Lab 5: Resistors in Series and Parallel

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1 Purpose

Familiarity with the behavior of resistors in both series and parallel configurations, as well as experimental verification of course material on series and parallel resistors.

2 Materials

- Handheld Digital Multimeter (DMM)
- Breadboard
- Assorted Resistors (270Ω, 330Ω, and 510Ω)
- Power Supply
- Wires
- Alligator Clips

3 Theory

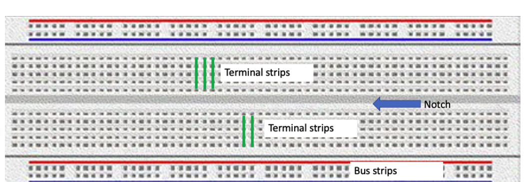
In this lab, we make use of the **ammeter** function in our digital multimeters for the final section. The electrical current is measured in Amperes, which is one coulomb per second ($1.0A = \frac{1.0C}{1.0s}$).

Additionally, we made use of the most useful feature of a digital multimeter, being the **voltmeter**. With this mode, our multimeter is able to measure the potential difference between any two points with the units of volts (ΔV), which gives us an idea of the difference in potential energy between two points in our circuit.

Resistors have the main property of "resistance", measured in Ohms (Ω), which can be thought of as a ratio of Volts over Amperes, or how many volts will be dropped across the resistor for a certain amount of current. Each resistor generally has 4-6 colored bands printed onto them, which indicate the value of its resistance. All but the last two colored bands indicate numbers in decimal increments, the second to last indicates a multiplier, and the last band indicates the tolerance of the resistor with either a silver or gold band.

A **Breadboard** is a useful tool for prototyping small electric circuits, as it lets you consistently connect electrical components together without need for wire nuts or soldering. A breadboard is essentially a grid of termination points, with rows of these points connected together. Using this principle, one row of a standard breadboard can electrically connect 5 different components together in order to make more complex circuits.

Figure 1: Labeled diagram of a breadboard



4 Experiment Analysis

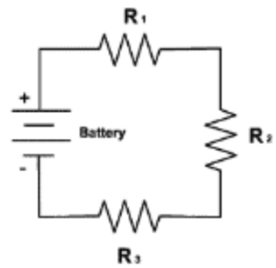
Resistors in series

$$R_{eq} = R_1 + R_2 + R_3$$

The total Voltage across resistors in series is equal to the sum of voltage drops across each subsequent resistor.

$$V_{eq} = \varepsilon = V_1 + V_2 + V_3 = IR_1 + IR_2 + IR_3$$

Figure 2: Resistors in Series



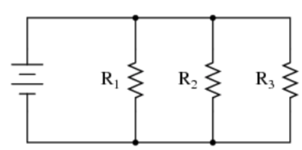
Resistors in parallel

$$R_{eq} = \left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_2}\right)$$

The voltage drop across each resistor in a parallel setup is equal to the potential difference of the battery ε.

$$V_{eq} = \varepsilon = V_1 = V_2 = V_3$$

Figure 3: Resistors in Parallel



5 Procedure

5.1 Measurement of the resistors using DMM

To perform the first section of this lab, we took six differing resistors and connected them one-by-one to our digital multimeter, and recording the values in table 6.1. While measuring the actual value using the DMM, we also noted down the resistor color codes found in the same table.

5.2 Series Circuit

In this section of the lab, we are experimentally verifying the theory developed to predict the behavior of resistors in a series circuit, such as that the current flowing through all of them is the same, as well as the voltage drop across each resistor should be equal to the total current times the resistance.

