PillSafe Design Document

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INTRODUCTION

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.

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.

Visual Aid

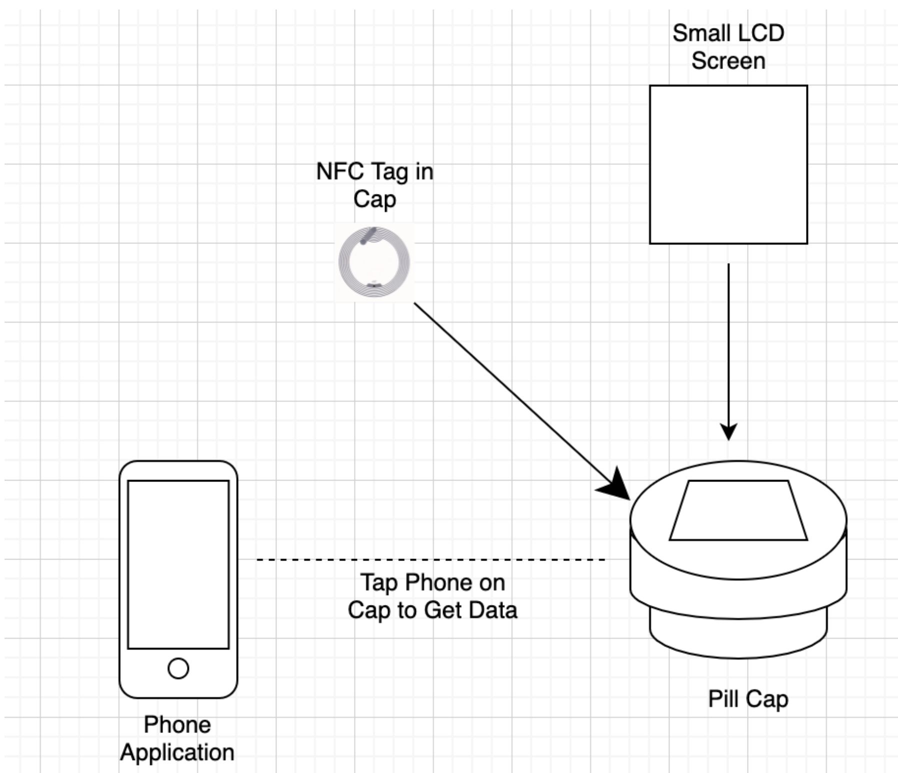


Figure above is visual aid, displaying the high level components of the final design

High-Level Requirements List

- 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.
- 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%. This is calculated as # of times one pill is dispensed / total # times mechanism was used
- 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.

