Pillsafe Smart Cap and App

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1. Introduction

1.1 Objective

Many people are struggling with drug abuse in the world. This problem has aroused great concern of the government. According to the National Center for Drug Abuse Statistics (NCDAS), 700,000 drug overdose deaths have happened in the US since 2000 [1]. $34.6bn has been used for the Federal budget for drug control in 2020 [1]. More often, the overuse occurs in daily life, because doctors and guardians are hard to supervise patients to use the correct number of pills. Although there are several commercial items related to drug use on the market now, most of them are easy to get smashed and can't prevent people from drug-abusing by just smashing the bottle [2]. For example, most of the existing smart pill boxes are not for drug abusers. Thus, we believe designing and building a device for preventing drug abuse is meaningful and useful.

Inspired by the Health Maker Lab project 5, we are going to design a smart cap for pill bottles. The smart cap has the following functions. Firstly, it has a dispenser system which can count exactly the number of specific pills needed for the patient each time to avoid overuse using a photoelectric sensor. Secondly, it has a security system to avoid any tampering with the cap or the bottle. Last but not the least, it has a notification system which involves three parts. One is an LCD to display the number of pills. Another is an LED which serves as an alarm to notify the user when he cannot take anymore. The last part is to notify the doctor or the guardian when the patient uses the drug and if the user has any misuse performances through our supporting apps.

1.2 Background

"The reality is that drug dealing can happen anywhere by anyone because prescription drugs are so easily accessible and their abuse is on the rise. According to the Center for Behavioral Health statistics and quality, an estimated 18 million people, 6% of whom are 12 and older have been reported to misuse prescription medications at least twice within the past year [3]." A 2017 National survey on drug use and health estimates that 2 million Americans have misused prescription painkillers for the first time in the past year belching in an increase in addiction and at worst death by overdose [3]. There are not many products in the industry that can prevent people from drug abusing and this is why we are going to produce a device like this. For example, Johns Hopkins University mechanical engineering students developed a similar product called "tamper-proof bottle", but it is being proved that they can be easily smashed and can't prevent people from drug abusing [2]. We need a device that can prevent people from drug abusing and PillSafe Smart Cap could accomplish that.