$$V_{\text{drop}} = I_{circuit} \cdot R_{\text{resistor}}$$

Figure 4: Six labeled resistors on a breadboard

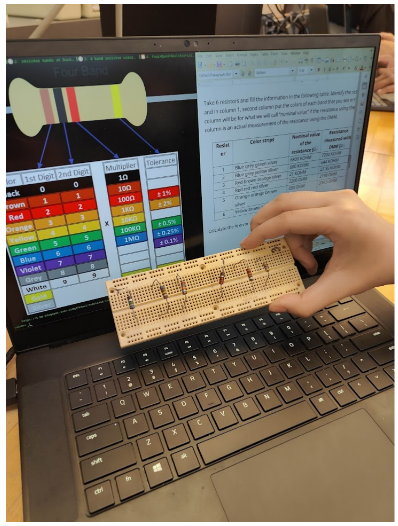
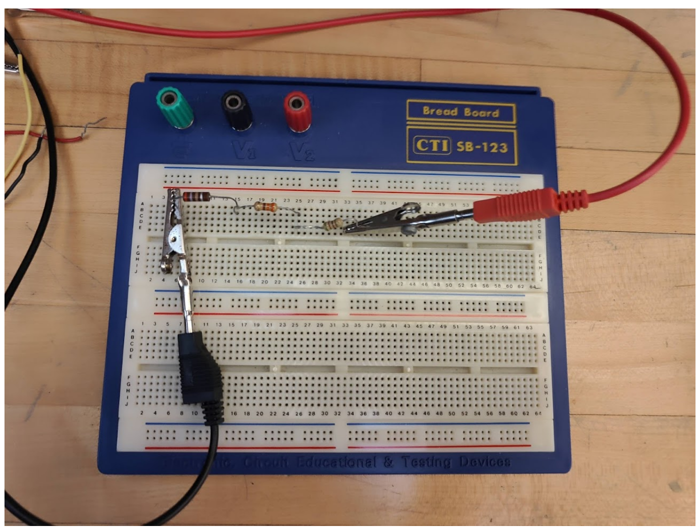


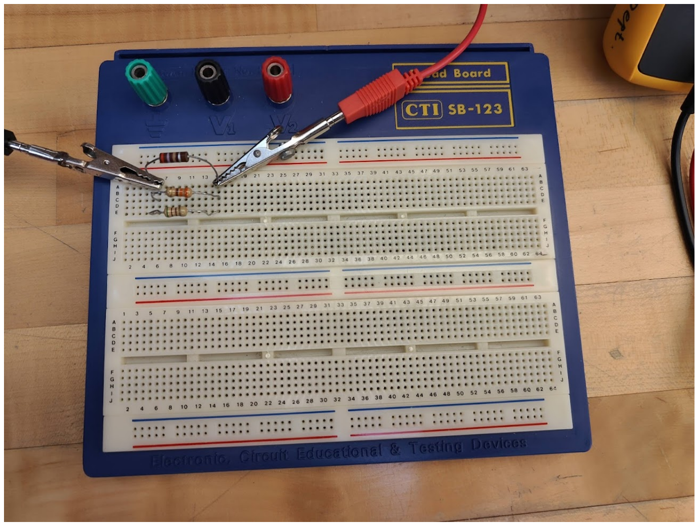
Figure 5: Resistors in a series configuration



5.3 Parallel Circuit

Similarly to the previous section, this experiment is helping us verify and gain a working understanding of the behavior of parallel resistors. Mainly, verifying that the voltage drop across each resistor is the same, as well as the current, all relative to an individual resistor's resistance value.

Figure 6: Resistors in a parallel configuration



6 Data and Graphs

6.1 Value of the Resistor

Resistor	Colors	Expected Resistance (Ω)	Actual Resistance (Ω)	Percent Error
1	Blue Grey Green Silver	6800kΩ ± 10%	7200kΩ	5.88%
2	Blue Grey Yellow Silver	680kΩ ± 10%	644kΩ	5.29%
3	Red Purple Orange Silver	27kΩ ± 10%	27.35kΩ	1.30%
4	Red Red Red Silver	2200Ω ± 10%	2198Ω	0.09%
5	Orange Orange Brown Silver	330Ω ± 10%	334.5Ω	1.36%
6	Yellow Purple Black Gold	47Ω ± 5%	47.5Ω	1.06%

6.2 Series Circuit

Resistor (Ω)	Measured Voltage Drop (V)	Calculated Current (mA)
368.2	1.2	3.26
328.7	1.07	3.26
521.9	1.7	3.26

