EGR 182 — Introductory Mathematics for Engineering Applications

Lab 4: Getting Started with Electric Circuits

California Baptist University

Fall Semester 2019

Number of Lab Periods: 2

Report Due: By beginning of Lab 5 (in two weeks)

1 Objectives

It is essential that all engineers have an understanding of the fundamental laws and concepts of electricity. In this lab, you will become familiar with two fundamental laws of electricity, i.e., Ohm's Law and Kirchhoff's Voltage Law. In addition, you will practice using some devices, equipment, and instrumentation typically encountered in an electronics lab. Some of these include the power supply, breadboard, multimeter, and circuitry components such as resistors. The implementation of these instruments are introduced in this lab.

2 Two Fundamental Laws of Electricity

2.1 Ohm's Law

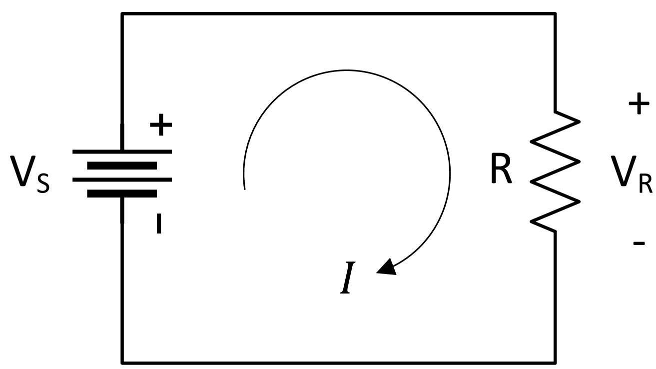

Figure 1: An electric circuit consisting of a voltage source ***V_s*** *and a resistive element* ***R***

Ohm's Law is a linear equation stating that the voltage across a resistor is equal to the current flowing through the resistor, multiplied by the value of that resistor. The following equation relates to Figure 1:

$$V_R = IR \tag{1}$$

The value V_R is the voltage across the resistor in volts (V), I is the current flowing through the resistor in amperes (A), and R is the resistance in ohms (Ω).

2.2 Kirchhoff's Voltage Law

Kirchhoff's Voltage Law states that the sum of the voltage rises is equal to the sum of the voltage drops in a closed circuit.

$$Voltage\ Rises = Voltage\ Drops$$

Therefore, for the circuit shown in Figure 1:

$$V_S = V_R = IR \tag{2}$$

3 Some Basic Equipment

A breadboard and resistors are two electrical components presented in this lab. The function of breadboards along with identification of resistor values will be reviewed. In addition, the usage of multimeters is introduced in this lab. Lastly, power supplies will be utilized in the circuit construction.

3.1 Breadboard

A breadboard is a medium to prototype a circuit. Circuit components are attached to the bread-board by inserting wires or leads into the small holes arranged in grids on the board. Since these components are not soldered in place, the pieces can be removed and the circuit easily changed. A standard breadboard is shown in Figure 2.

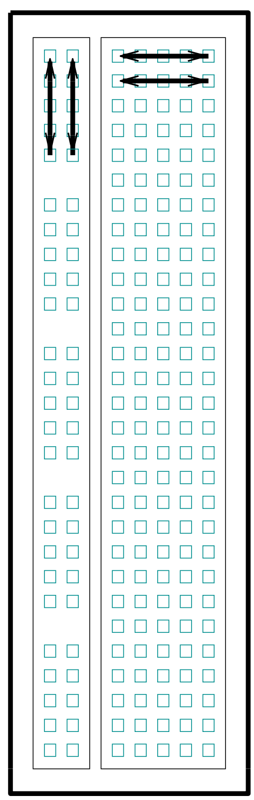

Figure 2: A standard breadboard layout

Inside the breadboard are metal contacts that connect the holes. These metal contacts join clusters of five holes together and are connected per the arrows shown in Figure 2. These clusters of five holes can be considered as one node.

3.2 Resistors

Resistors are electrical components that dissipate power as current passes through them. They are used to regulate the amount of current allowed to flow into succeeding components in the circuit.

