University ☺f P☺rtland
Sch☺☺l ☺f Engineering

EE 271–Electrical Circuits Laboratory
Spring 2016

Lab Experiment #1: Ohm's Law and Kirchhoff's Laws

Ohm's Law and Kirchhoff's Laws

I. Objective

In this experiment, the student will learn how to read resistor color codes and how to measure voltage, current, and resistance with the digital multimeter (DMM). The student will also build circuits and take measurements to verify Ohm's law, Kirchhoff's laws, and the conservation of energy.

II. Background: Resistor Color Codes

Standard resistors are labeled with a color code which indicates their resistance values. The value indicated by each color band is listed in Tables 1, 2, and 3, and the resistor's value can be computed by the following equation:

$$R = \left[\left(\text{1st Digit} \right) \times 10 + \left(\text{2nd Digit} \right) \right] \times \left(\text{Multiplier} \right)$$

Consider a resistor that has the following color bands: brown, green, orange, and silver. We first recognize that the silver band must be the tolerance band since the 1st Digit cannot be silver (see Tables 1 and 2). So the brown band must be the 1st band, which indicates that the value of the 1st Digit equals 1 (see Table 2). The second band, then, is green, which indicates that the value of the 2nd Digit equals 5 (see Table 2). The multiplier band is orange which indicates a value of 1 k (see Table 3). So the value of this resistor is $R = \left[(1) \times 10 + (5) \right] \times 1\text{k} = 15 \ \text{k}\Omega$. Furthermore, the silver tolerance band indicates that the actual value of the resistance might deviate by $\pm 10\%$ (see Table 1).

A resistor with the bands red, violet, red, gold, would have a value of $R = \left[(2) \times 10 + (7) \right] \times 100 = 2700 \ \Omega \ = \ 2.7 \ \text{k}\Omega$ with a tolerance of $\pm 5\%$.

A resistor with the bands orange, orange, brown, gold, would have a value of $R = \left[(3) \times 10 + (3) \right] \times 10 = 330 \ \Omega$ with a tolerance of $\pm 5\%$.

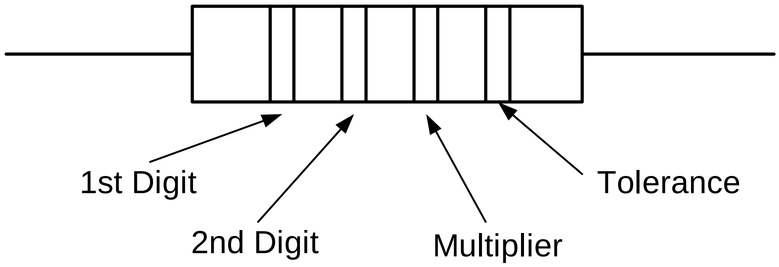

Figure 1. Resistor with 4 color bands.

Table 1. Tolerance band.

Color	Tolerance
Red	2%
Gold	5%
Silver	10%
none	20%

Table 2. 1st and 2nd digits.

Color	Value
Black	0
Brown	1
Red	2
Orange	3
Yellow	4
Green	5
Blue	6
Violet	7
Gray	8
White	9

Table 3. Multiplier band.

Color	Value
Silver	0.01
Gold	0.1
Black	1
Brown	10
Red	100
Orange	1 k
Yellow	10 k
Green	100 k
Blue	1 M
Violet	10 M
Gray	100 M

III. Procedure

PART A: Ohm's Law

Pre-lab Assignment A: Determine the color code for a 10 kΩ resistor with 5% tolerance. For the circuit shown in Figure 2, calculate the theoretical value of the current *I* (that is, I_{th}). Calculate the power absorbed by the resistor (P_R) and the power supplied by the voltage source (P_S). Show your work. Present all your results in table format using the appropriate tables provided. (You need to draw Tables 4, 5 and 6 in your lab notebook to summarize your pre-lab results.) The resistors we will use in the lab can safely handle power dissipation up to 0.25 W. Is it safe to use a 10 kΩ resistor with a power rating of 0.25 W in the circuit shown in Figure 2? State why. Is the conservation of energy satisfied in this circuit? State why.

