Student's Name: **Date:**

Introduction to Circuit Analysis Laboratory

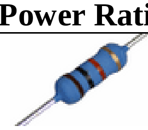
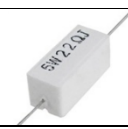
Lab Experiment 2

Resistors: Power rating, Color code, Resistance Measurements, Potentiometers

Part 1 – Resistors and Color Coding

Resistors are electronic components that introduce a specific amount of resistance into electric circuits. If you went to the store to buy a resistor you would have to know the required power rating, the required resistance value, the tolerance you can allow, and the material that the resistor should be made of.

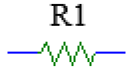
The power rating of a resistor is an indication of how hot the resistor can get before burning up. Power rating is expressed in watts. Some common power ratings range from 200W down to 1/8 W. Usually, the power rating of a resistor is directly proportional to the physical size of the resistor: the higher the power rating, the bigger the physical size of the resistor. Carbon composition resistors are very popular. These resistors come in power ratings of 2W, 1W, 1/2W, 1/4W and 1/8W. The 2W resistor is as thick as a pencil while the 1/8W resistor is the size of a grain of rice. Figure 2.1 shows the different size of resistors and its respective power rating.

Resistors and Power Rating					
					
1/8 W resistor	¼ W resistor	½ W resistor	1 W resistor	2 W resistor	5 W resistor
Table 2.1 – Resistors with difference power rating					

1.1 Resistance representation

The resistor is usually identified by the letter R and either another letter or a number. Its resistance value is written next to it. The unit for the resistance value is the ***ohm***, which is represented by upper case Greek omega (**Ω**). It is customary to use the omega next to resistor values smaller than 1,000 ohms. Resistor values in the 1,000-ohm range or bigger are usually shown without the ohm symbol. Examples: 10 Ω, 330 Ω, 1.2 kΩ, 1 MΩ.

R1



1 kΩ

1.2 Resistor Color Code

The value of the resistor in ohms and its tolerance are usually indicated by several bands of color grouped together on the left side of the resistor body. Most resistor has 4 bands together, the first and second band indicate the first two significant figures of the resistor value, the third band indicates the multiplier and the fourth band indicates the tolerance. Usually, the first three bands are close together and the fourth band is a little bit apart.

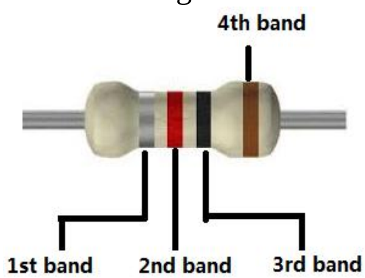


Figure 2.1 – Resistor with four color bands

Resistors that have more than four colors, the other colors usually indicate the reliability (failure rate) of the resistor in % over 1000 hours of operation. It means how many resistors out of 100 will change their values to fall outside the allowed tolerance range after 1000 hours of operation. Also, some resistors with five colors means that the three first colors are the three resistance digit respectively, the forth color is the multiplier, and the fifth band is the tolerance.

In order to indicate resistor values, manufacturers agreed to use the following value for each color:

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

Table 2.2 Color code for resistance value

Tolerance	Color
20%	**No color**
10%	**Silver**
5%	**Gold**
4%	**Yellow**
3%	**Orange**
2%	**Red**
1%	**Brown**
0.5%	**Green**
0.25%	**Blue**
0.1%	**Violet**
0.005%	**Gray**

Table 2.3 Color code for tolerance

Reliability (failure rate) is indicated by the following colors.

Reliability (failures)	**1/100 (absolute)**	**1/1,000 (absolute)**	**1/10,000**	**1/100,000**
Color	**Brown**	**Red**	**Orange**	**Yellow**

Table 2.4 Color Code for Reliability (failures) per 1,000 hours of operation

Example 2.1 – Finding the resistance value using color coding

For the following resistor,  read the resistance value of the following resistor and find the lowest and highest resistance value

Solution:
Identify the order of the color band and read the equivalent value for each color:

- 1^{st} band = Blue = **6**
- 2^{nd} band = Gray = **8**
- 3^{rd} band = Red = **2**
- 4^{th} band = Gold = $\pm$ **5%**

Combining all digits together, we have **6 8** $\times$ **10^2** $\pm$ **5% Ω**

Converting the value in engineering notation, we have $6.8 \times 10^{2+1} = 6.8 \times 10^3$

