Lab Report 1

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Multi-Meter Measurements

1. Pick 3 resistors with different color codes. If your resistors have 5 bands, consider only the first four bands. Measure their values with your DMM. Compare their stated values and tolerances (color code) with your measured multimeter results.

WORK SHEET HERE:

$\frac{\text{MEASURED-MARKED}}{\text{MARKED}}(100\%)$

Resistor #	Marked	DMM Measured	% Deviation from Marked
R_1	10Ω(±5%)	9.7 Ω	-3%
R_2	10KΩ(±5%)	9.9 KΩ	-1%
R_3	3.9 KΩ(±10%)	3.86KΩ	-1.026 %

Is the % Deviation greater or less than the indicated tolerance?

ANSWER HERE:
The % Deviation less than the indicated tolerance

2. If you look at a standard list of 20% resistors available, you will see 1000 ohms and 1500 ohms but not 1200 ohms. Why? If you look at 5% resistors, would the results be different? Why? [A listing of resistor values can be found on the wall of the laboratory.] Hint: Think about what tolerance means and how it differs from measurement error.

ANSWER HERE: Due to the 20% tolerance, 1000ohms & 1500ohms already cover 1200 ohms with in its tolerance. However, if we look at 5% resistor, the result would be different because both of them do not cover the 1200 ohms resistor with 5% tolerance. That's why we can see the 1200 ohms with 5% tolerance

3. Pick two resistors that are approximately two orders of magnitude different, i.e. 1,000 Ω and 100,000 Ω, or 22 Ω and 2,200 (See Figures 1-2, 1-3, and 1-4.)
   a. Measure them carefully. Note their actual values rather than the color code indicated value. WORK SHEET HERE:

R_1 Color Code Value: 1000 Ω R_1 Measured Value: 990 Ω

R_2 Color Code Value: 100 000 Ω R_2 Measured Value: 98 800 Ω

   b. Measure them in series and parallel connections.

WORK SHEET HERE:

R_{Series} Value: 99 800 Ω $R_{Parallel}$ Value: 989 Ω

c. Compare your measurements with the calculated values. Your calculated values should be calculated using the individually measured values from part a. Note: in series, the larger value dominates the measurement.

WORK SHEET HERE:

R Series Resistance Calculated: 99.79 kΩ Measured: 99.8kΩ % difference 0.01%

R Parallel Resistance Calculated: 980.18 Ω Measured: 989Ω % difference 0.9%

d. In the parallel connection, which resistor dominates and why? Let $R_1 = 1K\Omega$

e. In the series connection, which resistor dominates and why? $R_2 = 100K\Omega$

ANSWERS HERE: d) In parallel, $R_{eq} = \frac{R_1 R_2}{R_1 + R_2}$; $R_2 >> R_1 \Rightarrow R_1 + R_2 \approx R_2$

