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) AD2 Board	Analog Discovery 2
(1) Digital Multimeter (DMM)	Harbor Freight Model 63759 Handheld Digital Multimeter
(1) Breadboard	Prototype Breadboard
(1) 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	1.8MΩ	R_3	Basic/Resistor	---

Table 2 – Component List

OBJECTIVES

- To install Multisim on your home computer
- To determine a resistor’s resistance and tolerance using the resistor color code
- To measure a resistor’s resistance with the 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 the AD2.

INTRODUCTION

Understanding how to use the Analog Discovery 2 is going to be vital to succeeding in circuit theory. The AD2 is where any lab starts and what makes the experiments possible. The AD2, digital multimeter (DMM), and a breadboard will be used in almost every lab this semester, and possibly in future circuit- or electronics-based labs you take. Becoming familiar and comfortable with it will allow us to spend less time in future labs getting our experiments set up and more time 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 AD2 will be the source we use throughout the semester.

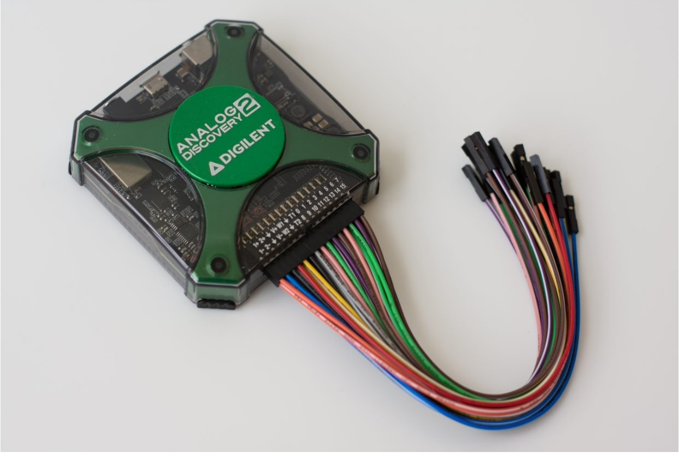


Figure 1 – Analog Discovery 2

The Basics:

- The AD2 provides up to +5V and -5V power supplies
- All the pins on the AD2 and its adapter are labeled, and each pin has a specific output. These outputs can be found in the AD2's manual. That manual can be found HERE.
- The AD2 can be managed using Digilent's "Waveform" software. It has multiple tabs that can be accessed and controlled, including a waveform generator, voltmeter, and power supply (which is the device used in this lab).

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 – Basic Handheld Multimeter

The Basics:

- The DMM can measure voltage (V), current (A), and resistance (Ω).
- It has three connections at the bottom right. The first is for DC current between 200mA and 5A. The second is for voltage, resistance, and DC current under 200m. The third is for ground, also known as common.

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.

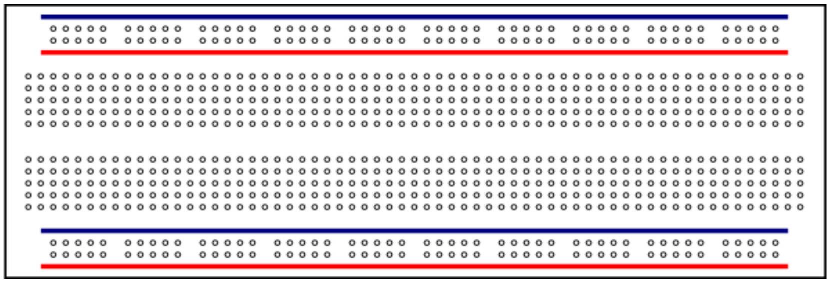


Figure 3 – Physical Top View of Breadboard

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.

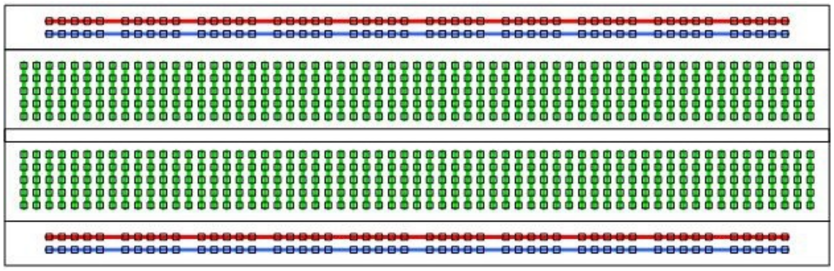


Figure 4 – Breadboard Internal Connections

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: https://blogs.gwu.edu/ecelabs/files/2016/07/resistorcharts-2d7s1jm.pdf