6.8 k Ω $\pm$ 5% (Actual resistance value)

To find the lowest and the highest resistance, we find the tolerance resistance first:

$$Tolerance\ resistance = 5\%\ of\ 6.8\ k\Omega = \left(\frac{5}{100}\right) \times 6.8\ k\Omega = \mathbf{0.34\ k\Omega}$$

Lowest resistance = actual resistance – tolerance resistance = 6.8 kΩ – 0.34 kΩ = **6.46 kΩ**

Highest resistance = actual resistance + tolerance resistance = 6.8 kΩ + 0.34 kΩ = **7.14 kΩ**

1.3 Electrical test equipment: multimeter

Multimeters are the most common piece of electrical test equipment. They have the ability to measure voltage, current, resistance, and often many other function such as checking the reverse biasing of a diode.

Understand the multimeter parts

Multimeter typically has a set of terminal sockets marked as VΩ, A, COM, and a function selector switch, measure dial, or set of push buttons to select ranges and measurement functions as shown in Figure 2.2

Terminal socket **VΩ** stands for Volts and Ohms, which are the electrical unit of voltage and resistance, respectively. This terminal is used to measure voltage and resistance. Terminal **A** stands for Ampere, which is the unit for electric current. This terminal is used to measure current. Some multimeters have **mAVΩ** in one socket and some others have them separated as **VΩ** and **A.** The terminal **COM** stands for common terminal and it is the common terminal for all measurements.

The function selector switch or measure dial has different measurement positions, the most of the basic

multimeter has five selections: two **V** settings, two **A** settings, and one **Ω** setting. The two settings, one have a pair of short horizontal lines, one solid line above one dashed line ⎓. This pair of parallel lines represent "DC", direct current. In other words, if you want to measure dc voltage, your measure dial must be position among the dc volts **V**⎓. The other setting has a wave ∿ which represents "AC", alternating current. If you want to measure ac voltage, the measure dial must be position among the ac volts **V**∿

The multimeter comes with testing leads or probes. There are many different testing probes available for multimeter. Some of the most common probes use in lab for multimeters are:

- Banana to alligator clips: good to connect large wires or pins on a breadboard.

- Banana to IC hook: good to work on smaller ICs and legs of ICs.

- Banana to test probes: good to work on one test measurement.

The red test lead is plugged in the **VΩ** or **A** socket and the black lead is plugged in the **COM**. As reference, the black lead is always plugged in the common socket.

1.4 Resistance Measurement using a multimeter DMM

Reading resistance using a multimeter is very simple:

- To begin, make sure that no current or voltage is running through the resistor or circuit.
- Set the multimeter to read resistance. Always try to set the DMM to read the highest resistance and then gradually adjusted the dial until it reads the resistance.

  Figure 2.2 shows the setup of a simple DMM to measure resistance. Also from Figure 2.2, the Display window shows “1” meaning “Open Circuit” or that the meter leads are not connected to everything. Open Circuit reading is different from meter to meter, some meters show OL (Over-Loaded) to represent an open circuit.

