PillSafe Design Document Revision

Team 17

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Contents

1 Introduction

1.1 Problem

The opioid epidemic has been a rising issue, and although there are some efforts to decrease this, none have been very successful. There needs to be a stricter way of informing a doctor when a patient is susceptible to addiction without taking away complete control from them. A pill cap that counts the number of pills coming from the box and sends that data to the doctor is a solution that could help greatly with this epidemic. The current design is big and simple, and we want to improve upon this by optimizing the size and functionality.

1.2 Solution

A smart medication pillbox with a built in mechanical component, wireless transmission capabilities, and an accompanying app to track the number of pills taken out of the pill box. To ensure accurate measurements of the number of pills taken out, we use a mechanical pill dispenser system to limit only one pill to be taken out at a time.

A small laser will be pointing across the opening of the pill box where pills can exit, while a photoresistor is placed on the other side of the opening, receiving the laser. The laser is blocked whenever a pill is taken out, which is sensed via the photoresistor, and this data is displayed on a small monitor, alongside being transmitted wirelessly to an app.

1.3 Visual Aid

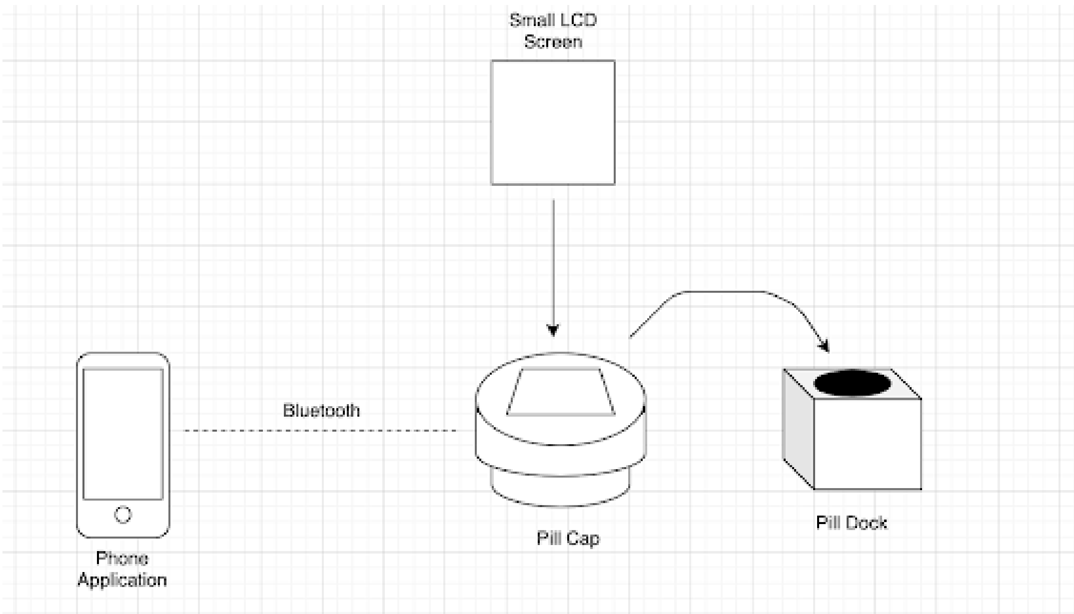

Figure 1: High Level Visual Aid

1.4 High-Level Requirements List

1. The pill dispensing mechanism, the bluetooth board, and the screen should fit in a space of 2.9718 cm in diameter (diameter of a pill cap) and 1.5 cm in height.

2. The pill dispensing mechanism must trigger the laser to turn on. The mechanism must also only dispense one pill at a time with an accuracy of at least 95%.

3. The battery powering the microcontroller, laser, as well as bluetooth chip should be able to last a week. The pill dispensing mechanism will trigger the whole system to stay on for 5 seconds to conserve energy.

