Multi-Functional Shoe Cabinet

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Abstract

Shoe storage had always been a complex issue for people because shoes require a certain combination of air conditions to maintain their quality. After evaluating a list of parameters required, the group choose to design the multi-functional shoe cabinet that can store and sterilize the shoes at the same time by controlling the temperature and humidity inside and producing ozone. The design made uses of the HTU21D sensor and Peltier coolers to achieve the control of the temperature and humidity at the same time by heating up or cooling down accordingly. In addition, the status LED will light when the timer of the sterilization device goes off. The status LED indicates the completion of the ozone production process and therefore the safety for human beings and their pets.

Contents

1. Introduction

Shoes are a hotbed of fungi and bacteria. Researchers at the National Coordination center of Poland have confirmed that 88% of outdoor shoes were positive for at least two pathogenic bacteria [1]. Due to lack of proper shoe care, 15% to 25% of people are prone to have athlete's foot [2]. It is thus imperative to revolutionize the way we store shoes such that they are well-maintained in hygienic conditions.

Our goal is to build a prototype for next-generation shoe cabinets. Indeed, moisture and temperature levels play important roles in bacteria growth as well as leather properties. Leathers are prone to cracking if relative humidity drops to below 45% [3]. Thus, in addition to sterilization module that aims to bring bacteria level to a minimum, our cabinet provides a temperature and humidity module that monitors and maintains shoe conditions. Other modules include a key selection module, a dynamic display module that displays current room data, time and menu, WIFI module that connects mobile applications to control unit, alarm module, and a central control module.

Chapter 1 provides an overview of our product, followed by specific design and calculations for each component in Chapter 2. Chapter 3 explains the realization of the shoe cabinet and testing of main functionalities, including but not limited to interior temperature and humidity modulation, ozone gas sterilization, and timer. Chapter 4 calculates estimated labor and equipment costs. Lastly, potential improvements and further work will be addressed in Chapter 5, conclusions.

1.1 High Level Performance Requirements

1. The cabinet must constantly display humidity and temperature following the SHT20 sensor detection. This allows the user to monitor the cabinet's interior environmental data.

2. The Peltier Cooler 1 can increase interior temperature to the set range; The Peltier Cooler 2 can decrease interior humidity to the set range. Both will maintain constant settings within the ranges throughout.

3. The ozonator works under the duration of the set timer; It is able to release 0.5ppm of ozone gas in 406.6 seconds, reducing 71.5% of bacteria. Attempts to open the cabinet lid within first 30 minutes of sterilization must trigger an alarm module, as ozone gas exposure is harmful to the human respiratory system [4].

4. A mobile application will display real-time temperature and humidity; This allows remote control of the shoe cabinet through the ESP8266 WIFI module.

1.2 Project Overview

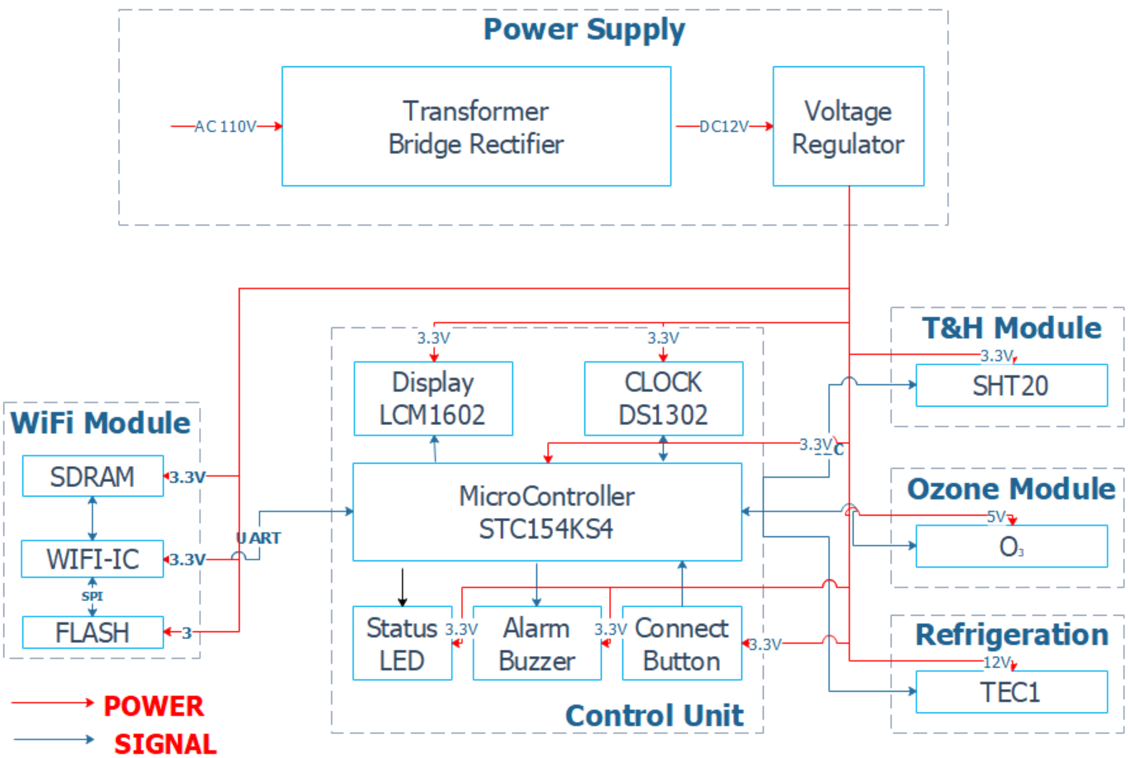

Figure 1. High level block diagram

As shown in Figure 1, the high-level block diagram, we include STC154KS4 as our microcontroller that programs and facilitates module coordination. The LCM1602 LCD screen constantly updates interior temperature and humidity reflected by T&H module; It also displays time and countdown signals passed by the DS1302 clock unit. The ozone module is responsible for sterilization and refrigeration module sets interior temperature and humidity. The WIFI module sends and receives data to and from mobile applications. The power supply module transforms and rectifies 110 V AC input voltage to DC output voltage.