All resistors have a maximum power limit. The tiny resistors used in lab are quarter watt resistors and the larger ones are one watt resistors. Because of physical size limitations for printing, a standard for defining resistor values has been developed. For the larger resistors, the value is printed right on the casing. This standard uses color coded bands that in conjunction with a chart, yield the resistor value. Figure 3 shows an example of a typical resistor defined by colored bands.

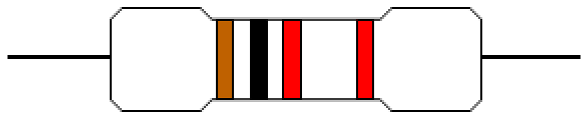

Figure 3: A 1kΩ resistor

The colored bands of this resistor correspond to the following Table 1 and Table 2. Reading from left to right, the first two bands give the first two digits of the resistor value. The third colored band is the multiplier. This value tells to what power of ten we multiply the first two digits. The resistor value in Figure 3 is found using Table 1 and Table 2 as follows:

- The Brown band corresponds to a 1.
- The Black band corresponds to a 0.
- The Red band indicates multiplying by 10^2.
- The next Red band indicates a tolerance of ±2%.

The value of this resistor is 10 times 10^2 resulting in 1000Ω with a tolerance of ±2%.

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

Table 1: Resistor color band values

Tolerance	±1%	±2%	±5%	±10%
Color	Brown	Red	Gold	Silver

Table 2: Resistor tolerance color band values

In practice, engineers use things called prefixes and scientific notation to indicate small or large numbers. Table 3 shows common prefixes and scientific notations used in electronics.

Number	**Name**	**Scientific Notation**	**Prefix**	**Abbreviation**
1,000,000,000	1 billion	10^9	giga	G
1,000,000	1 million	10^6	mega	M
1,000	1 thousand	10^3	kilo	k
0.001	1 thousandth	10^{-3}	milli	m
0.000001	1 millionth	10^{-6}	micro	μ
0.000000001	1 billionth	10^{-9}	nano	n
0.000000000001	1 trillionth	10^{-12}	pico	p

Table 3: Prefixes used in electronics

3.3 Multimeters

The multimeter is a basic tool for anyone working in electronics. It can be used to take a variety of electrical measurements, including DC, AC voltages and currents, resistance, etc. In this lab, the meters have four measurement modes, labeled on the face as follows:

- Ω = Resistance (ranging from *2M* down to *200* Ohms)
- V-- = Voltage, DC (ranging from *600* down to *200m* Volts)
- A-- = Current, DC (ranging from *10* down to *20μ* Amperes)
- V~ = Voltage, AC (ranging from *600* down to *200* Volts)

All multimeters come with a pair of test leads, one black and one red (black is for the ground connection; red is for the positive connection). Each test lead comes equipped with a metal probe. For measurement of voltage and current, the red lead may need to be plugged into different connectors (BE CAREFUL ABOUT THIS!). **Also, to keep from blowing the meter's fuse, select the desired measurement mode BEFORE touching the leads to the circuit!**

To measure the voltage across a component, the multimeter should be placed in parallel with the component whose voltage drop is being measured (see Figure 4). Note: If you in error connect up to the multimeter to take a voltage measurement but incorrectly have it on a current setting you will blow an internal fuse rendering your multimeter incapacitated for future measurements in your lab.

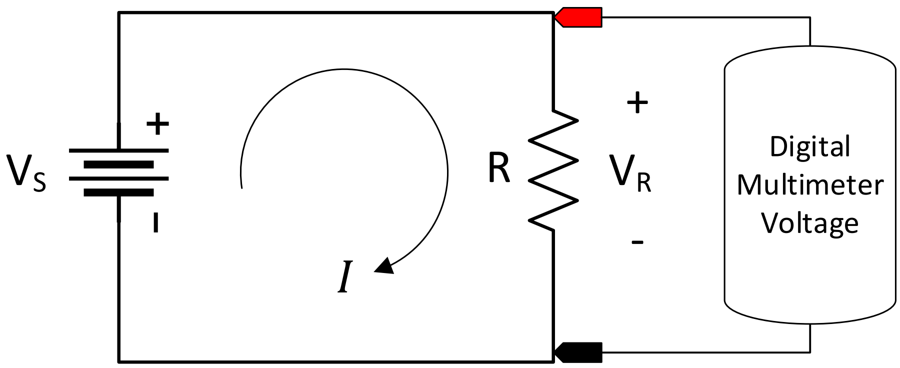

Figure 4: Using a multimeter to measure the voltage

To measure the current flowing through a component, the multimeter should be placed in series with the component (see Figure 5).

