ECSE 1010

## Class #2: Instruments & Protoboards

**Purpose:** The objective of this experiment is to explore Ohm's Law using a simple multi-meter and the Analog Discovery Board

Background: Before doing this experiment, students should be able to

- Use Ohm's Law to determine either I, V, or R when given the other two parameters.
- Analyze simple circuits consisting of series and parallel combinations of resistors, especially voltage dividers.

Learning Outcomes: Students will be able to

- Determine the value of a resistor from its color code, measurement with ohmmeter and using a voltage divider
- Plot the current through a resistor as a function of the voltage across the resistor and determine its resistance from the slope of this plot

Resources Required:

- Analog Discovery
- Multi-meter
- Protoboard (aka breadboard) from Parts Kit
- Resistors from Parts Kit

Helpful links for this experiment can be found on the course website under Class #2.

### Pre-Lab

*Required Reading:* Before beginning the lab, at least one team member must read over and be generally acquainted with this document and the other **required reading** materials.
*Required Viewing:* Before beginning the lab, each team member must view the videos posted for this experiment.
*Hand-Drawn Circuit Diagrams:* Before beginning the lab, hand-drawn circuit diagrams must be prepared for all circuits either to be physically built and characterized using Analog Discovery.
**Due:** At the beginning of Class #4

*Notes: For this experiment, it will be more convenient if you work together with one (or two) other students. You will be using a multi-meter and we have a limited number for the class. The two or three groups at each table can take turns using their meter. If you have your own meter, you are encouraged to share to help other groups complete their work in a timely manner.*

*You do not have to do the experiment in the order it is written, especially if you have to wait for a multi-meter.*

*For future experiments, you will be required to demonstrate some of your measurements to a TA or instructor and have a signature sheet signed. Because this is one of the first two experiments, show a TA or instructor your results from each activity when you have completed it. Your experiment must be running when you do this.*

**Background Theory.**

*Series and parallel circuits*: Another fundamental concept we need to understand in order to analyze the circuits we will build is how to mathematically combine resistances. If any number of resistances are connected in series, you simply add them to find the total resistance. If any number of resistances are wired in parallel, the total resistance is the reciprocal of the sum of the reciprocals of all of the resistances.

