Covid-19 Safety Door

ECE 445 Design Document

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1 Introduction

1.1 Problem and Solution Overview

Due to the Covid-19 pandemic and how quickly it became a major issue across the globe, businesses have been rushed to create solutions that allow them to operate in a safe manner. As a result the most common way for businesses to monitor who enters their business is a manual process. Businesses will use one employee to sit outside of their entrances and take the temperature of patrons as they enter the business. This process is an inefficient use of resources, and can become quite costly especially for small businesses.

To cut small business costs, keep businesses safe, and create a more streamlined process we will build an automated COVID-19 temperature monitor for independent businesses. Our product will be a temperature sensor placed outside of business entrances. Rather than a human manually scanning individuals our product will instruct the patron how to properly and safely take their temperature. The device will then inform patrons they can enter if their temperature is in an appropriate range, the device will inform the patron and business if a patron who does not have an appropriate temperature attempts to enter. This product will cut small business costs significantly, speed up the process to enter buildings, and keep communities safe.

1.2 High Level Requirements

- The Thermawave Monitor must be able to accurately measure the temperature of a person within a tolerance of 0.35°F standing anywhere from 2 to 4 inches in front of the sensor. If not in range the user will be prompted to properly adjust.
- The signaling system must be able to easily notify the patron that they are not allowed entry if their temperature is considered to be a fever. Any temperature below 100.3°F will be considered safe[1], and any temperature below 96.0°F will be considered abnormally low and also not granted entry.
- The entire process of admittance, defined as someone getting their temperature taken and walking through the door, should take less than 30 seconds.

2 Design

2.1 Block Diagram

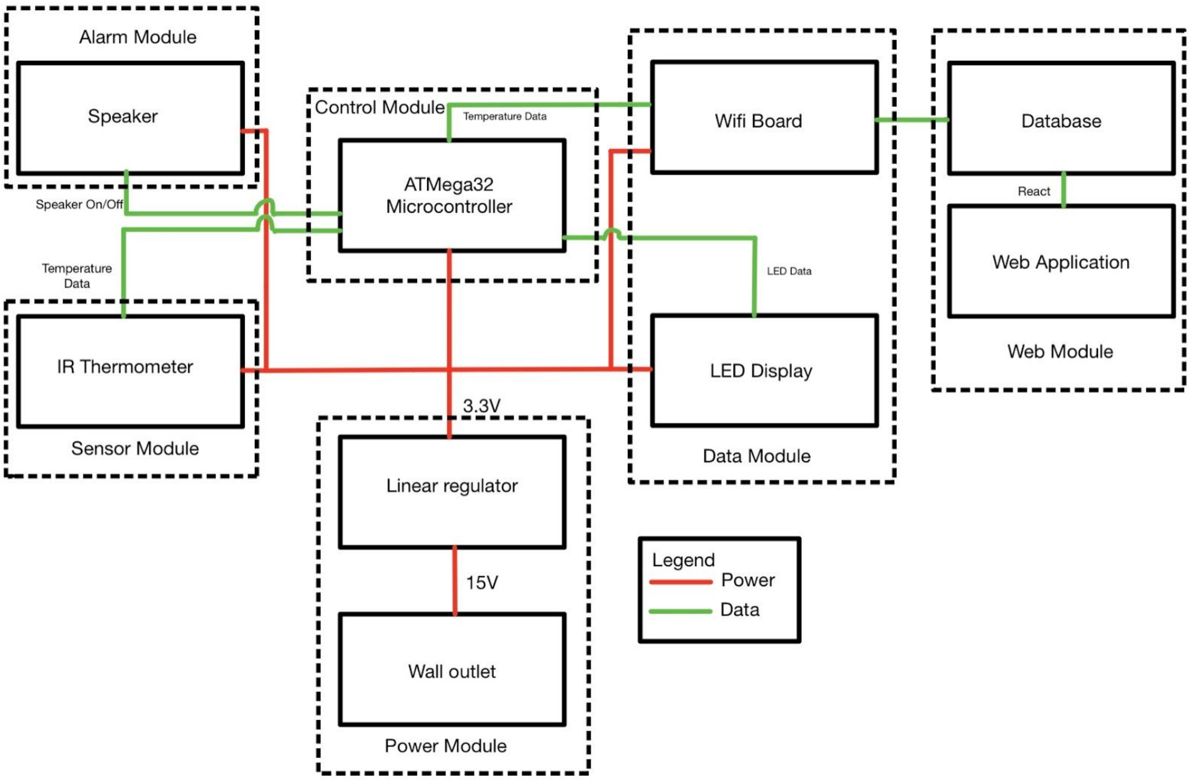

Figure 1: This is the block diagram for the entire project as a whole.

