ECE 445

SENIOR DESIGN LABORATORY

Design Document

Smart Pill Hub

Team #65

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1. Introduction

1.1 Problem and Solution

Problem:
With the world's population aging, old age well-being is a huge issue in society today. Illnesses are afflicting more and more elderly people, and probably all of them can't live without taking medication. However, doctor's orders can sometimes be confusing, especially for seniors with degenerative mental illnesses, such as Alzheimer's disease, and taking medication on time and as prescribed can be difficult. However, the cost of smart pill boxes on the market today is generally high, which is another huge expense for seniors who already have to pay high medical bills. On top of that, the features included in the smart pillboxes on the market seem to be less than satisfactory. The smart pillboxes nowadays only have some basic functions such as reminding you to take your medication. Therefore, a relatively inexpensive and feature-rich pillbox is urgently needed by society and the market nowadays.

Solution:
To solve the above problem, we propose a smart pill box that can store, dispense, and manage many different types of pills. Our smart pillbox has separate compartments, a precise dispensing mechanism, and a user-friendly mobile application that will be used as a control center for the pillbox. The mobile app will connect the box to the user's cell phone via Bluetooth or the Internet. Through the app, the user can make settings for the box, such as dosage, schedule, and number of tablets remaining. We have added a reminder system to our design which includes a buzzer and LED, this design reminds the user to take the pills at the set time. We designed a conveyor belt with dividers through which the smart pill box can dispense medication accurately. In addition, we designed a temperature and humidity sensor to monitor the temperature and humidity of the pillbox to prevent the pills from losing their medicinal properties.

1.2 Visual Aid

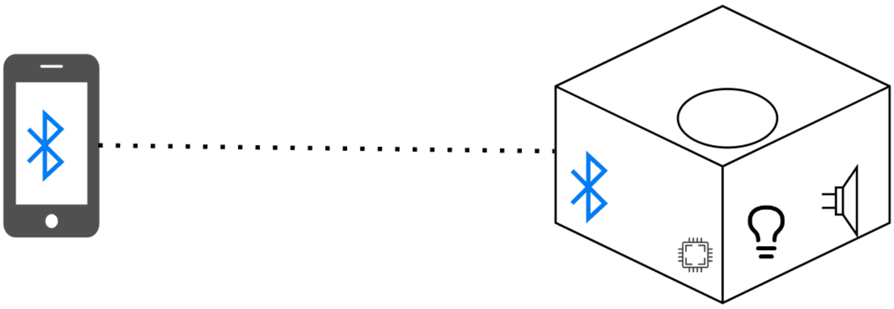


Figure 1: Visual Aid

As shown in the figure above, the pillbox we designed is mainly controlled by an app in the phone for scheduling and dosage adjustment. When users connect to the box via Bluetooth from their cell phones, they can set the date and dosage of their medication according to their needs. When the time set by the user is reached, the pillbox will remind the user to take the medicine through LED and buzzer. At the same time, the microprocessor in the box will control the box to dispense a precise dose of pills.

1.3 High-level requirements list

1. Our design will enable the dispensing of the correct number of pills, the number of errors should be less than 5 when dispensing 100 pills (An error is defined as any deviation from the expected quantity or type, including dispensing too many, too few, or incorrect pills), by coordinating the software with the hardware.

2.Our design will be realized according to all designed schedules. Users will be alerted when they do not take their medication at the prescribed time.

3. Our design will have a functioning app connected to our hardware device via Bluetooth and allows the user to set and adjust the schedule and dosage of medication on the box. The app should be able to communicate/set parameters for the box in around 10 meters.

