Using Multimeters and Power Supplies in Active DC Circuits

Up until now the circuits used in experimentation in this laboratory were not connected to **external** power supplies. We have experimented with combining capacitors and resistors in series and parallel while measuring their values using capacitance and resistance meters that **provided their own signal** to measure these intrinsic values of these devices. These circuit elements are called 'passive' devices. Measuring the value of a passive device means NOT measuring the value in an ACTIVE circuit. An ACTIVE circuit is one that has current and voltage applied to it. Therefore, any circuit with a power supply ON is an ACTIVE circuit. Remember these facts about resistors and capacitors when you wire circuits today. You MUST measure resistance without an attached power supply. Even if the power supply is OFF – it can have internal resistance and capacitance that would alter measurements.

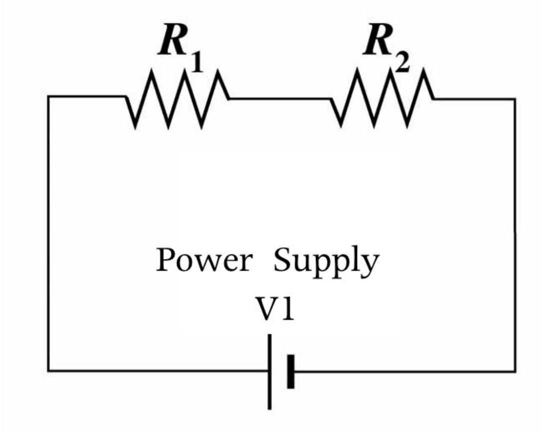

Figure 1: 2 Resistor Series circuit

To test this – wire up the circuit in Figure 1 but do not turn ON the power supply, V1. Measure the equivalent resistance (resistors and the power supply OFF but attached to circuit) of the circuit, and then remove the power supply from the circuit and re-measure the resistance across just the two resistors in the circuit. Choose a 10Ω and a 100Ω resistor as R1 and R2 respectively.

Question: Did your resistance values measured with and without the power supply equal?

Now, change R1 in the circuit to a 100Ω resistor; repeat the process you just completed above. Finally, repeat once again but with R1 changed to a 1kΩ resistor.

Question: Did you again see a change in resistance values with and without the power supply attached across the multimeter? If so, did the resistance difference match the one found in previous choice of resistors? Do you see any pattern to this difference? Do you think the difference is large enough to affect the precision of measurements – explain?

Now that we have seen how a power supply impacts passive circuit measurements, let's examine active circuits and how to measure DC current and voltage using the multimeter. Everything that your group found out about ranges for resistors and capacitors last class period is equally true to voltage and current measurements. Look at the new multimeter on the table. You will see this new multimeter has many more measurement ranges – some in white letter and some in grey. Be careful not to only look at the ones labeled in white as this meter measures both DC (direct current) and AC (alternating current). We will only be using DC today (or constant current) – so make sure that you always have the meter on V (DC) and A (DC) for voltage and current measurements. The symbol for DC is ⎓ . ***Note, that if you choose AC or ∿ since the voltage and/or current in non-changing you will always measure '0' V or A.*** Look at figure 2 to see the circled DC and AC areas on your multimeter for voltage and current measurements.

Figure 2: Tenma 72 Multimeter

Looking at figure 2 you will also see banana ports that allow the user to make measurements. To make measurements on this meter you must ensure that you have the banana wires in the appropriate plugs. Look at the 'zoomed in' image of the bottom of the meter in figure 3, notice how there are white lines connecting banana plugs – these lines show the user HOW to connect banana wires for different measurements using the meter. Make sure you follow the white lines or the colored circles and lines in Figure 3 to connect to the correct locations on the meter. Notice that the 'COM' or 'common' on the meter acts as the 'Negative' lead for all but capacitance labeled Cx. This is important as DC measurements have a SIGN, + or -. To examine this – turn ON the power supply to the circuit you assembled from figure 1. Set the input voltage supply to 2V. Now to use the multimeter to measure this voltage – see below on steps to do this measurement.

Measuring Voltage:
A voltmeter has a HIGH internal resistance and is placed in PARALLEL with the power supply or resistor/s to measure the voltage change across the circuit elements. Thus for a voltmeter to work properly there MUST be a voltage RISE OR DROP across the + and – leads attached to the meter. If you attach a wire the + or V plug of the meter to the + port of the power supply and another wire to the – or COM of the meter to the – of the power supply (and dial to the proper range and position for DC voltage on the multimeter), you should see a value of voltage across the power supply.

