Metal Oxide Semiconductor Field Effect Transistors

Acknowledgements: Developed by Ronnie Wilson, Faculty of Austin Community College, Austin, Texas. Special thanks to Electronic Workbench for providing this simulation as a stand-alone activity.

Special Notes: This simulation should be completed after you have read the WRE Metal Oxide Semiconductor Field Effect Transistors (MOSFETs) and Common Electronic Circuits Module. This module should be completed before starting the Enhancement Mode MOSFET Transistors simulations.

Approximate Time Required: 2 hours

Equipment: These simulations require no special software to run, but your computer needs to have internet access to download the required simulation file from the WRE web site. The required files are titled: MOSFET_Figure_1, MOSFET_Figure_2, and MOSFET_Figure_3. Your computer will need the Windows 98 operating system or higher to run these files.

Simulation Summary: The purpose of this interactive simulation is to prepare you for the hands-on lab related to MOSFET transistors. These circuit simulation labs introduce the operating characteristics of P and N E-MOSFETs analog and digital circuits. The simulation of these circuits is being provided on a version of MultiSim 8 software, which is self-running and does not require the MultiSim 8 program be installed on your computer.

The simulations describe small manageable block level discussions of the (a) characteristics of P and N E-MOSFET transistors, (b) Analog circuit application of E-MOSFET transistors, and (c) Digital Logic circuits.

Simulation Goal: Observe the operating characteristics of a P and N E-MOSFET transistors, the application of these characteristics to an Analog and Digital circuit.

Learning Objectives

1. Calculate the ON resistance for the simulated test transistor.
2. Complete a truth table for a NOR gate constructed from E-MOSFET transistors.

Grading Criteria: Your grade for this interactive simulation will be determined by your performance on the simulation and your answers to the simulation questions.

Simulation Preparation

1. Print a copy of the procedure to use as a reference, schematic, and workbook while completing the simulation.
2. Read the Introduction.
3. Review the Simulation Procedures.

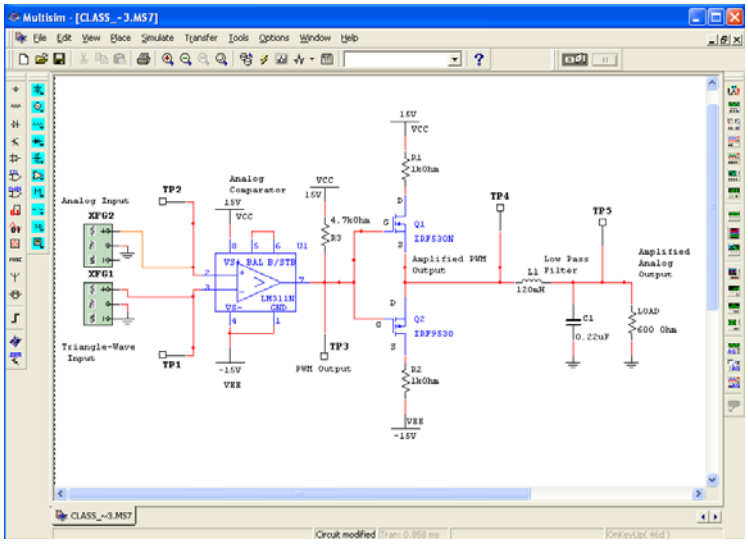
Software Alert: When performing circuit simulations, failing to read and follow directions exactly can result in incorrect circuit operation and data measurements. For instance, if you fail to stop or pause the circuit at the appropriate times and leave circuits running, functions within Multisim 7 may become inoperative.

Simulation Procedures

NOTE: The schematic, tables, and lab questions are at end of this section.

Using Multisim

1. Download the Multisim demo from the WRE Module Learning Resource tab.
2. Open the file called MOSFET_Figure_1.
3. If you have not used Multisim before, please review the following section.



a. The simulation circuit is in the center of the screen.

