SELF-CLEANING LOCKER

ECE 445 Design Document

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3/2/2021

1 Introduction

1.1 Objective

Sanitation means everything, especially in a pandemic. We must make sure that ourselves and our belongings are clean in order to help mitigate the spread of COVID. Especially with more companies, buildings, restaurants, and gyms opening up, it's becoming easier for the disease to spread. Particularly with gyms, people are constantly sharing lockers with others, which can easily spread germs due to the storage of their sweaty belongings and clothes.

To combat the spread of COVID, and germs in general, we are proposing a self-cleaning locker. When the locker detects that nothing is inside, it will automatically disinfect the inside of the locker using disinfectant sprays. An LED display on the outside of the locker door will display the status of whether or not it is cleaned, and if there is still disinfectant in the locker.

In addition, we will be building an app that will monitor the status of the locker. For gym owners, the app will allow them to keep track of all their self-cleaning lockers in their locker rooms and make sure that every locker is properly maintained for the safety of their employees and individuals using the gym’s lockers.

1.2 Background

We are trying to solve the issue of germs spreading between uses at gym lockers. The gym locker is the main area to hold someone’s belongings while using the gym, and everyone throws their belongings in there. However, no one knows who has used that particular locker before them, and if that person has been in contact with other people who have had COVID. Since the locker room is a shared space, an individual really has no choice where else to put their belongings, and whether or not the locker they choose is COVID, or germ free in general.

The gym is one of the easiest places where bacteria can spread. Many different parts of the building and locker room have a multitude of germs. For example, the gym faucet handle has 545,312 CFU (colony forming units), which has eight times as many bacteria than a school cafeteria water fountain spigot. Gym benches have 8,241 CFU, which has six times more bacteria than an animal cage [1]. Contact with these objects can easily lead to the spread of germs. In addition, research shows COVID can last up to two days on fabric, and even up to nine days on certain surfaces [2], [3].

This is where our project comes in. The main problem we are trying to solve is allowing users to have that ease of mind by not worrying about who has used the locker before them, and whether or not it’s clean to put their belongings in by eliminating bacteria that could be spread from surface to clothing, and ultimately an individual.

