Covid-19 Safety Door

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Abstract

The COVID-19 Safety Door is an autonomous temperature checker and warning system mounted on a stand. A person approaches the stand and playces their forehead in front of the sensor array in order to get their temperature checked. If a person does not have a fever, a symptom of COVID-19, they are allowed into the building. If a person has a fever they will not be allowed into the building. This stand is intended for use by businesses and should be placed just inside the entrance to the building. We have found that this stand is accurate and can easily alert owners to potential risks to public health. Additionally the stand is accurate to within 0.5℃ and at ranges of 2-4 inches of the sensor.

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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 built an automated COVID-19 temperature monitor for independent businesses. Our product is a temperature sensor placed outside of business entrances. Rather than a human manually scanning individuals our product instructs the patron how to properly and safely take their temperature. The device then informs patrons they can enter if their temperature is in an appropriate range, the device informs the patron and business if a patron who does not have an appropriate temperature attempts to enter. This product cuts small business costs significantly, speeds up the process to enter buildings, and keeps 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.

1.3 Block Diagram

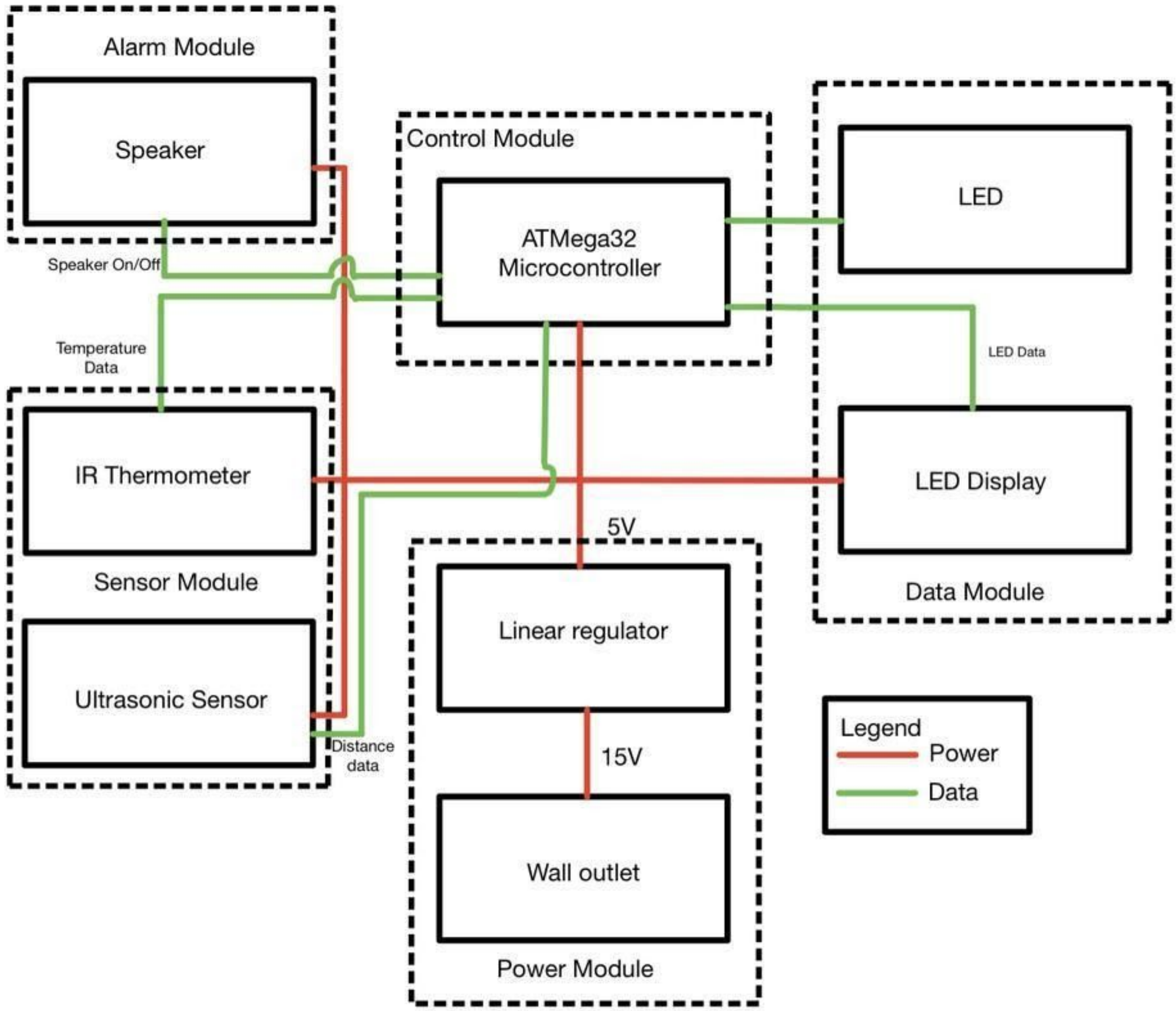


Figure 1: This is the block diagram for the entire project as a whole.

