Laboratory Goals

- Introduce students to the MOSFET transistors
- Familiarize students with MOSFET characteristics
- Learn how to properly bias a MOSFET transistor

Pre-lab / lab reading

- Course Textbook
- Oscilloscope User's Guides (Copies of these reference books are available in the lab, or at the website)
- BS170, BS250 & 2N7000 Transistor Data Sheets
- Read the pre-lab introduction below

Equipment needed

- Lab notebook, pencil
- Oscilloscope (Agilent or Tektronics)
- 2 oscilloscope probes (already attached to the oscilloscope)
- BNC/EZ Hook test leads
- Curve Tracer
- PB-503 Proto-Board
- Workstation PC, with PSICE application

Parts needed

- Resistors
- 1 BS170 or 1 2N7000 NMOS Transistor
- 1 BS250 PMOS Transistor
- ECE 206 Parts kit

Lab safety concerns

- Make sure before you apply an input signal to a circuit, that all connections are correct, and no shorted wires exist.
- Do not short the function generator signal and ground connections together
- Do not touch the circuit wiring while power is applied to it
- Ensure you connect the correct terminal of the transistor to prevent blowing the transistor

1. Pre-Lab Introduction

A bit of transistor history:

The IC industry started in the late 1960s and early 1970s with ten-micron technology. This design era is known as small-scale integration (SSI) and medium-scale integration (MSI) in which only a few hundred gates were on a chip. As predicted by Moore's law, twice the number of transistors can be integrated on the same sized chip every three years. In the 1970s thousands of gates were integrated on a single chip in which the era of large-scale integration (LSI) began. As a result, more powerful microprocessors became available, and memories with large storage capacities were developed. The 1980s brought about very large-scale integration (VLSI) in which the ability to fit one million gates on a single chip became feasible. The 1990s ushered in the sub-micron era, which began with metal line widths of the integrated circuits reaching 1µm and reducing to 0.5µm by the mid-1990s. Further advances have led to the deep submicron (DSM) era in which widths reduced to 250 nm and now 90 nm.

The TTL, bipolar transistor-transistor logic was one of the earliest families of standardized logic gates. Devices in this logic group were labeled with numbers starting with 74. Some examples are the 7400 2 input NAND gate and the 7404-hex inverter. TTL logic requires 5-volt power supply and is slow. The Schottky series, 74Sxx, was developed as an improvement and consisted of low power, fast, and advanced low power families.

Another early family of transistors often used in CMOS gates was numbered beginning with 40. These devices consume much less current but are slow devices. The voltage range for these devise ranges from 3 to 15 volts. An example of this logic family is the 4011, which is a quad 2-input NAND gate. The 40xx devices are not usually electrically compatible with the 74xx series due to discrepancies in the definition of high and low signals.

There is now a wide range of logic families. Texas Instruments alone has over 20 logic families available. The HC family is a good starting model if top speed, minimum current consumption, and very low voltages are not essential.

The commonly used logic families are based on the 74xx, so the 74 is typically dropped when referring to the logic series. Rather, the series would be referred to as the HC series logic or LVC series logic.

Many logic families are governed by standards; so theoretically, the 74HC00 produced by Texas Instruments should be the same as the 74HC00 made by Fairchild Semiconductor. The newer families have yet to be standardized however, so you should always refer to the manufactures data sheet.

While both this lab and the following focus on MOSFET transistors, there are many variations of transistors. Two very common types are the metal oxide semiconductor field effect transistor (MOSFET) and the junction field effect transistor (JFET).

Bipolar junction transistors are another common type of transistor. Some sub classifications of the field effect transistor are MOSFETs, JFETs, and High Mobility Electron Transistors (HEMTs). Further sub-categories of MOSFETS are the Nchannel MOSFET (NMOS), the P-channel MOSFET (PMOS), and the Complimentary-channel MOSFET (CMOS).

2. Pre-Lab Calculations

Calculate I_d, V_{GS} and V_{DS} for the circuits in Figures 1 through 4.
For the NMOS transistor use K_n= 1.825 mA/V^2, and W/L =1, V_{TN}=1V.
For the PMOS transistor use K_p= .111806 mA/V^2, and W/L=1, V_{TP} = -1V.

