Instructional Objectives

1. Measure Current and Voltage Using Digital Multi-meter.
2. Supply DC voltage to a circuit.
3. Take voltage readings at various points in a circuit.
4. Take current readings at various points in a circuit.

Equipment Familiarization

Some of you probably have not used some of the equipment you will use in todays lab. In particular, you will use a power supply and a digital multi-meter. Look at the Equipment Familiarization (Lab 0) document to review how to make measurements with the equipment we use in the lab today.

Procedure

0. You need a 887Ω, 2-10KΩ and a 3.3KΩ resistor for this lab.

1. In this part, you are required to measure the voltage across R1 and current flowing through R1 (I_{R1}) in the circuit given in figure 1 which is called a schematic diagram of the actual circuit. R1 is 887Ω.

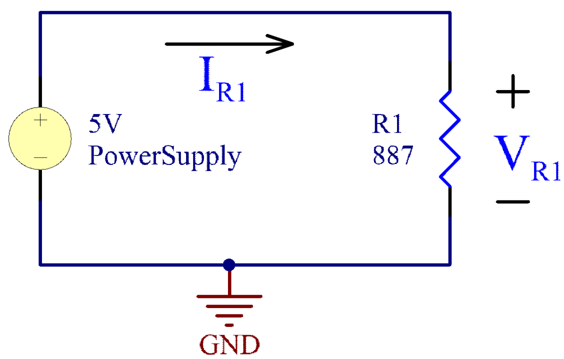


Figure 1: Schematic and Breadboard.

You will build the circuit as shown in the schematic in figure 1 on the proto board. For this setup, you are required to set up a $5V_{DC}$ source for the Power Supply shown in figure 2. Figure 3 and 4 show examples of how to build the circuit.

Simple Voltage and Current Division Procedure

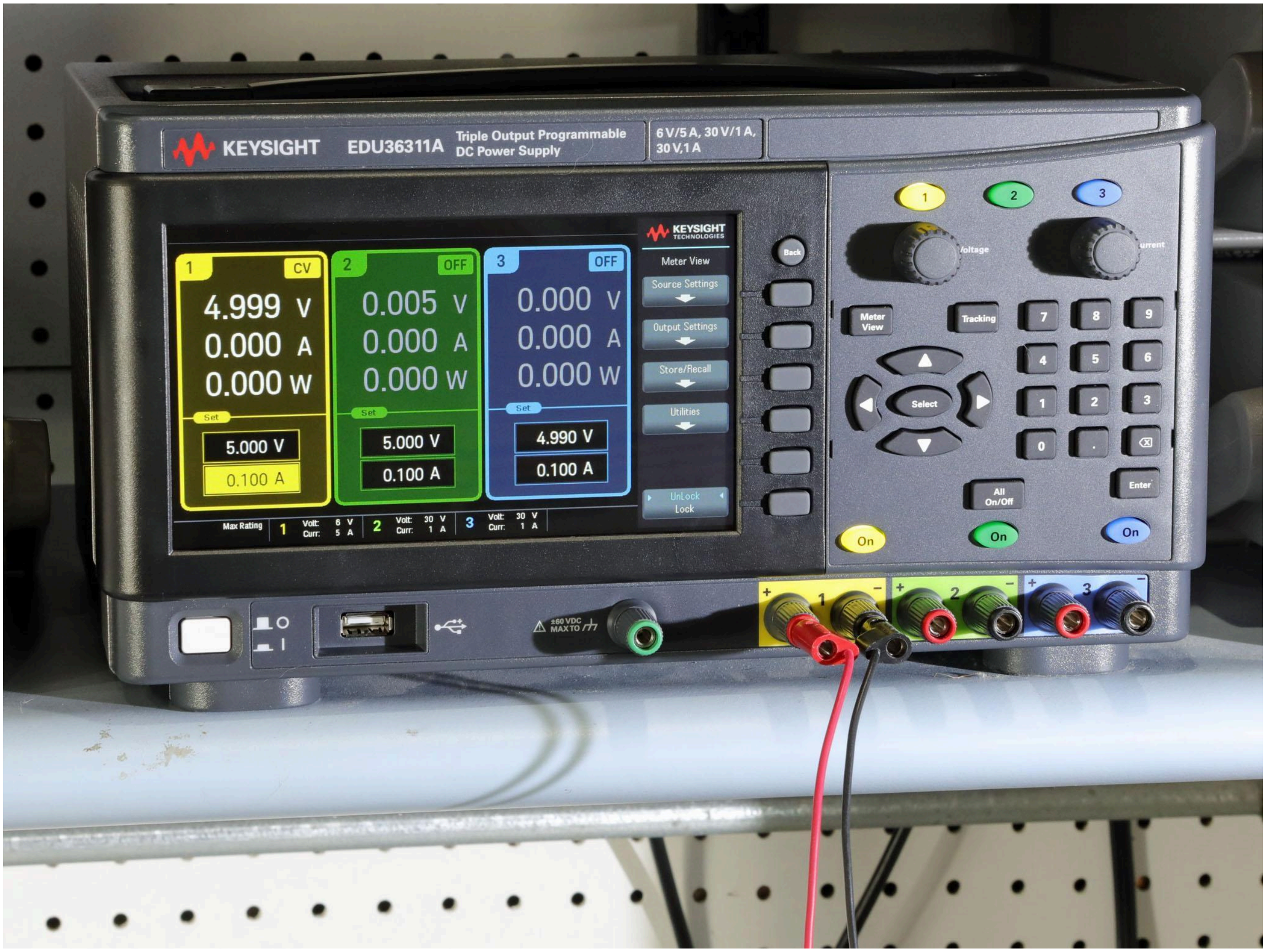
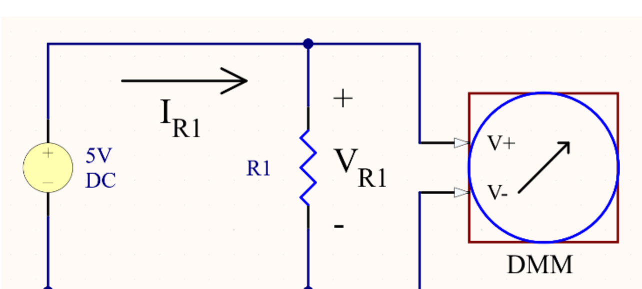