2.2 Physical Design

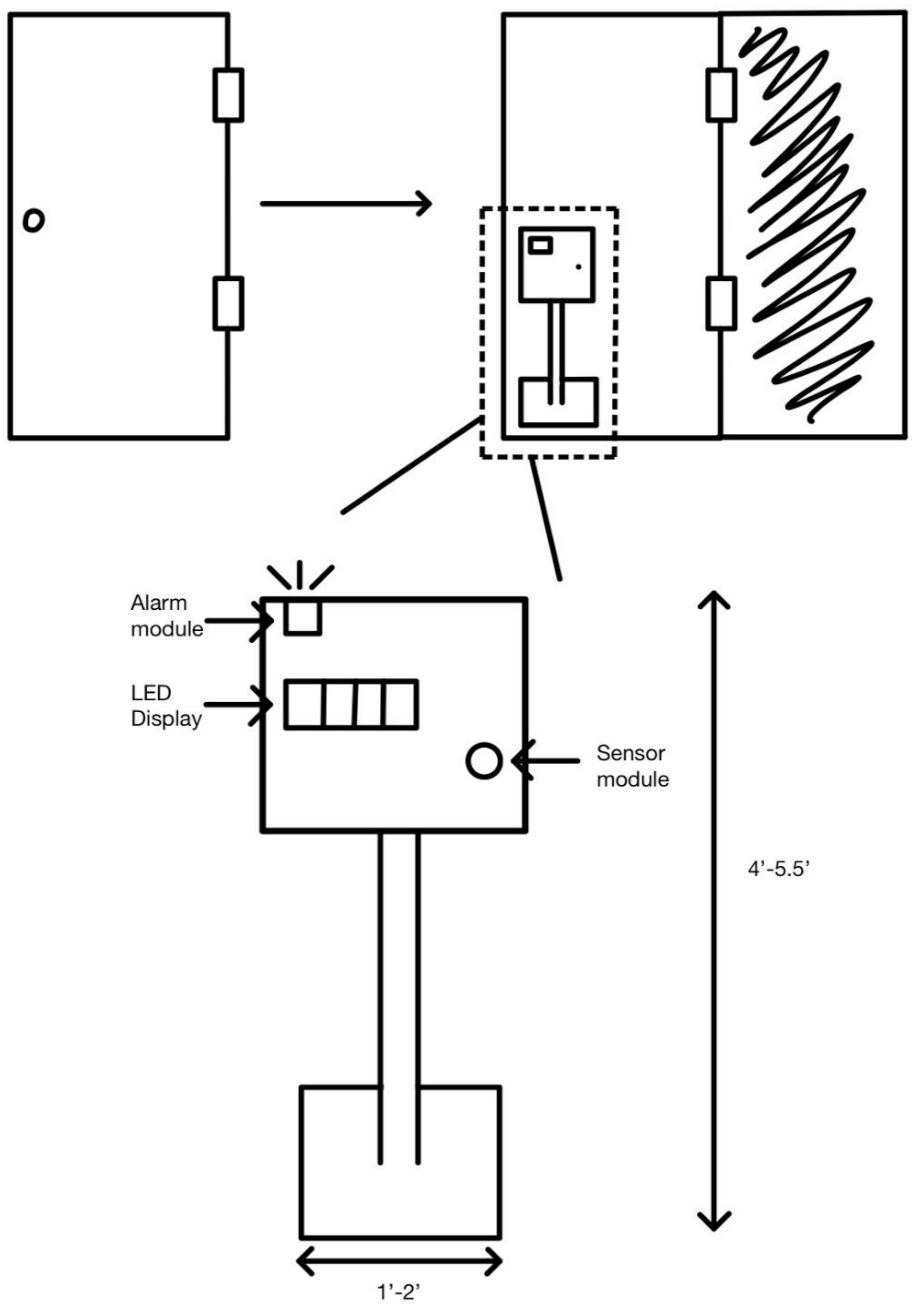

Figure 2: This is a sketch that represents the physical design of the project.

2.3 Subsystem Overview

Alarm Module

The primary component of this module is a speaker. The purpose of this module is to give audible feedback for patrons that are not granted access to enter the business. The speaker will be set to a frequency of 40Hz +/- 10Hz as a default, this is a frequency that is not audible to the human ear. When the control unit sends the alarm module a high voltage signal indicating that a patron is not permitted to end the business….

Sensor Module

This module will consist of the Infrared Temperature Sensor and Ultrasonic Sensor. At a high level, it will measure the temperature of the person who is trying to enter the store and if they are at a temperature range between 96.0 and 100.0 degrees fahrenheit, the module will send signals to the control module that inform other subsystems the patron may enter. As an inverse, if the temperature is above 100.0 fahrenheit, or below 96.0 fahrenheit voltage responses are sent to the control module to indicate the patron can not enter the facility.

As the user is attempting to get their temperature taken, an ultrasonic sensor will run simultaneously. Based on our tolerance analysis on the relationship between distance and temperature sensor accuracy, users must be within 6 inches of the ultrasonic sensor to keep readings accurate, but more than 2 inches away from the sensor to ensure safe usage. Voltage signals will be sent from the ultrasonic sensor to the control unit informing the control unit if the user is too far, too close, or in range.

It is important this sensor is able to measure temperature accurately in order to ensure that those with a fever are kept out and those without a fever are allowed in.

