias dependence of CF.
65	$uo=0.05$ m ² /V/s	Zero-field mobility at TR.
66	$fbet1=0$	Relative mobility decrease due to first lateral profile.
67	$fbet1w=0$	Width dependence of relative mobility decrease due to first lateral profile.
68	$lp1=1e-08$ m	Mobility-related characteristic length of first lateral profile.
69	$lp1w=0$	Width dependence of mobility-related characteristic length of first lateral profile.
70	$fbet2=0$	Relative mobility decrease due to second lateral profile.
71	$lp2=1e-08$ m	Mobility-related characteristic length of second lateral profile.
72	$betw1=0$	First higher-order width scaling coefficient of BETN.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

73	<code>betw2=0</code>	Second higher-order width scaling coefficient of BETN.
74	<code>wbet=1e-09 m</code>	Characteristic width for width scaling of BETN.
75	<code>stbeto=1</code>	Geometry independent temperature dependence of BETN.
76	<code>stbetl=0</code>	Length dependence of temperature dependence of BETN.
77	<code>stbetw=0</code>	Width dependence of temperature dependence of BETN.
78	<code>stbetlw=0</code>	Area dependence of temperature dependence of BETN.
79	<code>mueo=0.5 m/V</code>	Geometry independent mobility reduction coefficient at TR.
80	<code>muew=0</code>	Width dependence of mobility reduction coefficient at TR.
81	<code>stmueo=0</code>	Temperature dependence of MUE.
82	<code>themuo=1.5</code>	Mobility reduction exponent at TR.
83	<code>stthemuo=1.5</code>	Temperature dependence of THEMU.
84	<code>cso=0</code>	Geometry independent coulomb scattering parameter at TR.
85	<code>cs1=0</code>	Length dependence of CS.
86	<code>cs1exp=0</code>	Exponent for length dependence of CS.
87	<code>csw=0</code>	Width dependence of CS.
88	<code>cslw=0</code>	Area dependence of CS.
89	<code>stcso=0</code>	Temperature dependence of CS.
90	<code>xcoro=0 V¹</code>	Geometry independent non-universality parameter.
91	<code>xcorl=0</code>	Length dependence of non-universality parameter.
92	<code>xcorw=0</code>	Width dependence of non-universality parameter.
93	<code>xcorlw=0</code>	Area dependence of non-universality parameter.
94	<code>stxcoro=0</code>	Temperature dependence of XCOR.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

95	$f_{etao}=1$	Effective field parameter.
96	$r_{sw1}=2.5e+03 \Omega$	Source/drain series resistance for 1 um wide channel at TR.
97	$r_{sw2}=0$	Higher-order width scaling of RS.
98	$strso=1$	Temperature dependence of RS.
99	$r_{sbo}=0 \text{ V}^{-1}$	Back-bias dependence of series resistance.
100	$r_{sgo}=0 \text{ V}^{-1}$	Gate-bias dependence of series resistance.
101	$thesato=0 \text{ V}^{-1}$	Geometry independent velocity saturation parameter at TR.
102	$thesatl=0.05 \text{ V}^{-1}$	Length dependence of THESAT.
103	$thesatlexp=1$	Exponent for length dependence of THESAT.
104	$thesatw=0$	Width dependence of velocity saturation parameter.
105	$thesatlw=0$	Area dependence of velocity saturation parameter.
106	$stthesato=1$	Geometry independent temperature dependence of THESAT.
107	$stthesatl=0$	Length dependence of temperature dependence of THESAT.
108	$stthesatw=0$	Width dependence of temperature dependence of THESAT.
109	$stthesatlw=0$	Area dependence of temperature dependence of THESAT.
110	$thesatbo=0 \text{ V}^{-1}$	Back-bias dependence of velocity saturation.
111	$thesatgo=0 \text{ V}^{-1}$	Gate-bias dependence of velocity saturation.
112	$axo=18$	Geometry independent linear/saturation transition factor.
113	$axl=0.4$	Length dependence of AX.
114	$alpl=0.0005$	Length dependence of ALP.
115	$alplexp=1$	Exponent for length dependence of ALP.
116	$alpw=0$	Width dependence of ALP.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

117	$\text{alp1l1}=0$ V	Length dependence of CLM enhancement factor above threshold.
118	$\text{alp1lexp}=0.5$	Exponent for length dependence of ALP1.
119	$\text{alp1l2}=0$	Second_order length dependence of ALP1.
120	$\text{alp1w}=0$	Width dependence of ALP1.
121	$\text{alp2l1}=0$ V ¹	Length dependence of CLM enhancement factor below threshold.
122	$\text{alp2lexp}=0.5$	Exponent for length dependence of ALP2.
123	$\text{alp2l2}=0$	Second_order length dependence of ALP2.
124	$\text{alp2w}=0$	Width dependence of ALP2.
125	$\text{vpo}=0.05$ V	CLM logarithmic dependence parameter.
126	$\text{a1o}=1$	Geometry independent impact-ionization pre-factor.
127	$\text{a1l}=0$	Length dependence of A1.
128	$\text{a1w}=0$	Width dependence of A1.
129	$\text{a2o}=10$ V	Impact-ionization exponent at TR.
130	$\text{sta2o}=0$ V	Temperature dependence of A2.
131	$\text{a3o}=1$	Geometry independent saturation-voltage dependence of II.
132	$\text{a3l}=0$	Length dependence of A3.
133	$\text{a3w}=0$	Width dependence of A3.
134	$\text{a4o}=0$ V ^{0.5}	Geometry independent back-bias dependence of II.
135	$\text{a4l}=0$	Length dependence of A4.
136	$\text{a4w}=0$	Width dependence of A4.
137	$\text{gcoo}=0$	Gate tunnelling energy adjustment.

Virtuoso Simulator Components and Device Models Reference
PSP Model (psp)

138	<code>iginv1w=0</code>	A	Gate channel current pre-factor for 1 μm^2 channel area.
139	<code>igovw=0</code>	A	Gate overlap current pre-factor for 1 μm wide channel.
140	<code>igovdw=0</code>	A	Gate overlap current pre-factor for 1 μm wide channel for drain side.
141	<code>stigo=2</code>		Temperature dependence of IGINV and IGOV.
142	<code>gc2o=0.375</code>		Gate current slope factor.
143	<code>gc3o=0.063</code>		Gate current curvature factor.
144	<code>chibo=3.1</code>	V	Tunnelling barrier height.
145	<code>agidlw=0</code>	A/V^3	Width dependence of GIDL pre-factor.
146	<code>agidldw=0</code>	A/V^3	Width dependence of GIDL pre-factor for drain side.
147	<code>bgidlo=41</code>	V	GIDL probability factor at TR.
148	<code>bgidldo=41</code>	V	GIDL probability factor at TR for drain side.
149	<code>stbgidlo=0</code>	V/K	Temperature dependence of BGIDL.
150	<code>stbgidldo=0</code>	V/K	Temperature dependence of BGIDL for drain side.
151	<code>cgidlo=0</code>		Back-bias dependence of GIDL.
152	<code>cgidldo=0</code>		Back-bias dependence of GIDL for drain side.
153	<code>cgbov1=0</code>	F	Oxide capacitance for gate-bulk overlap for 1 μm long channel.
154	<code>cfrw=0</code>	F	Outer fringe capacitance for 1 μm wide channel.
155	<code>cfrdw=0</code>	F	Outer fringe capacitance for 1 μm wide channel for drain side.
156	<code>fnto=1</code>		Thermal noise coefficient.
157	<code>nfalw=8e+22</code>	V^1/m^4	First coefficient of flicker noise for 1 μm^2 channel area.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

158	$nfb1w=3e+07 \text{ V}^{-1}/\text{m}^2$	Second coefficient of flicker noise for 1 μm^2 channel area.
159	$nfc1w=0 \text{ V}^{-1}$	Third coefficient of flicker noise for 1 μm^2 channel area.
160	$efo=1$	Flicker noise frequency exponent.
161	$lintnoi=0 \text{ m}$	Length offset for flicker noise.
162	$alpnoi=2$	Exponent for length offset for flicker noise.
163	$dta=0 \text{ K}$	Temperature offset w.r.t. ambient temperature.
164	$kvthoweo=0$	Geometrical independent threshold shift parameter.
165	$kvthowel=0$	Length dependent threshold shift parameter.
166	$kvthowew=0$	Width dependent threshold shift parameter.
167	$kvthowelw=0$	Area dependent threshold shift parameter.
168	$kuoweo=0$	Geometrical independent mobility degradation factor.
169	$kuowel=0$	Length dependent mobility degradation factor.
170	$kuowew=0$	Width dependent mobility degradation factor.
171	$kuowelw=0$	Area dependent mobility degradation factor.
172	$swnqs=0$	Flag for NQS, 0=off, 1, 2, 3, 5, or 9=number of collocation points.
173	$munqso=1$ unknown	Relative mobility for NQS modelling.
174	$rgo=0 \text{ } \Omega$	Gate resistance.
175	$rbulko=0 \text{ } \Omega$	Bulk resistance between node BP and BI.
176	$rwello=0 \text{ } \Omega$	Well resistance between node BI and B.
177	$rjunso=0 \text{ } \Omega$	Source-side bulk resistance between node BI and BS.
178	$rjundo=0 \text{ } \Omega$	Drain-side bulk resistance between node BI and BD.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

179	$r_{int}=0 \ \Omega/Sqr$	Contact resistance between silicide and poly.
180	$r_{vpoly}=0 \ \Omega/Sqr$	Vertical poly resistance.
181	$r_{shg}=0 \ \Omega/Sqr$	Gate electrode diffusion sheet resistance.
182	$d_{lsil}=0 \ m$	Silicide extension over the physical gate length.
183	$s_{aref}=1e-06 \ m$	Reference distance between OD-edge and poly from one side.
184	$s_{bref}=1e-06 \ m$	Reference distance between OD-edge and poly from other side.
185	$w_{lod}=0 \ m$	Width parameter.
186	$k_{uo}=0 \ m$	Mobility degradation/enhancement coefficient.
187	$k_{vsat}=0 \ m$	Saturation velocity degradation/enhancement coefficient.
188	$t_{kuo}=0$	Temperature dependence of KUO.
189	$l_{kuo}=0 \ m^{LLODKUO}$	Length dependence of KUO.
190	$w_{kuo}=0 \ m^{WLODKUO}$	Width dependence of KUO.
191	$p_{kuo}=0 \ m^{(LLODKUO+WLODKUO)}$	Cross-term dependence of KUO.
192	$l_{lodkuo}=0$	Length parameter for UO stress effect.
193	$w_{lodkuo}=0$	Width parameter for UO stress effect.
194	$k_{vtho}=0 \ Vm$	Threshold shift parameter.
195	$l_{kvtho}=0 \ m^{LLODVTH}$	Length dependence of KVTHO.
196	$w_{kvtho}=0 \ m^{WLODVTH}$	Width dependence of KVTHO.
197	$p_{kvtho}=0 \ m^{(LLODVTH+WLODVTH)}$	Cross-term dependence of KVTHO.
198	$l_{lodvth}=0$	Length parameter for VTH-stress effect.

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PSP Model (psp)

199	wlodvth=0	Width parameter for VTH-stress effect.
200	stetao=0 m	eta0 shift factor related to VTHO change.
201	lodetao=1	eta0 shift modification factor for stress effect.
202	scref=1e-05 m	Distance between OD-edge and well edge of a reference device.
203	web=0	Coefficient for SCB.
204	wec=0	Coefficient for SCC.
205	trj=21 C	reference temperature.
206	imax=1e+03 A	Maximum current up to which forward current behaves exponentially.
207	cjorbot=0.001 Fm ⁻²	Zero-bias capacitance per unit-of-area of bottom component for source-bulk junction.
208	cjorsti=1e-09 Fm ⁻¹	Zero-bias capacitance per unit-of-length of STI-edge component for source-bulk junction.
209	cjorgat=1e-09 Fm ⁻¹	Zero-bias capacitance per unit-of-length of gate-edge component for source-bulk junction.
210	vbirbot=1 V	Built-in voltage at the reference temperature of bottom component for source-bulk junction.
211	vbirsti=1 V	Built-in voltage at the reference temperature of STI-edge component for source-bulk junction.
212	vbirgat=1 V	Built-in voltage at the reference temperature of gate-edge component for source-bulk junction.
213	pbot=0.5	Grading coefficient of bottom component for source-bulk junction.
214	psti=0.5	Grading coefficient of STI-edge component for source-bulk junction.

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PSP Model (psp)

215	$p_{gat}=0.5$	Grading coefficient of gate-edge component for source-bulk junction.
216	$phigbot=1.16$ V	Zero-temperature bandgap voltage of bottom component for source-bulk junction.
217	$phigsti=1.16$ V	Zero-temperature bandgap voltage of STI-edge component for source-bulk junction.
218	$phiggat=1.16$ V	Zero-temperature bandgap voltage of gate-edge component for source-bulk junction.
219	$idsatrbot=1e-12$ $A m^{-2}$	Saturation current density at the reference temperature of bottom component for source-bulk junction.
220	$idsatrsti=1e-18$ $A m^{-1}$	Saturation current density at the reference temperature of STI-edge component for source-bulk junction.
221	$idsatrgat=1e-18$ $A m^{-1}$	Saturation current density at the reference temperature of gate-edge component for source-bulk junction.
222	$csrhibot=100$ $A m^{-3}$	Shockley-Read-Hall prefactor of bottom component for source-bulk junction.
223	$csrhisti=0.0001$ $A m^{-2}$	Shockley-Read-Hall prefactor of STI-edge component for source-bulk junction.
224	$csrhgat=0.0001$ $A m^{-2}$	Shockley-Read-Hall prefactor of gate-edge component for source-bulk junction.
225	$xjunsti=1e-07$ m	Junction depth of STI-edge component for source-bulk junction.
226	$xjungat=1e-07$ m	Junction depth of gate-edge component for source-bulk junction.
227	$ctatbot=100$ $A m^{-3}$	Trap-assisted tunneling prefactor of bottom component for source-bulk junction.

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PSP Model (psp)

- 228 $c_{\text{statsti}}=0.0001 \text{ Am}^{-2}$
Trap-assisted tunneling prefactor of STI-edge component for source-bulk junction.
- 229 $c_{\text{statgat}}=0.0001 \text{ Am}^{-2}$
Trap-assisted tunneling prefactor of gate-edge component for source-bulk junction.
- 230 $m_{\text{efftatbot}}=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of bottom component for source-bulk junction.
- 231 $m_{\text{efftatsti}}=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of STI-edge component for source-bulk junction.
- 232 $m_{\text{efftatgat}}=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of gate-edge component for source-bulk junction.
- 233 $c_{\text{bbtbot}}=1e-12 \text{ AV}^{-3}$
Band-to-band tunneling prefactor of bottom component for source-bulk junction.
- 234 $c_{\text{bbtsti}}=1e-18 \text{ AV}^{-3}_m$
Band-to-band tunneling prefactor of STI-edge component for source-bulk junction.
- 235 $c_{\text{bbtgat}}=1e-18 \text{ AV}^{-3}_m$
Band-to-band tunneling prefactor of gate-edge component for source-bulk junction.
- 236 $f_{\text{bbtrbot}}=1e+09 \text{ Vm}^{-1}$
Normalization field at the reference temperature for band-to-band tunneling of bottom component for source-bulk junction.
- 237 $f_{\text{bbtrsti}}=1e+09 \text{ Vm}^{-1}$
Normalization field at the reference temperature for band-to-band tunneling of STI-edge component for source-bulk junction.
- 238 $f_{\text{bbtrgat}}=1e+09 \text{ Vm}^{-1}$
Normalization field at the reference temperature for band-to-band tunneling of gate-edge component for source-bulk junction.

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PSP Model (psp)

239	<code>stfbbtbot=-0.001</code>	K^{-1}	Temperature scaling parameter for band-to-band tunneling of bottom component for source-bulk junction.
240	<code>stfbbtsti=-0.001</code>	K^{-1}	Temperature scaling parameter for band-to-band tunneling of STI-edge component for source-bulk junction.
241	<code>stfbbtgat=-0.001</code>	K^{-1}	Temperature scaling parameter for band-to-band tunneling of gate-edge component for source-bulk junction.
242	<code>vbrbot=10</code>	V	Breakdown voltage of bottom component for source-bulk junction.
243	<code>vbrsti=10</code>	V	Breakdown voltage of STI-edge component for source-bulk junction.
244	<code>vbrgat=10</code>	V	Breakdown voltage of gate-edge component for source-bulk junction.
245	<code>pbrbot=4</code>	V	Breakdown onset tuning parameter of bottom component for source-bulk junction.
246	<code>pbrsti=4</code>	V	Breakdown onset tuning parameter of STI-edge component for source-bulk junction.
247	<code>pbrgat=4</code>	V	Breakdown onset tuning parameter of gate-edge component for source-bulk junction.
248	<code>cjorbotd=0.001</code>	Fm^{-2}	Zero-bias capacitance per unit-of-area of bottom component for drain-bulk junction.
249	<code>cjorstid=1e-09</code>	Fm^{-1}	Zero-bias capacitance per unit-of-length of STI-edge component for drain-bulk junction.
250	<code>cjorgatd=1e-09</code>	Fm^{-1}	Zero-bias capacitance per unit-of-length of gate-edge component for drain-bulk junction.

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PSP Model (psp)

251	vbirbotd=1 V	Built-in voltage at the reference temperature of bottom component for drain-bulk junction.
252	vbirstid=1 V	Built-in voltage at the reference temperature of STI-edge component for drain-bulk junction.
253	vbirgatd=1 V	Built-in voltage at the reference temperature of gate-edge component for drain-bulk junction.
254	pbotd=0.5	Grading coefficient of bottom component for drain-bulk junction.
255	pstid=0.5	Grading coefficient of STI-edge component for drain-bulk junction.
256	pgatd=0.5	Grading coefficient of gate-edge component for drain-bulk junction.
257	phigbotd=1.16 V	Zero-temperature bandgap voltage of bottom component for drain-bulk junction.
258	phigstid=1.16 V	Zero-temperature bandgap voltage of STI-edge component for drain-bulk junction.
259	phiggatd=1.16 V	Zero-temperature bandgap voltage of gate-edge component for drain-bulk junction.
260	idsatrbotd=1e-12	Am^{-2} Saturation current density at the reference temperature of bottom component for drain-bulk junction.
261	idsatrstid=1e-18	Am^{-1} Saturation current density at the reference temperature of STI-edge component for drain-bulk junction.
262	idsatrgatd=1e-18	Am^{-1} Saturation current density at the reference temperature of gate-edge component for drain-bulk junction.
263	csrhibotd=100	Am^{-3} Shockley-Read-Hall prefactor of bottom component for drain-bulk junction.
264	csrhistid=0.0001	Am^{-2} Shockley-Read-Hall prefactor of STI-edge component for drain-bulk junction.

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PSP Model (psp)

- 265 `csrhtagatd=0.0001` Am^{-2}
Shockley-Read-Hall prefactor of gate-edge component for drain-bulk junction.
- 266 `xjunstid=1e-07` m Junction depth of STI-edge component for drain-bulk junction.
- 267 `xjungatd=1e-07` m Junction depth of gate-edge component for drain-bulk junction.
- 268 `ctatbotd=100` Am^{-3} Trap-assisted tunneling prefactor of bottom component for drain-bulk junction.
- 269 `ctatstid=0.0001` Am^{-2}
Trap-assisted tunneling prefactor of STI-edge component for drain-bulk junction.
- 270 `ctatgatd=0.0001` Am^{-2}
Trap-assisted tunneling prefactor of gate-edge component for drain-bulk junction.
- 271 `mefftatbotd=0.25` Effective mass (in units of m_0) for trap-assisted tunneling of bottom component for drain-bulk junction.
- 272 `mefftatstid=0.25` Effective mass (in units of m_0) for trap-assisted tunneling of STI-edge component for drain-bulk junction.
- 273 `mefftatgatd=0.25` Effective mass (in units of m_0) for trap-assisted tunneling of gate-edge component for drain-bulk junction.
- 274 `cbbtbotd=1e-12` AV^3
Band-to-band tunneling prefactor of bottom component for drain-bulk junction.
- 275 `cbbtstid=1e-18` AV^{-3}m
Band-to-band tunneling prefactor of STI-edge component for drain-bulk junction.
- 276 `cbbtgatd=1e-18` AV^{-3}m
Band-to-band tunneling prefactor of gate-edge component for drain-bulk junction.
- 277 `fbbtbotd=1e+09` Vm^{-1}
Normalization field at the reference temperature for band-to-band tunneling of bottom component for drain-bulk junction.

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PSP Model (psp)

- 278 `fbbtrstid=1e+09` V m^{-1}
Normalization field at the reference temperature for band-to-band tunneling of STI-edge component for drain-bulk junction.
- 279 `fbbtrgatd=1e+09` V m^{-1}
Normalization field at the reference temperature for band-to-band tunneling of gate-edge component for drain-bulk junction.
- 280 `stfbbtbotd=-0.001` K^{-1}
Temperature scaling parameter for band-to-band tunneling of bottom component for drain-bulk junction.
- 281 `stfbbtstid=-0.001` K^{-1}
Temperature scaling parameter for band-to-band tunneling of STI-edge component for drain-bulk junction.
- 282 `stfbbtgatd=-0.001` K^{-1}
Temperature scaling parameter for band-to-band tunneling of gate-edge component for drain-bulk junction.
- 283 `vbrbotd=10` V
Breakdown voltage of bottom component for drain-bulk junction.
- 284 `vbrstid=10` V
Breakdown voltage of STI-edge component for drain-bulk junction.
- 285 `vbrgatd=10` V
Breakdown voltage of gate-edge component for drain-bulk junction.
- 286 `pbrbotd=4` V
Breakdown onset tuning parameter of bottom component for drain-bulk junction.
- 287 `pbrstid=4` V
Breakdown onset tuning parameter of STI-edge component for drain-bulk junction.
- 288 `pbrgatd=4` V
Breakdown onset tuning parameter of gate-edge component for drain-bulk junction.
- 289 `swjunexp=0`
Flag for JUNCAP-express; 0=full model, 1=express model.
- 290 `vjunref=2.5`
Typical maximum junction voltage; usually about $2 \cdot \text{VSUP}$.

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PSP Model (psp)

291	$f_{junq}=0.03$	Fraction below which junction capacitance components are considered negligible.
292	$v_{junrefd}=2.5$	Typical maximum drain-bulk junction voltage; usually about $2 \cdot VSUP$.
293	$f_{junqd}=0.03$	Fraction below which drain-bulk junction capacitance components are considered negligible.
294	$m_{beo}=0.0$	DCmatch parameter.
295	$m_{vto}=0.0$	DCmatch parameter.
296	t_{nom} (C)	alias of t_{nom} .
297	t_{ref} (C)	alias of t_{nom} .

Operating-Point Parameters

1	$ctype$	Flag for channel type.
2	$sdint$	Flag for source-drain interchange.
3	w_{eff} (m)	Effective channel width for geometrical models.
4	l_{eff} (m)	Effective channel length for geometrical models.
5	i_{se} (A)	Total source current.
6	i_{ge} (A)	Total gate current.
7	i_{de} (A)	Total drain current.
8	i_{be} (A)	Total bulk current.
9	i_{ds} (A)	Drain current, excl. avalanche, tunnel, GISL, GIDL, and junction currents.
10	i_{db} (A)	Drain to bulk current.
11	i_{sb} (A)	Source to bulk current.
12	i_{gs} (A)	Gate-source tunneling current.

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13	i_{gd} (A)	Gate-drain tunneling current.
14	i_{gb} (A)	Gate-bulk tunneling current.
15	i_{gcs} (A)	Gate-channel tunneling current (source component).
16	i_{gcd} (A)	Gate-channel tunneling current (drain component).
17	i_{avl} (A)	Substrate current due to weak avalanche.
18	i_{gisl} (A)	Gate-induced source leakage current.
19	i_{gidl} (A)	Gate-induced drain leakage current.
20	i_{js} (A)	Total source junction current.
21	i_{jsbot} (A)	Source junction current (bottom component).
22	i_{jsgat} (A)	Source junction current (gate-edge component).
23	i_{jsssti} (A)	Source junction current (STI-edge component).
24	i_{jd} (A)	Total drain junction current.
25	i_{jdbot} (A)	Drain junction current (bottom component).
26	i_{jdgat} (A)	Drain junction current (gate-edge component).
27	i_{jdsti} (A)	Drain junction current (STI-edge component).
28	v_{ds} (V)	Drain-source voltage.
29	v_{gs} (V)	Gate-source voltage.
30	v_{sb} (V)	Source-bulk voltage.
31	v_{to} (V)	Zero-bias threshold voltage.
32	v_{ts} (V)	Threshold voltage including back bias effects.
33	v_{th} (V)	Threshold voltage including back bias and drain bias effects.

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34	v_{gt} (V)	Effective gate drive voltage including back bias and drain bias effects.
35	v_{dss} (V)	Drain saturation voltage at actual bias.
36	v_{sat} (V)	Saturation limit.
37	g_m ($1/\Omega$)	Transconductance.
38	g_{mb} ($1/\Omega$)	Substrate transconductance.
39	g_{ds} ($1/\Omega$)	Output conductance.
40	g_{js} ($1/\Omega$)	Source junction conductance.
41	g_{jd} ($1/\Omega$)	Drain junction conductance.
42	c_{dd} (F)	Drain capacitance.
43	c_{dg} (F)	Drain-gate capacitance.
44	c_{ds} (F)	Drain-source capacitance.
45	c_{db} (F)	Drain-bulk capacitance.
46	c_{gd} (F)	Gate-drain capacitance.
47	c_{gg} (F)	Gate capacitance.
48	c_{gs} (F)	Gate-source capacitance.
49	c_{gb} (F)	Gate-bulk capacitance.
50	c_{sd} (F)	Source-drain capacitance.
51	c_{sg} (F)	Source-gate capacitance.
52	c_{ss} (F)	Source capacitance.
53	c_{sb} (F)	Source-bulk capacitance.
54	c_{bd} (F)	Bulk-drain capacitance.

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PSP Model (psp)

55	cbg (F)	Bulk-gate capacitance.
56	cbs (F)	Bulk-source capacitance.
57	cbb (F)	Bulk capacitance.
58	cgsol (F)	Total gate-source overlap capacitance.
59	cgdol (F)	Total gate-drain overlap capacitance.
60	cjs (F)	Total source junction capacitance.
61	cjsbot (F)	Source junction capacitance (bottom component).
62	cjsgat (F)	Source junction capacitance (gate-edge component).
63	cjssti (F)	Source junction capacitance (STI-edge component).
64	cjd (F)	Total drain junction capacitance.
65	cjdbot (F)	Drain junction capacitance (bottom component).
66	cjdgat (F)	Drain junction capacitance (gate-edge component).
67	cjdsti (F)	Drain junction capacitance (STI-edge component).
68	u	Transistor gain.
69	rout (Ω)	Small-signal output resistance.
70	vearly (V)	Equivalent Early voltage.
71	bef _f (A/V ²)	Gain factor.
72	fug (Hz)	Unity gain frequency at actual bias.
73	sfl (A/Hz)	Flicker noise current density at 1 Hz.
74	sqrtsff (V/ $\sqrt{\text{Hz}}$)	Input-referred RMS white noise voltage density at 1 kHz.
75	sqrtsfw (V/ $\sqrt{\text{Hz}}$)	Input-referred RMS white noise voltage density.

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PSP Model (psp)

76	sid (A ² /Hz)	White noise current density.
77	sig (A ² /Hz)	Induced gate noise current density at 1 Hz.
78	cigid	Imaginary part of correlation coefficient between Sig and Sid.
79	fknee (Hz)	Cross-over frequency above which white noise is dominant.
80	sigs (A ² /Hz)	Gate-source current noise spectral density.
81	sigd (A ² /Hz)	Gate-drain current noise spectral density.
82	siavl (A ² /Hz)	Impact ionization current noise spectral density.
83	ssi (A ² /Hz)	Total source junction current noise spectral density.
84	sdi (A ² /Hz)	Total drain junction current noise spectral density.
85	lv2 (m)	alias of weff.
86	lv1 (m)	alias of leff.
87	lx4 (A)	alias of ids.
88	lx3 (V)	alias of vds.
89	lx2 (V)	alias of vgs.
90	lv9 (V)	alias of vth.
91	lx7 (1/Ohm)	alias of gm.
92	lx8 (1/Ohm)	alias of gds.
93	lx9 (1/Ohm)	alias of gmb.
94	lx33 (F)	alias of cdd.
95	lx32 (F)	alias of cdg.
96	lx34 (F)	alias of cds.
97	lx19 (F)	alias of cgd.

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98	1x18 (F)	alias of cgg.
99	1x20 (F)	alias of cgs.
100	1x22 (F)	alias of cbd.
101	1x21 (F)	alias of cbg.
102	1x23 (F)	alias of cbs.
103	1v10 (V)	alias of vdss.
104	1x5 (A)	alias of ijs.
105	1x6 (A)	alias of ijd.
106	1x28 (F)	alias of cjs.
107	1x29 (F)	alias of cjd.
108	table_ids (A)	Current.
109	table_vth (V)	Threshold voltage including back-bias and drain-bias effects.
118	table_qg (Coul)	Charge at g node.
111	table_qd (Coul)	Charge at d node.
112	table_qb (Coul)	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.

all M-123

ctype OP-1

lpck M-35

stigo M-136

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PSP Model (psp)

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a3w	M-129	dphiblexp	M-44	lvarw	M-11	stthesato	M-102
a4l	M-131	dphiblw	M-46	m	I-27	stthesatw	M-104
a4o	M-130	dphibo	M-42	mbeo	M-238	stvfbl	M-24
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axo	M-108	gc3o	M-138	nsubo	M-29	thesatlexp	M-99
beff	OP-71	gcoo	M-133	nsubw	M-30	thesatlw	M-101
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PSP Model (psp)

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cgb	OP-49	iginvlw	M-134	rjunso	M-164	vdss	OP-35
cgbovl	M-144	igisl	OP-18	rout	OP-69	vearly	OP-70
cgd	OP-46	igovw	M-135	rsbo	M-95	vfb1	M-20
cgdol	OP-59	igs	OP-12	rsgo	M-96	vfb1w	M-22
cgg	OP-47	ijd	OP-24	rshg	M-168	vfbo	M-19
cgidlo	M-143	ijdbot	OP-25	rsw1	M-92	vfbw	M-21
cgs	OP-48	ijdgat	OP-26	rsw2	M-93	vgs	OP-29
cgsol	OP-58	ijdsti	OP-27	rvpoly	M-167	vgt	OP-34
chibo	M-139	ijs	OP-20	rwello	M-163	vjunref	M-236
cigid	OP-78	ijsbot	OP-21	sa	I-3	vnsubo	M-39
cjd	OP-64	ijsgat	OP-22	saref	M-170	vpo	M-121
cjdbot	OP-65	ijssti	OP-23	sb	I-4	vsat	OP-36
cjdgat	OP-66	imax	M-193	sbref	M-171	vsb	OP-30
cjdsti	OP-67	isb	OP-11	sc	I-9	vth	OP-33
cjorbot	M-194	ise	OP-5	sca	I-6	vto	OP-31

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

cjorgat M-196	kuo M-173	scb I-7	vts OP-32
cjorsti M-195	kuowel M-156	scc I-8	w I-2
cjs OP-60	kuowelw M-158	scref M-189	wbet M-70
cjsbot OP-61	kuoweo M-155	sd I-5	web M-190
cjsgat OP-62	kuowew M-157	sdi OP-84	wec M-191
cjssti OP-63	kvsat M-174	sdint OP-2	weff OP-3
csb OP-53	kvtho M-181	sfl OP-73	wkuo M-177
csd OP-50	kvthowel M-152	siavl OP-82	wkvtho M-183
csg OP-51	kvthowelw M-154	sid OP-76	wlod M-172
csl M-81	kvthoweo M-151	sig OP-77	wlodkuo M-180
cslexp M-82	kvthowew M-153	sigd OP-81	wlodvth M-186
cslw M-84	l I-1	sigs OP-80	wot M-16
cso M-80	lap M-12	sqrtsff OP-74	wseg M-31
csrbot M-209	leff OP-4	sqrtsfw OP-75	wsegp M-34
csrhgat M-211	level M-1	ssi OP-83	wvarl M-14
csrhisti M-210	lgdrain I-17	sta2o M-126	wvaro M-13
css OP-52	lgsource I-14	stbetl M-72	wvarw M-15
csw M-83	lkuo M-176	stbetlw M-74	xcorl M-87
ctatbot M-214	lkvtho M-182	stbeto M-71	xcorlw M-89
ctatgat M-216	llodkuo M-179	stbetw M-73	xcoro M-86
ctatsti M-215	llodvth M-185	stbgidlo M-142	xcorw M-88

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

ctl	M-50	lodetao	M-188	stcso	M-85	xgw	I-25
ctlexp	M-51	lov	M-55	stetao	M-187	xjungat	M-213
ctlw	M-53	lp1	M-64	stfbbtbot	M-226	xjunsti	M-212
cto	M-49	lp1w	M-65	stfbbtgat	M-228		
ctw	M-52	lp2	M-67	stfbbtsti	M-227		

PSP NQS MOSFET Model (pspnqs1021)

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 d g s b ModelName parameter=value ...

Instance Parameters

1	l=1e-05 m	Design length.
2	w=1e-05 m	Design width.
3	sa=0 m	Distance between OD-edge and poly from one side.
4	sb=0 m	Distance between OD-edge and poly from other side.
5	sd=0 m	Distance between neighbouring fingers.
6	sca=0	Integral of the first distribution function for scattered well dopants.
7	scb=0	Integral of the second distribution function for scattered well dopants.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

8	<code>scc=0</code>	Integral of the third distribution function for scattered well dopants.
9	<code>sc=0 m</code>	Distance between OD-edge and nearest well edge.
10	<code>delvto=0 V</code>	Threshold voltage shift parameter.
11	<code>factuo=1</code>	Zero-field mobility pre-factor.
12	<code>absource=1e-12 m²</code>	Bottom area of source junction.
13	<code>lssource=1e-06 m</code>	STI-edge length of source junction.
14	<code>lgsource=1e-06 m</code>	Gate-edge length of source junction.
15	<code>abdRAIN=1e-12 m²</code>	Bottom area of drain junction.
16	<code>lsdRAIN=1e-06 m</code>	STI-edge length of drain junction.
17	<code>lgdRAIN=1e-06 m</code>	Gate-edge length of drain junction.
18	<code>as=1e-12 m²</code>	Bottom area of source junction.
19	<code>ps=1e-06 m</code>	Perimeter of source junction.
20	<code>ad=1e-12 m²</code>	Bottom area of drain junction.
21	<code>pd=1e-06 m</code>	Perimeter of drain junction.
22	<code>mult=1</code>	Number of devices in parallel.
23	<code>nf=1</code>	Number of fingers.
24	<code>ngcon=1</code>	Number of gate contacts.
25	<code>xgw=1e-07 m</code>	Distance from the gate contact to the channel edge.
26	<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> , <code>subth</code> , <code>rev</code> , <code>fwd</code> , or <code>brk</code> .
27	<code>m=1</code>	Multiplicity factor.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

28 `trise=0` Temperature rise from ambient.

29 `area=1` alias of `mult`.

Model Definition

```
model modelName pspnqsl021 parameter=value ...
```

Model Parameters

1 `level=1.02e+03` Model level.

2 `type=n` Channel type parameter, +1=NMOS -1=PMOS.
Possible values are n, p, npn, pnp, npnv, pnpv, npnl, or pnp1.

3 `tr=21 C` nominal (reference) temperature.

4 `swigate=0` Flag for gate current, 0=turn off IG.

5 `swimpact=0` Flag for impact ionization current, 0=turn off II.

6 `swgidl=0` Flag for GIDL current, 0=turn off IGIDL.

7 `swjuncap=0` Flag for juncap, 0=turn off juncap.

8 `swjunasym=0` Flag for asymmetric junctions; 0=symmetric, 1=asymmetric.

9 `qmc=1` Quantum-mechanical correction factor.

10 `lvaro=0 m` Geometry independent difference between actual and programmed poly-silicon gate length.

11 `lvarl=0` Length dependence of difference between actual and programmed poly-silicon gate length.

12 `lap=0 m` Effective channel length reduction per side due to lateral diffusion of source/drain dopant ions.

13 `wvaro=0 m` Geometry independent difference between actual and programmed field-oxide opening.

14 `wvarw=0` Width dependence of difference between actual and programmed field-oxide opening.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

15	$w_{ot}=0$ m	Effective reduction of channel width per side due to lateral diffusion of channel-stop dopant ions.
16	$dlq=0$ m	Effective channel length reduction for CV.
17	$dwq=0$ m	Effective channel width reduction for CV.
18	$p_{ovfb}=-1$ V	Coefficient for the geometry independent part of VFB.
19	$p_{lvfb}=0$ V	Coefficient for the length dependence of VFB.
20	$p_{wvfb}=0$ V	Coefficient for the width dependence of VFB.
21	$p_{lwvfb}=0$ V	Coefficient for the length times width dependence of VFB.
22	$postvfb=0.0005$ V/K	Coefficient for the geometry independent part of STVFB.
23	$p_{lstvfb}=0$ V/K	Coefficient for the length dependence of STVFB.
24	$p_{wstvfb}=0$ V/K	Coefficient for the width dependence of STVFB.
25	$p_{lwstvfb}=0$ V/K	Coefficient for the length times width dependence of STVFB.
26	$p_{otox}=2e-09$ m	Coefficient for the geometry independent part of TOX.
27	$p_{oepsrox}=3.9$	Coefficient for the geometry independent part of EPSOX.
28	$p_{oneff}=5e+23$ m ⁻³	Coefficient for the geometry independent part of NEFF.
29	$p_{lneff}=0$ m ⁻³	Coefficient for the length dependence of NEFF.
30	$p_{wneff}=0$ m ⁻³	Coefficient for the width dependence of NEFF.
31	$p_{lwneff}=0$ m ⁻³	Coefficient for the length times width dependence of NEFF.
32	$p_{ovnsb}=0$ V	Coefficient for the geometry independent part of VNSUB.
33	$p_{onslp}=0.05$ V	Coefficient for the geometry independent part of NSLP.
34	$p_{odnsb}=0$ V ¹	Coefficient for the geometry independent part of DNSUB.
35	$p_{odphib}=0$ V	Coefficient for the geometry independent part of DPHIB.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

36	$p_{ldphib}=0$	V	Coefficient for the length dependence of DPHIB.
37	$p_{wdphib}=0$	V	Coefficient for the width dependence of DPHIB.
38	$p_{lwdphib}=0$	V	Coefficient for the length times width dependence of DPHIB.
39	$p_{onp}=1e+26$	m^{-3}	Coefficient for the geometry independent part of NP.
40	$p_{lnp}=0$	m^{-3}	Coefficient for the length dependence of NP.
41	$p_{wnp}=0$	m^{-3}	Coefficient for the width dependence of NP.
42	$p_{lwnp}=0$	m^{-3}	Coefficient for the length times width dependence of NP.
43	$p_{oct}=0$		Coefficient for the geometry independent part of CT.
44	$p_{lct}=0$		Coefficient for the length dependence of CT.
45	$p_{wct}=0$		Coefficient for the width dependence of CT.
46	$p_{lwct}=0$		Coefficient for the length times width dependence of CT.
47	$p_{otoxov}=2e-09$	m	Coefficient for the geometry independent part of TOXOV.
48	$p_{otoxovd}=2e-09$	m	Coefficient for the geometry independent part of TOXOV for drain side.
49	$p_{onov}=5e+25$	m^{-3}	Coefficient for the geometry independent part of NOV.
50	$p_{lnov}=0$	m^{-3}	Coefficient for the length dependence of NOV.
51	$p_{wnov}=0$	m^{-3}	Coefficient for the width dependence of NOV.
52	$p_{lwnov}=0$	m^{-3}	Coefficient for the length times width dependence of NOV.
53	$p_{onovd}=5e+25$	m^{-3}	Coefficient for the geometry independent part of NOV for drain side.
54	$p_{lnovd}=0$	m^{-3}	Coefficient for the length dependence of NOV for drain side.
55	$p_{wnovd}=0$	m^{-3}	Coefficient for the width dependence of NOV for drain side.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

56	$p_{lwnovd}=0 \text{ m}^{-3}$	Coefficient for the length times width dependence of NOV for drain side.
57	$p_{ocf}=0 \text{ V}^{-1}$	Coefficient for the geometry independent part of CF.
58	$p_{lcf}=0 \text{ V}^{-1}$	Coefficient for the length dependence of CF.
59	$p_{wcf}=0 \text{ V}^{-1}$	Coefficient for the width dependence of CF.
60	$p_{lwcf}=0 \text{ V}^{-1}$	Coefficient for the length times width dependence of CF.
61	$p_{ocfb}=0 \text{ V}^{-1}$	Coefficient for the geometry independent part of CFB.
62	$p_{obetn}=0.07 \text{ m}^2/\text{V}/\text{s}$	Coefficient for the geometry independent part of BETN.
63	$p_{lbetn}=0 \text{ m}^2/\text{V}/\text{s}$	Coefficient for the length dependence of BETN.
64	$p_{wbetn}=0 \text{ m}^2/\text{V}/\text{s}$	Coefficient for the width dependence of BETN.
65	$p_{lwbetn}=0 \text{ m}^2/\text{V}/\text{s}$	Coefficient for the length times width dependence of BETN.
66	$p_{ostbet}=1$	Coefficient for the geometry independent part of STBET.
67	$p_{lstbet}=0$	Coefficient for the length dependence of STBET.
68	$p_{wstbet}=0$	Coefficient for the width dependence of STBET.
69	$p_{lwestbet}=0$	Coefficient for the length times width dependence of STBET.
70	$p_{omue}=0.5 \text{ m}/\text{V}$	Coefficient for the geometry independent part of MUE.
71	$p_{lmue}=0 \text{ m}/\text{V}$	Coefficient for the length dependence of MUE.
72	$p_{wmue}=0 \text{ m}/\text{V}$	Coefficient for the width dependence of MUE.
73	$p_{lwmue}=0 \text{ m}/\text{V}$	Coefficient for the length times width dependence of MUE.
74	$p_{ostmue}=0$	Coefficient for the geometry independent part of STMUE.
75	$p_{othemu}=1.5$	Coefficient for the geometry independent part of THEMU.
76	$p_{ostthemu}=1.5$	Coefficient for the geometry independent part of STTHEMU.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

77	$pocs=0$	Coefficient for the geometry independent part of CS.
78	$plcs=0$	Coefficient for the length dependence of CS.
79	$pwcs=0$	Coefficient for the width dependence of CS.
80	$plwcs=0$	Coefficient for the length times width dependence of CS.
81	$postcs=0$	Coefficient for the geometry independent part of STCS.
82	$poxcor=0 \ V^{-1}$	Coefficient for the geometry independent part of XCOR.
83	$plxcor=0 \ V^{-1}$	Coefficient for the length dependence of XCOR.
84	$pwxcor=0 \ V^{-1}$	Coefficient for the width dependence of XCOR.
85	$plwxcor=0 \ V^{-1}$	Coefficient for the length times width dependence of XCOR.
86	$postxcor=0$	Coefficient for the geometry independent part of STXCOR.
87	$pofeta=1$	Coefficient for the geometry independent part of FETA.
88	$pors=30 \ \Omega$	Coefficient for the geometry independent part of RS.
89	$plrs=0 \ \Omega$	Coefficient for the length dependence of RS.
90	$pwr=0 \ \Omega$	Coefficient for the width dependence of RS.
91	$plwrs=0 \ \Omega$	Coefficient for the length times width dependence of RS.
92	$postrs=1$	Coefficient for the geometry independent part of STRS.
93	$porsb=0 \ V^{-1}$	Coefficient for the geometry independent part of RSB.
94	$porsg=0 \ V^{-1}$	Coefficient for the geometry independent part of RSG.
95	$pothesat=1 \ V^{-1}$	Coefficient for the geometry independent part of THESAT.
96	$plthesat=0 \ V^{-1}$	Coefficient for the length dependence of THESAT.
97	$pwthesat=0 \ V^{-1}$	Coefficient for the width dependence of THESAT.
98	$plwthesat=0 \ V^{-1}$	Coefficient for the length times width dependence of THESAT.

Virtuoso Simulator Components and Device Models Reference
PSP Model (psp)

99	<code>postthesat=1</code>	Coefficient for the geometry independent part of STTHESAT.
100	<code>plstthesat=0</code>	Coefficient for the length dependence of STTHESAT.
101	<code>pwstthesat=0</code>	Coefficient for the width dependence of STTHESAT.
102	<code>plwstthesat=0</code>	Coefficient for the length times width dependence of STTHESAT.
103	<code>pothesatb=0</code> V^{-1}	Coefficient for the geometry independent part of THESATB.
104	<code>plthesatb=0</code> V^{-1}	Coefficient for the length dependence of THESATB.
105	<code>pwthesatb=0</code> V^{-1}	Coefficient for the width dependence of THESATB.
106	<code>plwthesatb=0</code> V^{-1}	Coefficient for the length times width dependence of THESATB.
107	<code>pothesatg=0</code> V^{-1}	Coefficient for the geometry independent part of THESATG.
108	<code>plthesatg=0</code> V^{-1}	Coefficient for the length dependence of THESATG.
109	<code>pwthesatg=0</code> V^{-1}	Coefficient for the width dependence of THESATG.
110	<code>plwthesatg=0</code> V^{-1}	Coefficient for the length times width dependence of THESATG.
111	<code>poax=3</code>	Coefficient for the geometry independent part of AX.
112	<code>plax=0</code>	Coefficient for the length dependence of AX.
113	<code>pwax=0</code>	Coefficient for the width dependence of AX.
114	<code>plwax=0</code>	Coefficient for the length times width dependence of AX.
115	<code>poalp=0.01</code>	Coefficient for the geometry independent part of ALP.
116	<code>plalp=0</code>	Coefficient for the length dependence of ALP.
117	<code>pwalp=0</code>	Coefficient for the width dependence of ALP.
118	<code>plwalp=0</code>	Coefficient for the length times width dependence of ALP.
119	<code>poalp1=0</code> V	Coefficient for the geometry independent part of ALP1.
120	<code>plalp1=0</code> V	Coefficient for the length dependence of ALP1.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

121	$p_{w1}p_1=0$	V	Coefficient for the width dependence of ALP1.
122	$p_{l1}w_1p_1=0$	V	Coefficient for the length times width dependence of ALP1.
123	$p_{o1}p_2=0$	V^{-1}	Coefficient for the geometry independent part of ALP2.
124	$p_{l1}p_2=0$	V^{-1}	Coefficient for the length dependence of ALP2.
125	$p_{w1}p_2=0$	V^{-1}	Coefficient for the width dependence of ALP2.
126	$p_{l1}w_1p_2=0$	V^{-1}	Coefficient for the length times width dependence of ALP2.
127	$p_{ov}p=0.05$	V	Coefficient for the geometry independent part of VP.
128	$p_{o1}=1$		Coefficient for the geometry independent part of A1.
129	$p_{l1}=0$		Coefficient for the length dependence of A1.
130	$p_{w1}=0$		Coefficient for the width dependence of A1.
131	$p_{l1}w_1=0$		Coefficient for the length times width dependence of A1.
132	$p_{o2}=10$	V	Coefficient for the geometry independent part of A2.
132	$p_{o2}a_2=0$	V	Coefficient for the geometry independent part of STA2.
133	$p_{o3}=1$		Coefficient for the geometry independent part of A3.
134	$p_{l3}=0$		Coefficient for the length dependence of A3.
136	$p_{w3}=0$		Coefficient for the width dependence of A3.
137	$p_{l1}w_3=0$		Coefficient for the length times width dependence of A3.
138	$p_{o4}=0$	$V^{-0.5}$	Coefficient for the geometry independent part of A4.
139	$p_{l4}=0$	$V^{-0.5}$	Coefficient for the length dependence of A4.
140	$p_{w4}=0$	$V^{-0.5}$	Coefficient for the width dependence of A4.
141	$p_{l1}w_4=0$	$V^{-0.5}$	Coefficient for the length times width dependence of A4.
142	$p_{ogco}=0$		Coefficient for the geometry independent part of GCO.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

143	<code>poiginv=0</code>	A	Coefficient for the geometry independent part of IGINV.
144	<code>pliginv=0</code>	A	Coefficient for the length dependence of IGINV.
145	<code>pwiginv=0</code>	A	Coefficient for the width dependence of IGINV.
146	<code>plwiginv=0</code>	A	Coefficient for the length times width dependence of IGINV.
147	<code>poigov=0</code>	A	Coefficient for the geometry independent part of IGOV.
148	<code>pligov=0</code>	A	Coefficient for the length dependence of IGOV.
149	<code>pwigov=0</code>	A	Coefficient for the width dependence of IGOV.
150	<code>plwigov=0</code>	A	Coefficient for the length times width dependence of IGOV.
151	<code>poigovd=0</code>	A	Coefficient for the geometry independent part of IGOV for drain side.
152	<code>pligovd=0</code>	A	Coefficient for the length dependence of IGOV for drain side.
153	<code>pwigovd=0</code>	A	Coefficient for the width dependence of IGOV for drain side.
154	<code>plwigovd=0</code>	A	Coefficient for the length times width dependence of IGOV for drain side.
155	<code>postig=2</code>		Coefficient for the geometry independent part of STIG.
156	<code>pogc2=0.375</code>		Coefficient for the geometry independent part of GC2.
157	<code>pogc3=0.063</code>		Coefficient for the geometry independent part of GC3.
158	<code>pochib=3.1</code>	V	Coefficient for the geometry independent part of CHIB.
159	<code>poagidl=0</code>	A/V^3	Coefficient for the geometry independent part of AGIDL.
160	<code>plagidl=0</code>	A/V^3	Coefficient for the length dependence of AGIDL.
161	<code>pwagidl=0</code>	A/V^3	Coefficient for the width dependence of AGIDL.
162	<code>plwagidl=0</code>	A/V^3	Coefficient for the length times width dependence of AGIDL.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

163	$p_{oagidl}=0$	A/V^3	Coefficient for the geometry independent part of AGIDL for drain side.
164	$p_{lagidl}=0$	A/V^3	Coefficient for the length dependence of AGIDL for drain side.
165	$p_{wagidl}=0$	A/V^3	Coefficient for the width dependence of AGIDL for drain side.
166	$p_{lwagidl}=0$	A/V^3	Coefficient for the length times width dependence of AGIDL for drain side.
167	$p_{obgidl}=41$	V	Coefficient for the geometry independent part of BGIDL.
168	$p_{obgidld}=41$	V	Coefficient for the geometry independent part of BGIDL for drain side.
169	$p_{ostbgidl}=0$	V/K	Coefficient for the geometry independent part of STBGIDL.
170	$p_{ostbgidld}=0$	V/K	Coefficient for the geometry independent part of STBGIDL for drain
171	$p_{ocgidl}=0$		Coefficient for the geometry independent part of CGIDL.
172	$p_{ocgidld}=0$		Coefficient for the geometry independent part of CGIDL for drain side.
173	$p_{ocox}=1e-14$	F	Coefficient for the geometry independent part of COX.
174	$p_{lcox}=0$	F	Coefficient for the length dependence of COX.
175	$p_{wcox}=0$	F	Coefficient for the width dependence of COX.
176	$p_{lwcox}=0$	F	Coefficient for the length times width dependence of COX.
177	$p_{ocgov}=1e-15$	F	Coefficient for the geometry independent part of CGOV.
178	$p_{lcgov}=0$	F	Coefficient for the length dependence of CGOV.
179	$p_{wcgov}=0$	F	Coefficient for the width dependence of CGOV.
180	$p_{lwcgov}=0$	F	Coefficient for the length times width dependence of CGOV.
181	$p_{ocgovd}=1e-15$	F	Coefficient for the geometry independent part of CGOV for drain side.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

182	<code>plcgovd=0</code>	F	Coefficient for the length dependence of CGOV for drain side.
183	<code>pwcgovd=0</code>	F	Coefficient for the width dependence of CGOV for drain side.
184	<code>plwcgovd=0</code>	F	Coefficient for the length times width dependence of CGOV for drainside.
185	<code>pocgbov=0</code>	F	Coefficient for the geometry independent part of CGBOV.
186	<code>plcgbov=0</code>	F	Coefficient for the length dependence of CGBOV.
187	<code>pwcgbov=0</code>	F	Coefficient for the width dependence of CGBOV.
188	<code>plwcgbov=0</code>	F	Coefficient for the length times width dependence of CGBOV.
189	<code>pocfr=0</code>	F	Coefficient for the geometry independent part of CFR.
190	<code>plcfr=0</code>	F	Coefficient for the length dependence of CFR.
191	<code>pwcfr=0</code>	F	Coefficient for the width dependence of CFR.
192	<code>plwcfr=0</code>	F	Coefficient for the length times width dependence of CFR.
193	<code>pocfrd=0</code>	F	Coefficient for the geometry independent part of CFR for drain side.
194	<code>plcfrd=0</code>	F	Coefficient for the length dependence of CFR for drain side.
195	<code>pwcfrd=0</code>	F	Coefficient for the width dependence of CFR for drain side.
196	<code>plwcfrd=0</code>	F	Coefficient for the length times width dependence of CFR for drainside.
197	<code>pofnt=1</code>		Coefficient for the geometry independent part of FNT.
198	<code>ponfa=8e+22</code>	V^{-1}/m^4	Coefficient for the geometry independent part of NFA.
199	<code>plnfa=0</code>	V^{-1}/m^4	Coefficient for the length dependence of NFA.
200	<code>pwnfa=0</code>	V^{-1}/m^4	Coefficient for the width dependence of NFA.
201	<code>plwnfa=0</code>	V^{-1}/m^4	Coefficient for the length times width dependence of NFA.

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202	$\text{ponfb}=3\text{e}+07 \text{ V}^{-1}/\text{m}^2$	Coefficient for the geometry independent part of NFB.
203	$\text{plnfb}=0 \text{ V}^{-1}/\text{m}^2$	Coefficient for the length dependence of NFB.
204	$\text{pwnfb}=0 \text{ V}^{-1}/\text{m}^2$	Coefficient for the width dependence of NFB.
205	$\text{plwnfb}=0 \text{ V}^{-1}/\text{m}^2$	Coefficient for the length times width dependence of NFB.
206	$\text{ponfc}=0 \text{ V}^{-1}$	Coefficient for the geometry independent part of NFC.
207	$\text{plnfc}=0 \text{ V}^{-1}$	Coefficient for the length dependence of NFC.
208	$\text{pwnfc}=0 \text{ V}^{-1}$	Coefficient for the width dependence of NFC.
209	$\text{plwnfc}=0 \text{ V}^{-1}$	Coefficient for the length times width dependence of NFC.
210	$\text{poef}=1$	Coefficient for the flicker noise frequency exponent.
211	$\text{dta}=0 \text{ K}$	Temperature offset w.r.t. ambient temperature.
212	$\text{pokvthowe}=0$	Coefficient for the geometry independent part of KVTHOWE.
213	$\text{plkvthowe}=0$	Coefficient for the length dependence part of KVTHOWE.
214	$\text{pwkvthowe}=0$	Coefficient for the width dependence part of KVTHOWE.
215	$\text{plwkvthowe}=0$	Coefficient for the length times width dependence part of KVTHOWE.
216	$\text{pokuowe}=0$	Coefficient for the geometry independent part of KUOWE.
217	$\text{plkuowe}=0$	Coefficient for the length dependence part of KUOWE.
218	$\text{pwkuowe}=0$	Coefficient for the width dependence part of KUOWE.
219	$\text{plwkuowe}=0$	Coefficient for the length times width dependence part of KUOWE.
220	$\text{lmin}=0 \text{ m}$	Dummy parameter to label binning set.
221	$\text{lmax}=1 \text{ m}$	Dummy parameter to label binning set.

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222	wmin=0 m	Dummy parameter to label binning set.
223	wmax=1 m	Dummy parameter to label binning set.
224	swnqs=0	Flag for NQS, 0=off, 1, 2, 3, 5, or 9=number of collocation points.
225	munqso=1 unknown	Relative mobility for NQS modelling.
226	rgo=0 Ω	Gate resistance.
227	rbulko=0 Ω	Bulk resistance between node BP and BI.
228	rwello=0 Ω	Well resistance between node BI and B.
229	rjunso=0 Ω	Source-side bulk resistance between node BI and BS.
230	rjundo=0 Ω	Drain-side bulk resistance between node BI and BD.
231	rint=0 Ω/Sqr	Contact resistance between silicide and poly.
232	rvpoly=0 Ω/Sqr	Vertical poly resistance.
233	rshg=0 Ω/Sqr	Gate electrode diffusion sheet resistance.
234	dlsil=0 m	Silicide extension over the physical gate length.
235	saref=1e-06 m	Reference distance between OD-edge and poly from one side.
236	sbref=1e-06 m	Reference distance between OD-edge and poly from other side.
237	wlod=0 m	Width parameter.
238	kuo=0 m	Mobility degradation/enhancement coefficient.
239	kvsat=0 m	Saturation velocity degradation/enhancement coefficient.
240	tkuo=0	Temperature dependence of KUO.
241	lkuo=0 m ^{LLODKUO}	Length dependence of KUO.
242	wkuo=0 m ^{WLODKUO}	Width dependence of KUO.

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PSP Model (psp)

243	$p_{kuo}=0 \text{ m}^{(LLODKUO+WLODKUO)}$	Cross-term dependence of KUO.
244	$l_{lodkuo}=0$	Length parameter for UO stress effect.
245	$w_{lodkuo}=0$	Width parameter for UO stress effect.
246	$k_{vtho}=0 \text{ Vm}$	Threshold shift parameter.
247	$l_{kvtho}=0 \text{ m}^{LLODVTH}$	Length dependence of KVTHO.
248	$w_{kvtho}=0 \text{ m}^{WLODVTH}$	Width dependence of KVTHO.
249	$p_{kvtho}=0 \text{ m}^{(LLODVTH+WLODVTH)}$	Cross-term dependence of KVTHO.
250	$l_{lodvth}=0$	Length parameter for VTH-stress effect.
251	$w_{lodvth}=0$	Width parameter for VTH-stress effect.
252	$s_{etao}=0 \text{ m}$	η_0 shift factor related to VTHO change.
253	$l_{odetao}=1$	η_0 shift modification factor for stress effect.
254	$s_{cref}=1e-05 \text{ m}$	Distance between OD-edge and well edge of a reference device.
255	$w_{eb}=0$	Coefficient for SCB.
256	$w_{ec}=0$	Coefficient for SCC.
257	$t_{rj}=21 \text{ C}$	reference temperature.
258	$i_{max}=1e+03 \text{ A}$	Maximum current up to which forward current behaves exponentially.
259	$c_{jorbot}=0.001 \text{ Fm}^{-2}$	Zero-bias capacitance per unit-of-area of bottom component.
260	$c_{jorsti}=1e-09 \text{ Fm}^{-1}$	Zero-bias capacitance per unit-of-length of STI-edge component.

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PSP Model (psp)

261	$c_{jorgat}=1e-09$	Fm^{-1}	Zero-bias capacitance per unit-of-length of gate-edge component.
262	$v_{birbot}=1$	V	Built-in voltage at the reference temperature of bottom component.
263	$v_{birsti}=1$	V	Built-in voltage at the reference temperature of STI-edge component.
264	$v_{birgat}=1$	V	Built-in voltage at the reference temperature of gate-edge component.
265	$p_{bot}=0.5$		Grading coefficient of bottom component.
266	$p_{sti}=0.5$		Grading coefficient of STI-edge component.
267	$p_{gat}=0.5$		Grading coefficient of gate-edge component.
268	$phigbot=1.16$	V	Zero-temperature bandgap voltage of bottom component.
269	$phigsti=1.16$	V	Zero-temperature bandgap voltage of STI-edge component.
270	$phiggat=1.16$	V	Zero-temperature bandgap voltage of gate-edge component.
271	$idsatrbot=1e-12$	Am^{-2}	Saturation current density at the reference temperature of bottom component.
272	$idsatrsti=1e-18$	Am^{-1}	Saturation current density at the reference temperature of STI-edge component.
273	$idsatrgat=1e-18$	Am^{-1}	Saturation current density at the reference temperature of gate-edge component.
274	$csrbot=100$	Am^{-3}	Shockley-Read-Hall prefactor of bottom component.
275	$csrhisti=0.0001$	Am^{-2}	Shockley-Read-Hall prefactor of STI-edge component.

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PSP Model (psp)

- 276 $\text{csrhat}=0.0001 \text{ Am}^{-2}$ Shockley-Read-Hall prefactor of gate-edge component.
- 277 $\text{xjunsti}=1\text{e-}07 \text{ m}$ Junction depth of STI-edge component.
- 278 $\text{xjngat}=1\text{e-}07 \text{ m}$ Junction depth of gate-edge component.
- 279 $\text{ctatbot}=100 \text{ Am}^{-3}$ Trap-assisted tunneling prefactor of bottom component.
- 280 $\text{ctatsti}=0.0001 \text{ Am}^{-2}$ Trap-assisted tunneling prefactor of STI-edge component.
- 281 $\text{ctatgat}=0.0001 \text{ Am}^{-2}$ Trap-assisted tunneling prefactor of gate-edge component.
- 282 $\text{mefftatbot}=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of bottom component.
- 283 $\text{mefftatsti}=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of STI-edge component.
- 284 $\text{mefftatgat}=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of gate-edge component.
- 285 $\text{cbbtbot}=1\text{e-}12 \text{ AV}^{-3}$ Band-to-band tunneling prefactor of bottom component.
- 286 $\text{cbbtsti}=1\text{e-}18 \text{ AV}^{-3}_m$ Band-to-band tunneling prefactor of STI-edge component.
- 287 $\text{cbbtgat}=1\text{e-}18 \text{ AV}^{-3}_m$ Band-to-band tunneling prefactor of gate-edge component.
- 288 $\text{fbbtrbot}=1\text{e+}09 \text{ Vm}^{-1}$ Normalization field at the reference temperature for band-to-band tunneling of bottom component.
- 289 $\text{fbbtrsti}=1\text{e+}09 \text{ Vm}^{-1}$ Normalization field at the reference temperature for band-to-band tunneling of STI-edge component.

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PSP Model (psp)

- 290 `fbttrgat=1e+09` Vm^{-1}
Normalization field at the reference temperature for band-to-band tunneling of gate-edge component.
- 291 `stfbbtbot=-0.001` K^{-1}
Temperature scaling parameter for band-to-band tunneling of bottom component.
- 292 `stfbbtsti=-0.001` K^{-1}
Temperature scaling parameter for band-to-band tunneling of STI-edge component.
- 293 `stfbbtgat=-0.001` K^{-1}
Temperature scaling parameter for band-to-band tunneling of gate-edge component.
- 294 `vbrbot=10` V
Breakdown voltage of bottom component.
- 295 `vbrsti=10` V
Breakdown voltage of STI-edge component.
- 296 `vbrgat=10` V
Breakdown voltage of gate-edge component.
- 297 `pbrbot=4` V
Breakdown onset tuning parameter of bottom component.
- 298 `pbrsti=4` V
Breakdown onset tuning parameter of STI-edge component.
- 299 `pbrgat=4` V
Breakdown onset tuning parameter of gate-edge component.
- 300 `cjorbotd=0.001` Fm^{-2}
Zero-bias capacitance per unit-of-area of bottom component for drain-bulk junction.
- 301 `cjorstid=1e-09` Fm^{-1}
Zero-bias capacitance per unit-of-length of STI-edge component for drain-bulk junction.
- 302 `cjorgatd=1e-09` Fm^{-1}
Zero-bias capacitance per unit-of-length of gate-edge component for drain-bulk junction.
- 303 `vbirbotd=1` V
Built-in voltage at the reference temperature of bottom component for drain-bulk junction.

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PSP Model (psp)

304	<code>vbirstid=1</code>	V	Built-in voltage at the reference temperature of STI-edge component for drain-bulk junction.
305	<code>vbirgatd=1</code>	V	Built-in voltage at the reference temperature of gate-edge component for drain-bulk junction.
306	<code>pbotd=0.5</code>		Grading coefficient of bottom component for drain-bulk junction.
307	<code>pstid=0.5</code>		Grading coefficient of STI-edge component for drain-bulk junction.
308	<code>pgatd=0.5</code>		Grading coefficient of gate-edge component for drain-bulk junction.
309	<code>phigbotd=1.16</code>	V	Zero-temperature bandgap voltage of bottom component for drain-bulk junction.
310	<code>phigstid=1.16</code>	V	Zero-temperature bandgap voltage of STI-edge component for drain-bulk junction.
311	<code>phiggatd=1.16</code>	V	Zero-temperature bandgap voltage of gate-edge component for drain-bulk junction.
312	<code>idsatrbotd=1e-12</code>	Am^{-2}	Saturation current density at the reference temperature of bottom component for drain-bulk junction.
313	<code>idsatrstid=1e-18</code>	Am^{-1}	Saturation current density at the reference temperature of STI-edge component for drain-bulk junction.
314	<code>idsatrgatd=1e-18</code>	Am^{-1}	Saturation current density at the reference temperature of gate-edge component for drain-bulk junction.
315	<code>csrhbtd=100</code>	Am^{-3}	Shockley-Read-Hall prefactor of bottom component for drain-bulk junction.
316	<code>csrhistid=0.0001</code>	Am^{-2}	Shockley-Read-Hall prefactor of STI-edge component for drain-bulk junction.
317	<code>csrhgatd=0.0001</code>	Am^{-2}	Shockley-Read-Hall prefactor of gate-edge component for drain-bulk junction.

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PSP Model (psp)

- 318 $x_{junstid}=1e-07$ m Junction depth of STI-edge component for drain-bulk junction.
- 319 $x_{jungatd}=1e-07$ m Junction depth of gate-edge component for drain-bulk junction.
- 320 $ctatbotd=100$ A_m^{-3} Trap-assisted tunneling prefactor of bottom component for drain-bulk junction.
- 321 $ctatstid=0.0001$ A_m^{-2}
Trap-assisted tunneling prefactor of STI-edge component for drain-bulk junction.
- 322 $ctatgatd=0.0001$ A_m^{-2}
Trap-assisted tunneling prefactor of gate-edge component for drain-bulk junction.
- 323 $m_{efftatbotd}=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of bottom component for drain-bulk junction.
- 324 $m_{efftatstid}=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of STI-edge component for drain-bulk junction.
- 325 $m_{efftatgatd}=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of gate-edge component for drain-bulk junction.
- 326 $cbbtbotd=1e-12$ AV^3
Band-to-band tunneling prefactor of bottom component for drain-bulk junction.
- 327 $cbbtstid=1e-18$ AV^{-3}_m
Band-to-band tunneling prefactor of STI-edge component for drain-bulk junction.
- 328 $cbbtgatd=1e-18$ AV^{-3}_m
Band-to-band tunneling prefactor of gate-edge component for drain-bulk junction.
- 329 $fbbtrbotd=1e+09$ V_m^{-1}
Normalization field at the reference temperature for band-to-band tunneling of bottom component for drain-bulk junction.
- 330 $fbbtrstid=1e+09$ V_m^{-1}
Normalization field at the reference temperature for band-to-band tunneling of STI-edge component for drain-bulk junction.

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PSP Model (psp)

- 331 `fbtrgatd=1e+09` V m^{-1}
Normalization field at the reference temperature for band-to-band tunneling of gate-edge component for drain-bulk junction.
- 332 `stfbbtbotd=-0.001` K^{-1}
Temperature scaling parameter for band-to-band tunneling of bottom component for drain-bulk junction.
- 333 `stfbbtstid=-0.001` K^{-1}
Temperature scaling parameter for band-to-band tunneling of STI-edge component for drain-bulk junction.
- 334 `stfbbtgatd=-0.001` K^{-1}
Temperature scaling parameter for band-to-band tunneling of gate-edge component for drain-bulk junction.
- 335 `vbrbotd=10` V
Breakdown voltage of bottom component for drain-bulk junction.
- 336 `vbrstid=10` V
Breakdown voltage of STI-edge component for drain-bulk junction.
- 337 `vbrgatd=10` V
Breakdown voltage of gate-edge component for drain-bulk junction.
- 338 `pbrbotd=4` V
Breakdown onset tuning parameter of bottom component for drain-bulk junction.
- 339 `pbrstid=4` V
Breakdown onset tuning parameter of STI-edge component for drain-bulk junction.
- 340 `pbrgatd=4` V
Breakdown onset tuning parameter of gate-edge component for drain-bulk junction.
- 341 `swjunexp=0`
Flag for JUNCAP-express; 0=full model, 1=express model.
- 342 `vjunref=2.5`
Typical maximum junction voltage; usually about $2 \cdot \text{VSUP}$.
- 343 `fjunq=0.03`
Fraction below which junction capacitance components are considered negligible.
- 344 `vjunrefd=2.5`
Typical maximum drain-bulk junction voltage; usually about $2 \cdot \text{VSUP}$.

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PSP Model (psp)

345	$f_{juncqd}=0.03$	Fraction below which drain-bulk junction capacitance components are considered negligible.
346	$m_{beo}=0.0$	DCmatch parameter.
347	$m_{vto}=0.0$	DCmatch parameter.
348	t_{nom} (C)	alias of t_{nom} .
349	t_{ref} (C)	alias of t_{nom} .

Output Parameters

1	β_{etn} (A/V ²)	Gain factor.
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Operating-Point Parameters

1	$ctype$	Flag for channel type.
2	$sdint$	Flag for source-drain interchange.
3	w_{eff} (m)	Effective channel width for geometrical models.
4	l_{eff} (m)	Effective channel length for geometrical models.
5	i_{se} (A)	Total source current.
6	i_{ge} (A)	Total gate current.
7	i_{de} (A)	Total drain current.
8	i_{be} (A)	Total bulk current.
9	i_{ds} (A)	Drain current, excl. avalanche, tunnel, GISL, GIDL, and junction currents.
10	i_{db} (A)	Drain to bulk current.
11	i_{sb} (A)	Source to bulk current.
12	i_{gs} (A)	Gate-source tunneling current.

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PSP Model (psp)

13	i_{gd} (A)	Gate-drain tunneling current.
14	i_{gb} (A)	Gate-bulk tunneling current.
15	i_{gcs} (A)	Gate-channel tunneling current (source component).
16	i_{gcd} (A)	Gate-channel tunneling current (drain component).
17	i_{avl} (A)	Substrate current due to weak avalanche.
18	i_{gisl} (A)	Gate-induced source leakage current.
19	i_{gidl} (A)	Gate-induced drain leakage current.
20	i_{js} (A)	Total source junction current.
21	i_{jsbot} (A)	Source junction current (bottom component).
22	i_{jsgat} (A)	Source junction current (gate-edge component).
23	i_{jsssti} (A)	Source junction current (STI-edge component).
24	i_{jd} (A)	Total drain junction current.
25	i_{jdbot} (A)	Drain junction current (bottom component).
26	i_{jdgat} (A)	Drain junction current (gate-edge component).
27	i_{jdsti} (A)	Drain junction current (STI-edge component).
28	v_{ds} (V)	Drain-source voltage.
29	v_{gs} (V)	Gate-source voltage.
30	v_{sb} (V)	Source-bulk voltage.
31	v_{to} (V)	Zero-bias threshold voltage.
32	v_{ts} (V)	Threshold voltage including back bias effects.
33	v_{th} (V)	Threshold voltage including back bias and drain bias effects.

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PSP Model (psp)

34	v_{gt} (V)	Effective gate drive voltage including back bias and drain bias effects.
35	v_{dss} (V)	Drain saturation voltage at actual bias.
36	v_{sat} (V)	Saturation limit.
37	g_m ($1/\Omega$)	Transconductance.
38	g_{mb} ($1/\Omega$)	Substrate transconductance.
39	g_{ds} ($1/\Omega$)	Output conductance.
40	g_{js} ($1/\Omega$)	Source junction conductance.
41	g_{jd} ($1/\Omega$)	Drain junction conductance.
42	c_{dd} (F)	Drain capacitance.
43	c_{dg} (F)	Drain-gate capacitance.
44	c_{ds} (F)	Drain-source capacitance.
45	c_{db} (F)	Drain-bulk capacitance.
46	c_{gd} (F)	Gate-drain capacitance.
47	c_{gg} (F)	Gate capacitance.
48	c_{gs} (F)	Gate-source capacitance.
49	c_{gb} (F)	Gate-bulk capacitance.
50	c_{sd} (F)	Source-drain capacitance.
51	c_{sg} (F)	Source-gate capacitance.
52	c_{ss} (F)	Source capacitance.
53	c_{sb} (F)	Source-bulk capacitance.
54	c_{bd} (F)	Bulk-drain capacitance.

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PSP Model (psp)

55	cbg (F)	Bulk-gate capacitance.
56	cbs (F)	Bulk-source capacitance.
57	cbb (F)	Bulk capacitance.
58	cgsol (F)	Total gate-source overlap capacitance.
59	cgdol (F)	Total gate-drain overlap capacitance.
60	cjs (F)	Total source junction capacitance.
61	cjsbot (F)	Source junction capacitance (bottom component).
62	cjsgat (F)	Source junction capacitance (gate-edge component).
63	cjssti (F)	Source junction capacitance (STI-edge component).
64	cjd (F)	Total drain junction capacitance.
65	cjdbot (F)	Drain junction capacitance (bottom component).
66	cjdgat (F)	Drain junction capacitance (gate-edge component).
67	cjdsti (F)	Drain junction capacitance (STI-edge component).
68	u	Transistor gain.
69	rout (Ω)	Small-signal output resistance.
70	vearly (V)	Equivalent Early voltage.
71	bef ^{ff} (A/V ²)	Gain factor.
72	fug (Hz)	Unity gain frequency at actual bias.
73	sfl (A/Hz)	Flicker noise current density at 1 Hz.
74	sqrtsff (V/ $\sqrt{\text{Hz}}$)	Input-referred RMS white noise voltage density at 1 kHz.
75	sqrtsfw (V/ $\sqrt{\text{Hz}}$)	Input-referred RMS white noise voltage density.

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PSP Model (psp)

76	sid (A ² /Hz)	White noise current density.
77	sig (A ² /Hz)	Induced gate noise current density at 1 Hz.
78	cigid	Imaginary part of correlation coefficient between Sig and Sid.
79	fknee (Hz)	Cross-over frequency above which white noise is dominant.
80	sigs (A ² /Hz)	Gate-source current noise spectral density.
81	sigd (A ² /Hz)	Gate-drain current noise spectral density.
82	siavl (A ² /Hz)	Impact ionization current noise spectral density.
83	ssi (A ² /Hz)	Total source junction current noise spectral density.
84	sdi (A ² /Hz)	Total drain junction current noise spectral density.
85	lv2 (m)	alias of weff.
86	lv1 (m)	alias of leff.
87	lx4 (A)	alias of ids.
88	lx3 (V)	alias of vds.
89	lx2 (V)	alias of vgs.
90	lv9 (V)	alias of vth.
91	lx7 (1/Ω)	alias of gm.
92	lx8 (1/Ω)	alias of gds.
93	lx9 (1/Ω)	alias of gmb.
94	lx33 (F)	alias of cdd.
95	lx32 (F)	alias of cdg.
96	lx34 (F)	alias of cds.
97	lx19 (F)	alias of cgd.

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PSP Model (psp)

98	lx18 (F)	alias of cgg.
99	lx20 (F)	alias of cgs.
100	lx22 (F)	alias of cbd.
101	lx21 (F)	alias of cbg.
102	lx23 (F)	alias of cbs.
103	lv10 (V)	alias of vdss.
104	lx5 (A)	alias of ijs.
105	lx6 (A)	alias of ijd.
106	lx28 (F)	alias of cjs.
107	lx29 (F)	alias of cjd.
108	table_ids (A)	Current.
109	table_vth (V)	Threshold voltage including back-bias and drain-bias effects.
110	table_qg (Coul)	Charge at g node.
111	table_qd (Coul)	Charge at d node.
112	table_qb (Coul)	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.

abdrain I-15 lkuo M-215 plwthesat M-92 pwnp M-40

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PSP Model (psp)

absorce	I-12	lkvtho	M-221	plwthesatb	M-100	pwrs	M-84
ad	I-20	llodkuo	M-218	plwthesatg	M-104	pwstbet	M-62
area	I-28	llodvth	M-224	plwvfb	M-20	pwstthesat	M-95
as	I-18	lmax	M-195	plwxcor	M-79	pwstvfb	M-23
beff	OP-71	lmin	M-194	plxcor	M-77	pwthesat	M-91
betn	O-1	lodetao	M-227	poal	M-122	pwthesatb	M-99
cbb	OP-57	lsdrain	I-16	poa2	M-126	pwthesatg	M-103
cbbtbot	M-259	lssource	I-13	poa3	M-128	pwvfb	M-19
cbbtgat	M-261	lvar1	M-10	poa4	M-132	pwxcor	M-78
cbbtsti	M-260	lvaro	M-9	poagidl	M-149	qmc	M-8
cbd	OP-54	m	I-27	poalp	M-109	rbulko	M-201
cbg	OP-55	mbeo	M-277	poalpl	M-113	region	I-26
cbs	OP-56	mefftatbot	M-256	poalp2	M-117	rgo	M-200
cdb	OP-45	mefftatgat	M-258	poax	M-105	rint	M-205
cdd	OP-42	mefftatsti	M-257	pobetn	M-56	rjundo	M-204
cdg	OP-43	mult	I-22	pobgidl	M-153	rjunso	M-203
cds	OP-44	munqso	M-199	pocf	M-51	rout	OP-69
cgb	OP-49	mvto	M-278	pocfb	M-55	rshg	M-207
cgd	OP-46	nf	I-23	pocfr	M-168	rvpoly	M-206
cgdol	OP-59	ngcon	I-24	pocgbov	M-164	rwello	M-202
cgg	OP-47	pbot	M-239	pocgidl	M-155	sa	I-3

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PSP Model (psp)

cgs OP-48	pbrbot M-271	pocgov M-160	saref M-209
cgsol OP-58	pbrgat M-273	pochib M-148	sb I-4
cigid OP-78	pbrsti M-272	pocox M-156	sbref M-210
cjd OP-64	pd I-21	pocs M-71	sc I-9
cjdbot OP-65	pgat M-241	poct M-42	sca I-6
cjdgat OP-66	phigbot M-242	podnsub M-33	scb I-7
cjdsti OP-67	phiggat M-244	podphib M-34	scc I-8
cjorbot M-233	phigsti M-243	poepsrox M-26	scref M-228
cjorgat M-235	pkuo M-217	pofeta M-81	sd I-5
cjorsti M-234	pkvtho M-223	pofnt M-172	sdi OP-84
cjs OP-60	pla1 M-123	pogc2 M-146	sdint OP-2
cjsbot OP-61	pla3 M-129	pogc3 M-147	sfl OP-73
cjsgat OP-62	pla4 M-133	pogco M-136	siavl OP-82
cjssti OP-63	plagidl M-150	poiginv M-137	sid OP-76
csb OP-53	plalp M-110	poigov M-141	sig OP-77
csd OP-50	plalp1 M-114	pokuowe M-190	sigd OP-81
csg OP-51	plalp2 M-118	pokvthowe M-186	sigs OP-80
csrbot M-248	plax M-106	pomue M-64	sqrtsff OP-74
csrbot M-250	plbetn M-57	poneff M-27	sqrtsfw OP-75
csrbot M-249	plcf M-52	ponfa M-173	ssi OP-83
css OP-52	plcfr M-169	ponfb M-177	stetao M-226

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

ctatbot	M-253	plcgbov	M-165	ponfc	M-181	stfbbtbot	M-265
ctatgat	M-255	plcgov	M-161	ponov	M-47	stfbbtgat	M-267
ctatsti	M-254	plcox	M-157	ponp	M-38	stfbbtsti	M-266
ctype	OP-1	plcs	M-72	ponslp	M-32	swgidl	M-6
delvto	I-10	plct	M-43	pors	M-82	swigate	M-4
dlq	M-15	pldphib	M-35	porsb	M-87	swimpact	M-5
dlsil	M-208	pliginv	M-138	porsg	M-88	swjuncap	M-7
dta	M-185	pligov	M-142	posta2	M-127	swjunexp	M-274
dwq	M-16	plkuowe	M-191	postbet	M-60	swnqs	M-198
factuo	I-11	plkvthowe	M-187	postbgidl	M-154	table_ids	OP-85
fbbtbot	M-262	plmue	M-65	postcs	M-75	table_qb	OP-89
fbbtgat	M-264	plneff	M-28	postig	M-145	table_qd	OP-88
fbbtsti	M-263	plnfa	M-174	postmue	M-68	table_qg	OP-87
fjunq	M-276	plnfb	M-178	postrs	M-86	table_vth	OP-86
fknee	OP-79	plnfc	M-182	postthemu	M-70	tkuo	M-214
fug	OP-72	plnov	M-48	postthesat	M-93	tnom	M-279
gds	OP-39	plnp	M-39	postvfb	M-21	tr	M-3
gjd	OP-41	plrs	M-83	postxcor	M-80	tref	M-280
gjs	OP-40	plstbet	M-61	pothemu	M-69	trj	M-231
gm	OP-37	plstthesat	M-94	pothesat	M-89	type	M-2
gmb	OP-38	plstvfb	M-22	pothesatb	M-97	u	OP-68

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

iavl	OP-17	plthesat	M-90	pothesatg	M-101	vbirbot	M-236
ibe	OP-8	plthesatb	M-98	potox	M-25	vbirgat	M-238
idb	OP-10	plthesatg	M-102	potoxov	M-46	vbirsti	M-237
ide	OP-7	plvfb	M-18	povfb	M-17	vbrbot	M-268
ids	OP-9	plwa1	M-125	povnsb	M-31	vbrgat	M-270
idsatrbot	M-245	plwa3	M-131	povp	M-121	vbrsti	M-269
idsatrgat	M-247	plwa4	M-135	poxcor	M-76	vds	OP-28
idsatrsti	M-246	plwagidl	M-152	ps	I-19	vdss	OP-35
igb	OP-14	plwalp	M-112	pssti	M-240	vearly	OP-70
igcd	OP-16	plwalp1	M-116	pwal	M-124	vgs	OP-29
igcs	OP-15	plwalp2	M-120	pwa3	M-130	vgt	OP-34
igd	OP-13	plwax	M-108	pwa4	M-134	vjunref	M-275
ige	OP-6	plwbetn	M-59	pwagidl	M-151	vsat	OP-36
igidl	OP-19	plwcf	M-54	pwalp	M-111	vsb	OP-30
igisl	OP-18	plwcfrr	M-171	pwalp1	M-115	vth	OP-33
igs	OP-12	plwcgbov	M-167	pwalp2	M-119	vto	OP-31
ijd	OP-24	plwcgov	M-163	pwax	M-107	vts	OP-32
ijdbot	OP-25	plwcox	M-159	pwbetn	M-58	w	I-2
ijdgat	OP-26	plwcs	M-74	pwcf	M-53	web	M-229
ijdsti	OP-27	plwct	M-45	pwcfrr	M-170	wec	M-230
ijs	OP-20	plwdphib	M-37	pwcgbov	M-166	weff	OP-3

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

ijsbot	OP-21	plwiginv	M-140	pwcgov	M-162	wkuo	M-216
ijsgat	OP-22	plwigo	M-144	pwcox	M-158	wkvtho	M-222
ijssti	OP-23	plwkuowe	M-193	pwcs	M-73	wlod	M-211
imax	M-232	plwkvthowe	M-189	pwct	M-44	wlodkuo	M-219
isb	OP-11	plwmue	M-67	pwdphib	M-36	wlodvth	M-225
ise	OP-5	plwneff	M-30	pwiginv	M-139	wmax	M-197
kuo	M-212	plwnfa	M-176	pwigo	M-143	wmin	M-196
kvsat	M-213	plwnfb	M-180	pwkuowe	M-192	wot	M-14
kvtho	M-220	plwnfc	M-184	pwkvthowe	M-188	wvaro	M-12
l	I-1	plwnov	M-50	pwmue	M-66	wvarw	M-13
lap	M-11	plwnp	M-41	pwneff	M-29	xgw	I-25
leff	OP-4	plwrs	M-85	pwnfa	M-175	xjungat	M-252
level	M-1	plwstbet	M-63	pwnfb	M-179	xjunsti	M-251
lgdrain	I-17	plwstthesat	M-96	pwnfc	M-183		
lgsource	I-14	plwstvfb	M-24	pwnov	M-49		

PSP NQS local MOSFET Model (pspnqs102e)

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.doc/libphilips_sh.so

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

Instance Definition

Name d g s b ModelName parameter=value ...

Instance Parameters

- | | | |
|----|-------------------------------|--|
| 1 | delvto=0 V | Threshold voltage shift parameter. |
| 2 | factuo=1 | Zero-field mobility pre-factor. |
| 3 | absource=1e-12 m ² | Bottom area of source junction. |
| 4 | lssource=1e-06 m | STI-edge length of source junction. |
| 5 | lgsource=1e-06 m | Gate-edge length of source junction. |
| 6 | abdrain=1e-12 m ² | Bottom area of drain junction. |
| 7 | lsdrain=1e-06 m | STI-edge length of drain junction. |
| 8 | lgdrain=1e-06 m | Gate-edge length of drain junction. |
| 9 | as=1e-12 m ² | Bottom area of source junction. |
| 10 | ps=1e-06 m | Perimeter of source junction. |
| 11 | ad=1e-12 m ² | Bottom area of drain junction. |
| 12 | pd=1e-06 m | Perimeter of drain junction. |
| 13 | jw=1e-06 m | Gate-edge length of source/drain junction. |
| 14 | mult=1 | Number of devices in parallel. |
| 15 | region=triode | Estimated DC operating region, used as a convergence aid. Possible values are off, triode, sat, subth, rev, fwd, or brk. |
| 16 | m=1 | Multiplicity factor. |
| 17 | trise=0 | Temperature rise from ambient. |
| 18 | area=1 | alias of mult. |

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

Model Definition

model modelName pspnqs102e parameter=value ...

Model Parameters

1	level=102	Model level.
2	type=n	Channel type parameter, +1=NMOS -1=PMOS. Possible values are n, p, npn, pnp, npnv, pnpv, npnl, or pnp1.
3	tr=21 C	nominal (reference) temperature.
4	swigate=0	Flag for gate current, 0=turn off IG.
5	swimpact=0	Flag for impact ionization current, 0=turn off II.
6	swgidl=0	Flag for GIDL current, 0=turn off IGIDL.
7	swjuncap=0	Flag for juncap, 0=turn off juncap.
8	swjunasym=0	Flag for asymmetric junctions; 0=symmetric, 1=asymmetric.
9	qmc=1	Quantum-mechanical correction factor.
10	vfb=-1 V	Flatband voltage at TR.
11	stvfb=0.0005 V/K	Temperature dependence of VFB.
12	tox=2e-09 m	Gate oxide thickness.
13	epsrox=3.9	Relative permittivity of gate dielectric.
14	neff=5e+23 m ⁻³	Effective substrate doping.
15	vnsb=0 V	Effective doping bias-dependence parameter.
16	nslp=0.05 V	Effective doping bias-dependence parameter.
17	dnsub=0 V ¹	Effective doping bias-dependence parameter.
18	dphib=0 V	Offset parameter for PHIB.
19	np=1e+26 m ⁻³	Gate poly-silicon doping.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

20	$ct=0$	Interface states factor.
21	$toxov=2e-09$ m	Overlap oxide thickness.
22	$toxovd=2e-09$ m	Overlap oxide thickness for drain side.
23	$nov=5e+25$ m ⁻³	Effective doping of overlap region.
24	$novd=5e+25$ m ⁻³	Effective doping of overlap region for drain side.
25	$cf=0$ V ⁻¹	DIBL-parameter.
26	$cfb=0$ V ⁻¹	Back bias dependence of CF.
27	$betn=0.07$ m ² /V/s	Channel aspect ratio times zero-field mobility.
28	$stbet=1$	Temperature dependence of BETN.
29	$mue=0.5$ m/V	Mobility reduction coefficient at TR.
30	$stmue=0$	Temperature dependence of MUE.
31	$themu=1.5$	Mobility reduction exponent at TR.
32	$stthemu=1.5$	Temperature dependence of THEMU.
33	$cs=0$	Coulomb scattering parameter at TR.
34	$stcs=0$	Temperature dependence of CS.
35	$xcor=0$ V ⁻¹	Non-universality factor.
36	$stxcor=0$	Temperature dependence of XCOR.
37	$feta=1$	Effective field parameter.
38	$rs=30$ Ω	Series resistance at TR.
39	$strs=1$	Temperature dependence of RS.
40	$rsb=0$ V ⁻¹	Back-bias dependence of series resistance.
41	$rsg=0$ V ⁻¹	Gate-bias dependence of series resistance.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

42	$\text{thesat}=1 \text{ V}^{-1}$	Velocity saturation parameter at TR.
43	$\text{stthesat}=1$	Temperature dependence of THESAT.
44	$\text{thesatb}=0 \text{ V}^{-1}$	Back-bias dependence of velocity saturation.
45	$\text{thesatg}=0 \text{ V}^{-1}$	Gate-bias dependence of velocity saturation.
46	$\text{ax}=3$	Linear/saturation transition factor.
47	$\text{alp}=0.01$	CLM pre-factor.
48	$\text{alp1}=0 \text{ V}$	CLM enhancement factor above threshold.
49	$\text{alp2}=0 \text{ V}^{-1}$	CLM enhancement factor below threshold.
50	$\text{vp}=0.05 \text{ V}$	CLM logarithm dependence factor.
51	$\text{a1}=1$	Impact-ionization pre-factor.
52	$\text{a2}=10 \text{ V}$	Impact-ionization exponent at TR.
53	$\text{sta2}=0 \text{ V}$	Temperature dependence of A2.
54	$\text{a3}=1$	Saturation-voltage dependence of impact-ionization.
55	$\text{a4}=0 \text{ V}^{-0.5}$	Back-bias dependence of impact-ionization.
56	$\text{gco}=0$	Gate tunnelling energy adjustment.
57	$\text{iginv}=0 \text{ A}$	Gate channel current pre-factor.
58	$\text{igov}=0 \text{ A}$	Gate overlap current pre-factor.
59	$\text{igovd}=0 \text{ A}$	Gate overlap current pre-factor for drain side.
60	$\text{stig}=2$	Temperature dependence of IGINV and IGOV.
61	$\text{gc2}=0.375$	Gate current slope factor.
62	$\text{gc3}=0.063$	Gate current curvature factor.
63	$\text{chib}=3.1 \text{ V}$	Tunnelling barrier height.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

64	$agidl=0$	A/V^3	GIDL pre-factor.
65	$agidld=0$	A/V^3	GIDL pre-factor for drain side.
66	$bgidl=41$	V	GIDL probability factor at TR.
67	$bgidld=41$	V	GIDL probability factor at TR for drain side.
68	$stbgidl=0$	V/K	Temperature dependence of BGIDL.
69	$stbgidld=0$	V/K	Temperature dependence of BGIDL for drain side.
70	$cgidl=0$		Back-bias dependence of GIDL.
71	$cgidld=0$		Back-bias dependence of GIDL for drain side.
72	$cox=1e-14$	F	Oxide capacitance for intrinsic channel.
73	$cgov=1e-15$	F	Oxide capacitance for gate-drain/source overlap.
74	$cgovd=1e-15$	F	Oxide capacitance for gate-drain overlap.
75	$cgbov=0$	F	Oxide capacitance for gate-bulk overlap.
76	$cfr=0$	F	Outer fringe capacitance.
77	$cfrd=0$	F	Outer fringe capacitance for drain side.
78	$fnt=1$		Thermal noise coefficient.
79	$nfa=8e+22$	V^{-1}/m^4	First coefficient of flicker noise.
80	$nfb=3e+07$	V^1/m^2	Second coefficient of flicker noise.
81	$nfc=0$	V^{-1}	Third coefficient of flicker noise.
82	$ef=1$		Flicker noise frequency exponent.
83	$swnqs=0$		Flag for NQS, 0=off, 1, 2, 3, 5, or 9=number of collocation points.
84	$munqs=1$	unknown	Relative mobility for NQS modelling.
85	$rg=0$	Ω	Gate resistance.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

86	$r_{bulk}=0 \ \Omega$	Bulk resistance between node BP and BI.
87	$r_{well}=0 \ \Omega$	Well resistance between node BI and B.
88	$r_{juns}=0 \ \Omega$	Source-side bulk resistance between node BI and BS.
89	$r_{jund}=0 \ \Omega$	Drain-side bulk resistance between node BI and BD.
90	$tr_j=21 \ C$	reference temperature.
91	$i_{max}=1e+03 \ A$	Maximum current up to which forward current behaves exponentially.
92	$c_{jorbot}=0.001 \ Fm^{-2}$	Zero-bias capacitance per unit-of-area of bottom component for source-bulk junction.
93	$c_{jorsti}=1e-09 \ Fm^{-1}$	Zero-bias capacitance per unit-of-length of STI-edge component for source-bulk junction.
94	$c_{jorgat}=1e-09 \ Fm^{-1}$	Zero-bias capacitance per unit-of-length of gate-edge component for source-bulk junction.
95	$v_{birbot}=1 \ V$	Built-in voltage at the reference temperature of bottom component for source-bulk junction.
96	$v_{birsti}=1 \ V$	Built-in voltage at the reference temperature of STI-edge component for source-bulk junction.
97	$v_{birgat}=1 \ V$	Built-in voltage at the reference temperature of gate-edge component for source-bulk junction.
98	$p_{bot}=0.5$	Grading coefficient of bottom component for source-bulk junction.
99	$p_{sti}=0.5$	Grading coefficient of STI-edge component for source-bulk junction.
100	$p_{gat}=0.5$	Grading coefficient of gate-edge component for source-bulk junction.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

101	<code>phigbot=1.16</code>	V	Zero-temperature bandgap voltage of bottom component for source-bulk junction.
102	<code>phigsti=1.16</code>	V	Zero-temperature bandgap voltage of STI-edge component for source-bulk junction.
103	<code>phiggat=1.16</code>	V	Zero-temperature bandgap voltage of gate-edge component for source-bulk junction.
104	<code>idsatrbot=1e-12</code>	Am^{-2}	Saturation current density at the reference temperature of bottom component for source-bulk junction.
105	<code>idsatrsti=1e-18</code>	Am^{-1}	Saturation current density at the reference temperature of STI-edge component for source-bulk junction.
106	<code>idsatrgat=1e-18</code>	Am^{-1}	Saturation current density at the reference temperature of gate-edge component for source-bulk junction.
107	<code>csrhibot=100</code>	Am^{-3}	Shockley-Read-Hall prefactor of bottom component for source-bulk junction.
108	<code>csrhisti=0.0001</code>	Am^{-2}	Shockley-Read-Hall prefactor of STI-edge component for source-bulk junction.
108	<code>csrhgat=0.0001</code>	Am^{-2}	Shockley-Read-Hall prefactor of gate-edge component for source-bulk junction.
110	<code>xjunsti=1e-07</code>	m	Junction depth of STI-edge component for source-bulk junction.
111	<code>xjngat=1e-07</code>	m	Junction depth of gate-edge component for source-bulk junction.
112	<code>ctatbot=100</code>	Am^{-3}	Trap-assisted tunneling prefactor of bottom component for source-bulk junction.
113	<code>ctatsti=0.0001</code>	Am^{-2}	Trap-assisted tunneling prefactor of STI-edge component for source-bulk junction.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

- 114 $ctatgat=0.0001 \text{ Am}^{-2}$ Trap-assisted tunneling prefactor of gate-edge component for source-bulk junction.
- 115 $mefftatbot=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of bottom component for source-bulk junction.
- 116 $mefftatsti=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of STI-edge component for source-bulk junction.
- 117 $mefftatgat=0.25$ Effective mass (in units of m_0) for trap-assisted tunneling of gate-edge component for source-bulk junction.
- 118 $cbbtbot=1e-12 \text{ AV}^{-3}$ Band-to-band tunneling prefactor of bottom component for source-bulk junction.
- 119 $cbbtsti=1e-18 \text{ AV}^{-3}_m$ Band-to-band tunneling prefactor of STI-edge component for source-bulk junction.
- 120 $cbbtgat=1e-18 \text{ AV}^{-3}_m$ Band-to-band tunneling prefactor of gate-edge component for source-bulk junction.
- 121 $fbbtrbot=1e+09 \text{ Vm}^{-1}$ Normalization field at the reference temperature for band-to-band tunneling of bottom component for source-bulk junction.
- 122 $fbbtrsti=1e+09 \text{ Vm}^{-1}$ Normalization field at the reference temperature for band-to-band tunneling of STI-edge component for source-bulk junction.
- 123 $fbbtrgat=1e+09 \text{ Vm}^{-1}$ Normalization field at the reference temperature for band-to-band tunneling of gate-edge component for source-bulk junction.
- 124 $stfbbtbot=-0.001 \text{ K}^{-1}$ Temperature scaling parameter for band-to-band tunneling of bottom component for source-bulk junction.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

125	<code>stfbbtsti=-0.001</code>	K^{-1}	Temperature scaling parameter for band-to-band tunneling of STI-edge component for source-bulk junction.
126	<code>stfbbtgat=-0.001</code>	K^{-1}	Temperature scaling parameter for band-to-band tunneling of gate-edge component for source-bulk junction.
127	<code>vbrbot=10</code>	V	Breakdown voltage of bottom component for source-bulk junction.
128	<code>vbrsti=10</code>	V	Breakdown voltage of STI-edge component for source-bulk junction.
129	<code>vbrgat=10</code>	V	Breakdown voltage of gate-edge component for source-bulk junction.
130	<code>pbrbot=4</code>	V	Breakdown onset tuning parameter of bottom component for source-bulk junction.
131	<code>pbrsti=4</code>	V	Breakdown onset tuning parameter of STI-edge component for source-bulk junction.
132	<code>pbrgat=4</code>	V	Breakdown onset tuning parameter of gate-edge component for source-bulk junction.
133	<code>cjorbotd=0.001</code>	Fm^{-2}	Zero-bias capacitance per unit-of-area of bottom component for drain-bulk junction.
134	<code>cjorstid=1e-09</code>	Fm^{-1}	Zero-bias capacitance per unit-of-length of STI-edge component for drain-bulk junction.
135	<code>cjorgatd=1e-09</code>	Fm^{-1}	Zero-bias capacitance per unit-of-length of gate-edge component for drain-bulk junction.
136	<code>vbirbotd=1</code>	V	Built-in voltage at the reference temperature of bottom component for drain-bulk junction.
137	<code>vbirstid=1</code>	V	Built-in voltage at the reference temperature of STI-edge component for drain-bulk junction.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

138	<code>vbirgatd=1</code>	V	Built-in voltage at the reference temperature of gate-edge component for drain-bulk junction.
139	<code>pbotd=0.5</code>		Grading coefficient of bottom component for drain-bulk junction.
140	<code>pstid=0.5</code>		Grading coefficient of STI-edge component for drain-bulk junction.
141	<code>pgatd=0.5</code>		Grading coefficient of gate-edge component for drain-bulk junction.
142	<code>phigbotd=1.16</code>	V	Zero-temperature bandgap voltage of bottom component for drain-bulk junction.
143	<code>phigstid=1.16</code>	V	Zero-temperature bandgap voltage of STI-edge component for drain-bulk junction.
144	<code>phiggatd=1.16</code>	V	Zero-temperature bandgap voltage of gate-edge component for drain-bulk junction.
145	<code>idsatrbotd=1e-12</code>	Am^{-2}	Saturation current density at the reference temperature of bottom component for drain-bulk junction.
146	<code>idsatrstid=1e-18</code>	Am^{-1}	Saturation current density at the reference temperature of STI-edge component for drain-bulk junction.
147	<code>idsatrgatd=1e-18</code>	Am^{-1}	Saturation current density at the reference temperature of gate-edge component for drain-bulk junction.
148	<code>csrbotd=100</code>	Am^{-3}	Shockley-Read-Hall prefactor of bottom component for drain-bulk junction.
149	<code>csrhistid=0.0001</code>	Am^{-2}	Shockley-Read-Hall prefactor of STI-edge component for drain-bulk junction.
150	<code>csrhgatd=0.0001</code>	Am^{-2}	Shockley-Read-Hall prefactor of gate-edge component for drain-bulk junction.
151	<code>xjunstid=1e-07</code>	m	Junction depth of STI-edge component for drain-bulk junction.
152	<code>xjungaltd=1e-07</code>	m	Junction depth of gate-edge component for drain-bulk junction.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

- 153 `ctatbotd=100` Am^{-3} Trap-assisted tunneling prefactor of bottom component for drain-bulk junction.
- 154 `ctatstid=0.0001` Am^{-2} Trap-assisted tunneling prefactor of STI-edge component for drain-bulk junction.
- 155 `ctatgatd=0.0001` Am^{-2} Trap-assisted tunneling prefactor of gate-edge component for drain-bulk junction.
- 156 `mefftatbotd=0.25` Effective mass (in units of m_0) for trap-assisted tunneling of bottom component for drain-bulk junction.
- 157 `mefftatstid=0.25` Effective mass (in units of m_0) for trap-assisted tunneling of STI-edge component for drain-bulk junction.
- 158 `mefftatgatd=0.25` Effective mass (in units of m_0) for trap-assisted tunneling of gate-edge component for drain-bulk junction.
- 159 `cbbtbotd=1e-12` AV^3 Band-to-band tunneling prefactor of bottom component for drain-bulk junction.
- 160 `cbbtstid=1e-18` AV^{-3}m Band-to-band tunneling prefactor of STI-edge component for drain-bulk junction.
- 161 `cbbtgatd=1e-18` AV^{-3}m Band-to-band tunneling prefactor of gate-edge component for drain-bulk junction.
- 162 `fbbtrbotd=1e+09` Vm^{-1} Normalization field at the reference temperature for band-to-band tunneling of bottom component for drain-bulk junction.
- 163 `fbbtrstid=1e+09` Vm^{-1} Normalization field at the reference temperature for band-to-band tunneling of STI-edge component for drain-bulk junction.
- 164 `fbbtrgatd=1e+09` Vm^{-1} Normalization field at the reference temperature for band-to-band tunneling of gate-edge component for drain-bulk junction.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

165	$stfbbtbotd=-0.001 \text{ K}^{-1}$	Temperature scaling parameter for band-to-band tunneling of bottom component for drain-bulk junction.
166	$stfbbtstid=-0.001 \text{ K}^{-1}$	Temperature scaling parameter for band-to-band tunneling of STI-edge component for drain-bulk junction.
167	$stfbbtgatd=-0.001 \text{ K}^{-1}$	Temperature scaling parameter for band-to-band tunneling of gate-edge component for drain-bulk junction.
168	$vbrbotd=10 \text{ V}$	Breakdown voltage of bottom component for drain-bulk junction.
169	$vbrstid=10 \text{ V}$	Breakdown voltage of STI-edge component for drain-bulk junction.
170	$vbrgatd=10 \text{ V}$	Breakdown voltage of gate-edge component for drain-bulk junction.
171	$pbrbotd=4 \text{ V}$	Breakdown onset tuning parameter of bottom component for drain-bulk junction.
172	$pbrstid=4 \text{ V}$	Breakdown onset tuning parameter of STI-edge component for drain-bulk junction.
173	$pbrgatd=4 \text{ V}$	Breakdown onset tuning parameter of gate-edge component for drain-bulk junction.
174	$swjunexp=0$	Flag for JUNCAP-express; 0=full model, 1=express model.
175	$vjunref=2.5$	Typical maximum junction voltage; usually about $2*VSUP$.
176	$fjunq=0.03$	Fraction below which junction capacitance components are considered negligible.
177	$vjunrefd=2.5$	Typical maximum drain-bulk junction voltage; usually about $2*VSUP$.
178	$fjunqd=0.03$	Fraction below which drain-bulk junction capacitance components are considered negligible.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

179	<code>dta=0 K</code>	Temperature offset w.r.t. ambient temperature.
180	<code>mbe=0.0</code>	DCmatch parameter.
181	<code>mvt=0.0</code>	DCmatch parameter.
182	<code>tnom (C)</code>	alias of <code>tnom</code> .
183	<code>tref (C)</code>	alias of <code>tnom</code> .

Operating-Point Parameters

1	<code>ctype</code>	Flag for channel type.
2	<code>sdint</code>	Flag for source-drain interchange.
3	<code>weff (m)</code>	Effective channel width for geometrical models.
4	<code>leff (m)</code>	Effective channel length for geometrical models.
5	<code>ise (A)</code>	Total source current.
6	<code>ige (A)</code>	Total gate current.
7	<code>ide (A)</code>	Total drain current.
8	<code>ibe (A)</code>	Total bulk current.
9	<code>ids (A)</code>	Drain current, excl. avalanche, tunnel, GISL, GIDL, and junction currents.
10	<code>idb (A)</code>	Drain to bulk current.
11	<code>isb (A)</code>	Source to bulk current.
12	<code>igs (A)</code>	Gate-source tunneling current.
13	<code>igd (A)</code>	Gate-drain tunneling current.
14	<code>igb (A)</code>	Gate-bulk tunneling current.
15	<code>igcs (A)</code>	Gate-channel tunneling current (source component).

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

16	<code>igcd</code> (A)	Gate-channel tunneling current (drain component).
17	<code>iavl</code> (A)	Substrate current due to weak avalanche.
18	<code>igisl</code> (A)	Gate-induced source leakage current.
19	<code>igidl</code> (A)	Gate-induced drain leakage current.
20	<code>ijs</code> (A)	Total source junction current.
21	<code>ijsbot</code> (A)	Source junction current (bottom component).
22	<code>ijsgat</code> (A)	Source junction current (gate-edge component).
23	<code>ijssti</code> (A)	Source junction current (STI-edge component).
24	<code>ijd</code> (A)	Total drain junction current.
25	<code>ijdbot</code> (A)	Drain junction current (bottom component).
26	<code>ijdgat</code> (A)	Drain junction current (gate-edge component).
27	<code>ijdsti</code> (A)	Drain junction current (STI-edge component).
28	<code>vds</code> (V)	Drain-source voltage.
29	<code>vgs</code> (V)	Gate-source voltage.
30	<code>vsb</code> (V)	Source-bulk voltage.
31	<code>vt0</code> (V)	Zero-bias threshold voltage.
32	<code>vtS</code> (V)	Threshold voltage including back bias effects.
33	<code>vtH</code> (V)	Threshold voltage including back bias and drain bias effects.
34	<code>vgt</code> (V)	Effective gate drive voltage including back bias and drain bias effects.
35	<code>vdss</code> (V)	Drain saturation voltage at actual bias.
36	<code>vsat</code> (V)	Saturation limit.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

37	g_m ($1/\Omega$)	Transconductance.
38	g_{mb} ($1/\Omega$)	Substrate transconductance.
39	g_{ds} ($1/\Omega$)	Output conductance.
40	g_{js} ($1/\Omega$)	Source junction conductance.
41	g_{jd} ($1/\Omega$)	Drain junction conductance.
42	c_{dd} (F)	Drain capacitance.
43	c_{dg} (F)	Drain-gate capacitance.
44	c_{ds} (F)	Drain-source capacitance.
45	c_{db} (F)	Drain-bulk capacitance.
46	c_{gd} (F)	Gate-drain capacitance.
47	c_{gg} (F)	Gate capacitance.
48	c_{gs} (F)	Gate-source capacitance.
49	c_{gb} (F)	Gate-bulk capacitance.
50	c_{sd} (F)	Source-drain capacitance.
51	c_{sg} (F)	Source-gate capacitance.
52	c_{ss} (F)	Source capacitance.
53	c_{sb} (F)	Source-bulk capacitance.
54	c_{bd} (F)	Bulk-drain capacitance.
55	c_{bg} (F)	Bulk-gate capacitance.
56	c_{bs} (F)	Bulk-source capacitance.
57	c_{bb} (F)	Bulk capacitance.
58	c_{gsol} (F)	Total gate-source overlap capacitance.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

59	<code>cgdol</code> (F)	Total gate-drain overlap capacitance.
60	<code>cjs</code> (F)	Total source junction capacitance.
61	<code>cjsbot</code> (F)	Source junction capacitance (bottom component).
62	<code>cjsgat</code> (F)	Source junction capacitance (gate-edge component).
63	<code>cjssti</code> (F)	Source junction capacitance (STI-edge component).
64	<code>cjd</code> (F)	Total drain junction capacitance.
65	<code>cjdbot</code> (F)	Drain junction capacitance (bottom component).
66	<code>cjdgat</code> (F)	Drain junction capacitance (gate-edge component).
67	<code>cjdsti</code> (F)	Drain junction capacitance (STI-edge component).
68	<code>u</code>	Transistor gain.
69	<code>rout</code> (Ω)	Small-signal output resistance.
70	<code>vearly</code> (V)	Equivalent Early voltage.
71	<code>beff</code> (A/V^2)	Gain factor.
72	<code>fug</code> (Hz)	Unity gain frequency at actual bias.
73	<code>sfl</code> (A/Hz)	Flicker noise current density at 1 Hz.
74	<code>sqrtsff</code> ($V/\sqrt{\text{Hz}}$)	Input-referred RMS white noise voltage density at 1 kHz.
75	<code>sqrtsfw</code> ($V/\sqrt{\text{Hz}}$)	Input-referred RMS white noise voltage density.
76	<code>sid</code> (A^2/Hz)	White noise current density.
77	<code>sig</code> (A^2/Hz)	Induced gate noise current density at 1 Hz.
78	<code>cigid</code>	Imaginary part of correlation coefficient between Sig and Sid.
79	<code>fknee</code> (Hz)	Cross-over frequency above which white noise is dominant.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

80	<code>sig_s</code> (A^2/Hz)	Gate-source current noise spectral density.
81	<code>sig_d</code> (A^2/Hz)	Gate-drain current noise spectral density.
82	<code>siavl</code> (A^2/Hz)	Impact ionization current noise spectral density.
83	<code>ssi</code> (A^2/Hz)	Total source junction current noise spectral density.
84	<code>sdi</code> (A^2/Hz)	Total drain junction current noise spectral density.
85	<code>lv2</code> (m)	alias of <code>weff</code> .
86	<code>lv1</code> (m)	alias of <code>leff</code> .
87	<code>lx4</code> (A)	alias of <code>ids</code> .
88	<code>lx3</code> (V)	alias of <code>vds</code> .
89	<code>lx2</code> (V)	alias of <code>vgs</code> .
90	<code>lv9</code> (V)	alias of <code>vth</code> .
91	<code>lx7</code> (1/Ohm)	alias of <code>gm</code> .
92	<code>lx8</code> (1/Ohm)	alias of <code>gds</code> .
93	<code>lx9</code> (1/Ohm)	alias of <code>gmb</code> .
94	<code>lx33</code> (F)	alias of <code>cdd</code> .
95	<code>lx32</code> (F)	alias of <code>cdg</code> .
96	<code>lx34</code> (F)	alias of <code>cds</code> .
97	<code>lx19</code> (F)	alias of <code>cgd</code> .
98	<code>lx18</code> (F)	alias of <code>cgg</code> .
99	<code>lx20</code> (F)	alias of <code>cgs</code> .
100	<code>lx22</code> (F)	alias of <code>cbd</code> .
101	<code>lx21</code> (F)	alias of <code>cbg</code> .

