COVID-Safe Fitting Room

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Abstract

Several media outlets have reported the effects of fitting closures on the store owners and customers since the beginning of the COVID-19 pandemic. These reports usually display the financial damage and the decreased customer satisfaction the fitting room closures have caused. Here we propose a solution that will allow safe reopening of fitting rooms in the stores. Our solution is a self sanitizing fitting room that starts a sanitization process when the customer leaves the room. Our system uses an advanced detection scheme consisting of ultrasonic and PIR sensors to detect the customers entering or leaving the fitting room. According to this detection, the system starts a sanitization process that uses HEPA filters, sanitizer sprayers, and UV light. Our research shows that using these three methods of sanitization is enough to eliminate COVID-19 particles in the air and on surfaces inside the room. The system is also designed to be user-friendly by including indicator lights that signal the state of the room to the customers. The LED lights on top of the room signal whether the room is open, occupied or in the sanitization process. This report outlines the problem overview, solution overview, the design requirements and consideration, the design analysis and testing, costs, ethics, and safety aspects of our project with an engineering perspective.

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1 Introduction

1.1 Problem Overview

Due to Covid, most stores closed their fitting rooms to customers as a safety measure [1]. This has made buying new clothes an unpleasant experience as people cannot use the fitting rooms to make sure they are buying the right size of the clothing. This is also costing money to clothing stores because of decreased customer satisfaction. The stores that have reopened their fitting rooms during the pandemic have to go through disinfection procedures in order to ensure the safety of their customers [2]. This includes spraying down all the high concentration surfaces inside the fitting rooms and still wearing masks to prevent infection from airborne particles [1].

1.2 Solution Overview

We are proposing a Covid-safe fitting room that can detect when a customer enters the fitting room and leaves it in order to start a disinfection process that involves using an air filter and sanitizer spray. A PIR sensor inside the room and two ultrasonic sensors installed near each other at the entrance of the fitting room determine whether a customer is entering or leaving depending on which one of the two sensors is triggered first. When a customer enters the fitting room the occupied state starts, and the Covid-Safe fitting room waits for the customer to leave. When the ultrasonic sensors detect the customer has left, the indicator light changes, and the sanitizer and air filters are then turned on to sanitize the air and surfaces in the fitting room. In addition to sensors at the entrance, a PIR sensor can be used in the fitting room to make the customer detection more accurate. Also, a panic button inside prevents the customers from being stuck inside when the disinfection process starts. Another button can be put to put it into a maintenance state if a worker has to fix the fitting room components or refill the sanitizing spray. Another feature of the room is the indicator light which changes color according to the state of the room. For example if someone is in the room it lights up yellow, when the disinfection is taking place it lights up red, and when the room is empty and disinfected it lights up green.

This product would allow users to feel safe going into cleaned and sanitized rooms all the time as well as providing stores a more efficient process to cleaning. This way, the store employees would not always have to be monitoring and cleaning the fitting rooms whenever a customer wants to use them. It also ensures that the rooms are always clean and customers are happy. The value behind this product lies in the efficiency and user interface of the system. Customers find the value in the easy to understand indication lights for knowing when a room has been thoroughly cleaned for them to use. Stores will want to incorporate this product into their own fitting rooms in order to increase the customer satisfaction as well as provide a more efficient system where their employees do not have to worry about always monitoring and cleaning the rooms but can direct their attention to more important matters around the store.

1.3 Visual Aid/Physical Diagram

The physical diagram shown below in Figure 1 is an initial sketch of what the final project organization and layout will look like. This design is based off of the locker provided to us by the machine shop in order to create a scaled down project of a fitting room. The individual components and sensors are labeled and in an approximate location in the sketch. With the ultrasonic sensors, the sensor pictured on the right of the diagram will actually be placed slightly further back inside the locker rather than at the entrance. The exact distance will be discussed later in the document. The three indicator lights at the top of the picture are red, yellow, and green LEDs respectively. Each color represents a separate state of OCCUPIED, SANITIZE, and OPEN. The sanitizer spray nozzles seen at the left of the picture are all placed on a board in order to control the spraying of liquid in order to increase the safety of the project as the testing will occur in a lab with many electrical parts. The UV lights and PIR sensor are positioned at the top of the locker in order to cover the most area with the UVC light and pick up any extra noise from an occupant to increase accuracy of detecting if an occupant is in the room or not.

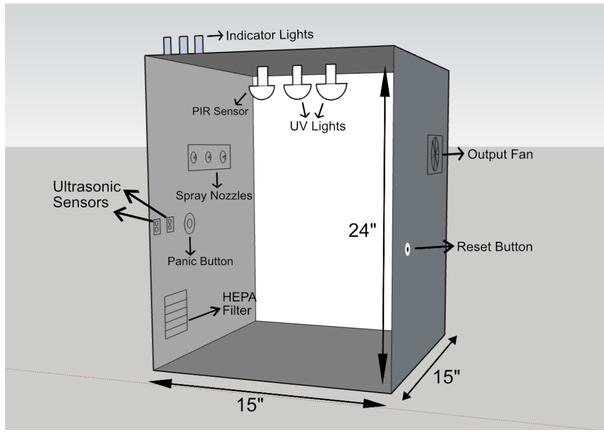

Figure 1: Physical Sketch of the Project with Dimensions

1.4 High Level Requirements

- 95% of the air in the fitting room +/- 5% must be filtered during the disinfection process.
- The fitting room must go through the entire disinfection process within 3 minutes +/- 10 seconds of detecting the occupant leaving with the disinfectant covering 95% +/- 5% of the bench, hangar, and doorknob surfaces.
- The detection system of an occupant in the fitting room must be accurate 95% of the time +/- 5%.