2 Design

2.1 Block Diagram

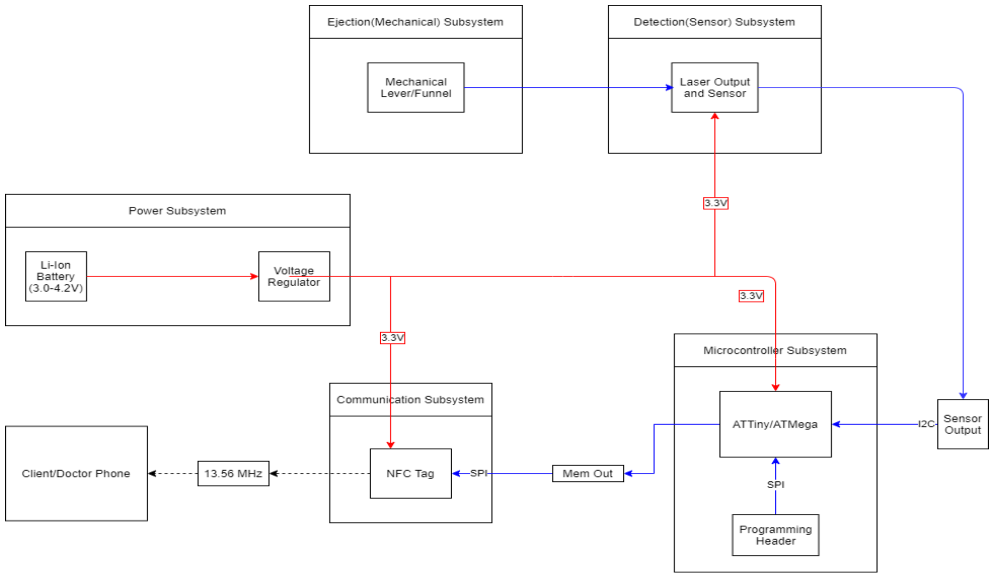

Figure 2: High Level Block Diagram

2.2 Power Subsystem

The power subsystem [5] provides power to all other systems of the design. It has a rechargeable 3.7V battery that is then connected to a voltage regulator so it can output a voltage of 3.3V. The charging system takes in a micro USB which is connected to a charge controller. The battery being used (3.7V 100 mAh Li-Po battery) is 20mmx20mmx4mm which fits in the dimensions of the cap. Battery capacity needs to be at least 3.3V and 100mAh.

