UNIVERSITY OF ALASKA FAIRBANKS

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 14 FEB 2022		
TYPE OF SUBMISSION	LABORATORY REPORT	**NUMBER OF SUBMISSION**	4
TITLE OF SUBMISSION	TEMPERATURE SENSOR DESIGN		
METHOD OF SUBMISSION	ONLINE TO: maher.albadri@alaska.edu		
DUE DATE OF SUBMISSION	MONDAY 21 FEB 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:

TEMPERATURE SENSOR DESIGN

Objective

In this lab, you are asked to use what you have learned in the previous labs and in class to design a temperature sensor using **Thermistor** and **Arduino ATmega328p Microcontroller**.

Design

Your boss has told you to design a temperature sensor capable of measuring temperature over a range of **-20 ˚F to +70 ˚F**. Your officemate tells you that the company has a large stock of Arduinos and thermistors you can use. **Design a circuit containing your thermistor which will be connected to the A0 input of the Arduino. This circuit should be optimized to give a maximum voltage difference on A0 for the range of desired temperatures**.

Procedure

1. Build up the diagram shown in **Figure 1** using your lab kit components.

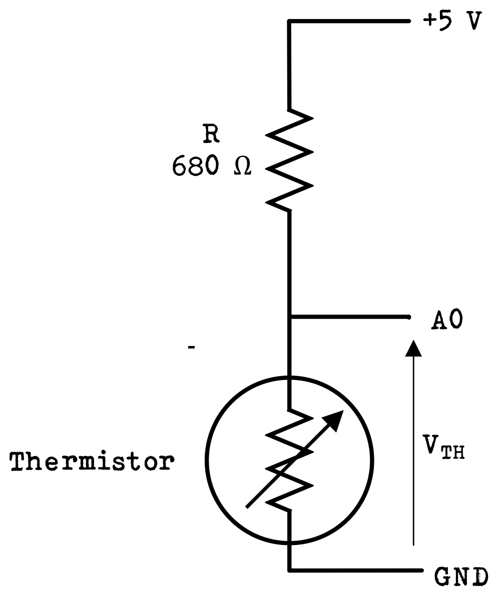


Figure 1. Circuit diagram.

The circuit should be similar to the one shown in **Figure 2**.