2 Design

2.1 Block Diagram

The block diagram shown below in Figure 2 consists of 5 main subsystems that are connected through a power line (represented by red), a digital I/O line (represented by blue), or an analog I/O. The sensing subsystem provides the input to the microcontroller. This subsystem consists of two ultrasonics sensors, one panic button and a PIR sensor. The components in this subsystem are powered by the power circuit that delivers 5V. The microcontroller in the control subsystems processes the inputs from the sensing subsystem to decide on the state of the room and produce output signals accordingly. The control subsystem and the sensing subsystem are connected to each other through digital I/O and analog I/O lines. The microcontroller delivers the output signals to the switches of the mechanical subsystem and to the light subsystem through digital I/O lines. Both the mechanical subsystem and the light subsystem are powered by the power circuit that delivers 12V. The mechanical subsystem consists of the HEPA filter and the sanitizer sprayer, which the microcontroller outputs turn on only during the SANITIZE state. The light subsystem consists of the UV light and the indicator light, which are connected to the microcontroller as well. The outputs from the microcontroller turn on the UV light only during the SANITIZE state, and they light up a different colored LED for each state.

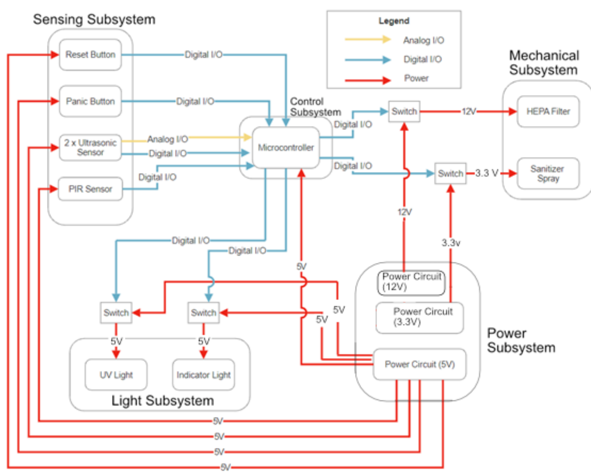

Figure 2: Block Diagram of the System

2.2 Sensing Subsystem

This subsystem has the sensors used for the advance detection scheme. The two ultrasonic sensors detect the entrance and exit of the customer depending on which sensor is triggered first. These sensors will be placed at the entrance and they will provide input to the microcontroller. Depending on this input the microcontroller will switch between OPEN, OCCUPIED and SANITIZE states. The sensor will interact with the microcontroller through GPIO connection. It will be powered by the power subsystem delivering 5V to it.

To make it more accurate a PIR sensor will be placed in the room. These sensors will interact with the microcontroller through digital I/O and analog I/O connections. The inputs from the sensor will determine the state of the room and the microcontroller will produce outputs accordingly. It will be powered by the 5V input coming from the power subsystem.

The panic button is also included in this subsystem. The panic button will reset the state of the microcontroller to OCCUPIED, in which the indicator light will be yellow and the mechanical subsystem as well as the UV light will remain powered off. It will be powered by the 5V input coming from the power subsystem.

2.2.1 Ultrasonic Sensors

Two ultrasonic sensors are placed next to each other horizontally. The ultrasonic sensors are powered through their Vcc pins using 5V and are connected to the microcontroller through digital I/O and analog I/O lines. The ultrasonic sensors measure the distance between the sensor and the door frame. When a change in distance is detected they send a signal to the microcontroller. Therefore, depending on which of the two sensors detect a change in distance, the microcontroller changes states. If the outer ultrasonic sensor is triggered before the inner sensor, the microcontroller changes the state to OCCUPIED, if the inner ultrasonic sensor is triggered before the outer sensor, the microcontroller changes the state to SANITIZE. The Requirements and Verification Table can be found in Appendix A, Table 4. Below are the calculations we performed to see how far to space out the ultrasonic sensors inside the fitting room. We decided that the average spacing should be 10 cm based on the average walking speed of humans.

$$1 \text{ m/s} * 50 \text{ ms} = 5 \text{ cm} \tag{1}$$
$$1 \text{ m/s} * 100 \text{ ms} = 10 \text{ cm} \tag{2}$$

$$2 \text{ m/s} * 50 \text{ ms} = 10 \text{ cm} \tag{3}$$
$$2 \text{ m/s} * 100 \text{ ms} = 20 \text{ cm} \tag{4}$$

2.2.2 PIR Sensor

The PIR sensor is placed inside the room. It is powered through the Vcc pin using 5V and connected to the microcontroller through digital I/O lines. The PIR sensor works as a second layer of security for the detection system. After the ultrasonic sensors detect the customer leaving the fitting room, the PIR sensor should not pick up any motion because if it does, that would mean the ultrasonic sensors were triggered by mistake. Therefore, after the customer leaves, the microcontroller waits for the PIR sensor to confirm that the room is ready to switch to SANITIZE state. The PIR sensor input is ignored during the SANITIZE state. The potentiometer on the sensor is used to adjust the sensitivity of the sensor. The Requirements and Verification Table can be found in Appendix A, Table 4.