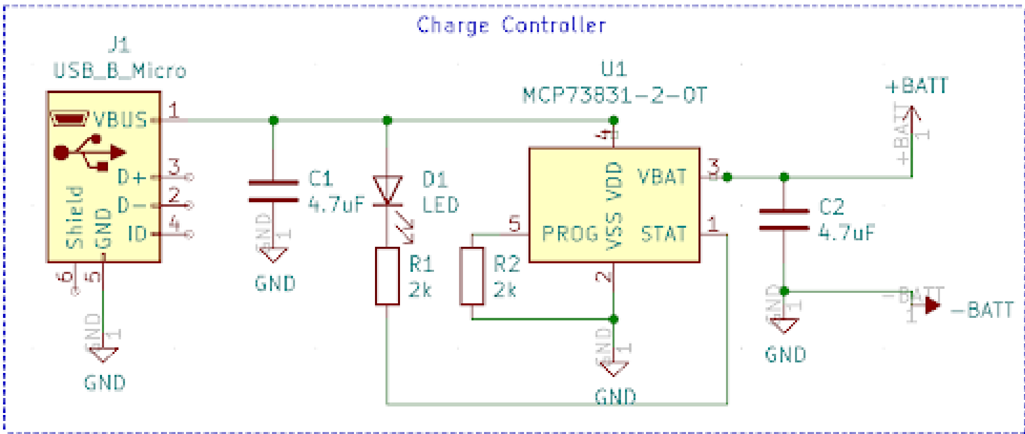

Figure 3: Charge Controller Schematic

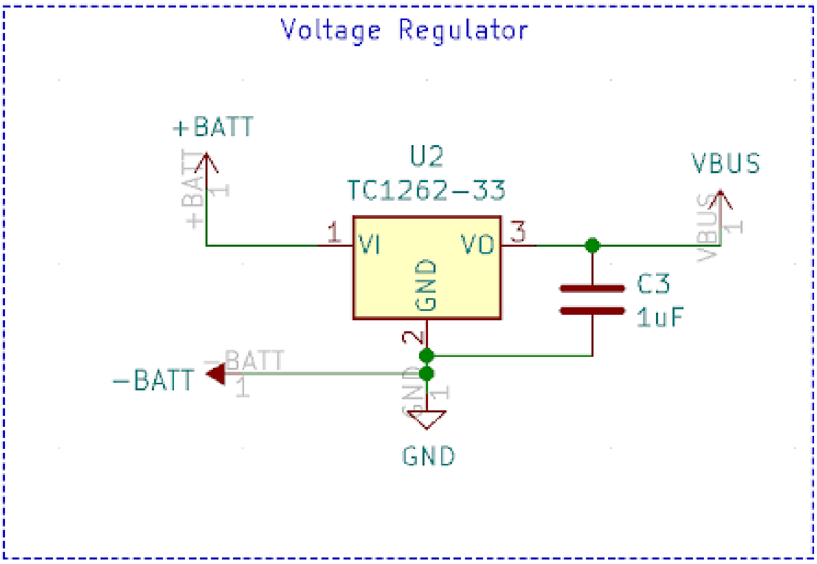

Figure 4: Voltage Regulator Schematic

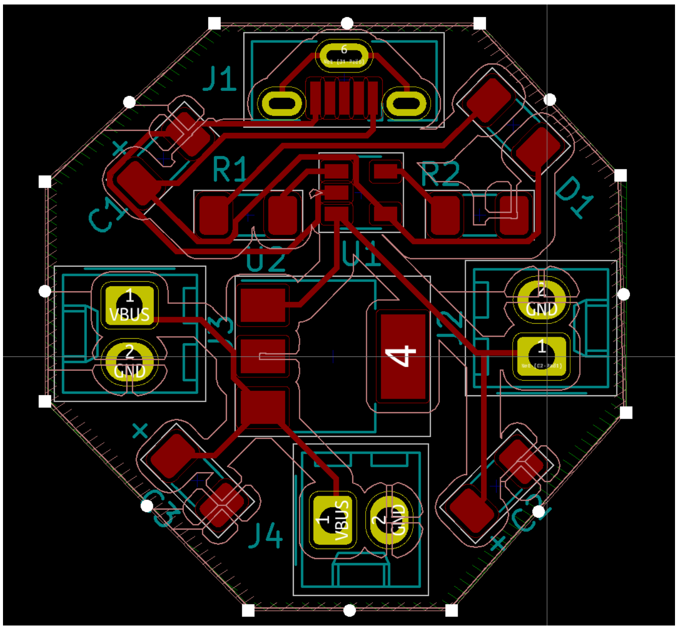

Figure 5: PCB for Charge Controller and Voltage Regulator

Table 1: Power Subsystem RV Table

Requirements	Verification
Voltage regulator must be able to regulate battery output voltage to 3.3V±0.5V. Microcontroller, laser, and photodiode all operate at 3.3V, with tolerances ranging of around 1.0V.	1. Measure voltage of battery input in the voltage regulator using a voltmeter which should be 3.7V. 2. Measure voltage at the end of the voltage regulator system using a voltmeter and verify it is 3.3V±0.5V.
Battery must be reliably rechargeable, so successive uses after recharging have similar battery life (within 90%)	1. Fully charge the battery. (The LED on the PCB of the power subsystem indicates when the battery is fully charged.) 2. Record voltage of battery using a voltmeter. 3. Repeat steps 1 and 2 100 times after each full charge of the battery. 4. Verify voltage does not fall under 90% of 3.7V (3.33V).

2.3 Communication Subsystem

The communication subsystem consists of an NFC tag [7] with a built in EEPROM for memory. It is used for easy communication of the data stored on the pillbox to users, both patients and doctors. We need the NFC EEPROM to have enough memory to store at least one week's worth of data(pill count + timestamp). Timestamp takes about 7-13 bytes, and pill count takes 4 bytes. This means a max of 17 bytes, and assuming 5 pills taken a day, that gives us 35 entries a week. This means we need storage of at least 595 bytes.