1.3 Physical Design

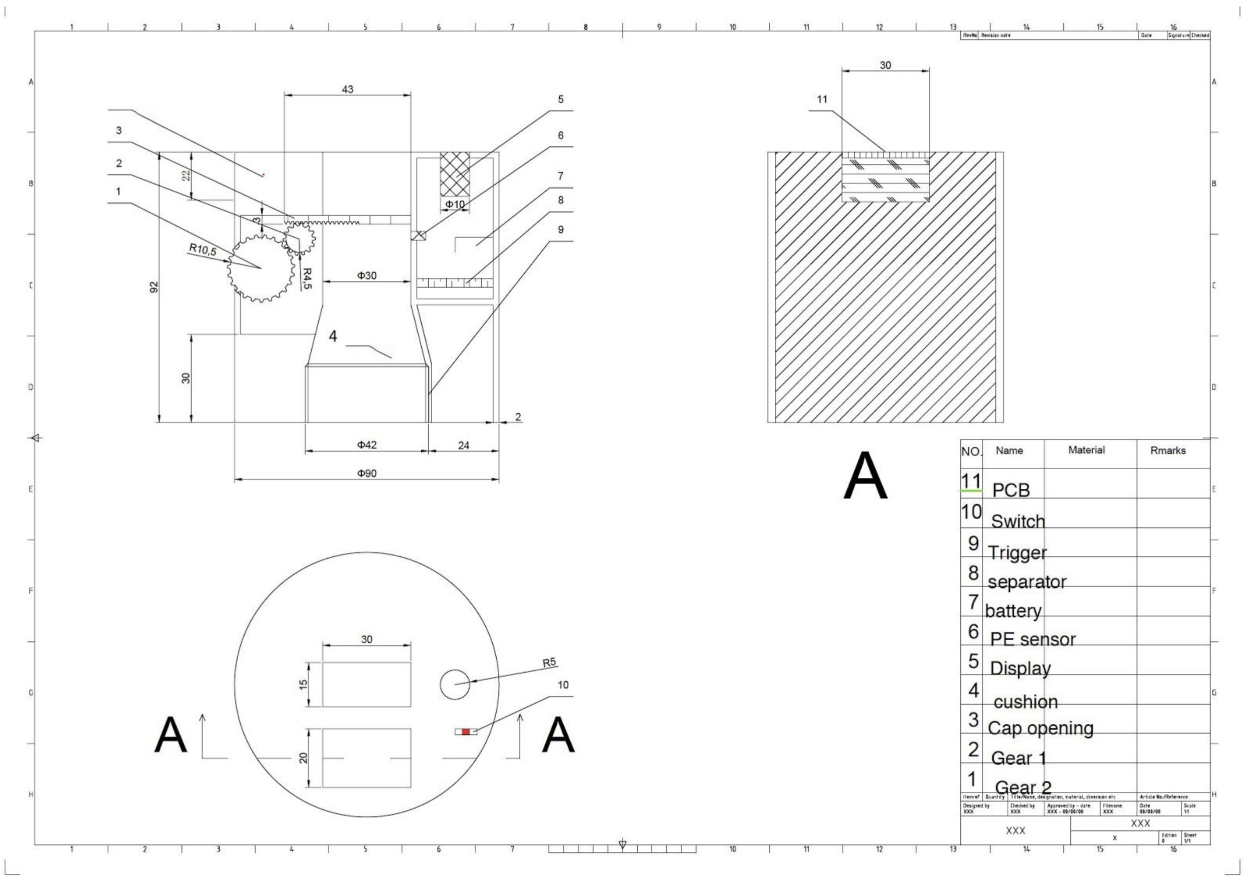

Figure 1: Physical design

All functions are contained in Figure 1. The pill leak mouth (dispenser), LCD, LED, and the switch are on the top surface of the cap as shown in the picture left-down. The moveable gear to control the dispenser is on the side of the cap. The cushion and mechanical separations above the leak mouth to prevent users from dispensing pills too fast. The photoelectric sensor, control unit ,and wifi module are inside the cap. The separation detector is on the side of the cap which can be attached to any pill bottles. The inside view of the cap is shown in the picture left-up. The labeling for each part is shown in the table on the picture right-down. The right-up is a side view of where PCB is placed inside the cap.

1.4 High-level requirements list

- The PillSafe cap can identify the number of pills being dispensed and display the number of remaining pills in the bottle on the LCD with over 90% of accuracy.
- The PillSafe cap can detect violations, such as breaking the bottle or taking more pills than allowed out at a time with an accuracy rate of over 90% and the cap can create alarms at the same time with LED light when a violation is detected. Notifications on users' software app will appear in 3s, with at most 5s lagging.
- Patients/doctors/guardians are able to use the app to set and update the allowed number of pills that should be dispensed at a time. The number updated on the app will be enforced to the bottle and presented on the LCD screen within 5s.