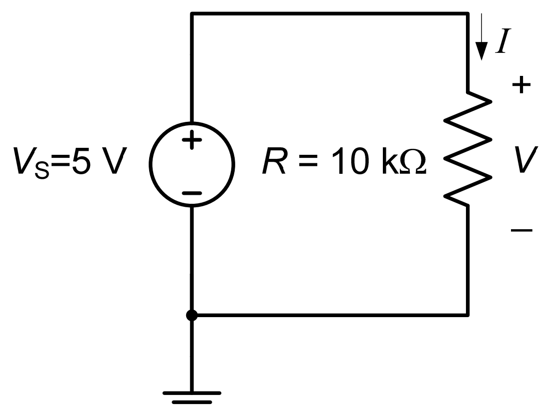

Figure 2. A simple resistive circuit.

Table 4. Color code for the 10 kΩ resistor (Figure 2 circuit).

First	Second	Third	Fourth

Table 5. Theoretical resistor, voltage and current values (Figure 2 circuit).

R_{th} (kΩ)	V_{th} (V)	I_{th} (mA)
10		

Table 6. Power values calculated (Figure 2 circuit).

P_R (mW)	P_S (mW)	Safe or not?	Energy conserved?

Lab Experiment A:

Draw Table 7 in your lab notebook including the measurements and calculated values related to the circuit shown in Figure 2.

Table 7. Theoretical and measured resistor, voltage and current values (Figure 2 circuit).

R_{th} (kΩ)	R_m (kΩ)	V_{th} (V)	V_m (V)	I_{th} (mA)	I_m (mA)

Pick up a 10 kΩ resistor and measure its actual value using the handheld DMM. Compute the % error in the resistance value by using the following formula: $\% \quad \text{error} = \frac{R_{\text{theoretical}} - R_{\text{measured}}}{R_{\text{theoretical}}} \times 100$ where $R_{\text{theoretical}} = 10 \quad k\Omega$.

Is the % error less than the tolerance specified by the tolerance color band? Complete Table 8.

Table 8. Percentage error in the actual value of the 10 kΩ resistor (Figure 2 circuit).

R_{th} (kΩ)	R_m (kΩ)	% error	Less than tolerance value?
10			

Construct the circuit shown in Figure 2 using the 5-volt supply in your lab kit (the red terminal). Use the DMM to measure the voltage *V* represented by V_m and substitute the measured V_m value into Ohm's law to calculate I_m.

Compare the measured value of *I* to the theoretical value from the pre-lab using percent error as follows: $\% \quad \text{error} = \frac{I_{\text{theoretical}} - I_{\text{measured}}}{I_{\text{theoretical}}} \times 100$. If the theoretical and measured values for the current *I* differ, explain why.

Table 9. Percentage error in current value (Figure 2 circuit).

% error in I_{th}

Use the measured values to calculate the power absorbed by the resistor and supplied by the voltage source. Is conservation of energy satisfied in this circuit? State why.

Table 10. Power values calculated (Figure 2 circuit).

P_R (mW)	P_S (mW)	Energy conserved?

PART B: Kirchhoff's Voltage Law

In this part of the experiment, we will add two more resistors (1.8 kΩ and 4.7 kΩ) to the circuit shown in Figure 2 to obtain the circuit shown in Figure 3.

Pre-lab Assignment B:

Determine the color codes for 1.8 kΩ and 4.7 kΩ resistors with 5% tolerance and present them in Table 11 format in your lab notebook. Additionally, what condition must be satisfied by the four voltages indicated in Figure 3 based on Kirchhoff's voltage law (KVL)? (Box this condition.)

Table 11. Color codes for the 1.8 & 4.7 kΩ resistors (Figure 3 circuit).

R (kΩ)	First	Second	Third	Fourth
1.8				
4.7				

Lab Experiment B:

Draw Table 12 in your lab notebook to tabulate theoretical and measured resistor values related to the circuit shown in Figure 3.

Table 12. Theoretical and measured values of the resistors (circuit in Figure 3).

$R_{1,th}$ (kΩ)	$R_{1,m}$ (kΩ)	$R_{2,th}$ (kΩ)	$R_{2,m}$ (kΩ)	$R_{3,th}$ (kΩ)	$R_{3,m}$ (kΩ)
10		4.7		1.8	

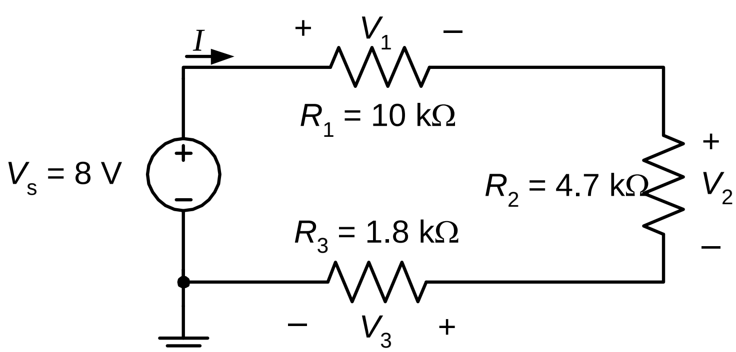

Figure 3. Resistors connected in series.