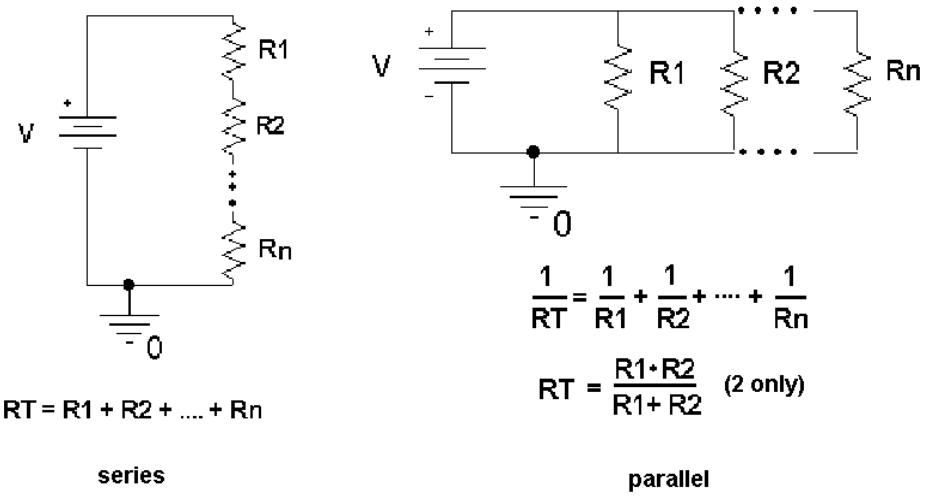
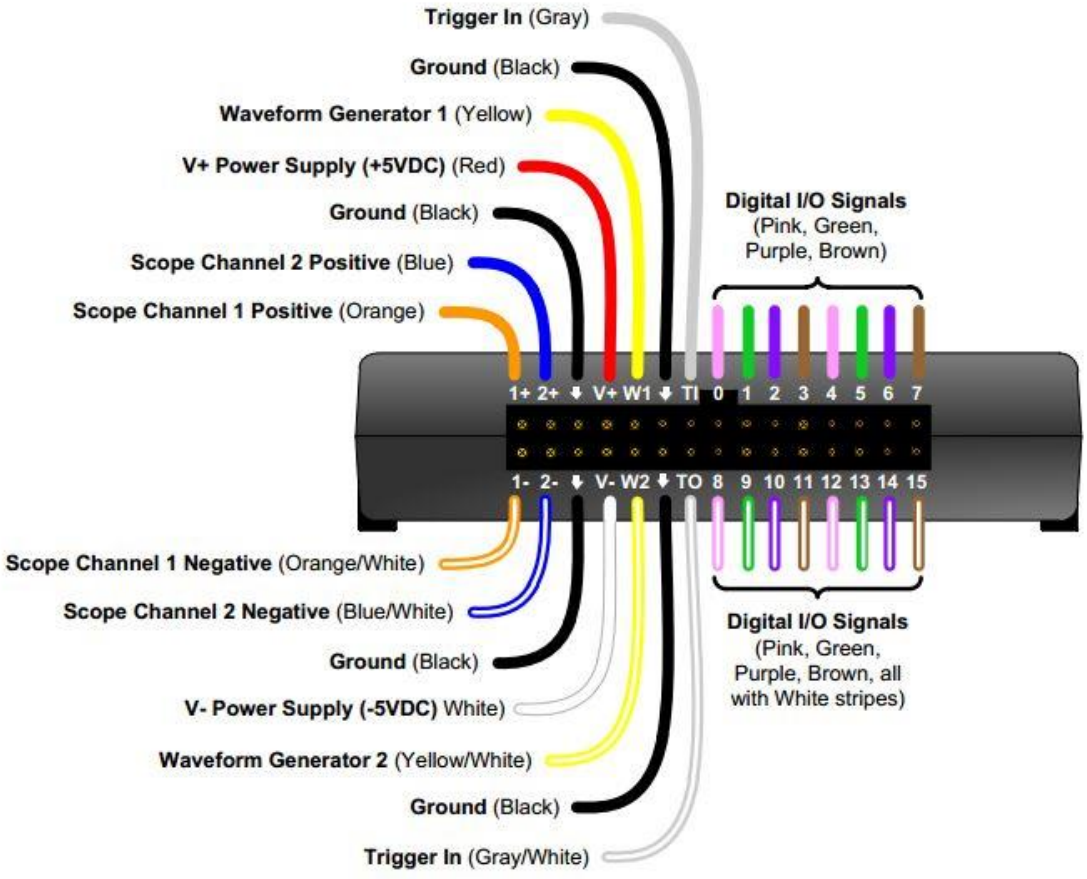



**Figure B-3.**

**Discovery Board**

The following layout details the various connections available on the Discovery Board. In the laboratory description, the Waveform Generator (WaveGen) and Scope Channel connections will be used.

