Lab 1: Measurements In Resistive Networks And Circuit Laws

OBJECTIVES
* To provide working knowledge of the voltmeter, ammeter, and ohmmeter as well as their limitations in making measurements in resistive networks.
* To understand how to use the myDAQ to provide the various above functions as well as others.
* Verification of Ohm's Law, Kirchhoff's Voltage Law, and Kirchhoff's Current Laws
* To understand the design and use of a potentiometer.
* To understand current and voltage division.

MATERIALS
* Your myDAQ and entire lab kit
* Graph paper
* Read section 3.5 in the textbook.

INTRODUCTION
A *voltmeter* is used for measuring voltages. For the measurement of a voltage across a circuit component, a voltmeter must be connected in *parallel* with the component so that the voltage across the voltmeter is the same as that across the component. An *oscilloscope* is a special type of voltmeter that can display voltage as a function of time (usually). We will discuss and use an oscilloscope in some future laboratories.

An *ammeter* is used for measuring currents. For the measurement of a current flowing through a circuit component, an ammeter is connected in *series* with the component so that the current flowing through the ammeter is the same as that flowing through the component. In other words, the branch must be disconnected, the ammeter inserted, and the branch reconnected.

An *ohmmeter* is used for measuring resistances of resistors. If a resistor is in a powered circuit, one end of the resistor must be disconnected from the circuit before a resistance measurement is made. Then, the ohmmeter leads are connected to the resistor terminals. *Never* connect an ohmmeter to an energized circuit because the reading will be incorrect and the meter might be damaged.

Using any of these meters can affect the operation of the circuit being measured. This is undesirable. Understanding how these meters affect the circuits in which they are used will allow you to minimize the effects that the meters have on the parameter being measured.

In measuring a voltage or a current, always start at a high range setting and work down to a suitable range. This safety precaution will prevent the meter from being destroyed by an unexpected high voltage or current.

An ideal voltmeter or an ideal oscilloscope has infinite input resistance; an ideal ammeter has zero internal resistance. Since such ideal meters do not exist, the effect of inserting a meter must be considered, i.e., the meter resistance must be included in the circuit analysis.

Consider the circuit shown in Fig. 1 in which a voltmeter with input resistance R_V is connected to measure the voltage across resistor R_2. Ideally, if $R_V=\infty$, voltage division can be used to find the voltmeter reading of

$$V_{IDEAL} = V_S * R_2 / (R_1 + R_2) \ .$$

The actual reading, however, will be

$$V = V_S * (R_2 \mathbin{\|} R_V) / (R_1 + R_2 \mathbin{\|} R_V)$$

in which $R_2 \mathbin{\|} R_V$ designates the resistance of the parallel combination of R_2 and R_V. Since

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$$R_2 \parallel R_V = R_V * R_2 / (R_V + R_2),$$

As the resistance R_V approaches infinity, the voltmeter reading approaches the correct value. Thus, it is desirable for the voltmeter input resistance to be much greater than the resistor that the voltmeter is connected across, i.e., $R_V \gg R_L$. Then, the voltmeter will not "load" the circuit.
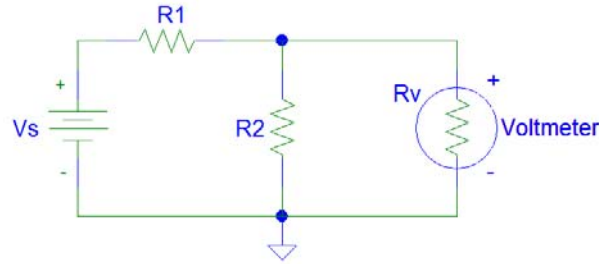

Figure 1 – Voltmeter measurement.

Now consider the circuit shown in Fig. 2 in which an ammeter, with internal resistance R_A, is connected to measure the current flowing through resistor R_L. The current, *I*, that the ammeter will measure is

$$I = V_S / (R_A + R_L)$$

instead of the ideal value of

$$I_{IDEAL} = V_S / R_L \quad .$$

The ammeter reading will approach the ideal value as R_A approaches zero. Thus, the internal resistance of an ammeter should be much smaller than the resistor in series., i.e., in the below case, $R_A \ll R_L$.
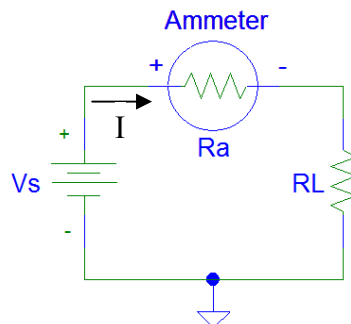

Figure 2 – Ammeter measurement.

Summarizing, an analysis should be made of the "new" circuit consisting of the circuit under test plus the resistance of the meter. Often, this analysis will show that the meter has a negligible effect on the circuit operation. In this case, the meter resistance can be ignored. This is the desired condition, but one which should be assumed only after careful consideration.