NOTE: This is an example only. The circuit you are using is at the end of this procedure.

b. The Run/Stop and Pause/Resume simulation buttons are on the tool bar near the Help (?) button. Run/Stop is on the left and Pause/Resume is on the right.

c. The instrument toolbar is on the right border. As you move your mouse over the instrument, the name should appear. For this simulation, you will use the multimeter that are already hooked up in the simulation.

N-Channel E-MOSFET Simulation

The first simulation will be of an N-channel E-MOSFET circuit that will provide the value of the threshold voltage for the transistor and the necessary values of V_{DS} and I_D to calculate the transistors ON resistance.

1. Load the MultiSIM file MOSFET_Figure_1 from the WRE web site.
   a. The major component is an N-channel E-MOSFET.
   b. The circuit is used to set the V_{DS} to zero volts and I_D to zero.
   c. Voltmeter V1 is used to measure the voltage across R_1 so the value of I_D can be calculated.
   d. Voltmeter V_2 measures the total voltage applied to the circuit which is normally referred to as V_{DD}.
   e. Voltmeter V3 is measuring the voltage from drain to source for the transistor.
2. Turn the Run/Stop switch to the On position to start the simulation.
3. Press the A or SHIFT A on your keyboard to adjust the position of the wiper of the potentiometer. It will move either toward 0% or toward 100% and cause the voltage across the circuit to vary.
4. Begin the simulation by moving the wiper of the potentiometer to 100%. This will cause the voltage across the circuit to be approximately zero volts.
5. Enter the values associated with the circuit in Table 1.
   a. The value you enter in the V_{DD} column is the voltage on voltmeter V_2.
   b. The value you enter for V_{DS} is shown on V_3.
   c. The value for $V_{RESISTOR}$ is the value shown on V_1.
6. Reduce the value of R_2 one step at a time and enter the values of each voltmeter in Table 1.
7. Upon completing the measurements, turn the Run/Stop switch to the Off position and plot the data in Graph 1.
8. Answer questions 1, 2, 3, and 4.

P-Channel E-MOSFET Simulation

The second simulation will be of a P-channel E-MOSFET circuit that will provide the value of the threshold voltage for the transistor and the necessary values of V_{DS} and I_D to calculate the transistors ON resistance.

1. Load the MultiSIM file MOSFET_Figure_2 from the WRE web site.
   a. The major component is a P-channel E-MOSFET.
   b. The circuit is used to set the V_{DS} to zero volts and I_D to zero.
   c. Voltmeter V1 is used to measure the voltage across R_1 so the value of I_D can be calculated.

d. Voltmeter V_2 measures the total voltage applied to the circuit which is normally referred to as V_{DD}.

e. Voltmeter V3 is measuring the voltage from drain to source for the transistor.

2. Turn the Run/Stop switch to the On position to start the simulation.
3. Press the A or SHIFT A on your keyboard to adjust the position of the wiper of the potentiometer. It will move either toward 0% or toward 100% and cause the voltage across the circuit to vary.
4. Begin the simulation by moving the wiper of the potentiometer to 100%. This will cause the voltage across the circuit to be approximately zero volts.
5. Enter the values associated with the circuit in Table 1.
   a. The value you enter in the V_{DD} column is the voltage on voltmeter V_2.
   b. The value you enter for V_{DS} is shown on V_3.
   c. The value for $V_{RESISTOR}$ is the value shown on V_1.
6. Reduce the value of R_2 one step at a time and enter the values of each voltmeter in Table 2.
7. Upon completing the measurements, turn the Run/Stop switch to the Off position and plot the data on graph 2.
8. Answer questions 5, 6, 7, and 8.

NOR Gate Made From P- and N-Channel E-MOSFET Transistors Simulation

The third simulation will be of a NOR gate circuit made from P- and N- channel E-MOSFET transistors as shown in figure 3.

