COLLEGE OF ENGINEERING AND MINES
DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

COURSE CODE	EE F102 F01 (CRN: 34544)
COURSE NAME	INTRODUCTION TO ELECTRICAL AND COMPUTER ENGINEERING

SEMESTER	SPRING	**YEAR**	2022

LABORATORY LOCATION	ELIF 331 (ELECTRONICS LAB)
LAB SESSION DATE AND TIME	MONDAY 24 JAN 2022

TYPE OF SUBMISSION	LABORATORY REPORT	**NUMBER OF SUBMISSION**	1

TITLE OF SUBMISSION	MEASURING RESISTANCE
METHOD OF SUBMISSION	ONLINE TO: maher.albadri@alaska.edu

DUE DATE OF SUBMISSION	MONDAY 31 JAN 2022	**DUE TIME OF SUBMISSION**	23:59

STUDENT NAME	

MAKE THIS FORM A "COVER PAGE" FOR YOUR REPORT SUBMISSION.

FOR THE TA USE ONLY

REMARKS:

Measuring Resistance

Objective
In this lab we will gain experience using a multimeter. We will learn how to measure resistance. We will characterize the operation of a thermistor over temperature. We will also characterize the possible variations for resistors around their nominal value.

Equipment
Agilent 34401A Multimeter Thermometer
Hot water
Ice

Resistors
Resistors come in a variety of different types from the very small chip resistors (see Figure 1[f] to the very large power resistors (see Figure 1[a]). Some resistors have a fixed value and some have a value that is variable. Variable resistors may be varied mechanically like the potentiometer (see Figure 1[g]) or due to other external parameters like temperature (i.e., thermistor, see Figure 1[h]) or light (i.e., photoresistor). Resistors are defined by their resistance value, power rating, tolerance, and sometimes temperature coefficient. The power rating of a resistor is often determined by the resistor size. The larger the resistor the more power it can dissipate. The resistance value and tolerance are given by colored bands printed directly onto the resistor or by printed numbers as is common for chip resistors (see Figure 2).

Table 1 gives the definitions for the colors used in the resistor color code. The color bands define the significant digits of the resistance value, multiplier, and the tolerance. For example, a 120 kΩ 5% resistor would have the color bands: brown = 1, red = 2, yellow = x 10 kΩ (i.e. 10^4), gold = 5%. The tighter tolerance of a 1% resistor requires an additional color band to show an additional significant digit. For example, a 274 kΩ 1% resistor has the color bands: red = 2, violet = 7, yellow = 4, orange = x 1 kΩ (i.e. 10^3), brown = 1%.

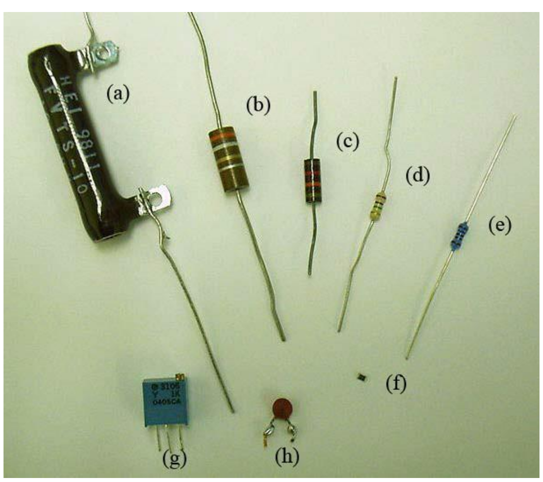

Figure 1: Resistors (a) 2 W fixed, (b) 1 W fixed, (c) 1/2 W fixed, (d) 1/4 W fixed 5%, (e) 1/4 W fixed 1%, (f) chip resistor, (g) potentiometer, (h) thermistor

