Notes on Experiment #2

The purpose of this experiment is to get some practice measuring voltage using the oscilloscope. You will be practicing direct and differential measuring techniques. You will also learn that under certain conditions the scope can give what appears to be wrong values if connected to the circuit incorrectly.

You will also learn how to construct a circuit on the "breadboard" and how to set the DC and AC power supplies.

Your circuit analysis will lead you to the expected values of the various voltages indicated in the circuit diagram. You will then measure the voltages and compare that data to your calculated values from your circuit analysis. (i.e. do some error analysis) To find a voltage in this circuit first use Ohm's law to find the total current. Then find the individual voltages using Ohm's law again.

So,

\[ I = \frac{V_s}{R_1 + R_2 + R_3} \]
\[ V_1 = I \times R_1 \]
\[ V_2 = I \times R_2 \]
\[ V_3 = I \times R_3 \]
\[ V_4 = I \times (R_1 + R_2) \]
\[ V_5 = I \times (R_2 + R_3) \]

Note if \( V_s \) is a pure DC voltage then all of the above voltages will also be pure DC (i.e. constant values.) If \( V_s \) is an AC voltage then all of the voltages will also be AC.

DC + AC Example (NOTE: THESE ARE NOT THE VALUES FROM THE EXPERIMENT)

- \( V_s = 10 + 25 \sin(100t) \) volts
- \( R_1 = 10K \)
- \( R_2 = 15K \)
- \( R_3 = 25K \)

\[ I = \frac{10 + 25 \sin(100t)}{10K + 15K + 25K} \]
\[ = 0.2 + 0.5 \sin(100t) \text{ mA.} \]

So,
\[ V_2 = 0.2 + 0.5 \sin(100t) \text{ mA.} \times 15K \]
\[ = 3 + 7.5 \sin(100t) \text{ volts} \]
Hope this helps you with your preparation for experiment #2. Please note that calculations like the above are the work that you must do (for each section of the experiment) as your preliminary work. Also, make a list all of the questions you find in the text of the experiment. These questions will require answers that must be included in your write-up. Experiment 2 takes a lot of time. Prepare as much of your report as possible BEFORE going to lab.
ECE 225 Experiment #2

Practice in DC and AC measurements using the oscilloscope

Be sure to bring a copy of this experiment and a copy of experiment 1 (as a reference for equipment operation) to the lab this week.

Purpose: To familiarize yourself with the DC voltage supply, and to practice using the oscilloscope DC and AC measurements.

Equipment: Agilent 54622A Oscilloscope, Agilent 33120A 15MHz Function/Arbitrary Waveform Generator, Agilent E3631A Triple Output DC Power Supply, Universal Breadbox

1. The Agilent E3631A Triple Output DC Power Supply

The Agilent E3631A has three power supplies, a +6 V supply capable of delivering 5A, and two supplies of +25 and -25 V capable of delivering 1A each. The 
ground) output is the reference ground and is connected to the ground of the building. Under normal use (for safety reasons) it is important to connect the COM (common) terminal of the +25 V supplies, and the (-) terminal of the +6 V supply to the 
ground) reference.

1. Looking now at the control keys:

The Output ON/OFF key turns the output ON or OFF.

2. To Set the Output Voltage:
   a. Press the +6, +25, -25 keys to select the power supply to be set.
   b. Press Voltage/Current key so that the Volt Display is active.
   c. Use the circular control knob to set the output voltage. Use the arrow keys for selecting the resolution.

3. To Set the Maximum Output Current:
   a. The Display Limit key lets you select the maximum current that the power supply can deliver (up to 5A for the 6V and 1A for the +25V supplies). This is basically your current protection feature.
   b. Press Voltage/Current the key so that the Current Display is active.
   c. Use the circular control knob and the resolution keys to set this limit (if needed).
   d. Practice. Set each output to 3.7 volts with current limit at 0.100 amps.
4. **To Read the Output Voltage or Output Current:**
   a. The **Voltage/Current** key also shows the output voltage and the output current of the power supply.
   b. To measure the output current of the supply, make sure that the **Display Limit** key is not active.

II. **The Oscilloscope As A DC Voltmeter: Direct Measurement**

Warm up the oscilloscope, function generator, and the DC supply.

Set up the circuit in Figure 1 below using the + and **COM** terminal of the +25 volt output terminal of the DC supply for $V_S$. So, the + side of $V_S$ is the + side of the +25 terminals and the - side of $V_S$ is the **COM** side of the +25 terminals. Set $V_S$ to 8 Volts. Set the current limit to 0.100 Amps.