1.3 Physical Design

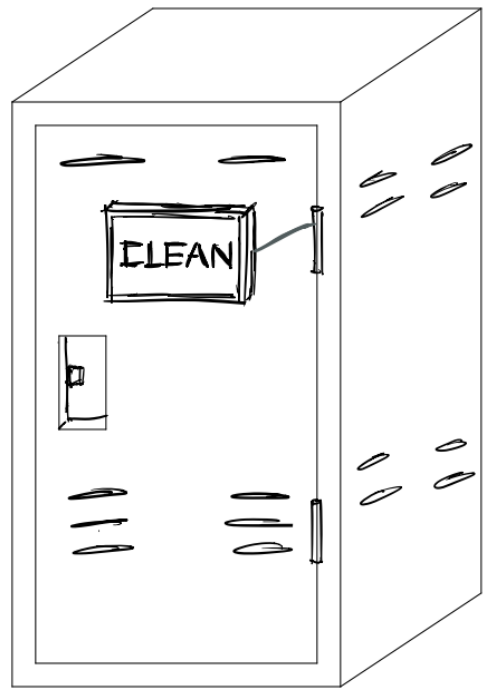


Figure 1: Sketch of locker exterior

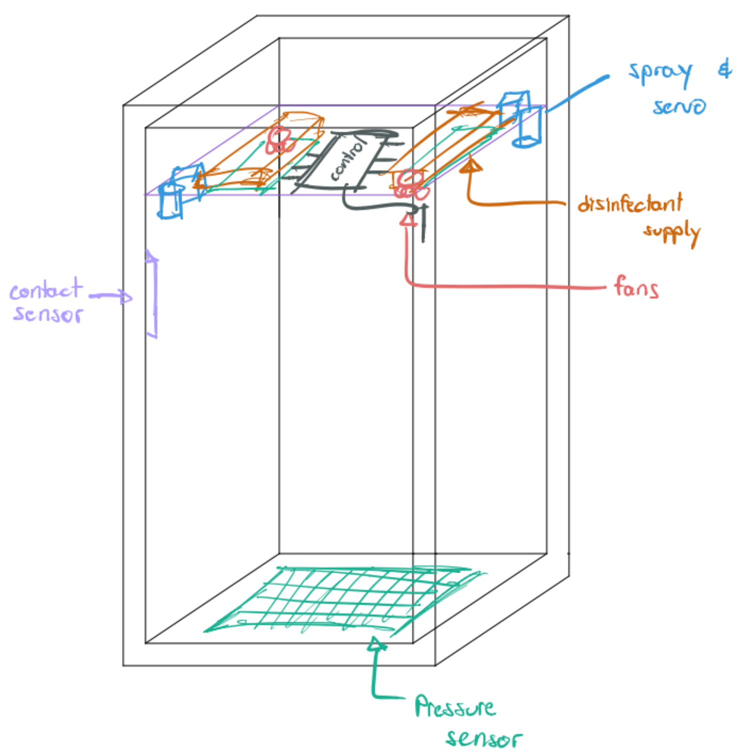


Figure 2: Sketch of locker interior with subsystems

1.4 High Level Requirements

- Weight sensors correctly detect when items weighing at least 250 grams are on top of them with an error range of roughly 5%.
- Spray correctly cleans the inside of the locker when it is empty and closed, covering at least 90% of each surface on the interior.
- Project correctly detects disinfectant supply levels with an error range of around 5%.
- Android application that communicates with the locker to get the status to display to the user. We will need a Bluetooth sensor capable of transmitting between 20 and 30 feet.

2 Design

The three main subsystem modules we will be using for our project will consist of a control unit, disinfectant unit, and monitoring unit. We will go into each module into further detail.

