# Mushroom Incubator

ECE 445 Design Document - Spring 2024

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Team #6

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**Contents**

**1. Introduction....3**
1.1 Problem....3
1.2 Solution....4
1.3 Visual Aid....5
1.4 High Level Requirements....6
**2. Design....6**
2.1 Physical Design....6
2.2 Block Diagram....7
2.3 Control Subsystem....7
2.3.1 Subsystem Overview....7
2.3.2 Components....8
2.3.3 Requirements and Verification....8
2.4 Power Subsystem....8
2.4.1 Subsystem Overview....8
2.4.2 Components....8
2.4.3 Requirements and Verification....8
2.5 Regulation Subsystem....9
2.5.1 Subsystem Overview....9
2.5.2 Components....9
- **CRAFTSMAN 1-Gallons Battery Operated Pump Sprayer....9**
2.5.3 Requirements and Verification....9
2.6 Sensing Subsystem....10
2.6.1 Subsystem Overview....10
2.6.2 Components....10
2.6.3 Requirements and Verification....11
2.7 UI Subsystem....11
2.7.1 Subsystem Overview....11
2.7.2 Components....11
2.7.3 Requirements and Verification....12
2.8 Tolerance Analysis....12
**3. Cost and Schedule....13**
3.1 Cost Analysis....13

3.1.1 Purchased Parts/Materials List........................................................... 13
3.1.2 Student Wages/Hours of Development............................................... 13
3.1.3 External Resources........................................................................... 13
3.1.4 Total Cost.......................................................................................... 14
3.2 Schedule.................................................................................................. 14
**4. Ethics and Safety........................................................................................16**
4.1 Ethics...................................................................................................... 16
4.2 Safety...................................................................................................... 16
**5. References..................................................................................................16**

# 1. Introduction

## 1.1 Problem

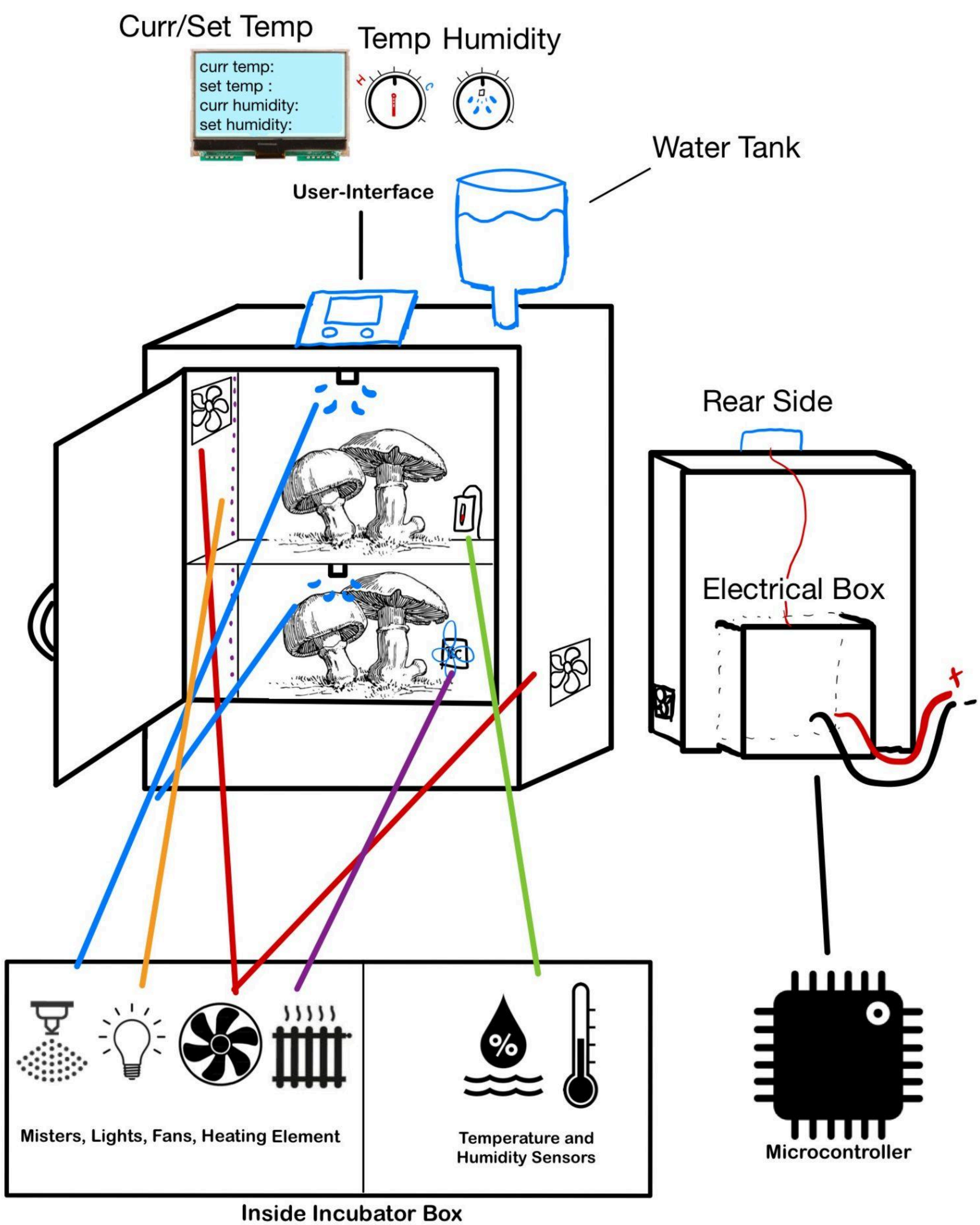
Many people want to grow mushrooms in their own homes to experiment with safe cooking recipes, rather than relying on risky seasonal foraging, expensive trips to the store, or time and labor-intensive DIY growing methods. However, living in remote areas, specific environments, or not having the experience makes growing your own mushrooms difficult, as well as dangerous. Without proper conditions and set-up, there are fire, electrical, and health risks.