2. Design and Requirements

2.1 Block Diagram

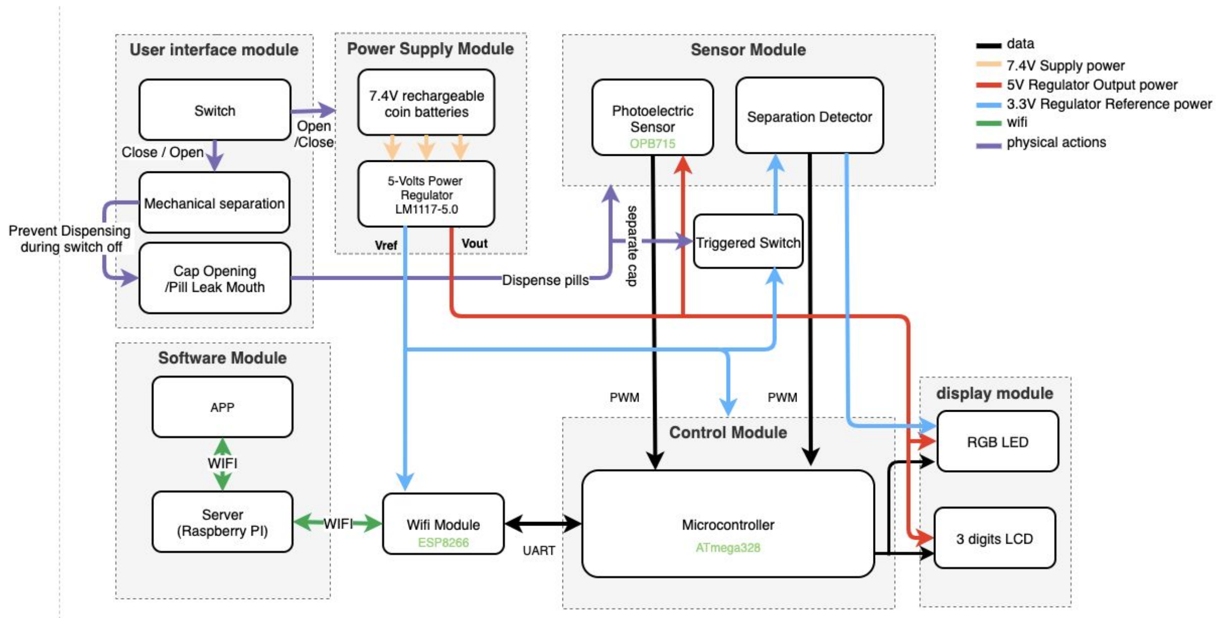

Figure 2: Block diagram

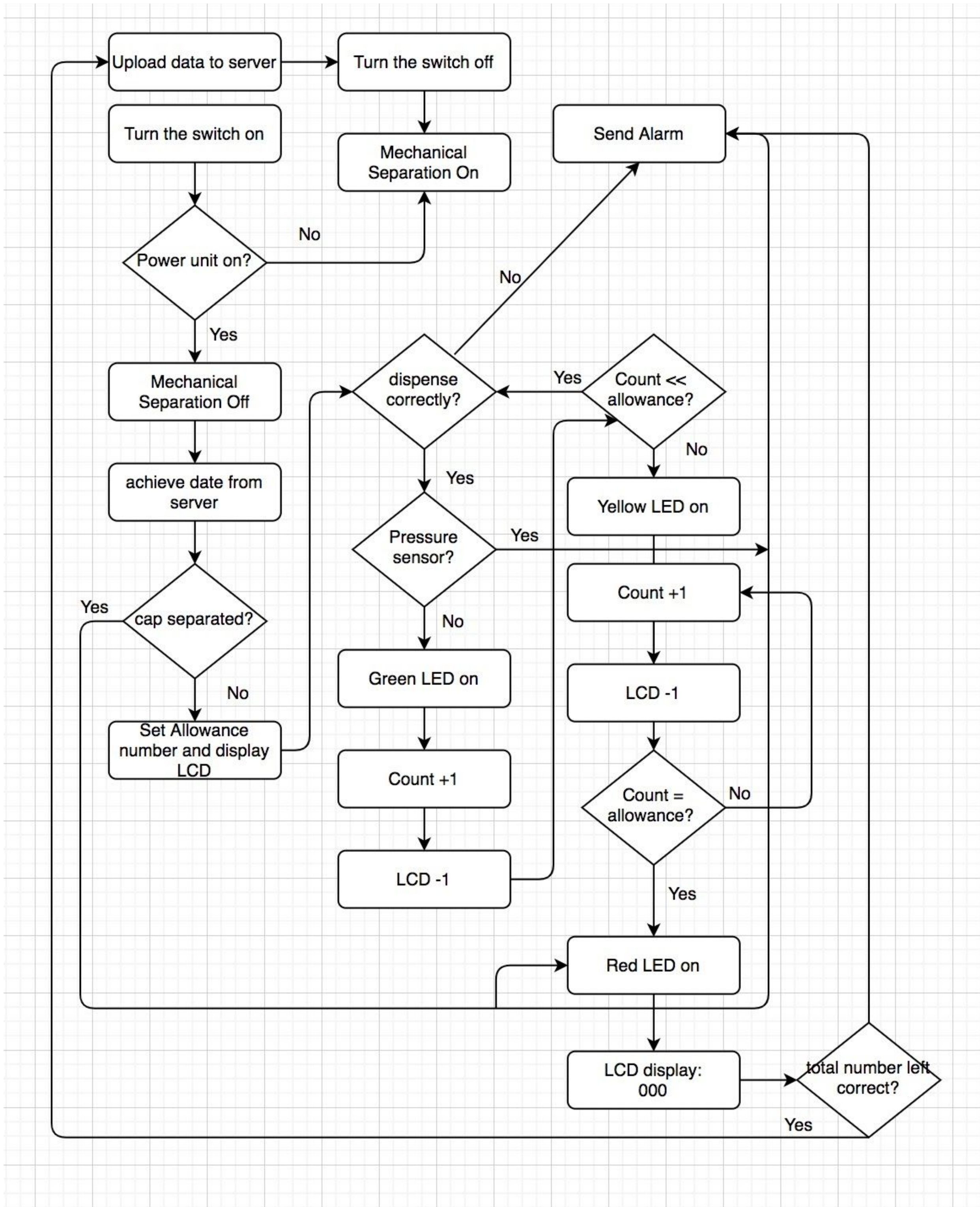

Figure 3: Software flowchart

2.2 Functional Overview & Block Requirements

2.2.1 Power Supply Module

2.2.1.i Li-Battery

The batteries are LIR2032 rechargeable button battery coin cells. We choose this type for the following reasons: 1) It is small in size and cheap in price; 2) It is rechargeable so users do not need to worry about power consumption issues. 3) It provides steady 3.7 Volts power which is enough for the system.

Requirement	Verification
1. Power supply provides 7.4 +/- 0.2 Volts when on and 0 Volt when off. 2. The serial battery pack should have Voltage output of 7.4 V at 0.2C mA, 80mAh with a 5% error	Step 1. Fully charging the battery Step 2. Start discharging it at a constant current of the active mode of the system Step 3. Probe the output voltage and record the duration. the readings should be 7.4 +/- 0.2Volts and the discharging time should last for 8 +/- 1 minutes.