1.3 Block-level Modifications

While we thrive to strictly abide by the guideline, we set in design review, possible minor changes and improvements are made to refine our prototype as we start physically implementing it.

1.3.1 Refrigeration Block

A water cycling module is added to the refrigeration block. Due to heat conduction from the heating side of Peltier board, the cooling side needs better heat dissipation to dehumidify the cabinet interior environment. A water container, connected to a water pump through two tubes, is attached to the heating side of Peltier cooler for higher heat dissipation rate.

1.3.2 T&H Block

The HTU21D is used to replace SHT20 for temperature and humidity measurements, as the suppliers for the later chip are limited. Both the HTU21D and SHT20 chips serve same functions and have same precision to 0. 01 ℃and 0.01% relative humidity.

1.3.3 Control Block

In designing key buttons, we changed their purpose from selecting shoe types to menu scrolling, KEY_1 now corresponds to “Menu Enter” and “Confirmation”, KEY_2 and KEY_3 represent “Scroll Up” and “Scroll Down” separately and KEY_4 holds a “Return” function. This way our shoe cabinet is able to achieve more functionalities given the key set.

2 Design

2.1 Power Module

2.1.1 110 V AC to 12 V DC Converter

The first task for this project is to provide a stable and correct power source for all subcomponents. The main power driving force for this system is the 12 V DC power source converted from 110 V AC by a transformer and a rectifier. This is the power source for two TEC1-12706 modules. The capacity of the adapter is 24 A, powering TEC modules according to Table1.

Table 1. Current drawn by devices operating under 12 V

Item	Quantity	Maximum Current Draw	Total Maximum Current Drawn
TEC	2	6 A	12 A
FAN	2	0.1 A	0.2 A

2.1.2 Voltage Regulator

In our design, there are two kinds of voltage regulators. The first one is 12 V to the 5 V regulator, providing power to ozonation and relays which opens or closes the circuit electronically. When the microcontroller sends a signal to utilize the Peltier cooler, the circuit will power the corresponding relay with 5 V so that a 12 V voltage will be applied to the TEC module. For the rest of the components, such as the SHT20 sensor, the LCM1602 LCD screen, the STC15 microcontroller, 3.3 V voltage is supplied using 5 V to the 3.3 V voltage regulator, as shown in Figure 2.

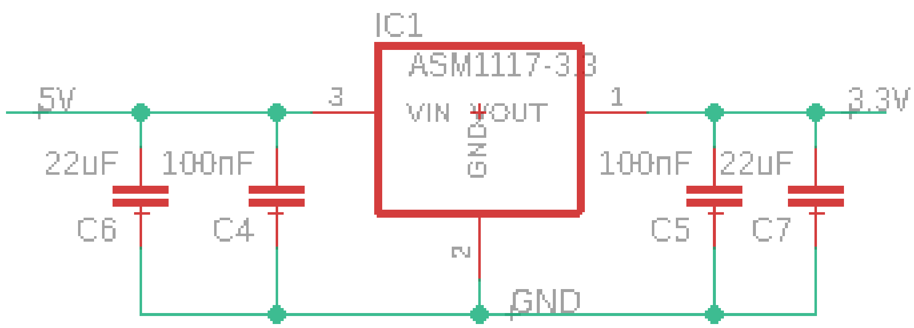

Figure 2. ASM1117-3.3V voltage regulator

2.2 Control Module

2.2.1 Microcontroller

The STC154KS4 microcontroller has 40 pins which provide enough ports for our design and digital process. The microcontroller receives data sent from the SHT20 sensor and controls two Peltier coolers and fans in In-Home HVAC module; It also processes the display on the user interface and transmits and receives data to and from the WIFI module.

2.2.2 Control Button Module

There are four buttons in the control button module, represented by KEY_1, KEY_2, KEY_3 and KEY_4 respectively. Each of them has its own function: KEY_1 corresponds to "Menu Confirmation"; KEY_2 and KEY_3 corresponds to "Scroll Up" and "Scroll Down" separately; KEY_4 holds a "Return" function. Figure 3 below shows the schematic of buttons.

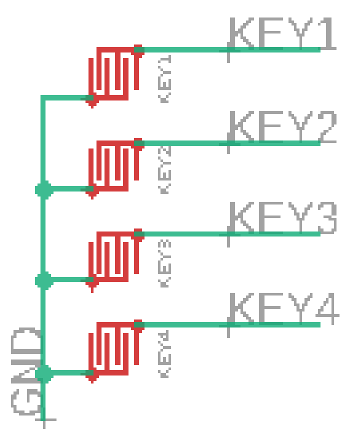

Figure 3. Buttons schematic

Specifically, by pushing KEY_1, LCD will change the main display from date/time/current temperature and humidity inside the shoe cabinet to the setup menu. Five setting options are included: Temperature setup, Humidity setup, the ozonator setup, Time and Date setup. The user could enter or scroll up/down by pushing KEY_1 and KEY_2 or KEY_3 separately. By pushing KEY_1 under temperature setup, the user will enter into a new interface which has two input values required to set the respective highest temperature and the lowest temperature desired. The user could either increase/ decrease the temperature by pushing KEY_2/ KEY_3, forwarding to the lowest temperature value setup menu by pushing KEY_1 or exiting the page by pushing KEY_4. This setup is similar for the rest of the options.