Figure 2: DC Power Supply set up to deliver 5VDC 100mA max.

Notice the black and red leads connected to +5V supply. Usually the YELLOW + output of the power supply. and YELLOW - on the power supply. **NOTE:** Don't use the green banana jack on the power supply for circuit GND. The green connection is for earth ground and has nothing to do with the power supply ground. The green connector is to connect your whole circuit to the earth which you don't need to do for these experiments.

The red and black leads terminate in mini-grabber connectors. These are shown in the next figures. It is convenient to connect the power supply to many circuits using the mini-grabbers. In this case you can connect the power supply directly to the resistor without using any more wires. It is a good idea to minimize wires because it is just another point where there can be an error in the circuit.

Figure 3 shows the breadboard setup with a few wires as possible. The mini grabbers are from the power supply and the test leads (in my hands) are from the multi-meter set to VDC.



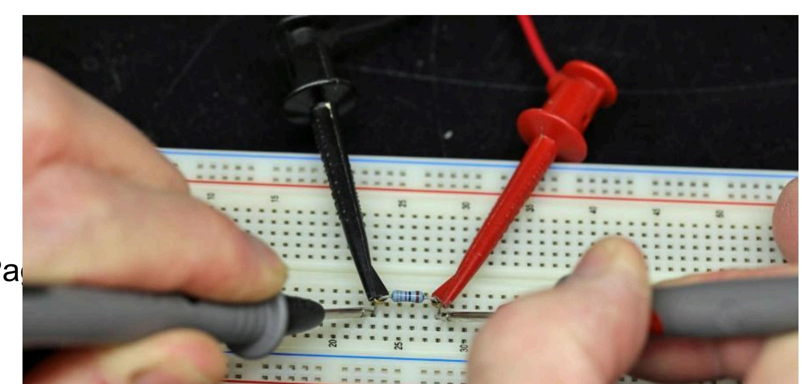


Figure 3: Measuring the voltage on a single resistor.

Notice the tips of the probes are put into the same breadboard holes as the resistor leads. They don't fit in the holes but putting them together guarantees a good connection. SO DO THIS !!! DO NOT put the tips in empty holes!!! An alternative is to use mini-grabbers for the DMM (multi-meter) leads instead of the probes.

- Set the power supply up to generate 5V using the YELLOW supply.
- Set the current limit of the YELLOW supply to 25mA.
- Connect the supply using the mini-grabbers to the resistor.
- Set the DMM to VDC. Use Auto ranging for convenience.
- Put the red and black probes on the resistor as shown in Figure 3.

What is V_{R1} ____4.999_____ volts

Figure 4 shows measuring the current through the resistor. Remember current is a through variable so you need to beak the circuit and insert the meter where the connection used to be.