DESIGN

Block Diagram

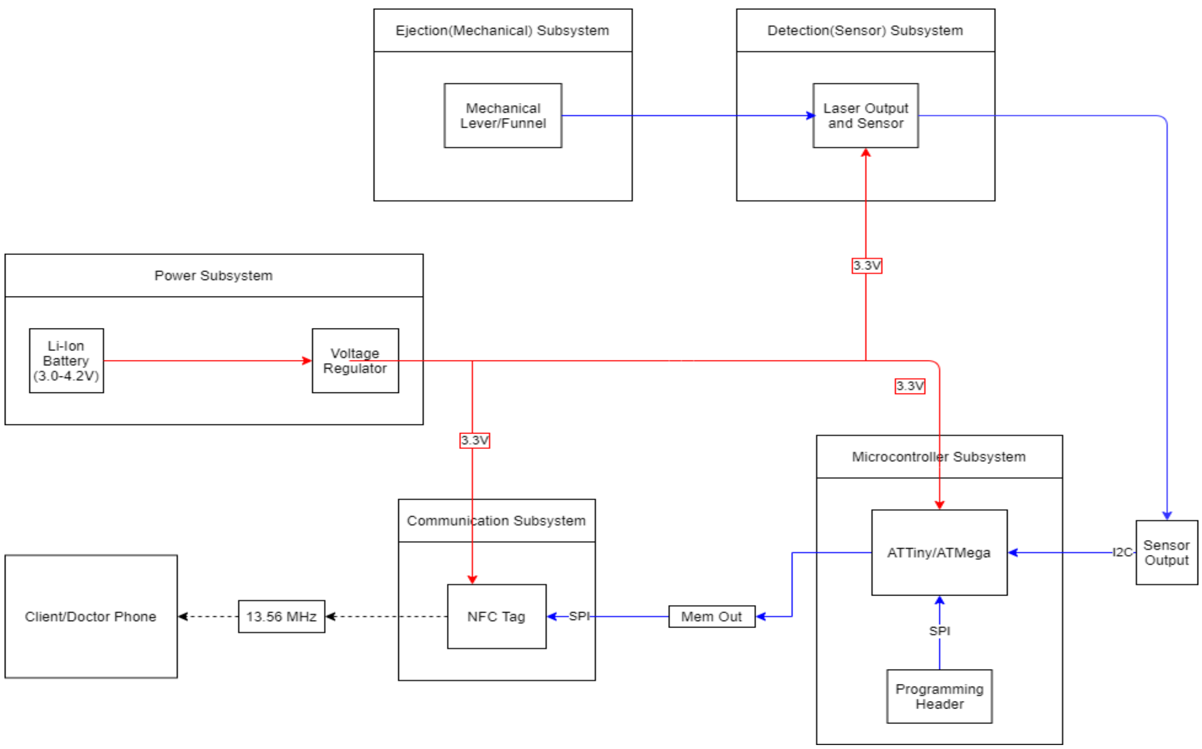
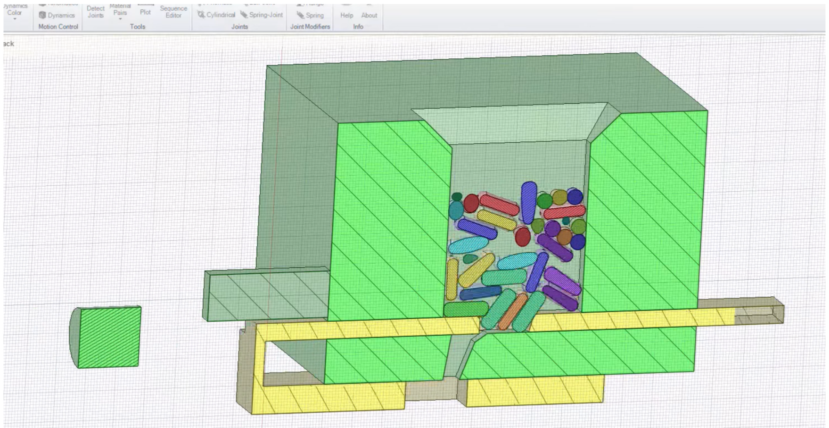


Figure above is the block diagram which shows how all of the subsystems are connected to each other.

Physical Design

We will use a mechanical lever system in the lid to ensure that only one pill is dispensed at a time. There are two slots that a pill to be dispensed will reside: one “loading slot” that the pill first enters, and a “release slot” that the pill falls out of the lid from. A laser will be placed across the release slot, with a photodiode across from the laser to receive the light. When the pill drops through and momentarily blocks the laser, a signal is sent as a pill being detected. There will be a button/contact pad part on the lever that powers on the entire circuit when the lever is pulled, in order to save battery life.