## 1.2 Solution

We would like to build a mushroom incubator with humidity and temperature sensors that could monitor the internal temperature and humidity, and heating, and humidity systems to match user settings continuously. There would be a visual interface to display the current temperature and humidity within the environment. It would be medium-sized (around 6 sq ft) and able to grow several batches at a time, with more success and less risk than relying on a DIY mushroom tent.

Some solutions to home-grown mushroom automation already exist. However, there is not yet a solution that encompasses all problems we have outlined. Some solutions are too small of a scale, so they don't have the heating/cooling power for a larger scale solution[1]. Therefore, it's not enough to yield consistent batches. Additionally, there are solutions that give you a heater, a light set, and a humidifier, but it's up to the user to juggle all of these modules[2]. These can be difficult to balance and keep an eye on, but also dangerous if the user does not have experience. Spores can get released, heaters can overheat, and bacteria and mold can grow. Our solution offers an all-in-one, simple, user-friendly environment to bulk growing.

### 1.3 Visual Aid



## 1.4 High Level Requirements

In order for this project to be considered successful, it must accomplish the following:

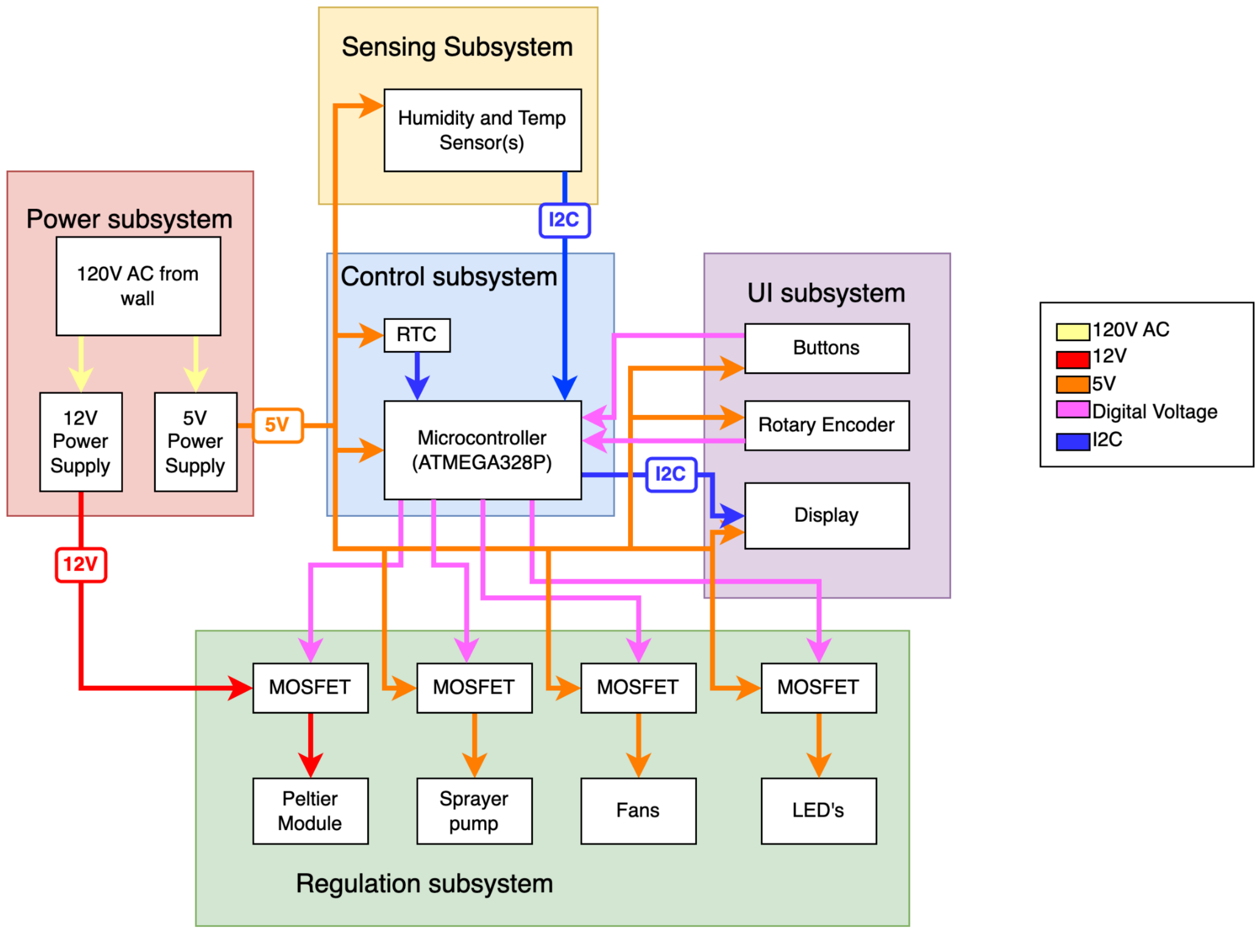
- For the control unit and user interface, we will demonstrate that the user can change the set temperature and humidity values through buttons or knobs, and the display will output the correct set temperature and current temperature within 10 seconds.
    - Ex.) If the user changes the set temperature to 80℉, the change in set and current temperature will be reflected promptly on the display and be verified independently.
- The humidity sensing and control system's functionality will demonstrate that introducing dry air into the device activates the misting system, which requires functional sensors and a water pump.