Figure 3: Zoom in on Multimeter --- color---coded plugs to unit shown

Question: Since the voltmeter is attached in parallel to the power supply, and the fact it has a very HIGH internal resistance (typically 10MegaOhms), can you predict how much current will go through the voltmeter relative to the current going into the 2 resistors of the assembled circuit? Explain.

Question: How close is this value to the 2V dialed on the face of the power supply? Do you have higher precision using the multimeter? If not, can you dial to an appropriate setting such that your measurement is more precise on the multimeter? Explain.

Now, without changing any dial of the multimeter, exchange the + and – wires on the power supply that are connected to the meter.
Question: What changes on the multimeter? Can you reason why this occurs thinking about the voltage change? Explain.

Measuring Current:
An ammeter or current meter has a LOW internal resistance so that it can be incorporated directly into the circuit to monitor the 'flow' of current without substantially changing the equivalent resistance of the circuit.

Question: Thinking about the fact that the ammeter has a LOW internal resistance (typically Rammeter << 1 Ohm), and that it is incorporated directly into the circuit, thus in 'series' to the other resistors, predict the voltage drop across the ammeter in comparison with the resistors R1 and R2. Would this make sense if the goal of the meter were NOT to change the nominal values of the circuit? Explain. Add the multimeter as a DC ammeter to the circuit drawn in figure 4; did the voltage drops/rises measured match your answer to this question? Explain.

Now that you have reviewed how to properly measure voltage and current in a live circuit. Let's try measuring these values and gain insight into how the power supply works when dialed to a particular voltage output.

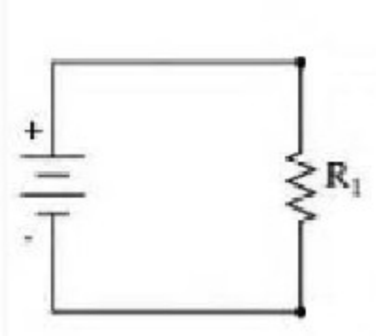

Figure 4: Single R circuit

Assemble a single resistor circuit as shown in figure 4 – use a 1kΩ resistor for R1 in the circuit. Notice that the power supply symbol has changed, there are many ways that scientists indicate DC power input – but typically it is either as shown in figure 1 or figure 4. The long line indicates the positive and the shorter line indicates the negative side of the power supply. Thus, it is not essential that the + and – be drawn directly in the circuit as shown in figure 4.

Starting with the Voltage input of 1.00 V (or as close as possible – recording the ACTUAL value) take measurements approximately every 1V to 10V.
After each voltage supply change – measure the output current from the power supply by attaching an **ammeter in series** with the R1 resistor and power supply (see Appendix on HOW to measure current in a circuit).
Make a table of the data showing the Voltage and Current. Make sure you used the most precise ranges for both measurements. State what range was used in your table title for this data.

Question: Looking at the data, what do you notice about the current as the voltage is increased? Does this make sense with what you know about Ohm's Law? Explain.

Question: Make a graph of the data, what is the significance of the slope of the graph created? Explain.

Finally, using the slope value and converting it if needed to make a comparison, compare the appropriate value to the resistance of R1 as measured directly from the multimeter (as an ohmmeter).

Question: Using the measurement uncertainty table to accurately calculate the uncertainty for the R1 resistor (See Resources – Measurement Uncertainty Manufacturer), does this value equal the predicted measured value of resistance within uncertainty? If not, explain why this may be expected when thinking of the measured values of voltage and current with the meter?

Now, if you again take data of voltage and current but change the resistor, rather than the voltage level, can you predict what, if anything will happen to circuit values?

Prediction: Write your prediction down in the data for this lab report with an explanation.

Verification: Using 1kΩ, 2.2kΩ, OR 3.9kΩ resistors and a voltage input of 2.00V – take data and either verify or demonstrate your prediction was incorrect. If verified – move on. If incorrect, explain what went wrong with your reasoning.

How the DC Power Supply Operates: Looking at the data obtained above for the last two mini---experiments – clearly state how your table's DC power supply operates when dialed to a particular voltage. What stays constant? What changes when different circuits are attached to the power supply? Be as complete as possible.