$\Rightarrow R_{eq} \simeq \frac{R_1 R_2}{R_2} = R_1$

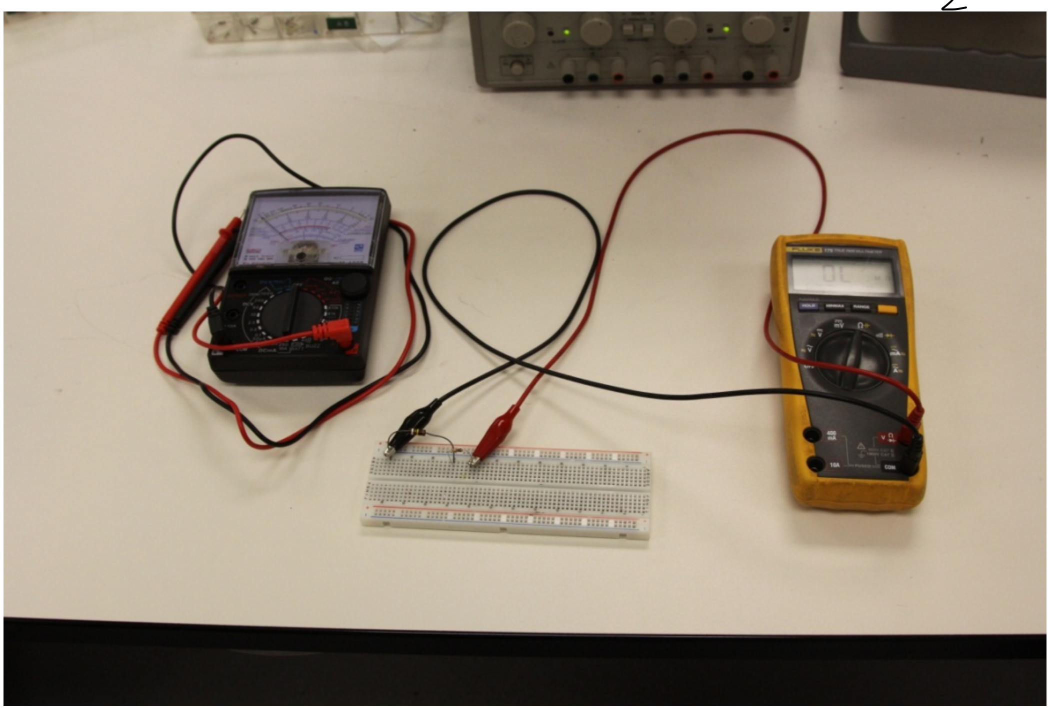


FIGURE 1-1. MULTIMETERS CONNECTED
TO RESISTOR ON PROTO-BOARD
[Left side: Analog Multimeter Right side: Digital Multimeter]

Practically, $R_{eq} = 989\ \Omega \simeq R_1 = 1000\ \Omega$

$\Rightarrow$ In parallel connection, $R_1 = 1K\Omega$ dominates the measurement

e) In the series, $R_{eq} = R_1 + R_2$, also $R_2 >> R_1$

$\Rightarrow R_{eq} \simeq R_2$

$99.8k\Omega \simeq 100k\Omega$ $\Rightarrow$ in this case, $R_2 = 100$ dominates the measurement