The COVID-19 Safety Door consists of five modules. The Power Module provides power to the ATMEGA and all the sensors involved. The Control Module consists of an ATMEGA328 which is the firmware for the project. The ATMEGA is able to make decisions from the data given from the sensors. The Sensor Module consists of an ultrasonic sensor and IR thermometer. These two sensors work in conjunction in order to ensure that an accurate temperature is read. The Data Module consists of an LED and an alphanumeric LED display. The LED lets the user know if their forehead is in range. The LED display presents commands to the user and displays the temperature once it is taken. Finally, the Alarm module consists of a speaker which alerts the user if they are allowed into the building or denied.

1.4 Semester Changes

After our design review, it was determined that we needed to ensure a specific distance for temperature readings. In order to ensure that a forehead is close enough to the IR sensor, we decided to add an ultrasonic sensor. We went further into the distance vs. temperature relationship as discussed later.

At the beginning of the semester we included an addition within the Data Module. In the Data Module we had a Wifi chip that was used to collect data of all the temperatures taken. We decided to take this out because this module did not add a tremendous amount of value for the additional time and resources that it required.

2 Design
2.1 Design Procedure

Alarm Module

The purpose of the alarm module is to alert the business owners to patrons with fevers that serve as potential risks to public health. Additionally, it serves to notify the user whether they pass or fail the temperature test. We chose audio feedback as our alert system because it is the most accessible form of feedback. There are concerns for deaf patrons but those are resolved in the data module. We chose two distinct chimes for a passing test and a failing test to make it clear to the user whether they passed or failed. We chose a simple speaker so that it can both be powered and controlled through the datalines on the ATMega328P.

Sensor Module

This module will consist of the IR thermometer sensor and ultrasonic sensor. 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 that 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. We chose an IR thermometer sensor for collecting temperature data because a completely contactless process for each user ensures prevention of further disease spread. They also come in a compact and low power form factor.

As the user is attempting to get their temperature taken, an ultrasonic sensor will run simultaneously. Due to the tolerance analysis we ran on the IR thermometer sensor, its optimal range is 2 to 4 inches away from the sensor. To ensure the user is within this range, we deployed an ultrasonic sensor to measure their distance. This allows the stand to take accurate reading and eliminate false temperature results.

Control Module

The Control Module is a central component to our project. All of the sensor inputs go into this unit and all of the peripheral outputs are generated here. As far as inputs go, the control module takes in temperature and distance data and uses these two values to calculate whether the user is allowed inside the business or not. The main control loop is a state machine and the user has to pass through a certain order of states in order to pass or to fail. The outputs are generated and either sent over the I2C bus or over the built in data lines. We chose an ATMega as our microcontroller because it has widespread online support and many libraries constructed for its use. It is also trivial to upload programs to it using an arduino microcontroller. Additionally it has an out of the box functioning I2C bus that we used to connect our IR thermometer sensor and the alphanumeric LED display.

Power Module

The power module consists of the wall plug and a voltage regulator. 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. An AC/DC wall plug will be used to step the 110 V down to 15 V. This will ensure safety at the wall outlet. A LM7805 linear voltage regulator will be used to step the 15 V down to 5 V. This will also reduce the current to 1.2 A. This is enough to run the microcontroller and all of the sensors. 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 consists of the components in our project that show the user data feedback. These components are the LED and the alphanumeric LED display. The LED will turn on when the user is in the 2 to 4 inch range for the IR thermometer to give the user visual feedback that they are in range and the alphanumeric LED display will show the user first if they are accepted or denied and then their temperature. At first we had a more basic seven segment LED display that could only display digits but then we decided we needed a display capable of showing letters so that we could give users commands and to show them what step of the test they are on.

2.2 Design Details

For each module, we chose components that fit our specifications and offered low power consumption along with reliability. The speaker we ended up choosing was the EMB-3008A from Sparkfun that only has a power consumption of 0.2 W. This speaker does not use up much power and as a result is able to be powered with the data signal sent from the ATMega328. Following that we chose the MLX90614 as our IR thermometer sensor. This sensor operates at 5V so we were able to connect it to our main power line. It also has a rated temperature accuracy of 0.5℃, as shown in Figure 2, which is within our specified temperature range. Additionally, as shown in Figure 3, the optimal FOV of the sensor corresponds with our use case as the user's forehead with fill up the required FOV. This IR thermometer sensor all communicates through the I2C bus.

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.