Now, using the circuit drawn in figure 5 – assemble the circuit on your breadboard. The nominal values of the resistors are given as R1=100Ω, R2=220Ω, R3=1kΩ, R4=2.2kΩ, and R5=220Ω. Make sure to measure the resistor values (using the multimeter as an ohmmeter) after assembly but before attaching the power supply.

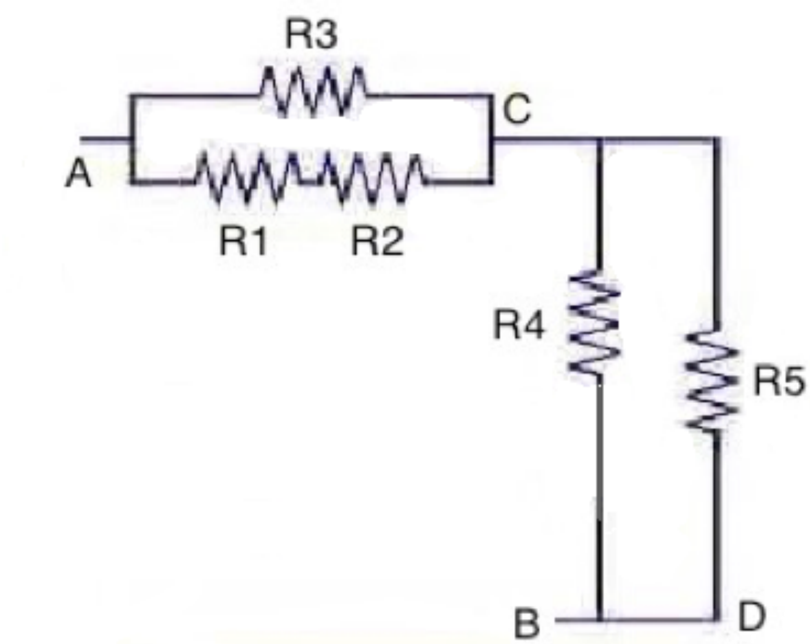

Figure 5: Complex Circuit

Attach the power supply across positions A and B. Set the power supply to 5.00V. Now using the multimeter as both a voltmeter and an ammeter, create a table of all voltage drops across each resistor and the power supply, and currents that run through each resistor as well as out of the power supply. Think how best to construct this table so that data is easily read AND that you demonstrate that Ohm's Law is verified for each resistor and the equivalent resistance for the circuit. Thus, you need to include measured R, V, and I and a predicted value of Voltage from the measured R and I values. If you wish – you may predict R or I rather than V since Ohm's Law is V = IR and thus it can be rewritten as I = V/R and R = V/I. Discuss if your values are reasonably close to the predicted values using the measured multimeter values for the predictive equation

Appendix A: How to Measure Current in a DC circuit

To measure current through a resistor, one cannot break the resistor open and measure the flow of charge, one must measure the flow of charge going into or out of the resistor. Since charge is not lost or destroyed, what enters the resistors, exits the resistor. This can be verified by measuring both the incoming and outgoing currents for a given resistor to demonstrate this statement is accurate.

Current is a flow of charge, as such measurements need to be made in the circuit, monitoring the flow much like a water meter measures the flow of water through a pipe. To do this type of measurement, the flow must be momentarily interrupted or broken, while the meter is placed into the circuit to monitor the flow when resumed. Look at figure 1; here the flow out of R3 and into R4 can be measured by the insertion of the ammeter into the circuit. To measure the current into or out of R2, the ammeter would be disconnected from its present location and moved either above or below R2. This again could be repeated to measure the current into or out of R1, by moving the ammeter to either side of R1. So, to measure current in each section, or 'leg' of the circuit, the meter must be placed in series with the resistor.

