# MAE 3340 Laboratory Exercise 3
# Spring 2015

## *Introduction to the Digital Multimeter for DC Voltage, Resistance, and Current Measurements*

**Introduction**:

Resistors are the most common component found in all electrical and electronic circuits. Resistors are found in many shapes, sizes, and values. The most common shape is a two lead cylinder component with leads coming out each end and color bands painted around the cylinder to indicate the nominal resistor value and its tolerance.

This lab exercise demonstrates how to use the NI myDAQ to measure resistance *R*, current *I*, and voltage *V*. The relationship between *R, I, and V* (Ohm's Law) is studied. Also examined are sensors that convert physical measurements like temperature, pressure, and/or strain into a resistance, a current, or a voltage.

**Equipment**:

• NI myDAQ
• Red and Black DMM Probes
• Various Resistors and a Potentiometer
• Solderless Breadboard

**Pre-Lab Preparations:**

1. Review Prerequisite Materials *before class!*
   a. Using the myDAQ Digital Ohmmeter DMM(WΩ):
      i. http://decibel.ni.com/content/docs/DOC-12938
   b. Using the myDAQ Digital Ammeter DMM(I):
      i. http://decibel.ni.com/content/docs/DOC-12878
   c. Using myDAQ Digital Voltmeter DMM(V):
      i. http://decibel.ni.com/content/docs/DOC-12937
   d. Resistor Color Codes:
      i. http://www.allaboutcircuits.com/vol_5/chpt_2/1.html

**Background on Digital Multimeter:**

This exercise will use the digital multimeter functions of NI MyDAQ to examine the properties of resistors, understand the transmission of current through a sample circuit as the resistance is varied. Figure 1 shows the image of a typical hand-held multimeter, one of the most useful laboratory tools. The device is called a "MultiMeter" because of its ability to perform multiple functions. These functions are labeled on figure 1. The NI MyDAQ device will emulate the functions of a typical multimeter.

