48521 FUNDAMENTALS of ELECTRICAL ENGINEERING

LECTURE 10A

MOSFET Voltage Amplifiers

MOSFET : Small-Signal Model

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

$$g_m = \left.\frac{\partial i_D}{\partial v_{GS}}\right|_{v_{DS}=V_{DSQ}} = \begin{cases} 2\sqrt{KI_{DQ}} \ ; & \text{in saturation} \\ 2KV_{DSQ} \ ; & \text{in triode region} \end{cases}$$

MOSFET : Small-Signal Model

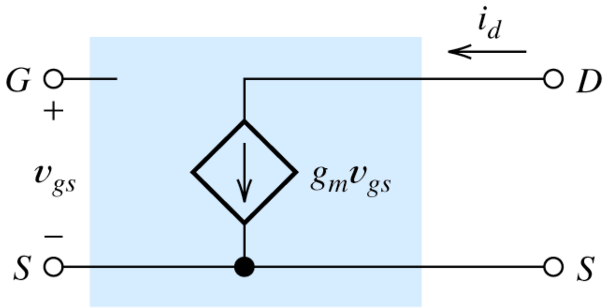
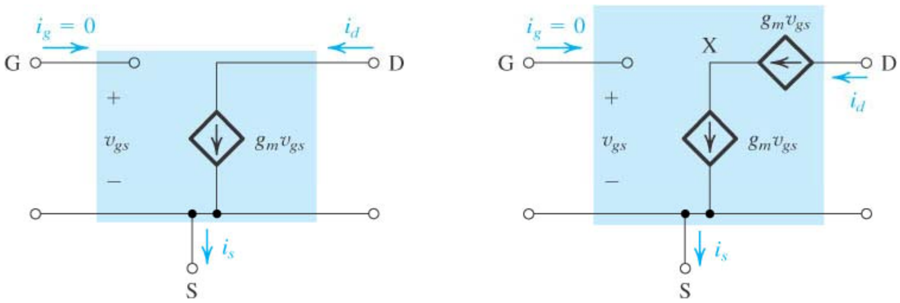


Figure 12.19 Small-signal equivalent circuit for FETs.

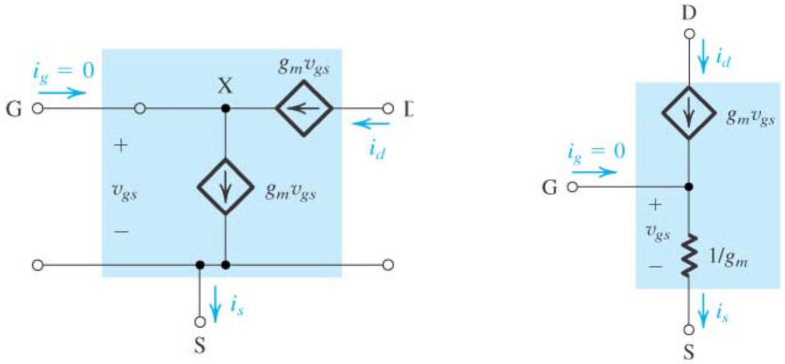
MOSFET : Small-Signal Model

Development of the T equivalent circuit model

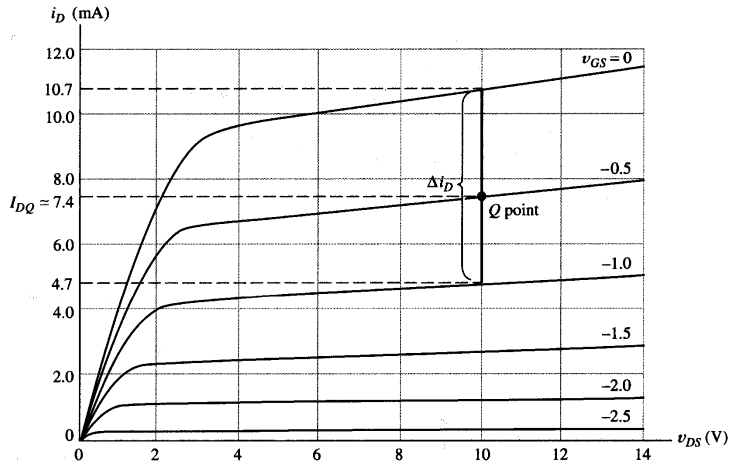


MOSFET : Small-Signal Model

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)