2.2.3 Panic Button

A push button will be used to reset the microcontroller if it accidentally switches to SANITIZE state. The button will be debounced by using the code installed in the microcontroller to delay the reading from the button by a small amount of time. When pressed, the button should return the microcontroller from the SANITIZE state to the OCCUPIED state. The Requirements and Verification Table can be found in Appendix A, Table 4.

2.2.4 Maintenance Button

A push button will also be used to put the microcontroller into a maintenance state in case a worker needs to fix something on the fitting room or refill the sanitizer. Similar to the panic button, it will be debounced by using the code installed in the microcontroller to delay the reading from the button by a small amount of time. When pressed, the button should change the microcontroller from the OPEN state to the MAINTENANCE state. The Requirements and Verification Table can be found in Appendix A, Table 4.

2.3 Control Subsystem

The control subsystem consists of a microcontroller that handles the input and outputs. The inputs to the microcontroller consist of sensor data and the outputs determine whether to run the mechanical parts and the lights. The duration of the SANITIZE state in which the HEPA filter runs is determined by the amount of time it takes the HEPA filter to filter the volume of air in the room. In this state sanitizer is also sprayed to certain areas in the room that are touched the most. In the OCCUPIED state, the indicator light changes to a color that indicates the room is occupied. In the OPEN state, the HEPA filter stops running, the sanitizer stops being sprayed and the UV light turns off.

2.3.1 Microcontroller

ATMEGA32 microprocessor is used to switch between different states according to the input coming from the PIR sensor, the ultrasonic sensors, and the panic button through the GPIO pins. It also sends the necessary output signals to the light subsystem and mechanical subsystems. These output signals are used to turn these subsystems on and off using a MOSFET. The microcontroller starts in the OPEN state, which turns off the HEPA filter, the UV light, and the sprays, while turning the indicator light to green. When a change in distance that ultrasonic sensors measure is detected they send a signal to the microcontroller. Therefore, depending on which of the two sensors detect a change in distance, the microcontroller changes states to either OCCUPIED or SANITIZE. If the outer ultrasonic sensor is triggered before the inner sensor, the microcontroller changes the state to OCCUPIED, if the inner ultrasonic sensor is triggered before the outer sensor, the microcontroller changes the state to SANITIZE. In the OCCUPIED state, the only change happens in the indicator light as it turns from green to yellow indicating the room is occupied. Therefore, the microcontroller output signals sent to the MOSFETs connecting the light subsystem to the power subsystem light up the yellow indicator light and turn off the green indicator light. In the SANITIZE state, the microcontroller output signals turn on the UV light, change the indicator light to red, and start the HEPA filter and the sprayer. The output signals from the microcontroller turn off the sprayer after 5 to 10 seconds and turn off the HEPA filter and the UV light after 3 minutes. After 3 minutes, the microcontroller switches back to OPEN state. A flowchart for the microcontroller code can be found in Figure 3 on the next page. The Requirements and Verification Table can be found in Appendix A, Table 4.

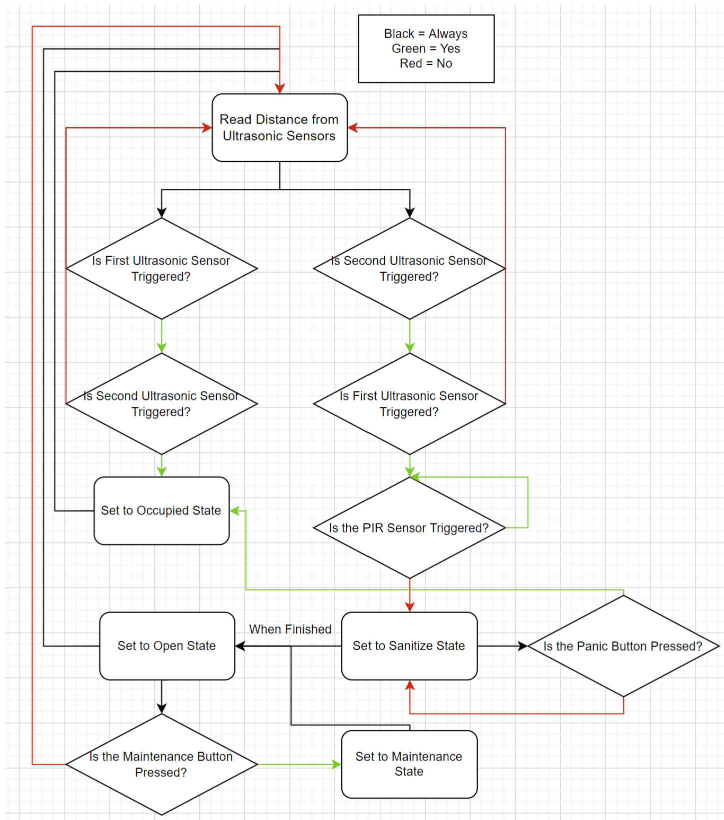

Figure 3: Flowchart for Microcontroller

2.4 Power Subsystem

Provides power to different subsystems with different voltage requirements. The voltage requirements of the microcontroller and sensors are different from the voltage requirements of the mechanical parts and lights. There will be an AC to DC converter that will provide 12V DC power that can be applied to the HEPA filter fans, sanitizer spray, UV lights, and indicator LED lights. A buck converter will convert the 12V DC to 5V DC to provide power to the maintenance button, panic button, ultrasonic sensors, PIR sensor, and microcontroller.