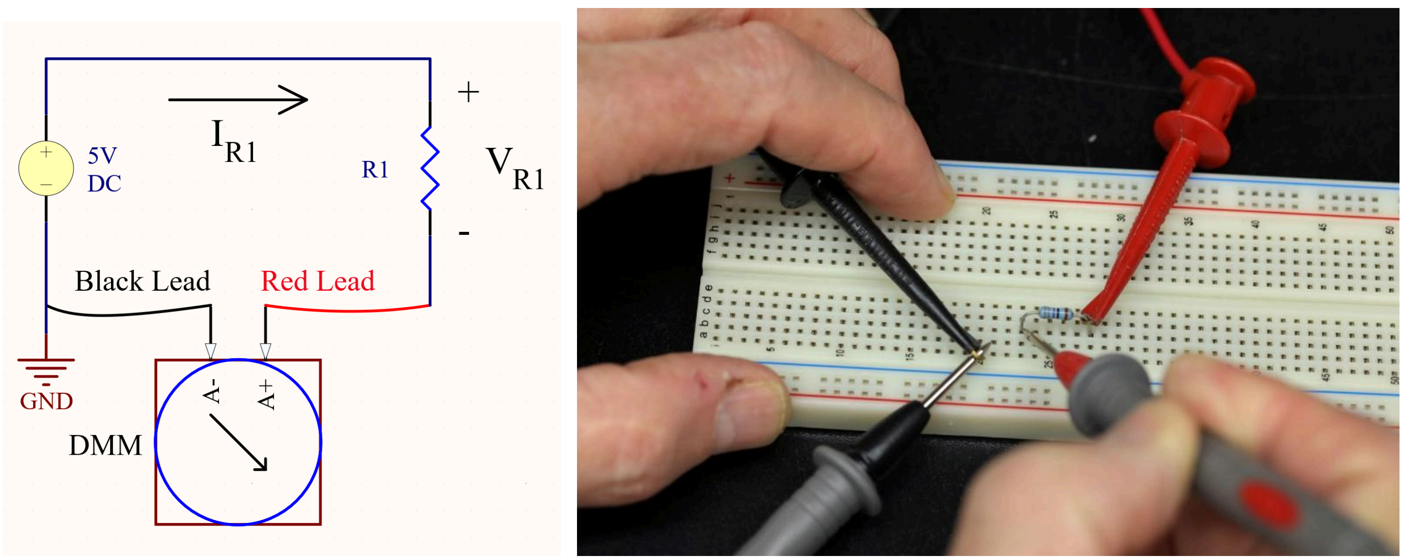


Figure 4: Measuring current through a single resistor.

The current measurement deserves some describing. First of all the circuit was "broken" at the place where ground is connected to the resistor. That is why the black mini-grabber was disconnected. Next the loose end of R1, where ground used to be connected, is shorted back to power supply ground (Black Mini-grabber). We set the multi-meter to IDC to measure the current. This makes the current that flows through the resistor flow through the meter before it goes to ground. They are all in series. Remember that the multi-meter in current measurement mode is a short circuit so the break in the circuit you created by disconnecting the black mini-grabber was reconnected by the (short) multi-meter in current mode.

- Set the power supply up to generate 5V using the YELLOW supply.
- Plug the red banana plug into the 3A current input.
- Connect the Red mini-grabber to one end of the resistor.
- Set the DMM (multi-meter) to I_{DC}.
- Leave the range set to Auto.
- Connect the red probe to the opposite end of the resistor from the power supply.
- Connect the black mini-grabber to the black DMM probe as shown in Figure 4.

Simple Voltage and Current Division Procedure

Once, you have the correct setup, read the DMM display to get the value of I_{R1}. I_{R1}=__5.637*10^-3_A = __5.637__mA

Note: If the value of current is just over 5mA then you are measuring the current correctly.

If you get a reading of you have probably connected the current meter up incorrectly and the current limit probably saved you from burning out the fuse of the DVM.

As engineers you should know we like to do things efficiently and quickly. I'm not saying we should be lazy but we should let "lazy" be an important factor in deciding how certain things are done.

When measuring current sometimes it is easier to measure the voltage across a resistor and divide that by the resistance to get current. I would like to say any time you can do that in this class you should. This is efficient as you no longer 'have to' change the circuit to make the measurement. $I_{R1} = V_{R1}/R1$. For calculating the current in this manner, implement the following steps:

- Measure R1 with the DMM. Remember you can't measure with the power supply connected to both ends of the resistor or you will get a wrong value. R1 __885.45__ Ω
- Use the voltage you measured across R1 in the first step V_{R1} = __4.999___V

Calculate the value of $I_{R1} = V_{R1}/R1$ = ___5.645*10^-3___ A.

How does this value of current compare to the value of current you found in the previous step?

Very close!.

Why do you think you get the wrong value of R1 if the power supply is still connected to the resistor? This is related to the method the meter uses to measure resistance.

The DMM would read current response from an additional voltage source, therefore inaccurate.

2. Pick 2 resistors with a nominal value of 10K. These are R1 and R3. Pick a resistor with a nominal value of 3.3K. This is R2. Record the nominal (Marked) and measured values of R1, R2 and R3 in Table 1. Then

Table 1	Nominal Value	Measured value	Measured Voltage Drop
R1	10 KΩ	9.99 KΩ	2.14V
R2	3.3 KΩ	3.323 KΩ	0.713V
R3	10 KΩ	9.963 KΩ	2.14V

Table 1:

Simple Voltage and Current Division Procedure

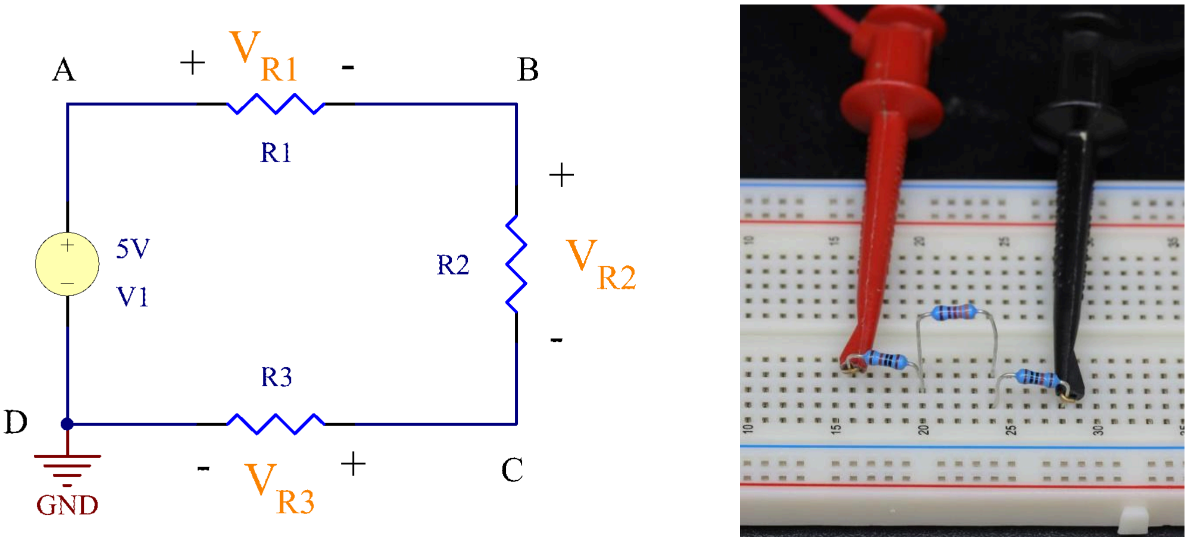


Figure 5: Series schematic and Breadboard example.