2. Design

2.1 Block Diagram

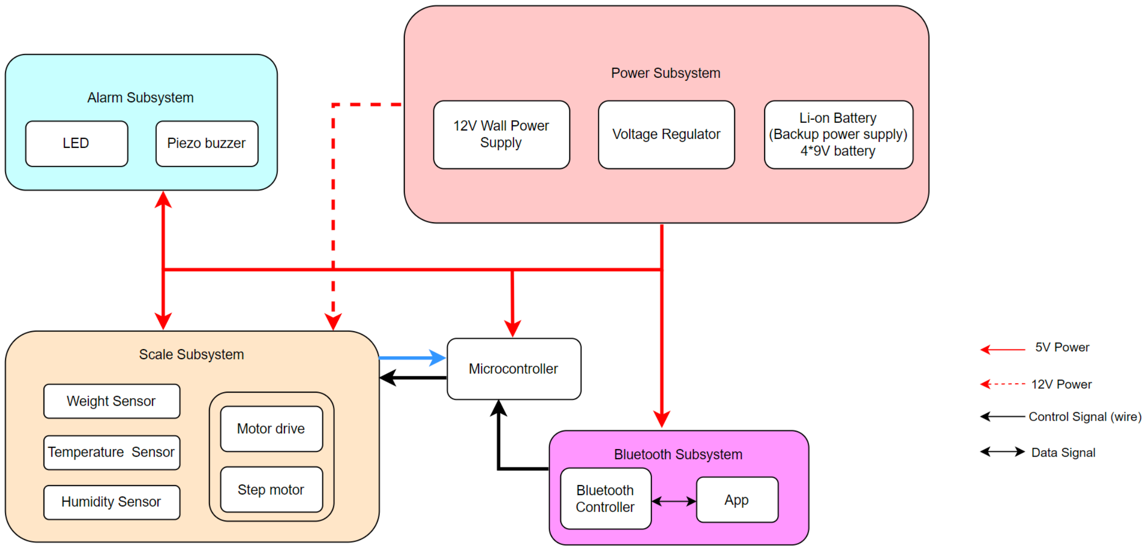


Figure 2: Block Diagram

2.2 Physical Design

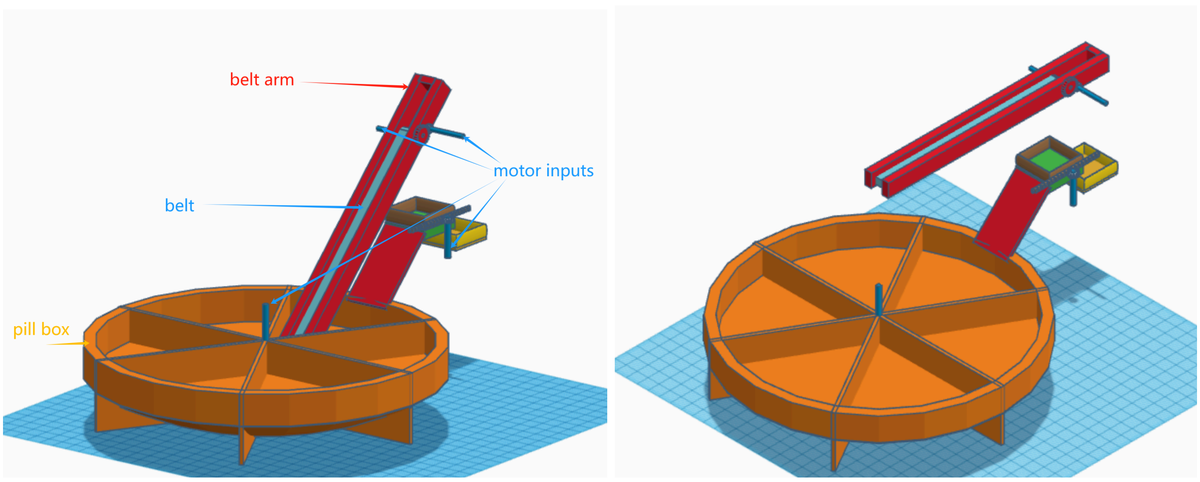


Figure 3: Physical Design (Side View)