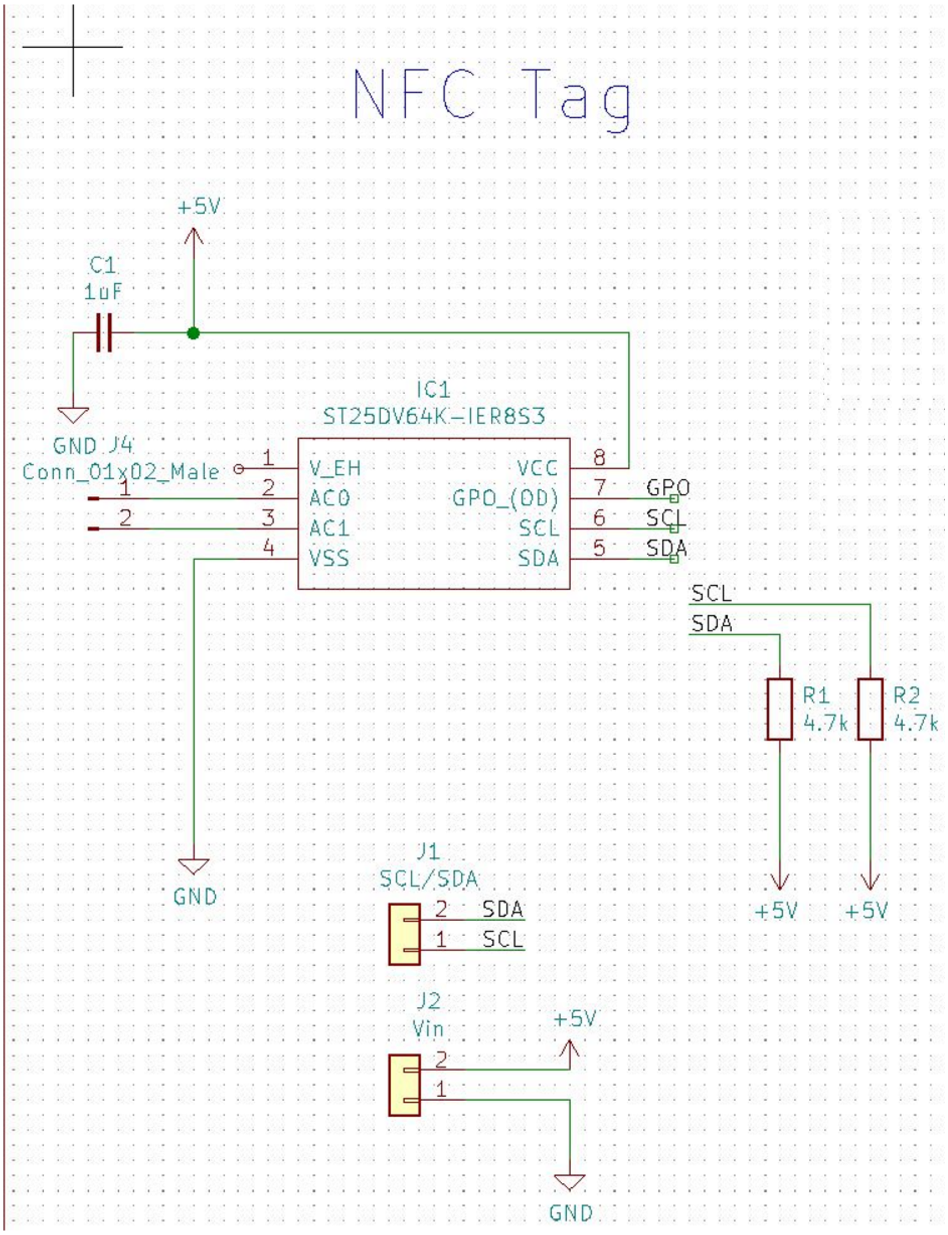

Figure 6: NFC Tag Schematic

Table 2: Communication Subsystem RV Table

Requirements	Verification
90% successful communication rate	1. Tap surface of testing device(phone) onto lid where NFC tag resides 2. Verify on app whether a count is displayed 3. Repeat steps 1 and 2 total of 10 times, noting down times of successful communication 4. Calculate success rate
Establish connection and transmit/receive data under 5 s	1. Tap surface of testing device(phone) onto lid where NFC tag resides while starting timer 2. Record time when signal received from NFC tag on phone 3. Repeat steps 1 and 2 10 times, noting down time taken or each attempt 4. Check each communication time is under 5 s.