Measure the actual values of the 1.8 kΩ and 4.7 kΩ resistors in Figure 3 and calculate the % error for each resistor. Are all the % errors less than the tolerance specified by the tolerance color band? Draw Table 13 in your lab notebook and fill all the entries.

Table 13. Percentage error in the values of 1.8 and 4.7 kΩ resistors (Figure 3 circuit).

R (kΩ)	% error	Less than tolerance value?
1.8		
4.7		

Draw Table 14 in your lab notebook to tabulate the measured voltage and current values in the circuit shown in Figure 3.

Table 14. Measured voltage values (circuit in Figure 3).

V_1 (V)	V_2 (V)	V_3 (V)	% KVL error	KVL satisfied?

Set the adjustable power supply (the yellow terminal labeled +1.3 to 15V) in your lab kit to 8V. Then construct the circuit shown in Figure 3. Measure the voltages V_s, V_1, V_2, and V_3. Do the measured voltage values in this circuit satisfy KVL? Using the measured values, calculate the percentage error in KVL defined with respect to the source voltage as

$$\%\text{ error in KVL} = \frac{V_S - (V_1 + V_2 + V_3)}{V_S} \times 100$$

<u>PART C: Kirchhoff's Current Law</u>

In this part of the experiment, we will change the circuit shown in Figure 3 to the circuit shown in Figure 4.

<u>Pre-lab Assignment C:</u> What condition must the three currents satisfy at node A (see Figure 4) based on Kirchhoff's current law (KCL) ? (<u>Box this condition.</u>)

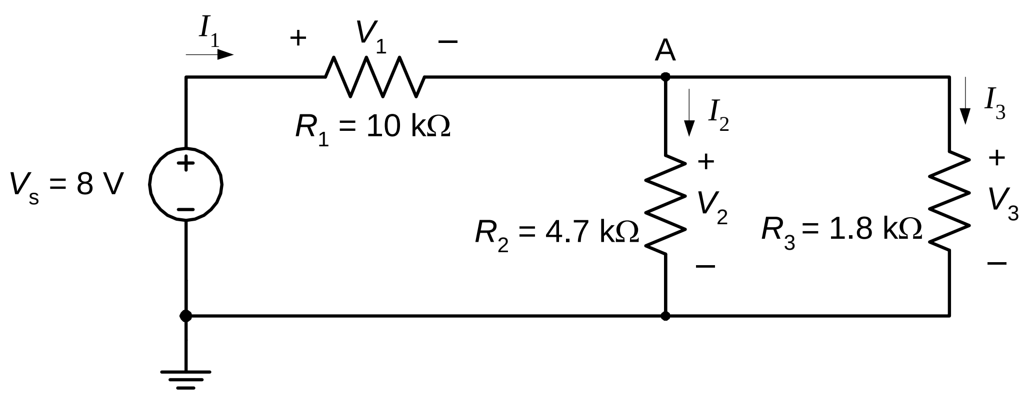

Figure 4. Parallel and series resistors.

<u>Lab Experiment C:</u>

Provide the following table in your lab notebook to tabulate measured current values in Figure 4.

Table 15. Measured current values (circuit in Figure 4).

I_1 (mA)	I_2 (mA)	I_3 (mA)	% error in I_1

Using the same resistors that you used in the last section, construct the circuit shown in Figure 4. Measure the currents I_1, I_2, and I_3 by measuring the voltages V_1, V_2, and V_3 and using Ohm's law. Do the measured currents in this circuit satisfy Kirchhoff's current law at node A? Using the measured values, calculate the percentage error in KCL defined with respect to the current I_1 as

$$\%\text{ error in KCL} = \frac{I_1 - (I_2 + I_3)}{I_1} \times 100$$

IV. Conclusion

Write a couple of paragraphs to summarize the following items:

1. What was the objective of this experiment and was the objective achieved?
2. Did your measured values agree with the theoretical values? What was the maximum % error in your calculations?
3. What sources of error may have contributed to the differences between the theoretical values and the measured values?
4. Other comments relevant to this experiment.