    - If the humidity sensor detects that the humidity is below the set point, the misting system will activate, allowing for an increase in the humidity at a rate of 1% per minute.
    - If the humidity in the chamber is too high, the fans will activate, reducing the humidity at a rate of 1% every 2 minutes.
- The temperature sensing and control system demo will show that the heater and fans respond appropriately:
    - If the measured temperature is above the set point, the heater turns off and the fans run at high speed, reducing the temperature towards the set point at a rate of at least 1°F/minute
    - If the measured temperature is below the set point, heater turns on and the fans run at low speed, increasing the temperature towards the set point at a rate of at least 1℉ /minute.
- The air quality control system's success will be demonstrated as air movement coming from the fan enters the tent, passing through the filter, and exits the tent.
    - The air should circulate through the incubator constantly, not stopping.
- The lighting system will turn on the lights at a set time of day, and then turn them off at a set time of day.

# 2. Design

## 2.1 Physical Design

Our project will consist of a 15" x 15" x 27" locker that will enclose our growing area. Inside we will have a polyethylene layer along the walls, ceiling and floor that will help to keep the area insulated from outside influences as well as keep humidity trapped inside, along with a temperature and humidity sensor located hear the back of the locker. We will also have 2 misting sprayers (supplied with water from the upper water tank) that will provide water when required to the mushrooms. On the back side of the locker, we will have a small electrical box that will house all our control and regulation components, as well as a LED display screen that will allow the user to see current temperature and humidity as well as use 2 knobs to adjust the setpoint values for both metrics.