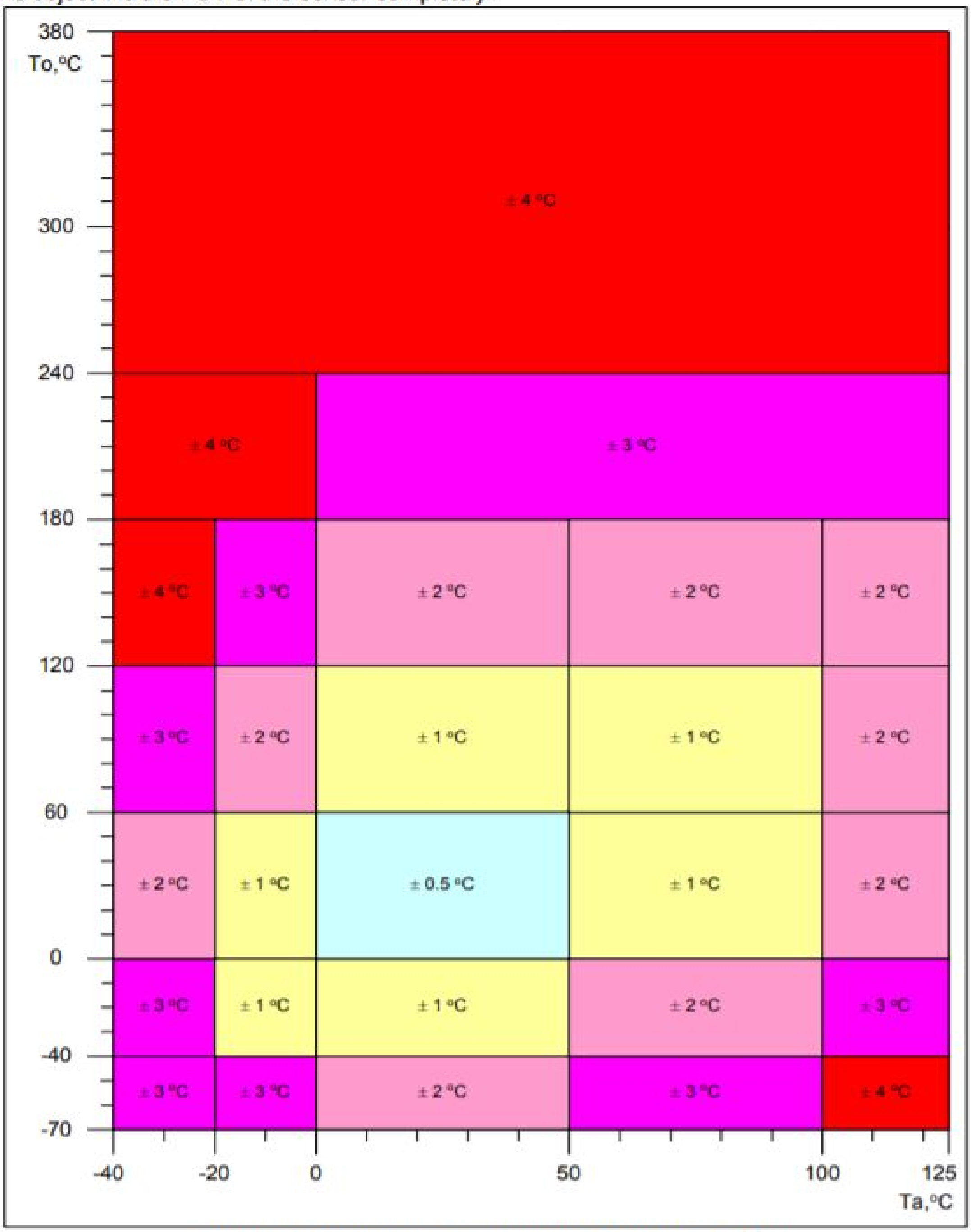


Figure 2: This plot shows the accuracy of the sensor in dependence with the temperature.