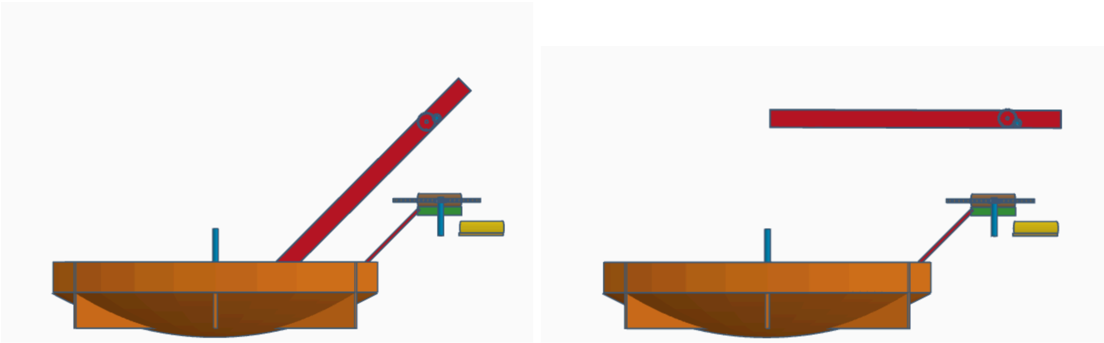


Figure 4: Physical Design (Front View)

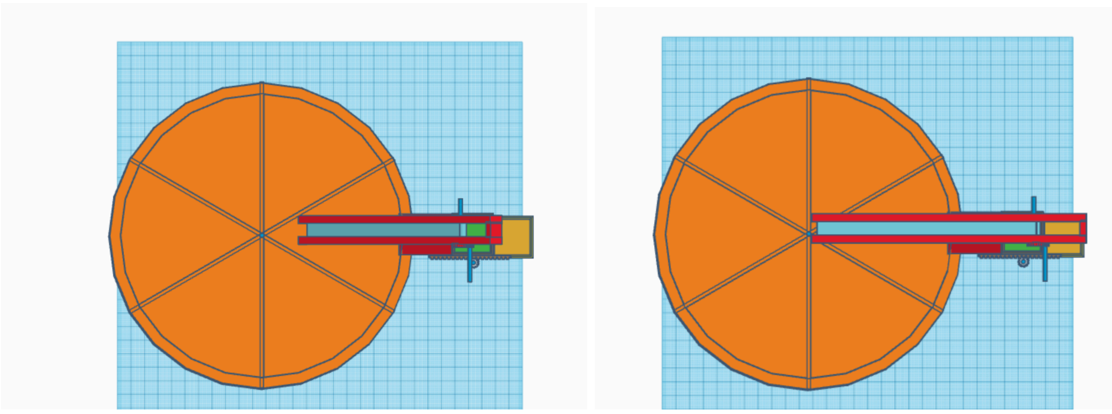


Figure 5: Physical Design (Top View)

The picture above shows the mechanical part of our design, and we will be utilizing 3D printing technology to complete our design. We will be modeling more accurately as well as having a more logical layout. Also to increase the overall portability of the pillbox, we will be using a method that uses battery power.