EEPROM has enough data for one week's worth of usage	1. Activate pillbox lever 5 times a day 2. Manually track the number of times the lever was used 3. Tap phone onto NFC tag each time lever is used 4. Verify each tap that data communicated by NFC tag remains accurate 5. Continue steps 1 - 4 for a period of one week

2.4 Microcontroller Subsystem

We are using a ATTiny204 [6] as our microcontroller. The purpose of the microcontroller is to translate the signals received from the sensor subsystem into data to send to the communication subsystem, so as to be displayed to the user.

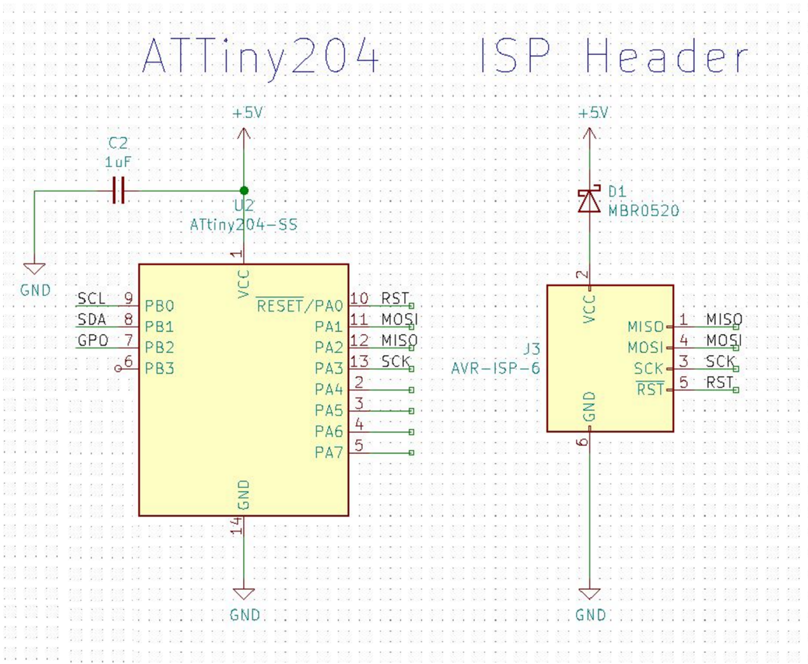

Figure 7: ATTiny204 MCU Schematic

The MCU and NFC subsystems are build onto the same PCB as the following:

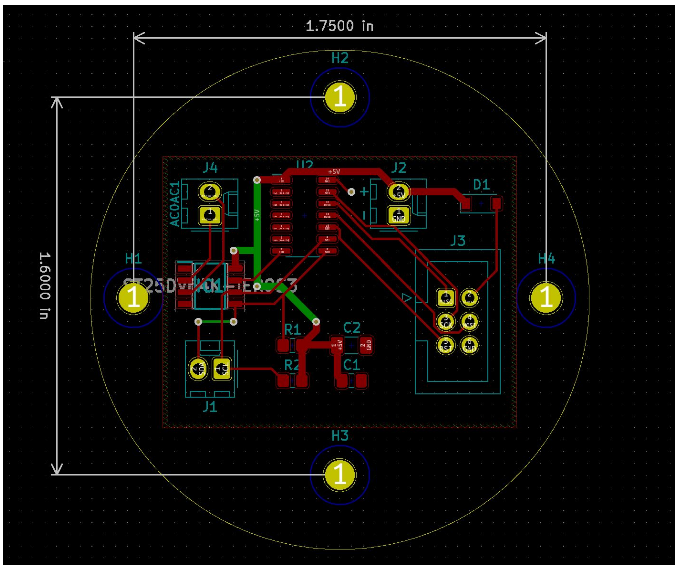

Figure 8: NFC + MCU PCB

Table 3: Microcontroller Subsystem RV Table

Requirements	Verification
Process sensor data, both amount and timestamps accurately with 100% success rate.	1. Connect ATTiny204 to laptop 2. Release one pill from the pill lid, recording the time 3. Call file.print on Arduino IDE to check data stored on ATTiny204 4. Repeat steps a - c for 10 times, verifying each time that the amount released and time any single pill released is correct
Output data accurately to NFC EEPROM consistently of 90% success rate.	1. Connect ATTiny204 to laptop 2. Release one pill from the pill lid 3. Call file.print on Arduino IDE to check data stored on ATTiny204 4. Tap phone onto NFC 5. Repeat steps a - d 10 times, verifying that the data from ATTiny204 matches data from NFC tag

2.5 Detection Subsystem

We are using Adafruit VEML7700 Lux Sensor [10] as our LED Light sensor and PL 520 Laser Diode [2] as our laser transmitter. The purpose of the detection subsystem is to detect when a pill has been crossed and notify this action to the MCU.

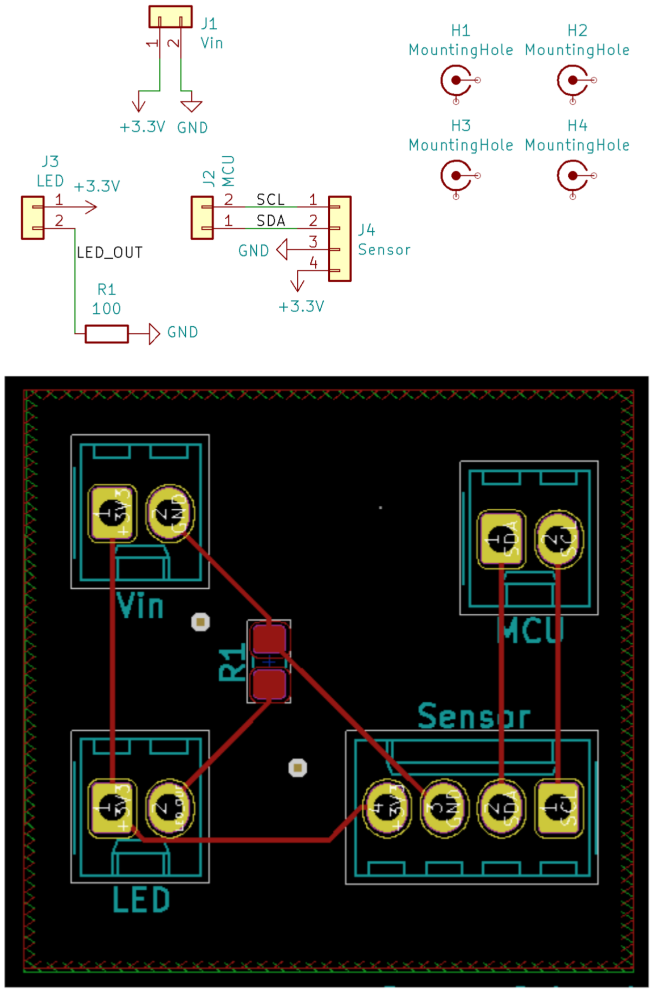

Figure 9: Photodiode + Laser Schematic and PCB

Table 4: Detection Subsystem RV Table

Requirements	Verification
Be able to accurately detect when a pill has crossed, with a 90% success rate.	1. Connect LED Light Sensor to Arduino to computer to display real time data from LED Sensor 2. Eject a pill out of the container using mechanical component 3. Check if the laser beam from laser emitter to sensor was disrupted, and displayed real time on computer 4. Repeat steps a and b for a total of 10 times to see how many times laser was disrupted vs total number of times mechanical ejection was used
Sends detection data consistently to the microcontroller with a 90% success rate.	1. Eject a pill out of the container using mechanical component 2. Check the Communication Subsystem to see if data of detection was received 3. Repeat steps a and b for a total of 10 times to see how many times detection data was sent to the communication subsystem vs total number of times mechanical ejection was used