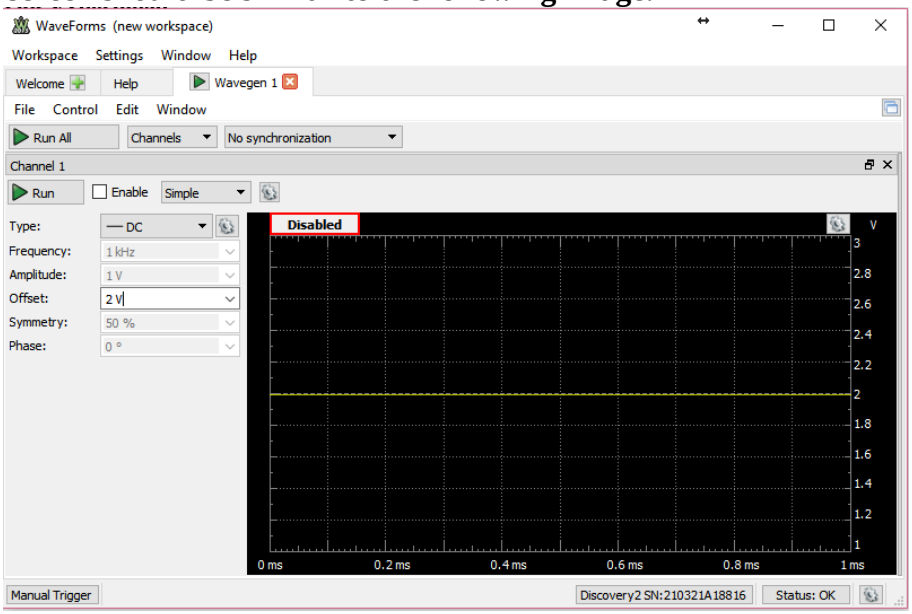


**For This Experiment:**

**Analog Discovery Board signals and measurements.**

1. On the Welcome tab, select Wavegen. To generate a 2V output, complete the following.
   - **a.** Under the Channels drop down list, make sure a check mark is next to Channel 1. You can turn off Channel 2 for now (we will use it later).
   - **b.** On the Channel 1 screen, select the Type drown down list and choose DC.
   - **c.** Set the Offset value to 2V

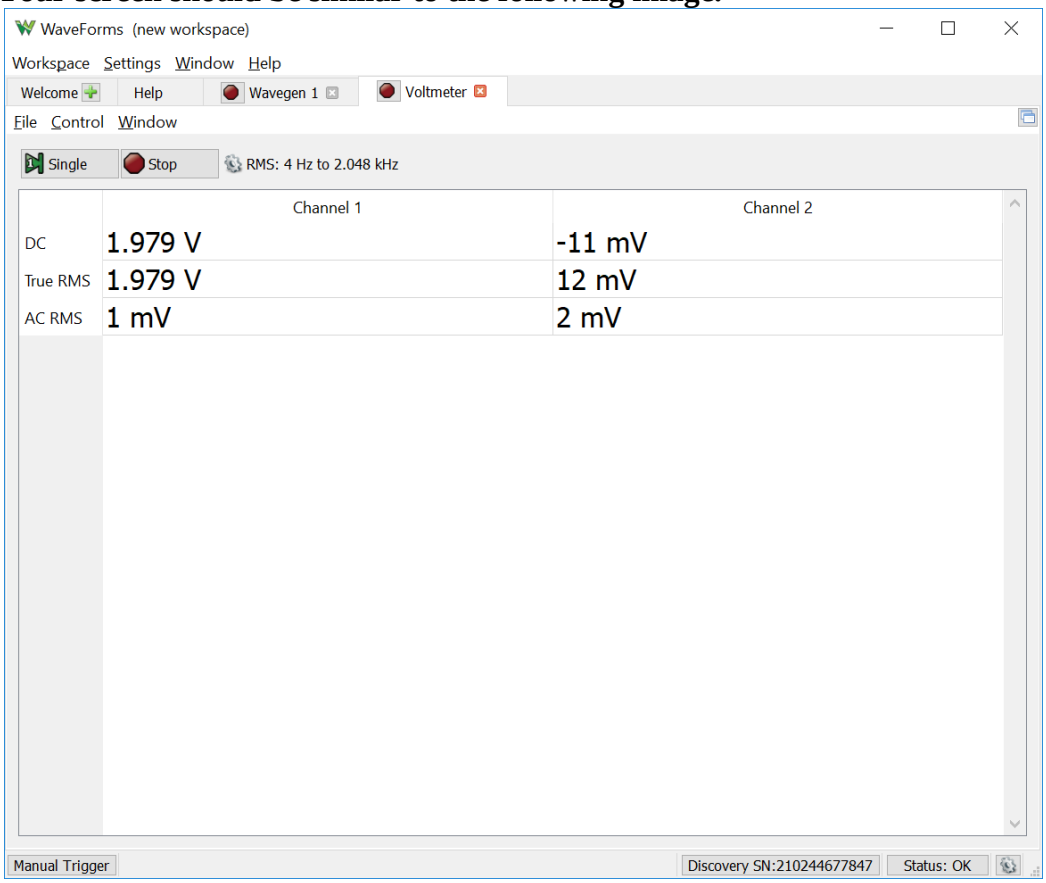
**Your screen should be similar to the following image.**