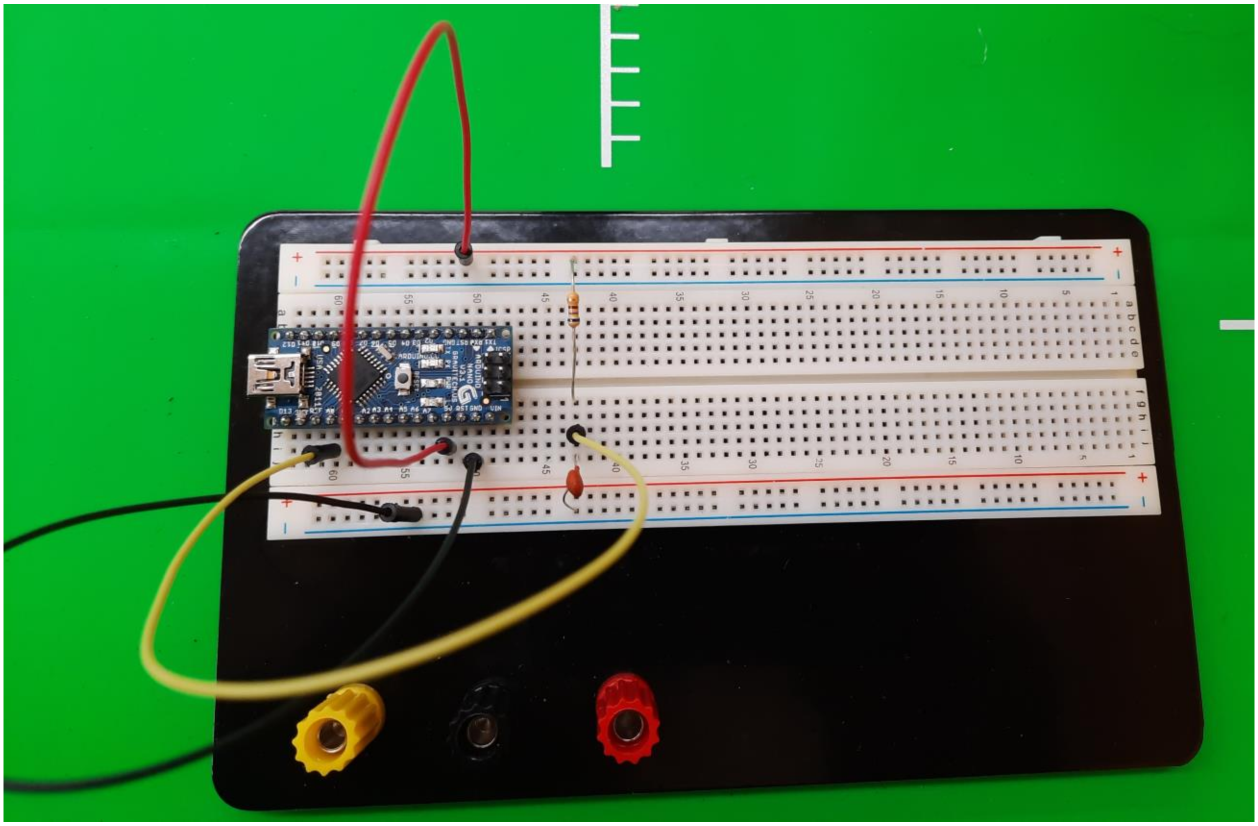


Figure 2. Built circuit.

This is a voltage divider system. We know that the thermistor changes its resistance (**R_{TH}**) according to the temperature (**T_{TH}**). When **R_{TH}** changes, it will change the voltage drop across itself, which is the voltage across **A0** and the ground point **GND** which are information that are fed to the microcontroller. Thus, we need to make this change in voltage to be processed in the microcontroller via a proper coding, which will finally produce the temperature information. This can be carried out using the following logic.

2. Check your thermistor model and look into the datasheet provided in the appendix of this document. Look at the graph seen in the datasheet. The temperature range is **-30°C** to **120°C**. Use the following formula to convert °C to °F:

$$\boldsymbol{{}^{o}F = \frac{9}{5}\,{}^{o}C + 32} \tag{1}$$

Thus, the range is **-22°F** to **248°F**. This confirms that Thermistor 103 meets the design requirements (**-20°F** to **70°F**).

3. For **Thermistor 103**, the following data are found:

Resistance (R_2) at 25 °C (Ω)	**B Constant 25/50 °C (K)**	**Resistance Temp (T_2) Coeff 25 °C (%/°C)**
10,000	4,100	-4.6

4. We use the following formula, seen in the datasheet, which relates the temperature to the thermistor resistance.

$$\boldsymbol{R_{TH} = R_2 e^{B\left(\frac{1}{T_{TH}} - \frac{1}{T_2}\right)}} \tag{2}$$

The temperatures **T_{TH}** and **T_2**, in equation (2), must be in Kelvin. To convert from ℃ to K, we use the following formula,

$$\boldsymbol{K = {}^{o}C + 273.15} \tag{3}$$

5. The outcome of the previous step is the value of $\boldsymbol{R_{TH}}$ that corresponds to the variable temperature $\boldsymbol{T_{TH}}$. This value corresponds to the voltage across **A0** and the ground point **GND**, let's call it $\boldsymbol{V_{TH}}$. This relationship between $\boldsymbol{R_{TH}}$ and $\boldsymbol{V_{TH}}$ can be expressed by the voltage divider rule, as follows:

$$\boldsymbol{V_{TH} = 5\text{ V}\,\frac{R_{TH}}{R_{TH} + R}} \tag{4}$$

6. Equation (4) indicates that by measuring the voltage $\boldsymbol{V_{TH}}$, the resistance $\boldsymbol{R_{TH}}$ can be determined as follows:

$$\boldsymbol{R_{TH} = \frac{V_{TH} R}{5 - V_{TH}}} \tag{5}$$

7. Equation (2) will be used in equation to determine the thermistor temperature $\boldsymbol{T_{TH}}$. Equation (2) can be rewritten as follows:

$$\boldsymbol{T_{TH} = \frac{1}{\frac{1}{B} ln\left(\frac{R_{TH}}{R_2}\right) + \frac{1}{T_2}}} \tag{6}$$