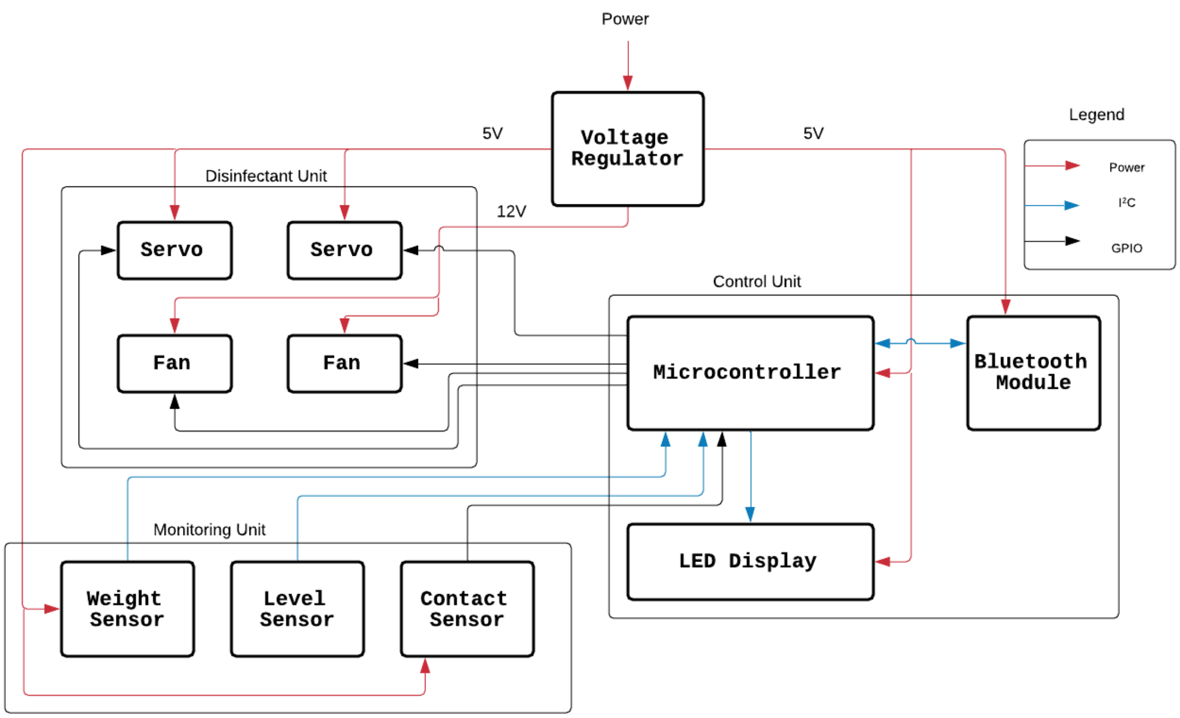


Figure 3: Block Diagram

2.1 Power Supply

Our locker will be plugged into a wall outlet but will make use of a voltage regulator to fine tune how much voltage we want to supply to certain components in our design. We will be using a power supply with two voltage rails. The first will be a 5V rail that will go to every device but the fans. We decided that we needed to have powerful fans to be able to quickly dry the locker after cleaning. Thus, we wanted to use bigger 12V fans optimized for airflow rather than tiny 5V fans that cannot really push much air.

2.1.1 Voltage Regulator

The voltage regulator will allow us to choose how much power to supply to each of our subsystems.

Requirements	Verification
1. Provide 12V +/- 5% from outlet plug	1. Measure output voltage using an oscilloscope, checking that the output voltage stays within 5% of 12V

2.2 Control Unit

Our control unit allows for all our subsystems to communicate with one another on which actions to perform depending on the conditions met within our locker.

2.2.1 Microcontroller

The microcontroller we are using, the ATMEGA328P-PU, will be used to program our LED display, along with handling communication between all our subsystems. This will control when to activate our sanitizing module and fans, and then display on our LED display whether the locker is ready to use.

Requirements	Verification
1. Microcontroller correctly communicates when sanitation process is in progress 2. Microcontroller correctly communicates when sanitation process is finished 3. Microcontroller correctly communicates when 25% of total disinfectant supply remains (+/- 5% error)	1. LED displays “CLEANING” when sanitation process is in progress 2. LED displays “CLEAN” when sanitation process is finished 3. LED displays “LOW SUPPLY” when solution hits 25% of total disinfectant supply left (+/- 5%)

2.2.2 Bluetooth Module

The Bluetooth module will be used to communicate the level of disinfectant supply within our locker to our Android application. This will take in the output of the weight sensor underneath our disinfectant supply tubes and forward it to our Android application.

Requirements	Verification
1. Have module correctly communicate information about disinfectant supply level at 100%, 75%, 50%, 25%, and 0% (with 5% error range) 2. Have Bluetooth module be able to get information from up to 20-30 feet away	1. Using Bluetooth terminal application on Android phone along with code on Arduino, check if output on Bluetooth terminal shows values equal to output of weight sensor for disinfectant supply 2. Test on physical Android phone walking 20 to 30 feet away from locker and checking if connection holds

2.2.3 LED Display

The LED should communicate with our microcontroller on what the display should show on the outside of the locker.

Requirements	Verification
1. LED should be visible from one meter away 2. LED should display “CLEANING” when locker is sanitizing 3. LED should display “CLEAN” when locker sanitation has finished 4. LED should display “LOW SUPPLY” when disinfectant supply is low	1. Stand about one meter away and see if LED display is legible 2. LED displays correct message depending on sanitation cycle

2.3 Disinfectant Unit

The disinfectant unit will be used to sanitize the interior of our locker when no items are inside the locker. Fans will be used to help dry the interior after we spray disinfectant on the surfaces of the inside.