PRE-LAB AND QUESTIONS

Design the circuit of Fig. 3 in Multisim, available on the myDAQ Software Suite DVD (included in your myDAQ box). Remove the voltage source and then use Multisim to determine the equivalent resistance as seen by the source, i.e., at the nodes where the source was removed. Use the *Agilent Multimeter* (in MultiSim) to determine the equivalent resistance. (See file Resis_series or Resis_parallel on the class website at http://mil.ufl.edu/3111/examples/Multisim). Use the top and middle terminals to connect to the locations where the voltage source was removed. Print the circuit diagram **with the resistance from**

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the Agilent Multimer shown. To do this, first **copy** the circuit with the meter by holding the keyboard *Alt* key while then selecting the *PrtScn* key. You can then **paste** the "screen shot" into a Word or PowerPoint file. **Crop** this figure as necessary. Label this schematic. Save this file and add the other screen shots from this lab into this same document. Also save the Multisim file. You will email this file (and several others) to your TA (3111uf@gmail.com) **BEFORE** your lab.

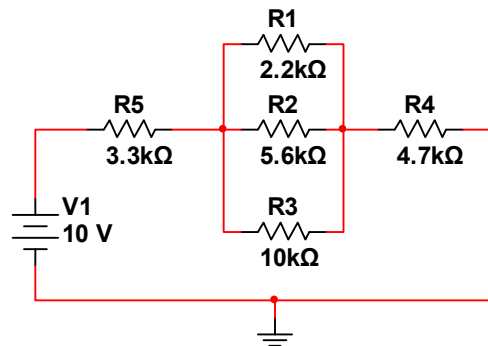Calculate the equivalent (show all your work) and verify that the resistances are the same (or nearly the same).

Figure 3 – Prelab circuit.

Re-insert the voltage source and then add the *Multimeter* (in Multisim) across R4. (See file Multimeter_voltage.ms11 on the class website). Double-click on the Multimeter and then select "V" for voltage.

1. Select "Set…". Set the *Voltmeter resistance* equal to 1 GΩ. Accept this value and then run the simulation to determine the voltage across R4. Copy the schematic with this voltage output to your Word or PowerPoint file. Crop this figure as necessary and label this schematic appropriately.
2. Set the *Voltmeter resistance* equal to 1 MΩ. Run the simulation to determine the voltage across R4. Copy the schematic with this voltage output to your Word or PowerPoint file. Crop this figure as necessary and label this schematic appropriately.
3. Set the *Voltmeter resistance* equal to 1 kΩ. Run the simulation to determine the voltage across R4. Copy the schematic with this voltage output to your Word or PowerPoint file. Crop this figure as necessary and label this schematic appropriately.
4. Calculate (show all work) what the voltage across R4 should be if the voltmeter resistance was infinite.
5. Compare the results of 1 through 3 above and comment on the implications.

Add the *Multimeter* (in Multisim) between the R4 and the ground symbol. (See file Multimeter_current.ms11 on the class website). Double-click on the Multimeter and then select "A".

1. Select "Set…". Set the *Ammeter resistance* equal to 1 nΩ. Accept this value and then run the simulation to determine the current through R4. Copy the schematic with this current output to your Word or PowerPoint file. Crop this figure as necessary.
2. Set the *Ammeter resistance* equal to 100Ω. Run the simulation to determine the current through R4. Copy the schematic with this voltage output to your Word or PowerPoint file. Crop this figure as necessary and label this schematic appropriately.
3. Set the *Ammeter resistance* equal to 1 kΩ. Run the simulation to determine the current through R4. Copy the schematic with this voltage output to your Word or PowerPoint file. Crop this figure as necessary and label this schematic appropriately.

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4. Calculate (show all work) what the current through R4 should be if the ammeter resistance was zero.
5. Compare the results of 1 through 3 above and comment on the implications.

Compare the equivalent resistance that you found above with the value that can be found by dividing the voltage of the source by the current that you found.

Build the resistor components of Fig 3. on your myDAQ breadboard **BEFORE** your lab. Try not to use too much space, so you can fit the other circuits (Fig. 4 and Fig. 5) that you will build DURING lab.

LAB PROCEDURE AND QUESTIONS

Ohm's Law
1. Construct the circuit of Fig. 4. Use a resistor, R, of unknown resistance (obtained from the laboratory TA). Connect an ammeter (use your myDAQ!) to measure the current through R and a voltmeter (use your myDAQ!) to measure the voltage across R. Remember to connect the ammeter in series and the voltmeter in parallel. Be sure to use the DC setting on the meters. V_S is a variable voltage source.
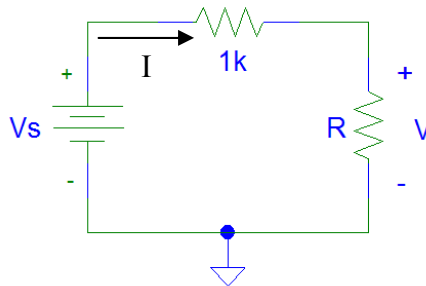

Figure 4 – Circuit to demonstrate Ohm's Law.

