

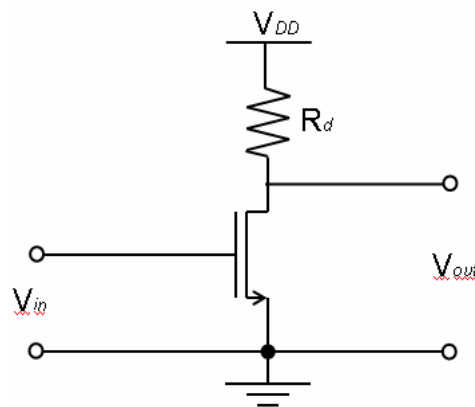
**UNIVERSITY OF CALIFORNIA, BERKELEY**  
**EE40: Introduction to Microelectronic Circuits**

**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  $V_{ds}$  which is equal to the output voltage  $V_{out}$ . On the vertical axis we plot the DC drain current  $I_d$  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.

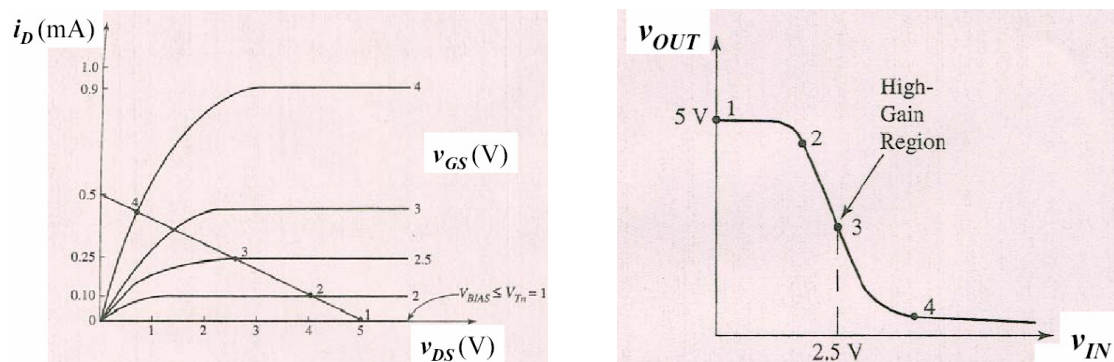
We plot a load line on the same graph as the MOS transistor characteristics. The equation of this line is given by

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

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  $R_d$  and the drain current  $I_d$  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 Figure 2 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

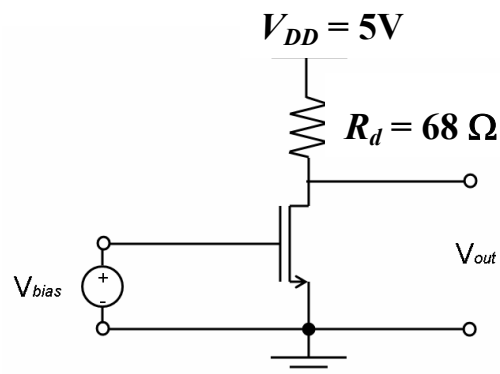
$V_{DD}$ . As we increase the bias voltage above the threshold voltage, drain current begins to flow and the output voltage falls below  $V_{DD}$  (2). This output voltage rapidly falls toward a low voltage by further increasing the bias voltage. This high-gain region of the transfer characteristic (3) 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  $V_{DD}=5V$ ,  $R_d=10k$ ). (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  $V_{out}$  vs.  $V_{in}$  (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  $V_{in}$ - $V_{out}$  graph.
3. Identify the optimal DC bias with maximum slope in  $V_{in}$ - $V_{out}$  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  $V_{bias}$  from the circuit. Add  $R_1$ ,  $R_2$  to set the bias at its optimal point. Use multi-meter to make sure the  $V_{gs}$  is what you want. (You need chose the right  $R_2$  to get this)

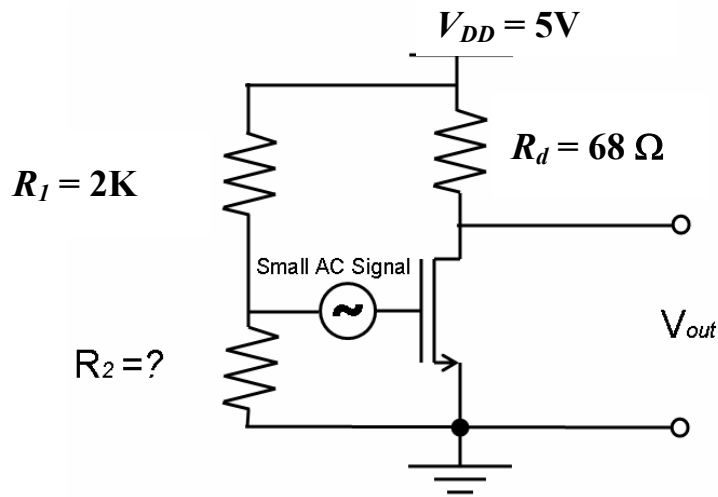


Figure 4

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

- Increase the amplitude of input AC signal ( ~ 2-3 volts)
- change  $R_2$  to move the bias off the 'optimal' operation point

Explain why