UNIVERSITY OF NORTH CAROLINA AT CHARLOTTE
Department of Electrical and Computer Engineering

EXPERIMENT 8 – MOSFET AMPLIFIER CONFIGURATIONS AND INPUT/OUTPUT IMPEDANCE

OBJECTIVES

The purpose of this experiment are to familiarize the student with

- the three types of MOSFET transistor amplifier configurations: common-source, common-gate, and common-drain (often called the source follower).
- the measurement of the input and output impedances of a single-stage MOSFET amplifier.

INTRODUCTION

MOSFET Amplifier Configurations

The three types of MOSFET transistor amplifier configurations: common-source, common-gate, and common-drain (often called the source follower). Each of these configurations exhibit certain characteristics that make them more desirable in certain circuit applications than the others. A qualitative comparison of these three configurations is shown below in Table 8-1.

Table 8-1. Summary of MOSFET Amplifier Characteristics

	Common-source	common-gate	common-drain
Input Impedance	Very High(∞)	Low	Very High(∞)
Output Impedance	Medium	Very High	Low
Current Gain	High(β)	Low(α)	High
Voltage Gain	High	High	Low

Most MOSFET amplifiers are fabricated on integrated circuits. This fabrication process, with such small feature processing, makes it very difficult to create resistors on an integrated circuit. When fabricated, the resistors often have very undesirable tolerance values than can be as high as 10-20%, such that a large variation of resistance values results. This makes design very difficult. In this experiment, resistors will be used to perform the biasing of the MOSFET and to set the amplification. It is important to note that, because of the aforementioned fact, resistors are not used to bias and set amplification in modern MOSFET technology. Instead, MOSFET devices themselves are used as resistors and used to set bias conditions.

MOSFET Amplifier Input/Output Impedance

Using calculations, the impedances are usually found by setting up either a test voltage source and finding the resulting input current into a point of interest, or by setting up a test current and finding the resultant voltage at the point of interest. The following is a display of the first method, setting up a test voltage v_x and finding the resulting input current i_x.

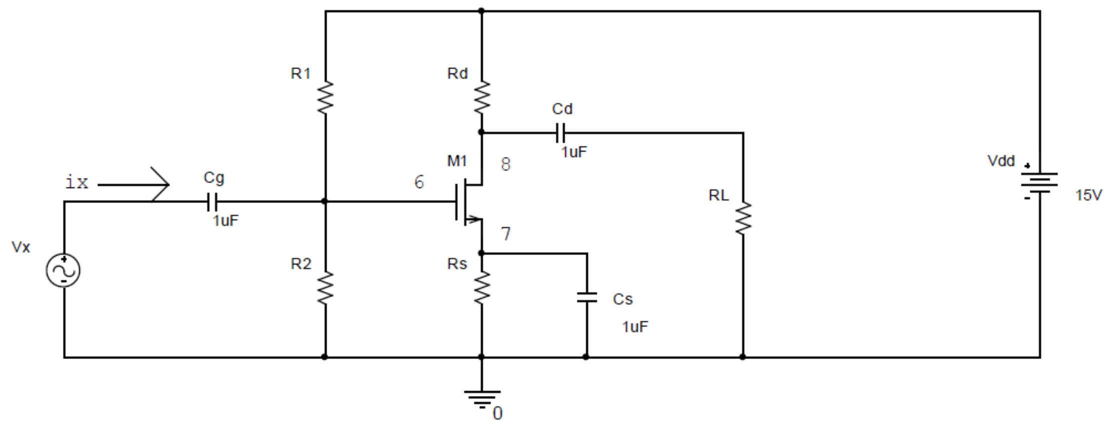

Figure 8-1 Inserting Test Voltage to Find Input Impedance

Here the capacitors are considered significantly large enough so that they appear as an AC ground and the DC supply is considered as an AC ground. This same approach can be applied to the output. It is important when solving for the ouput impedance that the point where the input source was connected to the original amplifier circuit be set as an AC ground point. The detailed technique for finding the input and output impedances can be found in any analog electronics textbook.