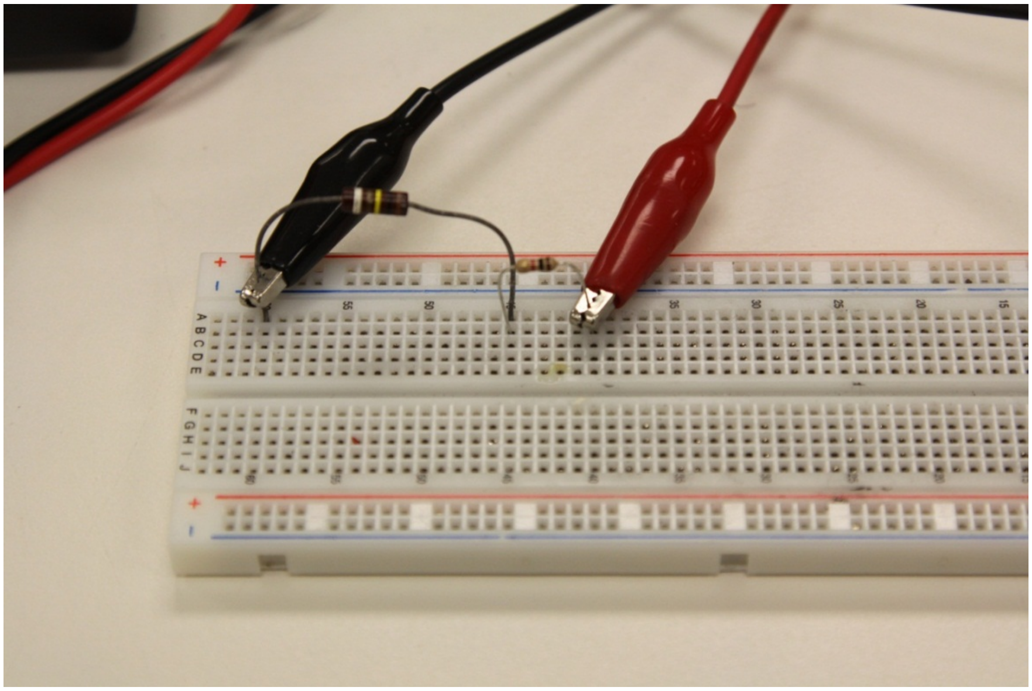


FIGURE 1-2. RESISTORS CONNECTED IN SERIES ON PROTO-BOARD

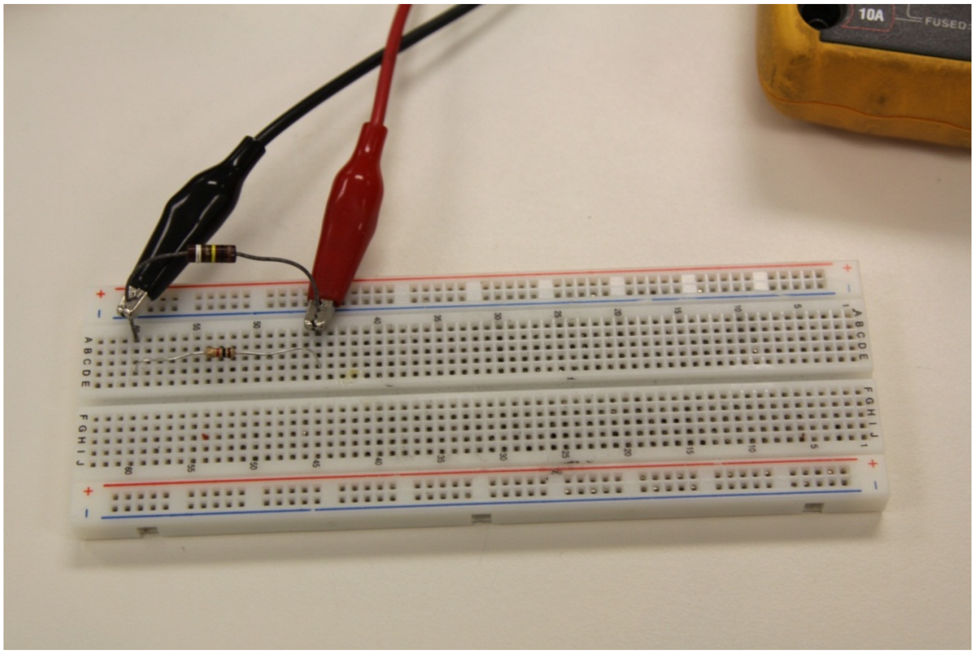
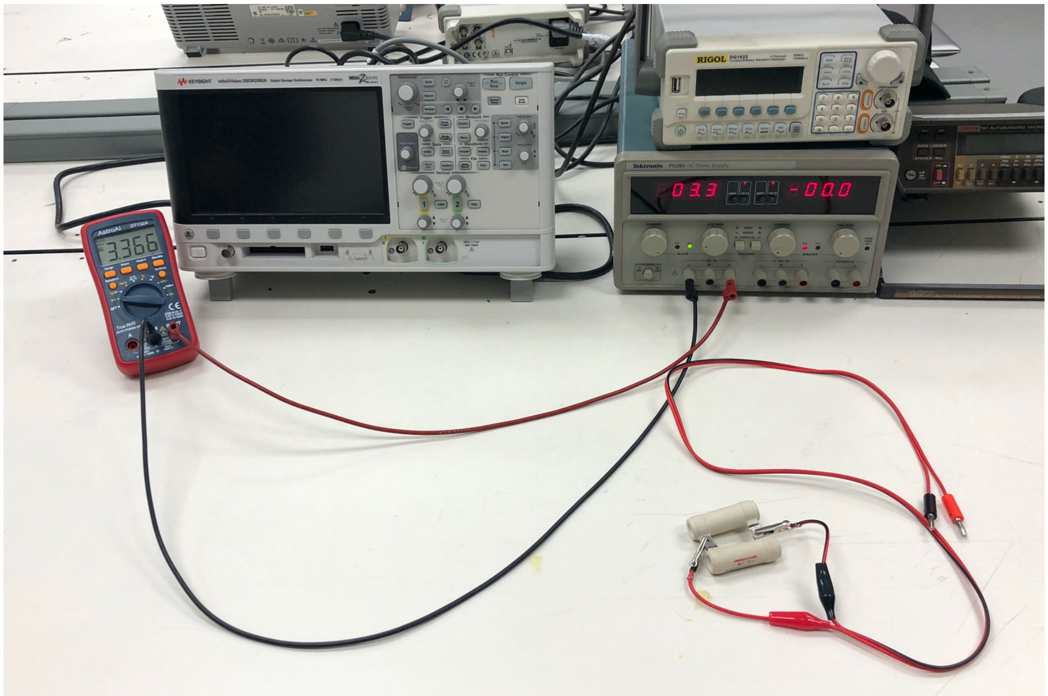


