Oakland University
School of Electrical & Computer Engineering
Winter 2023
ECE 4721/5721
Professor Phares Noel, Ph.D., PE
Lab #4
Due on April 4, 2023
Laboratory located in EC 461

1. For this problem, refer to Listing 6.5 and 6.6 in Chapter 6 of the Textbook *Embedded Systems Fundamentals* as a guide. Build the circuit in *Figure 1 and* utilize the FRDM-KL25Z Development Board and associated peripherals to measure the temperature from the sensor and convert the sensed data to a digital value and display the values utilizing two (2) Seven Segment LED's.

   *Note: **See Appendix A** at the end of this document for additional information on completing this part.*

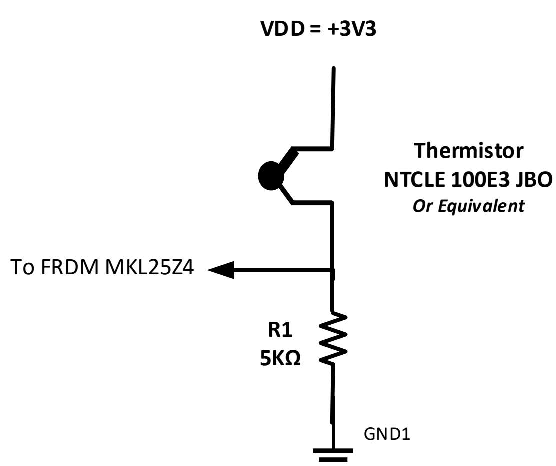

Figure 1.

2. For this problem refer to listing 6.1 1 and 6.12 in Chapter 6 of the Textbook *Embedded Systems Fundamentals* as guide. Utilize the circuit in *Figure 2*, and connect the IR Emitter, Optocoupler and RGB LED to the FRDM Development Board's input and output and utilize the Boards associated peripherals to detect the presence of objects. Have the appropriate LEDs to function as described in the section entitled *"Infrared Proximity Sensor"* found of page 174 of the textbook. You may also utilize the Development Boards internal RGB if you so choose.

   This circuit theoretically functions, in principle, as the same sort of proximity detector utilized in the automotive industry.

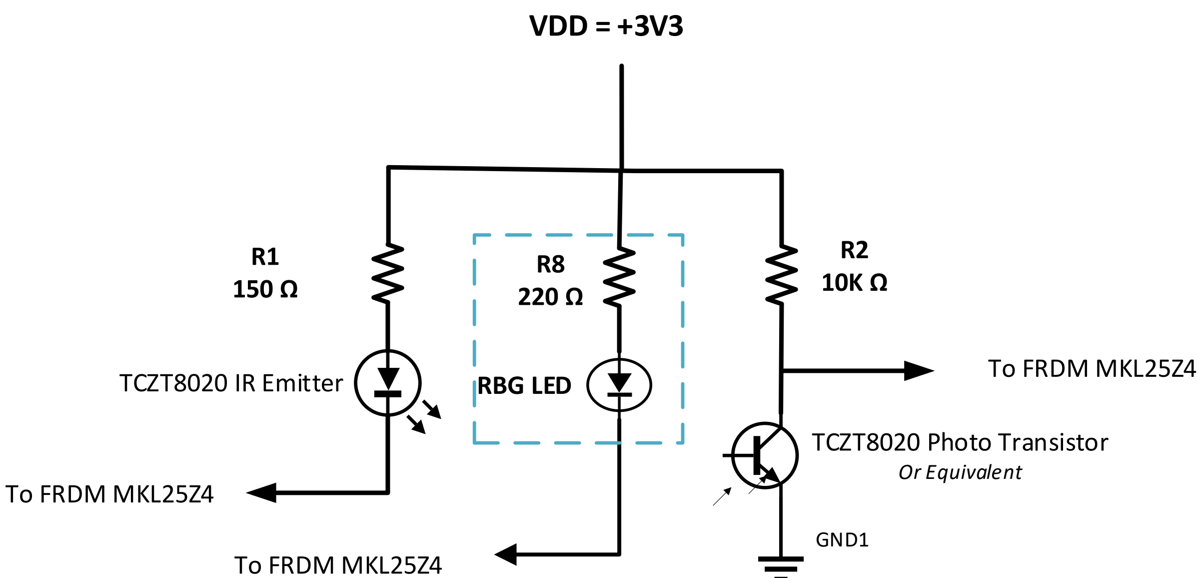

Figure 2.

Submit your project report, along with a copy of your fully commented Program Listing of your final designs, per the instructions issued for Lab Submittals. Failure to adhere to the Lab Submittal Guidelines will result in a deduction in your final score.