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

102	lx23 (F)	alias of cbs.
103	lv10 (V)	alias of vdss.
104	lx5 (A)	alias of ijs.
105	lx6 (A)	alias of ijd.
106	lx28 (F)	alias of cjs.
107	lx29 (F)	alias of cjd.
108	table_ids (A)	Current.
109	table_vth (V)	Threshold voltage including back-bias and drain-bias effects.
118	table_qg (Coul)	Charge at g node.
111	table_qd (Coul)	Charge at d node.
112	table_qb (Coul)	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	M-48	csrhgat	M-98	jw	I-13	stcs	M-31
a2	M-49	csrhisti	M-97	leff	OP-4	stfbbtbot	M-113
a3	M-51	css	OP-52	level	M-1	stfbbtgat	M-115
a4	M-52	ct	M-19	lgdrain	I-8	stfbbtsti	M-114
abdrain	I-6	ctatbot	M-101	lgsource	I-5	stig	M-56

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

absource	I-3	ctatgat	M-103	lsdrain	I-7	stmue	M-27
ad	I-11	ctatsti	M-102	lssource	I-4	strs	M-36
agidl	M-60	ctype	OP-1	m	I-16	stthemu	M-29
alp	M-44	delvto	I-1	mbe	M-126	stthesat	M-40
alp1	M-45	dnsub	M-16	mefftatbot	M-104	stvfb	M-10
alp2	M-46	dphib	M-17	mefftatgat	M-106	stxcor	M-33
area	I-17	dta	M-125	mefftatsti	M-105	swgidl	M-6
as	I-9	epsrox	M-12	mue	M-26	swigate	M-4
ax	M-43	factuo	I-2	mult	I-14	swimpact	M-5
beff	OP-71	fbtrbot	M-110	munqs	M-73	swjuncap	M-7
betn	M-24	fbtrgat	M-112	mvt	M-127	swjunexp	M-122
bgidl	M-61	fbtrsti	M-111	neff	M-13	swnqs	M-72
cbb	OP-57	feta	M-34	nfa	M-69	table_ids	OP-85
cbbtbot	M-107	fjunq	M-124	nfb	M-70	table_qb	OP-89
cbbtgat	M-109	fknee	OP-79	nfc	M-71	table_qd	OP-88
cbbtsti	M-108	fnt	M-68	nov	M-21	table_qg	OP-87
cbd	OP-54	fug	OP-72	np	M-18	table_vth	OP-86
cbg	OP-55	gc2	M-57	nslp	M-15	themu	M-28
cbs	OP-56	gc3	M-58	pbot	M-87	thesat	M-39
cdb	OP-45	gco	M-53	pbrbot	M-119	thesatb	M-41
cdd	OP-42	gds	OP-39	pbrgat	M-121	thesatg	M-42

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

cdg	OP-43	gjd	OP-41	pbrsti	M-120	tnom	M-128
cds	OP-44	gjs	OP-40	pd	I-12	tox	M-11
cf	M-22	gm	OP-37	pgat	M-89	toxov	M-20
cfb	M-23	gmb	OP-38	phigbot	M-90	tr	M-3
cfr	M-67	iavl	OP-17	phiggat	M-92	tref	M-129
cgb	OP-49	ibe	OP-8	phigsti	M-91	trj	M-79
cgbov	M-66	idb	OP-10	ps	I-10	type	M-2
cgd	OP-46	ide	OP-7	pssti	M-88	u	OP-68
cgdol	OP-59	ids	OP-9	qmc	M-8	vbirbot	M-84
cgg	OP-47	idsatrbot	M-93	rbulk	M-75	vbirgat	M-86
cgidl	M-63	idsatrgat	M-95	region	I-15	vbirsti	M-85
cgov	M-65	idsatrsti	M-94	rg	M-74	vbrbot	M-116
cgs	OP-48	igb	OP-14	rjund	M-78	vbrgat	M-118
cgsol	OP-58	igcd	OP-16	rjuns	M-77	vbrsti	M-117
chib	M-59	igcs	OP-15	rout	OP-69	vds	OP-28
cigid	OP-78	igd	OP-13	rs	M-35	vdss	OP-35
cjd	OP-64	ige	OP-6	rsb	M-37	vearly	OP-70
cjdbot	OP-65	igidl	OP-19	rsg	M-38	vfb	M-9
cjdgat	OP-66	iginv	M-54	rwell	M-76	vgs	OP-29
cjdsti	OP-67	igisl	OP-18	sdi	OP-84	vgt	OP-34
cjorbot	M-81	igov	M-55	sdint	OP-2	vjunref	M-123

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

cjorgat M-83	igs OP-12	sfl OP-73	vnsb M-14
cjorsti M-82	ijd OP-24	siavl OP-82	vp M-47
cjs OP-60	ijdbot OP-25	sid OP-76	vsat OP-36
cjsbot OP-61	ijdgat OP-26	sig OP-77	vsb OP-30
cjsgat OP-62	ijdsti OP-27	sigd OP-81	vth OP-33
cjssti OP-63	ijs OP-20	sigs OP-80	vto OP-31
cox M-64	ijsbot OP-21	sqrtsff OP-74	vts OP-32
cs M-30	ijsgat OP-22	sqrtsfw OP-75	weff OP-3
csb OP-53	ijssti OP-23	ssi OP-83	xcor M-32
csd OP-50	imax M-80	sta2 M-50	xjungat M-100
csg OP-51	isb OP-11	stbet M-25	xjunsti M-99
csrbot M-96	ise OP-5	stbgidl M-62	

PSP MOSFET Model (psp103)

Geometry dependence and other effects

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

$$W_f = \frac{W}{NF}$$

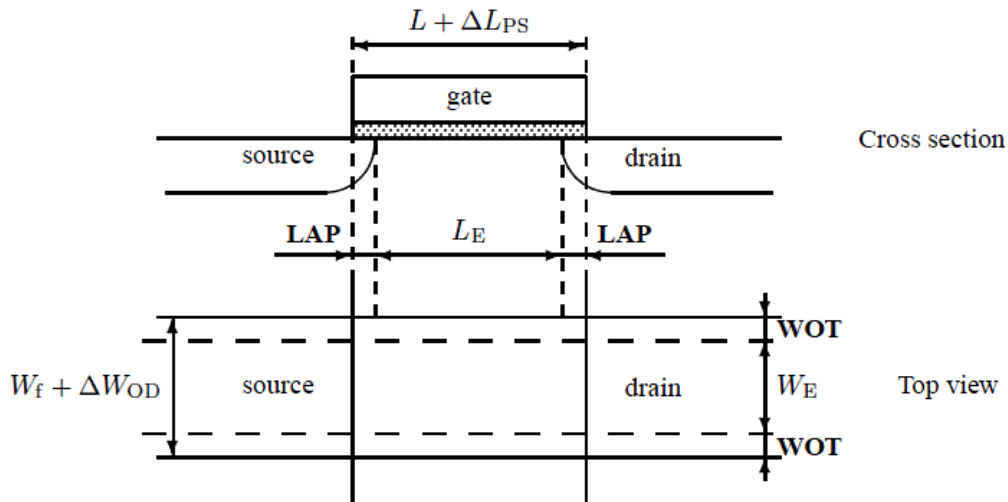
$$L_{EN} = 10^{-6}$$

$$W_{EN} = 10^{-6}$$

$$\Delta L_{PS} = LVARO \cdot \left(1 + LVARL \cdot \frac{L_{EN}}{L} \right) \cdot \left(1 + LVARW \cdot \frac{W_{EN}}{W_f} \right)$$

$$\Delta W_{OD} = WVARO \cdot \left(1 + WVARL \cdot \frac{L_{EN}}{L} \right) \cdot \left(1 + WVARW \cdot \frac{W_{EN}}{W_f} \right)$$

Figure 23-5 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

$$VF_B = VF_{B0} + VF_{BL} \cdot \frac{L_{EN}}{L_E} + VF_{BW} \cdot \frac{W_{EN}}{W_E} + VF_{BLW} \cdot \frac{W_{EN} \cdot L_{EN}}{W_E \cdot L_E}$$

$$STVF_B = STVF_{B0} + STVF_{BL} \cdot \frac{L_{EN}}{L_E} + STVF_{BW} \cdot \frac{W_{EN}}{W_E} + STVF_{BLW} \cdot \frac{W_{EN} \cdot L_{EN}}{W_E \cdot L_E}$$

$$TOX = TOXO$$

$$EPSROX = EPSROXO$$

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

$$N_{\text{sub0,eff}} = \text{NSUBO} \cdot \text{MAX} \left(\left[1 + \text{NSUBW} \cdot \frac{W_{\text{EN}}}{W_{\text{E}}} \cdot \ln \left(1 + \frac{W_{\text{E}}}{W_{\text{SECF}}} \right) \right], 10^{-3} \right)$$

$$N_{\text{pck,eff}} = \text{NPCK} \cdot \text{MAX} \left(\left[1 + \text{NPCKW} \cdot \frac{W_{\text{EN}}}{W_{\text{E}}} \cdot \ln \left(1 + \frac{W_{\text{E}}}{W_{\text{SECF}}} \right) \right], 10^{-3} \right)$$

$$L_{\text{pck,eff}} = \text{LPCK} \cdot \text{MAX} \left(\left[1 + \text{LPCKW} \cdot \frac{W_{\text{EN}}}{W_{\text{E}}} \cdot \ln \left(1 + \frac{W_{\text{E}}}{W_{\text{SECF}}} \right) \right], 10^{-3} \right)$$

$$a = 7.5 \cdot 10^{10}$$

$$b = \sqrt{N_{\text{sub0,eff}} + 0.5 \cdot N_{\text{pck,eff}}} - \sqrt{N_{\text{sub0,eff}}}$$

$$N_{\text{sub}} = \begin{cases} N_{\text{sub0,eff}} + N_{\text{pck,eff}} \cdot \left[2 - \frac{L_{\text{E}}}{L_{\text{pck,eff}}} \right] & \text{for } L_{\text{E}} < L_{\text{pck,eff}} \\ N_{\text{sub0,eff}} + N_{\text{pck,eff}} \cdot \frac{L_{\text{pck,eff}}}{L_{\text{E}}} & \text{for } L_{\text{pck,eff}} \leq L_{\text{E}} \leq 2 \cdot L_{\text{pck,eff}} \\ \left[\sqrt{N_{\text{sub0,eff}}} + a \cdot \ln \left(1 + 2 \cdot \frac{L_{\text{pck,eff}}}{L_{\text{E}}} \cdot \left[\exp \left(\frac{b}{a} \right) - 1 \right] \right) \right]^2 & \text{for } L_{\text{E}} > 2 \cdot L_{\text{pck,eff}} \end{cases}$$

$$\text{NEFF} = N_{\text{sub}} \cdot \left(1 - \text{FOL1} \cdot \frac{L_{\text{EN}}}{L_{\text{E}}} - \text{FOL2} \cdot \left[\frac{L_{\text{EN}}}{L_{\text{E}}} \right]^2 \right)$$

$$\begin{aligned} \text{FACNEFFAC} &= \text{FACNEFFACO} + \text{FACNEFFACL} \cdot \frac{L_{\text{EN}}}{L_{\text{E}}} \\ &+ \text{FACNEFFACW} \cdot \frac{W_{\text{EN}}}{W_{\text{E}}} + \text{FACNEFFACLW} \cdot \frac{L_{\text{EN}} \cdot W_{\text{EN}}}{L_{\text{E}} \cdot W_{\text{E}}} \end{aligned}$$

$$\begin{aligned} \text{GFACNUD} &= \text{GFACNUDO} + \text{GFACNUDL} \cdot \left[\frac{L_{\text{EN}}}{L_{\text{E}}} \right]^{\text{GFACNUDEX}} \\ &+ \text{GFACNUDW} \cdot \frac{W_{\text{EN}}}{W_{\text{E}}} + \text{GFACNUDLW} \cdot \frac{L_{\text{EN}} \cdot W_{\text{EN}}}{L_{\text{E}} \cdot W_{\text{E}}} \end{aligned}$$

$$\text{VSBNUD} = \text{VSBNUDO}$$

$$\text{DVSBNUD} = \text{DVSBNUDO}$$

$$\text{VNSUB} = \text{VNSUBO}$$

$$\text{NSLP} = \text{NSLPO}$$

$$\text{DNSUB} = \text{DNSUBO}$$

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

$$\begin{aligned} \text{DPHIB} = & \text{DPHIBO} + \text{DPHIBL} \cdot \left[\frac{L_{\text{EN}}}{L_{\text{E}}} \right]^{\text{DPHIBLEN}} \\ & + \text{DPHIBW} \cdot \frac{W_{\text{EN}}}{W_{\text{E}}} + \text{DPHIBLW} \cdot \frac{W_{\text{EN}} \cdot L_{\text{EN}}}{W_{\text{E}} \cdot L_{\text{E}}} \end{aligned}$$

$$\begin{aligned} \text{DELVTAC} = & \text{DELVTACO} + \text{DELVTACL} \cdot \left[\frac{L_{\text{EN}}}{L_{\text{E}}} \right]^{\text{DELVTACLEN}} \\ & + \text{DELVTACW} \cdot \frac{W_{\text{EN}}}{W_{\text{E}}} + \text{DELVTACLW} \cdot \frac{W_{\text{EN}} \cdot L_{\text{EN}}}{W_{\text{E}} \cdot L_{\text{E}}} \end{aligned}$$

$$\text{NP} = \text{NPO} \cdot \text{MAX} \left(10^{-6}, 1 + \text{NPL} \cdot \frac{L_{\text{EN}}}{L_{\text{E}}} \right)$$

$$\begin{aligned} \text{CT} = & \left(\text{CTO} + \text{CTL} \cdot \left[\frac{L_{\text{EN}}}{L_{\text{E}}} \right]^{\text{CTLEN}} \right) \cdot \left(1 + \text{CTW} \cdot \frac{W_{\text{EN}}}{W_{\text{E}}} \right) \\ & \cdot \left(1 + \text{CTLW} \cdot \frac{W_{\text{EN}} \cdot L_{\text{EN}}}{W_{\text{E}} \cdot L_{\text{E}}} \right) \end{aligned}$$

$$\text{TOXOV} = \text{TOXOVO}$$

$$\text{TOXOVD} = \text{TOXOVDO}$$

$$\text{NOV} = \text{NOVO}$$

$$\text{NOVD} = \text{NOVDO}$$

DIBL Parameters

$$\text{CF} = \text{CFL} \cdot \left[\frac{L_{\text{EN}}}{L_{\text{E}}} \right]^{\text{CFLEN}} \cdot \left(1 + \text{CFW} \cdot \frac{W_{\text{EN}}}{W_{\text{E}}} \right)$$

$$\text{CFB} = \text{CFBO}$$

$$F_{\beta 1, \text{eff}} = \text{FBET1} \cdot \left(1 + \text{FBET1W} \cdot \frac{W_{\text{EN}}}{W_{\text{E}}} \right)$$

$$L_{\text{P1,eff}} = \text{LP1} \cdot \text{MAX} \left(\left[1 + \text{LP1W} \cdot \frac{W_{\text{EN}}}{W_{\text{E}}} \right], 10^{-3} \right)$$

$$\begin{aligned} G_{\text{P,E}} = & 1 + F_{\beta 1, \text{eff}} \cdot \frac{L_{\text{P1,eff}}}{L_{\text{E}}} \cdot \left[1 - \exp \left(-\frac{L_{\text{E}}}{L_{\text{P1,eff}}} \right) \right] \\ & + \text{FBET2} \cdot \frac{\text{LP2}}{L_{\text{E}}} \cdot \left[1 - \exp \left(-\frac{L_{\text{E}}}{\text{LP2}} \right) \right] \end{aligned}$$

$$G_{\text{W,E}} = 1 + \text{BETW1} \cdot \frac{W_{\text{EN}}}{W_{\text{E}}} + \text{BETW2} \cdot \frac{W_{\text{EN}}}{W_{\text{E}}} \cdot \ln \left(1 + \frac{W_{\text{E}}}{\text{WBET}} \right)$$

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

$$\mathbf{BETN} = \frac{\mathbf{UO}}{G_{P,E}} \cdot \frac{W_E}{L_E} \cdot G_{W,E}$$

$$\mathbf{STBET} = \mathbf{STBETO} + \mathbf{STBEL} \cdot \frac{L_{EN}}{L_E} + \mathbf{STBETW} \cdot \frac{W_{EN}}{W_E} + \mathbf{STBELTW} \cdot \frac{W_{EN} \cdot L_{EN}}{W_E \cdot L_E}$$

$$\mathbf{MUE} = \mathbf{MUEO} \cdot \left[1 + \mathbf{MUEW} \cdot \frac{W_{EN}}{W_E} \right]$$

$$\mathbf{STMUE} = \mathbf{STMUEO}$$

$$\mathbf{THEMU} = \mathbf{THEMUO}$$

$$\mathbf{STTHEMU} = \mathbf{STTHEMUO}$$

$$\mathbf{CS} = \left(\mathbf{CSO} + \mathbf{CSL} \cdot \left[\frac{L_{EN}}{L_E} \right]^{\mathbf{CSLEXP}} \right) \cdot \left(1 + \mathbf{CSW} \cdot \frac{W_{EN}}{W_E} \right) \cdot \left(1 + \mathbf{CSLW} \cdot \frac{W_{EN} \cdot L_{EN}}{W_E \cdot L_E} \right)$$

$$\mathbf{STCS} = \mathbf{STCSO}$$

$$\mathbf{XCOR} = \mathbf{XCORO} \cdot \left(1 + \mathbf{XCORL} \cdot \frac{L_{EN}}{L_E} \right) \cdot \left(1 + \mathbf{XCORW} \cdot \frac{W_{EN}}{W_E} \right) \cdot \left(1 + \mathbf{XCORLW} \cdot \frac{W_{EN} \cdot L_{EN}}{W_E \cdot L_E} \right)$$

$$\mathbf{STXCOR} = \mathbf{STXCORO}$$

$$\mathbf{FETA} = \mathbf{FETAO}$$

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

$$\text{AGIDL} = \text{AGIDLW} \cdot \frac{W_E \cdot \text{LOV}}{W_{\text{EN}} \cdot L_{\text{EN}}}$$

$$\text{AGIDLD} = \text{AGIDLW} \cdot \frac{W_E \cdot \text{LOVD}}{W_{\text{EN}} \cdot L_{\text{EN}}}$$

$$\text{BGIDL} = \text{BGIDLO}$$

$$\text{BGIDLD} = \text{BGIDLDO}$$

$$\text{STBGIDL} = \text{STBGIDLO}$$

$$\text{STBGIDLD} = \text{STBGIDLDO}$$

$$\text{CGIDL} = \text{CGIDLO}$$

$$\text{CGIDLD} = \text{CGIDLDO}$$

Charge Model Parameters

$$\text{COX} = \epsilon_{\text{ox}} \cdot \frac{W_{\text{E,CV}} \cdot L_{\text{E,CV}}}{\text{TOX}}$$

$$\text{CGOV} = \epsilon_{\text{ox}} \cdot \frac{W_{\text{E,CV}} \cdot \text{LOV}}{\text{TOXOV}}$$

$$\text{CGOVD} = \epsilon_{\text{ox}} \cdot \frac{W_{\text{E,CV}} \cdot \text{LOVD}}{\text{TOXOVD}}$$

$$\text{CGBOV} = \text{CGBOVL} \cdot \frac{L_{\text{G,CV}}}{L_{\text{EN}}}$$

$$\text{CFR} = \text{CFRW} \cdot \frac{W_{\text{G,CV}}}{W_{\text{EN}}}$$

$$\text{CFRD} = \text{CFRDW} \cdot \frac{W_{\text{G,CV}}}{W_{\text{EN}}}$$

Noise Model Parameters

$$L_{noi} = \text{MAX} \left(1 - \frac{2 \cdot \text{LINTNOI}}{L_E}, 10^{-3} \right)$$

$$L_{red} = \frac{1}{L_{noi}^{\text{ALPNOI}}}$$

$$\text{NFA} = L_{red} \cdot \text{NFALW} \cdot \frac{W_{EN} \cdot L_{EN}}{W_E \cdot L_E}$$

$$\text{NFB} = L_{red} \cdot \text{NFBLW} \cdot \frac{W_{EN} \cdot L_{EN}}{W_E \cdot L_E}$$

$$\text{NFC} = L_{red} \cdot \text{NFCLW} \cdot \frac{W_{EN} \cdot L_{EN}}{W_E \cdot L_E}$$

$$\text{EF} = \text{EFO}$$

WPE Parameters

$$K_{vthowe} = \text{KVTHOWEO} + \text{KVTHOWEL} \cdot \frac{L_{EN}}{L_E} + \text{KVTHOWEW} \cdot \frac{W_{EN}}{W_E}$$

$$+ \text{KVTHOWELW} \cdot \frac{L_{EN} \cdot W_{EN}}{L_E \cdot W_E}$$

$$K_{uowe} = \text{KUOWEO} + \text{KUOWEL} \cdot \frac{L_{EN}}{L_E} + \text{KUOWEW} \cdot \frac{W_{EN}}{W_E}$$

$$+ \text{KUOWELW} \cdot \frac{L_{EN} \cdot W_{EN}}{L_E \cdot W_E}$$

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

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

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 L_E , $1/L_E$, W_E , and $1/W_E$ (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.

Virtuoso Simulator Components and Device Models Reference
PSP Model (psp)

Table 23-1 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				

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

Effective length and width

$$L_{EN} = 10^{-6}$$

$$W_{EN} = 10^{-6}$$

$$\Delta L_{PS} = LVARO \cdot \left(1 + LVARL \cdot \frac{L_{EN}}{L}\right)$$

$$\Delta W_{OD} = WVARO \cdot \left(1 + WVARW \cdot \frac{W_{EN}}{W_f}\right)$$

$$L_E = L - \Delta L = L + \Delta L_{PS} - 2 \cdot LAP$$

$$W_E = W_f - \Delta W = W_f + \Delta W_{OD} - 2 \cdot WOT$$

$$L_{E,CV} = L + \Delta L_{PS} - 2 \cdot LAP + DLQ$$

$$W_{E,CV} = W_f + \Delta W_{OD} - 2 \cdot WOT + DWQ$$

$$L_{G,CV} = L + \Delta L_{PS} + DLQ$$

$$W_{G,CV} = W_f + \Delta W_{OD} + DWQ$$

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

$$VFB = POVFB + PLVFB \cdot \frac{L_{EN}}{L_E} + PWVFB \cdot \frac{W_{EN}}{W_E} + PLWVFB \cdot \frac{L_{EN} \cdot W_{EN}}{L_E \cdot W_E}$$

$$STVFB = POSTVFB + PLSTVFB \cdot \frac{L_{EN}}{L_E} \\ + PWSTRVFB \cdot \frac{W_{EN}}{W_E} + PLWSTRVFB \cdot \frac{L_{EN} \cdot W_{EN}}{L_E \cdot W_E}$$

$$TOX = POTOX$$

$$EPSROX = POEPSROX$$

$$NEFF = PONEFF + PLNEFF \cdot \frac{L_{EN}}{L_E} + PWNEFF \cdot \frac{W_{EN}}{W_E} + PLWNEFF \cdot \frac{L_{EN} \cdot W_{EN}}{L_E \cdot W_E}$$

$$FACNEFFAC = POFACNEFFAC + PLFACNEFFAC \cdot \frac{L_{EN}}{L_E} \\ + PWFACNEFFAC \cdot \frac{W_{EN}}{W_E} + PLWFACNEFFAC \cdot \frac{L_{EN} \cdot W_{EN}}{L_E \cdot W_E}$$

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

$$\begin{aligned} \text{GFACNUD} &= \text{POGFACNUD} + \text{PLGFACNUD} \cdot \frac{L_{\text{EN}}}{L_{\text{E}}} \\ &\quad + \text{PWGFACNUD} \cdot \frac{W_{\text{EN}}}{W_{\text{E}}} + \text{PLWGFACNUD} \cdot \frac{L_{\text{EN}} \cdot W_{\text{EN}}}{L_{\text{E}} \cdot W_{\text{E}}} \end{aligned}$$

$$\text{VSBNUD} = \text{POVSBNUD}$$

$$\text{DVSBNUD} = \text{PODVSBNUD}$$

$$\text{VNSUB} = \text{POVNSUB}$$

$$\text{NSLP} = \text{PONS LP}$$

$$\text{DNSUB} = \text{PODNSUB}$$

$$\begin{aligned} \text{DPHIB} &= \text{PODPHIB} + \text{PLDPHIB} \cdot \frac{L_{\text{EN}}}{L_{\text{E}}} \\ &\quad + \text{PWDPHIB} \cdot \frac{W_{\text{EN}}}{W_{\text{E}}} + \text{PLWDPHIB} \cdot \frac{L_{\text{EN}} \cdot W_{\text{EN}}}{L_{\text{E}} \cdot W_{\text{E}}} \end{aligned}$$

$$\begin{aligned} \text{DELVTAC} &= \text{PODELVTAC} + \text{PLDELVTAC} \cdot \frac{L_{\text{EN}}}{L_{\text{E}}} \\ &\quad + \text{PWDELVTAC} \cdot \frac{W_{\text{EN}}}{W_{\text{E}}} + \text{PLWDELVTAC} \cdot \frac{L_{\text{EN}} \cdot W_{\text{EN}}}{L_{\text{E}} \cdot W_{\text{E}}} \end{aligned}$$

$$\text{NP} = \text{PONP} + \text{PLNP} \cdot \frac{L_{\text{EN}}}{L_{\text{E}}} + \text{PWNP} \cdot \frac{W_{\text{EN}}}{W_{\text{E}}} + \text{PLWNP} \cdot \frac{L_{\text{EN}} \cdot W_{\text{EN}}}{L_{\text{E}} \cdot W_{\text{E}}}$$

$$\text{CT} = \text{POCT} + \text{PLCT} \cdot \frac{L_{\text{EN}}}{L_{\text{E}}} + \text{PWCT} \cdot \frac{W_{\text{EN}}}{W_{\text{E}}} + \text{PLWCT} \cdot \frac{L_{\text{EN}} \cdot W_{\text{EN}}}{L_{\text{E}} \cdot W_{\text{E}}}$$

$$\text{TOXOV} = \text{POTOXOV}$$

$$\text{TOXOVD} = \text{POTOXOVD}$$

$$\text{NOV} = \text{PONOVD} + \text{PLNOV} \cdot \frac{L_{\text{EN}}}{L_{\text{E}}} + \text{PWNOV} \cdot \frac{W_{\text{EN}}}{W_{\text{E}}} + \text{PLWNOV} \cdot \frac{L_{\text{EN}} \cdot W_{\text{EN}}}{L_{\text{E}} \cdot W_{\text{E}}}$$

$$\text{NOVD} = \text{PONOVD} + \text{PLNOVD} \cdot \frac{L_{\text{EN}}}{L_{\text{E}}} + \text{PWNOVD} \cdot \frac{W_{\text{EN}}}{W_{\text{E}}} + \text{PLWNOVD} \cdot \frac{L_{\text{EN}} \cdot W_{\text{EN}}}{L_{\text{E}} \cdot W_{\text{E}}}$$

DIBL Parameters

$$\text{CF} = \text{POCF} + \text{PLCF} \cdot \frac{L_{\text{EN}}}{L_{\text{E}}} + \text{PWCF} \cdot \frac{W_{\text{EN}}}{W_{\text{E}}} + \text{PLWCF} \cdot \frac{L_{\text{EN}} \cdot W_{\text{EN}}}{L_{\text{E}} \cdot W_{\text{E}}}$$

$$\text{CFB} = \text{POCFB}$$

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

Mobility Parameters

$$\text{BETN} = \frac{W_E}{L_E} \cdot \left(\text{POBETN} + \text{PLBETN} \cdot \frac{L_{EN}}{L_E} + \text{PWBETN} \cdot \frac{W_{EN}}{W_E} + \text{PLWBETN} \cdot \frac{L_{EN} \cdot W_{EN}}{L_E \cdot W_E} \right)$$

$$\text{STBET} = \text{POSTBET} + \text{PLSTBET} \cdot \frac{L_{EN}}{L_E} + \text{PWSTRBET} \cdot \frac{W_{EN}}{W_E} + \text{PLWSTRBET} \cdot \frac{L_{EN} \cdot W_{EN}}{L_E \cdot W_E}$$

$$\text{MUE} = \text{POMUE} + \text{PLMUE} \cdot \frac{L_{EN}}{L_E} + \text{PWMUE} \cdot \frac{W_{EN}}{W_E} + \text{PLWMUE} \cdot \frac{L_{EN} \cdot W_{EN}}{L_E \cdot W_E}$$

$$\text{STMUE} = \text{POSTMUE}$$

$$\text{THEMU} = \text{POTHEMU}$$

$$\text{STHEMU} = \text{POSTTHEMU}$$

$$\text{CS} = \text{POCS} + \text{PLCS} \cdot \frac{L_{EN}}{L_E} + \text{PWCS} \cdot \frac{W_{EN}}{W_E} + \text{PLWCS} \cdot \frac{L_{EN} \cdot W_{EN}}{L_E \cdot W_E}$$

$$\text{STCS} = \text{POSTCS}$$

$$\text{XCOR} = \text{POXCOR} + \text{PLXCOR} \cdot \frac{L_{EN}}{L_E} + \text{PWXCOR} \cdot \frac{W_{EN}}{W_E} + \text{PLWXCOR} \cdot \frac{L_{EN} \cdot W_{EN}}{L_E \cdot W_E}$$

$$\text{STXCOR} = \text{POSTXCOR}$$

$$\text{FETA} = \text{POFETA}$$

Series Resistance Parameters

$$\text{RS} = \text{PORS} + \text{PLRS} \cdot \frac{L_{EN}}{L_E} + \text{PWRS} \cdot \frac{W_{EN}}{W_E} + \text{PLWRS} \cdot \frac{L_{EN} \cdot W_{EN}}{L_E \cdot W_E}$$

$$\text{STRS} = \text{POSTRS}$$

$$\text{RSB} = \text{PORSB}$$

$$\text{RSG} = \text{PORSG}$$

Velocity Saturation Parameters

$$\begin{aligned} \text{THESAT} = & \text{POTHESAT} + \text{PLTHESAT} \cdot \frac{L_{\text{EN}}}{L_{\text{E}}} \\ & + \text{PWTTHESAT} \cdot \frac{W_{\text{EN}}}{W_{\text{E}}} + \text{PLWTHESAT} \cdot \frac{L_{\text{EN}} \cdot W_{\text{EN}}}{L_{\text{E}} \cdot W_{\text{E}}} \end{aligned}$$

$$\begin{aligned} \text{STTHESAT} = & \text{POSTTHESAT} + \text{PLSTTHESAT} \cdot \frac{L_{\text{EN}}}{L_{\text{E}}} \\ & + \text{PWSSTTHESAT} \cdot \frac{W_{\text{EN}}}{W_{\text{E}}} + \text{PLWSTTHESAT} \cdot \frac{L_{\text{EN}} \cdot W_{\text{EN}}}{L_{\text{E}} \cdot W_{\text{E}}} \end{aligned}$$

$$\begin{aligned} \text{THESATB} = & \text{POTHESATB} + \text{PLTHESATB} \cdot \frac{L_{\text{EN}}}{L_{\text{E}}} \\ & + \text{PWTTHESATB} \cdot \frac{W_{\text{EN}}}{W_{\text{E}}} + \text{PLWTHESATB} \cdot \frac{L_{\text{EN}} \cdot W_{\text{EN}}}{L_{\text{E}} \cdot W_{\text{E}}} \end{aligned}$$

$$\begin{aligned} \text{THESATG} = & \text{POTHESATG} + \text{PLTHESATG} \cdot \frac{L_{\text{EN}}}{L_{\text{E}}} \\ & + \text{PWTTHESATG} \cdot \frac{W_{\text{EN}}}{W_{\text{E}}} + \text{PLWTHESATG} \cdot \frac{L_{\text{EN}} \cdot W_{\text{EN}}}{L_{\text{E}} \cdot W_{\text{E}}} \end{aligned}$$

Saturation Voltage Parameters

$$\text{AX} = \text{POAX} + \text{PLAX} \cdot \frac{L_{\text{EN}}}{L_{\text{E}}} + \text{PWAX} \cdot \frac{W_{\text{EN}}}{W_{\text{E}}} + \text{PLWAX} \cdot \frac{L_{\text{EN}} \cdot W_{\text{EN}}}{L_{\text{E}} \cdot W_{\text{E}}}$$

Channel Length Modulation (CLM) Parameters

$$\text{ALP} = \text{POALP} + \text{PLALP} \cdot \frac{L_{\text{EN}}}{L_{\text{E}}} + \text{PWALP} \cdot \frac{W_{\text{EN}}}{W_{\text{E}}} + \text{PLWALP} \cdot \frac{L_{\text{EN}} \cdot W_{\text{EN}}}{L_{\text{E}} \cdot W_{\text{E}}}$$

$$\text{ALP1} = \text{POALP1} + \text{PLALP1} \cdot \frac{L_{\text{EN}}}{L_{\text{E}}} + \text{PWALP1} \cdot \frac{W_{\text{EN}}}{W_{\text{E}}} + \text{PLWALP1} \cdot \frac{L_{\text{EN}} \cdot W_{\text{EN}}}{L_{\text{E}} \cdot W_{\text{E}}}$$

$$\text{ALP2} = \text{POALP2} + \text{PLALP2} \cdot \frac{L_{\text{EN}}}{L_{\text{E}}} + \text{PWALP2} \cdot \frac{W_{\text{EN}}}{W_{\text{E}}} + \text{PLWALP2} \cdot \frac{L_{\text{EN}} \cdot W_{\text{EN}}}{L_{\text{E}} \cdot W_{\text{E}}}$$

$$\text{VP} = \text{POVP}$$

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

Impact Ionization (II) Parameters

$$A1 = POA1 + PLA1 \cdot \frac{L_{EN}}{L_E} + PWA1 \cdot \frac{W_{EN}}{W_E} + PLWA1 \cdot \frac{L_{EN} \cdot W_{EN}}{L_E \cdot W_E}$$

$$A2 = POA2$$

$$STA2 = POSTA2$$

$$A3 = POA3 + PLA3 \cdot \frac{L_{EN}}{L_E} + PWA3 \cdot \frac{W_{EN}}{W_E} + PLWA3 \cdot \frac{L_{EN} \cdot W_{EN}}{L_E \cdot W_E}$$

$$A4 = POA4 + PLA4 \cdot \frac{L_{EN}}{L_E} + PWA4 \cdot \frac{W_{EN}}{W_E} + PLWA4 \cdot \frac{L_{EN} \cdot W_{EN}}{L_E \cdot W_E}$$

Gate Current Parameters

$$GCO = POGCO$$

$$\begin{aligned} IGINV &= POIGINV + PLIGINV \cdot \frac{L_E}{L_{EN}} \\ &\quad + PWIGINV \cdot \frac{W_E}{W_{EN}} + PLWIGINV \cdot \frac{L_E \cdot W_E}{L_{EN} \cdot W_{EN}} \end{aligned}$$

$$IGOV = POIGOV + PLIGOV \cdot \frac{L_{EN}}{L_E} + PWIGOV \cdot \frac{W_E}{W_{EN}} + PLWIGOV \cdot \frac{W_E \cdot L_{EN}}{W_{EN} \cdot L_E}$$

$$\begin{aligned} IGOVD &= POIGOVD + PLIGOVD \cdot \frac{L_{EN}}{L_E} \\ &\quad + PWIGOVD \cdot \frac{W_E}{W_{EN}} + PLWIGOVD \cdot \frac{W_E \cdot L_{EN}}{W_{EN} \cdot L_E} \end{aligned}$$

$$STIG = POSTIG$$

$$GC2 = POGC2$$

$$GC3 = POGC3$$

$$CHIB = POCHIB$$

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

Gate Induced Drain Leakage (GIDL) Parameters

$$\begin{aligned} \text{AGIDL} = & \text{POAGIDL} + \text{PLAGIDL} \cdot \frac{L_{\text{EN}}}{L_{\text{E}}} \\ & + \text{PWAGIDL} \cdot \frac{W_{\text{E}}}{W_{\text{EN}}} + \text{PLWAGIDL} \cdot \frac{W_{\text{E}} \cdot L_{\text{EN}}}{W_{\text{EN}} \cdot L_{\text{E}}} \end{aligned}$$

$$\begin{aligned} \text{AGIDLD} = & \text{POAGIDLD} + \text{PLAGIDLD} \cdot \frac{L_{\text{EN}}}{L_{\text{E}}} \\ & + \text{PWAGIDLD} \cdot \frac{W_{\text{E}}}{W_{\text{EN}}} + \text{PLWAGIDLD} \cdot \frac{W_{\text{E}} \cdot L_{\text{EN}}}{W_{\text{EN}} \cdot L_{\text{E}}} \end{aligned}$$

$$\text{BGIDL} = \text{POBGIDL}$$

$$\text{BGIDLD} = \text{POBGIDLD}$$

$$\text{STBGIDL} = \text{POSTBGIDL}$$

$$\text{STBGIDLD} = \text{POSTBGIDLD}$$

$$\text{CGIDL} = \text{POCGIDL}$$

$$\text{CGIDLD} = \text{POCGIDLD}$$

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

Charge Model Parameters

$$COX = POXCOX + PLCOX \cdot \frac{L_{E,CV}}{L_{EN}} + PWCXOX \cdot \frac{W_{E,CV}}{W_{EN}} + PLWCXOX \cdot \frac{L_{E,CV} \cdot W_{E,CV}}{L_{EN} \cdot W_{EN}}$$

$$CGOV = POCGOV + PLCGOV \cdot \frac{L_{EN}}{L_{E,CV}} + PWCGOV \cdot \frac{W_{E,CV}}{W_{EN}} + PLWCGOV \cdot \frac{W_{E,CV} \cdot L_{EN}}{W_{EN} \cdot L_{E,CV}}$$

$$CGOVD = POCGOVD + PLCGOVD \cdot \frac{L_{EN}}{L_{E,CV}} + PWCGOVD \cdot \frac{W_{E,CV}}{W_{EN}} + PLWCGOVD \cdot \frac{W_{E,CV} \cdot L_{EN}}{W_{EN} \cdot L_{E,CV}}$$

$$CGBOV = POCGBOV + PLCGBOV \cdot \frac{L_{G,CV}}{L_{EN}} + PWCGBOV \cdot \frac{W_{G,CV}}{W_{EN}} + PLWCGBOV \cdot \frac{L_{G,CV} \cdot W_{G,CV}}{L_{EN} \cdot W_{EN}}$$

$$CFR = POCFR + PLCFR \cdot \frac{L_{EN}}{L_{G,CV}} + PWCFR \cdot \frac{W_{G,CV}}{W_{EN}} + PLWCFR \cdot \frac{W_{G,CV} \cdot L_{EN}}{W_{EN} \cdot L_{G,CV}}$$

$$CFRD = POCFRD + PLCFRD \cdot \frac{L_{EN}}{L_{G,CV}} + PWCFRD \cdot \frac{W_{G,CV}}{W_{EN}} + PLWCFRD \cdot \frac{W_{G,CV} \cdot L_{EN}}{W_{EN} \cdot L_{G,CV}}$$

Noise Model Parameters

$$FNT = POFNT$$

$$NFA = PONFA + PLNFA \cdot \frac{L_{EN}}{L_E} + PWNFA \cdot \frac{W_{EN}}{W_E} + PLWNFA \cdot \frac{L_{EN} \cdot W_{EN}}{L_E \cdot W_E}$$

$$NFB = PONFB + PLNFB \cdot \frac{L_{EN}}{L_E} + PWNFB \cdot \frac{W_{EN}}{W_E} + PLWNFB \cdot \frac{L_{EN} \cdot W_{EN}}{L_E \cdot W_E}$$

$$NFC = PONFC + PLNFC \cdot \frac{L_{EN}}{L_E} + PWNFC \cdot \frac{W_{EN}}{W_E} + PLWNFC \cdot \frac{L_{EN} \cdot W_{EN}}{L_E \cdot W_E}$$

$$EF = POEF$$

WPE Parameters

$$K_{vthowe} = \text{POKVTHOWE} + \text{PLKVTHOWE} \cdot \frac{L_{EN}}{L_E} + \text{PWKVTHOWE} \cdot \frac{W_{EN}}{W_E} \\ + \text{PLWKVTHOWE} \cdot \frac{L_{EN} \cdot W_{EN}}{L_E \cdot W_E}$$

$$K_{uowe} = \text{POKUOWE} + \text{PLKUOWE} \cdot \frac{L_{EN}}{L_E} + \text{PWKUOWE} \cdot \frac{W_{EN}}{W_E} \\ + \text{PLWKUOWE} \cdot \frac{L_{EN} \cdot W_{EN}}{L_E \cdot W_E}$$

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 [23-6](#). At this moment, only the gate resistance is scaled with geometry (facilitating the implementation of multi-finger devices).

Note: The resistance equations are calculated when **SWGEO** = 1 or 2.

$$L_f = L + \Delta L_{PS}$$

$$L_{sil,f} = L_f + \mathbf{DLSIL}$$

$$W_{E,f} = W_f + \Delta W_{OD}$$

$$X_{GWE} = \mathbf{XGW} - 0.5 \cdot \Delta W_{OD}$$

$$\mathbf{RG} = \mathbf{RGO} + \frac{1}{\mathbf{NF}} \cdot \left[\frac{\mathbf{RSHG} \cdot \left(\frac{W_{E,f}}{3 \cdot \mathbf{NGCON}} + X_{GWE} \right)}{\mathbf{NGCON} \cdot L_{sil,f}} + \frac{\mathbf{RINT} + \mathbf{RVPOLY}}{W_{E,f} \cdot L_f} \right]$$

$$\mathbf{RSE} = \mathbf{NRS} \cdot \mathbf{RSH}$$

$$\mathbf{RDE} = \mathbf{NRD} \cdot \mathbf{RSH}$$

$$\mathbf{RBULK} = \mathbf{RBULKO}$$

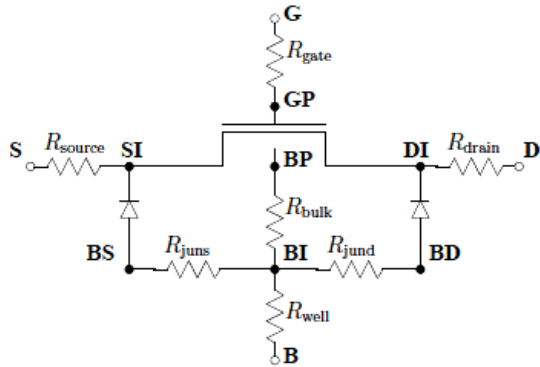
$$\mathbf{RWELL} = \mathbf{RWELLO}$$

$$\mathbf{RJUNS} = \mathbf{RJUNSO}$$

$$\mathbf{RJUND} = \mathbf{RJUNDO}$$

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 23-6 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 23-7 A typical layout of multi-finger devices with an additional instance parameters SD.

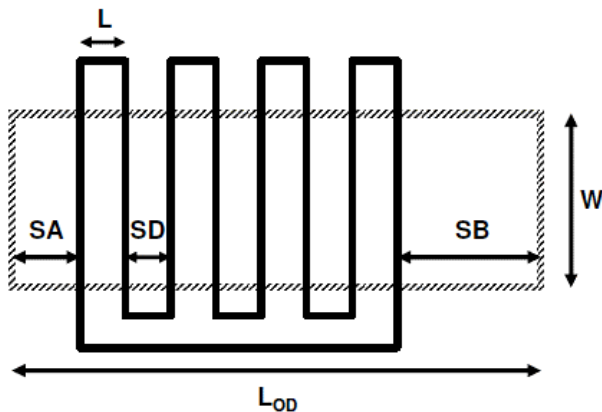
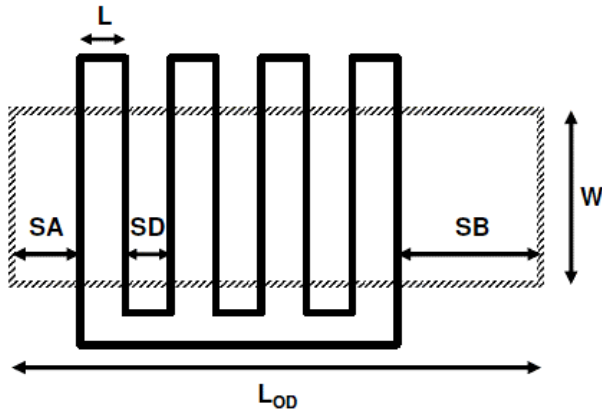


Figure 23-8 Typical layout of a MOSFET. Note that $L_{OD} = SA + SB + L$, where OD is the active region definition.



Parameter Modifications

Mobility related equations

$$K_{u0} = \left(1 + \frac{LK_{UO}}{(L + \Delta L_{PS})^{LLODKUO}} + \frac{WK_{UO}}{(W_f + \Delta W_{OD} + WL_{OD})^{WLODKUO}} + \frac{PK_{UO}}{(L + \Delta L_{PS})^{LLODKUO} \cdot (W_f + \Delta W_{OD} + WL_{OD})^{WLODKUO}} \right) \cdot \left[1 + TK_{UO} \cdot \left(\frac{T_{KD}}{T_{KR}} - 1 \right) \right]$$

$$\rho_{\beta} = \frac{K_{UO}}{K_{u0}} \cdot (R_A + R_B)$$

$$\rho_{\beta,ref} = \frac{K_{UO}}{K_{u0}} \cdot (R_{A,ref} + R_{B,ref})$$

$$BETN = \frac{1 + \rho_{\beta}}{1 + \rho_{\beta,ref}} \cdot BETN_{ref}$$

$$THESAT = \frac{1 + \rho_{\beta}}{1 + \rho_{\beta,ref}} \cdot \frac{1 + KVSAT \cdot \rho_{\beta,ref}}{1 + KVSAT \cdot \rho_{\beta}} \cdot THESAT_{ref}$$

Threshold Voltage related equations

$$K_{vth0} = 1 + \frac{LKVTHO}{(L + \Delta L_{PS})^{LLODVTH}} + \frac{WKVTHO}{(W_f + \Delta W_{OD} + WL_{OD})^{WLODVTH}} + \frac{PKVTHO}{(L + \Delta L_{PS})^{LLODVTH} \cdot (W_f + \Delta W_{OD} + WL_{OD})^{WLODVTH}}$$

$$\Delta R = R_A + R_B - R_{A,ref} - R_{B,ref}$$

$$VFB = VFB_{ref} + KVTIHO \cdot \frac{\Delta R}{K_{vth0}}$$

$$CF = CF_{ref} + SIETAO \cdot \frac{\Delta R}{K_{vth0}^{LODETAO}}$$

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:

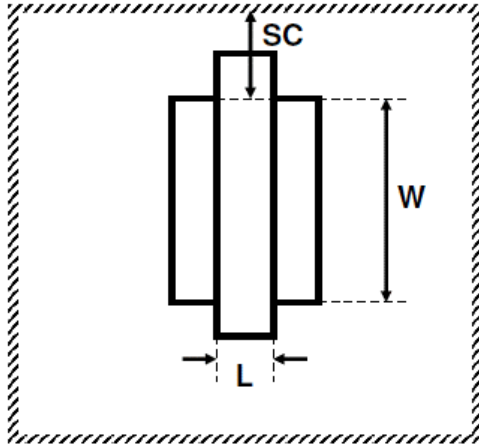
- After modification of the local parameters by the WPE equations, clipping is applied according to Section "Intrinsic Parameters for the model".
- If SCA, SCB, SCC and SC are all set to 0, the WPE equations are not computed.
- The WPE equations are calculated when SWGEO = 1 or 2.

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 23-9 A layout of MOS devices for pre-layout simulation using estimated value for SC.



$$\begin{aligned}
 SCB &= \frac{1}{W_f \cdot SCREF} \cdot \left[\frac{SCREF}{10} \cdot SC \cdot \exp\left(-10 \cdot \frac{SC}{SCREF}\right) + \frac{SCREF^2}{100} \cdot \exp\left(-10 \cdot \frac{SC}{SCREF}\right) \right. \\
 &\quad \left. - \frac{SCREF}{10} \cdot (SC + W_f) \cdot \exp\left(-10 \cdot \frac{SC + W_f}{SCREF}\right) \right. \\
 &\quad \left. - \frac{SCREF}{10} \cdot (SC + W_f) \cdot \exp\left(-10 \cdot \frac{SC + W_f}{SCREF}\right) \right. \\
 &\quad \left. - \frac{SCREF^2}{100} \cdot \exp\left(-10 \cdot \frac{SC + W_f}{SCREF}\right) \right] \\
 SCC &= \frac{1}{W_f \cdot SCREF} \cdot \left[\frac{SCREF}{20} \cdot SC \cdot \exp\left(-20 \cdot \frac{SC}{SCREF}\right) + \frac{SCREF^2}{400} \cdot \exp\left(-20 \cdot \frac{SC}{SCREF}\right) \right. \\
 &\quad \left. - \frac{SCREF}{20} \cdot (SC + W_f) \cdot \exp\left(-20 \cdot \frac{SC + W_f}{SCREF}\right) \right]
 \end{aligned}$$

Calculation of parameter modifications

The calculation of K_{vthowe} and K_{uowe} is given in Sections for Global Model or Binning Model.

$$VFB = VFB_{ref} + K_{vthowe} \cdot (SCA + WEB \cdot SCB + WEC \cdot SCC)$$

$$BETN = BETN_{ref} \cdot [1 + K_{uowe} \cdot (SCA + WEB \cdot SCB + WEC \cdot SCC)]$$

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

$$\phi_T^* = \phi_T \cdot \left(1 + \mathbf{CT} \cdot \frac{T_{KR}}{T_{KD}} \right)$$

$$\mathbf{V}_{FB} = \mathbf{VFB} + \mathbf{STVFB} \cdot \Delta T + \mathbf{DELVTIO}$$

$$E_g/q = 1.179 - 9.025 \cdot 10^{-5} \cdot T_{KD} - 3.05 \cdot 10^{-7} \cdot T_{KD}^2$$

$$r_T = (1.045 + 4.5 \cdot 10^{-4} \cdot T_{KD}) \cdot (0.523 + 1.4 \cdot 10^{-3} \cdot T_{KD} - 1.48 \cdot 10^{-6} \cdot T_{KD}^2)$$

$$n_i = 2.5 \cdot 10^{25} \cdot r_T^{3/4} \cdot (T_{KD}/300)^{3/2} \cdot \exp\left(-\frac{E_g/q}{2 \cdot \phi_T}\right)$$

$$\phi_{B,dc}^{cl} = \mathbf{MAX}(\mathbf{DPHIB} + 2 \cdot \phi_T \cdot \ln[\mathbf{NEFF}/n_i], 0.05)$$

$$N_{eff,ac} = \mathbf{MIN}[\mathbf{MAX}(\mathbf{FACNEFFAC} \cdot \mathbf{NEFF}, 10^{20}), 10^{26}]$$

$$\phi_{B,ac}^{cl} = \mathbf{MAX}(\mathbf{DPHIB} + \mathbf{DELVTAC} + 2 \cdot \phi_T \cdot \ln[N_{eff,ac}/n_i], 0.05)$$

$$\epsilon_{ox} = \mathbf{EPSROX} \cdot \epsilon_0$$

$$C_{ox} = \epsilon_{ox} / \mathbf{TOX}$$

$$\epsilon_{Si} = \epsilon_{r,Si} \cdot \epsilon_0$$

$$\gamma_{0,dc} = \sqrt{2 \cdot q \cdot \epsilon_{Si} \cdot \mathbf{NEFF}} / C_{ox}$$

$$\gamma_{0,ac} = \sqrt{2 \cdot q \cdot \epsilon_{Si} \cdot N_{eff,ac}} / C_{ox}$$

$$G_{0,dc}^{cl} = \gamma_{0,dc} / \sqrt{\phi_T}$$

$$G_{0,ac}^{cl} = \gamma_{0,ac} / \sqrt{\phi_T}$$

Polysilicon depletion parameter

$$k_p = \begin{cases} \text{if } NP = 0 & \left\{ \begin{array}{l} k_p = 0 \end{array} \right. \\ \text{if } NP > 0 & \left\{ \begin{array}{l} NP_1 = \text{MAX}(NP, 8 \cdot 10^7 / \text{TOX}^2) \\ NP_2 = \text{MAX}(NP_1, 5 \cdot 10^{24}) \\ k_p = 2 \cdot \phi_T \cdot C_{ox}^2 / (q \cdot \epsilon_{Si} \cdot NP_2) \end{array} \right. \end{cases}$$

Quantum-mechanical correction parameters

$$q_{lim} = 10 \cdot \phi_T$$

$$q_q = \begin{cases} 0.4 \cdot \text{QMC} \cdot QM_N \cdot C_{ox}^{2/3} & \text{for NMOS} \\ 0.4 \cdot \text{QMC} \cdot QM_P \cdot C_{ox}^{2/3} & \text{for PMOS} \end{cases}$$

$$q_{b0,dc} = \gamma_{0,dc} \cdot \sqrt{\phi_{B,dc}^{cl}}$$

$$q_{b0,ac} = \gamma_{0,ac} \cdot \sqrt{\phi_{B,ac}^{cl}}$$

$$\phi_{B,dc} = \phi_{B,dc}^{cl} + 0.75 \cdot q_q \cdot q_{b0,dc}^{2/3}$$

$$\phi_{B,ac} = \phi_{B,ac}^{cl} + 0.75 \cdot q_q \cdot q_{b0,ac}^{2/3}$$

$$G_{0,dc} = G_{0,dc}^{cl} \cdot \left(1 + q_q \cdot q_{b0,dc}^{-1/3}\right)$$

$$G_{0,ac} = G_{0,ac}^{cl} \cdot \left(1 + q_q \cdot q_{b0,ac}^{-1/3}\right)$$

VSF-clipping parameters

$$\phi_{X,dc} = 0.95 \cdot \phi_{B,dc}$$

$$\phi_{X,ac} = 0.95 \cdot \phi_{B,ac}$$

$$a_{\phi,dc} = 2.5 \cdot 10^{-3} \cdot \phi_{B,dc}^2$$

$$a_{\phi,ac} = 2.5 \cdot 10^{-3} \cdot \phi_{B,ac}^2$$

$$b_{\phi,dc} = 2.5 \cdot 10^{-3} \cdot \phi_{B,dc}^2$$

$$b_{\phi,ac} = 2.5 \cdot 10^{-3} \cdot \phi_{B,ac}^2$$

$$\phi_{X,dc}^* = 0.5 \cdot \sqrt{b_{\phi,dc}}$$

$$\phi_{X,ac}^* = 0.5 \cdot \sqrt{b_{\phi,ac}}$$

$$\phi_{X,dc}^* = \text{MINA}(\phi_{X,dc} - \phi_{X,dc}^*, 0, a_{\phi,dc})$$

$$\phi_{X,ac}^* = \text{MINA}(\phi_{X,ac} - \phi_{X,ac}^*, 0, a_{\phi,ac})$$

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

$$\beta = FACTUO \cdot BETN \cdot C_{ox} \cdot (T_{KR}/T_{KD})^{STBET}$$

$$\theta_{\mu} = THEMU \cdot (T_{KR}/T_{KD})^{STHEMU}$$

$$\mu_E = MUE \cdot (T_{KR}/T_{KD})^{STMUE}$$

$$X_{cor} = XCOR \cdot (T_{KR}/T_{KD})^{STXCOR}$$

$$C_S = CS \cdot (T_{KR}/T_{KD})^{STCS}$$

$$E_{eff0} = 10^{-8} \cdot C_{ox} / \epsilon_{Si}$$

$$\eta_{\mu} = \begin{cases} 1/2 \cdot FETA & \text{for NMOS} \\ 1/3 \cdot FETA & \text{for PMOS} \end{cases}$$

$$\eta_{\mu,ac} = \begin{cases} 1/2 & \text{for NMOS} \\ 1/3 & \text{for PMOS} \end{cases}$$

Series resistance parameter

$$R_s = RS \cdot (T_{KR}/T_{KD})^{STRS}$$

$$\theta_R = 2 \cdot \beta \cdot R_s$$

Velocity saturation parameter

$$\theta_{sat} = THESAT \cdot (T_{KR}/T_{KD})^{STHESAT}$$

Impact-ionization parameter

$$\alpha_2 = A2 \cdot (T_{KD}/T_{KR})^{STA2}$$

Gate current parameters

$$I_{GINV} = IGINV \cdot (T_{KD}/T_{KR})^{STIG}$$

$$I_{GOV} = IGOV \cdot (T_{KD}/T_{KR})^{STIG}$$

$$I_{GOVD} = IGOVD \cdot (T_{KD}/T_{KR})^{STIG}$$

$$B = \frac{4}{3} \cdot \frac{TOX}{\hbar} \cdot \sqrt{2 \cdot q \cdot m_0 \cdot CHIB} = 6.830909 \cdot 10^9 \cdot TOX \cdot \sqrt{CHIB}$$

$$B_{ov} = B \cdot TOXOV/TOX$$

$$B_{ovd} = B \cdot TOXOVD/TOX$$

$$GC_Q = \begin{cases} -0.99 \cdot \frac{GC2}{2 \cdot GC3} & \text{for } GC3 < 0 \\ 0 & \text{for } GC3 \geq 0 \end{cases}$$

$$\alpha_b = \frac{E_g/q + \phi_B}{2}$$

$$D_{ch} = GCO \cdot \phi_T^*$$

$$D_{ov} = GCO \cdot \phi_T$$

Gate-induced drain leakage parameters

$$A_{\text{CIDL}} = \text{AGIDL} \cdot \left(\frac{2 \cdot 10^{-9}}{\text{TOXOV}} \right)^2$$

$$A_{\text{CIDLD}} = \text{AGIDLD} \cdot \left(\frac{2 \cdot 10^{-9}}{\text{TOXOVD}} \right)^2$$

$$B_{\text{CIDL}} = \text{BGIDL} \cdot \text{MAX}([1 + \text{STBGIDL} \cdot \Delta T], 0) \cdot \left(\frac{\text{TOXOV}}{2 \cdot 10^{-9}} \right)$$

$$B_{\text{CIDLD}} = \text{BGIDLD} \cdot \text{MAX}([1 + \text{STBGIDLD} \cdot \Delta T], 0) \cdot \left(\frac{\text{TOXOVD}}{2 \cdot 10^{-9}} \right)$$

Noise parameter

$$N_T = \text{FNT} \cdot 4 \cdot k_B \cdot T_{\text{KD}}$$

Additional internal parameters

$$x_1 = 1.25$$

$$x_{g1} = x_1 + G_{ov} \cdot \sqrt{\exp(-x_1) + x_1 - 1}$$

$$x_{dg1} = x_1 + G_{dov} \cdot \sqrt{\exp(-x_1) + x_1 - 1}$$

Current Model

In this section, the current model equations of the PSP-model are given. Use is made of the applied terminal bias values VGS, VDS and VSB, 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

$\text{SWNUD} \neq 0$ and $\text{GFACNUD} \neq 1$:

$$V_{mB} = V_{SB}^* + 0.5 \cdot (V_{DS} - V_{dsx})$$

$$u_s = \sqrt{V_{mB} + \phi_B} - \sqrt{\phi_B}$$

$$p = 2 \cdot \frac{u_s - u_{s1}}{u_{s21}} - 1$$

$$u_{s,nud} = u_s - 0.25 \cdot (1 - \text{GFACNUD}) \cdot u_{s21} \cdot \left\{ p + \sqrt{p^2 + [\ln(2)]^2} \right\}$$

$$V_{mB,nud} = (u_{s,nud} + 2 \cdot \sqrt{\phi_B}) \cdot u_{s,nud}$$

$$V_{SB}^{nud} = V_{mB,nud} - 0.5 \cdot (V_{DS} - V_{dsx})$$

$$V_{SB,dc}^* = V_{SB}^{nud}$$

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 $\text{SWNUD} = 1$ or $\text{SWDELVTAC} = 1$, calculations are done a second time using

$$V_{SB}^* = V_{SB,ac}^*, \phi_B = \phi_{B,ac}, \text{ and } G_0 = G_{0,ac}.$$

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

$$V_{DB}^* = V_{DS} + V_{SB}^*$$

$$V_{sbx} = V_{SB}^* + \frac{V_{DS} - V_{dsx}}{2}$$

Drain-induced barrier lowering:

$$\Delta V_G = CF \cdot V_{dsx} \cdot (1 + CFB \cdot V_{sbx})$$

$$V_{GB}^* = V_{GS} + V_{SB}^* + \Delta V_G - V_{FB}$$

$$x_g = V_{GB}^* / \phi_T^*$$

Bias-Dependent Body Factor

$$D_{nsub} = DNSUB \cdot \text{MAXA}(0, V_{GS} + V_{SB} - VNSUB, NSLP)$$

$$G = G_0 \cdot \sqrt{1 + D_{nsub}}$$

Surface Potential at Source Side and Related Variables

$$\xi = 1 + G/\sqrt{2}$$

$$x_{ns} = \frac{\phi_B + V_{SB}^*}{\phi_T^*}$$

$$\Delta_{ns} = \exp(-x_{ns})$$

$$x_{mrg} = 10^{-5} \cdot \xi$$

Virtuoso Simulator Components and Device Models Reference
PSP Model (psp)

$$\text{if } x_g < -x_{\text{mrg}} \left\{ \begin{array}{l} y_g = -x_g \\ z = 1.25 \cdot y_g / \xi \\ \eta = \left[z + 10 - \sqrt{(z-6)^2 + 64} \right] / 2 \\ a = (y_g - \eta)^2 + G^2 \cdot (\eta + 1) \\ c = 2 \cdot (y_g - \eta) - G^2 \\ \tau = -\eta + \ln(a/G^2) \\ y_0 = \sigma_1(a, c, \tau, \eta) \\ \Delta_0 = \exp(y_0) \\ p = 2 \cdot (y_g - y_0) + G^2 \cdot [\Delta_0 - 1 + \Delta_{\text{ns}} \cdot (1 - \chi'(y_0) - 1/\Delta_0)] \\ q = (y_g - y_0)^2 + G^2 \cdot [y_0 - \Delta_0 + 1 + \Delta_{\text{ns}} \cdot (1 + \chi(y_0) - 1/\Delta_0 - 2 \cdot y_0)] \\ x_s = -y_0 - \frac{2 \cdot q}{p + \sqrt{p^2 - 2 \cdot q \cdot \{2 - G^2 \cdot [\Delta_0 + \Delta_{\text{ns}} \cdot (1/\Delta_0 - \chi''(y_0))]\}}} \end{array} \right.$$

$$\text{if } |x_g| \leq x_{\text{mrg}} \left\{ x_s = \frac{x_g}{\xi} \cdot \left[1 + G \cdot x_g \cdot \frac{1 - \Delta_{\text{ns}}}{\xi^2 \cdot 6 \cdot \sqrt{2}} \right] \right.$$

$$\text{if } x_g > x_{\text{mrg}} \left\{ \begin{array}{l} \hat{x}_{g1} = x_1 + G \cdot \sqrt{\exp(-x_1) + x_1 - 1} \\ \bar{x} = \frac{x_g}{\xi} \cdot [1 + x_g \cdot (\xi \cdot x_1 - \hat{x}_{g1}) / \hat{x}_{g1}^2] \\ x_0 = x_g + G^2/2 - G \cdot \sqrt{x_g + G^2/4 - 1 + \exp(-\bar{x})} \\ b_x = x_{\text{ns}} + 3 \\ \eta = \text{MINA}(x_0, b_x, 5) - (b_x - \sqrt{b_x^2 + 5}) / 2 \\ a = (x_g - \eta)^2 - G^2 \cdot [\exp(-\eta) + \eta - 1 - \Delta_{\text{ns}} \cdot (\eta + 1 + \chi(\eta))] \\ b = 1 - G^2/2 \cdot [\exp(-\eta) - \Delta_{\text{ns}} \cdot \chi''(\eta)] \\ c = 2 \cdot (x_g - \eta) + G^2 \cdot [1 - \exp(-\eta) - \Delta_{\text{ns}} \cdot (1 + \chi'(\eta))] \\ \tau = x_{\text{ns}} - \eta + \ln(a/G^2) \\ y_0 = \sigma_2(a, b, c, \tau, \eta) \\ \Delta_0 = \exp(y_0) \\ p = 2 \cdot (x_g - y_0) + G^2 \cdot [1 - 1/\Delta_0 + \Delta_{\text{ns}} \cdot (\Delta_0 - 1 - \chi'(y_0))] \\ q = (x_g - y_0)^2 - G^2 \cdot [y_0 + 1/\Delta_0 - 1 + \Delta_{\text{ns}} \cdot (\Delta_0 - y_0 - 1 - \chi(y_0))] \\ x_s = y_0 + \frac{2 \cdot q}{p + \sqrt{p^2 - 2 \cdot q \cdot \{2 - G^2 \cdot [1/\Delta_0 + \Delta_{\text{ns}} \cdot (\Delta_0 - \chi''(y_0))]\}}} \end{array} \right.$$

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

Calculations are only done for $x_g > 0$.

$$E_s = \exp(-x_s)$$

$$D_s = [1/E_s - x_s - 1 - \chi(x_s)] \cdot \Delta_{ns}$$

$$P_s = x_s - 1 + E_s$$

$$x_{gs} = \begin{cases} x_g - x_s & \text{for } x_g \leq 0 \\ G \cdot \sqrt{D_s + P_s} & \text{for } x_g > 0 \end{cases}$$

$$\psi_{ss} = \phi_T^* \cdot x_s$$

Drain Saturation Voltage

Calculations are only done for $x_g > 0$.

$$q_{is} = \frac{G^2 \cdot \phi_T^* \cdot D_s}{x_{gs} + G \cdot \sqrt{P_s}}$$

$$\alpha_s = 1 + \frac{G \cdot (1 - E_s)}{2 \cdot \sqrt{P_s}}$$

$$q_{bs} = \phi_T^* \cdot G \cdot \sqrt{P_s}$$

$$\rho_b = \begin{cases} 1 + \text{RSB} \cdot V_{sbx} & \text{for } \text{RSB} \geq 0 \\ \frac{1}{1 - \text{RSB} \cdot V_{sbx}} & \text{for } \text{RSB} < 0 \end{cases}$$

$$\rho_{g,s} = \begin{cases} \frac{1}{1 + \text{RSG} \cdot q_{is}} & \text{for } \text{RSG} \geq 0 \\ 1 - \text{RSG} \cdot q_{is} & \text{for } \text{RSG} < 0 \end{cases}$$

$$\rho_s = \theta_R \cdot \rho_b \cdot \rho_{g,s} \cdot q_{is}$$

$$\mu_x = \frac{1 + X_{cor} \cdot V_{sbx}}{1 + 0.2 \cdot X_{cor} \cdot V_{sbx}}$$

$$E_{eff,s} = E_{eff0} \cdot (q_{bs} + \eta_\mu \cdot q_{is})$$

$$G_{mob,s} = \frac{1 + (\mu_E \cdot E_{eff,s})^{\theta_\mu} + C_S \cdot \left(\frac{q_{bs}}{q_{is} + q_{bs}}\right)^2 + \rho_s}{\mu_x}$$

$$\xi_{tb} = \begin{cases} 1 + \text{THESATB} \cdot V_{sbx} & \text{for } \text{THESATB} \geq 0 \\ \frac{1}{1 - \text{THESATB} \cdot V_{sbx}} & \text{for } \text{THESATB} < 0 \end{cases}$$

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

$$w_{\text{sat},s} = \frac{100 \cdot q_{\text{is}} \cdot \xi_{\text{tb}}}{100 + q_{\text{is}} \cdot \xi_{\text{tb}}}$$

$$\theta_{\text{sat},s}^* = \begin{cases} \frac{\theta_{\text{sat}}}{G_{\text{mob},s}} \cdot (1 + \text{THESATG} \cdot w_{\text{sat},s}) & \text{for } \text{THESATG} \geq 0 \\ \frac{\theta_{\text{sat}}}{G_{\text{mob},s}} \cdot \frac{1}{1 - \text{THESATG} \cdot w_{\text{sat},s}} & \text{for } \text{THESATG} < 0 \end{cases}$$

$$\phi_{\infty} = q_{\text{is}}/\alpha_s + \phi_{\text{T}}^*$$

$$y_{\text{sat}} = \begin{cases} \theta_{\text{sat},s}^* \cdot \phi_{\infty}/\sqrt{2} & \text{for NMOS} \\ \frac{\theta_{\text{sat},s}^* \cdot \phi_{\infty}/\sqrt{2}}{\sqrt{1 + \theta_{\text{sat},s}^* \cdot \phi_{\infty}/\sqrt{2}}} & \text{for PMOS} \end{cases}$$

$$z_{\text{a}} = \frac{2}{1 + \sqrt{1 + 4 \cdot y_{\text{sat}}}}$$

$$\phi_0 = \phi_{\infty} \cdot z_{\text{a}} \cdot \left[1 + 0.86 \cdot z_{\text{a}} \cdot y_{\text{sat}} \cdot \frac{1 - z_{\text{a}}^2 \cdot y_{\text{sat}}}{1 + 4 \cdot z_{\text{a}}^3 \cdot y_{\text{sat}}^2} \right]$$

$$a_{\text{sat}} = x_{\text{gs}} + G^2/2$$

$$\phi_2 = \frac{\phi_{\text{T}}^* \cdot 0.98 \cdot G^2 \cdot D_s}{a_{\text{sat}} + \sqrt{a_{\text{sat}}^2 - 0.98 \cdot G^2 \cdot D_s}}$$

$$\phi_{\text{sat}} = \frac{2 \cdot \phi_0 \cdot \phi_2}{\phi_0 + \phi_2 + \sqrt{(\phi_0 + \phi_2)^2 - 3.96 \cdot \phi_0 \cdot \phi_2}}$$

$$V_{\text{dsat}} = \phi_{\text{sat}} - \phi_{\text{T}}^* \cdot \ln \left[1 + \frac{\phi_{\text{sat}} \cdot (\phi_{\text{sat}} - 2 \cdot a_{\text{sat}} \cdot \phi_{\text{T}}^*)}{G^2 \cdot D_s \cdot \phi_{\text{T}}^{*2}} \right]$$

$$V_{\text{dse}} = \frac{V_{\text{DS}}}{\left[1 + (V_{\text{DS}}/V_{\text{dsat}})^{\text{AX}} \right]^{1/\text{AX}}}$$

Surface Potential at Drain Side and Related Variables

Calculations are only done for $x_g > 0$.

$$x_{nd} = \frac{\phi_B + V_{SB}^* + V_{dse}}{\phi_I^*}$$

$$k_{ds} = \exp(-V_{dse}/\phi_I^*)$$

$$\Delta_{nd} = \Delta_{ns} \cdot k_{ds}$$

$$\text{if } x_g \leq x_{mrg} \left\{ \begin{array}{l} x_d = \frac{x_g}{\xi} \cdot \left[1 + G \cdot x_g \cdot \frac{1 - \Delta_{nd}}{\xi^2 \cdot 6 \cdot \sqrt{2}} \right] \end{array} \right.$$

$$\text{if } x_g > x_{mrg} \left\{ \begin{array}{l} b_x = x_{nd} + 3.0 \\ \eta = \text{MINA}(x_0, b_x, 5) - (b_x - \sqrt{b_x^2 + 5}) / 2 \\ a = (x_g - \eta)^2 - G^2 \cdot [\exp(-\eta) + \eta - 1 - \Delta_{nd} \cdot (\eta + 1 + \chi(\eta))] \\ b = 1 - G^2 / 2 \cdot [\exp(-\eta) - \Delta_{nd} \cdot \chi''(\eta)] \\ c = 2 \cdot (x_g - \eta) + G^2 \cdot [1 - \exp(-\eta) - \Delta_{nd} \cdot (1 + \chi'(\eta))] \\ \tau = x_{nd} - \eta + \ln(a/G^2) \\ y_0 = \sigma_2(a, b, c, \tau, \eta) \\ \Delta_0 = \exp(y_0) \\ p = 2 \cdot (x_g - y_0) + G^2 \cdot [1 - 1/\Delta_0 + \Delta_{nd} \cdot (\Delta_0 - 1 - \chi'(y_0))] \\ q = (x_g - y_0)^2 - G^2 \cdot [y_0 + 1/\Delta_0 - 1 + \Delta_{nd} \cdot (\Delta_0 - y_0 - 1 - \chi(y_0))] \\ x_d = y_0 + \frac{2 \cdot q}{p + \sqrt{p^2 - 2 \cdot q \cdot \{2 - G^2 \cdot [1/\Delta_0 + \Delta_{nd} \cdot (\Delta_0 - \chi''(y_0))]\}}} \end{array} \right.$$

$$x_{ds} = x_d - x_s$$

$$\text{if } x_{ds} < 10^{-10} \left\{ \begin{array}{l} p = 2 \cdot x_{gs} + G^2 \cdot [1 - E_s + \Delta_{nd} \cdot (1/E_s - 1 - \chi'(x_s))] \\ q = G^2 \cdot (1 - k_{ds}) \cdot D_s \\ \xi = 1 - G^2 / 2 \cdot [E_s + \Delta_{nd} (1/E_s - \chi''(x_s))] \\ x_{ds} = \frac{2 \cdot q}{p + \sqrt{p^2 - 4 \cdot \xi \cdot q}} \\ x_d = x_s + x_{ds} \end{array} \right.$$

$$E_d = \exp(-x_d)$$

$$D_d = (1/E_d - x_d - 1 - \chi(x_d)) \cdot \Delta_{nd}$$

$$\Delta\psi = \phi_I^* \cdot x_{ds}$$

$$\psi_{sd} = \phi_I^* \cdot x_d$$

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

$$R_1 = q_{im}/q_{im}^*$$

$$R_2 = \phi_T^* \cdot \alpha_m/q_{im}^*$$

$$T_1 = \ln \left(\frac{1 + \frac{V_{DS} - \Delta\psi}{VP}}{1 + \frac{V_{dse} - \Delta\psi}{VP}} \right)$$

$$T_2 = \ln \left(1 + \frac{V_{dsx}}{VP} \right)$$

$$\Delta L/L = ALP \cdot T_1$$

$$G_{\Delta L} = \frac{1}{1 + \Delta L/L + (\Delta L/L)^2}$$

$$\Delta L_1/L = \left[ALP + \frac{ALP1}{q_{im}^*} \cdot R_1 \right] \cdot T_1 + ALP2 \cdot q_{bm} \cdot R_2^2 \cdot T_2$$

$$F_{\Delta L} = [1 + \Delta L_1/L + (\Delta L_1/L)^2] \cdot G_{\Delta L}$$

Velocity Saturation

$$w_{sat} = \frac{100 \cdot q_{im} \cdot \xi_{tb}}{100 + q_{im} \cdot \xi_{tb}}$$

$$\theta_{sat}^* = \begin{cases} \frac{\theta_{sat}}{G_{mob,s} \cdot G_{\Delta L}} \cdot (1 + THESATG \cdot w_{sat}) & \text{for THESATG} \geq 0 \\ \frac{\theta_{sat}}{G_{mob,s} \cdot G_{\Delta L}} \cdot \frac{1}{1 - THESATG \cdot w_{sat}} & \text{for THESATG} < 0 \end{cases}$$

$$z_{sat} = \begin{cases} (\theta_{sat}^* \cdot \Delta\psi)^2 & \text{for NMOS} \\ \frac{(\theta_{sat}^* \cdot \Delta\psi)^2}{1 + \theta_{sat}^* \cdot \Delta\psi} & \text{for PMOS} \end{cases}$$

$$G_{vsat} = \frac{G_{mob} \cdot G_{\Delta L}}{2} \cdot (1 + \sqrt{1 + 2 \cdot z_{sat}})$$

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

Auxiliary Variables for Calculation of Intrinsic Charges and Gate Current. are only calculated for $x_g > 0$.

$$V_{oxm} = \phi_{\text{T}}^* \cdot x_{gm}$$

$$\alpha'_m = \alpha_m \cdot \left[1 + \frac{z_{\text{sat}}}{2} \cdot \left(\frac{G_{\text{mob}} \cdot G_{\Delta L}}{G_{\text{vsat}}} \right)^2 \right]$$

$$H = \frac{G_{\text{mob}} \cdot G_{\Delta L}}{G_{\text{vsat}}} \cdot \frac{q_{\text{im}}^*}{\alpha'_m}$$

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 of 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:

$$x_g, q_{\text{eff1}}, V_{\text{oxm}}, q_{\text{im}}, q_{\text{im}}^*, \alpha_m, \Delta\psi, G_{\Delta L}, F_{\Delta L}, H, \eta_p, G_{\text{vsat}}, V_{\text{dse}}, G_{\text{mob}}, x_m, G, x_{gm}, \theta_{\text{sat}}^*$$

Drain source channel current

$$I_{\text{DS}} = \begin{cases} 0 & \text{for } x_{g,\text{dc}} \leq 0 \\ \beta \cdot F_{\Delta L,\text{dc}} \cdot \frac{q_{\text{im,dc}}^*}{G_{\text{vsat,dc}}} \cdot \Delta\psi_{\text{dc}} & \text{for } x_{g,\text{dc}} > 0 \end{cases}$$

Impact Ionization or Weak-Avalanche

The equations in this section are only calculated when **SWIMPACT** = 1 and $x_g > 0$.

$$a_2^* = a_2 \cdot \left[1 + \mathbf{A4} \cdot \left(\sqrt{V_{SB,dc}^* + \phi_B} - \sqrt{\phi_B} \right) \right]$$

$$\Delta V_{sat} = V_{DS} - \mathbf{A3} \cdot \Delta \psi_{dc}$$

$$M_{avl} = \begin{cases} 0 & \text{for } \Delta V_{sat} \leq 0 \\ \mathbf{A1} \cdot \Delta V_{sat} \cdot \exp\left(-\frac{a_2^*}{\Delta V_{sat}}\right) & \text{for } \Delta V_{sat} > 0 \end{cases}$$

$$I_{avl} = M_{avl} \cdot I_{DS}$$

Surface Potential in Gate Overlap Regions

$$x_{sov}(x_g) = \begin{cases} \text{if } x_g < -x_{mrgov} \left\{ \begin{array}{l} y_g = -x_g \\ z = x_1 \cdot y_g / \xi_{ov} \\ \eta = \left[z + 10 - \sqrt{(z - 6)^2 + 64} \right] / 2 \\ a = (y_g - \eta)^2 + G_{ov}^2 \cdot (\eta + 1) \\ c = 2 \cdot (y_g - \eta) - G_{ov}^2 \\ \tau = -\eta + \ln(a / G_{ov}^2) \\ y_0 = \sigma_1(a, c, \tau, \eta) \\ \Delta_0 = \exp(y_0) \\ p = 2 \cdot (y_g - y_0) + G_{ov}^2 \cdot (\Delta_0 - 1) \\ q = (y_g - y_0)^2 + G_{ov}^2 \cdot (y_0 - \Delta_0 + 1) \\ x_{sov} = -y_0 - \frac{2 \cdot q}{p + \sqrt{p^2 - 2 \cdot q \cdot (2 - G_{ov}^2 \cdot \Delta_0)}} \end{array} \right. \\ \\ \text{if } |x_g| < x_{mrgov} \left\{ \begin{array}{l} x_{sov} = x_g / \xi_{ov} \end{array} \right. \\ \\ \text{if } x_g > x_{mrgov} \left\{ \begin{array}{l} \bar{x} = x_g / \xi_{ov} \cdot \left[1 + x_g \cdot (\xi_{ov} \cdot x_1 - x_{g1}) / x_{g1}^2 \right] \\ \omega = 1 - \exp(-\bar{x}) \\ x_0 = x_g + G_{ov}^2 / 2 - G_{ov} \cdot \sqrt{x_g + G_{ov}^2 / 4 - \omega} \\ \Delta_0 = \exp(-x_0) \\ p = 2 \cdot (x_g - x_0) + G_{ov}^2 \cdot (1 - \Delta_0) \\ q = (x_g - x_0)^2 - G_{ov}^2 \cdot (x_0 + \Delta_0 - 1) \\ x_{sov} = x_0 + \frac{2 \cdot q}{p + \sqrt{p^2 - 2 \cdot q \cdot (2 - G_{ov}^2 \cdot \Delta_0)}} \end{array} \right. \end{cases}$$

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

$$x_{\text{dov}}(x_g) = \begin{cases} \text{if } x_g < -x_{\text{mrgdov}} \left\{ \begin{array}{l} y_g = -x_g \\ z = \mathbf{x}_1 \cdot y_g / \xi_{\text{dov}} \\ \eta = \left[z + 10 - \sqrt{(z - 6)^2 + 64} \right] / 2 \\ a = (y_g - \eta)^2 + G_{\text{dov}}^2 \cdot (\eta + 1) \\ c = 2 \cdot (y_g - \eta) - G_{\text{dov}}^2 \\ \tau = -\eta + \ln(a / G_{\text{dov}}^2) \\ y_0 = \sigma_1(a, c, \tau, \eta) \\ \Delta_0 = \exp(y_0) \\ p = 2 \cdot (y_g - y_0) + G_{\text{dov}}^2 \cdot (\Delta_0 - 1) \\ q = (y_g - y_0)^2 + G_{\text{dov}}^2 \cdot (y_0 - \Delta_0 + 1) \\ x_{\text{dov}} = -y_0 - \frac{2 \cdot q}{p + \sqrt{p^2 - 2 \cdot q \cdot (2 - G_{\text{dov}}^2 \cdot \Delta_0)}} \end{array} \right. \\ \\ \text{if } |x_g| < x_{\text{mrgdov}} \left\{ x_{\text{dov}} = x_g / \xi_{\text{dov}} \right. \\ \\ \text{if } x_g > x_{\text{mrgdov}} \left\{ \begin{array}{l} \bar{x} = x_g / \xi_{\text{dov}} \cdot \left[1 + x_g \cdot (\xi_{\text{dov}} \cdot \mathbf{x}_1 - x_{\text{dgl}}) / x_{\text{dgl}}^2 \right] \\ \omega = 1 - \exp(-\bar{x}) \\ x_0 = x_g + G_{\text{dov}}^2 / 2 - G_{\text{dov}} \cdot \sqrt{x_g + G_{\text{dov}}^2 / 4 - \omega} \\ \Delta_0 = \exp(-x_0) \\ p = 2 \cdot (x_g - x_0) + G_{\text{dov}}^2 \cdot (1 - \Delta_0) \\ q = (x_g - x_0)^2 - G_{\text{dov}}^2 \cdot (x_0 + \Delta_0 - 1) \\ x_{\text{dov}} = x_0 + \frac{2 \cdot q}{p + \sqrt{p^2 - 2 \cdot q \cdot (2 - G_{\text{dov}}^2 \cdot \Delta_0)}} \end{array} \right. \end{cases}$$

$$\psi_{\text{sov}} = -\phi_{\mathbf{T}} \cdot x_{\text{sov}} \left(-\frac{V_{\text{GS}}}{\phi_{\mathbf{T}}} \right)$$

$$\psi_{\text{dov}} = -\phi_{\mathbf{T}} \cdot x_{\text{dov}} \left(-\frac{V_{\text{GS}} - V_{\text{DS}}}{\phi_{\mathbf{T}}} \right)$$

$$V_{\text{ov}_0} = V_{\text{GS}} - \psi_{\text{sov}}$$

$$V_{\text{ov}_L} = V_{\text{GS}} - V_{\text{DS}} - \psi_{\text{dov}}$$

Gate Current

The equations in this Section are only calculated when **SWIGATE** = 1.

Source/Drain gate overlap current

$$I_{GSov}(V_{GX}, \psi_{ov}, V_{ov}) = \left\{ \begin{array}{l} V_{ov}^* = \sqrt{V_{ov}^2 + 10^{-6}} \\ \psi_{tov} = \text{MINA}(0, V_{ov} + D_{ov}, 0.01) \\ z_g = \begin{cases} \text{MINA}\left(\frac{V_{ov}^*}{\text{CHIB}}, GC_Q, 10^{-6}\right) & \text{for } GC3 < 0 \\ \frac{V_{ov}^*}{\text{CHIB}} & \text{for } GC3 \geq 0 \end{cases} \\ \Delta_{Siov} = \exp\left(\frac{3.0 \cdot \phi_T + \psi_{ov} + \psi_{tov}}{\phi_T}\right) \\ F_{Sov} = \ln\left[\frac{1 + \Delta_{Siov}}{1 + \Delta_{Siov} \cdot \exp(-V_{GX}/\phi_T)}\right] \\ I_{Gov} = I_{GOV} \cdot F_{Sov} \cdot \\ \exp\left(B_{ov} \cdot \left[-\frac{3}{2} + z_g \cdot (GC2 + GC3 \cdot z_g)\right]\right) \end{array} \right.$$

$$I_{GDov}(V_{GX}, \psi_{ov}, V_{ov}) = \left\{ \begin{array}{l} V_{ov}^* = \sqrt{V_{ov}^2 + 10^{-6}} \\ \psi_{tov} = \text{MINA}(0, V_{ov} + D_{ov}, 0.01) \\ z_g = \begin{cases} \text{MINA}\left(\frac{V_{ov}^*}{\text{CHIB}}, GC_Q, 10^{-6}\right) & \text{for } GC3 < 0 \\ \frac{V_{ov}^*}{\text{CHIB}} & \text{for } GC3 \geq 0 \end{cases} \\ \Delta_{Siov} = \exp\left(\frac{3.0 \cdot \phi_T + \psi_{ov} + \psi_{tov}}{\phi_T}\right) \\ F_{Sov} = \ln\left[\frac{1 + \Delta_{Siov}}{1 + \Delta_{Siov} \cdot \exp(-V_{GX}/\phi_T)}\right] \\ I_{Gov} = I_{GOVD} \cdot F_{Sov} \cdot \\ \exp\left(B_{dov} \cdot \left[-\frac{3}{2} + z_g \cdot (GC2 + GC3 \cdot z_g)\right]\right) \end{array} \right.$$

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

$$I_{GSov} = I_{GSov}(V_{GS}, \psi_{sov}, V_{ov0})$$

$$I_{GDov} = I_{GDov}(V_{GS} - V_{DS}, \psi_{dov}, V_{ovL})$$

Gate-channel current:

$$V_m = V_{SB,dc}^* + \phi_T^* \cdot \left[\frac{x_{ds,dc}}{2} - \ln \left(\frac{1 + \exp(x_{ds,dc} - V_{dse,dc}/\phi_T^*)}{2} \right) \right]$$

$$\psi_t = \text{MINA}(0, V_{oxm,dc} + D_{ch}, 0.01)$$

$$V_{oxm}^* = \sqrt{V_{oxm,dc}^2 + 10^{-6}}$$

$$z_g = \begin{cases} \text{MINA} \left(\frac{V_{oxm}^*}{\text{CHIB}}, GC_Q, 10^{-6} \right) & \text{for } GC3 < 0 \\ \frac{V_{oxm}^*}{\text{CHIB}} & \text{for } GC3 \geq 0 \end{cases}$$

$$\Delta_{Si} = \exp \left(x_{m,dc} - \frac{\alpha_b + V_m - \psi_t}{\phi_T^*} \right)$$

$$F_S = \ln \left[\frac{1 + \Delta_{Si}}{1 + \Delta_{Si} \cdot \exp \left(-\frac{V_{GS} + V_{SB,dc}^* - V_m}{\phi_T^*} \right)} \right]$$

$$I_{GCO} = I_{CNV} \cdot F_S \cdot \exp(B \cdot [-3/2 + z_g \cdot (GC2 + GC3 \cdot z_g)])$$

$$\text{if } x_{g,dc} > 0 \left\{ \begin{array}{l} u_0 = \text{CHIB} / [B \cdot (GC2 + 2 \cdot GC3 \cdot z_g)] \\ x = \Delta\psi_{dc} / (2 \cdot u_0) \\ b = u_0 / H_{dc} \\ B_g = b \cdot (1 - b) / 2 \\ A_g = 1/2 - 3 \cdot B_g \\ p_{gc} = (1 - b) \cdot \frac{\sinh(x)}{x} + b \cdot \cosh(x) \\ p_{gd} = \frac{p_{gc}}{2} - B_g \cdot \sinh(x) - A_g \cdot \frac{\sinh(x)}{x} \cdot \left[\coth(x) - \frac{1}{x} \right] \end{array} \right.$$

$$\text{if } x_{g,dc} \leq 0 \begin{cases} p_{gc} = 1 \\ p_{gd} = 1/2 \end{cases}$$

$$S_g = \frac{1}{2} \cdot \left(1 + \frac{x_{g,dc}}{\sqrt{x_{g,dc}^2 + 10^{-6}}} \right)$$

$$I_{GC} = I_{GCO} \cdot p_{gc} \cdot S_g$$

$$I_{GCD} = I_{GCO} \cdot p_{gd} \cdot S_g$$

$$I_{GCS} = I_{GC} - I_{GCD}$$

$$I_{GB} = I_{GCO} \cdot p_{gc} \cdot (1 - S_g)$$

Gate-Induced Drain/Source Leakage Current

The equations in this section are only calculated when **SWGIDL** = 1.

$$I_{gisl}(V_{ov}, V) = \begin{cases} V_{tov} = \sqrt{V_{ov}^2 + CGIDL^2 \cdot V^2 + 10^{-6}} \\ t = V \cdot V_{tov} \cdot V_{ov} \\ I_{gisl} = \begin{cases} -A_{CIDL} \cdot t \cdot \exp\left(-\frac{B_{CIDL}}{V_{tov}}\right) & \text{for } V_{ov} < 0 \\ 0 & \text{for } V_{ov} \geq 0 \end{cases} \end{cases}$$

$$I_{gidl}(V_{ov}, V) = \begin{cases} V_{tov} = \sqrt{V_{ov}^2 + CGIDL^2 \cdot V^2 + 10^{-6}} \\ t = V \cdot V_{tov} \cdot V_{ov} \\ I_{gidl} = \begin{cases} -A_{CIDLD} \cdot t \cdot \exp\left(-\frac{B_{CIDLD}}{V_{tov}}\right) & \text{for } V_{ov} < 0 \\ 0 & \text{for } V_{ov} \geq 0 \end{cases} \end{cases}$$

$$I_{gisl} = I_{gisl}(V_{ov0}, V_{SB})$$

$$I_{gidl} = I_{gidl}(V_{ovL}, V_{DS} + V_{SB})$$

Total Terminal Currents

$$I_D = I_{DS} + I_{avl} - I_{GDov} - I_{GCD} + I_{gidl}$$

$$I_S = -I_{DS} - I_{GSov} - I_{GCS} + I_{gisl}$$

$$I_G = I_{GC} + I_{GB} + I_{GDov} + I_{GSov}$$

$$I_B = -I_{avl} - I_{GB} - I_{gidl} - I_{gisl}$$

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

$$q_{\text{eff},ac} = \begin{cases} V_{\text{oxm},ac} & \text{for } x_{g,ac} \leq 0 \\ q_{\text{eff1},ac} & \text{for } x_{g,ac} > 0 \end{cases}$$

$$C_{\text{OX}}^{\text{qm}} = \begin{cases} \mathbf{COX} & \text{for } q_q = 0 \\ \frac{\mathbf{COX}}{1 + q_q / (q_{\text{eff},ac}^2 + q_{\text{lim}}^2)^{1/6}} & \text{for } q_q > 0 \end{cases}$$

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:

$$Q_{sov} = \mathbf{CGOV} \cdot (V_{GS} - \psi_{sov})$$

$$Q_{dov} = \mathbf{CGOVD} \cdot (V_{GS} - V_{DS} - \psi_{dov})$$

The charge of the bulk overlap region

$$Q_{bov} = \mathbf{CGBOV} \cdot (V_{GS} + V_{SB})$$

Outer fringe charge:

$$Q_{ofs} = \mathbf{CFR} \cdot V_{GS}$$

$$Q_{ofd} = \mathbf{CFRD} \cdot (V_{GS} - V_{DS})$$

Total Terminal Charges

$$Q_G = Q_G^{(i)} + Q_{\text{sov}} + Q_{\text{dov}} + Q_{\text{ofs}} + Q_{\text{ofd}} + Q_{\text{bov}}$$

$$Q_S = Q_S^{(i)} - Q_{\text{sov}} - Q_{\text{ofs}}$$

$$Q_D = Q_D^{(i)} - Q_{\text{dov}} - Q_{\text{ofd}}$$

$$Q_B = Q_B^{(i)} - Q_{\text{bov}}$$

Noise Model

Equations are only calculated for $x_g > 0$. In these equations f_{op} represents the operation frequency of the transistor and $j = \sqrt{-1}$

$$N^* = \frac{C_{\text{ox}}}{q} \cdot \alpha_{\text{m,dc}} \cdot \phi_{\text{T}}$$

$$N_{\text{m}}^* = \frac{C_{\text{ox}}}{q} \cdot q_{\text{im,dc}}^*$$

$$\Delta N = \frac{C_{\text{ox}}}{q} \cdot \alpha_{\text{m,dc}} \cdot \Delta \psi_{\text{dc}}$$

$$S_{\text{fl}} = \frac{q \cdot \phi_{\text{T}}^2 \cdot \beta \cdot I_{\text{DS}}}{(f_{\text{op}})^{\text{EF}} \cdot C_{\text{ox}} \cdot G_{\text{vsat,dc}} \cdot N^*} \cdot \left[(\text{NFA} - \text{NFB} \cdot N^* + \text{NFC} \cdot N^{*2}) \cdot \ln \left(\frac{N_{\text{m}}^* + \Delta N/2}{N_{\text{m}}^* - \Delta N/2} \right) + (\text{NFB} + \text{NFC} \cdot [N_{\text{m}}^* - 2 \cdot N^*]) \cdot \Delta N \right]$$

Virtuoso Simulator Components and Device Models Reference
PSP Model (psp)

$$H_0 = \frac{q_{im,dc}^*}{\alpha_{m,dc}}$$

$$t_1 = \frac{q_{im,dc}}{q_{im,dc}^*}$$

$$t_2 = \left(\frac{\Delta\psi_{dc}}{12 \cdot H_0} \right)^2$$

$$R = \frac{H_0}{H} - 1$$

$$l_c = 1 - 12 \cdot t_2 \cdot R$$

$$g_{ideal} = \frac{\beta \cdot q_{im,dc}^*}{G_{vsat,dc}} \cdot F_{\Delta L,dc}$$

$$C_{Geff} = \left(\frac{G_{vsat,ac}}{G_{mob,ac} \cdot G_{\Delta L,ac}} \right)^2 \cdot C_{OX}^{qm} \cdot \eta_{P,ac}$$

$$m_{id} = \frac{g_{ideal}}{l_c^2} \cdot [t_1 + 12 \cdot t_2 - 24 \cdot (1 + t_1) \cdot t_2 \cdot R]$$

$$S_{id} = N_T \cdot m_{id}$$

$$m_{ig} = \frac{1}{l_c^2 \cdot g_{ideal}} \cdot \left[\frac{t_1}{12} - t_2 \cdot \left(t_1 + \frac{1}{5} - 12 \cdot t_2 \right) - \frac{8}{5} \cdot t_2 \cdot (t_1 + 1 - 12 \cdot t_2) \cdot R \right]$$

$$S_{ig} = N_T \cdot \frac{(2 \cdot \pi \cdot f_{op} \cdot C_{Geff})^2 \cdot m_{ig}}{1 + (2 \cdot \pi \cdot f_{op} \cdot C_{Geff} \cdot m_{ig})^2}$$

$$m_{igid} = \frac{\sqrt{t_2}}{l_c^2} \cdot \left[1 - 12 \cdot t_2 - \left(t_1 + \frac{96}{5} \cdot t_2 - 12 \cdot t_1 \cdot t_2 \right) \cdot R \right]$$

$$S_{igid} = N_T \cdot \frac{2 \cdot \pi \cdot j \cdot f_{op} \cdot C_{Geff} \cdot m_{igid}}{1 + 2 \cdot \pi \cdot j \cdot f_{op} \cdot C_{Geff} \cdot m_{ig}}$$

Gate current shot noise

$$S_{igs} = 2 \cdot q \cdot (I_{GCS} + I_{GSov})$$

$$S_{igd} = 2 \cdot q \cdot (I_{GCD} + I_{GDov})$$

Avalanche current shot noise

$$S_{avl} = 2 \cdot q \cdot (1 + M_{avl}) \cdot I_{avl}$$

Thermal noise for parasitic resistances

$$S_{R_G} = 4 \cdot k_B \cdot T_{KD} / R_{gate}$$

$$S_{R_{BULK}} = 4 \cdot k_B \cdot T_{KD} / R_{bulk}$$

$$S_{R_{WELL}} = 4 \cdot k_B \cdot T_{KD} / R_{well}$$

$$S_{R_{JUNS}} = 4 \cdot k_B \cdot T_{KD} / R_{juns}$$

$$S_{R_{JUND}} = 4 \cdot k_B \cdot T_{KD} / R_{jund}$$

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:

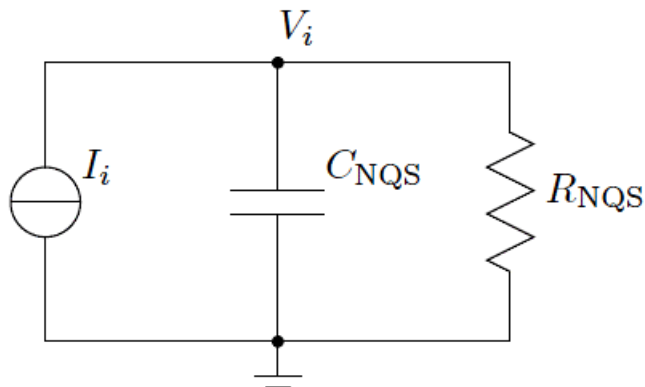
$$\begin{cases} \frac{dQ_1}{dt} = f_1(Q_1, \dots, Q_N) \\ \vdots \\ \frac{dQ_N}{dt} = f_N(Q_1, \dots, Q_N) \end{cases}$$

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 23-10 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.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

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 $(n + 1)$ $(n + 1)$ -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

$$\left. \begin{aligned} p &= 2 + v_{i-1}/2 \\ v_i &= -1/(2 \cdot p) \\ A_{i,i-1} &= 1/h \\ A_{i,i} &= -2/h \\ A_{i,i+1} &= 1/h \\ A_{i,j} &= \frac{1}{p} \cdot (3 \cdot A_{i,j}/h - A_{i-1,j}/2) \end{aligned} \right\} \begin{array}{l} \text{for } i = 1 \dots (n-1) \\ \text{for } j = 0 \dots n \end{array}$$

Second loop (back substitution)

$$A_{i,j} = v_i \cdot A_{i+1,j} + A_{i,j} \quad \text{for } j = 0 \dots n \quad \left. \vphantom{A_{i,j}} \right\} \text{for } i = (n-1) \dots 0$$

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

$$\Pi(x_g) = \begin{cases} \text{if } x_g < -p_{\text{mrg}} & \left\{ \begin{array}{l} y_g = -x_g \\ z = 1.25 \cdot y_g / a_p \\ \eta = [z + 10 - \sqrt{(z - 6)^2 + 64}] / 2 \\ a = (y_g - \eta)^2 + G_p^2 \cdot (\eta + 1) \\ c = 2 \cdot (y_g - \eta) - G_p^2 \\ \tau = -\eta + \ln(a / G_p^2) \\ y_0 = \sigma_1(a, c, \tau, \eta) \\ \Delta_0 = \exp(y_0) \\ \xi = 1 - G_p^2 \cdot \Delta_0 / 2 \\ p = 2 \cdot (y_g - y_0) + G_p^2 \cdot (\Delta_0 - 1) \\ q = (y_g - y_0)^2 + G_p^2 \cdot (y_0 - \Delta_0 + 1) \\ \Pi = -y_0 - \frac{2 \cdot q}{p + \sqrt{p^2 - 4 \cdot q \cdot \xi}} \end{array} \right. \\ \text{if } |x_g| \leq p_{\text{mrg}} & \left\{ \begin{array}{l} \Pi = \frac{x_g}{a_p} \end{array} \right. \\ \text{if } x_g > p_{\text{mrg}} & \left\{ \begin{array}{l} \hat{x}_{g1} = x_1 + G_p \cdot \sqrt{\exp(-x_1) + x_1 - 1} \\ \bar{x} = \frac{x_g}{a_p} \cdot [1 + x_g \cdot (x_1 \cdot a_p / \hat{x}_{g1} - 1) / \hat{x}_{g1}] \\ x_0 = x_g + G_p^2 / 2 - G_p \cdot \sqrt{x_g + G_p^2 / 4 - 1 + \exp(-\bar{x})} \\ \Delta_0 = \exp(-x_0) \\ \xi = 1 - G_p^2 \cdot \Delta_0 / 2 \\ p = 2 \cdot (x_g - x_0) + G_p^2 \cdot (1 - \Delta_0) \\ q = (x_g - x_0)^2 - G_p^2 \cdot (x_0 + \Delta_0 - 1) \\ \Pi = x_0 + \frac{2 \cdot q}{p + \sqrt{p^2 - 4 \cdot q \cdot \xi}} \end{array} \right. \end{cases}$$

$$X(x_g, q_{\text{inv}}) = \Pi(x_g + q_{\text{inv}} / p_d)$$

Auxillary 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

$$f(x_g, q, q', q'') = \begin{cases} x_z = X(x_g, q) \\ q_{x1} = \frac{\partial q}{\partial x}(x_z) = p_d - q'_b(x_z) \\ q_{x2} = \frac{\partial^2 q}{\partial x^2}(x_z) = q''_b(x_z) \\ f_0 = \psi(q, q_{x1}) \cdot q'' + \phi(q, q_{x1}, q_{x2}) \cdot q'^2 \\ x_{y1} = \frac{\partial x_z}{\partial y} = q' / q_{x1} \\ z_{\text{sat}} = \begin{cases} \left(\theta_{\text{sat,ac}}^* \cdot \phi_{\text{T}}^* \cdot x_{y1}\right)^2 & \text{for NMOS} \\ \frac{\left(\theta_{\text{sat,ac}}^* \cdot \phi_{\text{T}}^* \cdot x_{y1}\right)^2}{1 + \theta_{\text{sat,ac}}^* \cdot \Delta\psi_{\text{ac}}} & \text{for PMOS} \end{cases} \\ \zeta = \sqrt{1 + 2 \cdot z_{\text{sat}}} \\ F_{\text{vsat}} = 2 / (1 + \zeta) \\ f = F_{\text{vsat}} \cdot \left[f_0 - F_{\text{vsat}} \cdot \frac{z_{\text{sat}}}{\zeta} \cdot \psi(q, q_{x1}) \cdot (q'' + x_{y1}^2 \cdot q''_b(x_z)) \right] \end{cases}$$

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.

$$\begin{cases} \frac{\partial q_i}{\partial t}(t) + T_{\text{norm}} \cdot f\left(x_{g,\text{ac}}, q_i(t), \frac{\partial q_i}{\partial y}(t), \frac{\partial^2 q_i}{\partial y^2}(t)\right) = 0 \\ q_i(0) = q_{i,0} \end{cases} \quad \text{for } 1 \leq i \leq n-1$$

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 [23-10](#).

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):

$$q_G^{\text{NQS}} = p_d \cdot \left[x_{g,ac} - \frac{h}{3} \cdot \left(X(x_{g,ac}, q_0) + 4 \cdot \sum_{i=1}^{n/2} X(x_{g,ac}, q_{2i-1}) + 2 \cdot \sum_{i=1}^{n/2-1} X(x_{g,ac}, q_{2i}) + X(x_{g,ac}, q_n) \right) \right]$$

If **SWNQS** = 2 (that is, n = 3):

$$q_G^{\text{NQS}} = p_d \cdot \left[x_{g,ac} - \frac{3 \cdot h}{8} \cdot (X(x_{g,ac}, q_0) + 3 \cdot X(x_{g,ac}, q_1) + 3 \cdot X(x_{g,ac}, q_2) + X(x_{g,ac}, q_3)) \right]$$

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

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= | Design length. |
| 2 | w= | Design width. |
| 3 | sa= | Distance between OD-edge and poly from one side. |
| 4 | sb= | Distance between OD-edge and poly from other side. |
| 5 | sd= | Distance between neighbouring fingers. |
| 6 | sca= | Integral of the first distribution function for scattered well dopants. |
| 7 | scb= | Integral of the second distribution function for scattered well dopants. |
| 8 | scc= | Integral of the third distribution function for scattered well dopants. |
| 9 | sc= | Distance between OD-edge and nearest well edge. |
| 10 | nf= | Number of fingers. |
| 11 | ngcon= | Number of gate contacts. |
| 12 | xgw= | Distance from the gate contact to the channel edge. |

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

13	<code>nrs=</code>	Number of squares of source diffusion.
14	<code>nrd=</code>	Number of squares of drain diffusion.
15	<code>trise=</code>	Temperature rise from ambient.
16	<code>jw=</code>	Gate-edge length of source/drain junction.
17	<code>delvto=</code>	Threshold voltage shift parameter.
18	<code>factuo=</code>	Zero-field mobility pre-factor.
19	<code>absource=</code>	Bottom area of source junction.
20	<code>lssource=</code>	STI-edge length of source junction.
21	<code>lgsource=</code>	Gate-edge length of source junction.
22	<code>abdRAIN=</code>	Bottom area of drain junction.
23	<code>lsdRAIN=</code>	STI-edge length of drain junction.
24	<code>lgdRAIN=</code>	Gate-edge length of drain junction.
25	<code>as=</code>	Bottom area of source junction.
26	<code>ps=</code>	Perimeter of source junction.
27	<code>ad=</code>	Bottom area of drain junction.
28	<code>pd=</code>	Perimeter of drain junction.
29	<code>mult=</code>	Number of devices in parallel.
30	<code>isnoisy=</code>	Should device generate noise. Possible values are <code>no</code> or <code>yes</code> .
31	<code>m=</code>	Alias of <code>mult</code> .

Model Definition

```
model modelName psp103 parameter=value ...
```


Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

Model Parameters

1	level=	Model level.
2	type=	Channel type parameter, n=NMOS p=PMOS. Possible values are n or p.
3	tr=	nominal (reference) temperature.
4	swnqs=	Flag for NQS, 0=off, 1, 2, 3, 5, or 9=number of collocation points.
5	swgeo=	Flag for geometrical model, 0=local, 1=global, 2=binning.
6	swigate=	Flag for gate current, 0=turn off IG.
7	swimpact=	Flag for impact ionization current, 0=turn off II.
8	swgidl=	Flag for GIDL current, 0=turn off IGIDL.
9	swjuncap=	Flag for juncap, 0=turn off juncap.
10	swjunasym=	Flag for asymmetric junctions; 0=symmetric, 1=asymmetric.
11	swnud=	Flag for NUD-effect; 0=off, 1=on, 2=on+CV-correction.
12	swdelvtac=	Flag for separate capacitance calculation; 0=off, 1=on.
13	qmc=	Quantum-mechanical correction factor.
14	version=	Model version selector.
15	minr=	Minimum resistance, in order to be compatible with the original model, set its default to 0.0.
16	vfb=	Flat band voltage at TR.
17	stvfb=	Temperature dependence of VFB.
18	tox=	Gate oxide thickness.
19	epsrox=	Relative permittivity of gate dielectric.
20	neff=	Effective substrate doping.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

21	facneffac=	Pre-factor for effective substrate doping in separate charge calculation.
22	gfacnud=	Bodyfactor change due to NUD-effect.
23	vsbnud=	Lower Vsb value for NUD-effect.
24	dvsbnud=	Vsb-range for NUD-effect.
25	vnsb=	Effective doping bias-dependence parameter.
26	nslp=	Effective doping bias-dependence parameter.
27	dnsub=	Effective doping bias-dependence parameter.
28	dphib=	Offset parameter for PHIB.
29	delvtac=	Offset parameter for PHIB in separate charge calculation.
30	np=	Gate poly-silicon doping.
31	ct=	Interface states factor.
32	toxov=	Overlap oxide thickness.
33	toxovd=	Overlap oxide thickness for drain side.
34	nov=	Effective doping of overlap region.
35	novd=	Effective doping of overlap region for drain side.
36	cf=	DIBL-parameter.
37	cfb=	Back bias dependence of CF.
38	betn=	Channel aspect ratio times zero-field mobility.
39	stbet=	Temperature dependence of BETN.
40	mue=	Mobility reduction coefficient at TR.
41	stmue=	Temperature dependence of MUE.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

42	themu=	Mobility reduction exponent at TR.
43	stthemu=	Temperature dependence of THEMU.
44	cs=	Coulomb scattering parameter at TR.
45	stcs=	Temperature dependence of CS.
46	xcor=	Non-universality factor.
47	stxcor=	Temperature dependence of XCOR.
48	feta=	Effective field parameter.
49	rs=	Series resistance at TR.
50	strs=	Temperature dependence of RS.
51	rsb=	Back-bias dependence of series resistance.
52	rsg=	Gate-bias dependence of series resistance.
53	thesat=	Velocity saturation parameter at TR.
54	stthesat=	Temperature dependence of THESAT.
55	thesatb=	Back-bias dependence of velocity saturation.
56	thesatg=	Gate-bias dependence of velocity saturation.
57	ax=	Linear/saturation transition factor.
58	alp=	CLM pre-factor.
59	alp1=	CLM enhancement factor above threshold.
60	alp2=	CLM enhancement factor below threshold.
61	vp=	CLM logarithm dependence factor.
62	a1=	Impact-ionization pre-factor.
63	a2=	Impact-ionization exponent at TR.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

64	sta2=	Temperature dependence of A2.
65	a3=	Saturation-voltage dependence of impact-ionization.
66	a4=	Back-bias dependence of impact-ionization.
67	gco=	Gate tunneling energy adjustment.
68	iginv=	Gate channel current pre-factor.
69	igov=	Gate overlap current pre-factor.
70	igovd=	Gate overlap current pre-factor for drain side.
71	stig=	Temperature dependence of IGINV and IGOV.
72	gc2=	Gate current slope factor.
73	gc3=	Gate current curvature factor.
74	chib=	Tunneling barrier height.
75	agidl=	GIDL pre-factor.
76	agidld=	GIDL pre-factor for drain side.
77	bgidl=	GIDL probability factor at TR.
78	bgidld=	GIDL probability factor at TR for drain side.
79	stbgidl=	Temperature dependence of BGIDL.
80	stbgidld=	Temperature dependence of BGIDL for drain side.
81	cgidl=	Back-bias dependence of GIDL.
82	cgidld=	Back-bias dependence of GIDL for drain side.
83	cox=	Oxide capacitance for intrinsic channel.
84	cgov=	Oxide capacitance for gate-drain/source overlap.
85	cgovd=	Oxide capacitance for gate-drain overlap.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

86	<code>cgbov=</code>	Oxide capacitance for gate-bulk overlap.
87	<code>cfr=</code>	Outer fringe capacitance.
88	<code>cfrd=</code>	Outer fringe capacitance for drain side.
89	<code>fnt=</code>	Thermal noise coefficient.
90	<code>nfa=</code>	First coefficient of flicker noise.
91	<code>nfb=</code>	Second coefficient of flicker noise.
92	<code>nfc=</code>	Third coefficient of flicker noise.
93	<code>ef=</code>	Flicker noise frequency exponent.
94	<code>munqs=</code>	Relative mobility for NQS modelling.
95	<code>rg=</code>	Gate resistance.
96	<code>rse=</code>	External source resistance.
97	<code>rde=</code>	External drain resistance.
98	<code>rbulk=</code>	Bulk resistance between node BP and BI.
99	<code>rwell=</code>	Well resistance between node BI and B.
100	<code>rjuns=</code>	Source-side bulk resistance between node BI and BS.
101	<code>rjund=</code>	Drain-side bulk resistance between node BI and BD.
102	<code>povfb=</code>	Coefficient for the geometry independent part of VFB.
103	<code>plvfb=</code>	Coefficient for the length dependence of VFB.
104	<code>pwvfb=</code>	Coefficient for the width dependence of VFB.
105	<code>plwvfb=</code>	Coefficient for the length times width dependence of VFB.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

106	postvfb=	Coefficient for the geometry independent part of STVFB.
107	plstvfb=	Coefficient for the length dependence of STVFB.
108	pwstvfb=	Coefficient for the width dependence of STVFB.
109	plwstvfb=	Coefficient for the length times width dependence of STVFB.
110	potox=	Coefficient for the geometry independent part of TOX.
111	poepsrox=	Coefficient for the geometry independent part of EPSOX.
112	poneff=	Coefficient for the geometry independent part of NEFF.
113	plneff=	Coefficient for the length dependence of NEFF.
114	pwneff=	Coefficient for the width dependence of NEFF.
115	plwneff=	Coefficient for the length times width dependence of NEFF.
116	pofacneffac=	Coefficient for the geometry independent part of FACNEFFAC.
117	plfacneffac=	Coefficient for the length dependence of FACNEFFAC.
118	pwfacneffac=	Coefficient for the width dependence of FACNEFFAC.
119	plwfacneffac=	Coefficient for the length times width dependence of FACNEFFAC.
120	pogfacnud=	Coefficient for the geometry independent part of GFACNUD.
121	plgfacnud=	Coefficient for the length dependence of GFACNUD.
122	pwgfacnud=	Coefficient for the width dependence of GFACNUD.
123	plwgfacnud=	Coefficient for the length times width dependence of GFACNUD.
124	povsbnud=	Coefficient for the geometry independent part of VSBNUD.
125	podvsbnud=	Coefficient for the geometry independent part of DVSBNUD.
126	povnsu=	Coefficient for the geometry independent part of VNSUB.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

127	<code>ponslp=</code>	Coefficient for the geometry independent part of NSLP.
128	<code>podnsub=</code>	Coefficient for the geometry independent part of DNSUB.
129	<code>podphib=</code>	Coefficient for the geometry independent part of DPHIB.
130	<code>pldphib=</code>	Coefficient for the length dependence of DPHIB.
131	<code>pwdphib=</code>	Coefficient for the width dependence of DPHIB.
132	<code>plwdphib=</code>	Coefficient for the length times width dependence of DPHIB.
133	<code>podelvtac=</code>	Coefficient for the geometry independent part of DELVTAC.
134	<code>pldelvtac=</code>	Coefficient for the length dependence of DELVTAC.
135	<code>pwdelvtac=</code>	Coefficient for the width dependence of DELVTAC.
136	<code>plwdelvtac=</code>	Coefficient for the length times width dependence of DELVTAC.
137	<code>ponp=</code>	Coefficient for the geometry independent part of NP.
138	<code>plnp=</code>	Coefficient for the length dependence of NP.
139	<code>pwnp=</code>	Coefficient for the width dependence of NP.
140	<code>plwnp=</code>	Coefficient for the length times width dependence of NP.
141	<code>poct=</code>	Coefficient for the geometry independent part of CT.
142	<code>plct=</code>	Coefficient for the length dependence of CT.
143	<code>pwct=</code>	Coefficient for the width dependence of CT.
144	<code>plwct=</code>	Coefficient for the length times width dependence of CT.
145	<code>potoxov=</code>	Coefficient for the geometry independent part of TOXOV.
146	<code>potoxovd=</code>	Coefficient for the geometry independent part of TOXOV for drain side.
147	<code>ponov=</code>	Coefficient for the geometry independent part of NOV.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

148	<code>p_{lnov}</code> =	Coefficient for the length dependence of NOV.
149	<code>p_{wnov}</code> =	Coefficient for the width dependence of NOV.
150	<code>p_{lwnov}</code> =	Coefficient for the length times width dependence of NOV.
151	<code>p_{onovd}</code> =	Coefficient for the geometry independent part of NOV for drain side.
152	<code>p_{lnovd}</code> =	Coefficient for the length dependence of NOV for drain side.
153	<code>p_{wnovd}</code> =	Coefficient for the width dependence of NOV for drain side.
154	<code>p_{lwnovd}</code> =	Coefficient for the length times width dependence of NOV for drain side.
155	<code>p_{ocf}</code> =	Coefficient for the geometry independent part of CF.
156	<code>p_{lcf}</code> =	Coefficient for the length dependence of CF.
157	<code>p_{wcf}</code> =	Coefficient for the width dependence of CF.
158	<code>p_{lwcf}</code> =	Coefficient for the length times width dependence of CF.
159	<code>p_{ocfb}</code> =	Coefficient for the geometry independent part of CFB.
160	<code>p_{obetn}</code> =	Coefficient for the geometry independent part of BETN.
161	<code>p_{lbetn}</code> =	Coefficient for the length dependence of BETN.
162	<code>p_{wbetn}</code> =	Coefficient for the width dependence of BETN.
163	<code>p_{lwbetn}</code> =	Coefficient for the length times width dependence of BETN.
164	<code>p_{ostbet}</code> =	Coefficient for the geometry independent part of STBET.
165	<code>p_{lstbet}</code> =	Coefficient for the length dependence of STBET.
166	<code>p_{wstbet}</code> =	Coefficient for the width dependence of STBET.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

167	<code>plwstbet=</code>	Coefficient for the length times width dependence of STBET.
168	<code>pomue=</code>	Coefficient for the geometry independent part of MUE.
169	<code>plmue=</code>	Coefficient for the length dependence of MUE.
170	<code>pwmue=</code>	Coefficient for the width dependence of MUE.
171	<code>plwmue=</code>	Coefficient for the length times width dependence of MUE.
172	<code>postmue=</code>	Coefficient for the geometry independent part of STMUE.
173	<code>pothemu=</code>	Coefficient for the geometry independent part of THEMU.
174	<code>postthemu=</code>	Coefficient for the geometry independent part of STTHEMU.
175	<code>pocs=</code>	Coefficient for the geometry independent part of CS.
176	<code>plcs=</code>	Coefficient for the length dependence of CS.
177	<code>pwcs=</code>	Coefficient for the width dependence of CS.
178	<code>plwcs=</code>	Coefficient for the length times width dependence of CS.
179	<code>postcs=</code>	Coefficient for the geometry independent part of STCS.
180	<code>poxcor=</code>	Coefficient for the geometry independent part of XCOR.
181	<code>plxcor=</code>	Coefficient for the length dependence of XCOR.
182	<code>pwxcor=</code>	Coefficient for the width dependence of XCOR.
183	<code>plwxcor=</code>	Coefficient for the length times width dependence of XCOR.
184	<code>postxcor=</code>	Coefficient for the geometry independent part of STXCOR.
185	<code>pofeta=</code>	Coefficient for the geometry independent part of FETA.
186	<code>pors=</code>	Coefficient for the geometry independent part of RS.
187	<code>plrs=</code>	Coefficient for the length dependence of RS.
188	<code>pwr=</code>	Coefficient for the width dependence of RS.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

189	<code>plwrs=</code>	Coefficient for the length times width dependence of RS.
190	<code>postrs=</code>	Coefficient for the geometry independent part of STRS.
191	<code>porsb=</code>	Coefficient for the geometry independent part of RSB.
192	<code>porsg=</code>	Coefficient for the geometry independent part of RSG.
193	<code>pothesat=</code>	Coefficient for the geometry independent part of THESAT.
194	<code>plthesat=</code>	Coefficient for the length dependence of THESAT.
195	<code>pwthesat=</code>	Coefficient for the width dependence of THESAT.
196	<code>plwthesat=</code>	Coefficient for the length times width dependence of THESAT.
197	<code>postthesat=</code>	Coefficient for the geometry independent part of STTHESAT.
198	<code>plstthesat=</code>	Coefficient for the length dependence of STTHESAT.
199	<code>pwstthesat=</code>	Coefficient for the width dependence of STTHESAT.
200	<code>plwstthesat=</code>	Coefficient for the length times width dependence of STTHESAT.
201	<code>pothesatb=</code>	Coefficient for the geometry independent part of THESATB.
202	<code>plthesatb=</code>	Coefficient for the length dependence of THESATB.
203	<code>pwthesatb=</code>	Coefficient for the width dependence of THESATB.
204	<code>plwthesatb=</code>	Coefficient for the length times width dependence of THESATB.
205	<code>pothesatg=</code>	Coefficient for the geometry independent part of THESATG.
206	<code>plthesatg=</code>	Coefficient for the length dependence of THESATG.
207	<code>pwthesatg=</code>	Coefficient for the width dependence of THESATG.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

208	plwthesatg=	Coefficient for the length times width dependence of THESATG.
209	poax=	Coefficient for the geometry independent part of AX.
210	plax=	Coefficient for the length dependence of AX.
211	pwax=	Coefficient for the width dependence of AX.
212	plwax=	Coefficient for the length times width dependence of AX.
213	poalp=	Coefficient for the geometry independent part of ALP.
214	plalp=	Coefficient for the length dependence of ALP.
215	pwalp=	Coefficient for the width dependence of ALP.
216	plwalp=	Coefficient for the length times width dependence of ALP.
217	poalp1=	Coefficient for the geometry independent part of ALP1.
218	plalp1=	Coefficient for the length dependence of ALP1.
219	pwalp1=	Coefficient for the width dependence of ALP1.
220	plwalp1=	Coefficient for the length times width dependence of ALP1.
221	poalp2=	Coefficient for the geometry independent part of ALP2.
222	plalp2=	Coefficient for the length dependence of ALP2.
223	pwalp2=	Coefficient for the width dependence of ALP2.
224	plwalp2=	Coefficient for the length times width dependence of ALP2.
225	povp=	Coefficient for the geometry independent part of VP.
226	poa1=	Coefficient for the geometry independent part of A1.
227	pla1=	Coefficient for the length dependence of A1.
228	pwa1=	Coefficient for the width dependence of A1.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

229	plwa1=	Coefficient for the length times width dependence of A1.
230	poa2=	Coefficient for the geometry independent part of A2.
231	posta2=	Coefficient for the geometry independent part of STA2.
232	poa3=	Coefficient for the geometry independent part of A3.
233	pla3=	Coefficient for the length dependence of A3.
234	pwa3=	Coefficient for the width dependence of A3.
235	plwa3=	Coefficient for the length times width dependence of A3.
236	poa4=	Coefficient for the geometry independent part of A4.
237	pla4=	Coefficient for the length dependence of A4.
238	pwa4=	Coefficient for the width dependence of A4.
239	plwa4=	Coefficient for the length times width dependence of A4.
240	pogco=	Coefficient for the geometry independent part of GCO.
241	poiginv=	Coefficient for the geometry independent part of IGINV.
242	pliginv=	Coefficient for the length dependence of IGINV.
243	pwiginv=	Coefficient for the width dependence of IGINV.
244	plwiginv=	Coefficient for the length times width dependence of IGINV.
245	poigov=	Coefficient for the geometry independent part of IGOV.
246	pligov=	Coefficient for the length dependence of IGOV.
247	pwigov=	Coefficient for the width dependence of IGOV.
248	plwigov=	Coefficient for the length times width dependence of IGOV.
249	poigovd=	Coefficient for the geometry independent part of IGOV for drain side.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

250	<code>pIgovd=</code>	Coefficient for the length dependence of IGOV for drain side.
251	<code>pWigovd=</code>	Coefficient for the width dependence of IGOV for drain side.
252	<code>pLwigovd=</code>	Coefficient for the length times width dependence of IGOV for drain side.
253	<code>postig=</code>	Coefficient for the geometry independent part of STIG.
254	<code>pogc2=</code>	Coefficient for the geometry independent part of GC2.
255	<code>pogc3=</code>	Coefficient for the geometry independent part of GC3.
256	<code>pochib=</code>	Coefficient for the geometry independent part of CHIB.
257	<code>poagidl=</code>	Coefficient for the geometry independent part of AGIDL.
258	<code>plagidl=</code>	Coefficient for the length dependence of AGIDL.
259	<code>pwagidl=</code>	Coefficient for the width dependence of AGIDL.
260	<code>plwagidl=</code>	Coefficient for the length times width dependence of AGIDL.
261	<code>poagidld=</code>	Coefficient for the geometry independent part of AGIDL for drain side.
262	<code>plagidld=</code>	Coefficient for the length dependence of AGIDL for drain side.
263	<code>pwagidld=</code>	Coefficient for the width dependence of AGIDL for drain side.
264	<code>plwagidld=</code>	Coefficient for the length times width dependence of AGIDL for drain side.
265	<code>pobgidl=</code>	Coefficient for the geometry independent part of BGIDL.
266	<code>pobgidld=</code>	Coefficient for the geometry independent part of BGIDL for drain side.
267	<code>postbgidl=</code>	Coefficient for the geometry independent part of STBGIDL.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

268	postbgidld=	Coefficient for the geometry independent part of STBGIDL for drain side.
269	pocgidl=	Coefficient for the geometry independent part of CGIDL.
270	pocgidld=	Coefficient for the geometry independent part of CGIDL for drain side.
271	pocox=	Coefficient for the geometry independent part of COX.
272	plcox=	Coefficient for the length dependence of COX.
273	pwcox=	Coefficient for the width dependence of COX.
274	plwcox=	Coefficient for the length times width dependence of COX.
275	pocgov=	Coefficient for the geometry independent part of CGOV.
276	plcgov=	Coefficient for the length dependence of CGOV.
277	pwcgov=	Coefficient for the width dependence of CGOV.
278	plwcgov=	Coefficient for the length times width dependence of CGOV.
279	pocgovd=	Coefficient for the geometry independent part of CGOV for drain side.
280	plcgovd=	Coefficient for the length dependence of CGOV for drain side.
281	pwcgovd=	Coefficient for the width dependence of CGOV for drain side.
282	plwcgovd=	Coefficient for the length times width dependence of CGOV for drain side.
283	pocgbov=	Coefficient for the geometry independent part of CGBOV.
284	plcgbov=	Coefficient for the length dependence of CGBOV.
285	pwcgbov=	Coefficient for the width dependence of CGBOV.
286	plwcgbov=	Coefficient for the length times width dependence of CGBOV.
287	pocfr=	Coefficient for the geometry independent part of CFR.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

288	<code>plcfr=</code>	Coefficient for the length dependence of CFR.
289	<code>pwcfr=</code>	Coefficient for the width dependence of CFR.
290	<code>plwcfr=</code>	Coefficient for the length times width dependence of CFR.
291	<code>pocfrd=</code>	Coefficient for the geometry independent part of CFR for drain side.
292	<code>plcfrd=</code>	Coefficient for the length dependence of CFR for drain side.
293	<code>pwcfrd=</code>	Coefficient for the width dependence of CFR for drain side.
294	<code>plwcfrd=</code>	Coefficient for the length times width dependence of CFR for drain side.
295	<code>pofnt=</code>	Coefficient for the geometry independent part of FNT.
296	<code>ponfa=</code>	Coefficient for the geometry independent part of NFA.
297	<code>plnfa=</code>	Coefficient for the length dependence of NFA.
298	<code>pwnfa=</code>	Coefficient for the width dependence of NFA.
299	<code>plwnfa=</code>	Coefficient for the length times width dependence of NFA.
300	<code>ponfb=</code>	Coefficient for the geometry independent part of NFB.
301	<code>plnfb=</code>	Coefficient for the length dependence of NFB.
302	<code>pwnfb=</code>	Coefficient for the width dependence of NFB.
303	<code>plwnfb=</code>	Coefficient for the length times width dependence of NFB.
304	<code>ponfc=</code>	Coefficient for the geometry independent part of NFC.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

305	<code>p_{lnfc}</code> =	Coefficient for the length dependence of NFC.
306	<code>p_{wnfc}</code> =	Coefficient for the width dependence of NFC.
307	<code>p_{lwnfc}</code> =	Coefficient for the length times width dependence of NFC.
308	<code>p_{oef}</code> =	Coefficient for the flicker noise frequency exponent.
309	<code>p_{okvthowe}</code> =	Coefficient for the geometry independent part of KVTHOWE.
310	<code>p_{lkvthowe}</code> =	Coefficient for the length dependence part of KVTHOWE.
311	<code>p_{wkvthowe}</code> =	Coefficient for the width dependence part of KVTHOWE.
312	<code>p_{lwkvthowe}</code> =	Coefficient for the length times width dependence part of KVTHOWE.
313	<code>p_{okuowe}</code> =	Coefficient for the geometry independent part of KUOWE.
314	<code>p_{lkuowe}</code> =	Coefficient for the length dependence part of KUOWE.
315	<code>p_{wkuowe}</code> =	Coefficient for the width dependence part of KUOWE.
316	<code>p_{lwk_{uowe}}</code> =	Coefficient for the length times width dependence part of KUOWE.
317	<code>l_{min}</code> =	Dummy parameter to label binning set.
318	<code>l_{max}</code> =	Dummy parameter to label binning set.
319	<code>w_{min}</code> =	Dummy parameter to label binning set.
320	<code>w_{max}</code> =	Dummy parameter to label binning set.
321	<code>l_{var0}</code> =	Geom. independent difference between actual and programmed gate length.
322	<code>l_{var1}</code> =	Length dependence of LVAR.
323	<code>l_{varw}</code> =	Width dependence of LVAR.
324	<code>l_{ap}</code> =	Effective channel length reduction per side.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

325	wvaro=	Geom. independent difference between actual and programmed field-oxide opening.
326	wvarl=	Length dependence of WVAR.
327	wvarw=	Width dependence of WVAR.
328	wot=	Effective channel width reduction per side.
329	dlq=	Effective channel length reduction for CV.
330	dwq=	Effective channel width reduction for CV.
331	vfb0=	Geometry-independent flat-band voltage at TR.
332	vfb1=	Length dependence of flat-band voltage.
333	vfbw=	Width dependence of flat-band voltage.
334	vfb1w=	Area dependence of flat-band voltage.
335	stvfbo=	Geometry-independent temperature dependence of VFB.
336	stvfbl=	Length dependence of temperature dependence of VFB.
337	stvfbw=	Width dependence of temperature dependence of VFB.
338	stvfblw=	Area dependence of temperature dependence of VFB.
339	tox0=	Gate oxide thickness.
340	epsrox0=	Relative permittivity of gate dielectric.
341	nsub0=	Geometry independent substrate doping.
342	nsubw=	Width dependence of background doping NSUBO due to segregation.
343	wseg=	Char. length of segregation of background doping NSUBO.
344	npck=	Pocket doping level.
345	npckw=	Width dependence of pocket doping NPCK due to segregation.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

346	wsegp=	Char. length of segregation of pocket doping NPCK.
347	lpck=	Char. length of lateral doping profile.
348	lpckw=	Width dependence of char. length of lateral doping profile.
349	f0l1=	First length dependence coefficient for short channel body effect.
350	f0l2=	Second length dependence coefficient for short channel body effect.
351	facneffaco=	Geom. independent pre-factor for effective substrate doping in separate charge calculation.
352	facneffacl=	Length dependence of FACNEFFAC.
353	facneffacw=	Width dependence of FACNEFFAC.
354	facneffaclw=	Area dependence of FACNEFFAC.
355	gfacnudo=	Geom. independent bodyfactor change due to NUD-effect.
356	gfacnudl=	Length dependence of GFACNUD.
357	gfacnudlexp=	Exponent for length dependence of GFACNUD.
358	gfacnudw=	Width dependence of GFACNUD.
359	gfacnudlw=	Area dependence of GFACNUD.
360	vsbnudo=	Lower Vsb value for NUD-effect.
361	dvsbnudo=	Vsb range for NUD-effect.
362	vnsubo=	Effective doping bias-dependence parameter.
363	nslpo=	Effective doping bias-dependence parameter.
364	dnsubo=	Effective doping bias-dependence parameter.
365	dphibo=	Geometry independent offset of PHIB.
366	dphibl=	Length dependence offset of PHIB.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

367	dphiblexp=	Exponent for length dependence of offset of PHIB.
368	dphibw=	Width dependence of offset of PHIB.
369	dphibl=	Area dependence of offset of PHIB.
370	delvtaco=	Geom. independent offset parameter for PHIB in separate charge calculation.
371	delvtacl=	Length dependence of DELVTAC.
372	delvtaclexp=	Exponent for length dependence of offset of DELVTAC.
373	delvtacw=	Width dependence of DELVTAC.
374	delvtaclw=	Area dependence of DELVTAC.
375	npo=	Geometry-independent gate poly-silicon doping.
376	npl=	Length dependence of gate poly-silicon doping.
377	cto=	Geometry-independent interface states factor.
378	ctl=	Length dependence of interface states factor.
379	ctlexp=	Exponent for length dependence of interface states factor.
380	ctw=	Width dependence of interface states factor.
381	ctlw=	Area dependence of interface states factor.
382	toxovo=	Overlap oxide thickness.
383	toxovdo=	Overlap oxide thickness for drain side.
384	lov=	Overlap length for gate/drain and gate/source overlap capacitance.
385	lovd=	Overlap length for gate/drain overlap capacitance.
386	novo=	Effective doping of overlap region.
387	novdo=	Effective doping of overlap region for drain side.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

388	<code>cfl=</code>	Length dependence of DIBL-parameter.
389	<code>cfl_{exp}=</code>	Exponent for length dependence of CF.
390	<code>cfw=</code>	Width dependence of CF.
391	<code>cfbo=</code>	Back-bias dependence of CF.
392	<code>uo=</code>	Zero-field mobility at TR.
393	<code>fbet1=</code>	Relative mobility decrease due to first lateral profile.
394	<code>fbet1w=</code>	Width dependence of relative mobility decrease due to first lateral profile.
395	<code>lp1=</code>	Mobility-related characteristic length of first lateral profile.
396	<code>lp1w=</code>	Width dependence of mobility-related characteristic length of first lateral profile.
397	<code>fbet2=</code>	Relative mobility decrease due to second lateral profile.
398	<code>lp2=</code>	Mobility-related characteristic length of second lateral profile.
399	<code>betw1=</code>	First higher-order width scaling coefficient of BETN.
400	<code>betw2=</code>	Second higher-order width scaling coefficient of BETN.
401	<code>wbet=</code>	Characteristic width for width scaling of BETN.
402	<code>stbeto=</code>	Geometry independent temperature dependence of BETN.
403	<code>stbetl=</code>	Length dependence of temperature dependence of BETN.
404	<code>stbetw=</code>	Width dependence of temperature dependence of BETN.
405	<code>stbetlw=</code>	Area dependence of temperature dependence of BETN.
406	<code>mueo=</code>	Geometry independent mobility reduction coefficient at TR.
407	<code>muew=</code>	Width dependence of mobility reduction coefficient at TR.
408	<code>stmueo=</code>	Temperature dependence of MUE.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

409	themuo=	Mobility reduction exponent at TR.
410	stthemuo=	Temperature dependence of THEMU.
411	cs0=	Geometry independent coulomb scattering parameter at TR.
412	cs1=	Length dependence of CS.
413	cs1exp=	Exponent for length dependence of CS.
414	csw=	Width dependence of CS.
415	cslw=	Area dependence of CS.
416	stcs0=	Temperature dependence of CS.
417	xcoro=	Geometry independent non-universality parameter.
418	xcor1=	Length dependence of non-universality parameter.
419	xcorw=	Width dependence of non-universality parameter.
420	xcorlw=	Area dependence of non-universality parameter.
421	stxcoro=	Temperature dependence of XCOR.
422	fetao=	Effective field parameter.
423	rsw1=	Source/drain series resistance for 1 um wide channel at TR.
424	rsw2=	Higher-order width scaling of RS.
425	strso=	Temperature dependence of RS.
426	rsbo=	Back-bias dependence of series resistance.
427	rsgo=	Gate-bias dependence of series resistance.
428	thesato=	Geometry independent velocity saturation parameter at TR.
429	thesat1=	Length dependence of THESAT.
430	thesat1exp=	Exponent for length dependence of THESAT.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

431	thesatw=	Width dependence of velocity saturation parameter.
432	thesatlw=	Area dependence of velocity saturation parameter.
433	stthesato=	Geometry independent temperature dependence of THESAT.
434	stthesatl=	Length dependence of temperature dependence of THESAT.
435	stthesatw=	Width dependence of temperature dependence of THESAT.
436	stthesatlw=	Area dependence of temperature dependence of THESAT.
437	thesatbo=	Back-bias dependence of velocity saturation.
438	thesatgo=	Gate-bias dependence of velocity saturation.
439	axo=	Geometry independent linear/saturation transition factor.
440	axl=	Length dependence of AX.
441	alp1=	Length dependence of ALP.
442	alp1exp=	Exponent for length dependence of ALP.
443	alp1w=	Width dependence of ALP.
444	alp1l1=	Length dependence of CLM enhancement factor above threshold.
445	alp1l1exp=	Exponent for length dependence of ALP1.
446	alp1l12=	Second_order length dependence of ALP1.
447	alp1w=	Width dependence of ALP1.
448	alp2l1=	Length dependence of CLM enhancement factor below threshold.
449	alp2l1exp=	Exponent for length dependence of ALP2.
450	alp2l12=	Second_order length dependence of ALP2.
451	alp2w=	Width dependence of ALP2.