2.3 In-Home HVAC Module

The In-Home HVAC module includes temperature and humidity (T&H) sensor module and T&H control module. The overall goal of in-home HVAC module is detecting humidity and temperature data inside the shoe cabinet and updating humidity and temperature into the desired intervals constantly.

2.3.1 Humidity and Temperature Detection Module

The SHT20 temperature and humidity sensor in our design could effectively measure the temperature and humidity inside the shoe cabinet and send all information to the microcontroller. SHT20 temperature and humidity sensor have the accuracy of +/-3% RH (relative humidity, as compared to saturated vapor pressure) and +/-0.3 °C. It performs best working condition under 3.3 V +/- 5%. Figure 4 shows the schematic of the SHT20 sensor module. Referring to physical design, the SHT20 sensor is fixed at the top middle portion inside the shoe cabinet.

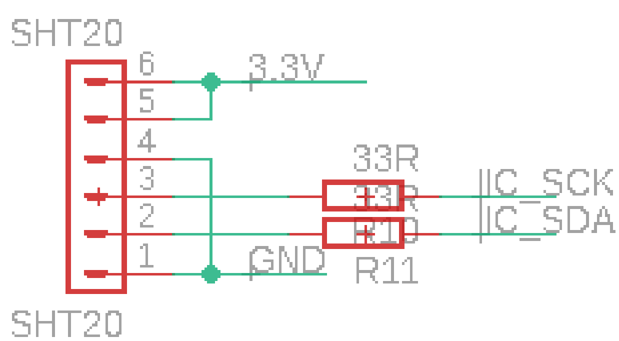

Figure 4. Temperature and Humidity Sensor Schematic

2.3.2 Humidity and Temperature Control Module

Our design uses two 12 V 60 W TEC-12706 Peltier coolers to deal with temperature and humidity control. They are represented by TEC1 and TEC2, respectively. Thermoelectric cooling uses the Peltier effect to create a heat flux between the junction of two types of materials [5]. It has two sides, one contributing to "cooling" effect and the other side in charge of "heating" effect. Two TECs are located on the left and right side of the shoe cabinet, performing "heat" and "cool" function separately. Each TEC has two cooling fins and two 12 V fans to dissipate heat. TEC2, which is used as a cooling function, has one water pump connected to give TEC2 better heat transfer service. Our shoe cabinet has interior dimension of 33 cm* 30 cm* 23 cm, with 2cm foam insulation. The testing data for working TECs collected inside and outside the box is shown in Table 2.

Table 2. Sample temperature and humidity data

Temperature outside the box	Humidity outside the box	Temperature onside the box	Humidity onside the box
25.7 ℃	38.6% RH	31.5 ℃	32.2% RH

Figure 5 shows the effect of TEC2 on interior humidity when it is hardwired to 12V DC. Water drops are formed on cooling fins at 245 seconds. Figure 6 shows the effect of TEC1 on interior temperature 5.8 ℃ is raised for 400 seconds.

