UNIVERSITY OF CALIFORNIA, BERKELEY
EE40: Introduction to Microelectronic Circuits

Common-Source Amplifier Lab Guide

Objective: Build a CS Amplifier and understand how it works

Common-Source NMOS Amplifier

Although the MOS transistor is most famous for its use in digital circuits, it can also be used as an amplifying device. Common Source amplifier simply means the input and output terminals share the "source" of the amplifying transistor. One possible circuit implementation of a common-source amplifier is shown in Figure 1.

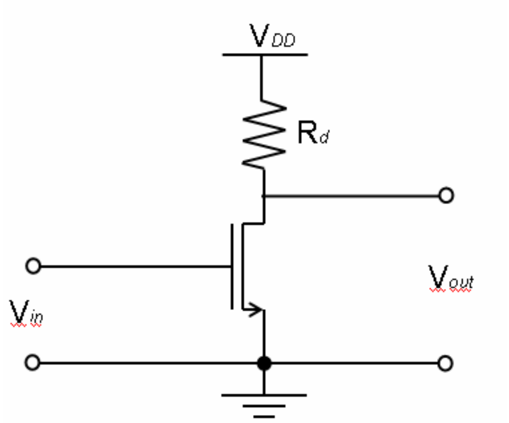

Figure 1.

We use graphical analysis to understand the qualitative operation of the common-source amplifier. In Figure 2 (a) we show typical NMOS transistor characteristics. On the horizontal axis we plot Vds which is equal to the output voltage Vout. On the vertical axis we plot the DC drain current Id and vary the DC input bias voltage as a parameter. The MOS transistor is a square law device with a drain current that depends quadratically on the gate-source voltage in the constant-current region.

We plot a load line on the same graph as the MOS transistor characteristics. The equation of this line is given by

$$V_{out} = V_{dd} - I_d R_d$$

Using the load line analysis, we can graphically determine how the output voltage changes with the input bias voltage and the value of the corresponding drain current. The current through resistor Rd and the drain current Id are equal. Therefore, the operation point for this circuit occurs at the intersection of the load line and transistor characteristics. The specific operating point is defined by setting either the drain current or the bias voltage.

To see the relationship between the voltage transfer function shown in Figure2 and the load line analysis, note where the MOS transistor is biased below its threshold voltage (cutoff) and no current is flowing (1). Under this condition the output voltage is equal to

Vdd. As we increase the bias voltage above the threshold voltage, drain current begins to flow and the output voltage falls below Vdd (2). This output voltage rapidly fals toward a low voltage by further increasing the bias voltage. This high-gain region of the transfer characteristic (3) is where the MOS transistor is operating in the constant-current region As the bias voltage is further increased, the transistor enters the triode region (4) .Our goal is to operate this common-source amplifier in the high-gain region by setting the bias voltage so we are operating near point (3).

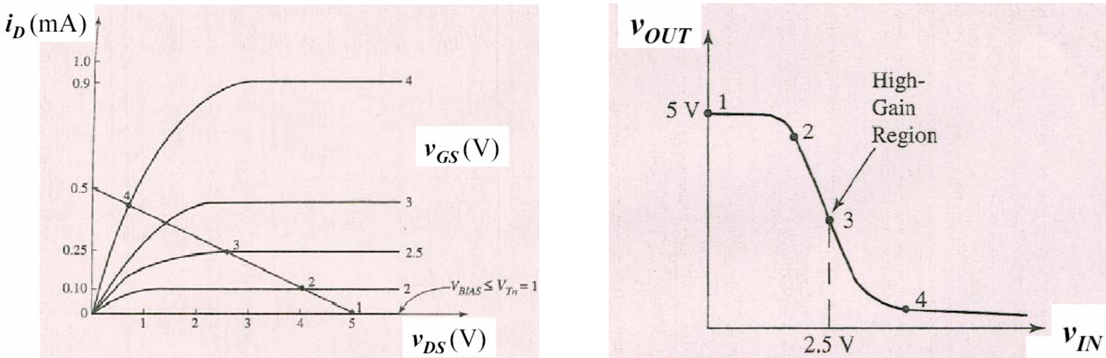

Figure 2 (a) NMOS transistor characteristics for the common-source configuration with a load line (assume Vdd=5V, Rd=10k). (b) Common-source amplifier voltage transfer function.

Hands On

1. Build the common-source amplifier circuit. (Power-supply voltage = 5V, load resistor = 68 ohm)

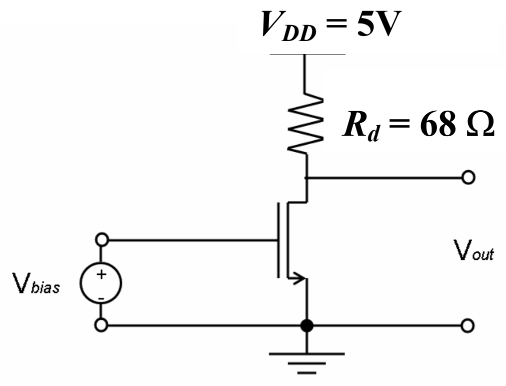

Figure 3

2. Experimentally determine the V_{output} vs. V_{input} (voltage transfer) characteristic: Manually adjust V_{bias} from 0V to 5V with 0.5V intervals between testing points, record input and output voltages and draw the Vin-Vout graph.

3. Identify the optimal DC bias with maximum slope in Vin-Vout graph, this is the area where the amplifier provides the best performance. Add two testing points on your graph around this point to make sure you measure the slope precisely (so you will have 13 points on your graph after this).

4. Take out the power supply Vbias from the circuit. Add R1, R2 to set the bias at its optimal point. Use multi-meter to make sure the Vgs is what you want. (You need chose the right R2 to get this)

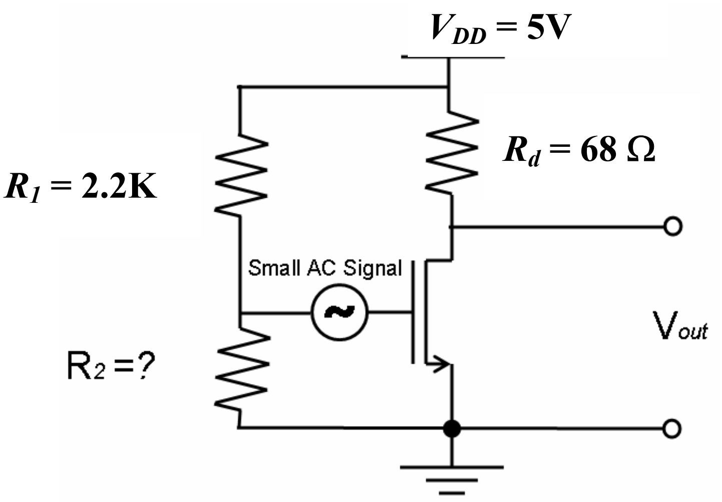

Figure 4

5. Apply a small-signal (sinusoidal waveform) on the input (Figure 4). Observe the input and output voltage waveforms on oscilloscope; determine the gain.

6. For fun, see what happen in the output signal

   a. Increase the amplitude of input AC signal (~ 2-3 volts)

   b. change R2 to move the bias off the 'optimal' operation point

Explain why