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PSP Model (psp)

452	vpo=	CLM logarithmic dependence parameter.
453	a1o=	Geometry independent impact-ionization pre-factor.
454	a1l=	Length dependence of A1.
455	a1w=	Width dependence of A1.
456	a2o=	Impact-ionization exponent at TR.
457	sta2o=	Temperature dependence of A2.
458	a3o=	Geometry independent saturation-voltage dependence of I1.
459	a3l=	Length dependence of A3.
460	a3w=	Width dependence of A3.
461	a4o=	Geometry independent back-bias dependence of I1.
462	a4l=	Length dependence of A4.
463	a4w=	Width dependence of A4.
464	gcoo=	Gate tunneling energy adjustment.
465	iginv1w=	Gate channel current pre-factor for 1 μm^2 channel area.
466	igovw=	Gate overlap current pre-factor for 1 μm wide channel.
467	igovdw=	Gate overlap current pre-factor for 1 μm wide channel for drain side.
468	stigo=	Temperature dependence of IGINV and IGOV.
469	gc2o=	Gate current slope factor.
470	gc3o=	Gate current curvature factor.
471	chibo=	Tunneling barrier height.
472	agidlw=	Width dependence of GIDL pre-factor.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

473	agidldw=	Width dependence of GIDL pre-factor for drain side.
474	bgidlo=	GIDL probability factor at TR.
475	bgidldo=	GIDL probability factor at TR for drain side.
476	stbgidlo=	Temperature dependence of BGIDL.
477	stbgidldo=	Temperature dependence of BGIDL for drain side.
478	cgidlo=	Back-bias dependence of GIDL.
479	cgidldo=	Back-bias dependence of GIDL for drain side.
480	cgbovl=	Oxide capacitance for gate-bulk overlap for 1 um long channel.
481	cfrw=	Outer fringe capacitance for 1 um wide channel.
482	cfrdw=	Outer fringe capacitance for 1 um wide channel for drain side.
483	fnto=	Thermal noise coefficient.
484	nfalw=	First coefficient of flicker noise for 1 um ² channel area.
485	nfblw=	Second coefficient of flicker noise for 1 um ² channel area.
486	nfclw=	Third coefficient of flicker noise for 1 um ² channel area.
487	efo=	Flicker noise frequency exponent.
488	lintnoi=	Length offset for flicker noise.
489	alpnoi=	Exponent for length offset for flicker noise.
490	kvthoweo=	Geometrical independent threshold shift parameter.
491	kvthowel=	Length dependent threshold shift parameter.
492	kvthowew=	Width dependent threshold shift parameter.
493	kvthowelw=	Area dependent threshold shift parameter.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

494	kuoweo=	Geometrical independent mobility degradation factor.
495	kuowel=	Length dependent mobility degradation factor.
496	kuowew=	Width dependent mobility degradation factor.
497	kuowelw=	Area dependent mobility degradation factor.
498	munqso=	Relative mobility for NQS modelling.
499	rgo=	Gate resistance.
500	rint=	Contact resistance between silicide and poly.
501	rvpoly=	Vertical poly resistance.
502	rshg=	Gate electrode diffusion sheet resistance.
503	dlsil=	Silicide extension over the physical gate length.
504	rsh=	Sheet resistance of source diffusion.
505	rshd=	Sheet resistance of drain diffusion.
506	rbulko=	Bulk resistance between node BP and BI.
507	rwello=	Well resistance between node BI and B.
508	rjunso=	Source-side bulk resistance between node BI and BS.
509	rjundo=	Drain-side bulk resistance between node BI and BD.
510	saref=	Reference distance between OD-edge and poly from one side.
511	sbref=	Reference distance between OD-edge and poly from other side.
512	wlod=	Width parameter.
513	kuo=	Mobility degradation/enhancement coefficient.
514	kvsat=	Saturation velocity degradation/enhancement coefficient.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

515	tkuo=	Temperature dependence of KUO.
516	lkuo=	Length dependence of KUO.
517	wkuo=	Width dependence of KUO.
518	pkuo=	Cross-term dependence of KUO.
519	llodkuo=	Length parameter for UO stress effect.
520	wlodkuo=	Width parameter for UO stress effect.
521	kvtho=	Threshold shift parameter.
522	lkvtho=	Length dependence of KVTHO.
523	wkvtho=	Width dependence of KVTHO.
524	pkvtho=	Cross-term dependence of KVTHO.
525	llodvth=	Length parameter for VTH-stress effect.
526	wlodvth=	Width parameter for VTH-stress effect.
527	stetao=	eta0 shift factor related to VTHO change.
528	lodetao=	eta0 shift modification factor for stress effect.
529	scref=	Distance between OD-edge and well edge of a reference device.
530	web=	Coefficient for SCB.
531	wec=	Coefficient for SCC.
532	imax=	Maximum current up to which forward current behaves exponentially.
533	trj=	reference temperature.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

534	<code>cjorbot=</code>	Zero-bias capacitance per unit-of-area of bottom component for source-bulk junction.
535	<code>cjorsti=</code>	Zero-bias capacitance per unit-of-length of STI-edge component for source-bulk junction.
536	<code>cjorgat=</code>	Zero-bias capacitance per unit-of-length of gate-edge component for source-bulk junction.
537	<code>vbirbot=</code>	Built-in voltage at the reference temperature of bottom component for source-bulk junction.
538	<code>vbirsti=</code>	Built-in voltage at the reference temperature of STI-edge component for source-bulk junction.
539	<code>vbirgat=</code>	Built-in voltage at the reference temperature of gate-edge component for source-bulk junction.
540	<code>pbot=</code>	Grading coefficient of bottom component for source-bulk junction.
541	<code>psti=</code>	Grading coefficient of STI-edge component for source-bulk junction.
542	<code>pgat=</code>	Grading coefficient of gate-edge component for source-bulk junction.
543	<code>phigbot=</code>	Zero-temperature bandgap voltage of bottom component for source-bulk junction.
544	<code>phigsti=</code>	Zero-temperature bandgap voltage of STI-edge component for source-bulk junction.
545	<code>phiggat=</code>	Zero-temperature bandgap voltage of gate-edge component for source-bulk junction.
546	<code>idsatrbot=</code>	Saturation current density at the reference temperature of bottom component for source-bulk junction.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

547	<code>idsatrsti=</code>	Saturation current density at the reference temperature of STI-edge component for source-bulk junction.
548	<code>idsatrgat=</code>	Saturation current density at the reference temperature of gate-edge component for source-bulk junction.
549	<code>csrhhbot=</code>	Shockley-Read-Hall prefactor of bottom component for source-bulk junction.
550	<code>csrhsti=</code>	Shockley-Read-Hall prefactor of STI-edge component for source-bulk junction.
551	<code>csrhhgat=</code>	Shockley-Read-Hall prefactor of gate-edge component for source-bulk junction.
552	<code>xjunsti=</code>	Junction depth of STI-edge component for source-bulk junction.
553	<code>xjungat=</code>	Junction depth of gate-edge component for source-bulk junction.
554	<code>ctatbot=</code>	Trap-assisted tunneling prefactor of bottom component for source-bulk junction.
555	<code>ctatsti=</code>	Trap-assisted tunneling prefactor of STI-edge component for source-bulk junction.
556	<code>ctatgat=</code>	Trap-assisted tunneling prefactor of gate-edge component for source-bulk junction.
557	<code>mefftatbot=</code>	Effective mass (in units of m_0) for trap-assisted tunneling of bottom component for source-bulk junction.
558	<code>mefftatsti=</code>	Effective mass (in units of m_0) for trap-assisted tunneling of STI-edge component for source-bulk junction.
559	<code>mefftatgat=</code>	Effective mass (in units of m_0) for trap-assisted tunneling of gate-edge component for source-bulk junction.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

560	<code>cbbtbot=</code>	Band-to-band tunneling prefactor of bottom component for source-bulk junction.
561	<code>cbbtsti=</code>	Band-to-band tunneling prefactor of STI-edge component for source-bulk junction.
562	<code>cbbtgat=</code>	Band-to-band tunneling prefactor of gate-edge component for source-bulk junction.
563	<code>fbbtrbot=</code>	Normalization field at the reference temperature for band-to-band tunneling of bottom component for source-bulk junction.
564	<code>fbbtrsti=</code>	Normalization field at the reference temperature for band-to-band tunneling of STI-edge component for source-bulk junction.
565	<code>fbbtrgat=</code>	Normalization field at the reference temperature for band-to-band tunneling of gate-edge component for source-bulk junction.
566	<code>stfbbtbot=</code>	Temperature scaling parameter for band-to-band tunneling of bottom component for source-bulk junction.
567	<code>stfbbtsti=</code>	Temperature scaling parameter for band-to-band tunneling of STI-edge component for source-bulk junction.
568	<code>stfbbtgat=</code>	Temperature scaling parameter for band-to-band tunneling of gate-edge component for source-bulk junction.
569	<code>vbrbot=</code>	Breakdown voltage of bottom component for source-bulk junction.
570	<code>vbrsti=</code>	Breakdown voltage of STI-edge component for source-bulk junction.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

571	vbrgat=	Breakdown voltage of gate-edge component for source-bulk junction.
572	pbrbot=	Breakdown onset tuning parameter of bottom component for source-bulk junction.
573	pbrsti=	Breakdown onset tuning parameter of STI-edge component for source-bulk junction.
574	pbrgat=	Breakdown onset tuning parameter of gate-edge component for source-bulk junction.
575	cjorbotd=	Zero-bias capacitance per unit-of-area of bottom component for drain-bulk junction.
576	cjorstid=	Zero-bias capacitance per unit-of-length of STI-edge component for drain-bulk junction.
577	cjorgatd=	Zero-bias capacitance per unit-of-length of gate-edge component for drain-bulk junction.
578	vbirbotd=	Built-in voltage at the reference temperature of bottom component for drain-bulk junction.
579	vbirstid=	Built-in voltage at the reference temperature of STI-edge component for drain-bulk junction.
580	vbirgatd=	Built-in voltage at the reference temperature of gate-edge component for drain-bulk junction.
581	pbotd=	Grading coefficient of bottom component for drain-bulk junction.
582	pstid=	Grading coefficient of STI-edge component for drain-bulk junction.
583	pgatd=	Grading coefficient of gate-edge component for drain-bulk junction.
584	phigbotd=	Zero-temperature bandgap voltage of bottom component for drain-bulk junction.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

585	phigstid=	Zero-temperature bandgap voltage of STI-edge component for drain-bulk junction.
586	phiggatd=	Zero-temperature bandgap voltage of gate-edge component for drain-bulk junction.
587	idsatrbotd=	Saturation current density at the reference temperature of bottom component for drain-bulk junction.
588	idsatrstid=	Saturation current density at the reference temperature of STI-edge component for drain-bulk junction.
589	idsatrgatd=	Saturation current density at the reference temperature of gate-edge component for drain-bulk junction.
590	csrbotd=	Shockley-Read-Hall prefactor of bottom component for drain-bulk junction.
591	csrhostid=	Shockley-Read-Hall prefactor of STI-edge component for drain-bulk junction.
592	csrhgatd=	Shockley-Read-Hall prefactor of gate-edge component for drain-bulk junction.
593	xjunstid=	Junction depth of STI-edge component for drain-bulk junction.
594	xjungatd=	Junction depth of gate-edge component for drain-bulk junction.
595	ctatbotd=	Trap-assisted tunneling prefactor of bottom component for drain-bulk junction.
596	ctatstid=	Trap-assisted tunneling prefactor of STI-edge component for drain-bulk junction.

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PSP Model (psp)

597	ctatgatd=	Trap-assisted tunneling prefactor of gate-edge component for drain-bulk junction.
598	mefftatbotd=	Effective mass (in units of m_0) for trap-assisted tunneling of bottom component for drain-bulk junction.
599	mefftatstid=	Effective mass (in units of m_0) for trap-assisted tunneling of STI-edge component for drain-bulk junction.
600	mefftatgatd=	Effective mass (in units of m_0) for trap-assisted tunneling of gate-edge component for drain-bulk junction.
601	cbbtbotd=	Band-to-band tunneling prefactor of bottom component for drain-bulk junction.
602	cbbtstid=	Band-to-band tunneling prefactor of STI-edge component for drain-bulk junction.
603	cbbtgatd=	Band-to-band tunneling prefactor of gate-edge component for drain-bulk junction.
604	fbbtrbotd=	Normalization field at the reference temperature for band-to-band tunneling of bottom component for drain-bulk junction.
605	fbbtrstid=	Normalization field at the reference temperature for band-to-band tunneling of STI-edge component for drain-bulk junction.
606	fbbtrgatd=	Normalization field at the reference temperature for band-to-band tunneling of gate-edge component for drain-bulk junction.
607	stfbbtbotd=	Temperature scaling parameter for band-to-band tunneling of bottom component for drain-bulk junction.

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608	stfbbtstid=	Temperature scaling parameter for band-to-band tunneling of STI-edge component for drain-bulk junction.
609	stfbbtgatd=	Temperature scaling parameter for band-to-band tunneling of gate-edge component for drain-bulk junction.
610	vbrbotd=	Breakdown voltage of bottom component for drain-bulk junction.
611	vbrstid=	Breakdown voltage of STI-edge component for drain-bulk junction.
612	vbrgatd=	Breakdown voltage of gate-edge component for drain-bulk junction.
613	pbrbotd=	Breakdown onset tuning parameter of bottom component for drain-bulk junction.
614	pbrstid=	Breakdown onset tuning parameter of STI-edge component for drain-bulk junction.
615	pbrgatd=	Breakdown onset tuning parameter of gate-edge component for drain-bulk junction.
616	swjunexp=	Flag for JUNCAP-express; 0=full model, 1=express model.
617	vjunref=	Typical maximum source-bulk junction voltage; usually about $2 \cdot VSUP$.
618	fjunq=	Fraction below which source-bulk junction capacitance components are considered negligible.
619	vjunrefd=	Typical maximum drain-bulk junction voltage; usually about $2 \cdot VSUP$.
620	fjunqd=	Fraction below which drain-bulk junction capacitance components are considered negligible.
621	dta=	Temperature offset w.r.t. ambient temperature.
622	w=	Default width.

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PSP Model (psp)

623	<code>l=</code>	Default length.
624	<code>nf=</code>	Number of fingers, It served as the default value of instance <code>nf</code> .
625	<code>mvt=</code>	DCmatch parameter.
626	<code>mvt0=</code>	DCmatch parameter.
627	<code>mbe=</code>	DCmatch parameter.
628	<code>mbeo=</code>	DCmatch parameter.
629	<code>dcmmbetn=</code>	
630	<code>betn_mismatch=</code>	

Operating-Point Parameters

1	<code>l=</code>	Design length.
2	<code>w=</code>	Design width.
3	<code>sa=</code>	Distance between OD-edge and poly from one side.
4	<code>sb=</code>	Distance between OD-edge and poly from other side.
5	<code>sd=</code>	Distance between neighbouring fingers.
6	<code>sca=</code>	Integral of the first distribution function for scattered well dopants.
7	<code>scb=</code>	Integral of the second distribution function for scattered well dopants.
8	<code>scc=</code>	Integral of the third distribution function for scattered well dopants.
9	<code>sc=</code>	Distance between OD-edge and nearest well edge.
10	<code>nf=</code>	Number of fingers.
11	<code>ngcon=</code>	Number of gate contacts.

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PSP Model (psp)

12	xgw=	Distance from the gate contact to the channel edge.
13	nrs=	Number of squares of source diffusion.
14	nrd=	Number of squares of drain diffusion.
15	trise=	Temperature rise from ambient.
16	jw=	Gate-edge length of source/drain junction.
17	delvto=	Threshold voltage shift parameter.
18	factuo=	Zero-field mobility pre-factor.
19	absource=	Bottom area of source junction.
20	lssource=	STI-edge length of source junction.
21	lgsource=	Gate-edge length of source junction.
22	abdRAIN=	Bottom area of drain junction.
23	lsdRAIN=	STI-edge length of drain junction.
24	lgdRAIN=	Gate-edge length of drain junction.
25	as=	Bottom area of source junction.
26	ps=	Perimeter of source junction.
27	ad=	Bottom area of drain junction.
28	pd=	Perimeter of drain junction.
29	mult=	Number of devices in parallel.
30	ctype	Flag for channel type.
31	sdint	Flag for source-drain interchange.
32	ise ()	Total source current.

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PSP Model (psp)

33	<code>ige ()</code>	Total gate current.
34	<code>ide ()</code>	Total drain current.
35	<code>ibe ()</code>	Total bulk current.
36	<code>ids ()</code>	Drain current, excl. avalanche, tunnel, GISL, GIDL, and junction currents.
37	<code>idb ()</code>	Drain to bulk current.
38	<code>isb ()</code>	Source to bulk current.
39	<code>igs ()</code>	Gate-source tunneling current.
40	<code>igd ()</code>	Gate-drain tunneling current.
41	<code>igb ()</code>	Gate-bulk tunneling current.
42	<code>igcs ()</code>	Gate-channel tunneling current (source component.
43	<code>igcd ()</code>	Gate-channel tunneling current (drain component.
44	<code>iavl ()</code>	Substrate current due to weak avalanche.
45	<code>igisl ()</code>	Gate-induced source leakage current.
46	<code>igidl ()</code>	Gate-induced drain leakage current.
47	<code>ijs ()</code>	Total source junction current.
48	<code>ijsbot ()</code>	Source junction current (bottom component.
49	<code>ijsgat ()</code>	Source junction current (gate-edge component.
50	<code>ijssti ()</code>	Source junction current (STI-edge component.
51	<code>ijd ()</code>	Total drain junction current.
52	<code>ijdbot ()</code>	Drain junction current (bottom component.
53	<code>ijdgat ()</code>	Drain junction current (gate-edge component.

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PSP Model (psp)

54	<code>ijdsti ()</code>	Drain junction current (STI-edge component).
55	<code>qg</code>	Intrinsic gate charge.
56	<code>qd</code>	Intrinsic drain charge.
57	<code>qb</code>	Intrinsic bulk charge.
58	<code>qs</code>	Intrinsic source charge.
59	<code>qgs_ov</code>	Overlap charge for gate-source.
60	<code>qgd_ov</code>	Overlap charge for gate-drain.
61	<code>qfgs</code>	Total outerFringe + overlap for gate-source.
62	<code>qfgd</code>	Total outerFringe + overlap for gate-drain.
63	<code>qgb_ov</code>	Gate-bulk overlap charge.
64	<code>qjun_s</code>	Junction charge on source side.
65	<code>qjun_d</code>	Junction charge on drain side.
66	<code>vds ()</code>	Drain-source voltage.
67	<code>vgs ()</code>	Gate-source voltage.
68	<code>vsb ()</code>	Source-bulk voltage.
69	<code>vt0 ()</code>	Zero-bias threshold voltage.
70	<code>vtS ()</code>	Threshold voltage including back bias effects.
71	<code>vtH ()</code>	Threshold voltage including back bias and drain bias effects.
72	<code>vgt ()</code>	Effective gate drive voltage including back bias and drain bias effects.
73	<code>vdss ()</code>	Drain saturation voltage at actual bias.
74	<code>vsat</code>	Saturation limit.

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PSP Model (psp)

75	gm ()	Transconductance.
76	gmb ()	Substrate transconductance.
77	gds ()	Output conductance.
78	gjs ()	Source junction conductance.
79	gjd ()	Drain junction conductance.
80	cdd ()	Drain capacitance.
81	cdg ()	Drain-gate capacitance.
82	cds ()	Drain-source capacitance.
83	cdb ()	Drain-bulk capacitance.
84	cgd ()	Gate-drain capacitance.
85	cgg ()	Gate capacitance.
86	cgs ()	Gate-source capacitance.
87	cgb ()	Gate-bulk capacitance.
88	csd ()	Source-drain capacitance.
89	csg ()	Source-gate capacitance.
90	css ()	Source capacitance.
91	csb ()	Source-bulk capacitance.
92	cbd ()	Bulk-drain capacitance.
93	cbg ()	Bulk-gate capacitance.
94	cbs ()	Bulk-source capacitance.
95	cbb ()	Bulk capacitance.
96	cgso1 ()	Total gate-source overlap capacitance.

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PSP Model (psp)

97	<code>cgdo1</code> ()	Total gate-drain overlap capacitance.
98	<code>cjs</code> ()	Total source junction capacitance.
99	<code>cjsbot</code> ()	Source junction capacitance (bottom component.
100	<code>cjsgat</code> ()	Source junction capacitance (gate-edge component.
101	<code>cjssti</code> ()	Source junction capacitance (STI-edge component.
102	<code>cjd</code> ()	Total drain junction capacitance.
103	<code>cjdbot</code> ()	Drain junction capacitance (bottom component.
104	<code>cjdgat</code> ()	Drain junction capacitance (gate-edge component.
105	<code>cjdsti</code> ()	Drain junction capacitance (STI-edge component.
106	<code>weff</code> ()	Effective channel width for geometrical models.
107	<code>leff</code> ()	Effective channel length for geometrical models.
108	<code>u</code>	Transistor gain.
109	<code>rout</code> ()	Small-signal output resistance.
110	<code>vearly</code> ()	Equivalent Early voltage.
111	<code>beff</code> ()	Gain factor.
112	<code>fug</code> ()	Unity gain frequency at actual bias.
113	<code>rg</code> ()	Gate resistance.
114	<code>sfl</code>	Flicker noise current density at 1 Hz.
115	<code>sqrtsff</code>	Input-referred RMS white noise voltage density at 1 kHz.
116	<code>sqrtsfw</code>	Input-referred RMS white noise voltage density.
117	<code>sid</code>	White noise current density.
118	<code>sig</code>	Induced gate noise current density at 1 Hz.

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PSP Model (psp)

119	<code>cigid</code>	Imaginary part of correlation coefficient between Sig and Sid.
120	<code>fknee</code>	Cross-over frequency above which white noise is dominant.
121	<code>sigs</code>	Gate-source current noise spectral density.
122	<code>sigd</code>	Gate-drain current noise spectral density.
123	<code>siavl</code>	Impact ionization current noise spectral density.
124	<code>ssi</code>	Total source junction current noise spectral density.
125	<code>sdi</code>	Total drain junction current noise spectral density.
126	<code>lp_vfb ()</code>	Local parameter VFB after T-scaling and clipping.
127	<code>lp_stvfb ()</code>	Local parameter STVFB after clipping.
128	<code>lp_tox ()</code>	Local parameter TOX after clipping.
129	<code>lp_epsrox</code>	Local parameter EPSROX after clipping.
130	<code>lp_neff ()</code>	Local parameter NEFF after clipping.
131	<code>lp_facneffac</code>	Local parameter FACNEFFAC after clipping.
132	<code>lp_gfacnud</code>	Local parameter GFACNUD after clipping.
133	<code>lp_vsbnud ()</code>	Local parameter VSBNUD after clipping.
134	<code>lp_dvsbnud ()</code>	Local parameter DVSBNUD after clipping.
135	<code>lp_vnsub ()</code>	Local parameter VNSUB after clipping.
136	<code>lp_nslp ()</code>	Local parameter NSLP after clipping.
137	<code>lp_dnsud ()</code>	Local parameter DNSUB after clipping.
138	<code>lp_dphib ()</code>	Local parameter DPHIB after clipping.
139	<code>lp_delvtac ()</code>	Local parameter DELVTAC after clipping.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

140	lp_np ()	Local parameter NP after clipping.
141	lp_ct	Local parameter CT after clipping.
142	lp_toxov ()	Local parameter TOXOV after clipping.
143	lp_toxovd ()	Local parameter TOXOVD after clipping.
144	lp_nov ()	Local parameter NOV after clipping.
145	lp_novd ()	Local parameter NOVD after clipping.
146	lp_cf	Local parameter CF after clipping.
147	lp_cfb ()	Local parameter CFB after clipping.
148	lp_betn ()	Local parameter BETN after T-scaling and clipping.
149	lp_stbet	Local parameter STBET after clipping.
150	lp_mue ()	Local parameter MUE after T-scaling and clipping.
151	lp_stmue	Local parameter STMUE after clipping.
152	lp_themu	Local parameter THEMU after T-scaling and clipping.
153	lp_stthemu	Local parameter STTHEMU after clipping.
154	lp_cs	Local parameter CS after T-scaling and clipping.
155	lp_stcs	Local parameter STCS after clipping.
156	lp_xcor ()	Local parameter XCOR after T-scaling and clipping.
157	lp_stxcor	Local parameter STXCOR after clipping.
158	lp_feta	Local parameter FETA after clipping.
159	lp_rs ()	Local parameter RS after T-scaling and clipping.
160	lp_strs	Local parameter STRS after clipping.

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PSP Model (psp)

161	lp_rsb ()	Local parameter RSB after clipping.
162	lp_rsg ()	Local parameter RSG after clipping.
163	lp_thesat ()	Local parameter THESAT after T-scaling and clipping.
164	lp_stthesat	Local parameter STTHESAT after clipping.
165	lp_thesatb ()	Local parameter THESATB after clipping.
166	lp_thesatg ()	Local parameter THESATG after clipping.
167	lp_ax	Local parameter AX after clipping.
168	lp_alp	Local parameter ALP after clipping.
169	lp_alp1 ()	Local parameter ALP1 after clipping.
170	lp_alp2 ()	Local parameter ALP2 after clipping.
171	lp_vp ()	Local parameter VP after clipping.
172	lp_a1	Local parameter A1 after clipping.
173	lp_a2 ()	Local parameter A2 after T-scaling and clipping.
174	lp_sta2	Local parameter STA2 after clipping.
175	lp_a3	Local parameter A3 after clipping.
176	lp_a4 ()	Local parameter A4 after clipping.
177	lp_gco	Local parameter GCO after clipping.
178	lp_iginv ()	Local parameter IGINV after T-scaling and clipping.
179	lp_igov ()	Local parameter IGOV after T-scaling and clipping.
180	lp_igovd ()	Local parameter IGOVD after T-scaling and clipping.

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PSP Model (psp)

181	<code>lp_stig</code>	Local parameter STIG after clipping.
182	<code>lp_gc2</code>	Local parameter GC2 after clipping.
183	<code>lp_gc3</code>	Local parameter GC3 after clipping.
184	<code>lp_chib ()</code>	Local parameter CHIB after clipping.
185	<code>lp_agidl ()</code>	Local parameter AGIDL after clipping.
186	<code>lp_agidld ()</code>	Local parameter AGIDLD after clipping.
187	<code>lp_bgidl ()</code>	Local parameter BGIDL after T-scaling and clipping.
188	<code>lp_bgidld ()</code>	Local parameter BGIDLD after T-scaling and clipping.
189	<code>lp_stbgidl ()</code>	Local parameter STBGIDL after clipping.
190	<code>lp_stbgidld ()</code>	Local parameter STBGIDLD after clipping.
191	<code>lp_cgidl</code>	Local parameter CGIDL after clipping.
192	<code>lp_cgidld</code>	Local parameter CGIDLD after clipping.
193	<code>lp_cox ()</code>	Local parameter COX after clipping.
194	<code>lp_cgov ()</code>	Local parameter CGOV after clipping.
195	<code>lp_cgovd ()</code>	Local parameter CGOVD after clipping.
196	<code>lp_cgbov ()</code>	Local parameter CGBOV after clipping.
197	<code>lp_cfr ()</code>	Local parameter CFR after clipping.
198	<code>lp_cfrd ()</code>	Local parameter CFRD after clipping.
199	<code>lp_fnt</code>	Local parameter FNT after clipping.

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PSP Model (psp)

200 lp_nfa ()	Local parameter NFA after clipping.
201 lp_nfb ()	Local parameter NFB after clipping.
202 lp_nfc ()	Local parameter NFC after clipping.
203 lp_ef	Local parameter EF after clipping.
204 lp_rg ()	Local parameter RG after clipping.
205 lp_rse ()	Local parameter RSE after clipping.
206 lp_rde ()	Local parameter RDE after clipping.
207 lp_rbulk ()	Local parameter RBULK after clipping.
208 lp_rwell ()	Local parameter RWELL after clipping.
209 lp_rjuns ()	Local parameter RJUNS after clipping.
210 lp_rjund ()	Local parameter RJUND after clipping.
211 lp_munqs	Local parameter MUNQS after clipping.
212 m=	Alias of mult.
213 table_ids ()	For table model.
214 table_vth ()	For table model.
215 table_qg ()	For table model.
216 table_qd ()	For table model.
217 table_qb ()	For table model.
218 table_id ()	For table model.
219 table_isub ()	For table model.
220 table_ibs ()	For table model.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

221	table_ibd ()	For table model.
222	table_igd ()	For table model.
223	table_igb ()	For table model.
224	table_igs ()	For table model.
225	table_gds ()	For table model.
226	table_gm ()	For table model.
227	table_gmbs ()	For table model.
228	table_qbs ()	For table model.
229	table_qbd ()	For table model.
230	table_vdsat ()	For table model.
231	table_leff ()	For table model.
232	table_weff ()	For table model.
233	table_aseff ()	For table model.
234	table_adeff ()	For table model.
235	table_pseff ()	For table model.
236	table_pdeff ()	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.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

a1	M-62	iginv	M-68	plalp	M-214	qs	OP-58
a1l	M-454	iginvlw	M-465	plalpl	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
ad	I-27	ise	OP-32	pliginv	M-242	rsgo	M-427
ad	OP-27	isnoisy	I-30	pligov	M-246	rsh	M-504

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PSP Model (psp)

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
alp	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
as	I-25	lgdrain	I-24	plwa1	M-229	scc	I-8
as	OP-25	lgdrain	OP-24	plwa3	M-235	scc	OP-8

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

ax	M-57	lgsource	I-21	plwa4	M-239	scref	M-529
axl	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	plwcfrr	M-290	sigd	OP-122
bgidldo	M-475	lov	M-384	plwcfrrd	M-294	sigss	OP-121
bgidlo	M-474	lovd	M-385	plwcgbov	M-286	sqrtsff	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	stbetl	M-403
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

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PSP Model (psp)

cbg	OP-93	lp_agidld	OP-186	plwgfacnud	M-123	stbetw	M-404
cbs	OP-94	lp_alp	OP-168	plwginv	M-244	stbgidl	M-79
cdb	OP-83	lp_alp1	OP-169	plwigov	M-248	stbgidld	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
cfl	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	stigo	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
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

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

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_dnsbub	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	poal	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	stvfbl	M-336
cgsol	OP-96	lp_fnt	OP-199	poagidld	M-261	stvfblw	M-338
chib	M-74	lp_gc2	OP-182	poalp	M-213	stvfbo	M-335
chibo	M-471	lp_gc3	OP-183	poalpl	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
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

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

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
csq	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
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

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

csrhgat	M-551	lp_stbet	OP-149	pofnt	M-295	table_pdeff	OP-236
csrhgatd	M-592	lp_stbgidl	OP-189	pogc2	M-254	table_pseff	OP-235
csrhsti	M-550	lp_stbgidld	OP-190	pogc3	M-255	table_qb	OP-217
csrhstid	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
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

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

ctype	OP-30	lp_vfb	OP-126	ponslp	M-127	thesatlexp	M-430
dcmmbetn	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
delvtacl	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
delvtaclw	M-374	lpck	M-347	postbet	M-164	tox	M-18
delvtaco	M-370	lpckw	M-348	postbgidl	M-267	toxov	M-32
delvtacw	M-373	lsdrain	I-23	postbgidld	M-268	toxovd	M-33
delvto	I-17	lsdrain	OP-23	postcs	M-179	toxovdo	M-383
delvto	OP-17	lssource	I-20	postig	M-253	toxovo	M-382
dlq	M-329	lssource	OP-20	postmue	M-172	tr	M-3
dlsil	M-503	lvarl	M-322	postrs	M-190	trise	I-15
dnsub	M-27	lvaro	M-321	postthemu	M-174	trise	OP-15
dnsubo	M-364	lvarw	M-323	postthesat	M-197	trj	M-533
dphib	M-28	m	I-31	postvfb	M-106	type	M-2
dphibl	M-366	m	OP-212	postxcor	M-184	u	OP-108
dphiblexp	M-367	mbe	M-627	pothemu	M-173	uo	M-392
dphiblw	M-369	mbeo	M-628	pothesat	M-193	vbirbot	M-537
dphibo	M-365	mefftatbot	M-557	pothesatb	M-201	vbirbotd	M-578
dphibw	M-368	mefftatbotd	M-598	pothesatg	M-205		

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

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	povnsb M-126	vbrbot M-569
efo M-487	mue M-40	povp M-225	vbrbotd 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	ps M-541	vds OP-66
facneffaco M-351	munqso M-498	ps M-582	vdss OP-73
facneffacw M-353	mvt M-625	pwal 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
fbtrbotd M-604	nf M-624	pwagidld M-263	vfb1w M-334
fbtrrgat M-565	nf OP-10	pwalp M-215	vfb0 M-331
fbtrrgatd M-606	nfa M-90	pwalp1 M-219	vfbw M-333
fbtrrsti M-564	nfalw M-484	pwalp2 M-223	vgs OP-67

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

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
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

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

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
idsatrbot	M-546	phigbotd	M-584	pwxcor	M-182	xcorlw	M-420
idsatrbotd	M-587	phiggat	M-545	q	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

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

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		

PSP NQS MOSFET Model (pspnqs103)

Instance Definition

Name d g s b ModelName parameter=value ...

Instance Parameters

- 1 l= Design length.
- 2 w= Design width.
- 3 sa= Distance between OD-edge and poly from one side.
- 4 sb= Distance between OD-edge and poly from other side.
- 5 sd= Distance between neighbouring fingers.
- 6 sca= Integral of the first distribution function for scattered well dopants.
- 7 scb= Integral of the second distribution function for scattered well dopants.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

8	scc=	Integral of the third distribution function for scattered well dopants.
9	sc=	Distance between OD-edge and nearest well edge.
10	nf=	Number of fingers.
11	ngcon=	Number of gate contacts.
12	xgw=	Distance from the gate contact to the channel edge.
13	nrs=	Number of squares of source diffusion.
14	nrd=	Number of squares of drain diffusion.
15	trise=	Temperature rise from ambient.
16	jw=	Gate-edge length of source/drain junction.
17	delvto=	Threshold voltage shift parameter.
18	factuo=	Zero-field mobility pre-factor.
19	absource=	Bottom area of source junction.
20	lssource=	STI-edge length of source junction.
21	lgsource=	Gate-edge length of source junction.
22	abdRAIN=	Bottom area of drain junction.
23	lsdRAIN=	STI-edge length of drain junction.
24	lgdRAIN=	Gate-edge length of drain junction.
25	as=	Bottom area of source junction.
26	ps=	Perimeter of source junction.
27	ad=	Bottom area of drain junction.
28	pd=	Perimeter of drain junction.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

- 29 `mult=` Number of devices in parallel.
- 30 `isnoisy=` Should device generate noise.
Possible values are `no` or `yes`.
- 31 `m=` Alias of `mult`.

Model Definition

```
model modelName pspnqs103 parameter=value ...
```

Model Parameters

- 1 `level=` Model level.
- 2 `type=` Channel type parameter, `n`=NMOS `p`=PMOS.
Possible values are `n` or `p`.
- 3 `tr=` nominal (reference) temperature.
- 4 `swnqs=` Flag for NQS, 0=off, 1, 2, 3, 5, or 9=number of collocation points.
- 5 `swgeo=` Flag for geometrical model, 0=local, 1=global, 2=binning.
- 6 `swigate=` Flag for gate current, 0=turn off IG.
- 7 `swimpact=` Flag for impact ionization current, 0=turn off II.
- 8 `swgidl=` Flag for GIDL current, 0=turn off IGIDL.
- 9 `swjuncap=` Flag for juncap, 0=turn off juncap.
- 10 `swjunasym=` Flag for asymmetric junctions; 0=symmetric, 1=asymmetric.
- 11 `swnud=` Flag for NUD-effect; 0=off, 1=on, 2=on+CV-correction.
- 12 `swdelvtac=` Flag for separate capacitance calculation; 0=off, 1=on.
- 13 `qmc=` Quantum-mechanical correction factor.
- 14 `version=` Model version selector.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

15	minr=	Minimum resistance, in order to be compatible with the original model, set its default to 0.0.
16	vfb=	Flat band voltage at TR.
17	stvfb=	Temperature dependence of VFB.
18	tox=	Gate oxide thickness.
19	epsrox=	Relative permittivity of gate dielectric.
20	neff=	Effective substrate doping.
21	facneffac=	Pre-factor for effective substrate doping in separate charge calculation.
22	gfacnud=	Bodyfactor change due to NUD-effect.
23	vsbnud=	Lower Vsb value for NUD-effect.
24	dvvsbnud=	Vsb-range for NUD-effect.
25	vnsb=	Effective doping bias-dependence parameter.
26	nslp=	Effective doping bias-dependence parameter.
27	dnsub=	Effective doping bias-dependence parameter.
28	dphib=	Offset parameter for PHIB.
29	delvtac=	Offset parameter for PHIB in separate charge calculation.
30	np=	Gate poly-silicon doping.
31	ct=	Interface states factor.
32	toxov=	Overlap oxide thickness.
33	toxovd=	Overlap oxide thickness for drain side.
34	nov=	Effective doping of overlap region.
35	novd=	Effective doping of overlap region for drain side.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

36	cf=	DIBL-parameter.
37	cfb=	Back bias dependence of CF.
38	betn=	Channel aspect ratio times zero-field mobility.
39	stbet=	Temperature dependence of BETN.
40	mue=	Mobility reduction coefficient at TR.
41	stmue=	Temperature dependence of MUE.
42	themu=	Mobility reduction exponent at TR.
43	stthemu=	Temperature dependence of THEMU.
44	cs=	Coulomb scattering parameter at TR.
45	stcs=	Temperature dependence of CS.
46	xcor=	Non-universality factor.
47	stxcor=	Temperature dependence of XCOR.
48	feta=	Effective field parameter.
49	rs=	Series resistance at TR.
50	strs=	Temperature dependence of RS.
51	rsb=	Back-bias dependence of series resistance.
52	rsg=	Gate-bias dependence of series resistance.
53	thesat=	Velocity saturation parameter at TR.
54	stthesat=	Temperature dependence of THESAT.
55	thesatb=	Back-bias dependence of velocity saturation.
56	thesatg=	Gate-bias dependence of velocity saturation.
57	ax=	Linear/saturation transition factor.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

58	alp=	CLM pre-factor.
59	alp1=	CLM enhancement factor above threshold.
60	alp2=	CLM enhancement factor below threshold.
61	vp=	CLM logarithm dependence factor.
62	a1=	Impact-ionization pre-factor.
63	a2=	Impact-ionization exponent at TR.
64	sta2=	Temperature dependence of A2.
65	a3=	Saturation-voltage dependence of impact-ionization.
66	a4=	Back-bias dependence of impact-ionization.
67	gco=	Gate tunneling energy adjustment.
68	iginv=	Gate channel current pre-factor.
69	igov=	Gate overlap current pre-factor.
70	igovd=	Gate overlap current pre-factor for drain side.
71	stig=	Temperature dependence of IGINV and IGOV.
72	gc2=	Gate current slope factor.
73	gc3=	Gate current curvature factor.
74	chib=	Tunneling barrier height.
75	agidl=	GIDL pre-factor.
76	agidld=	GIDL pre-factor for drain side.
77	bgidl=	GIDL probability factor at TR.
78	bgidld=	GIDL probability factor at TR for drain side.
79	stbgidl=	Temperature dependence of BGIDL.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

80	stbgidld=	Temperature dependence of BGIDL for drain side.
81	cgidl=	Back-bias dependence of GIDL.
82	cgidld=	Back-bias dependence of GIDL for drain side.
83	cox=	Oxide capacitance for intrinsic channel.
84	cgov=	Oxide capacitance for gate-drain/source overlap.
85	cgovd=	Oxide capacitance for gate-drain overlap.
86	cgbov=	Oxide capacitance for gate-bulk overlap.
87	cfr=	Outer fringe capacitance.
88	cfrd=	Outer fringe capacitance for drain side.
89	fnt=	Thermal noise coefficient.
90	nfa=	First coefficient of flicker noise.
91	nfb=	Second coefficient of flicker noise.
92	nfc=	Third coefficient of flicker noise.
93	ef=	Flicker noise frequency exponent.
94	munqs=	Relative mobility for NQS modelling.
95	rg=	Gate resistance.
96	rse=	External source resistance.
97	rde=	External drain resistance.
98	rbulk=	Bulk resistance between node BP and BI.
99	rwell=	Well resistance between node BI and B.
100	rjuns=	Source-side bulk resistance between node BI and BS.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

101	<code>rjund=</code>	Drain-side bulk resistance between node BI and BD.
102	<code>povfb=</code>	Coefficient for the geometry independent part of VFB.
103	<code>plvfb=</code>	Coefficient for the length dependence of VFB.
104	<code>pwvfb=</code>	Coefficient for the width dependence of VFB.
105	<code>plwvfb=</code>	Coefficient for the length times width dependence of VFB.
106	<code>postvfb=</code>	Coefficient for the geometry independent part of STVFB.
107	<code>plstvfb=</code>	Coefficient for the length dependence of STVFB.
108	<code>pwstvfb=</code>	Coefficient for the width dependence of STVFB.
109	<code>plwstvfb=</code>	Coefficient for the length times width dependence of STVFB.
110	<code>potox=</code>	Coefficient for the geometry independent part of TOX.
111	<code>poepsrox=</code>	Coefficient for the geometry independent part of EPSOX.
112	<code>poneff=</code>	Coefficient for the geometry independent part of NEFF.
113	<code>plneff=</code>	Coefficient for the length dependence of NEFF.
114	<code>pwneff=</code>	Coefficient for the width dependence of NEFF.
115	<code>plwneff=</code>	Coefficient for the length times width dependence of NEFF.
116	<code>pofacneffac=</code>	Coefficient for the geometry independent part of FACNEFFAC.
117	<code>plfacneffac=</code>	Coefficient for the length dependence of FACNEFFAC.
118	<code>pwfacneffac=</code>	Coefficient for the width dependence of FACNEFFAC.
119	<code>plwfacneffac=</code>	Coefficient for the length times width dependence of FACNEFFAC.
120	<code>pogfacnud=</code>	Coefficient for the geometry independent part of GFACNUD.
121	<code>plgfacnud=</code>	Coefficient for the length dependence of GFACNUD.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

122	pwgfacnud=	Coefficient for the width dependence of GFACNUD.
123	plwgfacnud=	Coefficient for the length times width dependence of GFACNUD.
124	povsbnud=	Coefficient for the geometry independent part of VSBNUD.
125	podvsbnud=	Coefficient for the geometry independent part of DVSBNUD.
126	povnsub=	Coefficient for the geometry independent part of VNSUB.
127	ponslp=	Coefficient for the geometry independent part of NSLP.
128	podnsub=	Coefficient for the geometry independent part of DNSUB.
129	podphib=	Coefficient for the geometry independent part of DPHIB.
130	pldphib=	Coefficient for the length dependence of DPHIB.
131	pwdphib=	Coefficient for the width dependence of DPHIB.
132	plwdphib=	Coefficient for the length times width dependence of DPHIB.
133	podelvtac=	Coefficient for the geometry independent part of DELVTAC.
134	pldelvtac=	Coefficient for the length dependence of DELVTAC.
135	pwdelvtac=	Coefficient for the width dependence of DELVTAC.
136	plwdelvtac=	Coefficient for the length times width dependence of DELVTAC.
137	ponp=	Coefficient for the geometry independent part of NP.
138	plnp=	Coefficient for the length dependence of NP.
139	pwnp=	Coefficient for the width dependence of NP.
140	plwnp=	Coefficient for the length times width dependence of NP.
141	poct=	Coefficient for the geometry independent part of CT.
142	plct=	Coefficient for the length dependence of CT.
143	pwct=	Coefficient for the width dependence of CT.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

144	<code>plwct=</code>	Coefficient for the length times width dependence of CT.
145	<code>potoxov=</code>	Coefficient for the geometry independent part of TOXOV.
146	<code>potoxovd=</code>	Coefficient for the geometry independent part of TOXOV for drain side.
147	<code>ponov=</code>	Coefficient for the geometry independent part of NOV.
148	<code>plnov=</code>	Coefficient for the length dependence of NOV.
149	<code>pwnov=</code>	Coefficient for the width dependence of NOV.
150	<code>plwnov=</code>	Coefficient for the length times width dependence of NOV.
151	<code>ponovd=</code>	Coefficient for the geometry independent part of NOV for drain side.
152	<code>plnovd=</code>	Coefficient for the length dependence of NOV for drain side.
153	<code>pwnovd=</code>	Coefficient for the width dependence of NOV for drain side.
154	<code>plwnovd=</code>	Coefficient for the length times width dependence of NOV for drain side.
155	<code>pocf=</code>	Coefficient for the geometry independent part of CF.
156	<code>plcf=</code>	Coefficient for the length dependence of CF.
157	<code>pwcf=</code>	Coefficient for the width dependence of CF.
158	<code>plwcf=</code>	Coefficient for the length times width dependence of CF.
159	<code>pocfb=</code>	Coefficient for the geometry independent part of CFB.
160	<code>pobetn=</code>	Coefficient for the geometry independent part of BETN.
161	<code>plbetn=</code>	Coefficient for the length dependence of BETN.
162	<code>pwbetn=</code>	Coefficient for the width dependence of BETN.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

163	plwbetn=	Coefficient for the length times width dependence of BETN.
164	postbet=	Coefficient for the geometry independent part of STBET.
165	plstbet=	Coefficient for the length dependence of STBET.
166	pwstbet=	Coefficient for the width dependence of STBET.
167	plwstbet=	Coefficient for the length times width dependence of STBET.
168	pomue=	Coefficient for the geometry independent part of MUE.
169	plmue=	Coefficient for the length dependence of MUE.
170	pmue=	Coefficient for the width dependence of MUE.
171	plwmue=	Coefficient for the length times width dependence of MUE.
172	postmue=	Coefficient for the geometry independent part of STMUE.
173	pothemu=	Coefficient for the geometry independent part of THEMU.
174	postthemu=	Coefficient for the geometry independent part of STTHEMU.
175	pocs=	Coefficient for the geometry independent part of CS.
176	plcs=	Coefficient for the length dependence of CS.
177	pwcs=	Coefficient for the width dependence of CS.
178	plwcs=	Coefficient for the length times width dependence of CS.
179	postcs=	Coefficient for the geometry independent part of STCS.
180	poxcor=	Coefficient for the geometry independent part of XCOR.
181	plxcor=	Coefficient for the length dependence of XCOR.
182	pwxcor=	Coefficient for the width dependence of XCOR.
183	plwxcor=	Coefficient for the length times width dependence of XCOR.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

184	<code>postxcor=</code>	Coefficient for the geometry independent part of STXCOR.
185	<code>pofeta=</code>	Coefficient for the geometry independent part of FETA.
186	<code>pors=</code>	Coefficient for the geometry independent part of RS.
187	<code>plrs=</code>	Coefficient for the length dependence of RS.
188	<code>pwr=</code>	Coefficient for the width dependence of RS.
189	<code>plwrs=</code>	Coefficient for the length times width dependence of RS.
190	<code>postrs=</code>	Coefficient for the geometry independent part of STRS.
191	<code>porsb=</code>	Coefficient for the geometry independent part of RSB.
192	<code>porsg=</code>	Coefficient for the geometry independent part of RSG.
193	<code>pothesat=</code>	Coefficient for the geometry independent part of THESAT.
194	<code>plthesat=</code>	Coefficient for the length dependence of THESAT.
195	<code>pwthesat=</code>	Coefficient for the width dependence of THESAT.
196	<code>plwthesat=</code>	Coefficient for the length times width dependence of THESAT.
197	<code>postthesat=</code>	Coefficient for the geometry independent part of STTHESAT.
198	<code>plstthesat=</code>	Coefficient for the length dependence of STTHESAT.
199	<code>pwstthesat=</code>	Coefficient for the width dependence of STTHESAT.
200	<code>plwstthesat=</code>	Coefficient for the length times width dependence of STTHESAT.
201	<code>pothesatb=</code>	Coefficient for the geometry independent part of THESATB.
202	<code>plthesatb=</code>	Coefficient for the length dependence of THESATB.
203	<code>pwthesatb=</code>	Coefficient for the width dependence of THESATB.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

204	plwthesatb=	Coefficient for the length times width dependence of THESATB.
205	pothesatg=	Coefficient for the geometry independent part of THESATG.
206	plthesatg=	Coefficient for the length dependence of THESATG.
207	pwthesatg=	Coefficient for the width dependence of THESATG.
208	plwthesatg=	Coefficient for the length times width dependence of THESATG.
209	poax=	Coefficient for the geometry independent part of AX.
210	plax=	Coefficient for the length dependence of AX.
211	pwax=	Coefficient for the width dependence of AX.
212	plwax=	Coefficient for the length times width dependence of AX.
213	poalp=	Coefficient for the geometry independent part of ALP.
214	plalp=	Coefficient for the length dependence of ALP.
215	pwalp=	Coefficient for the width dependence of ALP.
216	plwalp=	Coefficient for the length times width dependence of ALP.
217	poalp1=	Coefficient for the geometry independent part of ALP1.
218	plalp1=	Coefficient for the length dependence of ALP1.
219	pwalp1=	Coefficient for the width dependence of ALP1.
220	plwalp1=	Coefficient for the length times width dependence of ALP1.
221	poalp2=	Coefficient for the geometry independent part of ALP2.
222	plalp2=	Coefficient for the length dependence of ALP2.
223	pwalp2=	Coefficient for the width dependence of ALP2.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

224	p1walp2=	Coefficient for the length times width dependence of ALP2.
225	povp=	Coefficient for the geometry independent part of VP.
226	poa1=	Coefficient for the geometry independent part of A1.
227	pla1=	Coefficient for the length dependence of A1.
228	pwa1=	Coefficient for the width dependence of A1.
229	plwa1=	Coefficient for the length times width dependence of A1.
230	poa2=	Coefficient for the geometry independent part of A2.
231	posta2=	Coefficient for the geometry independent part of STA2.
232	poa3=	Coefficient for the geometry independent part of A3.
233	pla3=	Coefficient for the length dependence of A3.
234	pwa3=	Coefficient for the width dependence of A3.
235	plwa3=	Coefficient for the length times width dependence of A3.
236	poa4=	Coefficient for the geometry independent part of A4.
237	pla4=	Coefficient for the length dependence of A4.
238	pwa4=	Coefficient for the width dependence of A4.
239	plwa4=	Coefficient for the length times width dependence of A4.
240	pogco=	Coefficient for the geometry independent part of GCO.
241	poiginv=	Coefficient for the geometry independent part of IGINV.
242	pliginv=	Coefficient for the length dependence of IGINV.
243	pwiginv=	Coefficient for the width dependence of IGINV.
244	plwiginv=	Coefficient for the length times width dependence of IGINV.
245	poigov=	Coefficient for the geometry independent part of IGOV.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

246	<code>pligov=</code>	Coefficient for the length dependence of IGOV.
247	<code>pwigov=</code>	Coefficient for the width dependence of IGOV.
248	<code>plwigov=</code>	Coefficient for the length times width dependence of IGOV.
249	<code>poigovd=</code>	Coefficient for the geometry independent part of IGOV for drain side.
250	<code>pligovd=</code>	Coefficient for the length dependence of IGOV for drain side.
251	<code>pwigovd=</code>	Coefficient for the width dependence of IGOV for drain side.
252	<code>plwigovd=</code>	Coefficient for the length times width dependence of IGOV for drain side.
253	<code>postig=</code>	Coefficient for the geometry independent part of STIG.
254	<code>pogc2=</code>	Coefficient for the geometry independent part of GC2.
255	<code>pogc3=</code>	Coefficient for the geometry independent part of GC3.
256	<code>pochib=</code>	Coefficient for the geometry independent part of CHIB.
257	<code>poagidl=</code>	Coefficient for the geometry independent part of AGIDL.
258	<code>plagidl=</code>	Coefficient for the length dependence of AGIDL.
259	<code>pwagidl=</code>	Coefficient for the width dependence of AGIDL.
260	<code>plwagidl=</code>	Coefficient for the length times width dependence of AGIDL.
261	<code>poagidld=</code>	Coefficient for the geometry independent part of AGIDL for drain side.
262	<code>plagidld=</code>	Coefficient for the length dependence of AGIDL for drain side.
263	<code>pwagidld=</code>	Coefficient for the width dependence of AGIDL for drain side.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

264	<code>plwagidl=</code>	Coefficient for the length times width dependence of AGIDL for drain side.
265	<code>pobgidl=</code>	Coefficient for the geometry independent part of BGIDL.
266	<code>pobgidld=</code>	Coefficient for the geometry independent part of BGIDL for drain side.
267	<code>postbgidl=</code>	Coefficient for the geometry independent part of STBGIDL.
268	<code>postbgidld=</code>	Coefficient for the geometry independent part of STBGIDL for drain side.
269	<code>pocgidl=</code>	Coefficient for the geometry independent part of CGIDL.
270	<code>pocgidld=</code>	Coefficient for the geometry independent part of CGIDL for drain side.
271	<code>pocox=</code>	Coefficient for the geometry independent part of COX.
272	<code>plcox=</code>	Coefficient for the length dependence of COX.
273	<code>pwcox=</code>	Coefficient for the width dependence of COX.
274	<code>plwcox=</code>	Coefficient for the length times width dependence of COX.
275	<code>pocgov=</code>	Coefficient for the geometry independent part of CGOV.
276	<code>plcgov=</code>	Coefficient for the length dependence of CGOV.
277	<code>pwcgov=</code>	Coefficient for the width dependence of CGOV.
278	<code>plwcgov=</code>	Coefficient for the length times width dependence of CGOV.
279	<code>pocgovd=</code>	Coefficient for the geometry independent part of CGOV for drain side.
280	<code>plcgovd=</code>	Coefficient for the length dependence of CGOV for drain side.
281	<code>pwcgovd=</code>	Coefficient for the width dependence of CGOV for drain side.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

282	<code>plwcgovd=</code>	Coefficient for the length times width dependence of CGOV for drain side.
283	<code>pocgbov=</code>	Coefficient for the geometry independent part of CGBOV.
284	<code>plcgbov=</code>	Coefficient for the length dependence of CGBOV.
285	<code>pwcgbov=</code>	Coefficient for the width dependence of CGBOV.
286	<code>plwcgbov=</code>	Coefficient for the length times width dependence of CGBOV.
287	<code>poccfr=</code>	Coefficient for the geometry independent part of CFR.
288	<code>plcfr=</code>	Coefficient for the length dependence of CFR.
289	<code>pwccfr=</code>	Coefficient for the width dependence of CFR.
290	<code>plwccfr=</code>	Coefficient for the length times width dependence of CFR.
291	<code>poccfrd=</code>	Coefficient for the geometry independent part of CFR for drain side.
292	<code>plcfrd=</code>	Coefficient for the length dependence of CFR for drain side.
293	<code>pwccfrd=</code>	Coefficient for the width dependence of CFR for drain side.
294	<code>plwccfrd=</code>	Coefficient for the length times width dependence of CFR for drain side.
295	<code>pofnt=</code>	Coefficient for the geometry independent part of FNT.
296	<code>ponfa=</code>	Coefficient for the geometry independent part of NFA.
297	<code>plnfa=</code>	Coefficient for the length dependence of NFA.
298	<code>pwnfa=</code>	Coefficient for the width dependence of NFA.
299	<code>plwnfa=</code>	Coefficient for the length times width dependence of NFA.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

300 ponfb=	Coefficient for the geometry independent part of NFB.
301 plnfb=	Coefficient for the length dependence of NFB.
302 pwnfb=	Coefficient for the width dependence of NFB.
303 plwnfb=	Coefficient for the length times width dependence of NFB.
304 ponfc=	Coefficient for the geometry independent part of NFC.
305 plnfc=	Coefficient for the length dependence of NFC.
306 pwnfc=	Coefficient for the width dependence of NFC.
307 plwnfc=	Coefficient for the length times width dependence of NFC.
308 poef=	Coefficient for the flicker noise frequency exponent.
309 pokvthowe=	Coefficient for the geometry independent part of KVTHOWE.
310 plkvthowe=	Coefficient for the length dependence part of KVTHOWE.
311 pwkvthowe=	Coefficient for the width dependence part of KVTHOWE.
312 plwkvthowe=	Coefficient for the length times width dependence part of KVTHOWE.
313 pokuowe=	Coefficient for the geometry independent part of KUOWE.
314 plkuowe=	Coefficient for the length dependence part of KUOWE.
315 pwkuowe=	Coefficient for the width dependence part of KUOWE.
316 plwkuowe=	Coefficient for the length times width dependence part of KUOWE.
317 lmin=	Dummy parameter to label binning set.
318 lmax=	Dummy parameter to label binning set.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

319	wmin=	Dummy parameter to label binning set.
320	wmax=	Dummy parameter to label binning set.
321	lvaro=	Geom. independent difference between actual and programmed gate length.
322	lvarl=	Length dependence of LVAR.
323	lvarw=	Width dependence of LVAR.
324	lap=	Effective channel length reduction per side.
325	wvaro=	Geom. independent difference between actual and programmed field-oxide opening.
326	wvarl=	Length dependence of WVAR.
327	wvarw=	Width dependence of WVAR.
328	wot=	Effective channel width reduction per side.
329	dlq=	Effective channel length reduction for CV.
330	dwq=	Effective channel width reduction for CV.
331	vfbo=	Geometry-independent flat-band voltage at TR.
332	vfb1=	Length dependence of flat-band voltage.
333	vfbw=	Width dependence of flat-band voltage.
334	vfb1w=	Area dependence of flat-band voltage.
335	stvfbo=	Geometry-independent temperature dependence of VFB.
336	stvfb1=	Length dependence of temperature dependence of VFB.
337	stvfbw=	Width dependence of temperature dependence of VFB.
338	stvfb1w=	Area dependence of temperature dependence of VFB.
339	tox0=	Gate oxide thickness.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

340	<code>epsroxo=</code>	Relative permittivity of gate dielectric.
341	<code>nsubo=</code>	Geometry independent substrate doping.
342	<code>nsubw=</code>	Width dependence of background doping NSUBO due to segregation.
343	<code>wseg=</code>	Char. length of segregation of background doping NSUBO.
344	<code>npck=</code>	Pocket doping level.
345	<code>npckw=</code>	Width dependence of pocket doping NPCK due to segregation.
346	<code>wsegp=</code>	Char. length of segregation of pocket doping NPCK.
347	<code>lpck=</code>	Char. length of lateral doping profile.
348	<code>lpckw=</code>	Width dependence of char. length of lateral doping profile.
349	<code>fol1=</code>	First length dependence coefficient for short channel body effect.
350	<code>fol2=</code>	Second length dependence coefficient for short channel body effect.
351	<code>facneffaco=</code>	Geom. independent pre-factor for effective substrate doping in separate charge calculation.
352	<code>facneffacl=</code>	Length dependence of FACNEFFAC.
353	<code>facneffacw=</code>	Width dependence of FACNEFFAC.
354	<code>facneffaclw=</code>	Area dependence of FACNEFFAC.
355	<code>gfacnudo=</code>	Geom. independent bodyfactor change due to NUD-effect.
356	<code>gfacnudl=</code>	Length dependence of GFACNUD.
357	<code>gfacnudlexp=</code>	Exponent for length dependence of GFACNUD.
358	<code>gfacnudw=</code>	Width dependence of GFACNUD.
359	<code>gfacnudlw=</code>	Area dependence of GFACNUD.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

360	<code>vsbnudo=</code>	Lower V_{sb} value for NUD-effect.
361	<code>dvsbnudo=</code>	V_{sb} range for NUD-effect.
362	<code>vnsubo=</code>	Effective doping bias-dependence parameter.
363	<code>nslpo=</code>	Effective doping bias-dependence parameter.
364	<code>dnsubo=</code>	Effective doping bias-dependence parameter.
365	<code>dphibo=</code>	Geometry independent offset of PHIB.
366	<code>dphibl=</code>	Length dependence offset of PHIB.
367	<code>dphiblexp=</code>	Exponent for length dependence of offset of PHIB.
368	<code>dphibw=</code>	Width dependence of offset of PHIB.
369	<code>dphiblw=</code>	Area dependence of offset of PHIB.
370	<code>delvtaco=</code>	Geom. independent offset parameter for PHIB in separate charge calculation.
371	<code>delvtacl=</code>	Length dependence of DELVTAC.
372	<code>delvtaclexp=</code>	Exponent for length dependence of offset of DELVTAC.
373	<code>delvtacw=</code>	Width dependence of DELVTAC.
374	<code>delvtaclw=</code>	Area dependence of DELVTAC.
375	<code>npo=</code>	Geometry-independent gate poly-silicon doping.
376	<code>npl=</code>	Length dependence of gate poly-silicon doping.
377	<code>cto=</code>	Geometry-independent interface states factor.
378	<code>ctl=</code>	Length dependence of interface states factor.
379	<code>ctlexp=</code>	Exponent for length dependence of interface states factor.
380	<code>ctw=</code>	Width dependence of interface states factor.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

381	ctlw=	Area dependence of interface states factor.
382	toxovo=	Overlap oxide thickness.
383	toxovdo=	Overlap oxide thickness for drain side.
384	lov=	Overlap length for gate/drain and gate/source overlap capacitance.
385	lovd=	Overlap length for gate/drain overlap capacitance.
386	novo=	Effective doping of overlap region.
387	novdo=	Effective doping of overlap region for drain side.
388	cfl=	Length dependence of DIBL-parameter.
389	cflexp=	Exponent for length dependence of CF.
390	cfw=	Width dependence of CF.
391	cfbo=	Back-bias dependence of CF.
392	uo=	Zero-field mobility at TR.
393	fbet1=	Relative mobility decrease due to first lateral profile.
394	fbet1w=	Width dependence of relative mobility decrease due to first lateral profile.
395	lp1=	Mobility-related characteristic length of first lateral profile.
396	lp1w=	Width dependence of mobility-related characteristic length of first lateral profile.
397	fbet2=	Relative mobility decrease due to second lateral profile.
398	lp2=	Mobility-related characteristic length of second lateral profile.
399	betw1=	First higher-order width scaling coefficient of BETN.
400	betw2=	Second higher-order width scaling coefficient of BETN.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

401	wbet=	Characteristic width for width scaling of BETN.
402	stbeto=	Geometry independent temperature dependence of BETN.
403	stbetl=	Length dependence of temperature dependence of BETN.
404	stbetw=	Width dependence of temperature dependence of BETN.
405	stbetlw=	Area dependence of temperature dependence of BETN.
406	mueo=	Geometry independent mobility reduction coefficient at TR.
407	muew=	Width dependence of mobility reduction coefficient at TR.
408	stmueo=	Temperature dependence of MUE.
409	themuo=	Mobility reduction exponent at TR.
410	stthemuo=	Temperature dependence of THEMU.
411	cso=	Geometry independent coulomb scattering parameter at TR.
412	csl=	Length dependence of CS.
413	cslexp=	Exponent for length dependence of CS.
414	csw=	Width dependence of CS.
415	cslw=	Area dependence of CS.
416	stcso=	Temperature dependence of CS.
417	xcoro=	Geometry independent non-universality parameter.
418	xcorl=	Length dependence of non-universality parameter.
419	xcorw=	Width dependence of non-universality parameter.
420	xcorlw=	Area dependence of non-universality parameter.
421	stxcoro=	Temperature dependence of XCOR.
422	fetao=	Effective field parameter.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

423	<code>rsw1=</code>	Source/drain series resistance for 1 um wide channel at TR.
424	<code>rsw2=</code>	Higher-order width scaling of RS.
425	<code>strso=</code>	Temperature dependence of RS.
426	<code>rsbo=</code>	Back-bias dependence of series resistance.
427	<code>rsgo=</code>	Gate-bias dependence of series resistance.
428	<code>thesato=</code>	Geometry independent velocity saturation parameter at TR.
429	<code>thesatl=</code>	Length dependence of THESAT.
430	<code>thesatlexp=</code>	Exponent for length dependence of THESAT.
431	<code>thesatw=</code>	Width dependence of velocity saturation parameter.
432	<code>thesatlw=</code>	Area dependence of velocity saturation parameter.
433	<code>stthesato=</code>	Geometry independent temperature dependence of THESAT.
434	<code>stthesatl=</code>	Length dependence of temperature dependence of THESAT.
435	<code>stthesatw=</code>	Width dependence of temperature dependence of THESAT.
436	<code>stthesatlw=</code>	Area dependence of temperature dependence of THESAT.
437	<code>thesatbo=</code>	Back-bias dependence of velocity saturation.
438	<code>thesatgo=</code>	Gate-bias dependence of velocity saturation.
439	<code>axo=</code>	Geometry independent linear/saturation transition factor.
440	<code>axl=</code>	Length dependence of AX.
441	<code>alpl=</code>	Length dependence of ALP.
442	<code>alplexp=</code>	Exponent for length dependence of ALP.
443	<code>alpw=</code>	Width dependence of ALP.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

444	alp1l1=	Length dependence of CLM enhancement factor above threshold.
445	alp1lexp=	Exponent for length dependence of ALP1.
446	alp1l2=	Second_order length dependence of ALP1.
447	alp1w=	Width dependence of ALP1.
448	alp2l1=	Length dependence of CLM enhancement factor below threshold.
449	alp2lexp=	Exponent for length dependence of ALP2.
450	alp2l2=	Second_order length dependence of ALP2.
451	alp2w=	Width dependence of ALP2.
452	vpo=	CLM logarithmic dependence parameter.
453	a1o=	Geometry independent impact-ionization pre-factor.
454	a1l=	Length dependence of A1.
455	a1w=	Width dependence of A1.
456	a2o=	Impact-ionization exponent at TR.
457	sta2o=	Temperature dependence of A2.
458	a3o=	Geometry independent saturation-voltage dependence of II.
459	a3l=	Length dependence of A3.
460	a3w=	Width dependence of A3.
461	a4o=	Geometry independent back-bias dependence of II.
462	a4l=	Length dependence of A4.
463	a4w=	Width dependence of A4.
464	gcoo=	Gate tunneling energy adjustment.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

465	<code>iginvlw=</code>	Gate channel current pre-factor for 1 μm^2 channel area.
466	<code>igovw=</code>	Gate overlap current pre-factor for 1 μm wide channel.
467	<code>igovdw=</code>	Gate overlap current pre-factor for 1 μm wide channel for drain side.
468	<code>stigo=</code>	Temperature dependence of IGINV and IGOV.
469	<code>gc2o=</code>	Gate current slope factor.
470	<code>gc3o=</code>	Gate current curvature factor.
471	<code>chibo=</code>	Tunneling barrier height.
472	<code>agidlw=</code>	Width dependence of GIDL pre-factor.
473	<code>agidldw=</code>	Width dependence of GIDL pre-factor for drain side.
474	<code>bgidlo=</code>	GIDL probability factor at TR.
475	<code>bgidldo=</code>	GIDL probability factor at TR for drain side.
476	<code>stbgidlo=</code>	Temperature dependence of BGIDL.
477	<code>stbgidldo=</code>	Temperature dependence of BGIDL for drain side.
478	<code>cgidlo=</code>	Back-bias dependence of GIDL.
479	<code>cgidldo=</code>	Back-bias dependence of GIDL for drain side.
480	<code>cgbovl=</code>	Oxide capacitance for gate-bulk overlap for 1 μm long channel.
481	<code>cfrw=</code>	Outer fringe capacitance for 1 μm wide channel.
482	<code>cfrdw=</code>	Outer fringe capacitance for 1 μm wide channel for drain side.
483	<code>fnto=</code>	Thermal noise coefficient.
484	<code>nfalw=</code>	First coefficient of flicker noise for 1 μm^2 channel area.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

485	<code>nfblw=</code>	Second coefficient of flicker noise for 1 μm^2 channel area.
486	<code>nfclw=</code>	Third coefficient of flicker noise for 1 μm^2 channel area.
487	<code>efo=</code>	Flicker noise frequency exponent.
488	<code>lintnoi=</code>	Length offset for flicker noise.
489	<code>alpnoi=</code>	Exponent for length offset for flicker noise.
490	<code>kvthoweo=</code>	Geometrical independent threshold shift parameter.
491	<code>kvthowel=</code>	Length dependent threshold shift parameter.
492	<code>kvthowew=</code>	Width dependent threshold shift parameter.
493	<code>kvthowelw=</code>	Area dependent threshold shift parameter.
494	<code>kuoweo=</code>	Geometrical independent mobility degradation factor.
495	<code>kuowel=</code>	Length dependent mobility degradation factor.
496	<code>kuowew=</code>	Width dependent mobility degradation factor.
497	<code>kuowelw=</code>	Area dependent mobility degradation factor.
498	<code>munqso=</code>	Relative mobility for NQS modelling.
499	<code>rgo=</code>	Gate resistance.
500	<code>rint=</code>	Contact resistance between silicide and poly.
501	<code>rvpoly=</code>	Vertical poly resistance.
502	<code>rshg=</code>	Gate electrode diffusion sheet resistance.
503	<code>dlsil=</code>	Silicide extension over the physical gate length.
504	<code>rsh=</code>	Sheet resistance of source diffusion.
505	<code>rshd=</code>	Sheet resistance of drain diffusion.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

506	<code>rbulko=</code>	Bulk resistance between node BP and BI.
507	<code>rwello=</code>	Well resistance between node BI and B.
508	<code>rjunso=</code>	Source-side bulk resistance between node BI and BS.
509	<code>rjundo=</code>	Drain-side bulk resistance between node BI and BD.
510	<code>saref=</code>	Reference distance between OD-edge and poly from one side.
511	<code>sbref=</code>	Reference distance between OD-edge and poly from other side.
512	<code>wlod=</code>	Width parameter.
513	<code>kuo=</code>	Mobility degradation/enhancement coefficient.
514	<code>kvsat=</code>	Saturation velocity degradation/enhancement coefficient.
515	<code>tkuo=</code>	Temperature dependence of KUO.
516	<code>lkuo=</code>	Length dependence of KUO.
517	<code>wkuo=</code>	Width dependence of KUO.
518	<code>pkuo=</code>	Cross-term dependence of KUO.
519	<code>llodkuo=</code>	Length parameter for UO stress effect.
520	<code>wlodkuo=</code>	Width parameter for UO stress effect.
521	<code>kvtho=</code>	Threshold shift parameter.
522	<code>lkvtho=</code>	Length dependence of KVTHO.
523	<code>wkvtho=</code>	Width dependence of KVTHO.
524	<code>pkvtho=</code>	Cross-term dependence of KVTHO.
525	<code>llodvth=</code>	Length parameter for VTH-stress effect.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

526	wlodvth=	Width parameter for VTH-stress effect.
527	stetao=	eta0 shift factor related to VTHO change.
528	lodetao=	eta0 shift modification factor for stress effect.
529	scref=	Distance between OD-edge and well edge of a reference device.
530	web=	Coefficient for SCB.
531	wec=	Coefficient for SCC.
532	imax=	Maximum current up to which forward current behaves exponentially.
533	trj=	reference temperature.
534	cjorbot=	Zero-bias capacitance per unit-of-area of bottom component for source-bulk junction.
535	cjorsti=	Zero-bias capacitance per unit-of-length of STI-edge component for source-bulk junction.
536	cjorgat=	Zero-bias capacitance per unit-of-length of gate-edge component for source-bulk junction.
537	vbirbot=	Built-in voltage at the reference temperature of bottom component for source-bulk junction.
538	vbirsti=	Built-in voltage at the reference temperature of STI-edge component for source-bulk junction.
539	vbirgat=	Built-in voltage at the reference temperature of gate-edge component for source-bulk junction.
540	pbot=	Grading coefficient of bottom component for source-bulk junction.
541	psti=	Grading coefficient of STI-edge component for source-bulk junction.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

542	<code>pgat=</code>	Grading coefficient of gate-edge component for source-bulk junction.
543	<code>phigbot=</code>	Zero-temperature bandgap voltage of bottom component for source-bulk junction.
544	<code>phigsti=</code>	Zero-temperature bandgap voltage of STI-edge component for source-bulk junction.
545	<code>phiggat=</code>	Zero-temperature bandgap voltage of gate-edge component for source-bulk junction.
546	<code>idsatrbot=</code>	Saturation current density at the reference temperature of bottom component for source-bulk junction.
547	<code>idsatrsti=</code>	Saturation current density at the reference temperature of STI-edge component for source-bulk junction.
548	<code>idsatrgat=</code>	Saturation current density at the reference temperature of gate-edge component for source-bulk junction.
549	<code>csrhibot=</code>	Shockley-Read-Hall prefactor of bottom component for source-bulk junction.
550	<code>csrhisti=</code>	Shockley-Read-Hall prefactor of STI-edge component for source-bulk junction.
551	<code>csrhgat=</code>	Shockley-Read-Hall prefactor of gate-edge component for source-bulk junction.
552	<code>xjunsti=</code>	Junction depth of STI-edge component for source-bulk junction.
553	<code>xjungat=</code>	Junction depth of gate-edge component for source-bulk junction.
554	<code>ctatbot=</code>	Trap-assisted tunneling prefactor of bottom component for source-bulk junction.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

555	<code>ctatsti=</code>	Trap-assisted tunneling prefactor of STI-edge component for source-bulk junction.
556	<code>ctatgat=</code>	Trap-assisted tunneling prefactor of gate-edge component for source-bulk junction.
557	<code>mefftatbot=</code>	Effective mass (in units of m_0) for trap-assisted tunneling of bottom component for source-bulk junction.
558	<code>mefftatsti=</code>	Effective mass (in units of m_0) for trap-assisted tunneling of STI-edge component for source-bulk junction.
559	<code>mefftatgat=</code>	Effective mass (in units of m_0) for trap-assisted tunneling of gate-edge component for source-bulk junction.
560	<code>cbbtbot=</code>	Band-to-band tunneling prefactor of bottom component for source-bulk junction.
561	<code>cbbtsti=</code>	Band-to-band tunneling prefactor of STI-edge component for source-bulk junction.
562	<code>cbbtgat=</code>	Band-to-band tunneling prefactor of gate-edge component for source-bulk junction.
563	<code>fbbtrbot=</code>	Normalization field at the reference temperature for band-to-band tunneling of bottom component for source-bulk junction.
564	<code>fbbtrsti=</code>	Normalization field at the reference temperature for band-to-band tunneling of STI-edge component for source-bulk junction.
565	<code>fbbtrgat=</code>	Normalization field at the reference temperature for band-to-band tunneling of gate-edge component for source-bulk junction.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

566	stfbbtbot=	Temperature scaling parameter for band-to-band tunneling of bottom component for source-bulk junction.
567	stfbbtsti=	Temperature scaling parameter for band-to-band tunneling of STI-edge component for source-bulk junction.
568	stfbbtgat=	Temperature scaling parameter for band-to-band tunneling of gate-edge component for source-bulk junction.
569	vbrbot=	Breakdown voltage of bottom component for source-bulk junction.
570	vbrsti=	Breakdown voltage of STI-edge component for source-bulk junction.
571	vbrgat=	Breakdown voltage of gate-edge component for source-bulk junction.
572	pbrbot=	Breakdown onset tuning parameter of bottom component for source-bulk junction.
573	pbrsti=	Breakdown onset tuning parameter of STI-edge component for source-bulk junction.
574	pbrgat=	Breakdown onset tuning parameter of gate-edge component for source-bulk junction.
575	cjorbotd=	Zero-bias capacitance per unit-of-area of bottom component for drain-bulk junction.
576	cjorstid=	Zero-bias capacitance per unit-of-length of STI-edge component for drain-bulk junction.
577	cjorgatd=	Zero-bias capacitance per unit-of-length of gate-edge component for drain-bulk junction.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

578	<code>vbirbotd=</code>	Built-in voltage at the reference temperature of bottom component for drain-bulk junction.
579	<code>vbirstid=</code>	Built-in voltage at the reference temperature of STI-edge component for drain-bulk junction.
580	<code>vbirgatd=</code>	Built-in voltage at the reference temperature of gate-edge component for drain-bulk junction.
581	<code>pbotd=</code>	Grading coefficient of bottom component for drain-bulk junction.
582	<code>pstid=</code>	Grading coefficient of STI-edge component for drain-bulk junction.
583	<code>pgatd=</code>	Grading coefficient of gate-edge component for drain-bulk junction.
584	<code>phigbotd=</code>	Zero-temperature bandgap voltage of bottom component for drain-bulk junction.
585	<code>phigstid=</code>	Zero-temperature bandgap voltage of STI-edge component for drain-bulk junction.
586	<code>phiggatd=</code>	Zero-temperature bandgap voltage of gate-edge component for drain-bulk junction.
587	<code>idsatrbotd=</code>	Saturation current density at the reference temperature of bottom component for drain-bulk junction.
588	<code>idsatrstid=</code>	Saturation current density at the reference temperature of STI-edge component for drain-bulk junction.
589	<code>idsatrgatd=</code>	Saturation current density at the reference temperature of gate-edge component for drain-bulk junction.
590	<code>csrbotd=</code>	Shockley-Read-Hall prefactor of bottom component for drain-bulk junction.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

591	<code>csrhistid=</code>	Shockley-Read-Hall prefactor of STI-edge component for drain-bulk junction.
592	<code>csrhgatd=</code>	Shockley-Read-Hall prefactor of gate-edge component for drain-bulk junction.
593	<code>xjunstid=</code>	Junction depth of STI-edge component for drain-bulk junction.
594	<code>xjungatd=</code>	Junction depth of gate-edge component for drain-bulk junction.
595	<code>ctatbotd=</code>	Trap-assisted tunneling prefactor of bottom component for drain-bulk junction.
596	<code>ctatstid=</code>	Trap-assisted tunneling prefactor of STI-edge component for drain-bulk junction.
597	<code>ctatgatd=</code>	Trap-assisted tunneling prefactor of gate-edge component for drain-bulk junction.
598	<code>mefftatbotd=</code>	Effective mass (in units of m_0) for trap-assisted tunneling of bottom component for drain-bulk junction.
599	<code>mefftatstid=</code>	Effective mass (in units of m_0) for trap-assisted tunneling of STI-edge component for drain-bulk junction.
600	<code>mefftatgatd=</code>	Effective mass (in units of m_0) for trap-assisted tunneling of gate-edge component for drain-bulk junction.
601	<code>cbbtbotd=</code>	Band-to-band tunneling prefactor of bottom component for drain-bulk junction.
602	<code>cbbtstid=</code>	Band-to-band tunneling prefactor of STI-edge component for drain-bulk junction.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

603	<code>cbbtgatd=</code>	Band-to-band tunneling prefactor of gate-edge component for drain-bulk junction.
604	<code>fbbtbotd=</code>	Normalization field at the reference temperature for band-to-band tunneling of bottom component for drain-bulk junction.
605	<code>fbbtstid=</code>	Normalization field at the reference temperature for band-to-band tunneling of STI-edge component for drain-bulk junction.
606	<code>fbbtgatd=</code>	Normalization field at the reference temperature for band-to-band tunneling of gate-edge component for drain-bulk junction.
607	<code>stfbbtbotd=</code>	Temperature scaling parameter for band-to-band tunneling of bottom component for drain-bulk junction.
608	<code>stfbbtstid=</code>	Temperature scaling parameter for band-to-band tunneling of STI-edge component for drain-bulk junction.
609	<code>stfbbtgatd=</code>	Temperature scaling parameter for band-to-band tunneling of gate-edge component for drain-bulk junction.
610	<code>vbrbotd=</code>	Breakdown voltage of bottom component for drain-bulk junction.
611	<code>vbrstid=</code>	Breakdown voltage of STI-edge component for drain-bulk junction.
612	<code>vbrgatd=</code>	Breakdown voltage of gate-edge component for drain-bulk junction.
613	<code>pbrbotd=</code>	Breakdown onset tuning parameter of bottom component for drain-bulk junction.
614	<code>pbrstid=</code>	Breakdown onset tuning parameter of STI-edge component for drain-bulk junction.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

615	pbrgatd=	Breakdown onset tuning parameter of gate-edge component for drain-bulk junction.
616	swjunexp=	Flag for JUNCAP-express; 0=full model, 1=express model.
617	vjunref=	Typical maximum source-bulk junction voltage; usually about 2*VSUP.
618	fjunq=	Fraction below which source-bulk junction capacitance components are considered negligible.
619	vjunrefd=	Typical maximum drain-bulk junction voltage; usually about 2*VSUP.
620	fjunqd=	Fraction below which drain-bulk junction capacitance components are considered negligible.
621	dta=	Temperature offset w.r.t. ambient temperature.
622	w=	Default width.
623	l=	Default length.
624	nf=	Number of fingers, It served as the default value of instance nf.
625	mvt=	DCmatch parameter.
626	mvto=	DCmatch parameter.
627	mbe=	DCmatch parameter.
628	mbeo=	DCmatch parameter.
629	dcmmbetn=	
630	betn_mismatch=	

Operating-Point Parameters

1	l=	Design length.
2	w=	Design width.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

3	sa=	Distance between OD-edge and poly from one side.
4	sb=	Distance between OD-edge and poly from other side.
5	sd=	Distance between neighbouring fingers.
6	sca=	Integral of the first distribution function for scattered well dopants.
7	scb=	Integral of the second distribution function for scattered well dopants.
8	scc=	Integral of the third distribution function for scattered well dopants.
9	sc=	Distance between OD-edge and nearest well edge.
10	nf=	Number of fingers.
11	ngcon=	Number of gate contacts.
12	xgw=	Distance from the gate contact to the channel edge.
13	nrs=	Number of squares of source diffusion.
14	nrd=	Number of squares of drain diffusion.
15	trise=	Temperature rise from ambient.
16	jw=	Gate-edge length of source/drain junction.
17	delvto=	Threshold voltage shift parameter.
18	factuo=	Zero-field mobility pre-factor.
19	absource=	Bottom area of source junction.
20	lssource=	STI-edge length of source junction.
21	lgsource=	Gate-edge length of source junction.
22	abdRAIN=	Bottom area of drain junction.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

23	lsdrain=	STI-edge length of drain junction.
24	lgdrain=	Gate-edge length of drain junction.
25	as=	Bottom area of source junction.
26	ps=	Perimeter of source junction.
27	ad=	Bottom area of drain junction.
28	pd=	Perimeter of drain junction.
29	mult=	Number of devices in parallel.
30	ctype	Flag for channel type.
31	sdint	Flag for source-drain interchange.
32	ise ()	Total source current.
33	ige ()	Total gate current.
34	ide ()	Total drain current.
35	ibe ()	Total bulk current.
36	ids ()	Drain current, excl. avalanche, tunnel, GISL, GIDL, and junction currents.
37	idb ()	Drain to bulk current.
38	isb ()	Source to bulk current.
39	igs ()	Gate-source tunneling current.
40	igd ()	Gate-drain tunneling current.
41	igb ()	Gate-bulk tunneling current.
42	igcs ()	Gate-channel tunneling current (source component.
43	igcd ()	Gate-channel tunneling current (drain component.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

44	<code>iavl ()</code>	Substrate current due to weak avalanche.
45	<code>igisl ()</code>	Gate-induced source leakage current.
46	<code>igidl ()</code>	Gate-induced drain leakage current.
47	<code>ijs ()</code>	Total source junction current.
48	<code>ijsbot ()</code>	Source junction current (bottom component.
49	<code>ijsgat ()</code>	Source junction current (gate-edge component.
50	<code>ijssti ()</code>	Source junction current (STI-edge component.
51	<code>ijd ()</code>	Total drain junction current.
52	<code>ijdbot ()</code>	Drain junction current (bottom component.
53	<code>ijdgat ()</code>	Drain junction current (gate-edge component.
54	<code>ijdsti ()</code>	Drain junction current (STI-edge component.
55	<code>qg</code>	Intrinsic gate charge.
56	<code>qd</code>	Intrinsic drain charge.
57	<code>qb</code>	Intrinsic bulk charge.
58	<code>qs</code>	Intrinsic source charge.
59	<code>qgs_ov</code>	Overlap charge for gate-source.
60	<code>qgd_ov</code>	Overlap charge for gate-drain.
61	<code>qfgs</code>	Total outerFringe + overlap for gate-source.
62	<code>qfgd</code>	Total outerFringe + overlap for gate-drain.
63	<code>qgb_ov</code>	Gate-bulk overlap charge.
64	<code>qjun_s</code>	Junction charge on source side.
65	<code>qjun_d</code>	Junction charge on drain side.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

66	v_{ds} ()	Drain-source voltage.
67	v_{gs} ()	Gate-source voltage.
68	v_{sb} ()	Source-bulk voltage.
69	v_{to} ()	Zero-bias threshold voltage.
70	v_{ts} ()	Threshold voltage including back bias effects.
71	v_{th} ()	Threshold voltage including back bias and drain bias effects.
72	v_{gt} ()	Effective gate drive voltage including back bias and drain bias effects.
73	v_{dss} ()	Drain saturation voltage at actual bias.
74	v_{sat}	Saturation limit.
75	g_m ()	Transconductance.
76	g_{mb} ()	Substrate transconductance.
77	g_{ds} ()	Output conductance.
78	g_{js} ()	Source junction conductance.
79	g_{jd} ()	Drain junction conductance.
80	c_{dd} ()	Drain capacitance.
81	c_{dg} ()	Drain-gate capacitance.
82	c_{ds} ()	Drain-source capacitance.
83	c_{db} ()	Drain-bulk capacitance.
84	c_{gd} ()	Gate-drain capacitance.
85	c_{gg} ()	Gate capacitance.
86	c_{gs} ()	Gate-source capacitance.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

87	<code>cgb</code> ()	Gate-bulk capacitance.
88	<code>csd</code> ()	Source-drain capacitance.
89	<code>csq</code> ()	Source-gate capacitance.
90	<code>css</code> ()	Source capacitance.
91	<code>csb</code> ()	Source-bulk capacitance.
92	<code>cbd</code> ()	Bulk-drain capacitance.
93	<code>cbg</code> ()	Bulk-gate capacitance.
94	<code>cbs</code> ()	Bulk-source capacitance.
95	<code>cbb</code> ()	Bulk capacitance.
96	<code>cgso1</code> ()	Total gate-source overlap capacitance.
97	<code>cgdo1</code> ()	Total gate-drain overlap capacitance.
98	<code>cjs</code> ()	Total source junction capacitance.
99	<code>cjsbot</code> ()	Source junction capacitance (bottom component.
100	<code>cjsgat</code> ()	Source junction capacitance (gate-edge component.
101	<code>cjssti</code> ()	Source junction capacitance (STI-edge component.
102	<code>cjd</code> ()	Total drain junction capacitance.
103	<code>cjdbot</code> ()	Drain junction capacitance (bottom component.
104	<code>cjdgat</code> ()	Drain junction capacitance (gate-edge component.
105	<code>cjdsti</code> ()	Drain junction capacitance (STI-edge component.
106	<code>weff</code> ()	Effective channel width for geometrical models.
107	<code>leff</code> ()	Effective channel length for geometrical models.
108	<code>u</code>	Transistor gain.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

109	<code>rout</code> ()	Small-signal output resistance.
110	<code>vearly</code> ()	Equivalent Early voltage.
111	<code>beff</code> ()	Gain factor.
112	<code>fug</code> ()	Unity gain frequency at actual bias.
113	<code>rg</code> ()	Gate resistance.
114	<code>sfl</code>	Flicker noise current density at 1 Hz.
115	<code>sqrtsff</code>	Input-referred RMS white noise voltage density at 1 kHz.
116	<code>sqrtsfw</code>	Input-referred RMS white noise voltage density.
117	<code>sid</code>	White noise current density.
118	<code>sig</code>	Induced gate noise current density at 1 Hz.
119	<code>cigid</code>	Imaginary part of correlation coefficient between Sig and Sid.
120	<code>fknee</code>	Cross-over frequency above which white noise is dominant.
121	<code>sig_s</code>	Gate-source current noise spectral density.
122	<code>sig_d</code>	Gate-drain current noise spectral density.
123	<code>siavl</code>	Impact ionization current noise spectral density.
124	<code>ssi</code>	Total source junction current noise spectral density.
125	<code>sdi</code>	Total drain junction current noise spectral density.
126	<code>lp_vfb</code> ()	Local parameter VFB after T-scaling and clipping.
127	<code>lp_stvfb</code> ()	Local parameter STVFB after clipping.
128	<code>lp_tox</code> ()	Local parameter TOX after clipping.
129	<code>lp_epsrox</code>	Local parameter EPSROX after clipping.
130	<code>lp_neff</code> ()	Local parameter NEFF after clipping.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

131	<code>lp_facneffac</code>	Local parameter FACNEFFAC after clipping.
132	<code>lp_gfacnud</code>	Local parameter GFACNUD after clipping.
133	<code>lp_vsbnud ()</code>	Local parameter VSBNUD after clipping.
134	<code>lp_dvsbnud ()</code>	Local parameter DVSBNUD after clipping.
135	<code>lp_vnsub ()</code>	Local parameter VNSUB after clipping.
136	<code>lp_nslp ()</code>	Local parameter NSLP after clipping.
137	<code>lp_dnsud ()</code>	Local parameter DNSUD after clipping.
138	<code>lp_dphib ()</code>	Local parameter DPHIB after clipping.
139	<code>lp_delvtac ()</code>	Local parameter DELVTAC after clipping.
140	<code>lp_np ()</code>	Local parameter NP after clipping.
141	<code>lp_ct</code>	Local parameter CT after clipping.
142	<code>lp_toxov ()</code>	Local parameter TOXOV after clipping.
143	<code>lp_toxovd ()</code>	Local parameter TOXOVD after clipping.
144	<code>lp_nov ()</code>	Local parameter NOV after clipping.
145	<code>lp_novd ()</code>	Local parameter NOVD after clipping.
146	<code>lp_cf</code>	Local parameter CF after clipping.
147	<code>lp_cfb ()</code>	Local parameter CFB after clipping.
148	<code>lp_betn ()</code>	Local parameter BETN after T-scaling and clipping.
149	<code>lp_stbet</code>	Local parameter STBET after clipping.
150	<code>lp_mue ()</code>	Local parameter MUE after T-scaling and clipping.

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PSP Model (psp)

151	<code>lp_stmue</code>	Local parameter STMUE after clipping.
152	<code>lp_themu</code>	Local parameter THEMU after T-scaling and clipping.
153	<code>lp_stthemu</code>	Local parameter STTHEMU after clipping.
154	<code>lp_cs</code>	Local parameter CS after T-scaling and clipping.
155	<code>lp_stcs</code>	Local parameter STCS after clipping.
156	<code>lp_xcor ()</code>	Local parameter XCOR after T-scaling and clipping.
157	<code>lp_stxcor</code>	Local parameter STXCOR after clipping.
158	<code>lp_feta</code>	Local parameter FETA after clipping.
159	<code>lp_rs ()</code>	Local parameter RS after T-scaling and clipping.
160	<code>lp_strs</code>	Local parameter STRS after clipping.
161	<code>lp_rsb ()</code>	Local parameter RSB after clipping.
162	<code>lp_rsg ()</code>	Local parameter RSG after clipping.
163	<code>lp_thesat ()</code>	Local parameter THESAT after T-scaling and clipping.
164	<code>lp_stthesat</code>	Local parameter STTHESAT after clipping.
165	<code>lp_thesatb ()</code>	Local parameter THESATB after clipping.
166	<code>lp_thesatg ()</code>	Local parameter THESATG after clipping.
167	<code>lp_ax</code>	Local parameter AX after clipping.
168	<code>lp_alp</code>	Local parameter ALP after clipping.
169	<code>lp_alp1 ()</code>	Local parameter ALP1 after clipping.
170	<code>lp_alp2 ()</code>	Local parameter ALP2 after clipping.

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

171	lp_vp ()	Local parameter VP after clipping.
172	lp_a1	Local parameter A1 after clipping.
173	lp_a2 ()	Local parameter A2 after T-scaling and clipping.
174	lp_sta2	Local parameter STA2 after clipping.
175	lp_a3	Local parameter A3 after clipping.
176	lp_a4 ()	Local parameter A4 after clipping.
177	lp_gco	Local parameter GCO after clipping.
178	lp_iginv ()	Local parameter IGINV after T-scaling and clipping.
179	lp_igov ()	Local parameter IGOV after T-scaling and clipping.
180	lp_igovd ()	Local parameter IGOVD after T-scaling and clipping.
181	lp_stig	Local parameter STIG after clipping.
182	lp_gc2	Local parameter GC2 after clipping.
183	lp_gc3	Local parameter GC3 after clipping.
184	lp_chib ()	Local parameter CHIB after clipping.
185	lp_agidl ()	Local parameter AGIDL after clipping.
186	lp_agidld ()	Local parameter AGIDLD after clipping.
187	lp_bgidl ()	Local parameter BGIDL after T-scaling and clipping.
188	lp_bgidld ()	Local parameter BGIDLD after T-scaling and clipping.
189	lp_stbgidl ()	Local parameter STBGIDL after clipping.

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PSP Model (psp)

190 lp_stbgidld ()	Local parameter STBGIDLD after clipping.
191 lp_cgidl	Local parameter CGIDL after clipping.
192 lp_cgidld	Local parameter CGIDLD after clipping.
193 lp_cox ()	Local parameter COX after clipping.
194 lp_cgov ()	Local parameter CGOV after clipping.
195 lp_cgovd ()	Local parameter CGOVD after clipping.
196 lp_cgbov ()	Local parameter CGBOV after clipping.
197 lp_cfr ()	Local parameter CFR after clipping.
198 lp_cfrd ()	Local parameter CFRD after clipping.
199 lp_fnt	Local parameter FNT after clipping.
200 lp_nfa ()	Local parameter NFA after clipping.
201 lp_nfb ()	Local parameter NFB after clipping.
202 lp_nfc ()	Local parameter NFC after clipping.
203 lp_ef	Local parameter EF after clipping.
204 lp_rg ()	Local parameter RG after clipping.
205 lp_rse ()	Local parameter RSE after clipping.
206 lp_rde ()	Local parameter RDE after clipping.
207 lp_rbulk ()	Local parameter RBULK after clipping.
208 lp_rwell ()	Local parameter RWELL after clipping.
209 lp_rjuns ()	Local parameter RJUNS after clipping.

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PSP Model (psp)

210	lp_rjund ()	Local parameter RJUND after clipping.
211	lp_munqs	Local parameter MUNQS after clipping.
212	m=	Alias of mult.
213	table_ids ()	For table model.
214	table_vth ()	For table model.
215	table_qg ()	For table model.
216	table_qd ()	For table model.
217	table_qb ()	For table model.
218	table_id ()	For table model.
219	table_isub ()	For table model.
220	table_ibs ()	For table model.
221	table_ibd ()	For table model.
222	table_igd ()	For table model.
223	table_igb ()	For table model.
224	table_igs ()	For table model.
225	table_gds ()	For table model.
226	table_gm ()	For table model.
227	table_gmbs ()	For table model.
228	table_qbs ()	For table model.
229	table_qbd ()	For table model.
230	table_vdsat ()	For table model.
231	table_leff ()	For table model.

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PSP Model (psp)

232	<code>table_weff</code>	()	For table model.
233	<code>table_aseff</code>	()	For table model.
234	<code>table_adeff</code>	()	For table model.
235	<code>table_pseff</code>	()	For table model.
236	<code>table_pdeff</code>	()	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.

<code>a1</code>	M-62	<code>iginv</code>	M-68	<code>plalp</code>	M-214	<code>qs</code>	OP-58
<code>a1l</code>	M-454	<code>iginvlw</code>	M-465	<code>plalpl</code>	M-218	<code>rbulk</code>	M-98
<code>a1o</code>	M-453	<code>igisl</code>	OP-45	<code>plalp2</code>	M-222	<code>rbulko</code>	M-506
<code>a1w</code>	M-455	<code>igov</code>	M-69	<code>plax</code>	M-210	<code>rde</code>	M-97
<code>a2</code>	M-63	<code>igovd</code>	M-70	<code>plbetn</code>	M-161	<code>rg</code>	M-95
<code>a2o</code>	M-456	<code>igovdw</code>	M-467	<code>plcf</code>	M-156	<code>rg</code>	OP-113
<code>a3</code>	M-65	<code>igovw</code>	M-466	<code>plcfr</code>	M-288	<code>rgo</code>	M-499
<code>a3l</code>	M-459	<code>igs</code>	OP-39	<code>plcfrd</code>	M-292	<code>rint</code>	M-500
<code>a3o</code>	M-458	<code>ijd</code>	OP-51	<code>plcgbv</code>	M-284	<code>rjund</code>	M-101
<code>a3w</code>	M-460	<code>ijdbot</code>	OP-52	<code>plcgov</code>	M-276	<code>rjundo</code>	M-509
<code>a4</code>	M-66	<code>ijdgat</code>	OP-53	<code>plcgovd</code>	M-280	<code>rjuns</code>	M-100

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PSP Model (psp)

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
absorce I-19	imax M-532	plfacneffac M-117	rse M-96
absorce OP-19	isb OP-38	plgfacnud M-121	rsg M-52
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
agidd M-76	jw OP-16	plkuowe M-314	rshg M-502
agiddw 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
alpll1 M-444	kuowew M-496	plnfb M-301	rwello M-507
alpll2 M-446	kvsat M-514	plnfc M-305	sa I-3
alpllexp M-445	kvtho M-521	plnov M-148	sa OP-3
alplw M-447	kvthowel M-491	plnovd M-152	saref M-510
alp2 M-60	kvthowelw M-493	plnp M-138	sb I-4

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PSP Model (psp)

alp2l1	M-448	kvthoweo	M-490	plrs	M-187	sb	OP-4
alp2l2	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
alpl	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
as	I-25	lgdrain	I-24	plwal	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
axl	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	plwcfrr	M-290	sigd	OP-122

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PSP Model (psp)

bgidldo M-475	lov M-384	plwcfird M-294	sigs OP-121
bgidlo M-474	lovd M-385	plwcgbov M-286	sqrtsff 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	plwdehvtac M-136	stbetl M-403
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_agidld 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	stbgidld 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	stfbtbot M-566
cf1 M-388	lp_cfb OP-147	plwnfb M-303	stfbtbotd M-607

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PSP Model (psp)

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_cgidd 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
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
cgidd M-82	lp_dphib OP-138	plxcor M-181	stthesatl M-434
cgiddo 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

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PSP Model (psp)

cgsol	OP-96	lp_fnt	OP-199	poagidld	M-261	stvfblw	M-338
chib	M-74	lp_gc2	OP-182	poalp	M-213	stvfbo	M-335
chibo	M-471	lp_gc3	OP-183	poalpl	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
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

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PSP Model (psp)

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
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
csrhisti	M-550	lp_stbgidld	OP-190	pogc3	M-255	table_qb	OP-217
csrhistid	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

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PSP Model (psp)

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
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
dcmmbetn	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	toxov	M-32
delvtacw	M-373	lsdrain	I-23	postbgidld	M-268	toxovd	M-33
delvto	I-17	lsdrain	OP-23	postcs	M-179		

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PSP Model (psp)

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	lvarl	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
dphibl	M-366	m	OP-212	postxcor	M-184	type	M-2
dphiblexp	M-367	mbe	M-627	pothemu	M-173	u	OP-108
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	vbrbot	M-569
efo	M-487	mue	M-40	povp	M-225	vbrbotd	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

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PSP Model (psp)

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	pwal	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
fbbtrbot	M-563	nf	I-10	pwagidl	M-259	vfb1	M-332
fbbtrbotd	M-604	nf	M-624	pwagidld	M-263	vfb1w	M-334
fbbtrgat	M-565	nf	OP-10	pwalp	M-215	vfbo	M-331
fbbtrgatd	M-606	nfa	M-90	pwalp1	M-219	vfbw	M-333
fbbtrsti	M-564	nfalw	M-484	pwalp2	M-223	vgs	OP-67
fbbtrstid	M-605	nfb	M-91	pwax	M-211	vgt	OP-72
fbet1	M-393	nfb1w	M-485	pwbetn	M-162	vjunref	M-617
fbet1w	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

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

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
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	pkvthowe	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	pwrns	M-188	wot	M-328

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

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
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	qid	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		

Virtuoso Simulator Components and Device Models Reference

PSP Model (psp)

PSP-Based MOS Varactor Model (mosvar)

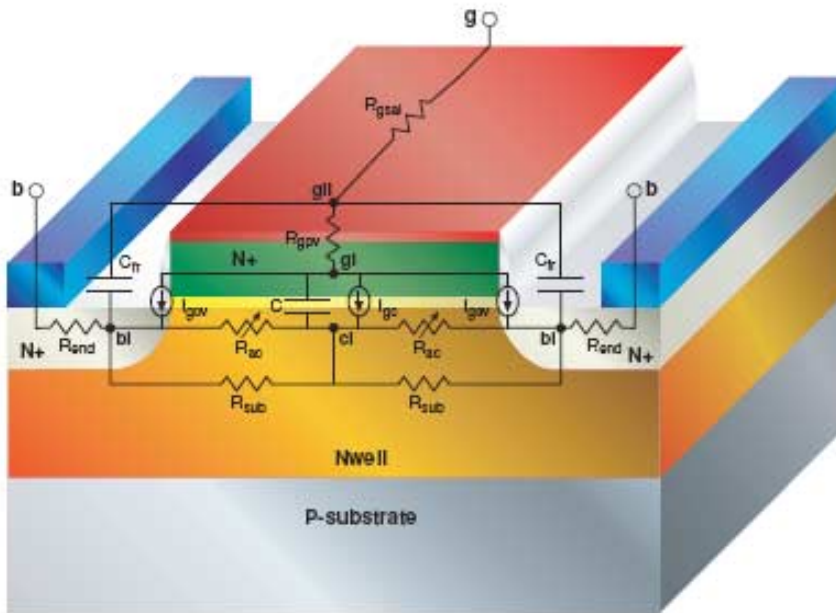
The PSP-based varactor model is intended for analog and radio-frequency circuit design. It includes dynamic inversion, finite poly doping, quantum mechanics, gate tunneling for different polarity combinations, and parasitics to model advanced MOS technologies.

This chapter contains the following information about the PSP model:

- [Device Structure](#) on page 1788
- [RC Circuit Model for Inversion Charge](#) on page 1789
- [Parameter Initializing](#) on page 1789
- [Parameter Extraction](#) on page 1795
- [Component Statements](#) on page 1796

Device Structure

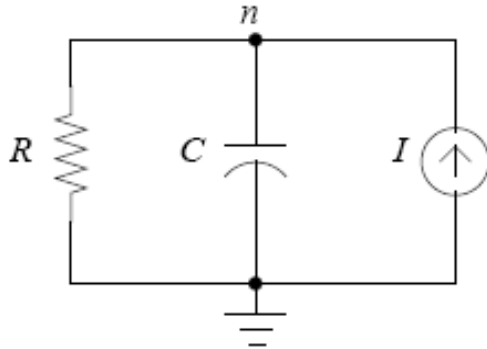
The following figure shows a cross section of the standard MOS varactor offered in the current MOS technologies with its equivalent circuit model overlapped on it. g , bi and b are the external terminals while gii , gi and ci are the internal nodes.