2. Vary V_S from –10 V to +10 V (using the myDAQ) in steps of approximately 2.5 V. Measure the voltage of the voltage source (using a lab multimeter) to assure its value. Measure the current through R and the voltage across R (using your myDAQ!). Record these values.
3. Plot these results with current on the horizontal axis and voltage on the vertical axis. Determine the resistance from the plot. Does the plot go through the origin? Should the plot go through the origin?
4. Check the resistance using the digital ohmmeter.
5. Insert a DC voltage source of 5 V in series with *R*, as shown in Fig. 5. Place the voltmeter across both *R* and the 5 V source and repeat steps 2 and 3, i.e., repeat steps 2 and 3 but this time measure the current through *R* and the 5 V source and the voltage across *R* **AND** the 5 V source (**not** as shown).

Figure 5 – Modification of Figure 4.

   Comment on the meaning of the term "resistance" by comparing the two graphs.
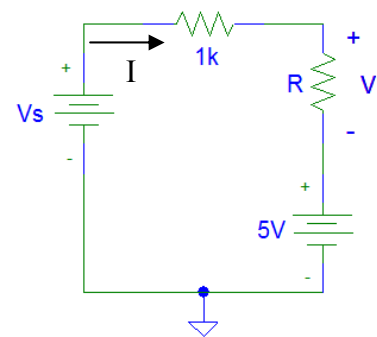
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Kirchhoff's Voltage Law and Kirchhoff's Current Law
1. Complete the construction of the circuit from the pre-lab in Fig. 3 (repeated below) by adding the voltage source (provided from your myDAQ).
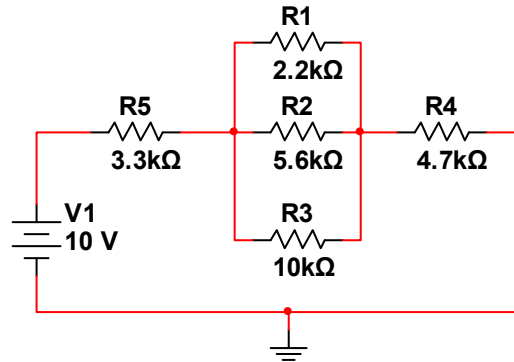2. Measure the voltage across each resistor and the current in each branch.

Figure 3 – Prelab circuit.

3. Using the data collected in step 2, verify Kirchhoff's Voltage Law (KVL) and Kirchhoff's Current Law (KCL).
4. Using the pertinent results from step 2, experimentally determine the total resistance by measuring V1 and I, or with the help of Ohm's law. Compare this with the calculated resistance.

Potentiometer

A potentiometer (or "pot") is a variable resistor also known as a rheostat. A potentiometer is a circuit component with three terminals as shown in Fig. 6. Terminal 3, called the wiper, is connected to a movable contact or arm as shown in Fig. 6a. The resistance between terminals 1 and 2 is fixed and is equal to the rated value for the potentiometer.   The resistance between terminals 3 and 1 or between 3 and 2 can be varied by rotating the center post (or screw head) in Fig. 6b, which corresponds to rotating the wiper. If terminals 1 and 2 are connected across a voltage source, then the voltage between terminals 3 and 1 and between 3 and 2 can be varied by rotating the dial. Fig. 6c shows the schematic symbol for a potentiometer.
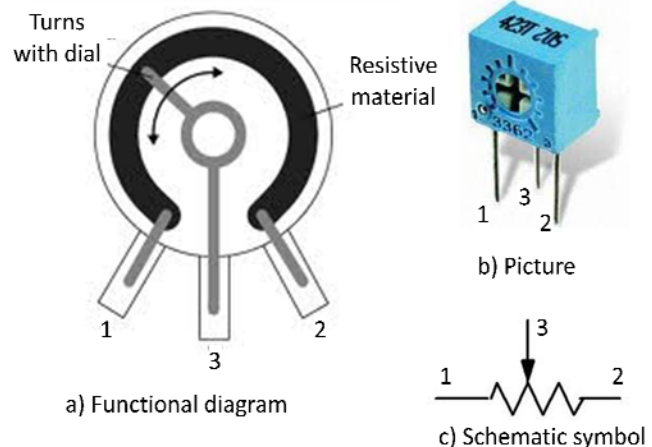

Figure 6 – Potentiometer description (left) and circuit symbol (right).

1. Measure the resistance across the entire potentiometer (pins 1 to 2 in Fig. 6) in your lab kit.
2. Construct the circuit shown in Fig. 7.
3. Adjust the potentiometer to yield an output voltage V_O = 3 V. Measure the resistance between points 1 and 3 and then measure the resistance between points 2 and 3 for each case. Do the same for and V_O = 6 V. Record all this data neatly in a table.
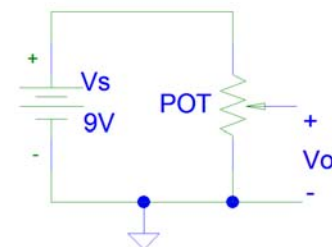

Figure 7 – Circuit to demonstrate a potentiometer.

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4. Explain to your TA how the results agree with voltage division.

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