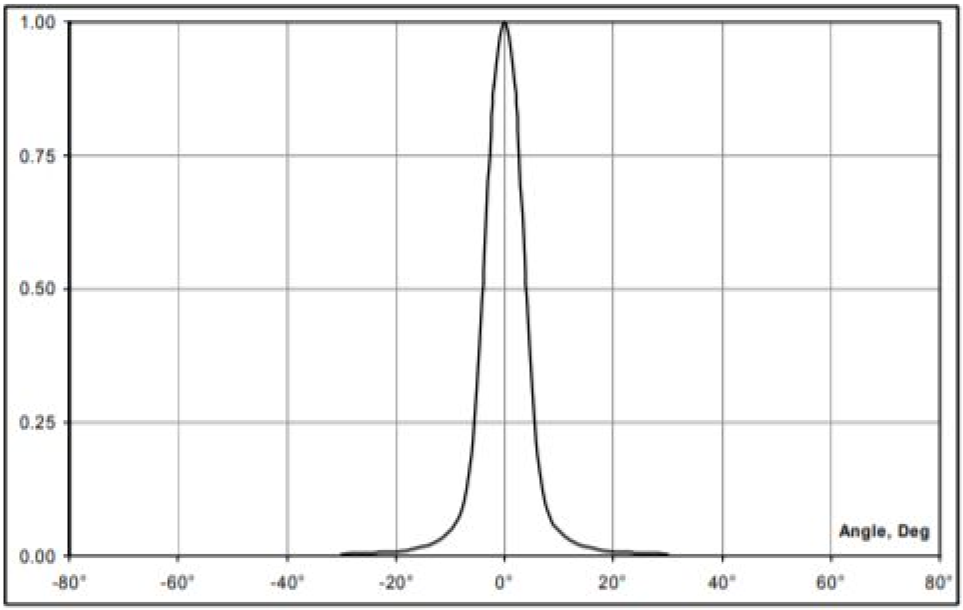
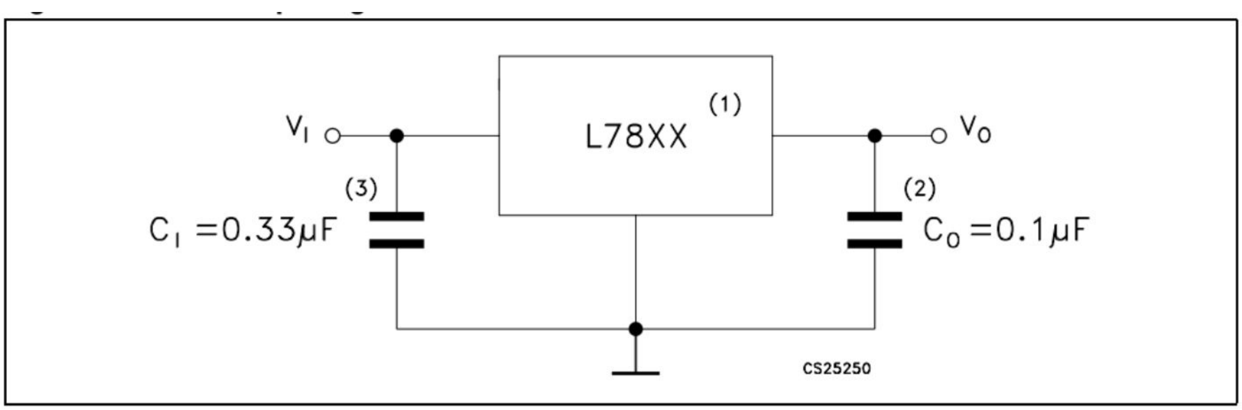


Figure 3: This plot show the FOV of the sensor in dependence of the temperature

For the ultrasonic sensor, we chose the HC-SR04 from Sparkfun because it operates at 5 V so we can connect it to the main power line as well as it having a measurement range from 2 cm to 4 m which suits our use case. For the Data Module, we had two components to choose. The first was the LED indicator for our distance and for that we chose the basic LED from Sparkfun which was an easy component to use as it takes power from the ATMega. The alphanumeric display we chose was the HT16K33 from Adafruit. This display operates at 5 V and is able to connect to and I2C bus for easy communication. We needed this display to be bright in order to be visible and be able to display both ASCII characters and floating point numbers, which it does. Lastly, we chose the ATMega328P as our microcontroller due to its small form factor and capabilities. It also operates at 5 V making it easy to connect to our power line and contains an on board crystal oscillator, eliminating the need for an external crystal. The ATmega328P also contains an I2C bus which was vital due to two of our components needing it in order to send and receive data.



1. To specify an output voltage, substitute voltage value for "XX".
2. Although no output capacitor is need for stability, it does improve transient response.
3. Required if regulator is locate an appreciable distance from power supply filter.

Figure 4: This schematic shows the capacitors used to eliminate noise

Our power circuit is shown in Figure 5 and it lays out the circuit design for our project. Shown near the microcontroller are three capacitors that are there to smooth the output from the linear voltage regulator and to eliminate noise as the ATMega328 cannot guarantee functionality undfer a noisy power input. This can be seen in Figure 4. Our board design found in Figure 6 shows how we laid out the components on the physical PCB. We chose to place the most of the components on the outside edge of the board for easy access when soldering. Additionally, for the IR thermometer, ultrasonic sensor, LED, and alphanumeric display we chose to solder wires to the PCB and have those components be mounted separately from the PCB as seen in Figure 8.