2.2.1.ii Voltage Regulator

The voltage regulator is LM1117-5.0. We choose the 5.0 version since our input voltage is in the range of 6 to 10 Volts. The LM1117-5.0 can provide a steady voltage between 4.75 to 5.25 Volts, nominal voltage is 5 Volts, which is the standard voltage for the LCD and the sensors. The voltage regulator also has a simple voltage dividing circuit to produce a reference voltage of 3.3 Volts. The reference voltage will be used for microcontroller, LED, and the wifi-module.

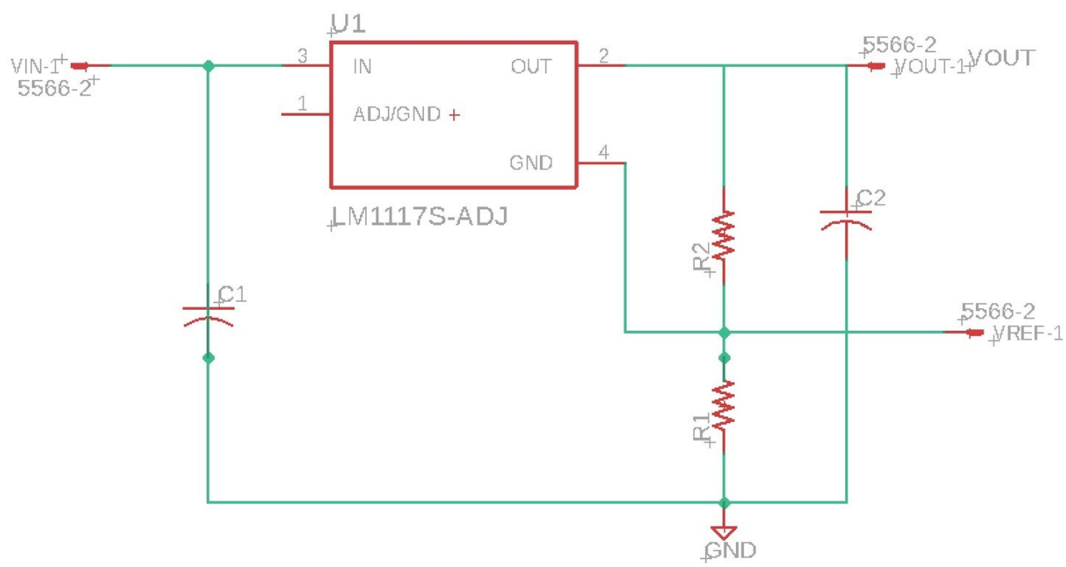

Figure 4: Schematic diagram

Requirements	Verifications
1. Supply Vout at 4.75-5.25V, with 100µA. 2. Using voltage divider circuit to supply Vref at 2.5-3.6V,with 100µA	Step 1. Attach 33 k resistor as load Step 2. Attach oscilloscope across load Step 3. Supply regulator with 7 V DC Step 4. Ensure output voltage remains 4.75 V and 5.25. V Step 5. Ensure the reference voltage is 2.5-3.6 V Step 6. Measure all the current using oscilloscope, ensuring the error within 5%