**Note: Depending on your software installation, the red wire ($V^+$) can also be used as a variable DC source. You can see if that option is available by clicking the Supplies tab on the Welcome tab.**

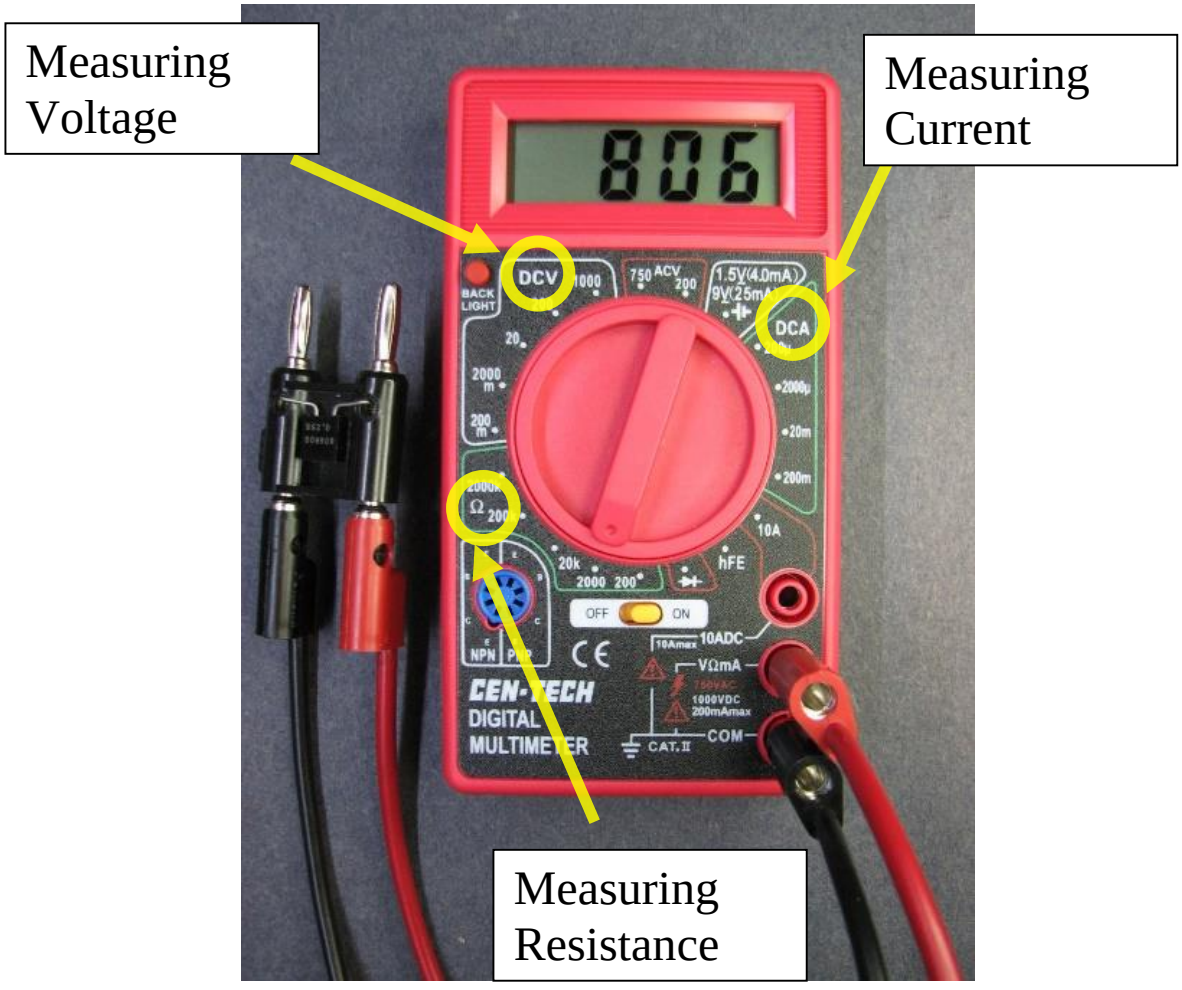
2. Before clicking Run, we will want to wire up the circuit. Supplying power to a circuit before it is complete can be a little dangerous. The +2V output from Channel 1 on Wavegen will be on the solid yellow wire (W1).
3. To make DC measurements (we will make other types of measurements later), select the Voltmeter option on the Welcome tab. A window will open with several measurement options. For now, we will be using Channel 1, DC measurements.
4. Measurement inputs are performing using Channel 1 (**not the same thing as Channel 1 on the Wavegen tab**). The two connections are the orange wire ($1^+$) and the orange/white striped wire ($1^-$).
5. To verify that Wavegen is producing a +2V signal, connect the Wavegen Channel 1 output (W2) to the Voltmeter input ($1^+$). The most accurate measurements use both inputs, so connect any **black** ground wire (they are all the same) to the Voltmeter input ($1^-$).
6. On the Wavegen page, click Run. A 2V output should now be applied on W2.
7. On the Voltmeter page, click Run. If the circuit is connected correctly, you should now see a value very close to 2V displayed in the Channel 1, DC box of the Voltmeter.