2.6 Mechanical Ejection Subsystem

This subsystem will be completed by the machine shop. A mechanical lever [1] in the lid ensures that only one pill is dispensed at a time. There are two slots that a pill to be dispensed will reside: a "loading slot" that the pill first enters, and a "release slot" that the pill falls out from. A laser is placed across the release slot paired with a photodiode.When the pill drops through and momentarily blocks the laser, a signal is sent as a pill being detected. A contact pad on the lever completes the circuit when the lever is pulled.

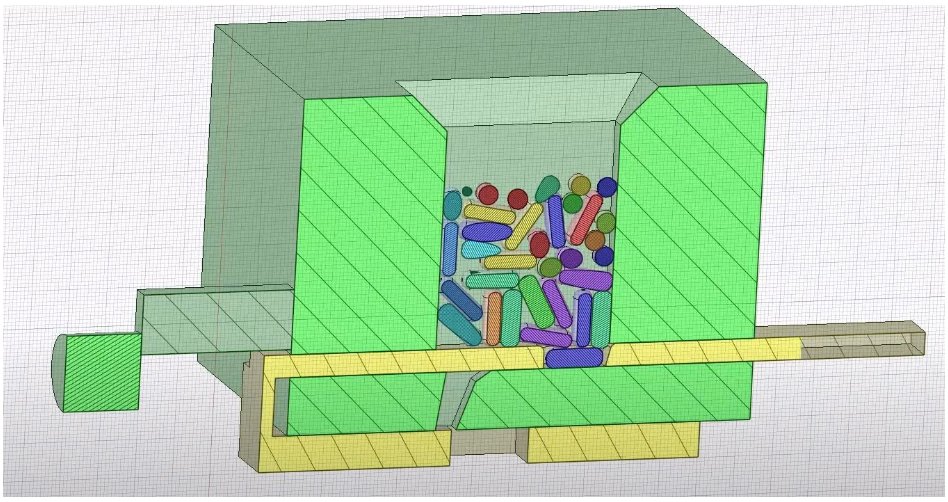

Figure 10: Mechanical Ejection Subsystem

Table 5: Mechanical Ejection Subsystem RV Table

Requirements	Verification
Be able to eject one and only one pill each time with a success rate of 90%.	1. Pull the lever 2. Check to see how many pills have been ejected by the action 3. Repeat steps a and b for a total of 10 times
Power up the entire circuit when the lever is pulled, with a 90% success rate.	1. Pull the lever 2. Check if LED/components on ALL circuit boards are powered 3. Repeat steps a and b 10 times

3 Cost and Schedule

3.1 Cost Analysis

1. Labor

   a. Avg UIUC EE salary: $79714. [3] Avg UIUC CE Salary: $96992. [3] Avg comes out to be $88353/yr.

   b. A 9-5 job of 52 weeks comes out to be 2080 hours, so hourly is $42.48/hr.

   c. We estimate about 50 hours for the app + NFC, 15 hours for firmware, 30 hours for PCB design, 30 hours for debugging, 15 hours for documentation + videos, 10 hours future planning, 10 hours part selection + compatibility testing + sourcing.

   d. Total hours is 160 hours, so total labor cost is $6796.38.

2. Parts

   a. Off the shelf parts generally cost less than $5.

   b. We need a laser, photodiode, microcontroller, NFC tag, NFC antenna, battery housing, battery, PCB.

   c. Assuming a higher $8 average, this comes out to $64.