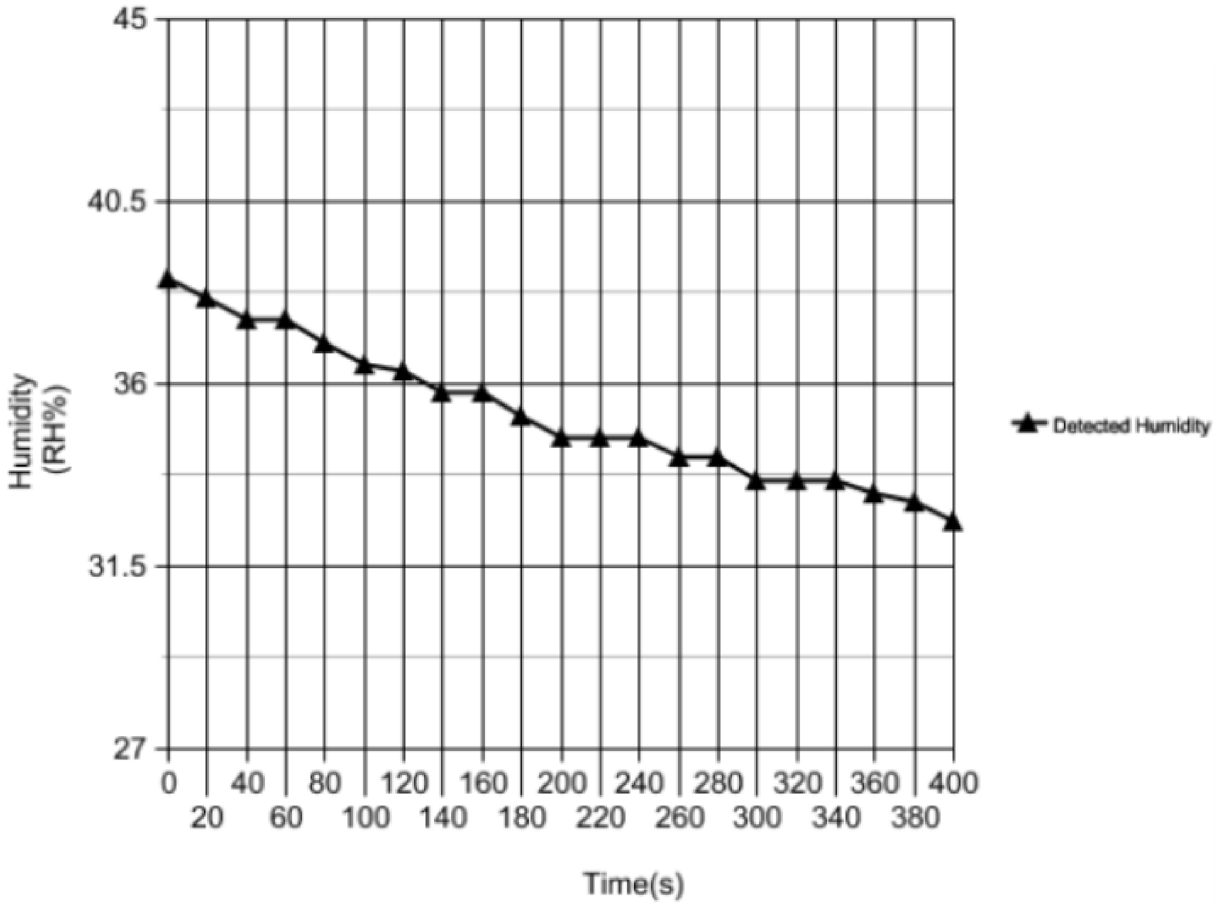

Figure 5. Cabinet interior humidity over time

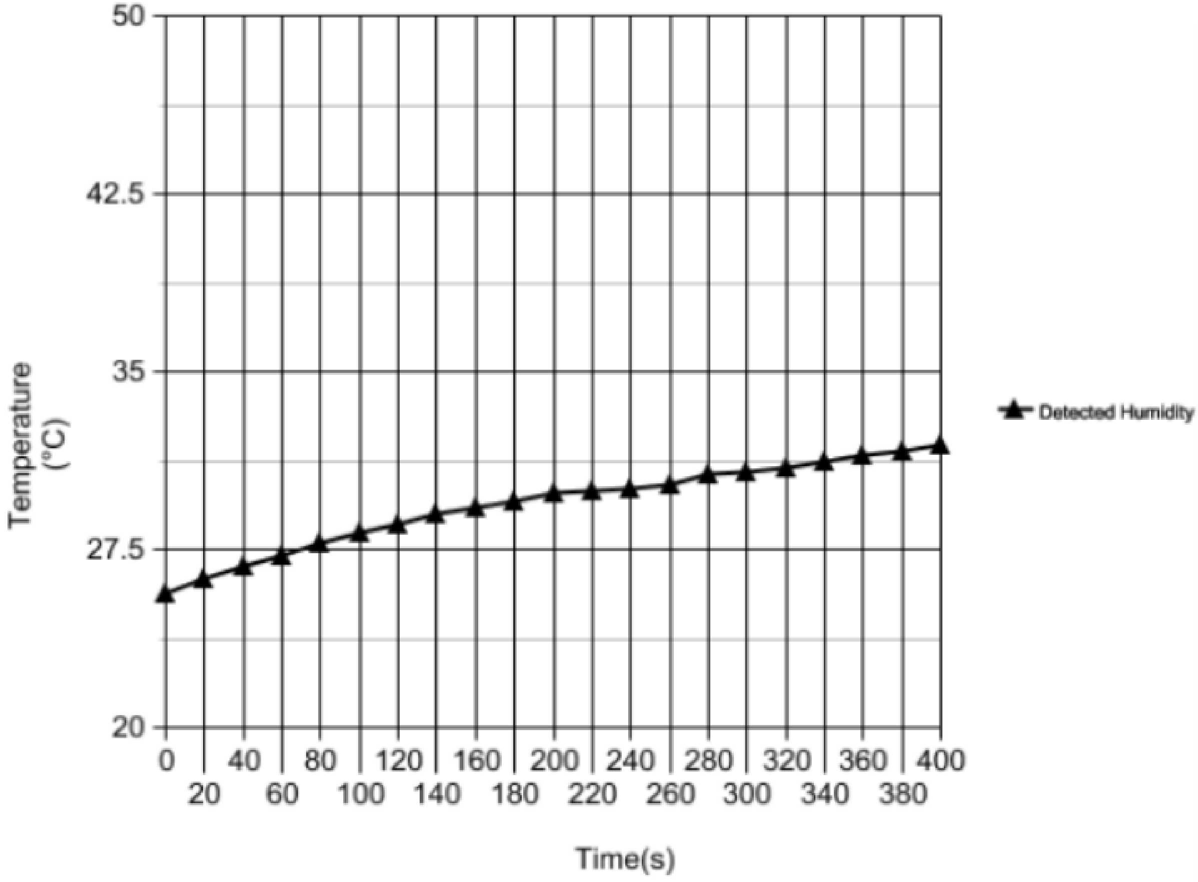

Figure 6. Cabinet interior temperature over time

2.4 Sterilization Module

The ozonator is used in the sterilization process. The model we picked can produce 100 mg ozone gas per hour, under the condition of the direct current/voltage of 2A/5V. To reach a practical and safe sterilization result, the minimum operating time of the ozonator is calculated as follows:

$$v_{rate} = \frac{100mg}{hour} = \frac{0.028mg}{second} \tag{2.1}$$

$$V_{interior} = W * L * H = 33cm * 30cm * 23cm = 22770cm^3 = 22.77L \tag{2.2}$$

$$Target\ Concentration = \frac{0.5mg}{L} = 0.5ppm \quad (2.3)$$

$$M_{ozone\ gas} = Target\ Concentration * V_{interior} = 11.385mg \quad (2.4)$$

$$t_{target\ conc.} = M_{ozone\ gas}/\upsilon_{rate} = 406.6s \quad (2.5)$$

Where W, L, H in Equation (2.2) is interior width, length and height respectively. Target concentration in (2.3) corresponds to first data column in Table 3, where a reduction of 71.5 % in bacteria colony-forming units (CFU) is desired. Mass of required ozone gas is calculated in Equation (2.4), using Equations (2.3) and (2.2). The final Equation (2.5) calculates time to reach target concentration using Equations (2.1) and (2.4).