FIGURE 1-3. RESISTORS CONNECTED IN PARALLEL ON PROTOBOARD

Source Measurements

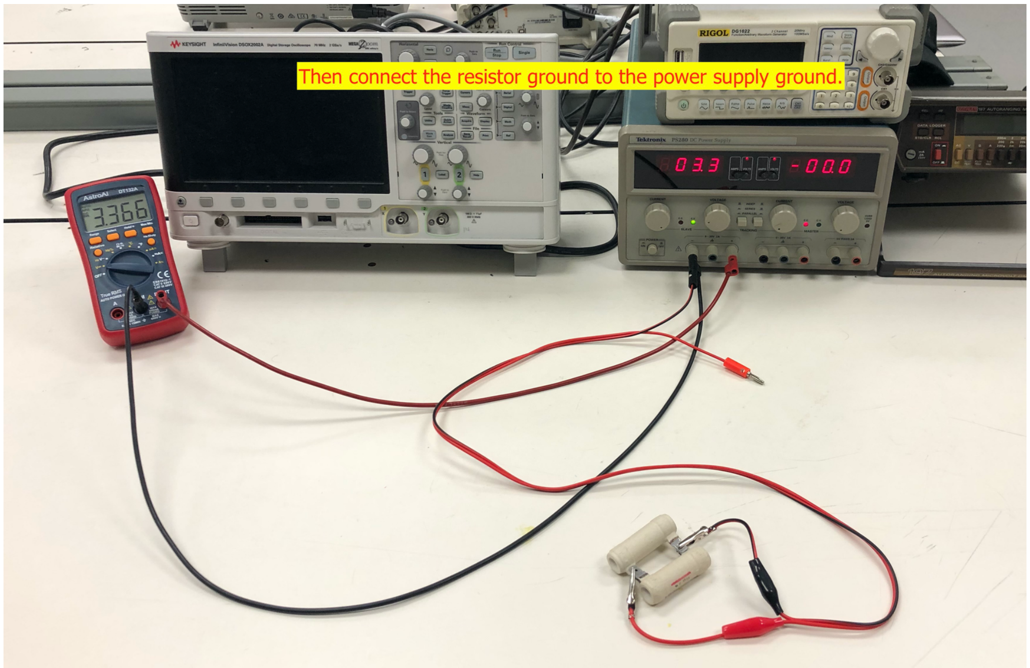
The Tektronix dual power supply you will be using can operate as a near ideal voltage source or a near ideal current source. When the green light is on (CV) it is a Controlled-Voltage source, and when the red light is on (CC) it is a Controlled-Current source.

