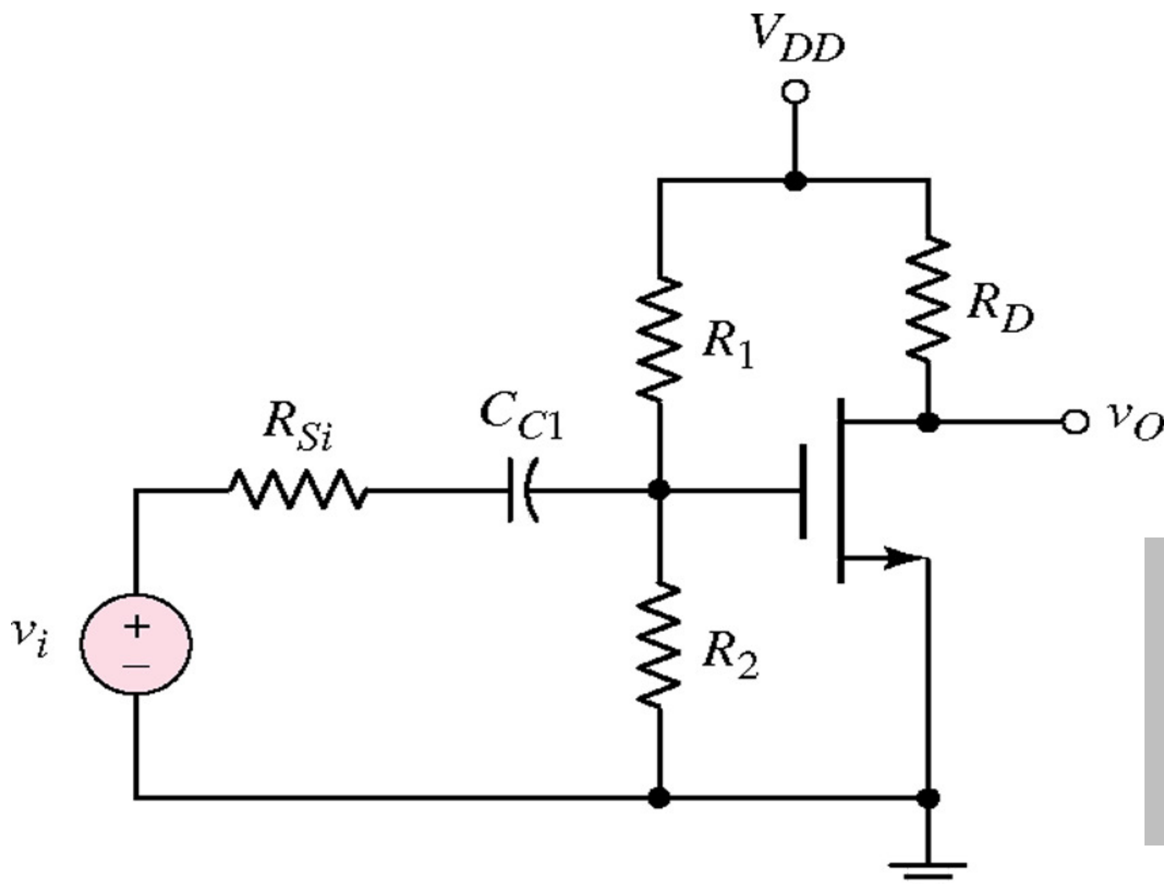
Faculty of Engineering

ECE 335: Electronic Circuits

Lecture 9:
MOSFET Amplifiers

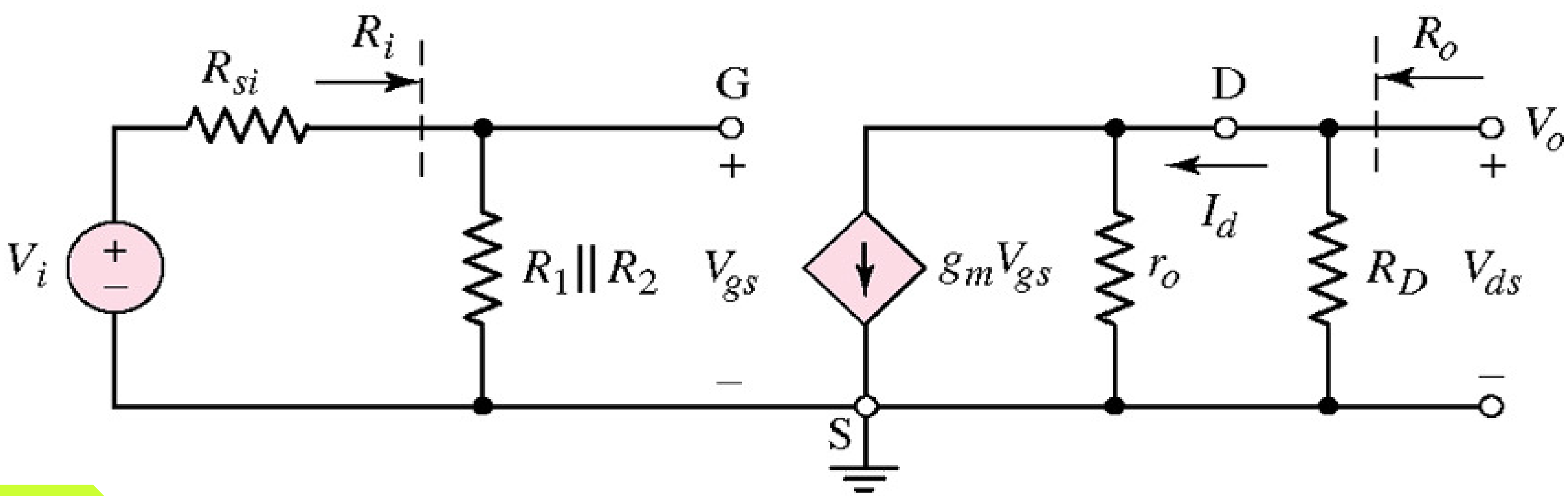
- **Common-Source Amplifier**
- **Common-Drain Amplifier**
- **Common-Gate Amplifier**