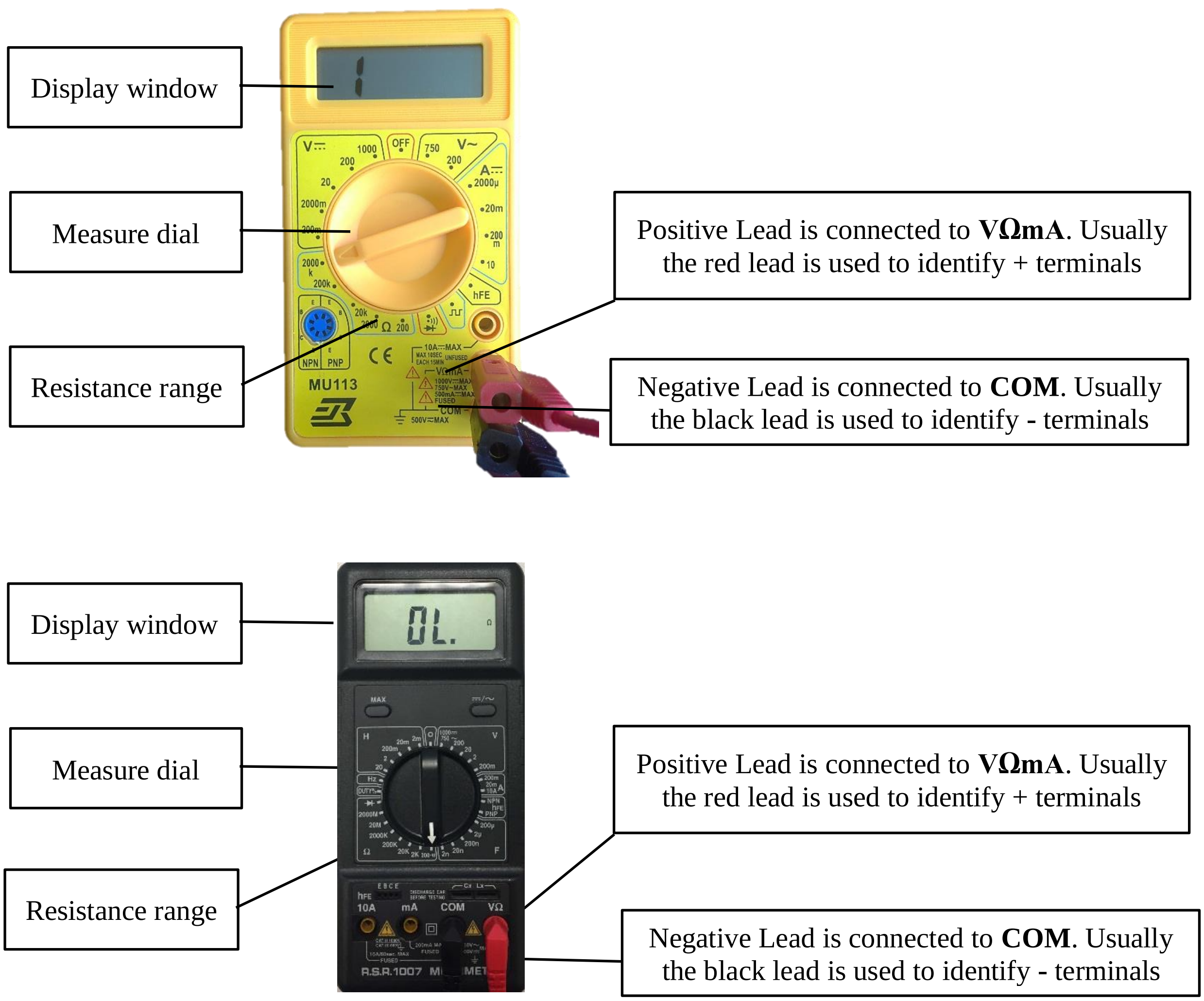


Figure 2.2 – DMM set to measure resistance

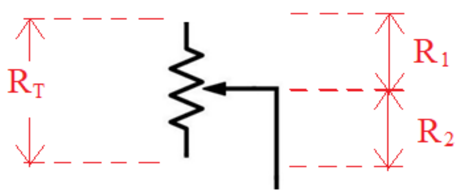
- Place the measurement leads parallel to the resistor.

Figure 2.3 – Resistance Measurement

- Record measurement from DMM's display window.

1.5 Variable Resistance: Potentiometer, POT

A potentiometer is a variable resistor that has 3 terminals. The value of a potentiometer is the maximum resistance of the potentiometer. This means that a potentiometer can be set between any resistances from around 0 Ω to its maximum resistance. As shown in Figure 2.4, the 2 outside terminals are connected to the ends of a distributed resistor. The middle terminal is connected to a wiper arm that moves along the resistor as the shaft is turned or as the slider is moved. The wiper arm always divides the total potentiometer resistance into 2 parts so that the total resistance is always the sum of the two parts.



$$R_T = R_1 + R_2$$

Figure 2.4 - Potentiometer

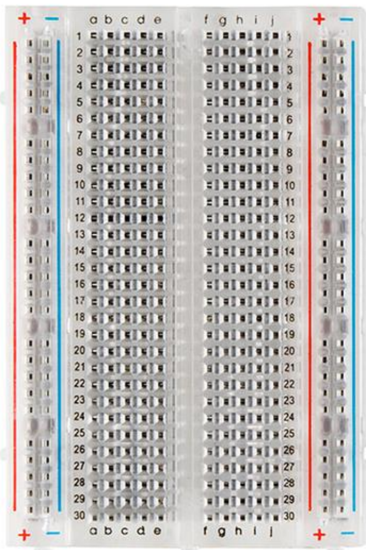
There are 2 types of potentiometers (also abbreviated as 'pots'). One has a linear distribution of resistance while the other has a logarithmic distribution. The linear potentiometer is said to have a 'linear taper' while the logarithmic potentiometer is said to have an 'audio taper'. The reason for the audio taper name is that the human ear responds logarithmically to sound energy. Audio taper pots are used in volume controls while linear taper pots are used in balance controls.