2.3.1 Servo Motors

The servo motors should be able to initiate the spraying mechanism to sanitize the interior of the locker.

Requirements	Verification
1. Motors need to be able to repeatedly push trigger for spraying mechanism as per instructions of microcontroller	1. Results of sprayed solution can be seen after cleaning process has been run

2.3.2 Fans

The fans will be used to air out the inside of the locker after the spray sanitizes the inside of the locker. The locker door should be closed when the fans operate as well.

Requirements	Verification
1. Fans should be powered with 12V +/- 5%	1. Use DMM to check output voltage

2.4 Monitoring Unit

The monitoring unit will be used to monitor whether there are items inside the locker and will communicate with our disinfecting unit on whether to initialize or not. This unit will also monitor the amount of disinfectant supply within the locker and will communicate with our LED display and an Android app about certain locker information, such as supply level, and whether it is in use.

2.4.1 HX711 Load Cell Amplifier

The load cell amplifier will be used to be able to read the change in resistance in our load cells to communicate with our MCU. This will be used to find a more specific value for our disinfectant supply level.

Requirements	Verification
1. Be able to detect if there is strain on the load cell connected.	1. Attach load cell to load cell amplifier, and check if there is a Voltage output using DMM.

2.4.2 Load Cell (Locker bottom)

This load cell will be located at the bottom of the inside of the locker to detect if there are any objects on top of it to communicate to the MCU whether to start the sanitation process.

Requirements	Verification
1. Check if load cell is able to detect at least 250 grams	1. Connect load cell to load cell amplifier / Wheatstone bridge circuit, and check if roughly 250-gram object gives an output Voltage using DMM.

2.4.3 Load Cell (Disinfectant Level Monitoring)

This second load cell will be used to measure how much disinfectant there is left in our locker in order to clean it.

Requirements	Verification
1. Load cell should detect change of weight of disinfectant supply	1. Connect load cell to load cell amplifier / Wheatstone bridge circuit, and check if Voltage output changes based on different weight values using a DMM.

2.4.4 Contact Sensor

The contact sensor will be attached to the inside of the locker door to check whether the door is closed or not.

Requirements	Verification
1. Have the sensor correctly output 0/1 based on whether the door is open / closed. (0 for open, 1 for closed)	1. Connect output of sensor to breadboard and use a simple LED to check if sensor correctly outputs 0 / 1 whether it's open or closed.

2.4.4 Application

The application will act as a central monitoring system for all connected lockers. Each locker will have its status listed for an employee to check on the locker room. This will be created using Android Studio.

Requirements	Verification
1. Have phone application be able to read locker disinfectant supply levels at 100%, 75%, 50%, 25%, and 0% (with around 5% error range) 2. Have range of 20-30 feet	1. Using Bluetooth terminal application on Android phone along with code on Arduino, check if output on Bluetooth terminal shows values equal to output of weight sensor for disinfectant supply. 2. Test on a physical Android phone walking 20 to 30 feet away from locker and checking if connection holds.