COMMON-SOURCE AMPLIFIER
- Basic Configuration



Common-source circuit with voltage divider biasing & coupling capacitor

Small-signal equivalent circuit



input resistance

$$R_i = R_1 \| R_2$$

input voltage

$$V_{gs} = \left(\frac{R_i}{R_i + R_{Si}} \right) V_i$$

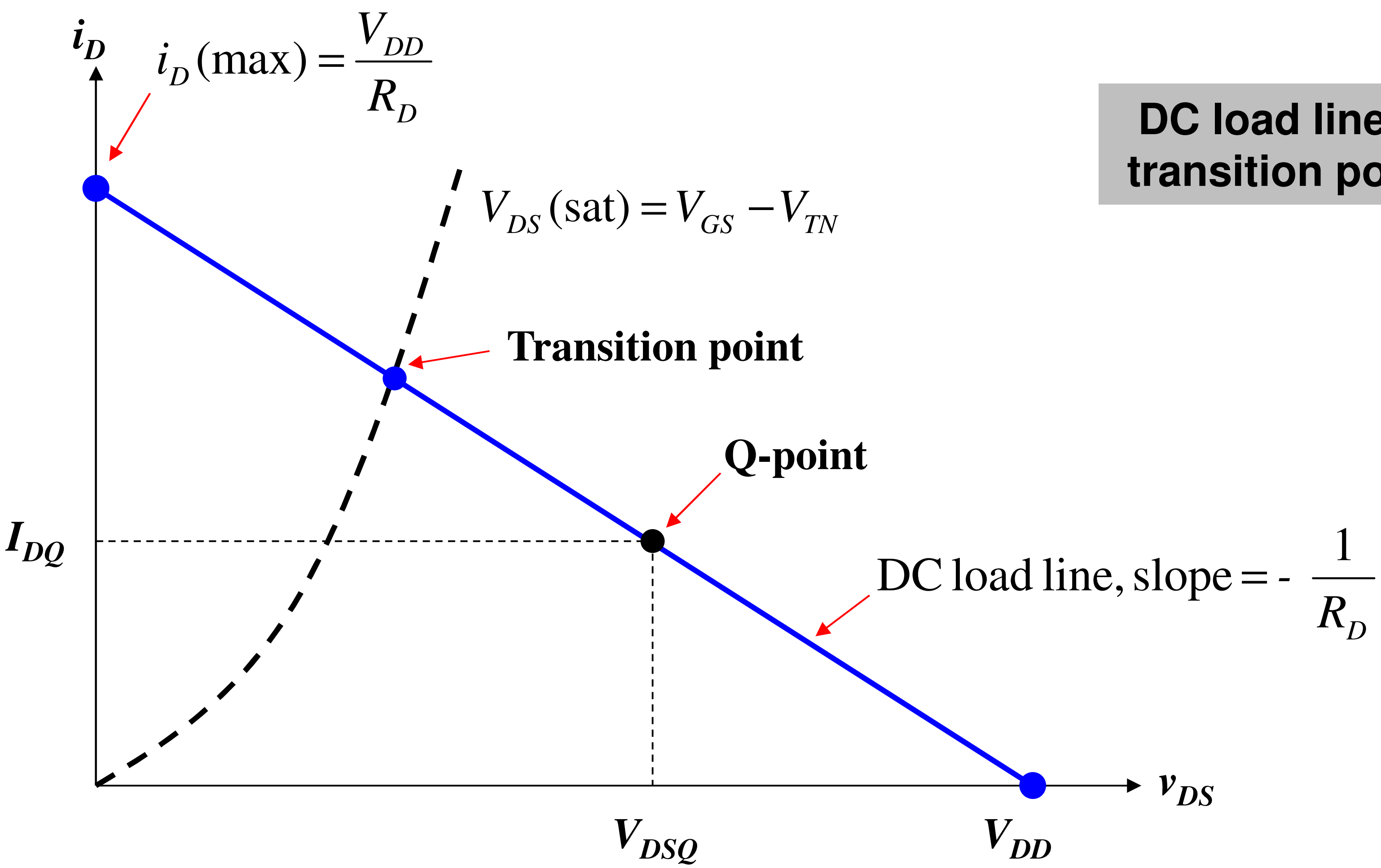
$$V_o = -g_m V_{gs} \left(r_o \| R_D \right)$$