1. Load the MultiSIM file MOSFET_Figure_3 from the WRE web site.
2. Turn the Run/Stop switch to the On position to start the simulation.
   a. The two switches on the left side of the circuit provide the input voltage for the two inputs of the NOR gate.
   b. The top switch is controlled by the A key on the keyboard and the second switch is controlled by the B key.
   c. When the switch is down, the input has zero volts applied and when it is up five volts are applied.
3. Test the NOR gate circuit by applying different combinations of input binary values to the circuit for all possible combination of inputs.
4. Record the results in Table 3.
5. Upon completing the measurements, turn the Run/Stop switch to the Off position and answer question 9.
6. Close the Multisim simulation.

NOTE: If the question appears asking to you to save changes, select No.

Simulation Tables

Table 1: MOSFET Basic Parameters N-Channel

V_{DD}	V_{DS}	$V_{RESISTOR}$	I_D	V_{DD}	V_{DS}	$V_{RESISTOR}$	I_D

Table 2: MOSFET Basic Parameters P-Channel

V_{DD}	V_{DS}	$V_{RESISTOR}$	I_D	V_{DD}	V_{DS}	$V_{RESISTOR}$	I_D

Table 3: MOSFET NOR Gate Circuit

V_A	V_B	V_{out}

Lab Questions:

Graph 1

1. What does the data tell you about this transistor simulation?

2. What is the value of V_{th}?

3. What is the value of R_{ON}? R_{ON}= is found by determining values for V_{DS} where the curve is linear (straight) and their corresponding values of I_D. R_{ON} =

4. From the data obtained from the circuit in figure 1 calculate the ON resistance for the transistor under test. R_{ON} =

Graph 2

5. What does the data tell you about this transistor simulation?

6. What is the value of V_{th}? V_{th} =

7. From the data obtained from the circuit in figure 2 calculate the ON resistance for the transistor under test. R_{ON} =

8. What is the value of R_{ON}? R_{ON}= is found by determining values for V_{DS} where the curve is linear (straight) and their corresponding values of I_D. R_{ON} =

9. Does the NOR gate constructed from E-MOSFET transistors operate as a digital NOR gate and does its truth table agree with a standard NOR gate circuit?