## 2.2 Block Diagram




## 2.3 Control Subsystem

### 2.3.1 Subsystem Overview

The control subsystem deals with deciding the necessary temperature and humidity adjustments for each moment in time based on the signals sent to it from the sensing subsystem, and then changes the relevant digital voltage signals to the regulation system, namely the MOSFETs connected to the Peltier module, sprayer pump, fans, and LED's. Additionally, it sends information to the display through I2C regarding the current and set temperature and humidity, which it receives from the sensing subsystem. The ATMEGA328P was chosen for our microcontroller because of its simplicity and popularity, which may be useful when we design our board. The RTC breakout board from Adafruit was chosen because of its simplicity and low cost.

### 2.3.2 Components

- ATMEGA328P-PU Microcontroller (Mouser #556-ATMEGA328P-PU)
- Adafruit PCF8523 RTC Breakout Board (Mouser #485-3295)

### 2.3.3 Requirements and Verification

| Requirements | Verification |
|---|---|
| The user can control the set points for the temperature, humidity, or using buttons or knobs. | Turn a knob or press a button. Verify that the corresponding set point value on the display changes within 10 seconds. |
| The display shows accurate time-of-day. | Observe the time displayed. Verify that it is within 2 minutes of the time on an independent synchronized clock, such as an iPhone. |

## 2.4 Power Subsystem

### 2.4.1 Subsystem Overview

The power subsystem is responsible for providing and regulating the power sent to all the other subsystems. It supplies both a 12V and 5V current through the use of voltage regulators. 12V are sent to the MOSFET for the Peltier module, and 5V is sent to the sensing subsystem, the UI subsystem, and the MOSFETS for the sprayer pump, LED's, and fans in the regulation subsystem.

### 2.4.2 Components

- 12V DC power supply cable
- 5V DC power converter

### 2.4.3 Requirements and Verification

| Requirements | Verification |
|---|---|
| The system must provide a steady and stable 5V(±0.3V) power supply that can source a maximum of 3.6A | Connect wires to the 5V power supply. Ensure the node is on, then measure the voltage between the power and ground and ensure it is between 4.7V and 5.3V. Now connect a 1.3Ω resistor and ensure that the voltage drop over it is at least 4.68V. |
| The system must also provide a steady and stable 12V(±0.3V) power supply that can source a maximum of 5A | Connect wires to the 12V supply. Ensure the node is active, then measure the voltage between power and ground and ensure it is between 11.7V and 12.3V. Now connect a 2.3Ω resistor and ensure the voltage dropped across it is at least 11.5V. |

## 2.5 Regulation Subsystem

### 2.5.1 Subsystem Overview

The regulation subsystem handles the actual adjustments that are made to keep the project working as intended based on the signals received from the rest of the system. It includes the Peltier module, sprayer pump, fans, LED's, and their respective MOSFETs. It receives 12V and 5V from the power subsystem, and digital voltage signals from the control subsystem in order to control the heating and humidity elements. For the LED's, we chose the white color option for the user's visual convenience, and because precise color frequencies are not crucial for the mushrooms' growth. The FQP30N06L was chosen because it is compatible with logic levels, so we can use these as switches with digital signals from our microcontroller.

### 2.5.2 Components

- Laird Thermal Systems Peltier Module (Mouser #739-387009475)
- DFRobot LED Flexible Strip Light (Mouser #426-FIT0709)
- CRAFTSMAN 1-Gallons Battery Operated Pump Sprayer
- 5V Fans (Digikey #259-4555HQ/MG75090V1-1C090-S9A-ND)
- HEPA and Carbon filters
- FQP30N06L N-Channel MOSFET