2.3 Subsystems

2.3.1 Bluetooth Subsystem

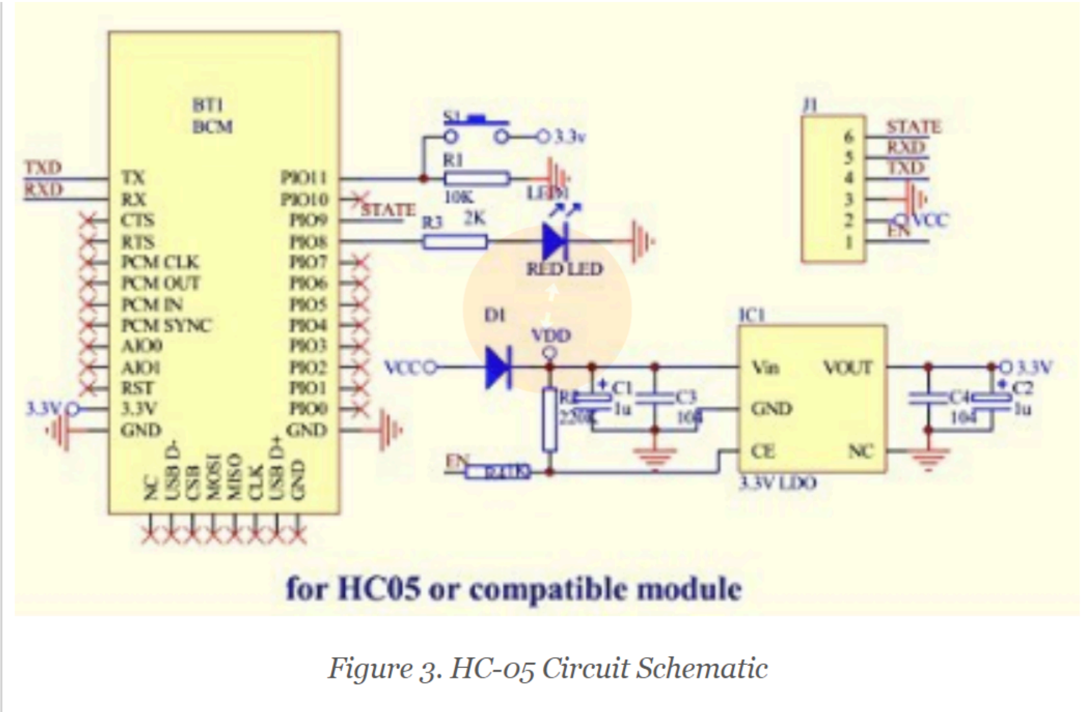


Figure 6: Bluetooth subsystem schematic

We will use hc-05 as the Bluetooth module for our design.hc-05 is a low power Bluetooth module. This Bluetooth module has a small size, low power consumption and can provide high performance wireless connectivity. Since this module is designed to be a low-power device it is suitable for battery power and therefore ideal for our design. In addition to that, this module has very high security features. This is one of the main reasons why we chose this module, as the dosage of the medication used by the user is private and therefore receives strict protection.

2.3.2 Sensor Subsystem

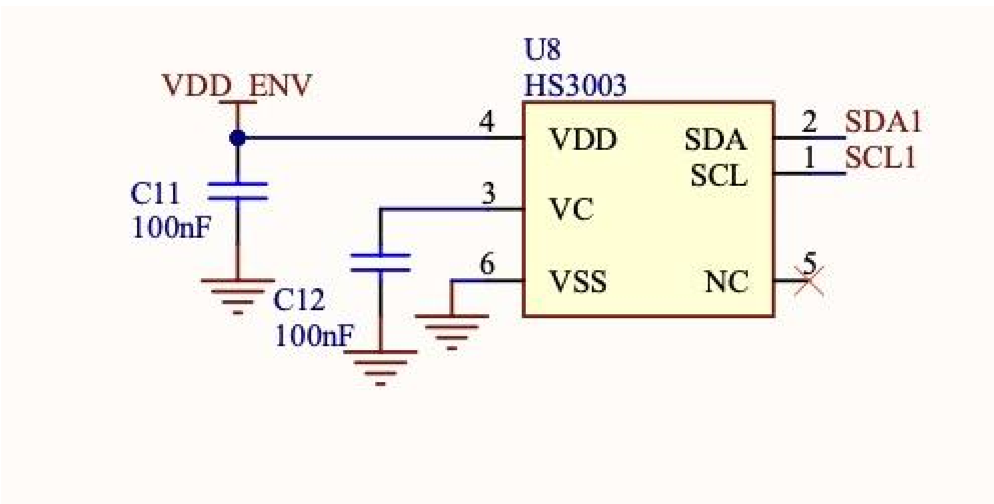


Figure 7: Sensor subsystem schematic

We will be choosing the HS3003 as our humidity and temperature sensor. This sensor will be used to monitor temperature and humidity inside the pill box. Because this sensor has high accuracy, long-term stability and low power consumption, it is perfect for our design.We will be using the CUSA-R75-18-2400-TH as an ultrasonic sensor in our Smart Pill Box. We will utilize this ultrasonic sensor to detect the exact amount of medication for precise pill dispensing.