build the circuit shown in Fig. 5, using V1 = 5V_{DC} and your selected R_1, R_2, and R_3. Be sure to keep track of the resistors and not mix them up since you will use the measured values later.

- Measure the voltages V_{R1}, V_{R2}, and $V_{R3.}$ Use the following procedure to measure the voltage values:

3. Use the DMM to measure the voltages V1, V_{R1}, V_{R2} and V_{R3}. Connect the red probe to the side of the resistor that corresponds to the plus sign in the schematic. Make sure the red probe is connected to the VΩ input on the DMM. Put the black probe on the – side of the resistor. Enter the voltages in Table 1 above. Remember to touch the DMM probe tips to the resistor leads where they go into the breadboard. Don't use an empty hole!

V1 = ______4.999__________V_{DC}

Using your measured values for R_1, R_2, R_3, and V_s, calculate the expected voltage drops for V_{R1}, V_{R2}, and V_{R3}. You can calculate this by hand or use a simulation to do it. (LTSpice works well)

V_{R1} __2.14_ V, V_{R2} __0.714__ V and V_{R3} _2.139__ V

4. Enter these in the "Calculated Voltage Drop" column in Table 2. Calculate the % error of your measured voltages from table 1 compared to the calculated voltages from table 2 using the calculated values as the reference values. Put this in table 2. Use the measured resistor values to calculate the reference values in Eq. (29). Place these results in Table 2. Remember % error is determined by:

$$\% \text{ error} = \frac{\text{measured - reference}}{\text{reference}} 100 \tag{29}$$

Voltage	Measured Voltage Drop copied from table 1 (V)	Calculated Voltage Drop from Ohms law (V)	Calculated to Measured Error %
V_{R1}	2.14	2.14	0
V_{R2}	0.713	0.714	-1.4%
V_{R3}	2.14	2.139	0.47%

Table 2: Calculated Data and Errors for Fig. 4.

5. The errors you obtained in Table 2 should be less than 5%. If they are not, try to find the reason why.

6. Using the readings from Table 1, measured R's and V's, calculate the current passing through resistors R1, R2 and R3.

Voltage	Measured Resistance	Current (I) = $V_{MEASURED} / R_{MEASURED}$
V_{R1} = 2.14 V	R_1 = 10 K Ω	I_{R1} = 0.214 mA
V_{R2} = 0.713 V	R_2 = 3.3 k Ω	I_{R2} = 0.215 mA
V_{R3} = 2.14 V	R_3 = 10 K Ω	I_{R3} = 0.215 mA

Table 3: Current through resistors

Nodes A, B, C and D (Fig 4) are wires. Determine the currents I_A = _0.214__, I_B = _0.214_, I_C = __0.214__, I_D = __0.214_ using the currents you just calculated in Table 3 I_{R1}, I_{R2} and I_{R3}. Describe the method you choose to make this determination. Include the units ie. A, mA, uA, etc in your description.

What is the average current for I_A, I_B, I_C and I_D I_{AVE} _0.214___

7. Using the DMM in voltage mode, measure the voltage drop from nodes A to C, B to D, and A to D in Fig. 5. Record these values in Table 4.

   V_{AtoC}_2.8538__V , V_{BtoD} ___2.8575_____V , V_{AtoD} __4.9987__V

8. **Calculate** the measured equivalent resistance from A to C, B to D, and A to D using the voltages you measured in step 7, the average current from step 6 and ohms law. For example, the equivalent resistance between nodes A and C is given by $R_{eq} = \frac{V_{AtoC}}{I_{AVE}}$. Where I_{AVE} = the current through R1, R2 and R3. Record the results in Table 4.

9. Add up the measured resistance values to compute a **Theoretical** equivalent resistance from nodes A to C, B to D, and A to D. Record the values in Table 4, and then calculate the percent error between the calculated measured and theoretical measured columns.

Voltage	Measured Voltage Drop (V)	Calculated equivalent resistance	Theoretical equivalent resistance	%error theoretical to calculated	Measured DMM equivalent resistance
V_{AC}	2.8538	**13.288 KΩ**	**13KΩ**	**-2.167% KΩ**	**13.261 KΩ**
V_{BD}	2.8575	**13.288KΩ**	**13KΩ**	**-2.167% KΩ**	**13.277 KΩ**
V_{AD}	4.9987	**23.279KΩ**	**23KΩ**	**-1.198% KΩ**	**23.214 KΩ**

Table 4: Data from Fig. 4.

10. Now measure the actual equivalent resistances with the DMM. Enter them into table 4. Remember the power supply has to be disconnected for this measurement.

11. Next we investigate a parallel circuit. Build the circuit in Fig. 6, using V1 = 5V, R_1, R_2 and R_3 from the series circuit in Figure 4.