8. Convert **K** to **℃** by using (7)

$$\boldsymbol{{}^{o}C = K - 273.15} \tag{7}$$

9. Convert **℃** to **℉** by using (1)
10. All previous steps are to be coded into the microcontroller.
11. Thus, use the code seen in **Figure 3** as a guide to write your own code. You can create your own comments for each coding line based on your understanding.

temp_sensor | Arduino 1.8.19 (Windows Store 1.8.57.0)

File Edit Sketch Tools Help

temp_sensor

```
/*
 * EE F102 Spring 2022
 * Laboratory 4
 * Temperature Sensor Design
 */
//component constants
int B = 4100;
int R2 = 10000;
float T2 = 298.15;
int R1 = 680;
float Vcc = 4.8; //measured between 5V and GND pins

void setup() {
  //setup serial connection
  Serial.begin(9600);
}

void loop() {
  // put your main code here, to run repeatedly:

  int tempVal = analogRead(A0); //sample temperature
  Serial.print("Temp sample: ");
  Serial.print(tempVal);

  float tempVolt = tempVal*Vcc/1023; //convert analog sample to voltage
  Serial.print("\tTemp voltage: ");
  Serial.print(tempVolt);

  float tempRes = tempVolt*R1/(Vcc-tempVolt); //convert voltage to thermistor resistance
  Serial.print("\tTemp resistance: ");
  Serial.print(tempRes);

  float tempKel = 1.0/((log(tempRes/R2)/B+(1.0/T2))); //convert thermistor resistance to temperature in Kelvin
  Serial.print("\tTemp in Kelvin: ");
  Serial.print(tempKel);

  float tempCel = tempKel - 273.15;
  Serial.print("\tTemp in Celsius: ");
  Serial.print(tempCel);

  float tempFahr = tempCel*9/5 + 32; //convert temperature in Kelvin to Fahrenheit
  Serial.print("\tTemp in Fahrenheit: ");
  Serial.print(tempFahr);

  Serial.print("\n");
  delay(2000);

}
```

Done Saving.

Figure 3. Lab 4 sketch.

12. **Run** the program and collect at least **10 different temperatures**. You can change the thermistor temperature by merely touching it.
13. **Tabulate** your data and include them into your report. **The table shall have a proper caption**.
14. Now, try to use your **Lab 3** skills to assign two different LEDs that respond to two different temperatures (*High* and *Low*). For example RED for high temperature, and GREEN for low temperature. To achieve this, you will need to add similar setup of Lab 3 to this lab setup. You will also need to add similar code of Lab 3 to the current code of this lab.
15. Once you are successful, use your smartphone to take two photographs of your setup that shows both cases (Red and Green lights). **Add the 2 photographs to your report with captions**.
16. **Copy** the program's modified code and paste it into your report.
17. Also, **include a screenshot of your code into your report with a proper caption**.

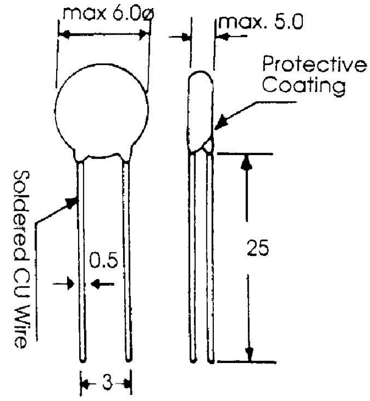
Question

1. Discuss how this design was optimized based on the chosen 680 Ω. Meaning, what change would happen if we choose the 1 kΩ resistor instead of the 680 Ω.

NTC THERMISTOR

Model No.	Resistance at 25˚C(Ω)	B Contant 25/50˚C (K)	Resistance Temp. Coeff 25˚C(%/˚C)
NTC-700	70	3,100	-3.5
NTC-900	90	3,100	-3.5
NTC-101	100	3,100	-3.5
NTC-121	120	3,100	-3.5
NTC-151	150	3,100	-3.5
NTC-201	200	3,100	-3.5
NTC-221	220	3,100	-3.5
NTC-251	250	3,100	-3.5
NTC-271	270	3,100	-3.5
NTC-301	300	3,100	-3.5
NTC-401	400	3,100	-3.5
NTC-501	500	3,100	-3.5
NTC-681	680	3,500	-3.9
NTC-102	1,000	3,800	-4.3
NTC-152	1,500	3,800	-4.3
NTC-202	2,000	3,800	-4.3
NTC-252	2,500	3,900	-4.4
NTC-302	3,000	3,900	-4.4
NTC-402	4,000	3,900	-4.4
NTC-502	5,000	3,900	-4.4
NTC-682	6,800	3,900	-4.4
NTC-103	10,000	4,100	-4.6
NTC-153	15,000	4,100	-4.6
NTC-203	20,000	4,200	-4.7
NTC-303	30,000	4,200	-4.7
NTC-503	50,000	4,200	-4.7
NTC-683	68,000	4,400	-4.9
NTC-104	100,000	4,400	-4.9
NTC-154	150,000	4,400	-4.9
NTC-204	200,000	4,500	-5.1
NTC-304	300,000	4,500	-5.1
NTC-504	500,000	4,600	-5.2