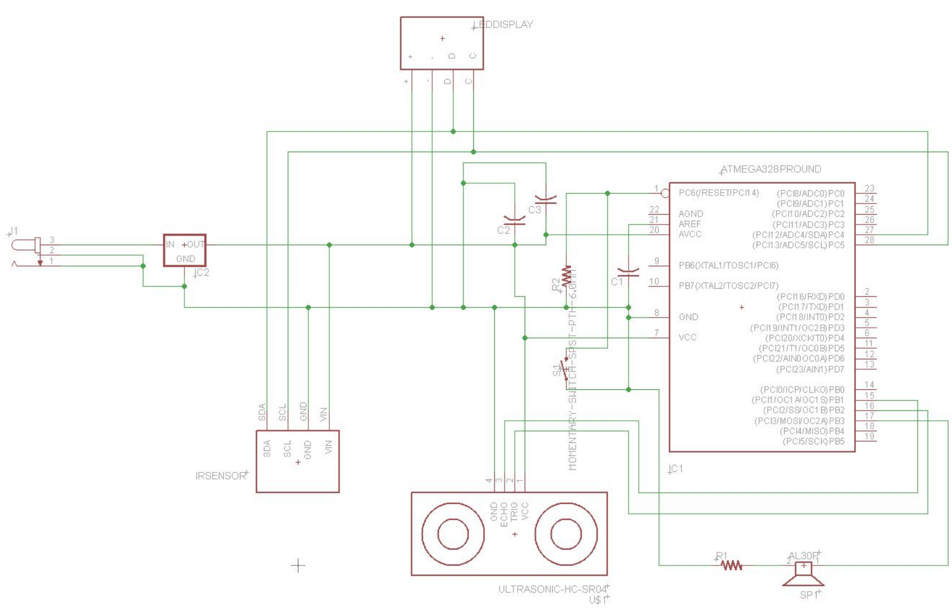


Figure 5: This is the circuit schematic of the design. It includes the microcontroller, voltage regulator, thermal IR sensor, speaker, ultrasonic sensor, power jack, and a set of four seven segment displays.

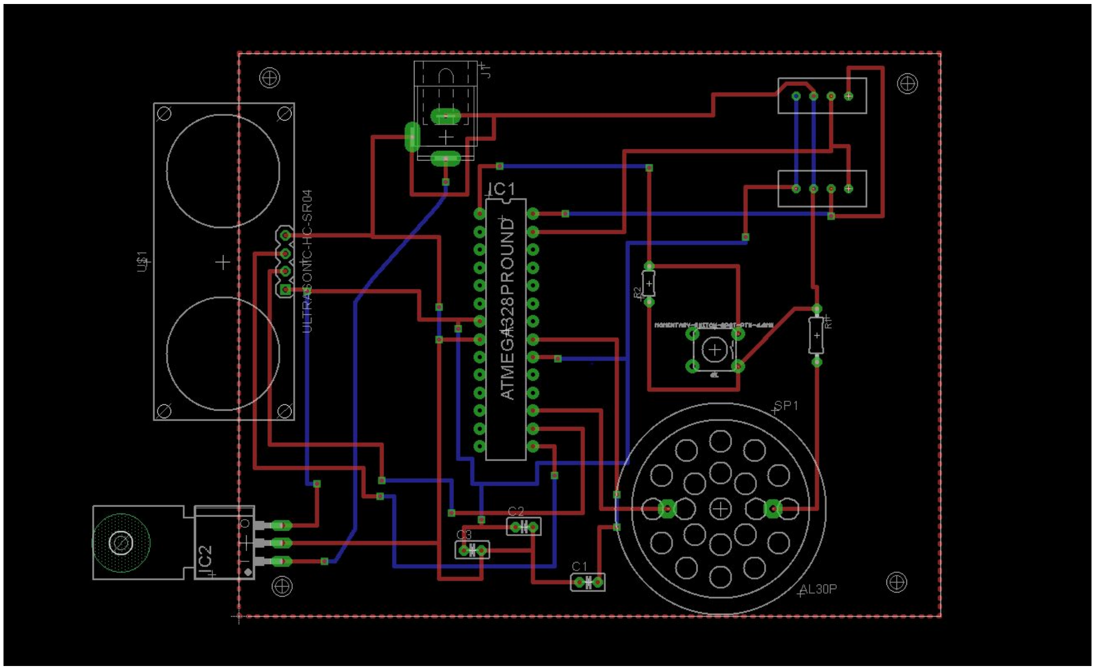


Figure 6: This is the PCB board layout of our design. This is with the soldering of all of the components.

Figure 7: Physical design of the stand showing the entire stand as well as the height adjusting mechanism

