THE GEORGE WASHINGTON UNIVERSITY

WASHINGTON, DC

SCHOOL OF ENGINEERING AND APPLIED SCIENCE
DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING
ECE 2110: CIRCUIT THEORY LABORATORY

Experiment #1:
Introduction to Lab Equipment: Power Supply, DMM, Breadboard, and Multisim

EQUIPMENT

Lab Equipment	*Equipment Description*
(1) DC Power Supply	Keysight E36311A Triple Output DC Power Supply
(1) Digital Multimeter (DMM)	Agilent 34460A/Keithley Model 175 Digital Multimeter (DMM)
(1) Breadboard	Prototype Breadboard
(2) Test Leads	Banana to Alligator Lead Set

Table 1 – Equipment List

COMPONENTS

Type	*Value*	*Symbol Name*	*Multisim Part*	*Description*
Resistor	200Ω	R_1	Basic/Resistor	---
Resistor	3.9kΩ	R_2	Basic/Resistor	---
Resistor	4.7MΩ	R_3	Basic/Resistor	---

Table 2 – Component List

OBJECTIVES

- To install Multisim on your personal computer
- To determine a resistor's resistance and tolerance using the resistor color code
- To measure a resistor's resistance with the Agilent 34460A Digital Multimeter (DMM) and find the percent error between the measured value and its rated value
- To use a solderless prototype bread board
- To determine a resistor's resistance by measuring the voltage across and current through the resistor using the DMM and an Agilent power supply

INTRODUCTION

Understanding how to use the equipment in the lab and how that equipment works is vital to succeeding in any laboratory class, but it is especially important in circuit theory. The equipment is where any lab starts and what makes the experiments possible. The power supply, digital multimeter (DMM), and breadboard will be used in almost every lab this semester as well as any future circuit or electronics based labs you take. Becoming familiar and comfortable with each of them will allow us to spend less time in future labs getting our experiments set up and more time actually building and analyzing the circuits we are interested in observing.

Introduction to the DC Power Supply

A power supply is an electronic device that supplies electric power to a circuit. In any circuit, there needs to be some power source, and the DC power supply will be the source we use throughout the semester.

Figure 1 – KEYSIGHT E3611A Triple Output Programmable DC Power Supply

The Basics:

- The power supply in lab has three outputs with limits of 6V, +25V, and -25V.
- The display of the power supply shows all three outputs' voltages and currents that are supplied. The upper values show what is being supplied, while the bottom values show what has been set.
- These devices allow you to set specific voltage and current values for the output.
    - This can be done either with the "Voltage" and "Current" knobs, or can be typed in with the keypad and the "Enter" button. **Make sure you have the correct setting highlighted before you make any changes. Also note that the current limit should *always* be set at or below 100mA for safety.**

Introduction to the Digital Multimeter (DMM)

A digital multimeter is a multipurpose electronic measurement device that is generally capable of measuring voltage, current, and resistance. The DMM will be used to make all DC measurements.

Figure 2 – Keithley 175/Agilent 34460A Autoranging Digital Multimeter

The Basics:

- The DMM can measure voltage (V), current (A), and resistance (Ω).
- There is an auto-range feature available for voltage and resistance but not for current.

Introduction to the Breadboard

We use solderless breadboards (**Figure 3**) to connect components and build circuits in ECE 2110. In a circuit, the legs or leads of components are placed in the holes (sockets). The holes are made so that they will securely hold the component in place. Each hole is connected to one of the metal strips, depicted in green (**Figure 4**), running beneath the board.

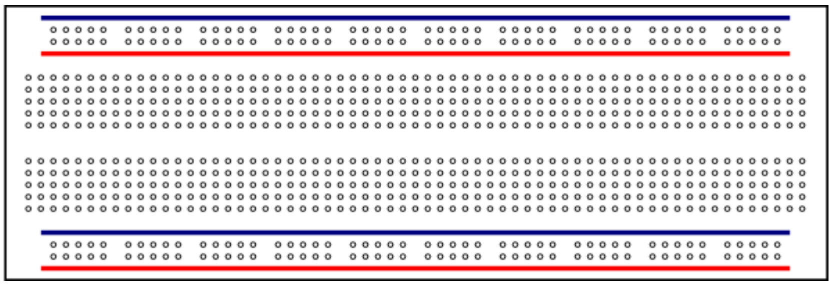

Figure 3 – Physical Top View of Breadboard

There are four rows or strips connecting the holes on the top of the board and several columns in the middle. Each row and column forms a node. A node is a point in a circuit where two or more components are connected. On the breadboard, a node is the row or the column of holes that are connected by the strip of metal underneath.