Load	Voltage	Max current	Active power (max)
microcontroller	3.3 V	20mA	0.066 W
PE sensor	5 V	30 mA	0.15 W
Separation Detector	3.3 Volts	20 mA	0.066 W

LED	5 V	20 mA	0.1 W
LCD	5 V	45 mA	0.3 W
Wifi Module	3.3 V	80 mA	0.264 W

Table 1: Power consumption for parts

Total active power is 0.946 W, the series battery pack is 80mAh, so the duration of active use is at least 5 mins.

2.2.2 User interface module

2.2.2.i Switch

The physical switch controls the power supply unit. The switch should be the only way to open/close the power supply when the pressure sensor is not detected. The switch will also control the mechanical separation between the cap and the bottle. The separation will be on when the switch is off to prevent dispensing pills.

Requirements	Verifications
1. Turn on/off the switch should turn on/off the power supply 2. Turn on/off the switch should turn off/on the mechanical separation	Step 1. probe the output voltage at the battery pack and see if it follows the pattern of the switch Step 2. verify the separation on/off by dispensing items. The dispensing action should fail when the separation on.

2.2.2.ii Cap Opening/ Pill Leak Mouth

The user interface module contains the safe opening on the cap. A moveable gear that can control the size of the leak mouth and a cushion with cuts on it set under the leak mouth. The user should be able to open the cap freely as they want. The leak mouth should fit at least 5 common pill sizes on the market. The cushion should prevent pills from falling out at once.

Requirements	Verifications
1. The cap opening should be 3 cm*1.5 cm large 2. The cushion should be soft material with a cross on it. The size should also be 3cm*1.5 cm 3. The gear should be able to switch the cap opening into four modes : 3 cm, 2.5 cm, 2 cm, and 1.5 cm 4. The allowance error for each length is 5% 5. When the switch is closed, the circuit is charged while pills are allowed to pass through cushion and cap. When the switch is open, the circuit is not charged and the pass between cushion and cap is closed. 6. Together with the photoelectric sensor, The pills passing through the leak mouth should not be too fast that the sensor can not record.	Step 1. All the mechanical functions can process well. Step 2. Prepare 5 common types of pill sizes on the market. Choose capsule size 000,00,0,1,3 Step 3. Use the cap opening to dispense pills. All 5 capsule should pass successfully and each time no more than 2 pills Step 4. Repeat step 1 to 3 by manually dispensing 2 pills at one time, verify that the photoelectric sensor can give the correct 2 output HIGH.

2.2.3 Sensor Module

2.2.3.i Photoelectric Sensor

The photoelectric sensor is used to count the pills dispensed by the user. It is a retro reflective photoelectric sensor with a collector and a receiver as a whole. It should be able to count the number of pills correctly. It should also have the function of distinguishing colors and shapes of different pills. This will be achieved by the different time frames/voltage outputs when dispensing the pill.

Requirements	Verifications
1. The photoelectric sensor must be able	Step 1. Using the oscilloscope to measure the

to detect items passing through within 13 mm +/- 1 mm. 2. The photoelectric sensor must be able to detect different sizes and colors of pills. 3. The photoelectric sensor must finish one logic cycle before the next pill comes through.	voltage output of the sensor when placing capsules at a distance of 0.2 cm Step 2. Repeat step 1, Record the time frame of logical 1 output from PE sensor when passing a pill. Step 3. Repeat step 1&2 for all capsule sizes 000,00,0,1,3. For each capsule, test two colors: green and yellow. The time frame of logical high should be different for different sizes, the voltage should be different for different colors.