PRELAB

MOSFET Amplifier Configurations

1. For the circuit of Figure 8-2, find the values for R_1, R_2, R_D, and R_S such that MOSFET is biased with a drain current I_{DS} of approximately 400µA, V_S = 4V, V_D = 9V, and V_{GS} = 2.3V. Make sure the MOSFET is in saturation Assume: $\mu_o C_{ox}(W/L) = 650\mu A/V^2$; V_T = 1.19V (Hint: Use standard resistor values less than or equal to 100kΩ.)

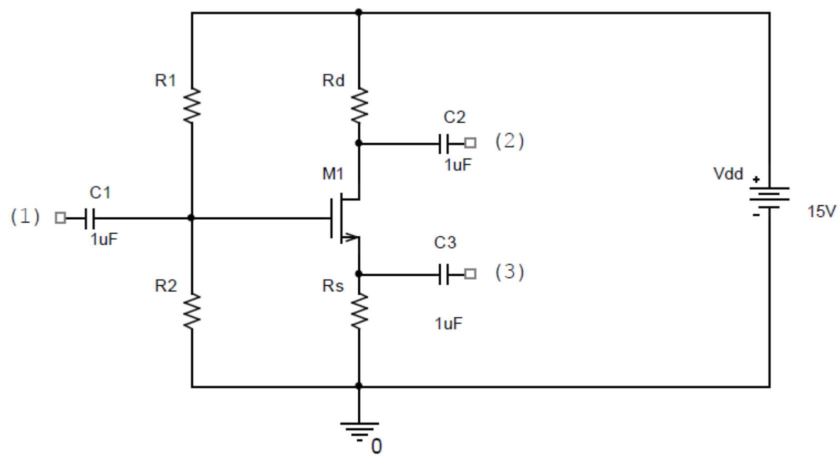

Figure 8-2 MOSFET Universal Amplifier Circuit

2. For the common-source configuration, input at (1) – output at (2) – (3) grounded, find the value of A_{VG-D}, the voltage gain from the gate to the drain, with a 10kΩ load connected to (2). Use your resistance values and bias conditions from Problem 1 and assume: $\mu_o C_{ox}(W/L) = 150\mu A/V^2$; V_T = 1.19V ; V_A = 100V.
3. Repeat Problem 2 for the common-gate configuration, input at (3) – output at (2) – (1) grounded. Find the voltage gain A_{VS-D}, the voltage gain from the source to the drain, with a 10kΩ load connected to (2).
4. Repeat Problem 2 for the common-drain(source-follower) configuration, input at (1) – output at (3) – (2) grounded. Find the voltage gain A_{VG-S}, the voltage gain from the gate to the source, with a 10kΩ load connected to (3).

BJT Amplifier Input/Output Impedance

5. For the circuit shown in Figure 8-3, find values for R_1, R_2, R_D and R_S such that the MOSFET is biased with an I_{DS} of approximately 400µA, a V_{GS} of 2.3V, a V_D of 9V, and a V_S of 4V. Verify that the MOSFET is in saturation. Assume: $\mu_o C_{ox}(W/L) = 650\mu A/V^2$, V_T = 1.19V , R_L = 10kΩ, and that the capacitors are open circuit to DC. Use only standard resistor values less than 150kΩ. Since all transistors have a variance in their characteristics, when building this circuit in the lab session, it may be necessary to make adjustments of the bias voltages to provide for the best signal swing. This can usually be accomplished by adjusting the value of R_S.

