Lecture 31: Common Source Amplifier.

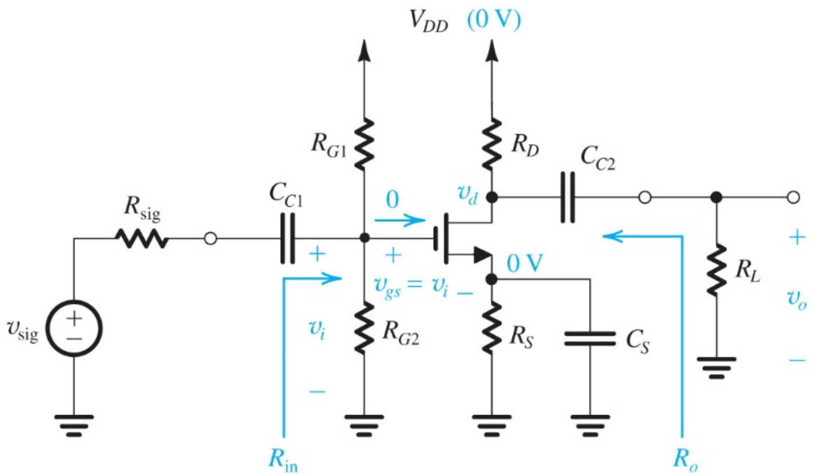
We've studied MOSFET small-signal equivalent models and the biasing of MOSFET amplifiers in the previous three lectures. We'll now apply those skills by looking closely at three basic MOSFET amplifier types:

1. Common source amplifiers, including configurations with a source resistor (called source degeneration).
2. Common gate amplifiers.
3. Common drain (or source follower) amplifiers.

All of these amplifier types are appropriate for discrete component designs. In the case of IC amplifiers, we'll also show corresponding designs implemented in CMOS, beginning in Lecture 33.

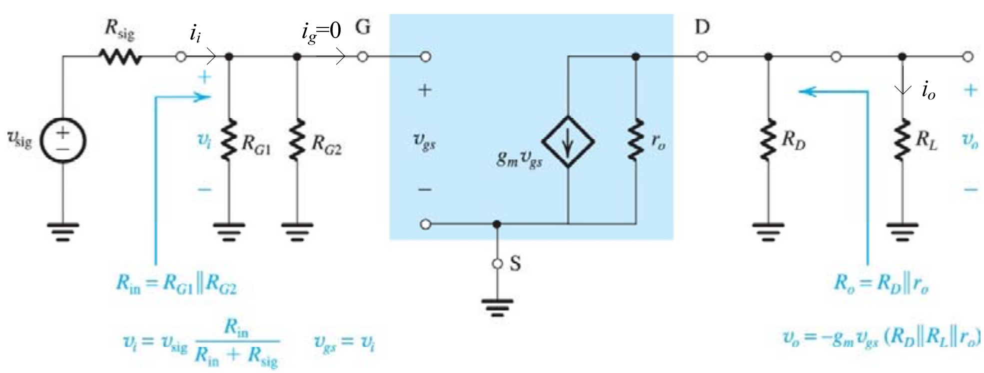
Common Source Small-Signal Amplifier

This type of amplifier is shown in Fig. 7.55(a) and is biased exclusively by a voltage source:



(Fig. 7.55a)

Assuming sufficiently large values for the coupling capacitors (C_{C1} and C_{C2}) and the bypass capacitor (C_S) – so that their reactances are very small at the frequency of operation – the equivalent small-signal circuit for this amplifier is shown in Fig. 7.55(b):



(Fig. 7.55b)

Small-Signal Amplifier Characteristics

As we did when studying BJT amplifiers, we'll calculate the following quantities for this MOSFET common source amplifier: R_{in}, A_v, G_v, G_i, and R_o.

- Input resistance, R_{in}. From the small-signal circuit above, and noting that $i_g = 0$, then

$$R_{\text{in}} = R_{G1} \,\|\, R_{G2} \tag{7.149),(1}$$

- Partial small-signal voltage gain, A_v. From the output side of the small-signal circuit

$$v_o = -g_m v_{gs} \left(r_o \,\|\, R_D \,\|\, R_L \right) \tag{2}$$

while at the input,

$$v_i = v_{gs} \tag{3}$$

Substituting (3) into (2), we find that the partial voltage gain as

$$A_v \equiv \frac{v_o}{v_i} = -g_m \left(r_o \,\|\, R_D \,\|\, R_L \right) \tag{4}$$

- Overall small-signal voltage gain, G_v. As we did with BJT amplifiers, we can derive an expression for G_v in terms of A_v. By definition,

$$G_v \equiv \frac{v_o}{v_{\text{sig}}} = \frac{v_i}{v_{\text{sig}}} \underbrace{\frac{v_o}{v_i}}_{=A_v} = \frac{v_i}{v_{\text{sig}}} A_v \tag{5}$$

Applying voltage division at the input of the small-signal equivalent circuit,

$$v_i = \frac{R_{\text{in}}}{R_{\text{in}} + R_{\text{sig}}} v_{\text{sig}} \underbrace{=}_{(1)} \frac{R_{G1} \,\|\, R_{G2}}{R_{G1} \,\|\, R_{G2} + R_{\text{sig}}} v_{\text{sig}} \tag{6}$$

Substituting (6) into (5) and using (4) we find

$$G_v = \frac{-R_{G1} \| R_{G2}}{R_{G1} \| R_{G2} + R_{\text{sig}}} g_m \left(r_o \| R_D \| R_L \right) \qquad (7.150),(7)$$

- <u>Overall small-signal current gain, G_i</u>. Using current division at the output in the small-signal model above

$$i_o = \frac{-r_o \| R_D}{r_o \| R_D + R_L} g_m v_{gs} \qquad (8)$$

while at the input,

$$v_{gs} = i_i \left(R_{G1} \| R_{G2} \right) \qquad (9)$$

Substituting (9) into (8) we find that the overall small-signal current gain is

$$G_i \equiv \frac{i_o}{i_i} = \frac{-r_o \| R_D}{r_o \| R_D + R_L} g_m \left(R_{G1} \| R_{G2} \right) \qquad (10)$$

Notice that as $R_{G1} \| R_{G2} \to \infty$ in this last expression, $G_i \to \infty$. Is this a problem? (To help answer this question, notice that as $R_{G1} \| R_{G2} \to \infty$, $i_i \to 0$.) Also, what does $G_i \to \infty$ as $R_{G1} \| R_{G2} \to \infty$ mean for the overall small-signal *output power* of this amplifier?

- <u>Output resistance, R_o</u>. To calculate the output resistance, we first set $v_{\text{sig}} = 0$, which also means that $g_m v_{gs} = 0$. The input impedance of the dependent current source is infinite. Consequently,

$$R_{\text{out}} = r_o \| R_D \qquad (11)$$

Summary

In summary, we find for the CS small-signal amplifier that it has a

- High input resistance [see (1)].
- Relatively high small-signal voltage gain [see (7)].
- Very high small-signal current gain [see (10)].
- Relatively high output resistance [see (11)].