6.3 Parallel Circuit

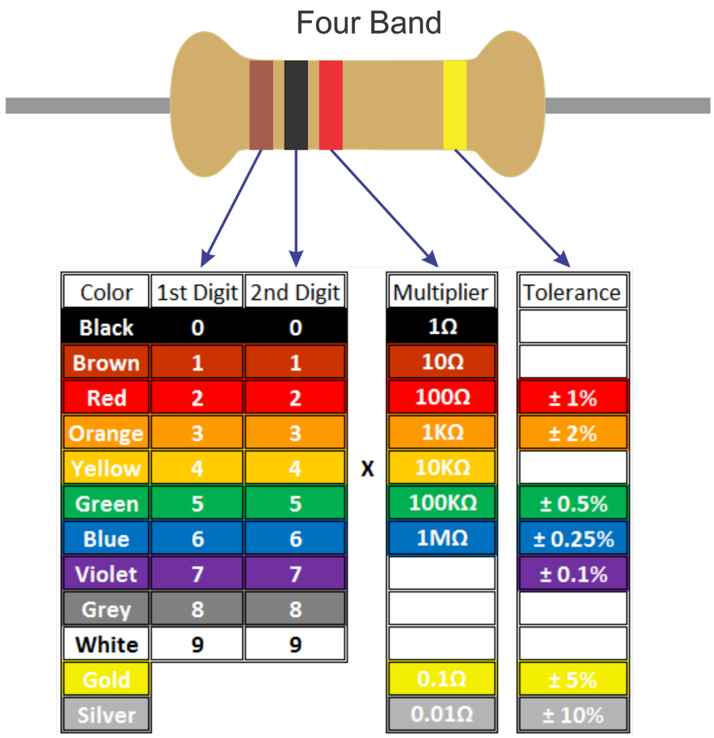
Resistor (Ω)	Measured Voltage Drop (V)	Calculated Current (mA)	Power Dissipated (W)
368.2	3.9	106	0.4134
328.7	3.9	119	0.4641
521.9	3.9	74.7	0.291

7 Calculations & Results

7.1 Value of the Resistor

In order to find the expected/nominal value of the resistor, Figure 7.1.1 was taken into consideration. Each colored stripe on the resistor corresponded to a digit, magnitude, or tolerance.

[Fig 7.1.1] 4-band Resistor Color Chart



Color	1st Digit	2nd Digit	Multiplier	Tolerance
Black	0	0	1Ω	
Brown	1	1	10Ω	
Red	2	2	100Ω	± 1%
Orange	3	3	1KΩ	± 2%
Yellow	4	4	10KΩ	
Green	5	5	100KΩ	± 0.5%
Blue	6	6	1MΩ	± 0.25%
Violet	7	7		± 0.1%
Grey	8	8		
White	9	9		
Gold			0.1Ω	± 5%
Silver			0.01Ω	± 10%

The actual resistance was found via the Digital Multimeter on resistor mode, and connecting one lead on each end of the resistor.

The percent error was found using the expression

$$\%E = \frac{|\text{Theoretical} - \text{Experimental}|}{\text{Theoretical}} \times 100$$

To check if the resistors are within specification, the tolerance was applied to the nominal value of the resistor. This was done by creating a range of values the resistance could fall into. To find the lower bound, the following equation was used:

$$\text{Lower Bound} = \text{Nominal Resistance} - \left(\frac{\text{Nominal Resistance} \times \text{Tolerance}}{100}\right)$$

To find the upper bound, the following equation was used:

$$\text{Upper Bound} = \text{Nominal Resistance} + \left(\frac{\text{Nominal Resistance} \times \text{Tolerance}}{100}\right)$$

Thus, all of the measured resistances fall into the specification range.

7.2 Series Circuit

In order to find the current over a specific resistor, the resistance and voltage drop of the resistor is needed. Then, the following equation is applied:

$$\mathrm{I} = \frac{\mathrm{V}}{\mathrm{R}}$$

To find the equivalent resistance of a circuit in series, the following formula was used:

$$\mathrm{V}_{eq} = \mathrm{R}_1 + \mathrm{R}_2 + \mathrm{R}_n + ...$$

To find the percent error in the voltage drops compared to the power supply value, the following equation is used:

$$\%E = \frac{|\text{Power Supply Voltage} - \text{Voltage Drop Total}|}{\text{Power Supply Voltage}} \times 100$$

7.3 Parallel Circuit

In order to find the current over a specific resistor, the resistance and voltage drop of the resistor is needed. Then, the following equation is applied:

$$\mathrm{I} = \frac{\mathrm{V}}{\mathrm{R}}$$

To find the power dissipated by each resistor in the circuit, apply the following equation:

$$\mathrm{P} = \mathrm{IV}$$

To find the equivalent resistance of a circuit in parallel, the following formula was used:

$$\frac{1}{\mathrm{R}_{eq}} = \frac{1}{\mathrm{R}_1} + \frac{1}{\mathrm{R}_2} + \frac{1}{\mathrm{R}_n} + ...$$

To find the current through the battery, apply the following equation using the battery voltage and the equivalent resistance.