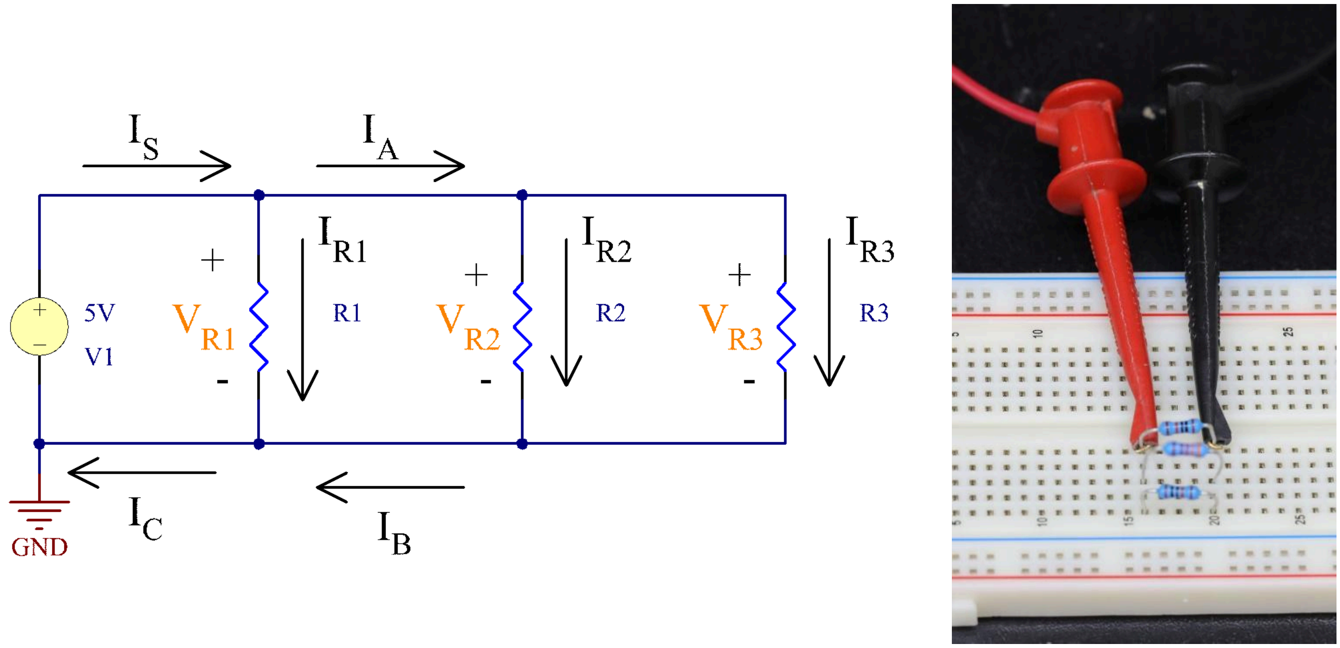
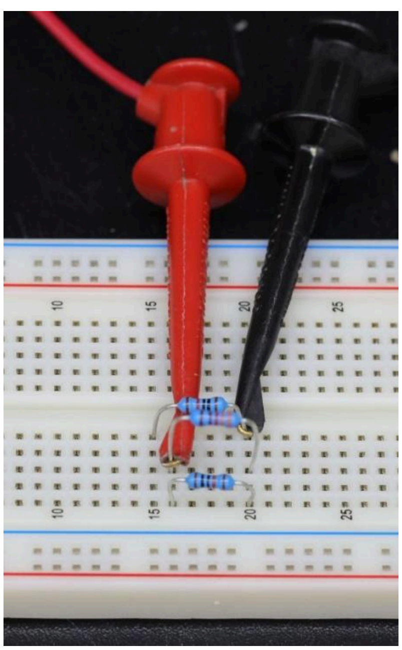


Figure 6: Parallel circuit schematic and breadboard example.

12. Copy the measured values of your resistors to Table 5, and then measure the voltage across and current through each resistor as labeled in Fig. 6 Use the DMM to measure voltage. Don't measure I_S, I_A, I_B or I_C yet. Look at figure 6 to see an easy way to measure the R1, R2 and R3 currents.

Resistor	Measured Resistance	Measured Voltage across	Actual Measured Current through
R_1	**9.9378 k Ω**	**4.9986 V**	**0.5028 mA**
R_2	**3.324 k Ω**	**4.9986 V**	**1.503 mA**
R_3	**9.954k Ω**	**4.9986 V**	**0.5021 mA**

Table 5: Data from Fig. 5.



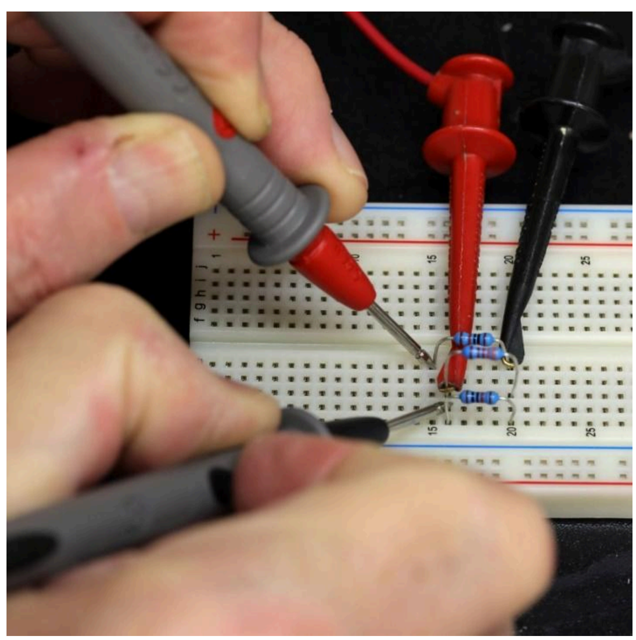


Figure 7: Parallel current measurement for a a single resistor R1. R1 has 1 lead pulled out (6a) and then shorted back in with the DMM probes (6b).

