

1.2.2: Dependent Sources and MOSFETs

Overview:

In this lab assignment, a qualitative discussion of dependent sources is presented in the context of MOSFETs (Metal Oxide Semiconductor Field Effect Transistors). A simple voltage controlled current source is constructed and tested.

Before beginning this lab, you should be able to:

- Use a DMM to measure voltage and current (Lab 1.2.1)
- Use the Analog Discovery power supplies to apply a fixed 5V voltage (Lab 1.2.1)
- Use the Analog Discovery voltmeter to measure a constant voltage (Lab 1.2.1)
- Write symbols for dependent voltage and current sources
- State governing equations for the four types of dependent sources

After completing this lab, you should be able to:

- Use MOSFETs as dependent sources
- Use the Analog Discovery waveform generators to apply constant voltages

This lab exercise requires:

- Analog Discovery
- Digilent Analog Parts Kit
- Digital multimeter

Symbol Key:

DEMO

Demonstrate circuit operation to teaching assistant; teaching assistant should initial lab notebook and grade sheet, indicating that circuit operation is acceptable.

ANALYSIS

Analysis; include principle results of analysis in laboratory report.

SIM

Numerical simulation (using PSPICE or MATLAB as indicated); include results of MATLAB numerical analysis and/or simulation in laboratory report.

DATA

Record data in your lab notebook.

General Discussion:

Many common circuit elements are *modeled* as dependent sources – that is, the mathematics describing the operation of the element is conveniently described by the equations governing a dependent source. In this portion of the lab assignment, we will build and test a circuit which acts as a Voltage Controlled Current Source (VCCS).

The primary circuit element used in this assignment is a Metal Oxide Semiconductor Field Effect Transistor (MOSFET). There are two basic types of MOSFETs: *n-channel* and *p-channel*; the discussion presented here is for n-channel MOSFETs, though similar concepts apply to p-channel MOSFETs. A MOSFET is a three-terminal device; the symbol commonly used to represent a MOSFET in circuit diagrams is shown in Figure 1(a). The three terminals of the device are called the source (S), the drain (D) and the gate (G). Our circuit will employ a ZVN2210A MOSFET; the physical appearance of this MOSFET is shown in Figure 1(b), along with the relative locations of the drain, gate and source for that model MOSFET.

An extremely simplified discussion of a MOSFET's operation is as follows: A “channel” is opened in the MOSFET by application of a voltage at the gate of the MOSFET. This channel allows current to flow from the drain to the source of the MOSFET (i_D in Figure 1(a)). Thus, if a power supply is connected to the drain of the MOSFET, the MOSFET can be used to control the power supply's current: increasing the gate voltage increases the current out of the power supply. A rough analogy to this process is a valve placed at the base of a water tank – opening the valve allows water to flow out of the tank. Likewise, increasing the gate voltage allows current to “flow” out of the power supply. A MOSFET, therefore, in conjunction with a power supply, can act as a voltage controlled current source in which the drain current is controlled by the gate voltage.

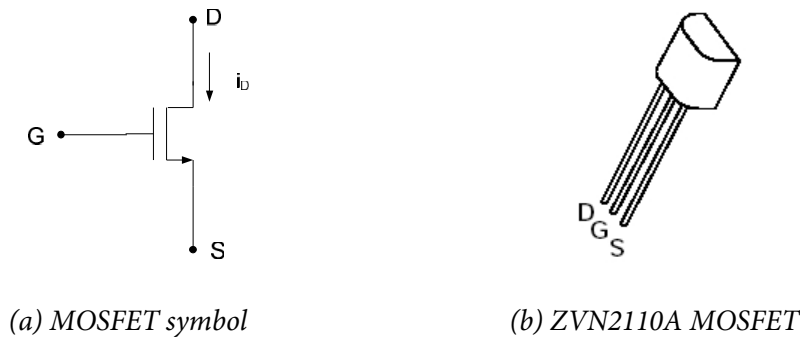


Figure 1. MOSFET symbol and typical physical appearance.

Pre-lab: None

Lab Procedures:

1. Connect the circuit shown in Figure 2. Two power supplies are used in the circuit. Use channel 1 of your Arbitrary Waveform Generator (W1) to apply the (variable) gate voltage, V_G . Use of the waveform generator to apply constant voltages is presented in Appendix A of this assignment. Use the positive power supply (VP+) to provide a constant 5V to the MOSFET drain; this power supply provides the drain current I_D .

The 100Ω resistor in Figure 2 is used to limit the amount of current flowing through the MOSFET. If no resistor is used between the power supply and the MOSFET, an excessive amount of current can flow through the MOSFET resulting in damage to the MOSFET and/or the rest of the circuit. The 100Ω resistors in your analog parts kit can be identified by the color bands on the side of the resistor – they will be as shown in Figure 3. We will discuss resistors in detail in later modules. Use an ohmmeter to measure the resistance of the resistor and record this value in your lab notebook (the actual resistance will most likely be slightly different from 100Ω).

DATA

Connect your DMM as shown in Figure 2 to measure the current I_D .

