ECE4902 C2012 Lab 4

MOSFET Common Source Amplifier with Resistive Load

PURPOSE:

The primary purpose of this lab is to measure the performance of the common source amplifier with a resistive load. The performance is measured in two ways: large signal and small signal.

First, you will plot an input-output characteristic on the oscilloscope: input voltage on the X-axis and output on the Y-axis, as shown in Fig. 4-1. This plot shows the large signal behavior of the amplifier, with the MOSFET in all three regions: cutoff, saturation, and triode. The cutoff and triode regions set limits on the output swing at or near the power supply voltage rails. In the saturation region, the output characteristic shows a quadratic shape due to the square-law I_D-V_{GS} behavior of the MOSFET in the saturation region.

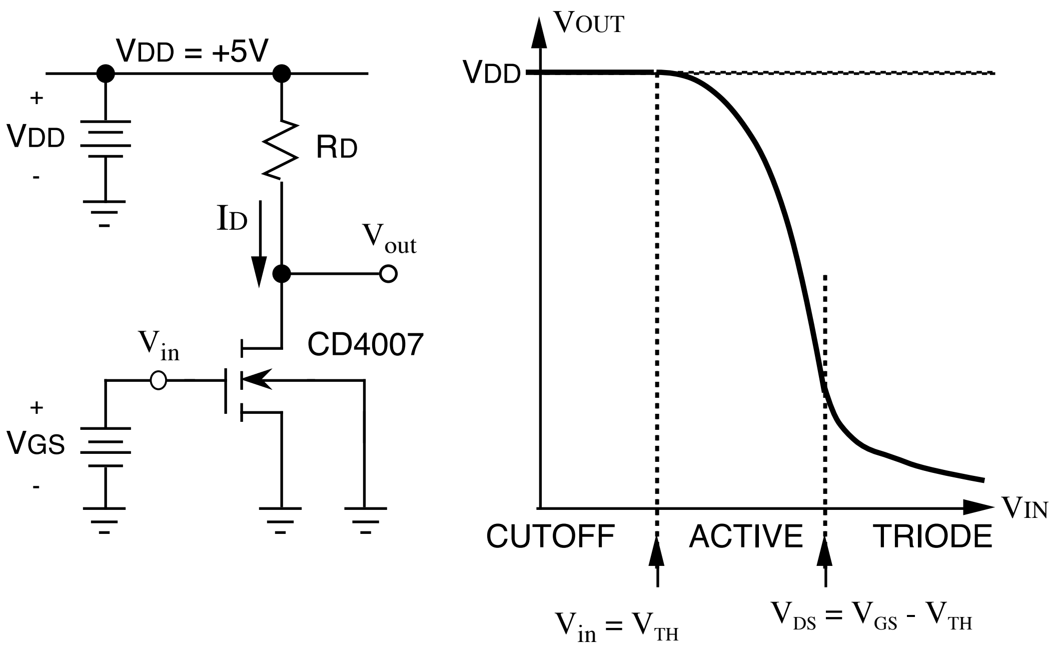


Fig. 4-1

To make this circuit function as a linear amplifier, we need to restrict the input signal amplitude so we use only a small portion of the characteristic in the saturation region, as shown in Fig. 4-2.

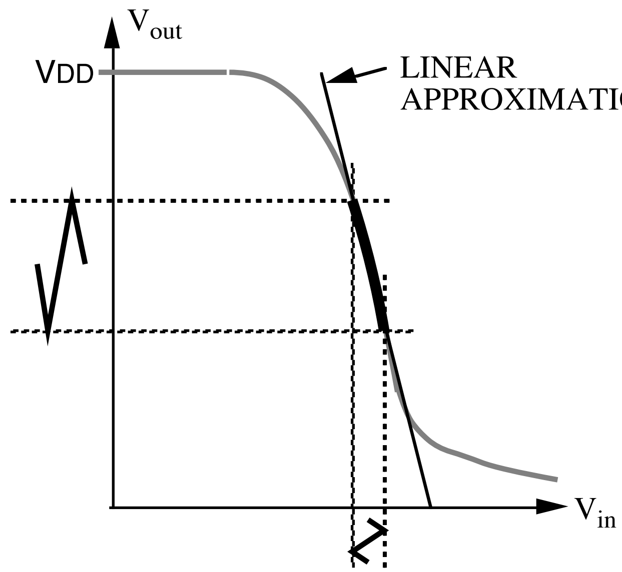


Fig. 4-2.