2.2.3.ii Separation action detector

The separation action detector is used to prevent users from physically separating the pill bottle and the smart cap. The detector should connect the power supply only when the switch is on. The switch on/off state is determined by the action of pulling the cap off. After the switch is on, an alarm will be sent. In order to achieve this, we designed a self-locked electronic switch. It will then light up a red LED on the cap for alarm and connect to the microcontroller. This circuit will not be affected by the power supply switch.

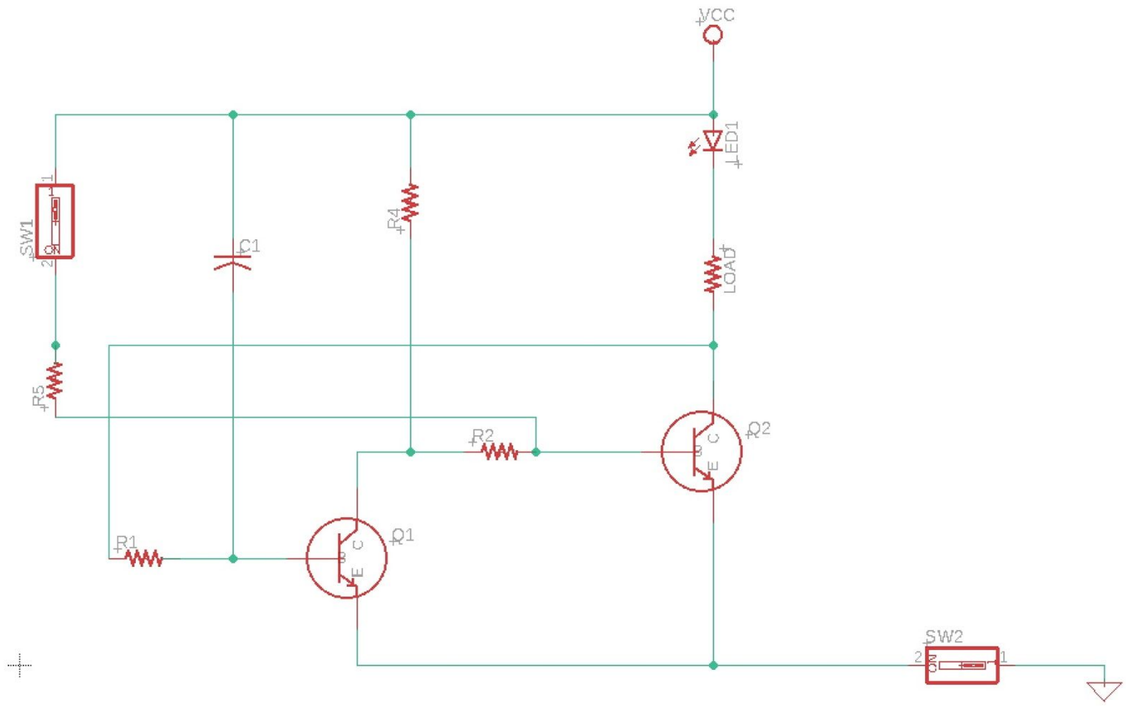

Figure 5: Schematic diagram

Requirements	Verifications
1. Red LED should light up when the switch is on 2. The circuit should give the microcontroller a HIGH output when the power supply switch is off.	Step 1. Build the circuit on the breadboard Step 2. Probe the voltage output of the circuit when the switch is on. It should be 2.5-3.6 Volts, based on what the reference voltage is. Step 3. Probe the voltage at the LED red leg, it should be the same as step 2. 5% errors are allowed due to losses. Step 4. Repeat the previous step when turning the power off.

2.2.3.iii Trigger Switch

The trigger switch is used as the switch for the separation detector circuit. We will use a force sensitive resistor as the trigger switch. The force sensitive resistor should be small enough to perform as a closed switch when detecting force and be large enough to perform as an open switch when no force is applied.

Requirement	Verifications
1. The resistance should be at least 100k ohm when there is no force applied. 2. The resistance should be at most 1k ohm when above 10N applied on it	Step 1. Build a test circuit with the FSR. Step 2. Use the ohmmeter to test the resistance of FSR. Step 3. Record and check the value when no force applied and forcely push it.

2.2.4 Control Module

This module contains the microcontroller. The microcontroller gets data inputs from the sensor module and the software module. It outputs data to the display module and the wifi module. It should be able to transfer the analog input from the photoelectric sensor and the pressure sensor to digital states and send it to the display module. It should also transfer data between the control unit and the software unit. The microcontroller should have little power consumption.