3. Sum total: $6860.39.

3.2 Schedule

Table 6: Mechanical Ejection Subsystem RV Table

	Yan-Jun	Sumuk	Apoorva
Week of 10/4	Finalize list of parts to use for microcontroller subsystem and finalize layout of PCB boards inside of the cap.	Finalize list of parts to use for detection and ejection subsystem and finalize layout of PCB boards inside of the cap.	Finalize list of parts to use for power subsystem and finalize layout of PCB boards inside of the cap.
Week of 10/11	Finalize the layout of the mechanical system with the PCB boards to minimize the dimensions of the pill cap.	Finalize the layout of the mechanical system with the PCB boards to minimize the dimensions of the pill cap.	Finalize the layout of the mechanical system with the PCB boards to minimize the dimensions of the pill cap.
Week of 10/18	Start individually testing microcontroller subsystem PCB boards. Fix any errors for the second round of PCB board orders.	Start individually testing detection and ejection subsystem PCB boards. Fix any errors for the second round of PCB board orders.	Start individually testing power subsystem PCB boards. Fix any errors for the second round of PCB board orders.
Week of 10/25	Make sure the second version of microcontroller subsystem PCB boards have no errors.	Make sure the second version of detection and ejection subsystem PCB boards have no errors.	Make sure the second version of power subsystem PCB boards have no errors.
Week of 11/1	Test second round microcontroller subsystem PCB boards and fix any errors on the extra PCB boards.	Test second round detection and ejection subsystem PCB boards and fix any errors on the extra PCB boards.	Test second round power subsystem PCB boards and fix any errors on the extra PCB boards.
Week of 11/8	Test all the PCB boards working as one unit.	Test all the PCB boards working as one unit.	Test all the PCB boards working as one unit.
Week of 11/15	Construct the cap with all the working parts.	Construct the cap with all the working parts.	Construct the cap with all the working parts.

3.3 Tolerance Analysis

The main risk to the project could potentially be ensuring the battery life is conserved and lasts a long time. The way we are tackling this is by making sure the laser module is switched completely off when a pill is not actively being dispensed. We also decided to adopt an NFC communication system rather than a WiFi communication system.
The battery that we will be using is a 3.3V battery system. Maximum power of laser = Voltage * Current = 5 * 40mA = 200mAh. Maximum power of light sensor = Voltage * Current = 3.3 * 100mA = 330mAh. Total maximum power consumption from sensors is = 200 + 330 = 530 mAh. We will use a 3.3V 100mAh battery, so: 100 / 530 = 0.1887 hours = 11.321 minutes. The laser and LED sensor will only turn on for 30 seconds when a pill is about to be dispensed so 11.321 / 0.5 = 22.642 pills dispensed. A high estimated average of 3 pills will be drawn in a day (for opioid medication), so 22.642 / 3 = 7.547 days.
So the battery and components we are using will last the patient just over one week.
Another thing to take into account for this would be detection accuracies. So for this we need to ensure that the pill cap is able to detect one and only one pill every time a pill goes through. We are aiming to ensure this by forcing a 95

3.4 Ethics and Safety

Our main concern is violating patient confidentiality. We want to avoid this issue by making sure the patient data is only accessible to the doctor, and the patient is allowed to take the cap off when they want. We will just track when the pills are coming out of the bottle through the pill cap. We want to make sure that we do not take any control for the patient which is why we did not enforce any type of lock on the Pill Safe cap.
Since this also contains medical information we need to comply with HIPAA to make sure all medical data is stored securely so no one else but the patient and concerned doctors/pharmacists can access it [9].
One way we are looking into this is to make sure to use established and secure protocols while transferring data through software. For example, when the data goes from the phone to the database, we need to make sure it has a low chance of being intercepted. Therefore, we are looking into established platforms such as Google Firebase and other databases which ensure this form of security.
Looking into the safety concerns, there could be some minor lab safety issues. Some safety issues may arise during soldering. We will need to ensure to wear proper eye protection and solder carefully to avoid any type of burns. We also need to make sure to turn off the soldering iron and keep the station clean. Another safety concern for the product would be to make sure the electrical and mechanical components do not interfere with the actual pill product. We need to ensure all electrical components are enclosed and would not accidentally fall or cause harm to the pill themselves.

4 Citations

References

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