2.3.3 Microcontroller

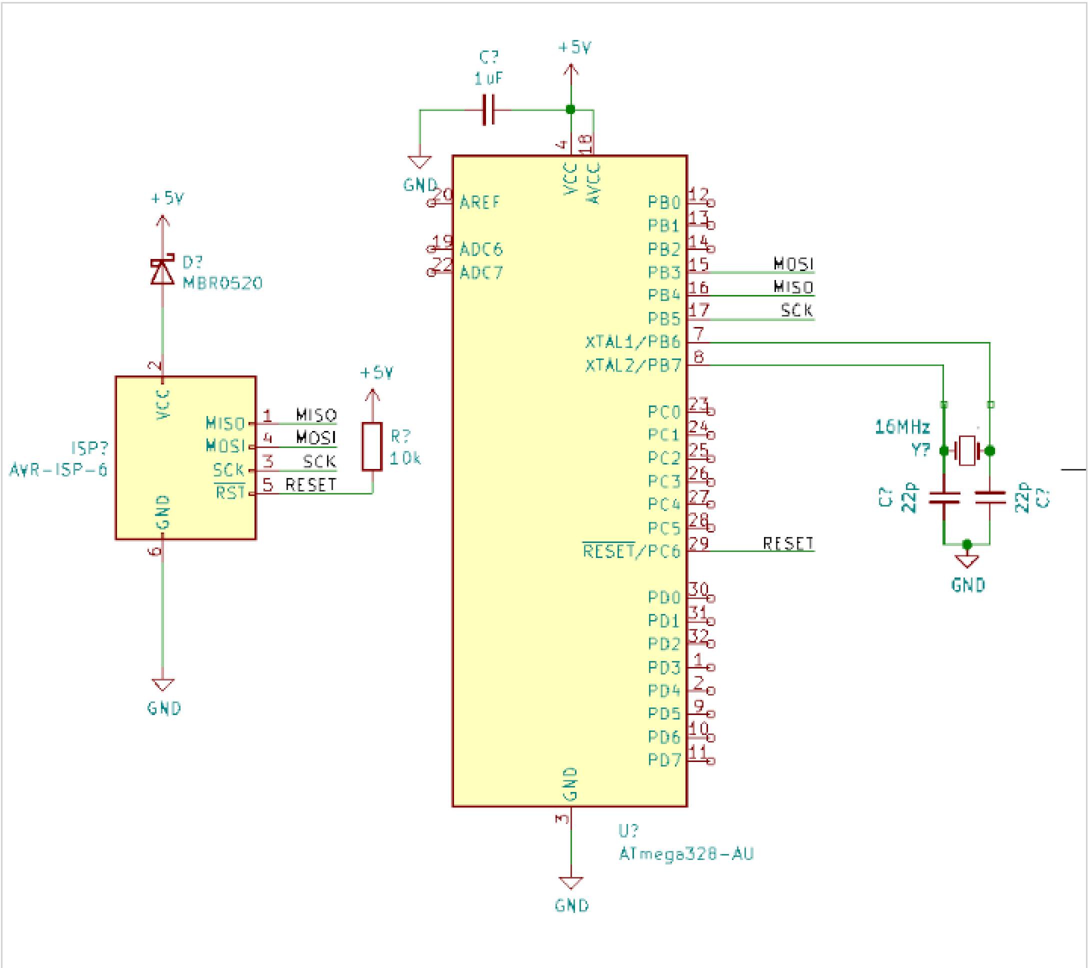


Figure 8: Microcontroller schematic

We will choose theatmega328p as our microcontroller. This microprocessor provides decent performance and low power consumption. So we can drive it with a battery in our design. This micro controller also has multiple communication interfaces and can be connected with a Bluetooth module. The acceptable response time and computational power allows this microprocessor to handle data from the software side.

2.3.4 Alarm Subsystem

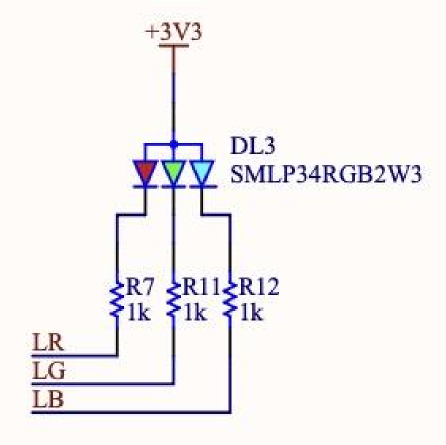


Figure 8: Alarm subsystem schematic *Figure 9: Buzzer*

We will use LED and Buzzer will provide different feedback under predefined conditions. For example, if the temperature and humidity do not meet the standards, or if there is an insufficient quantity of pills. The LED can blink, and the buzzer can emit sound. The microcontroller will analyze the signals provided by the sensor subsystem.