Control Module

The Control Module will determine if the temperature of the person is inside or outside the safe range. The ATMEGA will be used in order to ensure that only those within the safe range are allowed into the building. The safe range is 100.3F and below. The Control Module is the deciding factor if the temperature is inside or outside of range. The Control Module will also send a signal to the speaker. The correct frequencies for the speaker are listed in the Speaker Module. The Control Module will make the correct decision based off the temperature read by the IR Sensor.

This is especially important in order to ensure that the person with a safe temperature is allowed in the building and a person with an unsafe temperature is not allowed inside. If the ATMEGA were to make the incorrect decision, this could be detrimental to the business. Many customers and employees risk getting COVID.

Power Module
The power module consists of the wall plug and the voltage and current regulators. It will step down and regulate the voltage and current to a safe threshold. It will run the microcontroller and allow it to run for an extended period of time. A wall plug will be used to step the 110V down to 15V. A L7805 linear voltage regulator will be used to step the 15V down to 5V. This will also reduce the current to 1.2A. This will ensure the safety of the user. All of the sensors will be connected in parallel to ensure that there is not an overload of current going into the ATMEGA.

Data Module
The data module will take the data collected by the sensor module and display it on the 7 segment LED display on the device. Additionally it will send the data to an online database through the wifi board.

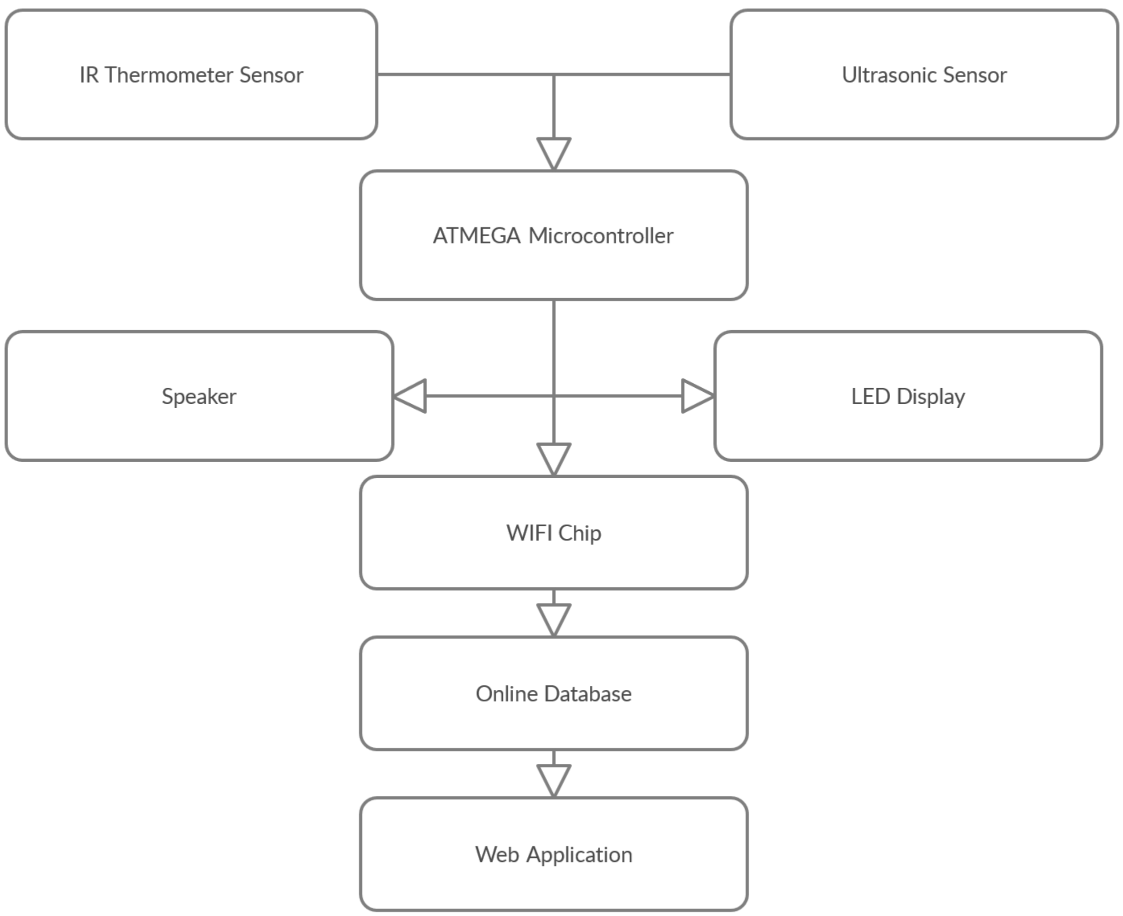

Figure 3: This is a data flow diagram which depicts where the data goes to during each computational step.

2.4 Subsystem R&V

Alarm Module R&V

This module consists of the speaker. The speaker will produce a high, alarming sound if there is someone who enters the business with a temperature considered a fever.

Requirements	Verification
• Speaker will start with a frequency of 40Hz +/- 10Hz and increase quickly to a frequency of 1,000Hz +/- 50 Hz. • The alarm will sound for four seconds.	1A. Measure the output wave of the speaker by connecting the oscilloscope pins to the output of the speaker 2A. Measure the amount of time that the signal is high by measuring the top most part of the square wave on the oscilloscope. This can be done by moving the measuring lines.