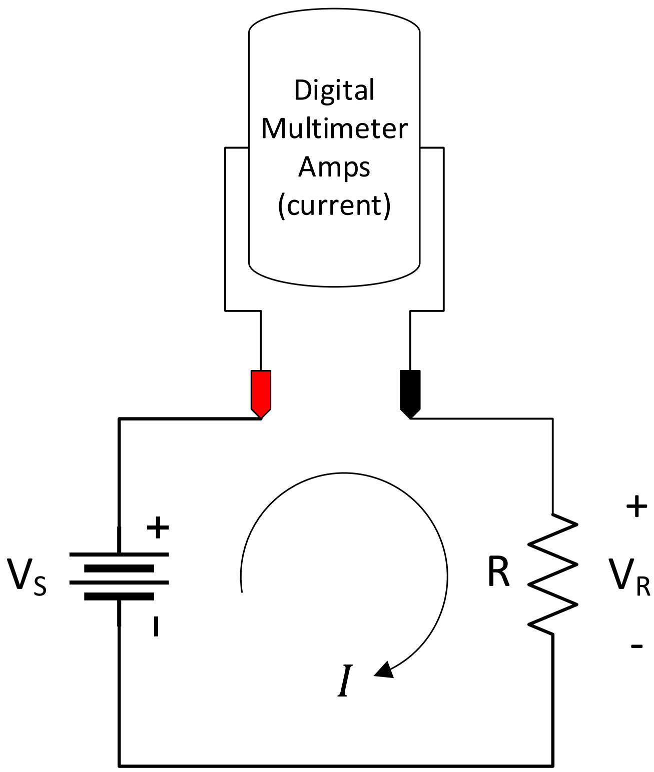

Figure 5: Using a multimeter to measure the current

4 Exercise 1 (Week 1)

In this lab, you are to construct the following simple circuit (see Figure 6) on a breadboard. Use the provided breadboard hook-up sketch (and accompanying predicted measurement calculations–also available on Blackboard). Here R_1=360Ω, R_2=360Ω, R_3=720Ω, and V_s = 6 V. Be sure to first measure and record the values of the resistors you use and the actual voltage value output by the power supply. Then power the circuit and use the multimeter to measure the voltages V_1, V_2 and V_3 across R_1, R_2 and R_3 respectively. Also measure the currents I_1, I_2 and I_3 flowing through R_1, R_2, and R_3

respectively. Fill in the table of measurements below. Show your circuit and your measurements to the instructor. *(Hint: For* $R_3 = 720\,\Omega$ *which is not readily available as a discrete resistor component in the lab, you may use a series connection of two* $360\,\Omega$ *resistors to form* R_3*)*

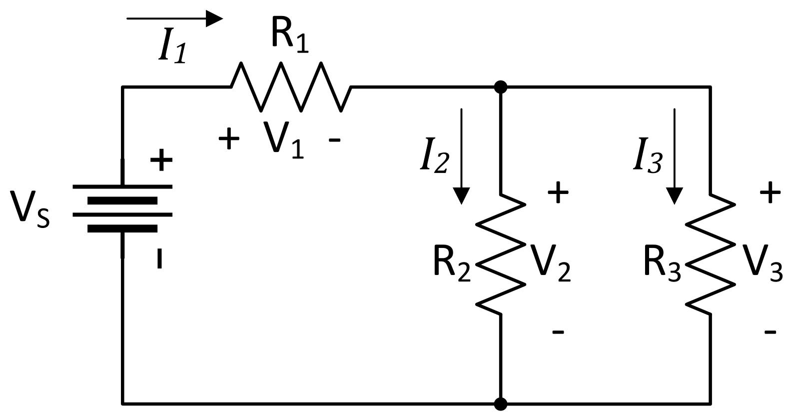

Figure 6: The circuit for the lab exercise

Measured Values						
Resistance (Ω)		Voltage (*V*)		Current (*mA*)		
R_1		V_{R_1}		I_{R_1}		
R_2		V_{R_2}		I_{R_2}		
R_{3A}		$V_{R_{3A}}$		$I_{R_{3A}}$		
R_{3B}		$V_{R_{3B}}$		$I_{R_{3B}}$		