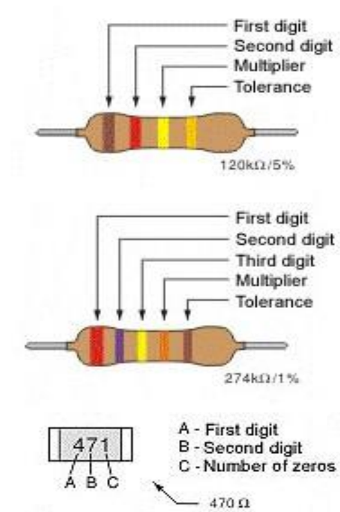

Figure 2: Resistor markings showing order of color bands

Table 1: Resistor color code

Color	Digit	Multiplier	Tolerance
Silver		x 0.01 Ω	±10%
Gold		x 0.1 Ω	±5%
Black	0	x 1 Ω	
Brown	1	x 10 Ω	±1%
Red	2	x 100 Ω	±2%
Orange	3	x 1 kΩ	
Yellow	4	x 10 kΩ	
Green	5	x 100 kΩ	±0.5%
Blue	6	x 1 MΩ	±0.25%
Violet	7	x 10 MΩ	±0.1%
Grey	8	x 100 MΩ	
White	9	x 1 GΩ	

Temperature Coefficient of Resistors

Inherent in all resistors is the variability of their resistance value over temperature. A first order (linear) approximation of the relationship between resistance and temperature is given by:

$$\Delta \boldsymbol{R} = \boldsymbol{k}\Delta \boldsymbol{T} \tag{1}$$

Resistors that are not thermistors (temperature dependent resistors or thermal resistors) are designed so that their resistance value changes only slightly, or not at all, with changes in temperature. In other words, non-thermal resistors have a very small *k*. A measure of the variability of the resistance over temperature is given by the temperature coefficient, α, of the resistor. The temperature coefficient of a resistor is defined as the *relative* change of resistance when the temperature is changed. Given the resistance value at a given temperature, T_0, and the temperature coefficient, α, for that resistor, the resistance value at a different temperature,

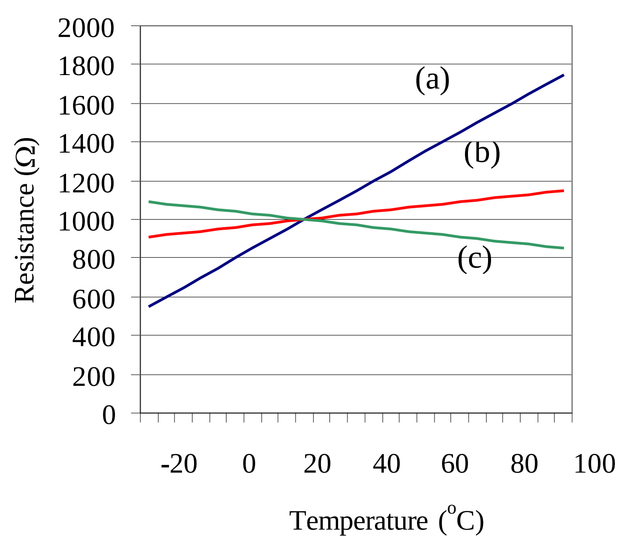

Figure 3: Resistance versus temperature for three different resistors.

T_1, is given by:

$$\boldsymbol{R_{T1}} = \boldsymbol{R_{T0}}[\boldsymbol{1} + \boldsymbol{\alpha}(\boldsymbol{T_1} - \boldsymbol{T_0})] \tag{2}$$

Examining equations (1) and (2) shows that $\alpha = k/R_{T0}$. In other words, k is the absolute change of resistance for a given temperature change while α is the relative change of resistance, i.e., relative to the resistance value where it is determined.

The temperature coefficient may be positive or negative. Figure 3 shows the resistance temperature relationship for three different resistors. Curve (a) has a large positive temperature coefficient (PTC), i.e., its resistance increases with increasing temperature. Curve (b) has a small positive temperature coefficient, and curve (c) has a small negative temperature coefficient. Each of these curves is linear so that k is a constant and is equal to the slope of the curve.

