

**Laboratory Goals**

- ☐ Introduce students to the NMOS transistor
- ☐ Familiarize students with the NMOS characteristics
- ☐ Use the curve tracer to verify the IV curve

**Pre-lab / lab reading**

- ☐ *Student Reference Manual for Electronic Instrumentation Laboratories* by Stanley Wolf and Richard Smith, Copyright 1990.
- ☐ Oscilloscope User's Guide (Copies of this reference book are available in the lab, or at the website)
- ☐ *Tektronics 571 Curve Tracer Manual*
- ☐ BS170 Transistor Data Sheet
- ☐ 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
- ☐ Tektronics 571 Curve Tracer
- ☐ PB-503 Proto-Board
- ☐ Workstation PC, with PSICE application

**Parts needed**

- ☐ 1 k $\Omega$ , 6.2 k $\Omega$ , and 0.5 k $\Omega$  Resistors
- ☐ 1 BS170 NMOS Transistor
- ☐ ECE 206 Parts kit

**Lab safety concerns**

- ☐ Make sure before you apply an input signal to a circuit, 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  $1\mu\text{m}$  and reducing to  $0.5\mu\text{m}$  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 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 devices 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 absolutely 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 manufacturer's 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 N-channel MOSFET (NMOS), the P-channel MOSFET (PMOS), and the Complimentary-channel MOSFET (CMOS).

## 2. Pre-Lab Calculations

In this NMOS transistor, calculate  $I_d$ ,  $V_{GS}$  and  $V_{DS}$  if  $K_n = 1.825 \text{ mA/V}^2$ , and  $W/L = 1$ ,  $V_{TN} = 1\text{V}$ .

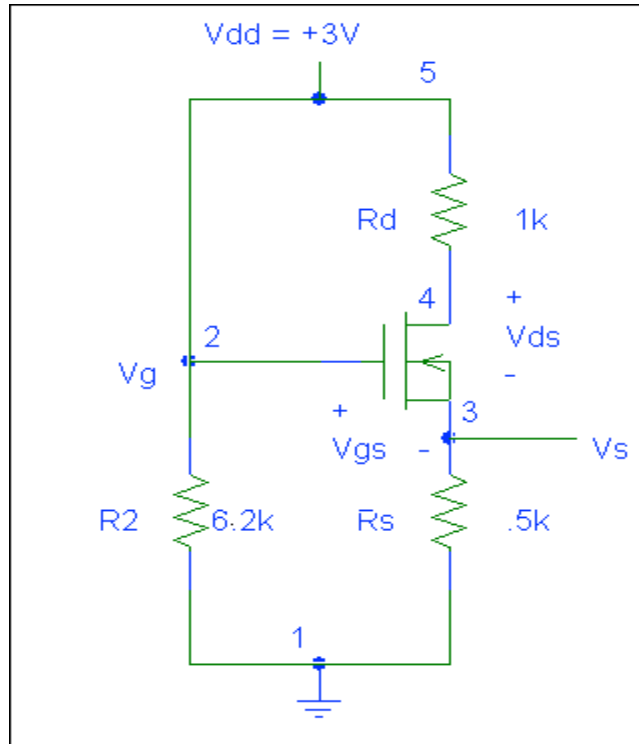


Figure 1: NMOS Circuit

- Create the following table in your lab notebook:

Element	Measured Resistance	Current	Voltage
R2			N/A
Rs			N/A
Rd			N/A
Vg	N/A	N/A	
Vs	N/A	N/A	
Vd	N/A	N/A	
$V_{DS}$	N/A	N/A	
$V_{GS}$	N/A	N/A	

**3. Circuit Construction and Signal Measurement**

- ☐ 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 which pins correspond to the source, drain, and gate
- ☐ Analyze all node voltages and currents completing the chart created in the pre-lab
- ☐ For various input voltages measure the circuit current
- ☐ In your lab notebook accurately graph the IV curve
- ☐ When all measurements are complete, turn the equipment off
- ☐ Disconnect the test leads from the circuit

**4. Curve Tracer**

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

**5. SPICE Simulation**

- ☐ Perform a SPICE and or Multisim simulation of the circuit shown in Figure 1
- ☐ Print out the source code and node voltages of the simulation to include in your lab report(if using PSpice).

**6. Analysis**

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

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

Identify and explain the operating regions of the IV curve generated for the transistor.

Compare and contrast the results of the hand computation, physical experiment, SPICE simulation and curve tracer output graph. 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).

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