Table 3. Bacteria reduction table for different ozone concentration

Ozone conc. (PPM)	0.5	2.5	5
Before Ozonation (CFU/m^3)	592	612	552
After Ozonation (CFU/m^3)	169	42	57
Reduction %	71.5	93.1	89.6

2.5 Dynamic Display Module

The LCM1602 LCD screen is the display user interface in our design. It has a resolution of 128*64 pixels and operates under a 3.3 V voltage supply. When the power supply is connected, ‘System Initiation’ will be displayed on the screen, and there are four keys that help users to set temperature or humidity range for the system. The current time, date, temperature, and humidity will also be displayed on the main screen by default.

2.6 Alarm Module

2.6.1 Status LED

There are two LEDs in our system to provide a visual signal. The green LED indicates at least one of our TEC modules is in operating status. The red LED was meant to signal that Ozonator is turned on and the cabinet is under the sterilization process. Both LEDs are connected in series with 1k ohm resistors, to a 3.3 V supply source.

2.6.2 Alarm Buzzer

A buzzer is integrated into our project such that it signals system booting up and serves to alarm user whenever the lid is opened under sterilization mode. A radar sensor is installed to detected lid distance. Whenever both radar sensor detection and sterilization evaluate to true, software alarm function is called.

2.7 WIFI Module

The WIFI module is used to connect the shoe cabinet to the mobile phone application. Its functions include real-time information of the cabinet environment, adjust button for temperature/humidity and alarm module to warn the user.

2.7.1 WIFI Microchip

We chose ESP8266 32-bit microchip for our UART-WIFI module. ESP8266 supports standard IEEE 802.11 b/g/n specification. It has a relatively low price and standby power of as low as 10mW. ESP8266 supports Smart Config function for Android and iOS products, which we will use for mobile control.

2.7.2 Application Design

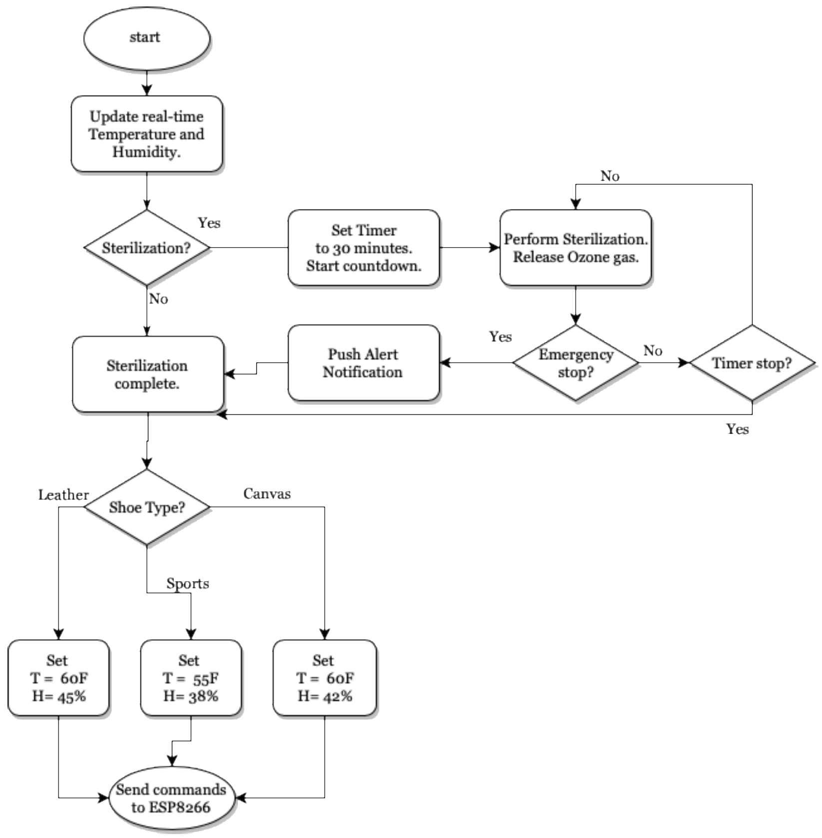

Figure 7. Flowchart for mobile application decision making

The application communicates with ESP8266 through wireless networks. According to flowchart in Figure 7, our shoe cabinet can tell the microcontroller to shutdown sterilization and sound an alert message to user on time. It also can adjust temperature and humidity settings according to shoe selection, as demonstrated in right portion of Figure 8.