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

RC Circuit Model for Inversion Charge



$$q_i = q_{i0} - \mathbf{TAU} \cdot \frac{dq_i}{dt}$$

Parameter Initializing

Capacitance of Oxide and Body Factors

$$C_{ox} = \epsilon_{ox} / \mathbf{TOXO}$$

$$\gamma_s = \sqrt{2 \cdot q \cdot \epsilon_{si} \cdot \mathbf{NSUBO}} / C_{ox}$$

$$\gamma_p = \sqrt{2 \cdot q \cdot \epsilon_{si} \cdot \mathbf{NPO}} / C_{ox}$$

$$\gamma_{ov,s} = \sqrt{2 \cdot q \cdot \epsilon_{si} \cdot \mathbf{NOVO}} / C_{ox}$$

$$\text{If } \mathbf{QMC} > 0 \quad q_q = \begin{cases} 0.4 \cdot \mathbf{QMN} \cdot \mathbf{QMC} \cdot (C_{ox})^{2/3}, & \text{if } \mathbf{TYPE} > 0 \\ 0.4 \cdot \mathbf{QMP} \cdot \mathbf{QMC} \cdot (C_{ox})^{2/3}, & \text{otherwise} \end{cases}$$

$$\text{else } q_q = 0$$

$$\eta_\mu = \begin{cases} 0.5 \cdot \mathbf{FETA}, & \text{if } \mathbf{TYPE} > 0 \\ \frac{1}{3} \cdot \mathbf{FETA}, & \text{otherwise} \end{cases}$$

$$\mathit{norm}_{tox} = \mathbf{TOXO} / 10^{-9};$$

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

$$nt0 = 4 \cdot \text{KBOL} \cdot T_{\text{KD}}$$

$$L_{\text{eff}} = L + \text{DLQ}$$

$$W_{\text{eff}} = W + \text{DWQ}$$

$$M_{\text{eff}} = M_{\text{SEG}} \cdot \text{MFACTOR_USE}$$

$$\text{INV}_{\text{Meff}} = 1.0 / M_{\text{eff}}$$

$$E_g = 1.179 - T_{\text{KD}} \cdot (9.025 \cdot 10^{-5} + 3.05 \cdot 10^{-7} \cdot T_{\text{KD}})$$

$$r_T = (1.045 + 4.5 \cdot 10^{-4} \cdot T_{\text{KD}}) \cdot (0.523 + 1.4 \cdot 10^{-3} \cdot T_{\text{KD}} - 1.48 \cdot 10^{-6} \cdot T_{\text{KD}}^2) \cdot \frac{T_{\text{KD}}^2}{90000}$$

$$\text{INV}_{\text{ni}} = 4 \cdot 10^{-26} \cdot r_T^{-0.75}$$

$$\phi_b = E_g + 2 \cdot \phi_T \cdot \ln(\text{NSUBO} \cdot \text{INV}_{\text{ni}})$$

$$k_{\text{se1}} = 230.26$$

$$k_{\text{se2}} = 460.52$$

Parameters Related to Polysilicon and Overlap Regions

$$G_p = \gamma_p / \sqrt{\phi_T}$$

$$\xi_p = 1 + G_p / \sqrt{2}$$

$$x_{\text{nrpp}} = 10^{-5} \cdot \xi_p$$

$$\phi_p = E_g + 2 \cdot \phi_T \cdot \ln(\text{NPO} \cdot \text{INV}_{\text{ni}})$$

$$x_{\text{np}} = \phi_p / \phi_T$$

$$\Delta_{\text{np}} = \begin{cases} \exp(-x_{\text{np}}), & \text{if } x_{\text{np}} < k_{\text{se2}} \\ \frac{10^{-200}}{\text{P3}(x_{\text{np}} - k_{\text{se2}})}, & \text{otherwise} \end{cases}$$

$$G_{\text{ov},s} = \gamma_{\text{ov},s} / \sqrt{\phi_T}$$

$$\xi_{\text{ov},s} = 1 + G_{\text{ov},s} / \sqrt{2}$$

$$x_{\text{nrpov},s} = 10^{-5} \cdot \xi_{\text{ov},s}$$

$$\phi_{\text{b,ov}} = E_g + 6 \cdot \phi_T$$

$$x_1 = 1.25$$

$$x_{\text{gl,ov}} = x_1 + G_{\text{ov},s} \cdot \sqrt{\exp(-x_1) + x_1 - 1}$$

Resistances

$$\begin{array}{l}
 \text{If SWRES} = \text{true} \left\{ \begin{array}{l}
 R_{gsal} = \frac{R_{shg, T} \cdot W}{L \cdot [3 + 9 \cdot (\text{NGCON} - 1)] \cdot M_{eff}} \\
 R_{gpv} = \frac{R_{pv, T}}{W \cdot L \cdot M_{eff}} \\
 R_{end} = \frac{R_{end, T}}{2 \cdot (W + \text{DWR}) \cdot M_{eff}} \\
 R_{sub} = \frac{R_{shs, T} \cdot L}{12 \cdot (W + \text{DWR}) \cdot M_{eff}} \\
 R_{gsal} = \text{'CLIP_BOTH}(R_{gsal}, 1.0e - 03, 1e01) \\
 R_{gpv} = \text{'CLIP_BOTH}(R_{gpv}, 1.0e - 03, 1e02) \\
 R_{end} = \text{'CLIP_BOTH}(R_{end}, 1.0e - 03, 1e01) \\
 R_{sub} = \text{'CLIP_BOTH}(R_{sub}, 1.0e - 03, 1e03) \\
 U_{ac, T} = \text{'CLIP_BOTH}(U_{ac, T}, 1.0e - 03, 2e01) \\
 G_{gsal} = 1/R_{gsal} \\
 G_{gpv} = 1/R_{gpv} \\
 G_{end} = 1/R_{end} \\
 G_{sub} = 1/R_{sub} \\
 G_{ac0} = 12 \cdot U_{ac, T} \cdot M_{eff} \cdot W/L
 \end{array} \right.
 \end{array}$$

$$\text{If SWRES} = \text{false} \left\{ \begin{array}{l}
 G_{gsal} = 0.0 \\
 G_{gpv} = 0.0 \\
 G_{end} = 0.0 \\
 G_{sub} = 0.0 \\
 G_{ac0} = 0.0
 \end{array} \right.$$

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, $Q_{CQ} = -0.495 \cdot GC2O/GC3O$, 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_0 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

$$C_{fr} = 2 \cdot CFRW \cdot W + 2 \cdot CFRL \cdot L$$

Auxiliary Equations

$$\text{MINA}(x, y, a) = \frac{1}{2} \cdot \left[x + y - \sqrt{(x - y)^2 + a} \right]$$

$$\text{MAXA}(x, y, a) = \frac{1}{2} \cdot \left[x + y + \sqrt{(x - y)^2 + a} \right]$$

$$v = a + c$$

$$\mu_1 = \frac{v^2}{\tau} + \frac{c^2}{2} - a$$

$$\sigma_1(a, c, \tau, \eta) = \frac{a \cdot v}{\mu_1 + (c^2/3 - a) \cdot c \cdot v / \mu_1} + \eta$$

$$\mu_2 = \frac{v^2}{\tau} + \frac{c^2}{2} - a \cdot b$$

$$\sigma_2(a, b, c, \tau, \eta) = \frac{a \cdot v}{\mu_2 + (c^2/3 - a \cdot b) \cdot c \cdot v / \mu_2} + \eta$$

$$\text{P3}(u) = 1 + u \cdot [1 + 0.5 \cdot u \cdot (1 + u/3)]$$

$$\text{expl}(x) = \begin{cases} \exp(x), & \text{if } |x| < k_{\text{se1}} \\ \frac{10^{-100}}{\text{P3}(-k_{\text{se1}} - x)}, & \text{if } x < -k_{\text{se1}} \\ 10^{100} \cdot \text{P3}(x - k_{\text{se1}}), & \text{otherwise} \end{cases}$$

$$\text{expl}_{\text{low}}(x) = \begin{cases} \exp(x), & \text{if } x > -k_{\text{se1}} \\ \frac{10^{-100}}{\text{P3}(-k_{\text{se1}} - x)}, & \text{otherwise} \end{cases}$$

$$\text{expl}_{\text{high}}(x) = \begin{cases} \exp(x), & \text{if } x < k_{\text{se1}} \\ 10^{100} \cdot \text{P3}(x - k_{\text{se1}}), & \text{otherwise} \end{cases}$$

Component Statements

MOSVAR Model 1.1.0

This is MOSVAR 1.1.0

This device is supported within altergroups.

Virtuoso Simulator Components and Device Models Reference

PSP-Based MOS Varactor Model (mosvar)

Instance Definition

Name g bi b ModelName <parameter=value> ...

Instance Parameters

- | | | |
|---|-----------|-------------------------------------|
| 1 | m=1.0 | Multiplicity factor. |
| 2 | w=1.0e-06 | Design width of varactor. |
| 3 | l=1.0e-06 | Design length of varactor. |
| 4 | ngcon=1 | Number of gate contacts. |
| 5 | dta=0.0 | Local temperature delta to ambient. |

Model Parameters

- | | | |
|----|----------------|--|
| 1 | version=1.1 | Model version. |
| 2 | subversion=0.0 | Model subversion. |
| 3 | revision=0.0 | Model revision. |
| 4 | level=1000 | Model level. |
| 5 | tmin=-100.0 | Minimum reference/ambient temperature. |
| 6 | tmax=500.0 | Maximum reference/ambient temperature. |
| 7 | vmax=10000.0 | Maximum voltage applied between nodes g and b. |
| 8 | tr=21.0 | Nominal (reference) temperature. |
| 9 | lmin=1.0e-08 | Minimum allowed drawn length. |
| 10 | lmax=9.9e+09 | Maximum allowed drawn length. |
| 11 | wmin=1.0e-08 | Minimum allowed drawn width. |
| 12 | wmax=9.9e+09 | Maximum allowed drawn width. |

Virtuoso Simulator Components and Device Models Reference

PSP-Based MOS Varactor Model (mosvar)

13	swres=1	Switch to control series resistance: 0=exclude and 1=include.
14	type=-1	Substrate doping TYPE: -1=n-TYPE and +1=p-TYPE.
15	typep=-1	Polysilicon doping TYPE: -1=n-TYPE and +1=p-TYPE.
16	tox=20.0e-10	Oxide thickness.
17	tau=0.1	Time constant for inversion charge recombination/generation.
18	vfbo=0.0	Flatband voltage (for p-TYPE substrate).
19	nsubo=3.0e+23	Substrate doping level.
20	mnsbo=1.0	Maximum change in absolute doping, limited to 1 order of mag up.
21	dnsubo=0.0	Doping profile slope parameter.
22	vnsbo=0.0	Doping profile corner voltage parameter.
23	nslo=0.1	Doping profile smoothing parameter.
24	npo=1.0e+27	Polysilicon doping level.
25	qmc=1.0	Quantum mechanical correction factor.
26	dlq=0.0	Length delta for capacitor size.
27	dwq=0.0	Width delta for capacitor size.
28	dwr=0.0	Width delta for substrate resistance calculation.
29	cfri=0.0	Fringing capacitance in length direction.
30	cfriw=0.0	Fringing capacitance in width direction.
31	rshg=1.0	Gate sheet resistance.
32	rpv=0.0	Vertical resistance down through gate in units of ohm*m ² .
33	rend=1.0e-04	End resistance (extrinsic well res. plus vertical contact res. to well) per width.

Virtuoso Simulator Components and Device Models Reference

PSP-Based MOS Varactor Model (mosvar)

34	rshs=1000.0	Substrate sheet resistance.
35	uac=5.0e-02	Accumulation layer zero bias mobility.
36	uacred=0.0	Accumulation layer mobility degradation factor.
37	stvfb=0.0	Temperature dependence of VFB.
38	strshg=0.0	Temperature dependence of RSHG.
39	strpv=0.0	Temperature dependence of RPV.
40	strend=0.0	Temperature dependence of REND.
41	strshs=0.0	Temperature dependence of RSHS.
42	stuac=0.0	Temperature dependence of UAC.
43	feta=1.0	Effective field parameter.
44	swigate=0	Flag for gate current: 0=turn off and 1=turn on.
45	chibo=3.1	Tunneling barrier height for electrons.
46	chibpo=4.5	Tunneling barrier height for holes.
47	stig=2.0	Common temperature coefficient for gate currents(ECB, HVB and HVB).
48	lov=0.0	Overlap length.
49	novo=5.0e+25	Effective doping level of overlap regions.
50	iginvlw=0.0	ECB gate channel current pre-factor for 1 um ² channel area.
51	igovw=0.0	ECB gate overlap current pre-factor for 1 um wide gate overlap region.
52	gcoo=0.0	ECB gate tunneling energy adjustment.
53	gc2o=0.375	ECB gate current slope factor.
54	gc3o=0.063	ECB gate current curvature factor.

Virtuoso Simulator Components and Device Models Reference

PSP-Based MOS Varactor Model (mosvar)

55	igchvlw=0.0	HVB gate channel current pre-factor for 1 um ² channel area.
56	igovhvw=0.0	HVB gate overlap current pre-factor for 1 um wide gate overlap region.
57	gcohvo=0.0	HVB gate tunneling energy adjustment.
58	gc2hvo=0.375	HVB gate current slope factor.
59	gc3hvo=0.063	HVB gate current curvature factor.
60	minr=0.001	Minimum resistor between bi and b.
61	igmax=1.0e-05	Maximum gate tunneling current.

Operating-Point Parameters

1	m=1.0	Multiplicity factor.
2	w=1.0e-06	Design width of varactor.
3	l=1.0e-06	Design length of varactor.
4	ngcon=1	Number of gate contacts.
5	dta=0.0	Local temperature delta to 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.

cfrl	M-29	iginvlw	M-50	nsipo	M-23	tau	M-17
cfrw	M-30	igmax	M-61	nsubo	M-19	tmax	M-6
chibo	M-45	igovhvw	M-56	qmc	M-25	tmin	M-5

Virtuoso Simulator Components and Device Models Reference

PSP-Based MOS Varactor Model (mosvar)

chibpo M-46	igovw M-51	rend M-33	toxox M-16
dlq M-26	l I-3	revision M-3	tr M-8
dnsubo M-21	l OP-3	rpv M-32	type M-14
dta I-5	level M-4	rshg M-31	typep M-15
dta OP-5	lmax M-10	rshs M-34	uac M-35
dwq M-27	lmin M-9	stig M-47	uacred M-36
dwr M-28	lov M-48	strend M-40	version M-1
feta M-43	m I-1	strpv M-39	vfbo M-18
gc2hvo M-58	m OP-1	strshg M-38	vmax M-7
gc2o M-53	minr M-60	strshs M-41	vnsubo M-22
gc3hvo M-59	mnsubo M-20	stuac M-42	w I-2
gc3o M-54	ngcon I-4	stvfb M-37	w OP-2
gcohvo M-57	ngcon OP-4	subversion M-2	wmax M-12
gcoo M-52	novo M-49	swigate M-44	wmin M-11
igchvlw M-55	npo M-24	swres M-13	

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 1804
- [Bulk Reference and Symmetry](#) on page 1804
- [Equivalent Circuit](#) on page 1805
- [Static Intrinsic Model](#) on page 1806
- [Quasi-static Model](#) on page 1814
- [Nonquasi-static \(NQS\) Model](#) on page 1817
- [Intrinsic Noise Model](#) on page 1818
- [Scaling Effects](#) on page 1819
- [Component Statements](#) on page 1819

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:

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EKV MOSFET Model (ekv)

$V_G = V_{GB}$ Intrinsic gate-to-bulk voltage

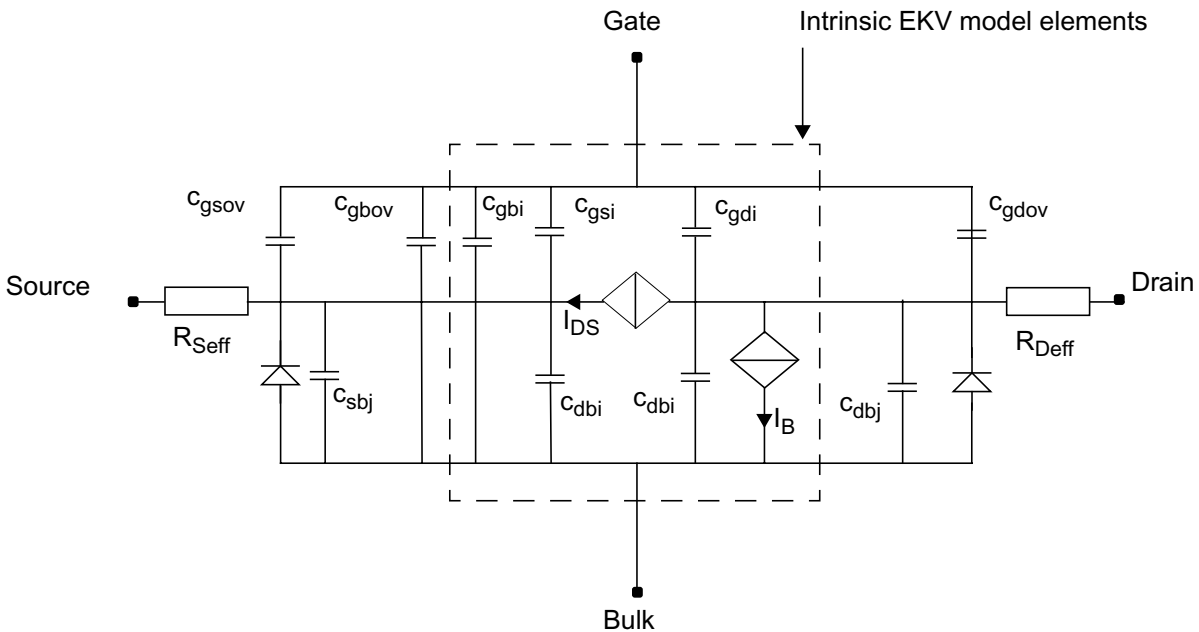
$V_S = V_{SB}$ Intrinsic source-to-bulk voltage

$V_D = V_{DB}$ 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

$$\epsilon_0 \epsilon_{si} = SCALE \cdot 104.5 \times 10^{-12} [F/m]$$

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 13, “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*:

Virtuoso Simulator Components and Device Models Reference

EKV MOSFET Model (ekv)

$$E0 = \begin{cases} 0 & \text{if } THETA \text{ specified} \\ \text{default} & \text{otherwise} \end{cases}$$

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:

Virtuoso Simulator Components and Device Models Reference

EKV MOSFET Model (ekv)

$$VTO_a = VTO + \frac{AVTO}{\sqrt{NP \cdot W_{eff} \cdot NS \cdot L_{eff}}}$$

$$KP_a = KP \cdot \left(1 + \frac{AKP}{\sqrt{NP \cdot W_{eff} \cdot NS \cdot L_{eff}}} \right)$$

$$GAMMA_a = GAMMA + \frac{AGAMMA}{\sqrt{NP \cdot W_{eff} \cdot NS \cdot L_{eff}}}$$

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

$$\Delta V = 4 \cdot V_t \cdot \sqrt{LAMBDA \cdot \left(\sqrt{i_f} - \frac{V_{DSS}}{V_t} \right) + \frac{1}{64}}$$

$$\Delta L = LAMBDA \cdot L_C \cdot \ln \left(1 + \frac{V_{ds} - V_{ip}}{L_C \cdot UCRIT} \right)$$

$$V_{ds} = \frac{V_D - V_S}{2}$$

$$L_C = \sqrt{\frac{\epsilon_0 \epsilon_{si}}{COX}} \cdot XJ$$

$$V_{ip} = \sqrt{V_{DSS}^2 + \Delta V^2} - \sqrt{(V_{ds} - V_{DSS})^2 + \Delta V^2}$$

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 1815.

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,

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

$$x_f = \sqrt{\frac{1}{4} + i_f}$$

$$x_r = \sqrt{\frac{1}{4} + i_r}$$

$$q_{Q_d} = -n_q \cdot \left(\frac{4}{15} \cdot \frac{3x_r^3 + 6x_r^2 x_f + 4x_r x_f^2 + 2x_f^3}{(x_f + x_r)^2} - \frac{1}{2} \right)$$

$$q_S = -n_q \cdot \left(\frac{4}{15} \cdot \frac{3x_f^3 + 6x_f^2 x_r + 4x_f x_r^2 + 2x_r^3}{(x_f + x_r)^2} - \frac{1}{2} \right)$$

$$q_I = q_S + q_D = -n_q \cdot \left(\frac{4}{3} \cdot \frac{x_f^2 + x_f x_r + x_r^2}{x_f + x_r} - 1 \right)$$

$$q_B = \begin{cases} \left(-GAMMA_a \cdot \sqrt{V_P + PHI + 10^{-6}} \right) \cdot \frac{1}{V_t} - \left(\frac{n_q - 1}{n_q} \right) \cdot q_I & \text{for } V'_G > 0 \\ -V'_G \cdot \frac{1}{V_t} & \text{for } V'_G \leq 0 \end{cases}$$

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EKV MOSFET Model (ekv)

$$q_G = -q_I - q_{OX} - q_B$$

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 1805 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`,

$$S_{flicker} = \frac{KF \times |I_{ds}|^{AF}}{NP \cdot W_{eff} \cdot NS \cdot L_{eff} \cdot COX \cdot f^{EF}}$$

When model parameter `noisemod=2`,

$$S_{flicker} = \frac{KF \cdot |I_{ds}|^{AF}}{NP \cdot L_{eff} \cdot NS \cdot L_{eff} \cdot COX \cdot f^{EF}}$$

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 222.

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 (Ω)	Drain contact resistance.
10	rsc (Ω)	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.

Virtuoso Simulator Components and Device Models Reference

EKV MOSFET Model (ekv)

15 `isnoisy=yes` Should resistor generate noise.
Possible values are `no` or `yes`.

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 `sspice`.

Process parameters

5 `tox=2e-8 m` Gate oxide thickness.

6 `cox=7e-4 F/m2` 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.

Virtuoso Simulator Components and Device Models Reference

EKV MOSFET Model (ekv)

Drain current model parameters

12	$v_{t0}=0.5 \text{ V}$	Threshold voltage at zero body bias.
13	$\gamma=1.0 \sqrt{\text{V}}$	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	$u_0 \text{ (cm}^2/\text{V s)}$	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	$\omega=0.25$	Narrow Channel Effect Coefficient.
24	$\eta=0.1$	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	$m_{e0}=0 \text{ m}$	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.
31	$i_{bn}=1.0$	Saturation velocity factor for impact ionization.

Virtuoso Simulator Components and Device Models Reference

EKV MOSFET Model (ekv)

Reverse Short Channel parameters

- 32 $q_0=0$ A s/m² Reverse short channel peak charge density.
- 33 $l_k=2.9e-7$ m Reverse short channel characteristic length.

Charge model selection parameters

- 34 $x_{qc}=0.0$ 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 $i_s=1e-14$ A Bulk junction reverse saturation current.
- 36 j_s (A/m²) Bulk junction reverse saturation current density.
- 37 $j_{sw}=0$ 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 $i_{melt}='imax'$ A Explosion current, diode is linearized beyond this current to aid convergence.

Junction capacitance model parameters

- 41 $c_{bd}=0$ F Bulk-drain zero-bias p-n capacitance.
- 42 $c_{bs}=0$ F Bulk-source zero-bias p-n capacitance.
- 43 $c_j=0$ F/m² Zero-bias junction bottom capacitance density.
- 44 $c_{jsw}=0$ F/m Zero-bias junction sidewall capacitance density.
- 45 $m_j=0.5$ Bulk junction bottom grading coefficient.
- 46 $m_{jsw}=0.33$ Bulk junction sidewall grading coefficient.

Virtuoso Simulator Components and Device Models Reference

EKV MOSFET Model (ekv)

47	$c_{jswg}=0$ F/m	Gate-side zero-bias junction sidewall capacitance density.
48	$m_{jswg}=0.33$	Gate-side bulk junction sidewall grading coefficient.
49	$p_{bswg}=0.8$ V	Gate-side junction built-in potential.
50	$f_c=0.5$	Forward-bias capacitance coefficient.
51	$p_b=0.8$ V	Bulk p-n bottom contact potential.
52	$p_{bsw}=0.8$ V	Side-wall contact potential.
53	$t_t=0.0$ V	Bulk p-n transit time.
54	$f_{csw}=0.5$	Side-wall forward-bias depletion capacitance threshold.

Overlap capacitance parameters

55	$c_{gso}=0$ F/m	Gate-source overlap capacitance.
56	$c_{gdo}=0$ F/m	Gate-drain overlap capacitance.
57	$c_{gbo}=0$ F/m	Gate-bulk overlap capacitance.

Parasitic resistance parameters

58	$r_s=0$ Ω	Source resistance.
59	$r_d=0$ Ω	Drain resistance.
60	$r_{sh}=0$ Ω/sqr	Source/drain diffusion sheet resistance.
61	$r_{ss}=0$ Ω m	Scalable source resistance.
62	$r_{dd}=0$ Ω m	Scalable drain resistance.
63	$r_{sc}=0$ Ω	Source contact resistance.
64	$r_{dc}=0$ Ω	Drain contact resistance.
65	$minr=0.1$ Ω	Minimum source/drain resistance.

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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/m² Maximum current density, currents above this limit generate a warning.

74 `vbox=1e9` `tox` V Oxide breakdown voltage.

75 `bvj=∞` 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.

80 `ucex=0.8` Longitudinal critical field temp. exponent.

81 `ibbt=9.0e-4` 1/C Temperature coefficient for IBB.

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EKV MOSFET Model (ekv)

82	<code>x_{ti}=3</code>	Saturation current temperature exponent.
83	<code>tlev=0</code>	DC temperature selector.
84	<code>tlevc=0</code>	AC temperature selector.
85	<code>phitmod=0</code>	phi(T) selector for sanyo.
86	<code>eg=1.12452 V</code>	Energy band gap.
87	<code>gap1=7.02e-4 V/C</code>	Band gap temperature coefficient.
88	<code>gap2=1108 C</code>	Band gap temperature offset.
89	<code>tr1=0.6</code>	First source-drain resistance temperature coefficient.
90	<code>tr2=0.6</code>	Second source-drain resistance temperature coefficient.
91	<code>ptc=0 V/C</code>	Surface potential temperature coefficient.
92	<code>pta=0 V/C</code>	Junction potential temperature coefficient.
93	<code>ptp=0 V/C</code>	Sidewall junction potential temperature coefficient.
94	<code>cta=0 1/C</code>	Junction capacitance temperature coefficient.
95	<code>ctp=0 1/C</code>	Sidewall junction capacitance temperature coefficient.

Default instance parameters

96	<code>w=3e-6 m</code>	Default channel width.
97	<code>l=3e-6 m</code>	Default channel length.
98	<code>as=0 m²</code>	Default area of source diffusion.
99	<code>ad=0 m²</code>	Default area of drain diffusion.
100	<code>ps=0 m</code>	Default perimeter of source diffusion.
101	<code>pd=0 m</code>	Default perimeter of drain diffusion.
102	<code>nrd=0 m/m</code>	Default number of squares of drain diffusion.

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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.

118 `msgskip=off` Skip some warning message customer requested.
Possible values are `off` or `on`.

119 `mvtwl=0.0` V m Threshold mismatch area dependence.

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EKV MOSFET Model (ekv)

- 120 $mvtwl2=0.0 \text{ v m}^{1.5}$ Threshold mismatch area square dependence.
- 121 $mvt0=0.0 \text{ V}$ Threshold mismatch intercept.
- 122 $mbe0=0.0$ Beta mismatch intercept.
- 123 $mbewl=0.0 \text{ m}$ Beta mismatch area dependence.

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:

$$l_{min} \leq inst_length < l_{max} \text{ and } w_{min} \leq inst_width < w_{max}$$

Example:

Virtuoso Simulator Components and Device Models Reference

EKV MOSFET Model (ekv)

```
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(alias lv2).
2	<code>l_{eff}</code> (m)	Effective channel length(alias lv1).
3	<code>r_{seff}</code> (Ω)	Effective source resistance(alias lv16).
4	<code>r_{deff}</code> (Ω)	Effective drain resistance(alias lv17).
5	<code>a_{seff}</code> (m ²)	Effective source area (alias=lv4).
6	<code>a_{deff}</code> (m ²)	Effective drain area (alias=lv3).
7	<code>p_{seff}</code> (m)	Effective source perimeter (alias=lv12).
8	<code>p_{deff}</code> (m)	Effective drain perimeter (alias=lv11).

Operating-Point Parameters

1	<code>type=n</code>	Transistor type. Possible values are n or p.
---	---------------------	---

Virtuoso Simulator Components and Device Models Reference

EKV MOSFET Model (ekv)

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>ids (A)</code>	Resistive drain-to-source current.
5	<code>vgs (V)</code>	Gate-source voltage(alias <code>lx2</code>).
6	<code>vds (V)</code>	Drain-source voltage(alias <code>lx3</code>).
7	<code>vbs (V)</code>	Bulk-source voltage(alias <code>lx1</code>).
8	<code>vp (V)</code>	Pinchoff voltage.
9	<code>vth (V)</code>	Threshold voltage.
10	<code>vdss (V)</code>	Drain-source saturation voltage.
11	<code>gm (S)</code>	Common-source transconductance(alias <code>lx7</code>).
12	<code>gds (S)</code>	Common-source output conductance(alias <code>lx8</code>).
13	<code>gmbs (S)</code>	Body-transconductance(alias <code>lx9</code>).
14	<code>nfac</code>	Slope factor.
15	<code>if (A)</code>	Forward current.
16	<code>ir (A)</code>	Reverse current.
17	<code>irprime (A)</code>	Reverse current.
18	<code>isub (A)</code>	Substrate Current.
19	<code>ibd (A)</code>	Bulk-drain junction current.
20	<code>ibs (A)</code>	Bulk-source junction current.
21	<code>pwr (W)</code>	Power at op point.

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EKV MOSFET Model (ekv)

22	gmoverid (1/V)	Gm/Ids.
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).
40	cbs (F)	Bulk-source capacitance(alias lx23).
41	cbb (F)	Bulk-bulk capacitance.
42	vm (V)	Early voltage.
43	vovrdr (V)	Overdrive voltage.

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EKV MOSFET Model (ekv)

44	τ (s)	NQS time constant.
45	τ_0 (s)	Intrinsic time constant.
46	r_{on} (Ω)	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
adef	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
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

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EKV MOSFET Model (ekv)

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
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

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EKV MOSFET Model (ekv)

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 1836
- [General Equations](#) on page 1838
- [Instance Level](#) on page 1838
- [Edge Conductance](#) on page 1850
- [Overlap Capacitances](#) on page 1852
- [Fringing Capacitance](#) on page 1854
- [Bias-Independent Overlap Capacitances](#) on page 1854
- [Gate Induced Drain and Source Current](#) on page 1855
- [Gate Current](#) on page 1855
- [Impact Ionization Current](#) on page 1858
- [Noise](#) on page 1858
- [Diodes](#) on page 1860
- [External Resistors \(Gate, Series, Bulk\)](#) on page 1862
- [Component Statements](#) on page 1864

Modes

Figure 26.1 illustrates the low-frequency macro model of EKV3 model that supports five versions of internal circuitry. Each version covers the needs of certain cases. These versions are listed in table 26.1. Also, some simple schematics that correspond to each mode, are provided in Figure 26.2.

Figure 26-1 EKV3 low-frequency macro model

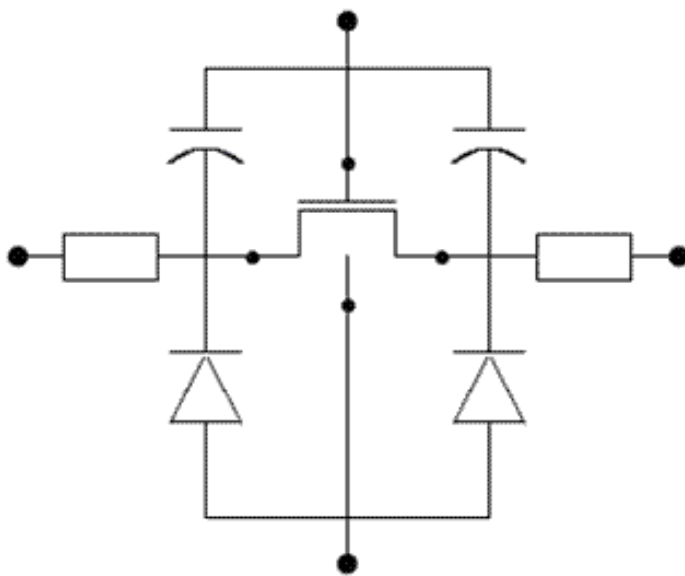
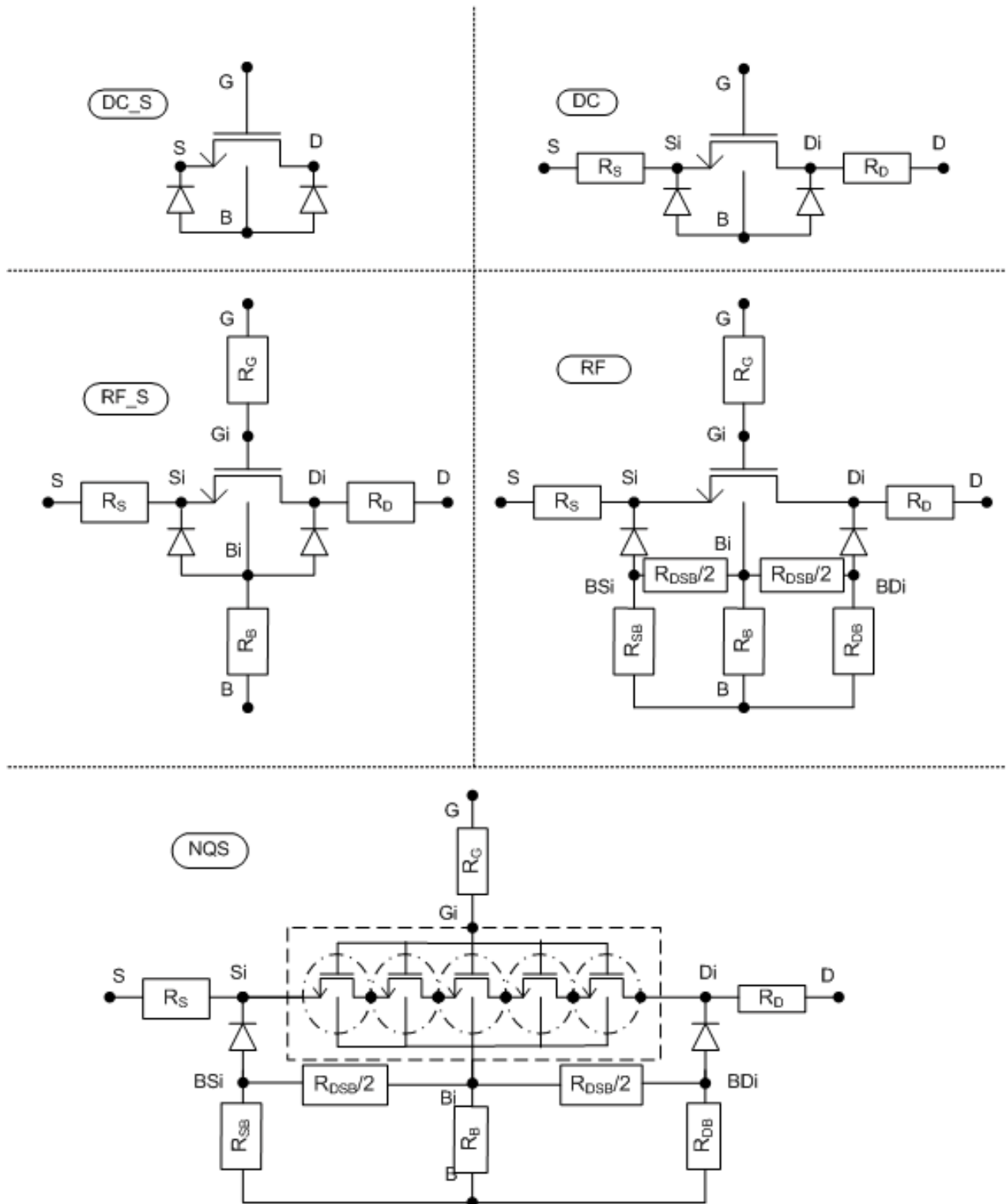


Table 26-1 Modes of the EKV3 model

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 26-2 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

$$\Delta VT_L = -AVT \cdot MX_S(\ln \frac{L_{eff}}{LVT}, 0, 10^{-2})$$

$$\Delta VT_W = -AVT \cdot MX_S(\ln \frac{W_{eff}}{WVT}, 0, 10^{-2})$$

$$\Delta GAMMA_L = -AGAM \cdot MX_S(\ln \frac{L_{eff}}{LGAM}, 0, 10^{-2})$$

$$\Delta GAMMA_W = -AGAM \cdot MX_S(\ln \frac{W_{eff}}{WGAM}, 0, 10^{-2})$$

Parameter width and length scaling

$$LR_g = LR + \frac{WLR}{W_{eff}}$$

$$QLR_g = QLR \cdot \left(1 + \frac{WQLR}{W_{eff}}\right)$$

$$NLR_g = NLR \cdot \left(1 + \frac{WNLR}{W_{eff}}\right)$$

$$E0_g = E0 \cdot \left(1 + \frac{WE0}{W_{eff}}\right)$$

$$E1_g = E1 \cdot \left(1 + \frac{WE1}{W_{eff}}\right)$$

$$UCRIT_g = UCRIT \cdot \left(1 + \frac{WUCRIT}{W_{eff}}\right)$$

$$LAMBDA_g = LAMBDA \cdot \left(1 + \frac{WLAMBDA}{W_{eff}}\right)$$

$$ETAD_g = ETAD \cdot \left(1 + \frac{WETAD}{W_{eff}}\right)$$

$$UCEX_g = UCEX \cdot \left(1 + \frac{WUCEX}{W_{eff}}\right)$$

$$WR_g = WR + \frac{LWR}{L_{eff}}$$

$$QWR_g = QWR \cdot \left(1 + \frac{LQWR}{L_{eff}}\right)$$

$$NWR_g = NWR \cdot \left(1 + \frac{LNWR}{L_{eff}}\right)$$

$$TCV_g = TCV + \frac{TCVL}{L_{eff}} + \frac{TCVW}{W_{eff}} + \frac{TCVWL}{W_{eff} \cdot L_{eff}}$$

Reverse short channel effect (RSCE)

$$\Delta V_{T_{RSCE}} = \frac{2 \cdot Q_{LR_g} \cdot \left(1 - \exp\left(\left(\frac{L_{eff}}{LR_g}\right)^2\right)\right)}{COX \cdot \frac{L_{eff}}{LR_g}}$$

$$GAMMA_{RSCE} = \sqrt{1.0 + \frac{2 \cdot N_{LR_g} \cdot \left(1 - \exp\left(\left(\frac{L_{eff}}{LR_g}\right)^2\right)\right)}{COX \cdot \frac{L_{eff}}{LR_g}}}$$

$$\Delta \Phi_{f,RSCE} = U_T \cdot FLR \cdot \ln \left(1 + \frac{2 \cdot N_{LR_g} \cdot \left(1 - \exp\left(\left(\frac{L_{eff}}{LR_g}\right)^2\right)\right)}{COX \cdot \frac{L_{eff}}{LR_g}}\right)$$

Inverse narrow width effect (INWE)

$$\Delta V_{T_{INWE}} = - \frac{2 \cdot Q_{WR_g} \cdot \left(1 - \exp\left(\left(\frac{W_{eff}}{WR_g}\right)^2\right)\right)}{COX \cdot \frac{W_{eff}}{WR_g}}$$

$$GAMMA_{INWE} = \frac{1}{\sqrt{1.0 + \frac{2 \cdot N_{WR_g} \cdot \left(1 - \exp\left(\left(\frac{W_{eff}}{WR_g}\right)^2\right)\right)}{COX \cdot \frac{W_{eff}}{WR_g}}}}$$

Mobility Scaling

$$KP_1 = \frac{1}{\left(1 + \frac{KA \cdot LA}{L_{eff}}\right) \cdot \left(1 - \exp\left(-\frac{L_{eff}}{LA}\right)\right) + \left(1 + \frac{KB \cdot LB}{L_{eff}}\right) \cdot \left(1 - \exp\left(-\frac{L_{eff}}{LB}\right)\right)}$$

$$KP_w = 1 + WKP2 \cdot \exp\left(-\left(\frac{\ln\left(\frac{W_{eff}}{WKP1}\right)}{WKP3}\right)^2\right)$$

Instance level parameters

$$VTO_g = VTO_a + \Delta VT_L + \Delta VT_W + \Delta VT_{RSCE} + \Delta VT_{INWE}$$

$$GAMMA_g = (GAMMA_a + \Delta GAMMA_L + \Delta GAMMA_W) \cdot GAMMA_{RSCE} \cdot GAMMA_{INWE}$$

$$\Phi_{f,g} = PHIF + \Delta \Phi_{f,RSCE}$$

$$KP_g = KP \cdot KP_1 \cdot KP_w$$

Temperature scaling

$$\Delta T = T - TNOM$$

$$rT = \frac{T}{TNOM}$$

$$VTO_{gt} = VTO_g - TCV_g \cdot \Delta T$$

$$KP_{gt} = KP_g \cdot rT^{BEX}$$

$$ETA_t = ETA - TETA \cdot \Delta T$$

$$E0_{gt} = E0_g \cdot rT^{E0EX}$$

$$E1_{gt} = E1_g \cdot rT^{E1EX}$$

$$\Phi_{f,gt} = \Phi_{f,g} \cdot rT - \frac{E_g(T) - E_g(TNOM) \cdot rT - 3 \cdot U_T \cdot \ln rT}{2}$$

Normalizing

$$\phi_f = \frac{\Phi_{f,gt}}{U_T}$$

$$vto = \frac{VTO_{gt}}{U_T}$$

$$\gamma = \frac{GAMMA_g}{\sqrt{U_T}}$$

$$\gamma_g = \frac{GAMMA_g}{\sqrt{U_T}}$$

$$\gamma_{ov} = \frac{GAMMA_{OV}}{\sqrt{U_T}}$$

$$vfb_{ov} = \frac{VFBOV}{U_T}$$

$$ucrit = \frac{UCRIT}{U_T}$$

$$xb = \frac{XB}{U_T}$$

$$ub = \frac{EB \cdot t_{ox}}{XB}$$

Slope factor nQ0

$$n_{Q0} = \begin{cases} 1 + \frac{\gamma}{2 \cdot \sqrt{2 \cdot \phi_f}}, & \text{if TG} = 0 \text{ or } 1 \\ \text{dfrac{1}{1} + \frac{\gamma}{\gamma_g^2} \cdot \frac{2 \cdot \sqrt{2 \cdot \phi_f}}{\gamma} + \frac{\gamma}{2 \cdot \sqrt{2 \cdot \phi_f}}, & \text{if TG} = -1 \end{cases}$$

Quantum mechanic effect

$$\alpha_{qma} = A_{QMA} \cdot \frac{COX^{2/3}}{U_T^{1/3}} \cdot ETA_{QM}^{2/3}$$

$$\delta_{qmi} = \frac{1}{3} \cdot A_{QMI} \cdot \frac{\gamma \cdot COX}{2 \cdot \phi_f \cdot \sqrt{U_T}} \left(\frac{2 \cdot ETA_{QM} \cdot n_{Q0} \cdot \sqrt{2 \cdot \phi_f}}{\gamma} - 1 \right)$$

$$\Delta\Psi_0 = A_{QMI} \cdot \frac{2}{3} \cdot \left(\gamma \cdot COX \cdot \sqrt{2 \cdot \phi_f} \right)^{2/3}$$

$$\Delta\psi_0 = \frac{\Delta\Psi_0}{U_T}$$

$$\phi = 2 \cdot \phi_f + \ln \left(4 \cdot n_{Q0} \cdot \frac{\sqrt{2 \cdot \phi_f}}{\gamma} \right) + \Delta\psi_0$$

Normalization factor for charges

$$Q_{0,C} = -W_{\text{eff},C} \cdot NF \cdot I_{\text{eff},C} \cdot U_T \cdot \frac{COX}{1 + \delta_{qmi}} \cdot \frac{W_{\text{eff}} - W_{\text{EDGE}}}{W_{\text{eff}}}$$

$$Q_{0,OV} = -W_{\text{eff}} \cdot NF \cdot LOV \cdot U_T \cdot \frac{COX}{1 + \delta_{qmi}}$$

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

$$\text{CHSH}_L = \text{LETA0} + \frac{\text{LETA}}{L_{\text{eff}}} + \frac{\text{LETA2}}{L_{\text{eff}}^2}$$

$$\text{CHSH}_W = \frac{\text{WETA}}{W_{\text{eff}}}$$

$$\text{NUV} = \text{N0} + 3 \cdot \text{NCS} \cdot t_{\text{ox}} \cdot \text{CHSH}_L$$

$$A_1 = 1 - \frac{\text{CHSH}_L \cdot t_{\text{si}}}{\gamma} \left(\sqrt{\text{MXS}(v_{\text{bi}} + v_s, 0, U_T^2)} + \sqrt{\text{MXS}(v_{\text{bi}} + v_d, 0, U_T^2)} \right)$$

$$A_2 = 2 \cdot A_1 - 1 + 2 \cdot \text{CHSH}_W \cdot \frac{\sqrt{\phi}}{\gamma}$$

$$A_3 = 1 + \text{CHSH}_W \cdot t_{\text{si}} \cdot \frac{\gamma}{\gamma_g} \cdot A_2$$

$$\gamma_{\text{chsh}} = \gamma \cdot \frac{A_1}{1 + \text{CHSH}_W}$$

$$\gamma_{\text{eff}} = \gamma \cdot \frac{A_1}{A_3}$$

$$A_{1,0} = 1 - 2 \cdot \frac{\text{CHSH}_L \cdot t_{\text{si}}}{\gamma} \cdot \sqrt{v_{\text{bi}}}$$

$$A_{2,0} = 2 \cdot A_{1,0} - 1 + 2 \cdot \text{CHSH}_W \cdot \frac{\sqrt{\phi}}{\gamma}$$

$$A_{3,0} = 1 + \text{CHSH}_W \cdot t_{\text{si}} \cdot \frac{\gamma^2}{\gamma_g^2} \cdot A_{2,0}$$

$$\gamma_{\text{chsh},0} = \gamma \cdot \frac{A_{1,0}}{1 + \text{CHSH}_W}$$

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

$$v'_g = v_g - v_{fb}$$

$$v'_{g,chsh} = \frac{v'_g}{1 + CHSHW \cdot t_{si}}$$

$$v'_{g,chsh,pd} = \frac{v'_g}{A_3}$$

$$v'_{g,chsh,pd,0} = \frac{v'_g}{A_{3,0}}$$

Pinch-off surface potential

Approximation around zero

$$\psi_{po} = \text{MXS} \left(v'_{g,chsh} - 6 \cdot \left(1 + \frac{\gamma_{chsh}}{\sqrt{2}} \right), 0, 6 \cdot v'_{g,chsh} \right)$$

$$\psi_{po,0} = \text{MXS} \left(v'_{g,chsh} - 6 \cdot \left(1 + \frac{\gamma_{chsh,0}}{\sqrt{2}} \right), 0, 6 \cdot v'_{g,chsh} \right)$$

Exact solution

$$\psi_p = \begin{cases} -\ln \left(1 - \psi_{po} + \left(\frac{\psi_{po} - v'_{g,chsh}}{\gamma_{chsh}} \right)^2 \right), & \text{if } v'_g < 0 \\ \left(\sqrt{v_{g,chsh,pd} - 1 + \exp(-\psi_{po}) + \frac{\gamma_{off}^2}{4} - \frac{\gamma_{off}}{2}} \right)^2 + 1 - \exp(-\psi_{po}), & \text{if } v'_g \geq 0 \end{cases} \quad (2.90)$$

$$\psi_{p,0} = \begin{cases} -\ln \left(1 - \psi_{po,0} + \left(\frac{\psi_{po,0} - v'_{g,chsh}}{\gamma_{chsh,0}} \right)^2 \right), & \text{if } v'_g < 0 \\ \left(\sqrt{v_{g,chsh,pd,0} - 1 + \exp(-\psi_{po,0}) + \frac{\gamma_{chsh,0}^2}{4} - \frac{\gamma_{chsh,0}}{2}} \right)^2 + 1 - \exp(-\psi_{po,0}), & \text{if } v'_g \geq 0 \end{cases}$$

Pinch-off voltage

$$v_p = \psi_p - \phi$$

Velocity saturation

$$e_{clm} = \frac{2}{u_{crit} \cdot L_{eff}}$$

$$q_{sat} = \frac{2 \cdot e_{clm} \cdot I_f}{e_{clm} + 2 + 2 \cdot e_{clm} \cdot q_s + \sqrt{(e_{clm} + 2)^2 + 8 \cdot e_{clm} \cdot q_s}}$$

$$v_{d,sat} = v_p - \frac{(2 \cdot q_{sat} + \ln q_{sat})(1 + e_{clm} \cdot (q_s - q_{sat}))}{\sqrt{1 + \frac{2 \cdot (e_{clm} \cdot (2 - DELTA) \cdot (q_s - q_{sat}))^2}{0.1 + e_{clm} \cdot (2 - DELTA) \cdot (q_s - q_{sat})} + e_{clm} \cdot (q_s - q_{sat})}}$$

$$v_{ds,sat} = MX_S(v_{d,sat} - v_s, 3, 4)$$

$$dv = \frac{ACLM}{DELTA} \cdot \frac{4 \cdot q_{sat} + DELTA}{q_s + 1}$$

$$v'_d = \frac{1}{2} \cdot \sqrt{\left((v_d - v_s) \cdot \sqrt{1 + \frac{4 \cdot dv}{v_{ds,sat}}} + v_{ds,sat} \right)^2 + 4 \cdot dv \cdot v_{ds,sat} - \frac{1}{2} \cdot \sqrt{\left((v_d - v_s) \cdot \sqrt{1 + \frac{4 \cdot dv}{v_{ds,sat}}} - v_{ds,sat} \right)^2 + 4 \cdot dv \cdot v_{ds,sat} + v_s}}$$

Channel length modulation

$$u_{clm} = \frac{e_{clm} \cdot L_{eff}}{L_C \cdot (v_d - v'_d)}$$

$$\alpha_{clm} = \frac{L_C}{L_{eff} - 2 \cdot L_C}$$

$$\delta L = LAMBDA_{g,t} \cdot L_C \cdot \ln \frac{\alpha_{clm} + u_{clm} + \sqrt{u_{clm}^2 + 2 \cdot \alpha_{clm} \cdot u_{clm} + 1}}{\alpha_{clm} + 1}$$

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

$$l_0 = ETA_g \cdot t_{si} \cdot \sqrt{\frac{2 \cdot \sqrt{\phi}}{\gamma}}$$

$$v_o = 4 + 40 \cdot \frac{l_0}{L_{eff}}$$

$$dv = MNS(v_p, MNS(v_s, v_d, v_o^2), v_o^2)$$

$$\delta\psi_s = \exp\left(-\frac{L_{eff}}{2 \cdot l_0}\right) \cdot \left(2 + SIGMAD \cdot \frac{L_{eff}}{2 \cdot l_0} \cdot \frac{dv}{2 \cdot \phi}\right) \cdot \sqrt{(mul + v_s - dv) \cdot (mul + v_d - dv)} \quad (2.97)$$

Normalized source inversion charge

$$q(v) = \begin{cases} \text{if } \frac{v}{NUV} < -0.6 \\ z_1 = \frac{1}{4} \cdot \left(\frac{v}{NUV} - 1.4 + \sqrt{\frac{v}{NUV} \cdot \left(\frac{v}{NUV} - 0.384936\right) + 9.662671}\right) \\ z_2 = \frac{\frac{v}{NUV} - (2 \cdot z_1 + \ln z_1)}{2 \cdot z_1 + 1} \\ z_1(1 + z_2 \cdot (1 + 0.07 \cdot z_2)) \cdot NUV \\ \text{if } \frac{v}{NUV} \geq -0.6 \\ z_{1,ln} = 0.5 \cdot \left(\frac{v}{NUV} - 0.201491 - \sqrt{\frac{v}{NUV} \cdot \left(\frac{v}{NUV} - 0.402982\right) + 2.446562}\right) \\ z_1 = \frac{1}{4} \cdot \left(\frac{v}{NUV} - 1.4 + \sqrt{\frac{v}{NUV} \cdot \left(\frac{v}{NUV} - 0.384936\right) + 9.662671}\right) \\ z_2 = \frac{\frac{v}{NUV} - (2 \cdot \exp(z_{1,ln}) + z_{1,ln})}{2z_1 + 1} \\ z_1(1 + z_2 \cdot (1 + 0.483 \cdot z_2)) \cdot NUV \end{cases}$$

$$q_s = q(v_p + \delta\psi_s - v_s)$$

Normalized forward current

$$i_f = q_s + q_s^2$$

Slope factor n_Q

$$\psi_{sa} = \psi_p - q_s - q_d \quad (2.112)$$

$$n_Q = \begin{cases} \text{if } TG < 0 \\ \frac{1 + \frac{\gamma^2}{\gamma_g^2} + \frac{GAMMA}{\sqrt{U_T}(\sqrt{\psi_p} + \sqrt{\psi_{sa}})}}{\frac{1}{2} + \frac{\gamma^2 \sqrt{U_T} \sqrt{\psi_{sa}}}{\gamma_g^2 GAMMA} + \sqrt{\left(\frac{1}{2} + \frac{\gamma^2 \sqrt{U_T} \sqrt{\psi_{sa}}}{\gamma_g^2 GAMMA}\right)^2 + \left(1 + \frac{\gamma^2}{\gamma_g^2} + \frac{GAMMA}{\sqrt{U_T}(\sqrt{\psi_p} + \sqrt{\psi_{sa}})}\right) \frac{q_s + q_d}{\gamma_g^2}}} \\ \text{if } TG \geq 0 \\ \frac{1}{1 + \frac{GAMMA}{\sqrt{U_T} \cdot (\sqrt{\psi_p} + \sqrt{\psi_{sa}})}} \end{cases}$$

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

$$q_s = \frac{n_Q}{3 \cdot (1 + \delta_{qmi})} \cdot \left(2 \cdot q_s + q_d + \frac{(1 + \frac{4}{5} \cdot q_s + \frac{6}{5} \cdot q_d) \cdot (q_s - q_d)^2}{2 \cdot (q_s + q_d + 1)^2} \right)$$

$$q_d = \frac{n_Q}{3 \cdot (1 + \delta_{qmi})} \cdot \left(q_s + 2 \cdot q_d + \frac{(1 + \frac{6}{5} \cdot q_s + \frac{4}{5} \cdot q_d) \cdot (q_s - q_d)^2}{2 \cdot (q_s + q_d + 1)^2} \right)$$

$$q_G = \begin{cases} \text{if } TG < 0 \\ \frac{v_{o,qm} + \frac{2 \cdot q_s}{1 + \delta_{qmi}}}{1 + 2 \cdot \sqrt{\frac{1}{4} + \frac{v_{o,qm} + \frac{2 \cdot q_s}{1 + \delta_{qmi}}}{\gamma_g^2}}} + \frac{v_{o,qm} + \frac{2 \cdot q_d}{1 + \delta_{qmi}}}{1 + 2 \cdot \sqrt{\frac{1}{4} + \frac{v_{o,qm} + \frac{2 \cdot q_d}{1 + \delta_{qmi}}}{\gamma_g^2}}} + \frac{1}{3 \cdot (1 + \delta_{qmi})} \cdot \frac{(q_s - q_d)^2}{\left(\sqrt{\frac{1}{4} + \frac{v_{o,qm} + \frac{2 \cdot q_s}{1 + \delta_{qmi}}}{\gamma_g^2}} + \sqrt{\frac{1}{4} + \frac{v_{o,qm} + \frac{2 \cdot q_d}{1 + \delta_{qmi}}}{\gamma_g^2}} \right)^3} \\ \cdot \frac{4}{5} \cdot \left(\sqrt{\frac{1}{4} + \frac{v_{o,qm} + \frac{2 \cdot q_s}{1 + \delta_{qmi}}}{\gamma_g^2}} + \sqrt{\frac{1}{4} + \frac{v_{o,qm} + \frac{2 \cdot q_d}{1 + \delta_{qmi}}}{\gamma_g^2}} \right)^2 \\ + \frac{4}{5} \cdot \sqrt{\frac{1}{4} + \frac{v_{o,qm} + \frac{2 \cdot q_s}{1 + \delta_{qmi}}}{\gamma_g^2}} \cdot \sqrt{\frac{1}{4} + \frac{v_{o,qm} + \frac{2 \cdot q_d}{1 + \delta_{qmi}}}{\gamma_g^2}} + \frac{2}{\gamma_g^2} \\ \text{if } TG \geq 0 \\ v_{o,qm} + q_s + q_d + \frac{1}{3 \cdot (1 + \delta_{qmi})} \cdot \frac{(q_s - q_d)^2}{q_s + q_d + 1} \end{cases}$$

$$q_I = q_S + q_D$$

$$q_B = q_G - q_S - q_D$$

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

$$e_{q0} = q_B + ETA_t \cdot n_v \cdot q_I$$

$$e_{q1} = \left(\gamma_{eff} \cdot \sqrt{\psi_p} + n_v \cdot (1 - ETA_t) - 1 \right)^2 + (n_v \cdot (1 - ETA_t) - 1)^2 \cdot (1 + 2 \cdot i_f + 2 \cdot i_r) - \frac{8}{3} \cdot (n_v \cdot (1 - ETA_t) - 1) \cdot (\gamma_{eff} \cdot \sqrt{\psi_p} + n_v \cdot (1 - ETA_t) - 1) \cdot \frac{i_f + i_r + 0.5 + \sqrt{(i_f + 0.25) \cdot (i_r + 0.25)}}{\sqrt{i_f + 0.25} + \sqrt{i_r + 0.25}}$$

$$\beta_{rvf,coul} = \frac{1 + \frac{U_T}{E0_{g,t} \cdot t_{si}} \cdot \gamma_{eff} \cdot \sqrt{\phi} + \left(\frac{U_T}{E1_{g,t} \cdot t_{si}} \cdot \gamma_{eff} \cdot \sqrt{\phi} \right)^2}{1 + \frac{U_T}{E0_{g,t} \cdot t_{si}} \cdot e_{q0} + \left(\frac{U_T}{E1_{g,t} \cdot t_{si}} \right)^2 \cdot e_{q1} + \beta_{coul}}$$

Channel length modulation

$$\beta_{clm} = \left(\sqrt{1 + \frac{2 \cdot (e_{clm} \cdot (2 - DELTA) \cdot (q_s - q_d))^2}{0.1 + e_{clm} \cdot (2 - DELTA) \cdot (q_s - q_d)}} + (e_{clm} \cdot (q_s - q_d))^2 \right)^{-1}$$

Overall effect

$$\beta = KP_{g,t} \cdot \beta_{rvf,coul} \cdot \beta_{clm}$$

Specific current

$$I_{SPEC} = \frac{2 \cdot n_Q \cdot U_T^2 \cdot \beta}{1 + \delta_{qmi}} \cdot \frac{(W_{eff} - WEDGE) \cdot NF}{L_{eff} - \delta L}$$

Drain induced threshold shift

$$v_{dits} = \frac{1}{1 + FPROUT \cdot \frac{L_{eff}}{qI + 2}} \cdot \frac{PDITS}{PDITS} \cdot (1 + (1 + PDITSL \cdot L_{eff}) \cdot \exp(PDITSD \cdot (v_d - v_s) \cdot U_T))$$

$$v_{ds,dits} = v_{ds,sat} - MXS(v_{ds,sat} - (v_d - v_s) - DDITS, 0, 4 \cdot DDITS \cdot v_{ds,sat})$$

$$f_{dits} = 1 + \frac{v_d - v_s - v_{ds,dits}}{v_{dits}}$$

Denormalizing

$$Q_S = q_S \cdot Q_0$$

$$Q_D = q_D \cdot Q_0$$

$$Q_G = -q_G \cdot Q_0$$

$$Q_B = q_B \cdot Q_0$$

$$I_{ds} = I_{SPEC} \cdot (i_f - i_r) \cdot f_{dits}$$

Edge Conductance

Normalization Factors (Edge Device)

$$I_{SPEC,edge} = \frac{2 \cdot n_Q \cdot U_T^2 \cdot \beta \cdot W_{eff} \cdot NF}{1 + \delta_{qmi}} \cdot \frac{W_{eff} - WEDGE}{L_{eff} - \delta L} \cdot \frac{W_{eff} - WEDGE}{W_{eff}}$$

$$Q_{0,edge} = -W_{eff,C} \cdot NF \cdot L_{eff,C} \cdot U_T \cdot \frac{COX}{1 + \delta_{qmi}} \cdot \frac{WEDGE}{W_{eff}}$$

Scaling - Normalizing

$$\delta\gamma_{edge} = \frac{DGAMMAEDGE}{\sqrt{U_T}} \cdot \left(1.0 + \frac{WLDGAMMAEDGE}{W_{eff} \cdot L_{eff}}\right)$$

$$\delta\phi_{edge} = \frac{DPHIEDGE}{U_T} \cdot \left(1.0 + \frac{LDPHIEDGE}{L_{eff}}\right) \cdot \left(1.0 + \frac{WDPHIEDGE}{W_{eff}}\right) \cdot \left(1.0 + \frac{WLDPHIEDGE}{W_{eff} \cdot L_{eff}}\right)$$

$$\delta v_{p,edge} = -\delta\gamma_{edge} \cdot \frac{\psi_p}{\sqrt{\psi_p} + \frac{\gamma}{2}} - \delta\phi_{edge}$$

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)

$$i_{f,edge} = q_s^2 + q_{s,edge}$$

$$i_{r,edge} = q_d^2 + q_{d,edge}$$

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

$$v'_{gs,ov} = v_g - VOV \cdot v_s - vfb_{ov}$$

if $TG < 0$

$$\gamma_{dep,sov} = \begin{cases} \gamma_{g,ov} & \text{if } v'_{gs,ov} \geq 0 \\ \gamma_{ov} & \text{if } v'_{gs,ov} < 0 \end{cases}$$

$$\gamma_{acc,sov} = \begin{cases} \gamma_{ov} & \text{if } v'_{gs,ov} \geq 0 \\ \gamma_{g,ov} & \text{if } v'_{gs,ov} < 0 \end{cases}$$

$$V_{0,sov} = \begin{cases} v'_{gs,ov} & \text{if } v'_{gs,ov} \geq 0 \\ -v'_{gs,ov} & \text{if } v'_{gs,ov} < 0 \end{cases}$$

$$a_{0,sov} = 1.0 + \frac{\gamma_{acc,sov}}{\sqrt{2}}$$

$$a_{1,sov} = \frac{\gamma_{dep,sov}}{\gamma_{acc,sov}}$$

$$a_{2,sov} = \frac{a_{0,sov}}{a_{0,sov} + a_{1,sov}}$$

$$a_{3,sov} = 1 + \frac{\gamma_{dep,sov}}{\sqrt{2}} + a_{1,sov}$$

$$V_{1,sov} = \frac{V_{0,sov}}{2} - 3 \cdot a_{2,sov} \cdot a_{3,sov}$$

$$\delta\psi_{gs0} = V_{1,sov} + \sqrt{V_{1,sov}^2 + 6 \cdot a_{2,sov} \cdot a_{3,sov}}$$

$$\gamma_{dep2,sov} = \gamma_{dep,sov} \cdot \left(\frac{1}{2} + \frac{3}{3 \cdot \sqrt{2} \cdot \gamma_{acc,sov} + V_{0,sov} - \delta\psi_{gs0}} \right)$$

$$a_{4,sov} = 1 - \exp(-\delta\psi_{gs0})$$

$$V_{2,sov} = V_{0,sov} - a_{4,sov}$$

$$\delta\psi_{gs} = \left(\frac{V_{2,sov}}{\gamma_{dep2,sov} + \sqrt{\gamma_{dep2,sov}^2 + V_{2,sov}}} \right)^2 + a_{4,sov}$$

$$V_{2b,sov} = V_{0,sov} - \delta\psi_{gs}$$

$$V_{3,sov} = \frac{V_{2b,sov}}{2}$$

Virtuoso Simulator Components and Device Models Reference
EKV3 MOSFET Model (ekv3)

$$\delta\psi_{ox,s} = \begin{cases} v_{3,sov} - 3 \cdot a_{0,sov} + \sqrt{\left(\frac{v_{3,sov}}{3 \cdot a_{0,sov}}\right)^2 - 6 \cdot v_{2b,sov}} & \text{if } v'_{gs,ov} > 0 \\ -\left(v_{3,sov} - 3 \cdot a_{0,sov} + \sqrt{\left(\frac{v_{3,sov}}{3 \cdot a_{0,sov}}\right)^2 - 6 \cdot v_{2b,sov}}\right) & \text{if } v'_{gs,ov} < 0 \end{cases}$$

if $TG \geq 0$

if $v'_{gs,ov} \geq 0$

$$\gamma_{acc,sov} = \gamma_{ov}$$

$$v_{0,sov} = v_{gs,ov}$$

$$a_{0,sov} = 1 + \frac{\gamma_{acc,sov}}{\sqrt{2}}$$

$$v_{1,sov} = \frac{v_{0,sov}}{2} - 3 \cdot a_{0,sov}^2$$

$$\delta\psi_{gs0} = v_{1,sov} + \sqrt{v_{1,sov}^2}$$

$$\delta\psi_{gs} = 1 - \exp(-\delta\psi_{gs0})$$

$$v_{2b,sov} = v_{0,sov} - \delta\psi_{gs}$$

$$v_{3,sov} = \frac{v_{2b,sov}}{2}$$

$$\delta\psi_{ox,s} = v_{3,sov} - 2 \cdot a_{0,sov} + \sqrt{(v_{3,sov} + 3 \cdot a_{0,sov})^2 - 6 \cdot v_{2b,sov}}$$

if $v'_{gs,ov} < 0$

$$\gamma_{dep,sov} = \gamma_{ov}$$

$$v_{0,sov} = -v_{gs,ov}$$

$$a_{3,sov} = 1 + \frac{\gamma_{dep,sov}}{\sqrt{2}}$$

$$v_{1,sov} = \frac{v_{0,sov}}{2} - 3 \cdot a_{3,sov}^2$$

$$\delta\psi_{gs0} = v_{1,sov} + \sqrt{v_{1,sov}^2 + 6 \cdot v_{0,sov}}$$

$$\gamma_{dep2,sov} = \gamma_{dep,sov}^2$$

$$a_{4,sov} = 1 - \exp(-\delta\psi_{gs0})$$

$$v_{2,sov} = v_{0,sov} - a_{4,sov}$$

$$\delta\psi_{gs} = \left(\frac{V_{2,sov}}{\gamma_{dep2,sov} + \sqrt{\gamma_{dep2,sov}^2 + V_{2,sov}}} \right)^2 + a_{4,sov}$$

$$V_{2b,sov} = V_{0,sov} - \delta\psi_{gs}$$

$$\delta\psi_{cx,s} = -V_{2b,sov}$$

Denormalizing (Overlap)

$$Q_{S,OV} = -Q_{0,OV} \cdot \delta\psi_{cx,s}$$

$$Q_{D,OV} = -Q_{0,OV} \cdot \delta\psi_{cx,d}$$

Fringing Capacitance

$$Q_{S,FR} = W_{eff,c} \cdot NF \cdot KJF (1 + CJF \cdot U_T \cdot v_s) \cdot \sqrt{MX_S \left(v_{bi} + \frac{VFR}{U_T} + v_s - (\psi_P - 2 \cdot q_s), 0, DFR \right)} \quad (2.192)$$

$$Q_{D,FR} = W_{eff,c} \cdot NF \cdot KJF (1 + CJF \cdot U_T \cdot v'_d) \cdot \sqrt{MX_S \left(v_{bi} + \frac{VFR}{U_T} + v'_d - (\psi_P - 2 \cdot q'_d), 0, DFR \right)}$$

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 $((\psi_p \geq 0) \text{ and } (TG < 0))$ or $((\psi_p < 0) \text{ and } (TG \geq 0))$

$$v_1 = \sqrt{\frac{1}{4} + \frac{v_o + 2 \cdot q_s}{\gamma_g^2}}$$

$$v_2 = v_1 + \frac{1}{2}$$

$$\psi_{ox} = \frac{v_o + 2 \cdot q_s}{v_2}$$

$$\delta\psi_{dq} = \frac{2}{v_2} \cdot \left(1 - \frac{v_o + 2 \cdot q_s}{2 \cdot v_1 \cdot v_2 \gamma_g^2}\right)$$

if $((\psi_p \leq 0) \text{ and } (TG \leq 0))$ or $((\psi_p > 0) \text{ and } (TG > 0))$

$$\psi_{ox} = \frac{v_o + 2 \cdot q_s}{v_2}$$

$$\delta\psi_{dq} = 2$$

$$\psi_x = \frac{|\psi_{ox}|}{x_b}$$

Virtuoso Simulator Components and Device Models Reference
EKV3 MOSFET Model (ekv3)

$$P_{tun} = \begin{cases} \exp\left(-y_b \left(\frac{1}{1 + \sqrt{1 - \psi_x}} + \sqrt{1 - \psi_x}\right)\right) & \text{if } \psi_x < 1 \\ \exp\left(-\frac{u_b}{\psi_x}\right) & \text{if } \psi_x > 1 \end{cases}$$

$$i_{go} = q_s \cdot \psi_{ox} \cdot P_{tun}$$

if ($v_s = v_d$) or ($\psi_{ox} = 0$)

$$n_{igc} = i_{go} \cdot n_Q$$

$$n_{igs} = \frac{n_{igc}}{2}$$

$$n_{igd} = n_{igs}$$

if ($v_s \neq v_d$) and ($\psi_{ox} \neq 0$)

$$\delta Q_{\delta\xi} = \frac{i'_r - i_f}{1 + 2 \cdot q_s}$$

$$a_{gc} = \delta Q_{\delta\xi} \cdot \left(\frac{1}{q_s} + \frac{\delta\psi_{dq}}{\psi_{ox}}\right)$$

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 $\psi_x \geq 1$

$$b_{gc} = \delta Q_{\delta\xi} \cdot \delta\psi_{dq} \cdot \frac{u_b}{\psi_x + \psi_{ox}}$$

$$n_{igc} = i_{go} \cdot n_Q \cdot \frac{2 + a_{gc}}{2 - b_{gc}}$$

$$n_{igs} = \frac{1}{2} \cdot i_{go} \cdot n_Q \cdot \frac{3 + a_{gc}}{3 - b_{gc}}$$

$$n_{igd} = n_{igc} - n_{igs}$$

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

if $v_g \geq v_{fb}$

$$I_{GB} = 0$$

$$I_G = 2 \cdot KG \cdot W_{eff} \cdot NF \cdot L_{eff} \cdot U_T^2 \cdot n_{igc} \cdot P_{tun} \cdot T_{OX}^{-2}$$

$$I_{GD} = 2 \cdot KG \cdot W_{eff} \cdot NF \cdot L_{eff} \cdot U_T^2 \cdot n_{igd} \cdot P_{tun} \cdot T_{OX}^{-2}$$

$$I_{GS} = I_G - I_{GD}$$

if $v_g < v_{fb}$

$$I_{GB} = KG \cdot W_{eff} \cdot NF \cdot L_{eff} \cdot U_T^2 \cdot \psi_{oxc} \cdot |\psi_{oxc}| \cdot P_{tun} \cdot T_{OX}^{-2}$$

$$I_G = 0$$

$$I_{GD} = 0$$

$$I_{GS} = 0$$

Overlap Gate Current

Gate - Source (Overlap Current)

$$\psi_{oxr,sov} = \begin{cases} v_g - v_s - \left(\sqrt{v_g - v_s - v_{fb,ov} + \frac{\gamma_g^2}{4}} - \frac{\gamma_g}{2} \right)^2 & \text{if } v_g - v_s > v_{fb,ov} \\ v_g - v_s + \left(\sqrt{-v_g + v_s + v_{fb,ov} + \frac{\gamma_{ov}^2}{4}} - \frac{\gamma_{ov}}{2} \right)^2 & \text{if } v_g - v_s < v_{fb,ov} \end{cases}$$

$$\psi_{xr,sov} = \frac{|\psi_{oxr,sov}|}{X_b}$$

$$P_{tun,sov} = \begin{cases} \exp\left(-y_b \left(\frac{1}{1 + \sqrt{1 - \psi_{xr,sov}}} + \sqrt{1 - \psi_{xr,sov}} \right)\right) & \text{if } \psi_{xr,sov} < 1 \\ \exp\left(-\frac{y_b}{\psi_{xr,sov}}\right) & \text{if } \psi_{xr,sov} > 1 \end{cases}$$

$$I_{GSOV} = KG \cdot W_{eff} \cdot NF \cdot LOVIG \cdot \psi_{oxr,sov} \cdot |\psi_{oxr,sov}| \cdot U_T^2 \cdot P_{tun} \cdot T_{OX}^{-2}$$

Gate - Drain (Overlap Current)

Equations similar to Gate - Source (Overlap Current)

Impact Ionization Current

$$v_{ib} = v_d - v_s - 2 \cdot IBN \cdot v_{ds,sat}$$

$$I_{DB} = \begin{cases} I_{DS} \cdot v_{ib} \cdot U_T \cdot \exp\left(\frac{IBB_t \cdot L_C}{v_{ib} \cdot U_T}\right) \cdot \frac{IBA}{IBB_t} & \text{if } v_{ib} > 0 \\ 0 & \text{if } v_{ib} < 0 \end{cases}$$

Noise

Thermal Noise

$$g_n = \frac{2}{(1 + e_{clm} \cdot (q_s - q'_d))^2 \cdot (q_s + q'_d + 1)} \cdot \frac{1}{3} \cdot (q_s^2 + q_s + q'_d + q_d'^2) + e_{clm}^2 \cdot \frac{(i_f - i_r')^2}{4} +$$

$$+ \frac{(e_{clm} \cdot (i_f - i_r') + 1) \cdot (q_s + q'_d)}{4} +$$

$$+ \frac{e_{clm} \cdot (i_f - i_r') - 1}{8} \cdot e_{clm}^2 \cdot (i_f - i_r') \cdot (q_s + q'_d + 1) \cdot \ln \frac{q_s + \frac{1}{2} + \frac{e_{clm} \cdot (i_f - i_r')}{2}}{q'_d + \frac{1}{2} + \frac{e_{clm} \cdot (i_f - i_r')}{2}}$$

$$\text{thermal} = 4 \cdot K \cdot T \cdot \frac{I_{SPEC}}{U_T} \cdot g_n \cdot TH_{NOI}$$

Flicker Noise

$$g_{mg} = \frac{I_{SPEC}}{U_T} \cdot \frac{q_s - q'_d}{n_v}$$

$$\text{flicker} = \frac{KF \cdot g_{mg}^{EF} \cdot (\delta q_{mi} + 1)}{W_{eff} \cdot NF \cdot L_{eff} \cdot COX}$$

$$s_{id,flicker}(f) = \frac{\text{flicker}}{f^{AF}}$$

Induced Gate Noise

$$\omega_{\text{spec}} = \frac{\beta \cdot U_T}{\text{COX} \cdot L_{\text{eff}}^2}$$

$$x_f = q_b + \frac{1}{2}$$

$$x_r = q_d' + \frac{1}{2}$$

$$s_{n,\text{idid}} = \frac{4 \cdot x_f^2 - 3 \cdot x_f + 4 \cdot x_f \cdot x_r - 3 \cdot x_r + 4 \cdot x_r^2}{6 \cdot (x_f + x_r)}$$

$$s_{n,\text{igig}} = \frac{\omega^2}{\omega_{\text{spec}}^2} \frac{16x_f^4 + 16x_r^4 + 80x_fx_r^3 + 80x_f^3x_r + 168x_f^2x_r^2 - 15x_r^3 - 15x_f^3 - 75x_f^2x_r - 75x_r^2x_f}{540n_{q0}^2(x_f + x_r)^5}$$

$$s_{n,\text{ibib}} = \frac{s_{n,\text{igig}}}{(n_{q0} - 1)^2}$$

$$s_{n,\text{igid}} = \frac{J \cdot \frac{\omega}{\omega_{\text{spec}}} \cdot (x_f - x_r) \cdot (x_f^2 + 4 \cdot x_f \cdot x_r + x_r^2)}{18 \cdot n_{q0} \cdot (x_f + x_r)^3}$$

$$c_{\text{igid}} = J \frac{s_{n,\text{igid}}}{\sqrt{s_{n,\text{idid}} \cdot s_{n,\text{igig}}}}$$

Shot and Flicker Gate Noise

$$s_{\text{ig,shot}} = 2 \cdot q_b \cdot I_G$$

$$s_{\text{ig,flicker}}(f) = \frac{\text{KGFN} \cdot I_G^2}{f}$$

Diodes

Temperature Dependence

$$JS_t = JS \cdot \exp\left(\frac{\frac{E_{g,nom}}{U_{T,nom}} - \frac{E_g}{U_T} + XTI \cdot \frac{T}{T_{NOM}}}{ND}\right)$$

$$JSW_t = JSW \cdot \exp\left(\frac{\frac{E_{g,nom}}{U_{T,nom}} - \frac{E_g}{U_T} + XTI \cdot \frac{T}{T_{NOM}}}{ND}\right)$$

$$JSWG_t = JSWG \cdot \exp\left(\frac{\frac{E_{g,nom}}{U_{T,nom}} - \frac{E_g}{U_T} + XTI \cdot \frac{T}{T_{NOM}}}{ND}\right)$$

$$PB_t = PB - TPB \cdot (T - T_{NOM})$$

$$PBSW_t = PBSW - TPBSW \cdot (T - T_{NOM})$$

$$PBSWG_t = PBSWG - TPBSWG \cdot (T - T_{NOM})$$

$$CJ_t = CJ \cdot (1 + TCJ \cdot (T - T_{NOM}))$$

$$CJSW_t = CJSW \cdot (1 + TCJSW \cdot (T - T_{NOM}))$$

$$CJSWG_t = CJSWG \cdot (1 + TCJSWG \cdot (T - T_{NOM}))$$

$$JTS_t = JTS \cdot \exp\left(\frac{E_{g,nom}}{U_T} \cdot XTS \cdot \left(1 - \frac{T}{T_{NOM}}\right)\right)$$

$$JTSW_t = JTSW \cdot \exp\left(\frac{E_{g,nom}}{U_T} \cdot XTSW \cdot \left(1 - \frac{T}{T_{NOM}}\right)\right)$$

$$JTSWG_t = JTSWG \cdot \exp\left(\frac{E_{g,nom}}{U_T} \cdot XTSWG \cdot \left(1 - \frac{T}{T_{NOM}}\right)\right)$$

$$NJTS_t = NJTS \cdot \left(1 + \left(\frac{T}{T_{NOM}} - 1\right) \cdot TNJTS\right)$$

$$NJTSSW_t = NJTSSW \cdot \left(1 + \left(\frac{T}{T_{NOM}} - 1 \right) \cdot TNJTSSW \right)$$

$$NJTSSWG_t = NJTSSWG \cdot \left(1 + \left(\frac{T}{T_{NOM}} - 1 \right) \cdot TNJTSSWG \right)$$

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

$$I_{S,D} = JS_t \cdot AD + JSW_t \cdot PD + JSWG_t \cdot W_{eff} \cdot NF$$

$$f_{breakdown,d} = 1 + XJBV \cdot \exp \left(-\frac{-V(di, b) + BV}{U_T \cdot ND \cdot T_{NOM}} \right)$$

$$I_{DB,tun} = W_{eff} \cdot NF \cdot JTSSWG_t \cdot \left(\exp \left(\frac{V(di, b) \cdot T}{T_{NOM} \cdot U_T \cdot NJTSSWG_t \cdot VTSSWG + V(di, b)} \right) - 1 \right) \\
+ PD \cdot JTSSW_t \cdot \left(\exp \left(\frac{V(di, b) \cdot T}{T_{NOM} \cdot U_T \cdot NJTSSW_t \cdot VTSSW + V(di, b)} \right) - 1 \right) \\
+ AD \cdot JT_t \cdot \left(\exp \left(\frac{V(di, b) \cdot T}{T_{NOM} \cdot U_T \cdot NJTS_t \cdot VTS + V(di, b)} \right) - 1 \right)$$

$$I_{DBJ} = I_{S,D} \cdot \left(1 - \exp \left(-\frac{V(di, b) \cdot T}{T_{NOM} \cdot U_T \cdot ND} \right) \right) \cdot f_{breakdown,d} + V(di, b) \cdot GMIN$$

Junction Capacitance

if $V(\text{di}, \text{b}) \geq 0$

$$\begin{aligned} C_{\text{DBJ}} = & \text{CJ}_t \cdot \text{AD} \cdot \exp\left(\text{MJ} \cdot \ln\left(1 + \frac{V(\text{di}, \text{b})}{\text{PB}_t}\right)\right) + \\ & + \text{CJSW}_t \cdot \text{PD} \cdot \exp\left(\text{MJSW} \cdot \ln\left(1 + \frac{V(\text{di}, \text{b})}{\text{PBSW}_t}\right)\right) + \\ & + \text{CJSWG}_t \cdot \text{W}_{\text{eff}} \cdot \text{NF} \cdot \exp\left(\text{MJSWG} \cdot \ln\left(1 + \frac{V(\text{di}, \text{b})}{\text{PBSWG}_t}\right)\right) \end{aligned}$$

if $V(\text{di}, \text{b}) < 0$

$$\begin{aligned} C_{\text{DBJ}} = & \text{CJ}_t \cdot \text{AD} \cdot \left(1 - \text{MJ} \cdot \frac{V(\text{di}, \text{b})}{\text{PB}_t}\right) + \\ & + \text{CJSW}_t \cdot \text{PD} \cdot \left(1 - \text{MJSW} \cdot \frac{V(\text{di}, \text{b})}{\text{PBSW}_t}\right) + \\ & + \text{CJSWG}_t \cdot \text{W}_{\text{eff}} \cdot \text{NF} \cdot \left(1 - \text{MJSWG} \cdot \frac{V(\text{di}, \text{b})}{\text{PBSWG}_t}\right) \end{aligned}$$

External Resistors (Gate, Series, Bulk)

$$\text{RS} = \frac{\text{HDIF} \cdot \text{RSH} + \left(\text{LDIF} - \frac{\text{DL}}{2}\right) \cdot \text{RS}}{\text{W}_{\text{eff}} \cdot \text{NF}}$$

$$\text{RD} = \frac{\text{HDIF} \cdot \text{RSH} + \left(\text{LDIF} - \frac{\text{DL}}{2}\right) \cdot \text{RD}}{\text{W}_{\text{eff}} \cdot \text{NF}}$$

$$\text{RS}_g = \text{RS} \cdot \left(1 + \frac{\text{WRLX}}{\text{W}_{\text{eff}}}\right)$$

$$\text{RD}_g = \text{RD} \cdot \left(1 + \frac{\text{WRLX}}{\text{W}_{\text{eff}}}\right)$$

$$\text{RG} = \text{RGSH} \cdot \frac{\text{W}_{\text{eff}}}{3 \cdot \text{GC}^2 \cdot \text{NF} \cdot \text{L}_{\text{eff}}}$$

$$\text{RDSB} = \text{RDSBSH} \cdot \frac{\text{L}_{\text{eff}}}{\text{L}_{\text{eff}} \cdot \text{NF}}$$

Virtuoso Simulator Components and Device Models Reference
EKV3 MOSFET Model (ekv3)

if **RINGTYPE** = 1(HORSE – SHOE)

$$RB = \begin{cases} \frac{RBWSH}{2 \cdot W_{eff}} & \text{if } RBN = 0 \\ \frac{2 \cdot W_{eff}}{\frac{RBWSH}{RBN} + NF} & \text{if } RBN \neq 0 \end{cases}$$

if **NF** is even

$$RSB = \begin{cases} \frac{RSBWSH}{2 \cdot W_{eff}} & \text{if } RSBN = 0 \\ \frac{2 \cdot W_{eff}}{\frac{RSBWSH}{RSBN} + NF} & \text{if } RSBN \neq 0 \end{cases}$$

$$RDB = \begin{cases} \frac{RDBWSH}{2 \cdot W_{eff}} & \text{if } RDBN = 0 \\ \frac{2 \cdot W_{eff}}{\frac{RDBWSH}{RDBN} + NF} & \text{if } RDBN \neq 0 \end{cases}$$

if **NF** is odd

$$RSB = \begin{cases} \frac{RSBWSH}{W_{eff}} & \text{if } RSBN = 0 \\ \frac{W_{eff}}{\frac{RSBWSH}{RSBN} + NF} & \text{if } RSBN \neq 0 \end{cases}$$

$$RDB = RSB$$

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

$$RS_{gt} = RS_g \cdot (1 + TR \cdot (T - T_{NOM}) + TR^2 \cdot (T - T_{NOM})^2)$$

$$RD_{gt} = RD_g \cdot (1 + TR \cdot (T - T_{NOM}) + TR^2 \cdot (T - T_{NOM})^2)$$

$$RG_t = RG \cdot (1 + TR \cdot (T - T_{NOM}) + TR^2 \cdot (T - T_{NOM})^2)$$

$$RB_t = RB \cdot (1 + TR \cdot (T - T_{NOM}) + TR^2 \cdot (T - T_{NOM})^2)$$

$$RSB_t = RSB \cdot (1 + TR \cdot (T - T_{NOM}) + TR^2 \cdot (T - T_{NOM})^2)$$

$$RDB_t = RDB \cdot (1 + TR \cdot (T - T_{NOM}) + TR^2 \cdot (T - T_{NOM})^2)$$

$$RDSB_t = RDSB \cdot (1 + TR \cdot (T - T_{NOM}) + TR^2 \cdot (T - T_{NOM})^2)$$

Component Statements

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.

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

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 parameter=value ...
```

Model Parameters

1	<code>sign=(1)</code>	1 for nmose; -1 for pmos
2	<code>tg=((-1))</code>	type of gate
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.

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

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.
24	<code>eta=(0.5)</code>	Mobility Reduction due to Vertical Field Factor.
25	<code>zc=(1.0E-6)</code>	Coulomb Scattering coefficient.
26	<code>thc=(0.0)</code>	Coulomb Scattering coefficient.
27	<code>la=(1.0)</code>	First critical length for mobility length scaling.

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

28	<code>lb=(1.0)</code>	Second critical length for mobility length scaling.
29	<code>ka=(0.0)</code>	First factor for mobility length scaling.
30	<code>kb=(0.0)</code>	Second factor for mobility length scaling.
31	<code>wkp1=(1.0E-6)</code>	Width parameter for mobility profile vs. width.
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.

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

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>lrr=(50.0E-09)</code>	Length Factor for RSCE.
55	<code>qlrr=(0.5E-3)</code>	Threshold Voltage Factor of RSCE.
56	<code>nllr=(10.0E-3)</code>	Body Effect Coefficient Factor of RSCE.
57	<code>flrr=(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>wrr=(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.

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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.
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.

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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.
103	<code>wldphiedge=(0.0)</code>	Area scaling (fine tuning for short and narrow) of DPHIEDGE.
104	<code>wldgammaedge=(0.0)</code>	Area scaling (fine tuning for short and narrow) of DGAMMAEDGE.
105	<code>wedge=(0.0)</code>	Width of edge conduction area.
106	<code>dgammaedge=(0.0)</code>	Difference of body effect coefficient of edge conduction area with respect to the main part of the channel.
107	<code>dphiedge=(0.0)</code>	Difference of fermi potential of edge conduction area with respect to the main part of the channel.
108	<code>saref=(0.0)</code>	Reference distance from STI, for SA.
109	<code>sbref=(0.0)</code>	Reference distance from STI, for SB.
110	<code>wlod=(0.0)</code>	Width of common area between device and STI.

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111	$k_{kp} = (0.0)$	Mobility dependence on STI.
112	$l_{k_{kp}} = (0.0)$	Length scaling of mobility dependence on STI.
113	$w_{k_{kp}} = (0.0)$	Width scaling of mobility dependence on STI.
114	$p_{k_{kp}} = (0.0)$	Area scaling (fine tuning for short and narrow channel devices) of mobility dependence on STI.
115	$t_{k_{kp}} = (0.0)$	Temperature scaling of mobility dependence on STI.
116	$l_{lodk_{kp}} = (1.0)$	Exponent of length scaling of mobility dependence on STI.
117	$w_{lodk_{kp}} = (1.0)$	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.

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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.
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.

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153	<code>rsh=(0.0)</code>	Square resistance of active area.
154	<code>ldif=(0.0)</code>	Distance between the middle of the active area and the start of the channel.
155	<code>rs=(0.0)</code>	Source series resistance.
156	<code>rd=(0.0)</code>	Drain series resistance.
157	<code>rlx=((-1.0))</code>	Series resistance (symmetric model).
158	<code>rsx=((-1.0))</code>	Source series resistance (asymmetric model).
159	<code>rdx=((-1.0))</code>	Drain series resistance (asymmetric model).
160	<code>tr=(0.0)</code>	First order temperature coefficient of resistors.
161	<code>tr2=(0.0)</code>	Second order temperature coefficient of resistors.
162	<code>gmin=(0.0)</code>	Minimum conductance of diode.
163	<code>njs=(1.0)</code>	Slope factor for parasitic diodes(S).
164	<code>xjbvs=(0.0)</code>	Breakdown effect coefficient(S).
165	<code>bvs=(10.0)</code>	Breakdown Voltage(S).
166	<code>jss=(0.0E-09)</code>	Area component of diode current(S).
167	<code>jssws=(0.0E-12)</code>	Perimeter component of diode current(S).
168	<code>jsswgs=(0.0E-12)</code>	Gate side component of diode current(S).
169	<code>jtss=(0.0E-09)</code>	Area component of trap-assisted diode current(S).
170	<code>jtssws=(0.0E-12)</code>	Perimeter component of trap-assisted diode current(S).
171	<code>jtsswgs=(0.0E-12)</code>	Gate side component of trap-assisted diode current(S).
172	<code>njtss=(1.0)</code>	Area slope factor of trap-assisted diode current(S).
173	<code>njtssws=(1.0)</code>	Perimeter slope factor of trap-assisted diode current(S).

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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	$pbs=(0.800)$	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 n_{jtss} .
192	$tnjtssws=(0.0)$	Temperature dependence of n_{jtssws} .
193	$tnjtsswgs=(0.0)$	Temperature dependence of $n_{jtsswgs}$.

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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).
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).

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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	$t_{njtsd}=(0.0)$	Temperature dependence of n_{jtsd} .
229	$t_{njtsswd}=(0.0)$	Temperature dependence of n_{jtsswd} .
230	$t_{njtsswgd}=(0.0)$	Temperature dependence of $n_{jtsswgd}$.
231	$r_{gsh}=(3.0)$	Gate square resistance.
232	$g_c=(1)$	Gate contacts (single sided = 1, double sided = 2).
233	$k_{rgl1}=(0.0)$	Length dependence of r_g .
234	$r_{dsbsh}=(1.0E+3)$	Drain to source substrate sheet resistance.

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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 RINGTYPE=2).
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 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>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>l=(10.0E-06)</code>	GATES LENGTH.

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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).
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.

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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.

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.

aclm M-53

igdov OP-18

njtsswgs M-174

th_noi M-9

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ad	I-7	igidl	OP-22	njtssws	M-173	thc	M-26
ad	OP-6	igisl	OP-23	nlr	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	tnjtsd	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
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

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cgbo	M-147	kgamma	M-124	qib	OP-36	vgb	OP-39
cgdo	M-146	kgfn	M-87	qibedge	OP-32	vov	M-144
cgidl	M-82	kjfb	M-148	qid	OP-34	vsb	OP-40
cgso	M-145	kkp	M-111	qidedge	OP-30	vto	M-12
cjd	M-215	kp	M-21	qidfr	OP-25	vtstd	M-212
cjfb	M-149	krgl1	M-233	qidov	OP-27	vtss	M-175
cjs	M-178	kucrit	M-128	qig	OP-35	vtsswd	M-213
cjswd	M-216	kvto	M-118	qigedge	OP-31	vtsswdg	M-214
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 I-2		lambda	M-51	qsedge	OP-29	w	OP-4
cmi_limexp_method OP-2		lb	M-28	qsfr	OP-24	wdl	M-39
cox	M-10	ldif	M-154	qsov	OP-26	wdphiedge	M-102
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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

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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
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

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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
idb	OP-16	njs	M-163	tcvwl	M-139	xtsswg	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	njtsswg	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.

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

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).

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.

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	$\text{lv}t=(1.0)$	Length for long channel threshold voltage correction.
44	$\text{wv}t=(1.0)$	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	nfvta=(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	aclm=(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	nlr=(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.

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

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.
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.

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

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.
103	<code>wldphiedge=(0.0)</code>	Area scaling (fine tuning for short and narrow) of DPHIEDGE.
104	<code>wldgammaedge=(0.0)</code>	Area scaling (fine tuning for short and narrow) of DGAMMAEDGE.
105	<code>wedge=(0.0)</code>	Width of edge conduction area.
106	<code>dgammaedge=(0.0)</code>	Difference of body effect coefficient of edge conduction area with respect to the main part of the channel.
107	<code>dphiedge=(0.0)</code>	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	$jtsswgs=(0.0E-12)$	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).
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).

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	<code>vt_{sd}=(0.0)</code>	Area voltage factor of trap-assisted diode current(D).
213	<code>vt_{sswd}=(0.0)</code>	Perimeter voltage factor of trap-assisted diode current(D).
214	<code>vt_{sswgd}=(0.0)</code>	Gate side voltage factor of trap-assisted diode current(D).
215	<code>c_{jd}=(0.0E-06)</code>	Area component of diode capacitance(D).
216	<code>c_{jswd}=(0.0E-09)</code>	Perimeter component of diode capacitance(D).
217	<code>c_{jswgd}=(0.0E-09)</code>	Gate side component of diode capacitance(D).
218	<code>p_{bd}=(0.800)</code>	Area parameter of diode capacitance(D).
219	<code>p_{bswd}=(0.600)</code>	Perimeter parameter of diode capacitance(D).
220	<code>p_{bswgd}=(0.600)</code>	Gate side parameter of diode capacitance(D).
221	<code>m_{jd}=(0.900)</code>	Area exponent of diode capacitance(D).
222	<code>m_{jswd}=(0.700)</code>	Perimeter exponent of diode capacitance(D).
223	<code>m_{jswgd}=(0.700)</code>	Gate side exponent of diode capacitance(D).
224	<code>x_{tid}=(3.0)</code>	Temperature dependence of diode(D).
225	<code>x_{tsd}=(0.0)</code>	Area component of temperature dependence of trap-assisted diode current(D).
226	<code>x_{tsswd}=(0.0)</code>	Perimeter component of temperature dependence of trap-assisted diode current(D).
227	<code>x_{tsswgd}=(0.0)</code>	Gate side component of temperature dependence of trap-assisted diode current(D).
228	<code>tn_{jtsd}=(0.0)</code>	Temperature dependence of njtsd.
229	<code>tn_{j_tsswd}=(0.0)</code>	Temperature dependence of njtsswd.
230	<code>tn_{j_tsswgd}=(0.0)</code>	Temperature dependence of njtsswgd.
231	<code>rg_{sh}=(3.0)</code>	Gate square resistance.

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

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).

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

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.

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).

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

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).
21	<code>igs</code>	Gate current(source).
22	<code>igidl</code>	Gate induced drain current.
23	<code>igisl</code>	Gate induced source current.
24	<code>qsfr</code>	Fringing charge.
25	<code>qdfc</code>	Fringing charge.
26	<code>qsov</code>	Overlap charge.
27	<code>qdov</code>	Overlap charge.
28	<code>idsedge</code>	Edge drain current.
29	<code>qsedge</code>	Edge charge.
30	<code>qdedge</code>	Edge charge.
31	<code>qgedge</code>	Edge charge.
32	<code>qbedge</code>	Edge charge.
33	<code>qs</code>	Source charge.
34	<code>qd</code>	Drain charge.
35	<code>qg</code>	Gate charge.
36	<code>qb</code>	Bulk charge.

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

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	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	igid1	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	n1r	M-56	tnjtsd	M-228
agidl	M-80	jsd	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

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

as	I-8	jssws	M-167	pbswd	M-219	tnom	M-3
as	OP-7	jtssd	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
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	qj	OP-36	vsb	OP-40
cgidl	M-82	kkp	M-111	qjedge	OP-32	vto	M-12
cgso	M-145	kp	M-21	qd	OP-34	vtssd	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

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

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
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

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

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
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

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

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.

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

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.
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.

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

12	$v_{t0}=(0.3)$	THRESHOLD VOLTAGE.
13	$\text{phif}=(0.45)$	FERMI BULK POTENTIAL.
14	$\text{gamma}=(0.3)$	Body Effect Coefficient.
15	$\text{gammag}=(4.1)$	Body Effect Coefficient for Gate.
16	$n0=(1.0)$	Long Channel Slope Factor Fine Tuning.
17	$v_{bi}=(0.0)$	Built-in Voltage Drop.
18	$a_{qma}=(0.5)$	Quantum Effect Coefficient for Accumulation Region.
19	$a_{qmi}=(0.4)$	Quantum Effect Coefficient for Inversion Region.
20	$\text{etaqm}=(0.75)$	Quantum Effect Factor.
21	$k_p=(500.0E-06)$	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	$\text{eta}=(0.5)$	Mobility Reduction due to Vertical Field Factor.
25	$z_c=(1.0E-6)$	Coulomb Scattering coefficient.
26	$t_{hc}=(0.0)$	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.

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

33	wkp3=(1.0)	Span parameter for mobility profile vs. width.
34	d1=(-10.0E-9)	Effective Length Parameter.
35	d1c=(0.0)	Effective Length Parameter for Capacitance.
36	dw=(-10.0E-9)	Effective Width Parameter.
37	dwc=(0.0)	Effective Width Parameter for Capacitance.
38	ldw=(0.0)	Length Dependence of Effective Width.
39	wdl=(0.0)	Width Dependence of Effective Length.
40	ll=(0.0)	Base for Exponential Dependence of Effective Length.
41	lln=(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	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).

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

53	<code>ac1m=(0.83)</code>	Channel Length Modulation Factor.
54	<code>lr=(50.0E-09)</code>	Length Factor for RSCE.
55	<code>qlr=(0.5E-3)</code>	Threshold Voltage Factor of RSCE.
56	<code>n1r=(10.0E-3)</code>	Body Effect Coefficient Factor of RSCE.
57	<code>flr=(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>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.

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

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.
96	<code>wlambda=(0.0)</code>	Width scaling of LAMBDA.

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

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.
103	<code>wldphiedge=(0.0)</code>	Area scaling (fine tuning for short and narrow) of DPHIEDGE.
104	<code>wldgammaedge=(0.0)</code>	Area scaling (fine tuning for short and narrow) of DGAMMAEDGE.
105	<code>wedge=(0.0)</code>	Width of edge conduction area.
106	<code>dgammaedge=(0.0)</code>	Difference of body effect coefficient of edge conduction area with respect to the main part of the channel.
107	<code>dphiedge=(0.0)</code>	Difference of fermi potential of edge conduction area with respect to the main part of the channel.
108	<code>saref=(0.0)</code>	Reference distance from STI, for SA.
109	<code>sbref=(0.0)</code>	Reference distance from STI, for SB.
110	<code>wlod=(0.0)</code>	Width of common area between device and STI.
111	<code>kkp=(0.0)</code>	Mobility dependence on STI.
112	<code>lkkp=(0.0)</code>	Length scaling of mobility dependence on STI.
113	<code>wkkp=(0.0)</code>	Width scaling of mobility dependence on STI.
114	<code>pkkp=(0.0)</code>	Area scaling (fine tuning for short and narrow channel devices) of mobility dependence on STI.
115	<code>tkkp=(0.0)</code>	Temperature scaling of mobility dependence on STI.

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

116	$l_{lodkkp}=(1.0)$	Exponent of length scaling of mobility dependence on STI.
117	$w_{lodkkp}=(1.0)$	Exponent of width scaling of mobility dependence on STI.
118	$kv_{to}=(0.0)$	Threshold voltage dependence on STI.
119	$l_{kv_{to}}=(0.0)$	Length scaling of threshold voltage dependence on STI.
120	$w_{kv_{to}}=(0.0)$	Width scaling of threshold voltage dependence on STI.
121	$p_{kv_{to}}=(0.0)$	Area scaling (fine tuning for short and narrow channel devices) of threshold voltage dependence on STI.
122	$l_{lodkv_{to}}=(1.0)$	Exponent of length scaling of threshold voltage dependence on STI.
123	$w_{lodkv_{to}}=(1.0)$	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.

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

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.
143	$lov=(20.0E-9)$	Length of the overlap area.
144	$vov=(1.0)$	Vs dependence of Vgsov.
145	$cgs0=(0.0)$	Bias-independent gate to source overlap capacitance.
146	$cgd0=(0.0)$	Bias-independent gate to drain overlap capacitance.
147	$cgb0=(0.0)$	Bias-independent gate to bulk overlap capacitance.
148	$kjf=(0.0)$	Fringing capacitance factor.
149	$cjf=(0.0)$	Fringing capacitance bias factor.
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.

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

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	$tr = (0.0)$	First order temperature coefficient of resistors.
161	$tr2 = (0.0)$	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	$bvs = (10.0)$	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).

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

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	$pbs=(0.800)$	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.

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

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	$j_{sswg}=(0.0E-12)$	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	$v_{tsd}=(0.0)$	Area voltage factor of trap-assisted diode current(D).
213	$v_{tsswd}=(0.0)$	Perimeter voltage factor of trap-assisted diode current(D).
214	$v_{tsswg}=(0.0)$	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).

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

219	<code>pbswd=(0.600)</code>	Perimeter parameter of diode capacitance(D).
220	<code>pbswgd=(0.600)</code>	Gate side parameter of diode capacitance(D).
221	<code>mjd=(0.900)</code>	Area exponent of diode capacitance(D).
222	<code>mjswd=(0.700)</code>	Perimeter exponent of diode capacitance(D).
223	<code>mjswgd=(0.700)</code>	Gate side exponent of diode capacitance(D).
224	<code>xtid=(3.0)</code>	Temperature dependence of diode(D).
225	<code>xtsd=(0.0)</code>	Area component of temperature dependence of trap-assisted diode current(D).
226	<code>xtsswd=(0.0)</code>	Perimeter component of temperature dependence of trap-assisted diode current(D).
227	<code>xtsswgd=(0.0)</code>	Gate side component of temperature dependence of trap-assisted diode current(D).
228	<code>tnjttsd=(0.0)</code>	Temperature dependence of njttsd.
229	<code>tnjtsswd=(0.0)</code>	Temperature dependence of njtsswd.
230	<code>tnjtsswgd=(0.0)</code>	Temperature dependence of njtsswgd.
231	<code>rgsh=(3.0)</code>	Gate square resistance.
232	<code>gc=(1)</code>	Gate contacts (single sided = 1, double sided = 2).
233	<code>krgl1=(0.0)</code>	Length dependence of rg.
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 RINGTYPE=2).
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 RINGTYPE=2).

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

- 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.
- 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.

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

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).
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.

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

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.

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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ad	I-7	igdov	OP-18	njtssws	M-173	tkkp	M-115
ad	OP-6	igidl	OP-22	nlr	M-56	tlambda	M-130
af	M-85	igisl	OP-23	noi	O-9	tnjtsd	M-228

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EKV3 MOSFET Model (ekv3)

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agamma OP-14	jsd 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
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avto I-14	jtsswgd M-208	pditsd M-71	ucex M-133
avto OP-13	jtsswgs M-171	pditsl M-70	ucrit M-50
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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	qb 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

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

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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
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cjsws M-179	la M-27	qsedge OP-29	wdl M-39
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ddits M-72	ldw M-38	rbwsh M-235	weta M-61
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Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

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dwc M-37	llodkkp M-116	rs M-155	wldgammaedge M-104
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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
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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
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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
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EKV3 MOSFET Model (ekv3)

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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	tcvl	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
idsedge	OP-28	njtsswd	M-210	tg	M-2		
igb	OP-19	njtsswgd	M-211	th_noi	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 ...

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

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_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.
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.

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

18	$a_{qma}=(0.5)$	Quantum Effect Coefficient for Accumulation Region.
19	$a_{qmi}=(0.4)$	Quantum Effect Coefficient for Inversion Region.
20	$\eta_{aqm}=(0.75)$	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	$\eta_a=(0.5)$	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.

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

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.

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

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.

Virtuoso Simulator Components and Device Models Reference

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	<code>lov=(20.0E-9)</code>	Length of the overlap area.
144	<code>vov=(1.0)</code>	Vs dependence of Vgsov.
145	<code>cgso=(0.0)</code>	Bias-independent gate to source overlap capacitance.
146	<code>cgdo=(0.0)</code>	Bias-independent gate to drain overlap capacitance.
147	<code>cgbo=(0.0)</code>	Bias-independent gate to bulk overlap capacitance.
148	<code>kjf=(0.0)</code>	Fringing capacitance factor.
149	<code>cjf=(0.0)</code>	Fringing capacitance bias factor.
150	<code>vfr=(0.0)</code>	Built-in correction for fringing capacitance.
151	<code>dfr=(1.0E-3)</code>	Smooth factor of fringing capacitance model.
152	<code>hdif=(0.0e-6)</code>	Half length of active area.
153	<code>rsh=(0.0)</code>	Square resistance of active area.
154	<code>ldif=(0.0)</code>	Distance between the middle of the active area and the start of the channel.
155	<code>rs=(0.0)</code>	Source series resistance.
156	<code>rd=(0.0)</code>	Drain series resistance.
157	<code>rlx=((-1.0))</code>	Series resistance (symmetric model).
158	<code>rsx=((-1.0))</code>	Source series resistance (asymmetric model).
159	<code>rdx=((-1.0))</code>	Drain series resistance (asymmetric model).
160	<code>tr=(0.0)</code>	First order temperature coefficient of resistors.
161	<code>tr2=(0.0)</code>	Second order temperature coefficient of resistors.
162	<code>gmin=(0.0)</code>	Minimum conductance of diode.
163	<code>njs=(1.0)</code>	Slope factor for parasitic diodes(S).

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

164	$xj_{bvs} = (0.0)$	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	$jt_{ss} = (0.0E-09)$	Area component of trap-assisted diode current(S).
170	$jt_{ssws} = (0.0E-12)$	Perimeter component of trap-assisted diode current(S).
171	$jt_{sswgs} = (0.0E-12)$	Gate side component of trap-assisted diode current(S).
172	$n_{jt_{ss}} = (1.0)$	Area slope factor of trap-assisted diode current(S).
173	$n_{jt_{ssws}} = (1.0)$	Perimeter slope factor of trap-assisted diode current(S).
174	$n_{jt_{sswgs}} = (1.0)$	Gate side slope factor of trap-assisted diode current(S).
175	$vt_{ss} = (0.0)$	Area voltage factor of trap-assisted diode current(S).
176	$vt_{ssws} = (0.0)$	Perimeter voltage factor of trap-assisted diode current(S).
177	$vt_{sswgs} = (0.0)$	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	$m_{jsws}=(0.700)$	Perimeter exponent of diode capacitance(S).
186	$m_{jswgs}=(0.700)$	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

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205	$j_{sswd}=(0.0E-12)$	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	$j_{tsswd}=(0.0E-12)$	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	$n_{jtsswd}=(1.0)$	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	$v_{tsswd}=(0.0)$	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	$p_{bswd}=(0.600)$	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).

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

226	<code>xtsswd=(0.0)</code>	Perimeter component of temperature dependence of trap-assisted diode current(D).
227	<code>xtsswg=(0.0)</code>	Gate side component of temperature dependence of trap-assisted diode current(D).
228	<code>tnjtsd=(0.0)</code>	Temperature dependence of njtsd.
229	<code>tnjtsswd=(0.0)</code>	Temperature dependence of njtsswd.
230	<code>tnjtsswg=(0.0)</code>	Temperature dependence of njtsswg.
231	<code>rgsh=(3.0)</code>	Gate square resistance.
232	<code>gc=(1)</code>	Gate contacts (single sided = 1, double sided = 2).
233	<code>krgl1=(0.0)</code>	Length dependence of rg.
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 RINGTYPE=2).
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 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.

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EKV3 MOSFET Model (ekv3)

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	bdi	node: Internal bulk(D).
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.

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

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.
31	qgedge	Edge charge.
32	qbedge	Edge charge.
33	qs	Source charge.

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EKV3 MOSFET Model (ekv3)

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	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

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EKV3 MOSFET Model (ekv3)

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
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	qb	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	vtsd	M-212
cgso	M-145	kkp	M-111	qdfrr	OP-25	vtss	M-175
cjd	M-215	kp	M-21	qdov	OP-27	vtsswd	M-213

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EKV3 MOSFET Model (ekv3)

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
dw M-36	lln M-41	rlx M-157	wlambda M-96
dwc M-37	llodkkp M-116	rs M-155	wldgammaedge M-104

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

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
gmin	M-162	nf	I-6	tcjswg	M-196	xtsd	M-225
hdif	M-152	nf	OP-5	tcv	M-131	xtss	M-188

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EKV3 MOSFET Model (ekv3)

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 `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.

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

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_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.

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

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.
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.

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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.
32	$wkp2=(0.0)$	Amplitude parameter for mobility profile vs. width.
33	$wkp3=(1.0)$	Span parameter for mobility profile vs. width.
34	$d1=((-10.0E-9))$	Effective Length Parameter.
35	$d1c=(0.0)$	Effective Length Parameter for Capacitance.
36	$dw=((-10.0E-9))$	Effective Width Parameter.
37	$dwc=(0.0)$	Effective Width Parameter for Capacitance.
38	$ldw=(0.0)$	Length Dependence of Effective Width.
39	$wdl=(0.0)$	Width Dependence of Effective Length.
40	$ll=(0.0)$	Base for Exponential Dependence of Effective Length.
41	$lln=(1.0)$	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.

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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>lrr=(50.0E-09)</code>	Length Factor for RSCE.
55	<code>qlrr=(0.5E-3)</code>	Threshold Voltage Factor of RSCE.
56	<code>nllr=(10.0E-3)</code>	Body Effect Coefficient Factor of RSCE.
57	<code>flrr=(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>wrr=(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.

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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.
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.

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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 UCX.
102	<code>wdphiedge=(0.0)</code>	Width scaling of DPHIEDGE.
103	<code>wldphiedge=(0.0)</code>	Area scaling (fine tuning for short and narrow) of DPHIEDGE.
104	<code>wldgammaedge=(0.0)</code>	Area scaling (fine tuning for short and narrow) of DGAMMAEDGE.
105	<code>wedge=(0.0)</code>	Width of edge conduction area.
106	<code>dgammaedge=(0.0)</code>	Difference of body effect coefficient of edge conduction area with respect to the main part of the channel.
107	<code>dphiedge=(0.0)</code>	Difference of fermi potential of edge conduction area with respect to the main part of the channel.
108	<code>saref=(0.0)</code>	Reference distance from STI, for SA.
109	<code>sbref=(0.0)</code>	Reference distance from STI, for SB.
110	<code>wlod=(0.0)</code>	Width of common area between device and STI.
111	<code>kkp=(0.0)</code>	Mobility dependence on STI.
112	<code>lkkp=(0.0)</code>	Length scaling of mobility dependence on STI.

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113	wk _{kp} =(0.0)	Width scaling of mobility dependence on STI.
114	pk _{kp} =(0.0)	Area scaling (fine tuning for short and narrow channel devices) of mobility dependence on STI.
115	t _{kp} =(0.0)	Temperature scaling of mobility dependence on STI.
116	l _{lodkp} =(1.0)	Exponent of length scaling of mobility dependence on STI.
117	w _{lodkp} =(1.0)	Exponent of width scaling of mobility dependence on STI.
118	kv _{to} =(0.0)	Threshold voltage dependence on STI.
119	l _{kvto} =(0.0)	Length scaling of threshold voltage dependence on STI.
120	w _{kvto} =(0.0)	Width scaling of threshold voltage dependence on STI.
121	p _{kvto} =(0.0)	Area scaling (fine tuning for short and narrow channel devices) of threshold voltage dependence on STI.
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	k _{gamma} =(0.0)	Body effect dependence on STI.
125	l _{odkgamma} =(1.0)	Exponential dependence of body effect on STI .
126	ket _{ad} =(0.0)	Primary DIBL dependence on STI.
127	l _{odketad} =(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).

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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.
143	$lov=(20.0E-9)$	Length of the overlap area.
144	$vov=(1.0)$	Vs dependence of Vgsov.
145	$cgso=(0.0)$	Bias-independent gate to source overlap capacitance.
146	$cgdo=(0.0)$	Bias-independent gate to drain overlap capacitance.
147	$cgbo=(0.0)$	Bias-independent gate to bulk overlap capacitance.
148	$kjf=(0.0)$	Fringing capacitance factor.
149	$cjf=(0.0)$	Fringing capacitance bias factor.
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.

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154	<code>ldif=(0.0)</code>	Distance between the middle of the active area and the start of the channel.
155	<code>rs=(0.0)</code>	Source series resistance.
156	<code>rd=(0.0)</code>	Drain series resistance.
157	<code>rlx=((-1.0))</code>	Series resistance (symmetric model).
158	<code>rsx=((-1.0))</code>	Source series resistance (asymmetric model).
159	<code>rdx=((-1.0))</code>	Drain series resistance (asymmetric model).
160	<code>tr=(0.0)</code>	First order temperature coefficient of resistors.
161	<code>tr2=(0.0)</code>	Second order temperature coefficient of resistors.
162	<code>gmin=(0.0)</code>	Minimum conductance of diode.
163	<code>njs=(1.0)</code>	Slope factor for parasitic diodes(S).
164	<code>xjbvs=(0.0)</code>	Breakdown effect coefficient(S).
165	<code>bvs=(10.0)</code>	Breakdown Voltage(S).
166	<code>jss=(0.0E-09)</code>	Area component of diode current(S).
167	<code>jssws=(0.0E-12)</code>	Perimeter component of diode current(S).
168	<code>jsswgs=(0.0E-12)</code>	Gate side component of diode current(S).
169	<code>jtss=(0.0E-09)</code>	Area component of trap-assisted diode current(S).
170	<code>jtssws=(0.0E-12)</code>	Perimeter component of trap-assisted diode current(S).
171	<code>jtsswgs=(0.0E-12)</code>	Gate side component of trap-assisted diode current(S).
172	<code>njtss=(1.0)</code>	Area slope factor of trap-assisted diode current(S).
173	<code>njtssws=(1.0)</code>	Perimeter slope factor of trap-assisted diode current(S).
174	<code>njtsswgs=(1.0)</code>	Gate side slope factor of trap-assisted diode current(S).

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175	<code>vtss=(0.0)</code>	Area voltage factor of trap-assisted diode current(S).
176	<code>vtssws=(0.0)</code>	Perimeter voltage factor of trap-assisted diode current(S).
177	<code>vtsswgs=(0.0)</code>	Gate side voltage factor of trap-assisted diode current(D).
178	<code>cjs=(0.0E-06)</code>	Area component of diode capacitance(S).
179	<code>cjsws=(0.0E-09)</code>	Perimeter component of diode capacitance(S).
180	<code>cjswgs=(0.0E-09)</code>	Gate side component of diode capacitance(S).
181	<code>pbs=(0.800)</code>	Area parameter of diode capacitance(S).
182	<code>pbsws=(0.600)</code>	Perimeter parameter of diode capacitance(S).
183	<code>pbswgs=(0.600)</code>	Gate side parameter of diode capacitance(S).
184	<code>mjs=(0.900)</code>	Area exponent of diode capacitance(S).
185	<code>mjsws=(0.700)</code>	Perimeter exponent of diode capacitance(S).
186	<code>mjswgs=(0.700)</code>	Gate side exponent of diode capacitance(S).
187	<code>xtis=(3.0)</code>	Temperature dependence of diode(S).
188	<code>xtss=(0.0)</code>	Area component of temperature dependence of trap-assisted diode current(S).
189	<code>xtssws=(0.0)</code>	Perimeter component of temperature dependence of trap-assisted diode current(S).
190	<code>xtsswgs=(0.0)</code>	Gate side component of temperature dependence of trap-assisted diode current(S).
191	<code>tnjtss=(0.0)</code>	Temperature dependence of njtss.
192	<code>tnjtssws=(0.0)</code>	Temperature dependence of njtssws.
193	<code>tnjtsswgs=(0.0)</code>	Temperature dependence of njtsswgs.
194	<code>tcj=(0.0)</code>	Temperature dependence of CJ.