A potentiometer is linear if it measures half the total resistance when the wiper arm is set in the middle. If the resistance in the middle setting is not half the total, then the pot is logarithmic.

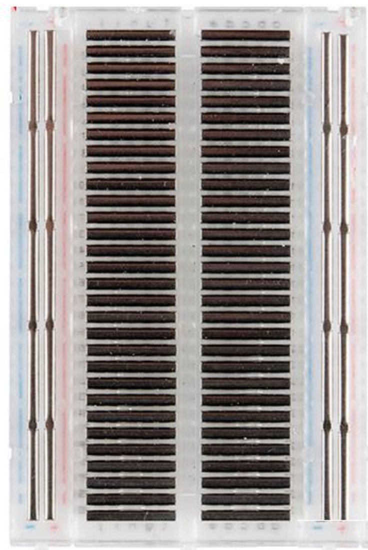
Potentiometers also have power ratings. Usually, the bigger (physically) the potentiometer, the more power it can handle (it can get hotter without burning up).

Part 2 – Breadboard/Protoboard

The protoboard that will be used in this lab is a very simple plastic block with holes onto which circuit elements are plugged in and interconnected. In order to use it properly, you must understand its construction. This particular protoboard has two lines of holes on each long side of the board. 0n each long side, one is identified with a red line (labeled with a +), and one with a blue line (labeled -). All the holes in each long line of holes are connected together underneath the board. Each line of connection is known as a *node*. In other words, there is a short circuit between any two holes on any long outside line that is identified with red or blue. In the middle (running the long way), there is an indentation in the board. This indentation separates the two halves of the board. Each line of 5 holes on either side of the indentation is a short circuit. Each five holes on either side of the indentation are connected together. Check Figure 2.6 for reference.



Protoboard Front View



Protoboard Internal Connections

Figure 2.6 - Protoboard Connections

Lab Experiment Procedure

Part 1 – Resistors and Color Coding

Exercise 2.1 – Resistance reading using color coding

Given the following nominal or actual resistance, find the color of each band, the tolerance resistance, and the maximum and minimum resistance. Record all results in Table 2.5

	Nominal Value	**1st band**	**2nd band**	**3rd band**	**4th band**	**Tolerance resistance**	**Minimum resistance**	**Maximum resistance**
A	57 Ω ± 20%							
B	0.68 Ω ± 5 %							
C	260 kΩ ± 0.25%							
D	3.9 MΩ ± 10%							

Table 2.5 – Resistance Reading and Color Coding

Show Calculations Here

Exercises 2.2 – Measuring the resistance value using a DMM

a. Using the table below, pick one resistor from each column. Circle your choice

Resistor 1, R_1	Resistor 2, R_2	Resistor 3, R_3	Resistor 4, R_4	Resistor 5, R_5
240 kΩ	15 kΩ	1.3 kΩ	470 Ω	47 Ω
430 kΩ	18 kΩ	1.5 kΩ	560 Ω	120 Ω
470 kΩ	27 kΩ	1.8 kΩ	620 Ω	150 Ω
560 kΩ	47 kΩ	3.6 kΩ	680 Ω	270 Ω
1 MΩ	68 kΩ	3.9 kΩ	820 Ω	390 Ω

b. Obtain the five resistors from step a. from your components' kit.
c. Write the actual resistance in Table 2.6.
d. Prepare a DMM to measure resistance. Remember to set the resistance reading to the highest resistance first.
e. Using as reference Figure 2.3, measure each resistor and record its resistance value in Table 2.6. Write your measurement in engineering notation with its respective prefix and unit.
f. Find the *Percent of Difference %* using the following formula and write the answer in Table 2.6.

$$\% \; of \; Difference = \left(\frac{Resistance_{Actual} - Resistance_{Measured}}{Resistance_{Actual}}\right) \times 100 \;\%$$

Resistor	Measured Resistance	Actual Resistance	Percent of Difference %
R_1			
R_2			
R_3			
R_4			
R_5			

Table 2.6 – Measured resistance value using a DMM

g. Turn off the DMM and place the resistors back to the components' kit.