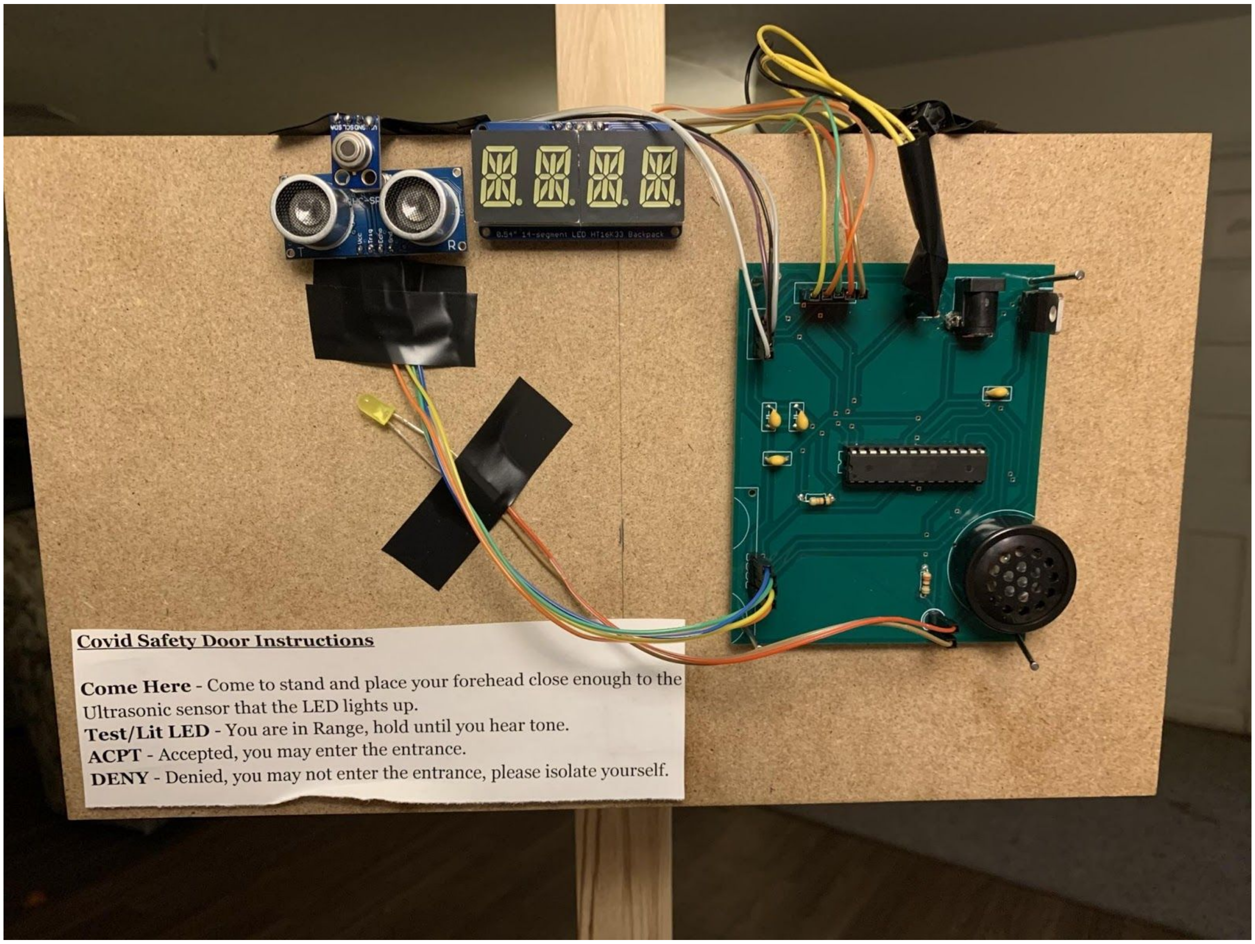


Figure 8: Close up view of the main component board.

3 Verification

3.1 Module Verification

The specific R&V tables for each module can be found in Appendix A.

Alarm Module R&V

This module consists of the speaker. The speaker produces a high, alarming sound if there is someone who enters the business with a temperature considered a fever. Those with standard acceptable temperatures will be allowed into the building using an acceptance sound. The alarm module was tested by connecting the echo and trigger pins to an oscilloscope and verifying the correct PWM wave was being emitted by the sensor as well as PWM signals consistent with the distance of test objects. The ATMEGA sends the speaker its specific frequency. This frequency was tested on the oscilloscope in order to verify. The length of the alarm can be measured by measuring the time that the square wave is high.

Sensor Module R&V

This module consists of the infrared temperature sensor and an ultrasonic sensor. It measures the temperature and distance of the person who is trying to enter the store at the same time. The infrared sensor was cross checked against an oral thermometer. The infrared sensor was easily cross checked in order to ensure the IR sensor had an accuracy of 0.50°F. The ultrasonic sensor was verified using an oscilloscope to measure the PWM wave. More testing was done to ensure quality measures by setting up the IR thermometer and the ultrasonic sensor in an array and exposing it to a known heat source to verify their functionality as shown in Figure 9. A further explanation is found in section 3.2.

Data Module R&V

The data module takes the data collected by the sensor module and displays it on the alphanumeric LED display on the device. The alphanumeric display was verified by displaying the data on a monitor and ensuring that it aligns with the LED display. In addition, the Data Module has an LED. The LED ensures that the forehead of a patron is close enough to the sensor module. The LED was verified by using an oscilloscope to measure the PWM wave. The oscilloscope was able to display the square wave.

Power Module R&V

The power module consists of the wall plug and the voltage regulators. It steps down and regulates the voltage and current to a safe threshold. It runs the microcontroller and allows it to run for an extended period of time. The AC/DC wall plug steps the voltage from 110V to 15V. The LM8705 steps the 15V down to 5V. The output current of the LM8705 is 1.2A. This was tested on a multimeter. To measure the output voltage, a multimeter was used in parallel. To measure the output current, a multimeter was used in series. This means that when measuring the current, the multimeter must become a part of the circuit.