Figure 1: Simulation Schematic N-Channel

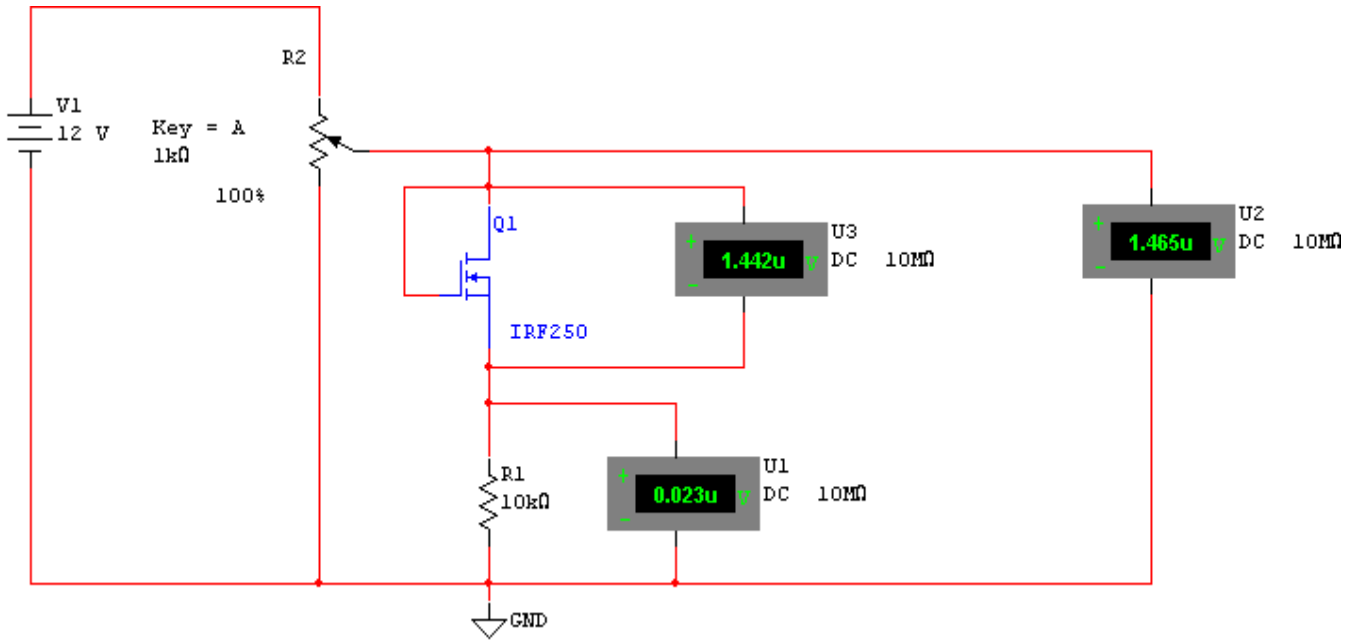


Figure 2: Simulation Schematic P-Channel

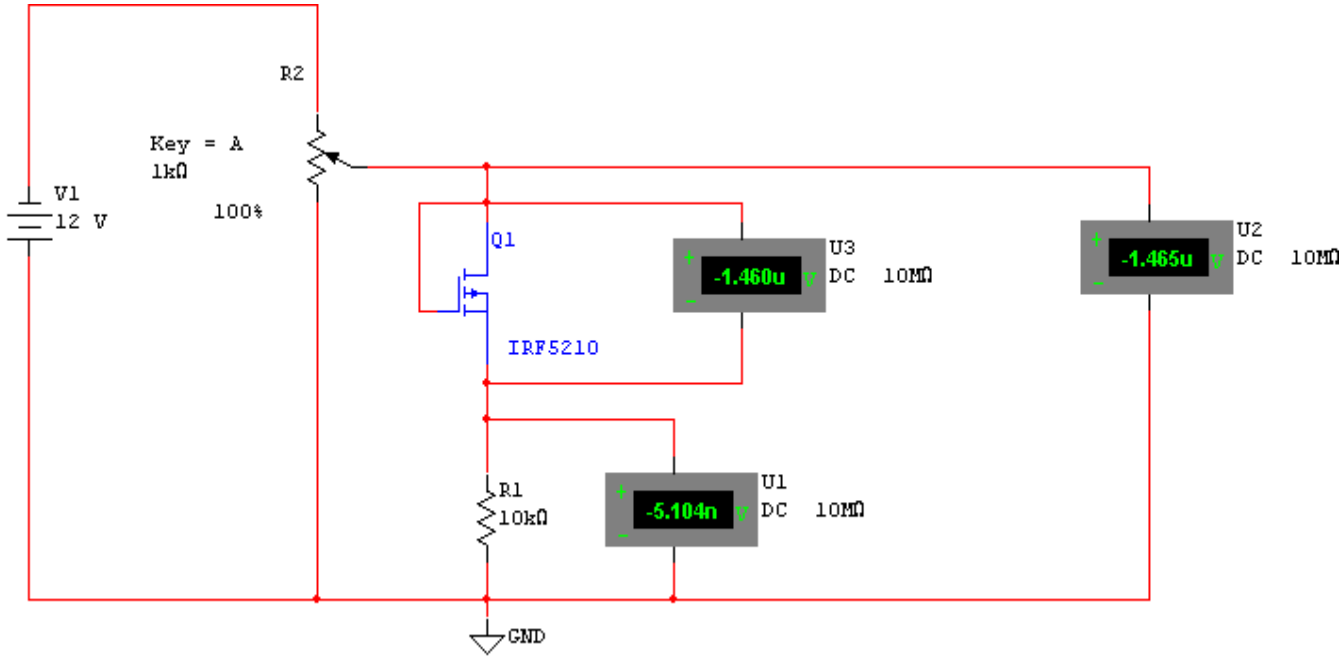


Figure 3: Simulation Schematic MOSFET NOR Gate Circuit