**Your screen should be similar to the following image.**



**Multimeters**

MultiMeters can measure voltage, current, & resistance. Shown here is the inexpensive CEN-TECH meter from Harbor Freight. To make a particular measurement, the dial must be set to the desired function (as indicated by the yellow circles) and the wires must be plugged into the appropriate location. For what we do in this course, the meter wires are always plugged in as shown. The dial shown here is for resistance measurements up to 2000Ω. In this experiment, you are to measure resistance and current with the Multimeter. For each measurement, choose the function with the dial, selecting the value that is larger than what you expect to measure. If you guess wrong, you can change the range. For resistance, the resistor must be disconnected from the circuit. For voltage, measure across the component of interest. For current, the red and black wires must be connected in series with the circuit (a circuit is shown later in the laboratory).



## A. Determining Resistor Values

Select any resistor from your parts box. (It is a good idea to pick a resistor smaller than 1MΩ, $10^6$Ω. The reason for this will be discussed in the next laboratory.) Write down the four color code for this resistor.

| | | | |
|---|---|---|---|
| | | | |

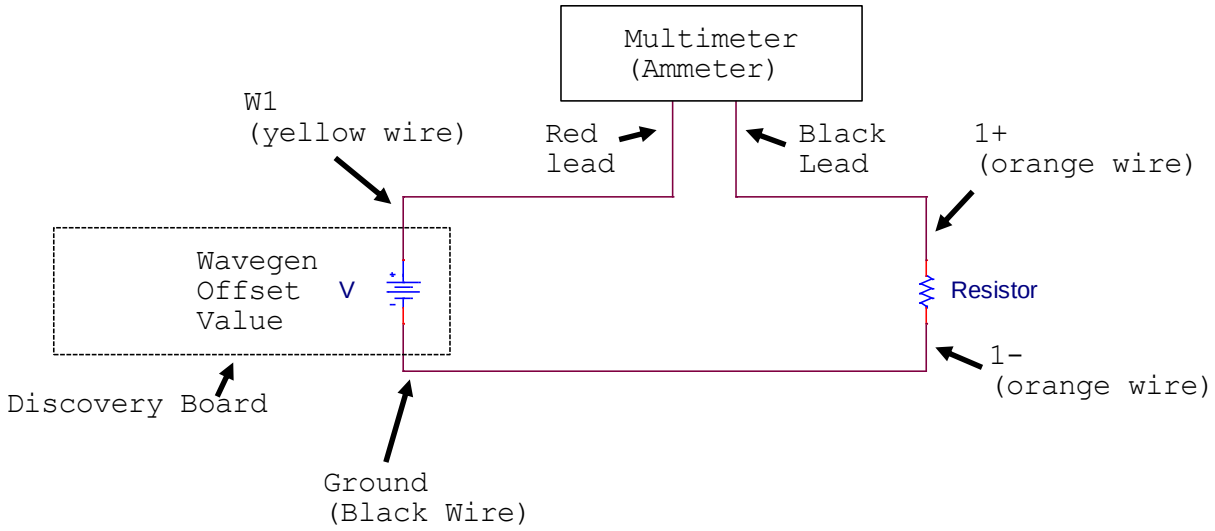
Using the information from the Quiz 1 Formula sheet or any other handy reference, identify the value of the resistor from its color code.

You can use an online resistor calculator to verify your calculation, a nice reference at All About Circuits is linked below.

https://www.allaboutcircuits.com/tools/resistor-color-code-calculator/

Use the ohmmeter function of a multi-meter to measure the actual resistance. Note, due to tolerance your value is likely a little bit different than the expected value.

## B. Current Measurements and Resistor I-V Plot




Measure the voltage across and the current through the resistor, as described below.