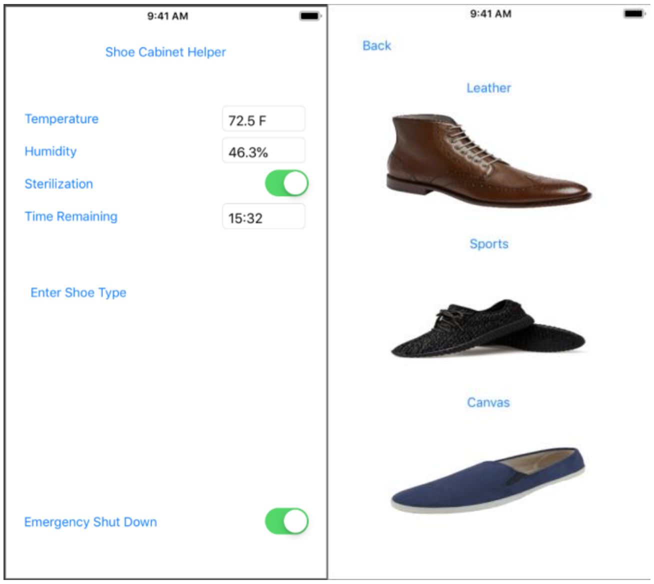

Figure 8. IPhone application interface

3. Design Verification

3.1 Power Module

3.1.1 110 V AC to 12 V DC Converter

The power supply in our design is used to transform 110 V AC down to 12 V DC voltage. We measured the output voltage of the voltage transformer and the result shows it could supply stable voltage range 12V+/- 5%, which fulfill our desired value, and could power TEC1 and TEC2 enough voltage.

3.1.2 Voltage Regulator

There are two voltage regulators in our design. One converts 12V DC to 5V DC and the other converts 5V DC to 3.3V DC. The first one is used to power the ozonator and the second one is used to power other parts such as microcontroller, temperature and humidity sensor and a dynamic display module. We used an oscilloscope to measure the output voltage of two voltage regulators (connect pin3 & pin2, pin2 & pin1 on Figure 1) and both of them fulfill our design requirements with output 5 V+/- 5 % and 3.3 V+/- 5% separately.

3.2 Control Module

3.2.1 Microcontroller

STC15W4K56S4 microcontroller belongs to the series of STC15W4K56S4. It is a system based on 8-bit MCU processing and needs 3.3V input voltage. We connect pin 40 and GND to measure the voltage of microcontroller and the result is 3.3V+/- 5%, which fulfill our design requirement.

3.2.2 Control Button Module

The four-control-button module we used should be pressed easily and should be debounced and allows only one per press. In our verification part, we pressed the button with little force and connected pins to measure the voltage; The result fulfilled our design requirements and the voltage of buttons are active-low signal when pressed or released.

3.3 In-Home HVAC Module

3.3.1 Humidity and Temperature Detection Module

SHT20 temperature and humidity sensors need to detect temperature and humidity values with precision +/-3% RH and +/-0.3 ℃. In our test case explained in section 2.3.2, we use another thermometer to measure the temperature and hydrometer to measure the humidity and at the same time compare the value acquired from the SHT20 sensor. The result shows the difference of two results is within acceptable precision range.

The SHT20 sensor works under 3.3 V +/- 5% voltage. Oscilloscope is used to measure the output voltage by connecting pin5 and pin4. The result fulfills our requirement.

3.3.2 Humidity and Temperature Control Module

The humidity and temperature control module met all requirements. It is powered by 12 V +/- 5% voltage and correctly manipulated by the H-bridge circuit. During the testing process explained in section 2.3.2, the dehumidification, the humidity inside the shoe cabinet decreases from 38.6% RH to 32.6% RH, and the change in temperature inside the shoe cabinet is from 25.7 ℃ to 31.9 ℃. It helped decrease the humidity down to 33% RH, which is the best humidity value for leather shoes. After the system reached the desired humidity value, the system will power off TEC2, and only allows TEC1 to work. Again, an oscilloscope is used to measure the voltage across TEC2. A 0V result verifies that TEC2 is turned off.

3.4 Sterilization Module

Our ozonator provides 100 mg ozone per hour and creates 1db noise. It can work under 5 V power supply and is connected in parallel with 5 V relay. To verify, we connected it to 5 V and observed little noise and a blue lighting along with an unpleasant odor.

3.5 Dynamic Display Module

An LCM1602 dynamic display module located on the shoe cabinet serves to display the current temperature/humidity in the shoe cabinet, the threshold and trigger value of our in-home HVAC system. It will also display the date and time on the screen. In verification, we connected oscilloscope with pin1 and pin2 and the test voltage is shown during test case is 5 V +/- 5%.

3.6 Alarm Module

3.6.1 Status LED

There are two LEDs in our design, each of them needs 3.3 V power supply. By checking the voltage of two LED, the result voltage fulfills the requirement, and both run correct algorithm during work.