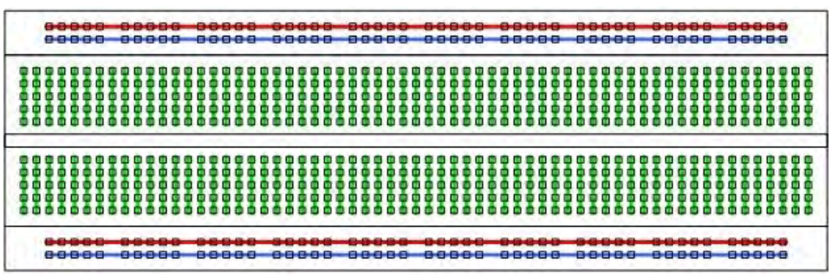

Figure 4 – Breadboard Internal Connections

The long top and bottom row of holes are usually used for power supply connections. The rest of the circuit is built by placing components on the breadboard and connecting them together with jumper wires. When a path is formed by wires and components from the positive supply node to the negative supply node, we can turn on the power, and current flows through the circuit.

Chips with many legs (ICs) are placed in the middle of the board so that their legs are on different nodes.

PRELAB

Part I – Resistor Color Code

1. **Download** and **Print** the color code: http://www.seas.gwu.edu/~ecelabs/appnotes/rcc/rcc.html

Color		*Value*	*Multiplier*	*Tolerance*
	Black	0	1	
	Brown	1	10^1	1%
	Red	2	10^2	2%
	Orange	3	10^3	
	Yellow	4	10^4	
	Green	5	10^5	0.5%
	Blue	6	10^6	0.25%
	Violet	7	10^7	0.1%
	Gray	8	10^8	
	White	9	10^9	
	Gold		10^{-1}	5%
	Silver		10^{-2}	10%
	None			20%

Table P.1 – Resistor Color Code

2. **Resistance Reading Steps:**
   a. Find the **tolerance band**, which is typically gold (5%) or silver (10%), and hold the resistor such that this band is at your right-hand side.
   b. Starting from the other end, identify the first band at your left-hand side. Write down the number associated with that color. For example, in the case of blue, write down '6.' Then, identify the color band next to it, and write down the number associated with that color. For example, if it were the color red, write down '2.' The first two bands are called **digit bands**.
   c. Read the third or **multiplier band** and write down that number of zeroes. For example, if the band is green, multiply the number indicated by the **digit bands** with 10^5.
   d. The resistance of the resistor in this example, color-coded by 'blue-red-green-gold" is $62x10^5\Omega = 6.2M\Omega \pm 5\%$.

   Tolerance Band: A perfect, linear resistor has a constant resistance independent of current, voltage, temperature, or other factors. In reality, no resistor is perfect. Therefore, in addition to their value, resistors are marked with an indication of inaccuracy, called tolerance, measured in percent. Most resistors have a tolerance of 5%, but if needed, resistors down to 1% are available. For example, if the nominal value is 100Ω and the tolerance is 5%, the measured value could be between 100 x 0.95 = 95Ω and 100 x 1.05 = 105Ω.

3. **Complete** the following table using the resistor color code:

Resistor Color Code	*Nominal Resistance* (Ω)	*Tolerance* (%)	*Minimum* (Ω)	*Maximum* (Ω)
red-red-black-silver				
brown-black-red-silver				
green-blue-brown-gold				
orange-blue-red-silver				
blue-gray-yellow-none				
green-red-green-silver				
gray-red-red-none				

Table P.2 – Resistor Color Code Practice

Part II – Scientific and Engineering Notation

1. **Understand** the difference between scientific and engineering notation.
    a. **<u>Scientific Notation</u>:** Compact representation of very large or very small numbers using powers of 10 (e.g. 31,000,000 could be written as 3.1×10^7 or 3.1E7)
    b. **<u>Engineering Notation</u>:** Similar to scientific notation, however, the exponent is always written as a multiple of three (e.g. 31,000,000 would be written as 31×10^6 or 31E6)
2. **Review** the following list of common prefixes used in engineering. Instead of writing out the exponent, these prefixes are used to describe the quantity.