output voltage

small-signal voltage gain

$$A_v = \frac{V_o}{V_i} = -g_m \left(r_o \| R_D \right) \left(\frac{Ri}{Ri + Rsi} \right)$$

DC Load Line



DC load line & transition point

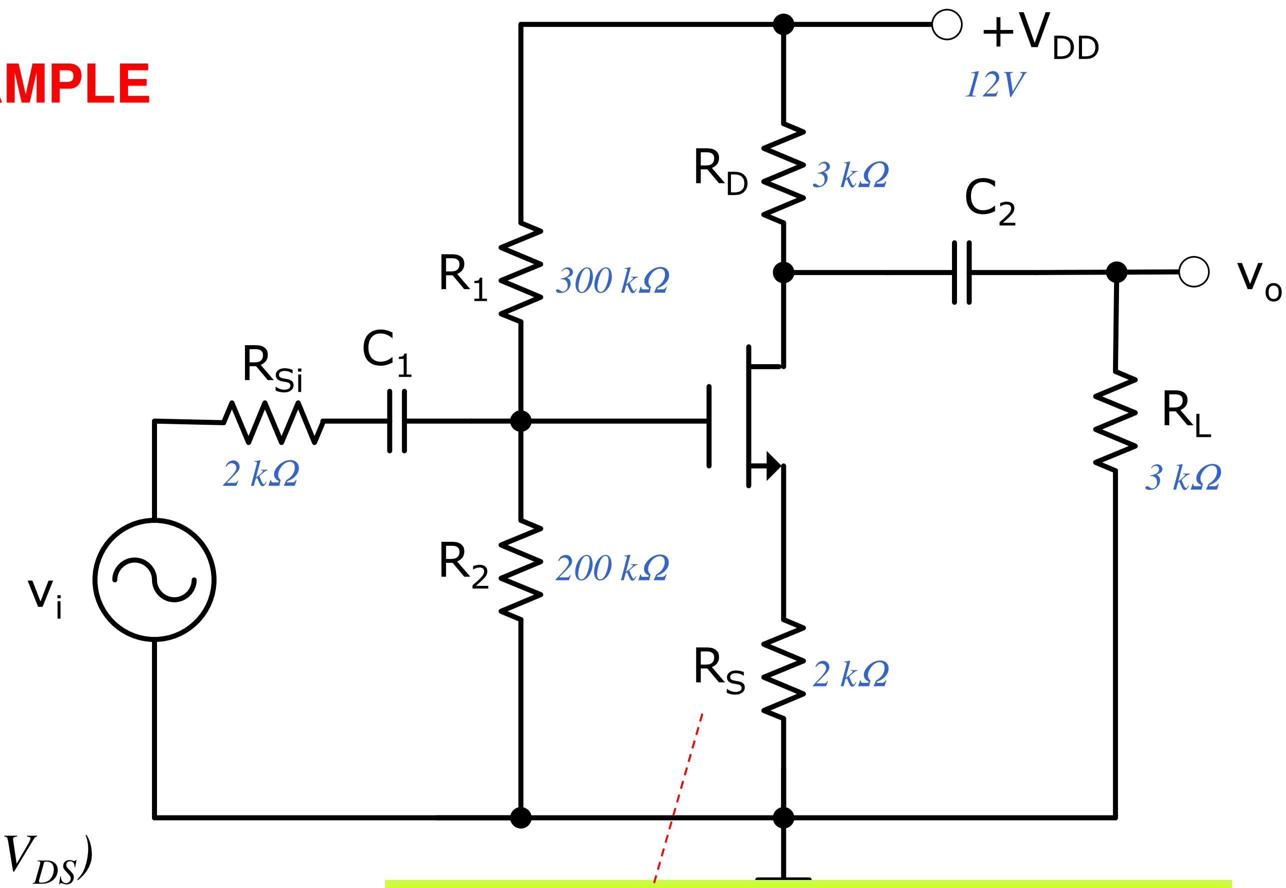
COMMON-SOURCE AMPLIFIER
- with Source Resistor

CALCULATION EXAMPLE

Given:

$V_{TN} = 2V,$
$K_n W/L = 2\ mA/V^2,$

$\lambda = 0$



Determine:

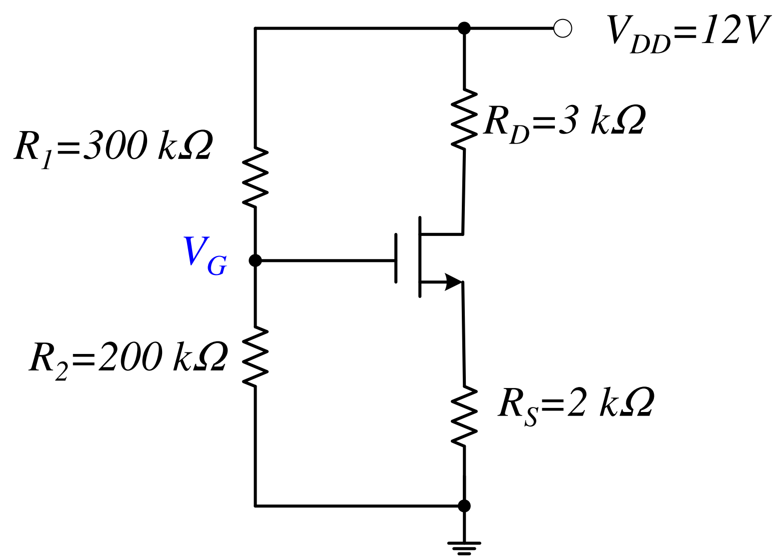
i- Q-point values $(I_D\ ,\ V_{DS})$

ii- small-signal voltage gain

Stabilize the Q-point against variation of transistor parameters

Q-point values

dc equivalent circuit



$$V_G = \left(\frac{R_2}{R_1 + R_2}\right) V_{DD} = \left(\frac{200k}{300k + 200k}\right) 12 = 4.8V$$

$$I_D = \frac{V_G - V_{GS}}{R_S} = \frac{K_n}{2} \frac{W}{L} \left(V_{GS} - V_{TN}\right)^2$$

Q-point values (Cont)

$$4.8 - V_{GS} = (1m)(2k)(V_{GS} - 2)^2$$

$$2(V_{GS})^2 - 7V_{GS} + 3.2 = 0$$

$$V_{GS} = \frac{7 \pm \sqrt{(7)^2 - 4(2)(3.2)}}{2(2)} = 0.54, 2.96$$

For V_{GS} = 0.54 V, MOSFET → *cutoff* 'coz V_{GS}<V_{TN} .

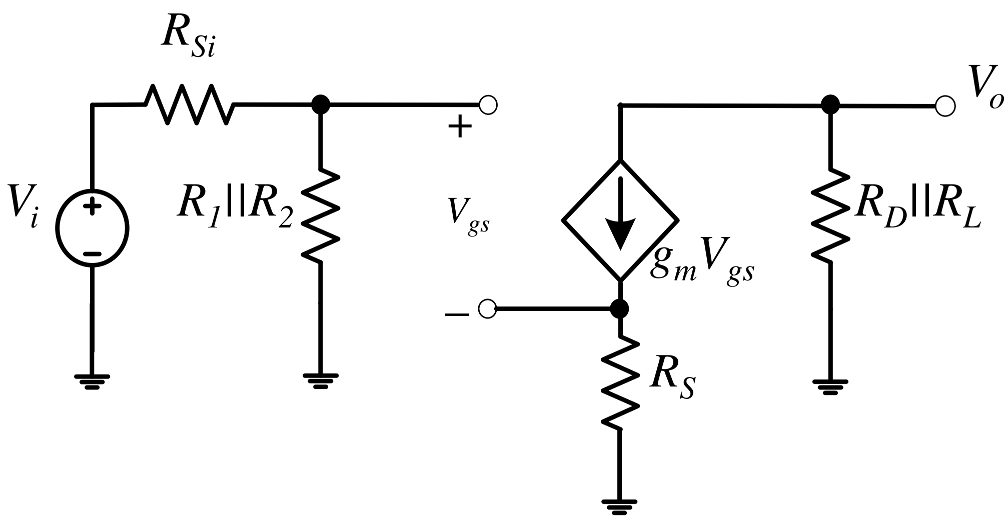
Therefore, V_{GS} = 2.96V

So, the Q point values:

$$I_D = K(V_{GS} - V_{TN})^2 = (1m)(2.96 - 2)^2 = 0.92mA$$

$$V_{DS} = V_{DD} - I_D(R_S + R_D) = 12 - (0.92m)(5k) = 7.4V$$

Small-signal analysis



$$g_m = 2K\left(V_{GS} - V_{TN}\right)$$
$$= 2(1m)(2.96-2) = 1.92mS$$
$$r_o = \left(\lambda I_{DQ}\right)^{-1} = \infty$$