ATmega328p pin connections:

- VCC is connecting to the Vref of the voltage regulator
- Photoelectric sensor Vout connects to the analog input pin PC0
- Separation detector circuit's Vout connects to the analog input pin PC1
- LED Green is connected to digital PWM output pin PB1; LED Yellow is connected to digital PWM output pin PB2; LED red is connected to digital PWM output pin PB3
- LCD is connected to digital output pin PD7
- Wifi module TX is connected to digital pin RX, PD0
- Wifi module RX is connected to digital pin TX, PD1

Requirements	Verifications
1. The microcontroller should communicate over a standard I2C bus and also a standard SPI bus. 2. The microcontroller should have at	Connections: All the connections are verified using the ATmega and driver codes are tested on the board as well.

least two analog input pins to get inputs from the sensors 3. The microcontroller should produce digital output HIGH when photoelectric sensor provides logical output 1, and produce digital output LOW when photoelectric sensor provides logical output 0. 4. The microcontroller should be able to receive input HIGH from the 5. The microcontroller should have at least 3 digital output pins to LED	Communications: This will be verified in the wifi module. Outputs: Step 1. Power the board with 3.3 Volts to VCC Step 2. Upload the driver codes and set PE sensor output to logical 0. Step 3. Probe each output pin to see if the voltage corresponding to "LOW" Step 4. Set the PE sensor output to logical 1. Step 5. Probe the output pins for LEDs to test if they are 3.3 Volts Step 6. All the measurements above have a 5% error allowance.

2.2.5 Display Module

2.2.5.i LED

LED lights are used to notify the user the situation of dispensing. LED should have three modes: red, yellow and green. Green will light up when users start dispensing pills. Yellow will light up when the allowance number of pills is approaching. The approaching number can be set from the software by the user. Red will light up when met or beyond the exact number of allowance. The LED will be a common cathode RGB LED, and the color legs are connected to the digital output pins on the controller

Requirements	Verifications
1. The common Cathode RGB LED can light up three colors with 3.3 voltage inputs for each individual leg. 2. Green light should light up when the number of pills dispensed is greater than 0 and less than allowance-α. 3. Yellow should light up when number of pill dispensed is between	On the breadboard, connect the cathode to ground and RGB pins to a 3.3 volts DC voltage supply. Verify that the LED can light up correctly.Using the Arduino Development Board to do the testing with the driver code Step 1. In the driver codes, set the allowance number to 10, α to 2

allowance-ɑ and allowance number 4. Red should light up when the number of pills dispensed is exactly the allowance number or beyond.	Step 2. Upload the driver codes and power up the Arduino Board with 3.3V at VCC. Step 3. Manually set the number of pills dispensed in the code to 1, and verify if the green light is on. Step 4. Probe the other two LED lights to see if the output is LOW Step 5. Manually set the number of pills dispensed in the code to 8, and verify if the yellow light is on. Repeat step 4 for the safety check. Step 6. Manually set the number of pills dispensed in the code to 10, and verify if the red light is on. Repeat step 4 again.

2.2.5.ii LCD screen

The LCD screen is used to display the number of pills. The number is setted by the software each time the switch state changes. It will provide the remaining number of pills in the dispensing process and upload the number to the server. Together with the LED, it provides digital information to the user. We will use LCD-S301C31TR, which is a 3 digit LCD with a small size.

Requirements	Verifications
1. It should display the number of pills remaining and notify the user when the process finishes. The data is from the microcontroller. 2. The three-digit screen should be seen clearly. 3. The time delay of updating should be less than 5ms.	Step 1. Using the Arduino Development Board to test the LCD system. Step 2. Uploading the driver's code to the arduino and manually set the number of pills remaining to 1 Step 3. Probe the output pin and verify that the state is output HIGH Step 4. Verify that the number is shown clearly and correctly on the screen within 5 ms

	Step 5. Change the state to “finish” in the drivers’ code, verify that the digit shown on the LCD is flashing. Step 6. Repeat steps 2-4 with 10 and 100 (2 and 3 digit number)

2.2.6 Software Module

The application will have an interface with the display module and the control unit. It will set the allowance of pills and display on the LCD screen; it will use the data from the microcontroller to detect violation. Guardians/Doctors can reset the allowance number remotely . The application must be able to update the number of pills allowed taken by the patient displayed on our Cap within 3 seconds and it must be able to send the alarm to the doctor/provider when the patient is misusing the drugs within 3 seconds.