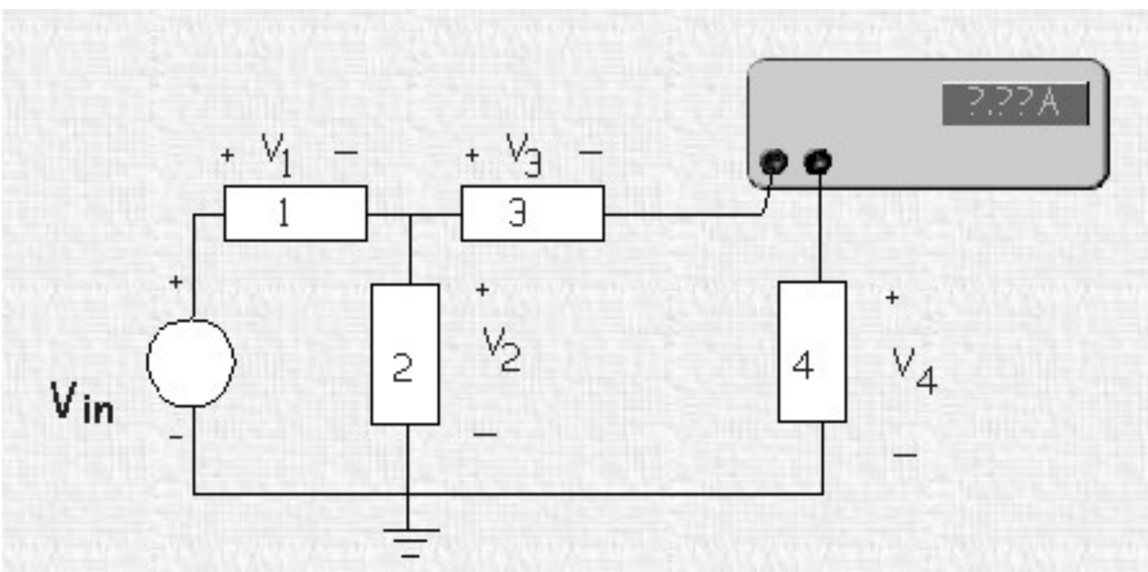

Figure 4: Ammeter in series with R3 and R4. This ammeter will tell us the flow of charge exiting R3 and flowing into R4.[1]

[1, 2] Illustration from: http://www.facstaff.bucknell.edu/mastascu/elessonshtml/Measurements/MeasIntro.htm

Appendix B: How to Measure Voltage in a DC circuit

A voltmeter will measure the change in electric potential from one point in a circuit to another, thus <u>this meter hugs or is placed in parallel over circuits elements where a potential drop or gain is seen</u>. The voltage source supplies voltage, thus, placing the voltmeter across the + and – outputs on the voltage supply will show the voltage input or gain into a circuit. Make sure to keep track of the + and – of the meter, as crossing the + and – leads will lead to the opposite sign of the voltage measurement.

Because a voltmeter is attached in parallel, it can be added after the circuit has been assembled and moved easily without breaking the circuit to measure voltage gains and drops from various voltage sources and resistors. Look at figure 2; here the voltage meter has been placed across the R4 resistor. This measurement gives the voltage drop across this resistor. This voltage drop by Ohm's Law should equal the value of R4 times the current measured through R4.

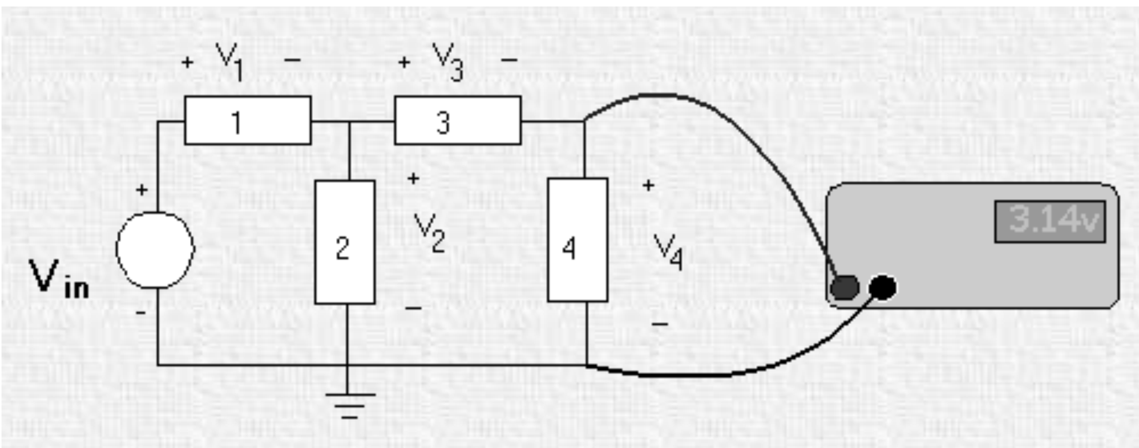

Figure 5: Voltage drop measurement across R4 in circuit.[2]