Control Module R&V

The Control Module determines if the temperature of the person is inside or outside the safe range. The safe range is 100.3F and below. In order to test this, an oral thermometer was needed. A person uses the oral thermometer and compares and contrasts it to the output measured on the alphanumeric display.

3.2 Ultrasonic and IR Thermometer Testing

There is an inverse relationship between distance from forehead 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.

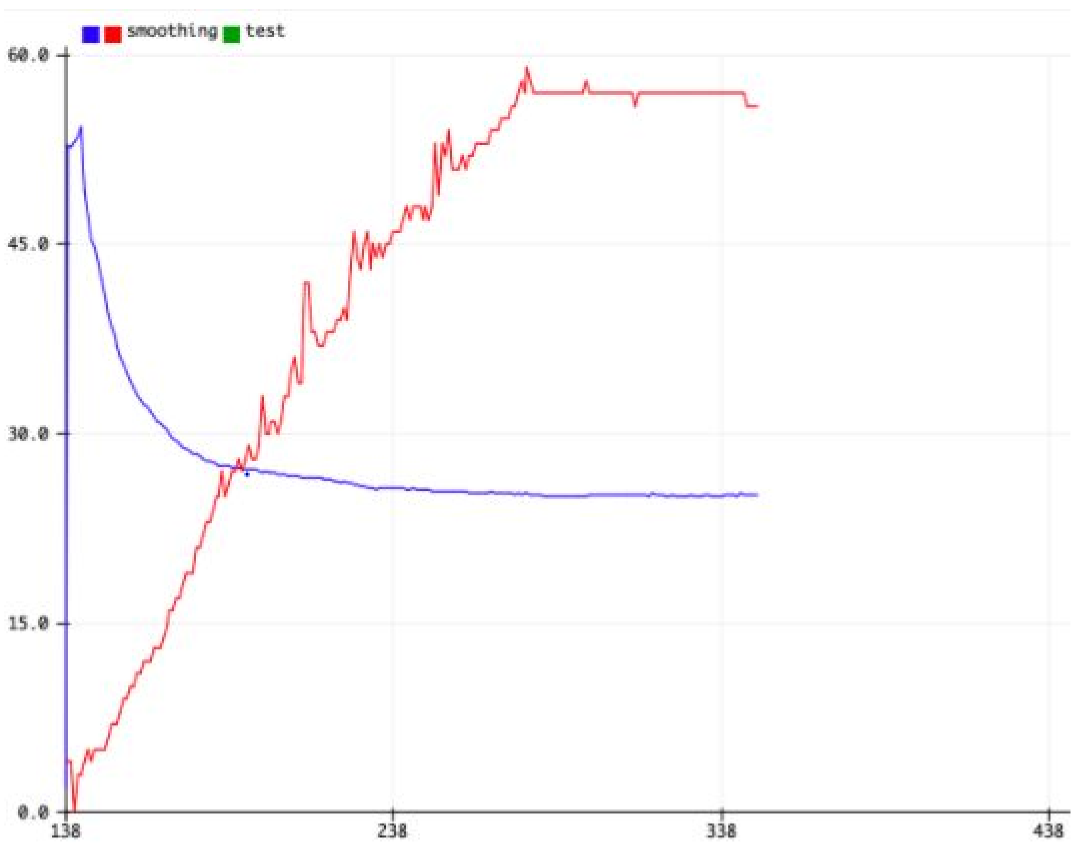


Figure 9: Plot displaying Temperature and Distance vs Time

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.