Let

\[ R_1 = 20K \]
\[ R_2 = 33K \]
\[ R_3 = 47K \]

Calculate $V_1$, $V_2$, $V_3$, $V_4$, and $V_5$. Measure each of the voltages using **channel 1** of the oscilloscope. (Press **Auto Scale** for easy scope measurements.) Note that these voltages are all DC values. So, be sure that the **channel 1 coupling** is set to DC. You should see only a straight horizontal line on the display of the scope. This line will be above the horizontal axis for channel 1. The distance above the axis times the vertical scale is the DC value of the voltage. If the image is very "fuzzy" try setting the channel 1 vertical scale (dial just above the **1** button) to a larger value like 2.00V/ or press the **Single** button. Record your measurements. Repeat these measurements using channel 2. Record these measurements. Do channels 1 and 2 give exactly the same measurements? Note that you could very accurately
measure the voltages using **Quick Measure** and the **average** value measurement option. Compare your measured values to your calculated values from your preliminary report and determine the percent error using:

\[
\% \text{ERR} = \left( \frac{\text{measured value} - \text{calculate value}}{\text{calculated value}} \right) \times 100
\]

### III. The Oscilloscope As A DC Voltmeter: Differential Measurement

Next we will be measure two voltages simultaneously and have the **math** mode feature of the scope display their difference. Connect the negative (black) terminals of both channel 1 and 2 to the **COM** terminal of the DC supply. (Note that **COM** is NOT the **ground** (\(\oplus\)) terminal.) To measure \(V_3\) connect the positive (red) terminal of channel 1 to the + polarity node of \(V_3\) and connect the positive (red) terminal of channel 2 to the - polarity node of \(V_3\). Now press the **Math** button and select option **1 - 2**. Turn off channels 1 and 2 (press the channel 1 and 2 buttons twice each.) The image on the display is now \(V_3\). Prove that this must be true using Kirchoff's voltage law. Remember that you are able to adjust the vertical scale of the math mode image. (See experiment 1.) Adjust the math mode vertical scale so that you may get an accurate measurement. You will notice that there is no horizontal axis marker at the left edge of the display. You can create a horizontal axis using the **cursor** option. Press the **cursor** button. Now choose the **XY** button to get the **Y** (horizontal) cursors. Select the **Y1** button and then turn the indicated dial knob to set the **Y1** cursor to read 0.00 volts. The position of this cursor is now the location of the horizontal axis. You can now measure the value of the voltage with respect to the location of the **Y1** cursor. To reposition the horizontal axis press the math button one time and select the **settings** option. Now select the **offset** option and then turn the indicated dial. Adjusting the offset will allow you to position the horizontal axis (the **Y1** cursor.) Use this method to move the axis down to the first line above the bottom of the display. Now select the scale option and adjust the scale to 2.00 V. You may need to reposition the axis again as explained above. You should now be able to get a very accurate measurement. Use the differential measuring method to measure all of the voltages in Figure 1 including \(V_5\). Record your measurement. Compare these measurements to your calculated values.

The following section was omitted from experiment 2. This should explain your data.

### IV. The Problem With Ground

Leave the circuit set up as it is. Get another black cable and use it to connect the ground terminal (\(\oplus\)) of the DC supply to the **COM** terminal of the +25 volt output of the DC supply. Doing this will have no effect on the circuit. However, this will cause a problem when measuring voltages with the scope. Repeat all of the measurements of the previous two sections. How has the accuracy of your measurements been affected.
The negative side of the scope is connected to earth ground through the chassis of the scope. So whenever a voltage measurement is made with the scope, the measurement is being made with respect to earth ground. There is no getting around that fact! Therefore if a circuit under investigation has a node connected to earth ground, then the negative side of the scope (the BLACK lead) must be connected to that node. If the negative side of the scope is connected elsewhere, a "short circuit" will be created and all voltage (and current) values in the circuit will change!

A source, instrument, or circuit that has no connection to earth ground is said to be "floating." When the ground terminal of the DC supply is not being used, the supply is floating, as it was in the initial part of this experiment. For a circuit that is floating the negative side of the scope may be connected to any node of the circuit without upsetting any voltage or current values. A short circuit can cause a disaster to a circuit and its components. So, if you are not sure about the ground situation for a circuit then use the differential measuring technique when measuring voltages with the scope.

V. Using The Scope For Direct And Differential AC Measurement

Remove the Agilent DC supply from the circuit and replace it with the Agilent function generator as the voltage source $V_S$. Be sure to use the black terminal of the function generator as the - side of $V_S$. Set $V_S = 5 \cos(3000 \pi t)$ volts. (Don't forget to set the function generator into the **HIGH Z** output mode. (See experiment 1.) Be sure that the DC offset is set to zero. Calculate $V_1$ through $V_5$. Using the differential measurement technique, measure and record $V_{\text{peak-to-peak}}$ for all of the voltages. Repeat all of the measurements using the direct measurement technique. Calculate the %ERR of each of the measured voltages with respect to the calculated values.