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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).
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).

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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	$tn_{jttsd} = (0.0)$	Temperature dependence of n_{jttsd} .
229	$tn_{jtsswd} = (0.0)$	Temperature dependence of n_{jtsswd} .
230	$tn_{jtsswgd} = (0.0)$	Temperature dependence of $n_{jtsswgd}$.
231	$rgsh = (3.0)$	Gate square resistance.
232	$gc = (1)$	Gate contacts (single sided = 1, double sided = 2).
233	$kr_{gl1} = (0.0)$	Length dependence of rg .
234	$r_{dsbsh} = (1.0E+3)$	Drain to source substrate sheet resistance.
235	$r_{bwsh} = (3.0E-3)$	Inner bulk to bulk sheet resistance.

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236	<code>rbn=(0.0)</code>	Inner bulk to bulk resistance per finger (for RINGTYPE=2).
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 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>noi</code>	node: Noise.

Operating-Point Parameters

1	<code>exp_cr=(80.0)</code>	The parameter is used by simulator.
2	<code>cml_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.

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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).
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.

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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.

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.

aclm	M-53	igidl	OP-22	njtssws	M-173	tkkp	M-115
ad	I-7	igisl	OP-23	nlr	M-56	tlambda	M-130
ad	OP-6	igs	OP-21	noi	O-5	tnjtssd	M-228
af	M-85	igsov	OP-17	nqs_noi	M-8	tnjtss	M-191

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agam	M-45	jsd	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	jttd	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
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	qjb	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	vttd	M-212

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cjd M-215	krll 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
cox M-10	ldphiedge M-91	qwr M-66	we1 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	wkcp 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

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

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
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

Virtuoso Simulator Components and Device Models Reference

EKV3 MOSFET Model (ekv3)

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	nfvta	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 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 behaviour exhibited in FD devcies.
- 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 1965
- [Model](#) on page 1965
- [Device Structure](#) on page 1966
- [Equivalent Circuit](#) on page 1967
- [Device Regions](#) on page 1967
- [Global Control Options](#) on page 1968
- [Model Version Update](#) on page 1969
 - [Version 3.2](#) on page 1969
 - [Version 4.0](#) on page 1969
 - [Version 4.1](#) on page 1970
 - [Version 4.2](#) on page 1970
- [Special bug fixed](#) on page 1970

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

- [Rth thermal resistance](#) on page 1970
- [Cth thermal capacity](#) on page 1971
- [ExpVgst bug handling](#) on page 1971
- [Temperature node tolerance and quantity](#) on page 1971
- [I_{jj} \(substrate current\)](#) on page 1972
- [Model Equations](#) on page 1972
 - [DC current](#) on page 1972
 - [Body current](#) on page 1973
 - [Leakage current](#) on page 1976
 - [Charge and Capacitance](#) on page 1979
 - [Selfheating](#) on page 1983
 - [RF model](#) on page 1983
 - [Noise](#) on page 1985
- [Component Statements](#) on page 1987
 - [Instance Parameters](#) on page 1987
 - [Model Parameters](#) on page 1989
 - [Output parameters](#) on page 2010
 - [Operating Point Parameters](#) on page 2010
 - [Parameter Index](#) on page 2015

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 1987.

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.

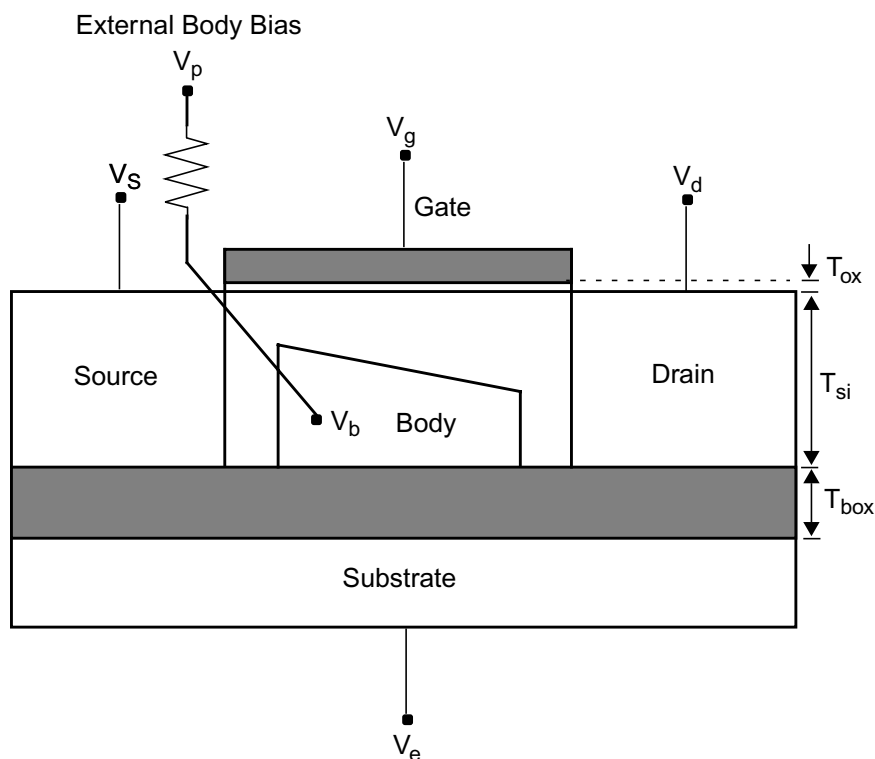
Simple Model statement

```
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 1987.

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 behaviours 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 behaviour;
- FD mode (soimod=2): the body potential is equal to ψ_{bi}

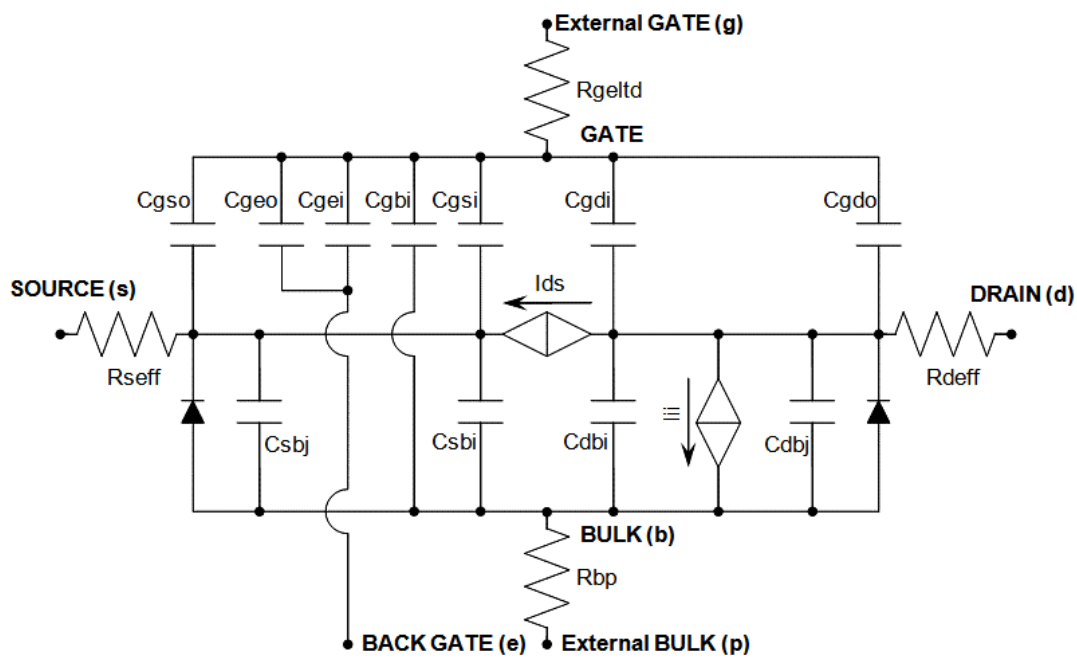
Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

Auto mode (soimod=3): determine the floating body model by with model parameters automatically.

Equivalent Circuit

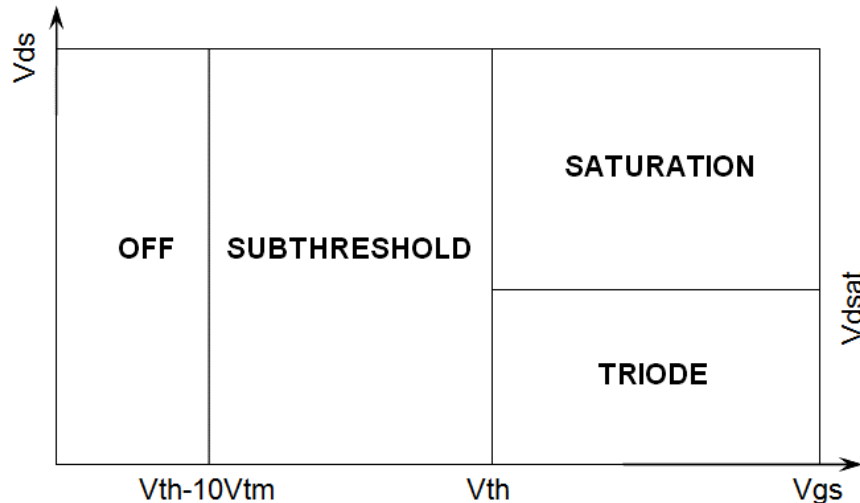
Since BSIMSOI model is developed based on BSIM3v3 model, it shares the similar basic equivalent circuit with BSIM3v3 model except the part of floating body. The followings show the equivalent circuits for BSIMSOI devices:



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:
 - a) Check if resistors are smaller than local minr, if so then remove the parasitic resistors, give warning message.
 - b) 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

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 lbs and lbd 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;

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.

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

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

$R_{th} = R_{th0} / (W_{eff} + W_{th0}) * N_{seg};$

Cadence

$R_{th} = R_{th0} / (NF * (W_{eff} + W_{th0})) * N_{seg};$

It is fixed in MMSIM611_ISR16

C_{th} thermal capacity

C_{th} is the thermal capacity of one device and should be the total resistance of the shunt connected fingers.

UC Berkeley

$C_{th} = C_{th0} * (W_{eff} + W_{th0}) / N_{seg};$

Cadence

$C_{th} = C_{th0} * (NF * (W_{eff} + W_{th0})) / N_{seg};$

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)

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_{ii} (substrate current)

I_{ii} is the impact ionization current from channel to bulk body for one finger and should multiply with number of finger to get the total impact ionization current. Cadence fixed it as I_{ii} * NF

It is fixed in MMSIM72 base release with BSIMSOI version 4.2.

Model Equations

DC current

$$I_{ds, MOSFET} = \frac{I_{ds0}}{1 + \frac{R_{ds} I_{ds0}}{V_{dseff}}} \left(1 + \frac{V_{ds} - V_{dseff}}{V_A} \right)$$

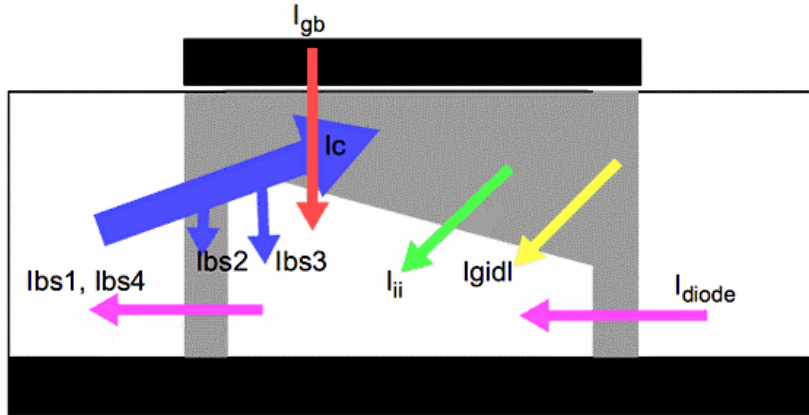
$$I_{ds0} = \frac{\beta V_{gsteff} \left(1 - A_{bulk} \frac{V_{dseff}}{2(V_{gsteff} + 2V_t)} \right) V_{dseff}}{1 + \frac{V_{dseff}}{E_{sat} L_{eff}}}$$

$$\beta = \mu_{eff} fC_{ox} \frac{W_{eff}}{L_{eff}}$$

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

$$I_{bs1} = W_{di0s} T_{si} j_{sdif} \left(e^{\frac{V_{bs}}{n_{di0sd} V_T}} - 1 \right)$$

$$I_{bd1} = W_{di0d} T_{si} j_{ddif} \left(e^{\frac{V_{bd}}{n_{di0dd} V_T}} - 1 \right)$$

The carrier recombination and trap-assisted tunneling current in the space-charge region is modeled by

$$I_{bs2} = W_{di0s} T_{si} j_{srec} \left(e^{\frac{V_{bs}}{0.026 n_{reft} V_T}} - e^{\frac{V_{db}}{0.026 n_{reft} V_{rec0}} \frac{V_{rec0}}{V_{rec0} - V_{db}}} \right)$$

$$I_{bd2} = W_{di0d} T_{si} j_{drec} \left(e^{\frac{V_{bd}}{0.026 n_{reft} V_T}} - e^{\frac{V_{db}}{0.026 n_{reft} V_{rec0d}} \frac{V_{rec0d}}{V_{rec0d} - V_{db}}} \right)$$

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

$$I_{bs4} = W_{di0s} T_{si} j_{stun} \left(1 - e^{-\frac{V_{sb}}{0.026 n_{tun}} \frac{V_{tun0}}{V_{tun0} + V_{sb}}} \right)$$

$$I_{bd4} = W_{di0d} T_{si} j_{dtun} \left(1 - e^{-\frac{V_{db}}{0.026 n_{tun d}} \frac{V_{tun0d}}{V_{tun0d} + V_{db}}} \right)$$

The recombination current in the neutral body can be described by

$$I_{bs3} = (1 - \alpha_{bjr}) I_{en} \left(e^{\frac{V_{bs}}{n_{bs} V_T}} - 1 \right) \frac{1}{\sqrt{E_{hfs} + 1}}$$

$$I_{bd3} = (1 - \alpha_{bjr}) I_{en} \left(e^{\frac{V_{bd}}{n_{bd} V_T}} - 1 \right) \frac{1}{\sqrt{E_{hfd} + 1}}$$

$$I_{en} = W_{eff} T_{si} j_{sbr} \left(L_{br0} \left(\frac{1}{L_{eff}} + \frac{1}{L_n} \right) \right)^N$$

$$E_{hfs} = A_{hfs_eff} \left(e^{\frac{V_{bs}}{n_{bs} V_T}} - 1 \right)$$

$$E_{hfd} = A_{hfd_eff} \left(e^{\frac{V_{bd}}{n_{bd} V_T}} - 1 \right)$$

$$\alpha_{bjr} = e^{-0.5 \left(\frac{L_{eff}}{L_n} \right)^2}$$

Virtuoso Simulator Components and Device Models Reference
BSIMSOI MOSFET Model (bsimsoi)

The BJT collector current is modeled as

$$I_c = \alpha_{\text{bjt}} I_{\text{en}} \left(e^{\frac{V_{be}}{n_{\text{base}} V_t}} - e^{\frac{V_{bd}}{n_{\text{base}} V_t}} \right) \frac{1}{E_{2nd}}$$

$$E_{2nd} = \frac{E_{\text{ely}} + \sqrt{E_{\text{ely}}^2 + 4E_{\text{hli}}}}{2}$$

$$E_{\text{ely}} = 1 + \frac{V_{bs} + V_{bd}}{V_{\text{deyt}} + A_{\text{ely}} L_{\text{eff}}}$$

$$E_{\text{hli}} = E_{\text{hli}s} + E_{\text{hli}d}$$

Impact Ionization Current Equation is modeled as

$$I_{\text{ii}} = \alpha_0 \left(I_{\text{ds}, \text{MOSFET}} + I_{\text{ii}, \text{BJT}} \right) e^{\frac{V_{\text{ag}}}{\beta_2 + \beta_1 V_{\text{ag}} + \beta_0 V_{\text{ag}}^2}}$$

In this expression, the parasitic BJT effect current is modeled as

- $I_{iiMod} = 0$

$$I_{ii_BJT} = F_{bjtii} I_c$$

$$V_{diff} = V_{ds} - V_{dsatii}$$

$$V_{dsatii} = V_{gsStep} + \left(V_{dsatii0} \left(1 + T_{ii} \left(\frac{T}{T_{nom}} - 1 \right) \right) - \frac{L_{ii}}{L_{eff}} \right)$$

$$V_{gsStep} = \left(\frac{E_{satii} L_{eff}}{1 + E_{satii} L_{eff}} \right) \left(\frac{1}{1 + S_{ii1} V_{gsteff}} + S_{ii2} \right) \left(\frac{S_{ii0} V_{gst}}{1 + S_{iid} V_{ds}} \right)$$

- $I_{iiMod} = 1$

$$I_{ii_BJT} = \frac{CBJTH + EBJTH \cdot L_{eff}}{L_{eff}} I_c (V_{bci} - V_{bd}) e^{-AEJTH \cdot (V_{bci} - V_{bd})^{MBJTH-1}}$$

$$V_{bci} = VBCCI \left(1 + TVBCCI \left(\frac{T}{T_{nom}} - 1 \right) \right)$$

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

$$I_{GIDL} = A_{GIDL} \cdot W_{diod} \cdot Nf \frac{V_{ds} - V_{gse} - E_{GIDL} + V_{fbod}}{3T_{oxe}} e^{-\frac{3T_{oxe}B_{GIDL}}{V_{ds} - V_{gse} - E_{GIDL}}} \frac{V_{db}^3}{C_{GIDL} + V_{db}^3}$$

$$I_{GISL} = A_{GISL} \cdot W_{diod} \cdot Nf \frac{-V_{ds} - V_{gde} - E_{GISL} + V_{fbod}}{3T_{oxe}} e^{-\frac{3T_{oxe}B_{GISL}}{-V_{ds} - V_{gde} - E_{GISL}}} \frac{V_{sb}^3}{C_{GISL} + V_{sb}^3}$$

gidlMod = 1

$$I_{GIDL} = A_{GIDL} \cdot W_{diod} \cdot Nf \frac{V_{ds} - R_{GIDL}V_{gse} - E_{GIDL} + V_{fbod}}{3T_{oxe}} e^{-\frac{3T_{oxe}B_{GIDL}}{V_{ds} - V_{gse} - E_{GIDL}}} e^{\frac{K_{GIDL}}{V_{ds} - E_{GIDL}}}$$

$$I_{GISL} = A_{GISL} \cdot W_{diod} \cdot Nf \frac{-V_{ds} - R_{GISL}V_{gde} - E_{GISL} + V_{fbod}}{3T_{oxe}} e^{-\frac{3T_{oxe}B_{GISL}}{-V_{ds} - V_{gde} - E_{GISL}}} e^{\frac{K_{GISL}}{V_{sb} - E_{GISL}}}$$

For thin oxide (below 2nm), oxide tunneling is important in the determination of floating-body potential. In inversion, the tunneling current is:

$$J_{gb} = A \frac{V_{gb} V_{aux}}{T_{ox}^2} \left(\frac{T_{oxTqf}}{T_{oxqW}} \right)^{N_{ov}} e^{\frac{-B(\alpha_{p1} - \beta_{p1}|V_{ox}|)V_{ox}}{1 - \frac{|V_{ox}|}{V_{p1}}}}$$

$$V_{aux} = V_{EFB} \ln \left(1 + e^{\frac{|V_{ox}| - \phi_b}{V_{p1}}} \right)$$

$$A = \frac{q^3}{8\pi h \phi_b}$$

$$B = \frac{8\pi \sqrt{2m_{ox}} \phi_b^{3/2}}{3hq}$$

$$\phi_b = 4.2eV$$

$$m_{ox} = 0.3m_0$$

Virtuoso Simulator Components and Device Models Reference
BSIMSOI MOSFET Model (bsimsoi)

In accumulation, the tunneling current is:

$$J_{gb} = A \frac{V_{gb} V_{max}}{T_{ox}^2} \left(\frac{T_{ox} \eta q^2}{T_{ox} q m} \right)^{N_{avr}} e^{\frac{-B(\alpha_{pb2} - \beta_{pb2}) |V_{ox}| V_{ox}}{1 - \frac{|V_{ox}|}{V_{pb2}}}}$$

$$V_{max} = V_{gcb} \ln \left(1 + e^{\frac{V_{gb} - V_{fb}}{V_{gcb}}} \right)$$

$$A = \frac{q^3}{8\pi h \phi_b}$$

$$B = \frac{8\pi \sqrt{2m_{ox}} \phi_b^{3/2}}{3hq}$$

$$\phi_b = 3.2eV$$

$$m_{ox} = 0.4m_0$$

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:

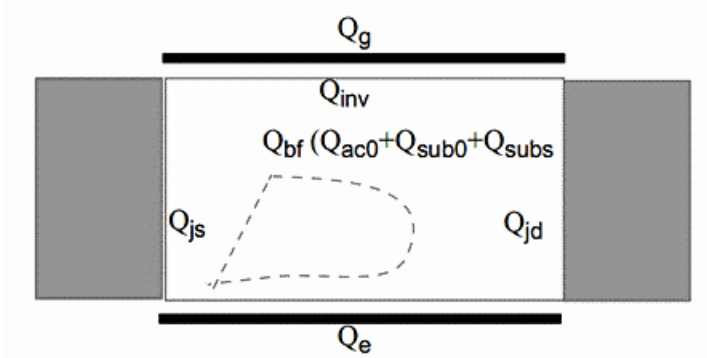
$$I_{g_agbcp2} = A \cdot A_{agbcp2} \min(V_{gp} - V_{fb2}, 0) \cdot V_{gp_eff} T_{ox} \eta q^2 e^{-B T_{ox} q m (A_{gbcp1} - B_{gbcp2} V_{gp_eff}) (1 + C_{gbcp1} V_{gp_eff})}$$

$$V_{gp_eff} = 0.5 \left(\sqrt{(V_{gp} - V_{fb2})^2 + \delta^2} - (V_{gp} - V_{fb2}) - \delta \right)$$

$$\delta = 0.01$$

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:

$$A_{bulkCV} = A_{bulk0} \left(1 + \left(\frac{CLC}{L_{active}} \right)^{CLB} \right)$$

$$A_{bulk0} = A_{bulk}(V_{gstgff} = 0)$$

The effective CV V_{gst} has two equations selected by model parameter `vgstcvmod`:

vgstcvmod = 0 and 1

$$V_{gstgffCV} = nV_t \ln \left(1 + e^{\frac{V_E - V_{th}}{nV_t}} \cdot e^{-\frac{deltar}{nV_t}} \right)$$

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

$$V_{gstgfcv} = \frac{nV_T \ln \left(1 + e^{\frac{m^{*cv} (V_{p_off} - V_{th} - dclvt)}{nV_T}} \right)}{m^{*cv} + nC_{ox} \sqrt{\frac{2\phi_s}{q\epsilon_{si} N_{dep}}}} e^{\frac{(1-m^{*cv})(V_{p_off} - V_{th} - dclvt) - V_{gfcv}}{nV_T}}$$

$$m^{*cv} = 0.5 + \frac{\arctan(MINCV)}{\pi}$$

Then the inversion charge can be expressed as:

$$Q_{inv} = -W_{active} L_{active} C_{ox} \left(V_{gstgfcv} - \frac{A_{bulkcv}^2 V_{dsCV}^2}{2} \right) + \frac{A_{bulkcv}^2 V_{dsCV}^2}{12 \left(V_{gstgfcv} - \frac{A_{bulkcv}^2 V_{dsCV}^2}{2} \right)}$$

$$V_{dsCV} = V_{dsatCV} - \frac{1}{2} \left(V_{dsatCV} - V_{ds} - \delta + \sqrt{(V_{dsatCV} - V_{ds} - \delta)^2 + 4\delta V_{dsatCV}} \right)$$

$$V_{dsatCV} = V_{gstgfcv} / A_{bulkcv}$$

The accumulation charge can be calculated as:

$$Q_{ac0} = -F_{body} W_{active} L_{active} C_{ox} (V_{FBeff} - V_{fb})$$

$$V_{FBeff} = V_{fb} - 0.5 \left((V_{fb} - V_{gb} - \delta) + \sqrt{(V_{fb} - V_{gb} - \delta)^2 + \delta^2} \right)$$

$$V_{gb} = V_{gs} - V_{bseff}$$

$$V_{fb} = V_{th} - \phi_s - K_{1eff} \sqrt{\phi_s - V_{bseff}}$$

Virtuoso Simulator Components and Device Models Reference
BSIMSOI MOSFET Model (bsimsoi)

The gate-induced depletion charge and drain-induced depletion charge can be expressed as:

$$Q_{sub0} = -F_{body} W_{active} L_{activeB} C_{ox} \frac{K_{1eff}^2}{2} \left(-1 + \sqrt{1 + \frac{4(V_{gs} - V_{FEff} - V_{gsteffCV} - V_{bseff})}{K_{1eff}^2}} \right)$$

$$Q_{subs} = F_{body} W_{active} L_{activeB} K_{1eff} C_{ox} (1 - A_{bulkCV}) \left(\frac{V_{dsCV}}{2} - \frac{A_{bulkCV} V_{dsCV}^2}{12(V_{gsteffCV} - A_{bulkCV} V_{dsCV} / 2)} \right)$$

The back gate body charge can be modeled by

$$Q_e = F_{body} W_{active} L_{activeBG} C_{box} (V_{es} - V_{jbb} - V_{bseff})$$

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:

$$Q_{bsdif} = \tau \frac{W'_{eff}}{N_{seg}} T_{si} J_{sbyt} \left(1 + L_{dif0} \left(L_{bj0} \left(\frac{1}{L_{eff}} - \frac{1}{L_n} \right) \right)^{N_{dif}} \right) \left(e^{\frac{V_{bs}}{n_{diod} V_t}} - 1 \right) \frac{1}{\sqrt{E_{hlis} + 1}}$$

$$Q_{bddif} = \tau \frac{W'_{eff}}{N_{seg}} T_{si} J_{dbyt} \left(1 + L_{dif0} \left(L_{bj0} \left(\frac{1}{L_{eff}} - \frac{1}{L_n} \right) \right)^{N_{dif}} \right) \left(e^{\frac{V_{bd}}{n_{diod} V_t}} - 1 \right) \frac{1}{\sqrt{E_{hlid} + 1}}$$

The depletion charges Q_{bddep}/Q_{bsdep} are modeled as:

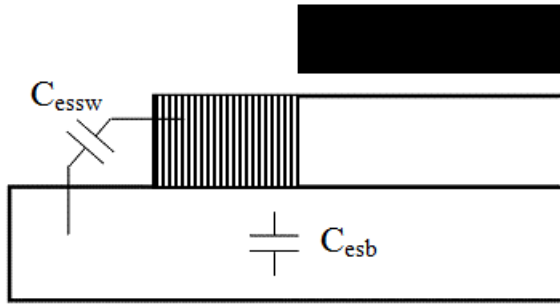
$$Q_{bsdep} = W_{dioCV} C_{jswgs} \frac{T_{si}}{10^{-7}} \frac{P_{bswgs}}{1 - M_{jswgs}} \left(1 - \left(1 - \frac{V_{bs}}{P_{bswgs}} \right)^{1 - M_{jswgs}} \right)$$

$$Q_{bddep} = W_{dioCV} C_{jswgd} \frac{T_{si}}{10^{-7}} \frac{P_{bswgd}}{1 - M_{jswgd}} \left(1 - \left(1 - \frac{V_{bd}}{P_{bswgd}} \right)^{1 - M_{jswgd}} \right)$$

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

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:

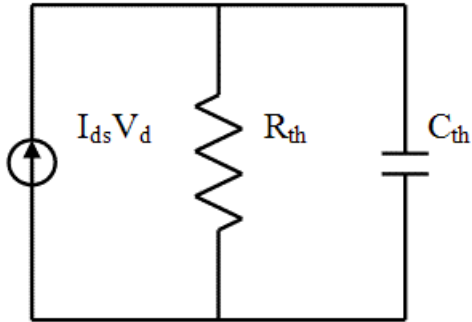
$$C_{esb} = \begin{cases} C_{box} & \text{if } V_{se} < V_{sdjb} \\ C_{box} - \frac{1}{A_{sd}} (C_{box} - C_{min}) \left(\frac{V_{se} - V_{sdjb}}{V_{sdth} - V_{sdjb}} \right)^2 & \text{elseif } V_{se} < V_{sdjb} + A_{sd} (V_{sdth} - V_{sdjb}) \\ C_{min} - \frac{1}{1 - A_{sd}} (C_{box} - C_{min}) \left(\frac{V_{se} - V_{sdth}}{V_{sdth} - V_{sdjb}} \right)^2 & \text{elseif } V_{se} < V_{sdth} \\ C_{min} & \text{else} \end{cases}$$

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 Rth and a thermal capacitance Cth.

$$R_{th} = \frac{R_{th0}}{W'_{eff} + W_{th0}}$$

$$C_{th} = C_{th0} (W'_{eff} + W_{th0})$$

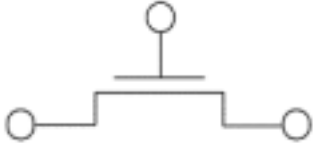
where Rth0 and Cth0 are normalized thermal resistance and capacitance respectively. Wth0 is the minimum width for thermal resistance calculation. The current source is driving a current equal to the power dissipated in the device.

$$P = |I_{ds} V_{ds}|$$

RF model

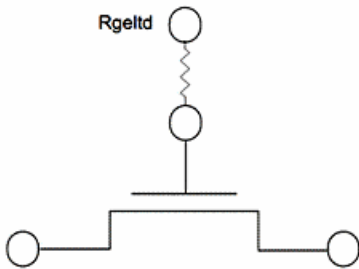
BSIMSOI provides the gate resistance model used in RF application. You have the following options for modeling gate electrode resistance (bias independent) and intrinsic-input resistance (R_{ij} , bias-dependent):

RgateMod=0 (zero-resistance)



In this case, no gate resistance is generated.

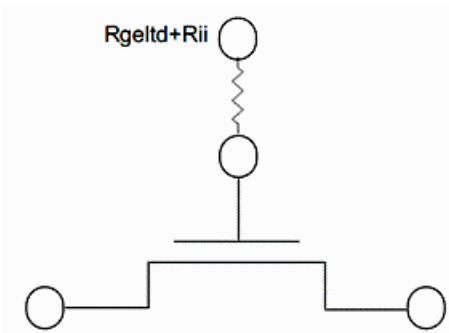
RgateMod=1 (constant-resistance)



In this case, only electrode gate resistance (bias-independent) is generated by adding an internal gate node. The electrode gate resistance is given by

$$R_{gelt} = \frac{R_{SH3} \left(X_{GW} + \frac{W_{eff}}{3N_{GCON} \cdot N_{seg}} \right)}{N_{GCON} (L_{drain} - X_{GL})}$$

RgateMod=2 (R_{||} model with variable resistance)



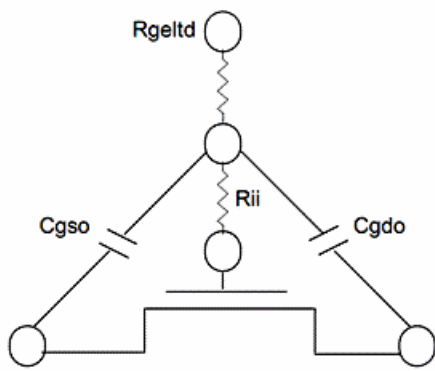
Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

The gate resistance here is the sum of the electrode resistance and the intrinsic-input resistance R_{ij} , as given by:

$$\frac{1}{R_{ij}} = X_{RCRG1} \left(\frac{I_{ds}}{V_{ds,eff}} + X_{RCRG2} \frac{W_{eff} \mu_{eff} C_{ox,eff} k_B T}{q L_{eff}} \right)$$

RgateMod=3 (R_{ij} model with two nodes)



The gate electrode resistance here is in series with the intrinsic-input resistance R_{ij} 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

$$S_{id}(f) = \left(\frac{W_{eff}}{W_{0,FLK}} \right)^{1-\alpha} \frac{K_f I_{ds}^{\alpha}}{C_{ox} L_{eff}^2 f^{\alpha}}$$

fnoiMod=1

The noise density in inversion region is given by:

$$S_{id,inv}(f) = \frac{k_B T q^2 \mu_{eff} I_{ds}}{C_{oxe} L_{eff}^2 A_{bulk} f^{ef} \cdot 10^{10}} \left(Noia \left(\frac{N_0 + N^*}{N_I + N^*} \right) + Noib(N_0 - N_I) + \frac{Noic}{2} (N_0^2 - N_I^2) \right) + \frac{k_B T \cdot I_{ds}^2 \Delta L_{cim}}{W_{eff} L_{eff}^2 f^{ef} \cdot 10^{10}} \frac{Noia + Noib \cdot N_I + Noic \cdot N_I^2}{(N_I + N^*)^2}$$

The noise density in subthreshold region is given by:

$$S_{id,subV_t}(f) = \frac{Noia \cdot k_B T \cdot I_{ds}^2}{W_{eff} L_{eff} f^{ef} (N^*)^2 \cdot 10^{10}}$$

The total flicker noise density is:

$$S_{id}(f) = \frac{S_{id,inv}(f) \times S_{id,subV_t}(f)}{S_{id,inv}(f) + S_{id,subV_t}(f)}$$

Two thermal noise models are provided in BSIMSOI model:

tnoiMod=0

$$\overline{i_d^2} = \frac{4k_B T \Delta f}{R_{ds} + \frac{L_{eff}}{\mu_{eff} |Q_{inv}|}} N_{tnoi}$$

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:

$$\overline{i_d^2} = 4k_B T \frac{V_{dseff} \Delta f}{I_{ds}} (G_{ds} + \beta_{tnoi} (G_m + G_{mbs}))^2 - \overline{v_d^2} (G_{ds} + G_m + G_{mbs})^2$$

Component Statements

This device is supported within altergroups.

Instance Parameters

1 w(m)	Channel width.
2 l(m)	Channel length.
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	Number of squares of drain diffusion.
9 nrs	Number of squares of source diffusion.
10 nrb	Number of body squares.
11 nbc=0	Number of body contact isolation edge.
12 nseg=1	Number of segments for channel width partitioning.
13 pdbc=0 m	Perimeter length for body contact parasitic at drain.
14 psbc=0 m	Perimeter length for body contact parasitic at source.

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

15 agbcp=0 m ²	Gate to body overlap area for body contact parasitic.
16 aebcp=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).
22 isnoisy=yes	Should device generate noise. Possible values are no or yes.
23 region=triode	Estimated operating region. Possible values are off, triode, sat, or subth.
24 rth0((m*C)/w)	Thermal resistance.
25 cth0(w*s/(m*C))	Thermal capacitance.
26 bjtoff=0	BJT off flag.
27 vbsusr=0 V	Optional initial value of Vbs for transient.
28 frbody=1	Layout dependent body-resistance coefficient.
29 sa=0 m	Distance between OD edge to poly of one side.
30 sb=0 m	Distance between OD edge to poly of the other side.
31 sd=0 m	Distance between neighbour fingers.
32 rbdb(Ohm)	Body resistance.
33 rbsb(Ohm)	Body resistance.
34 agbcpcd=agbcp	Gate to body overlap area for bc parasitics in DC.

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

35 `agbcp2=0 m2` Parasitic Gate to body overlap area for bc parasitics.

36 `delvto=0 V` Zero bias threshold voltage variation.

37 `trise` 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 `type=n` Transistor type. Possible values are n or p.

2 `version=3.0` Model version selector. The available version is 2.23, 3.0, 3.11, 3.2, 4.0, 4.1 and 4.2.

3 `binunit=1` Bin parameter unit selector: 1 for microns and 2 for meters.

4 `cdnver=1` Cadence version selector.

5 `soimod=0` SOI model selector. `SoiMod=0`: PD module. `SoiMod=1`: DD module. `SoiMod=2`: FD module.

6 `mtrlmod=0` parameter for non-silicon substrate or metal gate selector.

7 `mobmod=1` Mobility model selector.

8 `fdmod=0` Improved `dVbi` model selector.

9 `gidlmod=0` parameter for GIDL selector.

10 `gatetype=h` Gate structure type selector. Possible values are h or non_h.

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

11	capmod=2	Intrinsic charge model.
12	vgstcvmod=0	Improved VgsteffCV selector.
13	igmod=0	Gate tunneling current model selector.
14	igbmod=0	Gate-body tunneling current model selector.
15	igcmmod=0	Gate-channel tunneling current model selector.
16	iiimod=0	Parameter for lii selector.
17	rbodymod=0	Body R model selector.
18	rdsmod=0	Bias-dependent S/D resistance model selector.
19	rgatemod=0	Rgate flag.
20	shmod=0	Self-heating selector.
21	tlev=0	DC temperature selector.
22	tlevc=0	AC temperature selector.
23	noimod=1	Noise model selector.
24	fnoimod=1	Flicker Noise model selector.
25	tnoimod=0	Thermal Noise model selector.

Process parameters

26	nsub=6e16 cm ⁻³	Substrate doping concentration.
27	nch=1.7e17 cm ⁻³	Peak channel doping concentration.
28	ngate=0 cm ⁻³	Poly-gate doping concentration.
29	nsd=1.0e20 cm ⁻³	S/D doping concentration.
30	xj=0.15e-6 m	Source/drain junction depth.

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

31	$tsi=1e-7$ m	Silicon film thickness.
32	$etsi=1e-7$ m	Effective Silicon-on-insulator thickness in meters.
33	$tbox=3e-7$ m	Buried oxide thickness.
34	$tox=1e-8$ m	Gate oxide thickness.
35	$toxm(m)$	Gate oxide thickness used in extraction.
36	$toxp=tox$	Physical gate oxide thickness.
37	$xt=1.55e-7$ m	Doping depth.
38	$rdsw=100$	Width dependence of drain-source resistance.
39	$prwb=0$ V ^{-1/2}	Body-effect coefficient for Rds.
40	$prwg=0$ V ⁻¹	Gate-effect coefficient for Rds.
41	$wr=1$	Width offset for parasitic resistance.
42	$dwg=0$ m/V	Gate-bias dependence of channel width.
43	$dwb=0$ m/V ^{1/2}	Body-bias dependence of channel width.
44	$dwbc=0$ m	Width offset for body contact isolation edge.
45	$lint=0$ m	Lateral diffusion for one side.
46	$wint=0$ m	Width reduction for one side.
47	$ll=0$ m ^{lln}	Length dependence of delta L.
48	$lln=1$	Length exponent of delta L.
49	$llc=0$ m ^{lln}	Length dependence of delta LC.
50	$lwc=0$ m ^{wln}	Width dependence of delta LC.
51	$lwc=0$ m ^{lln+lwn}	Area dependence of delta LC.
52	$lw=0$ m ^{lwn}	Width dependence of delta L.

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

53	$lwn=1$	idth exponent of delta L.
54	$lwl=0 m^{ln+lwn}$	Area dependence of delta L.
55	$wl=0 m^{wn}$	Length dependence of delta W.
56	$wlc=0 m^{wn}$	Length dependence of delta WC.
57	$wwc=0 m^{wn}$	Width dependence of delta WC.
58	$wwlc=0 m^{wn+wn}$	Area dependence of delta WC.
59	$wln=1$	Length exponent of delta W.
60	$ww=0 m^{wn}$	Width dependence of delta W.
61	$wwn=1$	Width exponent of delta W.
62	$wwl=0 m^{wn+wln}$	Area dependence of delta W.
63	$xl=0 m$	Length variation due to masking and etching.
64	$xw=0 m$	Width variation due to masking and etching.

Material model parameters: (Version 4.1 or later)

65	$eot=100.0e-10 m$	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	$ni0sub=1.45e10 cm^{-3}$	Intrinsic carrier concentration of substrate at Tnom.
69	$bg0sub=1.16 eV$	Band-gap of substrate at T=0K.
70	$tbgasub=7.02e-4 V/K$	First parameter of band-gap change due to temperature.
71	$tbgbsub=1108.0 K$	Second parameter of band-gap change due to temperature.
72	$phig=4.05 eV$	Work function of gate.
73	$easub=4.05 eV$	Electron affinity of substrate.

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

74	leff _{tot} =1.0 μm	Effective length for extraction of EOT.
75	w _{eff_{tot}} =10.0 μm	Effective width for extraction of EOT.
76	v _{ddeot} =1.5 V	Voltage for extraction of EOT.
77	tem _{peot} =300.15 K	Temperature for extraction of EOT.
78	ados=1.0	Charge centroid parameter.
79	b _{dos} =1.0	Charge centroid parameter.
80	eps _{rgate} =11.7	Dielectric constant of gate relative to vacuum.

Threshold voltage parameters:

81	v _{th0} (V)	Threshold voltage at zero body bias for long-channel devices. For enhancement-mode devices, v _{th0} > 0 for n-channel and v _{th} < 0 for p-channel. Default value is calculated from other model parameters.
82	k ₁ =0.53 V ^{1/2}	Body-effect coefficient.
83	k _{1w1} =0 m	First body effect width dependent parameter.
84	k _{1w2} =0 m	Second body effect width dependent parameter.
85	k ₂ =-0.0186	Charge-sharing parameter.
86	k ₃ =0	Narrow width coefficient.
87	k _{3b} =0 V ⁻¹	Narrow width coefficient.
88	w ₀ =2.5e-6 m	Narrow width coefficient.
89	l _{pe0} =1.74e-7 m	Lateral nonuniform doping coefficient.
90	n _{lx} =1.74e-7 m	Lateral nonuniform doping coefficient.
91	l _{peb} =0 m	Lateral non-uniform doping effect for body bias.
92	dvt ₀ =2.2	First coefficient of short-channel effects.

Virtuoso Simulator Components and Device Models Reference
BSIMSOI MOSFET Model (bsimsoi)

93	$dvt1=0.53$	Second coefficient of short-channel effects.
94	$dvt2=-0.032\text{ V}^{-1}$	Body-bias coefficient of short-channel effects.
95	$dvt0w=0$	First coefficient of narrow-width effects.
96	$dvt1w=5.3e6$	Second coefficient of narrow-width effects.
97	$dvt2w=-0.032$	Body-bias coefficient of narrow-width effects.
98	$vbx=0\text{ V}$	Threshold voltage transition body voltage.
99	$vbm=-3\text{ V}$	Maximum applied body voltage.
100	$vfb=-1.0\text{ V}$	Flat Band Voltage.
101	$a0=1$	Nonuniform depletion width effect coefficient.
102	$b0=0\text{ m}$	Bulk charge coefficient due to narrow width effect.
103	$b1=0\text{ m}$	Bulk charge coefficient due to narrow width effect.
104	$a1=0$	No-saturation coefficient.
105	$a2=1$	No-saturation coefficient.
106	$ags=0\text{ V}^{-1}$	Gate-bias dependence of a_{bulk} .
107	$keta=-0.6\text{ V}^{-1}$	Body-bias coefficient for non-uniform depletion width effect.
108	$ketas=0\text{ V}$	Surface Potential adjustment for bulk charge effect.
109	$dvtp0=0\text{ m}$	First parameter for V_{th} shift due to pocket.
110	$dvtp1=0\text{ V}^{-1}$	Second parameter for V_{th} shift due to pocket.
111	$dvtp2=0$	Third parameter for V_{th} shift due to pocket.
112	$dvtp3=0$	Forth parameter for V_{th} shift due to pocket.
113	$dvtp4=0$	Fifth parameter for V_{th} shift due to pocket.
114	$minv=0$	For moderate inversion in V_{gsteff} .

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

115	$\text{pdits}=1\text{e-}20 \text{ V}^{-1}$	Coefficient for drain-induced V_{th} shifts.
116	$\text{pditsl}=0 \text{ m}^{-1}$	Length dependence of drain-induced V_{th} shifts.
117	$\text{pditsd}=0 \text{ V}^{-1}$	V_{ds} dependence of drain-induced V_{th} shifts.
118	$\text{gamma1}=0 \text{ V}^{-1/2}$	Body-effect coefficient near the surface.
119	$\text{gamma2}=0 \text{ V}^{-1/2}$	Body-effect coefficient in the bulk.

Mobility parameters:

120	$\text{u0}=670 \text{ cm}^2\text{V}^{-1}\text{s}$	Low-field surface mobility at ' t_{nom} '. Default is 250 for PMOS.
121	$\text{vsat}=8\text{e}4 \text{ m/s}$	Carrier saturation velocity at ' t_{nom} '.
122	$\text{ua}=2.25\text{e-}9 \text{ mV}^{-1}$	First-order mobility reduction coefficient.
123	$\text{ub}=5.87\text{e-}19 \text{ m}^2\text{V}^{-2}$	Second-order mobility reduction coefficient.
124	$\text{uc}=-4.65\text{e-}11 \text{ mV}^{-2}$	Body-bias dependence of mobility. Default is -0.046 and unit is 1/V for $\text{mobmod}=3$.
125	$\text{ud}=0 \text{ m}^{-2}$	Coulomb scattering factor of mobility.
126	$\text{eu}=1.67$	Mobility exponent.
127	$\text{ucs}=1.67$	Mobility exponent.

Subthreshold parameters

128	$\text{cdsc}=2.4\text{e-}4 \text{ Fm}^{-2}$	Source/drain and channel coupling capacitance.
129	$\text{cdscb}=0 \text{ Fm}^{-2}\text{V}$	Body-bias dependence of ' cdsc '.
130	$\text{cdscd}=0 \text{ Fm}^{-2}\text{V}$	Drain-bias dependence of ' cdsc '.
131	$\text{nfactor}=1$	Subthreshold swing coefficient.
132	$\text{cit}=0 \text{ Fm}^{-2}$	Interface trap parameter for subthreshold swing.
133	$\text{voff}=-0.08 \text{ V}$	Threshold voltage offset.

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

134	noff=1.0 V ⁻¹	C-V turn-on/off parameter.
135	dsub=drout	DIBL effect in subthreshold region.
136	eta0=0.08	DIBL coefficient subthreshold region.
137	etab=-0.07 V ⁻¹	Body-bias dependence of `et0'.

Output resistance parameters

138	drout=0.56	DIBL effect on output resistance coefficient.
139	fprout=0 Vm ^{-1/2}	Rout degradation coefficient for pocket devices.
140	pclm=1.3	Channel length modulation coefficient.
141	pdiblc1=0.39	First coefficient of drain-induced barrier lowering.
142	pdiblc2=8.6e-3	Second coefficient of drain-induced barrier lowering.
143	pdiblc3=0 V ⁻¹	Body-effect coefficient for DIBL.
144	pvag=0	Gate dependence of Early voltage.
145	delta=0.01 V	Effective drain voltage smoothing parameter.

Substrate current parameters

146	alpha0=0 m/V	Substrate current impact ionization coefficient.
147	beta0=0 V ⁻¹	First Vds dependent parameter of impact ionization current.
148	fbjtii=0	Fraction of bipolar current affecting the impact ionization.
149	beta1=0	Second Vds dependent parameter of impact ionization current.
150	beta2=0 V	Third Vds dependent parameter of impact ionization current.
151	vdsatii0=0.9 V	Nominal drain saturation voltage at threshold for impact ionization current.

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

152	$v_{bci}=0$ V	Internal B-C built-in potential.
153	$t_{ii}=0$	Temperature dependent parameter for impact ionization current.
154	$l_{ii}=0$	Channel length dependent parameter at threshold for impact ionization current.
155	$esat_{ii}=1e7$ Vm^{-1}	Saturation channel electric field for impact ionization current.
156	$s_{ii0}=0.5$ V^{-1}	First V_{gs} dependent parameter for impact ionization current.
157	$s_{ii1}=0.1$ V^{-1}	Second V_{gs} dependent parameter for impact ionization current.
158	$s_{ii2}=0$ V^{-1}	Third V_{gs} dependent parameter for impact ionization current.
159	$siid=0$ V^{-1}	V_{ds} dependent parameter of drain saturation voltage for impact ionization current.
160	$ebjt_{ii}=0$ V^{-1}	Impact ionization parameter for BJT part.
161	$cbjt_{ii}=0$ $m^{-1}V^{-1}$	Length scaling parameter for II BJT part.
162	$abjt_{ii}=0$	Exponent factor for avalanche current.
163	$mbjt_{ii}=0.4$	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	$bgidl=0$ Vm^{-1}	GIDL exponential coefficient.
168	$cgidl=0$ V^3	GIDL v_b parameter.
169	$rgidl=1.0$ V^{-1}	GIDL v_g parameter.
170	$kgidl=0$ V^{-1}	GIDL v_b parameter.
171	$fgidl=0$ V	GIDL v_b parameter.

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

172	egisl=egidl	GISL first parameter.
173	agisl=agidl	GISL constant.
174	bgisl=bgidl	GISL exponential coefficient.
175	cgisl=cgidl	GISL vb parameter.
176	rgisl=Rgidl	GISL vg parameter.
177	kgisl=kgidl	GISL vb parameter.
178	fgisl=fgidl	GISL vb parameter.
179	ntun=10	Reverse tunneling non-ideality factor.
180	ntund=ntun	Reverse tunneling non-ideality factor.
181	ndioded=ndiode	Diode non-ideality factor.
182	nrecf0=2.0	Recombination non-ideality factor at forward bias.
183	nrecr0=10	Recombination non-ideality factor at reversed bias.
184	nrecf0d=nrecf0	Recombination non-ideality factor at forward bias.
185	nrecr0d=nrecr0	Recombination non-ideality factor at reversed bias.
186	isbjt=1e-6 Am ⁻²	BJT saturation current.
187	isdif=0 Am ⁻²	Diffusion saturation current.
188	isrec=1e-5 Am ⁻²	Recombination saturation current.
189	istun=0 Am ⁻²	Tunneling saturation current.
190	idbjt=isbjt	BJT injection saturation current.
191	iddif=isdif	Body to source/drain injection saturation current.
192	idrec=isrec	Recombination saturation current.
193	idtun=idtun	Tunneling saturation current.

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BSIMSOI MOSFET Model (bsimsoi)

194	$l_n=2e-6$ m	Electron diffusion length.
195	$v_{rec0}=0$ V	Voltage dependent parameter for recombination current.
196	$v_{tun0}=0$ V	Voltage dependent parameter for tunneling current.
197	$v_{rec0d}=v_{rec0}$	Voltage dependent parameter for recombination current.
198	$v_{tun0d}=v_{tun0}$	Voltage dependent parameter for tunneling current.
199	$n_{bjt}=1$	Power coefficient of channel length dependency for bipolar current.
200	$l_{bjt0}=0.20e-6$ m	Reference channel length for bipolar current.
201	$v_{abjt}=10$ V	Early voltage for bipolar current.
202	$a_{ely}=0$ Vm^{-1}	Channel length dependency of early voltage for bipolar current.
203	$ah_{li}=0$	High level injection parameter for bipolar current.
204	$ah_{lid}=ah_{li}$	High level injection parameter for bipolar current.
205	$n_{diode}=1$	Diode non-ideality factor.
206	$v_{bsa}=0$ V	Non-ideal offset voltage.
207	$n_{offfd}=1.0$	Smooth parameter in FD module.
208	$v_{offfd}=0$	Smooth parameter in FD module.
209	$k_{1b}=1.0$	First backgate body effect parameter.
210	$k_{2b}=0$	Second backgate body effect parameter for short channel effect.
211	$dk_{2b}=0$	Third backgate body effect parameter for short channel effect.
212	$dv_{bd0}=0$	First short-channel effect parameter in FD module.
213	$dv_{bd1}=0$	Second short-channel effect parameter in FD module.
214	$m_{oinfd}=1.0e3$	Gate bias dependence coefficient of surface potential.

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

215 vbs0pd=0 V	Upper bound of built-in potential lowering for PD operation.
216 vbs0fd=0.5 V	Lower bound of built-in potential lowering for FD operation.

Parasitic resistance parameters

217 rbody=0 Ω	Body resistance.
218 rbsh=0 Ω	Extrinsic body contact sheet resistance.
219 rsh=0 Ω	Source/drain diffusion sheet resistance.
220 rs=0 Ω	Source resistance.
221 rd=0 Ω	Drain resistance.
222 rsc=0 Ω	Source contact resistance.
223 rdc=0 Ω	Drain contact resistance.
224 rsw=50 Ω	Source resistance per width.
225 rdw=50 Ω	Drain resistance per width.
226 rswmin=0 Ω	Source resistance per width at high V_g .
227 rdwmin=0 Ω	Drain resistance per width at high V_g .
228 rss=0 Ω	Scalable source resistance.
229 rdd=0 Ω	Scalable drain resistance.
230 rhalo=1.0e15 Ω	Body halo sheet resistance.
231 frbody=1	Layout dependent body-resistance coefficient.
232 minr=0.1 Ω	Minimum source/drain resistance.
233 hdif=0 m	Length of heavily doped diffusion.
234 ldif=0 m	Lateral diffusion beyond the gate.

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

Gate tunneling parameters

235	$n_{tox}=1.0$	Power term of gate current.
236	$tox_{qm}=Tox$	Effective oxide thickness considering quantum effects.
237	$tox_{ref}=2.5e-9$ m	Target oxide thickness.
238	$ebg=1.2$ V	Effective bandgap in gate current calculation.
239	$alpha_{gb1}=0.35$	First V_{ox} dependent parameter for gate current in inversion.
240	$beta_{gb1}=0.03$	Second V_{ox} dependent parameter for gate current in inversion.
241	$v_{gb1}=300$	Third V_{ox} dependent parameter for gate current in inversion.
242	$vevb=0.075$	Vaux parameter for valence-band electron tunneling.
243	$nevb=3.0$	Valence-band electron non-ideality factor.
244	$alpha_{gb2}=0.43$	First V_{ox} dependent parameter for gate current in accumulation.
245	$beta_{gb2}=0.05$	Second V_{ox} dependent parameter for gate current in accumulation.
246	$v_{gb2}=17$	Third V_{ox} dependent parameter for gate current in accumulation.
247	$vecb=0.026$	Vaux parameters for conduction-band electron tunneling.
248	$necb=1.0$	Conduction-band electron non-ideality factor.
249	$a_{igc}=0.43$	Parameter for I_{gc} .
250	$b_{igc}=0.054$	Parameter for I_{gc} .
251	$c_{igc}=0.075$ V ⁻¹	Parameter for I_{gc} .
252	$a_{igsd}=0.43$	Parameter for I_{gs}/I_{gd} .
253	$b_{igsd}=0.054$	Parameter for I_{gs}/I_{gd} .
254	$c_{igsd}=0.075$ V ⁻¹	parameter for I_{gs}/I_{gd} .

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

255	nigc=1.0	Parameter for I _{gc} slope.
256	pigcd=1.0	Parameter for I _{gc} partition.
257	poxedge=1.0	Factor for the gate edge Tox.
258	dlcig=lint	Delta Length for I _g model.
259	voxb=5.0 V	Limit of Vox in gate current calculation.
260	deltavox=0.005 V	Smoothing parameter in the Vox smoothing function.
261	aigbcp2=0.043	First V _{gp} dependent parameter for gate current in accumulation in AGBCP2 region.
262	bigbcp2=0.0054	Second V _{gp} dependent parameter for gate current in accumulation in AGBCP2 region.
263	cigbcp2=0.0075	Third V _{gp} dependent parameter for gate current in accumulation in AGBCP2 region.

Overlap capacitance parameters

264	cgso=0 F/m	Gate-source overlap capacitance.
265	cgdo=0 F/m	Gate-drain overlap capacitance.
266	cgeo=0 F/m	Gate-substrate overlap capacitance.
267	cgbo=0 F/m	Gate-bulk overlap capacitance.
268	cgsl=0 F/m	Gate-source overlap capacitance in LDD region.
269	cgdl=0 F/m	Gate-drain overlap capacitance in LDD region.
270	ckappa=0.6	Overlap capacitance fitting parameter.

Junction capacitance model parameters

271	cjswg=1e-10 Fm ⁻²	Zero-bias gate-side junction capacitance density.
272	mjswg=0.5	Gate-side junction grading coefficient.

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

273 pbswg=0.7 V	Gate-side junction built-in potential.
274 cjswgd=cjswg	Drain(gate side) sidewall junction capacitance per unit width.
275 mjswgd=mjswg	Drain (gate side) sidewall junction capacitance grading coefficient.
276 pbswgd=pbswg	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(V)	Source/Drain diffusion flatband voltage.
282 vsdth(V)	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 parameters

285 cf=0 Fm ⁻¹	Fringe capacitance parameter.
286 clc=1e-8 m	Intrinsic capacitance fitting parameter.
287 cle=0	Intrinsic capacitance fitting parameter.
288 dlc=lint	Delta L for capacitance model.
289 dlcb=0 m	Length offset fitting parameter for body charge.
290 dlbg=0 m	Length offset fitting parameter for backgate charge.
291 dwc=wint	Delta W for capacitance model.

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

292 delvt=0 V	Threshold voltage adjustment for C-V.
293 fbody=1.0	Scaling factor for body charge.
294 voffcv=-0.08 V	CV Threshold voltage offset.
295 minvcv=0	For moderate inversion in VgsteffCV.
296 dtoxcv=0 m	Delta oxide thickness in Capmod3.
297 kb1=1	Scaling factor for backgate charge.
298 kb3=1	Backgate coupling coefficient at subthreshold.
299 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.
300 vsce=0 V	SCE parameter for improved dVbi model.
301 cdsbs=0 Fm ⁻²	coupling from Vd to Vbs for improved dVbi model.

RF model parameters:

302 rshg=0.1	Gate sheet resistance.
303 xrcrg1	First fitting parameter the bias-dependent Rg.
304 xrcrg2	Second fitting parameter the bias-dependent Rg.
305 ngcon	Number of gate contact.
306 xgw	Distance from gate contact center to device edge.
307 xgl	Variation in Ldrawn.
308 rbdb=50 Ω	Resistance between bNode and dbNode.
309 rbsb=50 Ω	Resistance between bNode and sbNode.
310 gbmin=1e-12 S	Minimum body conductance.

Virtuoso Simulator Components and Device Models Reference
BSIMSOI MOSFET Model (bsimsoi)

Temperature effect parameters

311	$t_{nom}=27.0$ C	Parameters measurement temperature. Default set by 'options'.
312	$t_{rise}=0$ C	Temperature rise from ambient.
313	$t_{max}=500$ C	Maximum device temperature above ambient.
314	$kt1=-0.11$ V	Temperature coefficient for threshold voltage.
315	$kt1l=0$ Vm	Temperature coefficient for threshold voltage.
316	$kt2=0.022$	Temperature coefficient for threshold voltage.
317	$at=3.3e4$ m/s	Temperature coefficient for 'vsat'.
318	$tcjswg=0$ 1/K	Temperature coefficient of Cjswg.
319	$tpbswg=0$ V/K	Temperature coefficient of Pbswg.
320	$tcjswgd=tcjswg$	Temperature coefficient of Cjswgd.
321	$tpbswgd=tpbswg$	Temperature coefficient of Pbswgd.
322	$ua1=4.31e-9$ m/V	Temperature coefficient for 'ua'.
323	$ub1=-7.61e-18$ m ² V ⁻²	Temperature coefficient for 'ub'.
324	$uc1=-5.5e-11$ m/V ²	Temperature coefficient for 'uc'. Default is -0.056 for mobmod=3.
325	$ucste=-4.775e-3$ K ⁻¹	Temperature coefficient of UCS.
326	$ud1=0$ m ⁻² K ⁻¹	Temperature coefficient of ud.
327	$p_{rt}=0$ Û	Temperature coefficient for Rds.
328	$ute=-1.5$	Mobility temperature exponent.
329	$cth0=1e-5$ ws(mC) ⁻¹	Self-heating thermal capacitance.
330	$rth0=0$ mCw ⁻¹	Self-heating thermal resistance.
331	$ntrecf=0$	Temperature coefficient of Nrecf.

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

332 ntreocr=0	Temperature coefficient of Nrecr.
333 xbjt=1	BJT current temperature exponent.
334 xdif=2	Diffusion current temperature exponent.
335 xrec=1	Recombination current temperature exponent.
336 xtun=0	Tunneling current temperature exponent.
337 xdifd=xdif	Temperature coefficient for Iddif.
338 xrecd=xrec	Temperature coefficient for Idrec.
339 xtund=xtun	Temperature coefficient for Idtun.
340 wth0=0 um	Minimum width for thermal resistance calculation.
341 tvbci=0 VK ⁻¹	Temperature coefficient for vbci.
342 trs=0 1/C	Temperature parameter for source resistance.
343 trd=0 1/C	Temperature parameter for drain resistance.

Noise model parameters

344 tnoia=1.5	Thermal noise parameter.
345 tnoib=3.5	Thermal noise parameter.
346 rnoia=0.577	Thermal noise coefficient.
347 rnoib=0.37	Thermal noise coefficient.
348 ntnoi=1.0	Thermal noise coefficient.
349 noif=1	Floating body excess noise ideality factor.
350 w0flk=0 m	Width constant for flicker noise equation.
351 bf=2.0	Flicker noise length dependence exponent.
352 kf=0	Flicker (1/f) noise coefficient.

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BSIMSOI MOSFET Model (bsimsoi)

353 af=1	Flicker (1/f) noise exponent.
354 ef=1	Flicker (1/f) noise frequency exponent.
355 noia=1e20	Oxide trap density coefficient. Default is 9.9e18 for pmos.
356 noib=5e4	Oxide trap density coefficient. Default is 2.4e3 for pmos.
357 noic=-1.4e-12	Oxide trap density coefficient. Default is 1.4e-8 for pmos.
358 em=4.1e7 Vm ⁻¹	Maximum electric field.

Stress model parameters

359 saref=1e-6 m	Reference distance between OD edge to poly of one side.
360 sbref=1e-6 m	Reference distance between OD edge to poly of the other side.
361 wlod=0 m	Width parameter for stress effect.
362 ku0=0 m	Mobility degradation/enhancement coefficient for LOD.
363 tku0=0	Temperature coefficient of KU0.
364 llodku0=0	Length parameter for u0 LOD effect.
365 wlodku0=0	Width parameter for u0 LOD effect.
366 kvth0=0 Vm	Threshold degradation/enhancement parameter for LOD.
367 llodvth=0	Length parameter for vth LOD effect.
368 wlodvth=0	Width parameter for vth LOD effect.
369 kvsat=0 m	Saturation velocity degradation/enhancement parameter for LOD.
370 stk2=0 m	K2 shift factor related to stress effect on vth.
371 lodk2=1.0	K2 shift modification factor for stress effect.
372 steta0=0 m	eta0 shift factor related to stress effect on vth.

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BSIMSOI MOSFET Model (bsimsoi)

373 lodeta0=1.0 eta0 shift modification factor for stress effect.

Default instance parameters

374 w=5e-6 m Default channel width.

375 l=5e-6 m Default channel length.

376 as=0 m² Default area of source diffusion.

377 ad=0 m² Default area of drain diffusion.

378 ps=0 m Default perimeter of source diffusion.

379 pd=0 m Default perimeter of drain diffusion.

380 nrd=1 Default number of squares of drain diffusion.

381 nrs=1 Default number of squares of source diffusion.

382 nrb=1 Default body squares.

Auto Model Selector parameters

384 wmax=1 m Maximum channel width for which the model is valid.

385 wmin=0 m Minimum channel width for which the model is valid.

386 lmax=1 m Maximum channel length for which the model is valid.

387 lmin=0 m Minimum channel length for which the model is valid.

Compatibility model parameters

388 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.

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BSIMSOI MOSFET Model (bsimsoi)

Junction diode model parameters

389 dskip=yes Use simple piece-wise linear model for diode currents below $0.1 \cdot |i_{abstol}|$. Possible values are no or yes.

Operating region and warning control parameters

383 paramchk=1 Model parameter checking selector.

390 alarm=none Forbidden operating region. Possible values are none, off, triode, sat, subth, or rev.

391 imax=1 A Maximum allowable current.

392 bvj=infinity V Junction reverse breakdown voltage.

393 vbox=1e9*tox V Oxide breakdown voltage.

394 warn=on Parameter to turn warnings on and off. Possible values are off or on.

DC-mismatch dependent parameters

395 mismatchmod=0 select Mismatch mode.

396 mismatchdist=0 m Mismatch Distance.

397 mvtwl=0 Vm Threshold mismatch area dependence.

398 mvtwl2=0 Vm^{3/2} Threshold mismatch area square dependence.

399 mvt0=0 V Threshold mismatch intercept.

400 mbewl=0 m Beta mismatch area dependence.

401 mbe0=0 Beta mismatch intercept.

Note:

1. `cdnver` is a special flag, added by Cadence, to enable some specific bug-fix for BSIMSOI. The default value is 1, it can also help convergence for some case.

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

- `vgstcvmod` is a flag to select the equation of `vgsteff` for charge model. The default value is 0 before version 4.2 and changed to be 1 in version 4.2. The only difference between `vgstcvmod=0` and `vgstcvmod=1` is that a critical bug of `vgsteff` calculation in `vgstcvmod=0` is fixed in `vgstcvmod=1`. The bug affect charge model greatly, so Berkeley suggest to use `vgstcvmod=1`. But since most of current BSIMSOI model card is extracted with `vgstcvmod=0`, they kept it for backward compatible.
- Please refer to Berkeley's BSIMSOI manual for binning model parameters.

Output parameters

1	<code>weff(m)</code>	Effective channel width(alias= <code>lv2</code>).
2	<code>leff(m)</code>	Effective channel length(alias= <code>lv1</code>).
3	<code>leffcv(m)</code>	Effective channel length for CV(alias= <code>lx65</code>).
4	<code>weffcv(m)</code>	Effective channel width for CV(alias= <code>lx64</code>).
5	<code>rtheff(Ù)</code>	Effective thermal resistance.
6	<code>ctheff(F)</code>	Effective thermal capacitance.
7	<code>rseff(Ù)</code>	Effective source resistance.
8	<code>rdeff(Ù)</code>	Effective drain resistance.
9	<code>phi(V)</code>	Surface potential (phi alias= <code>lv50</code>).
10	<code>tox(m)</code>	Oxide thickness (tox alias= <code>lv51</code>).
11	<code>gseff(S)</code>	Effective source parasitic conductance (alias= <code>lv16</code>).
12	<code>gdeff(S)</code>	Effective drain parasitic conductance (alias= <code>lv17</code>).
13	<code>rds(Ù)</code>	Drain resistance (squares) (alias= <code>lv13</code>).
14	<code>rss(Ù)</code>	Source resistance (squares)(alias= <code>lv14</code>).

Operating Point Parameters

1	<code>type=n</code>	Transistor type. Possible values are n or p.
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Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

2	region=triode	Estimated operating region. Possible values are off, triode, sat, or subth.
3	reversed	Reverse mode indicator. Possible values are no or yes.
4	vgs(V)	Gate-source voltage.
5	vds(V)	Drain-source voltage.
6	vbs(V)	Bulk-source voltage.
7	vbgs(V)	Back-Gate-source voltage.
8	ids(A)	Resistive drain-to-source current.
9	ido(A)	Alias for ids, opposite sign when reversed (alias=lx4).
10	ibp(A)	Bulk to source substrate current (alias=lx50).
11	ic(A)	BJT collector current (alias=lx45).
12	igisl(A)	Source GIDL current.
13	igidl(A)	Drain GIDL current.
14	iii(A)	Impact ionization current (alias=lx46).
15	ibd(A)	Resistive bulk-to-drain junction current.
16	igbt(A)	Gate-to-body tunneling current.
17	ibs(A)	Resistive bulk-to-source junction current.
18	vth(V)	Threshold voltage.
19	vdsat(V)	Drain-source saturation voltage.
20	vfbeff(V)	Flat-band voltage (alias=lv26).
21	gm(S)	Common-source transconductance (alias=lx7).
22	gds(S)	Common-source output conductance (alias=lx8).

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

23 gmb(S)	Body-transconductance (alias=lx9).
24 gmbg(S)	Back-gate-transconductance.
25 ueff(cm ² V ⁻¹ s)	Effective mobility.
26 betaeff(AV ⁻²)	Effective `beta'.
27 qg(Coul)	Gate charge.
28 qd(Coul)	Drain charge.
29 qs(Coul)	Source charge.
30 qb(Coul)	Body charge.
31 qbg(Coul)	Back-Gate charge.
32 cgg(F)	dQg_dVg (alias=lx18).
33 cgd(F)	dQg_dVd.
34 cgs(F)	dQg_dVs.
35 cgb(F)	dQg_dVbk .
36 cdg(F)	dQd_dVg (alias=lx32).
37 cdd(F)	dQd_dVd (alias=lx33).
38 cds(F)	dQd_dVs (alias=lx34).
39 cdb(F)	dQd_dVb.
40 csg(F)	dQs_dVg (alias=lx59).
41 csd(F)	dQs_dVd (alias=lx60).
42 css(F)	dQs_dVs (alias=lx58).
43 csb(F)	dQs_dVb.
44 cbg(F)	dQb_dVg (alias=lx21).

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

45 cbd(F)	dQb_dVd (alias=lx22).
46 cbs(F)	dQb_dVs (alias=lx23).
47 cbb(F)	dQb_dVb.
48 id(A)	Total resistive drain current.
49 is(A)	Total resistive source current.
50 ib(A)	Total resistive bulk current.
51 pwr(W)	Power at op point.
52 gmoverid(V ⁻¹)	Gm/Ids.
53 tdev(°C)	Temperature rise from ambient.
54 qbint(Coul)	Qb intrinsic, opposite sign for pmos (alias=lx12).
55 qgint(Coul)	Qg intrinsic, opposite sign for pmos (alias=lx14).
56 qdint(Coul)	Qd intrinsic, opposite sign for pmos (alias=lx16).
57 qbd(Coul)	Drain junction diode charge(alias=lx24).
58 ibdo(A)	Drain junction diode current(alias=lx6).
59 ibso(A)	Source junction diode current(alias=lx5).
60 cap_bs(F)	Extrinsic drain to substrate Capacitancesi (alias=lx28).
61 cap_bd(F)	Extrinsic source to substrate Capacitances (alias=lx29).
62 cdebo(F)	intrinsic drain-to-substrate capacitance (alias=lx37).
63 cbebo(F)	intrinsic floating body-to-substrate capacitance (alias=lx38).
64 ceebo(F)	intrinsic substrate capacitance (alias=lx39).
65 i2(A)	Hspice alias of Total tunneling gate current.
66 i3(A)	Hspice alias of Total resistive source current.

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

67 igcs(A)	Igcs.
68 igcd(A)	Igcd.
69 cbgg(F)	intrinsic substrate-to-gate capacitance (alias=lx40).
70 cbgd(F)	intrinsic substrate-to-drain capacitance (alias=lx41).
71 cbgs(F)	intrinsic substrate-to-drain capacitance (alias=lx41).
72 rbp(Ù)	Resistor between external-bulk and bulk nodes
73 cgbg(F)	intrinsic gate-to-substrate capacitance (alias=lx57).
74 csbg(F)	intrinsic source-to-substrate capacitance (alias=lx61).
75 cggbm(F)	Total gate capacitance, and all overlap and fringing components (alias=lx82).
76 cgdbm(F)	Total gate-to-drain capacitance, and all overlap and fringing components (alias=lx83).
77 cgsgm(F)	Total gate-to-source capacitance, and all overlap and fringing components (alias=lx84).
78 cddb(m(F)	Total drain capacitance, and all overlap and fringing components (alias=lx85).
79 cdsbm(F)	Total drain-to-source capacitance (alias=lx86).
80 cdgbm(F)	Total drain-to-gate capacitance, and overlap and fringing components (alias=lx87).
81 cbgbm(F)	Total bulk-to-gate capacitance, and overlap and fringing components (alias=lx88).
82 cbdbm(F)	Total floating body-to-drain capacitance, and overlap and fringing components (alias=lx89).
83 cbsbm(F)	Total floating body-to-gate capacitance, and overlap and fringing components (alias=lx90).

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84	cdbgbm(F)	Total drain-to-substrate capacitance, and overlap and fringing components (alias=lx92).
85	csgbm(F)	Total source-to-gate capacitance, and overlap and fringing components (alias=lx93).
86	cssbm(F)	Total source capacitance, and overlap and fringing components (alias=lx94).
87	csbgbm(F)	Total source-to-substrate capacitance, and overlap and fringing components (alias=lx95).
88	cbgbgbm(F)	Total substrate capacitance, and overlap and fringing components (alias=lx96).

Note:

1. The output of charge q_b , q_d , and q_s are the sum of intrinsic charge and junction charge. The output of capacitors c_{dd} , c_{db} , c_{sb} , c_{bd} , c_{bb} , and c_{bs} 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 description for that parameter. For example, a reference of **M-35** means the 35th model parameter.

a0	M-101	lbt0	M-200	pcgid1	M-899	ud	M-125
a1	M-104	lcbjtii	M-560	pcgis1	M-944	ud1	M-326
a2	M-105	lcdsc	M-446	pcgs1	M-873	ueff	OP-25
abjtii	M-162	lcdscb	M-447	pcigbcp2	M-935	ute	M-328

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ad	I-5	lcdscd	M-448	pcigc	M-861	vabjt	M-201
ad	M-377	lcgdl	M-508	pcigsd	M-864	vbc1	M-152
ados	M-78	lcgidl	M-533	pcit	M-811	vbg	OP-7
aebcp	I-16	lcgisl	M-578	pckappa	M-875	vbm	M-99
aely	M-202	lcgsl	M-507	pclm	M-140	vbox	M-393
af	M-353	lcigbcp2	M-569	pd	I-7	vbs	OP-6
agbcp	I-15	lcigc	M-495	pd	M-379	vbs0fd	M-216
agbcp2	I-35	lcigsd	M-498	pdbc	I-13	vbs0pd	M-215
agbcpd	I-34	lcit	M-445	pdelta	M-821	vbsa	M-206
agidl	M-166	lckappa	M-509	pdelvt	M-856	vbsusr	I-27
agisl	M-173	ldelta	M-455	pdiblc1	M-141	vbx	M-98
ags	M-106	ldelvt	M-490	pdiblc2	M-142	vddeot	M-76
ahli	M-203	ldif	M-234	pdiblc3	M-143	vds	OP-5
ahlid	M-204	ldif0	M-279	pdits	M-115	vdsat	OP-19
aigbcp2	M-261	ldrout	M-453	pditsd	M-117	vdsatii0	M-151
aigc	M-249	ldsub	M-444	pditsl	M-116	vecb	M-247
aigsd	M-252	ldvt0	M-415	pdrou	M-819	version	M-2
alarm	M-390	ldvt0w	M-418	pdsb	M-810	vevb	M-242
alpha0	M-146	ldvt1	M-416	pdvt0	M-781	vfb	M-100
alphagb1	M-239	ldvt1w	M-419	pdvt0w	M-784	vfbef	OP-20
alphagb2	M-244	ldvt2	M-417	pdvt1	M-782	vgb1	M-241

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as	I-4	ldvt2w	M-420	pdvt1w	M-785	vgb2	M-246
as	M-376	ldvtp0	M-547	pdvt2	M-783	vgs	OP-4
asd	M-280	ldvtp1	M-548	pdvt2w	M-786	vgstcvmod	M-12
at	M-317	ldvtp2	M-564	pdvtp0	M-913	voff	M-133
b0	M-102	ldvtp3	M-565	pdvtp1	M-914	voffcv	M-294
b1	M-103	ldvtp4	M-566	pdvtp2	M-930	vofffd	M-208
bdos	M-79	ldwb	M-440	pdvtp3	M-931	voxh	M-259
beta0	M-147	ldwg	M-439	pdvtp4	M-932	vrec0	M-195
beta1	M-149	lebjtii	M-559	pdwb	M-806	vrec0d	M-197
beta2	M-150	leff	O-2	pdwg	M-805	vsat	M-121
betaeff	OP-26	leffcv	O-3	pegidl	M-900	vsce	M-300
betagb1	M-240	leffeot	M-74	pegisl	M-941	vsdfb	M-281
betagb2	M-245	legidl	M-534	pesatii	M-829	vsdth	M-282
bf	M-351	legisl	M-575	peta0	M-808	vth	OP-18
bg0sub	M-69	lesatii	M-463	petab	M-809	vtho	M-81
bgidl	M-167	leta0	M-442	peu	M-938	vtun0	M-196
bgisl	M-174	letab	M-443	pfbjtii	M-823	vtun0d	M-198
bigbcp2	M-262	leu	M-572	pfgidl	M-947	w	I-1
bigc	M-250	lfbjtii	M-457	pfgisl	M-950	w	M-374
bigsd	M-253	lfgidl	M-581	pfprout	M-916	w0	M-88
binunit	M-3	lfgisl	M-584	phi	O-9	w0flk	M-350

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bjtoff	I-26	lfprout	M-550	phig	M-72	wa0	M-609
bvj	M-392	lidbjt	M-539	pidbjt	M-905	wa1	M-615
cap_bd	OP-61	liddif	M-540	piddif	M-906	wa2	M-616
cap_bs	OP-60	lidrec	M-541	pidrec	M-907	wabjtii	M-744
capmod	M-11	lidtun	M-542	pidtun	M-908	wabjtii	M-927
cbb	OP-47	lii	M-154	pigcd	M-256	wacde	M-674
cbd	OP-45	lint	M-45	pisbjt	M-841	waely	M-667
cbdbm	OP-82	lisbjt	M-475	pisdif	M-842	wagidl	M-651
cbebo	OP-63	lisdif	M-476	pisrec	M-843	wagisl	M-759
cbg	OP-44	lisrec	M-477	pistun	M-844	wags	M-610
cbgbgbm	OP-88	listun	M-478	pk1	M-772	wahli	M-668
cbgbm	OP-81	lk1	M-406	pk1w1	M-773	wahlid	M-727
cbgd	OP-70	lk1w1	M-407	pk1w2	M-774	waigbcp2	M-750
cbgg	OP-69	lk1w2	M-408	pk2	M-775	waigc	M-676
cbgs	OP-71	lk2	M-409	pk3	M-776	waigsd	M-679
cbjtii	M-161	lk3	M-410	pk3b	M-777	walpha0	M-639
cbs	OP-46	lk3b	M-411	pkb1	M-778	walphagb1	M-686
cbsbm	OP-83	lkb1	M-412	pketa	M-796	walphagb2	M-687
cdb	OP-39	lketa	M-430	pketas	M-797	warn	M-394
cdbgbm	OP-84	lketas	M-431	pkgidl	M-946	wat	M-701
cdd	OP-37	lkgidl	M-580	pkgisl	M-949	wb0	M-611

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cddb	OP-78	lkgisl	M-583	pkt1	M-878	wb1	M-612
cdebo	OP-62	lkt1	M-512	pkt11	M-879	wbeta0	M-641
cdg	OP-36	lkt11	M-513	pkt2	M-880	wbeta1	M-642
cdgbm	OP-80	lkt2	M-514	pku0	M-919	wbeta2	M-643
cdnver	M-4	lku0	M-553	pkvth0	M-920	wbetagb1	M-688
cds	OP-38	lkvth0	M-554	plbjt0	M-848	wbetagb2	M-689
cdsbm	OP-79	ll	M-47	plii	M-828	wbgidl	M-652
cdsbs	M-301	llbjt0	M-482	plpe0	M-895	wbgisl	M-760
cdsc	M-128	llc	M-49	plpeb	M-896	wbigbcp2	M-751
cdscb	M-129	llii	M-462	pminv	M-915	wbigc	M-677
cdscd	M-130	lln	M-48	pminvcv	M-922	wbigsd	M-680
ceebo	OP-64	llodku0	M-364	pmoin	M-858	wcbjtii	M-743
cf	M-285	llodvth	M-367	pnbjt	M-847	wcbjtii	M-926
cgb	OP-35	llpe0	M-529	pnch	M-768	wcdsc	M-629
cgbg	OP-73	llpeb	M-530	pndif	M-876	wcdscb	M-630
cgbo	M-267	lmax	M-386	pndiode	M-838	wcdscd	M-631
cgd	OP-33	lmbjtii	M-562	pndioded	M-902	wcgdl	M-691
cgdbm	OP-76	lmin	M-387	pnfactor	M-804	wcgidl	M-715
cgdl	M-269	lminv	M-549	pngate	M-770	wcgisl	M-761
cgdo	M-265	lminvcv	M-556	pngidl	M-836	wcgsl	M-690
cgeo	M-266	lmoin	M-492	pnigc	M-865	wcigbcp2	M-752

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cgg OP-32	ln M-194	pnlx M-780	wcigc M-678
cggbm OP-75	lnbjt M-481	pnoff M-912	wcigsd M-681
cgidl M-168	lnch M-402	pnrecf0 M-839	wcit M-628
cgisl M-175	lndif M-510	pnrecf0d M-903	wckappa M-692
cgs OP-34	lndiode M-472	pnrecr0 M-840	wdelta M-638
cgsbm OP-77	lndioded M-536	pnrecr0d M-904	wdelvt M-673
cgs1 M-268	lnfactor M-438	pnsd M-936	wdrout M-636
cgs0 M-264	lngate M-404	pnsb M-769	wdsub M-627
cigbcp2 M-263	lngidl M-470	pntrrecf M-886	wdvt0 M-598
cigc M-251	lnigc M-499	pntrrecr M-887	wdvt0w M-601
cigsd M-254	lnlx M-414	pntun M-837	wdvt1 M-599
cit M-132	lnoff M-546	pntund M-901	wdvt1w M-602
cjswg M-271	lnrecf0 M-473	poxedge M-257	wdvt2 M-600
cjswgd M-274	lnrecf0d M-537	ppclm M-815	wdvt2w M-603
ckappa M-270	lnrecr0 M-474	ppdiblc1 M-816	wdvtp0 M-730
clc M-286	lnrecr0d M-538	ppdiblc2 M-817	wdvtp1 M-731
cle M-287	lnsd M-570	ppdiblcb M-818	wdvtp2 M-747
compatible M-388	lnsub M-403	ppdits M-917	wdvtp3 M-748
csb OP-43	lntrecf M-520	ppditsd M-918	wdvtp4 M-749
csbg OP-74	lntrecr M-521	ppigcd M-866	wdwb M-623
csbgbm OP-87	lntun M-471	ppoxedge M-867	wdwg M-622

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csd	OP-41	lntund	M-535	pprt	M-885	webjtii	M-742
csdesw	M-284	lodeta0	M-373	pprwb	M-801	webjtii	M-925
csdmin	M-283	lodk2	M-371	pprwg	M-802	weff	O-1
csq	OP-40	lpclm	M-449	ppvag	M-820	weffcv	O-4
csqbm	OP-85	lpdiblc1	M-450	prdsw	M-800	weffeot	M-75
css	OP-42	lpdiblc2	M-451	prdw	M-898	wegidl	M-716
cssbm	OP-86	lpdiblcb	M-452	prgidl	M-945	wegisl	M-758
cth0	I-25	lpdits	M-551	prgisl	M-948	wesatii	M-646
cth0	M-329	lpditsd	M-552	prsw	M-897	weta0	M-625
ctheff	O-6	lpe0	M-89	prt	M-327	wetab	M-626
delta	M-145	lpeb	M-91	prwb	M-39	weu	M-755
deltavox	M-260	lpigcd	M-500	prwg	M-40	wfbjtii	M-640
delvt	M-292	lpoxedge	M-501	ps	I-6	wfgidl	M-764
delvto	I-36	lprt	M-519	ps	M-378	wfgisl	M-767
dk2b	M-211	lprwb	M-435	psbcp	I-14	wfprout	M-733
dlbg	M-290	lprwg	M-436	psii0	M-830	widbjt	M-721
dlc	M-288	lpvag	M-454	psii1	M-831	widdif	M-722
dlcb	M-289	lrds	M-434	psii2	M-832	widrec	M-723
dlcig	M-258	lrdrw	M-532	psiid	M-833	widtun	M-724
drout	M-138	lrgidl	M-579	pu0	M-787	wint	M-46
dskip	M-389	lrgisl	M-582	pua	M-788	wisbjt	M-658

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dsub	M-135	lrs	M-531	pua1	M-881	wisdif	M-659
dtoxcv	M-296	lsii0	M-464	pub	M-789	wisrec	M-660
dvbd0	M-212	lsii1	M-465	pub1	M-882	wistun	M-661
dvbd1	M-213	lsii2	M-466	puc	M-790	wk1	M-589
dvt0	M-92	lsiid	M-467	puc1	M-883	wk1w1	M-590
dvt0w	M-95	lu0	M-421	pucs	M-939	wk1w2	M-591
dvt1	M-93	lua	M-422	pucste	M-940	wk2	M-592
dvt1w	M-96	lua1	M-515	pub	M-923	wk3	M-593
dvt2	M-94	lub	M-423	pub1	M-924	wk3b	M-594
dvt2w	M-97	lub1	M-516	pute	M-877	wkb1	M-595
dvtp0	M-109	luc	M-424	pvabjt	M-849	wketa	M-613
dvtp1	M-110	luc1	M-517	pvag	M-144	wketas	M-614
dvtp2	M-111	lucs	M-573	pvsatii0	M-827	wkgidl	M-763
dvtp3	M-112	lucste	M-574	pvfb	M-937	wkgisl	M-766
dvtp4	M-113	lud	M-557	pvoff	M-807	wkt1	M-695
dwb	M-43	lud1	M-558	pvoffcv	M-921	wkt11	M-696
dwbc	M-44	lute	M-511	pvrec0	M-845	wkt2	M-697
dwc	M-291	lvabjt	M-483	pvrec0d	M-909	wku0	M-736
dwg	M-42	lvbci	M-563	pvsat	M-791	wkvth0	M-737
easub	M-73	lvdsatii0	M-461	pvsdfb	M-854	wl	M-55
ebg	M-238	lvfb	M-571	pvsdth	M-855	wlbjt0	M-665

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ebjtii	M-160	lvoff	M-441	pvtho	M-771	wlc	M-56
ef	M-354	lvoffcv	M-555	pvtun0	M-846	wlii	M-645
egidl	M-165	lvrec0	M-479	pvtun0d	M-910	wln	M-59
egisl	M-172	lvrec0d	M-543	pw0	M-779	wlod	M-361
em	M-358	lvsat	M-425	pwr	M-803	wlodku0	M-365
eot	M-65	lvsdfb	M-488	pwr	OP-51	wlodvth	M-368
epsrgate	M-80	lvsdth	M-489	pxbjt	M-888	wlpe0	M-711
epsrox	M-66	lvtho	M-405	pxdif	M-889	wlpeb	M-712
epsrsub	M-67	lvtun0	M-480	pxdifd	M-892	wmax	M-384
esatii	M-155	lvtun0d	M-544	pxj	M-868	wmbjtii	M-745
eta0	M-136	lw	M-52	pxrcrg1	M-852	wmbjtii	M-928
etab	M-137	lw0	M-413	pxrcrg2	M-853	wmin	M-385
etsi	M-32	lwc	M-50	pxrec	M-890	wminv	M-732
eu	M-126	lwl	M-54	pxrecd	M-893	wminvcv	M-739
fbjtii	M-148	lwlc	M-51	pxtun	M-891	wmoin	M-675
fbody	M-293	lwn	M-53	pxtund	M-894	wnbjt	M-664
fdmod	M-8	lwr	M-437	qb	OP-30	wnch	M-585
fgidl	M-171	lxbjt	M-522	qbd	OP-57	wndif	M-693
fgisl	M-178	lxdif	M-523	qbg	OP-31	wndiode	M-655
fnoimod	M-24	lxdifd	M-526	qbint	OP-54	wndioded	M-718
fprout	M-139	lxj	M-502	qd	OP-28	wnfactor	M-621

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frbody	I-28	lxrcrg1	M-486	qdint	OP-56	wngate	M-587
frbody	M-231	lxrcrg2	M-487	qg	OP-27	wngidl	M-653
gamma1	M-118	lxrec	M-524	qgint	OP-55	wnigc	M-682
gamma2	M-119	lxrecd	M-527	qs	OP-29	wnlx	M-597
gatetype	M-10	lxtun	M-525	rddb	I-32	wnoff	M-729
gbmin	M-310	lxtund	M-528	rddb	M-308	wnrecf0	M-656
gdeff	O-12	m	I-17	rbody	M-217	wnrecf0d	M-719
gds	OP-22	mbe0	M-401	rbodymod	I-20	wnrecr0	M-657
gidlmod	M-9	mbewl	M-400	rbodymod	M-17	wnrecr0d	M-720
gm	OP-21	mbjtii	M-163	rbp	OP-72	wnsd	M-753
gmb	OP-23	minr	M-232	rbsb	I-33	wnsub	M-586
gmbg	OP-24	minv	M-114	rbsb	M-309	wntrecf	M-703
gmoverid	OP-52	minvcv	M-295	rbsh	M-218	wntrecr	M-704
gseff	O-11	mismatchdist	M-396	rd	M-221	wntun	M-654
hdif	M-233	mismatchmod	M-395	rdc	M-223	wntund	M-717
i2	OP-65	mjswg	M-272	rdd	M-229	wpclm	M-632
i3	OP-66	mjswgd	M-275	rdeff	O-8	wpdiblc1	M-633
ib	OP-50	mobmod	M-7	rds	O-13	wpdiblc2	M-634
ibd	OP-15	moinfd	M-214	rdsmod	M-18	wpdiblc3	M-635
ibdo	OP-58	mtrlmod	M-6	rdsd	M-38	wpdits	M-734

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ibp	OP-10	mvt0	M-399	rdw	M-225	wpditsd	M-735
ibs	OP-17	mvtwl	M-397	rdwmin	M-227	wpigcd	M-683
ibso	OP-59	mvtwl2	M-398	region	I-23	wpoxedge	M-684
ic	OP-11	nbc	I-11	region	OP-2	wprt	M-702
id	OP-48	nbjt	M-199	reversed	OP-3	wprwb	M-618
idbjt	M-190	nch	M-27	rgatemod	I-19	wprwg	M-619
iddif	M-191	ndif	M-278	rgatemod	M-19	wpvag	M-637
ido	OP-9	ndiode	M-205	rgidl	M-169	wr	M-41
idrec	M-192	ndioded	M-181	rgisl	M-176	wrdsw	M-617
ids	OP-8	necb	M-248	rhalo	M-230	wrdw	M-714
idtun	M-193	nevb	M-243	rnoia	M-346	wrgidl	M-762
igbmod	M-14	nf	I-3	rnoib	M-347	wrgisl	M-765
igbt	OP-16	nfactor	M-131	rs	M-220	wrsw	M-713
igcd	OP-68	ngate	M-28	rsc	M-222	wsii0	M-647
igcmmod	M-15	ngcon	M-305	rseff	O-7	wsii1	M-648
igcs	OP-67	ngidl	M-164	rsh	M-219	wsii2	M-649
igidl	OP-13	ni0sub	M-68	rshg	M-302	wsiid	M-650
igisl	OP-12	nigc	M-255	rss	M-228	wth0	M-340
igmod	M-13	nlx	M-90	rss	O-14	wu0	M-604
iii	OP-14	noff	M-134	rsw	M-224	wua	M-605
iiimod	M-16	nofffd	M-207	rswmin	M-226	wua1	M-698

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imax	M-391	noia	M-355	rth0	I-24	wub	M-606
is	OP-49	noib	M-356	rth0	M-330	wubl	M-699
isbjt	M-186	noic	M-357	rtheff	O-5	wuc	M-607
isdif	M-187	noif	M-349	sa	I-29	wucl	M-700
isnoisy	I-22	noimod	M-23	saref	M-359	wucs	M-756
isrec	M-188	nrb	I-10	sb	I-30	wucste	M-757
istun	M-189	nrb	M-382	sbref	M-360	wud	M-740
k1	M-82	nrd	I-8	sd	I-31	wudl	M-741
k1b	M-209	nrd	M-380	shmod	M-20	wute	M-694
k1w1	M-83	nrecf0	M-182	sii0	M-156	wvabjt	M-666
k1w2	M-84	nrecf0d	M-184	sii1	M-157	wvbci	M-746
k2	M-85	nrecr0	M-183	sii2	M-158	wvbci	M-929
k2b	M-210	nrecr0d	M-185	siid	M-159	wvdsatii0	M-644
k3	M-86	nrs	I-9	soimod	I-18	wvfb	M-754
k3b	M-87	nrs	M-381	soimod	M-5	wvoff	M-624
kb1	M-297	nsd	M-29	steta0	M-372	wvoffcv	M-738
kb3	M-298	nseg	I-12	stk2	M-370	wvrec0	M-662
keta	M-107	nsub	M-26	tbgasub	M-70	wvrec0d	M-725
ketas	M-108	ntnoi	M-348	tbgbsub	M-71	wvsat	M-608
kf	M-352	ntox	M-235	tbox	M-33	wvsdfb	M-671
kgidl	M-170	ntrecf	M-331	tcjswg	M-318	wvsdth	M-672

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

kgisl M-177	ntrecr M-332	tcjswgd M-320	wvtho M-588
kt1 M-314	ntun M-179	tdev OP-53	wvtun0 M-663
kt11 M-315	ntund M-180	tempeot M-77	wvtun0d M-726
kt2 M-316	pa0 M-792	tii M-153	ww M-60
ku0 M-362	pa1 M-798	tku0 M-363	ww0 M-596
kvsat M-369	pa2 M-799	tlev M-21	wwc M-57
kvth0 M-366	pacde M-857	tlevc M-22	wwl M-62
l I-2	paely M-850	tmax M-313	wwlc M-58
l M-375	pagidl M-834	tnodeout I-21	wwn M-61
la0 M-426	pagisl M-942	tnoia M-344	wwr M-620
la1 M-432	pags M-793	tnoib M-345	wxbjt M-705
la2 M-433	pahli M-851	tnoimod M-25	wxdif M-706
labjtii M-561	pahlid M-911	tnom M-311	wxdifd M-708
lacde M-491	paigbcp2 M-933	tox M-34	wxj M-685
laely M-484	paigc M-859	tox O-10	wxrcrg1 M-669
lagidl M-468	paigsd M-862	toxm M-35	wxrcrg2 M-670
lagisl M-576	palph0 M-822	toxp M-36	wxrec M-707
lags M-427	palphagb1 M-869	toxqm M-236	wxrecd M-709
lahli M-485	palphagb2 M-870	toxref M-237	wxtun M-728
lahlid M-545	paramchk M-383	tpbswg M-319	wxtund M-710
laigbcp2 M-567	pat M-884	tpbswgd M-321	xbjt M-333

Virtuoso Simulator Components and Device Models Reference

BSIMSOI MOSFET Model (bsimsoi)

laigc M-493	pb0 M-794	trd M-343	xdif M-334
laigsd M-496	pb1 M-795	trise I-37	xdifd M-337
lalpha0 M-456	pbeta0 M-824	trise M-312	xgl M-307
lalphagb1 M-503	pbeta1 M-825	trs M-342	xgw M-306
lalphagb2 M-504	pbeta2 M-826	tsi M-31	xj M-30
lat M-518	pbetagb1 M-871	tt M-277	xl M-63
lb0 M-428	pbetagb2 M-872	tvbci M-341	xpart M-299
lb1 M-429	pbgidl M-835	type M-1	xrcrg1 M-303
lbeta0 M-458	pbgis1 M-943	type OP-1	xrcrg2 M-304
lbeta1 M-459	pbigbcp2 M-934	u0 M-120	xrec M-335
lbeta2 M-460	pbigc M-860	ua M-122	xrecd M-338
lbetagb1 M-505	pbigsd M-863	ua1 M-322	xt M-37
lbetagb2 M-506	pbswg M-273	ub M-123	xtun M-336
lbgidl M-469	pbswgd M-276	ub1 M-323	xtund M-339
lbgisl M-577	pcdsc M-812	uc M-124	xw M-64
lbigbcp2 M-568	pcdscb M-813	uc1 M-324	
lbigc M-494	pcdscd M-814	ucs M-127	
lbigsd M-497	pcgdl M-874	ucste M-325	

BTA SOI Transistor (btasoi)

Cadence plans to stop supporting this model and recommends that you use the BSIMSOI model instead.

BTASOI is an SOI model developed by BTA Technology based on bsim3v3. It is a new, simple and compact SOI model that can accommodate both the fully-depleted, FD and partially-depleted, PD modes, adopting the transition voltage, V_{tr} , for the definition of body condition. It can also simulate the special characteristics of SOI devices such as kink effect and reduction of saturation current due to self-heating. Simulation results with this model are in excellent agreement with the experimental data for 0.25um SIMOX technology. BTASOI devices require that you use a model statement.

If you want to get more information about this model, please contact BTA Technology at <http://www.btat.com>

This device is supported within altergroups.

Sample Instance Statement:

```
m5 (1 2 0 0) nchmod l=1.5u w=100u as=450p ad=450p pd=209u ps=209u m=1
```

Sample Model Statement:

```
model nchmod btasoi type=n b3v3mod=no version=3.1 vtho=0.62 k1=0.672 k2=0.038
nlx=1.14e-7 dvt0=4.1 a0=1.08 nch=2.65e17 u0=4.01e-2 a1=0 a2=1 ags=9.8e-4 vsat=1.77e5
```

Instance Definition

```
Name d g s [bg] [b] ModelName parameter=value ...
```

Instance Parameters

1 w (m) Channel width.

Virtuoso Simulator Components and Device Models Reference

BTA SOI Transistor (btaso)

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> (m/m)	Number of squares of drain diffusion.
8	<code>nrs</code> (m/m)	Number of squares of source diffusion.
9	<code>m=1</code>	Multiplicity factor (number of MOSFETs in parallel).
10	<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> , or <code>subth</code> .
11	<code>trise</code>	Temperature rise from ambient.
12	<code>rbody</code> (Ω)	Body resistance.

Model Definition

```
model modelName btaso 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>b3v3mod=no</code>	B3v3 compatible flag. Possible values are <code>no</code> or <code>yes</code> .
3	<code>version=3.1</code>	Model version selector.
4	<code>btasoiver=1.0</code>	BTASOI Model version selector.

Virtuoso Simulator Components and Device Models Reference

BTA SOI Transistor (btasoi)

Threshold voltage parameters

5	v_{th0} (V)	Threshold voltage at zero body bias for long-channel devices. For enhancement-mode devices, $v_{th0} > 0$ for n-channel and $v_{th} < 0$ for p-channel. Default value is calculated from other model parameters.
6	$k_1=0.5$ \sqrt{V}	Body-effect coefficient.
7	$k_2=-0.0186$	Charge-sharing parameter.
8	$k_3=80$	Narrow width coefficient.
9	$k_{3b}=0$ 1/V	Narrow width coefficient.
10	$w_0=2.5e-6$ m	Narrow width coefficient.
11	$n_{lx}=1.74e-7$ m	Lateral nonuniform doping coefficient.
12	γ_1 (\sqrt{V})	Body-effect coefficient near the surface.
13	γ_2 (\sqrt{V})	Body-effect coefficient in the bulk.
14	v_{bx} (V)	Threshold voltage transition body voltage.
15	$v_{bm}=-3$ V	Maximum applied body voltage.
16	$d_{vt0}=2.2$	First coefficient of short-channel effects.
17	$d_{vt1}=0.53$	Second coefficient of short-channel effects.
18	$d_{vt2}=-0.032$ 1/V	Body-bias coefficient of short-channel effects.
19	$d_{vt0w}=0$	First coefficient of narrow-width effects.
20	$d_{vt1w}=5.3e6$	Second coefficient of narrow-width effects.
21	$d_{vt2w}=-0.032$ 1/V	Body-bias coefficient of narrow-width effects.
22	$a_0=1$	Nonuniform depletion width effect coefficient.
23	$b_0=0$ m	Bulk charge coefficient due to narrow width effect.

Virtuoso Simulator Components and Device Models Reference

BTA SOI Transistor (btasoi)

24	$b1=0$ m	Bulk charge coefficient due to narrow width effect.
25	$a1=0$	No-saturation coefficient.
26	$a2=1$	No-saturation coefficient.
27	$ags=0$ F/m ² V	Gate-bias dependence of A_{bulk} .
28	$keta=-0.047$ 1/V	Body-bias coefficient for non-uniform depletion width effect.

Process parameters

29	$n_{sub}=6e16$ cm ⁻³	Substrate doping concentration.
30	$n_{ch}=1.7e17$ cm ⁻³	Peak channel doping concentration.
31	n_{gate} (cm ⁻³)	Poly-gate doping concentration.
32	$x_j=0.15e-6$ m	Source/drain junction depth.
33	$l_{int}=0$ m	Lateral diffusion for one side.
34	$w_{int}=0$ m	Width reduction for one side.
35	$l1=0$ m	Length dependence of delta L.
36	$l1n=1$	Length exponent of delta L.
37	$lw=0$ m	Width dependence of delta L.
38	$lwn=1$	Width exponent of delta L.
39	$lw1=0$ m ²	Area dependence of delta L.
40	$w1=0$ m	Length dependence of delta W.
41	$w1n=1$	Length exponent of delta W.
42	$ww=0$ m	Width dependence of delta W.
43	$wwn=1$	Width exponent of delta W.

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BTA SOI Transistor (btasoi)

44	$wwl=0 \text{ m}^2$	Area dependence of delta W.
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	$t_{ox}=1.5e-8 \text{ m}$	Gate oxide thickness.
48	$t_{box}=4e-7 \text{ m}$	Buried oxide thickness.
49	$t_{si}=8e-8 \text{ m}$	Silicon film thickness.
50	$x_t=1.55e-7 \text{ m}$	Doping depth.
51	$rdsw=0 \text{ } \Omega \text{ } \mu\text{m}$	Width dependence of drain-source resistance.
52	$prwb=0 \text{ } 1/\sqrt{v}$	Body-effect coefficient for Rds.
53	$prwg=0 \text{ } 1/V$	Gate-effect coefficient for Rds.
54	$wr=1$	Width offset for parasitic resistance.
55	$x_l=0 \text{ m}$	Length variation due to masking and etching.
56	$x_w=0 \text{ m}$	Width variation due to masking and etching.
57	$binunit=1$	Bin parameter unit selector. 1 for microns and 2 for meters.

Mobility parameters

58	$mobmod=1$	Mobility model selector.
59	$u_0=670 \text{ cm}^2/\text{V s}$	Low-field surface mobility at t_{nom} . Default is 250 for PMOS.
60	$vsat=8e4 \text{ m/s}$	Carrier saturation velocity at t_{nom} .
61	$ua=2.25e-9 \text{ m}/\sqrt{v}$	First-order mobility reduction coefficient.
62	$ub=5.87e-19 \text{ m}^2/\sqrt{v}^2$	Second-order mobility reduction coefficient.

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BTA SOI Transistor (btaso)

63 $uc=-4.65e-11$ m/v² Body-bias dependence of mobility. Default is -0.046 and unit is 1/V for mobmod=3.

Output resistance parameters

64 $drout=0.56$ DIBL effect on output resistance coefficient.

65 $pclm=1.3$ Channel length modulation coefficient.

66 $pdiblc1=0.39$ First coefficient of drain-induced barrier lowering.

67 $pdiblc2=8.6e-3$ Second coefficient of drain-induced barrier lowering.

68 $pdiblcb=0$ 1/V Body-effect coefficient for DIBL.

69 $pscbe1=4.24e8$ V/m First coefficient of substrate current body effect.

70 $pscbe2=1e-5$ m/v Second coefficient of substrate current body effect.

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.

77 $cit=0$ F Interface trap parameter for subthreshold swing.

78 $voff=-0.08$ V Threshold voltage offset.

79 $dsub=drout$ DIBL effect in subthreshold region.

80 $eta0=0.08$ DIBL coefficient subthreshold region.

Virtuoso Simulator Components and Device Models Reference

BTA SOI Transistor (btasoi)

81 $etab=-0.07$ 1/V Body-bias dependence of $et0$.

Substrate current parameters

82 $alpha0=0$ m/v Substrate current impact ionization coefficient.

83 $beta0=30$ 1/V Substrate current impact ionization exponent.

Parasitic resistance parameters

84 $rsh=0$ Ω/sqr Source/drain diffusion sheet resistance.

85 $rs=0$ Ω Source resistance.

86 $rd=0$ Ω Drain resistance.

87 $rsc=0$ Ω Source contact resistance.

88 $rdc=0$ Ω Drain contact resistance.

89 $rss=0$ Ω m Scalable source resistance.

90 $rdd=0$ Ω m Scalable drain resistance.

91 $hdif=0$ m Length of heavily doped diffusion.

92 $ldif=0$ m Lateral diffusion beyond the gate.

93 $minr=0.1$ Ω Minimum source/drain resistance.

Junction diode model parameters

94 js (A/m^2) Bulk junction reverse saturation current density.

95 $jsw=0$ A/m Sidewall junction reverse saturation current density.

96 $is=1e-14$ A Bulk junction reverse saturation current.

97 $n=1$ Junction emission coefficient.

Virtuoso Simulator Components and Device Models Reference

BTA SOI Transistor (btasoi)

- 98 `dskip=yes` Use simple piecewise linear model for diode currents below $0.1 \cdot i_{abstol}$. Possible values are `no` or `yes`.
- 99 `imelt=`imax A`` Explosion current.
- 100 `imelt1=`imax' A/m` Explosion current density for `is1`.
- 101 `imelt2=`imax' A/m` Explosion current density for `is2`.
- 102 `imelt3=`imax' A/m` Explosion current density for `is3`.

Overlap capacitance parameters

- 103 `cgso (F/m)` Gate-source overlap capacitance.
- 104 `cgdo (F/m)` Gate-drain overlap capacitance.
- 105 `cgbo=2 Dwc Cox F/m` Gate-bulk overlap capacitance. The default value is 0 if `version=3.0`.
- 106 `meto=0 m` Metal overlap in fringing field.
- 107 `cgsl=0 F/m` Gate-source overlap capacitance in LDD region.
- 108 `cgdl=0 F/m` Gate-drain overlap capacitance in LDD region.
- 109 `ckappa=0.6` Overlap capacitance fitting parameter.

Junction capacitance model parameters

- 110 `cbs=0 F` Bulk-source zero-bias junction capacitance.
- 111 `cbd=0 F` Bulk-drain zero-bias junction capacitance.
- 112 `cj=5e-4 F/m2` Zero-bias junction bottom capacitance density.

Virtuoso Simulator Components and Device Models Reference

BTA SOI Transistor (btasoi)

113	$m_j=1/2$	Bulk junction bottom grading coefficient.
114	$p_b=1$ V	Bulk junction built-in potential.
115	$f_c=0.5$	Forward-bias depletion capacitance threshold.
116	$c_{jsw}=5e-10$ F/m	Zero-bias junction sidewall capacitance density.
117	$m_{jsw}=0.33$	Bulk junction sidewall grading coefficient.
118	$p_{bsw}=1$ V	Side-wall junction built-in potential.
119	$c_{jswg}=c_{jsw}$ F/m	Zero-bias gate-side junction capacitance density.
120	$m_{jswg}=m_{jsw}$	Gate-side junction grading coefficient.
121	$p_{bswg}=p_{bsw}$ V	Gate-side junction built-in potential.
122	$f_{csw}=f_c$	Side-wall forward-bias depletion capacitance threshold.
123	$\tau_{au}=0$ s	Transit time.

Charge model selection parameters

124	$capmod=2$	Intrinsic charge model.
125	$dwc=wint$ m	Delta W for capacitance model.
126	$dlc=lint$ m	Delta L for capacitance model.
127	$clc=1e-7$ m	Intrinsic capacitance fitting parameter.
128	$cle=0.6$	Intrinsic capacitance fitting parameter.
129	cf (F/m)	Fringe capacitance parameter.
130	$v_{fbcv}=-1$	Flat-band voltage for $capmod=0$.
131	$xpart=0$	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.

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BTA SOI Transistor (btasoi)

Default instance parameters

132	$w=5e-6$ m	Default channel width.
133	$l=5e-6$ m	Default channel length.
134	$a_s=0$ m ²	Default area of source diffusion.
135	$a_d=0$ m ²	Default area of drain diffusion.
136	$p_s=0$ m	Default perimeter of source diffusion.
137	$p_d=0$ m	Default perimeter of drain diffusion.
138	$nrd=0$ m/m	Default number of squares of drain diffusion.
139	$nrs=0$ m/m	Default number of squares of source diffusion.

Temperature effects parameters

140	t_{nom} (C)	Parameters measurement temperature. Default set by <code>options</code> .
141	$t_{max}=500$ C	Maximum device temperature above ambient.
142	$t_{rise}=0$ C	Temperature rise from ambient.
143	$selft=0$	Self heating option.
144	$t_{lev}=0$	DC temperature selector.
145	$t_{levc}=0$	AC temperature selector.
146	$e_g=1.12452$ V	Energy band gap.
147	$gap1=7.02e-4$ V/C	Band gap temperature coefficient.
148	$gap2=1108$ C	Band gap temperature offset.
149	$kt1=-0.11$ V	Temperature coefficient for threshold voltage.
150	$kt11=0$ v m	Temperature coefficient for threshold voltage.

Virtuoso Simulator Components and Device Models Reference

BTA SOI Transistor (btasoi)

151	$kt2=0.022$	Temperature coefficient for threshold voltage.
152	$at=3.3e4$ m/s	Temperature coefficient for v_{sat} .
153	$ua1=4.31e-9$ m/v	Temperature coefficient for u_a .
154	$ub1=-7.61e-18$ m^2/v^2	Temperature coefficient for u_b .
155	$uc1=-5.5e-11$ m/v^2	Temperature coefficient for u_c . Default is -0.056 for $mobmod=3$.
156	$prt=0$ Ω	Temperature coefficient for R_{ds} .
157	$trs=0$ 1/C	Temperature parameter for source resistance.
158	$trd=0$ 1/C	Temperature parameter for drain resistance.
159	$ute=-1.5$	Mobility temperature exponent.
160	$dt1=0$	First temperature coefficient for τ .
161	$dt2=0$	Second temperature coefficient for τ .
162	$x_{ti}=3$	Saturation current temperature exponent.
163	$x_{ti1}=3$	Saturation current temperature exponent.
164	$x_{ti2}=x_{ti1}$	Saturation current temperature exponent.
165	$x_{ti3}=x_{ti1}$	Saturation current temperature exponent.
166	$ptc=0$ V/C	Surface potential temperature coefficient.
167	$pta=0$ V/C	Junction potential temperature coefficient.
168	$ptp=0$ V/C	Sidewall junction potential temperature coefficient.
169	$cta=0$ 1/C	Junction capacitance temperature coefficient.
170	$ctp=0$ 1/C	Sidewall junction capacitance temperature coefficient.

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BTA SOI Transistor (btasoi)

Noise model parameters

171	<code>noimod=1</code>	Noise model selector.
172	<code>kf=0</code>	Flicker (1/f) noise coefficient.
173	<code>af=1</code>	Flicker (1/f) noise exponent.
174	<code>ef=1</code>	Flicker (1/f) noise frequency exponent.
175	<code>noia=1e20</code>	Oxide trap density coefficient. Default is 9.9e18 for pmos.
176	<code>noib=5e4</code>	Oxide trap density coefficient. Default is 2.4e3 for pmos.
177	<code>noic=-1.4e-12</code>	Oxide trap density coefficient. Default is 1.4e-8 for pmos.
178	<code>em=4.1e7 V/m</code>	Maximum electric field.

Auto Model Selector parameters

179	<code>wmax=1 m</code>	Maximum channel width for which the model is valid.
180	<code>wmin=0 m</code>	Minimum channel width for which the model is valid.
181	<code>lmax=1 m</code>	Maximum channel length for which the model is valid.
182	<code>lmin=0 m</code>	Minimum channel length for which the model is valid.

Operating region warning control parameters

183	<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> .
184	<code>imax=1 A</code>	Maximum allowable current.
185	<code>bvj=∞ V</code>	Junction reverse breakdown voltage.
186	<code>vbox=1e9 tox V</code>	Oxide breakdown voltage.
187	<code>warn=on</code>	Parameter to turn warnings on and off. Possible values are <code>off</code> or <code>on</code> .

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BTA SOI Transistor (btasoi)

SOI specific parameters

188	<code>vbtho=10 V</code>	Back-gate threshold voltage..
189	<code>vtr0=0.3 V</code>	Long-channel transition body voltage at $V_{ds}=0$.
190	<code>knk=0.01</code>	Vtr smoothing factor.
191	<code>dice=0</code>	Drain-induced charge-sharing parameter.
192	<code>dvtrd=0 V</code>	Vtr dependence on V_{ds} .
193	<code>dvtrg=1 V</code>	Vtr dependence on V_{gs} .
194	<code>dvtrbg=1.0</code>	Smoothing factor for back-gate bias.
195	<code>a0bg=0</code>	Back-gate saturation region coefficient.
196	<code>dbg=1</code>	Diode fully depletion adjustment factor.
197	<code>dvtr=1.0</code>	Diode back-gate dependence factor.
198	<code>vbgf=0.0</code>	Flat-band voltage for back-gate.
199	<code>rth0=0 Ω</code>	Self-heating thermal resistance.
200	<code>cth0=1 F</code>	Self-heating thermal capacitance.
201	<code>l1=0</code>	V_{gs} dependence of characteristic length.
202	<code>aii=0</code>	First parameter for critical field.
203	<code>bii=0</code>	Second parameter for critical field.
204	<code>cii=0</code>	Gate dependence of critical field.
205	<code>dii=0</code>	Body dependence of critical field.
206	<code>ndiode=1</code>	Diode non-ideality factor.
207	<code>nt=1</code>	Reverse tunneling non-ideality factor.
208	<code>is1=1e-16 A</code>	First diode parameter.

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BTA SOI Transistor (btaso)

209	$is2=0$ A	Second diode parameter.
210	$is3=0$ A	Tunneling diode parameter.
211	$edl=2e-6$ m	Electron diffusion length.
212	$kb=0$ m	Parasitic bipolar base width.
213	$delacc=0.02$ V	Capacitance smoothing parameter in accumulation region.
214	$delr=0.01$ V	V _{bs} smoothing parameter for C-V.
215	$dqsq=8e-3$ V	V _{tr} smoothing parameter for C-V.
216	$a0cv=0.1$	A0 for C-V calculation.
217	$qgvd0=1$	C _{gd} fitting parameter.

Length dependent parameters (Not listed)

Width dependent parameters (Not listed)

Cross-term dependent parameters (Not listed)

The j_{melt} parameter is used to aid convergence and prevent numerical overflow. The junction characteristics of the FET are accurately modeled for current (density) up to j_{melt} . For current density above j_{melt} , the junction is modeled as a linear resistor and a warning is printed.

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

Virtuoso Simulator Components and Device Models Reference

BTA SOI Transistor (btasoi)

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_{th_{eff}}</code> (Ω)	Effective thermal resistance.
4	<code>c_{th_{eff}}</code> (F)	Effective thermal capacitance.
5	<code>r_{seff}</code> (Ω)	Effective source resistance.
6	<code>r_{deff}</code> (Ω)	Effective drain resistance.

Virtuoso Simulator Components and Device Models Reference

BTA SOI Transistor (btasoi)

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> , or <code>subth</code> .
3	<code>reversed</code>	Reverse mode indicator. Possible values are <code>no</code> or <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>ids (A)</code>	Resistive drain-to-source current.
8	<code>isub (A)</code>	Resistive substrate current.
9	<code>ibd (A)</code>	Resistive bulk-to-drain junction current.
10	<code>ibs (A)</code>	Resistive bulk-to-source junction current.
11	<code>vth (V)</code>	Threshold voltage.
12	<code>vdsat (V)</code>	Drain-source saturation voltage.
13	<code>gm (S)</code>	Common-source transconductance.
14	<code>gds (S)</code>	Common-source output conductance.
15	<code>gmbs (S)</code>	Body-transconductance.
16	<code>ueff (cm²/V s)</code>	Effective mobility.
17	<code>betaeff (A/V²)</code>	Effective <code>beta</code> .
18	<code>cjd (F)</code>	Drain-bulk junction capacitance.
19	<code>cjs (F)</code>	Source-bulk junction capacitance.

Virtuoso Simulator Components and Device Models Reference

BTA SOI Transistor (btasoi)

20	c_{gg} (F)	dQ_{g_dVg} .
21	c_{gd} (F)	dQ_{g_dVd} .
22	c_{gs} (F)	dQ_{g_dVs} .
23	c_{gb} (F)	dQ_{g_dVbk} .
24	c_{dg} (F)	dQ_{d_dVg} .
25	c_{dd} (F)	dQ_{d_dVd} .
26	c_{ds} (F)	dQ_{d_dVs} .
27	c_{db} (F)	dQ_{d_dVb} .
28	c_{sg} (F)	dQ_{s_dVg} .
29	c_{sd} (F)	dQ_{s_dVd} .
30	c_{ss} (F)	dQ_{s_dVs} .
31	c_{sb} (F)	dQ_{s_dVb} .
32	c_{bg} (F)	dQ_{b_dVg} .
33	c_{bd} (F)	dQ_{b_dVd} .
34	c_{bs} (F)	dQ_{b_dVs} .
35	c_{bb} (F)	dQ_{b_dVb} .
36	r_{on} (Ω)	On-resistance.
37	i_d (A)	Total resistive drain current.
38	i_s (A)	Total resistive source current.
39	i_b (A)	Total resistive bulk current.
40	pwr (W)	Power at op point.
41	gm_{overid} (1/V)	G_m/I_{ds} .