2.4.1 AC/DC Converter

The AC/DC Converter will take the power from the wall at 120V AC and drop it down to about 12V DC in order to utilize it for multiple components in the project. The fans for the HEPA filter require 12V DC, so this converter supplies power directly to the fans. This 12V DC is also used as the input to a DC/DC buck converter to drop the voltage down to lower levels for powering other components of the design.The Requirements and Verification Table can be found in Appendix A, Table 4.

2.4.2 DC/DC Converter

From the AC/DC converter, 12V DC is supplied to the circuit. The microcontroller and other components of the circuit require 5V. Through further testing, we realized we needed to add 3V and 5V voltage regulators to help power the sensors, water pumps, and microcontroller as well. A DC/DC buck converter was also implemented so that all three power modules could supply power to the LED indicator lights, UV lights, microcontroller, button, ultrasonic sensors, and PIR sensor. The Requirements and Verification Table can be found in Appendix A, Table 4.

2.5 Light Subsystem

Light subsystem consists of two different types of light. The UV light is used for the SANITIZE state and only turns on during the sanitization process. The indicator light remains on during every state but changes color depending on the state. The different colors of light indicate whether the room is in OCCUPIED, SANITIZE, or OPEN state.

2.5.1 UV Light

The UV light is placed inside the room and its connection to the power circuit is controlled by a MOSFET that uses the output signal from the microcontroller to turn on and off the UV light. The power circuit powering the UV light delivers 5V. The UV light is only turned on during the SANITIZE state and it is turned off in the OCCUPIED and OPEN states. The Requirements and Verification Table can be found in Appendix A, Table 4.

2.5.2 Indication Lights

The indication lights consist of three LEDs with colors green, yellow and red. Depending on the state of the room the assigned color lights up indicating whether the room is in the OPEN, OCCUPIED, or SANITIZE state. The LEDs are connected to the power circuit that delivers 5V and they are controlled by MOSFETs which determine which LED will be turned on or off depending on the signal coming from the microcontroller. The green LED indicates OPEN state, the yellow LED indicates OCCUPIED state, and the red LED indicates SANITIZE state. The Requirements and Verification Table can be found in Appendix A, Table 4.

2.6 Mechanical Subsystem

Mechanical subsystem consists of the HEPA filter and the sanitizer sprayer. They interact with the microcontroller and depending on the state of the room the HEPA filter and sanitizer spray turn on. The HEPA filter helps filter Covid sized particles around 4-10 microns [3] [4].

2.6.1 HEPA Filter

The HEPA filter unit consists of a fan with a HEPA filter attached to it. It is also controlled by the microcontroller whose output controls a MOSFET connecting the power circuit to HEPA filter. Depending on the output signal from the microcontroller, the HEPA filter turns on and off. The HEPA filter remains turned off during the OPEN and OCCUPIED states. It only turns on during the SANITIZE state and remains turned on for 3 minutes, which is calculated to be enough time to filter all the air inside the room through the HEPA filter. After 3 minutes the microcontroller output signal changes again and turns off the HEPA filter through the MOSFET connecting it to the power circuit that delivers 12V. The Requirements and Verification Table can be found in Appendix A, Table 4.

2.6.2 Sanitizing Spray

The sanitizing spray consists of a fan with a submersible pump. It is controlled by the microcontroller whose output controls a MOSFET connecting the power circuit to the sanitizing spray. Depending on the output signal from the microcontroller, the sanitizing spray turns on and off. The spray remains turned off during the OPEN and OCCUPIED states. It only turns on during the SANITIZE state and remains turned on for 5 to 10 second. During this time it sprays sanitizer to 3 high contact surfaces. After 5 to 10 seconds the microcontroller output signal going to the sanitizing spray changes again and turns off the spray through the MOSFET connecting it to the power circuit that delivers 12V. The Requirements and Verification Table can be found in Appendix A, Table 4.

2.7 Simulations

While planning the design of the switching feature for some of our subsystems, we used LTSpice simulations to test the functionality. This main simulation can be seen below in Figure 4.

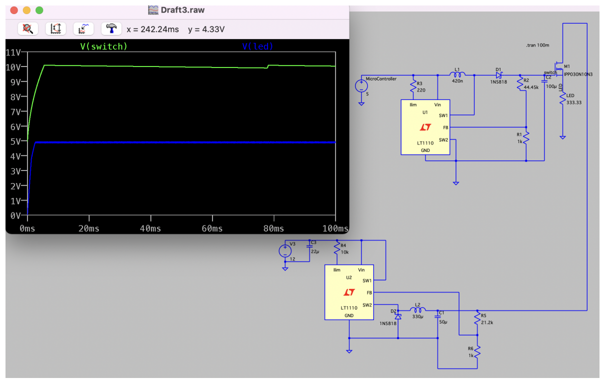

Figure 4: Simulation of the Switch (controlled by the Microcontroller) and the 5V supply to the LEDs

2.8 Schematics

After fully completing the design of each of our subsystems, we designed a PCB layout using KiCad to create our circuit board. Both the schematic and board layout can be found in Figures 5 and 6 respectively.