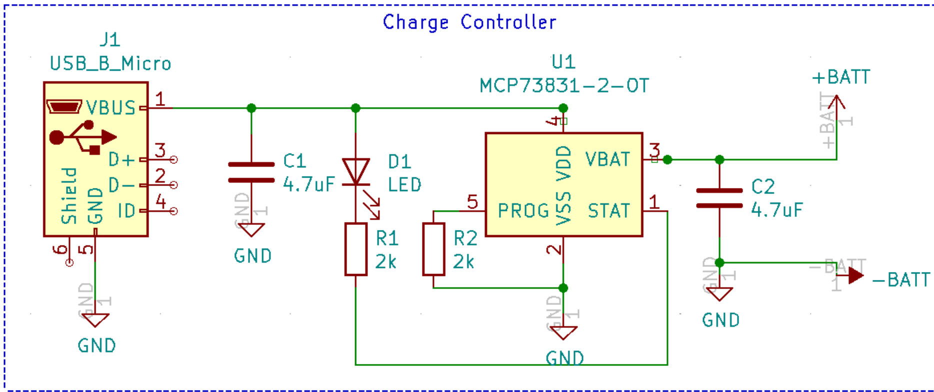
Mechanical Lever Diagram

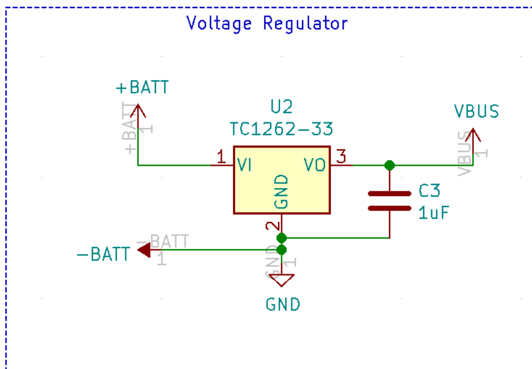


The figure above shows how the mechanical lever works for our ejection subsystem.

Power Subsystem

The power subsystem 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.





Figures above show the circuit diagram for the power subsystem.

Requirements	Verification
1. 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.
2. 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 after each full charge of the battery. 4. Verify voltage does not fall under 90% of 3.7V (3.33V).

The table above is the Requirements/Verification table for the power subsystem.