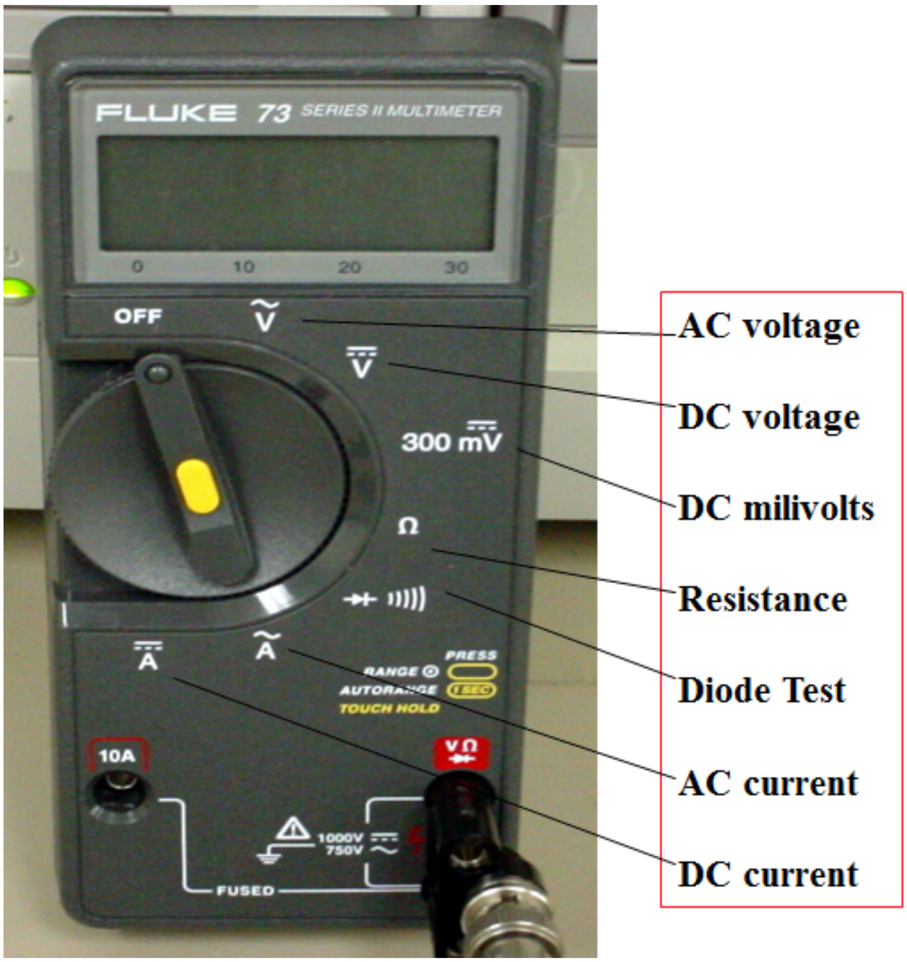


**Figure 1. Digital Multimeter Front Panel.**

**Voltage/Current Measurements Using DMM**

As shown by Figure 2, voltage is measured across ***(e.g., in parallel with)*** a component and current is measured through ***(e.g. in serial with)*** a component. *Resistance measurements must be made with NO POWER applied to the measured device. Make certain that the DVM is NOT set to measure resistance when wired to measure voltage or current.*

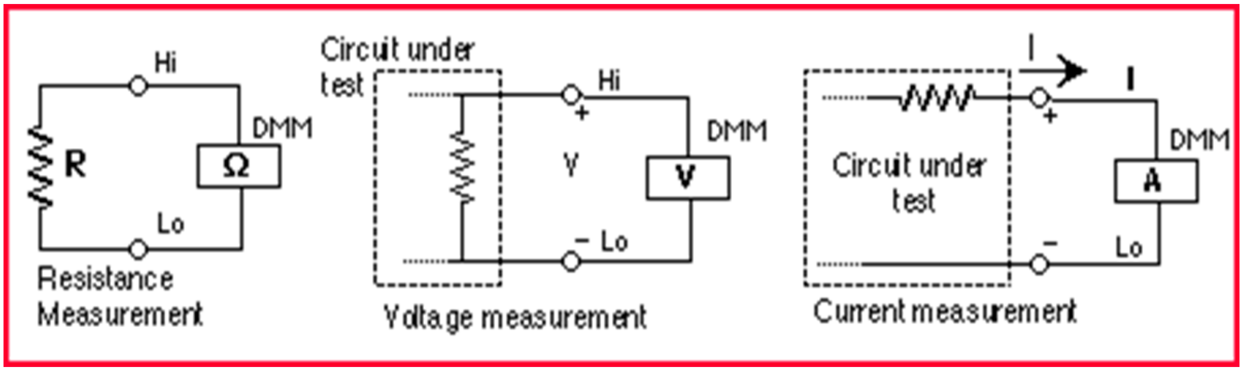


**Figure 2. Voltage, Current, and Resistance Measurements using DMM.**

Figure 3 shows an idealized schematic of the internal circuitry of a typical DMM. An ideal voltmeter has an infinite input resistance so that it will not draw any current from the circuit under testing. As a result, one has a voltage divider that will cause the voltage $V_m$ one sees at the input of the voltmeter to be slightly different from the actual voltage $V_S$ one wants to measure. Most DMM's have relatively large input resistances (~ 10 Mohm) (depending on the selected voltage range) so that the error will be small as long as $R_s << R_i$. We will talk more about this *"high-impedance"* concept later in the class when we introduce operational amplifiers.