2.3.5 Dispense Subsystem

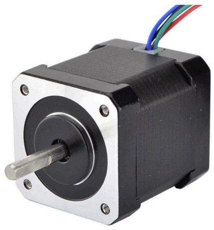
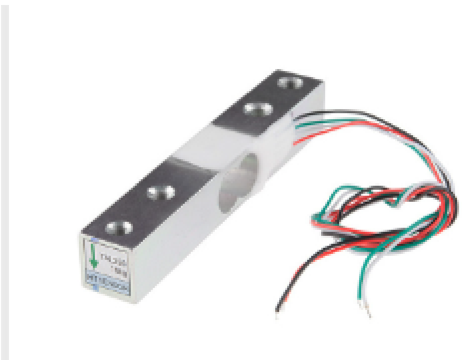


Figure 10: Stepper motor

We will be using NEMA 17 as our stepper motor for our design. Considering the possible weight of the pill box conveyor in our design, we have chosen this medium duty stepper motor. In addition, the stepper motor can be connected to a microcontroller through a digital interface and controlled through a program.



We will use the SEN-13329 load cell to weigh the unknown amount of pill and compare it to a known amount of pill to count the pill and we will use the load cell during dispensing to make sure it dispenses the correct amount.

2.4 Subsystem Requirements:

Subsystem 1: Pill Storage and Dispensing Mechanism Verification

Requirement	Verification
The mechanisms should be available that can accommodate different types of pills without causing contamination or damage.	Evaluate storage compartments for compatibility with different pill sizes and shapes to ensure no damage or contamination occurs. Test the mechanism's ability to prevent moisture or other environmental factors from affecting the pills.
The designed mechanism can dispense the pills associated with the command request received by the paired device.	Conduct tests using pills of various sizes to ensure the design can accommodate multiple sizes of pills. Perform multiple tests to eliminate randomness.

Subsystem 2: Control and Mobile Application with Bluetooth Connectivity Verification

Requirement	Verification
Must be able to pair seamlessly with a designated app on a smartphone or tablet to allow wireless transmission of distribution commands.	Verify the ability of the device to pair with apps on different devices (phones and tablets) and operating systems. Test the range and stability of Bluetooth connections to ensure commands are received without loss.
The device should provide operational status feedback through the application interface, including successful dispensing, errors, or warnings of insufficient pill stock as well as the schedule and does of dispensing.	Tests the ability of the system to provide feedback to the application about its status, including successful operations, errors (e.g., lag, empty storage), and warnings (e.g., low inventory). Tests the ability of the system to provide feedback to the application about its status, including successful operations, errors (e.g., lag, empty storage), and warnings (e.g., low inventory).

Subsystem 3: Integrated Digital Scales Verification

Requirement	Verification
The weight sensor detects the weight of the pills remaining in the pill box, as well as detecting the weight of the dispensed pills to evaluate the exact number of pills.	Ensure through testing that the weight sensor can detect the required weight changes. Conduct multiple tests to avoid randomness in the results. Ensure that the correct signals are received from the control subsystem and the correct commands are accomplished based on those signals.
Temperature, humidity and pressure sensors test the temperature, humidity and pressure in the pill box and display the data to the application.	Tested to ensure that the temperature humidity and pressure sensors can accurately detect the temperature humidity and pressure in the pill box.

	Ensure that this data can be transferred to the application via Bluetooth signal.
The motor can be rotated by a corresponding angle according to the received signal.	Test to make sure the motor can turn at the desired angle. Test to ensure that the motor is receiving signals and can fulfill the correct commands.