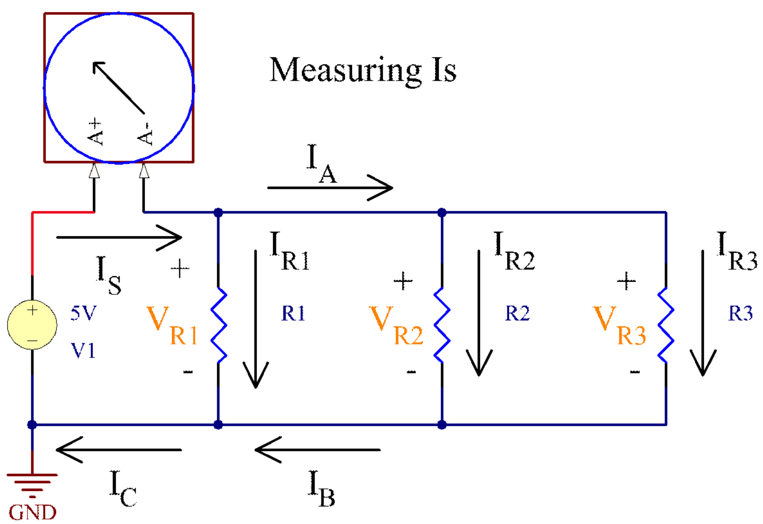
13. Calculate the current that should flow through R1, R2 and R3 using the measured V across and measured resistances from table 5. Record these values in Table 6. Calculate the % error of your measured currents from Table 5 compared to the Calculated current.

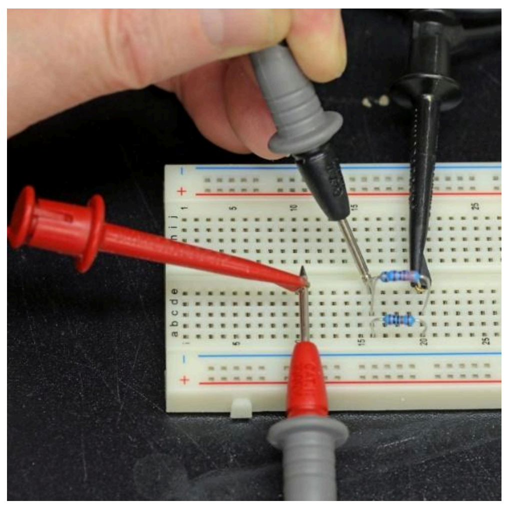
	Calculated current using measured V and R	**% error Measured to Calculated.**
R1	**0.502 mA**	0%
R2	**1.504 mA**	-0.06%
R3	**0.503 mA**	-0.19888%

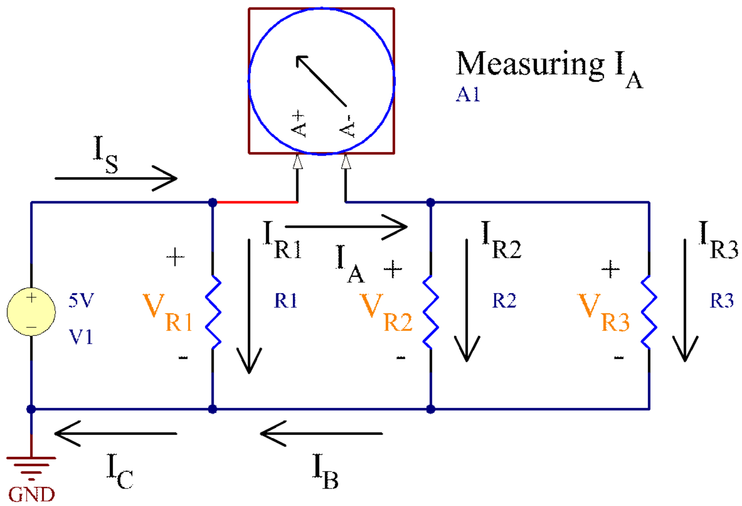
Table 6: calculations and errors from Fig. 6

14. Measure the currents labeled I_S, I_A, I_B, and I_C in Fig. 6 using the DMM. This procedure is similar to the one you followed in step 1 of this lab. Figure 8 illustrates how DMM can be connected to measure each current value:

