MOSFET Amplifier Configuration

- Single stage
- The signal is fed to the amplifier represented as $v_{\text{sig}}$ with an internal resistance $R_{\text{sig}}$.
- MOSFET is represented by its small signal model.
- Generally interested of gain, input and output resistance (overall amplifier circuit not only the small signal model).

![MOSFET Amplifier Configuration Diagrams](image)

- Considering only the small signal not the bias

(a) Common Source (CS)  (b) Common Gate (CG)  (c) Common Drain (CD)
Characterizing Amplifiers

- Find gain, input and output resistance

\[ R_{in} = \frac{v_i}{i_i} \]

\[ A_{vo} = \frac{v_o}{v_i} \mid_{R_L=\infty}, \quad A_v = \frac{v_o}{v_i} \]

\[ G_v = \frac{v_o}{v_{sig}} \] Overall voltage gain

Amplifier Configuration

- Common Source
- Common Source with a source resistance
- Common gate
- Common drain or voltage follower
Amplifiers

\[ v_o = A_{vo} v_i \frac{R_L}{R_L + R_o} \]

\[ v_i = v_{sig} \frac{R_{in}}{R_{in} + R_{sig}} \]

\[ A_v = A_{vo} \frac{R_L}{R_L + R_o} \]

\[ G_v = \frac{v_o}{v_{sig}} = \frac{R_{in}}{R_{in} + R_{sig}} A_{vo} \frac{R_L}{R_L + R_o} \]

Common Source

- Most widely used configuration
- In multistage amplifiers, the bulk of the gain is from common source.
- The source is grounded, making it common between input and output.
- We can use hybrid π model.
Common Source

For $R_o$, set $v_i = 0$

$$R_o = r_0 \parallel R_D$$

$$A_{vo} = -g_m (r_0 \parallel R_D)$$

Common Source with Source R

- For simplicity, $r_0$ is not included.
- No effect on discrete implementation, not so for IC’s
- $R_s$ provides a negative feedback to control the magnitude of the signal to prevent nonlinear distortion.
- Also reduces the voltage gain and extends the useful bandwidth.
Common Source with Source R

\[ v_{gs} = -g_m v_i \left( \frac{1}{g_m} + R_S \right) \]

\[ v_{gs} = \frac{v_i}{1 + g_m R_S} \]

Common Gate Amplifier
Common Drain Amplifier – Source Follower

Since there is a resistance $R_L$ connected to the source, it is easier to use the T-model.

Common Source – Voltage Follower

$R_i = \infty$
### Comparison

<table>
<thead>
<tr>
<th></th>
<th>CS</th>
<th>CS+RS</th>
<th>CG</th>
<th>CD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rin</td>
<td>$\infty$</td>
<td>$\infty$</td>
<td>$\frac{1}{g_m}$</td>
<td>$\infty$</td>
</tr>
<tr>
<td>Rout</td>
<td>$R_D \parallel R_o$</td>
<td>$R_D$</td>
<td>$R_D$</td>
<td>$\frac{1}{g_m}$</td>
</tr>
<tr>
<td>$G$</td>
<td>$-\frac{g_m(R_D \parallel R_L)}{r_o}$</td>
<td>$A_v = \frac{g_m(R_D \parallel R_L)}{1 + g_m R_S}$</td>
<td>$G_v = \frac{(R_D \parallel R_L)}{1/g_m + R_{diss}}$</td>
<td>$G_v = \frac{A_v}{R_L}$</td>
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#### Example E5.37

Given:
- $V_{DD} = V_{SS} = 10V$, $I = 0.5 mA$, $R_G = 4.7\, \Omega$, $R_D = 15K\, \Omega$,
- $V_t = 1.5V$, $k_i = 1mA/V^2$, $V_A = 75V$.

Find $V_{DS}$, $V_{GS}$, $V_{GS}$, $V_D$, $g_{m}$, $r_o$.

What is the max. possible voltage swing at drain and the MOSFET remains in saturation?
Example 5.38

Find \( R_{in}, A_{vo}, R_{o}, G_{m} \) with and without \( r_o \). \( R_{seg} = 100\text{K}\Omega \) and \( R_L = 15\text{K}\Omega \).

Biasing in MOS Amplifiers

- How to choose the operating point?
- Want a stable Q-point (known \( I_D \) and \( V_{DS} \)) to ensure operation in the saturation region.
Biasing -- Fixing $V_{GS}$

- $I_D$ depends on $\mu$, $C_{ox}$, $W/L$ and $V_t$, and $V_{GS}$
- $C_{ox}$, $V_{GS}$ (even $W/L$) can vary across devices of the same type.
- Constant $V_{GS}$ Not a good idea.
- $\mu$, $C_{ox}$ are a $f(t)$

Biasing – Fixing $V_G$ and $R_S$

- $R_S$ provides a negative feedback to stabilize $I_D$
Biasing – Fixing $V_G$ and $R_S$

- Uses one power supply
- What is the effect on input resistance when you add $V_{gs}$ signal

![Circuit Diagram](image)

Figure 5.53 Circuit for Example 5.12.
Biasing – D-to-G Resistor

- \( V_{GS} = V_{DS} = V_{DD} - I_D R_D \)
- \( V_{DD} = V_{GS} + I_D R_D \)
- Provides a feedback resistor to stabilize \( I_D \)

Biasing – Constant Current Source

Figure 5.55 (a) Biasing the MOSFET using a constant-current source \( I \). (b) Implementation of the constant-current source \( I \) using a current mirror.
Frequency Response

- Low-frequency band
  - Gain falls off due to the effect of $C_g$, $C_k$, and $C_C$
  - All capacitances can be neglected

- Midband
  - 3 dB

- High-frequency band
  - Gain falls off due to the internal capacitive effects of the MOSFET

$20 \log | \frac{V_o}{V_{in}} |$ (dB)