2.5 Software

2.6 Schematics

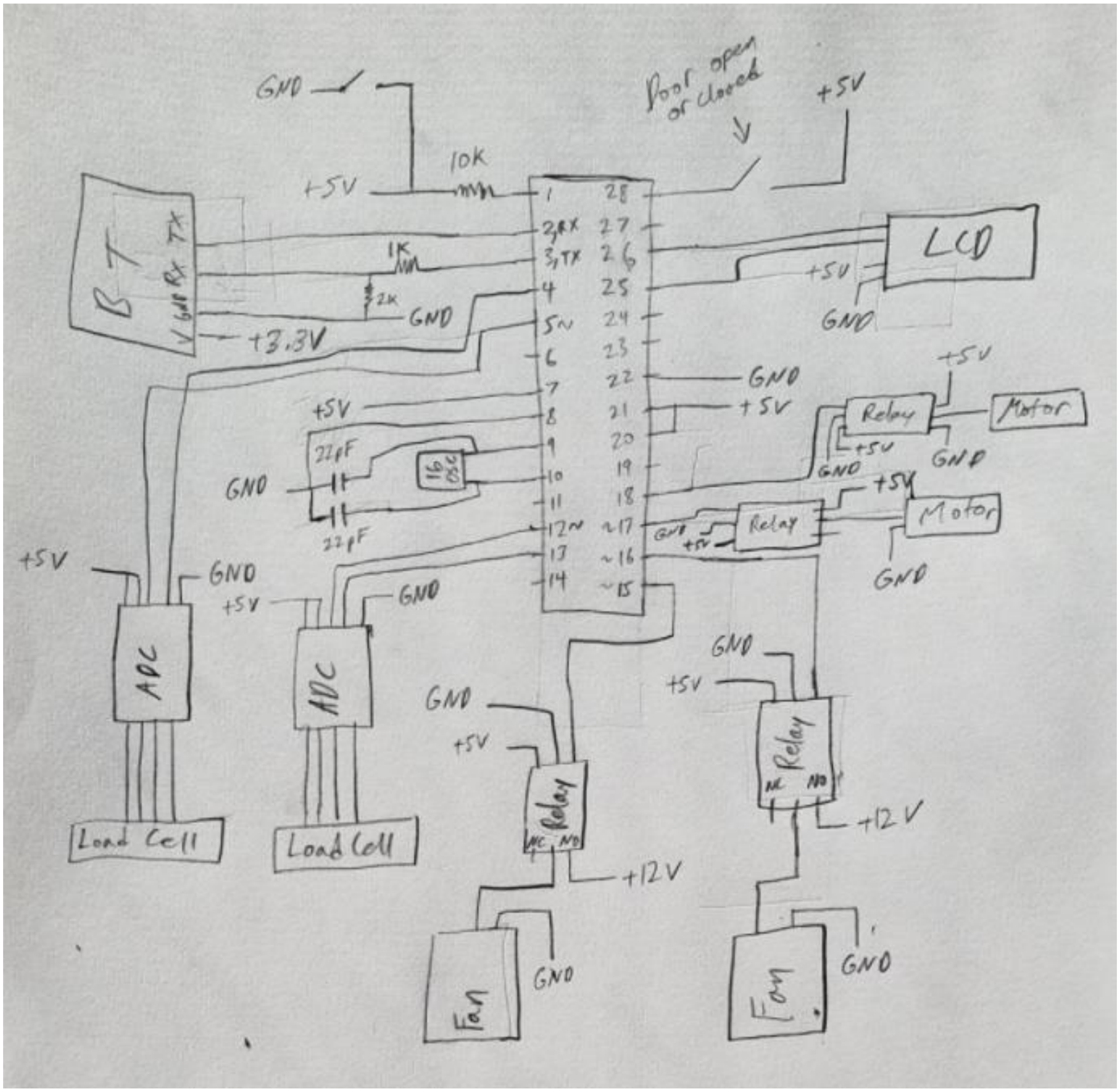


Figure 4: Rough Circuit Schematic (WIP)

2.7 Board Layout

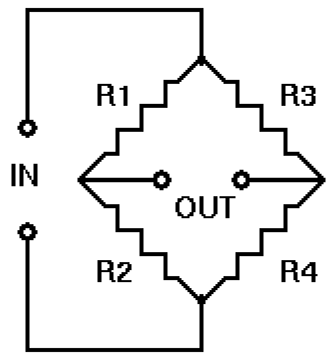
2.8 Tolerance Analysis

Load cell by itself does not detect much change in resistance.

- Formula: [GF * (strain)] * 100 = % change in resistance

To get a more accurate reading, we must use a Wheatstone Bridge Circuit:

- If R1 / R2 == R3 / R4, then Vout is 0, which means no weight on load cell.