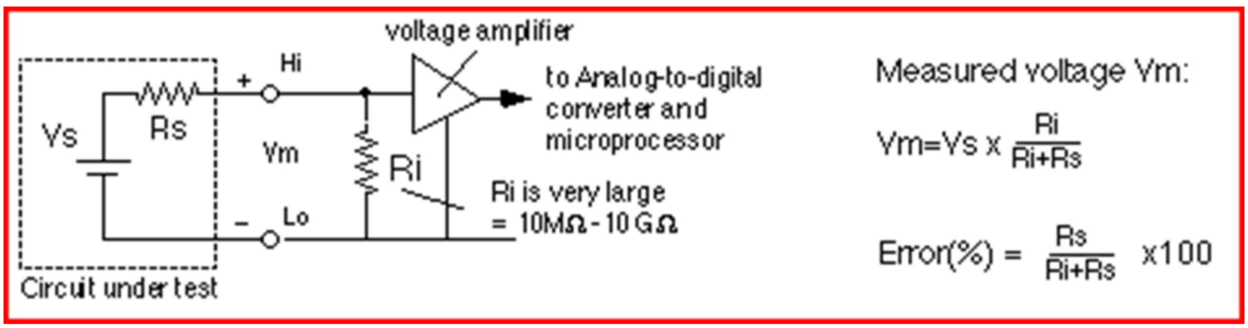


**Figure 3. Internal Circuitry of Typical DMM.**

**Lab Exercise 3.1: Resistance Measurements**

Ensure that the myDAQ software is properly installed onto your computer and then connect your myDAQ to the computer with the USB cable (supplied). Open the DMM VI at

**Start>>All Programs>>National Instruments>>NI ELVISmx for NI ELVIS and NI myDA>>NI ELVISmx Instrument Launcher. →Click DMM.**

The following screen (Figure 4) will open … Insert the "Banana Jacks" onto the appropriate portson the lower edge of the MyDAQ body. The **red jack** connects to the *V-Ω port*, and **black jack** connects to the *COM* port. The VI provides a "cheat Display" showing the connections based on the function that is selected.

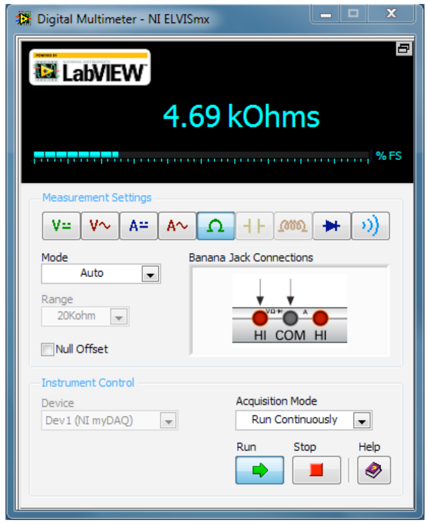


**Figure 4. NI ELVISmx DMM VI Screen**

From the collection of resistors supplied by the Lab TA, pick any four resistors and examine the color bands. Make sure that the 4th color band on each resistor is identical-- note the gap between this band and the first three bands. Reading from the end band closest to the leads, populate the rows and columns of Table 1. Using the Color Bands, the nominal resistance can be calculated using the color code in the class notes. Or you can "cheat" by using the VI link provided in Section 2 of the MAE 340 lecture notes.

**Table I: Resistor Color Bands.** *(Use spreadsheet file)*

| | **Color Band 1** | **Color Band 2** | **Color Band 3** | **Color Band 4** | **Nominal Resistance, Ω** | **Measured Resistance, Ω** | **Measured Tolerance (Error), Ω** | **Measured Tolerance (Error), %** |
|---|---|---|---|---|---|---|---|---|
| **Resistor 1** | | | | | | | | |
| **Resistor 2** | | | | | | | | |
| **Resistor 3** | | | | | | | | |
| **Resistor 4** | | | | | | | | |
| **Resistor 5** | | | | | | | | |
| **Resistor 6** | | | | | | | | |

- Select the resistance function [Ω] button and change the mode (Specify Range) to (Auto).
- Press [Run] to view the resistance measurement on the display.
- Measure each resistor used in above chart, and fill in the appropriate column.
- How do the measured values compare with the nominal value Calculated using the colored bands?

Resistor tolerance is defined as the percentage difference between the measured resistance $R_m$ and its nominal value $R_{nom}$,

$$R_{Tolerance} = 100\% \times \left( \frac{R_m - R_{nom}}{R_{nom}} \right)$$

The fourth band on the resistor indicates your chosen resistor's tolerance. It should have a tolerance less than 1% for brown, 2% for red, 5% for Gold, or 10% for silver. Calculate the mean tolerance for the 6 resistors and compare to the spec-tolerance for the resistors.