FOR TEMPERATURE COMPENSATION
5..ø NTC SERIES



* Resistance Value allowable difference.

J	K	L	M
±5%	±10%	±15%	±20%

. B-Constant deviation : ±10%(Calculated by R25 & R50)
. Thermal dissipation factor : 6.5mw/C
. Thermal time constant : 20 sec.
. Operating temp. range : - 30˚ ~ + 130˚C
. Max. Allowable power (25˚C): 0.55W

Jameco Part Number 207036

PHYSICAL PROPERTIES

RESISTANCE - TEMPERATURE CHARACTERISTICS

of the termistors is the relation between resistance & temperature, the expression as follows:

(1) R1=R2 exp B (1/T1 - 1/T2)

WHERE : R1 is the resistance value at absolute temperature T1
R2 is the resistance value at absolute temperature T2
B is a constant depending on each thermistor

(2) According to the above formula, B can be expressed by:
B=Ln(R1/R2)/(1/T1 - 1/T2)

TEMPERATURE COEFFICIENT OF RESISTANCE

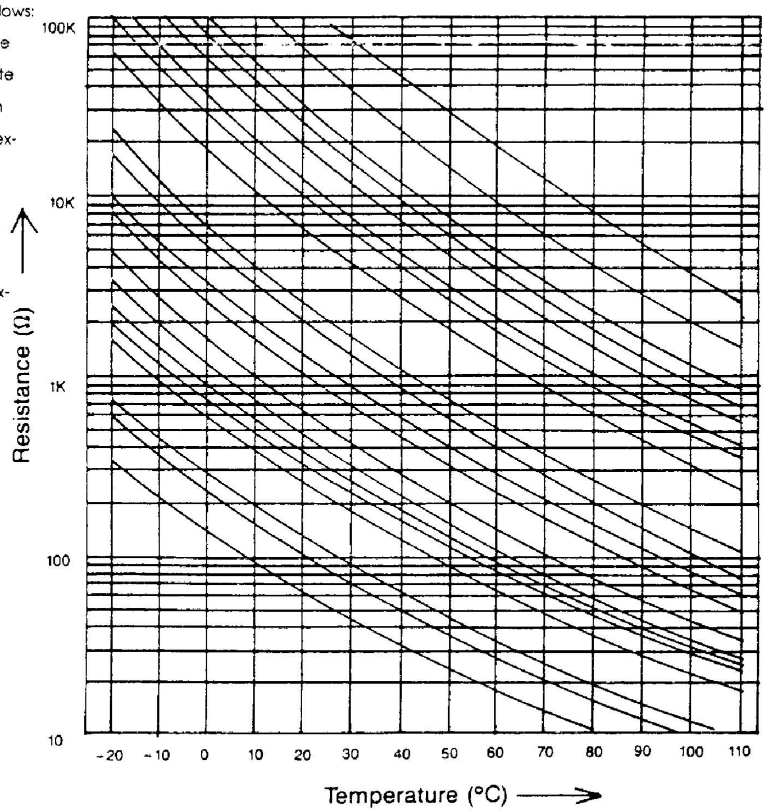
(α) originates from the above formula (1), the expression as follows:
α = - B/T ₂

DISSIPATION CONSTANT

(δ) is defined for power in milliwatts necessary for rasising temperature of the thermistor by 1˚C, as follows:
δ =P/Δt (mW/˚C)
(P : POWER Δt: rasie temperature)

TIME CONSTANT (T.C.)

is regard as the time required for a thermistor to change 63% of the difference between its initial and final temperature.



NTC SENSOR Thermistors Assembly

HOW TO ORDER

NTC- A

Model No. Assembly