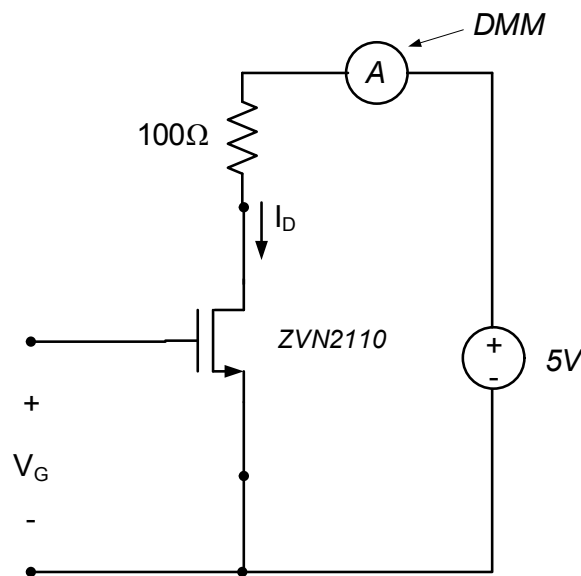


Figure 2. VCCS circuit schematic.

2. MOSFETs have a *threshold voltage*, below which essentially no current passes through the MOSFET. To determine the threshold voltage for our MOSFET, begin with zero voltage applied at the gate by the variable voltage source V_G ($V_G = 0V$). The drain current, with no voltage applied at the gate, should be essentially zero. Gradually increase the MOSFET gate voltage while monitoring the MOSFET drain current I_D . Record in your lab notebook the voltage at which the drain current begins to increase significantly. This is the MOSFET's threshold voltage.

DATA

DATA

3. Now characterize the MOSFET's relationship between gate voltage and drain current. Starting at the threshold voltage, continue to increase the gate voltage at increments of about 0.3V up to a maximum of about 5V. Record the gate voltages and their corresponding drain currents in your lab notebook. Plot the gate voltage vs. drain current data in your lab notebook. Comment on your observations relative to the data, especially relative to how the circuit behaves like a dependent source.

ANALYSIS

4. The parameter g of a VCCS provides a relationship between the rate of change between the applied voltage and the resulting current. This is essentially the slope of the data you plotted in part 3 above. Use the curve of part 3 to estimate the value of g for the circuit you built. Note: Your curve will most likely not be a straight line. Do your best to fit a straight line to the data you acquired in part 3 for your estimate of g .

DEMO

5. Demonstrate operation of your circuit to the Teaching Assistant. Have the TA initial the appropriate page(s) of your lab notebook and the lab checklist.

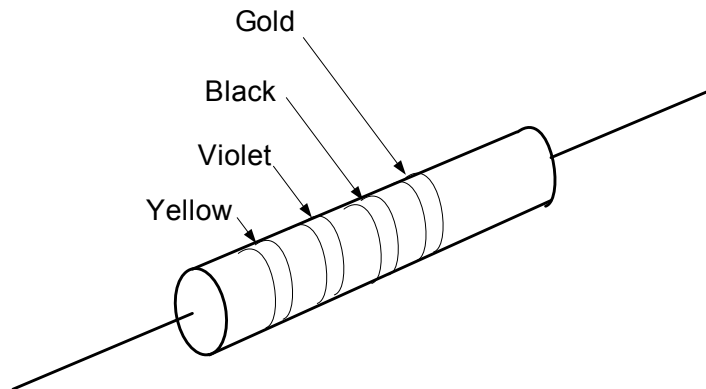
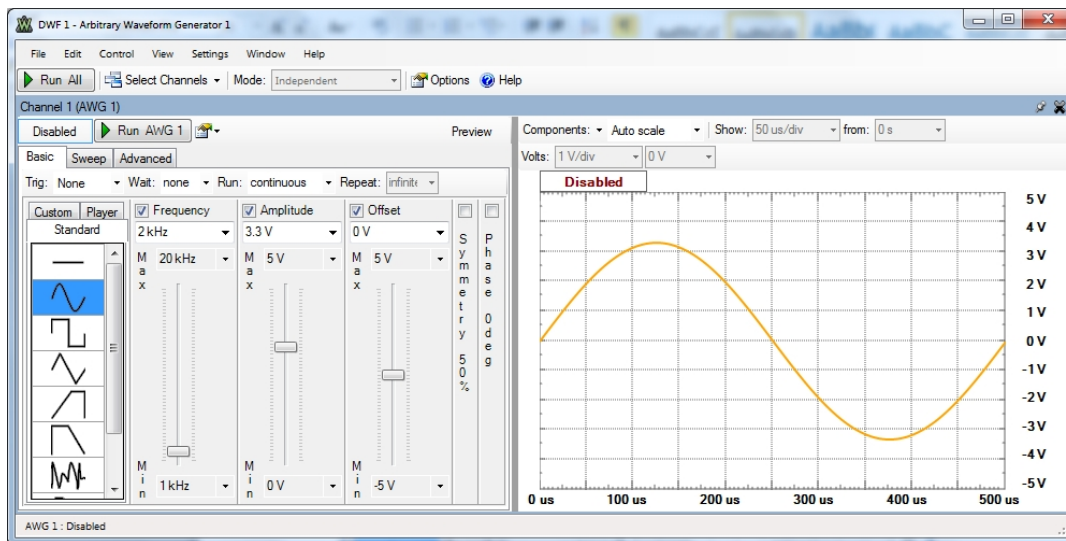


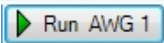
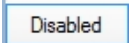
Figure 3. Color bands for 47Ω resistor.