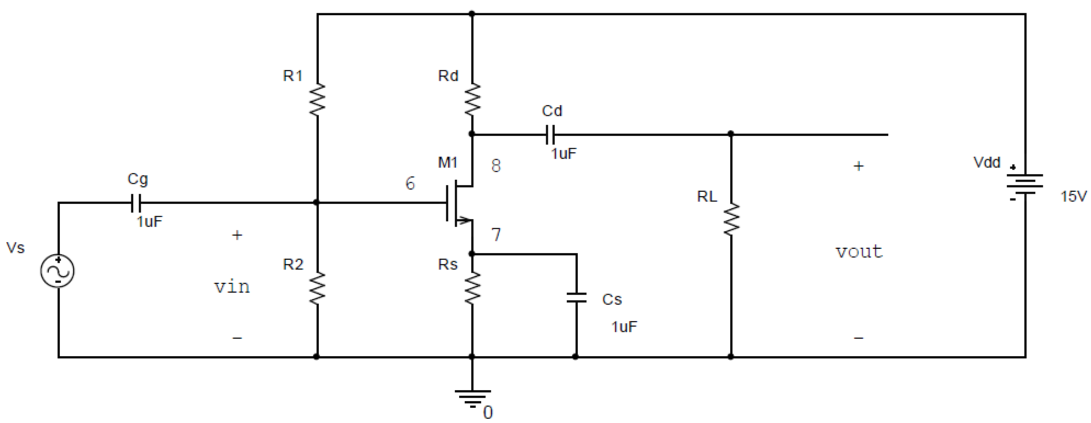

Figure 8-3 MOSFET Common-Source Amplifier

6. For the circuit of Figure 8-3, use the calculated values for R_1, R_2, R_D and R_S, assume the load resistance R_L is 10kΩ, and that capacitors and DC power supplies represent a short circuit to AC. Find the voltage gain $A_{VG\text{-}D} = v_{out}/v_{in}$, the input impedance r_i, and the output impedance r_o. Also, assume: $\mu_o C_{ox}(W/L) = 650\mu A/V^2$; $V_T = 1.19V$; and $V_A = 100V$.

*Note: The values given for the $\mu_o C_{ox}(W/L)$ and V_T were found using measured data on the CD4007UBE chip [1].

PROCEDURE

MOSFET Amplifier Configurations

1. Observe the schematic shown in Figure 8-4. Notice that the numbers 6, 7, and 8 correspond to the pin connections on the CD4007UBE chip.