Part 2 - Potentiometer

Exercises 2.3 – Potentiometer

a. From your component kit, take all the potentiometers for examination.

b. Look at the value code of the potentiometer (check Figure 2.5) and write its resistance value in increasing order: _______________ , ___________ , ____________, _____________ , ____________

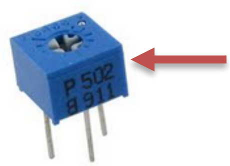
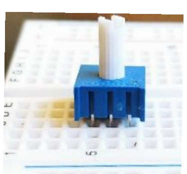


Figure 2.5 – Potentiometer value code location

c. Place a 50 kΩ potentiometer in a breadboard as the following



d. Turn on the DMM and set it to the appropriate resistance range to measure 50 kΩ. Measure the different nodes and record measurement in Table 2.7

Node	Measured Resistance
5 to 6	
6 to 7	
5 to 7	

Table 2.7 Potentiometer

Exercises 2.3 – Protoboards

Obtain a protoboard from your components' kit. Have a look at the protoboard and complete Table 2.8 using as reference *Figure 2.6*.

Description	Number nodes	Number of connection in a node
Power supply nodes: Each long red or blue line		
Basic nodes: Each short line (on each side of the indentation)		

Table 2.8 – Protoboard Description

Part 3. Resistance Measurement Practice

Exercises 2.4 – Connected resistors

a. Obtain a 470 Ω, 330 Ω, 220 Ω, 47Ω, and 10 Ω from the components' kit.
b. Connect the resistors together as a chain in the protoboard. Check Figure 2.7.

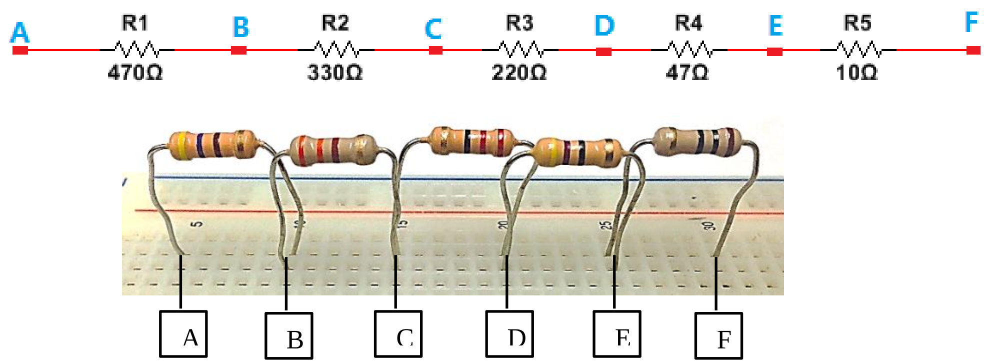


Figure 2.7 – Connecting resistors together as a chain

c. Set the DMM to measure resistance.
d. Measure from node to node according to Table 2.9. To measure from node to node, it is always recommended to use the DMM measurement leads as reference. For example, if you are measuring from node A to node B, then the red lead of the DMM is connected to A and black lead to B.

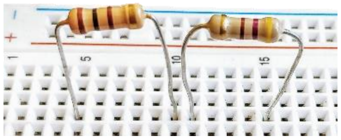
Node	Measured Resistance Value (include unit)
A to B	
A to C	
C to A	
F to C	
F to A	
B to D	
C to E	
F to E	

Table 2.9. Resistance measurement in a chain resistivity circuit

Turn off all lab and testing equipment, dissemble the circuit, and place all components back in the lab kit. Answer the following lab questions.

Questions

1. A student was building a circuit with two resistors, 100 Ω and 470 Ω, connected in a chain as the following:

   Now she turned on the ohmmeter and measured the resistance from Node 5 to Node 15. The meter read: OL. Why the DMM display OL? Justify your answer

2. A technician measured a resistor with an ohmmeter and got a reading of 940 Ω. The resistor was color coded Gray Green Brown Silver. Explain whether the resistor is within specifications.
3. If the resistor in the previous question had only three colors (Gray Green Brown), how would it affect your previous answer?

***Answers*:**

Student's Name: ______________________Lab instructor's signature _______________Date______________

-- **LAB EXPERIMENTS ENDS HERE** --