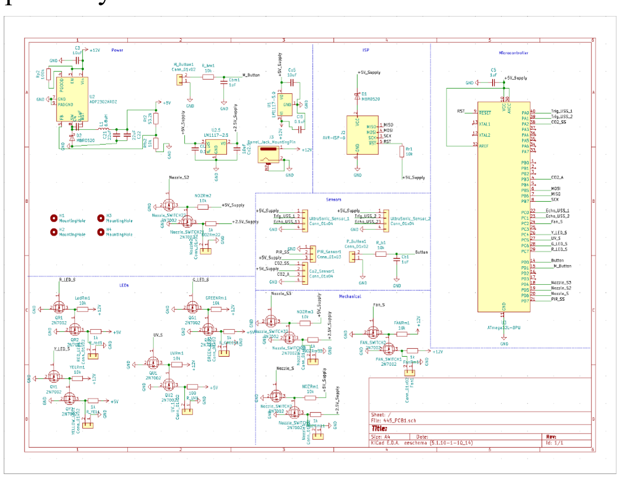

Figure 5: Schematics of the System

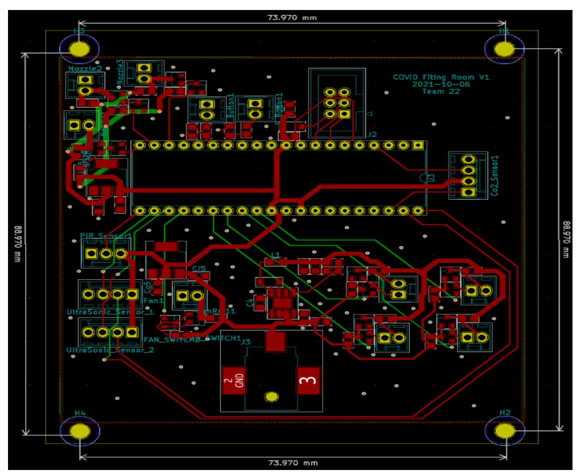

Figure 6: Board Layout of the System

3 Design Verification

We carried out the design verification process by first unit testing the individual components. Afterwards, we performed integration testing to minimize the errors that can occur in the system testing.

3.1 Sensing Subsystem

We initially tested the individual components of the sensing subsystem. The first component we tested was the ultrasonic sensor. We used a waveform generator to send a 10μs long HIGH signal to the ultrasonic sensor and measured the output signal from the ECHO pin using an oscilloscope. The duration of the ECHO signal matched the distance we were measuring with an accuracy of 95%. The ultrasonic sensor also drew 8mA at 5V during our testing.

The next component we tested was the PIR sensor. We triggered the PIR sensor by hand and measured the duration of its output signal using an oscilloscope. The PIR sensor picked up movements within the 5ft radius and provided the desired HIGH output duration with the required accuracy of 95%. It drew 24mA at 5V during our testing.

We tested the buttons using a power supply and a multimeter. The buttons shorted the node when pressed just as expected. When we integrated buttons into our overall design, the buttons, we connected the floating node to the microcontroller. The buttons provided a LOW input signal with 100% accuracy rate during our testing.

3.2 Mechanical Subsystem

The unit testing of the HEPA filtered fans showed that each fan draws 107mA at 12V. We knew the voltage rating of the fans. Therefore, we provided the fans with 12V using a power supply and measured the current they draw.

The water pumps could work between 2.5V-5V. Therefore, we tested them using 3.3V. Each pump drew 50mA at 3.3V. However, during the integration testing, we realized that due to a mistake we made in the PCB design, adding the resistances decreased the power we delivered to the water pumps. Designing a new PCB and adjusting the resistor values solved this problem and allowed the components to pass the integration testing. However, the nozzles and tubing were lower quality than expected so the spraying system was not able to pass our requirements of a specified time to spray each specific component of the fitting room. This was the only requirement that did not pass, but overall the water pumps still worked well and turned on in our final design.

3.3 Light Subsystem

We verified the light subsystem by powering each LED except the UV LED with the power supply. The LEDs drew 26mA at 5V. The UV LED was tested without connecting to power supply due to safety hazards. Instead, its testing was done only using a multimeter.

3.4 Power Subsystem

We tested the power subsystem during the integration testing since our main interest was verifying its performance under the real operating conditions. The table on the next page displays the verification results of the power subsystem in the integration testing.

Table 1: Verification Table of Power Subsystem

Power Component	3.3V Voltage Regulator	5V Voltage Regulator	Buck Converter	12V AC/DC Adapter
Supplied Component	Water Pumps	Ultrasonic Sensors, PIR Sensor, Microcontroller	LED Lights, 3.3V Voltage Regulator	Filter Fans, Buck Converter, 5V Voltage Regulator
Measured Voltage	3.302V	5.017V	4.617V	12.102V

During the integration testing, the overheating of the linear voltage regulator while supplying 400mA current caused a voltage fluctuation that burned the microcontroller. Therefore, the voltage regulator failed to meet the design requirement of supplying 800mA at 5V. However, this problem was resolved by using the buck converter through air wires to supply the microcontroller.

3.5 Control Subsystem

We tested the individual legs of the microcontroller using a test code during the unit testing. However, during the integration testing the microcontroller burned due to the malfunctioning of the linear voltage regulator. After correcting the power subsystem malfunctioning, the microcontroller worked properly in the integration testing and drew 40mA at 5V. In the system testing process, the microcontroller successfully switched between states with a 100% accuracy rate.