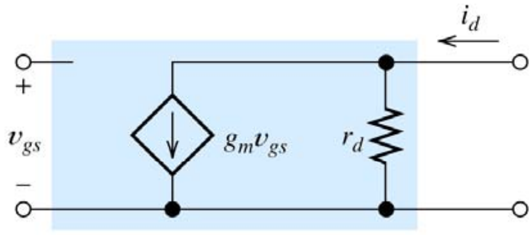
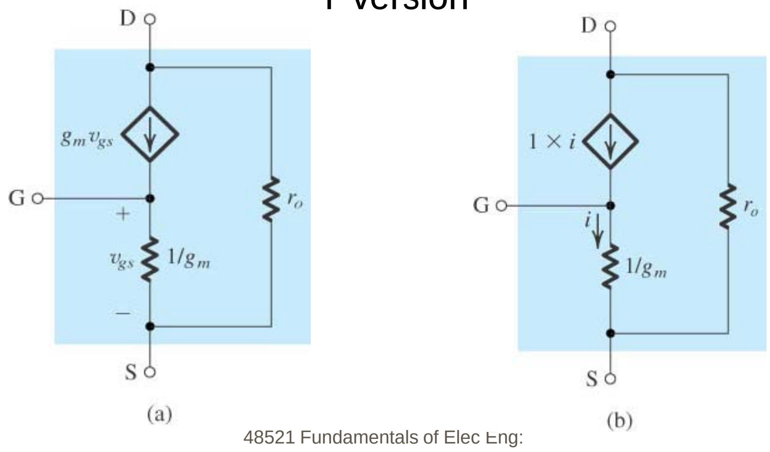


Figure 12.20 FET small-signal equivalent circuit that accounts for the dependence of i_D on v_{DS}.

MOSFET : Improved s-s Model

T version



Common-Source Amplifier

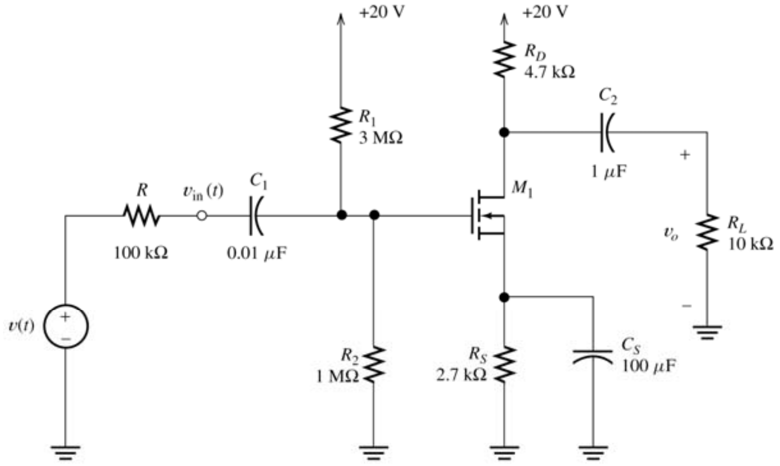
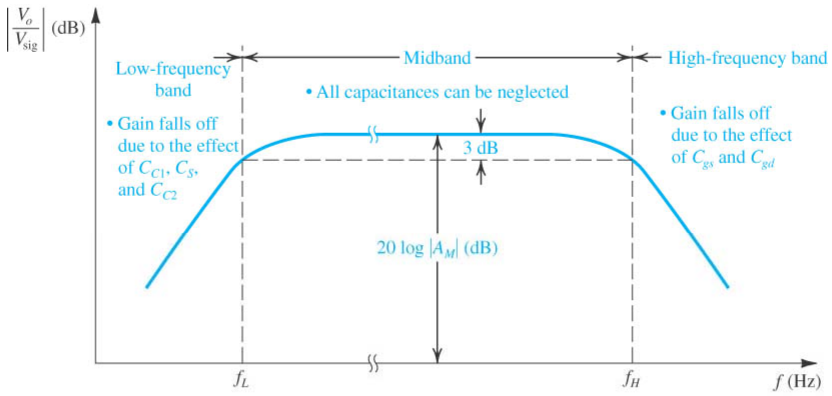


Figure 12.25 Common-source amplifier.

Common-Source Amplifier

Typical frequency response:

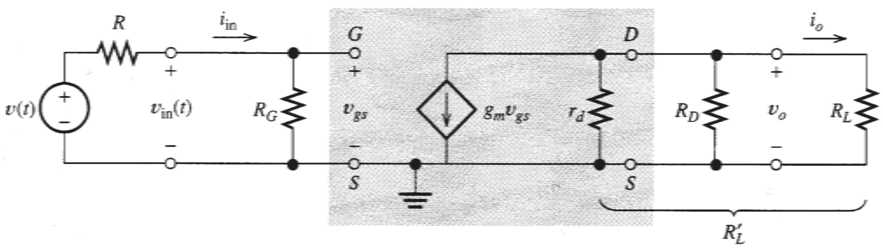


Common-Source Amplifier

- 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

Common-Source Amplifier

- Midband Small-Signal Equivalent Circuit:



