MOSFET : Small-Signal Model

Like for other semiconductor devices, to obtain a small-signal model, we linearise around the operating (quiescent) point:

\[ g_m = \left. \frac{\partial i_D}{\partial v_{GS}} \right|_{v_{DS}=V_{DSQ}} = \begin{cases} 2\sqrt{KI_D} & \text{in saturation} \\ 2KV_{DSQ} & \text{in triode region} \end{cases} \]
MOSFET: Small-Signal Model

**Development of the T equivalent circuit model**

**Figure 12.19** Small-signal equivalent circuit for FETs.
MOSFET: Small-Signal Model

Development of the T equivalent circuit model

MOSFET: real characteristic
MOSFET : Improved s-s Model

To account for a nonzero slope in saturation, we add the output resistance $r_d$ (or $r_o$).

![Figure 12.20](image-url) FET small-signal equivalent circuit that accounts for the dependence of $i_D$ on $v_{DS}$.

MOSFET : Improved s-s Model

T version

![Diagrams](image-url)
Common-Source Amplifier

Figure 12.25 Common-source amplifier.

Typical frequency response:

- Low-frequency band: Gain falls off due to the effect of $C_{gds}$, $C_D$, and $C_{gs}$.
- Midband: All capacitances can be neglected.
- High-frequency band: Gain falls off due to the effect of $C_{gd}$ and $C_{gs}$.

$20 \log |A(f)|$ (dB) vs. $f$ (Hz)
Common-Source Amplifier

To obtain a **midband** small-signal equivalent circuit:

- short-circuit all by-pass and coupling cap’s
- short-circuit all independent voltage sources
- open-circuit all independent current sources
- replace transistors by their small-signal models
- re-draw the circuit

Midband Small-Signal Equivalent Circuit:

Note that \( v_{gs} = v_{in} \)
Common-Source Amplifier

Voltage transmittance (voltage gain):

\[ A_v = \frac{v_o}{v_{in}} \]
\[ v_{gs} = v_{in} \]

\[ v_o = -g_m v_{gs} R_L = -g_m v_{in} (r_d \parallel R_D \parallel R_L) \]
\[ A_v = -g_m (r_d \parallel R_D \parallel R_L) \]

Common-Source Amplifier

Output Resistance:

\[ v_{gs} = 0 \rightarrow g_m v_{gs} = 0 \rightarrow R_o = r_d \parallel R_D \]
Common-Drain Amplifier (Source Follower)

\[ v_o = g_m v_{gs} (r_d \parallel R_S \parallel R_L) = g_m v_{gs} R_L' \]

\[ v_{gs} = v_{in} - v_o \]

\[ v_o = g_m (v_{in} - v_o) R_L' \]

\[ A_v = \frac{v_o}{v_i} = \frac{g_m R_L'}{1 + g_m R_L'} \]
**Source Follower: \( R_{\text{out}} \)**

![Source Follower Circuit Diagram](image)

**Figure 12.28** Equivalent circuit used to find the output resistance of the source follower.

\[
v_{gs} = v_g - v_s = 0 - v_x = -v_s
\]

\[
i_x = \frac{v_s}{R_S} + \frac{v_s}{r_d} + v_x g_m
\]

\[
R_o = \frac{v_s}{i_x} = \frac{1}{\frac{1}{R_S} + \frac{1}{r_d} + g_m}
\]