I_S = __2.5078_____, I_A = ___2.0049_____, I_B = ___2.0049_____, I_C=__2.5078_____






Measuring I_A
A1
A+
A-
I_S
I_{R1}
I_A
I_{R2}
I_{R3}
5V
V1
V_{R1}
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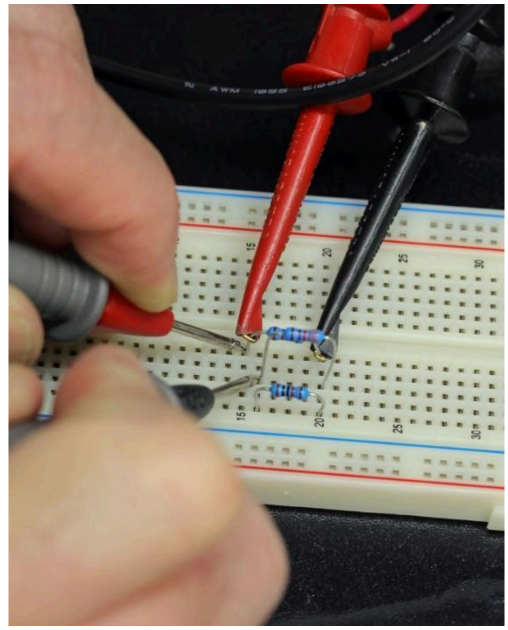
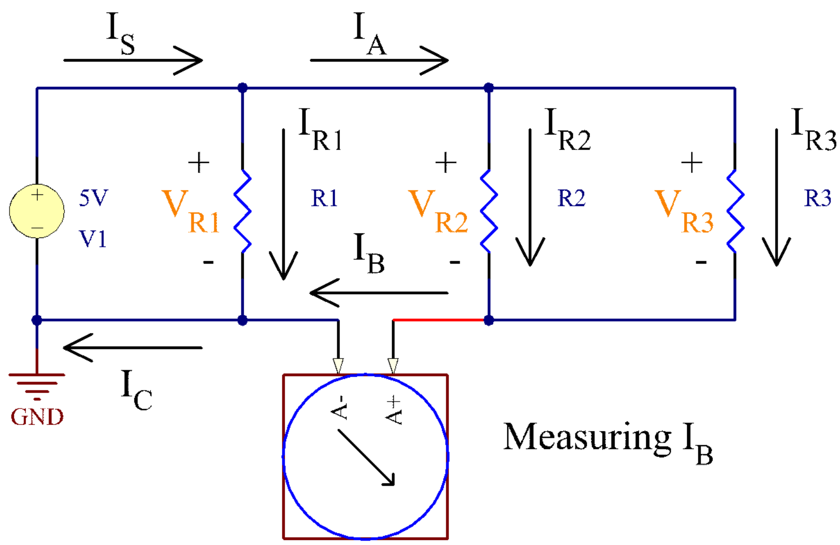
R3
GND
I_C
I_B




I_S
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I_C
A-
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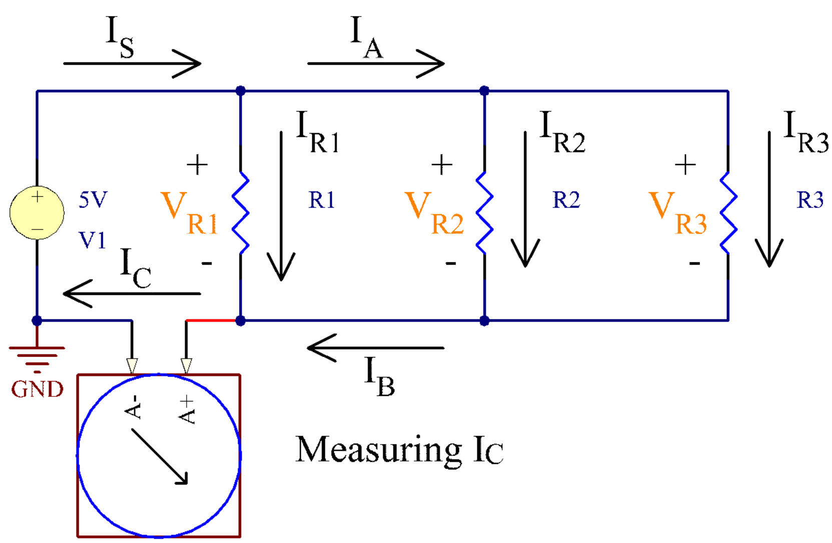
Measuring I_B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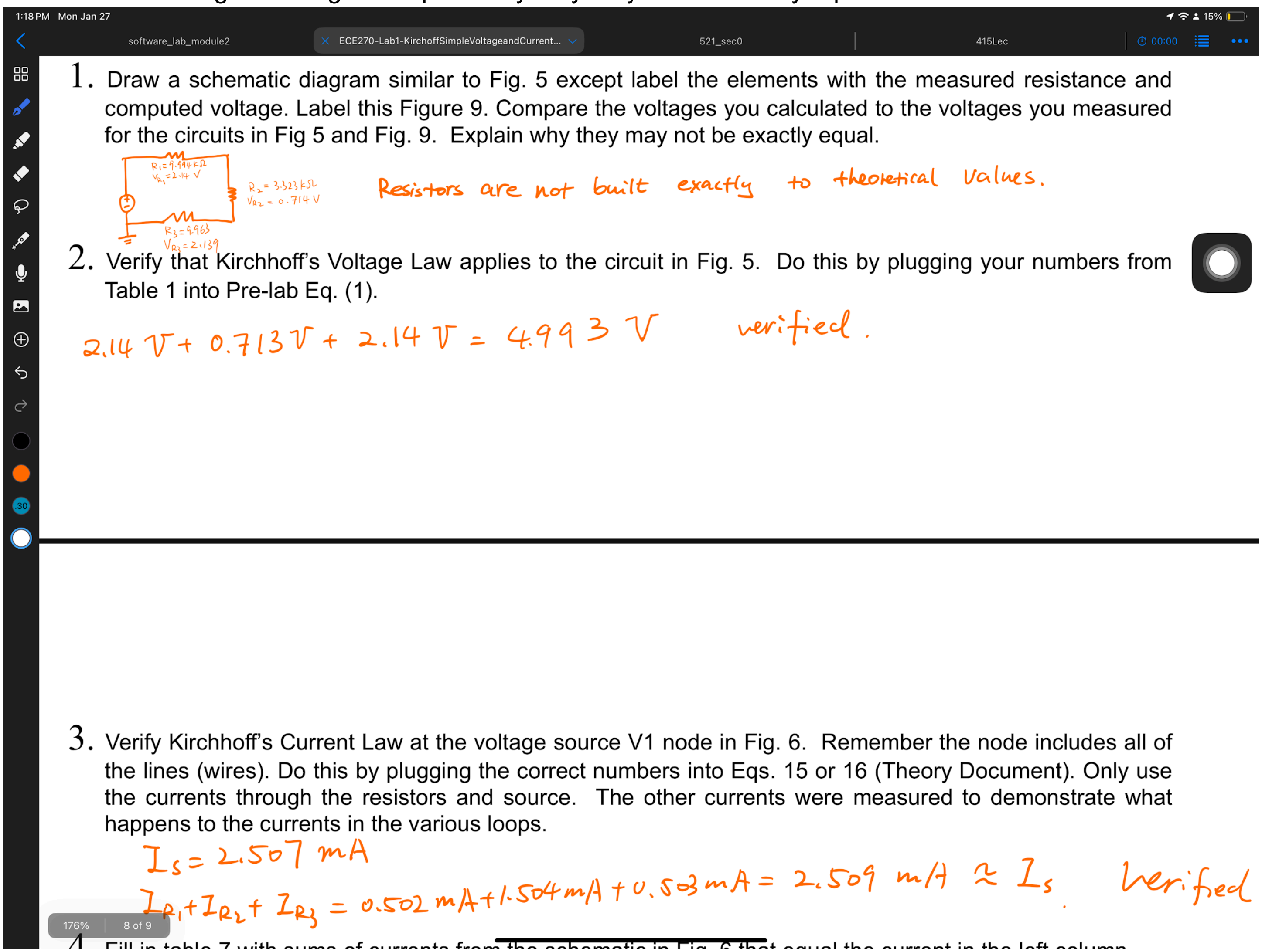
R3
I_C
GND
I_B
A-
A+
Measuring Ic