3.6 System Testing and High Level Requirements

After unit testing and integration testing, we tested the system as a whole with the possible real life scenarios. The system testing verified all of our high level requirements. The first high level requirement was filtering 95% of the air through the HEPA filter in the sanitization process. With the flow rate of our fans we were able to meet this requirement within our time constraints. Another higher level requirement was completing the disinfection process within 3 minutes. We managed to complete it within 1.5 minutes for the scaled down version of the fitting room we used as a proof of concept. Our last high level requirement was detecting customers with 95% accuracy. The system testing verified that our detection accuracy is around 95% just like we calculated. The addition of the panic button also further guaranteed meeting this requirement.

4 Costs and Schedule

4.1 Labor Costs

We estimated the average cost of labor for each person to be $30/hr and our team consists of 3 people, who are working approximately 10 hours per week. We used an overhead multiplier of 2.5 Considering we have 16 weeks in the semester, the total cost of labor is given by:

(16 weeks for entire semester) x (3 people) x (10 hours per week) * ($30/hr) x (2.5) = $36,000 (5)

The labor cost was not the only cost to consider. Table 2 below shows the parts cost required for our project.

4.2 Parts Cost

Table 2: Part Costs

Part	Quantity	Cost (Individual)	Cost (Total)
Ultrasonic HC-SR04 Module	3	$3.95	$11.85
Adafruit PIR Sensor (Product ID: 189)	1	$9.95	$9.95
ProTeam 107315 HEPA Replacement Filter	1	$13.10	$13.10
L933-UV265-2-20 (UV Light)	2	$10.22	$20.44
L314GT (Green LED)	10	$0.154	$1.54
L314YD (Yellow LED)	10	$0.154	$1.54
L314ET(Red LED)	10	$0.154	$1.54
40-1673-01 (Push button switch)	2	$1.65	$3.3
ATMEGA32L-8PU	2	$7.39	$14.78
LM1117MPX-50NOPB	1	$0.59	$0.59
ADP2302ARDZ (Buck Converter)	1	$3.15	$3.15
2N7002-G (MOSFET)	25	$0.488	$12.20
Submersible Water Pump (Product ID: 4547)	3	$2.95	$8.85
Tubing for Submersible Pumps - PVC 6mm ID - 1 Meter Long (Product ID:4545)	3	$1.50	$4.50
12V Wall to Barrel Adapter	1	$9.82	$9.82
474-PRT-10877	1	$1.50	$1.50
Barrel Jack (PJ-036AH-SMT-TR)	1	$1.36	$1.36
10k Ohm Resistor	20	$0.095	$1.80

1k Ohm Resistor	20	$0.098	$0.98
100 Ohm Resistor	3	$0.18	$0.54
100k Ohm Resistor	5	$0.20	$1
53.6k Ohm Resistor	3	$0.16	$0.48
10uF Capacitor	10	$0.183	$1.83
0.1uF Capacitors	10	$0.093	$0.93
1uF Capacitor	10	$0.113	$1.13
22uF Capacitor	10	$0.132	$1.32
1x2 pin connector headers	10	$0.155	$1.55
1x3 pin connector header	1	$0.254	$0.254
1x4 pin connector header	5	$0.653	$3.265
Schottky Diode	10	$0.261	$2.61
6.8uH Inductor	2	$0.28	$0.56
Total:	196	$70.94	$138.26

4.3 Total Cost

We found the cost of parts to be $138.26 and the cost of labor to be $36,000. The total cost of the project is given by:

Total cost = cost of labor + cost of parts = $36,138.26

4.4 Schedule

Table 3 belows shows the original schedule we wanted to stick to at the beginning of our project. We worked well and communicated effectively to continually hit our deadlines and eventually create a successful project.

Table 3: Project Schedule

Week	Ege	Bill	Arin
9/20/21	Design PCB circuits/schematics	Design PCB circuits/schematics	Research parts and components
9/28/21	Put together first draft of PCB design	Work on design document components	Work on design document components
10/4/21	Finalize PCB design/order PCB	Work with machine shop to make final revisions	Order parts and components
10/11/21	Research microcontroller coding	Research microcontroller coding	Test parts and components

10/18/21	Work on second PCB design (if necessary)	Research microcontroller coding	Test parts and components and integrate into project
10/25/21	Finalize and submit second PCB design	Write test codes for microcontroller	Test parts and components and integrate into project
11/1/21	Write test codes for microcontroller	Write test codes for microcontroller	Test parts and components and integrate into project
11/8/21	Start finalizing code and physical project	Start finalizing code and physical project	Start finalizing code and physical project
11/15/21	Finalize physical project for Mock Demo	Finalize physical project for Mock Demo	Finalize physical project for Mock Demo
11/22/21	FALL BREAK	FALL BREAK	FALL BREAK
11/29/21	Finalize any errors from Mock Demo/Prep for Demo/Create Presentation and Report	Finalize any errors from Mock Demo/Prep for Demo/Create Presentation and Report	Finalize any errors from Mock Demo/Prep for Demo/Create Presentation and Report
12/6/21	Create/Practice Presentation and Final Report	Create/Practice Presentation and Final Report	Create/Practice Presentation and Final Report

5 Conclusion

5.1 Accomplishments

Our biggest accomplishment in the project has been being able to prevent false triggering of the sensors. Due to privacy concerns we were not able to use visual cues for detection. The method we came up with was using ultrasonic sensors instead, which was a very risky decision in terms of false triggers. However, we were able to prevent their false triggering by making adjustments on the program we uploaded to the microcontroller. Adding delays at certain points in the code as well as using a PIR sensor as a second layer of security prevented accidental triggering.