Prefix	***Symbol***	***Factor***
tera	T	10^{12}
giga	G	10^{9}
mega	M	10^{6}
kilo	k	10^{3}
-----	-----	10^{0}
milli	m	10^{-3}
micro	µ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}
femto	f	10^{-15}

Table P.3 – Common SI Prefixes

3. **Complete** the last column of the table below about units of physical parameters.

Physical Parameter	***Primary Unit***	***Secondary Unit***	***Relationship Between Units***
Voltage (V)	Volt (V)	mV	1V= mV
Current (I)	Ampere (A)	mA, µA	1A= mA= µA
Resistance (R)	Ohm (Ω)	kΩ, MΩ	1Ω= kΩ= MΩ
Power (P)	Watt (W)	mW	1W= mW
Inductance (L)	Henry (H)	mH, µH	1H= mH= µH
Capacitance (C)	Farad (F)	µF, pF, fF	1F= µF= pF= fF

Table 6 – Common Units of Physical Parameters

4. **Write** the following values in proper engineering notation using the correct prefix and unit.

Given Form	***Proper Form***
0.005A	
59E6Ω	
45000mW	
62E-4V	
0.018kΩ	
47E-6F	
1.4E-5A	
0.0084mH	

Table P.4 – Practice with Common Units

LAB

Part I – Resistance Measurement

1. **Determine** the nominal resistor value and the nominal tolerance for the following resistors using the resistor color code: **R_1 = 200Ω**, **R_2 = 3.9kΩ**, **R_3 = 4.7MΩ**
2. **Measure** the actual value of each resistor with the Digital Multimeter (DMM):
   a. **Turn on** the Keithley 175 digital multimeter.
   b. **Set** the DMM to measure resistance by pressing the **Ohm** (Ω) button.
   c. **Enable** "**Auto Range**" in order to get the maximum number of significant digits during measurement.
   d. **Connect** the banana ends of the red and black banana to alligator test leads to the corresponding red and black terminals of the DMM.
   e. **Connect** an alligator end of the banana to alligator test leads on each side of the resistor.
   f. **Record** the resistance (value and units) shown on the DMM.
3. **Calculate** the **Percent Error** between the nominal and measured resistance values.
   a. For a given resistor, we can measure the percentage difference between its **nominal** (expected) resistance and **measured** resistance, which is called **percentage error**, using the following formula:

$$PE = \frac{|NV - MV|}{NV} * 100\%$$

Equation 1.1 – Percent Error (PE) Equation, Nominal Value (NV), Measured Value (MV)

4. **Complete** the table below using the steps described above.

Resistor	***Color Code***	***Nominal Resistance* (Ω)**	***Tolerance* (%)**	***Measured Resistance* (Ω)**	***Percent Error* (%)**
R_1					
R_2					
R_3					

Table 1.1 – Practice with Common Units

5. Do the measured values of the resistors fall within the tolerances indicated by the color code?
6. ***Show the GTA your completed Table 1.1 above before continuing with the rest of the lab.***

Part II – Solderless Prototype Breadboard

1. **Use** the **Ohm function** of the Keithley Model 175 to verify the connections of the breadboard.
   Hint: *If the resistance between two nodes in the board is 0Ω, that means that two nodes are connected. If the resistance is too high (Over Limit), two nodes are not connected.*
2. ***Call the GTA over to show how you verified the breadboard's connections.***

Part III – Resistance Determination Using Voltage and Current

The DMM can also be used to measure **voltage across** and **current through** a device. In this part of the lab, we will attach a resistor to the power supply and measure voltage and current to determine its resistance using Ohm's Law.

$$V = IR$$

Equation 3.1 – Ohm's Law

1. **Before** building any circuits, set the DC power supply to 1V.
2. **Set** the power supply to have a **100mA** current limit.
3. **Build** the following circuit using the breadboard, resistor **R_1 = 200Ω**, and the power supply.