Virtuoso Simulator Components and Device Models Reference

BTA SOI Transistor (btasoi)

42 tdev (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.

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a0bg M-195	dlc M-126	leff O-2	rtheff O-3
a0cv M-216	dqsq M-215	lint M-33	selft M-143
a1 M-25	drout M-64	ll M-35	tau M-123
a2 M-26	dskip M-98	lln M-36	tbox M-48
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cdsc	M-73	gmbs	OP-15	pbswg	M-121	version	M-3

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cth0	M-200	knk	M-190	reversed	OP-3	xti2	M-164
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delta	M-72	l	I-2	rsh	M-84		

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BTA SOI Transistor (btasoi)

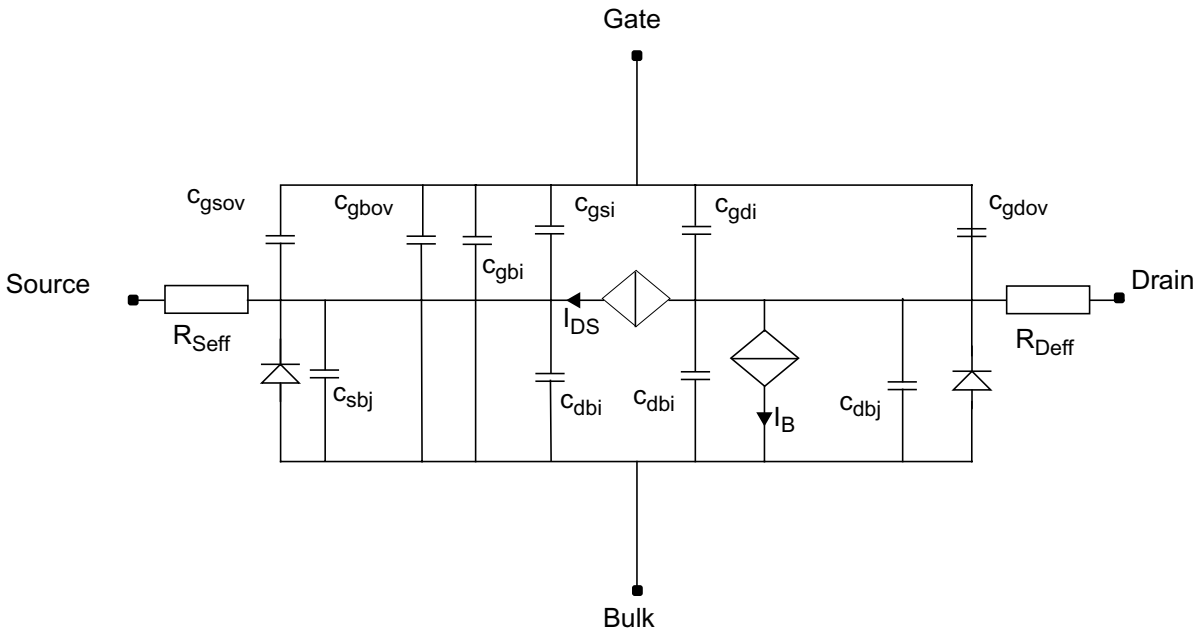
B3SOI-PD Transistor Model (b3soipd)

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 2052
- [BSIMPD2.0.1 CV](#) on page 2066
- [BSIMPD2.2](#) on page 2079
- [Scaling Effects](#) on page 2081
- [Component Statements](#) on page 2081

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

Virtuoso Simulator Components and Device Models Reference
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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B3SOI-PD Transistor Model (b3soipd)

$$C_{sddep} = \frac{\epsilon_{si}}{X_{sddep}}$$

$$C_{sdmin} = \frac{C_{sddep}C_{box}}{C_{sddep} + C_{box}}$$

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

$$dW' = W_{int} + \frac{W_l}{L W_{ln}} + \frac{W_w}{W W_{wn}} + \frac{W_{wl}}{L W_{ln} W W_{wn}}$$

$$dW = dW' + dW_g V_{gsteff} + dW_b (\sqrt{\Phi_s - V_{bseff}} - \sqrt{\Phi_s})$$

$$dL = L_{int} + \frac{L_l}{L L_{ln}} + \frac{L_w}{W L_{wn}} + \frac{L_{wl}}{L L_{ln} W L_{wn}}$$

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B3SOI-PD Transistor Model (b3soipd)

$$L_{eff} = L_{drawn} - 2dL$$

$$W_{eff} = W_{drawn} - N_{bc}dW_{bc} - (2 - N_{bc})dW$$

$$W_{eff}' = W_{drawn} - N_{bc}dW_{bc} - (2 - N_{bc})dW'$$

$$W_{diod} = \frac{W_{eff}'}{N_{seg}} + P_{dbcp}$$

$$W_{dios} = \frac{W_{eff}'}{N_{seg}} + P_{sbcp}$$

Threshold Voltage

$$\begin{aligned}
 V_{TH} = & V_{tho} - K_{1eff}(sqrtPhisExt - \sqrt{\Phi_s}) \\
 & - K_2V_{bseff} + K_{1eff} \left(\sqrt{1 + \frac{NLX}{L_{eff}}} - 1 \right) \sqrt{\Phi_s} + (K_3 + K_{3b}V_{bseff}) \frac{T_{ox}}{W_{eff} + W_o} \Phi_s \\
 & - D_{VT0w} \left(\exp\left(-D_{VT1w} \frac{W_{eff}L_{eff}}{2l_{tw}}\right) + 2 \exp\left(-D_{VT1w} \frac{W_{eff}L_{eff}}{l_{tw}}\right) \right) (V_{bi} - \Phi_s) \\
 & - D_{VT0} \left(\exp\left(-D_{VT1} \frac{L_{eff}}{2l_t}\right) + 2 \exp\left(-D_{VT1} \frac{L_{eff}}{l_t}\right) \right) (V_{bi} - \Phi_s) \\
 & - \left(\exp\left(-D_{sub} \frac{L_{eff}}{2l_{to}}\right) + 2 \exp\left(-D_{sub} \frac{L_{eff}}{l_{to}}\right) \right) (E_{tao} + E_{tab}V_{bseff}) V_{ds}
 \end{aligned}$$

$$l_t = \sqrt{\epsilon_{si} X_{dep} / C_{ox}} (1 + D_{VT2}V_{bseff})$$

$$sqrtPhisExt = \sqrt{\Phi_s - V_{bseff}} + s(V_{bsh} - V_{bseff})$$

$$s = -\frac{1}{2\sqrt{\Phi_s - \Phi_{s0}}}$$

$$K_{1eff} = K_1 \left(1 + \frac{K_{1w1}}{W'_{eff} + K_{1w2}} \right)$$

$$l_{tw} = \sqrt{\epsilon_{si} X_{dep} / C_{ox}} (1 + D_{VT2w} V_{bseff})$$

$$l_{to} = \sqrt{\epsilon_{si} X_{dep0} / C_{ox}}$$

$$X_{dep} = \sqrt{\frac{2\epsilon_{si}(\Phi_s - V_{bseff})}{qN_{ch}}}$$

$$X_{dep0} = \sqrt{\frac{2\epsilon_{si}\Phi_s}{qN_{ch}}}$$

$$V_{bi} = v_t \ln \left(\frac{N_{ch} N_{DS}}{n_i^2} \right)$$

Poly Depletion Effect

$$V_{poly} + \frac{1}{2} X_{poly} E_{poly} = \frac{qN_{gate} X_{poly}^2}{2\epsilon_{si}}$$

$$\epsilon_{ox} E_{ox} = \epsilon_{si} E_{poly} = \sqrt{2q\epsilon_{si} N_{gate} V_{poly}}$$

$$V_{gs} - V_{FB} - \phi_x = V_{poly} + V_{ox}$$

$$a(V_{gs} - V_{FB} - \phi_s - V_{poly})^2 - V_{poly} = 0$$

$$a = \frac{\epsilon_{ox}^2}{2q\epsilon_{si} N_{gate} T_{ox}^2}$$

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B3SOI-PD Transistor Model (b3soipd)

$$V_{gs_eff} = V_{FB} + \phi_s + \frac{q\epsilon_{si}N_{gate}T_{ox}^2}{\epsilon_{ox}^2} \times \left(\sqrt{1 + \frac{2\epsilon_{ox}^2(V_{gs} - V_{FB} - \phi_s)}{q\epsilon_{si}N_{gate}T_{ox}^2}} - 1 \right)$$

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 $\lambda \neq 1$,

$$V_{dsat} = \frac{-b - \sqrt{b^2 - 4ac}}{2a}$$

$$a = A_{bulk}^2 W_{eff} v_{sat} C_{ox} R_{ds} + \left(\frac{1}{\lambda} - 1 \right) A_{bulk}$$

$$b = - \left[(V_{gsteff} + 2v_t) \left(\frac{2}{\lambda} - 1 \right) + A_{bulk} E_{sat} L_{eff} + 3A_{bulk} (V_{gsteff} + 2v_t) W_{eff} v_{sat} C_{ox} R_{ds} \right]$$

$$c = (V_{gsteff} + 2v_t) E_{sat} L_{eff} + 2(V_{gsteff} + 2v_t)^2 W_{eff} v_{sat} C_{ox} R_{ds}$$

Virtuoso Simulator Components and Device Models Reference
B3SOI-PD Transistor Model (b3soipd)

$$\lambda = A_1 V_{gsteff} + A_2$$

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

$$I_{ds, MOSFET} = \frac{1}{N_{seg} \left(1 + \frac{R_{ds} I_{dso}(V_{dseff})}{V_{dseff}} \right)} \frac{I_{dso}(V_{dseff})}{V_{dseff}} \left(1 + \frac{V_{ds} - V_{dseff}}{V_A} \right)$$

$$\beta = \mu_{eff} C_{ox} \frac{W_{eff}}{L_{eff}}$$

$$I_{dso} = \frac{\beta V_{gsteff} \left(1 - A_{bulk} \frac{V_{dseff}}{2(V_{gsteff} + 2v_t)} \right) V_{dseff}}{1 + \frac{V_{dseff}}{E_{sat} L_{eff}}}$$

$$V_A = V_{Asat} + \left(1 + \frac{P_{vag} V_{gsteff}}{E_{sat} L_{eff}} \right) \left(\frac{1}{V_{ACLM}} + \frac{1}{V_{ADIBLC}} \right)^{-1}$$

Virtuoso Simulator Components and Device Models Reference

B3SOI-PD Transistor Model (b3soipd)

$$V_{ACLM} = \frac{A_{bulk} E_{sat} L_{eff} + V_{gsteff}}{P_{clm} A_{bulk} E_{sat} litl} (V_{ds} - V_{dseff})$$

$$V_{ADIBLC} = \frac{(V_{gsteff} + 2v_t)}{\theta_{rout}(1 + P_{DIBLCB} V_{bseff})} \left(1 - \frac{A_{bulk} V_{dsat}}{A_{bulk} V_{dsat} + 2v_t} \right)$$

$$\theta_{rout} = P_{DIBLC1} \left[\exp\left(-D_{ROUT} \frac{L_{eff}}{2l_{t0}}\right) + 2 \exp\left(-D_{ROUT} \frac{L_{eff}}{l_{t0}}\right) \right] + P_{DIBLC2}$$

$$V_{Asat} = \frac{E_{sat} L_{eff} + V_{dsat} + 2R_{ds} v_{sat} C_{ox} W_{eff} V_{gsteff} \left[1 - \frac{A_{bulk} V_{dsat}}{2(V_{gsteff} + 2v_t)} \right]}{2/\lambda - 1 + R_{ds} v_{sat} C_{ox} W_{eff} A_{bulk}}$$

$$litl = \sqrt{\frac{\epsilon_{si} T_{ox} T_{Si}}{\epsilon_{ox}}}$$

Drain/Source Resistance

$$R_{ds} = R_{dsw} \frac{1 + P_{rwg} V_{gsteff} + P_{rwb} (\sqrt{\phi_s - V_{bseff}} - \sqrt{\phi_s})}{(10^6 W_{eff})^{Wr}}$$

Impact Ionization Current

$$I_{ii} = \alpha_0 (I_{ds, MOSFET} + F_{bjtii} I_c) \exp\left(\frac{V_{diff}}{\beta_2 + \beta_1 V_{diff} + \beta_0 V_{diff}^2}\right)$$

$$V_{diff} = V_{ds} - V_{dsatii}$$

$$V_{dsatii} = V_{gsStep} + \left[V_{dsatii0} \left(1 + T_{ii} \left(\frac{T}{T_{nom}} - 1 \right) \right) + \frac{L_{ii}}{L_{eff}} \right]$$

$$V_{gsStep} = \left(\frac{E_{satii} L_{eff}}{1 + E_{satii} L_{eff}} \right) \left(\frac{1}{1 + S_{ii1} V_{gsteff}} + S_{ii2} \right) \left(\frac{S_{ii0} V_{gst}}{1 + S_{iid} V_{ds}} \right)$$

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

$$I_{bs2} = W_{dios}T_{si}j_{srec}\left(\exp\left(\frac{V_{bs}}{0.026n_{recf}}\right) - \exp\left(\frac{V_{sb}}{0.026n_{recr}}\frac{V_{rec0}}{V_{rec0} + V_{sb}}\right)\right)$$

$$I_{bd2} = W_{diod}T_{si}j_{srec}\left(\exp\left(\frac{V_{bd}}{0.026n_{recf}}\right) - \exp\left(\frac{V_{db}}{0.026n_{recr}}\frac{V_{rec0}}{V_{rec0} + V_{db}}\right)\right)$$

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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B3SOI-PD Transistor Model (b3soipd)

$$E_{2nd} = \frac{E_{ely} + \sqrt{E_{ely}^2 + 4E_{hli}}}{2}$$

$$E_{ely} = 1 + \frac{V_{bs} + V_{bd}}{V_{Abjt} + A_{ely}L_{eff}}$$

$$E_{hli} = E_{hlis} + E_{hlid}$$

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

$$A_{hli_eff} = A_{hli} \exp \left[\frac{-E_g(300K)}{n_{dio} V_t} X_{bjt} \left(1 - \frac{T}{T_{nom}} \right) \right]$$

$$V_{th(T)} = V_{th(T_{nom})} + (K_{T1} + K_{t1}l/L_{eff} + K_{T2}V_{bseff})(T/T_{nom} - 1)$$

$$\mu_o(T) = \mu_o(T_{nom}) \left(\frac{T}{T_{nom}} \right)^{\mu_{te}}$$

$$v_{sat(T)} = v_{sat(T_{nom})} - A_T(T/T_{nom} - 1)$$

$$R_{dsw(T)} = R_{dsw(T_{nom})} + P_{rt} \left(\frac{T}{T_{nom}} - 1 \right)$$

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B3SOI-PD Transistor Model (b3soipd)

$$U_{a(T)} = U_{a(Tnom)} + U_{a1} \left(\frac{T}{T_{nom}} - 1 \right)$$

$$U_{b(T)} = U_{b(Tnom)} + U_{b1} \left(\frac{T}{T_{nom}} - 1 \right)$$

$$U_{c(T)} = U_{c(Tnom)} + U_{c1} \left(\frac{T}{T_{nom}} - 1 \right)$$

$$R_{th} = \frac{R_{th0}}{W'_{eff}/N_{seg}}, C_{th} = C_{th0} \frac{W'_{eff}}{N_{seg}}$$

$$j_{sbjt} = j_{sbjt0} \exp \left[-\frac{E_g(300K)}{n_{dio} V_t} X_{bjt} \left(1 - \frac{T}{T_{nom}} \right) \right]$$

$$j_{sdif} = j_{sdif0} \exp \left[-\frac{E_g(300K)}{n_{dio} V_t} X_{dif} \left(1 - \frac{T}{T_{nom}} \right) \right]$$

$$j_{srec} = j_{srec0} \exp \left[-\frac{E_g(300K)}{n_{recf0} V_t} X_{rec} \left(1 - \frac{T}{T_{nom}} \right) \right]$$

$$j_{stun} = j_{stun0} \exp \left[X_{tun} \left(\frac{T}{T_{nom}} - 1 \right) \right]$$

$$n_{recf} = n_{recf0} \left[1 + nt_{recf} \left(\frac{T}{T_{nom}} - 1 \right) \right]$$

$$n_{recr} = n_{recr0} \left[1 + nt_{recr} \left(\frac{T}{T_{nom}} - 1 \right) \right]$$

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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B3SOI-PD Transistor Model (b3soipd)

$$\phi_{sd} = 2 \frac{kT}{q} \log \left(\frac{n_{sub}}{n_i} \right), \Upsilon_{sd} = \frac{5.753 \times 10^{-12} \sqrt{-n_{sub}}}{C_{box}}$$

$$V_{sdth} = V_{sdfb} - \phi_{sd} - \Upsilon_{sd} \sqrt{\phi_{sd}}$$

5.

$$X_{sddep} = \sqrt{\frac{2\epsilon_{si}\phi_{sd}}{q|n_{sub} \cdot 10^6|}}$$

$$C_{sddep} = \frac{\epsilon_{si}}{X_{sddep}}$$

$$C_{sdmin} = \frac{C_{sddep}C_{box}}{C_{sddep} + C_{box}}$$

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

$$W_{active} = W_{drawn} - N_{bc}dW_{bc} - (2 - N_{bc})\delta W_{eff}$$

$$\delta W_{eff} = DWC + \frac{W_{lc}}{L W_{ln}} + \frac{W_{wc}}{L W_{wn}} + \frac{W_{wlc}}{L W_{ln} W_{wn}}$$

$$L_{active} = L_{drawn} - 2\delta L_{eff}$$

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B3SOI-PD Transistor Model (b3soipd)

$$\delta L_{eff} = DLC + \frac{L_{lc}}{L^{L_{in}}} + \frac{L_{wc}}{W^{L_{wn}}} + \frac{L_{wlc}}{L^{L_{in}} W^{L_{wn}}}$$

$$L_{activeB} = L_{active} - DLCB$$

$$L_{activeBG} = L_{activeB} + 2\delta L_{bg}$$

$$W_{diosCV} = \frac{W_{active}}{N_{seg}} + P_{sbcp}$$

$$W_{diodCV} = \frac{W_{active}}{N_{seg}} + P_{dbcp}$$

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:

$$Q_{sub0} = -F_{body} \left(\frac{W_{active} L_{activeB}}{N_{seg}} + A_{gbcp} \right) C_{ox} \frac{K_{1\text{eff}}^2}{2} \left(-1 + \sqrt{1 + \frac{4(V_{gs} - V_{FB\text{eff}} - V_{g\text{steff}CV} - V_{b\text{seff}})}{K_{1\text{eff}}^2}} \right)$$

Drain-induced depletion charge:

Virtuoso Simulator Components and Device Models Reference
B3SOI-PD Transistor Model (b3soipd)

$$V_{dsat, cv} = V_{gsteffCV} / A_{bulkCV} \cdot A_{bulkCV} = A_{bulk0} \left[1 + \left(\frac{CLC}{L_{activeB}} \right)^{CLE} \right]$$

$$V_{dsCV} = V_{dsatCV} - \frac{1}{2} \left(V_{dsatCV} - V_{ds} - \delta + \sqrt{(V_{dsatCV} - V_{ds} - \delta)^2 + 4\delta V_{dsatCV}} \right)$$

$$Q_{subs} = F_{body} \left(\frac{W_{active} L_{activeB}}{N_{seg}} + A_{gbcp} \right) K_{1eff} C_{ox} (A_{bulkCV} - 1) \times$$

$$\left[\frac{V_{dsCV}}{2} - \frac{A_{bulkCV} V_{dsCV}^2}{12(V_{gsteffCV} - A_{bulkCV} V_{dsCV}/2)} \right]$$

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

$$V_4 = V_{dsat, CV} - V_{ds} - \delta_4; \delta_4 = 0.02$$

Virtuoso Simulator Components and Device Models Reference
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:

$$Q_{inv,s} = -\frac{W_{active}L_{active} + A_{gbcp}}{N_{seg}}C_{ox} \times \left(\frac{V_{gsteffCV}}{2} + \frac{A_{bulkCV}V_{cveff}}{4} - \frac{(A_{bulkCV}V_{cveff})^2}{24\left(V_{gsteffCV} - \frac{A_{bulkCV}}{2}V_{cveff}\right)} \right)$$

$$Q_{inv,d} = -\frac{W_{active}L_{active} + A_{gbcp}}{N_{seg}}C_{ox} \times \left(\frac{V_{gsteffCV}}{2} + \frac{3A_{bulkCV}V_{cveff}}{4} + \frac{(A_{bulkCV}V_{cveff})^2}{8\left(V_{gsteffCV} - \frac{A_{bulkCV}}{2}V_{cveff}\right)} \right)$$

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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B3SOI-PD Transistor Model (b3soipd)

$$Q_{acc} = -F_{body} \left(\frac{W_{active} L_{activeB}}{N_{seg}} + A_{gbcp} \right) C_{oxeff} V_{gbacc}$$

$$V_{gbacc} = 0.5 \left(V_0 + \sqrt{V_0^2 + 4\delta V_{fb}} \right)$$

$$V_0 = V_{fb} + V_{bseff} - V_{gs} - \delta$$

$$C_{oxeff} = \frac{C_{ox} C_{cen}}{C_{ox} + C_{cen}}$$

$$C_{cen} = \epsilon_{Si} / X_{DC}$$

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

$$V_{dsat,cv} = (V_{gsteffCV} - \Phi_{\delta}) / A_{bulkCV}$$

$$\Phi_{\delta} = \Phi_s - 2\Phi_B = v_t \ln \left[1 + \frac{V_{gsteffCV} (V_{gsteffCV} + 2K_{1eff} \beta_{ff} \sqrt{2\Phi_B})}{moinK_{1eff} v_t^2} \right]$$

$$V_{dsCV} = V_{dsatCV} - \frac{1}{2} \left(V_{dsatCV} - V_{ds} - \delta + \sqrt{(V_{dsatCV} - V_{ds} - \delta)^2 + 4\delta V_{dsatCV}} \right)$$

Virtuoso Simulator Components and Device Models Reference
B3SOI-PD Transistor Model (b3soipd)

$$Q_{subs} = F_{body} \left(\frac{W_{active} L_{activeB}}{N_{seg}} + A_{gbcp} \right) K_{1eff} C_{oxeff} (A_{bulkCV} - 1) \times \left[\frac{V_{dsCV}}{2} - \frac{A_{bulkCV} V_{dsCV}^2}{12(V_{gsteffCV} - \Phi_{\delta} - A_{bulkCV} V_{dsCV}/2)} \right]$$

Back Gate Body Charge

$$k_{b1} F_{body} \left(\frac{W_{active} L_{activeBG}}{N_{seg}} + A_{ebcp} \right) C_{box} (V_{es} - V_{fbb} - V_{bseff})$$

Inversion Charge

$$V_{cveff} = V_{dsat, CV} - 0.5 \left(V_4 + \sqrt{V_4^2 + 4\delta_4 V_{dsat, CV}} \right)$$

where

$$V_4 = V_{dsat, CV} - V_{ds} - \delta_4; \delta_4 = 0.02$$

$$Q_{inv} = - \left(\frac{W_{active} L_{active}}{N_{seg}} + A_{gbcp} \right) C_{oxeff} \times \left(\left(V_{gsteffCV} - \Phi_{\delta} - \frac{A_{bulkCV}}{2} V_{cveff} \right) + \frac{A_{bulkCV}^2 V_{cveff}^2}{12 \left(V_{gsteffCV} - \Phi_{\delta} - \frac{A_{bulkCV}}{2} V_{cveff} \right)} \right)$$

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:

$$\begin{aligned}
 Q_{inv, s} = & -\frac{\left(\frac{W_{active}L_{active}}{N_{seg}} + A_{gbcp}\right)C_{oxeff}}{2\left(V_{gsteffCV} - \Phi_{\delta} - \frac{A_{bulkCV}}{2}V_{cveff}\right)^2} \times \left((V_{gsteffCV} - \Phi_{\delta})^3 - \right. \\
 & \frac{4}{3}(V_{gsteffCV} - \Phi_{\delta})^2(A_{bulkCV}V_{cveff}) + \frac{2}{3}(V_{gsteffCV} - \Phi_{\delta})(A_{bulkCV}V_{cveff})^2 \\
 & \left. - \frac{2}{15}(A_{bulkCV}V_{cveff})^3 \right) \\
 \\
 Q_{inv, d} = & -\frac{\left(\frac{W_{active}L_{active}}{N_{seg}} + A_{gbcp}\right)C_{oxeff}}{2\left(V_{gsteffCV} - \Phi_{\delta} - \frac{A_{bulkCV}}{2}V_{cveff}\right)^2} \times \left((V_{gsteffCV} - \Phi_{\delta})^3 \right. \\
 & - \frac{5}{3}(V_{gsteffCV} - \Phi_{\delta})^2(A_{bulkCV}V_{cveff}) + (V_{gsteffCV} - \Phi_{\delta})(A_{bulkCV}V_{cveff})^2 \\
 & \left. - \frac{1}{5}(A_{bulkCV}V_{cveff})^3 \right)
 \end{aligned}$$

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B3SOI-PD Transistor Model (b3soipd)

$$Q_{inv, s} = -\frac{W_{active}L_{active} + A_{gbcp}}{N_{seg}}C_{oxeff} \times \left(\frac{V_{gsteff}CV - \Phi_{\delta}}{2} + \frac{A_{bulk}CVV_{cveff}}{4} - \frac{(A_{bulk}CVV_{cveff})^2}{24\left(V_{gsteff}CV - \Phi_{\delta} - \frac{A_{bulk}CVV_{cveff}}{2}\right)} \right)$$

0/100 charge partition:

$$Q_{inv, s} = -\frac{W_{active}L_{active} + A_{gbcp}}{N_{seg}}C_{oxeff} \times \left(\frac{V_{gsteff}CV - \Phi_{\delta}}{2} + \frac{A_{bulk}CVV_{cveff}}{4} - \frac{(A_{bulk}CVV_{cveff})^2}{24\left(V_{gsteff}CV - \Phi_{\delta} - \frac{A_{bulk}CVV_{cveff}}{2}\right)} \right)$$

Overlap Capacitance

Source Overlap Charge

$$Q_{inv, d} = -\frac{W_{active}L_{active} + A_{gbcp}}{N_{seg}}C_{oxeff} \times \left(\frac{V_{gsteff}CV - \Phi_{\delta}}{2} - \frac{3A_{bulk}CVV_{cveff}}{4} + \frac{(A_{bulk}CVV_{cveff})^2}{8\left(V_{gsteff}CV - \Phi_{\delta} - \frac{A_{bulk}CVV_{cveff}}{2}\right)} \right)$$

$$V_{gs, overlap} = \frac{1}{2} \left\{ (V_{gs} + \delta) + \sqrt{(V_{gs} + \delta)^2 + 4\delta} \right\}$$

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B3SOI-PD Transistor Model (b3soipd)

$$\frac{Q_{overlap,s}}{W_{diosCV}} = CGS0 \cdot V_{gs} + CGS1 \left\{ V_{gs} - V_{gs_overlap} + \frac{CKAPPA}{2} \left(-1 + \sqrt{1 + \frac{4V_{gs_overlap}}{CKAPPA}} \right) \right\}$$

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

Virtuoso Simulator Components and Device Models Reference

B3SOI-PD Transistor Model (b3soipd)

$$Q_{bsdep} = W_{dios} C V C_{jswg} \frac{T_{si}}{10^{-7}} \frac{P_{bswg}}{1 - M_{jswg}} \left[1 - \left(1 - \frac{V_{bs}}{P_{bswg}} \right)^{1 - M_{jswg}} \right]$$

$$Q_{bddep} = W_{diod} C V C_{jswg} \frac{T_{si}}{10^{-7}} \frac{P_{bswg}}{1 - M_{jswg}} \left[1 - \left(1 - \frac{V_{bd}}{P_{bswg}} \right)^{1 - M_{jswg}} \right]$$

$$Q_{bsdif} = \frac{W_{eff}'}{N_{seg}} T_{si} J_{sbt} \left[1 + L_{dif0} \cdot \left(L_{bj0} \cdot \left(\frac{1}{L_{eff}} + \frac{1}{L_n} \right)^{N_{dif}} \right) \right] \left[\exp \left(\frac{V_{bs}}{n_{dio} V_t} \right) - 1 \right] \frac{1}{\sqrt{E_{hlis} + 1}}$$

$$Q_{bddif} = \frac{W_{eff}'}{N_{seg}} T_{si} J_{sbt} \left[1 + L_{dif0} \cdot \left(L_{bj0} \cdot \left(\frac{1}{L_{eff}} + \frac{1}{L_n} \right)^{N_{dif}} \right) \right] \left[\exp \left(\frac{V_{bd}}{n_{dio} V_t} \right) - 1 \right] \frac{1}{\sqrt{E_{hlid} + 1}}$$

$$C_{jswg} = C_{jswg0} [1 + t_{cswg} (T - T_{nom})]$$

$$P_{bswg} = P_{bswg0} - t_{pbswg} (T - T_{nom})$$

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

$$J_{gb} = A \frac{V_{gb} V_{aux}}{T_{ox}^2} \left(\frac{T_{oxref}}{T_{oxqm}} \right)^{N_{tox}} \exp \left(\frac{-B(\alpha_{gb1} - \beta_{gb1} |V_{ox}|) T_{ox}}{1 - |V_{ox}|/V_{gb1}} \right)$$

$$V_{aux} = V_{EVB} \ln \left(1 + \exp \left(\frac{|V_{ox}| - \phi_g}{V_{EVB}} \right) \right)$$

$$A = \frac{q^3}{8\pi h \phi_b}$$

$$B = \frac{8\pi \sqrt{2m_{ox}} \phi_b^{3/2}}{3hq}$$

$$\phi_b = 4.2eV$$

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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

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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 222.

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>nbcb=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>pdbcpc=0</code> m	Perimeter length for body contact parasitic at drain.
18	<code>psbcpc=0</code> m	Perimeter length for body contact parasitic at source.
19	<code>agbcpc=0</code> m	Gate to body overlap for body contact parasitic.
20	<code>aebcpc=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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B3SOI-PD Transistor Model (b3soipd)

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	$dwbc=0.0$ 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	$rdsw=100$ Ω μ 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_{a0} .

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	$c_{gbo}=2 \text{ Dwc } C_{ox} \text{ F/m}$	Gate-bulk overlap capacitance..
113	$meto=0 \text{ m}$	Metal overlap in fringing field.
114	$c_{gsl}=0 \text{ F/m}$	Gate-source overlap capacitance in LDD region.
115	$c_{gdl}=0 \text{ F/m}$	Gate-drain overlap capacitance in LDD region.
116	$ckappa=0.6$	Overlap capacitance fitting parameter.

Junction capacitance model parameters

117	$c_{jswg}=c_{jsw} \text{ F/m}$	Zero-bias gate-side junction capacitance density.
118	$m_{jswg}=0.5$	Gate-side junction grading coefficient.
119	$p_{bswg}=0.7 \text{ V}$	Gate-side junction built-in potential.
120	$tt=1e-12 \text{ s}$	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	$dwc=wint \text{ m}$	Delta W for capacitance model.
125	$delvt=0.0 \text{ V}$	Threshold voltage adjustment for C-V.
126	$fbody=1.0$	Scaling factor for body charge.
127	$d_{lc}=lint \text{ m}$	Delta L for capacitance model.
128	$d_{lcb}=lint \text{ m}$	Length offset fitting parameter for body charge.
129	$d_{lbg}=0.0 \text{ m}$	Length offset fitting parameter for backgate charge.

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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.

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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	$kt1l=0$	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} .

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B3SOI-PD Transistor Model (b3soipd)

170	<code>ntreocr=0</code>	Temperature coefficient of Ntreocr.
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 none, off, triode, sat, subth, or rev.
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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.

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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	$nevb=3.0$	Valence-band electron non-ideality factor.
235	$alphagb1=0.35$	First V_{ox} dependent parameter for gate current in inversion..
236	$betagb1=0.03$	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	$alphagb2=0.43$	First V_{ox} dependent parameter for gate current in accumulation..
239	$betagb2=0.05$	Second V_{ox} dependent parameter for gate current in accumulation..
240	$necb=1.0$	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	$voxh=5.0 \text{ V}$	Limit of V_{ox} in gate current calculation..
244	$\delta_{taxox}=0.005 \text{ V}$	Smoothing parameter in the V_{ox} smoothing function..
245	$igmod=0$	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 Parmaters

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	vbx	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	pdhcp	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	pvt 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	qj OP-27	vtun0 M-222
cgs OP-31	k2 M-7	qjg 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		

HiSIM1 Field Effect Transistor Model (hisim)

Cadence plans to stop supporting the HiSIM1 model and recommends that you use the HiSIM2 model, instead.

The HiSIM (Hiroshima-university STARC IGFET Model) model was developed at Hiroshima University in collaboration with the STARC research center. The model is based on the drift-diffusion approximation. All device characteristics are described by channel-surface potentials at the source side and at the drain side. These surface potentials are implicit functions of applied voltages, therefore additional iteration procedures are required to global iterations in circuit simulation.

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 temp=350
```

Sample Model Statement:

```
model nch hisim version=111 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 | as (m ²) | Area of source diffusion. |
| 4 | ad (m ²) | Area of drain diffusion. |

Virtuoso Simulator Components and Device Models Reference

HiSIM1 Field Effect Transistor Model (hisim)

5	ps (m)	Perimeter of source diffusion.
6	pd (m)	Perimeter of drain diffusion.
7	temp (K)	Lattice temperature.
8	dtemp (K)	Lattice temperature rise from ambient.

Model Definition

```
model modelName hisim parameter=value ...
```

Model Parameters

Device type parameters

1	type=n	Transistor type. Possible values are n or p.
2	version=101	Version of HiSIM.
3	noise=5	Noise model selector.
4	corsrd=0	Flag for accounting Rs and Rd.
5	cocgso=0	Flag for calculate cgso.
6	cocgdo=0	Flag for calculate cgdo.
7	cocgbo=0	Flag for calculate cgbo.
8	coadov=1	Flag for overlap charges/capacitances.
9	coisub=0	Flag for calculate isub.
10	cogidl=0	Flag for calculate lgidl current.
11	coiigs=0	Flag for calculate lgate current.
12	coovlp=0	Flag for calculate overlap charge.
13	conois=0	Flag for calculate 1/f noise.

Virtuoso Simulator Components and Device Models Reference

HiSIM1 Field Effect Transistor Model (hisim)

- 14 `coisti=0` Flag for calculate STI HiSIM1.1.
- 15 `coiprv=1` Flag for use `ids_prv` as initial guess of `Ids`.
- 16 `copprrv=1` Flag for use `ps{0/l}_prv` as initial guess of `Ps{0/l}`.

Default for instance parameters

- 17 `w=5e-6 m` Default channel width.
- 18 `l=5e-6 m` Default channel length.
- 19 `as=0 m2` Default area of source diffusion.
- 20 `ad=0 m2` Default area of drain diffusion.
- 21 `ps=0 m` Default perimeter of source diffusion.
- 22 `pd=0 m` Default perimeter of drain diffusion.
- 23 `temp=300.15 K` Default lattice temperature.
- 24 `dtemp=0 K` Default lattice temperature rise from ambient.

Technological parameters

- 25 `tox=5.0e-9 m` Gate oxide thickness.
- 26 `xld=0 m` Gate-overlap length.
- 27 `xwd=0 m` Gate-overlap width.
- 28 `xpolyd=0 m` Difference between gate-poly and design lengths.
- 29 `tpoly=0 m` Height of the gate poly-si.
- 30 `nsubc=1.0e17 cm-3` Constant part of `Nsub`.
- 31 `nsubp=1.0e17 cm-3` Peak of the pocket concentration.

Virtuoso Simulator Components and Device Models Reference

HiSIM1 Field Effect Transistor Model (hisim)

32	$r_s=8.0e-5 \ \Omega \ m$	Source contact resistance.
33	$r_d=8.0e-5 \ \Omega \ m$	Drain contact resistance.
34	$v_{fbc}=-1.0 \ V$	Constant part of flat-band voltage.
35	$l_p=1.5e-8 \ m$	Length of the pocket penetration into the channel.
36	$x_j=0.0 \ m$	Junction depth, used only in HiSIM1.0.0.
37	$x_{qy}=0.0 \ m$	Distance from channel/drain junction to maximum electric field point, used only in HiSIM1.1.0.

Temperature dependence effects

38	$bgtmp1=9.02e-5 \ eV/K$	First order temperature coefficient for band gap.
39	$bgtmp2=1.0e-7 \ eV/K^2$	Second order temperature coefficient for band gap.

Quantum Mechanical Effects

40	$qme1=4.0e-11 \ m/V^2$	Coefficient for quantum mechanical effect.
41	$qme2=3.0e-10 \ V$	Coefficient for quantum mechanical effect.
42	$qme3=0.0 \ m$	Coefficient for quantum mechanical effect.

Poly Depletion Effects

43	$pgd1=0.01 \ V$	Strength of poly depletion.
44	$pgd2=1.0 \ V$	Threshold voltage of poly depletion.
45	$pgd3=0.8$	Vds dependence of poly depletion.

Short Channel Effects

46	<code>parl1=1.0</code>	Strength of lateral-electric-field gradient.
47	<code>parl2=0.0 m</code>	Depletion width of channel/contact junction.
48	<code>sc1=0.0 1/V</code>	Short-channel coefficient 1.
49	<code>sc2=0.0 1/V²</code>	Short-channel coefficient 2.
50	<code>sc3=0.0 m/V²</code>	Short-channel coefficient 3.
51	<code>scp1=0.0 1/V</code>	Short-channel coefficient 1 for pocket.
52	<code>scp2=0.0 1/V²</code>	Short-channel coefficient 2 for pocket.
53	<code>scp3=0.0 m/V²</code>	Short-channel coefficient 3 for pocket.

Narrow channel effects

54	<code>wfc=0.0 m F/cm²</code>	Threshold voltage reduction.
55	<code>mueph2=0.0</code>	Mobility reduction.
56	<code>w0=0.0 log(cm)</code>	Minimum gate width.
57	<code>wvthsc=0.0</code>	Short-channel effect at the STI edge.
58	<code>nsti=1.0e17 cm⁻³</code>	Substrate-impurity concentration at the SIT edge.
59	<code>wsti=0.0 m</code>	Width of the high-field region at STI.

Mobility Effects

60	<code>vds0=0.05 V</code>	Drain voltage for extracting the low-field mobility.
61	<code>muecb0=300.0 cm²/(V s)</code>	Coulomb scattering.
62	<code>muecb1=30.0 cm²/(V s)</code>	Coulomb scattering.

Virtuoso Simulator Components and Device Models Reference

HiSIM1 Field Effect Transistor Model (hisim)

- 63 $\text{mueph0}=0.3 \text{ cm}^2 (\text{V}/\text{cm})^{(\text{Muesr1})}/(\text{V s})$
Phonon scattering.
- 64 $\text{mueph1}=2.5\text{e}4$ Phonon scattering.
- 65 $\text{muetmp}=1.5$ Temperature dependence of phonon scattering.
- 66 $\text{muesr0}=2.0 \text{ cm}^2 (\text{V}/\text{cm})^{(\text{Muesr1})}/(\text{V s})$
Surface-roughness scattering.
- 67 $\text{muesr1}=2.0\text{e}15$ Surface-roughness scattering.
- 68 $\text{ndep}=1.0$ Coefficient of effective electric field.
- 69 $\text{ninv}=0.5$ Coefficient of effective electric field.
- 70 $\text{ninvd}=1.0\text{e}-9 \text{ 1}/\text{V}$ Modification of Ninv.
- 71 $\text{bb}=2.0$ High-field mobility degradation.
- 72 $\text{vmax}=7.0\text{e}6 \text{ cm}/\text{s}$ Maximum of electron saturation velocity.
- 73 $\text{vover}=0.01 \text{ cm}^{(\text{voverp})}$
Parameter for velocity overshoot.
- 74 $\text{voverp}=0.1$ Lgate dependence of velocity overshoot.
- 75 $\text{rpock1}=0.001 \text{ V}^2 \mu\text{m}^{(\text{Rpocp2}-1)}/\text{A}^{(\text{Rpocp1})}$
Pocket technology parameter for Ids.
- 76 $\text{rpock2}=0.1 \text{ V}$ Pocket technology parameter for Ids.
- 77 $\text{rpocp1}=1.0$ Pocket technology parameter for Ids(HiSIM1.1.0).
- 78 $\text{rpocp2}=0.5$ Pocket technology parameter for Ids(HiSIM1.1.0).

Channel Length Modulation Effects

- 79 $\text{clm1}=0.7$ First parameter for CLM.
- 80 $\text{clm2}=2.0 \text{ 1}/\text{m}$ Second parameter for CLM.

Virtuoso Simulator Components and Device Models Reference

HiSIM1 Field Effect Transistor Model (hisim)

81 $c_{lm3}=1.0$ Third parameter for CLM.

Substrate Current Effects

82 $sub1=10.0$ 1/V First parameter for I_{sub} .

83 $sub2=20.0$ V Second parameter for I_{sub} .

84 $sub3=0.8$ Third parameter for I_{sub} .

Gate Current Effects

85 $gleak1=1.0e4$ A/(V^{3/2} c^{1/2})
First gate current coefficient.

86 $gleak2=2.0e7$ 1/(V^{1/2} c^{3/2} m)
Second gate current coefficient.

87 $gleak3=0.3$ Third gate current coefficient.

GIDL Current Effects

88 $gidl1=5.0e-6$ A m/(V^{3/2} c^{1/2})
First parameter for GIDL.

89 $gidl2=1.0e6$ 1/(V^{1/2} c^{3/2} m)
Second parameter for GIDL.

90 $gidl3=0.3$ Third parameter for GIDL.

Noise 1/f Effects

91 $nfalp=1.0e-16$ Flicker (1/f) noise contribution of the mobility fluctuation.

92 $nftrp=1.0e10$ Flicker (1/f) noise ratio of trap density to attenuation coefficient.

93 $cit=0.0$ Flicker (1/f) noise interface trapped carriers capacitance.

94 $kf=0$ Flicker (1/f) noise coefficient.

Virtuoso Simulator Components and Device Models Reference

HiSIM1 Field Effect Transistor Model (hisim)

- 95 $af=1.0$ Flicker (1/f) noise exponent.
- 96 $ef=0.0$ Flicker (1/f) noise frequency exponent.

Symmetry for short-channel mosfet

- 97 $vzadd0=1.0e-2$ V $Vzadd$ at $Vds=0$.
- 98 $pzadd0=5.0e-3$ V $Pzadd$ at $Vds=0$.

P-N junctions parameters

- 99 $js0=1.0e-4$ A/m² Junction saturation current density.
- 100 $js0sw=0.0$ A/m Side-wall saturation current density.
- 101 $nj=1.0$ Junction emission coefficient.
- 102 $njsw=1.0$ Junction emission coefficient (sidewall).
- 103 $x_{ti}=3.0$ Junction saturation current temperature exponent coefficient.
- 104 $cj=5.0e-4$ F/m² Bottom junction capacitance per unit area at zero bias.
- 105 $cjsw=5e-10$ F/m Source/drain sidewall junction capacitance per unit length at zero bias.
- 106 $cjswg=5e-10$ F/m Source/drain sidewall junction capacitance grading coefficient per unit length at zero bias.
- 107 $mj=0.5$ Bulk junction bottom grading coefficient.
- 108 $mjsw=0.33$ Source/drain sidewall junction capacitance grading coefficient.
- 109 $mjswg=0.33$ Bottom junction capacitance grading coefficient.
- 110 $pb=1.0$ V Bottom junction build-in potential.
- 111 $pbsw=1.0$ V Source/drain sidewall junction build-in potential.
- 112 $pbswg=1.0$ V Source/drain gate sidewall junction build-in potential.

Overlap capacitance parameters

113	c_{gso} (F/m)	Gate-source overlap capacitance.
114	c_{gdo} (F/m)	Gate-drain overlap capacitance.
115	c_{gbo} (F/m)	Gate-bulk overlap capacitance.

Auto Model Selector parameters

116	$w_{max}=1$ m	Maximum channel width for which the model is valid.
117	$w_{min}=0$ m	Minimum channel width for which the model is valid.
118	$l_{max}=1$ m	Maximum channel length for which the model is valid.
119	$l_{min}=0$ m	Minimum channel length for which the model is valid.

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	$reversed$	Reverse mode indicator. Possible values are <code>no</code> or <code>yes</code> .
2	i_{ds} (A)	Resistive drain-to-source current.
3	v_{gs} (V)	Gate-source voltage.
4	v_{ds} (V)	Drain-source voltage.
5	v_{bs} (V)	Bulk-source voltage.

Virtuoso Simulator Components and Device Models Reference

HiSIM1 Field Effect Transistor Model (hisim)

6	v_{th} (V)	Threshold voltage.
7	g_m (S)	Common-source transconductance.
8	g_{ds} (S)	Common-source output conductance.
9	g_{mbs} (S)	Body-transconductance.
10	Q_b (Coul)	Q_b .
11	Q_d (Coul)	Q_d .
12	Q_g (Coul)	Q_g .
13	Q_s (Coul)	Q_s .
14	c_{jd} (F)	Drain-bulk junction capacitance.
15	c_{js} (F)	Source-bulk junction capacitance.
16	c_{gg} (F)	dQ_g/dV_g .
17	c_{gd} (F)	dQ_g/dV_d .
18	c_{gs} (F)	dQ_g/dV_s .
19	c_{gb} (F)	dQ_g/dV_{bk} .
20	c_{dg} (F)	dQ_d/dV_g .
21	c_{dd} (F)	dQ_d/dV_d .
22	c_{ds} (F)	dQ_d/dV_s .
23	c_{db} (F)	dQ_d/dV_b .
24	c_{sg} (F)	dQ_s/dV_g .
25	c_{sd} (F)	dQ_s/dV_d .
26	c_{ss} (F)	dQ_s/dV_s .
27	c_{sb} (F)	dQ_s/dV_b .

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HiSIM1 Field Effect Transistor Model (hisim)

28	cbg (F)	dQb_dVg.
29	cbd (F)	dQb_dVd.
30	cbs (F)	dQb_dVs.
31	cbb (F)	dQb_dVb.
32	id (A)	Resistive drain current.
33	is (A)	Resistive source current.
34	ibulk (A)	Resistive bulk current.
35	pwr (W)	Power at op point.
36	ps0 (V)	Surface potential at source side.
37	ps1 (V)	Surface potential at drain side.
38	pds (V)	Delta between ps1 and ps0.
39	isub (A)	Substrate current Isub.
40	gbds (S)	Substrate trans conductance (dIsub/dVds).
41	gbgs (S)	Substrate trans conductance (dIsub/dVgs).
42	gbbs (S)	Substrate transconductance (dIsub/dVbs).

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.

Qb	OP-10	coisub	M-9	mueph1	M-64	rseff	O-3
Qd	OP-11	conois	M-13	mueph2	M-55	sc1	M-48

Virtuoso Simulator Components and Device Models Reference

HiSIM1 Field Effect Transistor Model (hisim)

Qg	OP-12	coovlp	M-12	muesr0	M-66	sc2	M-49
Qs	OP-13	copprv	M-16	muesr1	M-67	sc3	M-50
ad	I-4	corsrd	M-4	muetmp	M-65	scp1	M-51
ad	M-20	csb	OP-27	ndep	M-68	scp2	M-52
af	M-95	csd	OP-25	nfalp	M-91	scp3	M-53
as	M-19	csg	OP-24	nftrp	M-92	sub1	M-82
as	I-3	css	OP-26	ninv	M-69	sub2	M-83
bb	M-71	dtemp	I-8	ninvd	M-70	sub3	M-84
bgtmp1	M-38	dtemp	M-24	nj	M-101	temp	I-7
bgtmp2	M-39	ef	M-96	njsw	M-102	temp	M-23
cbb	OP-31	gbbs	OP-42	noise	M-3	tox	M-25
cbd	OP-29	gbds	OP-40	nsti	M-58	tpoly	M-29
cbg	OP-28	gbgs	OP-41	nsubc	M-30	type	M-1
cbs	OP-30	gds	OP-8	nsubp	M-31	vbs	OP-5
cdb	OP-23	gidl1	M-88	parl1	M-46	vds	OP-4
cdd	OP-21	gidl2	M-89	parl2	M-47	vds0	M-60
cdg	OP-20	gidl3	M-90	pb	M-110	version	M-2
cds	OP-22	gleak1	M-85	pbsw	M-111	vfbc	M-34
cgb	OP-19	gleak2	M-86	pbswg	M-112	vgs	OP-3
cgbo	M-115	gleak3	M-87	pd	M-22	vmax	M-72
cgd	OP-17	gm	OP-7	pd	I-6	vover	M-73

Virtuoso Simulator Components and Device Models Reference

HiSIM1 Field Effect Transistor Model (hisim)

cgdo	M-114	gmbs	OP-9	pds	OP-38	voverp	M-74
cgg	OP-16	ibulk	OP-34	pgd1	M-43	vth	OP-6
cgs	OP-18	id	OP-32	pgd2	M-44	vzadd0	M-97
cgso	M-113	ids	OP-2	pgd3	M-45	w	I-1
cit	M-93	is	OP-33	ps	M-21	w	M-17
cj	M-104	isub	OP-39	ps	I-5	w0	M-56
cjd	OP-14	js0	M-99	ps0	OP-36	weff	O-1
cjs	OP-15	js0sw	M-100	ps1	OP-37	wfc	M-54
cjsw	M-105	kf	M-94	pwr	OP-35	wmax	M-116
cjswg	M-106	l	M-18	pzadd0	M-98	wmin	M-117
clm1	M-79	l	I-2	qme1	M-40	wsti	M-59
clm2	M-80	leff	O-2	qme2	M-41	wvthsc	M-57
clm3	M-81	lmax	M-118	qme3	M-42	xj	M-36
coadv	M-8	lmin	M-119	rd	M-33	xld	M-26
cocgbo	M-7	lp	M-35	rdeff	O-4	xpolyd	M-28
cocgdo	M-6	mj	M-107	reversed	OP-1	xqy	M-37
cocgso	M-5	mjsw	M-108	rpock1	M-75	xti	M-103
cogidl	M-10	mjswg	M-109	rpock2	M-76	xwd	M-27
coiigs	M-11	muecb0	M-61	rpocp1	M-77		
coiprv	M-15	muecb1	M-62	rpocp2	M-78		
coisti	M-14	mueph0	M-63	rs	M-32		

Virtuoso Simulator Components and Device Models Reference

HiSIM1 Field Effect Transistor Model (hisim)

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 $0.1\mu\text{m}$. 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.

This chapter contains the following information about the HiSIM2 model:

- [Schematic of the Model](#) on page 2121
- [Charges](#) on page 2121
- [Drain Current](#) on page 2126
- [Threshold Voltage Shift](#) on page 2127
- [Depletion Effect of the Gate Poly-Si](#) on page 2132
- [Quantum-Mechanical Effects](#) on page 2132
- [Mobility Model](#) on page 2134
- [Channel-Length Modulation](#) on page 2135

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HiSIM2 Model (hisim2)

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- [Source/Bulk and Drain/Bulk Diode Model](#) on page 2154
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- [Non-Quasi-Static \(NQS\) Model](#) on page 2163
- [Summary of Model Equations](#) on page 2165
- [Component Statements](#) on page 2172

Schematic of the Model

Figure 31-1 Schematic of the surface potential distribution in the channel

Charges

The effective channel length L_{eff} and width W_{eff} are calculated from the gate length L_{gate} and width W_{gate} where L_{gate} and width W_{gate} are equal to the gate drawn length and width.

For HiSIM2.4,

$$L_{\text{gate}} = L_{\text{drawn}} + XL$$
$$W_{\text{gate}} = \frac{W_{\text{drawn}}}{NF} + XW$$

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

where XLD and XWD account for the overlaps of source/drain contact and the 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 31-2 Cross section of the device

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. 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:

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.

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

By applying the Gauss law, the space charge density Q_{SP} is derived from the Poisson equation

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.

The quasi-Fermi potential $\phi_f(y)$ preserves the following relationship:

For HiSIM2.4,

$$\phi_f(L_{eff}) - \phi_f(0) = V_{ds,eff}$$

The electron concentration at equilibrium condition n_{p0} is

where the intrinsic carrier concentration n_i is

n_{p0} is approximated to be N_{sub} , and E_g describes the temperature dependence of the bandgap.

Figure 31-3 Surface Potentials as a Function of the Gate Voltage, V_{gs}

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

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

Figure 31-4 Charges as a Function of V_{gs}

Drain Current

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 TOX and the substrate doping concentration $NSUBC$ 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:

Figure 31-5 Schematic Plot of Separation of V_{th}

Short-Channel Effect

Four important phenomena are observed:

1. Reduction of V_{th} for reduced L_{gate}
2. V_{th} dependence on V_{ds}

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

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.

where W_d is the depletion-layer thickness written as

$$W_d = \sqrt{\frac{2\epsilon_{Si}(2\Phi_B - V_{bs})}{qN_{sub}}}$$

$$2\Phi_B = \frac{2}{\beta} \ln\left(\frac{N_{sub}}{n_i}\right)$$

$\frac{\delta E_y}{\delta y}$ is derived with model parameters in the form

$$\frac{dE_y}{dy} = \frac{2(V_{BI} - 2\Phi_B)}{(L_{gate} - PARL2)^2} \left(SC1 + SC2 \cdot V_{ds} + SC3 \cdot \frac{2\Phi_B - V_{bs}}{L_{gate}} + SC4 \cdot V_{ds} \cdot (2\Phi_B - V_{bs}) \right)$$

Reverse-Short-Channel Effects

**Impurity concentration inhomogeneity in the direction vertical to the channel
(Retrograded Implantation)**

where BS1 represents the strength of the deviation and BS2 is the starting value of V_{bs} where the deviation becomes visible.

**Impurity concentration inhomogeneity in the lateral direction parallel to the channel
(Pocket Implantation)**

$$\Delta V_{th,P} = (V_{th,R} - V_{th0}) \frac{\epsilon_{Si}}{C_{ox}} W_d \frac{dE_{y,P}}{dy} + dqb$$

$$V_{th,R} = VFBC + 2\Phi_B + \frac{Q_{B0}}{C_{ox}} + \frac{1}{\beta} \log \left(\frac{N_{subb}}{NSUBC} \right)$$

$$Q_{B0} = \sqrt{2q \cdot N_{sub} \cdot \epsilon_{Si} \cdot (2\Phi_B - V_{bs})}$$

$$V_{th0} = VFBC + 2\Phi_{BC} + \frac{\sqrt{2qNSUBC\epsilon_{Si}(2\Phi_{BC} - V_{bs})}}{C_{ox}}$$

$$\frac{dE_{y,P}}{dy} = \frac{2(VBI - 2\Phi_B)}{LP^2} \left(SCP1 + SCP2 \cdot V_{ds} + SCP3 \cdot \frac{2\Phi_B - V_{bs}}{LP} \right)$$

$$N_{subb} = 2 \cdot NSUBP - \frac{(NSUBP - NSUBC) \cdot L_{gate}}{LP} - NSUBC$$

$$dqb = \frac{Q_{B0} - Q_{Bmod}}{C_{ox}}$$

where

$$xx = 0.5 \cdot L_{gate} - LP .$$

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

$$POTENTIAL = (VBI - \phi_{S0})^{PTP}$$

The final drain current I_{ds} is written

$$I_{ds} = I_{ds} + PUNCH$$

$$PUNCH = \frac{W_{eff} \cdot NF}{L_{eff}} \frac{\mu}{\beta} \cdot (\phi_{SL} - \phi_{S0})$$

$$\left\{ C_{ox} \cdot \beta \frac{PTL}{(L_{gate} \cdot 10^6)^{PTLP}} \cdot POTENTIAL \cdot \left(1 + PT2 \cdot V_{ds} + \frac{PT4 \cdot (\phi_{S0} - V_{bs})}{(L_{gate} \cdot 10^6)^{PT4P}} \right) \right\}$$

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

$$I_{ds} = I_{ds} + \frac{W_{eff} \cdot NF}{L_{eff}} \frac{\mu}{\beta} \cdot (\phi_{SL} - \phi_{S0}) \cdot CONDUCTANCE$$

$$CONDUCTANCE = C_{ox} \cdot \beta \frac{GDL}{(L_{gate} \cdot 10^6 + GDL \cdot 10^6)^{GDLF}} \cdot V_{ds}$$

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.

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

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

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

where a , b , and c are fitting parameters, and,

For HiSIM2.4,

$$T_{ox} = TOX + \Delta T_{ox}$$
$$\Delta T_{ox} = \frac{QME1}{QME2^2} (V_{gs} - V_{th}(T_{ox} = TOX) - QME2)^2 + QME3$$

Mobility Model

$$\frac{1}{\mu_0} = \frac{1}{\mu_{CB}} + \frac{1}{\mu_{PH}} + \frac{1}{\mu_{SR}}$$

$$\mu_{CB}(\text{Coulomb}) = \text{MUECB0} + \text{MUECB1} \frac{Q_i}{q \cdot 10^{11}}$$

$$\mu_{PH}(\text{phonon}) = \frac{M_{uephonon}}{E_{eff}^{\text{MUEPH0}}}$$

$$\mu_{SR}(\text{surface roughness}) = \frac{\text{MUESR1}}{E_{eff}^{\text{MUESR1}}}$$

Here E_{eff} is the effective field normal to the surface and is written as

$$E_{eff} = \frac{1}{\epsilon_{Si}} (N_{dep} \cdot Q_b + \text{NINV} \cdot Q_i) \cdot f(\phi_s)$$

$$f(\phi_s) = \frac{1}{1 + (\phi_{s0} - \phi_{sL}) \cdot \text{NINVD}}$$

where N_{dep} considers the gate length dependence with two model parameters NDEPL and NDEPLP as

$$N_{dep} = \text{NDEP} \frac{L_{gate}^{\text{NDEPLP}}}{\text{NDEPL} + (L_{gate} \cdot 10^6)^{\text{NDEPLP}}}$$

The mobility preserves the following conditions:

Due to the carrier flow at increasing distance from the surface with reducing L_{gate} , the electric field experienced by the carriers is different from the field in the long L_{gate} 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

where the maximum velocity V_{max} is temperature dependent. V_{max} should be the maximum electron-saturation velocity ($\approx 1 \cdot 10^7 \text{cm/s}$), which is exceeded at reduced L_{gate} . This is called velocity overshoot, and is included in the mobility model in the following manner:

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 as depicted in the following figure.

Figure 31-6 Schematic of correlation among physical quantities in pinch-off region

where

and E_C is the electric field at $y=0$ '.

The above equation can be simplified as follows:

Occasionally it happens that the channel conductance g_{ds} is not smooth as a function of V_{ds} but shows wiggles. To eliminate the problem smoothing parameter CLM4 was introduced in the HiSIM2.3.1 version. This is removed in HiSIM2.4.0, and $V_{ds,eff}$ is introduced for the smoothing. To adjust the HiSIM2.3.1 parameter set to HiSIM2.4.0, fix model parameters for $V_{ds,eff}$

`DDLTMAX = 10`
`DDLTSLP = 0`
`5 ≤ DDLTICT ≤ 10`

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

Here, Tfox is the thickness of the oxide at the trench edge, and WFC is the model parameter for including the edge-fringing-capacitance effects.

$$N_{subp} = NSUBP \cdot \left(1 + \frac{NSUBPW}{(W_{gate} \cdot 10^6)^{NSUBPWP}} \right)$$

The width dependence of the substrate impurity concentration N_{SUBC} is also considered as

$$N_{sub} = NSUBC \cdot \left(1 + \frac{NSUBCW}{(W_{gate} \cdot 10^6)^{NSUBCWP}} \right) \cdot \left(1 + \frac{NSUBCW2}{(W_{gate} \cdot 10^6)^{NSUBCWP2}} \right)$$

$$N_{sub} \leq NSUBCMAX$$

Mobility Change

$$M_{uephonon} = M_{uephonon} \cdot \left(1 + \frac{MUEPHW}{(W_{gate} \cdot 10^6 + MUEPWD \cdot 10^6)^{MUEPWP}} \right) \cdot \left(1 + \frac{MUEPHW2}{(W_{gate} \cdot 10^6)^{MUEPWP2}} \right)$$

$$M_{uesurface} = M_{uesurface} \cdot \left(1 + \frac{MUESRW}{(W_{gate} \cdot 10^6)^{MUESWP}} \right)$$

Transistor Leakage due to Shallow Trench Isolation (STI): Hump in Ids

The shallow trench isolation induces also an undesired hump in the subthreshold region of the Ids-Vgs 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 Vth reduction there. Thus a MOSFET leakage current occurs at these edges, which is smaller than the main MOSFET current, and only important for modeling of the subthreshold characteristics of the

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MOSFET. The surface potential of the leakage regions at the trench edges can be derived analytically

where

$$Q_{N,STI} = q \cdot N_{STI}$$
$$N_{STI} = NSTI \cdot \left(1 + \frac{NSTIL}{(L_{gate} \cdot 10^6)NSTILP} \right)$$

$$V'_{gs,STI} = V_{gs} - VFBC + V_{thSTI} + \Delta V_{th,SCSTI}$$

where

$$V_{thSTI} = V_{THSTI} - V_{DSTI} \cdot V_{ds}$$

$$wl = (W_{gate} \cdot 10^6) \cdot (L_{gate} \cdot 10^6)$$

The final leakage current equation is written as

where W_{STI} determines the width of the high-field region.

$$W_{STI} = W_{STI} \left(1 + \frac{W_{STIL}}{(L_{gate,sm} \times 10^6) W_{STILP}} \right) \left(1 + \frac{W_{STIW}}{(W_{gate,sm} \times 10^6) W_{STIWP}} \right)$$

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

The mobility modification due to the small device geometry is also modeled in the phonon scattering as

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.

For HiSIM2.4,

$$N_{\text{substi}} = \frac{1 + T1 \cdot T2}{1 + T1 \cdot T3}$$

$$T1 = \frac{1}{1 + \text{NSUBPSTI2}}$$

$$T2 = \frac{\text{NSUBPSTI1}^{\text{NSUBPSTI3}}}{L_{\text{od_half}}}$$

$$T3 = \frac{\text{NSUBPSTI1}^{\text{NSUBPSTI3}}}{L_{\text{od_half_ref}}}$$

$$N_{\text{subp}} = N_{\text{subp}} \times N_{\text{substi}}$$

$$M_{\text{uesti}} = \frac{1 + T1 \cdot T2}{1 + T1 \cdot T3}$$

$$T1 = \frac{1}{1 + \text{MUESTI2}}$$

$$T2 = \frac{\text{MUESTI1}^{\text{MUESTI3}}}{L_{\text{od_half}}}$$

$$T3 = \frac{\text{MUESTI1}^{\text{MUESTI3}}}{L_{\text{od_half_eff}}}$$

$$M_{\text{uephonon}} = M_{\text{uephonon}} \times M_{\text{uesti}}$$

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

$$E_g = E_{g,\text{TNOM}} - \text{BGTMP1} \cdot (T - \text{TNOM}) - \text{BGTMP2} \cdot (T^2 - \text{TNOM}^2)$$

where T is the given temperature, and

$$E_{g,\text{TNOM}} = \text{EG0} - 90.25 \times 10^{-6} \cdot \text{TNOM} - 1.0 \times 10^{-7} \cdot \text{TNOM}^2$$

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where T is the given temperature. The temperature dependence of the intrinsic carrier concentration is given by

The temperature dependence of the gate current is given by modifying the bandgap specific for the gate current as

$$E_{gp} = E_{g,TNOM} + EGIG + IGTEMP2 \left(\frac{1}{T} - \frac{1}{TNOM} \right) + IGTEMP3 \left(\frac{1}{T^2} - \frac{1}{TNOM^2} \right)$$

For HiSIM2.4,

$$E_g = E_{g,TNOM} - BGTMP1 \cdot (T - TNOM) - BGTMP2 \cdot (T^2 - TNOM^2)$$
$$E_{gp} = E_{g,TNOM} + EGIG + IGTEMP2 \left(\frac{1}{T} - \frac{1}{TNOM} \right) + IGTEMP3 \left(\frac{1}{T^2} - \frac{1}{TNOM^2} \right)$$

Resistances

The source and the drain resistances R_s and R_d are considered by voltage drops on each terminal as:

where

$$I_{ds} = \frac{I_{ds0}}{1 + I_{ds0} \frac{R_d}{V_{ds}}}$$

where I_{ds0} is the drain current without the resistance effect.

For HiSIM2.4, a simple inclusion of the effect with an analytical solution is introduced in addition to the iterative calculation of the resistance effect. This is selected with $CORSRD = 2$.

Capacitances

Intrinsic Capacitances

In HiSIM2.4, to compensate the enhanced short-channel effect, determined by the current characteristics, two model parameters XQY1 and XQY2 are introduced.

$$Q_y = \epsilon_{Si} \cdot W_{eff} \cdot NF \cdot W_d \left(\frac{\phi_{s0} + V_{ds} - \phi_s(\Delta L)}{XQY} \right) + (W_{eff} \times 10^6) \cdot NF \cdot \frac{XQY1}{(L_{gate} \times 10^6)^{XQY2}} V_{bs}$$

Overlap Capacitances

The overlap charge at the drain side

where LOVER is the length of the overlap region of the gate over drain or source and

The overlap gate capacitance at the source side is modeled as

In HiSIM2.4, the model considering the impurity-concentration gradient along the junction surface is eliminated, and a new model considering the surface-potential change in the drain region as a function of applied voltages is introduced with model parameters NOVER and VFBOVER.

- under the depletion condition

$$Q_{\text{over}} = W_{\text{eff}} \cdot \text{NF} \cdot \text{LOVER} \left(\sqrt{\frac{2\epsilon_{\text{Si}}q\text{NOVER}}{\beta}} \sqrt{\beta(\phi_{\text{S}} + V_{\text{ds}}) - 1} \right)$$

- under the accumulation condition

$$Q_{over} = W_{eff} \cdot NF \cdot LOVER \cdot C_{ox} [(V_{gs} - V_{FBOVER} - \phi_s)]$$

This model is selected, if NOVER is not equal to zero.

Extrinsic Capacitances

The outer fringing capacitance is modeled as

Leakage Currents

Substrate Current

Figure 31-7 Schematic of the high field region

Impact-Ionization Induced Bulk Potential Change

where

IBPC1 and IBPC2 are model parameters.

Gate Current

Between Gate and Channel, I_{gate}

Figure 31-8 Gate leakage currents considered

where

Figure 31-9 Exact results of gate partitioning

Between Gate and Bulk, Igb

In HiSIM2.4, a model parameter GLKB3 is introduced in the field calculation for the case needed

$$E_{gb} = -\frac{V_{gs} - VFBC + GLKB3}{T_{ox}}$$

Between Gate and Source/Drain. Igs/Igd

Gate-Induced Drain Leakage (GIDL)

Conservation of Symmetry at $V_{ds}=0$

HiSIM preserves the symmetry at $V_{ds} = 0$ automatically due to the drift-diffusion approximation as demonstrated in [Figure 31-10](#) on page 2153. 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. A result with the damping at short channel length is shown in [Figure 31-11](#) on page 2153 for $L_{gate} = 0:13\mu m$. Other modeled phenomena, which include a V_{ds} dependence, cause a similar symmetry problem as the short-channel effects. They are therefore also damped.

Figure 31-10 Symmetry test at $V_{ds}=0$ for $L_{gate}=10\mu\text{m}$ and $V_{gs}=3\text{V}$

Figure 31-11 Symmetry test at $V_{ds}=0$ for $L_{gate}=0.13\mu\text{m}$ and $V_{gs}=3\text{V}$

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 [39], but include a number of modifications.

The two regions denoted (a) and (b) in the schematic diagram of [Figure 31-12](#) on page 2155, correspond to the forward-bias current saturation and the backward-bias region, respectively. These regions are distinguished in the modeling and are treated separately according to their origins.

Figure 31-12 I_{bd} and I_{bs} are modeled in two operating regions (a) and (b)

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

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.

Diode Capacitance

The notations

$\Theta = S$; $\theta = s$ (for source/bulk junction) and

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$\Theta = D; \theta = d$ (for drain/bulk junction) apply.

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Noise Models

1/f Noise Model

where the parameters NFALP and NFTRP represent the contribution of the mobility actuation and the ratio of trap density to attenuation coefficient, respectively. N0 and NL are carrier densities at source side and drain side or pinch-off point, respectively, as calculated in HiSIM.

$$N_{\text{flick}} = S_{I_{\text{ds}}} \cdot f^{\text{NFALP}}$$

Thermal Noise Model

According to the Nyquist theorem,

In HiSIM,

The final equations is,

where μ_s , μ_d and μ_{av} are mobilities at the source side, the drain side, and averaged, respectively.

Induced Gate Noise Model

Coupling Noise Model

Non-Quasi-Static (NQS) Model

Carrier Formation

Delay Mechanism

Time-Domain Analysis

Figure 31-13 Dynamically calculated transit delay times in the NQS model of HiSIM

AC Analysis

DFM Model

To support design for manufacturability (DFM) HiSIM2.4 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

$$\begin{aligned}M_{\text{uephonon}} &= M_{\text{uephonon}} [\text{MPHDFM}\{\ln(\text{NSUBCDFM}) - \ln(\text{NSUBC})\} + 1] \\ \text{NSUBP} &= \text{NSUBP} + (\text{NSUBCDFM} - \text{NSUBC}) \\ \text{NPEXT} &= \text{NPEXT} + (\text{NSUBCDFM} - \text{NSUBC})\end{aligned}$$

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

$$\text{Bin_HiSIM_model_parameter} = \text{HiSIM_model_parameter} + \frac{P1}{L_{\text{bin}}} + \frac{P2}{W_{\text{bin}}} + \frac{P3}{L_{\text{bin}} \cdot W_{\text{bin}}}$$

$$L_{\text{bin}} = (L_{\text{gate}} \times 10^6)^{L_{\text{BINN}}}$$

$$W_{\text{bin}} = (W_{\text{gate}} \times 10^6)^{W_{\text{BINN}}}$$

where P1, P2, and P3 are model parameters for L HiSIM model parameter, W HiSIM model parameter, and P HiSIM model parameter.

Summary of Model Equations

Physical Quantities

$$C_{\text{ox}} = \epsilon_0 \frac{\text{KAPPA}}{T_{\text{ox}}}$$

$$T_{\text{ox}} = \text{TOX} + \Delta T_{\text{ox}}$$

$$\Delta T_{\text{ox}} = \frac{\text{QME1}}{\text{QME2}^2} (V_{\text{gs}} - V_{\text{th}}(T_{\text{ox}} = \text{TOX}) - \text{QME2})^2 + \text{QME3}$$

$$V_{\text{G}}' = V_{\text{gs}} - \text{VFBC} + \Delta V_{\text{th}}$$

$$\beta = \frac{q}{kT}$$

$$V_{\text{th}} = \text{VFBC} + 2\Phi_{\text{B}} + \frac{\sqrt{2\epsilon_{\text{Si}}qN_{\text{sub}}}}{C_{\text{ox}}} \sqrt{2\Phi_{\text{B}}}$$

$$\Phi_{\text{B}} = \frac{2}{\beta} \ln \left(\frac{N_{\text{sub}}}{n_i} \right)$$

L_{eff} and W_{eff}

$$L_{\text{gate}} = L_{\text{drawn}} + \text{XL}$$

$$W_{\text{gate}} = \frac{W_{\text{drawn}}}{\text{NF}} + \text{XW}$$

$$L_{\text{poly}} = L_{\text{gate}} - 2 \times \frac{\text{LL}}{(L_{\text{gate}} + \text{LLD})^{\text{LLN}}}$$

$$W_{\text{poly}} = W_{\text{gate}} - 2 \times \frac{\text{WL}}{(W_{\text{gate}} + \text{WLD})^{\text{WLN}}}$$

$$L_{\text{eff}} = L_{\text{poly}} - 2 \times \text{XLD}$$

$$W_{\text{eff}} = W_{\text{poly}} - 2 \times \text{XWD}$$

Temperature Dependence

$$E_{\text{g}} = E_{\text{g,TNOM}} - \text{BGTMP1} \cdot (T - \text{TNOM}) - \text{BGTMP2} \cdot (T^2 - \text{TNOM}^2)$$

$$E_{\text{g,TNOM}} = \text{EG0} - 90.25 \times 10^{-6} \cdot \text{TNOM} - 1.0 \times 10^{-7} \cdot \text{TNOM}^2$$

$$n_{\text{i}} = n_{\text{i0}} \cdot T^{\frac{3}{2}} \cdot \exp\left(-\frac{E_{\text{g}}}{2q}\beta\right)$$

$$\mu_{\text{PH}}(\text{phonon}) = \frac{M_{\text{uephonon}}}{(T/\text{TNOM})^{\text{MUETMP}} \times E_{\text{eff}}^{\text{MUEPH0}}}$$

$$V_{\text{max}} = \frac{\text{VMAX}}{1.8 + 0.4(T/\text{TNOM}) + 0.1(T/\text{TNOM})^2 - \text{VTMP} \times (1 - T/\text{TNOM})}$$

$$E_{\text{gp}} = E_{\text{g,TNOM}} + \text{EGIG} + \text{IGTEMP2} \left(\frac{1}{T} - \frac{1}{\text{TNOM}} \right) + \text{IGTEMP3} \left(\frac{1}{T^2} - \frac{1}{\text{TNOM}^2} \right)$$

Drain Current I_{ds}

$$I_{ds} = \frac{W_{eff} \cdot NF}{L_{eff}} \cdot \mu \cdot \frac{I_{dd}}{\beta}$$

$$I_{dd} = C_{ox}(\beta V_G' + 1)(\phi_{SL} - \phi_{S0}) - \frac{\beta}{2} C_{ox}(\phi_{SL}^2 - \phi_{S0}^2)$$

$$- \frac{2}{3} const0 \left[\{\beta(\phi_{SL} - V_{bs}) - 1\}^{\frac{3}{2}} - \{\beta(\phi_{S0} - V_{bs}) - 1\}^{\frac{3}{2}} \right]$$

$$+ const0 \left[\{\beta(\phi_{SL} - V_{bs}) - 1\}^{\frac{1}{2}} - \{\beta(\phi_{S0} - V_{bs}) - 1\}^{\frac{1}{2}} \right]$$

$$const0 = qN_{sub}L_D\sqrt{2}$$

$$I_{ds} = I_{ds} + \frac{W_{eff} \cdot NF}{L_{eff}} \frac{\mu}{\beta} \cdot (\phi_{SL} - \phi_{S0})$$

$$\cdot \left\{ C_{ox} \cdot \beta \frac{PTL}{(L_{gate} \cdot 10^6)^{PTLP}} \cdot (V_{BI} - \phi_{S0})^{PTP} \cdot \left(1 + PT2 \cdot V_{ds} + \frac{PT4 \cdot (\phi_{S0} - V_{bs})}{(L_{gate} \cdot 10^6)^{PT4P}} \right) \right\}$$

$$+ \frac{W_{eff} \cdot NF}{L_{eff}} \frac{\mu}{\beta} \cdot (\phi_{SL} - \phi_{S0}) \cdot C_{ox} \cdot \beta \frac{GDL}{(L_{gate} \cdot 10^6 + GDLD \cdot 10^6)^{GDLP}} \cdot V_{ds}$$

Substrate Impurity Concentration ΔN_{sub}

$$N_{sub} = \frac{NSUBC(L_{gate} - LP) + N_{subp} \cdot LP}{L_{gate}} + \frac{NPEXT - NSUBC}{\left(\frac{1}{xx} + \frac{1}{LPEXT}\right) L_{gate}}$$

$$xx = 0.5 \times L_{gate} - LP$$

$$N_{sub} = NSUBC \cdot \left(1 + \frac{NSUBCW}{(W_{gate} \cdot 10^6)^{NSUBCWP}} \right) \cdot \left(1 + \frac{NSUBCW2}{(W_{gate} \cdot 10^6)^{NSUBCWP2}} \right)$$

$$N_{sub} \leq NSUBC_{MAX}$$

$$N_{subb} = 2 \cdot N_{subp} - \frac{(N_{subp} - NSUBC) \cdot L_{gate}}{LP} - NSUBC$$

$$N_{subp} = NSUBP \cdot \left(1 + \frac{NSUBPW}{(W_{gate} \cdot 10^6)^{NSUBPWP}} \right)$$

$$N_{subp} = NSUBP \cdot \left(\frac{2 \cdot (1 - NSUBPFAC)}{NSUBPL} \cdot L_{gate} \cdot 10^6 + 2 \cdot NSUBPFAC - 1 \right)$$

Threshold Voltage Shift ΔV_{th}

$$\Delta V_{th} = \Delta V_{th,SC} + \Delta V_{th,R} + \Delta V_{th,P} + \Delta V_{th,W} - \phi_{Spg}$$

$$\Delta V_{th,SC} = \frac{\epsilon_{Si}}{C_{ox}} \cdot W_d \frac{2(VBI - 2\Phi_B)}{(L_{gate} - PARL2)^2} \left(SC1 + SC2 \cdot V_{ds} + SC3 \cdot \frac{2\Phi_B - V_{bs}}{L_{gate}} \right. \\ \left. SC4 \cdot V_{ds} \cdot (2\Phi_B - V_{bs}) \right)$$

$$W_d = \sqrt{\frac{2\epsilon_{Si}(2\Phi_B - V_{bs})}{qN_{sub}}}$$

$$\Delta V_{th,P} = (V_{th,R} - V_{th0}) \frac{\epsilon_{Si}}{C_{ox}} W_d \frac{dE_{y,P}}{dy} + dqb - \frac{SCP22}{(SCP21 + V_{ds})^2}$$

$$V_{th,R} = VFBC + 2\Phi_B + \frac{Q_{B0}}{C_{ox}} + \log\left(\frac{N_{subb}}{NSUBC}\right)$$

$$Q_{B0} = \sqrt{2q \cdot N_{sub} \cdot \epsilon_{Si} \cdot (2\Phi_B - V_{bs})}$$

$$V_{th0} = VFBC + 2\Phi_{BC} + \frac{\sqrt{2qNSUBC\epsilon_{Si}(2\Phi_{BC} - V_{bs})}}{C_{ox}}$$

$$\Phi_{BC} = \frac{2}{\beta} \ln\left(\frac{NSUBC}{n_i}\right)$$

$$\Phi_B = \frac{2}{\beta} \ln\left(\frac{N_{sub}}{n_i}\right)$$

$$\frac{dE_{y,P}}{dy} = \frac{2(VBI - 2\Phi'_B)}{LP^2} \left(SCP1 + SCP2 \cdot V_{ds} + SCP3 \cdot \frac{2\Phi'_B - V_{bs}}{LP} \right)$$

$$dqb = \frac{Q_{B0} - Q_{Bmod}}{C_{ox}}$$

$$Q_{Bmod} = \sqrt{2q \cdot N_{sub} \cdot \epsilon_{Si} \cdot \left(2\Phi_B - V_{bs} - \frac{BS1}{BS2 - V_{bs}} \right)}$$

$$\Delta V_{th,W} = \left(\frac{1}{C_{ox}} - \frac{1}{C_{ox} + 2C_{ef}/(L_{eff}W_{eff})} \right) qN_{sub}W_d + \frac{WVTH0}{W_{gate} \times 10^6}$$

$$C_{ef} = \frac{2KAPPA}{\pi} L_{eff} \ln\left(\frac{2T_{fox}}{T_{ox}}\right) = \frac{WFC}{2} L_{eff}$$

$$\phi_{Spg} = PGD1 \left(\frac{N_{sub}}{NSUBC} \right)^{PGD4} \exp\left(\frac{V_{gs} - PGD2 - PGD3 \cdot V_{ds}}{V}\right)$$

Mobility Mode

$$\mu = \frac{\mu_0}{\left(1 + \left(\frac{\mu_0 E_y}{V_{\max}}\right)^{\frac{BB}{BB}}\right)^{\frac{1}{BB}}}$$

$$V_{\max} = V_{\max} \cdot \left(1 + \frac{VOVER}{(L_{\text{gate}} \times 10^6)^{VOVERP}}\right) \cdot \left(1 + \frac{VOVERWL}{(L_{\text{gate}} \times 10^6)^{VOVERWLP}}\right)$$

$$\frac{1}{\mu_0} = \frac{1}{\mu_{\text{CB}}} + \frac{1}{\mu_{\text{PH}}} + \frac{1}{\mu_{\text{SR}}}$$

$$\mu_{\text{CB}}(\text{Coulomb}) = \text{MUECB0} + \text{MUECB1} \frac{Q_i}{q \times 10^{11}}$$

$$\mu_{\text{PH}}(\text{phonon}) = \frac{M_{\text{uephonon}}}{E_{\text{eff}}^{\text{MUEPH0}}}$$

$$E_{\text{eff}} = \frac{1}{\epsilon_{\text{Si}}} (N_{\text{dep}} \cdot Q_b + \text{NINV} \cdot Q_i) \cdot f(\phi_s)$$

$$f(\phi_s) = \frac{1}{1 + (\phi_{\text{S0}} - \phi_{\text{SL}}) \cdot \text{NINVD}}$$

$$N_{\text{dep}} = \text{NDEP} \frac{L_{\text{gate}}^{\text{NDEPLP}}}{\text{NDEPL} + (L_{\text{gate}} \times 10^6)^{\text{NDEPLP}}}$$

$$M_{\text{uephonon}} = \text{MUEPH1} \cdot \left(1 + \frac{\text{MUEPHL}}{(L_{\text{gate}} \cdot 10^6 + \text{MUEPLD} \cdot 10^6)^{\text{MUEPLP}}}\right) \cdot \left(1 + \frac{\text{MUEPHL2}}{(L_{\text{gate}} \cdot 10^6)^{\text{MUEPLP2}}}\right)$$

$$M_{\text{uephonon}} = M_{\text{uephonon}} \times \left(1 + \frac{\text{MUEPHW}}{(W_{\text{gate}} \cdot 10^6 + \text{MUEPWD})^{\text{MUEPWP}}}\right) \cdot \left(1 + \frac{\text{MUEPHW2}}{(W_{\text{gate}} \cdot 10^6)^{\text{MUEPWP2}}}\right)$$

Channel-Length Modulation

$$L_{ch} = L_{eff} - \Delta L$$

$$\Delta L = \frac{1}{2} \left[-\frac{1}{L_{eff}} \left(2 \frac{I_{dd}}{\beta Q_i} z + 2 \frac{N_{sub}}{\epsilon_{Si}} (\phi_S(\Delta L) - \phi_{SL}) z^2 + E_0 z^2 \right) + \sqrt{\frac{1}{L_{eff}^2} \left(2 \frac{I_{dd}}{\beta Q_i} z + 2 \frac{N_{sub}}{\epsilon_{Si}} (\phi_S(\Delta L) - \phi_{SL}) z^2 + E_0 z^2 \right)^2 - 4 \left(2 \frac{N_{sub}}{\epsilon_{Si}} (\phi_S(\Delta L) - \phi_{SL}) z^2 + E_0 z^2 \right)} \right]$$

$$\phi_S(\Delta L) = (1 - CLM1) \cdot \phi_{SL} + CLM1 \cdot (\phi_{S0} + V_{ds})$$

$$z = \frac{\epsilon_{Si}}{CLM2 \cdot Q_b + CLM3 \cdot Q_i}$$

$$E_0 = 10^5$$

$$\Delta L = \Delta L (1 + CLM6 \times (L_{gate} \times 10^6)^{CLM5})$$

STI Effect

$$I_{ds,STI} = 2 \frac{W_{STI}}{L_{eff} - \Delta L} \mu \frac{Q_{i,STI}}{\beta} [1 - \exp(-\beta V_{ds})]$$

$$Q_{i,STI} = N_{sub,STI} L_{D,STI} \sqrt{2} \left[\exp\{-\beta(\phi_{S,STI} - V_{bs})\} + \beta(\phi_{S,STI} - V_{bs}) - 1 \right. \\ \left. + \frac{n_{p0}}{p_{p0}} \left\{ \exp(\beta(\phi_{S,STI} - \phi_f)) - \exp(\beta(V_{bs} - \phi_f)) \right\} \right]^{\frac{1}{2}} \\ - q N_{sub,STI} L_{D,STI} \sqrt{2} \left[\exp\{-\beta(\phi_{S,STI} - V_{bs})\} + \beta(\phi_{S,STI} - V_{bs}) - 1 \right]^{\frac{1}{2}}$$

$$V'_{gs,STI} = V_{gs} - VFBC + V_{thSTI} + \Delta V_{th,SCSTI}$$

$$V_{thSTI} = V_{THSTI} - V_{DSTI} \cdot V_{ds}$$

$$\Delta V_{th,SCSTI} = \frac{\epsilon_{Si}}{C_{ox}} \sqrt{\frac{2\epsilon_{Si}(2\Phi_B - V_{bs})}{qNSTI}} \frac{dE_y}{dy}$$

$$\frac{dE_y}{dy} = \frac{2(V_{BI} - 2\Phi_B)}{(L_{gate,sm} - PARL2)^2} \left(SCSTI1 + SCSTI2 \cdot V_{ds} + SCSTI3 \frac{2\Phi_B - V_{bs}}{L_{gate,sm}} \right)$$

$$\phi_{S,STI} = V'_{gs,STI} + \frac{\epsilon_{Si} Q_{N,STI}}{C'_{ox}} \left[1 - \sqrt{1 + \frac{2C'_{ox}}{\epsilon_{Si} Q_{N,STI}} \left(V'_{gs,STI} - V_{bs} - \frac{1}{\beta} \right)} \right]$$

$$Q_{N,STI} = q \cdot NSTI$$

$$Q_{N,STI} = q \cdot NSTI$$

$$NSTI = NSTI \cdot \left(1 + \frac{NSTIL}{(L_{gate} \cdot 10^6)^{NSTILP}} \right)$$

$$W_{d,STI} = \sqrt{\frac{2\epsilon_{Si}(2\Phi_{B,STI} - V_{bs})}{qNSTI}}$$

$$W_{STI} = W_{STI} \left(1 + \frac{W_{STIL}}{(L_{gate,sm} \times 10^6)^{W_{STILP}}} \right) \left(1 + \frac{W_{STIW}}{(W_{gate} \times 10^6)^{W_{STIWP}}} \right)$$

$$L_{gate,sm} = L_{gate} + \frac{WL1}{wl^{WL1P}}$$

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 congq=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 (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.
12	rbpb (W)	Substrate resistance network.

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

13	rbpd (W)	Substrate resistance network.
14	rbps (W)	Substrate resistance network.
15	rbdb (W)	Substrate resistance network.
16	rbsb (W)	Substrate resistance network.
17	corg	Gate-contact resistance selector.
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	sa=0.0 m	Distance from STI edge to Gate edge,existed from 2.40.
25	sb=0.0 m	Distance from STI edge to Gate edge,existed from 2.40.
26	sd=0.0 m	Distance from Gate edge to Gate edge,existed from 2.40.
27	nsubcdfm (cm-3)	Constant part of Nsub for DFM,existed from 2.40.
28	mphdfm	NSUBCDFM dependence of phonon scattering for DFM.
29	isnoisy=yes	Should device generate noise. Possible values are no or yes.

Model Definition

```
model modelName hisim2 parameter=value ...
```

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

Model Parameters

Device type parameters

1	type=n	Transistor type. Possible values are n or p.
2	subvers="sc8"	Model sub-version selector.
3	corsrd=0	Contact resistances Rs and Rd selector. 0 : no(default). 1 : yes, as internal resistances. -1 : yes, as external resistances.
4	coiprv=1	Previous Ids is used for calculating source/drain resistance effect. 0 : no(default). 1 : yes.
5	coprv=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. 0 : no(default). 1 : yes.
8	cogidl=0	GIDL current calculation selector. 0 : no(default). 1 : yes.
9	coiigs=0	Gate current calculation selector. 0 : no(default). 1 : yes.
10	coovlp=0	Overlap capacitance calculation selector. 0 : constant overlap capacitance(default). 1 : yes.
11	coflick=0	1/f noise calculation selector.
12	coisti=0	STI leakage current calculation selector. 0 : no(default). 1 : yes.
13	conqs=0	Non-quasi-static mode selector. 0 : no(default). 1 : yes.
14	cothrml=0	Thermal noise calculation selector. 0 : no(default). 1 : yes.
15	tnom (C)	Parameters measurement temperature. Default set by options.
16	corg=0	Gate-contact resistance calculation selector. 0 : no(default). 1 : yes.

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

17	corbnet=0	Substrate resistance network selector.
18	coign=0	Induced gate and cross correlation noise calculation selector.
19	alarm=none	Forbidden operating region. Possible values are none, off, triode, sat, subth, or rev.
20	codfm=0	Calculation of model for DFM selector, existed from 2.40.
21	corecip=0	capacitance reciprocity takes first priority.
22	coqy=0	calculate lateral-field-induced charge/capacitance.

Default for instance parameters

23	w=5e-6 m	Default gate width.
24	l=5e-6 m	Default gate length.
25	as=0 m ²	Default area of source junction.
26	ad=0 m ²	Default area of drain junction.
27	ps=0 m	Default perimeter of source junction.
28	pd=0 m	Default perimeter of drain junction.
29	temp=27 C	Default device temperature.
30	dtemp=0 K	Default device temperature rise from ambient.

Basic Device Parameters

31	tox=3.0e-9 m	Physical oxide thickness.
32	xld=0 m	Gate-overlap length.
33	xwd=0 m	Gate-overlap width.
34	tpoly=2.0E-7 m	Height of the gate poly-si for fringing capacitance.

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

35 $n_{subc}=5.0e+17 \text{ cm}^{-3}$ Substrate-impurity concentration.

36 $n_{subp}=1.0e+18 \text{ cm}^{-3}$

Maximum Pocket Concentration

37 $r_s=0.0 \text{ W m}$ Source contact resistance in LDD region.

38 $r_d=0.0 \text{ W m}$ Drain contact resistance in LDD region.

39 $v_{fbc}=-1.0 \text{ V}$ Constant part of flat-band voltage.

40 $l_p=1.5e-8 \text{ m}$ Length of the pocket penetration into the channel.

41 $x_{qy}=0.0 \text{ m}$ Distance from channel/drain junction to maximum electric field point.

42 $l_{over}=5.0E-8 \text{ m}$ overlap length.

43 $l_l=0.0$ gate length parameter.

44 $l_{ld}=0.0 \text{ m}$ gate length parameter.

45 $l_{ln}=0.0$ gate length parameter.

46 $w_l=0.0$ gate width parameter.

47 $w_{ld}=0.0 \text{ m}$ gate width parameter.

48 $w_{ln}=0.0$ gate width parameter.

49 $v_{bi}=1.0 \text{ V}$ built-in potential.

50 $n_{subpw}=0.0 \text{ cm}^{-3}$ pocket implant parameter.

51 $n_{subpwp}=1.0$ pocket implant parameter.

52 $l_{pext}=1.0E-50 \text{ m}$ Pocket extension.

53 $n_{pext}=5.0E17 \text{ cm}^{-3}$ Pocket extension.

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

54	rsh=0.0 V/A m	Source/drain diffusion sheet resistance.
55	rshg=0.0 V/A m	Gate-electrode sheet resistance.
56	rbpb=50.0 W	Substrate resistance network.
57	rbpd=50.0 W	Substrate resistance network.
58	rbps=50.0 W	Substrate resistance network.
59	rbdb=50.0 W	Substrate resistance network.
60	rbsb=50.0 W	Substrate resistance network.
61	gbmin=1.0E-12	Minimum conductance for substrate resistance network.
62	xl=0 m	Gate length offset due to mask/etch effect,existed from 2.40.
63	xw=0 m	Gate width offset due to mask/etch effect,existed from 2.40.
64	xqy1=0.0 F m ^{XQY2}	V _{bs} dependence of Q _y ,existed from 2.40.
65	xqy2=2.0	L _{gate} dependence of Q _y ,existed from 2.40.
66	nsubpl=0.001 mm	gate-length dependence of NSUBP.
67	nsubpfac=1.0	gate-length dependence of NSUBP.

Temperature dependence effects

68	eg0=1.1785 eV	constant bandgap.
69	bgtmp1=9.025e-5 eV/K	First order temperature coefficient for band gap.
70	bgtmp2=1.0e-7 eV/K ²	Second order temperature coefficient for band gap.

Quantum Mechanical Effects

71	qme1=0.0 m/V ²	Coefficient for quantum mechanical effect.
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Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

72	qme2=0.0 V	Coefficient for quantum mechanical effect.
73	qme3=0.0 m	Coefficient for quantum mechanical effect.
74	kappa=3.9	dielectric constant for high-k stacked gate.

Poly Depletion Effects

75	pgd1=1.0E-4 V	Strength of poly depletion.
76	pgd2=1.0 V	Threshold voltage of poly depletion.
77	pgd3=0.8	Vds dependence of poly depletion.
78	pgd4=0.0	parameter for gate-poly depletion.

Short Channel Effects

79	parl2=1.0e-8 m	Depletion width of channel/contact junction.
80	sc1=1.0 1/V	Short-channel coefficient 1.
81	sc2=0.0 1/V ²	Short-channel coefficient 2.
82	sc2b=0.0 1/V ³	Short-channel coefficient 2 Vb dependency coefficient.
83	sc3=0.0 m/V ²	Short-channel coefficient 3.
84	scp1=1.0 1/V	Short-channel coefficient 1 for pocket.
85	scp2=0.0 1/V ²	Short-channel coefficient 2 for pocket.
86	scp3=0.0 m/V ²	Short-channel coefficient 3 for pocket.
87	scp22=0.0 V ⁴	Short-channel-effect modification for small Vds.
88	scp21=0.0 V	Short-channel-effect modification for small Vds.
89	bs1=0.0 V ²	Body-coefficient modification by impurity profile.
90	bs2=0.9 V	Body-coefficient modification by impurity profile.

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

91	sc4=0.0	Short-channel coefficient 4.
<i>Narrow channel effects</i>		
92	wfc=0.0 m F/cm ²	Threshold voltage reduction.
93	mueph2=0.0	Mobility reduction.
94	w0=0.0 log(cm)	Minimum gate width.
95	wvthsc=0.0	Short-channel effect at the STI edge.
96	nsti=1.0e17 cm ⁻³	Substrate-impurity concentration at the SIT edge.
97	wsti=0.0 m	Width of the high-field region at STI.
98	muephw=0.0	phonon scattering parameter.
99	muepwp=1.0	phonon scattering parameter.
100	wvth0=0.0	threshold voltage shift.
101	mueswp=1.0	change of surface roughness related mobility.
102	vthsti=0.0	parameter for STI.
103	muesti1=0.0	STI Stress mobility parameter.
104	muesti2=0.0	STI Stress mobility parameter.
105	muesti3=1.0	STI Stress mobility parameter.
106	nsubpsti1=0.0 m	STI Stress pocket implant parameter.
107	nsubpsti2=0.0 m	STI Stress pocket implant parameter.
108	nsubpsti3=1.0 m	STI Stress pocket implant parameter.
109	wstil=0.0	Parameter for STI.
110	wstilp=1.0	Parameter for STI.
111	scsti1=0.0	Parameter for STI.

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

112 scsti2=0.0 1/V	Parameter for STI.
113 scsti3=0.0 m/V	Parameter for STI.
114 saref=1e-6 m	Reference distance from STI edge to Gate edge,existed from 2.40.
115 sbref=1e-6 m	Reference distance from STI edge to Gate edge,existed from 2.40.
116 wstiw=0.0	Parameter for STI,existed from 2.40.
117 wstiwp=1.0	Parameter for STI,existed from 2.40.
118 vdsti=0.0	parameter for STI,existed from 2.40.
119 nsubcw=0.0	Parameter for narrow channel effect.
120 nsubcwp=1.0	Parameter for narrow channel effect.
121 nsubcmax=1e18	Parameter for narrow channel effect.

Mobility Effects

122 vds0=0.05 V	Drain voltage for extracting the low-field mobility.
123 muecb0=1000.0 cm ² /(V s)	Coulomb scattering.
124 muecb1=100.0 cm ² /(V s)	Coulomb scattering.
125 mueph0=0.3 cm ² (V/cm) ^(Muesr1) /(V s)	Phonon scattering.
126 mueph1=2.5e4	Phonon scattering.
127 muetmp=1.5	Temperature dependence of phonon scattering.
128 muesr0=2.0 cm ² (V/cm) ^(Muesr1) /(V s)	Surface-roughness scattering.
129 muesr1=1.0e15	Surface-roughness scattering.

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

130	ndep=1.0	Coefficient of effective electric field.
131	ninv=0.5	Coefficient of effective electric field.
132	bb=2.0	High-field mobility degradation.
133	vmax=1.0e7 cm/s	Maximum of electron saturation velocity.
134	vover=0.3 cm ^(voverp)	Parameter for velocity overshoot.
135	voverp=0.3	Lgate dependence of velocity overshoot.
136	vovers=0.0	Parameter for overshoot.
137	voversp=0.0	Parameter for overshoot.
138	vtmp=0.0 cm/s	Temperature dependence of the saturation velocity.
139	muephl=0.0	phonon scattering parameter.
140	mueplp=1.0	phonon scattering parameter.
141	muesrl=0.0	surface roughness parameter.
142	muesrw=0.0	change of surface roughness related mobility.
143	mueslp=1.0	surface roughness parameter.
144	ndepl=0.0	Modification of Qb contribution for short-channel case, existed from 2.40.
145	ndeplp=1.0	Modification of Qb contribution for short-channel case, existed from 2.40.
146	ninvd=0.0 1/V	modification of Vdse dependence on Eeff.

Small size parameters

147	wl1=0.0	Threshold voltage shift of STI leakage due to small size effect.
148	wl1p=1.0	Threshold voltage shift of STI leakage due to small size effect.

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

149	wl2=0.0	Threshold voltage shift due to small size effect.
150	wl2p=1.0	Threshold voltage shift due to small size effect.
151	muephs=0.0	Mobility modification due to small size.
152	muepsp=1.0	Mobility modification due to small size.
153	muepwd=0.0	phonon scattering parameter.
154	muepld=0.0	phonon scattering parameter.

Channel Length Modulation Effects

155	clm1=0.7	First parameter for CLM.
156	clm2=2.0 1/m	Second parameter for CLM.
157	clm3=1.0	Third parameter for CLM.
158	clm4=5.0E-4	Smoothing coefficient for gds.
159	clm5=1.0	Effect of pocket implantation.
160	clm6=0.0	Effect of pocket implantation.

Substrate Current Effects

161	sub1=10.0 1/V	First parameter for Isub.
162	sub2=25.0 V	Second parameter for Isub.
163	svgs=0.8	Substrate current dependence on Vgs.
164	svbs=0.5	Substrate current dependence on Vbs.
165	svbsl=0.0	Lgate dependence of SVBS.
166	svds=0.8	Substrate current dependence on Vds.
167	slg=3.0E-8	Substrate current dependence on Lgate.

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

168	sub1l=2.5E-3	Lgate dependence of SUB1.
169	sub2l=2.0E-6	Lgate dependence of SUB2.
170	fn1=0.0	Coefficient of Fowler-Nordheim-current contribution.
171	fn2=0.0	Coefficient of Fowler-Nordheim-current contribution.
172	fn3=0.0	Coefficient of Fowler-Nordheim-current contribution.
173	fvbs=0.0	Modification of Vbs dependence.
174	svgs1=0.0	Lgate dependence of SVGS.
175	svgs1p=1.0	Lgate dependence of SVGS.
176	svgswp=1.0	Wgate dependence of SVGS.
177	svgsw=0.0	Wgate dependence of SVGS.
178	svbs1p=1.0	Lgate dependence of SVBS.
179	slgl=0.0	Substrate current dependence on Lgate.
180	slglp=1.0	Substrate current dependence on Lgate.
181	sub1lp=1.0	Lgate dependence of SUB1.
182	ibpc1=0.0	Impact-ionization induced bulk potential change.
183	ibpc2=0.0	Impact-ionization induced bulk potential change.

Gate Current Effects

184	glpart1=0.5	partitioning of gate current.
185	gleak1=50.0 A/(V ^(3/2) c ^(1/2))	First gate current coefficient.
186	gleak2=1.0E7 1/(V ^(1/2) c ^(3/2) m)	Second gate current coefficient.
187	gleak3=6.0E-2	Third gate current coefficient.

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

188	gleak4=4.0	parameter for gate current.
189	gleak5=7.5E3	parameter for gate current.
190	glksd1=1.0E-15	parameter for gate current.
191	glksd2=1e-2	parameter for gate current.
192	glksd3=-1e-2	parameter for gate current.
193	glkb0=0.0 V	parameter for gate current.
194	glkb1=5.0E-16	parameter for gate current.
195	glkb2=1.0	parameter for gate current.
196	igtemp1=0.0	parameter for gate current.
197	igtemp2=0.0	parameter for gate current.
198	igtemp3=0.0	parameter for gate current.
199	gleak6=0.25 V	Parameter for gate current.
200	gleak7=1.0E-6 m2	Parameter for gate current.
201	glkb3=0e0 V	parameter for gate current,existed from 2.40.
202	egig=1.1 V	parameter for gate current,existed from 2.40.

GIDL Current Effects

203	gidl1=2.0 A m/(V ^(3/2) c ^(1/2))	First parameter for GIDL.
204	gidl2=3.0E7 1/(V ^(1/2) c ^(3/2) m)	Second parameter for GIDL.
205	gidl3=0.9	Third parameter for GIDL.
206	gidl4=0.9	Parameter for GIDL.
207	gidl5=0.2	Parameter for GIDL.

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

Noise 1/f Effects

208 nfalp=1.0e-19	Flicker (1/f) noise contribution of the mobility fluctuation.
209 nfrtp=1.0e10	Flicker (1/f) noise ratio of trap density to attenuation coefficient.
210 cit=0.0	Flicker (1/f) noise interface trapped carriers capacitance.
211 falph=1.0	parameter for 1/f noise.

Subthreshold swing parameters

212 pthroub=0.0 1/V	modify subthreshold sloop.
---------------------	----------------------------

NQS parameters

213 dly1=1.0E-10	parameter for transit time.
214 dly2=0.7	parameter for transit time.
215 dly3=8.0E-7 W	parameter for transforming bulk charge.

Symmetry for short-channel mosfet

216 vzadd0=1.0e-2 V	Vzadd at Vds=0.
217 pzadd0=5.0e-3 V	Pzadd at Vds=0.

P-N junctions parameters

218 js0=5.0e-7 A/m ²	Junction saturation current density.
219 js0sw=0.0 A/m	Side-wall saturation current density.
220 nj=1.0	Junction emission coefficient.
221 njsw=1.0	Junction emission coefficient (sidewall).
222 xti=2.0	Junction saturation current temperature exponent coefficient.

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

223	$cj=5.0e-4$ F/m ²	Bottom junction capacitance per unit area at zero bias.
224	$cjsw=5e-10$ F/m	Source/drain sidewall junction capacitance per unit length at zero bias.
225	$cjswg=5e-10$ F/m	Source/drain sidewall junction capacitance grading coefficient per unit length at zero bias.
226	$mj=0.5$	Bulk junction bottom grading coefficient.
227	$mjsw=0.33$	Source/drain sidewall junction capacitance grading coefficient.
228	$mjswg=0.33$	Bottom junction capacitance grading coefficient.
229	$pb=1.0$ V	Bottom junction build-in potential.
230	$pbsw=1.0$ V	Source/drain sidewall junction build-in potential.
231	$pbswg=1.0$ V	Source/drain gate sidewall junction build-in potential.
232	$vdiffj=6.0E-4$ V	threshold voltage for S/D junction diode.
233	$xti2=0.0$	Temperature coefficient.
234	$cisb=0.0$	Reverse bias saturation current.
235	$cvb=0.0$	Bias dependence coefficient of $cisb$.
236	$ctemp=0.0$	Temperature coefficient.
237	$cisbk=0.0$ A	Reverse bias saturation current.
238	$cvbk=0.0$	Bias dependence coefficient of $cisb$.
239	$divx=0.0$ 1/V	Parameter for junction.
240	$tcjbs=0.0$	Temperature dependence of $czbs$.
241	$tcjbd=0.0$	Temperature dependence of $czbd$.
242	$tcjbssw=0.0$	Temperature dependence of $czbssw$.
243	$tcjbdsw=0.0$	Temperature dependence of $czbdsw$.

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

244 tcjbsswg=0.0 Temperature dependence of czbsswg.

245 tcjbdswg=0.0 Temperature dependence of czbdswg.

Overlap capacitance parameters

246 cgso=0.0 F/m Gate-source overlap capacitance.

247 cgdo=0.0 F/m Gate-dource overlap capacitance.

248 cgbo=0.0 F/m Gate-bource overlap capacitance.

249 ovslp=2.1E-7 Parameter for overlap capacitance.

250 ovmag=0.6 Parameter for overlap capacitance.

251 vfbover=-0.5 V Flat-band voltage in overlap region,existed from 2.40.

252 nover=0.0 cm-3 Impurity concentration in overlap region,existed from 2.40.

Smoothing coefficient between linear and saturation

253 ddltmax=10.0 Coefficient of effective electric field,existed from 2.40.

254 ddltslp=0.0 Lgate dependence of smoothing coefficient,existed from 2.40.

255 ddltict=10.0 Lgate dependence of smoothing coefficient,existed from 2.40.

DFM parameters

256 mphdfm=-0.3 NSUBCDFM dependence of phonon scattering for DFM,existed from 2.40.

Binning model parameters which are existed from 2.40

257 lbinn=1.0 L modulation coefficient for binning.

258 wbinn=1.0 W modulation coefficient for binning.

259 lvmax=0.0 cm/s Length dependence of vmax.

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

260 $lbgtmp1=0.0$ eV/K	Length dependence of $bgtmp1$.
261 $lbgtmp2=0.0$ eV/K ²	Length dependence of $bgtmp2$.
262 $leg0=0.0$ eV	Length dependence of $eg0$.
263 $llover=0.0$ m	Length dependence of $lover$.
264 $lvfbover=0.0$ V	Length dependence of $vfbover$.
265 $lnover=0.0$ cm ⁻³	Length dependence of $nover$.
266 $lwl2=0.0$	Length dependence of $wl2$.
267 $lvfbc=0.0$ V	Length dependence of $vfbc$.
268 $lnsubc=0.0$ cm ⁻³	Length dependence of $nsubc$.
269 $lnsubp=0.0$ cm ⁻³	Length dependence of $nsubp$.
270 $lscp1=0.0$ 1/V	Length dependence of $scp1$.
271 $lscp2=0.0$ 1/V ²	Length dependence of $scp2$.
272 $lscp3=0.0$ m/V ²	Length dependence of $scp3$.
273 $lsc1=0.0$ 1/V	Length dependence of $sc1$.
274 $lsc2=0.0$ 1/V ²	Length dependence of $sc2$.
275 $lsc3=0.0$ m/V ²	Length dependence of $sc3$.
276 $lpgd1=0.0$ V	Length dependence of $pgd1$.
277 $lpgd3=0.0$	Length dependence of $pgd3$.
278 $lndep=0.0$	Length dependence of $ndep$.
279 $lninv=0.0$	Length dependence of $ninv$.
280 $lmuecb0=0.0$ cm ² /(V s)	Length dependence of $muecb0$.

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

281	$l_{muecb1}=0.0 \text{ cm}^2/(\text{V s})$	Length dependence of $muecb1$.
282	$l_{mueph1}=0.0$	Length dependence of $mueph1$.
283	$l_{vtmp}=0.0 \text{ cm/s}$	Length dependence of $vtmp$.
284	$l_{wvth0}=0.0$	Length dependence of $wvth0$.
285	$l_{muesr1}=0.0$	Length dependence of $muesr1$.
286	$l_{muetmp}=0.0$	Length dependence of $muetmp$.
287	$l_{sub1}=0.0 \text{ 1/V}$	Length dependence of $sub1$.
288	$l_{sub2}=0.0 \text{ V}$	Length dependence of $sub2$.
289	$l_{svds}=0.0$	Length dependence of $svds$.
290	$l_{svbs}=0.0$	Length dependence of $svbs$.
291	$l_{svgs}=0.0$	Length dependence of $svgs$.
292	$l_{fn1}=0.0$	Length dependence of $fn1$.
293	$l_{fn2}=0.0$	Length dependence of $fn2$.
294	$l_{fn3}=0.0$	Length dependence of $fn3$.
295	$l_{fvbs}=0.0$	Length dependence of $fvbs$.
296	$l_{nsti}=0.0 \text{ cm}^{-3}$	Length dependence of $nsti$.
297	$l_{wsti}=0.0 \text{ m}$	Length dependence of $wsti$.
298	$l_{scsti1}=0.0$	Length dependence of $scsti1$.
299	$l_{scsti2}=0.0 \text{ 1/V}$	Length dependence of $scsti2$.
300	$l_{vthsti}=0.0$	Length dependence of $vthsti$.
301	$l_{muesti1}=0.0$	Length dependence of $muesti1$.

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

302	$l_{muesti2}=0.0$	Length dependence of m_{esti2} .
303	$l_{muesti3}=0.0$	Length dependence of m_{esti3} .
304	$l_{nsubpsti1}=0.0$ m	Length dependence of $n_{subpsti1}$.
305	$l_{nsubpsti2}=0.0$ m	Length dependence of $n_{subpsti2}$.
306	$l_{nsubpsti3}=0.0$ m	Length dependence of $n_{subpsti3}$.
307	$l_{cgso}=0.0$ F/m	Length dependence of c_{gso} .
308	$l_{cgdo}=0.0$ F/m	Length dependence of c_{gdo} .
309	$l_{js0}=0.0$ A/m ²	Length dependence of j_{s0} .
310	$l_{js0sw}=0.0$ A/m	Length dependence of j_{s0sw} .
311	$l_{nj}=0.0$	Length dependence of n_j .
312	$l_{cisbk}=0.0$ A	Length dependence of c_{isbk} .
313	$l_{clm1}=0.0$	Length dependence of $clm1$.
314	$l_{clm2}=0.0$ 1/m	Length dependence of $clm2$.
315	$l_{clm3}=0.0$	Length dependence of $clm3$.
316	$l_{wfc}=0.0$ m F/cm ²	Length dependence of w_{fc} .
317	$l_{gidl1}=0.0$ A m/(V ^(3/2) c ^(1/2))	Length dependence of $gidl1$.
318	$l_{gidl2}=0.0$ 1/(V ^(1/2) c ^(3/2) m)	Length dependence of $gidl2$.
319	$l_{gleak1}=0.0$ A/(V ^(3/2) c ^(1/2))	Length dependence of $gleak1$.
320	$l_{gleak2}=0.0$ 1/(V ^(1/2) c ^(3/2) m)	Length dependence of $gleak2$.
321	$l_{gleak3}=0.0$	Length dependence of $gleak3$.

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

322	$l_{\text{gleak6}}=0.0$ V	Length dependence of g_{leak6} .
323	$l_{\text{glksd1}}=0.0$	Length dependence of g_{lksd1} .
324	$l_{\text{glksd2}}=0.0$	Length dependence of g_{lksd2} .
325	$l_{\text{glkb1}}=0.0$	Length dependence of g_{lkb1} .
326	$l_{\text{glkb2}}=0.0$	Length dependence of g_{lkb2} .
327	$l_{\text{nftrp}}=0.0$	Length dependence of n_{ftrp} .
328	$l_{\text{nfalp}}=0.0$	Length dependence of n_{falp} .
329	$l_{\text{vdiffj}}=0.0$ V	Length dependence of v_{diffj} .
330	$l_{\text{ibpc1}}=0.0$	Length dependence of i_{bpc1} .
331	$l_{\text{ibpc2}}=0.0$	Length dependence of i_{bpc2} .
332	$l_{\text{sc4}}=0.0$	Length dependence of s_{c4} .
333	$w_{\text{vmax}}=0.0$ cm/s	Width dependence of v_{max} .
334	$w_{\text{bgtmp1}}=0.0$ eV/K	Width dependence of b_{gtmp1} .
335	$w_{\text{bgtmp2}}=0.0$ eV/K ²	Width dependence of b_{gtmp2} .
336	$w_{\text{eg0}}=0.0$ eV	Width dependence of e_{g0} .
337	$w_{\text{lover}}=0.0$ m	Width dependence of l_{over} .
338	$w_{\text{vfbover}}=0.0$ V	Width dependence of v_{fbover} .
339	$w_{\text{nover}}=0.0$ cm ⁻³	Width dependence of n_{over} .
340	$w_{\text{wl2}}=0.0$	Width dependence of w_{l2} .
341	$w_{\text{vfbc}}=0.0$ V	Width dependence of v_{fbc} .
342	$w_{\text{nsubc}}=0.0$ cm ⁻³	Width dependence of n_{subc} .

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

343	$w_{\text{subp}}=0.0 \text{ cm}^{-3}$	Width dependence of n_{subp} .
344	$w_{\text{scp1}}=0.0 \text{ 1/V}$	Width dependence of $scp1$.
345	$w_{\text{scp2}}=0.0 \text{ 1/V}^2$	Width dependence of $scp2$.
346	$w_{\text{scp3}}=0.0 \text{ m/V}^2$	Width dependence of $scp3$.
347	$w_{\text{sc1}}=0.0 \text{ 1/V}$	Width dependence of $sc1$.
348	$w_{\text{sc2}}=0.0 \text{ 1/V}^2$	Width dependence of $sc2$.
349	$w_{\text{sc3}}=0.0 \text{ m/V}^2$	Width dependence of $sc3$.
350	$w_{\text{pgd1}}=0.0 \text{ V}$	Width dependence of $pgd1$.
351	$w_{\text{pgd3}}=0.0$	Width dependence of $pgd3$.
352	$w_{\text{ndep}}=0.0$	Width dependence of $ndep$.
353	$w_{\text{ninv}}=0.0$	Width dependence of n_{inv} .
354	$w_{\text{muecb0}}=0.0 \text{ cm}^2/(\text{V s})$	Width dependence of $muecb0$.
355	$w_{\text{muecb1}}=0.0 \text{ cm}^2/(\text{V s})$	Width dependence of $muecb1$.
356	$w_{\text{mueph1}}=0.0$	Width dependence of $mueph1$.
357	$w_{\text{vtmp}}=0.0 \text{ cm/s}$	Width dependence of v_{tmp} .
358	$w_{\text{wvth0}}=0.0$	Width dependence of w_{vth0} .
359	$w_{\text{muesr1}}=0.0$	Width dependence of $muesr1$.
360	$w_{\text{muetmp}}=0.0$	Width dependence of $muetmp$.
361	$w_{\text{sub1}}=0.0 \text{ 1/V}$	Width dependence of $sub1$.
362	$w_{\text{sub2}}=0.0 \text{ V}$	Width dependence of $sub2$.
363	$w_{\text{svds}}=0.0$	Width dependence of $svds$.

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

364	wsvbs=0.0	Width dependence of svbs.
365	wsvgs=0.0	Width dependence of svgs.
366	wfn1=0.0	Width dependence of fn1.
367	wfn2=0.0	Width dependence of fn2.
368	wfn3=0.0	Width dependence of fn3.
369	wfvbs=0.0	Width dependence of fvbs.
370	wnsti=0.0 cm-3	Width dependence of nsti.
371	wwsti=0.0 m	Width dependence of wsti.
372	wscsti1=0.0	Width dependence of scsti1.
373	wscsti2=0.0 1/V	Width dependence of scsti2.
374	wvthsti=0.0	Width dependence of vthsti.
375	wmuesti1=0.0	Width dependence of muesti1.
376	wmuesti2=0.0	Width dependence of muesti2.
377	wmuesti3=0.0	Width dependence of muesti3.
378	wnsubpsti1=0.0 m	Width dependence of nsubpsti1.
379	wnsubpsti2=0.0 m	Width dependence of nsubpsti2.
380	wnsubpsti3=0.0 m	Width dependence of nsubpsti3.
381	wcgso=0.0 F/m	Width dependence of cgso.
382	wcgdo=0.0 F/m	Width dependence of cgdo.
383	wjs0=0.0 A/m ²	Width dependence of js0.
384	wjs0sw=0.0 A/m	Width dependence of js0sw.
385	wnj=0.0	Width dependence of nj.

