Notes on Experiment #3

This week you learn to measure voltage, current, and resistance with the digital multimeter (DMM). You must practice each of these measurements (especially current) as much as you can.

Be sure to calculate all of the expected voltages and currents of each circuit BEFORE you come to lab.
ECE 210 Experiment #3

Voltage, current, and resistance measurement

Purpose: To measure V, I, and R with a Digital Multimeter (DMM.) We will also verify Kirchoff’s Laws.

Equipment: Agilent 34401A Digital Multimeter (DMM), Agilent 33120A 15MHz Function/Arbitrary Waveform Generator, Agilent E3631A Triple Output DC Power Supply, Universal Breadbox

I. General Introduction to the DMM
   1. Voltage and Current

   The voltages and currents measured in this lab generally take on the form

   \[ v(t) = B + A\sin(\omega t) \text{ volts} \]

   where

   a. \( B \) is the DC component of \( v(t) \) called the DC offset or just offset
   b. \( A\sin(\omega t) \) is the AC component of \( v(t) \). Note that the AC component is a periodic function of time. The AC component has three parts: Shape (\( \sin \) implies a sinusoidal shape); Amplitude (\( A \) is the zero-to-peak amplitude); Frequency (in this example the frequency would be radian frequency).

   Recall these useful terms:

   Radian frequency \( \omega = 2\pi f \) where \( f \) is frequency in Hertz (i.e. cycles/second)

   Period \( T = 1/f = 2\pi /\omega \)

   Zero-to-Peak Amplitude = \( A \) for a sinusoidal function

   Peak-to-Peak Amplitude = \( 2A \) for a sinusoidal function

   RMS Amplitude = \( A /2^{1/2} \) for a sinusoidal function

   There are controls on the DMM that allow you to measure each of the parts of \( v(t) \) (\( B, A \) RMS, and frequency) very accurately. Note that each
key has two (or more) options. To select the function printed on a key just
press the key. To select the function printed just above the key you must
first press the blue Shift key and then the function key. For example, if
you wish to measure DC current then you must press the Shift key and
then the DC V key to put the DMM into DC I (DC current) measuring
mode. Note that you may only measure one quantity at a time. You must
select either the DC V or AC V key to measure DC or AC voltages
respectively.

2. Range Setting

The are two range modes: Auto ranging (the default mode) and Manual
ranging. You may toggle between the two ranges by pressing the
Auto/Man key. Pressing an arrow key puts the DMM into manual ranging
mode and allows you to select a higher (arrow up) or lower (arrow down)
range. If a range is too low for a value being measured then the meter goes
into an overload condition indicated by OVLD printed to the display. To
get out of overload simple select a higher range or select auto ranging. The
most accurate rage is the lowest possible range that does not put the meter
into an overload state.

3. Terminals

For voltage and resistance measurements use the two upper right hand
terminals just below the Omega V diode symbols. HI is the positive (+)
terminal and LO is the negative (-) terminal for the voltage measurement.
Use the two lower right hand terminals I and LO for current measurement.
The I terminal is the positive terminal for the current measurement. The
most common mistake in the lab will be forgetting to move the positive
connection from HI to I when going from a voltage measurement to a
current measurement.

4. How to measure current, voltage, and resistance

Your Teaching Assistant will explain to you how to use DMM to measure
currents, voltages, and resistances. However, note the following:

a. To measure voltages, you only need to attach the leads of the
DMM to two points of the circuit, select the DC V or AC V
function, and select a meter range. The meter reading gives the
voltage of the point connected to the HI terminal (use a red cable)
with respect to the point connected to the LO terminal (use a black
cable.) Voltage readings are the easiest type to take.

b. To measure currents, you must break the circuit at the point where
the unknown current flows, and re-route the current through the
meter, entering at the I terminal (use a red cable) and leaving at the
LO terminal (use a black cable.) Then you must select the DC I or AC I function, and select the appropriate range.

c. To measure resistance, you must disconnect at least one terminal of the resistor from the circuit before attaching it to the DMM terminals or leads. If you leave the resistor in the circuit and try to measure it in place, you are likely to get bizarre results. This is because the DMM sends current through the resistor to perform the measurement, and it assumes that the current flows only through that single resistor. If the resistor is still connected to the circuit, the current from the DMM might go through other paths, with unpredictable results. Press the key labeled **Omega 2W**. 2W stands for the "two wire" measurement. Now select a range.