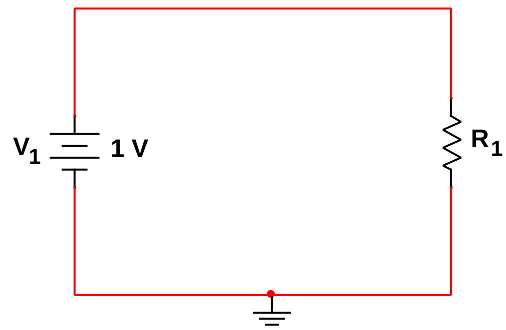

Figure 3.1 – Circuit Schematic

5. **Set** the DMM to Voltage mode and **attach** the alligator leads to measure the voltage **across** R_1.
6. Press the **ON** button to turn on the power supply and record the **voltage across** R_1. (If you are using Channel
   One, use the Yellow **ON** button.
7. **Turn off** the power supply's output.
8. **Attach** the DMM to measure the **current through** R_1 by **breaking the circuit** .
9. ******Show your GTA how you will be attaching the DMM prior to turning on the circuit.******
   a. Many students BLOW the 2A fuses on the DMM during this step. Be cautious, and show your GTA before continuing.
10. **Turn on** the power supply output and record the **current through** R_1.
11. **Repeat** steps 5-10 above replacing R_1 with resistors R_2 and R_3.

Resistor	***Voltage Across* (V)**	***Current Through* (A)**	***Calculated Resistance* (Ω)**	***Measured Resistance From Part I* (Ω)**	***Percent Error* (%)**
R_1					
R_2					
R_3					

Table 3.1 – Lab Measurement Results

12. **After** completing the measurements, **calculate** the resistance of each resistor. Simply divide the measured voltage by the measured current. **Record** this value in column 4 of the table above.
13. **Compare** the calculated resistance to the measured resistance found in Part I of this lab.

14. **Record** this comparison as percent error in column 6 of the table above.
15. ***Show your GTA the completed Table 3.1 before continuing.***

Part IV – Multisim Introduction

1. **Review** the "**Introduction to Multisim**" tutorial on the ECE 2110 website.
2. **Build** the following circuit in **Multisim**.

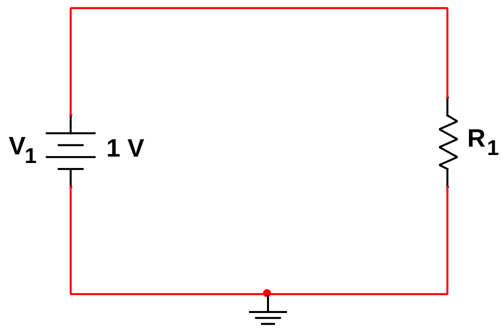

Figure 4.1 – Multisim Circuit Schematic

3. Perform a **DC Operating Point** simulation in **Multisim**.
4. **Record** the values for the **voltage across** R_1, the **current through** it, and the **power dissipated** by it, in the table below.
5. **Repeat** the simulation for R_2 and R_3.

Resistor	*Voltage Across* (V)	*Current Through* (A)	*Power Dissipated* (W)	*Calculated Resistance* (Ω)	*Measured Resistance From Part III* (Ω)
R_1					
R_2					
R_3					

Table 4.1 – Simulation Results

<u>POST-LAB ANALYSIS</u>

Installing Multisim

1. **Read** the tutorial on the lab website entitled "**<u>Installing Multisim at Home</u>**" under the tutorials section.
2. **Download** and **install** Multisim on your personal computer.
3. **Familiarize** yourself with simulating circuits in **Multisim** as it will be necessary for the next prelab.

Lab Report

1. Be sure to follow the **<u>Formal Lab Report Template</u>** and **<u>Instructions</u>** provided on the ECE 2110 website.
2. The lab report for this lab will be graded to give you feedback on how to properly write a formal lab report; however, this grade will not factor into your final lab grade.