- Note that $v_{gs} = v_{in}$

Common-Source Amplifier

- Voltage transmittance (voltage gain):

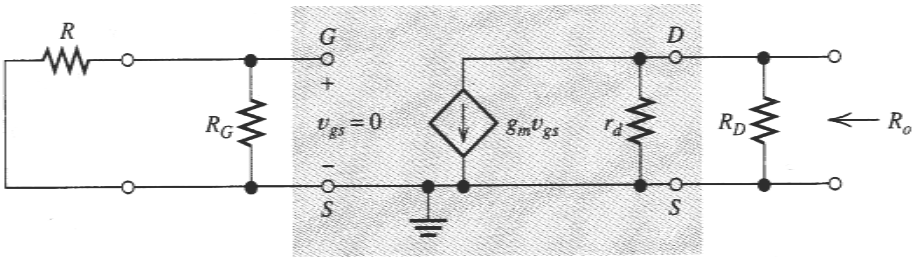
$$A_v = \frac{v_o}{v_{in}}; \quad v_{gs} = v_{in}$$

$$v_o = -g_m v_{gs} R_L' = -g_m v_{in} \left(r_d \parallel R_D \parallel R_L \right)$$

$$A_v = -g_m \left(r_d \parallel R_D \parallel R_L \right)$$

Common-Source Amplifier

- Output Resistance:



- $v_{gs} = 0 \rightarrow g_m v_{gs} = 0 \rightarrow R_o = r_d || R_D$

Common-Drain Amplifier (Source Follower)

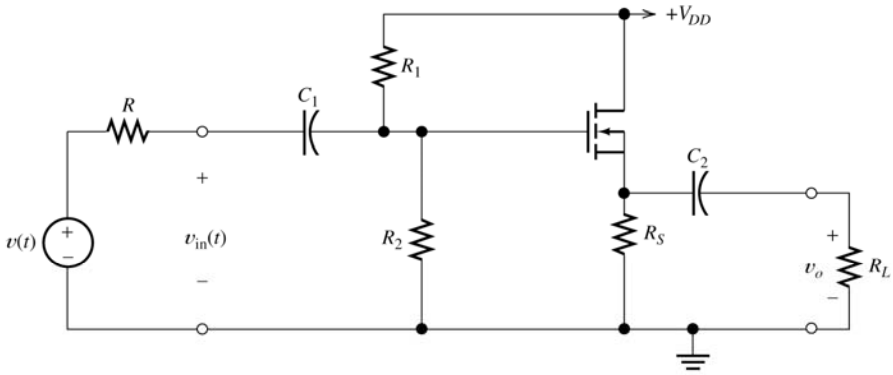


Figure 12.26 Source follower.

Source Follower: voltage gain

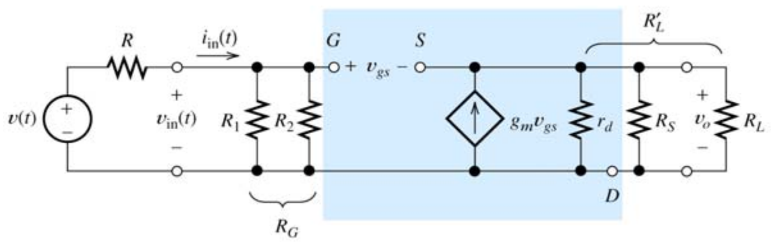


Figure 12.27 Small-signal ac equivalent circuit for the source follower.

$$v_o = g_m v_{gs}(r_d \parallel R_S \parallel R_L) = g_m v_{gs} R_L^{'}$$

$$v_{gs} = v_{in} - v_o$$

$$v_o = g_m (v_{in} - v_o) R_L^{'}$$

$$A_v = \frac{v_o}{v_i} = \frac{g_m R_L^{'}}{1 + g_m R_L^{'}}$$

Source Follower: R_{out}

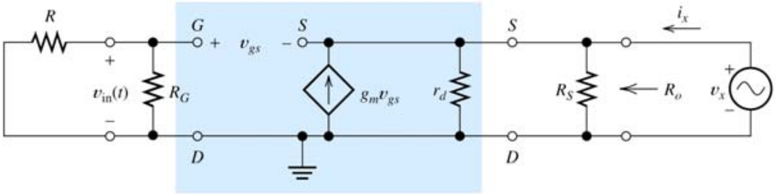


Figure 12.28 Equivalent circuit used to find the output resistance of the source follower.

$$v_{gs} = v_g - v_s = 0 - v_x = -v_x$$

$$i_x = \frac{v_x}{R_S} + \frac{v_x}{r_d} + v_x g_m$$

$$R_o = \frac{v_x}{i_x} = \frac{1}{\frac{1}{R_S} + \frac{1}{r_d} + g_m}$$