### 2.5.3 Requirements and Verification

| Requirements | Verification |
|---|---|
| The temperature sensing and control demo will show that the heater and fans respond appropriately:<br><br>If the measured temperature is above the set point, the heater turns off and the fans run at high speed, reducing the temperature towards the set point at a rate of at least 1℉/minute<br><br>If the measured temperature is below the set point, heater turns on and the fans run at low speed, increasing the temperature towards the set point at a rate of at least 1℉ /minute. | Increasing temperature: starting with air in enclosure at room temperature (~72℉), set the desired temperature to 80℉ using the interface buttons or knobs. Wait 1 minute and verify that the measured temperature has increased by at least 1℉.<br><br>Decreasing temperature: starting with air in the enclosure at least 5℉ above room temperature, set the desired temperature to 70℉ using the buttons or knobs. Wait 1 minute and verify that the measured temperature has decrease by at least 1℉. |

| | |
|---|---|
| The humidity sensing and control demo will show that the misting system and fans respond appropriately:<br><br>If the measured humidity is above the set point, the misting system will turn off(if not already) and the fans will run at high speed, cycling air and reducing the humidity at a rate of 1% every 2 minutes.<br><br>If the measured humidity is below the set point, the misting system will turn on and the fans will run at low speed, increasing the humidity at a rate of 1%/minute | Increasing humidity: Starting with the door open (humidity < 50%), then close the locker and set the desired humidity to 70%. Wait 1 minute and then check to ensure that the measured humidity has gone up by at least 1%.<br><br>Decreasing humidity: begin with the setpoint humidity at 80%, then change the value to 70%. Wait 2 minutes, then check to ensure that the measured humidity has gone down at least 1%. |

## 2.6 Sensing Subsystem

### 2.6.1 Subsystem Overview

The sensing subsystem is responsible for detecting the change in the temperature and humidity, and sending those signals to the microcontroller in the control subsystem via I2C. It is powered by the power subsystem. We chose Adafruit's SHT30 sensor because it can measure both temperature and humidity, reducing cost and parts compared to using two different sensors, and because it has an enclosed shell to prevent damage if water from the sprayer comes in contact with the components. The sensor will be placed within our enclosure to sense the overall temperature, rather than locating it near the Peltier module or fans which may interfere with accurate readings.

### 2.6.2 Components

- SHT30 Temperature And Humidity Sensor - Wired Enclosed Shell (Adafruit ID: 5064)

### 2.6.3 Requirements and Verification

| Requirements | Verification |
|---|---|
| This subsystem senses the temperature and humidity inside the enclosure, and sends it to the control subsystem. The sensors must both be able to withstand a temperature of 70-85°F and a humidity between 70-95% for prolonged periods. It must be supplied 5V +/- 0.5V at .98mA. | Sensing Temperature Change: Place a thermometer in the locker and wait for it to produce a steady reading. Ensure that the thermometer value and the sensor values are within 0.5°F of each other.<br><br>Sensing Humidity Change: Using a humidity detector, record the actual humidity value within the locker. Ensure that the recorded value and the sensor are within 1% humidity of each other. |

## 2.7 UI Subsystem

### 2.7.1 Subsystem Overview

The UI subsystem displays information about the current and set heating and humidity levels (switching between them by pressing the buttons), and allows the user to change the settings via rotary encoders. The buttons and rotary encoders communicate with the control subsystem via digital voltage, and in turn receives I2C data from the control subsystem about what to display.

### 2.7.2 Components

- Adafruit 1.14" 240x135 Color TFT Breakout LCD Display (Digikey #1528-4383-ND)
- 2x Rotary Encoder
- 2x Knobs

### 2.7.3 Requirements and Verification

| Requirements | Verification |
|---|---|
| When a knob is turned for either temperature or humidity, the updated set temperature or humidity is sent to the control subsystem.<br><br>Additionally, the current and set temperature should be visible on the display. | Take note of the current setpoint temperature/humidity shown on the UI display. Turn either the temperature or humidity knob and observe whether or not the shown value changes along with the knob. |

## 2.8 Tolerance Analysis

For most mushrooms, ideal growing temperatures are roughly in the range of 75-80°F. Anything past 83°F begins to lower the return and growth rate. For this reason, our temperature tolerance must be at or less than ±3°F to ensure that even at the highest temp we will use(roughly 80°F) there is no drop in growth quality. In terms of humidity, while the best amount varies based on the type of mushroom, the general rule is to stay between 75% and 90%. Any lower than roughly 70% and the mushroom will begin to dry out, and any higher than 95% will cause the caps to yellow or brown. For both of these reasons, the humidity tolerance will need to be at worst ±5% humidity, to ensure the optimal growing environment even at the extremes of our values.