Table 4 Measurements for circuit of Fig. 6 (R_3 formed by two 360 Ω resistors in series)

5 Exercise 2 (Week 1)

Disassemble the circuit from Exercise 1 and build the circuit shown in the attached Handout 2. Set $V_s = 6$ V, as before. Measure all of the voltage and current measurements for each resistor, as before. Record the data and present it in a table in your report. Note: in order for this to be correct, ensure you are using the same physical resistor for R_1 as before in the above circuit.

Measured Values			
Voltage (*V*)		Current (*mA*)	
V_{R_1}		I_{R_1}	
V_{R_2}		I_{R_2}	
$V_{R_{3A}}$		$I_{R_{3A}}$	
$V_{R_{3B}}$		$I_{R_{3B}}$	

Table 5 Measurements for circuit in handout 2 (R_3 formed by two 360 Ω resistors in parallel)

6 Exercise 3 (Week 1)

Create a MATLAB script m-file to make the calculations shown in the attached Handout 1B. Don't use semi-colons at the end of equations, so that the answers will be echoed on the command line.

In your report, attach a copy of the m-file and the printed results.

7 Exercise 4 (Week 2)

Build the circuit of Exercise 1 (shown in Handout 1A), but set Vs = 10V. Repeat all of the measurements done previously and record the data in a table in your report.

Measured Values						
Resistance (Ω)		Voltage (V)		Current (mA)		
R_1		V_{R_1}		I_{R_1}		
R_2		V_{R_2}		I_{R_2}		
R_{3A}		$V_{R_{3A}}$		$I_{R_{3A}}$		
R_{3B}		$V_{R_{3B}}$		$I_{R_{3B}}$		

Table 6 Measurements for circuit in handout 1 (R_3 formed by two 360 Ω resistors in series)

8 Exercise 5 (Week 2)

Disassemble the circuit from Exercise 4 and build the circuit shown in the attached Handout 2. This time, set Vs = 10 V. Measure all of the voltage and current measurements for each resistor, as before. Record the data and present it in a table in your report.

Measured Values			
Voltage (V)		Current (mA)	
V_{R_1}		I_{R_1}	
V_{R_2}		I_{R_2}	
$V_{R_{3A}}$		$I_{R_{3A}}$	
$V_{R_{3B}}$		$I_{R_{3B}}$	

Table 7 Measurements for circuit in handout 2 (R_3 formed by two 360 Ω resistors in parallel)

9 Exercise 6 (Week 2)

Create a second MATLAB script m-file to make the calculations shown in the attached Handout 1B – but using V_s = 10 V. Don't use semi-colons at the end of equations, so that the answers will be echoed on the command line. In your report, attach a copy of the m-file and the printed results.

10 Requirements—What You Must Do

1. Build the circuits as described in the Exercises and make the measurements in Table 4 (Resistance, Voltage, and Current)–for each circuit.
2. Create and submit your lab report
   (a) Use the Sample Lab Report from Lab 1 as a template (just the headings, not the words!)
      i. Two students are to work as a team to work on the lab exercises. The team submits one lab report.
   (b) Use the Lab Report Requirements document as a guide (on Blackboard)
      i. Include an Abstract that answers the 2 questions all Abstracts should cover

   ii. Make sure to include all the lab's objectives in the Introduction
   iii. Also be sure to talk about the key equations used in this lab

(c) Type out the measurements data into tables, and put them in the appropriate section of the report.
   i. Give some discussion about the data vs. the two key equations.

(d) You should also include hand-drawn sketches of the two types of circuit schematics (from Handouts 1A, 2) which you refer to in your report, but attach at the end of the document. Do not merely attach a copy of the handouts, rather, create your own hand-drawn version of the circuits. Create schematics only—not the breadboard layout.
   i. Indicate the voltages and currents in the diagrams.

(e) Attach two MATLAB files and the printouts showing the calculations.