$$V_{gs} = \frac{\left(R_1 \| R_2\right)}{R_1 \| R_2 + R_{Si}} \times V_i$$

$$V_i = V_{gs} + g_m V_{gs} R_S$$
$$= V_{gs}(1 + g_m R_S)$$

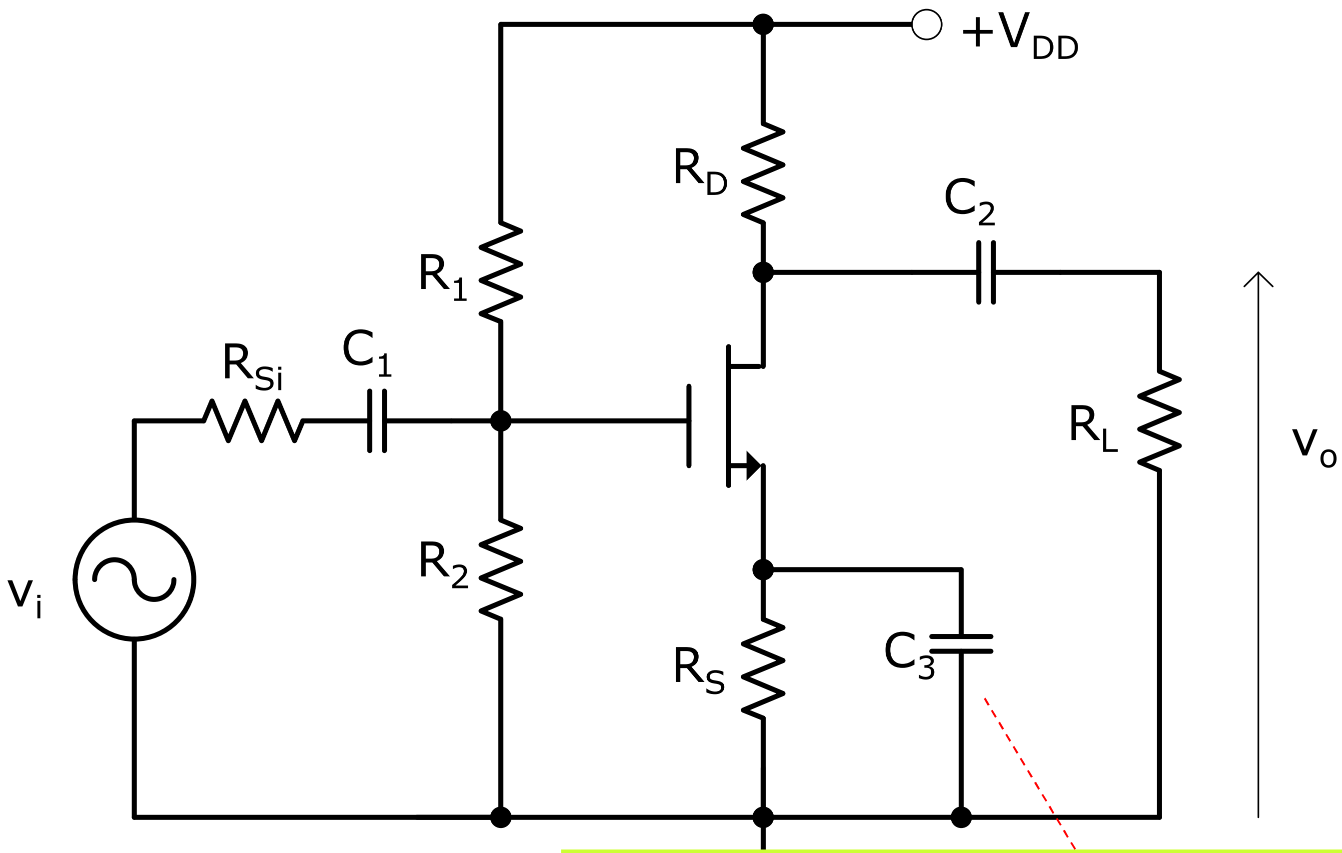
$$V_o = -g_m V_{gs}\left(R_D \| R_L\right)$$

$$A_V = \frac{-g_m\left(R_D \| R_L\right)}{1 + g_m R_S}$$

$$V_{gs} = \frac{\left(R_1 \| R_2\right)}{R_1 \| R_2 + R_{Si}} \times V_i = 0.984 V_i$$

$$A_v = \frac{V_o}{V_i} = \frac{-g_m\left(R_D \| R_L\right)}{1 + g_m R_S}$$
$$= -0.48$$