To test the voltage source, refer to the following figures:

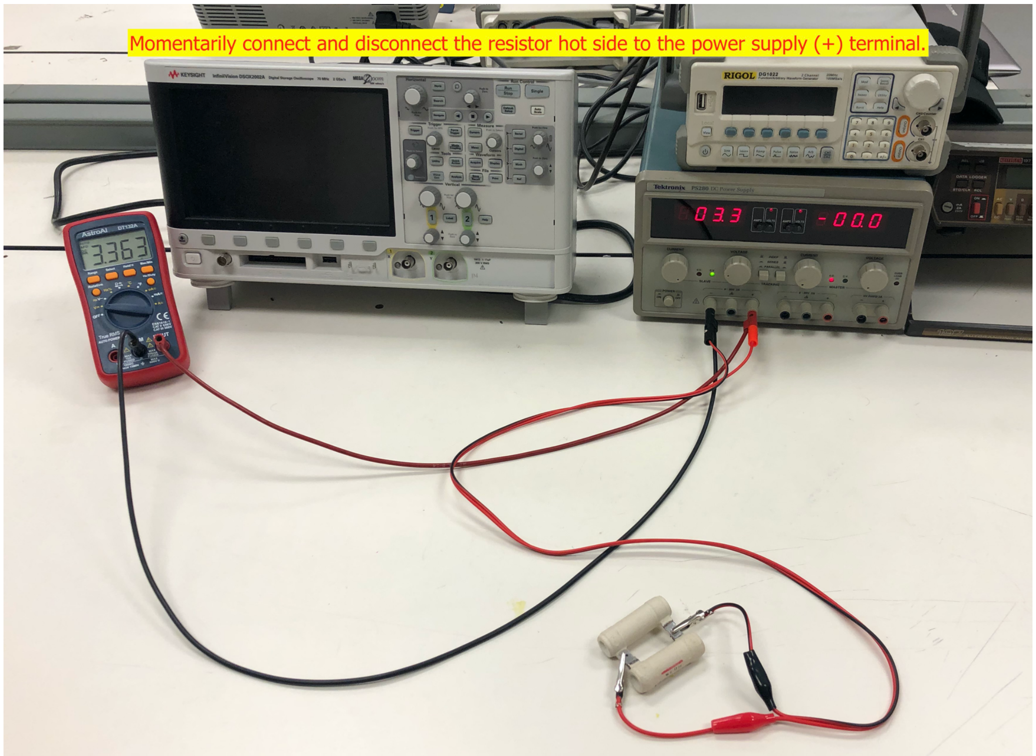


1. Set the DMM to read DC volts.
2. Using the left side of the power supply front panel, connect the positive terminal of the DMM to the positive terminal of the power supply. Do the same for the negative terminal.
3. Slide the switch on the power supply front panel to the left to display current.
4. Turn the current limit to full right (clockwise).
5. Set the output to ~3.3 volts as indicated on the DMM.
6. Be sure that the DMM display shows <u>three numerals to the right</u> of the decimal point. Lowering the voltage to ~5 V and then increasing it back to ~6 V usually forces 3 numerals.
7. Set up the 5 Ω resistor by connecting two white 10 Ω, 25 watt resistors in parallel as shown in the above picture.

By observing the following picture, connect the 5 Ω resistor ground (black lead) to the power supply ground. Leave the resistor hot side (red lead) disconnected.