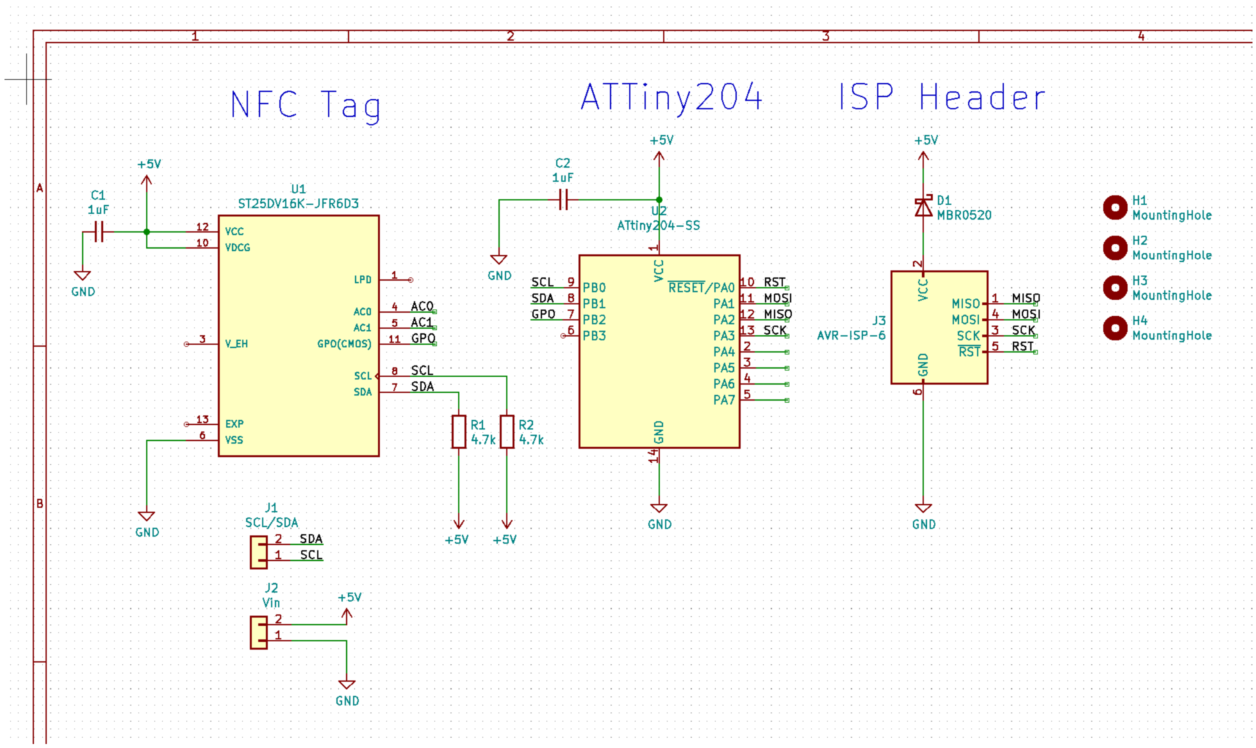
Communication Subsystem

The communication subsystem consists of an NFC tag 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 FC 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.

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

The table above is the Requirements/Verification table for the communication subsystem.

Microcontroller Subsystem
We are using a ATTiny 204 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.



Above is the circuit diagram of the microcontroller subsystem.

Requirements	Verification
1. Can be programmed consistently without altering data stored in NFC EEPROM. 2. Receive sensor data accurately, of 90% success rate. Calculated by # pills stored by microcontroller / # of total pills dispensed 3. Output data accurately to NFC EEPROM consistently of 90% success rate. Calculated # pills NFC outputs / # of total pills dispensed	1. Steps to verify 1. a. Read data stored on NFC EEPROM by tapping phone on NFC tag b. Program microcontroller using laptop connected to ATTiny204 via ISP header on board with the same firmware for normal operation c. Read data from NFC again d. Repeat steps a - c 10 times, verifying that each reprogram does not change the data communicated 2. Steps to verify 2. a. Connect ATTiny204 to laptop b. Release one pill from the pill lid c. Call file.print on Arduino IDE to

	check data stored on ATTiny204 d. Repeat steps a - c for 10 times, verifying each time that the data stored updates correctly 3. Steps to verify 3. a. Connect ATTiny204 to laptop b. Release one pill from the pill lid c. Call file.print on Arduino IDE to check data stored on ATTiny204 d. Tap phone onto NFC e. Repeat steps a - d 10 times, verifying that the data from ATTiny204 matches data from NFC tag

Above is the table for the Requirements/Verifications for the communication subsystem.

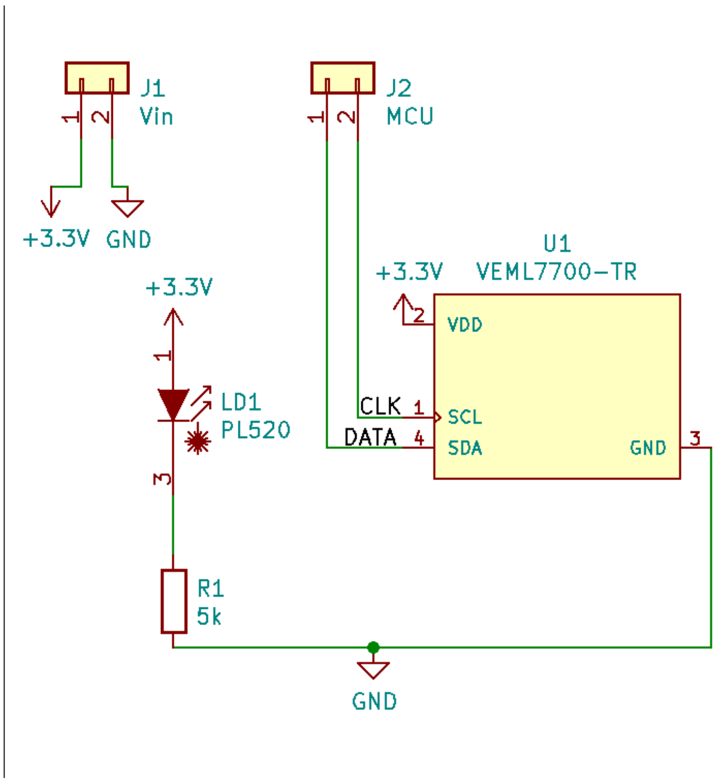
Detection Subsystem

We are using Adafruit VEML7700 Lux Sensor as our LED Light sensor and PL 520 Laser Diode 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.