**Lab Exercise 3.2: Ohm's Law (Voltage Divider)**

Connect the accompanying breadboard to the NI MyDAQ module and build the circuit shown by Figure 5. The +5V power is provided by the third pin on the breadboard through the MyDAQ USB power supply. Initially make the nominal values of $R_1 = R_2$, use at lease at least 1 kΩ resistors.

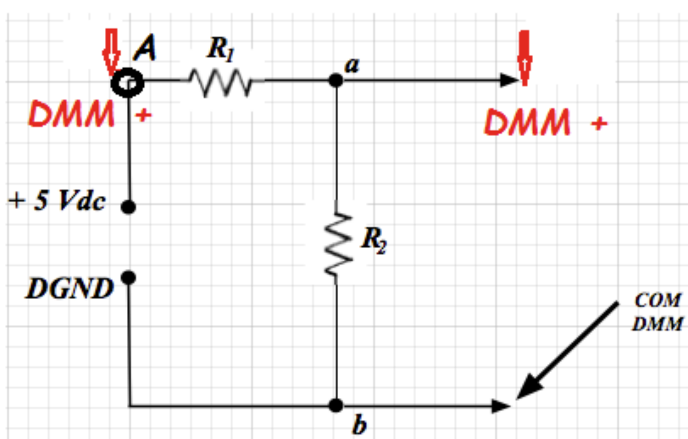


**Figure 5: Schematic of Test Circuit.**

- Set the DMM to DC Voltage *(V--)* and 20 V range. Measure the voltage across points *{A, b}*, and then across point *{a, b}*. Compare the values. What is the ratio of *V{a,b}/V{A,b}?*

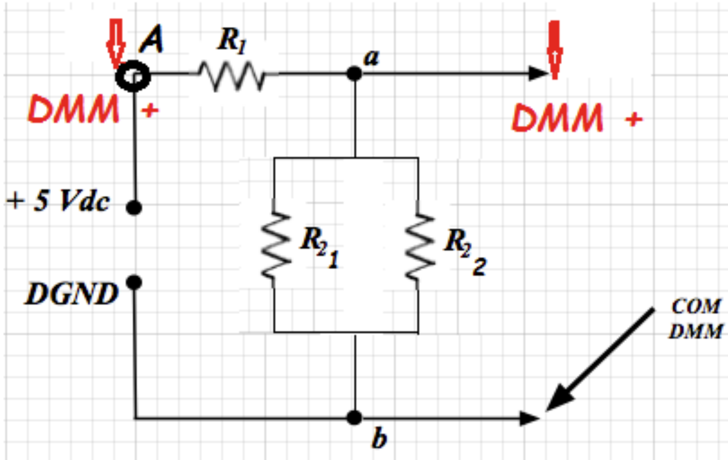


**Figure 6. Test Circuit with Parallel Resistors.**

- Now, as shown by Figure 6, wire a second resistor of the same nominal value in parallel with $R_2$. *Figure 7 shows a picture of this breadboard circuit*.
- Repeat the measurements for *V{A,b} and V{A,b}*. *Calculate the ratio V{a,b}/V{A,b}.*
- Complete the Table 2 below using now 3 and 4 resistors in parallel across. Be sure to log the actual values of each resistor. Also, be sure to *Disconnect the +5 V power input to the breadboard when measuring resistance with MyDAQ*. ***Make sure you specify all units.***
- Derive an expression for the voltage ratio, *V{a,b}/V{A,b},* in terms of $R_1$, *and n x* $R_2$ resistors in parallel.
- Compare the *voltage ratio* calculated using this expression to the measured *voltage ratio*.
- What can you conclude about this circuit?