Other main accomplishments were getting the switching circuit to work correctly, getting the microcontroller to switch states in the correct order, and turning on the mechanical components for the desired duration. All of these accomplishments were dependent on the PCB design. Therefore, some of these aspects were initially our failures. For example, we were not able to deliver the desired power to some of the mechanical components because of the errors in the PCB design that were preventing the switching circuit to work properly. However, these problems were resolved after our final PCB design, turning our failures into accomplishments in these areas. We were eventually able to integrate all of our subsystems successfully and demonstrate our final product. The final product can be seen in Figure 7 below.

Figure 7: Picture of Final Product Constructed

5.2 Failures and Uncertainties

There were many failures throughout the process of building this design. The first failure we faced was with the PCB design. Some MOSFET connections in our second PCB design were missing resistors. Even when we added the resistors in our next PCB design, we faced another problem. The power dissipated by the resistors we added was preventing us from delivering the right amount of power to water pumps. It took a little trial and error to find the right resistor values.

Our next failure was accidentally breaking one of the fan blades while trying to test it with the HEPA filters. This was an accident we were not prepared for. Fortunately, the fan rpm was not high enough to cause any damage when the blade broke. Therefore, a more serious accident was prevented.

One of the most concerning failures was burning our microcontroller. The voltage regulator we used was supposed to be able to supply up to 800mA. However, even at 400mA, the voltage regulator was overheating. In one of the trials, the overheating of the voltage regulator caused an unexpected voltage to be delivered to the microcontroller and burned our microcontroller. We overcame this problem by using air wires to use the buck converter instead of the voltage regulator to provide 5V to the 3.3V voltage regulator.

Another failure we faced was due to using a scaled down version of the fitting room. The small scale and smooth surfaces inside this scaled down version of the room was causing a lot of echo whenever we turned on the ultrasonic sensors. This was significantly decreasing the accuracy of our ultrasonic sensors. Since the ultrasonic sensors work by sending an acoustic burst and measuring the time it takes this burst to reflect from the surface, we discovered that using acoustic foam solves this problem right away.

The last failure was caused by the spraying system. The low quality of nozzles we used were causing the fluid to leak even after we stopped pumping it. In addition to this, the water pumps were having a hard time pumping the fluid whenever there was a sharp turn on the tubes we used. The solution to this problem would be either using pumps with higher power or higher quality tubes. Since we ran out of time we were not able to apply any of these solutions.

5.3 Ethical and Safety Considerations

One ethical issue pertaining to the project is the similarity to the Covid Convenience Locker which was done in the past. In order to prevent any plagiarism or copying from the previous project, we will make sure our solution is unique and have applications that are solely for fitting rooms rather than the locker which was done in the past. We will also make sure that all the work is evenly distributed amongst the group to treat everyone fairly and ensure it is a group project. We will abide by the IEEE Code of Ethics and make sure all research conducted is correctly cited and referenced [5].

Additionally, we want to ensure the privacy of the occupants within the fitting rooms. Many states have laws that make cameras inside fitting rooms illegal, so the use of cameras for occupant detection is eliminated [6]. There are a large number of concerns that customers have with being monitored while inside a changing room, so we have chosen to utilize multiple different types of sensors that do not require cameras or any pictures and videos. This eliminates the potential for customers to be uncomfortable using a self-cleaning fitting room that detects occupancy.

Now considering the safety aspects of the project, our project utilizes high current systems where we would have to physically test. This could create a dangerous environment if not controlled during the development and testing stage. We would also need to test these circuits on the PCB board, which due to its size can cause some accidents in addition to the potential risk while soldering the components onto the PCB. While testing we will ensure that we have a clear area, exercise caution, and follow all the lab safety guidelines described in the safety training required at the beginning of the course.

Additionally, long exposure to UV light can also present harmful effects. Direct exposure to skin and eyes from UV radiation could cause painful eye injury or rashes on the skin [7]. Therefore, the margin of error for the UV light is set very low at 1%. Also, it has been set to turn off within 10 minutes after the end of the SANITIZE state. The design also has a panic button that a user can press so if the detection system fails and an occupant is still inside during the disinfection stage, they can press the button to cancel the disinfection process. Similarly, we will have the sanitization zones and HEPA filter turn on first rather than the UV light in case this situation occurs.

While testing spray nozzles, we will use water instead of an alcohol based sanitizer since alcohol is both flammable and corrosive. Therefore, it would be dangerous to test it with real sanitizer in a lab setting. The nozzles will also be placed on a wooden plank separating them from the electrical components. This will allow us to control the area being sprayed so that the spray does not get into undesired locations within the lab. The lab has many different electrical components and parts, so the introduction of a liquid has to be controlled which will be solved by putting all nozzles on a board in an enclosed locker within the lab before testing.