Figure 8: Current meter connection guide.

Post Lab Questions

1. Draw a schematic diagram similar to Fig. 5 except label the elements with the measured resistance and computed voltage. Label this Figure 9. Compare the voltages you calculated to the voltages you measured for the circuits in Fig 5 and Fig. 9. Explain why they may not be exactly equal.



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1. Draw a schematic diagram similar to Fig. 5 except label the elements with the measured resistance and computed voltage. Label this Figure 9. Compare the voltages you calculated to the voltages you measured for the circuits in Fig 5 and Fig. 9. Explain why they may not be exactly equal.

$R_1 = 9.994\,k\Omega$, $V_{R_1} = 2.14\,V$

$R_2 = 3.323\,k\Omega$, $V_{R2} = 0.714\,V$

$R_3 = 9.963$, $V_{R_3} = 2.139$

Resistors are not built exactly to theoretical values.

2. Verify that Kirchhoff's Voltage Law applies to the circuit in Fig. 5. Do this by plugging your numbers from Table 1 into Pre-lab Eq. (1).

$2.14\,V + 0.713\,V + 2.14\,V = 4.993\,V$ verified.

3. Verify Kirchhoff's Current Law at the voltage source V1 node in Fig. 6. Remember the node includes all of the lines (wires). Do this by plugging the correct numbers into Eqs. 15 or 16 (Theory Document). Only use the currents through the resistors and source. The other currents were measured to demonstrate what happens to the currents in the various loops.

$I_s = 2.507\,mA$

$I_{R_1} + I_{R_2} + I_{R_3} = 0.502\,mA + 1.504\,mA + 0.503\,mA = 2.509\,mA \approx I_s$ verified

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4. Fill in table 7 with sums of currents from the schematic in Fig. 6 that equal the current in the left column.

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2. Fill in table 7 with sums of currents from the schematic in Fig. 6 that equal the current in the left column.

Current	Sums of Currents Use I_{R1}, I_{R2} and I_{R3}
$I_S = 2.5079$ mA	Symbolic: $I_{R1} + I_{R2} + I_{R3}$
	Numeric: 0.5028 mA + 1.503 mA + 0.5021 mA
$I_C = 2.5079$ mA	Symbolic: $I_{R1} + I_{R2} + I_{R3}$
	Numeric: 0.5028 mA + 1.503 mA + 0.5021 mA
$I_A = 2.0051$ mA	Symbolic: $I_{R2} + I_{R3}$

	Numeric: 1.503 mA + 0.5021 mA
I_B = 2.0051 mA	Symbolic: I_{R2} +I_{R3}
	Numeric: 1.503 mA + 0.5021 mA

Table 7