Sensor Module R&V

This module will consist of the Infrared Temperature Sensor. It will measure the temperature of the person who is trying to enter the store.

Requirements	Verification
1. IR Thermometer will read the temperature to an accuracy of 0.35°F	1A. Connect IR thermometer to a microcontroller 2A. Probe known temperatures 3A. Compare to oral thermometer with accuracy of 0.35°F

Data Module R&V

The data module will take the data collected by the sensor module and display it on the 7 segment LED display on the device. Additionally it will send the data to an online database through the wifi board.

Requirements	**Verification**
1. Send data with a BAUD rate of 9600 2. Show temperature on LED Display	1A. Send sample packet to remote computer 1B. Measure bit rate over a set time period 1C. Make sure the bit rate is 9600 BAUD. If needed, adjust bit rate using AT commands. 2A. Connect LED display to working microcontroller and oscilloscope. 2B. Send test data to display and measure data signals using an oscilloscope. 2C. For the test input the corresponding pins should be reading high.

Power Module R&V

The power module consists of the wall plug and the voltage and current regulators. It will step down and regulate the voltage and current to a safe threshold. It will run the microcontroller and allow it to run for an extended period of time.

Requirements	Verification
1. Provide 3.3V +/- 0.5% from 3.7V-4.2V Source 2. Can operate current within 0 - 170mA	1A. Measure the output voltage using an oscilloscope, ensuring the output voltage stays within 5% of 3.3V. 2A. Connect the output of the voltage regulator to VDD node in a constant current test circuit. 2B. Alter values of resistance until 170mA is achieved. 2C. Measure the output voltage using an oscilloscope, ensuring the output voltage stays within 5% of 3.3V.

Control Module R&V

The Control Module will determine if the temperature of the person is inside or outside the safe range. The safe range is 100.3F and below.

Requirements	Verification
● This ATMEGA Microcontroller will interpret input data from the IR Thermometer and decide whether to activate the speaker alert system. ● Any temperature above 100.3 degrees fahrenheit will set off the alarm	1A. Build a test program that will automatically send a series of ones and zeros 2A. Verify on the oscilloscope by connecting pins to the input of the speaker in order to ensure the correct decision was made within the tolerance.

2.5 Circuit Schematic and Board Layout

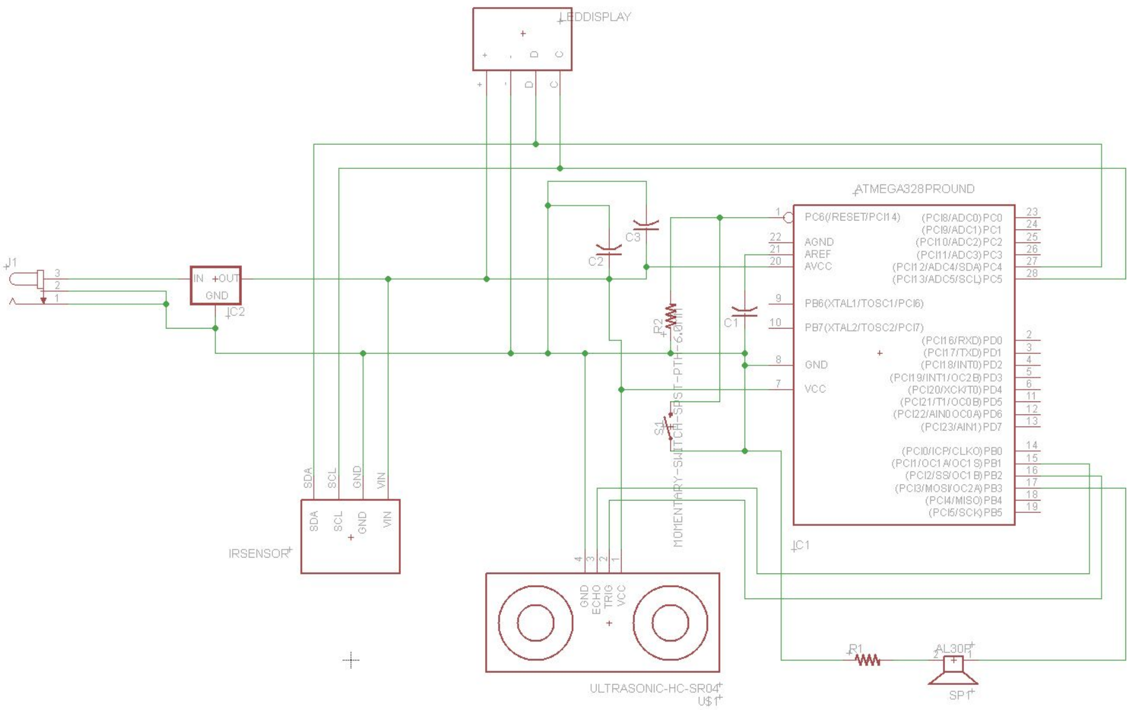

Figure 4: This is the circuit schematic of the design. It includes the microcontroller, voltage regulator, thermal IR sensor, speaker, ultrasonic sensor, power jack, and a set of four seven segment displays.