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

386	wcisbk=0.0 A	Width dependence of cisbk.
387	wclm1=0.0	Width dependence of clm1.
388	wclm2=0.0 1/m	Width dependence of clm2.
389	wclm3=0.0	Width dependence of clm3.
390	wwfc=0.0 m F/cm2	Width dependence of wfc.
391	wgidl1=0.0 A m/(V ^(3/2) c ^(1/2))	Width dependence of gidl1.
392	wgidl2=0.0 1/(V ^(1/2) c ^(3/2) m)	Width dependence of gidl2.
393	wgleak1=0.0 A/(V ^(3/2) c ^(1/2))	Width dependence of gleak1.
394	wgleak2=0.0 1/(V ^(1/2) c ^(3/2) m)	Width dependence of gleak2.
395	wgleak3=0.0	Width dependence of gleak3.
396	wgleak6=0.0 V	Width dependence of gleak6.
397	wglksd1=0.0	Width dependence of glksd1.
398	wglksd2=0.0	Width dependence of glksd2.
399	wglkb1=0.0	Width dependence of glkb1.
400	wglkb2=0.0	Width dependence of glkb2.
401	wnftrp=0.0	Width dependence of nftrp.
402	wnfalp=0.0	Width dependence of nfalp.
403	wvdiffj=0.0 V	Width dependence of vdiffj.
404	wibpc1=0.0	Width dependence of ibpc1.
405	wibpc2=0.0	Width dependence of ibpc2.

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

406 wsc4=0.0	Width dependence of sc4.
407 pvmax=0.0 cm/s	Cross-term dependence of vmax.
408 pbgtmp1=0.0 eV/K	Cross-term dependence of bgtmp1.
409 pbgtmp2=0.0 eV/K ²	Cross-term dependence of bgtmp2.
410 peg0=0.0 eV	Cross-term dependence of eg0.
411 plover=0.0 m	Cross-term dependence of lover.
412 pvfbover=0.0 V	Cross-term dependence of vfbover.
413 pnover=0.0 cm ⁻³	Cross-term dependence of nover.
414 pwl2=0.0	Cross-term dependence of wl2.
415 pvfbc=0.0 V	Cross-term dependence of vfbc.
416 pnsubc=0.0 cm ⁻³	Cross-term dependence of nsubc.
417 pnsubp=0.0 cm ⁻³	Cross-term dependence of nsubp.
418 pscp1=0.0 1/V	Cross-term dependence of scp1.
419 pscp2=0.0 1/V ²	Cross-term dependence of scp2.
420 pscp3=0.0 m/V ²	Cross-term dependence of scp3.
421 psc1=0.0 1/V	Cross-term dependence of sc1.
422 psc2=0.0 1/V ²	Cross-term dependence of sc2.
423 psc3=0.0 m/V ²	Cross-term dependence of sc3.
424 ppgd1=0.0 V	Cross-term dependence of pgd1.
425 ppgd3=0.0	Cross-term dependence of pgd3.
426 pndep=0.0	Cross-term dependence of ndep.

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

427	pninv=0.0	Cross-term dependence of ninv.
428	pmuecb0=0.0 cm ² /(V s)	Cross-term dependence of muecb0.
429	pmuecb1=0.0 cm ² /(V s)	Cross-term dependence of muecb1.
430	pmueph1=0.0	Cross-term dependence of mueph1.
431	pvtmp=0.0 cm/s	Cross-term dependence of vtmp.
432	pwvth0=0.0	Cross-term dependence of wvth0.
433	pmuesr1=0.0	Cross-term dependence of muesr1.
434	pmuetmp=0.0	Cross-term dependence of muetmp.
435	psub1=0.0 1/V	Cross-term dependence of sub1.
436	psub2=0.0 V	Cross-term dependence of sub2.
437	psvds=0.0	Cross-term dependence of svds.
438	psvbs=0.0	Cross-term dependence of svbs.
439	psvgs=0.0	Cross-term dependence of svgs.
440	pfn1=0.0	Cross-term dependence of fn1.
441	pfn2=0.0	Cross-term dependence of fn2.
442	pfn3=0.0	Cross-term dependence of fn3.
443	pfvbs=0.0	Cross-term dependence of fvbs.
444	pnsti=0.0 cm ⁻³	Cross-term dependence of nsti.
445	pwsti=0.0 m	Cross-term dependence of wsti.
446	pscsti1=0.0	Cross-term dependence of scsti1.
447	pscsti2=0.0 1/V	Cross-term dependence of scsti2.

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

448 pvthsti=0.0	Cross-term dependence of vthsti.
449 pmuesti1=0.0	Cross-term dependence of muesti1.
450 pmuesti2=0.0	Cross-term dependence of muesti2.
451 pmuesti3=0.0	Cross-term dependence of muesti3.
452 pnsupsti1=0.0 m	Cross-term dependence of nsupsti1.
453 pnsupsti2=0.0 m	Cross-term dependence of nsupsti2.
454 pnsupsti3=0.0 m	Cross-term dependence of nsupsti3.
455 pcgso=0.0 F/m	Cross-term dependence of cgso.
456 pcgdo=0.0 F/m	Cross-term dependence of cgdo.
457 pjs0=0.0 A/m ²	Cross-term dependence of js0.
458 pjs0sw=0.0 A/m	Cross-term dependence of js0sw.
459 pnj=0.0	Cross-term dependence of nj.
460 pcisbk=0.0 A	Cross-term dependence of cisbk.
461 pclm1=0.0	Cross-term dependence of clm1.
462 pclm2=0.0 1/m	Cross-term dependence of clm2.
463 pclm3=0.0	Cross-term dependence of clm3.
464 pwfc=0.0 m F/cm ²	Cross-term dependence of wfc.
465 pgidl1=0.0 A m/(V ^(3/2) c ^(1/2))	Cross-term dependence of gidl1.
466 pgidl2=0.0 1/(V ^(1/2) c ^(3/2) m)	Cross-term dependence of gidl2.
467 pgleak1=0.0 A/(V ^(3/2) c ^(1/2))	Cross-term dependence of gleak1.

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

468	$\text{pgleak2}=0.0 \text{ } 1/(\text{V}^{(1/2)} \text{ c}^{(3/2)} \text{ m})$	Cross-term dependence of gleak2.
469	$\text{pgleak3}=0.0$	Cross-term dependence of gleak3.
470	$\text{pgleak6}=0.0 \text{ V}$	Cross-term dependence of gleak6.
471	$\text{pglksd1}=0.0$	Cross-term dependence of glksd1.
472	$\text{pglksd2}=0.0$	Cross-term dependence of glksd2.
473	$\text{pglkb1}=0.0$	Cross-term dependence of glkb1.
474	$\text{pglkb2}=0.0$	Cross-term dependence of glkb2.
475	$\text{pnftrp}=0.0$	Cross-term dependence of nftrp.
476	$\text{pnfalp}=0.0$	Cross-term dependence of nfalp.
477	$\text{pvdifffj}=0.0 \text{ V}$	Cross-term dependence of vdiffj.
478	$\text{pibpc1}=0.0$	Cross-term dependence of ibpc1.
479	$\text{pibpc2}=0.0$	Cross-term dependence of ibpc2.
480	$\text{psc4}=0.0$	Cross-term dependence of sc4.

Auto Model Selector parameters

481	$\text{wmax}=1 \text{ m}$	Maximum channel width for which the model is valid.
482	$\text{wmin}=0 \text{ m}$	Minimum channel width for which the model is valid.
483	$\text{lmax}=1 \text{ m}$	Maximum channel length for which the model is valid.
484	$\text{lmin}=0 \text{ m}$	Minimum channel length for which the model is valid.

Output Parameters

1	$\text{weff} \text{ (m)}$	Effective channel width.
2	$\text{leff} \text{ (m)}$	Effective channel length.

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

3	rseff (W)	Effective source resistance.
4	rdeff (W)	Effective drain resistance.

Operating-Point Parameters

1	reversed	Reverse mode indicator. Possible values are no or yes.
2	ids (A)	Resistive drain-to-source current.
3	vgs (V)	Gate-source voltage.
4	vds (V)	Drain-source voltage.
5	vbs (V)	Bulk-source voltage.
6	vth (V)	Threshold voltage.
7	vdsat (V)	Drain-source saturation voltage.
8	gm (S)	Common-source transconductance.
9	gds (S)	Common-source output conductance.
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 .

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

19	cgs (F)	$dQg_dVs.$
20	cgb (F)	$dQg_dVb.$
21	cdg (F)	$dQd_dVg.$
22	cdd (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)	$dQb_dVs.$
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	psl (V)	Surface potential at drain side.
40	pds (V)	Delta surface potential between psl and ps0.

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

41	isub (A)	Substrate current I_{sub} .
42	gbds (S)	Substrate trans conductance (dI_{sub}/dV_{ds}).
43	gbgs (S)	Substrate trans conductance (dI_{sub}/dV_{gs}).
44	gbbs (S)	Substrate transconductance (dI_{sub}/dV_{bs}).
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.
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.

ad I-4

lclm1 M-313

pbsw M-230

svgs M-163

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

ad	M-26	lclm2	M-314	pbswg	M-231	svgs1	M-174
alarm	M-19	lclm3	M-315	pcgdo	M-456	svgs1p	M-175
as	I-3	leff	O-2	pcgso	M-455	svgs2	M-177
as	M-25	leg0	M-262	pcisbk	M-460	svgs2p	M-176
bb	M-132	lfn1	M-292	pclm1	M-461	tcjbd	M-241
bgtmp1	M-69	lfn2	M-293	pclm2	M-462	tcjbdsw	M-243
bgtmp2	M-70	lfn3	M-294	pclm3	M-463	tcjbdswg	M-245
bs1	M-89	lfvbs	M-295	pd	I-6	tcjbs	M-240
bs2	M-90	lgidl1	M-317	pd	M-28	tcjbssw	M-242
cbb	OP-32	lgidl2	M-318	pds	OP-40	tcjbsswg	M-244
cbd	OP-30	lgleak1	M-319	peg0	M-410	temp	I-7
cbg	OP-29	lgleak2	M-320	pfn1	M-440	temp	M-29
cbs	OP-31	lgleak3	M-321	pfn2	M-441	tnom	M-15
cdb	OP-24	lgleak6	M-322	pfn3	M-442	tox	M-31
cdd	OP-22	lglkb1	M-325	pfvbs	M-443	tpoly	M-34
cdg	OP-21	lglkb2	M-326	pgd1	M-75	type	M-1
cds	OP-23	lglksd1	M-323	pgd2	M-76	vbi	M-49
cgb	OP-20	lglksd2	M-324	pgd3	M-77	vbs	OP-5
cgbo	M-248	libpc1	M-330	pgd4	M-78	vdifj	M-232
cgbo	OP-54	libpc2	M-331	pgidl1	M-465	vds	OP-4
cgd	OP-18	ljs0	M-309	pgidl2	M-466	vds0	M-122
cgdo	M-247	ljs0sw	M-310	pgleak1	M-467	vdsat	OP-7
cgdo	OP-55	ll	M-43	pgleak2	M-468	vdsti	M-118
cgg	OP-17	lld	M-44	pgleak3	M-469	vfbc	M-39

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

cgs OP-19	lln M-45	pgleak6 M-470	vfbover M-251
cgso M-246	llover M-263	pglkb1 M-473	vgs OP-3
cgso OP-53	lmax M-483	pglkb2 M-474	vmax M-133
cisb M-234	lmin M-484	pglksd1 M-471	vover M-134
cisbk M-237	lmuecb0 M-280	pglksd2 M-472	voverp M-135
cit M-210	lmuecb1 M-281	pibpc1 M-478	vovers M-136
cj M-223	lmueph1 M-282	pibpc2 M-479	voversp M-137
cjd OP-15	lmuesr1 M-285	pjs0 M-457	vth OP-6
cjs OP-16	lmuesti1 M-301	pjs0sw M-458	vthsti M-102
cjsw M-224	lmuesti2 M-302	plover M-411	vtmp M-138
cjswg M-225	lmuesti3 M-303	pmuecb0 M-428	vzadd0 M-216
clm1 M-155	lmuetmp M-286	pmuecb1 M-429	w I-1
clm2 M-156	lndep M-278	pmueph1 M-430	w M-23
clm3 M-157	lnfalp M-328	pmuesr1 M-433	w0 M-94
clm4 M-158	lnfrp M-327	pmuesti1 M-449	wbgtmp1 M-334
clm5 M-159	lninv M-279	pmuesti2 M-450	wbgtmp2 M-335
clm6 M-160	lnj M-311	pmuesti3 M-451	wbinn M-258
coadov M-6	lnover M-265	pmuetmp M-434	wcgdo M-382
codfm M-20	lnsti M-296	pndep M-426	wcgso M-381
coflick M-11	lnsubc M-268	pnfalp M-476	wcisbk M-386
cogidl M-8	lnsubp M-269	pnfrp M-475	wclm1 M-387
coign M-18	lnsubpsti1 M-304	pninv M-427	wclm2 M-388
coiigs M-9	lnsubpsti2 M-305	pnj M-459	wclm3 M-389
coiprv M-4	lnsubpsti3 M-306	pnover M-413	weff O-1

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

coisti M-12	lod I-22	pnsti M-444	weg0 M-336
coisub M-7	lover M-42	pnsbc M-416	wfc M-92
conqs M-13	lp M-40	pnsbp M-417	wfn1 M-366
coovlp M-10	lpext M-52	pnsbpsi1 M-452	wfn2 M-367
copprv M-5	lpgd1 M-276	pnsbpsi2 M-453	wfn3 M-368
coqy M-22	lpgd3 M-277	pnsbpsi3 M-454	wfvbs M-369
corbnet I-11	lsc1 M-273	ppgd1 M-424	wgidl1 M-391
corbnet M-17	lsc2 M-274	ppgd3 M-425	wgidl2 M-392
corecip M-21	lsc3 M-275	ps I-5	wgleak1 M-393
corg I-17	lsc4 M-332	ps M-27	wgleak2 M-394
corg M-16	lscp1 M-270	ps0 OP-38	wgleak3 M-395
corsrd M-3	lscp2 M-271	psc1 M-421	wgleak6 M-396
cothrml M-14	lscp3 M-272	psc2 M-422	wglkb1 M-399
csb OP-28	lscsti1 M-298	psc3 M-423	wglkb2 M-400
csd OP-26	lscsti2 M-299	psc4 M-480	wglksd1 M-397
csq OP-25	lsub1 M-287	pscpi1 M-418	wglksd2 M-398
css OP-27	lsub2 M-288	pscpi2 M-419	wibpc1 M-404
ctemp M-236	lsvbs M-290	pscpi3 M-420	wibpc2 M-405
cvb M-235	lsvds M-289	pscsti1 M-446	wjs0 M-383
cvbk M-238	lsvgs M-291	pscsti2 M-447	wjs0sw M-384
ddltict M-255	lvdiffj M-329	psl OP-39	wl M-46
ddlmax M-253	lvfbc M-267	psub1 M-435	wl1 M-147
ddlslp M-254	lvfbover M-264	psub2 M-436	wl1p M-148
divx M-239	lvmax M-259	psvbs M-438	wl2 M-149

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

dly1 M-213	lvthsti M-300	psvds M-437	wl2p M-150
dly2 M-214	lvtmp M-283	psvgs M-439	wld M-47
dly3 M-215	lwfc M-316	pthroub M-212	wln M-48
dtemp I-8	lw12 M-266	pvdifffj M-477	wlover M-337
dtemp M-30	lwsti M-297	pvfbc M-415	wmax M-481
eg0 M-68	lwwth0 M-284	pvfbover M-412	wmin M-482
egig M-202	m I-23	pvmx M-407	wmuecb0 M-354
falph M-211	mj M-226	pvthsti M-448	wmuecb1 M-355
fn1 M-170	mjsw M-227	pvtmp M-431	wmueph1 M-356
fn2 M-171	mjswg M-228	pwfc M-464	wmuesr1 M-359
fn3 M-172	mphdfm I-28	pwl2 M-414	wmuesti1 M-375
fvbs M-173	mphdfm M-256	pwr OP-37	wmuesti2 M-376
gbbs OP-44	muecb0 M-123	pwsti M-445	wmuesti3 M-377
gbds OP-42	muecb1 M-124	pwvth0 M-432	wmuetmp M-360
gbgs OP-43	mueph0 M-125	pzadd0 M-217	wndep M-352
gbmin M-61	mueph1 M-126	qb OP-11	wnfalp M-402
gds OP-9	mueph2 M-93	qd OP-12	wnftrp M-401
gidl1 M-203	mueph1 M-139	qg OP-13	wninv M-353
gidl2 M-204	muephs M-151	qme1 M-71	wnj M-385
gidl3 M-205	muephw M-98	qme2 M-72	wnover M-339
gidl4 M-206	muepld M-154	qme3 M-73	wnsti M-370
gidl5 M-207	mueplp M-140	qs OP-14	wnsubc M-342
gleak1 M-185	muepsp M-152	rbdb I-15	wnsubp M-343
gleak2 M-186	muepwd M-153	rbdb M-59	wnsubpti1 M-378

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

gleak3 M-187	muepwp M-99	rbpb I-12	wnsubpsti2 M-379
gleak4 M-188	mueslp M-143	rbpb M-56	wnsubpsti3 M-380
gleak5 M-189	muesr0 M-128	rbpd I-13	wpgd1 M-350
gleak6 M-199	muesr1 M-129	rbpd M-57	wpgd3 M-351
gleak7 M-200	muesrl M-141	rbps I-14	wsc1 M-347
glkb0 M-193	muesrw M-142	rbps M-58	wsc2 M-348
glkb1 M-194	muesti1 M-103	rbsb I-16	wsc3 M-349
glkb2 M-195	muesti2 M-104	rbsb M-60	wsc4 M-406
glkb3 M-201	muesti3 M-105	rd M-38	wscp1 M-344
glksd1 M-190	mueswp M-101	rdeff O-4	wscp2 M-345
glksd2 M-191	muetmp M-127	reversed OP-1	wscp3 M-346
glksd3 M-192	ndep M-130	rs M-37	wscsti1 M-372
glpart1 M-184	ndepl M-144	rseff O-3	wscsti2 M-373
gm OP-8	ndeplp M-145	rsh M-54	wsti M-97
gmbs OP-10	nf I-21	rshg M-55	wstil M-109
ibd OP-52	nfalp M-208	sa I-24	wstilp M-110
ibpc1 M-182	nfrp M-209	saref M-114	wstiw M-116
ibpc2 M-183	ngcon I-18	sb I-25	wstiwsp M-117
ibs OP-51	ninv M-131	sbref M-115	wsub1 M-361
ibulk OP-36	ninvd M-146	sc1 M-80	wsub2 M-362
id OP-33	nj M-220	sc2 M-81	wsvbs M-364
ids OP-2	njsw M-221	sc2b M-82	wsvds M-363
ig OP-34	nover M-252	sc3 M-83	wsvgs M-365
igate OP-45	npext M-53	sc4 M-91	wvdiffj M-403

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

igateb OP-47	nrd I-10	scp1 M-84	wvfbcb M-341
igated OP-48	nrs I-9	scp2 M-85	wvfbover M-338
igates OP-46	nsti M-96	scp21 M-88	wvmax M-333
igidl OP-50	nsubc M-35	scp22 M-87	wvth0 M-100
igisl OP-49	nsubcdfm I-27	scp3 M-86	wvthsc M-95
igtemp1 M-196	nsubcmax M-121	scsti1 M-111	wvthsti M-374
igtemp2 M-197	nsubcw M-119	scsti2 M-112	wvtmp M-357
igtemp3 M-198	nsubcwp M-120	scsti3 M-113	wwfc M-390
is OP-35	nsubp M-36	sd I-26	wwl2 M-340
isnoisy I-29	nsubpfac M-67	slg M-167	wwsti M-371
isub OP-41	nsubpl M-66	slgl M-179	wwvth0 M-358
js0 M-218	nsubpsti1 M-106	slglp M-180	xgl I-20
js0sw M-219	nsubpsti2 M-107	sub1 M-161	xgw I-19
kappa M-74	nsubpsti3 M-108	sub1l M-168	xl M-62
l I-2	nsubpw M-50	sub1lp M-181	xld M-32
l M-24	nsubpwp M-51	sub2 M-162	xqy M-41
lbgtmp1 M-260	ovmag M-250	sub2l M-169	xqy1 M-64
lbgtmp2 M-261	ovslp M-249	subvers M-2	xqy2 M-65
lbinn M-257	parl2 M-79	svbs M-164	xti M-222
lcgdo M-308	pb M-229	svbsl M-165	xti2 M-233
lcgso M-307	pbgtmp1 M-408	svbslp M-178	xw M-63
lcisbk M-312	pbgtmp2 M-409	svds M-166	xwd M-33

Virtuoso Simulator Components and Device Models Reference

HiSIM2 Model (hisim2)

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.

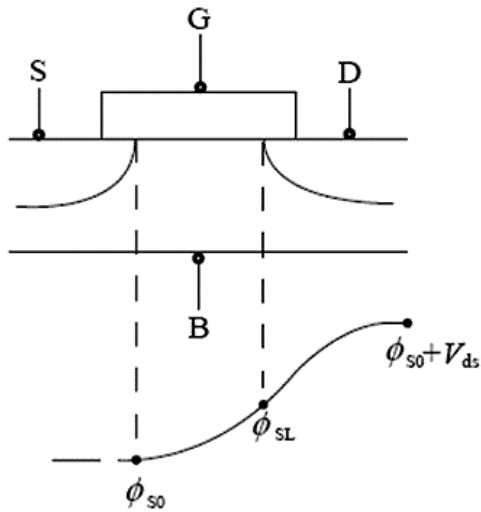
This chapter contains the following information about the HiSIM_HV model:

- [Model Concepts](#) on page 2210
- [Model Usage](#) on page 2213
 - [Instance Syntax](#) on page 2213
 - [Model Syntax](#) on page 2213
- [Version 1.20 Enhancement](#) on page 2214
 - [Inclusion of LDMOS-device Structures with a Substrate Node Vsub](#) on page 2214
 - [Activate 5th and 6th Terminal](#) on page 2214
 - [Model and Instance Parameters Changes](#) on page 2215
 - [Flag for Temperature Dependent Model Selection](#) on page 2215
 - [The Older Version Bug Fix](#) on page 2216
- [Model History and Development](#) on page 2216
- [Reference](#) on page 2217
 - [Model Equations](#) on page 2217
 - [Component Statements](#) on page 2233

Model Concepts

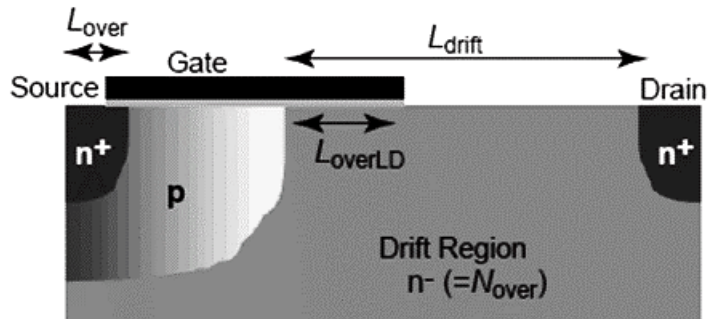
HiSIM (Hiroshima-university STARC IGFET Model) is the first complete surface-potential-based MOSFET model for circuit simulation based on the drift-diffusion theory, which was originally developed by Pao and Sah. The most important advantage of the surface-potential-based modeling is the unified description 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 32-1 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 Figure [32-2](#) for 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 32-2 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.

Three types of devices structure can be modeled with current 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. Figure [32-3](#) shows three different devices structures and table [32-1](#) shows the model parameters used by different structures.

Figure 32-3 Three different devices structure and related model parameters

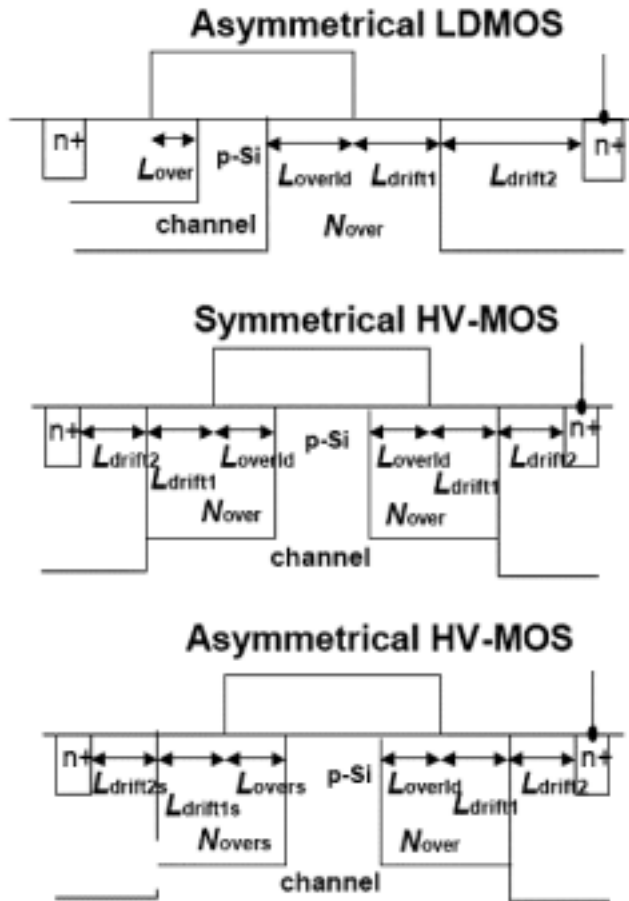


Table 32-1 The different model parameters used by different structures

	Structure	Source	Drain
COSYM=0	LDMOS	LOVERS	LOVERLD LDRIFT1 LDRIFT2 NOVER

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

	Structure	Source	Drain
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

```
m1 (vdd vgg vss vbb) n_ch w=10u l=2u m=1 nf=10
```

Model Syntax

The following syntax specifies HiSIM_HV model:

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

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 n_ch hisim_hv type=n cosym=0 tox=3e-8 corsrd=3 rs=1e-3 rd=5e-2 nover=2.5e16
xldld=0 rdtempl=1e-3 rdvd=1e-2
```

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.

$$R_{drift} = (R_d + V_{ds} \cdot R_{DVP}) \left(1 + RDVG11 - \frac{RDVG11}{RDVG12} \cdot V_{ds} \right) \cdot (1 - V_{be} \cdot RDVB) \cdot \left(\frac{L_{drift}}{DDRIFT - W_{dep}} \right)$$

$$W_{dep} = \sqrt{\frac{2 \epsilon_s \{ VBISUB - (RDVDSUB \cdot V_{ds} + RDVSUB \cdot V_{sub,s}) \}}{q}} \cdot \sqrt{\frac{NSUBSUB}{NOVER \cdot (NSUBSUB + NOVER)}}$$

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

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

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 $T_0 + \partial T$, and ∂T 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

Model History and Development

Cadence Virtuoso® Spectre and Ultrasim support all HiSIM_HV versions with different simulator versions. Version control is set during model implementation with the latest version 1.20. Two versions are maintained and can be obtained with model parameter setting `VERSION = 1.11` or `1.20`. If no version is set in model card, the latest 1.20 version is used. Following lists the recently several model versions and its corresponding simulator version for your reference:

- HiSIM_LDMOS SC3 => MMSIM 7.0
- HiSIM_HV 1.0.0 (SC4) => MMSIM 7.0 ISR
- HiSIM_HV 1.0.2 => MMSIM 7.1
- HiSIM_HV 1.1.1 => MMSIM 7.1.1

- HiSIM_HV 1.1.1 => MMSIM 7.2
- HiSIM_HV 1.2.0 => MMSIM 7.2

If you still have any questions, please contact Cadence support team.

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:

$$Q_G = -(Q_B + Q_I)$$

$$Q_B = W_{eff} \int_0^{L_{eff}} Q_b(y) dy$$

$$Q_I = W_{eff} \int_0^{L_{eff}} Q_i(y) dy$$

$$Q_D = W_{eff} \int_0^{L_{eff}} \frac{y}{L_{eff}} Q_i(y) dy$$

$$Q_S = Q_I - Q_D$$

where Q_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:

$$I_{ds} = W_{eff} \cdot NF \cdot q \cdot \mu \cdot n(y) \cdot \left(-\frac{d\phi_s(y)}{dy} + \frac{1}{\beta} \cdot \frac{d \ln n(y)}{dy} \right)$$

where $n(y)$ is the carrier density calculated from the relationship

$$Q_s(y) = q \cdot n(y)$$

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:

$$I_{ds} = \frac{W_{eff} \cdot NF}{L_{eff}} \cdot \mu \cdot \frac{I_{dd}}{\beta}$$

$$I_{dd} = C_{ox} (\beta V_G' + 1) (\phi_{s1} - \phi_{s0}) - \frac{\beta}{2} C_{ox} (\phi_{s1}^2 - \phi_{s0}^2)$$

$$- \frac{2}{3} \text{const0} \left[\{\beta(\phi_{s1} - V_{bs}) - 1\}^{\frac{3}{2}} - \{\beta(\phi_{s0} - V_{bs}) - 1\}^{\frac{3}{2}} \right]$$

$$+ \text{const0} \left[\{\beta(\phi_{s1} - V_{bs}) - 1\}^{\frac{1}{2}} - \{\beta(\phi_{s0} - V_{bs}) - 1\}^{\frac{1}{2}} \right]$$

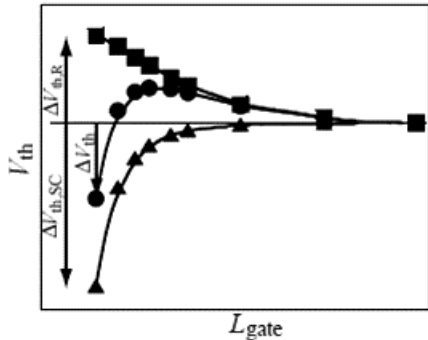
Threshold Voltage Shift

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 [32-4](#). This so-called V_{th} roll-off is very much dependent on the technology applied for MOSFET fabrication. Therefore, HiSIM can derive many detailed informations 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 ϕS 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 32-4.

Figure 32-4 Schematic plot of the separation of Vth 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:

$$\frac{1}{\mu_0} = \frac{1}{\mu_{CB}} + \frac{1}{\mu_{PH}} + \frac{1}{\mu_{SR}}$$

$$\mu_{CB}(\text{Coulomb}) = MUECB0 + MURCB1 \cdot \frac{Q_s}{q \times 10^{11}}$$

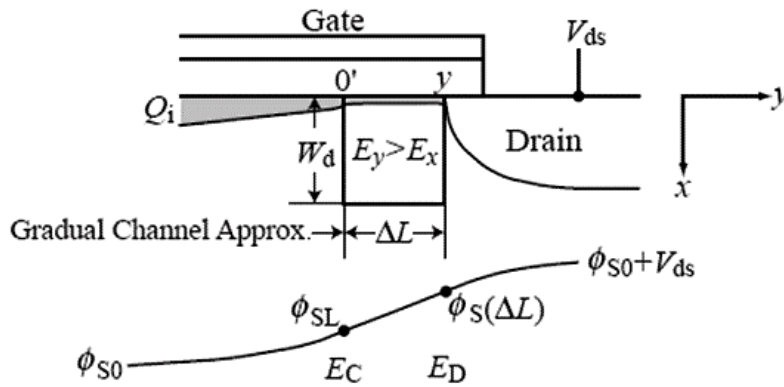
$$\mu_{PH}(\text{phonon}) = \frac{M_{\text{usphonon}}}{E_{\text{eff}}^{MUEPH0}}$$

$$\mu_{SR}(\text{surface roughness}) = \frac{MUESR1}{E_{\text{eff}}^{MUESR1}}$$

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 32-5:

Figure 32-5 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:

$$\Delta V_{th} = \Delta V_{th,SC} + \Delta V_{th,R} + \Delta V_{th,P} + \Delta V_{th,W} - \phi_{TFF}$$

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.

$$E_g = EG0 - BGTMP1 \cdot (T - TNOM) - BGTMP2 \cdot (T - TNOM)^2$$

$$\mu_{PH}(phonon) = \frac{M_{\text{phonon}}}{(T / TNOM)^{MUETMP} \times E_{eff}^{MUEPH0}}$$

$$V_{\text{max}} = \frac{VMAX}{1.8 + 0.4(T / TNOM) + 0.1(T / TNOM)^2 - VTMP \times (1 - T / TNOM)}$$

$$E_{eff} = E_{eff0} + EGIG + IGTEMP2(1/T - 1/TNOM) + IGTEMP3(1/T^2 - 1/TNOM^2)$$

Resistances

$$R_{d0,temp} = RDTEMP1 \cdot (T - TNOM) + RDTEMP2 \cdot (T - TNOM)^2$$

$$R_{divd,temp} = RDVDTEMP1 \cdot (TEMP - TNOM) + RDVDTEMP2 \cdot (TEMP^2 - TNOM^2)$$

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

$$T_{nom} = \frac{T}{TNOM}$$

$$j_s = JS0 \exp \left\{ \frac{(E_g(T = TNOM) \cdot \beta(T = TNOM) - E_g \beta + XTI \cdot \log(T_{nom}))}{NJ} \right\}$$

$$j_{sw} = JS0SW \exp \left\{ \frac{(E_g(T = TNOM) \cdot \beta(T = TNOM) - E_g \beta + XTI \cdot \log(T_{nom}))}{NJSW} \right\}$$

$$j_{s2} = JS0 \exp \left\{ \frac{(E_g(T = TNOM) \cdot \beta(T = TNOM) - E_g \beta + XTI2 \cdot \log(T_{nom}))}{NJ} \right\}$$

$$j_{sw2} = JS0SW \exp \left\{ \frac{(E_g(T = TNOM) \cdot \beta(T = TNOM) - E_g \beta + XTI2 \cdot \log(T_{nom}))}{NJSW} \right\}$$

$$CISB = CISB \cdot \exp\{(T_{nom} - 1)CTEMP\}$$

$$VDIFFJ = VDIFFJ \cdot (T_{nom})^2$$

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

$$R_s = \frac{RS}{W_{eff}} + NRS \cdot RSH$$

$$R_{drift} = (R_d + V_{ds} \cdot R_{DVD})(1 + RDVG11 - \frac{RDVG11}{RDVG12} \cdot V_{gs}) \cdot (1 - V_{bs} \cdot RDVB)$$

$$R_d = \frac{R_{d0}}{W_{eff}} \left(1 + \frac{RDS}{(W_{gate} \cdot 10^4 \times L_{gate} \cdot 10^4)^{RDSP}}\right) + RSH \cdot NRD$$

$$R_{d0} = (RD + R_{d0,temp}) \cdot f_1 \cdot f_2$$

$$R_{DVD} = \frac{RDVD + R_{dvd,temp} \cdot \exp(-RDVDL \times (L_{gate} \cdot 10^4)^{RDVDF})}{W_{eff}} \cdot \left(1 + \frac{RDVDS}{(W_{gate} \cdot 10^4 \times L_{gate} \cdot 10^4)^{RDVDSF}}\right) \cdot f_1 \cdot f_2 \cdot f_3$$

$$f_1(L_{drift1}) = \frac{LDRIFT1}{lum} \cdot RDSLPI + RDICT1$$

$$f_2(L_{drift2}) = \frac{LDRIFT2}{lum} \cdot RDSLPI2 + RDICT2$$

$$f_3(L_{over}) = 1 + (RDOV11 - \frac{RDOV11}{RDOV12}) \cdot \frac{LOVERLD}{lum} + (1 - RDOV13) \cdot \frac{LOVERLD}{lum}$$

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

RDSLP1, RDICT1, RDSLP2, 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 32-6 Model options of the overlap capacitance at the drain side are summarized.

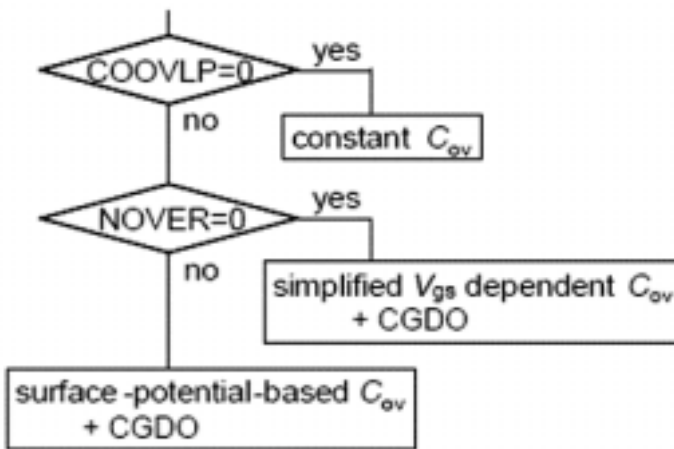
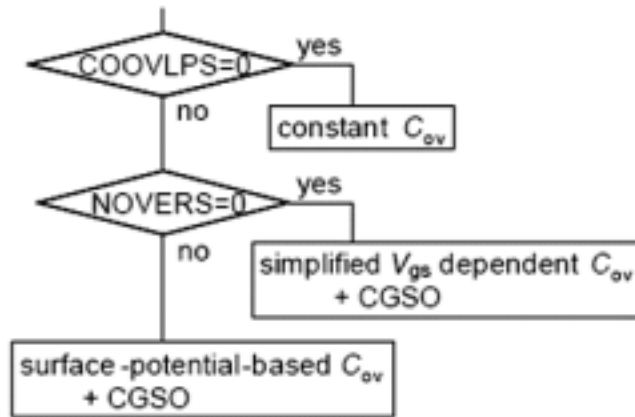


Figure 32-7 Model options of the overlap capacitance at the source side are summarized.

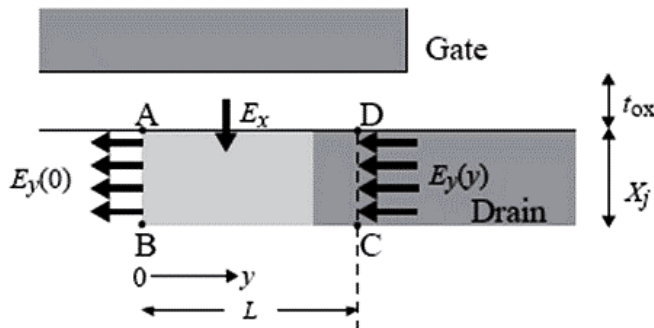


Leakage Currents

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.

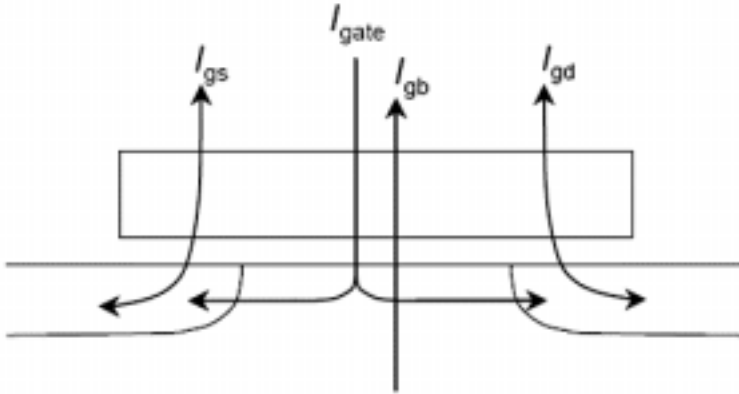
Gate Current

All possible gate leakage currents are schematically shown in Fig. 32.8

Between Gate and Channel, I_{gate}

$$I_{gate} = q \cdot GLEAK1 \cdot \frac{E^2}{E_{gs}^2} \cdot \exp\left(-\frac{E_{gs}^2 \times GLEAK2}{E}\right) \cdot \sqrt{\frac{Q_1}{const0}} \cdot W_{eff} \cdot NF \cdot L_{eff}$$

$$\frac{GLEAK6}{GLEAK6 + V_{ds}} \cdot \frac{GLEAK7}{GLEAK7 + W_{eff} \cdot NF \cdot L_{eff}}$$



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}

$$I_{gs} = \text{signGIKSDA} \cdot E_{gs}^2 \exp(T_{ox}(GLKSD2 \cdot V_{gs} + GLKSD3)) \cdot W_{eff} \cdot NF$$

$$I_{gd} = \text{signGIKSDA} \cdot E_{gd}^2 \exp(T_{ox}(GLKSD2 \cdot (-V_{gs} + V_{ds}) + GLKSD3)) \cdot W_{eff} \cdot NF$$

GIDL (Gate-Induced Drain Leakage)

$$I_{GIDL} = q \cdot GIDL1 \cdot \frac{E^2}{E_{\xi}^{\frac{1}{2}}} \cdot \exp(-GIDL2 \cdot \frac{E_{\xi}^{\frac{3}{2}}}{E}) \cdot W_{eff} \cdot NF$$

Source/Bulk and Drain/Bulk Diode Models

Diode Current

$$j_s = JS0$$

$$j_{s1w} = JS0SW$$

$$j_{s2} = JS0$$

$$j_{s1w2} = JS0SW$$

Between Drain and Bulk

$$V_{bd} \geq V_1$$

$$I_{bd} = I_{sbd} \cdot \left\{ \exp\left(\frac{V_1}{N_{vth}}\right) - 1 \right\} + \frac{I_{sbd}}{N_{vth}} \exp\left(\frac{V_1}{N_{vth}}\right) (V_{bd} - V_1) \\ + I_{sbd2} \cdot CISB \cdot \left\{ \exp\left(-\frac{V_{bd} \cdot CVB}{N_{vth}}\right) - 1 \right\} + CISBK \cdot \left\{ \exp\left(-\frac{V_{bd} \cdot CVB}{N_{vth}}\right) - 1 \right\}$$

$$V_1 \geq V_{bd}$$

$$I_{bd} = I_{sbd} \cdot \left\{ \exp\left(\frac{V_{bd}}{N_{vtn}}\right) - 1 \right\} + I_{sbd2} \cdot C_{ISB} \cdot \left\{ \exp\left(-\frac{V_{bd} \cdot CVB}{N_{vtn}}\right) - 1 \right\} + C_{ISBK} \cdot \left\{ \exp\left(-\frac{V_{bd} \cdot CVB}{N_{vtn}}\right) - 1 \right\}$$

$$N_{vtn} = \frac{NJ}{\beta}$$

$$V_1 = N_{vtn} \cdot \log\left\{ \frac{VDIFFJ}{I_{sbd}} + 1 \right\}$$

$$I_{bd} = I_{bd} + DIVX \cdot I_{sbd2} \cdot V_{bd}$$

Between Source and Bulk

$$V_{bs} \geq V_2$$

$$I_{bs} = I_{sbs} \cdot \left\{ \exp\left(\frac{V_2}{N_{vtn}}\right) - 1 \right\} + \frac{I_{sbs}}{N_{vtn}} \exp\left(\frac{V_2}{N_{vtn}}\right) (V_{bs} - V_2) \\ + I_{sbs2} \cdot C_{ISB} \cdot \left\{ \exp\left(-\frac{V_{bs} \cdot CVB}{N_{vtn}}\right) - 1 \right\} + C_{ISBK} \cdot \left\{ \exp\left(-\frac{V_{bs} \cdot CVB}{N_{vtn}}\right) - 1 \right\}$$

$$V_2 \geq V_{bs}$$

$$I_{bs} = I_{sbs} \cdot \left\{ \exp\left(\frac{V_{bs}}{N_{vtn}}\right) - 1 \right\} + I_{sbs2} \cdot C_{ISB} \cdot \left\{ \exp\left(-\frac{V_{bs} \cdot CVB}{N_{vtn}}\right) - 1 \right\} + C_{ISBK} \cdot \left\{ \exp\left(-\frac{V_{bs} \cdot CVB}{N_{vtn}}\right) - 1 \right\}$$

$$V_2 = N_{vtn} \cdot \log\left\{ \frac{VDIFFJ}{I_{sbs}} + 1 \right\}$$

$$I_{bs} = I_{bs} + DIVX \cdot I_{sbs2} \cdot V_{bs}$$

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

$$S_{I_L} = \frac{I_{ds}^2 NFTRP}{\beta f (L_{eff} - \Delta L) W_{eff} \cdot NF} \left[\frac{1}{(N_0 + N^*)(N_L + N^*)} + \frac{2\mu E_y NFALP}{N_L - N_0} \ln \left(\frac{N_L + N^*}{N_0 + N^*} \right) + (\mu E_y NFALP)^2 \right]$$

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

$$\tau_{cond} = DLY2 \cdot \frac{Q_i}{I_{ds}}$$

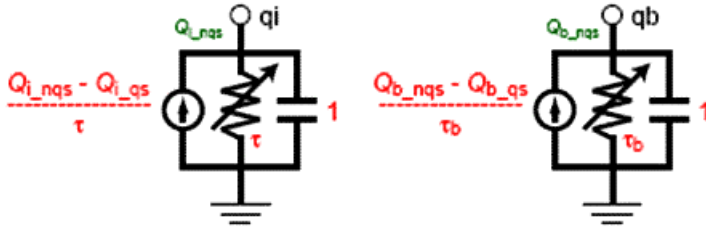
These two delay mechanisms (diffusion and conduction) are combined using the Matthiessen rule:

$$\frac{1}{\tau} = \frac{1}{\tau_{diff}} + \frac{1}{\tau_{cond}}$$

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

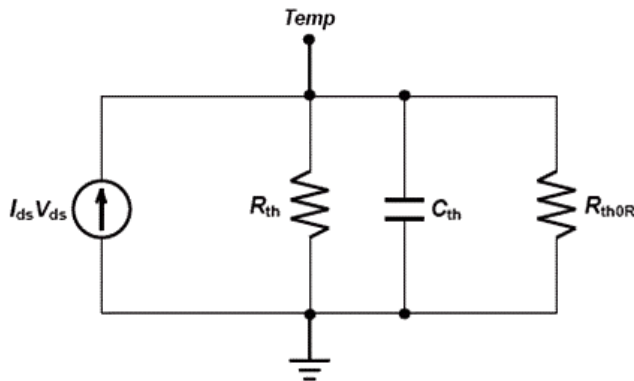
$$\tau_B = DLY3 \cdot C_{ox}$$

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

$$R_{th} = \frac{RTH0}{W_{eff}} \cdot \left(\frac{1}{NF^{RTH0NF}} \right) \left(1 + \frac{RTH0W}{(W_{gate} \cdot 10^4)^{RTH0WP}} \right)$$

$$C_{th} = CTH0 \cdot W_{eff}$$

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.

$$M_{\text{phonon}} = MUEPHI[MPHDFN\{\ln(NSUBCDFM) - \ln(N_{SUBC})\} + 1]$$

$$NSUBP = NSUBP + (N_{SUBCDFM} - N_{SUBC})$$

$$NEXT = NEXT + (NSUBCDFM - N_{SUBC})$$

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 (K)	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 (Ohm)	Substrate resistance network.
12	rbpd (Ohm)	Substrate resistance network.
13	rbps (Ohm)	Substrate resistance network.
14	rbdb (Ohm)	Substrate resistance network.
15	rbsb (Ohm)	Substrate resistance network.
16	cosubnode=0	Instance flag to switch tempnode to subnode. 1: 5th node is subnode; 0: 5th node is thermal node.
17	coselfheat=0	Calculation of self heating model.
18	corg=0	Gate-contact resistance selector.
19	ngcon=1.0	Number of gate contacts.
20	xgw=0.0 m	Distance from gate contact to channel edge.
21	xgl=0.0 m	Offset of gate length due to variation in patterning.
22	nf=1.0	Number of gate fingers.
23	lod=1.0e-5 m	Length of diffusion between gate and STI.
24	m=1	Multiplicity factor (number of MOSFETs in parallel).
25	subld1	Parameter for impact-ionization current in the drift region.
26	subld2 $((V^{3/2})/m)$	Parameter for impact-ionization current in the drift region.
27	ldrift1 (m)	Parameter for drift region length-1.
28	ldrift2 (m)	Parameter for drift region length-2.

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

29	lover (m)	Overlap length on source side.
30	lovers (m)	Overlap length on source side.
31	loverld (m)	Overlap length on drain side.
32	ldrift1s (m)	Parameter for drift region length-1 on source side.
33	ldrift2s (m)	Parameter for drift region length-2 on source side.
34	sa=0.0 m	Distance from STI edge to Gate edge.
35	sb=0.0 m	Distance from STI edge to Gate edge.
36	sd=0.0 m	Distance from Gate edge to Gate edge.
37	nsubcdfm (cm ⁻³)	Constant part of Nsub for DFM.
38	isnoisy=yes	Should device generate noise. Possible values are no or yes.

Model Definition

```
model modelName hisim_hv parameter=value ...
```

Model Parameters

Device type parameters

1	type=n	Transistor type. Possible values are n or p.
2	level=73	Level selector for spice compatible. 73 is valid level for hisim_hv model.
3	version=1.20	Model version 1.20. 1.20 is the latest version of HiSIM_HV.
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.

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

5	coiprv=1	Previous I _{ds} is used for calculating source/drain resistance effect. 0 : no(default). 1 : yes.
6	copprv=1	Previous surface potential is used for the initial guess. 0 : no(default). 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 on drain side. 0 : constant overlap capacitance(default). 1 : yes.
12	coovlps=0	Overlap capacitance calculation selector on source side. 0 : constant overlap capacitance(default). 1 : yes.
13	coflick=0	1/f noise calculation selector.
14	coisti=0	STI leakage current calculation selector. 0 : no(default). 1 : yes.
15	conqs=0	Non-quasi-static mode selector. 0 : no(default). 1 : yes.
16	cothrml=0	Thermal noise calculation selector. 0 : no(default). 1 : yes.
17	tnom (C)	Parameters measurement temperature. Default set by `options`.
18	corg=0	Gate-contact resistance calculation selector. 0 : no(default). 1 : yes.
19	corbnet=0	Substrate resistance network selector.
20	coign=0	Induced gate and cross correlation noise calculation selector..

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

21	alarm=none	Forbidden operating region. Possible values are none, off, triode, sat, subth, or rev.
22	codfm=0	Calculation of model for DFM selector.
23	coselfheat=0	Calculation of self heating model.
24	cosubnode=0	Flag to switch tempnode to subnode. 1: 5th node is subnode; 0: 5th node is thermal node.
25	cosym=0	Model selector for symmetry device.
26	cotemp=0	Model flag for temperature dependence.
27	coldrift=0	Selector for Ldrift parameter.

Default for instance parameters

28	w=5e-6 m	Default gate width.
29	l=2e-6 m	Default gate length.
30	as=0 m ²	Default area of source junction.
31	ad=0 m ²	Default area of drain junction.
32	ps=0 m	Default perimeter of source junction.
33	pd=0 m	Default perimeter of drain junction.
34	temp=27 C	Default device temperature.
35	dtemp=0 K	Default device temperature rise from ambient.

Basic Device Parameters

36	tox=3e-8 m	Physical oxide thickness.
37	xld=3e-8 m	Gate-overlap length.
38	xwd=0 m	Gate-overlap width.

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

39	xwdc=0.0 m	Gate-overlap width, for capacitance.
40	tpoly=2.0e-7 m	Height of the gate poly-si for fringing capacitance on source side.
41	nsubc=1.0e17 cm ⁻³	Substrate-impurity concentration.
42	nsubp=1.0e17 cm ⁻³	Maximum pocket concentration.
43	rs=0.0 Ohm*m	Source contact resistance in LDD region.
44	rd=5.0e-3 Ohm*m	Drain contact resistance in LDD region.
45	vfb=-1.0 V	Constant part of flat-band voltage.
46	lp=0.0 m	Length of the pocket penetration into the channel.
47	xqy=0.0 m	Distance from channel/drain junction to maximum electric field point.
48	lover=3.0e-8 m	Overlap length on source side.
49	ll=0.0	Gate length parameter.
50	lld=0.0 m	Gate length parameter.
51	lln=0.0	Gate length parameter.
52	wl=0.0	Gate width parameter.
53	wld=0.0 m	Gate width parameter.
54	wln=0.0	Gate width parameter.
55	vbi=1.0 V	Built-in potential.
56	nsubp0=0.0 cm ⁻³	Pocket implant parameter.
57	nsubwp=1.0	Pocket implant parameter.
58	lpext=1.0E-50 m	Pocket extension.

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

59	$npext=1.0e17 \text{ cm}^{-3}$	Pocket extension.
60	$rsh=0.0 \text{ V/A}\cdot\text{m}$	Source/drain diffusion sheet resistance.
61	$rshg=0.0 \text{ V/A}\cdot\text{m}$	Gate-electrode sheet resistance.
62	$rbpb=50.0 \text{ Ohm}$	Substrate resistance network.
63	$rbpd=50.0 \text{ Ohm}$	Substrate resistance network.
64	$rbps=50.0 \text{ Ohm}$	Substrate resistance network.
65	$rbdb=50.0 \text{ Ohm}$	Substrate resistance network.
66	$rbsb=50.0 \text{ Ohm}$	Substrate resistance network.
67	$gbmin=1.0e-12$	Minimum conductance for substrate resistance network.
68	$xl=0 \text{ m}$	Gate length offset due to mask/etch effect.
69	$xw=0 \text{ m}$	Gate width offset due to mask/etch effect.
70	$xqy1=0.0 \text{ F m}^{\{XQY2\}}$	V_{bs} dependence of Q_y .
71	$xqy2=2.0$	L_{gate} dependence of Q_y .
72	$xldld=1.0e-6 \text{ m}$	Lateral diffusion of Drain under the gate.
73	$xwdld=1.0e-6 \text{ m}$	Widening of drift width.
74	$rd2=0.0 \text{ Ohm}\cdot\text{m}$	Drain contact resistance in LDD region.
75	$rd3=0.0 \text{ Ohm}\cdot\text{m}$	Drain contact resistance in LDD region.
76	$rdov11=0.0$	Depedence coeff. for overlap length.
77	$rdov12=1.0$	Depedence coeff. for overlap length.
78	$rdov13=1.0$	Depedence coeff. for overlap length.
79	$rdslp1=0.0$	LDRIFT1 dependence of resistance for $CORSRD=1,3$.

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

80	rdict1=1.0	LDRIFT1 dependence of resistance for CORSRD=1,3.
81	rdslp2=1.0	LDRIFT2 dependence of resistance for CORSRD=1,3.
82	rdict2=0.0	LDRIFT2 dependence of resistance for CORSRD=1,3.
83	loverld=1.0e-6 m	Overlap length on the drain side.
84	lovers=3.0e-8 m	Overlap length on source side.
85	ldrift1=1.0e-6 m	Drift region length-1 on the drain side.
86	ldrift1s=0.0 m	Drift region length-1 on the source side.
87	ldrift2=1.0e-6 m	Drift region length-2 on the drain side.
88	ldrift2s=1.0e-6 m	Drift region length-2 on the source side.
89	subld1=0.0	Impact-ionization current in the drift region.
90	subld2=0.0 (V ^{3/2})/m	Impact-ionization current in the drift region.

Temperature dependence effects

91	eg0=1.1785 eV	Constant bandgap.
92	bgtmp1=9.025e-5 eV/K	First order temperature coefficient for band gap.
93	bgtmp2=1.0e-7 eV/K ²	Second order temperature coefficient for band gap.
94	igtemp1=0.0	Temperature dependence of gate current.
95	igtemp2=0.0 1/K	Temperature dependence of gate current.
96	igtemp3=0.0 1/K ²	Temperature dependence of gate current.
97	vmaxt1=0.0 1/K	Temperature dependence of velocity.
98	vmaxt2=0.0 1/K ²	Temperature dependence of velocity.

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

99	ninvdt1=0.0 1/K	Temperature dependence of universal mobility model.
100	ninvdt2=0.0 1/K ²	Temperature dependence of universal mobility model.
101	rdtemp1=0.0 1/K	Temperature-dependence of Rd.
102	rdtemp2=0.0 1/K ²	Temperature-dependence of Rd.
103	rdvdtemp1=0.0 1/K	Temperature-dependence of RDVD.
104	rdvdtemp2=0.0 1/K ²	Temperature-dependence of RDVD.
105	rthtemp1=0.0 1/K	Temperature dependence of thermal resistance.
106	rthtemp2=0.0 1/K ²	Temperature dependence of thermal resistance.
107	prattemp1=0.0 1/K	Temperature dependence of thermal dissipation.
108	prattemp2=0.0 1/K ²	Temperature dependence of thermal dissipation.

Quantum Mechanical Effects

109	qme1=0.0 m/V ²	Coefficient for quantum mechanical effect.
110	qme2=1.0 V	Coefficient for quantum mechanical effect.
111	qme3=0.0 m	Coefficient for quantum mechanical effect.
112	kappa=3.9	Dielectric constant for high-k stacked gate.

Poly Depletion Effects

113	pgd1=0.0 V	Strength of poly depletion.
114	pgd2=1.0 V	Threshold voltage of poly depletion.

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

- 115 pgd3=0.8 Vds dependence of poly depletion.
- 116 pgd4=0.0 Parameter for gate-poly depletion.

Short Channel Effects

- 117 parl2=1.0e-8 m Depletion width of channel/contact junction.
- 118 sc1=1.0 1/V Short-channel coefficient 1.
- 119 sc2=1.0 1/V² Short-channel coefficient 2.
- 120 sc2b=0.0 1/V³ Short-channel coefficient 2 Vb dependency coefficient.
- 121 sc3=0.0 m/V² Short-channel coefficient 3.
- 122 sc4=0.0 1/V Parameter for SCE.
- 123 scp1=1.0 1/V Short-channel coefficient 1 for pocket.
- 124 scp2=0.1 1/V² Short-channel coefficient 2 for pocket.
- 125 scp3=0.0 m/V² Short-channel coefficient 3 for pocket.
- 126 scp22=0.0 V⁴ Short-channel-effect modification for small Vds.
- 127 scp21=0.0 V Short-channel-effect modification for small Vds.
- 128 bs1=0.0 V² Body-coefficient modification by impurity profile.
- 129 bs2=0.9 V Body-coefficient modification by impurity profile.

Narrow channel effects

- 130 wfc=0.0 m²F/cm² Threshold voltage reduction.
- 131 nsubcw=0.0 Width dependence of substrate-impurity concentration.
- 132 nsubcwp=1.0 Width dependence of substrate-impurity concentration.
- 133 mueph2=0.0 Mobility reduction.

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

134	w0=0.0 log(cm)	Minimum gate width.
135	wvthsc=0.0	Short-channel effect at the STI edge.
136	nsti=1.0e17 cm ⁻³	Substrate-impurity concentration at the SIT edge.
137	wsti=0.0 m	Width of the high-field region at STI.
138	muephw=0.0	Phonon scattering parameter.
139	muepwp=1.0	Phonon scattering parameter.
140	wvth0=0.0	Threshold voltage shift.
141	mueswp=1.0	Change of surface roughness related mobility.
142	vthsti=0.0	Parameter for STI.
143	muesti1=0.0	STI Stress mobility parameter.
144	muesti2=0.0	STI Stress mobility parameter.
145	muesti3=1.0	STI Stress mobility parameter.
146	nsubpsti1=0.0 m	STI Stress pocket implant parameter.
147	nsubpsti2=0.0 m	STI Stress pocket implant parameter.
148	nsubpsti3=1.0 m	STI Stress pocket implant parameter.
149	wstil=0.0	Parameter for STI.
150	wstilp=1.0	Parameter for STI.
151	scsti1=0.0	Parameter for STI.
152	scsti2=0.0 1/V	Parameter for STI.
153	scsti3=0.0 m/V	Parameter for STI.
154	saref=1e-6 m	Reference distance from STI edge to Gate edge.

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

155	sbref=1e-6 m	Reference distance from STI edge to Gate edge.
156	wstiw=0.0	Parameter for STI.
157	wstiwp=1.0	Parameter for STI.
158	vdsti=0.0	Parameter for STI.

Mobility Effects

159	vds0=0.05 V	Drain voltage for extracting the low-field mobility.
160	muecb0=1.0e3 cm ² /(V*s)	Coulomb scattering.
161	muecb1=1.0e2 cm ² /(V*s)	Coulomb scattering.
162	mueph0=0.3 cm ² *(V/cm) ^(Muesr1) /(V*s)	Phonon scattering.
163	mueph1=2.5e4	Phonon scattering.
164	muetmp=1.7	Temperature dependence of phonon scattering.
165	muesr0=2.0 cm ² *(V/cm) ^(Muesr1) /(V*s)	Surface-roughness scattering.
166	muesr1=1.0e16	Surface-roughness scattering.
167	ndep=1.0	Coefficient of effective electric field.
168	ninv=0.5	Coefficient of effective electric field.
169	ninvd=0.0 1/V	Modification of Vdse dependence on Eeff.
170	ninvdw=0.0	Coeff of modification of Vdse dependence on Eeff.
171	ninvdwp=1.0	Coeff of modification of Vdse dependence on Eeff.
172	bb=2.0	High-field mobility degradation.

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

173	vmax=1.0e7 cm/s	Saturation velocity.
174	vover=0.3 cm^(voverp)	Parameter for velocity overshoot.
175	voverp=0.3	Lgate dependence of velocity overshoot.
176	vovers=0.0	Parameter for overshoot.
177	voversp=0.0	Parameter for overshoot.
178	vtmp=0.0 cm/s	Temperature dependence of the saturation velocity.
179	muephi=0.0	Phonon scattering parameter.
180	mueplp=1.0	Phonon scattering parameter.
181	muesrl=0.0	Surface roughness parameter.
182	muesrw=0.0	Change of surface roughness related mobility.
183	mueslp=1.0	Surface roughness parameter.
184	ndepl=0.0	Modification of Qb contribution for short-channel case.
185	ndeplp=1.0	Modification of Qb contribution for short-channel case.

Small size parameters

186	wl1=0.0	Threshold voltage shift of STI leakage due to small size effect.
187	wl1p=1.0	Threshold voltage shift of STI leakage due to small size effect.
188	wl2=0.0	Threshold voltage shift due to small size effect.
189	wl2p=1.0	Threshold voltage shift due to small size effect.
190	muephs=0.0	Mobility modification due to small size.
191	muepsp=1.0	Mobility modification due to small size.

Channel Length Modulation Effects

192	clm1=50e-3	First parameter for CLM.
193	clm2=2.0 1/m	Second parameter for CLM.
194	clm3=1.0	Third parameter for CLM.
195	clm4=5.0e-4	Smoothing coefficient for gds.
196	clm5=1.0	Effect of pocket implantation.
197	clm6=0.0	Effect of pocket implantation.

Substrate Current Effects

198	sub1=50e-3 1/V	First parameter for Isub.
199	sub2=1.0e2 V	Second parameter for Isub.
200	svgs=0.8	Substrate current dependence on Vgs.
201	svbs=0.5	Substrate current dependence on Vbs.
202	svbsl=0.0	Lgate dependence of SVBS.
203	svds=0.8	Substrate current dependence on Vds.
204	slg=3.0e-8	Substrate current dependence on Lgate.
205	sub1l=2.5e-3	Lgate dependence of SUB1.
206	sub2l=2.0e-6	Lgate dependence of SUB2.
207	fn1=50.0	Coefficient of Fowler-Nordheim-current contribution.
208	fn2=1.7e-4	Coefficient of Fowler-Nordheim-current contribution.
209	fn3=0.0	Coefficient of Fowler-Nordheim-current contribution.
210	fvbs=1.2e-2	Modification of Vbs dependence.
211	svgsl=0.0	Lgate dependence of SVGS.

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

212	svgslp=1.0	Lgate dependence of SVGS.
213	svgswp=1.0	Wgate dependence of SVGS.
214	svgsw=0.0	Wgate dependence of SVGS.
215	svbslp=1.0	Lgate dependence of SVBS.
216	slgl=0.0	Substrate current dependence on Lgate.
217	slglp=1.0	Substrate current dependence on Lgate.
218	sub1lp=1.0	Lgate dependence of SUB1.
219	ibpc1=0.0	Impact-ionization induced bulk potential change.
220	ibpc2=0.0	Impact-ionization induced bulk potential change.

Gate Current Effects

221	glpart1=0.5	Partitoning of gate current.
222	gleak1=50.0 $A/(V^{(3/2)}*c^{(1/2)})$	First gate current coefficient.
223	gleak2=1.0e7 $1/(V^{(1/2)}*c^{(3/2)*m})$	Second gate current coefficient.
224	gleak3=6.0e-2	Third gate current coefficient.
225	gleak4=4.0	Parameter for gate current.
226	gleak5=7.5e3	Parameter for gate current.
227	glksd1=1.0e-15	Parameter for gate current.
228	glksd2=5e6	Parameter for gate current.
229	glksd3=-5e6	Parameter for gate current.
230	glkb0=0.0 V	Parameter for gate current.
231	glkb1=5.0e-16	Parameter for gate current.

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

- 232 glkb2=1.0 Parameter for gate current.
- 233 gleak6=0.25 V Parameter for gate current.
- 234 gleak7=1.0e-6 m² Parameter for gate current.
- 235 glkb3=0.0 V Parameter for gate current.
- 236 egig=0.0 V Parameter for gate current.

GIDL Current Effects

- 237 gidl1=2.0 A*m/(V^(3/2)*c^(1/2))
First parameter for GIDL.
- 238 gidl2=3.0E7 1/(V^(1/2)*c^(3/2)*m)
Second parameter for GIDL.
- 239 gidl3=0.9 Third parameter for GIDL.
- 240 gidl4=0.9 Parameter for GIDL.
- 241 gidl5=0.2 Parameter for GIDL.

Noise 1/f Effects

- 242 nfalp=1.0e-19 Flicker (1/f) noise contribution of the mobility fluctuation.
- 243 falph=1.0 Parameter for 1/f noise.
- 244 nftrp=1.0e10 Flicker (1/f) noise ratio of trap density to attenuation coefficient.
- 245 cit=0.0 Flicker (1/f) noise interface trapped carriers capacitance.

Subthreshold swing parameters

- 246 pthrou=0.0 Modify subthreshold sloop.
- 247 pthroub=0.0 1/V Modify subthreshold sloop.

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

NQS parameters

248	dly1=1.0e-10	Parameter for transit time.
249	dly2=0.7	Parameter for transit time.
250	dly3=8.0e-7 Ohm	Parameter for transforming bulk charge.
251	dlyov=0.0 Ohm	Parameter for transforming overlap charge.
252	nqsscale	Symmetry for short-channel mosfet:
253	vzadd0=1.0e-2 V	Vzadd at Vds=0.
254	pzadd0=5.0e-3 V	Pzadd at Vds=0.

P-N junctions parameters

255	js0=5.0e-7 A/m ²	Junction saturation current density.
256	js0sw=0.0 A/m	Side-wall saturation current density.
257	nj=1.0	Junction emission coefficient.
258	njsw=1.0	Junction emission coefficient (sidewall).
259	xti=2.0	Junction saturation current temperature exponent coefficient.
260	cj=5.0e-4 F/m ²	Bottom junction capacitance per unit area at zero bias.
261	cjsw=5e-10 F/m	Source/drain sidewall junction capacitance per unit length at zero bias.
262	cjswg=5e-10 F/m	Source/drain sidewall junction capacitance grading coefficient per unit length at zero bias.
263	tcjbd=0.0	Temperature dependence of czbd.
264	tcjbdsw=0.0	Temperature dependence of czbdsw.
265	tcjbdswg=0.0	Temperature dependence of czbdswg.
266	tcjbs=0.0	Temperature dependence of czbs.

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

267	tcjbssw=0.0	Temperature dependence of czbssw.
268	tcjbsswg=0.0	Temperature dependence of czbsswg.
269	mj=0.5	Bulk junction bottom grading coefficient.
270	mjsw=0.33	Source/drain sidewall junction capacitance grading coefficient.
271	mjswg=0.33	Bottom junction capacitance grading coefficient.
272	pb=1.0 V	Bottom junction build-in potential.
273	pbsw=1.0 V	Source/drain sidewall junction build-in potential.
274	pbswg=1.0 V	Source/drain gate sidewall junction build-in potential.
275	vdiffj=6.0e-4 V	Threshold voltage for S/D junction diode.
276	x _{ti} ² =0.0	Temperature coefficient.
277	cisb=0.0	Reverse bias saturation current.
278	cvb=0.0	Bias dependence coefficient of cisb.
279	ctemp=0.0	Temperature coefficient.
280	cisbk=0.0 A	Reverse bias saturation current.
281	cvbk=0.0	Bias dependence coefficient of cisb.
282	divx=0.0 1/V	Parameter for junction.

Overlap capacitance parameters:

283	cgso=0.0 F/m	Gate-source overlap capacitance.
284	cgdo=0.0 F/m	Gate-dource overlap capacitance.
285	cgbo=0.0 F/m	Gate-bource overlap capacitance.
286	ovslp=2.0e-8	Parameter for overlap capacitance.
287	ovmag=500.0	Parameter for overlap capacitance.

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

288 vfbover=-0.5 V Flat-band voltage in overlap region.

289 nover=3.0e16 cm⁻³
Impurity concentration in overlap region.

290 novers=0.0 cm⁻³
Impurity concentration in overlap region.

Smoothing coefficient between linear and saturation:

291 ddltmax=1.0 Coefficient of effective electric field.

292 ddltslp=0.0 Lgate dependence of smoothing coefficient.

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 Vsub dependence of depletion width.

296 rdvds=0.3 Vds dependence of depletion width.

297 ddrift=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 Vsub dependence.

Operating region warning control parameters:

300 warn=off Parameter to turn warnings on and off. Possible values are off or on.

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

301	bvd (V)	Drain diode breakdown voltage.
302	bvs (V)	Source diode breakdown voltage.
303	bvj (V)	Junction reverse breakdown voltage, take effect when bvd and bvs not given.
304	vbox=3e9*tox V	Oxide breakdown voltage.

LDMOS special parameters:

305	rdvg11=0.0	Vgs dependence of RD.
306	rdvg12=1.0e2	Vgs dependence of RD.
307	vbsmin=-10.5 V	Minimum back bias voltage to be treated in hsmhveval.
308	rth0=0.1 Kcm/W	Thermal resistance.
309	cth0=1.0e-7 Ws/Kcm	Thermal capacitance.
310	qdfvtd=1.0	Qdrift Vd dependence.
311	rdvd=7.0e-2	Vds dependence of RD.
312	rdvb=0.0	Vbs dependence of RD.
313	rd20=0.0	RD23 boundary.
314	rd21=1.0	Vds dependence of RD.
315	rd22=0.0	Vbs dependence of RD.
316	rd22d=0.0	Vbs dependence of RD.
317	rd23=5e-3	Modification of RD.
318	rd24=0.0	Vgs dependence of RD.
319	rd25=0.0	Vgs dependence of RD.
320	rd26=0.2	Smoothing Qover at depletion/inversion transition.

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

321	govsm=0.2	Smoothing Qover at depletion/inversion transition.
322	rdvdl=0.0	Lgate dependence of RD.
323	rdvdlp=1.0	Lgate dependence of RD.
324	rdvds=0.0	Small size dependence of RD.
325	rdvdsp=1.0	Small size dependence of RD.
326	rd23l=0.0	Lgate dependence of RD21 boundary.
327	rd23lp=1.0	Lgate dependence of RD21 boundary.
328	rd23s=0.0	Small size dependence of RD21.
329	rd23sp=1.0	Small size dependence of RD21.
330	rds=0.0	Small size dependence of RD.
331	rdsp=1.0	Small size dependence of RD.
332	ldrift=1.0e-6	Length of drift region.
333	rth0r=0.0	Heat radiation for SHE.
334	rth0w=0.0	Width-dependence of RTH0.
335	rth0wp=1.0	Width-dependence of RTH0.
336	rth0nf=0.0	Nf-dependence of RTH0.
337	cvdsover=0.0	Modification of the Cgg spikes for Vds is not zero.
338	powrat=1.0	Thermal dissipation.

Auto Model Selector parameters:

339	wmax=1 m	Maximum channel width for which the model is valid.
340	wmin=0 m	Minimum channel width for which the model is valid.
341	lmax=1 m	Maximum channel length for which the model is valid.

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

342 $l_{min}=0$ m Minimum channel length for which the model is valid.

Binning model parameters

343 $l_{binn}=1.0$ L modulation coefficient for binning.

344 $w_{binn}=1.0$ W modulation coefficient for binning.

345 $l_{vmax}=0.0$ cm/s Length dependence of v_{max} .

346 $l_{bgtmp1}=0.0$ eV/K Length dependence of $bgtmp1$.

347 $l_{bgtmp2}=0.0$ eV/K²
Length dependence of $bgtmp2$.

348 $l_{eg0}=0.0$ eV Length dependence of $eg0$.

349 $l_{novers}=0.0$ cm⁻³
Length dependence of $novers$.

350 $l_{vfbover}=0.0$ V Length dependence of $vfbover$.

351 $l_{nover}=0.0$ cm⁻³ Length dependence of $nover$.

352 $l_{wl2}=0.0$ Length dependence of $wl2$.

353 $l_{vfbc}=0.0$ V Length dependence of $vfbc$.

354 $l_{nsubc}=0.0$ cm⁻³ Length dependence of $nsubc$.

355 $l_{nsubp}=0.0$ cm⁻³ Length dependence of $nsubp$.

356 $l_{scp1}=0.0$ 1/V Length dependence of $scp1$.

357 $l_{scp2}=0.0$ 1/V² Length dependence of $scp2$.

358 $l_{scp3}=0.0$ m/V² Length dependence of $scp3$.

359 $l_{sc1}=0.0$ 1/V Length dependence of $sc1$.

360 $l_{sc2}=0.0$ 1/V² Length dependence of $sc2$.

361 $l_{sc3}=0.0$ m/V² Length dependence of $sc3$.

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

362	lpgd1=0.0 V	Length dependence of pgd1.
363	lpgd3=0.0	Length dependence of pgd3.
364	lndep=0.0	Length dependence of ndep.
365	lninv=0.0	Length dependence of ninv.
366	lmuecb0=0.0 cm ² /(V*s)	Length dependence of muecb0.
367	lmuecb1=0.0 cm ² /(V*s)	Length dependence of muecb1.
368	lmueph1=0.0	Length dependence of mueph1.
369	lvtmp=0.0 cm/s	Length dependence of vtmp.
370	lvwth0=0.0	Length dependence of wvth0.
371	lmuesr1=0.0	Length dependence of muesr1.
372	lmuetmp=0.0	Length dependence of muetmp.
373	lsub1=0.0 1/V	Length dependence of sub1.
374	lsub2=0.0 V	Length dependence of sub2.
375	lsvds=0.0	Length dependence of svds.
376	lsvbs=0.0	Length dependence of svbs.
377	lsvgs=0.0	Length dependence of svgs.
378	lfn1=0.0	Length dependence of fn1.
379	lfn2=0.0	Length dependence of fn2.
380	lfn3=0.0	Length dependence of fn3.
381	lfvbs=0.0	Length dependence of fvbs.
382	lnsti=0.0 cm ⁻³	Length dependence of nsti.

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

383	lwsti=0.0 m	Length dependence of wsti.
384	lscsti1=0.0	Length dependence of scsti1.
385	lscsti2=0.0 1/V	Length dependence of scsti2.
386	lvthsti=0.0	Length dependence of vthsti.
387	lmuesti1=0.0	Length dependence of muesti1.
388	lmuesti2=0.0	Length dependence of muesti2.
389	lmuesti3=0.0	Length dependence of muesti3.
390	Insubpsti1=0.0 m	Length dependence of nsubpsti1.
391	Insubpsti2=0.0 m	Length dependence of nsubpsti2.
392	Insubpsti3=0.0 m	Length dependence of nsubpsti3.
393	lcgso=0.0 F/m	Length dependence of cgso.
394	lcgdo=0.0 F/m	Length dependence of cgdo.
395	ljs0=0.0 A/m ²	Length dependence of js0.
396	ljs0sw=0.0 A/m	Length dependence of js0sw.
397	lnj=0.0	Length dependence of nj.
398	lcisbk=0.0 A	Length dependence of cisbk.
399	lclm1=0.0	Length dependence of clm1.
400	lclm2=0.0 1/m	Length dependence of clm2.
401	lclm3=0.0	Length dependence of clm3.
402	lwfc=0.0 m ² F/cm ²	Length dependence of wfc.
403	lgidl1=0.0 A*m/(V ^{3/2} *c ^{1/2})	Length dependence of gidl1.

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

404	$1/(V^{1/2} * c^{3/2} * m)$	Length dependence of gidl2.
405	$A/(V^{3/2} * c^{1/2})$	Length dependence of gleak1.
406	$1/(V^{1/2} * c^{3/2} * m)$	Length dependence of gleak2.
407	0.0	Length dependence of gleak3.
408	V	Length dependence of gleak6.
409	0.0	Length dependence of glksd1.
410	0.0	Length dependence of glksd2.
411	0.0	Length dependence of glkb1.
412	0.0	Length dependence of glkb2.
413	0.0	Length dependence of nfrp.
414	0.0	Length dependence of nfalp.
415	0.0	Length dependence of pthrou.
416	V	Length dependence of vdiffj.
417	0.0	Length dependence of ibpc1.
418	0.0	Length dependence of cgbo.
419	0.0	Length dependence of cvdsover.
420	0.0	Length dependence of falph.
421	0.0	Length dependence of npext.
422	0.0	Length dependence of powrat.
423	0.0	Length dependence of rd.

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

424	lrd22=0.0	Length dependence of rd22.
425	lrd23=0.0	Length dependence of rd23.
426	lrd24=0.0	Length dependence of rd24.
427	lrdict1=0.0	Length dependence of rdict1.
428	lrdov13=0.0	Length dependence of rdov13.
429	lrdslp1=0.0	Length dependence of rds1p1.
430	lrdvb=0.0	Length dependence of rdvb.
431	lrdvd=0.0	Length dependence of rdvd.
432	lrdvg11=0.0	Length dependence of rdvg11.
433	lrs=0.0	Length dependence of rs.
434	lrth0=0.0	Length dependence of rth0.
435	lver=0.0	Length dependence of vover.
436	wvmax=0.0 cm/s	Width dependence of vmax.
437	wbgtmp1=0.0 eV/K	Width dependence of bgtmp1.
438	wbgtmp2=0.0 eV/K ²	Width dependence of bgtmp2.
439	weg0=0.0 eV	Width dependence of eg0.
440	wnovers=0.0 cm ⁻³	Width dependence of novers.
441	wvfbover=0.0 V	Width dependence of vfbover.
442	wnover=0.0 cm ⁻³	Width dependence of nover.
443	wwl2=0.0	Width dependence of wl2.
444	wvfbc=0.0 V	Width dependence of vfbc.

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

445	wnsubc=0.0 cm ⁻³	Width dependence of nsubc.
446	wnsubp=0.0 cm ⁻³	Width dependence of nsubp.
447	wscp1=0.0 1/V	Width dependence of scp1.
448	wscp2=0.0 1/V ²	Width dependence of scp2.
449	wscp3=0.0 m/V ²	Width dependence of scp3.
450	wsc1=0.0 1/V	Width dependence of sc1.
451	wsc2=0.0 1/V ²	Width dependence of sc2.
452	wsc3=0.0 m/V ²	Width dependence of sc3.
453	wpgd1=0.0 V	Width dependence of pgd1.
454	wpgd3=0.0	Width dependence of pgd3.
455	wndep=0.0	Width dependence of ndep.
456	wninv=0.0	Width dependence of ninv.
457	wmuecb0=0.0 cm ² /(V*s)	Width dependence of muecb0.
458	wmuecb1=0.0 cm ² /(V*s)	Width dependence of muecb1.
459	wmueph1=0.0	Width dependence of mueph1.
460	wvtmp=0.0 cm/s	Width dependence of vtmp.
461	wwvth0=0.0	Width dependence of wvth0.
462	wmuesr1=0.0	Width dependence of muesr1.
463	wmuetmp=0.0	Width dependence of muetmp.
464	wsub1=0.0 1/V	Width dependence of sub1.
465	wsub2=0.0 V	Width dependence of sub2.

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

466	wsvds=0.0	Width dependence of svds.
467	wsvbs=0.0	Width dependence of svbs.
468	wsvgs=0.0	Width dependence of svgs.
469	wfn1=0.0	Width dependence of fn1.
470	wfn2=0.0	Width dependence of fn2.
471	wfn3=0.0	Width dependence of fn3.
472	wfvbs=0.0	Width dependence of fvbs.
473	wnsti=0.0 cm ⁻³	Width dependence of nsti.
474	wwsti=0.0 m	Width dependence of wsti.
475	wscsti1=0.0	Width dependence of scsti1.
476	wscsti2=0.0 1/V	Width dependence of scsti2.
477	wvthsti=0.0	Width dependence of vthsti.
478	wmuesti1=0.0	Width dependence of muesti1.
479	wmuesti2=0.0	Width dependence of muesti2.
480	wmuesti3=0.0	Width dependence of muesti3.
481	wnsubpsti1=0.0 m	Width dependence of nsubpsti1.
482	wnsubpsti2=0.0 m	Width dependence of nsubpsti2.
483	wnsubpsti3=0.0 m	Width dependence of nsubpsti3.
484	wcgso=0.0 F/m	Width dependence of cgso.
485	wcgdo=0.0 F/m	Width dependence of cgdo.
486	wjs0=0.0 A/m ²	Width dependence of js0.
487	wjs0sw=0.0 A/m	Width dependence of js0sw.

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

488	$w_{nj}=0.0$	Width dependence of n_j .
489	$w_{cisbk}=0.0$ A	Width dependence of $cisbk$.
490	$w_{clm1}=0.0$	Width dependence of $clm1$.
491	$w_{clm2}=0.0$ 1/m	Width dependence of $clm2$.
492	$w_{clm3}=0.0$	Width dependence of $clm3$.
493	$w_{wfc}=0.0$ m ² /cm ²	Width dependence of wfc .
494	$w_{gidl1}=0.0$ A*m/(V ^{3/2} *c ^{1/2})	Width dependence of $gidl1$.
495	$w_{gidl2}=0.0$ 1/(V ^{1/2} *c ^{3/2} *m)	Width dependence of $gidl2$.
496	$w_{gleak1}=0.0$ A/(V ^{3/2} *c ^{1/2})	Width dependence of $gleak1$.
497	$w_{gleak2}=0.0$ 1/(V ^{1/2} *c ^{3/2} *m)	Width dependence of $gleak2$.
498	$w_{gleak3}=0.0$	Width dependence of $gleak3$.
499	$w_{gleak6}=0.0$ V	Width dependence of $gleak6$.
500	$w_{glksd1}=0.0$	Width dependence of $glksd1$.
501	$w_{glksd2}=0.0$	Width dependence of $glksd2$.
502	$w_{glkb1}=0.0$	Width dependence of $glkb1$.
503	$w_{glkb2}=0.0$	Width dependence of $glkb2$.
504	$w_{nftrp}=0.0$	Width dependence of $nftrp$.
505	$w_{nfalp}=0.0$	Width dependence of $nfalp$.
506	$w_{pthrou}=0.0$	Width dependence of $pthrou$.

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

507	wvdiffj=0.0 V	Width dependence of vdiffj.
508	wibpc1=0.0	Width dependence of ibpc1.
509	wibpc2=0.0	Width dependence of ibpc2.
510	wcgbo=0.0	Width dependence of cgbo.
511	wcvdsover=0.0	Width dependence of cvdsover.
512	wfalph=0.0	Width dependence of falph.
513	wnpext=0.0	Width dependence of npext.
514	wpowrat=0.0	Width dependence of powrat.
515	wrd=0.0	Width dependence of rd.
516	wrd22=0.0	Width dependence of rd22.
517	wrd23=0.0	Width dependence of rd23.
518	wrd24=0.0	Width dependence of rd24.
519	wrdict1=0.0	Width dependence of rdict1.
520	wrdov13=0.0	Width dependence of rdov13.
521	wrdslp1=0.0	Width dependence of rds1p1.
522	wrdvb=0.0	Width dependence of rdvb.
523	wrdvd=0.0	Width dependence of rdvd.
524	wrdvg11=0.0	Width dependence of rdvg11.
525	wrs=0.0	Width dependence of rs.
526	wrth0=0.0	Width dependence of rth0.
527	wvover=0.0	Width dependence of vover.
528	pvmax=0.0 cm/s	Cross-term dependence of vmax.

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

529	pbgtmp1=0.0 eV/K	Cross-term dependence of bgtmp1.
530	pbgtmp2=0.0 eV/K ²	Cross-term dependence of bgtmp2.
531	peg0=0.0 eV	Cross-term dependence of eg0.
532	pnovers=0.0 cm ⁻³	Cross-term dependence of novers.
533	pvfbover=0.0 V	Cross-term dependence of vfbover.
534	pnover=0.0 cm ⁻³	Cross-term dependence of nover.
535	pwl2=0.0	Cross-term dependence of wl2.
536	pvfbc=0.0 V	Cross-term dependence of vfbc.
537	pnsbc=0.0 cm ⁻³	Cross-term dependence of nsbc.
538	pnsbp=0.0 cm ⁻³	Cross-term dependence of nsbp.
539	pscp1=0.0 1/V	Cross-term dependence of scp1.
540	pscp2=0.0 1/V ²	Cross-term dependence of scp2.
541	pscp3=0.0 m/V ²	Cross-term dependence of scp3.
542	psc1=0.0 1/V	Cross-term dependence of sc1.
543	psc2=0.0 1/V ²	Cross-term dependence of sc2.
544	psc3=0.0 m/V ²	Cross-term dependence of sc3.
545	ppgd1=0.0 V	Cross-term dependence of pgd1.
546	ppgd3=0.0	Cross-term dependence of pgd3.
547	pndep=0.0	Cross-term dependence of ndep.
548	pninv=0.0	Cross-term dependence of ninv.

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

549	$\text{pmuecb0}=0.0 \text{ cm}^2/(\text{V}\cdot\text{s})$	Cross-term dependence of muecb0.
550	$\text{pmuecb1}=0.0 \text{ cm}^2/(\text{V}\cdot\text{s})$	Cross-term dependence of muecb1.
551	$\text{pmueph1}=0.0$	Cross-term dependence of mueph1.
552	$\text{pvtmp}=0.0 \text{ cm/s}$	Cross-term dependence of vtmp.
553	$\text{pwvth0}=0.0$	Cross-term dependence of wvth0.
554	$\text{pmuesr1}=0.0$	Cross-term dependence of muesr1.
555	$\text{pmuetmp}=0.0$	Cross-term dependence of muetmp.
556	$\text{psub1}=0.0 \text{ 1/V}$	Cross-term dependence of sub1.
557	$\text{psub2}=0.0 \text{ V}$	Cross-term dependence of sub2.
558	$\text{psvds}=0.0$	Cross-term dependence of svds.
559	$\text{psvbs}=0.0$	Cross-term dependence of svbs.
560	$\text{psvgs}=0.0$	Cross-term dependence of svgs.
561	$\text{pfn1}=0.0$	Cross-term dependence of fn1.
562	$\text{pfn2}=0.0$	Cross-term dependence of fn2.
563	$\text{pfn3}=0.0$	Cross-term dependence of fn3.
564	$\text{pfvbs}=0.0$	Cross-term dependence of fvbs.
565	$\text{pnsti}=0.0 \text{ cm}^{-3}$	Cross-term dependence of nsti.
566	$\text{pwsti}=0.0 \text{ m}$	Cross-term dependence of wsti.
567	$\text{pscsti1}=0.0$	Cross-term dependence of scsti1.
568	$\text{pscsti2}=0.0 \text{ 1/V}$	Cross-term dependence of scsti2.
569	$\text{pvthsti}=0.0$	Cross-term dependence of vthsti.

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

570	pmuesti1=0.0	Cross-term dependence of muesti1.
571	pmuesti2=0.0	Cross-term dependence of muesti2.
572	pmuesti3=0.0	Cross-term dependence of muesti3.
573	pnsupsti1=0.0 m	Cross-term dependence of nsupsti1.
574	pnsupsti2=0.0 m	Cross-term dependence of nsupsti2.
575	pnsupsti3=0.0 m	Cross-term dependence of nsupsti3.
576	pcgso=0.0 F/m	Cross-term dependence of cgso.
577	pcgdo=0.0 F/m	Cross-term dependence of cgdo.
578	pjs0=0.0 A/m ²	Cross-term dependence of js0.
579	pjs0sw=0.0 A/m	Cross-term dependence of js0sw.
580	pnj=0.0	Cross-term dependence of nj.
581	pcisbk=0.0 A	Cross-term dependence of cisbk.
582	pclm1=0.0	Cross-term dependence of clm1.
583	pclm2=0.0 1/m	Cross-term dependence of clm2.
584	pclm3=0.0	Cross-term dependence of clm3.
585	pwfc=0.0 m ² F/cm ²	Cross-term dependence of wfc.
586	pgidl1=0.0 A*m/(V ^{3/2} *c ^{1/2})	Cross-term dependence of gidl1.
587	pgidl2=0.0 1/(V ^{1/2} *c ^{3/2} *m)	Cross-term dependence of gidl2.
588	pgleak1=0.0 A/(V ^{3/2} *c ^{1/2})	Cross-term dependence of gleak1.

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

589	$pgleak2=0.0 \ 1/(V^{1/2} * c^{3/2} * m)$	Cross-term dependence of gleak2.
590	$pgleak3=0.0$	Cross-term dependence of gleak3.
591	$pgleak6=0.0 \ V$	Cross-term dependence of gleak6.
592	$pglksd1=0.0$	Cross-term dependence of glksd1.
593	$pglksd2=0.0$	Cross-term dependence of glksd2.
594	$pglkb1=0.0$	Cross-term dependence of glkb1.
595	$pglkb2=0.0$	Cross-term dependence of glkb2.
596	$pnftrp=0.0$	Cross-term dependence of nftrp.
597	$pnfalp=0.0$	Cross-term dependence of nfalp.
598	$ppthrou=0.0$	Cross-term dependence of pthrou.
599	$pvdifffj=0.0 \ V$	Cross-term dependence of vdiffj.
600	$pibpc1=0.0$	Cross-term dependence of ibpc1.
601	$pibpc2=0.0$	Cross-term dependence of ibpc2.
602	$pcgbo=0.0$	Cross-term dependence of cgbo.
603	$pcvdsover=0.0$	Cross-term dependence of cvdsover.
604	$pfalph=0.0$	Cross-term dependence of falph.
605	$pnpext=0.0$	Cross-term dependence of npext.
606	$ppowrat=0.0$	Cross-term dependence of powrat.
607	$prd=0.0$	Cross-term dependence of rd.
608	$prd22=0.0$	Cross-term dependence of rd22.
609	$prd23=0.0$	Cross-term dependence of rd23.

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

610	prd24=0.0	Cross-term dependence of rd24.
611	prdict1=0.0	Cross-term dependence of rdict1.
612	prdov13=0.0	Cross-term dependence of rdov13.
613	prdslp1=0.0	Cross-term dependence of rdslp1.
614	prdvb=0.0	Cross-term dependence of rdvb.
615	prdvd=0.0	Cross-term dependence of rdvd.
616	prdvg11=0.0	Cross-term dependence of rdvg11.
617	prs=0.0	Cross-term dependence of rs.
618	prth0=0.0	Cross-term dependence of rth0.
619	pver=0.0	Cross-term dependence of vover.

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 or 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.

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

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.
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	cjd (F)	Drain-bulk junction capacitance.
22	cjs (F)	Source-bulk junction capacitance.
23	cgg (F)	Intrinsic dQ_g/dV_g .
24	cgd (F)	dQ_g/dV_d .
25	cgs (F)	dQ_g/dV_s .
26	cgb (F)	dQ_g/dV_b .
27	cdg (F)	dQ_d/dV_g .
28	cdd (F)	Intrinsic dQ_d/dV_d .
29	cds (F)	dQ_d/dV_s .
30	cdb (F)	dQ_d/dV_b .
31	csg (F)	dQ_s/dV_g .
32	csd (F)	dQ_s/dV_d .

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

33	css (F)	Intrinsic dQs_dVs.
34	csb (F)	dQs_dVb.
35	cbg (F)	dQb_dVg.
36	cbd (F)	dQb_dVd.
37	cbs (F)	dQb_dVs.
38	cbb (F)	Intrinsic dQb_dVb.
39	cdd_tot (F)	Total dQd_dVd.
40	cgg_tot (F)	Total dQg_dVg.
41	css_tot (F)	Total dQs_dVs.
42	cbb_tot (F)	Total dQb_dVb.
43	id (A)	Resistive drain current.
44	ig (A)	Gate current.
45	is (A)	Resistive source current.
46	ibulk (A)	Resistive bulk current.
47	pwr (W)	Power at operating point.
48	ps0 (V)	Surface potential at source side.
49	psl (V)	Surface potential at drain side.
50	pds (V)	Delta surface potential between psl and ps0.
51	isub (A)	Substrate current Isub.
52	gbds (S)	Substrate trans conductance (dIsub/dVds).
53	gbgs (S)	Substrate trans conductance (dIsub/dVgs).
54	gbbs (S)	Substrate transconductance (dIsub/dVbs).

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

55	igate (A)	Gate current due to tunneling.
56	igates (A)	Tunneling current from gate to source.
57	igateb (A)	Tunneling current from gate to bulk.
58	igated (A)	Tunneling current from gate to drain.
59	igisl (A)	Gate-induced source leakage current.
60	igidl (A)	Gate-induced drain leakage current.
61	ibs (A)	Source-bulk diode current.
62	ibd (A)	Source-drain diode current.
63	cgso (F)	Gate-source overlap capacitance.
64	cgbo (F)	Gate-bulk overlap capacitance.
65	cgdo (F)	Gate-drain overlap capacitance.
66	weff (m)	Effective channel width.
67	leff (m)	Effective channel length.
68	rseff (Ohm)	Effective source resistance.
69	rdeff (Ohm)	Effective drain resistance.
70	rsdrift (Ohm)	The resistance of drift region for source side.
71	rdrift (Ohm)	The resistance of drift region for drain side.
72	gmt (S)	Temp transconductance.

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

HISIM_HV Model (hisim_hv)

ad	I-4	lgidl1	M-403	pglkb1	M-594	sub21	M-206
ad	M-31	lgidl2	M-404	pglkb2	M-595	subld1	I-25
alarm	M-21	lgleak1	M-405	pglksd1	M-592	subld1	M-89
as	I-3	lgleak2	M-406	pglksd2	M-593	subld2	I-26
as	M-30	lgleak3	M-407	pibpc1	M-600	subld2	M-90
bb	M-172	lgleak6	M-408	pibpc2	M-601	svbs	M-201
bgtmp1	M-92	lglkb1	M-411	pjs0	M-578	svbs1	M-202
bgtmp2	M-93	lglkb2	M-412	pjs0sw	M-579	svbslp	M-215
bs1	M-128	lglksd1	M-409	pmuecb0	M-549	svds	M-203
bs2	M-129	lglksd2	M-410	pmuecb1	M-550	svgs	M-200
bvd	M-301	libpc1	M-417	pmueph1	M-551	svgs1	M-211
bvj	M-303	ljs0	M-395	pmuesr1	M-554	svgs1p	M-212
bvs	M-302	ljs0sw	M-396	pmuesti1	M-570	svgs1w	M-214
cbb	OP-38	ll	M-49	pmuesti2	M-571	svgs1wp	M-213
cbb_tot	OP-42	lld	M-50	pmuesti3	M-572	tcjbd	M-263
cbd	OP-36	lln	M-51	pmuetmp	M-555	tcjbdsw	M-264
cbg	OP-35	lmax	M-341	pndep	M-547	tcjbdswg	M-265
cbs	OP-37	lmin	M-342	pnfalp	M-597	tcjbs	M-266
cdb	OP-30	lmuecb0	M-366	pnftrp	M-596	tcjbssw	M-267
cdd	OP-28	lmuecb1	M-367	pninv	M-548	tcjbsswg	M-268

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

cdd_tot	OP-39	lmueph1	M-368	pnj	M-580	temp	M-34
cdg	OP-27	lmuesr1	M-371	pnover	M-534	temp	OP-1
cds	OP-29	lmuesti1	M-387	pnovers	M-532	tnom	M-17
cgb	OP-26	lmuesti2	M-388	pnpext	M-605	tox	M-36
cgbo	M-285	lmuesti3	M-389	pnsti	M-565	tpoly	M-40
cgbo	OP-64	lmuetmp	M-372	pnsbuc	M-537	type	M-1
cgd	OP-24	lndep	M-364	pnsbuc	M-538	vbi	M-55
cgdo	M-284	lnfalp	M-414	pnsbucsti1	M-573	vbisub	M-298
cgdo	OP-65	lnftrp	M-413	pnsbucsti2	M-574	vbox	M-304
cgg	OP-23	lninv	M-365	pnsbucsti3	M-575	vbs	OP-7
cgg_tot	OP-40	lnj	M-397	powrat	M-338	vbsmin	M-307
cgs	OP-25	lnover	M-351	ppgd1	M-545	vdifffj	M-275
cgso	M-283	lnovers	M-349	ppgd3	M-546	vds	OP-6
cgso	OP-63	lnpext	M-421	ppowrat	M-606	vds0	M-159
cisb	M-277	lnsti	M-382	ppthrou	M-598	vdsat	OP-9
cisbk	M-280	lnsubc	M-354	prattemp1	M-107	vdsti	M-158
cit	M-245	lnsubp	M-355	prattemp2	M-108	version	M-3
cj	M-260	lnsubpsti1	M-390	prd	M-607	vfbc	M-45
cjd	OP-21	lnsubpsti2	M-391	prd22	M-608	vfbover	M-288
cjs	OP-22	lnsubpsti3	M-392	prd23	M-609	vgs	OP-5
cjsw	M-261	lod	I-23	prd24	M-610	vmax	M-173

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

cjswg	M-262	lover	I-29	prdict1	M-611	vmaxt1	M-97
clm1	M-192	lover	M-48	prdov13	M-612	vmaxt2	M-98
clm2	M-193	loverld	I-31	prdslp1	M-613	vover	M-174
clm3	M-194	loverld	M-83	prdvb	M-614	voverp	M-175
clm4	M-195	lovers	I-30	prdvd	M-615	vovers	M-176
clm5	M-196	lovers	M-84	prdvgl1	M-616	voversp	M-177
clm6	M-197	lp	M-46	prs	M-617	vth	OP-8
coadv	M-7	lpext	M-58	prth0	M-618	vthsti	M-142
codfm	M-22	lpgd1	M-362	ps	I-5	vtmp	M-178
coflick	M-13	lpgd3	M-363	ps	M-32	vzadd0	M-253
cogidl	M-9	lpowrat	M-422	ps0	OP-48	w	I-1
coign	M-20	lpthrou	M-415	psc1	M-542	w	M-28
coiigs	M-10	lrd	M-423	psc2	M-543	w0	M-134
coiprv	M-5	lrd22	M-424	psc3	M-544	warn	M-300
coisti	M-14	lrd23	M-425	pscp1	M-539	wbgtmp1	M-437
coisub	M-8	lrd24	M-426	pscp2	M-540	wbgtmp2	M-438
coldrift	M-27	lrdict1	M-427	pscp3	M-541	wbinn	M-344
conqs	M-15	lrdov13	M-428	pscsti1	M-567	wcgbo	M-510
coovlp	M-11	lrdslp1	M-429	pscsti2	M-568	wcgdo	M-485
coovlps	M-12	lrdvb	M-430	psl	OP-49	wcgso	M-484
copprv	M-6	lrdvd	M-431	psub1	M-556	wcisbk	M-489

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

corbnet	I-10	lrdvg11	M-432	psub2	M-557	wclm1	M-490
corbnet	M-19	lrs	M-433	psvbs	M-559	wclm2	M-491
corg	I-18	lrth0	M-434	psvds	M-558	wclm3	M-492
corg	M-18	lsc1	M-359	psvgs	M-560	wcvdsover	M-511
corsrd	M-4	lsc2	M-360	pthrou	M-246	weff	OP-66
coselfheat	I-17	lsc3	M-361	pthroub	M-247	weg0	M-439
coselfheat	M-23	lscp1	M-356	pvdifffj	M-599	wfalph	M-512
cosubnode	I-16	lscp2	M-357	pvfbc	M-536	wfc	M-130
cosubnode	M-24	lscp3	M-358	pvfbover	M-533	wfn1	M-469
cosym	M-25	lscsti1	M-384	pvmax	M-528	wfn2	M-470
cotemp	M-26	lscsti2	M-385	pvoover	M-619	wfn3	M-471
cothrml	M-16	lsub1	M-373	pvthsti	M-569	wfvbs	M-472
csb	OP-34	lsub2	M-374	pvtmp	M-552	wgidl1	M-494
csd	OP-32	lsvbs	M-376	pwfc	M-585	wgidl2	M-495
csg	OP-31	lsvds	M-375	pwl2	M-535	wgleak1	M-496
css	OP-33	lsvgs	M-377	pwr	OP-47	wgleak2	M-497
css_tot	OP-41	lvdiffj	M-416	pwsti	M-566	wgleak3	M-498
ctemp	M-279	lvfbc	M-353	pwvth0	M-553	wgleak6	M-499
cth0	M-309	lvfbover	M-350	pzadd0	M-254	wglkb1	M-502
cvb	M-278	lvmax	M-345	qb	OP-13	wglkb2	M-503
cvbk	M-281	lvover	M-435	qb_itr	OP-17	wglksd1	M-500

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cvdsover	M-337	lvthsti	M-386	qd	OP-14	wglksd2	M-501
ddltict	M-293	lvtmp	M-369	qd_itr	OP-18	wibpc1	M-508
ddltmax	M-291	lwfc	M-402	qdftvd	M-310	wibpc2	M-509
ddltslp	M-292	lw12	M-352	qg	OP-15	wjs0	M-486
ddrift	M-297	lwsti	M-383	qg_itr	OP-19	wjs0sw	M-487
divx	M-282	lvvth0	M-370	qme1	M-109	w1	M-52
dly1	M-248	m	I-24	qme2	M-110	w11	M-186
dly2	M-249	mj	M-269	qme3	M-111	w11p	M-187
dly3	M-250	mjsw	M-270	qovsm	M-321	w12	M-188
dlyov	M-251	mjswg	M-271	qs	OP-16	w12p	M-189
dtemp	I-7	mphdfm	M-294	qs_itr	OP-20	w1d	M-53
dtemp	M-35	muecb0	M-160	rbdb	I-14	w1n	M-54
eg0	M-91	muecb1	M-161	rbdb	M-65	wmax	M-339
egig	M-236	mueph0	M-162	rbpb	I-11	wmin	M-340
falph	M-243	mueph1	M-163	rbpb	M-62	wmuecb0	M-457
fn1	M-207	mueph2	M-133	rbpd	I-12	wmuecb1	M-458
fn2	M-208	mueph1	M-179	rbpd	M-63	wmueph1	M-459
fn3	M-209	muephs	M-190	rbps	I-13	wmuesr1	M-462
fvbs	M-210	muephw	M-138	rbps	M-64	wmuesti1	M-478
gbbs	OP-54	mueplp	M-180	rbsb	I-15	wmuesti2	M-479
gbds	OP-52	muepsp	M-191	rbsb	M-66	wmuesti3	M-480

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

gbgs	OP-53	muepwp	M-139	rd	M-44	wmuetmp	M-463
gbmin	M-67	mueslp	M-183	rd2	M-74	wndep	M-455
gds	OP-11	muesr0	M-165	rd20	M-313	wnfalp	M-505
gidl1	M-237	muesr1	M-166	rd21	M-314	wnftrp	M-504
gidl2	M-238	muesr1	M-181	rd22	M-315	wninv	M-456
gidl3	M-239	muesrw	M-182	rd22d	M-316	wnj	M-488
gidl4	M-240	muesti1	M-143	rd23	M-317	wnover	M-442
gidl5	M-241	muesti2	M-144	rd231	M-326	wnovers	M-440
gleak1	M-222	muesti3	M-145	rd23lp	M-327	wnpext	M-513
gleak2	M-223	mueswp	M-141	rd23s	M-328	wnsti	M-473
gleak3	M-224	muetmp	M-164	rd23sp	M-329	wnsuabc	M-445
gleak4	M-225	ndep	M-167	rd24	M-318	wnsuabp	M-446
gleak5	M-226	ndep1	M-184	rd25	M-319	wnsuabpsti1	M-481
gleak6	M-233	ndep1p	M-185	rd26	M-320	wnsuabpsti2	M-482
gleak7	M-234	nf	I-22	rd3	M-75	wnsuabpsti3	M-483
glkb0	M-230	nfalp	M-242	rdeff	OP-69	wpgd1	M-453
glkb1	M-231	nftrp	M-244	rdict1	M-80	wpgd3	M-454
glkb2	M-232	ngcon	I-19	rdict2	M-82	wpowrat	M-514
glkb3	M-235	ninv	M-168	rdov11	M-76	wpthrou	M-506
glksd1	M-227	ninvd	M-169	rdov12	M-77	wrd	M-515
glksd2	M-228	ninvdt1	M-99	rdov13	M-78	wrd22	M-516

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

glksd3	M-229	ninvdt2	M-100	rdrift	OP-71	wrd23	M-517
glpart1	M-221	ninvdw	M-170	rds	M-330	wrd24	M-518
gm	OP-10	ninvdwp	M-171	rdslp1	M-79	wrdict1	M-519
gmbs	OP-12	nj	M-257	rdslp2	M-81	wrdov13	M-520
gmt	OP-72	njsw	M-258	rdsp	M-331	wrdslp1	M-521
ibd	OP-62	nover	M-289	rdtemp1	M-101	wrdvb	M-522
ibpcl	M-219	novers	M-290	rdtemp2	M-102	wrdvd	M-523
ibpc2	M-220	npext	M-59	rdvb	M-312	wrdvg11	M-524
ibs	OP-61	nqsscale	M-252	rdvd	M-311	wrs	M-525
ibulk	OP-46	nrd	I-9	rdvd1	M-322	wrth0	M-526
id	OP-43	nrs	I-8	rdvd1p	M-323	wsc1	M-450
ids	OP-4	nsti	M-136	rdvds	M-324	wsc2	M-451
ig	OP-44	nsubc	M-41	rdvdsp	M-325	wsc3	M-452
igate	OP-55	nsubcdfm	I-37	rdvdsub	M-296	wscp1	M-447
igateb	OP-57	nsubcw	M-131	rdvdtemp1	M-103	wscp2	M-448
igated	OP-58	nsubcwp	M-132	rdvdtemp2	M-104	wscp3	M-449
igates	OP-56	nsubp	M-42	rdvg11	M-305	wscstil	M-475
igidl	OP-60	nsubp0	M-56	rdvg12	M-306	wscsti2	M-476
igisl	OP-59	nsubpstil	M-146	rdvsub	M-295	wsti	M-137
igtemp1	M-94	nsubpsti2	M-147	reversed	OP-3	wstil	M-149
igtemp2	M-95	nsubpsti3	M-148	rs	M-43	wstilp	M-150

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HISIM_HV Model (hisim_hv)

igtemp3	M-96	nsubsub	M-299	rsdrift	OP-70	wstiw	M-156
is	OP-45	nsubwp	M-57	rseff	OP-68	wstiwp	M-157
isnoisy	I-38	ovmag	M-287	rsh	M-60	wsub1	M-464
isub	OP-51	ovslp	M-286	rshg	M-61	wsub2	M-465
js0	M-255	parl2	M-117	rth0	M-308	wsvbs	M-467
js0sw	M-256	pb	M-272	rth0nf	M-336	wsvds	M-466
kappa	M-112	pbgtmp1	M-529	rth0r	M-333	wsvgs	M-468
l	I-2	pbgtmp2	M-530	rth0w	M-334	wvdiffj	M-507
l	M-29	pbsw	M-273	rth0wp	M-335	wvfbc	M-444
lbgtmp1	M-346	pbswg	M-274	rthtemp1	M-105	wvfbover	M-441
lbgtmp2	M-347	pcgbo	M-602	rthtemp2	M-106	wvmax	M-436
lbinn	M-343	pcgdo	M-577	sa	I-34	wvover	M-527
lcgbo	M-418	pcgso	M-576	saref	M-154	wvth0	M-140
lcgdo	M-394	pcisbk	M-581	sb	I-35	wvthsc	M-135
lcgso	M-393	pclm1	M-582	sbref	M-155	wvthsti	M-477
lcisbk	M-398	pclm2	M-583	sc1	M-118	wvtmp	M-460
lclm1	M-399	pclm3	M-584	sc2	M-119	wwfc	M-493
lclm2	M-400	pcvdsover	M-603	sc2b	M-120	wwl2	M-443
lclm3	M-401	pd	I-6	sc3	M-121	wwsti	M-474
lcvdsover	M-419	pd	M-33	sc4	M-122	wwvth0	M-461
ldrift	M-332	pds	OP-50	scpl	M-123	xgl	I-21

Virtuoso Simulator Components and Device Models Reference

HISIM_HV Model (hisim_hv)

ldrifft1	I-27	peg0	M-531	scp2	M-124	xgw	I-20
ldrifft1	M-85	pfalph	M-604	scp21	M-127	xl	M-68
ldrifft1s	I-32	pfn1	M-561	scp22	M-126	xld	M-37
ldrifft1s	M-86	pfn2	M-562	scp3	M-125	xldld	M-72
ldrifft2	I-28	pfn3	M-563	scsti1	M-151	xqy	M-47
ldrifft2	M-87	pfvbs	M-564	scsti2	M-152	xqy1	M-70
ldrifft2s	I-33	pgd1	M-113	scsti3	M-153	xqy2	M-71
ldrifft2s	M-88	pgd2	M-114	sd	I-36	xti	M-259
leff	OP-67	pgd3	M-115	shetemp	OP-2	xti2	M-276
leg0	M-348	pgd4	M-116	slg	M-204	xw	M-69
level	M-2	pgidl1	M-586	slgl	M-216	xwd	M-38
lfalph	M-420	pgidl2	M-587	slglp	M-217	xwdc	M-39
lfn1	M-378	pgleak1	M-588	sub1	M-198	xwdld	M-73
lfn2	M-379	pgleak2	M-589	sub1l	M-205		
lfn3	M-380	pgleak3	M-590	sub1lp	M-218		
lfvbs	M-381	pgleak6	M-591	sub2	M-199		

Virtuoso Simulator Components and Device Models Reference
HISIM_HV Model (hisim_hv)

Surface Potential Based Compact MOSFET Model (spmos)

This chapter contains the following information about the SPMOS model:

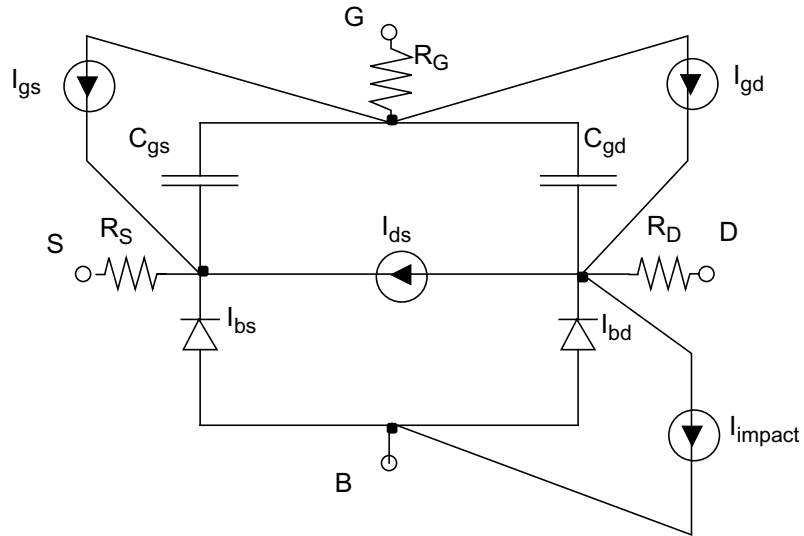
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Virtuoso Simulator Components and Device Models Reference

Surface Potential Based Compact MOSFET Model (spmoss)

- [Parameters with Different Default Values for SPMOS Version 34](#) on page 2321

Equivalent Circuit



Core Model

Lateral Gradient Factor

The lateral field gradient in SPMOS is reduced with surface potential through the following semi-empirical formula:

$$\epsilon = f_0 + B_f x_j$$

where

$$\epsilon = \frac{F_0}{1 + B_f V_{sbx1} + (C_f V_{dsx} + A_f V_{sbx1})(1 + EF \cdot A_f V_{sbx1}) + h_{lo}} + 0.0$$

$$h_{lo} = H_{lo1} \cdot V_{hlo}^2 \left| H_{lo2} \cdot \sqrt{V_{hlo}} \right.$$

$$V_{hlo} = \frac{V_{dsx} \cdot W_{hlo}}{V_{dsx} + W_{hlo} + 10^{-8}}$$

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Surface Potential Based Compact MOSFET Model (spmos)

$$V_{dsx} = \sqrt{V_{hlo}^2 + 0.01} - 0.1$$

$$V_{sbx1} = \text{MAXA}(V_{sbx}, 0, 10^{-4})$$

$$v_{sbx} = V_{sb} + \frac{1}{2}(V_{ds} - V_{dsx})$$

$$\beta_t = (f_0 - 0.01)B_f V_i$$

$$x_f = \frac{\phi_f}{V_t}$$

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 (spmos)

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 $\phi = \phi/V_t$
3. Compute $x_d = x_s + \phi$.

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

$$\Delta_{nd} = \frac{1}{f} \exp(-x_{nd})$$

Virtuoso Simulator Components and Device Models Reference

Surface Potential Based Compact MOSFET Model (spmos)

$$x_{nd} = (2\phi_b + V_{sb} + V_{dse})/V_t$$

Mid-Point Surface Potential

$$\phi_m = \frac{1}{2}(\phi_{ss} + \phi_{sd})$$

The following variables are used:

$$x_m = \frac{1}{2}(x_s + x_d)$$

$$E_m = \sqrt{E_s E_d}$$

$$D_m = \frac{1}{2}(D_s + D_d) + \frac{1}{8}\phi^2 \left(E_m - \frac{2}{G_f^2} \right)$$

$$P_m = x_m - 1 + E_m$$

$$x_{gm} = G_f \sqrt{D_m + P_m}$$

$$S_m = \sqrt{P_m}$$

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:

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Surface Potential Based Compact MOSFET Model (spmos)

$$R_t = \frac{R_{t1}(1 + RB \cdot V_{sbx})}{1 + R_g V_m}$$

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 $\phi = (\phi_{sd} - \phi_{ss})/V_t$.

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)

$$\phi = \phi^{(0)} \cdot \frac{k_m(\bar{D} + d_0)}{d + k_m \bar{D} \alpha_{QM}}$$

where

$$u_{QM} = \frac{q_{QM}}{p_{QM} - q_{QM}/p_{QM}}$$

$$q_{QM} = G_f^2 D_m^{(0)} \Delta e'_g$$

$$\Delta e'_g = g_{QMP} \Delta e_g$$

$$\Delta e_g = q_q x_{gm}^{2/3}$$

$$g_{QMP} = \frac{D_m^{(0)}}{D_m^{(0)} + P_m^{(0)}}$$

$$p_{QM} = 2x_{gm} + G_f^2 [1 - E_m^{(0)} + D_m^{(0)} \alpha_{QM}]$$

$$\alpha_{QM} = 1 + \frac{2\Delta e'_g}{3x_{gm}}$$

$$k_m = \exp(\alpha_{QM} u_{QM} - \Delta e'_g)$$

$$\bar{D} = \frac{D_s + D_d}{2}$$

$$d_0 = 1 - E_m^{(0)} + 2x_{gm}/G_f^2$$

$$d = d_0 + (E_m^{(0)} - 2/G_f^2) u_{QM}$$

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Surface Potential Based Compact MOSFET Model (spmos)

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.

Virtuoso Simulator Components and Device Models Reference
Surface Potential Based Compact MOSFET Model (spmos)

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 2290 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 2294 and [“Intrinsic Charges”](#) on page 2295 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 $u_{sat} < 0.3VSAT$ 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

$$|Q_B| = Q_G - |Q_I|$$

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 modelling 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 modelling, which is accomplished in SPMOS using the symmetrical linearization method.

Virtuoso Simulator Components and Device Models Reference
Surface Potential Based Compact MOSFET Model (spmos)

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

$$F_{sovs} = \ln \left[\frac{1 + \Delta_{Siovs}}{1 + \Delta_{Siovs} \exp(-V_{gs}/V_t)} \right]$$

$$\Delta_{Siovs} = \exp \left[\frac{3.0 + \phi_{sov} + \Psi_{tovs}}{V_t} \right]$$

$$\Psi_{tovs} = MINA(0, V_{oxovs} + GC0 \cdot V_t, 0.05)$$

Drain overlap region contribution

$$I_{gdov} = W \cdot LOV \cdot J_{gdov}$$

$$J_{gdov} = J_0 F_{sovd} \exp \left\{ B_{ov} \cdot \left[-GC1 + \frac{U_{oxovd}}{\chi_B} \left(GC2 + \frac{GC3 \cdot U_{oxovd}}{\chi_B} \right) \right] \right\}$$

$$U_{oxovd} = \sqrt{V_{oxovd}^2 + 10^{-6}}$$

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

$$I_b = a_1 \cdot (V_{ds} - a_3\phi) \cdot \exp \left(-\frac{a_2}{(V_{ds} - a_3\phi)} \right) \cdot I_d$$

$$a_1 = IIA1 + IIA1L \cdot A_L + IIA1W \cdot B_w + IIA1P \cdot A_L \cdot B_w$$

$$a_2 = IIA2 \left[1 + a_4 (\sqrt{V_{sb} + 2\phi_b} - \sqrt{2\phi_b}) \right] \left(\frac{TABS}{T_n} \right)^{TK_IIA2}$$

$$a_3 = IIA3 + IIA3L \cdot A_L$$

$$a_4 = IIA4 + IIA4L \cdot A_L$$

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) SPMOS 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)

$$S_{I_d^2}(f) = S_{I_d^2}(drift) + S_{I_d^2}(diff)$$

$$S_{I_d^2}(drift) = \frac{C_{ox}\phi_t I_d \mu_m}{\alpha_m \gamma_{FN} L_{red}^2 f^{NEF}} \left\{ [NOIC \cdot (V_m - 2 \cdot V_*) + B^* - u_n V_*] \alpha_m \phi + \right. \\ \left. (A^* - 2B^* \cdot V_* + 3 \cdot NOIC \cdot V_*^2) \ln(q_+/q_-) \right\}$$

$$S_{I_d^2}(diff) = \frac{C_{ox}\phi_t^2 I_d \mu_m}{\gamma_{FN} L_{red}^2 f^{NEF}} \{ [(NOIC + u_n) \alpha_m \phi + (B^* - 2 \cdot NOIC \cdot V_*) \ln(q_+/q_-)] \}$$

$$\gamma_{FN} = 10^{10} [m^{-1}]$$

$$V_* = \phi_t \left(1 + \frac{G}{2\sqrt{x_m + 10^{-6}}} \right)$$

$$A^* = NOIA \cdot q^2 / C_{ox}^2$$

$$B^* = NOIB \cdot q / C_{ox}$$

$$u_n = (A^* - B^* \cdot V_* + NOIC \cdot V_*^2) / (q_+ q_-)$$

$$q_+ = V_* + V_m + \alpha_m \phi$$

$$q_- = V_* + V_m - \alpha_m \phi$$

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 Surface Potential Based Compact MOSFET Model (spmos)

If SW_FLICKER is set to 1 then

$$S_{I_d^2} = \frac{KF \cdot g_m^2}{C_{ox} WL f^{NEF}}$$

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 $V_{oxovd} < 0$

$$I_{GIDL} = -A_{GIDL0} V_{db} V_{oxovd} V_{tovd} \exp\left(-\frac{B_{GIDL0}}{V_{tovd}}\right)$$

$$A_{GIDL0} = 10^{13} \cdot AGIDL \cdot W_{eff} L_{OV}$$

$$B_{GIDL0} = BGIDL \cdot (1 + dt \cdot TK_BGIDL)$$

$$V_{tovd} = \sqrt{V_{oxovd}^2 + CGIDL^2 \cdot V_{db}^2 + 10^{-6}}$$

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,

$$C_{ox} = C_{ox}(L + 10^{-6} \cdot DLQ)(W + 10^{-6} \cdot DWQ)$$

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

$$\mu_E = MU1 \left(1 + \frac{MU1W}{W_{\mu m}} \right)$$

$$\theta_{MU} = MU2 \left(1 + \frac{MU3}{W_{\mu m}} \right)$$

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 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° to 150°)

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

$$MU0 = MU0(T_n) \left(\frac{T_n}{TABS} \right)^{n_{\mu 0}}$$

$$n_{\mu 0} = TK_MU0 + \frac{\Delta T}{T_n} \left(\frac{TK_MUL}{L_{\mu m}} + \frac{TK_MUW}{W_{\mu m}} + \frac{TK_MUP}{W_{\mu m} L_{\mu m}} \right)$$

$$\theta_{mu} = \theta_{mu}(T_n) \left(\frac{T_n}{TABS} \right)^{TK_THM}$$

$$\mu_E = \mu_E(T_n) \frac{1 + TK_MU1 \exp(\Delta T/20)}{1 + TK_MU1}$$

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Surface Potential Based Compact MOSFET Model (spmos)

$$X_{cor} = X_{cor}(T_n) \left(\frac{T_n}{TABS} \right)^{n_{\mu 0}}$$

$$CS = CS(T_n) \left(\frac{T_n}{TABS} \right)^{TK_CS}$$

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 33-1 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

Virtuoso Simulator Components and Device Models Reference
Surface Potential Based Compact MOSFET Model (spm0s)

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 33-2 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.

Virtuoso Simulator Components and Device Models Reference
Surface Potential Based Compact MOSFET Model (spmoss)

Table 33-3 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

$$DL_{\mu m} = DLO + DLL \cdot A_L + DLW \cdot B_W$$

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, $P_w=1/4$.

Virtuoso Simulator Components and Device Models Reference
Surface Potential Based Compact MOSFET Model (spmoss)

Table 33-4 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

$$X_{cor} = \max\{X_{cor}, 0\}$$

Virtuoso Simulator Components and Device Models Reference
Surface Potential Based Compact MOSFET Model (spmoss)

Table 33-5 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 33-6 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
Surface Potential Based Compact MOSFET Model (spmoss)

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]

$$a_x = \min\{20, \max\{2, a_x\}\}$$

Virtuoso Simulator Components and Device Models Reference
Surface Potential Based Compact MOSFET Model (spmos)

Table 33-7 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 33-8 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	$-AF0 \cdot P_L^2 L_{CLAMP, \mu m}^2$	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	$-CF0 \cdot P_L^2 L_{CLAMP, \mu m}^2$	10
KL	μm^2	Scaling parameter for C_{LW}	0	$-KL0$ (See Note ²)	KLO

Virtuoso Simulator Components and Device Models Reference
Surface Potential Based Compact MOSFET Model (spmoss)

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

$$\frac{\partial}{\partial V_{dsx}} \left(\frac{F_0}{f_0} - 1 - B_f V_{sbx1} \right) > 0$$

$$KLO = \min \left\{ 3.6L_{CLAMP, \mu m}^2, 0.9L_{CLAMP, \mu m} / A_{mr} \right\}$$

Table 33-9 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.

Virtuoso Simulator Components and Device Models Reference
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
IT0		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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Surface Potential Based Compact MOSFET Model (spmpos)

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	$\mu m / \sqrt{1/2}$	Substrate current scaling parameter	0	-1	1
IIA1P	$\mu m / \sqrt{1/2}$	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.

Virtuoso Simulator Components and Device Models Reference

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 $type=n$ Transistor type.
Possible values are n or p.
- 2 i_d (A) Resistive drain current.
- 3 v_{gs} (V) Gate-source voltage.
- 4 v_{ds} (V) Drain-source voltage.
- 5 v_{bs} (V) Bulk-source voltage.
- 6 v_{th} (V) Threshold voltage.
- 7 v_{dsat} (V) Drain-source saturation voltage.
- 8 g_m (S) Common-source transconductance.
- 9 g_{ds} (S) Common-source output conductance.
- 10 c_{gs} (F) Gate-source capacitance.
- 11 c_{gd} (F) Gate-drain capacitance.
- 12 c_{gate} (F) Gate-Ground capacitance.
- 13 r_{on} (Ω) On-resistance.
- 14 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

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	l	I-2	tox	M-5	vth	OP-6
cgate	OP-12	l	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 substate, -1 = same as substate, 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 $bi0$.

Virtuoso Simulator Components and Device Models Reference

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 `trsr=0 1/C` Temperature parameter for source resistance.
- 80 `trdr=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)

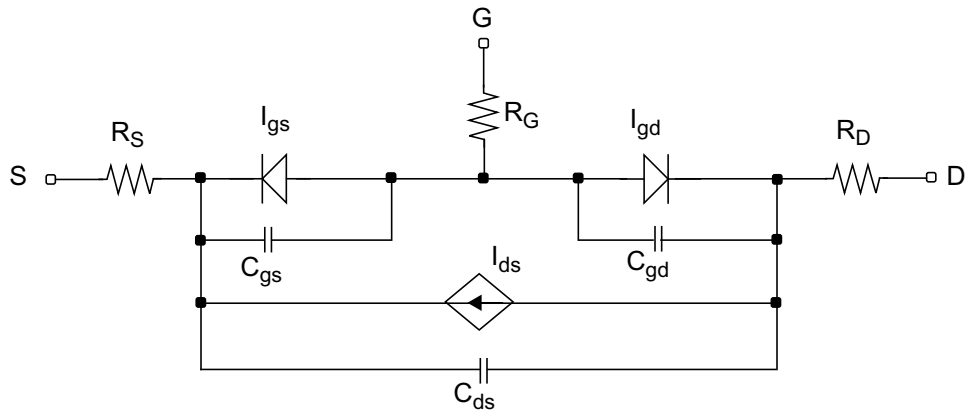
GaAs Model (gaas)

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 2340
- [Drain Current for the Triode Region](#) on page 2340
- [Drain Current for the Saturation Region](#) on page 2341
- [Gate Junction Currents](#) on page 2341
- [Gate Junction Capacitance](#) on page 2342
- [Temperature Effect](#) on page 2343
- [Noise Model](#) on page 2344
- [Scaling Effects](#) on page 2345
- [Component Statements](#) on page 2345

Virtuoso Simulator Components and Device Models Reference

GaAs Model (gaas)



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

$$C_{GS(V)} = \begin{cases} C_{gs, Fwd} & \text{if } V_{DS} \geq 1/\alpha \\ cgs & \text{if } V_{DS} \leq -1/\alpha \\ T_{fs} C_{gs, Fwd} + T_{fd} cgs & \text{otherwise} \end{cases}$$

$$C_{GD(V)} = \begin{cases} cgd & \text{if } V_{DS} \geq 1/\alpha \\ C_{gd, Fwd} & \text{if } V_{DS} \leq -1/\alpha \\ T_{fs} cgd + T_{fd} C_{gd, Fwd} & \text{otherwise} \end{cases}$$

where

$$C_{GS, Fwd} = \begin{cases} \frac{cgs V_{GST}}{2\sqrt{1 - V_{ps}/pb} \sqrt{V_{GST}^2 + \delta^2}} & \text{if } V_{ps} \leq fc * pb \\ \frac{cgs V_{GST}}{2\sqrt{1 - fc} \sqrt{V_{GST}^2 + \delta^2}} & \text{otherwise} \end{cases}$$

$$C_{GD, Fwd} = \begin{cases} \frac{cgd V_{GDT}}{2\sqrt{1 - V_{pd}/pb} \sqrt{V_{GDT}^2 + \delta^2}} & \text{if } V_{pd} \leq fc * pb \\ \frac{cgd V_{GDT}}{2\sqrt{1 - fc} \sqrt{V_{GDT}^2 + \delta^2}} & \text{otherwise} \end{cases}$$

$$V_{ps} \equiv \frac{1}{2}[V_{GS} + vto + \sqrt{V_{GST}^2 + \delta^2}]$$

$$V_{pd} \equiv \frac{1}{2}[V_{GD} + vto + \sqrt{V_{GDT}^2 + \delta^2}]$$

$$T_{fs} = \frac{1}{4}[2 + 3\alpha V_{DS} - (\alpha V_{DS})^3]$$

$$T_{fd} = 1 - T_{fs}$$

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 | <code>area=1</code> | Junction area factor. |
| 2 | <code>m=1</code> | Multiplicity factor. |
| 3 | <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

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	<code>n=1</code>	Emission coefficient for the gate junction.
13	<code>imelt=`imax' A</code>	Explosion current (*area).
14	<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> .

Junction capacitance model parameters

15	<code>capmod=2</code>	Charge model selector.
16	<code>cgs=0 F</code>	Gate-source zero-bias junction capacitance (*area).
17	<code>cgd=0 F</code>	Gate-drain zero-bias junction capacitance (*area).
18	<code>pb=1 V</code>	Gate junction potential.
19	<code>fc=0.5</code>	Junction capacitor forward-bias threshold.
20	<code>delta=0.2 V</code>	Gate capacitance pinch-off transition width.

Temperature effects parameters

21	<code>tnom (C)</code>	Parameters measurement temperature. Default set by options.
22	<code>trise=0 C</code>	Temperature rise from ambient.
23	<code>x_{ti}=3</code>	Temperature exponent for effect on <code>i_s</code> .

Operating region warning control parameters

24	<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> .
25	<code>imax=1 A</code>	Maximum allowable current (*area).
26	<code>b_{vj}=∞ V</code>	Junction reverse breakdown voltage.

Virtuoso Simulator Components and Device Models Reference

GaAs Model (gaas)

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		

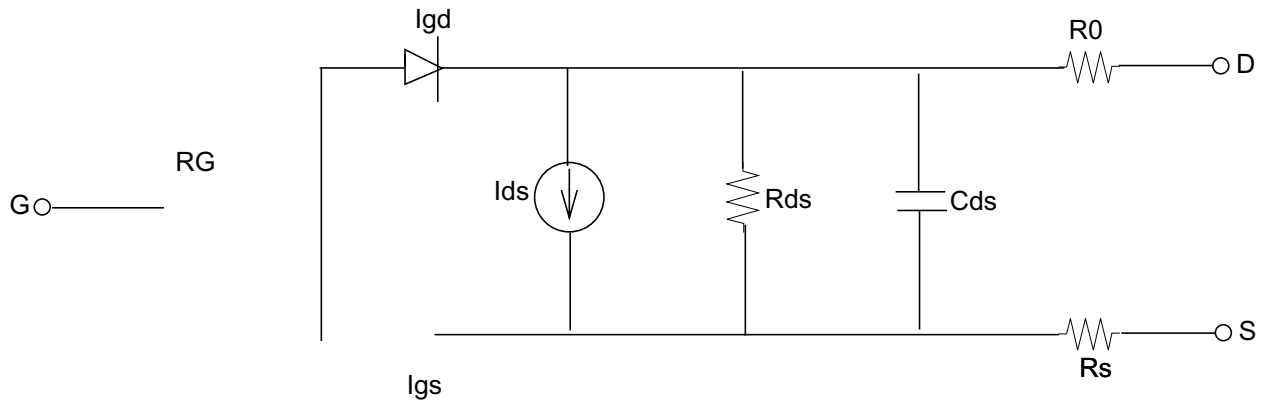
TriQuint Owned Models (tom2 and tom3)

The TOM2 and TOM3 models are developed by TriQuint. This chapter contains the following information for the two models:

- [Circuit Diagrams](#) on page 2352
- [Channel Current Ids](#) on page 2353
- [Gate Current Ig](#) on page 2354
- [Gate Capacitance](#) on page 2355
- [Temperature Effect](#) on page 2358
- [Noise Model](#) on page 23590
- [Scaling Effects](#) on page 2359
- [Component Statements](#) on page 2360

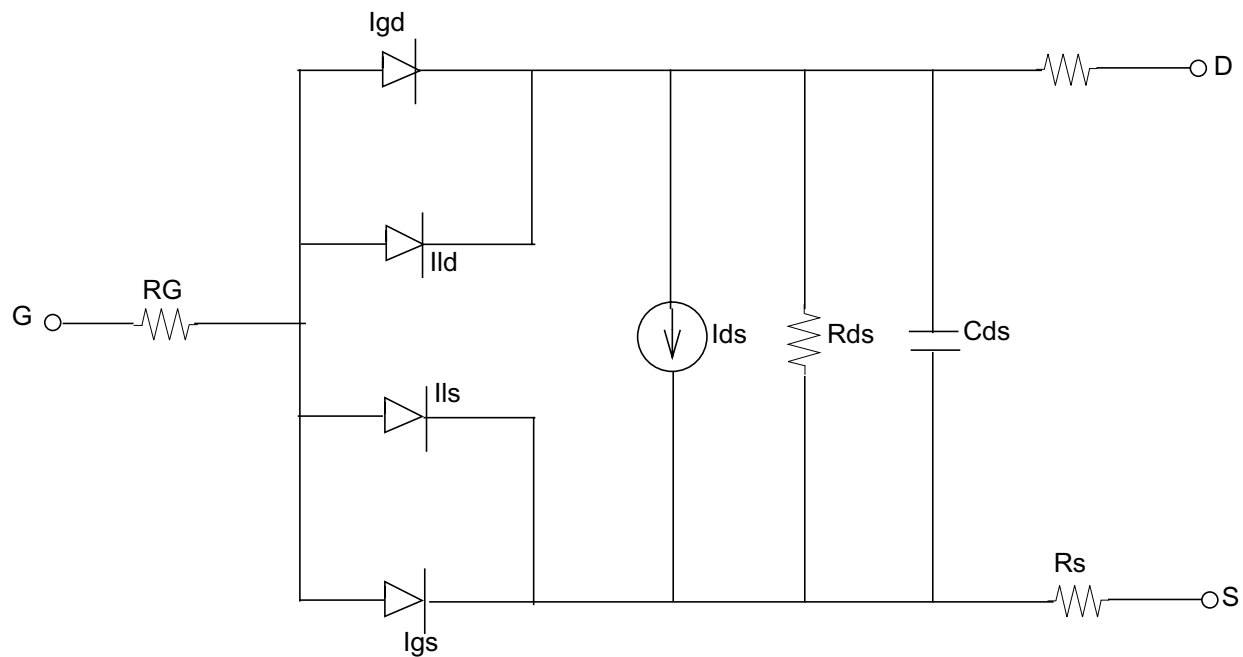
Circuit Diagrams

TOM2

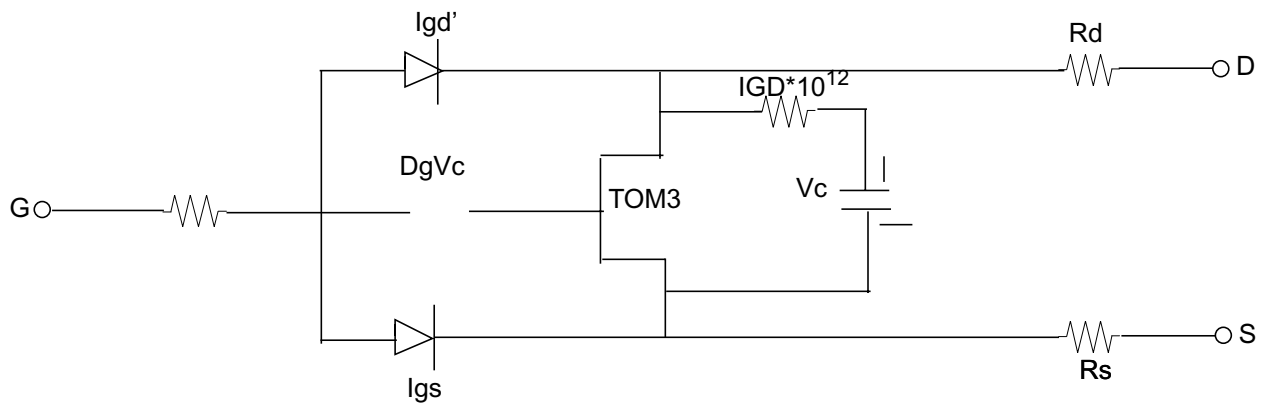


TOM3

Spectre Implementation



TOM3 with SubCircuit



Channel Current Ids

TOM2

$$I_{DS} = \frac{I_{ds0}}{1 + \delta V_{ds} I_{ds0}}$$

where

$$I_{ds0} = \beta V_{gsteff}^Q \frac{\alpha V_{ds}}{\sqrt{(\alpha V_{ds})^2 + 1}}$$

TOM3

$$I_{DS} = I_0(1 + \lambda V_{ds})$$

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 I_g

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

$$I_{gs} = I_s \left(e^{\frac{V_{gs}}{\eta V_T}} - 1 \right)$$

$$I_{gd} = I_s \left(e^{\frac{V_{gd}}{\eta V_T}} - 1 \right)$$

$$I_{ls} = I_{LK} \left(1 - e^{\frac{-V_{gsi}}{\phi LK}} \right)$$

$$I_{ld} = I_{LK} \left(1 - e^{\frac{-V_{gdi}}{\phi LK}} \right)$$

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

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

$$Q_{GG} = Q_{GL}f_T + Q_{GH}(1 - f_T) + Q_{GG0}(V_{GSI} + V_{GDI})$$

$$C_{GS} = C_{GSL}f_T + C_{GSH}(1 - f_T) + (Q_{GL} - Q_{GH})\left(\frac{\partial f_T}{\partial V_{GSI}}\right) + Q_{GG0}$$

$$C_{GD} = C_{GDL}f_T + C_{GDH}(1 - f_T) + (Q_{GL} - Q_{GH})\left(\frac{\partial f_T}{\partial V_{GDI}}\right) + Q_{GG0}$$

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

$$V_{st}(T) = V_{st}(T_{nom}) + T_{V_{st}}(T - T_{nom})$$

$$M_{st}(T) = M_{st}(T_{nom}) + T_{M_{st}}(T - T_{nom})$$

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

$$V'_{DS} = \text{MAX}(V_{DS}, V_{DSAT})$$

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*.

Component Statements

TOM2

Sample Instance Statement