3.7 WIFI Module

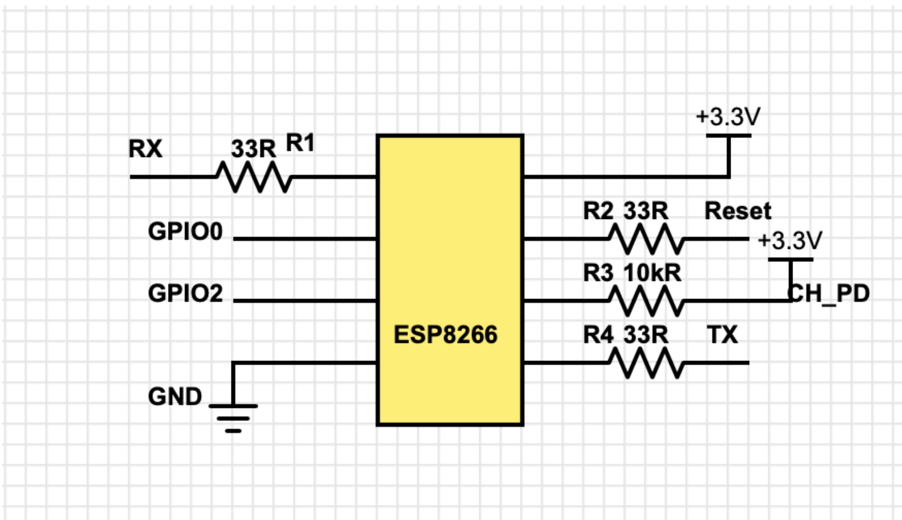

Figure 9. WIFI module schematics

For the WIFI module, we connected the ESP8266 microchip as shown in Figure 9, with voltage divider, designed as 5 V to 3.3 V converter, served as power input. We tested the WIFI connection ESP8266WIFI library and local IP address is shown correctly. Figure 10 shows a snippet of testing code.

```
Serial.print("Trying to connect");
while (WiFi.status() != WL_CONNECTED)
{
  delay(300);
  Serial.print("..");
}
Serial.println();
Serial.print("Connected, IP address: ");
Serial.println(WiFi.localIP());
```

Figure 10. IP address testing code snippet for ESP8266

4. Costs

4.1 Parts

The following table is cost for the basic components.

Table 4. Hardware Costs

Part	**Manufacturer**	**Retail Cost ($)**	**Quantity**	**Bulk Purchase Cost ($)**
ASM1117 -3.3V	Advanced Monolithic Systems	0.79	2	1.58
SHT20-I2C Temperature & Humidity Sensor with waterproof probe	DFRobot	22.50	1	22.50
ESP8266 WIFI module	Speed Technology	6.95	1	6.95
Mini Push Button Switch	SparkFun(Retailer)	0.35	4	1.40
DS1302 Trickle-Charge Timekeeping Chip	Maxim Integrated	3.35	1	3.35
LED (Red, Yellow and Green)	YoungSun LED	0.35	3	1.05
Thermo-Electric Cooler Module	Peltier	34.95	2	69.90
LCM1602 LCD module	EONE	4.81	1	4.81
Total				190.12

4.2 Labor

The following table is the hardware cost table for three team members.

Table 5. Labor Costs

Name	**Salary** ($/hour)	**Hours** (hrs/16 weeks)	**Total**	**Total** (2.5 multiplier)
Yupei Mao	35	200	7000	17500
Yuguang Chen	35	200	7000	17500
Haochuan Jiang	35	200	7000	17500
Total	105	600	21000	52500

4.3 Total

Grand cost = Labor costs + Hardware costs = **$ 52690.12**

5. Conclusion

5.1 Accomplishments

Our shoe cabinet can successfully update and set interior temperature and humidity using the SHT20 sensor and Peltier coolers. The ozonator starts sterilization properly when timer starts to countdown. The status LEDs are light when respective module it turned on. These accomplishments fulfill our primary goals of building the shoe cabinet.

5.2 Uncertainties

- Although we used two layers of industrial duct tape to seal all junctions of foam board, the tightness of interior compartment remains unknown. Because of necessary holes we cut for wires and water tubes, a small amount of ozone gas may leak out.

- Radar sensor in alarm module was not successfully integrated into the circuit board. Although the red status LED may signal that ozone gas is released at the time, considering that underage group may accidentally open the cabinet as it performs sterilization tasks, the lack of auditory warning poses a threat to their health.

5.3 Ethical Considerations

It is of paramount importance to address ethical and safety issues as we are obligated to devote ourselves to good conducts which positively affect our communities.

We acknowledge that some process of our project imposes potential safety challenges. For instance, ozone gas, used in the sterilization process here cause problems including shortness of breath and damage in the airways. [6] Therefore, even though it is impossible to design a completely airtight chamber since the cabinet needs to meet other requirements, we added special features to the cabinet so that the leakage of ozone gas, and thus damage to human health would be minimized. Additionally, people, while being completely safe if getting to close to the cabinet during the sterilization process, are still not suggested to do so for their safety concerns. It is calculated that the whole process of sterilization is 30 minutes, with 50mg of ozone gas produced. With our design of minimizing ozone leakage, we assume that there will be 5mg gas leakage during the working process, being not harmful to human health. We also suggest that people come around and open the door of the cabinet 30 minutes later than the sterilization process ends. As indicated by the ACM Code of Ethics and Professional Conduct 1.2: “Avoid harm” [7], after all, ensuring physical safety is the top consideration for our product.

Temperature regulator can burn shoes and circuits, leading to irrevocable consequences. After detecting a drop in temperature, the controller can order an amplified power to the heater. To prevent this, we will set upper and lower temperature thresholds to be 28.5 °C and 18.5 °C respectively. Also, the heater device will be isolated from the rest of the circuit to meet the higher safety standard.

We are accountable for stating correct data of relevant variables in our project, such as temperature and humidity. In rare cases, unexpected feedback from the temperature sensor may be monitored. Regardless, we will be truthful in disclosing it, as honesty is more valued than desirable results. This is in accordance with the IEEE Code of Ethics, #3: “To be honest and realistic in stating claims or estimates based on available data” [8].

While it feels satisfying to be recognized for contributing thoughts and hard work towards our project, we should invariably remain humble to accept constructive feedback and to admit and rectify errors. Proper compliments should be awarded towards insightful contributions, as we adhere to #7 of the IEEE Code of Ethics: "to seek, accept, and offer honest criticism of technical work..." [8]. For instance, when one group member finds out that one dehydrates poses better control over moisture, he should not hesitate to ask for testing and renewal, even though it means replacement of another members' work.