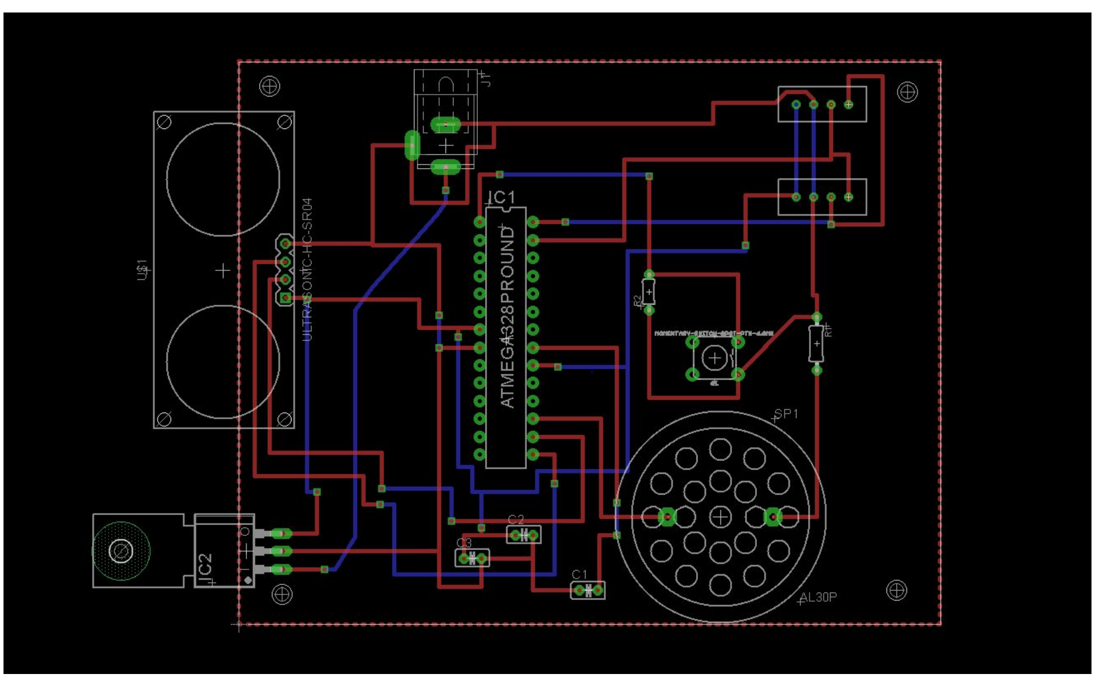

Figure 5: This is the PCB board layout of our design. This is with the soldering of all of the components.

2.6 Tolerance Analysis

There is an inverse relationship between distance from head to sensor and temperature. As the object moves away from the sensor, the temperature that is read by the sensor decreases. The ultrasonic sensor is used in order to ensure that the distance between a forehead and the sensor is accurate. For this analysis, an equation can be created in order to relate the relationship between the distance and the temperature. For example, a temperature at 4cm away from the sensor is the same as a different measured temperature 2cms away from the sensor.

In order to illustrate this relationship, initial testing of the IR sensor and ultrasonic sensor was conducted in order to derive a formula for this exponential relationship.