II. **Current, Voltage, and Resistance**

Set up the circuit in Figure 1 using the DC supply for $V_S$ and a 3.3K resistor for $R$. Adjust the DC voltage supply until the DMM, used as an ammeter, shows that the current is 1.00 mA. Then remove the DMM from the circuit (don't forget to re-connect the bottom of $R$ to $V_S$) and use it, now as a voltmeter, to measure the voltage across the resistor. Last, disconnect the resistor from the circuit and use the DMM to measure its resistance. Do the three readings verify Ohm's Law? Record the measurements and the percent error observed between $R$ measured directly, and $R$ calculated by $R = V/I$. Compare both of these values with the value of the resistor read from its color code (the so-called "nominal" value) and see whether or not the value is within the stated percentage tolerance.

![Figure 1](image-url)
### III. Measuring Voltage

Set up the circuit in Figure 2 with:
- \( R_1 = 20\,\text{K} \)
- \( R_2 = 33\,\text{K} \)
- \( R_3 = 47\,\text{K} \)
- \( V_6 = 8 \text{ Volts} \) (use the +25 - COM terminals of the DC supply with the current limit set to 100mA. Remember that you are setting the maximum current that the generator will be able to deliver and not the actual value that is being delivered - you will measure that value.)

![Figure 2](image)

Measure all six voltages with the voltmeter (the DMM set on the DC voltage setting.) Using your DATA, make a table indicating the percent inaccuracy, according to your measurements (i.e. your DATA), in these three Kirchoff voltage law relationships:

\[
V_1 + V_2 = V_4 \\
V_2 + V_3 = V_5 \\
V_1 + V_2 + V_3 = V_6
\]

Do the data values on the left sum to the data on the right? That is the inaccuracy error that you are checking.

Measure the three resistors with the DMM and make a table indicating the percent inaccuracy, according to your measurements, in the relationships

\[
\frac{V_3}{R_3} = \frac{V_2}{R_2} = \frac{V_1}{R_1} = I
\]
We have not measured I yet. But each of the above ratios should equal the same value of I since the same I is flowing in all three resistors. Are the currents the same?

Now remove the DC supply from the circuit and insert the function generator as Vs. Set Vs = 4sin(3000πt) volts. The DC offset should be set to zero. Now repeat the above experiment making AC voltage measurements.

IV. Measuring Currents

There are two ways to measure currents: (1) directly, using an ammeter, and (2) indirectly, using a voltmeter (or a scope) to measure the voltage across a resistor and then calculating the current by use of Ohm's Law. The second method, of course, is only accurate if you have an accurate value for the resistor.

Set up the circuit in Figure 3 with
R₁ = 20K
R₂ = 33K
R₃ = 47K
Vs = 8 Volts (use the +25 - COM terminals of the DC supply with the current limit set to 100mA.)

Measure the indicated currents directly by inserting the ammeter (the DMM set on the DC I setting) into the circuit at the locations indicated by "I₁", "I₂", etc. Record your observations in a table and indicate the percent inaccuracy, according to your measurements, in the Kirchoff's current law relationships

\[ I₁ + I₂ = I₄ \]

\[ I₃ + I₄ = I₅ \]
Now measure the indicated currents indirectly (by measuring the voltages, measuring the resistances, and using Ohm's law) and repeat the above calculations of inaccuracy.

We will not do AC current measurements in this experiment.