Subsystem 4: Alert System Verification
This subsystem consists of LEDs and buzzers that are responsible for providing visual and auditory feedback to the user.The LEDs and buzzers will be used to alert the user that the time for taking the medication or the ambient conditions inside the box (e.g., temperature and humidity) do not meet the preset criteria. The use of LEDs and buzzers has been chosen because they are effective in getting the user's attention while avoiding over-stimulating the user. Each alarm device will be controlled via the digital pins of the control unit, utilizing switching transistors to regulate the input voltage, allowing full control over the intensity of the alarm. The brightness of the LEDs and the volume of the buzzer will be adjusted by varying the power supplied to the motors.

Requirement	Verification
Alarm device exist	Perform a physical check to confirm that the LEDs and buzzers are properly installed in the system, and verify their operating status with a simple circuit test (e.g., activation with a test power supply).
Adjustable alarm strength	Using a PWM signal generator, provide "high" and "low" PWM signals to the switching transistors controlling the LED and buzzer, respectively. Observe and record the change in brightness of the LED and the change in volume of the buzzer to verify the ability to adjust the intensity of the alarm.
Ability to work independently	Verify that the LEDs and buzzers can operate independently based on the input signal by controlling the alarm subsystem directly (not through the main control system). This can be tested by manually supplying a voltage or by sending a PWM signal using a simple controller.
Ability to integrate work	Integrate the alarm subsystem with the main control unit to simulate an actual use scenario (e.g., setting specific warning conditions) and verify the response of the alarm subsystem in the integrated environment. This can be accomplished by controlling the main control unit with software that triggers the alarm subsystem under predetermined conditions.

Subsystem 5: Backup Battery
This subsystem consists of a battery backup designed to ensure that the Smart Pill Hub program seamlessly continues to operate and provide continuous service in the event of a mains power failure. The backup battery is introduced to automatically switch to the backup power supply in the event of power failure or instability, safeguarding the normal operation of the system and the continuous user experience. The backup battery is designed with sufficient capacity to support system operation for a certain period of time without external power supply, ensuring that users' medication management tasks are not affected until power is restored.

For seamless switchover, the system will be equipped with a power management module that monitors the status of both the primary and backup power supplies and immediately activates the backup power supply when an interruption in the primary power supply is detected. This process is designed with the goal of minimizing switchover delays and avoiding any kind of operational disruption. The power management module will also be responsible for automatically switching back to the main power supply once it has been restored and simultaneously charging the backup battery in case of emergency.

Requirement	Verification
Non-disruptive switching capability	Test the system's ability to immediately and seamlessly switch to the backup power supply by simulating a mains power failure. This can be achieved by disconnecting the mains power supply and immediately monitoring whether the system continues to operate without any functional interruption. Focus on how quickly the system switches to the alternate power supply and whether there are any operational interruptions.
Long-term backup power supply capacity	Test the durability and reliability of the backup power supply by running the system continuously for a certain period of time (e.g., a few hours to a day) while it is powered by the backup power supply. This will verify that the system can maintain normal operation and its endurance in the absence of primary power.
Power supply fluctuation adaptability	Simulate power fluctuations, such as short-term voltage drops or instability, and test whether the system can continue to operate stably or automatically switch to a backup power source when the main power source is unstable. Observe the system's response to power fluctuations to ensure that system operation is not affected during fluctuations.

Subsystem 6: Control

Requirement	Verification
Receive the signals from the application program and complete the correct operations according to the instructions. Signals can be communicated with motors and weight sensors.	Ensure that the control sensor can dispense the correct tablets based on the date and measurement set by the application. Ensure that signals can be exchanged with weight sensors, temperature humidity and pressure sensors and motors. To accurately control the angle of rotation of the motor and the weight of the pills as well as the temperature, humidity and pressure in the pill box.