It is inevitable to find out there exist the enormous number of gendered products on the market. Some are optionally made for men or one race only, while others are labeled with higher prices against women [9]. This kind of merchandise goes against gender and racial equality and places women and minorities at an inferior level. As the IEEE Code of Ethics indicates: "to treat fairly all persons and to not engage in acts of discrimination..." we promote equality by fully designing shoe cabinets. In addition to loafers, options of heel shoes and sandals will be added with more adjustments. Dryer module will be turned on for a longer period if moisture sensor detects more sweat residues on these shoes.

5.4 Future Work

- A radar sensor will be integrated into the alarm module. If the sensor detects that the cabinet lid is opened when the ozonator is performing sterilization, it signals a warning through the buzzer.

- The WIFI module will be better configured to properly send and receive data. Our current ESP8266 microchip fails to detect WIFI network. Further AT commands should be tested.
- There is room for better temperature controller algorithm. Proportional-Integral-Derivative (PID) control aims to minimize the difference in detected temperature and set value by adjusting the control variable calculated from three terms. It will be studied and incorporated into our project to eliminate existing fluctuations in temperature around the set range.

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Appendix A Requirement and Verification Table

Requirement	Verification	Verified? (Y/N)
The voltage should transform from 110 V to around 12 V+/- 5%	Use an oscilloscope to measure the output voltage, ensuring that the output voltage stays within 5% of 12 V	Y
The voltage should change from AC to DC	Use an oscilloscope to test outflow current, and make sure is DC	Y
The voltage regulator should output around 5 V +/- 5% DC voltage from 12 V source	Use an oscilloscope to measure the output voltage, by connecting pin 3 & pin2 (Figure 4), to ensure that the output voltage stays within 5% of 5 V	Y
The voltage regulator should output 3.3 V +/- 5% DC voltage from 12 V source	Use an oscilloscope to measure the output voltage, by connecting pin2 & pin1 (Figure 4), to ensure that the output voltage stays within 5% of 3.3 V	Y
The LCM1602 displays	Combinate it with a microcontroller to test the rightfulness	Y

temperature/humidity, date and time	of display	
The LCD display should work under 5 V +/- 5%	According to Figure 12, test the voltage of the LCD by connect oscilloscope with pin1 & pin2, check the working voltage is within the desired voltage range	Y
The clock chip should collect currently time and date	If it works properly, the LCD will display correct time and date, and use the voltmeter to test both ends of the voltage transformer, make sure voltage matched with desire value	Y
The clock chip should work under around 5 V +/- 5%	Connect the oscilloscope to pin8 & pin4 (Figure 10) to measure the voltage of the clock chip, make sure the working voltage is in desired voltage range	Y
The buttons should be pressed easily	Press the button with little force to check if it works	Y
The buttons need to be debounced and allows only one input per press	Connect pin to the button and measure the voltage, should be active -low signal when pressed or released.	Y
The humidity and temperature must be displayed on the screen with the correct value with +/-3% RH and +/- 0.3 ℃	By applying different humidity and temperature to test the correctness of sensors.	Y
The SHT20 sensor should work under 3.3 V +/- 5%	Use an oscilloscope to measure the output voltage, by connecting pin5 & pin4 (Figure 5), to ensure that the output voltage stays within 5% of 3.3 V	Y
Only one Peltier cooler (far to the condenser) work during heating/cooling process	Use an oscilloscope to test outflow current, and make sure the other Peltier cooler is power off	Y
Two Peltier coolers should work under the same power during the dehumidification process	The temperature detected during the dehumidification process should maintain ±4 ℃, check by the LCD screen	Y
The humidity should decrease to	The humidity sensor should return humidity lower than 31%	Y

under 31% RH within 10 minutes of the dehumidification process	RH after dehumidification process after 10 minutes.	
The water tank should locate under the cabinet and could collect water from the condenser	Check water tank contains water after the dehumidification process completed	N
The dimension of ventilation should be 2 inches * 2 inches, small enough to fit inside the cabinet	Locate the ventilator on the left-up corner of the cabinet, should smaller enough and work every 10 minutes after 30 minutes of dehumidification process	N
The ozone concentration must be designed carefully to due to safety reason.	The maximum ppm for a human to stay close to ozone is 0.1, our ozone generator can generate 350 mg /h. By control the time of generation time we can guarantee that dosage of ozone won't do harm to users.	Y
The ozonator should work under 5 V +/- 5%	Use an oscilloscope to measure the output voltage, by connecting pin1 & GND (Figure 9), to ensure that the output voltage stays within 5% of 5 V	Y
The WIFI microchip must be capable of sending signals following IEEE 802.11b/g/n specification	Use Arduino IDE AT command to Detect and Connect to WIFI Network. If WIFI microchip is IEEE 802.11b/g/n-compatible, it will be successfully connected.	Y
The WIFI module ESP8226 holds a service voltage from 3 V~3.6 V, here we use 3.3V and should make sure within range of 3.3 V +/- 5%	Use an oscilloscope to measure the output voltage, by connecting pin8 & GND (Figure 6), to ensure that the output voltage stays within 5% of 3.3V	Y
The LED should be red when ozonator is working.	The red LED is on when in sterilization process	Y
The LED should be green when either of TECs is working	The green LED is on when one of TECs working	Y
The alarm buzzer should work under 5 V +/- 5%	Use an oscilloscope to measure the output voltage, by connecting pin1 & GND (Figure 7), to ensure that the output	Y

	voltage stays within 5% of 5 V	
The volume of the alarm should be maintained at 70 decibels for awareness	Use decibel meter to measure the alarm buzzer to be above 70 decibels.	Y
The alarm is turned on when the cabinet is opened during first 30 minutes after the ozonator works	The alarm buzzer will work when cabinet first 30 minutes after the ozonator works, at the same time the LED turns from yellow to red.	N