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 the band is 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 62x10^5Ω = 6.2MΩ ± 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 = 1.8MΩ**
2. **Measure** the actual value of each resistor with the Digital Multimeter (DMM):
   a. **Plug in** your leads into your multimeter. Black goes to common (COM), and red goes to VΩ. Each port should be labeled.
   b. **Turn** the dial of the multimeter to Ω. The multimeter's range is manually set by the position of dial. The range should always be higher than the value you are attempting to measure. For R_1, the range is 2000 Ω.
   c. **Turn on** the multimeter by switching the ON/OFF switch to ON.
   d. **Connect** an alligator end of the banana to alligator test leads on each side of the resistor.
   e. **Record** the resistance (value and units) shown on the DMM.
   f. **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 Prototyping Breadboard

1. **Use** the 200 **function** of your multimeter 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.*

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. **Build** the circuit shown below. The "V+" pin is the positive terminal and the ⬇ pin is ground.
2. **Open** the Waveforms application on your computer. Ensure that your AD2 is plugged into the computer as well.
3. **Click** on the tab labeled "**Supplies**".
4. **Ensure** the "Positive Supply (V+) Rdy" is set to 1V.

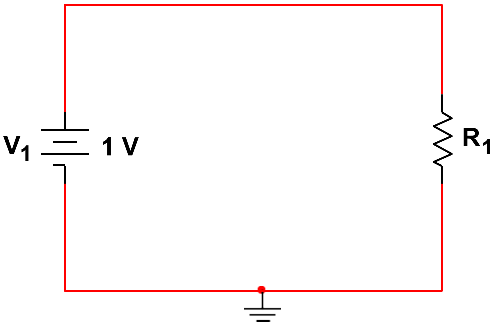
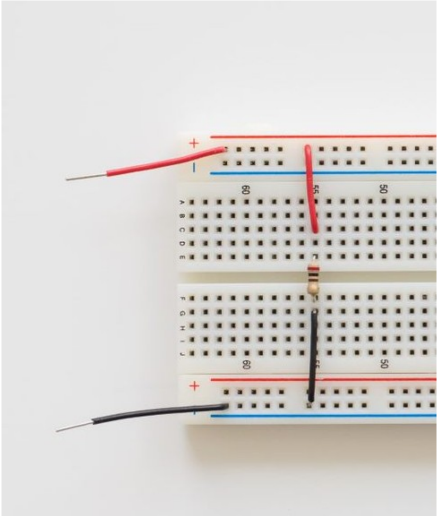


Figure 3.1 – Circuit Schematic



5. **Set** the DMM's dial to 20 DCV and turn it on
6. **Attach** the alligator leads to each side of the resistor.
7. **Click** the play button on the "Supplies tab" and **Record** the voltage in Table 3.1 below.
8. **Click** the stop button on the "Supplies tab" to turn off the 1V.
9. **Attach** the DMM to measure the **current through** R_1 by **breaking the circuit**.
    a. **Disconnect** the alligator leads from your circuit before adjusting the DMM.
    b. **Switch** to **DCA** on your DMM. You will need to manually set the range.
    c. **Break the circuit** at the point you wish to measure current.
    d. **Connect** the DMM in **series** with your circuit

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

10. . ******Show your GTA how you will be attaching the DMM prior to turning on the circuit. ******
    a. Many students BLOW the fuses on the DMM during this step. Be cautious and show your GTA before continuing.
11. **Turn on** the power supply output and record the **current through** R_1 in Table 3.1 above
12. **Repeat** steps 5-11 above replacing R_1 with resistors R_2 and R_3.
13. **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.
14. **Compare** the calculated resistance to the measured resistance found in Part I of this lab.
15. **Record** this comparison as percent error in column 6 of the table above.

Part IV – Multisim Introduction

1. **Review** the "**Introduction to Multisim**" tutorial on the ECE 2110 website.
2. **Connect** to the SEAS ECE Virtual Lab
    a. Go to https://gwu.apporto.com/
    b. Login with your GW NetID and password
    c. Launch the SEAS ECE Lab. A virtual Windows 10 desktop will load in your browser
    d. Launch MultiSim 14.2
3. **Build** the following circuit in **Multisim**.

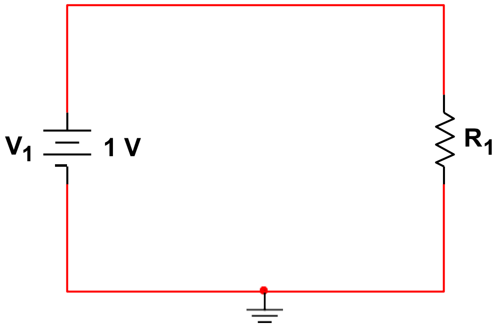


Figure 4.1 – Multisim Circuit Schematic

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

Table 4.1 – Simulation Results

POST-LAB ANALYSIS

Installing Multisim

1. **Follow** the instructions on the SEAS Computing Facility website entitled "**How to Get Multisim**"
2. **Download** and **install** Multisim on your home 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 **Formal Lab Report Template** and **Instructions** 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.