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- Vout = [(R3 / (R3 + R4) – R2 / (R1 + R2))] * Vin

2.9 Risk Analysis

We think that the disinfectant supply monitoring block, specifically the application we are trying to develop, would be the most significant risk towards the completion of our overall project. None of us in the group have had to work with Android Studio in developing an app, on top of having it communicate information from our PCB through the Bluetooth module.

We would have to make sure that our Bluetooth module relays precise enough information so that our app can display different levels of disinfectant supply, similar to how modern day devices show the battery icon dwindles down as it loses charge. We would have to then figure out how to use that data within Android Studio in regards to programming our app.

In case we run into serious issues with Android Studio or time constraints on the project, our contingency plan is to create a simple website to interface with the Bluetooth module.

For our contingency plan if the whole class were to go remote, we would continue to get tested through the school, and hopefully be able to meet up in order to complete our project. If one member of the group were to test positive for COVID, we would redistribute the work to the two other members if the third member was not able to work due to feeling ill.

3 Costs

Our fixed development cost is estimated to be around …

Our parts and manufacturing prototype costs are estimated around …

Part	Cost (prototype)	Cost (bulk)
Outlet Plug-In (12V DC 2A Wall Power Supply Adapter; Amazon)	$9.99	
Mini360 3A DC Voltage Step Down Power Converter (Amazon)	$6.88	
HX711 Load Cell Amplifier (SparkFun)	$9.95	
Microcontroller (ATMEGA328P-PU)		
Bluetooth Module (HiLetgo HC-05 Wireless Bluetooth RF Transceiver; Amazon)	$7.99	
LED Display (KNACRO IIC I2C TWI 1602 Serial Blue Backlight LCD Module; Amazon)	$5.99	
Fan (Computer Case Fan DC 12V Cooling Fan; Amazon)	$13.99	
Strain Gauge Load Cell – 20kg (Adafruit) (3)	$11.85	
Gikfun MC-38 Wired Door Sensor	$7.29	
Servo Motor		
Spray Tube		
Total	$73.93	

We will only be making one board, and therefore our total cost will be …

4 Schedule

Week	Chilo	Nithin	Immanuel

5 Ethics and Safety

We are responsible for keeping the public's safety, health, and welfare in mind when designing this project. This refers to the IEEE Code of Ethics, #1, stating "to hold paramount the safety, health, and welfare of the public" [7]. We must be sure that our locker does not pose any safety concerns for people when using our device. We will go into how we would implement the required safety restrictions in our project later in this section.

Another ethical concern that is out of our control would be the discrimination of use with our product. This refers to the IEEE Code of Ethics #7, stating "to treat all persons fairly and with respect, and to not engage in discrimination based on characteristics such as race, religion, gender, disability, age, national origin, sexual orientation, gender identity, or gender expression" [7]. While we will never discriminate the use of our product based on the characteristics of a person such as race and gender, in a real-world application of our product where it is readily available in public gyms, certain establishments may discriminate against certain people on the use of the lockers. We do not have a solution for this, as it is out of our control as to how someone else may allow others to use our locker. The best thing we can do is to investigate whether or not a buyer has a good record of respecting an individual's race, gender, religion, etc., if we were to sell this product.

In terms of safety for our self-cleaning locker, we must make sure that our pressure sensor is accurate in detecting whether there are items, even small ones, in our locker. We have to make sure that no one's belongings get wet on accident by our sensor not detecting that they are there. Another safety issue that can come up is the issue of wiring in our project. We want to make sure that our wires do not short and cause damage to anything. We will address this by covering our wires with electrical tape whenever possible.

Going along with the issue of wiring in our project, we are going with a plastic build for our locker. Although most gym lockers are made up of metal, if anything were to go wrong with our circuit, and have that touch our locker, it could send an electrical current through the locker, injuring people who are in contact with the locker. We decided to use a plastic locker frame to avoid this potential safety hazard.

References

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