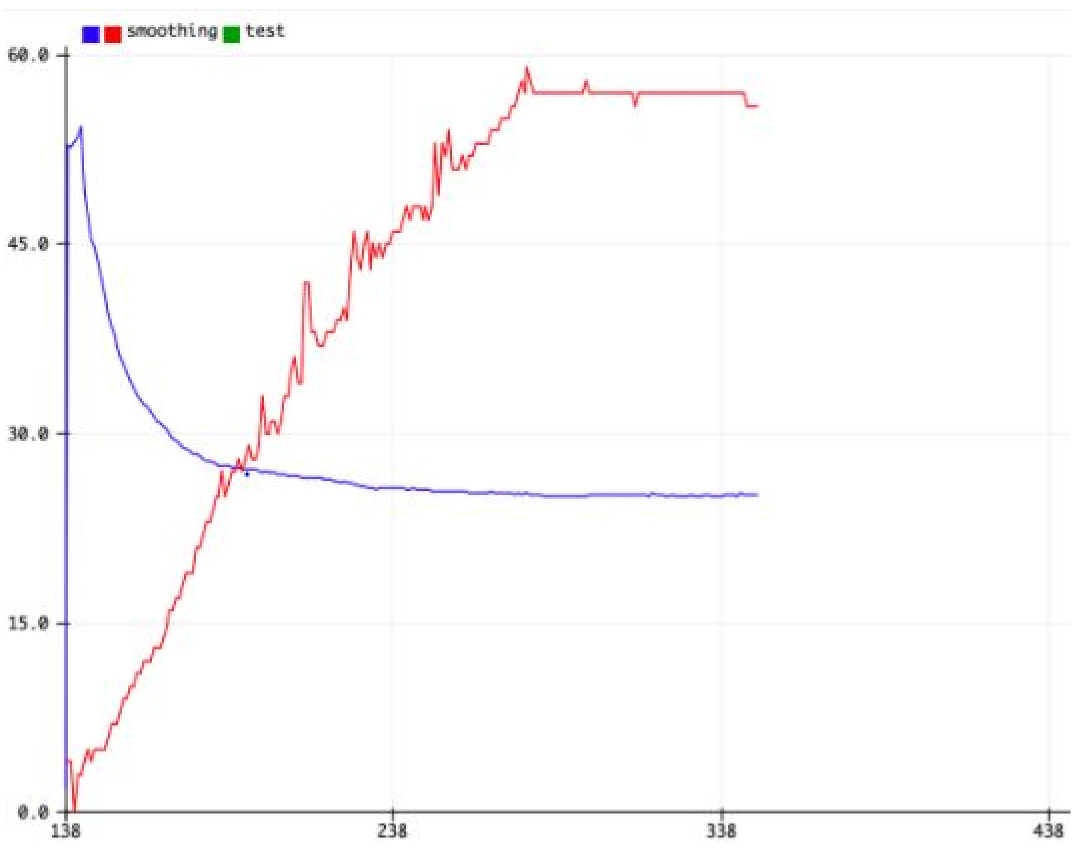

Figure 6: Plot displaying Temperature and Distance vs Time

Initially, this plot was created in order to illustrate the inverse relationship. The blue line is temperature and the red line is distance. The x-axis represents time in seconds. The y-axis for the blue line is temperature in celsius and the red line is distance in cms. It is clear from this graph that as the object is moved away from the IR sensor the temperature decreases.

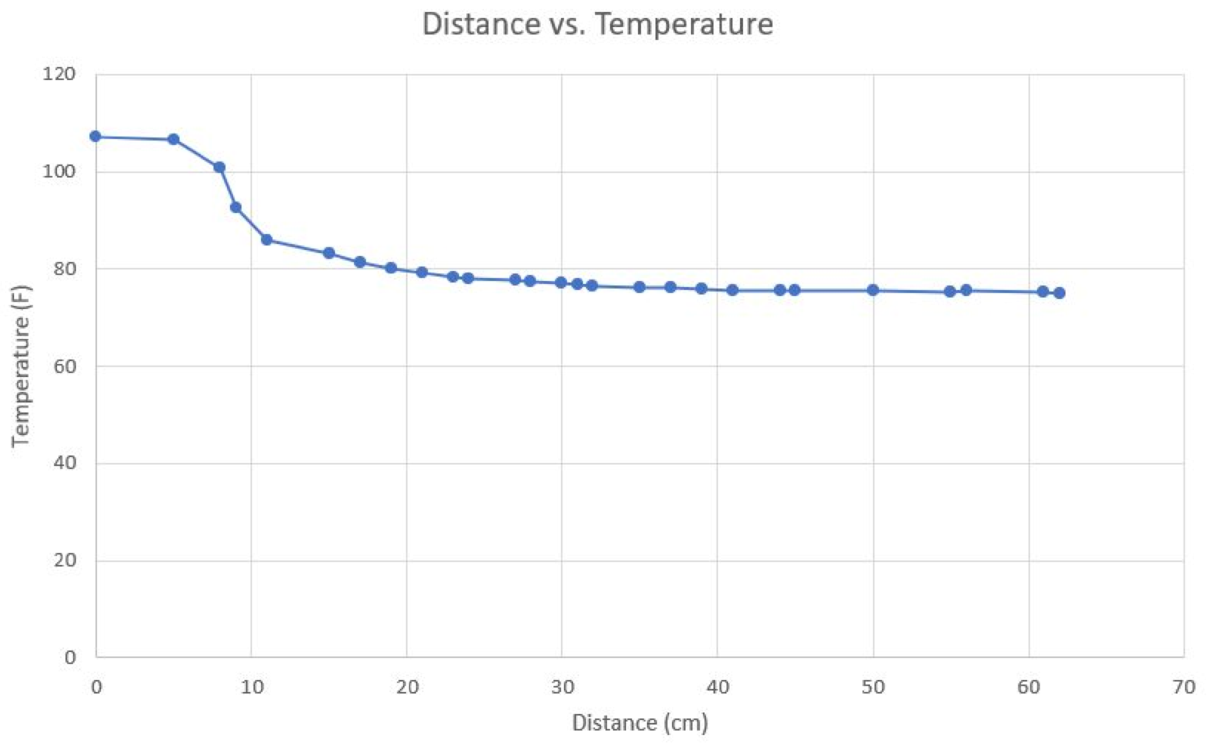

Figure 7: Plot displaying Temperature vs Distance

We used a 115° F heat source to create the above graph in addition to our IR sensor and Ultrasonic sensor to measure distance. Using this graph we were able to derive an exponential equation that relates distance from the IR sensor to the temperature reading from the sensor in order to more accurately calculate the correct temperature. This is given as:

$$T = 114e^{-0.02d}$$

where T is temperature in fahrenheit and d is the distance from the sensor.