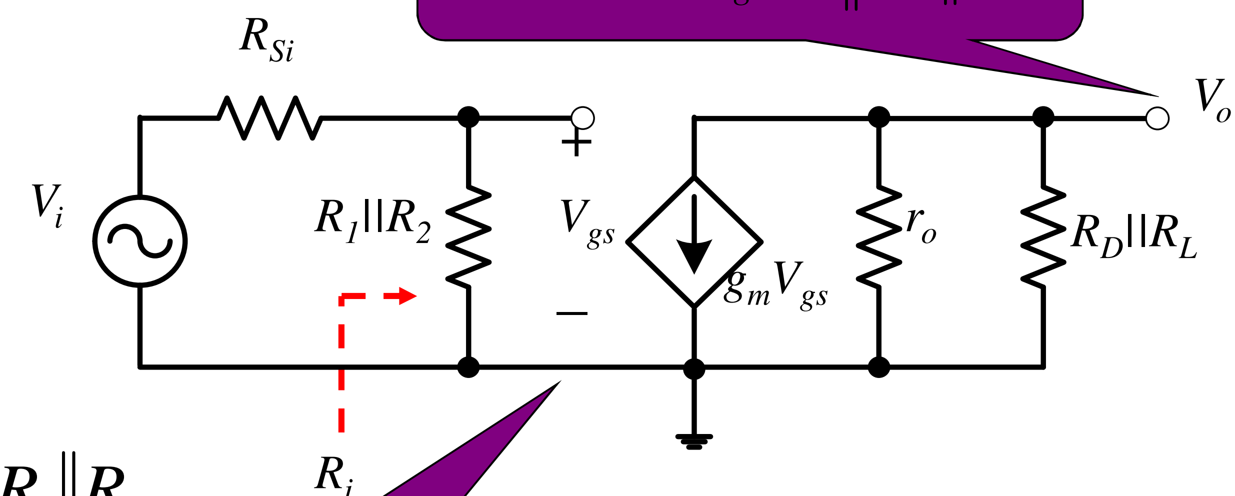
COMMON-SOURCE AMPLIFIER
- with Bypass Capacitor



Minimize the lost in small-signal voltage gain while maintaining the Q-point stability