By using only a small portion of the quadratic, there is negligible deviation from a linear approximation, and the amplifier functions as a linear (almost) system.

Upon completion of this lab you should be able to:

- Recognize the three regions of MOSFET operation in the input-output characteristic.
- Recognize linear amplifier operation for small signals.
- Measure the small-signal gain.
- Recognize the importance of operating at the proper bias point.

LAB PROCEDURE

CIRCUIT: MOSFET COMMON SOURCE AMPLIFIER WITH RESISTIVE LOAD

L4-1. Build the circuit in Fig. 4-3.

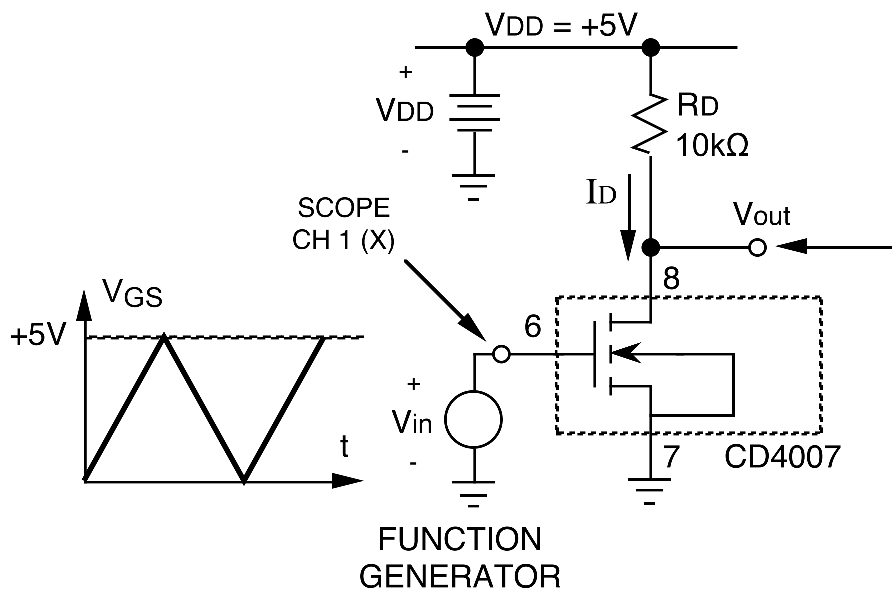


Fig. 4-3.

L4-2. Configure the function generator to set up the input V_{in}: adjust the frequency to around 1kHz; adjust the offset and amplitude to get a 0 to +5V triangle wave. *Be sure to set the function generator output menu to Hi-Z mode so the voltage readings on the function generator are correct.*

L4-3. Configure the oscilloscope. Set the CH1 scale to 1V/div and the CH2 scale to 1V/div. In the DISPLAY menu, set up scope for an X-Y display. This will display CH1 on the X-axis and CH2 on the Y-axis. Position the origin of the X-Y plot, using the vertical menu to ground each channel, and adjusting the position of the X-axis (CH 2 grounded) and Y-axis (CH 1 grounded).

L4-4. Now set CH1 and CH2 to DC coupling. You should see a plot similar to Fig. 4-1. Record the shape of the input-output plot.

L4-5: Determine as accurately as possible the values of V_{in} and V_{out} at the cutoff-saturation and saturation-triode boundaries (see Fig. 4-1). These can be thought of as "outer limits" of operation for this circuit as a linear amplifier.