1. Using the process described in the introduction, configure Wavegen Channel 1 as a DC source. The value of the DC source will be adjusted to make multiple measurements.
2. The source part of the circuit shown above is built using the Discovery Board connections. The yellow wire (W1) is the output of Wavegen Channel 1, our DC source that can produce voltages between -5V and +5V. The yellow wire with the white stripe (W2) is the output of Wavegen Channel 2. We will not be using it in this experiment. The source also needs a reference. We will use the black wire because it is a ground (0V).
3. Connect the red lead of the Multimeter to W1. Connect the black lead of the Multimeter to the resistor.
4. Connect the other side of the resistor to the ground (black wire) of the Discovery Board.
5. To measure the voltage across the resistor, connect 1+ (orange wire) to one side of the resistor and 1- (orange/white wire) to the other side of the resistor.
6. Once you have your circuit built, open Waveforms 2015, but do not turn on the Wave Generator (W1) until you have had your circuit checked by a TA or instructor. Turn the supply/source off whenever you are making changes to your circuit.

Once your circuit has been approved, turn on the power supply and change the Offset value to vary the voltage from 0V to 3V in 0.5V increments. For each voltage, record the current measured by the multi-meter and the voltage measured by the Discovery Board voltmeter. Make sure the multimeter is set to measure current.

| Supply Voltage (V) | Current | Resistor Voltage |
|---|---|---|
| 0 | | |
| 0.5 | | |
| 1 | | |
| 1.5 | | |
| 2 | | |
| 2.5 | | |
| 3 | | |

Plot the current I (x-axis) vs the voltage V (y-axis). From the slope of your plot, determine the value of the resistor. Compare the value of resistance determined in this manner with the two previous values you obtained from the color code and the ohmmeter measurements.

### C. Mystery Resistor

Have another student in your group select a random resistor from their parts kit. Repeat the process you used in the previous part to determine the resistance, taking measurements and determining the slope.