Small signal equivalent circuit

$$V_o = -g_m V_{gs} \left(r_o \| R_D \| R_L \right)$$

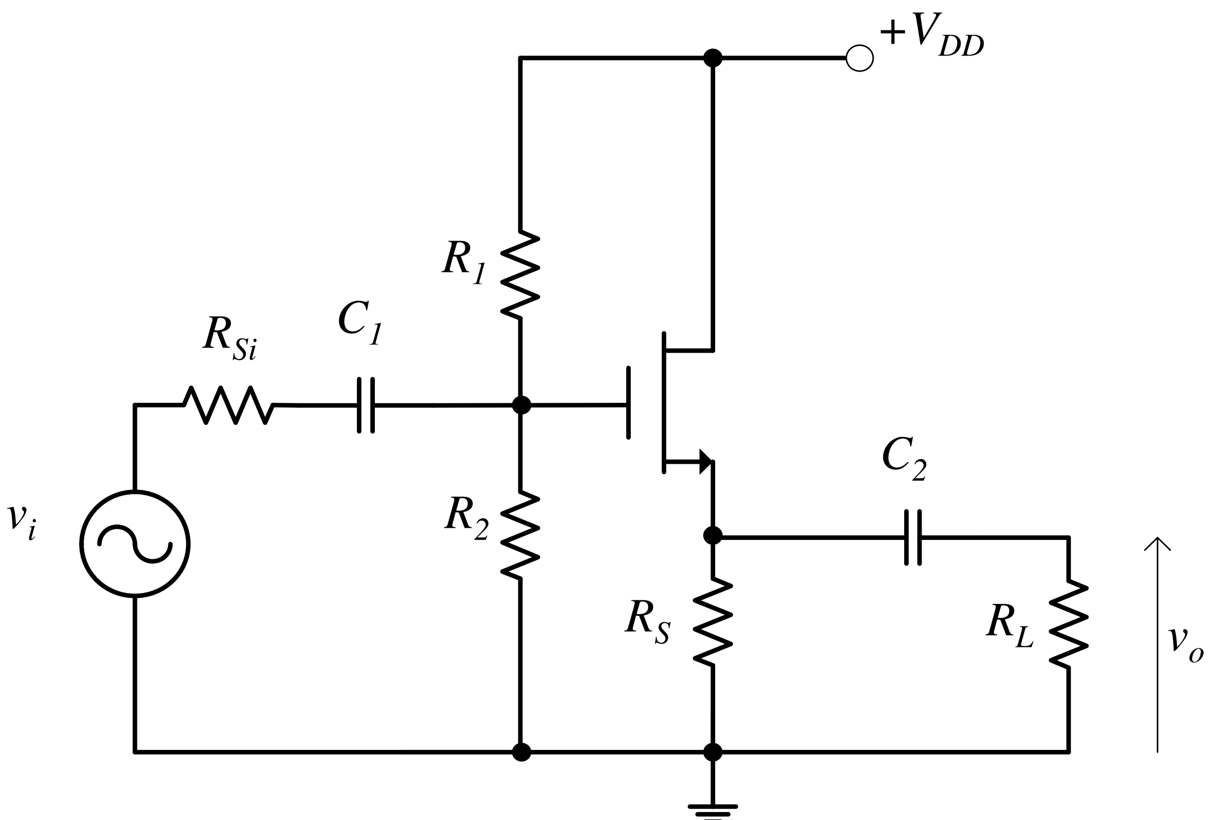


$$R_i = R_1 \| R_2$$

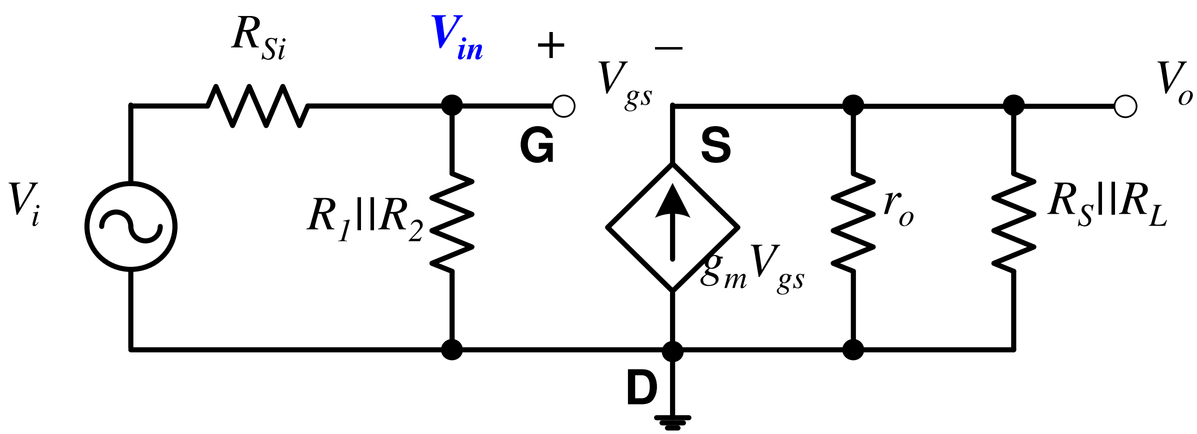
$$V_{gs} = \left(\frac{R_i}{R_i + R_{Si}} \right) \times V_i$$

$$A_v = \frac{V_o}{V_i} = -g_m \left(r_o \| R_D \| R_L \right) \left(\frac{R_i}{R_i + R_{Si}} \right)$$