For our sensor, the tolerance range is ±2% RH and ±0.36°F. This allows us to stay within the required ranges stated above to ensure the environment stays at the correct conditions. Along with this, the sensor takes in a voltage input of 2.19-5.5V, meaning that for our 5V power supply, the voltage source must have a range of at most ±0.5V to prevent an excessive voltage from entering the sensor.

Electrically, for our voltage converter(the VGS-35W-5), we will be dropping from 12V to 5V at maximum 7A based on the preliminary parts list. With this in mind,

$$P_{in} = P_{out} + P_{heat}$$

$$P_{out} = V * I \ -> \ P_{out} = 5 * 7A = 35W$$

$$P_{in} = P_{out}/efficiency \ -> \ P_{in} = 35W/ 81\% = 43.21W$$

$$P_{heat} = P_{in} - P_{out} = 43.21W - 35W = 8.21W$$

This will leave us with a heat dissipation of 8.21W or 29.56kJ/h

# 3. Cost and Schedule

## 3.1 Cost Analysis

### 3.1.1 Purchased Parts/Materials List

| | |
|---|---|
| 1 x Temp and Humidity Sensor | $8.95 |
| 1 x ATmega328P-PU | $5.78 |
| 1 x Peltier Module | $30.00 |
| 2 x LED strips | $15.80(7.90 per one) |
| 2 x Sprayer | $17.96(8.98 per one) |
| 1 x Filter | $9.99 |
| 2 x Fans | $16.72(8.36 per one) |
| 1 x Display | $9.95 |
| 1 x 5V Power Supply | $15.10 |
| Total Cost: | $130.25 |

### 3.1.2 Student Wages/Hours of Development

According to the Grainger College of Engineering, the average Electrical Engineering graduate from UIUC makes on average roughly $87,000, or roughly $41.83/hr. Taking that into account for our student wages and assuming each member spends a minimum of 1 hour per day working on the project, we can find the total student wage.

$$T = \$/hr * students * hrs/day * days$$

$$T = 41.83 * 3 * 1 * 68$$

$$T = \$8533.32$$

Thus, our student wage equates to $8533.32 for this project.

### 3.1.3 External Resources

Outside of the parts we were required to order mentioned in 3.1.1, we also had access to other resources. Such resources include:

- Machine Shop Resources: For this project we required the assistance of the ECEB machine shop, specifically for the actual locker structure that our projects involves. On top of that, we also worked with the machine shop to create an insulating layer on the inside to prevent the escape of any humidity as well as to keep any outside influences on the temperature to a minimum.

- Senior Design Lab Resources: For the creation of our PCB specifically, we require a soldering iron, the solder itself, an oscilloscope, and a multimeter, all of which are provided by the Senior Design Lab.
- Supply Shop Resources: For our UI subsystem, we need knobs and rotary encoders, both of which can be found in the ECE supply shop for no cost. Other items we  got from the supply shop included a power button and a TEC heat sink.
- Personal items: Our team already had the RTC module and battery on hand, so we did not need to purchase this.

#### 3.1.4 Total Cost

In total, with all the purchases and work hours added up, the total cost for our project comes out to be:

$$T = C_{parts} + C_{hours}$$

$$T = 130.25 + 8533.32$$

$$T = \$8663.57$$

In total, the project will cost $8663.57 to complete from both cost of parts and wages.

### 3.2 Schedule

| **Week** | **Goals** |
|---|---|
| Feb 18th | Cameron: Design Doc<br>Dylan: Design Doc<br>Elizabeth: Make changes on Project Proposal, Design Doc<br><br>Assignments Due: Finish Design Doc by 2/22 |
| Feb 25th | Cameron: Design schematic for our PCB, start PCB layout<br>Dylan: Research code associated with the purchased sensor<br>Elizabeth: Github, Research existing UI firmware, start designing interface<br><br>Assignments Due: Design Review 2/26 and PCB Review 3/1 |
| March 3th | Cameron: Finish PCB layout, submit by 3/5, order parts for PCB<br>Dylan: Begin researching firmware for subsystem interaction<br>Elizabeth: Designing Interface<br><br>Assignments Due: Order PCB 3/5 and Teamwork Evaluation 3/6 |