```
mt1 (2 1 0) tom2mos area=1 region=fwd
```

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/V2` Transconductance parameter.
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.

Virtuoso Simulator Components and Device Models Reference

TriQuint Owned Models (tom2 and tom3)

Junction diode model parameters

14	<code>is=1e-14 A</code>	Gate diode saturation current (*area).
15	<code>n=1</code>	Emission coefficient for the gate junction.
16	<code>imelt=`imax' A</code>	Explosion current (*area).
17	<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> .

Junction capacitance model parameters

18	<code>capmod=2</code>	Charge model selector.
19	<code>cgs=0 F</code>	Gate-source zero-bias junction capacitance (*area).
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> .

Virtuoso Simulator Components and Device Models Reference

TriQuint Owned Models (tom2 and tom3)

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>trsl=0 1/C</code>	Temperature parameter for source resistance.
35	<code>trdl=0 1/C</code>	Temperature parameter for drain resistance.
36	<code>trgl=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	<code>imax=1 A</code>	Maximum allowable current (*area).
40	<code>bvj=∞ V</code>	Junction reverse breakdown voltage.

Noise model parameters

41	<code>kf=0</code>	Flicker (1/f) noise coefficient.
42	<code>af=1</code>	Flicker (1/f) noise exponent.
43	<code>kfd=0</code>	Flicker noise (1/f) coefficient for gate diodes.
44	<code>afg=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.

Virtuoso Simulator Components and Device Models Reference

TriQuint Owned Models (tom2 and tom3)

Operating-Point Parameters

1	<code>type=n</code>	Transistor type. Possible values are <code>n</code> or <code>p</code> .
2	<code>region=fwd</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>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.
13	<code>cds (F)</code>	Drain-source capacitance.
14	<code>pwr (W)</code>	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.

Virtuoso Simulator Components and Device Models Reference

TriQuint Owned Models (tom2 and tom3)

af	M-42	cgstce	M-38	kfd	M-43	trgl	M-36
afg	M-44	delta	M-6	m	I-2	trise	I-4
alpha	M-3	dskip	M-17	minr	M-13	trs1	M-34
alphatce	M-31	eg	M-28	n	M-15	type	M-1
area	I-1	gamma	M-5	nd	M-9	type	OP-1
beta	M-4	gammatc	M-33	ng	M-8	vbi	M-22
betatce	M-32	gds	OP-9	pwr	OP-14	vbitc	M-30
bvj	M-40	gm	OP-8	q	M-7	vdelta	M-24
capmod	M-18	id	OP-5	rd	M-10	vds	OP-4
cds	M-21	ids	OP-7	region	I-5	vgs	OP-3
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	trdl	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.

Virtuoso Simulator Components and Device Models Reference

TriQuint Owned Models (tom2 and tom3)

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. |
| 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. |
|---|------------|--------------------|

Virtuoso Simulator Components and Device Models Reference

TriQuint Owned Models (tom2 and tom3)

3	$\alpha=2$ 1/V	Knee-voltage parameter.
4	$\beta=0.1$ A/V ²	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	$v_{st}=1$ V	Subthreshold slope.
10	$m_{st}=0$ 1/V	Subthreshold slope darin parameter.

Parasitic resistance parameters

11	$r_d=0$ Ω	Drain resistance (/area).
12	$r_s=0$ Ω	Source resistance (/area).
13	$r_g=0$ Ω	Gate resistance (/area).
14	$minr=0.1$ Ω	Minimum source/drain/gate resistance.

Junction diode model parameters

15	$i_s=0.0$ A	Gate diode saturation current (*area).
16	$n=1$	Emission coefficient for the gate junction.
17	$i_{melt}='imax'$ A	Explosion current (*area).
18	$dskip=yes$	Use simple piece-wise linear model for diode currents below $0.1*i_{abstol}$. Possible values are no or yes.
19	$ilk=0.0$ A	Gate leakage diode saturation current (*area).

Virtuoso Simulator Components and Device Models Reference

TriQuint Owned Models (tom2 and tom3)

20 `plk=1.0 V` Gate leakage diode potential.

Junction capacitance model parameters

21 `cds=0 F` Drain-to-source capacitance.

22 `tau=0 s` Conduction current delay time.

23 `qgqh=0.0` Charge parameter.

24 `qgsh=0.0` Charge parameter.

25 `qgdh=0.0` Charge parameter.

26 `qgio=1.0e-06` Charge parameter.

27 `qgql=0.0` Charge parameter.

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 `xti=0` Temperature exponent for effect on `is`.

35 `eg=1.11 V` Energy band gap.

36 `vtotc=0 V/C` Temperature coefficient for `vto`.

37 `alphatce=0 1/C` Temperature coefficient for `alpha`.

38 `betatce=0 1/C` Temperature coefficient for `beta`.

Virtuoso Simulator Components and Device Models Reference

TriQuint Owned Models (tom2 and tom3)

39	<code>gammatc=0</code>	1/C	Temperature coefficient for <code>gamma</code> .
40	<code>trsl=0</code>	1/C	Temperature parameter for source resistance.
41	<code>trdl=0</code>	1/C	Temperature parameter for drain resistance.
42	<code>trgl=0</code>	1/C	Temperature parameter for gate resistance.
43	<code>vsttc=0</code>	1/C	Temperature coefficient for <code>Vst</code> .
44	<code>msttc=0</code>	1/C	Temperature coefficient for <code>Mst</code> .

Operating region warning control parameters

45	<code>imax=1</code>	A	Maximum allowable current (*area).
46	<code>bvj=∞</code>	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> .

Virtuoso Simulator Components and Device Models Reference

TriQuint Owned Models (tom2 and tom3)

3	v_{gs} (V)	Gate-source voltage.
4	v_{ds} (V)	Drain-source voltage.
5	i_d (A)	Drain current.
6	i_g (A)	Gate current.
7	i_{ds} (A)	Drain-to-source current.
8	g_m (S)	Common-source transconductance.
9	g_{ds} (S)	Common-source output conductance.
10	v_{th} (V)	Threshold voltage.
11	c_{gs} (F)	Gate-source capacitance.
12	c_{gd} (F)	Gate-drain capacitance.
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.

a_f M-48

i_d OP-5

pwr OP-17

r_g M-13

Virtuoso Simulator Components and Device Models Reference

TriQuint Owned Models (tom2 and tom3)

afd	M-50	ids	OP-7	q	M-7	rs	M-12
alpha	M-3	ig	OP-6	qd	OP-15	tau	M-22
alphatce	M-37	ilk	M-19	qg	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	trg1	M-42
betatce	M-38	is	M-15	qgcl	M-30	trise	I-5
bvj	M-46	isnoisy	I-3	qgdh	M-25	trs1	M-40
cds	M-21	k	M-8	qggb	M-31	type	M-1
cds	OP-13	kf	M-47	qggo	M-32	type	OP-1
cgd	OP-12	kfd	M-49	qgio	M-26	vds	OP-4
cgs	OP-11	lambda	M-6	qgqh	M-23	vgs	OP-3
dskip	M-18	m	I-2	qgql	M-27	vst	M-9
eg	M-35	minr	M-14	qgsh	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

Virtuoso Simulator Components and Device Models Reference

TriQuint Owned Models (tom2 and tom3)

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 2375
 - [Equivalent Circuit](#) on page 2375
 - [Model Features](#) on page 2375
 - [Channel Width and Length](#) on page 2376
 - [Drain and Source Parasitic Resistance](#) on page 2376
 - [Threshold Voltage](#) on page 2377
 - [Effective Mobility](#) on page 2377
 - [Unified Electron Sheet Charge Density Per Unit Area](#) on page 2378
 - [Channel Conductance](#) on page 2378
 - [Saturation Voltage](#) on page 2379
 - [Channel Current](#) on page 2379
 - [Kink Effect Current](#) on page 2380
 - [Subthreshold Leakage Current](#) on page 2380
 - [Parasitic Resistance Dependence](#) on page 2381
 - [Gate-Drain/Source Resistance](#) on page 2382
 - [Temperature Dependence](#) on page 2382
 - [Capacitance](#) on page 2382
 - [ACM Option](#) on page 2387
 - [Scaling Effects](#) on page 2387

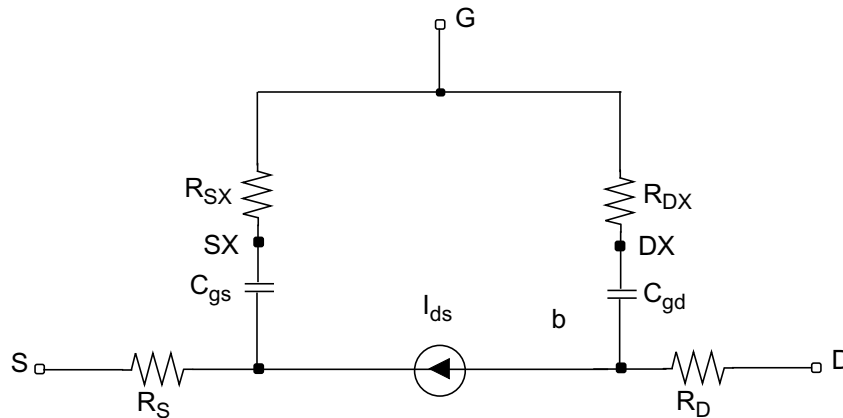
Virtuoso Simulator Components and Device Models Reference

RPI TFT Models

- [Component Statements](#) on page 2387
- [Amorphous-Si TFT Model \(ATFT\)](#) on page 2399
 - [Equivalent Circuit](#) on page 2399
 - [Model Features](#) on page 2399
 - [Drain Current](#) on page 2400
 - [Temperature Dependence](#) on page 2403
 - [Capacitance](#) on page 2403
 - [Scaling Effects](#) on page 2404
 - [Component Statements](#) on page 2404

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

$$w = \begin{cases} w \cdot Wm1t + Xw - 2Wd, & \text{if ACM is given} \\ w, & \text{if ACM is not given} \end{cases}$$

$$l = \begin{cases} l \cdot Lm1t + Xl - 2Ld, & \text{if ACM is given} \\ l, & \text{if ACM is not given} \end{cases}$$

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,

$$rd = \begin{cases} (Ld + Ldif) \cdot rd/w + nrd \cdot rsh + rdc, & \text{if nrd is given} \\ rdc + \frac{Hdif \cdot rsh + (Ld + Ldif) \cdot rd}{w}, & \text{otherwise} \end{cases}$$

$$rs = \begin{cases} (Ld + Ldif) \cdot rs/w + nrs \cdot rsh + rsc, & \text{if nrd is given} \\ rsc + \frac{Hdif \cdot rsh + (Ld + Ldif) \cdot rs}{w}, & \text{otherwise} \end{cases}$$

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

$$\eta_f = \frac{\eta_a}{1 + \eta_a \cdot \text{meta} \cdot \frac{i1}{1 + i1}}$$

$$i1 = \text{Kinkfac} \cdot (V_{ds} - V_{dse}) \cdot e^{-vkink/(V_{ds} - V_{dse})}$$

$$\text{Kinkfac} = A_{kink} \cdot w/l$$

$$A_{kink} = \frac{(lkink/l)^{mkink}}{vkink}$$

$$V_{dse} = \frac{V_{ds}}{\left(1 + \left(\frac{V_{ds}}{V_{dsat}}\right)^{mss}\right)^{1/mss}}$$

where

$$V_{sat} = V_{gte}$$

$$n_s = 2 \cdot n_0 \cdot \log\left(1 + \frac{1}{2} \cdot e^{\frac{V_{gt}}{\eta_f \cdot V_t}}\right)$$

$$n_0 = \frac{\epsilon_{SiO_2} \cdot \eta_a \cdot V_t}{2 \cdot q \cdot tox}$$

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

$$V_{DSAT} = \frac{I_{sat}}{g_{ch}}$$

$$I_{sat} = \frac{g_{chi} \cdot V_{gte}}{\left(1 + \frac{V_{gte}}{V_l}\right) + g_{chi} \cdot RSS + \sqrt{1 + 2 \cdot RSS \cdot g_{chi} + (1 + V_{gte}/V_l)^2}}$$

$$V_l = \frac{vmax \cdot l}{mueff}$$

Channel Current

$$i_{choo} = \frac{g_{ch} \cdot V_{ds} \cdot (1 + lambda \cdot V_{ds})}{\left[1 + \left(\frac{V_{ds}}{V_{dsat}}\right)^{me}\right]^{1/(me)}}$$

$$V_{satnew} = \frac{2 \cdot vmax \cdot l \cdot q \cdot (n_s - i_{choo} \cdot CRC)}{q \cdot (n_s - i_{choo} \cdot CRC) \cdot mueff + 2 \cdot vmax \cdot l \cdot \frac{C_{ox}}{\alpha_{sat}}}$$

where

$$C_{ox} = \frac{\epsilon_{SiO_2}}{tox}$$

If lsubmod=1

lambda=0

$$I_{ds} = \frac{i_{choo}}{1 - deltal/l}$$

$$deltal = \frac{ls \cdot \ln\left(1 + \frac{V_{disi} - V_{dsenew}}{vp}\right) / (\ln(10))}{1 + \frac{V_{dsenew}}{V_p} + w \cdot CRL \cdot mueff \cdot V_{dsenew}}$$

$$V_{disi} = V_{ds} - i_{choo} \cdot RT$$

$$V_{dsenew} = \frac{V_{disi}}{\left(1 + \left(\frac{V_{disi}}{V_{satnew}}\right)^{mss}\right)^{1/mss}}$$

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

$$I_{leak} = clk \cdot w \cdot \left[e^{\frac{blk \cdot V_{ds}}{V_t}} - 1 \right] \cdot [X_{TFE} + X_{TE}] + I_{diode}$$

$$X_{TFE} = \frac{X_{TFE, lo} \cdot X_{TFE, hi}}{X_{TFE, lo} + X_{TFE, hi}}$$

$$X_{TE} = e^{-W_C}$$

$$W_C = (E_c - E_t)/(k \cdot T) = 0.55 eV / (k \cdot T)$$

$$X_{TFE, lo} = \left\{ \begin{array}{ll} \frac{4\sqrt{\pi}}{3} \cdot f \cdot e^{\left(\frac{4}{27} \cdot f^2 - W_C\right)} & \text{for } f \leq f_{lo} \\ X_{TFE, lo}(f_{lo}) \cdot e^{\left[\left(\frac{1}{f_{lo}} + \frac{8}{27} \cdot f_{lo}\right) \cdot (f - f_{lo})\right]} & \text{for } f > f_{lo} \end{array} \right.$$

Virtuoso Simulator Components and Device Models Reference

RPI TFT Models

$$f = \frac{1}{2} \cdot FMIN \cdot \left(1 + \frac{f_0}{FMIN} + \sqrt{\text{delta}^2 + \left(\frac{f_0}{FMIN} - 1 \right)^2} \right)$$

where FMIN=0.0001

$$f_0 = \left(\frac{V_{ds}}{dd} - \frac{V_{gs} - vfb}{dg} \right) / F_0$$

where

$$F_0 = (k \cdot T)^{3/2} \cdot \frac{4}{3} \cdot \frac{2\pi\sqrt{2m}}{qh}$$

$$m = 0.27 \cdot m_0$$

$$f_{lo} = \frac{3}{2} \cdot (\sqrt{W_C + 1} - 1)$$

$$X_{TFE, hi} = \begin{cases} \frac{2 \cdot W_c}{3} \cdot e^{\left(1 - \frac{2 \cdot W_c}{3}\right)} & \text{for } f \leq f_{hi} \\ \left(1 - \frac{W_c}{2 \cdot f}\right)^{-1} \cdot e^{\left(\frac{-W_c^{3/2}}{f}\right)} & \text{for } f > f_{hi} \end{cases}$$

$$f_{hi} = 3 \cdot \left(\frac{W_C^{3/2}}{2 \cdot W_C - 3} \right)$$

$$I_{diode} = i00 \cdot w \cdot e^{\left(\frac{eb}{k \cdot T}\right)} \cdot \left[1 - e^{\left(\frac{-V_{ds}}{V_t}\right)} \right]$$

Parasitic Resistance Dependence

If intdsnod=0 , extrinsic characteristics are used.

$$RSS = rs$$

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RPI TFT Models

$$RT = rs + rd$$

$$CRC = C_{ox} \cdot rd/q$$

$$CRL = C_{ox} \cdot rs/l$$

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

$$V_{thx} = vto - dvto \cdot (T - T_{nom})$$

$$\mu_1 = mu1 + dmu1 \cdot (T - T_{nom})$$

$$\alpha_{sat} = asat - \frac{lasat}{l} - dasat \cdot (T - T_{nom})$$

Capacitance

When $capmod=0$,

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RPI TFT Models

$$C_{gs} = C_f + \frac{2}{3} \cdot C_{gcs} \cdot \left[1 - \left(\frac{V_{dsat} - V_{dse}}{2 \cdot V_{dsat} - V_{dse}} \right)^2 \right]$$

$$C_{gd} = C_f + \frac{2}{3} \cdot C_{gcd} \cdot \left[1 - \left(\frac{V_{dsat}}{2 \cdot V_{dsat} - V_{dse}} \right)^2 \right]$$

$$C_f = \frac{1}{2} \cdot \epsilon_{si} \cdot w$$

$$C_{gcs} = \frac{w \cdot l \cdot \epsilon_{SiO_2} / tox}{1 + etac0 \cdot e^{\left(-\frac{V_{gt}}{etac0 \cdot V_t} \right)}}$$

$$C_{gcd} = \frac{w \cdot l \cdot \epsilon_{SiO_2} / tox}{1 + \eta_{cd} \cdot e^{\left(-\frac{V_{gt} - V_{dse}}{\eta_{cd} \cdot V_t} \right)}}$$

$$\eta_{cd} = etac0 + etac00 \cdot V_{dse}$$

$$V_{dsex} = \frac{V_{ds}}{\left(1 + \left(\frac{V_{ds}}{V_{dsat}} \right)^{mc} \right)^{1/mc}}$$

$$V_{gt} = V_{gs} - V_{thx}$$

When capmod=1

If ZEROC=1,

$$C_{gcs} = C_{gcd} = 0$$

If ZEROC=0 ,

$$C_{gs} = C_{gd} = 0 \text{ if } V_{gt} < -\frac{\phi_i}{2} \text{ where } \phi_i = 0.6$$

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RPI TFT Models

$$C_{gs} = w \cdot l \cdot \epsilon_{SiO_2} / tox \cdot \left(\frac{4 \cdot V_{gt}}{3 \cdot phi} + \frac{2}{3} \right) C_{gd} = 0 \text{ if } \frac{-phi}{2} \leq V_{gt} < 0$$

$$\text{if } V_{gt} < -\frac{phi}{2}$$

$$\left(\begin{array}{l} C_{gs} = \frac{2 \cdot w \cdot l \cdot \epsilon_{SiO_2}}{3 \cdot tox}, C_{gd} = 0, V_{ds} \geq V_{dsat} \\ C_{gs} = \frac{2 \cdot w \cdot l \cdot \epsilon_{SiO_2}}{3 \cdot tox} \cdot \left[1 - \left(\frac{V_{dsat} - V_{dse}}{2 \cdot V_{dsat} - V_{dse}} \right)^2 \right], C_{gd} = \frac{2 \cdot w \cdot l \cdot \epsilon_{SiO_2}}{3 \cdot tox} \cdot \left[1 - \left(\frac{V_{dsat}}{2 \cdot V_{dsat} - V_{dse}} \right)^2 \right] \\ V_{ds} < V_{dsat} \end{array} \right)$$

When capmod=2

Charge conservation capacitance model

$$V_{gsteff, cv} = noff \cdot eta \cdot V_t \cdot \log \left(1 + e^{\left(\frac{V_{gs} - V_{thx} - voffcv}{noff \cdot eta \cdot V_t} \right)} \right)$$

$$V_{gs} = V_{sxs} \text{ for Qs evaluation}$$

$$V_{gs} = V_{dxs} \text{ for Qd evaluation}$$

$$V_{dsat, cv} = \frac{V_{gsteff, cv}}{A_{sat}}$$

$$A_{sat} = \left(1 + \left(\frac{CLC}{L_{activ}} \right)^{CLE} \right) / \alpha_{sat}$$

$$V_{cveff} = V_{dsat, cv} - 0.5 \left(V_4 + \sqrt{V_4^2 + 4\delta_4 V_{dsat, cv}} \right)$$

where

$$V_4 = V_{dsat, cv} - V_{ds} - \delta_4$$

$$\delta_4 = 0.02$$

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RPI TFT Models

$$L_{active} = l \cdot LMLT + XL - 2DLC$$

$$W_{active} = w \cdot WMLT + XW - 2DWC$$

$$Q_g = -W_{active} \cdot L_{active} \cdot \epsilon_{SiO_2} / tox \left(\left(V_{gsteff, cv} - \frac{1}{2} V_{cveff} \right) + \frac{A_{sat} V_{cveff}^2}{12 \left(V_{gsteff, cv} - \frac{A_{sat}}{2} V_{cveff} \right)} \right)$$

$$Q_s = - \left(\frac{W_{active} \cdot L_{active} \cdot \epsilon_{SiO_2} / tox}{2 \left(V_{gsteff, cv} - \frac{A_{sat}}{2} V_{cveff} \right)^2} \left(V_{gsteff, cv}^3 - \frac{1}{3} V_{gsteff, cv}^2 V_{cveff} - V_{gsteff, cv}^2 A_{sat} V_{cveff} + \right. \right. \\ \left. \left. \frac{5}{12} V_{gsteff, cv} A_{sat} V_{cveff}^2 + \frac{1}{4} V_{gsteff, cv} (A_{sat} V_{cveff})^2 - \frac{2}{15} (A_{sat} V_{cveff})^2 V_{cveff} \right) \right)$$

$$Q_d = - \left(\frac{W_{active} \cdot L_{active} \cdot \epsilon_{SiO_2} / tox}{2 \left(V_{gsteff, cv} - \frac{A_{sat}}{2} V_{cveff} \right)^2} \left(V_{gsteff, cv}^3 - \frac{2}{3} V_{gsteff, cv}^2 V_{cveff} - V_{gsteff, cv}^2 A_{sat} V_{cveff} + \right. \right. \\ \left. \left. \frac{3}{4} V_{gsteff, cv} A_{sat} V_{cveff}^2 + \frac{1}{4} V_{gsteff, cv} (A_{sat} V_{cveff})^2 - \frac{1}{5} (A_{sat} V_{cveff})^2 V_{cveff} \right) \right)$$

$$Q_{sx} = -Q_s \quad Q_{dx} = -Q_d$$

$$Q_{dx} = -Q_d$$

$$C_{ss} = \frac{dQ_s}{dV_s} \quad C_{sd} = \frac{dQ_s}{dV_d} \quad C_{ssx} = \frac{dQ_s}{dV_{sx}} \quad C_{sdx} = 0$$

$$C_{ds} = \frac{dQ_d}{dV_s} \quad C_{dd} = \frac{dQ_d}{dV_d} \quad C_{ddx} = \frac{dQ_d}{dV_{dx}} \quad C_{dsx} = 0$$

$$C_{sxs} = \frac{dQ_{sx}}{dV_s} \quad C_{sxd} = \frac{dQ_{sx}}{dV_d} \quad C_{sxsx} = \frac{dQ_{sx}}{dV_{sx}} \quad C_{sxdx} = 0$$

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RPI TFT Models

$$C_{dxs} = \frac{dQ_{dx}}{dV_s} C_{dxd} = \frac{dQ_{dx}}{dV_d} C_{dxdx} = \frac{dQ_{dx}}{dV_{dx}} C_{dxxs} = 0$$

$$C_{gs} = C_{sxs} + C_{dxs} \quad C_{gd} = C_{dxd} + C_{sxd} \quad C_{gg} = C_{gs} + C_{gd}$$

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,

$$\text{Overlap}C_{gs} = \begin{cases} (w + 2Wd) \cdot C_{gso}, & \text{if } C_{gso} \text{ is given} \\ (w + 2Wd) \cdot (Ld + Metro) \cdot \epsilon_{SiO_2} / tox, & \text{if } C_{gso} \text{ is not given} \end{cases}$$

$$\text{Overlap}C_{gd} = \begin{cases} (w + 2Wd) \cdot C_{gdo}, & \text{if } C_{gdo} \text{ is given} \\ (w + 2Wd) \cdot (Ld + Metro) \cdot \epsilon_{SiO_2} / tox, & \text{if } C_{gdo} \text{ is not given} \end{cases}$$

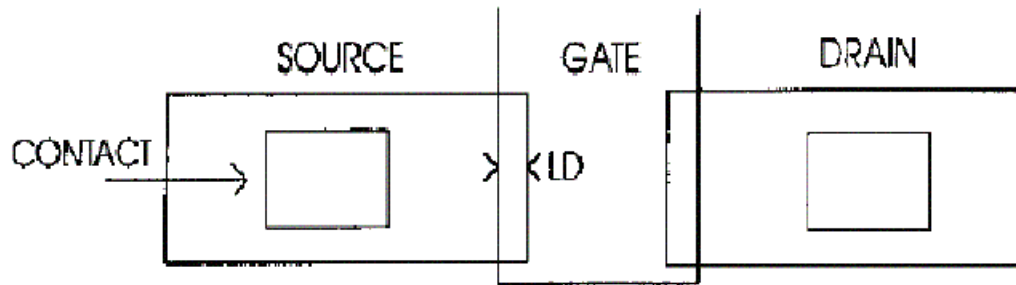
Else,

$$\text{Overlap}C_{gs} = w \cdot C_{gso}$$

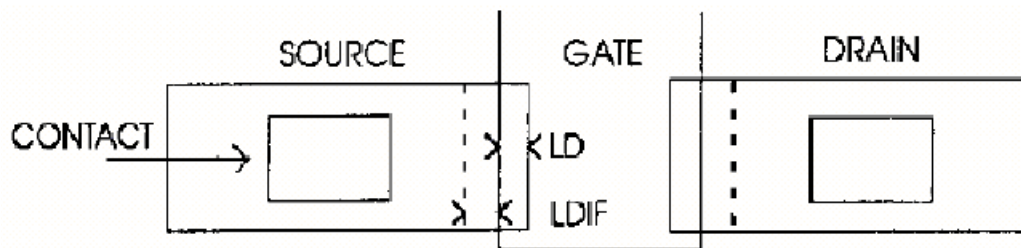
$$\text{Overlap}C_{gd} = w \cdot C_{gdo}$$

ACM Option

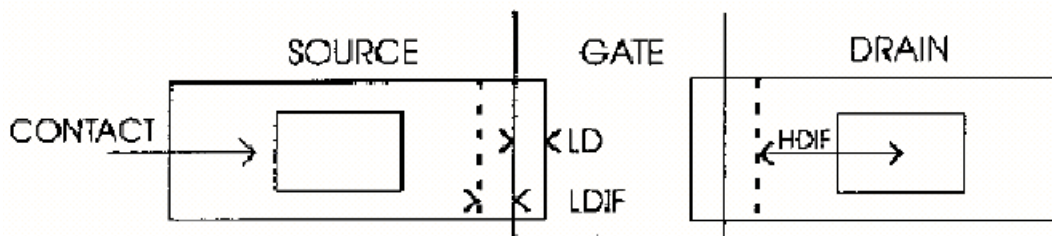
When ACM=0



When ACM=1



When ACM=2



Scaling Effects

For scaling effects, see [Scaling Factors \(scale and scalem\)](#) on page 222.

Component Statements

This device is supported within altergroups.

Virtuoso Simulator Components and Device Models Reference

RPI TFT Models

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 <code>off</code> , <code>triode</code> , <code>sat</code> , or <code>subth</code> . |
| 7 | isnoisy=yes | Should resistor generate noise.
Possible values are <code>no</code> or <code>yes</code> . |
| 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).

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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	$dvt0=0$ V/C	Temperature coefficient of VTO (BIN).
39	$dmu1=0$ cm^2/V s C	Temperature coefficient of MU1 (BIN).

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RPI TFT Models

40	<code>dasat=0</code>	1/C	Temperature coefficient of ASAT (BIN).
41	<code>lasat=0</code>	m	Coefficient of length dependence of ASAT (BIN).
42	<code>von=0</code>	V	On-Voltage (BIN).
43	<code>cgso=0</code>	F/m	Gate-source overlap capacitance.
44	<code>cgdo=0</code>	F/m	Gate-drain overlap capacitance.
45	<code>vsigma=0.2</code>	V	Above threshold DIBL parameter (BIN).
46	<code>vsigmat=1.7</code>	V	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</code>	m	Channel-length modulation coefficient 1 (BIN).
52	<code>vp=0.2</code>	V	Channel-length modulation coefficient 2 (BIN).
53	<code>isubmod=0</code>		Channel-length modulation model version.
54	<code>vmax=4e4</code>	m/s	Carrier saturation velocity (BIN).
55	<code>theta=0</code>	1/V	Mobility modulation coefficient (BIN).
56	<code>mss=1.5</code>		Vdse transition parameter parameter (BIN).
57	<code>kss=0</code>		Fractions of the channel resistance coefficient.
58	<code>rsh=0</code>	Ω/sqr	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).

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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.

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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.

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 (A)</code>	Resistive drain-to-source current (alias = <code>lx4</code>).
5	<code>vgs (V)</code>	Gate-source voltage (alias = <code>lx2</code>).
6	<code>vds (V)</code>	Drain-source voltage (alias = <code>lx3</code>).
7	<code>vth (V)</code>	Threshold voltage (alias = <code>lv9</code>).
8	<code>vdsat (V)</code>	Drain-source saturation voltage (alias = <code>lv10</code>).
9	<code>gm (S)</code>	Common-source transconductance (alias = <code>lx7</code>).
10	<code>gds (S)</code>	Common-source output conductance (alias = <code>lx8</code>).
11	<code>tdev (C)</code>	Temperature rise from ambient.
12	<code>cgd (F)</code>	Gate-drain capacitance (alias = <code>lx19</code>).
13	<code>cgs (F)</code>	Gate-source capacitance (alias = <code>lx20</code>).
14	<code>cgg (F)</code>	<code>Cgg</code> (only for <code>capmod=2</code>).
15	<code>css (F)</code>	Intrinsic capacitance <code>dQs_dVs</code> (only for <code>capmod=2</code>).
16	<code>csd (F)</code>	Intrinsic capacitance <code>dQs_dVd</code> (only for <code>capmod=2</code>).
17	<code>cssx (F)</code>	Intrinsic capacitance <code>dQs_dVsx</code> (only for <code>capmod=2</code>).
18	<code>csdx (F)</code>	Intrinsic capacitance <code>dQs_dVdx</code> (only for <code>capmod=2</code>).
19	<code>cds (F)</code>	Intrinsic capacitance <code>dQd_dVs</code> (only for <code>capmod=2</code>).

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RPI TFT Models

20	<code>cdd</code> (F)	Intrinsic capacitance dQd_dVd (only for <code>capmod=2</code>).
21	<code>cdsx</code> (F)	Intrinsic capacitance dQd_dVsx (only for <code>capmod=2</code>).
22	<code>cddx</code> (F)	Intrinsic capacitance dQd_dVdx (only for <code>capmod=2</code>).
23	<code>csxs</code> (F)	Intrinsic capacitance $dQsx_dVs$ (only for <code>capmod=2</code>).
24	<code>csxd</code> (F)	Intrinsic capacitance $dQsx_dVd$ (only for <code>capmod=2</code>).
25	<code>csxsx</code> (F)	Intrinsic capacitance $dQsx_dVsx$ (only for <code>capmod=2</code>).
26	<code>csxdx</code> (F)	Intrinsic capacitance $dQsx_dVdx$ (only for <code>capmod=2</code>).
27	<code>cdxs</code> (F)	Intrinsic capacitance $dQdx_dVs$ (only for <code>capmod=2</code>).
28	<code>cdxd</code> (F)	Intrinsic capacitance $dQdx_dVd$ (only for <code>capmod=2</code>).
29	<code>cdxsx</code> (F)	Intrinsic capacitance $dQdx_dVsx$ (only for <code>capmod=2</code>).
30	<code>cdxdx</code> (F)	Intrinsic capacitance $dQdx_dVdx$ (only for <code>capmod=2</code>).
31	<code>cgso</code> (F)	Gate-Source overlap capacitance.
32	<code>cgdo</code> (F)	Gate-Drain overlap capacitance.
33	<code>qs</code> (Coul)	Qs (only for <code>capmod=2</code>).
34	<code>qd</code> (Coul)	Qd (only for <code>capmod=2</code>).
35	<code>qg</code> (Coul)	Qg (only for <code>capmod=2</code>).
36	<code>qsx</code> (Coul)	Charge of <code>sx</code> internal node (only for <code>capmod=2</code>).
37	<code>qdx</code> (Coul)	Charge of <code>dx</code> internal node (only for <code>capmod=2</code>).
38	<code>ron</code> (Ω)	On-resistance.
39	<code>id</code> (A)	Resistive drain current.
40	<code>is</code> (A)	Resistive source current.
41	<code>pwr</code> (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

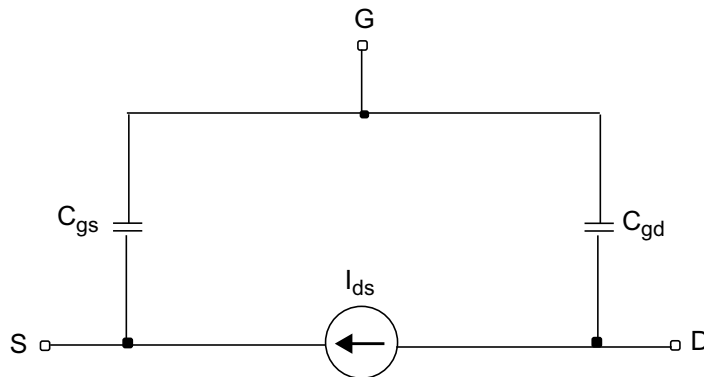
Virtuoso Simulator Components and Device Models Reference

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

Virtuoso Simulator Components and Device Models Reference

RPI TFT Models

- 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

$$I_{ds} = I_{leakage} + I_{ab}$$

$$I_{leakage} = I_{hl} + I_{min}$$

$$I_{hl} = IOL \left[\exp\left(\frac{V_{ds}}{V_{DSL}}\right) - 1 \right] \exp\left(-\frac{V_{gs}}{V_{GSL}}\right) \exp\left[\frac{EL}{q} \left(\frac{1}{V_{tho}} - \frac{1}{V_{th}}\right)\right]$$

$$I_{ab} = g_{ch} V_{dse} (1 + LAMBDA \cdot V_{ds})$$

$$V_{dse} = \frac{V_{ds}}{\left[1 + \left(\frac{V_{ds}}{V_{sate}}\right)^M \right]^{\frac{1}{M}}}$$

$$V_{sate} = \alpha_{sat} V_{gte}$$

Virtuoso Simulator Components and Device Models Reference

RPI TFT Models

$$g_{ch} = \frac{g_{chi}}{1 + g_{chi}(RS + RD)}$$

$$g_{chi} = q \cdot n_s \cdot MUBAND \cdot \frac{W}{L}$$

$$n_s = \frac{n_{sa}n_{sb}}{n_{sa} + n_{sb}}$$

$$n_{sa} = \frac{EPSI \cdot V_{gte}}{q \cdot TOX} \left(\frac{V_{gte}}{V_{aat}} \right)^{GAMMA}$$

$$n_{sb} = n_{so} \left(\frac{t_m}{TOX} \frac{V_{gfbe} EPSI}{V_0 EPS} \right)^{\frac{2V_0}{V}}$$

$$n_{so} = N_c t_m \frac{V_e}{V_0} \exp\left(-\frac{DEF0}{V_{th}}\right)$$

$$N_c = 3.0 \cdot 10^{25} m^{-3}$$

$$V_e = \frac{2 \cdot V_0 \cdot V_{tho}}{2 \cdot V_0 - V_{th}}$$

$$t_m = \sqrt{\frac{EPS}{2q \cdot GMIN}}$$

$$V_{gte} = \frac{VMIN}{2} \left[1 + \frac{V_{gt}}{VMIN} + \sqrt{DELTA^2 + \left(\frac{V_{gt}}{VMIN} - 1 \right)^2} \right]$$

$$V_{gt} = V_{gs} - V_T$$

$$V_{gfbe} = \frac{VMIN}{2} \left[1 + \frac{V_{gfb}}{VMIN} + \sqrt{DELTA^2 + \left(\frac{V_{gfb}}{VMIN} - 1 \right)^2} \right]$$

$$V_{gfb} = V_{gs} - VFB$$

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,

$$rd = \begin{cases} (Ld + Ldif) \cdot rd/w + nrd \cdot rsh + rdc, & \text{if } nrd \text{ is given} \\ rdc + \frac{Hdif \cdot rsh + (Ld + Ldif) \cdot rd}{w}, & \text{otherwise} \end{cases}$$

$$rs = \begin{cases} (Ld + Ldif) \cdot rs/w + nrs \cdot rsh + rsc, & \text{if } nrs \text{ is given} \\ rsc + \frac{Hdif \cdot rsh + (Ld + Ldif) \cdot rs}{w}, & \text{otherwise} \end{cases}$$

Temperature Dependence

$$V_{tho} = k_B \cdot TNOM / q$$

$$V_{th} = k_B \cdot TNOM / q$$

$$V_{aat} = VAA \cdot \exp\left[\frac{EMU}{q \cdot GAMMA} \left(\frac{1}{V_{th}} - \frac{1}{V_{tho}}\right)\right]$$

$$V_T = VTO + KVT(TEMP - TNOM)$$

$$\alpha_{sat} = ALPHASAT + KASAT(TEMP - TNOM)$$

Capacitance

$$C_{gs} = C_f + \frac{2}{3}C_{gc} \left[1 - \left(\frac{V_{sate} - V_{dse}}{2V_{sate} - V_{dse}} \right) \right]$$

$$C_{gd} = C_f + \frac{2}{3}C_{gc} \left[1 - \left(\frac{V_{sate}}{2V_{sate} - V_{dse}} \right) \right]$$

$$C_f = 0.5 \cdot EPS \cdot W$$

$$C_{gs} = q \frac{dn_{sc}}{dV_{gs}}$$

$$n_{sc} = \frac{n_{sac} n_{sbc}}{n_{sac} + n_{sbc}}$$

$$n_{sac} = \frac{EPSI \cdot V_{gte}}{q \cdot TOX}$$

$$n_{sbc} = n_{sb}$$

Scaling Effects

For scaling effects, see [Scaling Factors \(scale and scalem\)](#) on page 222.

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.

Virtuoso Simulator Components and Device Models Reference

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 none, off, triode, sat, subth, or rev.
----	-------------------------	---

Auto Model Selector parameters

49	<code>wmax=1 m</code>	Maximum channel width for which the model is valid.
----	-----------------------	---

Virtuoso Simulator Components and Device Models Reference

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.

Virtuoso Simulator Components and Device Models Reference

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	il (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	il	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

Virtuoso Simulator Components and Device Models Reference

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

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:

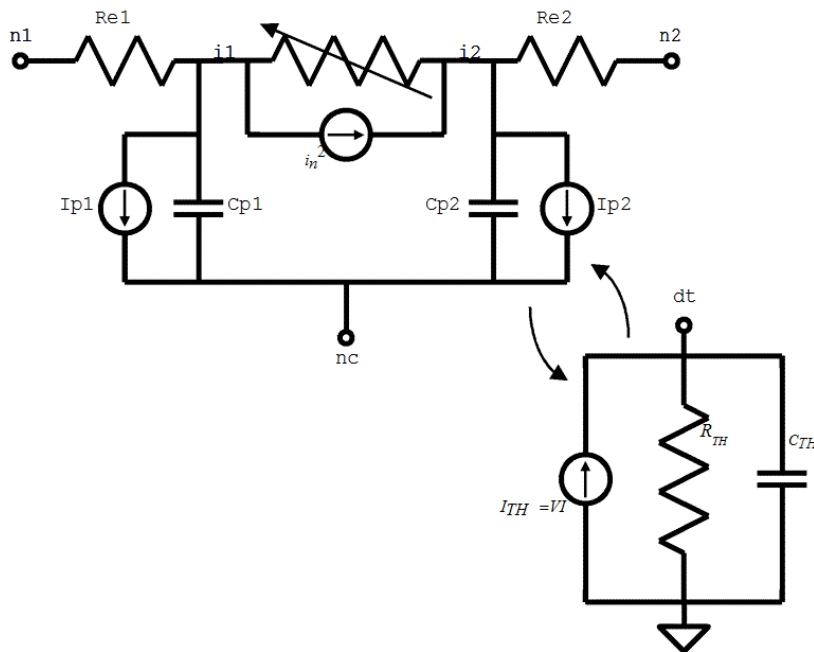
- [Usage](#) on page 2412
- [Bias Dependence of Resistor Body Current](#) on page 2413
- [Bias Dependence of Parasitics](#) on page 2415
- [Geometry Dependence](#) on page 2417
- [Temperature Dependence](#) on page 2421
- [Noise](#) on page 2423
- [Operating Point Information](#) on page 2424
- [Statistical Variation](#) on page 2424
- [Notes on Parameter Extraction](#) on page 2427
- [Parameter Descriptions](#) on page 2433

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 39-1 r3 Model Equivalent Network



Example

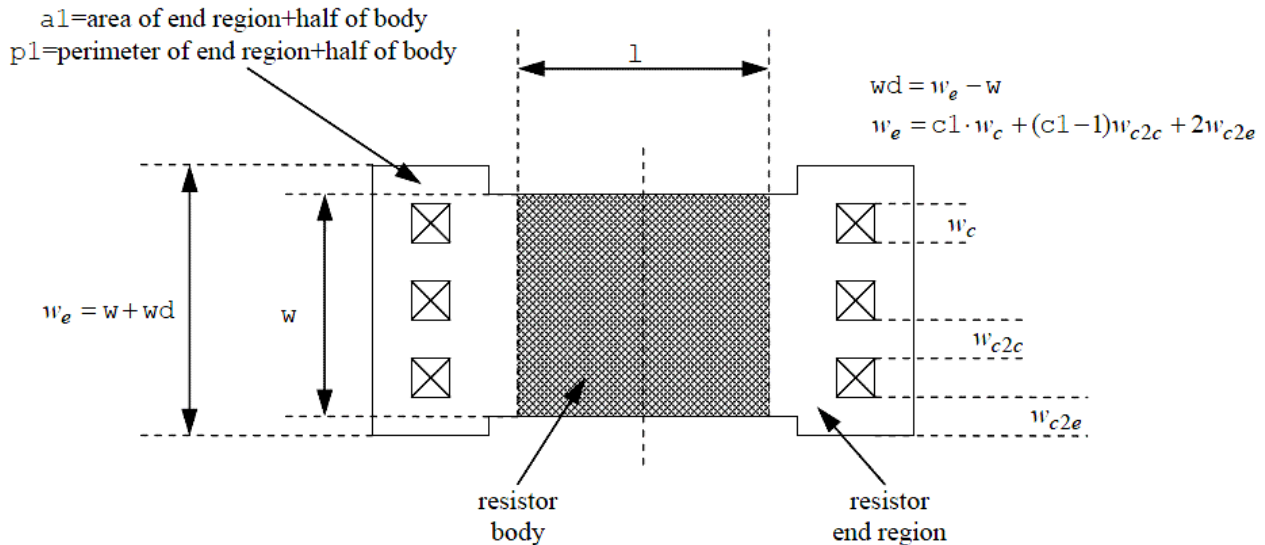
```
r00 n1 n2 n3 p0 l = 2e-6 w = 10e-6 m = 10 sw_et = 1
```

```
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
+tc1vbw=1e-3 tc2vbw=1e-4 tc1nbv=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 39-2 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 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.

Virtuoso Simulator Components and Device Models Reference

Three-Terminal Nonlinear (Diffused and Poly-Silicon) Resistor Model and JFET Model (r3)

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 $1 + (E_{\text{corn}}/E_{\text{crit}})$ for large field $E = V_{21}/(l_{\text{eff_um}} + dx_{\text{lsat}})$ ($l_{\text{eff_um}}$ is defined in the next section).

$$\mu_{red} = 1 + \sqrt{\left(\frac{E - E_{ce}}{2E_{crit}}\right)^2 + \frac{du E_{ce}}{E_{crit}}} + \sqrt{\left(\frac{E + E_{ce}}{2E_{crit}}\right)^2 + \frac{du E_{ce}}{E_{crit}}} - \sqrt{\left(\frac{E_{ce}}{E_{crit}}\right)^2 + \frac{4 du E_{ce}}{E_{crit}}}$$

(see Figure [39-3](#)) where

$$E_{ce} = \sqrt{E_{corn}^2 + (2 du \cdot E_{crit})^2} - 2 du \cdot E_{crit}.$$

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.

$$V_{21,eff} = \frac{2V_{21}V_{sat}}{\sqrt{(V_{21} - V_{sat})^2 + 4ats^2} + \sqrt{(V_{21} + V_{sat})^2 + 4ats^2}}$$

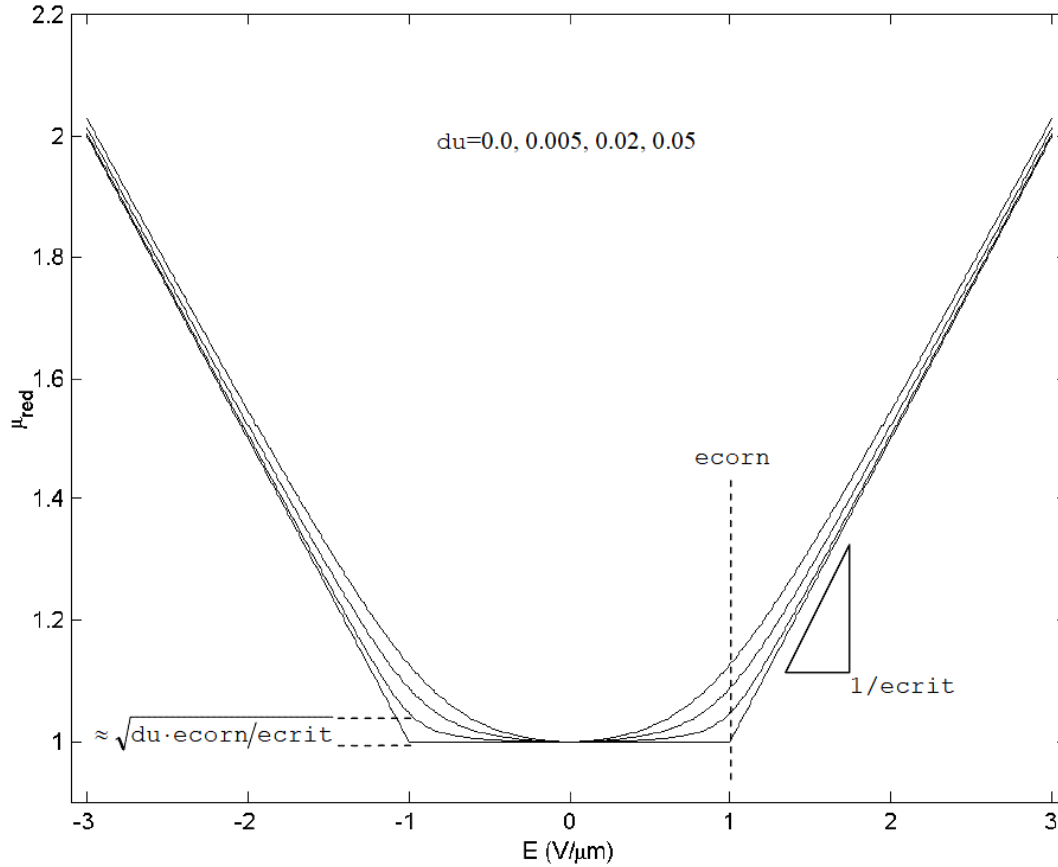
where ats is a model parameter that controls the limiting. This limiting function differs from those often used in compact MOSFET models; it preserves symmetry. The control voltage used is also limited, to the pinch-off voltage

$$V_{1c,eff} = V_{po} - nstV_{tv} \ln \left(1 + \exp \left(\frac{V_{po} - V_{1c}}{nstV_{tv}} \right) \right), \quad V_{po} = \frac{1}{2df^2} - 0.5dp, \quad V_{tv} = kT/q.$$

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 [39-1](#) is then

$$I_{21} = I_{depl} / \mu_{red}$$

Figure 39-3 Velocity Saturation Model



Bias Dependence of Parasitics

If there are no area or perimeter component of saturation current, e.g. for poly resistors,

$$I_{p1} = I_{p2} = 0$$

If there are area and/or perimeter components of saturation current, e.g. as for diffused resistors, the parasitic diode currents are

$$I_{p1} = p1_um \cdot I_{sp}(T) \left(\exp(V_{c1} / (n_p \cdot V_{tv})) - 1 \right) + a1_um2 \cdot I_{sa}(T) \left(\exp(V_{c1} / (n_a \cdot V_{tv})) - 1 \right) + gmin \cdot V_{c1}$$

$$I_{p2} = p2_um \cdot I_{sp}(T) \left(\exp(V_{c2} / (n_p \cdot V_{tv})) - 1 \right) + a2_um2 \cdot I_{sa}(T) \left(\exp(V_{c2} / (n_a \cdot V_{tv})) - 1 \right) + gmin \cdot V_{c2}$$

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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

$$I_{b1} = -i_{bv} \left(\exp(-V_{c1} + V_{bv}(T)) / (n_{bv}(T)V_{iv}) - \exp(-V_{bv}(T) / (n_{bv}(T)V_{iv})) \right),$$

$$I_{b2} = -i_{bv} \left(\exp(-V_{c2} + V_{bv}(T)) / (n_{bv}(T)V_{iv}) - \exp(-V_{bv}(T) / (n_{bv}(T)V_{iv})) \right)$$

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.

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 for LOCOS, the webbing effect, and the finite dopant source effect. The effective electrical width, in microns, is

$$weff_um = \frac{w_um + xw + (nw \cdot xw / w_um) + fdxw \cdot inf(1 - \exp(-w_um / fdrw))}{1 - wexw \cdot wd_um / (l_um \cdot w_um)}$$

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where the width of the dogbone (see Figure 39-2), 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

$$df = df_{inf} + \frac{df_w}{W} + \frac{df_l}{L} + \frac{df_{wl}}{WL}$$

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

$$R_0 = r_{sh} \frac{leff_um}{weff_um} (1.0 - df \sqrt{dp}), \quad gf = 1/R_0$$

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

$$T_{C1}^{eff} = tc1 + \frac{0.5((c1 > 0) + (c2 > 0))tc1l}{leff_um} + \frac{tc1w}{weff_um},$$

$$T_{C2}^{eff} = tc2 + \frac{0.5((c1 > 0) + (c2 > 0))tc2l}{leff_um} + \frac{tc2w}{weff_um}$$

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, 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

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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 unsaliced 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

$$\begin{aligned} g_{TH} &= g_{th0} + g_{thp}(2l_{um} + 2w_{um} + 4\Delta) + g_{tha}(l_{um} + \Delta)(w_{um} + \Delta) \\ &= (g_{th0} + 4g_{thp} \cdot \Delta + g_{tha} \cdot \Delta^2) + (g_{thp} + 0.5g_{tha} \cdot \Delta)p_{um} + g_{tha} \cdot a_{um2} \end{aligned}$$

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.

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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

$$E = V_{d1} / (l_{eff_um} + dx_{lsat}).$$

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 [39-2](#)). 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) spacing between contacts be w_{c2c} . If (as in some older technologies) contacts can be scaled, then rc 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.

The parasitic diode saturation currents vary with temperature as

$$I_{sa}(T) = isa \cdot rT^{xis/na} \exp \left(-ea \frac{1-rT}{na \cdot V_{tv}} \right)$$

$$I_{sp}(T) = isp \cdot rT^{xis/np} \exp \left(-ea \frac{1-rT}{np \cdot V_{tv}} \right)$$

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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

$$C_{ja}(T) = c_{ja} \left(\frac{p_a}{P_a(T)} \right)^{ma}$$

and

$$C_{jp}(T) = c_{jp} \left(\frac{p_p}{P_p(T)} \right)^{mp}$$

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

$$V_{bv}(T) = v_{bv} (1 + t_{c1vbv} \cdot dT + t_{c2vbv} \cdot dT^2),$$

$$n_{bv}(T) = n_{bv} (1 + t_{c1nbv} \cdot dT).$$

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 shot 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.

$$i_{flicker,body}^2 = K_{FN}(T) \left(\frac{I_{21}}{W} \right)^{afn} \frac{W}{L} \frac{1}{f^{bfm}}$$

where f is frequency (in Hz), afn and bfm 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_fngo` 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 39-1 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.

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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_mmgeo` 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),

$$\sigma_{total}^2 = \sigma_{global}^2 + \sigma_{local}^2(\bar{g}).$$

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.

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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

$$weff_um = weff_um_{nom} + n_{sig_w} \cdot sig_w + \frac{n_{smm_w} \cdot smm_w}{\sqrt{m \cdot L}}$$

$$leff_um = leff_um_{nom} + n_{sig_l} \cdot sig_l + \frac{n_{smm_l} \cdot smm_l}{\sqrt{m \cdot W}}$$

$$rsh = rsh_{nom} \exp \left(0.01 \left(n_{sig_rsh} \cdot sig_rsh + \frac{n_{smm_rsh} \cdot smm_rsh}{\sqrt{m \cdot WL}} \right) \right)$$

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 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 $\exp \langle \chi \rangle \approx \langle 1 + \chi \rangle$ hence the `rsh` 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 `rsh`, 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 `rsh` if the variation is large. Note that strictly the unit “%” for the standard deviations of `rsh`

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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 `smm_w`, `smm_l`, and `smm_rsh`.

If mismatch analysis is not selected, then the total variance is used as the global variance,

$$weff_um = weff_um_{nom} + nsig_w \cdot sig_w + \frac{nsmm_w \cdot smm_w}{\sqrt{m \cdot L}}$$

$$leff_um = leff_um_{nom} + nsig_l \cdot sig_l + \frac{nsmm_l \cdot smm_l}{\sqrt{m \cdot W}}$$

$$rsh = rsh_{nom} \exp \left(0.01 \left(nsig_rsh \cdot sig_rsh + \frac{nsmm_rsh \cdot smm_rsh}{\sqrt{m \cdot WL}} \right) \right)$$

Note that the `nsig` 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).

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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 $g_g=I/V$ 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 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

$$\frac{\sqrt{d_p + V_2} - \sqrt{d_p + V_1}}{g_1 - g_2} - \frac{\sqrt{d_p + V_3} - \sqrt{d_p + V_1}}{g_1 - g_3} = 0.$$

Starting with an initial estimate of $d_p = 2$, the equation can be solved using Newton-Raphson iteration. Then

$$d_f = \frac{g_1 - g_3}{g_1 \sqrt{d_p + V_3} - g_3 \sqrt{d_p + V_1}}$$

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 $dp = 2$, and then calculate an initial df at the highest V_i . A 3 dimensional Newton-Raphson iteration can then be used to solve for gf , df , and dp 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

$$p_1 = 1/df^2 gf^2 \quad \text{and} \quad p_2 = 1/df^2 gf .$$

These two quantities can be calculated from the V_i and g_i data using the above equation

$$gf = p_2 / p_1 ,$$

$$df = 1/\sqrt{p_2 gf} ,$$

$$dp = \frac{1}{df^2} + \frac{g_1^2}{df^2 gf^2} - \frac{2g_1}{df^2 gf} - V_i .$$

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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.

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

$$g \approx gf \left(1 - df \sqrt{d_p} - df V_{1c} / \sqrt{d_p} \right).$$

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 $g_0 = gf \langle 1 - df \sqrt{d_p} \rangle$ and the slope $s = -(gdf) / (\sqrt{d_p})$. Yet there are three parameters for the model. Physical quantities are needed to break this indeterminacy.

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The value of $V_0 = q\epsilon_{Si}N/C_{ox}^2$ 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

$$dp = \frac{\epsilon_{Si}T_{ox}^2}{\mu_0 X \rho_s \epsilon_{ox}^2}$$

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

$$df = -\frac{s\sqrt{dp}}{g_0 - s\sqrt{dp}}$$

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).

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

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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

$$\frac{I_p}{I_m} = \frac{I(+V)}{I(-V)} \Big|_{V_{cl}=0} = \frac{1 - df \sqrt{dp + V}}{1 - df \sqrt{dp - V}} \approx 1 - V \frac{df}{\sqrt{dp}}$$

and therefore reveal the effect of depletion pinching. As with the low v bias analysis above, d_p 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

$$\frac{g(V)}{g(0)} = 1 + \frac{T_{C1}}{g_{tha} \cdot r_{sh}} \left(\frac{V}{L} \right)^2$$

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.

Parameter Descriptions

Instance Parameters

Name	Default	Min.	Max.	Units	Description
m	1	0	inf		multiplicity factor (number in parallel)
w	1.0e-6	0.0	inf	m	design width of resistor body
l	1.0e-6	0.0	inf	m	design length of resistor body
wd	0.0	0.0	inf	m	dogbone width (total; not per side)
a1	0.0	0.0	inf	m ²	area of node n1 partition
p1	0.0	0.0	inf	m	perimeter of node n1 partition
c1	0	0	inf		# contacts at n1 terminal
a2	0.0	0.0	inf	m ²	area of node n2 partition
p2	0.0	0.0	inf	m	perimeter of node n2 partition
c2	0	0	inf		# contacts at n2 terminal
trise	0.0			°C	local temperature delta to ambient (before self-heating)
sw_noise	1	0	1		switch for including noise: 0=no 1=yes
sw_et	1	0	1		switch for turning off self-heating: 0=exclude 1=include
sw_mman	0	0	1		switch for mismatch analysis: 0=no and 1=yes
nsmm_rsh	0.0				number of standard deviations of local variation for rsh
nsmm_w	0.0				number of standard deviations of local variation for w
nsmm_l	0.0				number of standard deviations of local variation for l

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Special Model Parameters

Name	Default	Min.	Max.	Units	Description
version					model version (major model change)
subversion					model subversion (minor model change)
revision					model revision (implementation update)
level	1003				model level
type	-1	-1	+1		resistor type: -1=n-body and +1=p-body
scale	1.0	0.0	1.0		scale factor for instance geometries
shrink	0.0	0.0	100.0	%	shrink percentage for instance geometries
tmin	-100.0	-250.0	27.0	°C	minimum ambient temperature
tmax	500.0	27.0	1000.0	°C	maximum ambient temperature
rthresh	0.001	0.0	inf	Ω	threshold to switch end resistance to V=I*R form
gmin	1.0e-12	0.0	inf	S	minimum conductance (for parasitic branches)
imax	1.0	0.0	inf		current at which to linearize diode currents
lmin	0.0	0.0	inf	μm	minimum allowed drawn length
lmax	9.9e99	lmin	inf	μm	maximum allowed drawn length
wmin	0.0	0.0	inf	μm	minimum allowed drawn width
wmax	9.9e99	wmin	inf	μm	maximum allowed drawn width
jmax	100.0	0.0	inf	A/um	maximum current density
vmax	9.9e99	0.0	inf	V	maximum voltage w.r.t. control node nc
tminclip	-100.0	-250.0	27.0	°C	clip minimum temperature
tmaxclip	500.0	27.0	1000.0	°C	clip maximum temperature

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 Three-Terminal Nonlinear (Diffused and Poly-Silicon) Resistor Model and JFET Model (r3)

Model Parameters

Name	Default	Min.	Max.	Units	Description
tnom	27.0	-250.0	1000.0	°C	nominal (reference) temperature
rsh	100.0	0.0	inf	Ω/\square	sheet resistance
xw	0.0			μm	width offset (total)
nwxw	0.0			μm^2	narrow width width offset correction coefficient
wexw	0.0			μm	webbing effect width offset correction coefficient (for dog-boned devices)
fdrw	1.0	0.0	inf	μm	finite doping width offset reference width
fdxwinf	0.0			μm	finite doping width offset width value for wide devices
xl	0.0			μm	length offset (total)
xlw	0.0				width dependence of length offset
dxlsat	0.0			μm	additional length offset for velocity saturation calculation
nst	1.0	0.1	5.0		subthreshold slope parameter
ats	0.0	0.0	inf	V	saturation smoothing parameter
dfinf	0.01	0.0001	10.0	$1/\sqrt{\text{V}}$	depletion factor for wide/long device
dfw	0.0			$\mu\text{m}/\sqrt{\text{V}}$	depletion factor l/w coefficient
df1	0.0			$\mu\text{m}/\sqrt{\text{V}}$	depletion factor l/l coefficient
dfw1	0.0			$\mu\text{m}^2/\sqrt{\text{V}}$	depletion factor l/(w*l) coefficient
sw_dfgeo	1	0	1		switch for depletion factor geometry dependence: 0=drawn and 1=effective
dp	2.0	0.1	1000.0	V	depletion potential
ecrit	4.0	0.02	1000.0	$\text{V}/\mu\text{m}$	velocity saturation critical field
ecorn	0.4	0.01	ecrit	$\text{V}/\mu\text{m}$	velocity saturation corner field
du	0.02	0.0	1000.0		mobility reduction at ecorn
rc	0.0	0.0	inf	Ω	resistance per contact
rcw	0.0	0.0	inf	$\Omega\mu\text{m}$	width adjustment for contact resistance
fc	0.9	0.0	0.99		depletion capacitance linearization factor
isa	0.0	0.0	inf	$\text{A}/\mu\text{m}^2$	diode saturation current per unit area
na	1.0	0.0	inf		ideality factor for isa
ca	0.0	0.0	inf	$\text{F}/\mu\text{m}^2$	fixed capacitance per unit area
cja	0.0	0.0	inf	$\text{F}/\mu\text{m}^2$	depletion capacitance per unit area
pa	0.75	0.0	inf	V	built-in potential for cja
ma	0.33	0.0	1.0		grading coefficient for cja
aja	-0.5			V	smoothing parameter for cja

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Name	Default	Min.	Max.	Units	Description
isp	0.0	0.0	inf	A/ μm	diode saturation current per unit perimeter
np	1.0	0.0	inf		ideality factor for isp
cp	0.0	0.0	inf	F/ μm	fixed capacitance per unit perimeter
cjp	0.0	0.0	inf	F/ μm	depletion capacitance per unit perimeter
pp	0.75	0.0	inf	V	built-in potential for cjp
mp	0.33	0.0	1.0		grading coefficient for cjp
ajp	-0.5			V	smoothing parameter for cjp
vbv	0.0	0.0	inf	V	breakdown voltage
ibv	1.0e-6	0.0	inf	A	current at breakdown
nbv	1.0	0.0	inf		ideality factor for breakdown current
kfn	0.0	0.0	inf		flicker noise coefficient (unit depends on afn)
afn	2.0	0.0	inf		flicker noise current exponent
bfm	1.0	0.0	inf		flicker noise 1/f exponent
sw_fngeo	0	0	1		switch for flicker noise geometry calculation: 0=drawn 1=effective
ea	1.12			V	activation voltage for diode temperature dependence
xis	3.0				exponent for diode temperature dependence
tc1	0.0			/K	resistance linear TC
tc2	0.0			/K ²	resistance quadratic TC
tc1l	0.0			$\mu\text{m}/\text{K}$	resistance linear TC length coefficient
tc2l	0.0			$\mu\text{m}/\text{K}^2$	resistance quadratic TC length coefficient
tc1w	0.0			$\mu\text{m}/\text{K}$	resistance linear TC width coefficient
tc2w	0.0			$\mu\text{m}/\text{K}^2$	resistance quadratic TC width coefficient
tc1rc	0.0			/K	contact resistance linear TC
tc2rc	0.0			/K ²	contact resistance quadratic TC
tc1kfn	0.0			/K	flicker noise coefficient linear TC
tc1vbv	0.0			/K	breakdown voltage linear TC
tc2vbv	0.0			/K ²	breakdown voltage quadratic TC
tc1nbv	0.0			/K	breakdown ideality factor linear TC
gth0	1.0e+6	0.0	inf	W/K	thermal conductance fixed component
gthp	0.0	0.0	inf	W/K μm	thermal conductance perimeter component
gtha	0.0	0.0	inf	W/K μm^2	thermal conductance area component
gthc	0.0	0.0	inf	W/K	thermal conductance contact component
cth0	0.0	0.0	inf	sW/K	thermal capacitance fixed component
cthp	0.0	0.0	inf	sW/K μm	thermal capacitance perimeter component

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Name	Default	Min.	Max.	Units	Description
ctha	0.0	0.0	inf	sW/K μm^2	thermal capacitance area component
cthc	0.0	0.0	inf	sW/K	thermal capacitance contact component
nsig_rsh	0.0				number of standard deviations of global variation for rsh
nsig_w	0.0				number of standard deviations of global variation for w
nsig_l	0.0				number of standard deviations of global variation for l
sig_rsh	0.0	0.0	inf	%	global variation standard deviation for rsh (relative)
sig_w	0.0	0.0	inf	μm	global variation standard deviation for w (absolute)
sig_l	0.0	0.0	inf	μm	global variation standard deviation for l (absolute)
smm_rsh	0.0	0.0	inf	% μm	local variation standard deviation for rsh (relative)
smm_w	0.0	0.0	inf	$\mu\text{m}^{1.5}$	local variation standard deviation for w (absolute)
smm_l	0.0	0.0	inf	$\mu\text{m}^{1.5}$	local variation standard deviation for l (absolute)
sw_mmgeo	0	0	1		switch for flicker noise geometry calculation: 0=drawn and 1=effective

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Three-Terminal Nonlinear (Diffused and Poly-Silicon) Resistor Model and JFET Model (r3)

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 2440
- [CV Model](#) on page 2440
- [Equivalent Circuit](#) on page 2440
- [Model Features](#) on page 2441
- [Parameter Descriptions](#) on page 2443

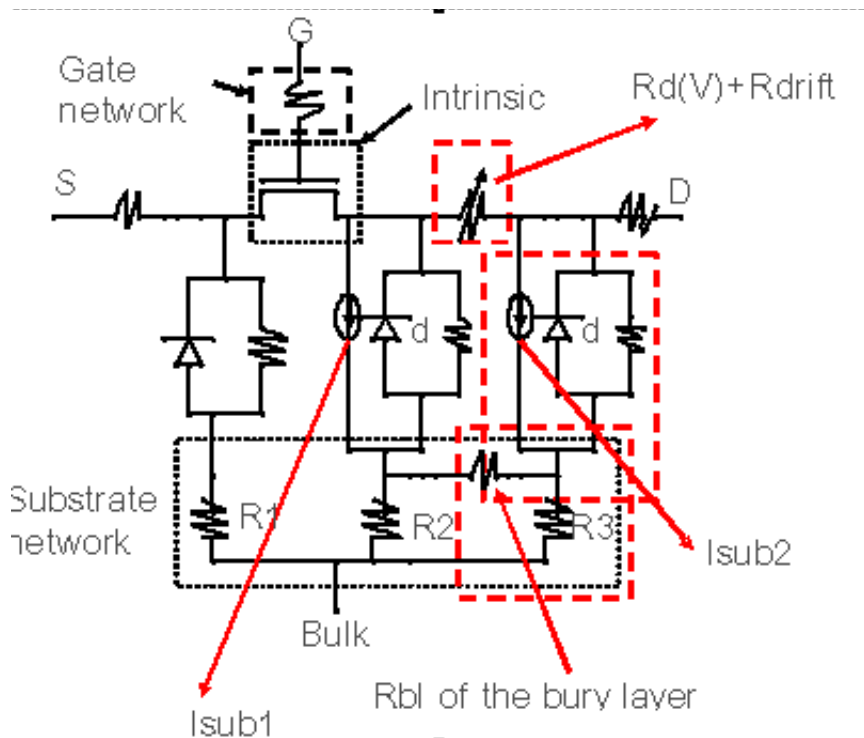
DC Model

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

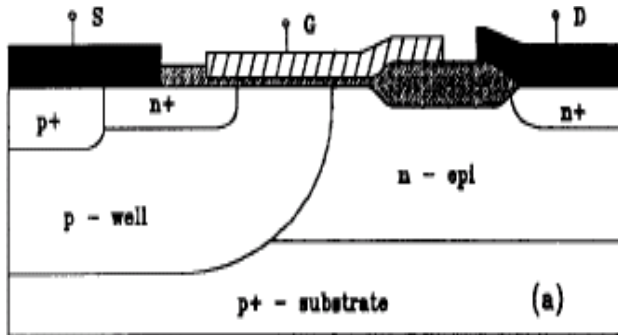
The LDMOS CV model is based on charge conservation. It includes gate and substrate network for RF modelling.

Equivalent Circuit



- The intrinsic transistor is the same as BSIM3.

- 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}

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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

to describe LDMOS in a more accurate way, it's therefore necessary to adopt the non uniform doping channel model.

Parameter Descriptions

Table 40-1 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 of source diffusion	0	
Nrd	Number of squares of 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

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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 40-2 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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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	
XPART	S/D partition	0	

Virtuoso Simulator Components and Device Models Reference
Laterally Double Diffused Metal Oxide Semiconductor FET Model (LDMOS)

Table 40-3 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	
WINT	Width offset	0	
WMLT	Diffusion layer width shrinking factor	1	
XL	Length offset for masking and etching effects	0	

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Laterally Double Diffused Metal Oxide Semiconductor FET Model (LDMOS)

Parameter Name	Description	Default Value	Unit
XW	Width offset for masking and etching effects	0	

Table 40-4 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 40-5 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		
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		

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Parameter Name	Description	Default Value	Unit
CJGATE	Zero bias gate edge sidewall bulk junction capacitance		
CJ	Bottom junction capacitance per unit area at zero bias	5.00WE-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
IGCD	Gate-to-contact length of drain side	0	m
IGCS	Gate-to-contact length of source side	0	m
LGCD			
LGCS			

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Parameter Name	Description	Default Value	Unit
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
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		

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Parameter Name	Description	Default Value	Unit
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
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

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Parameter Name	Description	Default Value	Unit
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 40-6 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
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	

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Parameter Name	Description	Default Value	Unit
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
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

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Table 40-7 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

Table 40-8 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

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Parameter Name	Description	Default Value	Unit
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 40-9 Output Resistance Parameters

Parameter Name	Description	Default Value	Unit
DELTA	Effective VDS parameter	0.01	V
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	

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Parameter Name	Description	Default Value	Unit
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 40-10 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	
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

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Parameter Name	Description	Default Value	Unit
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 40-11 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		
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

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Parameter Name	Description	Default Value	Unit
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 40-12 Temperature Effects Parameters

Parameter Name	Description	Default Value	Unit
AT	Temperature coefficient for saturation	3.30E+04	m/sec
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	

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Parameter Name	Description	Default Value	Unit
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 40-13 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
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+Lln}

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Parameter Name	Description	Default Value	Unit
LWLC	Coefficient of length and width dependence for CV channel length offset	0	$m^{L_{wn}+L_{ln}}$
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	$m^{W_{ln}}$
WLC	Coefficient of length dependence for CV channel width offset	0	$m^{W_{ln}}$
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	$m^{W_{wn}}$
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		

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Table 40-14 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 Vbs=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 Vgsteff calculation for weak to strong inversion	0	V
Qmacov	Smooth coefficient for accumulation charge in the overlap region	0.02	V^2
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	$V^{0.5m}$
K1cww	Width dependent of body effect coefficient for capacitance model	0	$V^{0.5m}$
Vth0ovw	Width dependent of threshold voltage for overlap region	0	Vm

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Parameter Name	Description	Default Value	Unit
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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Distributed Components

This chapter describes component statements for the following components:

- [Microstrip Line \(msline\)](#) on page 2464
- [Multi-Conductor Transmission Line \(mtline\)](#) on page 2464
- [Delay Line \(delay\)](#) on page 2480
- [Four Terminal Relay \(relay\)](#) on page 2481
- [Linear Two Winding Ideal Transformer \(transformer\)](#) on page 2484

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. |

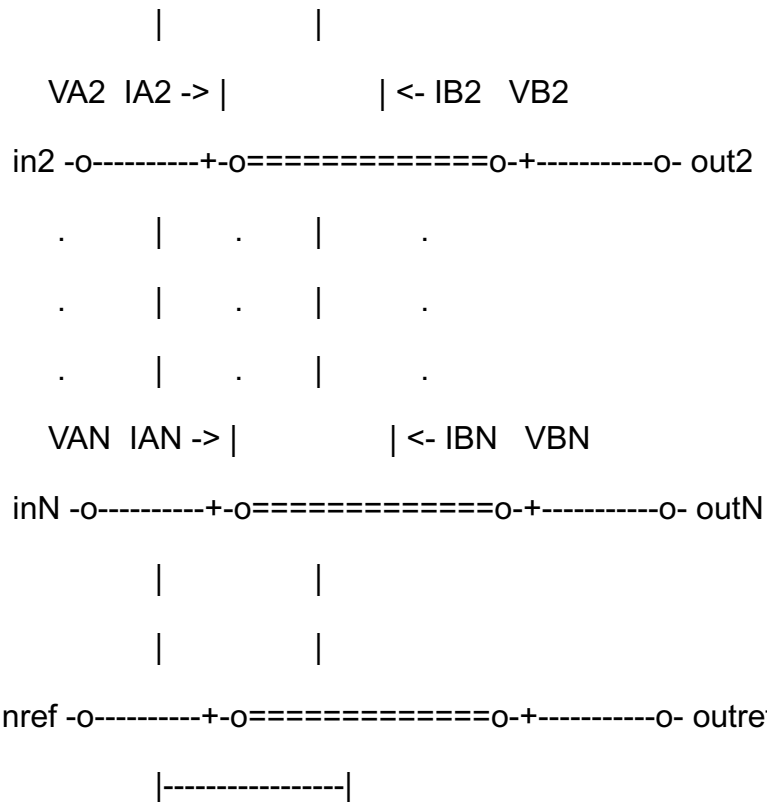
Multi-Conductor Transmission Line (mtline)

```
VA1 IA1 -> |-----| <- IB1 VB1
```

```
in1 -o-----+o=====o+-----o- out1
```

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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.

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

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(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.

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

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$$G(f) = g + f * gdloss,$$

where f stands for frequency, or

$$G(f) = g + f * gdloss / \sqrt{1 + (f/gdloss)^2}$$

if the `fgdloss` 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
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
```

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```
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.

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 `fmax`. For the narrow band model, the RLGC data is calculated at

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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 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 `dlosstype` 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

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`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

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.

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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
```

```
+ c=[ 0.35p
+     -0.03p 0.35p ]
+ file="rl.data" scale=1
```

Virtuoso Simulator Components and Device Models Reference

Distributed Components

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.

2-D Field Solver parameters

12 linetype=sublossline
Transmission line type.
Possible values are microstrip, stripline, coplanar, or sublossline.

Virtuoso Simulator Components and Device Models Reference

Distributed Components

- 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.

Rational fitting parameters

- 27 `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

- 28 `z0=50` Ω Characteristic impedance of lossless line.

Virtuoso Simulator Components and Device Models Reference

Distributed Components

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	$dcr=0$ 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.
41	$alpha_d=0$ dB/m	Dielectric loss (low loss approximation).
42	$q_d=\infty$	Dielectric loss quality factor at f_d (low loss approximation).

Noise parameters

43	$trise$ (C)	Temperature rise from ambient.
----	-------------	--------------------------------

Virtuoso Simulator Components and Device Models Reference

Distributed Components

- 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=[...]` $\Omega/\text{m} \sqrt{\text{Hz}}$ Skin effect resistance matrix per unit length.
- 6 `gdloss=[...]` $\text{S}/\text{m Hz}$ Dielectric loss conductance matrix per unit length.
- 7 `fgdloss` (Hz) Dielectric loss cut-off frequency.
- 8 `file` RLGC data file that contains the frequency dependent RLGC data or S-parameter data file.
- 9 `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

- 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.
- 23 `gndthickness=[...]` m Ground plane thickness.
- 24 `gndsigma` (S/m) Ground plane conductivity.

Virtuoso Simulator Components and Device Models Reference

Distributed Components

Rational fitting parameters

25 $f_{\max}=2.5e10$ Hz Maximum signal frequency used to determine the relevant range of rational fitting or used in the 2D field solver.

TLINE-related parameters

26 $z_0=50$ 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 f_c (Hz) Conductor loss measurement frequency (use with r , q_c , or $alphac$).

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 $q_c=\infty$ Conductor loss quality factor at f_c (low loss approximation).

TLINE dielectric loss parameters

35 f_d (Hz) Dielectric loss measurement frequency (use with q_d).

36 $shuntg=0$ S/m Dielectric (shunt) conductance per unit length.

37 $alphad=0$ dB/m Dielectric loss (low loss approximation).

38 $q_d=\infty$ Dielectric loss quality factor at f_d (low loss approximation).

Virtuoso Simulator Components and Device Models Reference

Distributed Components

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

$$R(f) = r + \sqrt{f} * (1 + j) * r_{\text{skin}},$$

and the following equation can be used to model dielectric loss with the constant RLGC matrices

$$G(f) = g + f * g_{\text{dloss}},$$

where f stands for frequency, or

$$G(f) = g + f * g_{\text{dloss}} / \sqrt{1 + (f/g_{\text{dloss}})^2}$$

Virtuoso Simulator Components and Device Models Reference

Distributed Components

if the `fgdloss` 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.

<code>alphac</code>	I-37	<code>fgdloss</code>	I-9	<code>lineheight</code>	M-20	<code>qc</code>	M-34
<code>alphac</code>	M-33	<code>fgdloss</code>	M-7	<code>linesigma</code>	I-24	<code>qd</code>	I-42
<code>alphad</code>	I-41	<code>file</code>	I-10	<code>linesigma</code>	M-22	<code>qd</code>	M-38
<code>alphad</code>	M-37	<code>file</code>	M-8	<code>linespace</code>	I-23	<code>r</code>	I-3
<code>c</code>	I-6	<code>fmax</code>	I-27	<code>linespace</code>	M-21	<code>r</code>	M-1
<code>c</code>	M-4	<code>fmax</code>	M-25	<code>linethickness</code>	I-21	<code>rskin</code>	I-7
<code>corner</code>	I-33	<code>freqscale</code>	I-11	<code>linethickness</code>	M-19	<code>rskin</code>	M-5
<code>corner</code>	M-29	<code>freqscale</code>	M-9	<code>linetype</code>	I-12	<code>seriesr</code>	I-36
<code>dcr</code>	I-34	<code>g</code>	I-5	<code>linetype</code>	M-10	<code>seriesr</code>	M-32
<code>dcr</code>	M-30	<code>g</code>	M-3	<code>linewidth</code>	I-20	<code>shuntg</code>	I-40
<code>dloss</code>	I-19	<code>gdloss</code>	I-8	<code>linewidth</code>	M-18	<code>shuntg</code>	M-36
<code>dloss</code>	M-17	<code>gdloss</code>	M-6	<code>m</code>	I-2	<code>td</code>	I-29
<code>dlossstype</code>	I-18	<code>gndsigma</code>	I-26	<code>modeltype</code>	I-13	<code>thermalnoise</code>	I-44

Virtuoso Simulator Components and Device Models Reference

Distributed Components

dlosstype	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 td=0.0 s Time delay.
- 2 gain=1 Gain parameter.
- 3 m=1 Multiplicity factor.

Operating-Point Parameters

1 v (V) 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 r_{open} and r_{closed} , the open relay resistance and closed relay resistance, respectively. These resistance values correspond to control voltages of $vt1$ and $vt2$ respectively. The four parameters, $vt1$, $vt2$, r_{open} , and r_{closed} , can be instance or model parameters.

As an alternative, you can specify the threshold voltage v_{th} and a transition width $trans$ rather than specifying $vt1$ and $vt2$. These two parameters are then calculated from v_{th} and $trans$. If all four parameters are specified, v_{th} 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 v_{th} 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 V_c lies between $vt1$ and $vt2$,

$$G = G_{min} + (G_{min} - G_{max}) * [2 * (V_c - vt1)^3 - 3 * (vt2 - vt1) * (V_c - vt1)^2] / (vt2 - vt1)^3$$

Otherwise, if $vt1 < vt2$, then

$$G = G_{min} \quad \text{for } V_c < vt1 \text{ and}$$

$$G = G_{max} \quad \text{for } V_c > vt2.$$

If $vt1 > vt2$,

$$G = G_{min} \quad \text{for } V_c > vt1 \text{ and}$$

Virtuoso Simulator Components and Device Models Reference

Distributed Components

$G = G_{max}$ for $V_c < vt2$.

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 | <code>vt1 (V)</code> | Relay resistance is <code>ropen</code> at this voltage. |
| 2 | <code>vt2=vt1+1.0 V</code> | Relay resistance is <code>rclosed</code> at this voltage. |
| 3 | <code>ropen=∞ Ω</code> | Resistance of a fully open relay. |
| 4 | <code>rclosed=1.0 Ω</code> | Resistance of a fully closed relay. |
| 5 | <code>m=1.0</code> | Multiplicity factor. |
| 6 | <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> . |

Model Definition

```
model modelName relay parameter=value ...
```

Model Parameters

- | | | |
|---|----------------------|---|
| 1 | <code>vt1 (V)</code> | Relay resistance is <code>ropen</code> at this voltage. |
|---|----------------------|---|

Virtuoso Simulator Components and Device Models Reference

Distributed Components

- | | | |
|---|--|---|
| 2 | <code>vt2=vt1+1.0 V</code> | Relay resistance is <code>rclosed</code> at this voltage. |
| 3 | <code>ropen=∞ Ω</code> | Resistance of a fully open relay. |
| 4 | <code>rclosed=1.0 Ω</code> | Resistance of a fully closed relay. |
| 5 | <code>hysteresis=0.0 V</code> | Switching Hysteresis. |
| 6 | <code>vth=0.0 V</code> | Threshold Voltage. |
| 7 | <code>trans=0.0 V</code> | 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 (Ω)</code> | 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.

<code>hysteresis</code> M-5	<code>region</code> I-6	<code>ropen</code> M-3	<code>vt2</code> I-2
<code>m</code> I-5	<code>region</code> OP-1	<code>trans</code> M-7	<code>vt2</code> M-2
<code>rclosed</code> I-4	<code>res</code> OP-2	<code>vt1</code> I-1	<code>vth</code> M-6
<code>rclosed</code> M-4	<code>ropen</code> I-3	<code>vt1</code> M-1	

Linear Two Winding Ideal Transformer (transformer)

Winding 1 connects terminals t_1 and b_1 , and winding 2 connects t_2 and b_2 . The number of turns on windings 1 and 2 are given by n_1 and n_2 , respectively, and n_2 must not be zero. The absolute number of turns of each winding is not important, only the ratio of n_1 to n_2 . 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

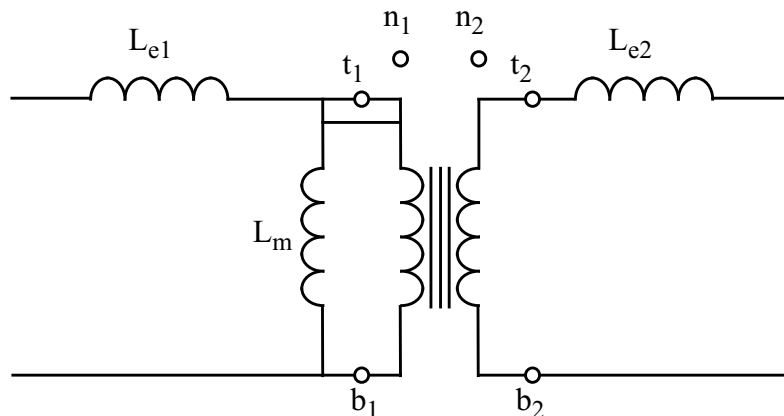
$$\frac{v_1}{v_2} = \frac{t_1}{t_2} = \frac{i_2}{i_1}$$

To model a physical transformer with L_1 and L_2 as the inductance of the windings and k as the coupling coefficient, add an inductor $L_m = k.L_1$ in parallel with winding 1 and inductors $L_{e1} = L_1.(1 - k)$ and $L_{e2} = L_2.(1 - k)$ 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 L_1 (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 | n1=1 | Number of turns on winding 1. |
| 2 | n2=1 | Number of turns on winding 2. |
| 3 | m=1 | 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 2488
- [MISN Field Effect Transistor \(misnan\)](#) on page 2508
- [Diffusion Resistor Model \(rdiff\)](#) on page 2517

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) hvmmos 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 hvmmos 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.

Virtuoso Simulator Components and Device Models Reference

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	$w_{l=0}$ m ²	Area dependence of delta W.
43	$w_{min=0}$ m	The minimum channel width for which the model is still valid.
44	$w_{max=1}$ m	The maximum channel width for which the model is still valid.
45	$d_{wg=0}$ m/v	Gate-bias dependence of channel width.
46	$d_{wb=0}$ m/ \sqrt{v}	Body-bias dependence of channel width.
47	$t_{ox=1.5e-8}$ m	Gate oxide thickness.
48	$x_t=1.55e-7$ m	Doping depth.
49	$r_{d0=0}$ Ω	Fixed drain resistance.
50	$r_{s0=0}$ Ω	Fixed source resistance.
51	$r_{dw=0}$ Ω μm	Width dependence of drain resistance.
52	$r_{sw=0}$ Ω μm	Width dependence of source resistance.
53	$r_{dsw=0}$ Ω μm	Width dependence of drain-source resistance.
54	$p_{rwb=0}$ $1/\sqrt{v}$	Body-effect coefficient for Rds.
55	$p_{rwg=0}$ $1/\sqrt{v}$	Gate-effect coefficient for Rds.
56	$w_r=1$	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	$u_{0f=670}$ cm ² /V s	Forward low-field surface mobility at t_{nom} . Default is 250 for PMOS.
60	$u_{0r}=u_{0f}$ cm ² /V s	Reverse low-field surface mobility at t_{nom} .
61	$vsatf=8e4$ m/s	Forward carrier saturation velocity at t_{nom} .

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- 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 $\text{pscbelf}=4.24\text{e}8$ 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 $\text{pscbeg}=0$ V/m Third coefficient of substrate current body effect.
- 87 $\text{pscbelr}=\text{pscbelf}$ 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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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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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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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 ≥ 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 ≥ 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.

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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	$ad=0$ m ²	Default area of drain diffusion.
175	$ps=0$ m	Default perimeter of source diffusion.
176	$pd=0$ m	Default perimeter of drain diffusion.
177	$nrd=0$ m/m	Default number of squares of drain diffusion.
178	$nrs=0$ m/m	Default number of squares of source diffusion.
179	$xw=0$ m	Width variation due to masking and etching.
180	$xl=0$ m	Length variation due to masking and etching.

Temperature effects parameters

181	$tnom$ (C)	Parameters measurement temperature. Default set by <code>options</code> .
182	$trise=0$ C	Temperature rise from ambient.
183	$tlev=0$	DC temperature selector.
184	$tlevc=0$	AC temperature selector.
185	$eg=1.12452$ 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 $vsatf$.
192	$atr=atf$ m/s	Temperature coefficient for $vsatr$.
193	$at1f=0$ m/s	Temperature coefficient for $dvsatf$.
194	$at1r=at1f$ m/s	Temperature coefficient for $dvsatr$.

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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 ua_r .
200	$ub1r=ub1f$ m ² /v ²	Temperature coefficient for ub_r .
201	$uc1r=uc1f$ m/v ²	Temperature coefficient for uc_r .
202	$ud1r=0$ m/v ²	Temperature coefficient for ud_r .
203	$rth=0$ Ω	Self-heating thermal resistance.
204	$rthg=0$ 1/V	Gate-effect coefficient for R_{th} .
205	$rthb=0$ 1/ \sqrt{v}	Body-effect coefficient for R_{th} .
206	$p_{rt}=0$ Ω	Temperature coefficient for R_{ds} .
207	$tr_s=0$ 1/C	Temperature parameter for source resistance.
208	$tr_d=0$ 1/C	Temperature parameter for drain resistance.
209	$ute=-1.5$	Mobility temperature exponent.
210	$x_{ti}=3$	Saturation current temperature exponent.
211	$p_{tc}=0$ V/C	Surface potential temperature coefficient.
212	$t_{cv}=0$ V/C	Threshold voltage temperature coefficient.
213	$p_{ta}=0$ V/C	Junction potential temperature coefficient.
214	$t_{pb}=0$ V/C	Junction potential temperature coefficient.
215	$p_{tp}=0$ 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	$cta=0$ 1/C	Junction capacitance temperature coefficient.
218	$tcj=0$ 1/C	Junction capacitance temperature coefficient.
219	$ctp=0$ 1/C	Sidewall junction capacitance temperature coefficient.
220	$tcj_{sw}=0$ 1/C	Sidewall junction capacitance temperature coefficient.
221	$tcj_{swg}=0$ 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 $b_{vj}=\infty$ V Junction reverse breakdown voltage.

235 $v_{box}=1e9$ tox V Oxide breakdown voltage.

Length dependent parameters (Not listed)

Width dependent parameters (Not listed)

Cross-term dependent parameters (Not listed)

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 `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.

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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 beta.
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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28	csb (F)	Csb.
29	cbg (F)	Cbg.
30	cbd (F)	Cbd.
31	cbs (F)	Cbs.
32	cbb (F)	Cbb.
33	ron (Ω)	On-resistance.
34	id (A)	Resistive drain current.
35	ibulk (A)	Resistive bulk current.
36	pwr (W)	Power at op point.
37	gmoverid (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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a0r	M-18	dvsatr	M-65	n	M-128	rthg	M-204
a1	M-21	dvt0	M-14	nch	M-27	sc	M-121
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betaeff OP-13	gap2 M-187	pclmbr M-93	u0r M-60
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Other Models

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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	pdiblclf	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	pdiblchr	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
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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	rdsw	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	wwl	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

Virtuoso Simulator Components and Device Models Reference

Other Models

droun	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.

Virtuoso Simulator Components and Device Models Reference

Other Models

3	$as=3e-11 \text{ m}^2$	Area of source diffusion.
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	$doplidd=3.2e17 \text{ cm}^{-3}$	LDD region doping concentration. Default = $3.2e19$ for pmos.

Virtuoso Simulator Components and Device Models Reference

Other Models

Geometry parameters

7	$lvar=0 \mu\text{m}$	Gate length correction.
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.
----	-----------------------------------	---

Virtuoso Simulator Components and Device Models Reference

Other Models

21	$\text{mutxp}=1.72$	Temperature coefficient for the carrier mobility. Default = 1.01 for pmos.
22	$\text{kg}=1.4\text{e-}7$ cm/V	Gate field factor. Default = 1.685e-7.
23	$\text{v0}=3.21\text{e}7$ cm/s	Scattering limited velocity. Default = 2.45e7.
24	$\text{v0txp}=-6.3$	Temp coefficient for scattering limited velocity. Default = -5 for pmos.
25	$\text{find}=1.25$	Field mobility index factor. Default = 1.9 for pmos.
26	$\text{gfc}=9.1\text{e-}10$	Gate voltage dependence of enhanced gate-field scattering. Default = 1.05e-10 for pmos.
27	$\text{gfc}m=3\text{e-}5$	Drain voltage dependence of enhanced gate-field scattering. Default = 2.3e-3 for pmos.
28	$\text{gfmb}=1.45\text{e-}3$	Factor controlling substrate bias dependence of enhanced gate-field scattering. Default 3.3e-3 for pmos.
29	$\text{csf}=1.06\text{e-}11$	Drain voltage dependence of coulombic scattering. Default = 1.35e-12 for pmos.
30	$\text{csfb}=1.61\text{e-}3$	Body voltage dependence of coulombic scattering. Default = 8.5e-3 for pmos.

Saturation parameters

31	$\text{dprat}=15$	Drain region/channel doping ration. Default = 2 for pmos.
32	$\text{satpr}=0.2$	Saturation region shaping factor. Default = 1.0 for pmos.
33	$\text{sbd}r=0.3535534$	Primary parameter controlling the onset of saturation.
34	$\text{sadr}=5$	Secondary parameter controlling the onset of saturation.

Capacitance parameters

35	$\text{sccf}=0.25$	Inner fringing factor for the N+ S/D.
----	--------------------	---------------------------------------

Virtuoso Simulator Components and Device Models Reference

Other Models

Extrinsic parameters

- 36 $r_{ws}=480 \text{ } \Omega \text{ } \mu\text{m}$ Source series resistance. Default = 1180 for pmos.
- 37 $r_{wd}=480 \text{ } \Omega \text{ } \mu\text{m}$ Drain series resistance. Default = 1180 for pmos.
- 38 $r_{sd}=-1 \text{ } \Omega \text{ } \mu\text{m}$ Drain/source series resistance. Negative value for asymmetrical devices.
- 39 $r_{gsh}=0 \text{ } \Omega \text{ } \mu\text{m}$ Gate series resistance.
- 40 $w_{tgf}=0.28 \text{ } \mu\text{m}$ Width of transition from gate to field oxide under poly.
- 41 $c_{pts}=5.7e-9 \text{ F/cm}^2$ Poly-to-substrate capacitance per unit area.
- 42 $c_{gfrs}=1e-12 \text{ F/cm}$ Gate-source overlap fringing field capacitance.
- 43 $c_{gfrd}=1e-12 \text{ F/cm}$ Gate-drain overlap fringing field capacitance.
- 44 $c_{gfr}=1.36e-12 \text{ F/cm}$ Gate overlap fringing field capacitance.

Junction parameters

- 45 $i_s=1.02e-12 \text{ A/cm}^2$ Sat current per unit area of S/D region-injection component. Default = $9.21e-13$ for pmos.
- 46 $i_{sg}=1e-20 \text{ A/cm}$ Sat current per unit length of gate oxide periphery-injection component. Default = $1.17e-20$.
- 47 $i_{sf}=1e-20 \text{ A/cm}$ Sat current per unit length of field oxide periphery-injection component. Default = $1.17e-20$.
- 48 $i_g=1.31e-10 \text{ A/cm}^2$ Sat current per unit area of S/D region-generation component. Default = $8.27e-10$.
- 49 $i_{gg}=6.99e-14 \text{ A/cm}$ Sat current per unit length of gate oxide periphery-generation/recombination component. Default = $6.47e-14$.

Virtuoso Simulator Components and Device Models Reference

Other Models

- 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/cm² Zero bias junction capacitance per unit area. Default = $1.273e-7$ for pmos.
- 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.

Virtuoso Simulator Components and Device Models Reference

Other Models

65 `dept=3e-7` Depth of trap distribution.

Operating-Point Parameters

1	<code>vgs</code> (V)	Gate-source voltage.
2	<code>vds</code> (V)	Drain-source voltage.
3	<code>vbs</code> (V)	Bulk-source voltage.
4	<code>id</code> (A)	Drain current.
5	<code>vth</code> (V)	Threshold voltage.
6	<code>vdsat</code> (V)	Drain-source saturation voltage.
7	<code>gm</code> (S)	Common-source transconductance.
8	<code>gd</code> (S)	Common-source output conductance.
9	<code>gs</code> (S)	Body-transconductance.
10	<code>gmb</code> (S)	Body transconductance.
11	<code>gjs</code> (S)	Drain-bulk junction conductance.
12	<code>ibs</code> (A)	Drain-bulk junction current.
13	<code>gjd</code> (S)	Source-bulk junction conductance.
14	<code>ibd</code> (A)	Source-bulk junction current.
15	<code>qgg</code> (Coul)	Gate charge.
16	<code>qss</code> (Coul)	Source charge.
17	<code>qdd</code> (Coul)	Drain charge.
18	<code>qbb</code> (Coul)	Bulk charge.
19	<code>cgg</code> (F)	C _{gg} .
20	<code>cgs</code> (F)	C _{gs} .

Virtuoso Simulator Components and Device Models Reference

Other Models

21	cgd (F)	Cgd.
22	cgb (F)	Cgb.
23	csg (F)	Csg.
24	css (F)	Css.
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

Virtuoso Simulator Components and Device Models Reference

Other Models

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
cbd	OP-33	dld	M-10	isf	M-47	sbdrr	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	doplidd	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	gfcmm	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

Virtuoso Simulator Components and Device Models Reference

Other Models

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_l , the setting of $V_{bl} = \text{abs}(V_b - V_l)$ is replaced by $V_{bl} = \text{min}(\text{abs}(V_b - V_h), \text{abs}(V_b - V_l))$. 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
```

Virtuoso Simulator Components and Device Models Reference

Other Models

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 ...
```

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. |

Virtuoso Simulator Components and Device Models Reference

Other Models

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 v_p .
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>vh1 (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.

Virtuoso Simulator Components and Device Models Reference

Other 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.

dta	M-5	r	OP-4	tcrint1	M-16	vhl	OP-1
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		

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