COMMON-DRAIN AMPLIFIER



Small signal equivalent circuit



$$V_{in} = V_{gs} + V_o$$

input impedance

$$R_i = R_1 \| R_2$$

Output impedance

$$R_o = \frac{1}{g_m} \| R_S \| r_o \| R_L$$

input voltage

$$V_{in} = \left(\frac{R_i}{R_i + R_{Si}} \right) \times V_i$$

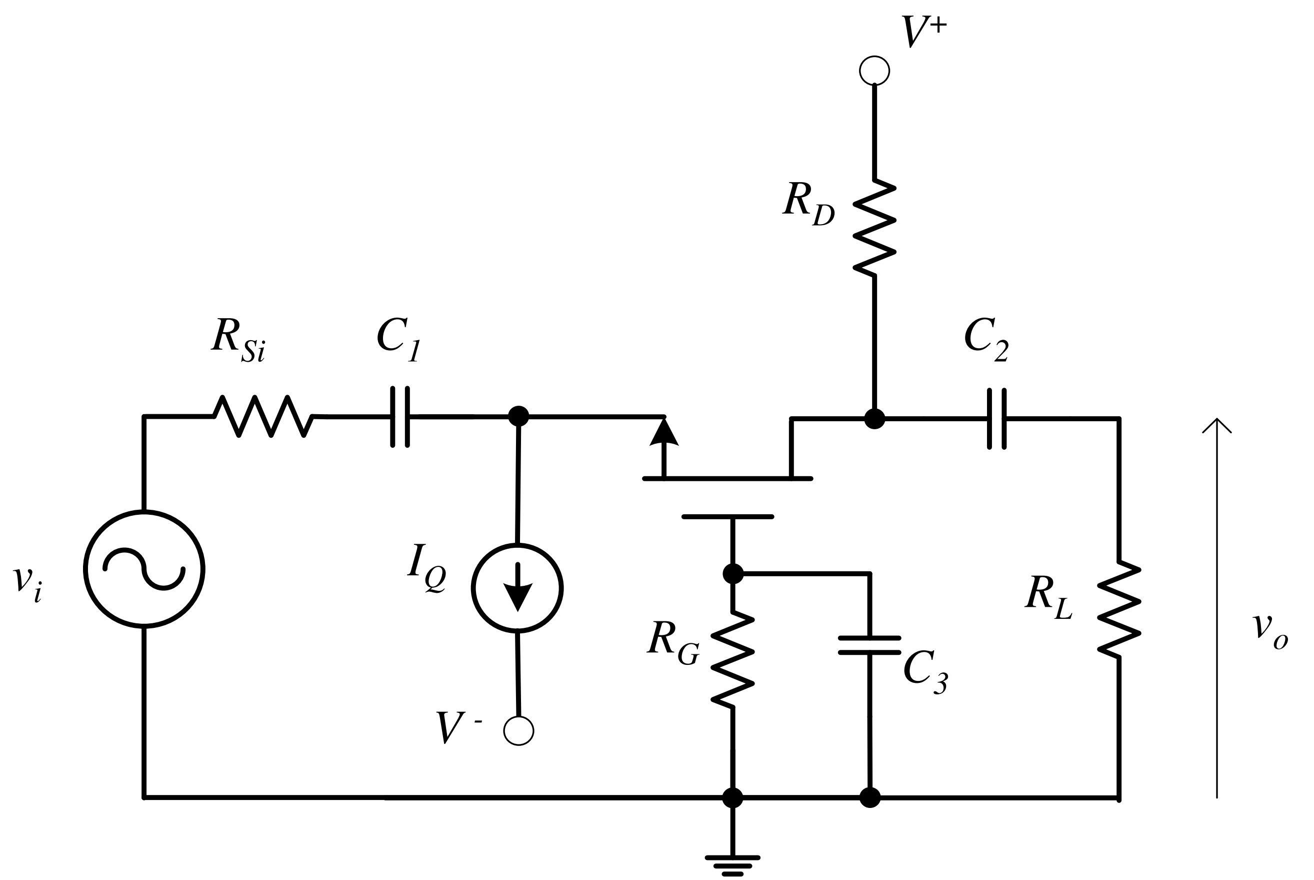
output voltage

$$V_o = g_m V_{gs} \left(R_S \| R_L \| r_o \right)$$

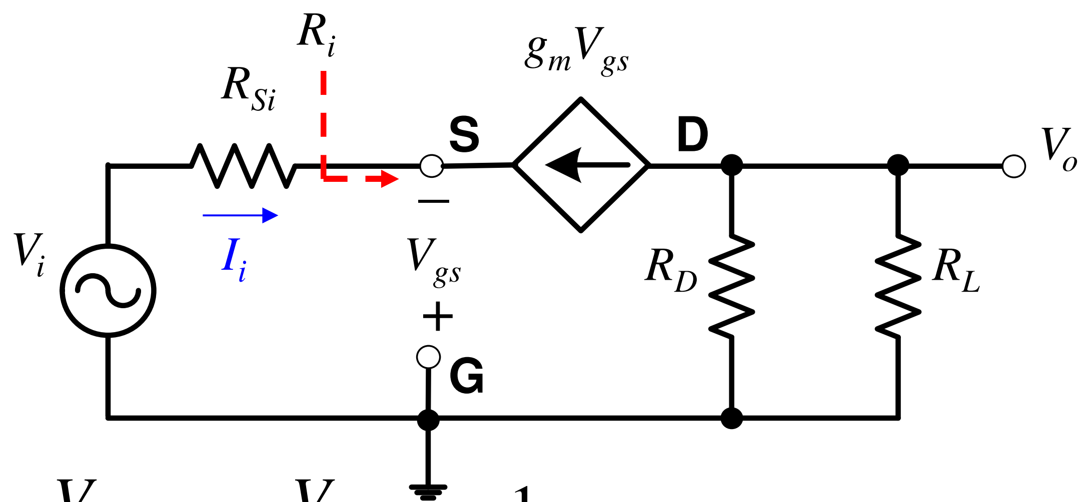
small-signal voltage gain

$$A_v = \frac{V_o}{V_i} = \frac{g_m \left(R_S \| R_L \| r_o \right)}{1 + g_m \left(R_S \| R_L \| r_o \right)} \left(\frac{R_i}{R_i + R_{Si}} \right)$$

COMMON-GATE AMPLIFIER



Small-signal equivalent circuit



input impedance

$$R_i = \frac{-V_{gs}}{I_i} = \frac{-V_{gs}}{-g_m V_{gs}} = \frac{1}{g_m}$$

input voltage

$$V_i = I_i R_{Si} - V_{gs}$$

input current

$$V_{gs} = \frac{-V_i}{1 + g_m R_{Si}}$$

$$I_i = -g_m V_{gs}$$

output voltage

$$V_o = -\left(g_m V_{gs}\right)\left(R_D \| R_L\right)$$

small-signal voltage gain

$$A_v = \frac{V_o}{V_i} = \frac{g_m \left(R_D \| R_L\right)}{1 + g_m R_{Si}}$$

Comparison of Amplifier Topologies

Common Source

- Large $A_v < 0$
- Large R_{in}
- $R_{out} \cong R_D$

Common Gate

- Large $A_v > 0$
- Small R_{in}
- $R_{out} \cong R_D$

Source Follower

- $0 < A_v \leq 1$
- Large R_{in}
- Small R_{out}