Requirements	Verification
1. Be able to accurately detect when a pill has crossed, with a 90% success rate. Calculated as # pills detected / # of total pills crossed 2. Sends detection data consistently to the microcontroller with a 90% success rate. Calculated as # of pills NFC reports / # total pills dispensed	1. Steps to verify 1. a. Connect LED Light Sensor to Arduino to computer to display real time data from LED Sensor b. Eject a pill out of the container using mechanical component c. Check if the laser beam from laser emitter to sensor was disrupted, and displayed real time on computer d. 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 2. Steps to verify 2. a. Eject a pill out of the

	container using mechanical component b. Check the Communication Subsystem to see if data of detection was received c. 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

Above is the Requirements/Verification table for the detection subsystem.



Above is the circuit diagram for the detection subsystem.

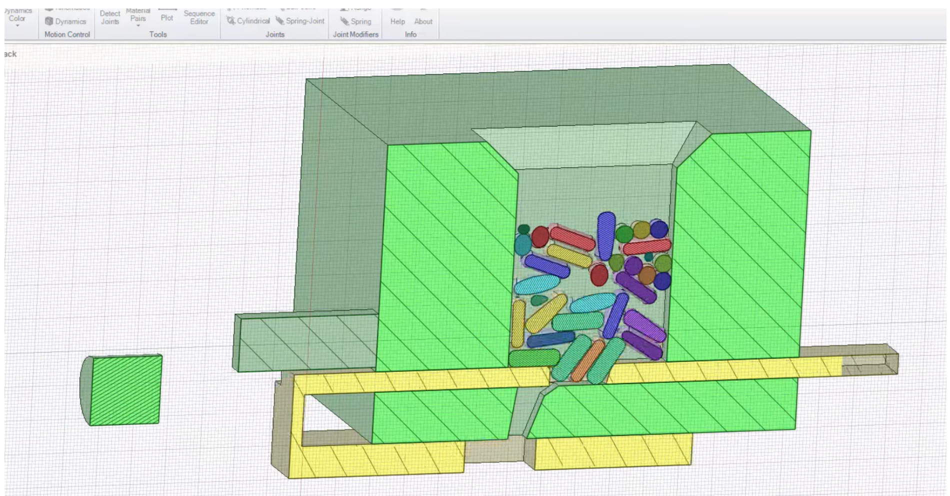
Ejection Subsystem

This subsystem will be completed by the machine shop. The purpose of this subsystem is to ensure that only one pill is ejected when someone wants to take a pill out of the bottle. This should also then power up the circuit when being used.

Requirements	Verification
1. Be able to eject one and only one pill each time with a success rate of 90%. This is calculated by # of	1. Steps to verify 1. a. Pull the lever b. Check to see how many

times one pill is dispensed / # of times mechanism used 2. Power up the entire circuit when the lever is pulled, with a 90% success rate. We can use an LED in the circuit somewhere to show that the circuit is powered on. Success rate calculated as # of times light turns on / # of times lever pulled.	pills have been ejected by the action c. Repeat steps a and b to find the # of times a pill comes out vs # of times the lever is pulled 2. Steps to verify 2. a. Pull the lever b. Check if the LED in the circuit has turned on c. Repeat steps a and b to find the # of times the circuit turns on vs # of times the lever has been pulled

Above is the Requirements/Verification table for the ejection subsystem



Above is the image of how the ejection subsystem will work

COST AND SCHEDULE

Cost Analysis

1. Labor
    a. Avg EE salary: $79714. Avg CE Salary: $96992. Avg comes out to be $88353/yr. A 9-5 job of 52 weeks comes out to be 2080 hours, so hourly is $42.48/hr. 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. Total hours is 160 hours, so total labor cost is $6796.38.
2. Parts
    a. Off the shelf parts generally cost less than $5. We need a laser, photodiode, microcontroller, NFC tag, NFC antenna, battery housing, battery, PCB. Assuming a higher $8 average, this comes out to $64
3. Sum total is $6860.39

Schedule

	Jacky	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.

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 and 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.

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.

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.

References

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