| | Current | Voltage |
|---|---|---|
| Random resistor | | |

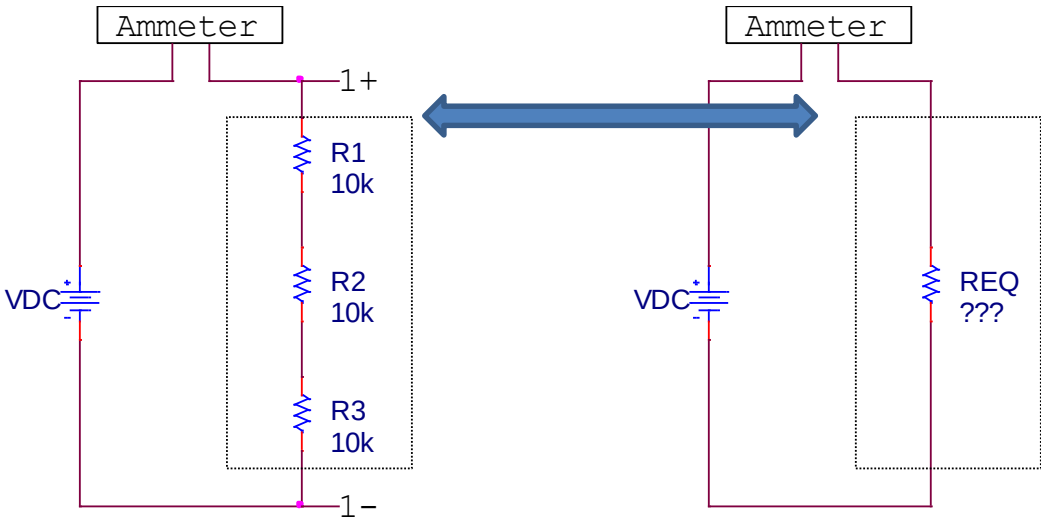
Compare your resistance value to that indicated by the color code. If it is off by more than a few percent, double check your current and voltage measurements. Why would it be off by a little bit?

Obtain a mystery resistor from a TA or instructor. Replace the resistor from the previous part with the mystery resistor. Take measurements at a few voltages and use the slope to determine the unknown resistance.

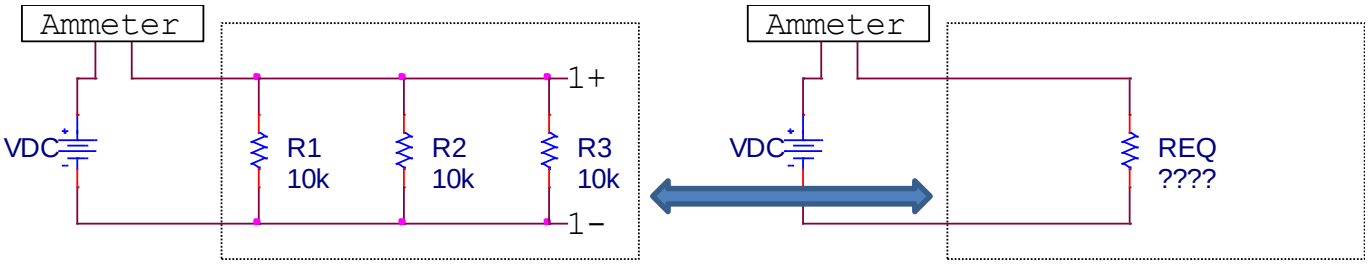
| | Current | Voltage |
|---|---|---|
| Mystery resistor | | |

Check the resistance of the mystery resistor with the Ohmmeter feature of the multimeter. If the values are not the same, double check your current and voltage measurements.

## D. Distributing Current and Voltage




Replace the single resistor in the previous parts with three 10kΩ resistors in series. In circuit analysis, we frequently want to find an equivalent resistance (impedance) of a collection of components. In the introduction of the laboratory, the equivalent resistance of resistors in series is provided. Using the same process developed previously, use the Ammeter to measure the current and the Channel 1 inputs of the Discovery Board to measure the voltage across all three resistors (as indicated in the figure). Use those measurements to experimentally determine the equivalent resistance. How does your measurement compare to the calculated value?




Resistors in parallel are another basic circuit configuration. Again, referring to the section at the beginning of the laboratory, you can determine the equivalent resistance. Once again, use the Ammeter and Voltmeter to experimentally find the equivalent resistance. How does your measurement compare to the calculated value?