5.4 Future Work

The self-sanitizing fitting room will remain a useful tool even after the COVID-19 pandemic ends since it cuts the cleaning costs and it is effective against other viral infections as well. However, the newer iterations of the project can use some improvements, especially in the mechanical subsystem. One failure that we did not have time to solve was getting the sanitizer sprayers to work properly. Therefore, the newer versions of the project can benefit from water pumps with higher power and nozzles that can prevent fluid leakage after the pumps are turned off. Other improvements on the project include using more and higher quality sensors. Since we are limited to sensors that do not use visual cues, one way of increasing the sensing accuracy is using more sensors. Even though we already achieved a really high accuracy rate with the current sensing scheme, the system can still greatly benefit from these sensor improvements.

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Appendix A: Requirements and Verifications Table

Table 4: Requirements and Verifications

Requirement	Verification	Verification Status (Y/N)
1. The ultrasonic sensors are going to be placed 10cm apart, which will be able to tell whether a person is entering or leaving a room (with 95% +/- 5% accuracy) with an average speed of 1m/s to 4m/s depending on the order of triggering of the sensors.	1A. Connect the ultrasonic sensor to the microcontroller after verifying the microcontroller requirements. 1B. Place the sensors 10cm apart and trigger them with a mock object entering the room with an average speed of 1m/s to 4m/s. 1C. Measure the output signals of the ultrasonic sensors going into the microcontroller using a test code to see the sequence of triggering for detection.	Y
2. PIR Sensor should not pick up motion due to air movement 95% +/- 5% of the time.	2A. Connect the output pin of the PIR to a 100ohm resistor that is serially connected to an LED. 2B. Connect the GND pin of the LED and the PIR sensor to ground, and Vdd pin of the PIR sensor to 5V DC. 2C. Check if PIR correctly outputs a signal when moving hand in front of the sensor and observe if there are any false detections using LED as the indicator.	Y
3. Panic button should always reset the microcontroller to the OCCUPIED state.	3A. Connect the panic button to the microcontroller after verifying the microcontroller requirements. 3B. Set the microcontroller to start in the SANITIZE state at the beginning. 3C. Press the panic button and check the output signals from the microcontroller to verify the OCCUPIED state should be observed.	Y
4. The Maintenance button should always reset the microcontroller to the MAINTENANCE state.	4A. Connect the maintenance button to the microcontroller after verifying the microcontroller requirements. 4B. Set the microcontroller to start in the	Y

	OPEN state at the beginning. 4C. Press the maintenance button and check the output signals from the microcontroller to verify the MAINTENANCE state should be observed.	
5. Microcontroller should send correct output signals in each of the OPEN, SANITIZE, and OCCUPIED states with 99% accuracy.	5A. Connect the microcontroller to a 5V DC power source. 5C. Install the code that specifies output signals for each of the OPEN, SANITIZE, and OCCUPIED states. 5D. Measure the output signals using an oscilloscope while the state variable is set to a particular state. 5E. Switch the state using the state variable in the code and measure the outputs for every state.	Y
6. Power circuits for mechanical and light subsystems should provide 12V +/- 5V and 300mA from a source of 120V.	6A. Connect the power circuit to a 120V wall plug. 6B. Measure the output from the circuit using an oscilloscope to make sure it supplies 12V +/- 5V and 0-300mA.	Y
7. Power circuits for control and sensor subsystems must be able to supply 5V +/- 0.2V and 0-250mA to the microcontroller, ultrasonic sensors, and PIR sensor from a source of 120V.	7A. Connect the power circuit to a 120V wall plug 7B. Measure the output from the circuit using an oscilloscope to make sure it supplies 5 V +/- 0.2V and 0-250mA.	Y
8. UV light should always turn on within 10 seconds after the sanitization process starts.	8A. Connect the panic button to the microcontroller after verifying the microcontroller requirements. 8B. Switch the microcontroller from OPEN state to OCCUPIED state and then to SANITIZE state. 8C. Check if the light turns on in the SANITIZE state and turns off in the OPEN and OCCUPIED state.	Y

	8D. Repeat the procedure several times to verify the required confidence interval.	
9. Lights must indicate the occupancy and state of the room within 10 seconds of changing states.	9A. Connect the panic button to the microcontroller after verifying the microcontroller requirements. 9B. Switch the microcontroller from OPEN state to OCCUPIED state and then to SANITIZE state. 9C. Check if the correct led lights up in every state. Red led should light up in SANITIZE state, yellow led should light up in OCCUPIED state, green led should light up in OPEN state. 9D. Repeat the procedure several times to verify the required confidence interval.	Y
10. The HEPA filter should run for 3 minutes in order to circulate 95% +/- 5% of the air in the fitting room through the filter.	10A. Connect the HEPA filter to the microcontroller and to the power circuit. 10B. Switch the microcontroller from OPEN state to OCCUPIED state and then to SANITIZE state. 10C. Check if the HEPA filter turns on for a selected amount of time (3 minutes) in the SANITIZE state and turns off in the OPEN and OCCUPIED state. 10D. Repeat the procedure several times to verify the required confidence interval.	Y
11. The concentration zones of the doorknob, hangar, and bench must receive sanitizer spray for 10 seconds +/- 5 seconds, 5 seconds +/- 2 seconds, and 5 seconds +/- 2 seconds respectively.	11A. Connect the sprayer to the microcontroller after verifying the microcontroller requirements and to the power circuit after verifying the power circuit requirements. 11B. Switch the microcontroller from OPEN state to OCCUPIED state and then to SANITIZE state. 11C. Check if the sprayers turn on in the SANITIZE state for the specified amount of time and turn off in the OPEN and OCCUPIED state.	N