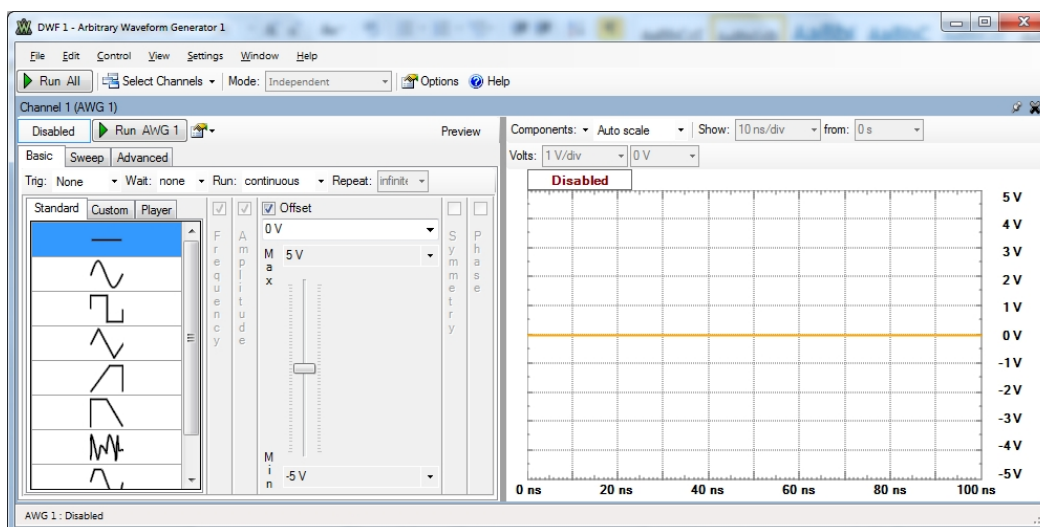
Appendix A – Waveform Generator to apply constant voltages

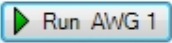
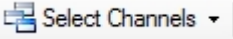
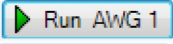
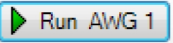
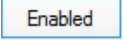
The Voltage instrument on the Analog Discovery provides the capability to apply fixed $\pm 5\text{V}$ voltages to a circuit. Sometimes, however, it is desirable to apply arbitrary voltages to a circuit. The waveform generator on the Analog Discover provides this capability. To do this, follow the steps below:

1. Click on the **WaveGen** icon in the **WaveForms** main window to open the waveform generator window. This window should appear approximately as shown below:

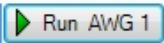
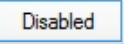
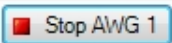
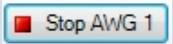
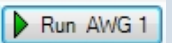


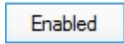
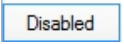
2. There are a series of icons in a column in the lower-left corner of the screen. These icons allow you to select the “shape” of the waveform which will be applied to your circuit. (If the icons are not visible, click on the **Basic** tab (if it is not already selected) and then click on the **Standard** option. The icons indicating the shape of the available waveforms should appear.) In order to apply a constant voltage, click on the  icon. The waveform generator window should alter its appearance so that it looks as shown below. The button to the immediate left of the  button should appear as . If it displays **Enabled**, click on it to disable the waveform generator.



3. The value of the constant voltage to be applied to the circuit is specified in the **Offset** column (the value is limited to between +5V and -5V). The desired value can be set with any of the following approaches:
 - using the slider bar,
 - clicking on the ▼ button in the text box and selecting a value from the resulting drop-down menu, or
 - simply typing the desired value in the text box and pressing the **Enter** button on your keyboard.
4. Click on  to apply power to channel 1 (W1) of the waveform generator. (Each waveform generator channel has its own interface, you can select the desired channel with the  button.) Clicking on the  button automatically enables the function generator; the button to the immediate left of the  button should now appear as .

Important notes relative to the Enabled/Disabled button:

- The button to the left of the  button allows you to “enable” or “disable” the AWG. This button is used to turn off all power provided by the waveform generator channel. Thus, if you are working on your circuit with the waveform generator probes are connected, this button should always be set to .
- Clicking on , when the waveform generator is running, only removes the time-varying component of the signal, not any constant components. If we are applying only a constant voltage to the circuit (as in this lab assignment), the  button has no effect on the voltages being applied to the circuit.
- Clicking on  automatically enables the waveform generator, so that both time-varying and constant components are applied to the circuit.
- Closing the waveform generator window also turns off all power applied by the waveform generator.

5. To turn off power to your circuit, click on the  button so that it displays .