Grading Rubric

Note: *Submission must have mandatory Title Page with Name/Date, etc. per syllabus.* ***5 points*** *will be deducted from final score if not present in submission.*

Part 1, Thermistor (50 points)

25 points - Video demonstration of thermistor outputting the measured temperature to the 7-Segment display (submitted along with report)
10 points - Description of experiment
5 points - Full source code in report
5 points - Hardware Description (I/O pins used, external components, etc.)
5 points – Flow diagram explaining your implementation

Part 2, Proximity Sensor (50 points)

25 points - Video demonstration of the IR proximity sensor detecting an object at varying distances (submitted along with report)
10 points - Description of experiment
5 points - Full source code in report
5 points - Hardware Description (I/O pins used, external components, etc.)
5 points – Flow diagram explaining your implementation

APPENDIX A

Thermistor Datasheet Information

https://www.mouser.com/datasheet/2/427/VISH_S_A0012091193_1-2572478.pdf

FORMULAE TO DETERMINE NOMINAL RESISTANCE VALUES

The resistance values at intermediate temperatures, or the operating temperature values, can be calculated using the following interpolation laws (extended *"Steinhart and Hart"*):

$$R_{(T)} = R_{ref} \times e^{(A + B/T + C/T^2 + D/T^3)}$$

$$T_{(R)} = \left(A_1 + B_1 \ln \frac{R}{R_{ref}} + C_1 \ln^2 \frac{R}{R_{ref}} + D_1 \ln^3 \frac{R}{R_{ref}}\right)^{-1}$$

where:

A, B, C, D, A_1, B_1, C_1 and D_1 are constant values depending on the material concerned; see table below.

$R_{ref.}$ is the resistance value at a reference temperature (in this event 25 °C, $R_{ref.} = R_{25}$).

T is the temperature in K. T (°C) = T (K) - 273.15

Reference Page 9 Table Values

Our thermistor operates at about 25°C when R(t) = 1000 ohms. TCR = -3.87 (%/K). delta R / R due to B_{tol} = 0%.

Reference Page 2 Table Values

A 1000-ohm resistor has been chosen for our circuit, so we get $B_{25/85}$ = 3528 K

Reference Page 4 Table Values

Since $B_{25/85}$ = 3528 K we want row number 6. Looking at the footnote, since room temperature is typically < 25°C, we will use the top row (1) of number 6.

PARAMETER FOR DETERMINING NOMINAL RESISTANCE VALUES

NUMBER	$B_{25/85}$ (K)	NAME	TOL. B (%)	A	B (K)	C (K^2)	D (K^3)	A_1	B_1 (K^{-1})	C_1 (K^{-2})	D_1 (K^{-3})
6	3528 (1)	Mat I. with Bn = 3528K	0.5	- 12.0596	3687.667	- 7617.13	- 5.914730E+06	3.354016E-03	2.909670E-04	1.632136E-06	7.192200E-08
	3528 (2)			- 21.0704	11903.95	- 2504699	2.470338E+08	3.354016E-03	2.933908E-04	3.494314E-06	- 7.712690E-07

We can use "log" in C to get the natural log of a number, but don't forget to include the math library in your program. https://en.cppreference.com/w/c/numeric/math/log

Calculating Temperature from Thermistor

The thermistor used by the textbook is different from the thermistor included in the lab BOM, the conversion from an analog voltage to a temperature measurement must be modified. The datasheet for the NTCLE100E3102JBO thermistor specifies the following equation to solve for the temperature experienced at the thermistor:

$$T_R = \left(A_1 + B_1 \ln \frac{R_{therm}}{R_{ref}} + C_1 \ln^2 \frac{R_{therm}}{R_{ref}} + D_1 \ln^3 \frac{R_{therm}}{R_{ref}}\right)^{-1} \qquad (1)$$

Equation 1 solves for the current temperature based on the resistance of the thermistor itself. Where R_{ref} is the resistance of the thermistor at 25℃, for the NTCLE100E3102JBO $R_{ref} = 1000\Omega$. In order to calculate the thermistor value with relation to the reference resistor we must apply the voltage divider equation. Assuming that the input voltage to the circuit is 3.3V (Provided by the KL25Z) the voltage measured at the voltage divider is:

$$V_{out} = 3.3V \frac{R_1}{R_{therm} + R_1}$$

Solving for R_{therm} we get:

$$R_{therm} = R_1 \left(\frac{3.3V}{V_{out}} - 1\right) \qquad (2)$$

The constants for Equation 1 are provided in the above table for $B_{25/85}$ = 3528 K. The steps to calculate the temperature experienced by the thermistor are:

- Read the ADC value for the voltage between the thermistor and R_1
- Convert the ADC value into a voltage
- Solve for the resistance of the thermistor through Equation 2
- Apply Equation 1 with the constants from the previous page to solve for the temperature in Kelvin
- Convert Kelvin temperature to Celsius
- Output the result on the 7-segment display

EXAMPLE TITLE PAGE FOR LAB & HOMEWORK SUBMISSIONS

Oakland University
School of Electrical & Computer Engineering
Winter 2023
ECE 4721/5721
Embedded System Design

Title of

Lab Report
&/or
Homework Submissions

Student First & Last Name
Date of Submission