| | |
|---|---|
| March 10th | Cameron: Plan and reflect<br>Dylan: Enjoy Break<br>Elizabeth: Happy Spring Break<br><br>Assignments Due: N/A |
| March 17th | Cameron: Assemble PCB<br>Dylan: Continue research until board is assembled, then begin testing<br>Elizabeth: Finish 1st Round UI,<br><br>Assignments Due: Second Round of PCB Orders 3/19 |
| March 24th | Cameron: Test PCB with off-board parts<br>Dylan: Test PCB with off-board parts<br>Elizabeth: Test PCB with off-board parts<br><br>Assignments Due: Individual Progress Report due 3/27 |
| March 31st | Cameron: Documentation, PCB revisions if necessary<br>Dylan:Continue debugging firmsoft/software and assemble full model<br>Elizabeth: Integrate features into model (Fans, UI)<br><br>Assignments Due: N/A |
| April 7 | Cameron: Finish assembly and begin testing<br>Dylan:Finish assembly and begin testing<br>Elizabeth: Testing on full model (Fans, UI)<br><br>Assignments Due:N/A |
| April 14th | Cameron: Prepare Plots for Mock Demo (Lighting, control unit)<br>Dylan: Prepare Plots for Mock Demo(Sensing)<br>Elizabeth: Prepare Plots for Mock Demo (Fans, UI)<br><br>Assignments Due: Mock Demo and Team Contract Fulfillment |
| April 21st | Cameron: Make necessary changes, prepare for Final Demo/presentation<br>Dylan: Make necessary changes, prepare for Final Demo/presentation<br>Elizabeth: Make necessary changes for Final Demo, practice and prepare presentation<br><br>Assignments Due: Final Demo and Mock Presentation |
| April 28th | Cameron: Present and work on final paper<br>Dylan:Present and work on final paper<br>Elizabeth: Prepare final Presentation/ Paper |

| | |
|---|---|
| | Assignments Due: Final Presentation and Final Paper due 5/1 |

# 4. Ethics and Safety

## 4.1 Ethics

In relation to the IEEE Code of Ethics,

○ We must comply with ethical design and sustainable development practices and disclose factors that might endanger the public or environment. In relation to our project, our growing environment must not in any way harm the surrounding environment.

○ Since there is a group doing something similar in terms of measuring values relating to plants (they are measuring moisture values), we must make sure all our ideas are our own and original.

○ We must make sure all our claims and estimates are accurate and realistic, and accept honest feedback and criticism from our TA to make our project as precise as possible.

○ We must credit any sources, code, data, or information we use in the process of making our project.

○ We must use any equipment only if trained or experienced to use them.

○ We must work well with our team, and treat each other fairly and with respect.

Additionally, we do not condone the use of our produce for the purposes of growing illegal substances as stated by US federal regulations.

## 4.2 Safety

● Make sure safety protocols are followed while in the lab soldering, using our PCB, and testing our sensors.

● Make sure to be aware when something can put ourselves at risk (when testing and building)

● Set boundaries, and make sure to work collaboratively so that not one person is more at risk for injury than another.

● Make sure that the end-product is safe and does not harm the user of the device, the environment, and the public.

# 5. References

[1] “Grow mushrooms you can’t find anywhere,” Shrooly, https://shrooly.com/#faq (accessed Feb. 8, 2024).

[2] “IEEE code of Ethics,” IEEE, https://www.ieee.org/about/corporate/governance/p7-8.html (accessed Feb. 22, 2024).

[3] “Ultimate Mushroom Growing & Incubator kit,” Midwest Grow Kits, https://www.midwestgrowkits.com/Ultimate-Mushroom-Growing-and-Incubator-Kit (accessed Feb. 8, 2024).

[4] ATMEGA328PB - Microchip Technology, https://www.microchip.com/en-us/product/atmega328pb (accessed Feb. 9, 2024).

[5] VGS-35C-15 Cui Inc. | mouser, https://www.mouser.com/datasheet/2/670/vgs_35w-2474743.pdf (accessed Feb. 21, 2024).