Figure 8: This is a picture of the sensor.

2.7 Plots

10.1 Temperature accuracy of the MLX90614

All accuracy specifications apply under settled isothermal conditions only. Furthermore, the accuracy is only valid if the object fills the FOV of the sensor completely.

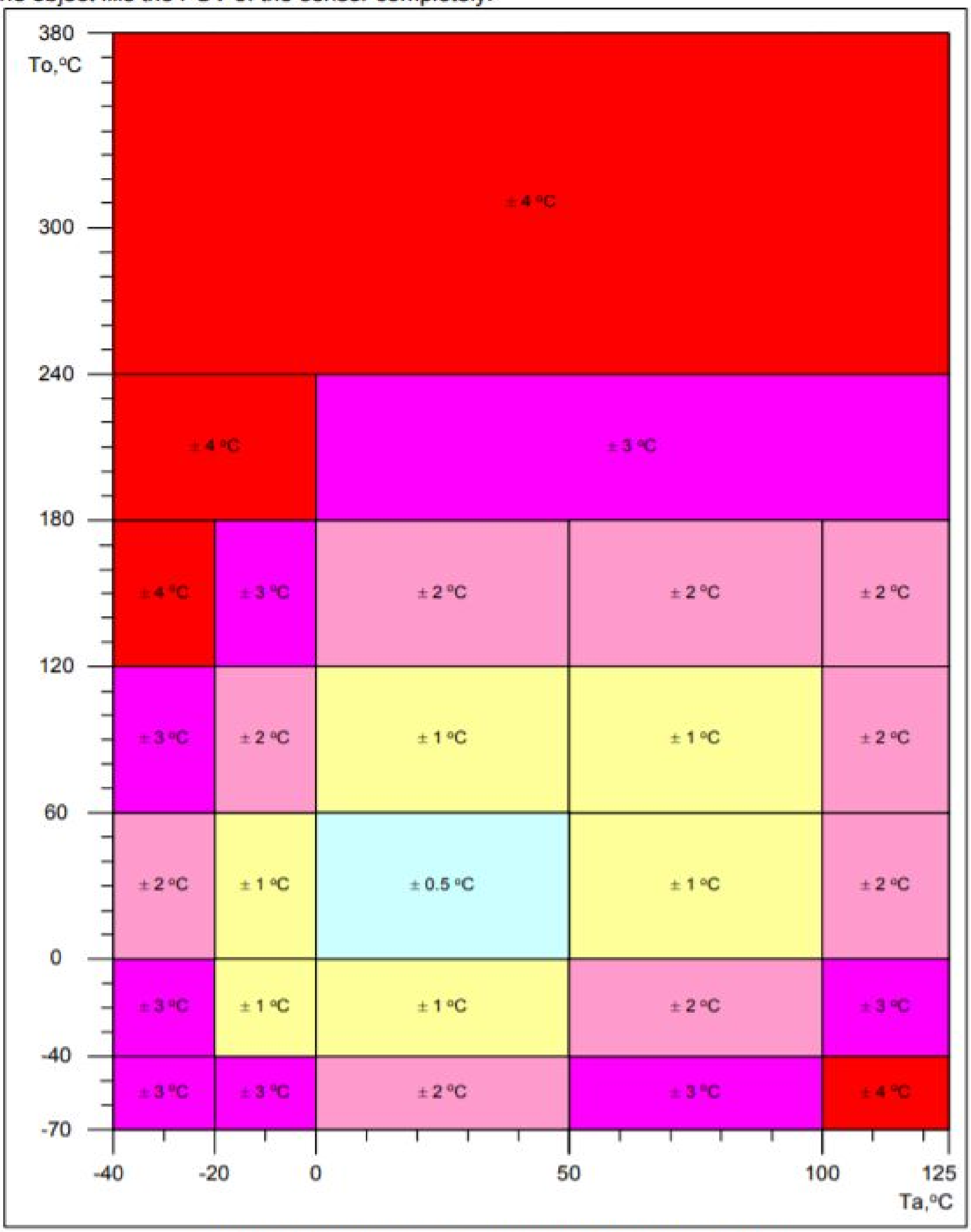

Figure 9: This plot shows the accuracy of the sensor in dependence with the temperature.