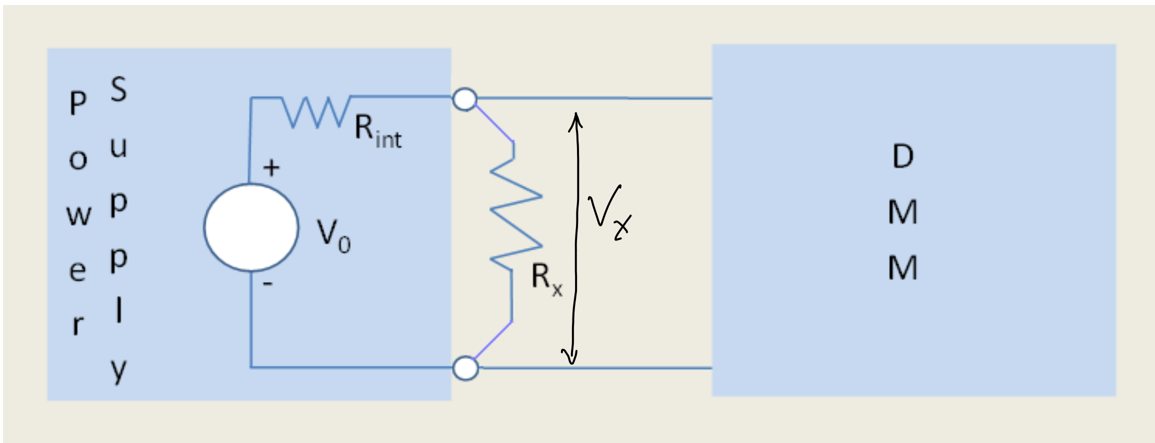

Then connect the resistor ground to the power supply ground.

Now, by observing the following picture, momentarily connect and disconnect the resistor hot side (red lead) to the power supply (+) terminal. Note: the resistor will dissipate energy and could get quite HOT!! Take care not to burn yourself. Record the DMM readings in the work-sheet below when connected and when disconnected. The difference between the two readings should be a few millivolts.



Measuring Internal Resistance of a Power Supply

Observe carefully the small change in the output voltage that occurs when the 5 Ω resistor (Rx) is connected as shown below. From the change in this voltage, calculate the internal resistance of the voltage source. The circuit equivalent to the above pictures is:



(The DMM input resistance is extremely large compared to R_x !)

$R_x = 5\,\Omega$

WORK SHEET HERE:

Unloaded voltage (i.e. without 5 Ω resistor): 3.308 V

Loaded voltage (with 5 Ω resistor): 3.305 V

Voltage shift: 0.003 V

Calculate internal resistance: (Hint: The voltage divider equation will be useful here)

We have $V_x = \frac{R_x}{R_{int} + R_x} V_0$ (Voltage divider equation)

Besides, $V_x = V_{loaded} = 3.305V$, $V_0 = V_{unloaded} = 3.308V$

$\Rightarrow \frac{V_0}{V_x} = \frac{R_{int} + R_x}{R_x} = 1 + \frac{R_{int}}{R_x} \Rightarrow R_{int} = \left(\frac{V_0}{V_x} - 1\right) R_x$

$\Rightarrow R_{int} = \left(\frac{3.308V}{3.305V} - 1\right) \times 5\Omega = \boxed{0.00454\,\Omega}$

Unloaded and Loaded Voltage Dividers

We will investigate the effect that loading has on a voltage divider circuit. Loading, as you recall from lecture, is the demand for current from a voltage source. That demanded current has an effect on the performance of the circuit. We will be measuring the amount of that performance change.

You will need the following components:

1 KΩ resistors (2)

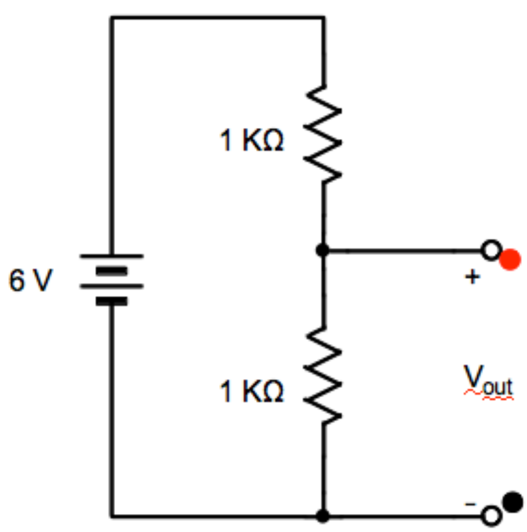
3.3 KΩ resistor

Breadboard

DMM

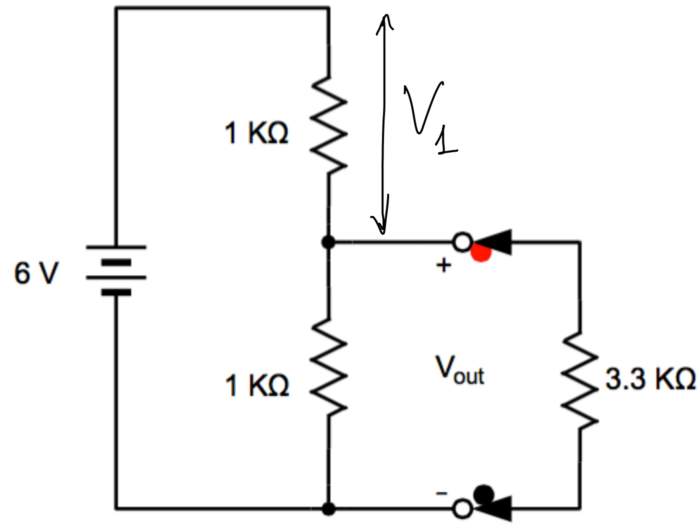
Tektronix DC Power Supply

1. Construct the voltage divider circuit as shown below. This is an unloaded voltage divider.



2. Measure V_{out} at the red and black dots. Record the value here 3.004 V.

3. Now load the circuit by attaching the 3.3 KΩ load resistor across the lower 1 KΩ resistor, as shown below. The 3.3 KΩ resistor is now demanding current from the voltage divider.



4. Measure the new V_{out} as in Step 2. Record the value here: 2.604 V
5. Fill out the following table:

	UNLOADED VOLTAGE DIVIDER	LOADED VOLTAGE DIVIDER
V_{out} (measurement)	3.004 V	2.604 V
$V_{upper1K}$ (calculation)	2.996 V	3.396 V
I_{total} (calculation)	2.996 mA	3.396 mA

Why does an increase in total current result in lower output voltage of the loaded voltage divider circuit?

We have $V_1 + V_{out} = 6V \Rightarrow V_{out} = 6 - V_1$

Also $V_1 = I_{total} \times 1 K\Omega$, so when the total current I_{total} increase that makes the Voltage V_1 on $1 K\Omega$ increase too. Consequently, the output of the loaded voltage divider $V_{out} = 6 - V_1$ is going to be lower than before.

Validation of Kirchhoff's Laws

In this lab, we will be showing that Kirchhoff's Laws are actually true with the Digital Multimeter (DMM).