Present the results in your lab notebook using the following tables:

	Circuit 1			Circuit 2		
Element	**Resistance**	**Current**	**Voltage**	**Resistance**	**Current**	**Voltage**
R1						
R2						
Rs						
Rd						
Vg	N/A	N/A		N/A	N/A	
Vs	N/A	N/A		N/A	N/A	
Vd	N/A	N/A		N/A	N/A	
V_{DS}	N/A	N/A		N/A	N/A	
V_{GS}	N/A	N/A		N/A	N/A	
I_D	N/A		N/A	N/A		N/A

	Circuit 3			Circuit 4		
Element	**Resistance**	**Current**	**Voltage**	**Resistance**	**Current**	**Voltage**
R1						
R2						
Rs						
Rd						
Vg	N/A	N/A		N/A	N/A	
Vs	N/A	N/A		N/A	N/A	
Vd	N/A	N/A		N/A	N/A	
V_{DS}	N/A	N/A		N/A	N/A	
V_{GS}	N/A	N/A		N/A	N/A	
I_D	N/A		N/A	N/A		N/A

4. Circuit Construction and Testing

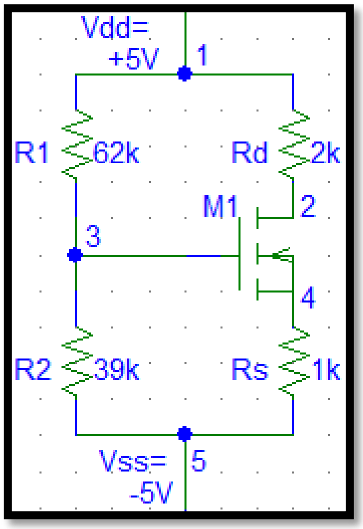

Figure 1. NMOS Circuit

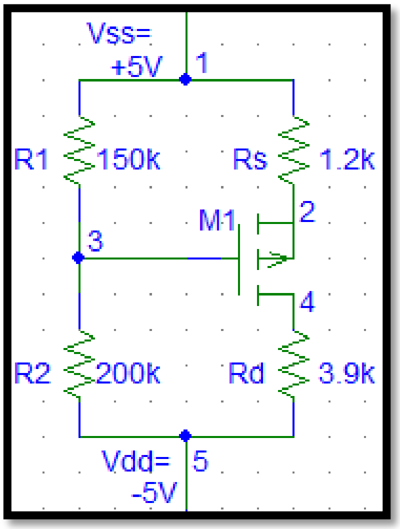

Figure 2. PMOS Circuit

- ☐ Build the circuit shown above in Figure 1 using a transistor provided by your teaching assistant and available resistors.
- ☐ Read the transistor data sheet to identify the source, drain, and gate pins.
- ☐ Measure all node voltages and currents completing another table like in the prelab.
- ☐ In which mode of operation is the transistor working?
- ☐ Repeat the previous steps for circuits 2, 3 and 4.

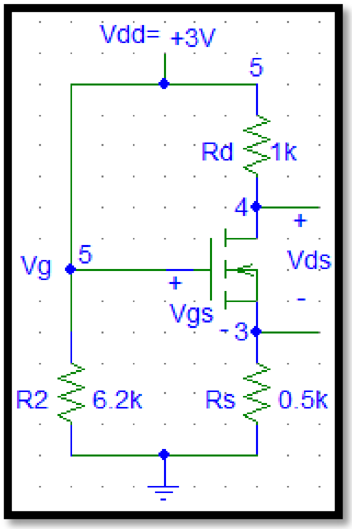

Figure 3. NMOS Circuit

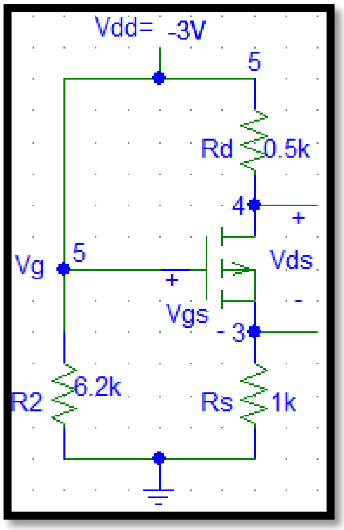

Figure 4. PMOS Circuit

Before leaving the lab, take a few minutes to clean up your workstation, and return all equipment to your cabinet.

4. Curve Tracer

- ☐ Use the curve tracer to obtain the IV curve produced by the transistor
- ☐ The Teaching Assistant will verify the produced curve and sign your lab notebook

5. SPICE Simulation

Perform SPICE simulations of the all the circuits. How do they compare to your calculations and to the measurements?

6. Analysis

Write a brief summary report for the lab. Be sure to also include the following topics:

Draw an NMOS and a PMOS cross section diagram and be sure to include the channel, body, gate, drain, source, etc.

Identify and explain the operating regions of the IV curves generated.

Compare and contrast the results of the hand computation, physical experiment, and SPICE simulation. Do the values generally agree? Explain possible reasons for any differences in the data.

Explain any difficulties you had with these labs. (Please include any suggestions to improve them).