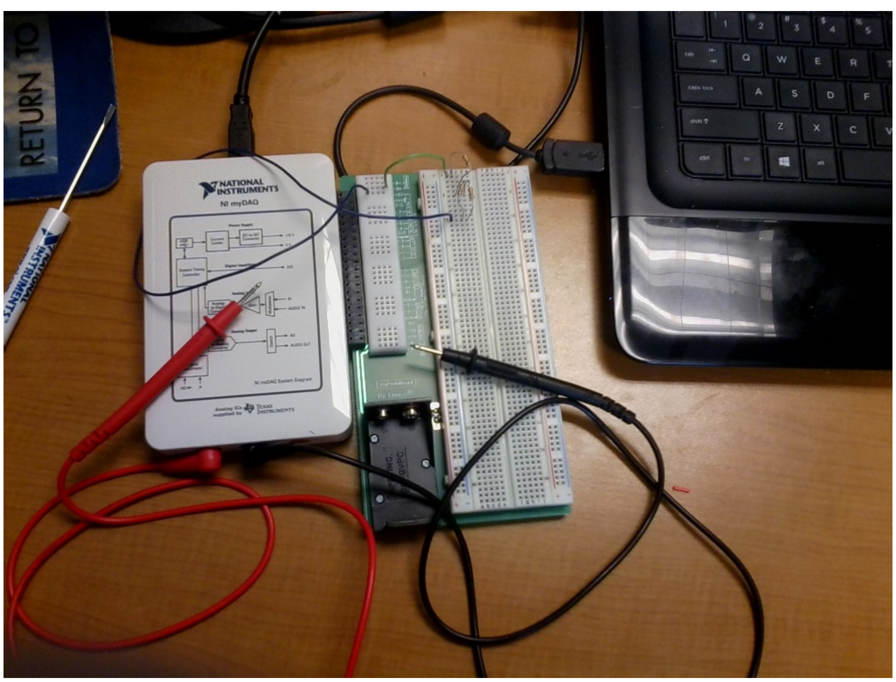

**Figure 7. Lab 3 Voltage Divide Breadboard Circuit.**

**Table 2. MyDAQ Voltage Measurements.**

| **Excitation Voltage: (V)** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Case** | $R_{1:\Omega}$ | $R_{2\,1:\Omega}$ | $R_{2\,2:\Omega}$ | $R_{2\,3:\Omega}$ | $R_{2\,4:\Omega}$ | $R_{2\,eq:\Omega}$ | **V{A,b}** | **V{a,b}** | **V{a,b}/ V{A,b}** Measured | **V{a,b}/ V{A,b}** Calculated |
| **1** | | | | | | | | | | |
| **2** | | | | | | | | | | |
| **3** | | | | | | | | | | |
| **4** | | | | | | | | | | |

**Lab Exercise 3.3: Ohm's Law (Conservation of Current)**

Now set the MyDAQ DMM for current measurements. Repeat the circuit cases from exercise 3.2 and populate the columns and rows of Table 3. Measure the current flow across each resistor in the circuit. ***Be sure to put the Red Banana Jack plug into the proper port on the MyDAQ chassis.*** Calculate the summation currents through the parallel branches. Compare to the current through $R_1$. What can you conclude?

**Table 3. MyDAQ Measurements.**

| **Excitation Voltage: (V)** | | | | | | |
|---|---|---|---|---|---|---|
| **Case** | $I_{1:}$ | $I_{2\,1:}$ | $I_{2\,2:}$ | $I_{2\,3:}$ | $I_{2\,4:}$ | $\sum_{i=1}^{4} I_{R_{2i}}$ |
| **1** | | | | | | |
| **2** | | | | | | |
| **3** | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| **4** | | | | | | |

## Lab Report Format:

1. **Team Name:**
2. **Individual Student Name:**
3. **Executive Summary:**
4. ***Fully Populated* Data Tables for All Data (See Tables 1, 2, 3 Examples.**
5. **Derived expression for** $V\{a,b\}/V\{A,b\}$, **in terms of** $R_1$, *and n* $x\ R_2$ **resistors in parallel.** ***Show your work!***
6. **Specifically answer each question itemized in red in this document.**