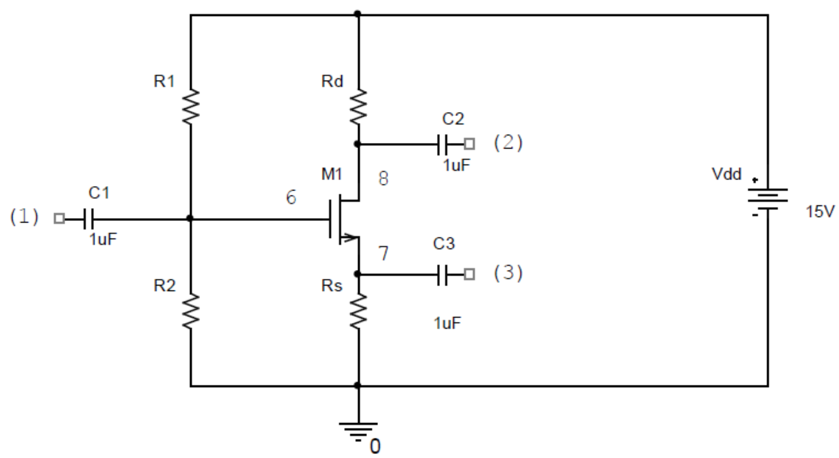

Figure 8-4 MOSFET Universal Amplifier Using CD4007

2. Before connecting the circuit in Figure 8-4, make sure to adjust the power supply for V_{DD} to ensure a voltage of +15V.
3. Connect the circuit shown in Figure 8-4. Measure and record the bias voltages V_D, V_G, and V_S.
4. Prepare a function generator for an input signal of 100mVp-p at 1kHz.
5. Connect a load resistor of 10kΩ to node (2) and bypass R_S by grounding node (3). If R_S is not bypassed the gain will be very small (much less than 1). Now connect the function generator to node (1).
6. Measure the voltage at node (2) and calculate the voltage gain $A_{VG\text{-}D}$, it should be approximately the same as the value calculated in the Prelab. Remove node (3) from ground and observe the reduction of gain.
7. Vary the function generator frequency, while maintaining the voltage level, in order to obtain the necessary data to plot a frequency response curve for the voltage gain $A_{VG\text{-}D}$.
8. Disconnect the function generator from the circuit while leaving the 10kΩ resistor connected to (2).
9. Now connect the function generator to node (3). Set the function generator to 1kHz, make sure the amplitude is still 100mVp-p. Measure the voltage at node (2) and calculate the voltage gain $A_{VS\text{-}D}$, it should be approximately the same as calculated in the Prelab.
10. Vary the function generator frequency, while maintaining the voltage level, in order to obtain the necessary data to plot a frequency response curve for the voltage gain $A_{VS\text{-}D}$.
11. Now disconnect the function generator and the 10kΩ resistor from the circuit.
12. Connect the function generator to node (1) and connect the 10kΩ resistor to node (3).
13. Set the function generator to 1kHz, make sure the amplitude is still 100mVp-p. Measure the voltage at node (3) and calculate the voltage gain $A_{VG\text{-}S}$, it should be approximately the same as calculated in the Prelab.

14. Vary the function generator frequency, while maintaining the voltage level, in order to obtain the necessary data to plot a frequency response curve for the voltage gain A_{VG-S}.

MOSFET Amplifier Input/Output Impedance

15. Before connecting the circuit shown in Figure 8-5, prepare the power supply for V_{DD} to ensure a DC voltage of 15V and adjust the function generator for V_S to a voltage level of approximately 100mVp-p at a frequency of 1kHz.

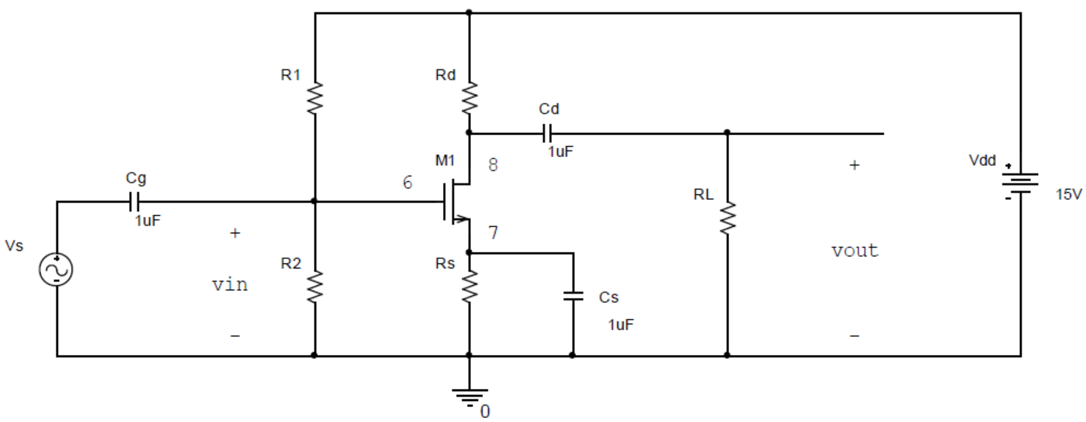

Figure 8-5 MOSFET Common-source Configuration

16. Now connect the circuit as shown using your values for the resistors R_1, R_2, R_D, and R_S calculated in the Prelab section. Use a load resistance RL of 10kΩ. Measure and record the values of V_D, V_G,V_S.
17. Measure the voltage v_{out} using an oscilloscope and calculate the voltage gain $A_{VG-D} = v_{out}/v_{in}$. If the output waveform is distorted, adjust the input voltage, and, if necessary, the bias voltages by changing R_S to remove the distortion.
18. Vary the frequency of the function generator in order to obtain the necessary data to plot a frequency response curve for the voltage gain.
19. Measure the input impedance r_i. To do this, use the setup shown in the circuit diagram in Figure 8-6. Use the original input signal from the function generator (100mVp-p @ 1kHz).