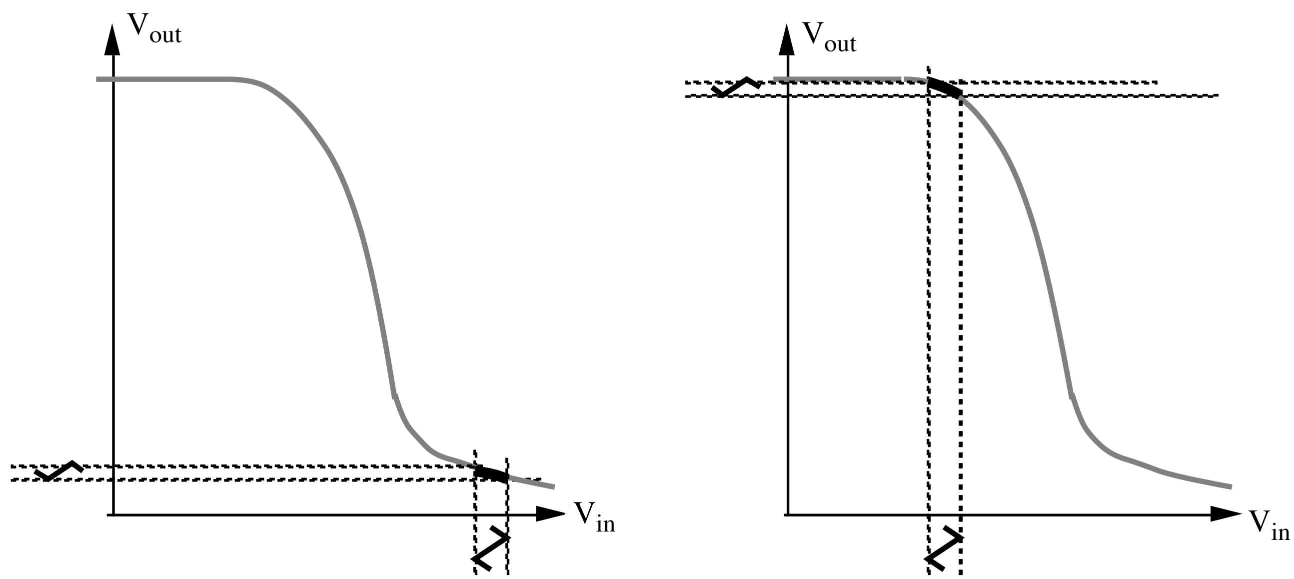
L4-6. Switch the display to YT format, to show both V_{in} and V_{out}. Note that the output waveform does not resemble a linear scaling of the input triangle wave, but is actually severely distorted. Record a cycle of V_{in} and V_{out} waveforms.

L4-7. Return to XY format. Adjust the gain and offset of the function generator until V_{out} is using only about the middle 20% of the output range (from 2V to 3V, approximately). Determine (as well as you can) the slope of the input-output characteristic over this range. The slope will correspond to the small-signal gain you will measure in the next part.

L4-8. Switch the display to YT format, to show both V_{in} and V_{out}. Now you should see that the output looks like a linear scaling of the input triangle wave. Record a cycle of V_{in} and V_{out} waveforms.

L4-9. Measure the peak-to-peak amplitude of the input and output waveforms, and calculate the small-signal gain magnitude $|v_{out}/v_{in}|$ of this amplifier. You may want to go to AC coupling at a finer V/div resolution to more accurately measure the input and output amplitudes. Also measure the average (bias point) for each of V_{in} and V_{out} (be sure you're on DC coupling to measure the DC bias points).

L4-10. Using DC coupling, display both V_{in} and V_{out} on the scope. Using the DC offset control on the function generator, adjust the input bias point away from the operating point you set in part L4-7. Note how the gain drops and the output waveform becomes distorted if the input bias point is too high or too low, as shown in Fig. 4-4.



Input bias point too high.

Input bias point too low.

Fig. 4-4.

Lab 4 Writeup

W4-1. Using your MOSFET parameters, calculate the expected values of V_{in} and V_{out} at the cutoff-saturation and saturation-triode boundaries (see Fig. 4-1). Compare the measured values from L4-5 to your calculated values. Some inaccuracy is expected due to the fuzzy nature of the boundary on the scope plot. The point is for you to recognize that there are limits to the linear range of this circuit's operation as an amplifier.

W4-2. Show a cycle of the large signal V_{in} and V_{out} waveforms from L4-6. Comment on the limits of linear operation.

W4-3. Sketch a cycle of the small signal V_{in} and V_{out} waveforms from L4-8. Comment on the linearity of the input-output relationship for the large-signal and small-signal cases,

W4-4. Compare the measured slope of the input-output plot in the linear range (from L4-7) to the small-signal gain magnitude $|v_{out}/v_{in}|$ measured from the peak-to-peak input and output amplitudes measured in L4-9. Also note the sign of the gain: inverting or noninverting.

W4-5. Using your MOSFET parameters and the average DC bias point measurements from L4-9, determine the small-signal transconductance g_m for the MOSFET. Draw the small-signal model for the circuit, calculate the expected small-signal gain, and compare the expected value to the small-signal gains measured in W4-4.