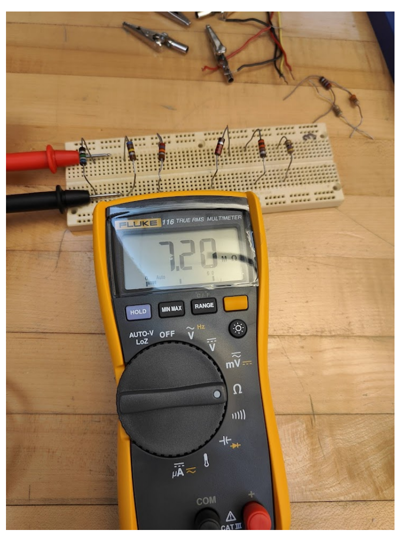
$$\mathrm{I} = \frac{\mathrm{V}}{\mathrm{R}}$$

8 Questions

Part 1 - Measurement of Resistors

1. Include here a picture of the set-up of just one measurement of resistance (showing the value in the display of the DMM)

Figure 7: Resistance measurement setup



(There is a hand maintaining pressure on the probes for optimal contact just outside of the frame)

2. Do some research about the meaning of the tolerance (gold or silver colors). Are the resistors within specification? Explain

The gold and silver bands on the resistor indicate the plus or minus percentage for the lower and upper bounds of the accepted value of resistance for the resistor. Therefore, the lower and upper bounds of acceptance can be found using the equation

$$\text{Lower Bound} = \text{Nominal Resistance} - \left(\frac{\text{Nominal Resistance} \times \text{Tolerance}}{100}\right)$$

To find the upper bound, the following equation was used:

$$\text{Upper Bound} = \text{Nominal Resistance} + \left(\frac{\text{Nominal Resistance} \times \text{Tolerance}}{100}\right)$$

Applying these equations, the measured resistances fall within accepted bounds.

Part 2 - Series Circuit

1. Did you get the same value of current across all the resistors?
   Yes sir!

2. What is the equivalent resistance of the circuit
   $\mathbf{R_{eq} = 1221.2\Omega}$

3. Did the voltage drop across the resistors add up to the value of the power supply? What is the percent error?
   Nearly, we had 0.75% error, off by 0.03 Volts

Part 3 - Parallel Circuit

1. Do you obtain the same voltage across each resistor?
   Yes sir!

2. Calculate the equivalent resistance of the circuit

$$\mathbf{R_{eq} = 1218.8\Omega}$$

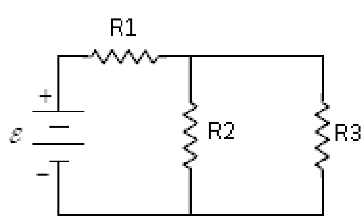
3. Calculate the current through the battery using the power supply value and the equivalent resistance

$$\mathbf{I = \frac{V}{R} = \frac{4.0V}{1218.8\Omega} = 3.28mA}$$

4. Is the power dissipated through each resistor the same? If no, through what resistor is the power the greatest?
   No chief, it isn't. R2 has the greatest power dissipation

Part 4 - Series and Parallel Circuit

Figure 8: Series and parallel circuit diagram



- Battery Voltage: $\varepsilon = \mathbf{3.88V}$
- Resistor values

$$\mathbf{R_1 = 368.2\Omega,\ R_2 = 328.7\Omega,\ R_3 = 521.9\Omega}$$

- What is the equivalent resistance?

$$\mathbf{R_{eq} = 0.575k\Omega}$$

- Potential difference across each resistor

$$\mathbf{V_1 = 2.472V,\ V_2 = 1.406V,\ V_3 = 1.406V}$$

- Current flowing through each resistor

$$\mathbf{I_1 = 6.80mA,\ ,I_2 = 4.13mA,\ I_3 = 2.62mA}$$

- Power dissipated by each resistor

$$\mathbf{P_1 = 16.8mW, P_2 = 5.81mW, P_3 = 3.68mW}$$

- Total current supplied by battery

$$\mathbf{I_{total} = 6.8mA}$$

9 Conclusion

This lab succeeded in its objective to verify the relationship between voltage, current, and resistance in varying configurations of series and parallel resistors. With relatively low percentage errors, the only variations between our calculations and measurements were resulting from the tolerances of the resistors selected for each circuit. All of the measured resistances were found to be within the allotted tolerances, with the highest percent difference being 5.88%. Especially with modern digital multimeters and power supplies, there is basically no human error that can throw off the accuracy of measurements, aside from misconfiguring a circuit.