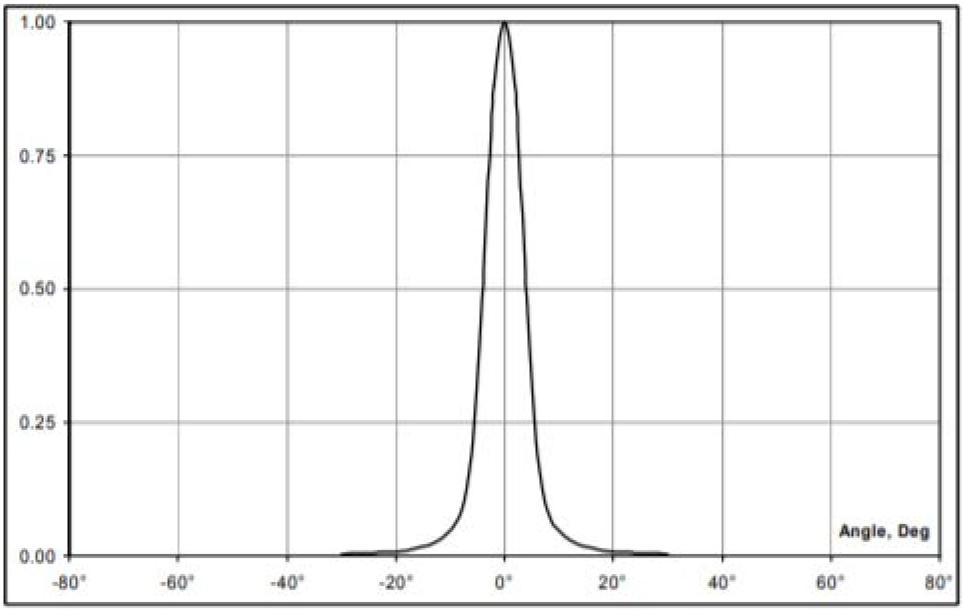

Figure 10: This plot show the FOV of the sensor in dependence of the temperature

2.8 Contingency Plan

In the state that the University of Illinois shuts down due to the COVID-19 pandemic, we will continue to work on campus. Both Claire Lundtveit and Jack Lanser plan to live in Champaign-Urbana regardless of the state of the University. They will be able to work on the hardware portion of the project. Andrew Kelley will continue to work on the software portion of the project. As a team, we will continue to meet virtually as we usually do. We are confident in our abilities to work together as a team virtually.

3 Cost and Schedule

3.1 Cost

Labor Cost:

In terms of labor, the three of us are working about 10 hours each over 16 weeks, a typical ECE new grad can expect to make roughly $40/hour.

3 * $40/hour * 10 hour/week * 16 weeks * 2.5 = $48,000

Part	Cost
Microcontroller	3.10
LM317 3 Terminal Adjustable Voltage Regulator	3.30
Non-Contact Infrared Sensor MLX90614ESF	12.49
Arduino Speaker	0.00
4-Digit Tube LED Segment Display Module Red Common Anode TM1637 Drive Chip Tube Clock	5.49
TOTAL PARTS COST	24.48

In total this project cost about $48,024.48 with $48,000 coming from labor and $24.48 from parts.

3.2 Schedule

Week	Task
10/05	Finalize PCB design and initial validation to sensors and components
10/12	Validate entire sensor module, validate alarm module, and validate entire power module, begin initial stages of webpage
10/19	Begin assembling control module, and complete and validate the data module
10/26	Complete and validate the control module, being to test some of the initial data lines between the control module and other completed modules
11/02	Assure all modules are working individually as expected and then begin to validate that all modules work in tandem
11/09	Final adjustments of project, documenting all relevant data points, and beginning zoom presentation and final paper
11/16	Demonstrate final project and continue to work on zoom presentation as well as final paper
11/23	Complete final touches on final presentation and continue to work on final paper
11/30	Present final presentation and and complete final paper

12/07	Complete final revisions on final paper

4 Safety and Ethics

4.1 Ethics

The main ethical concern associated with this product is the usage and distribution of the medical data collected at the door by our product. If medical data were to be directly attached to individual users and tracked this product would violate both IEEE and HIPAA standards.

In our design temperatures of specific individuals are not tied to one's identity in any way, keeping our product in line with IEEE[2], and HIPAA[3] ethical guidelines.

More specifically each individual entering the store will have their temperature taken. This temperature will not be matched to a specific name or identity. It will simply state whether or not the temperature is in a healthy range. This ensures that we are not taking unethical information.

4.2 Safety

In terms of physical safety, the only concern is the 110V outlet we will be using. These outlets kill many people, year after year so it is important to ensure that we are following the guidelines. We will follow every guideline that OSHA[5] states in their electrical safety packet.

4 Citations

[1] Center for Disease Control and Prevention, 'Taking a client's temperature using a temporal thermometer', 2020 [Online].Available: https://www.cdc.gov/coronavirus/2019-ncov/community/homeless-shelters/screening-clients-respiratory-infection-symptoms.html#:~:text=Fever%3A%20Any%20temperature%20100.4,is%20considered%20a%20fever

[2]IEEE, 'IEEE Code of Ethics', 2020 [Online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html

[3] HIPAA, 'Understanding Some of HIPAA's Permitted Uses and Disclosures', 2020 [Online]. Available: https://www.hhs.gov/hipaa/for-professionals/privacy/guidance/permitted-uses/index.html

[4]Melexis, ' MLX90614 Single and Dual Zone InfraRed Thermometer in TO-39', 2009 [Online]. Available:

https://www.sparkfun.com/datasheets/Sensors/Temperature/SEN-09570-datasheet-3901090614M005.pdf

[5]OSHA, ‘Construction Safety and Health’, 2018 [Online]. Available: https://www.osha.gov/sites/default/files/2018-12/fy07_sh-16586-07_4_electrical_safety_participant_guide.pdf