2.5 Tolerance Analysis

We recognize that there will be some errors in our system. According to the FDA, pill sizes in the US are very close to each other. Then, because of a series of irresistible forces such as different manufacturers. Tablets from each manufacturer leave the factory with slight variations in size. In addition, during transportation, the tablets may also be bumped, which can lead to a change in size. Therefore, we will allow some margin of error in our designed dispensing mechanism. More specifically, we will allow for one more or one less tablet per twenty deliveries. On the software side, according to the datasheet of our chosen Bluetooth module. This module will have a 1 in 1,000 chance of losing the connection. This means that the connection between our designs is not perfect and stable, and in addition to this, there will be a delay in the signal transmitted via Bluetooth. Therefore, we will allow the connection between our software and hardware to fail once every twenty data transfers. Depending on the datasheet of the microprocessor we have chosen, we will also allow for delays in the processing of data from the software by our hardware, as well as system crashes due to the design of the chip itself. We set the threshold for this to no more than once every fifty times. According to the datasheet data sheets of the ultrasonic sensors and weight sensors we use, their sensitivity can deviate from perfection. This is an unavoidable problem with the products themselves, so we allow for one pill more or one pill less per twenty dispensations during the measurement.

3. Cost and Schedule

3.1 Cost Analysis

Description	Part number	Unit Price	Quantity	Total Price
Temperature & humidity sensor	HS3003	2.82	1	2.82
LED	SMLP34RGB2W3	1.06	1	1.06
Buzzer	CPI-3016-90L080	6.13	1	6.13
Bluetooth	hc-05	14.35	1	14.35
Ultrasonicsensor	CUSA-R75-18-2400-TH	3.73	1	3.73
Weight Sensor	MF01A-N-221-A06	6.6	1	6.6
Microcontroller	atmega328p	11.81	1	11.81
Step Motor	NEMA 17	13.99	3	41.97

3.2 Schedule

	Jerry Ning	Eric Cheng	Jinpeng Liu
Week of 2/26	Start PCB design	Secure parts of testing such as stepper motors, sensors	Create a debugging setup to simulate the inputs to the board and LEDs.
Week of 3/4	Ensure all parts we need are ordered	Assost om testing on protoboard	Assist in the creation of PCB schematic
Week of 3/11	PCB ordering	Check the PCB design	Check the physical design
Week of 3/18	Program the control system	Testing the physical design	Testing the code on the present PCB
Week of 3/25	Test the backup power	Connect the PCB with the mechanical component	Assist with the connection of PCB and mechanical component
Week of 4/1	Programming the Bluetooth on PCB.	Looking for possible weaknesses with the current PCB design	Make sure the PCB performs the same way the Arduino performed
Week of 4/8	Testing possible bugs	Testing all functionality	Check the tolerance
Week of 4/15	Testing the Bluetooth to be ready for demo	Testing Software App to be ready for demo	Polishing the overall product
Week of 4/22	Final demo mock presentation	Final demo mock presentation	Final demo mock presentation
Week of 4/29	Final presentation Final paper	Final presentation Final paper	Final presentation Final paper

4. Discussion of Ethics and Safety

In terms of ethics, our group is primarily guided by the IEEE Code of Ethics adopted by the IEEE Board of Directors[1]. We recognize that technology can change a person's life, so our team will professionally conduct our work. We will hold ourselves to the highest ethical standards. We will seek and provide honest evaluations and feedback on our technical work. We will continue to learn and master our skills through training and design, and all members of our team have completed CAD training and PCB soldering training and have passed lab safety tests. We will continue to complete the training required by the program. We will treat everyone with respect and kindness, understanding and helping each other. We know the power of technology and we are always learning with a humble heart. We believe that technology is in the service of people, so we will design our project with the user as the primary focus. Our team in the lab will follow the strict rules of the lab for our safety. When it comes to network connections and sensor data, we will ensure that the user's network or Bluetooth connection is private and secure. We will ensure that the user's connection to our system is private and secure including, but not limited to, the data in the IP packets. We will adhere to the rule of not using the user's data for any purpose other than the project. We will comply with any relevant license terms in all software used.

5. Citation

[1] IEEE. " "IEEE Code of Ethics"." (2016), [Online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html (visited on 02/08/2020).

[2] FDA "Size, Shape, and Other Physical Attributes of Generic Tablets and Capsules Guidance for Industry," (2015), [Online]. Available: https://www.fda.gov/files/drugs/published/Size--Shape--and-Other-Physical-Attributes-of-Generic-Tablets-and-Capsules.pdf