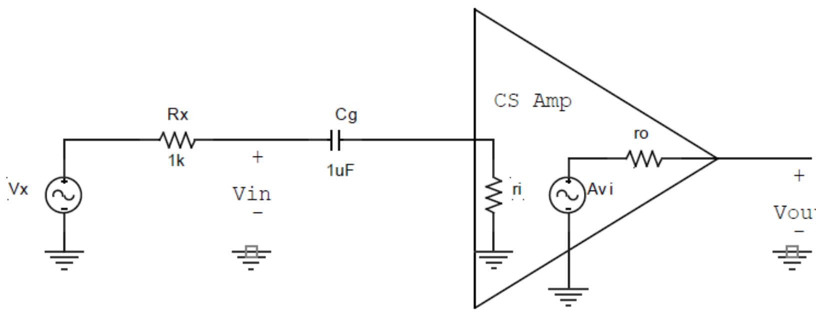

Figure 8-6 Input Impedance Measurement Setup

20. Measure the value of v_{in}. Set up an equation relating v_x and v_{in}. Use that equation to solve for the value of the AC input impedance z_i.
21. Vary the frequency of the function generator in order to obtain the necessary data to plot a frequency response curve for AC input impedance z_i.
22. Measure the output impedance r_o. To do this, use the setup shown in the circuit diagram in Figure 8-7. Use the same input signal from the function generator (100mVp-p @ 1kHz).

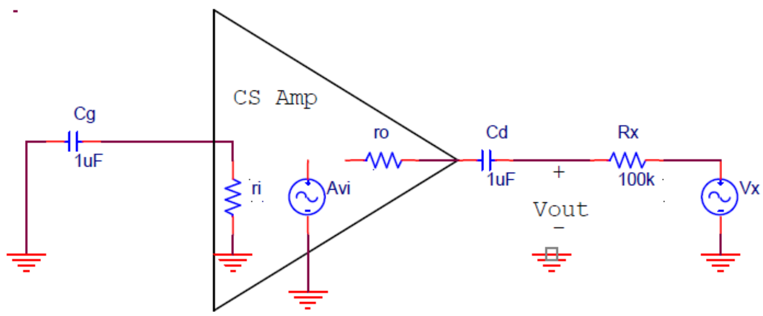

Figure 8-7 Output Impedance Measurement Setup

23. Measure the value of v_{out}. Set up an equation relating v_{out} and v_x. Use that equation to solve for the value of the AC output impedance z_o. Make sure that R_L is not connected for this measurement!
24. Vary the frequency of the function generator in order to obtain the necessary data to plot a frequency response curve for the output impedance z_o.

DATA/OBSERVATIONS

INSTRUCTOR'S INITIALS:		DATE:	

POSTLAB

Post-Lab questions must be answered in each experiment's laboratory report.

MOSFET Amplifier Configurations

1. How did your calculated values for biasing and for the voltage gain compare with the measured values obtained in the experiment (for each configuration)?
2. Using Excel or similar spreadsheet software prepare a frequency response curve for each of the three configurations. Compare the behavior of the three configurations, i.e. compare voltage gain, -3dB frequencies, and bandwidth.

MOSFET Amplifier Input/Output Impedance

3. Using the measured bias voltages V_D, V_G, and V_S, calculate the bias current I_{DS}. Compare these values with those calculated in the Prelab. Also compare the measured voltage gain, input impedance, and output impedance at 1kHz with that obtained in the Prelab.
4. Plot a frequency response curve for the voltage gain, input impedance, and the output impedance from the measured data collected. Use Excel or a similar spreadsheet software to plot the curves.
5. Comment on the behavior of the voltage gain, input impedance, and the output impedance as they relate to frequency.

Note: When plotting the frequency response curves make sure the x axis is log (i.e. 1 10 100 1000, etc.) in Excel and for PSpice or Multisim.