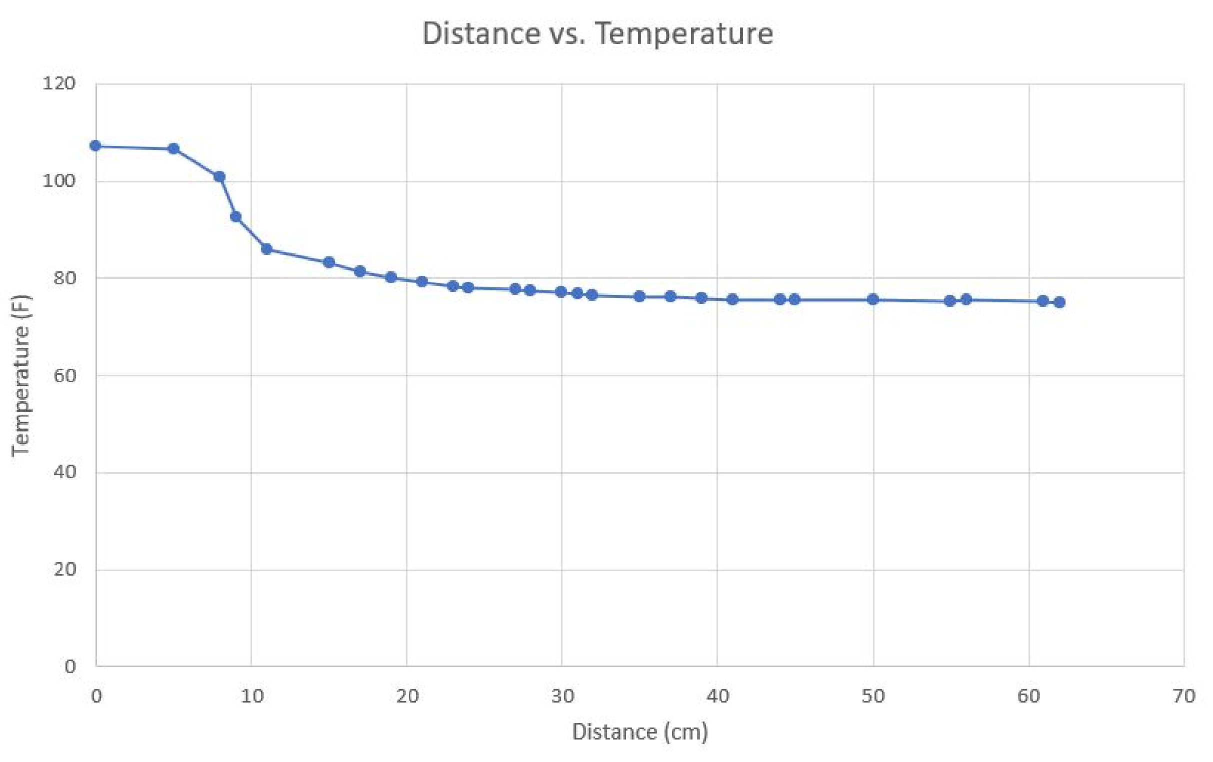


Figure 10: Plot displaying Temperature vs Distance

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.

4 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**
ATMEGA328 Microcontroller	3.10
LM8705 3 Terminal Adjustable Voltage Regulator	3.30
Non-Contact Infrared Sensor MLX90614ESF	12.49
Arduino Speaker	1.95
Ultrasonic Sensor	3.95
Yellow LED	1.30
4-Digit Alphanumeric Tube LED Segment Display Module Red Common Anode TM1637 Drive Chip Tube Clock	13.95
TOTAL PARTS COST	40.04

In total this project cost about $48,040.04 with $48,000 coming from labor and $40.44 from parts.

5 Conclusion

5.1 Accomplishments

This project is fully functioning and can measure the temperature of any person and deny or allow them into the building. The mounting of the yellow LED was designed through human centered design in order to ensure that the forehead is within range of the two sensors, the ultrasonic and IR sensor. The LED is mounted right where the eyes of the user should be in order to easily inform the user if they are within the distance or not. The color yellow was chosen for the LED because it symbolizes the process of waiting. Green means go and red means stop, but we did not want the LED to be too aggressive; therefore, we choose yellow as an in between color.

The actual stand itself can be moved up and down. This accounts for those who are shorter, children, or those with disabilities. Our design is able to solve the needs of a diverse background of people and businesses. This device could be put outside of ECEB in order to stop the spread of coronavirus.

5.2 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.

5.3 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.

5.4 Impacts

Our project came as a direct result of the COVID-19 pandemic and this has many implications. We believe that this is a reliable solution for small business in order to reduce staff and save money in an already trying financial time while at the same time being quick enough to avoid having lines of people out of the door at their business. Our stand is an affordable solution that is capable of being mass produced, further bringing costs down and can be deployed in many countries.

6 References

[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

Appendix A

Alarm Module R&V

Requirements	Verification
- Speaker will start with a frequency of 10Hz +/- 10Hz and increase quickly to a frequency of 300 Hz +/- 100 Hz for a deny signal. - The deny alarm will sound for 1.5 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

Requirements	Verification
1. IR Thermometer will read the temperature to an accuracy of 0.50°F	1A. Connect IR thermometer to a microcontroller 2A. Probe known temperatures 3A. Compare to oral thermometer with accuracy of 0.50°F

Display Module R&V

Requirements	Verification
1. Show temperature on LED Display	1A. Connect LED display to working microcontroller. 1B. Send test data to display 1C. Read display and verify that corresponding segments are lit.

Power Module R&V

Requirements	Verification
1. Provide 5.0V +/- 5% from 12V Source 2. Can operate current within 0 - 1.2A	1A. Measure the output voltage using an oscilloscope, ensuring the output voltage stays within 5% of 5.0V. 2A. Connect the output of the voltage regulator to VDD node in a constant current test circuit. 2B. Alter values of resistance until 1.2A is achieved. 2C. Measure the output voltage using an oscilloscope, ensuring the output voltage stays within 5% of 5.0V.

Control Module R&V

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.