Both equations (1) and (2) are good approximations so long as the change of temperature is small. Thermistors are typically used over a wide range of temperatures and do not have a linear relationship between their resistance and temperature. This means that equations (1) and (2) are not good approximations of their resistance-temperature relationship. A better approximation is given in the thermistor datasheet and reproduced here:

$$\boldsymbol{R_{T1} = R_{T0} exp\left[B\left(\frac{1}{T_1} - \frac{1}{T_0}\right)\right]} \tag{3}$$

where R_{T1} is the resistance at absolute temperature (i.e., ˚K) T_1 and R_{T0} is the resistance at absolute temperature T_0. B is a constant depending on each thermistor and has units of ˚K. The exp(x) function represents e^x, where e is the irrational constant 2.718281828459. A thermistor's response to temperature is dependent on the type of material used in its construction. The thermistor we are using is the NTC-103. Review the datasheet provided in the Lab Introduction module for the parameters for B, R_{T0}, and T_0.

Hints for using the multimeter

The Null button allows you to make a relative measurement, i.e., **result = reading – null**. To null the test lead resistance for more accurate two-wire ohm measurements, short the ends of the leads together and then press NULL. This measurement will be stored in the NULL register. The null register is cleared when you: change functions, turn null off, and/or turn off the power.

Resistance Measurements

In lab

1. Identify the **four 680 Ω** resistors, **one 1 kΩ** resistor, and **one 47 kΩ** resistor in your parts kit.
2. Measure the resistance of each resistor and enter those values using the online spreadsheet file provided via Canvas. **Be careful to enter the value in the unit requested!**
3. In a table similar to that shown below, record the color band sequence and the measured resistance value for your specific resistors.

Component	Component Marking	Decoded Value	Measured Resistance	% Difference
Example	brn, blk, grn, gold	$10 \times 10^5 = 1$ MΩ 5%	1.018 MΩ	1.8%
Example	brn, blk, blk, brn, brn	$100 \times 10^1 = 1$ kΩ 1%	0.994 kΩ	0.66%

4. Measure the resistance of the thermistor at 3 different temperatures (**ambient, cold, hot**).
5. Record both the temperature at which the measurement is made and the resistance value measured and enter those values using the spreadsheet file provided via Canvas. **Be careful to upload the value in the unit requested!**
6. Record your specific measurements in a table similar to that shown below.

Measurement	Temperature	Measured Resistance	Expected Resistance	% Difference
Room Temp				
Cold				
Hot				

Out of lab

1. Decode the color code of your resistors measured in lab and recode the nominal (decoded) value in your table. Calculate the % difference between the measured value and the nominal value. The % difference is calculated with the following formula:

$$\%\boldsymbol{diff} = \frac{\boldsymbol{R_{mominal}} - \boldsymbol{R_{measured}}}{\boldsymbol{R_{nominal}}} \times \mathbf{100} \tag{4}$$

2. Download the class's measured resistor values and create a histogram for each resistor value measured by the class. You should have three histograms (680 Ω, 1 kΩ, 47 kΩ).
3. Using Equation (3) determine the expected resistance of your thermistor for the same temperatures that you measured the resistance at. Determine the %difference between your measured and expected values. Record these calculations in your table.

4. Download the class's measured values for the thermistor at the three different temperatures. Overlay the class's values on the theoretical plot you created.

Lab 1 report should contain

1. Objective(s) of the project.
2. Take the appropriate measurements and record the values in appropriate tables.
3. Create appropriate captions for each table.
4. Perform the appropriate calculations and record the results in tables
5. Create the three histogram plots requested.
6. Create the thermistor plot which should include the theoretical resistance versus temperature that you plotted and the class's three measured values from this lab *on the same plot*. Insert these plots into your document and provide appropriate captions.
7. Provide appropriate discussion of the measurements, plots, and tables (using cross- references) including equations used in calculations. Note only complex equations (like the thermistor equation) need to be formatted on a separate line with an equation number.
8. Discuss the histograms of the three resistors in terms of the nominal expected value and the tolerance.
9. Discuss the classes measured values for the thermistor in comparison with the theoretical curve.