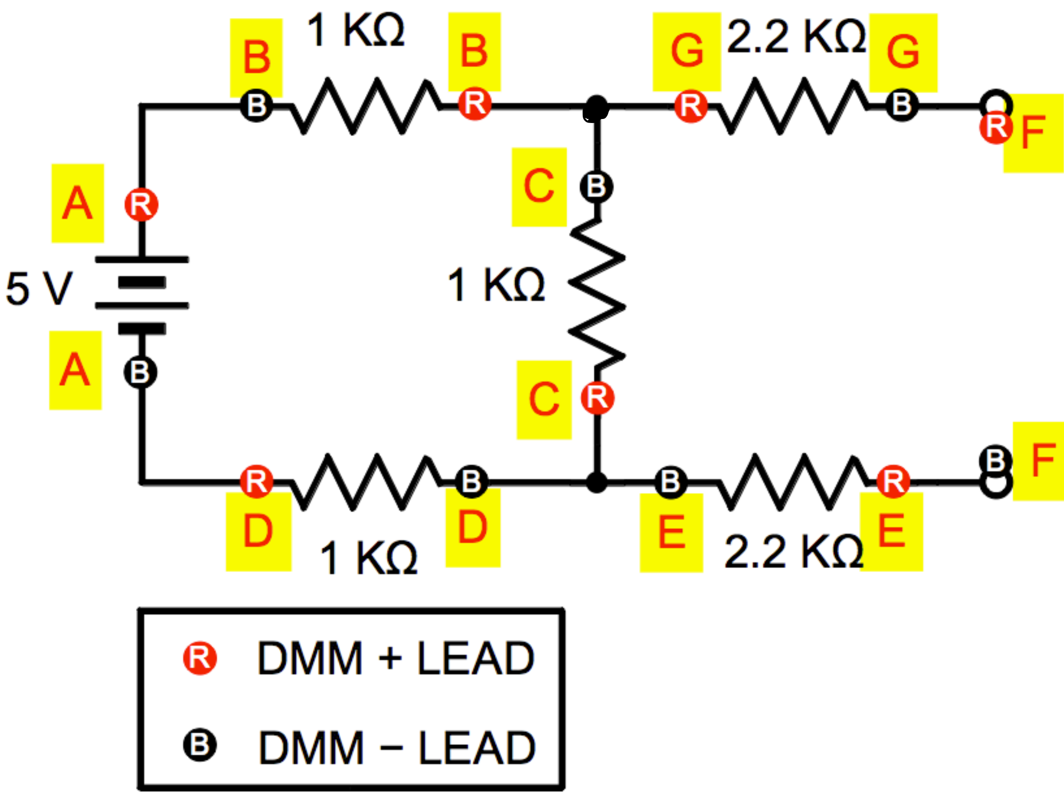
In addition to a DMM and the power supply, you will need the following components:

1 KΩ resistors (3)

2.2 KΩ resistors (2)

Breadboard

1. Construct the following circuit using the power supply, breadboard, and resistors:



2. Using the DMM, and following the polarities indicated, take DC voltage measurements A through G. Follow STRICTLY the (R) and (B) circles! Fill in the blanks on the next page.

MEASUREMENT	VALUE
A	5.07V
B	-1.693 V
C	-1.685V
D	-1.692V
E	0V
F	+1.684V
G	0V

3. Add measurements A through D. Put your answer here: 0V (KVL)
4. Add measurements C, E, F, and G. Put your answer here: -0.001 V ≃ 0V (KVL)
5. Now, use a jumper wire to connect the two open circles (at Measurement F).
6. Repeat measurements A-G.

MEASUREMENT	VALUE
A	5.07V
B	-1.804 V
C	-1.460 V
D	-1.802V
E	0.730V
F	0V
G	0.730V

7. Using Ohm's Law, calculate the ABSOLUTE VALUE of the current through resistors B, C, and G (answers in "CURRENT" column in the table below). Also, using the Passive Sign Convention, determine whether the current through each resistor is entering or leaving the B-C-G node connecting the three resistors ("CHOOSE ONE" column).

RESISTOR	CURRENT	CHOOSE ONE	
B	1.804 mA	☐ LEAVE	☑ ENTER
C	1.46 mA	☑ LEAVE	☐ ENTER
G	0.332 mA	☑ LEAVE	☐ ENTER

8. Using [a] the Passive Sign Convention rule** (see footnote) and [b] the NVA convention that currents leaving the node are positive, attach the + or – sign to the currents and **add them up to see if KCL holds**. NVA rule: currents leaving the node are marked +; currents entering the node are marked −.

9. Put your sum here: $-1.804\,mA + 1.46\,mA + 0.332\,mA = \boxed{-0.012\,mA}$

SHOW YOUR CALCULATIONS TO INSTRUCTOR OR TA BEFORE LEAVING LAB!

$\approx 0A$ (KCL)

Discuss your answers to Steps 3, 4, and 9. In particular, did you validate Kirchhoff's Laws?

Based on the result of Steps 3, 4, and 9, the voltages are equal 0 (KVL), and the total current at node is equal 0 also (KCL), that's why we have validated the Kirchhoff's Laws.

Week 1 Lab End

** The Passive Sign Convention says, among other things, that the positive end of a resistor is where the current always enters. Conversely, the negative end of a resistor is where the current always leaves.