Requirements	Verifications
1. The software can detect the power on/off stage of the cap 2. After detecting that power is on, send the last recorded remaining pill number from the server to the microcontroller 3. Send alarm to users/doctors/guardians when any misusing happen, include: over dispensing, bottle separation and low battery 4. Update the number of remaining pills regularly to the server if the user dispensed pills correctly	Step 1. Open the software and create the user account. Step 2. Add authority accounts in the software, for example, doctors or guardians. Step 3. In the authority accounts, set the allowance number. Step 4. Connect with the cap through WiFi Step 5. Run the drivers’ codes to verify the allowance number inputted. Step 6. Change to the exactly correct remaining number of pills in the driver code, and turn off the switch. Verify that the remaining number is updated in all the accounts Step 7. Change to an incorrect remaining number of pills in the driver code, and

	turn off the switch. Verify that the alarm is sent to all accounts.

2.2.7 WiFi Module

The microcontroller in the PillSafe Cap uses WiFi protocol to transfer the data between the control unit and the software module. It must be able to allow the data from the microcontroller to be sent via UART and be able to be accessed on a WiFi network. The connection should be stable within 10 meters.

Requirements	Verifications
1. The wifi module should be able to connect with the microcontroller under a standard I2C bus 2. The wifi module should be able to connect to phone via WiFi IEEE 802.11b/g/n and exchange the data with server 3. The wifi module should be able to connect to a phone for a range of at least 10 meters without blocking 4. The wifi module should be able to send data from the server set numbers in the controller's driver code 5. The wifi module should be able to upload data from the microcontroller to the server	I2C connection: Step 1. Connect the Voltage/Current Monitoring system to the microcontroller and wifi modules' I2C lines. Step 2. Run the i2cScanner sketch on the arduino. Step 3. Verify the addresses are found. Wifi connections: Step 1. connect the wifi module to the microcontroller via RX/TX pins Step 2. Use the Arduino Development Board to test driver codes' functionality, which includes sending data from server to microcontroller and receiving data backwards. Step 3. Using a WiFi hotspot and try to connect the wifi module to this WiFi Step 4. Test through HTTP protocol Step 5. Repeat step 1-4 and adding distances until the module fails to connect

Module Name	**High Level Requirement**	**Points**

Power Module	● This module should supply enough steady power to the circuit ● This module should supply steady Vref and Vout for other modules	**7**
User Interface Module	● This module should have a switch which can control the power supply and mechanical separation ● This module should have a gear to control the leak to fit at least five common capsule sizes	**8**
Control Module	● This module should communicate with the server through wifi module under operation ● This module should gather analog inputs from sensor modules and create correct digital outputs to display modules	**5**
Display Module	● This module should display different color LED lights for different stages to notify users. ● This module should display the remaining pills on the LCD and notify the user when the process finishes.	**5**
Sensor Module	● This module should count the correct number of pills dispensed through the photoelectric sensor. ● The PE sensor should detect different type of pills successfully ● The detector should notice non-reasonable actions such as separating the bottle ● The force sensitive resistor should perform as a trigger switch.	**10**
Wifi Module	● This module should create communication between the hardware and the software through the server	**5**

Software Module	● This module should be able to send default settings to the controller ● This module should be able to send notifications while detecting faults from users ● This module should be able to gather data from the controller and display more detailed information in the software	**10**
Total		**50**

Table 2: Point assignment

2.3 Project Differences Analysis

The current similar product is the "tamper-proof bottles" designed by Johns Hopkins University mechanical engineering students. [2] The primary function of their product is "lock." They tried to lock the pill box and only dispense the pre-set number of pills. Their ideas include:

- Med-O-Wheel SECURE: this locked pill box dispenses the prescribed dose of medication at a pre-set times
- Timer Cap: this cap is equipped with a built-in-timer to count the time of using drugs.
- Safer Lock: The pill bottle includes a four-digit combination lock in the cap.

Even though their ideas are good, they do not provide solutions to the issue. Users can easily destroy the box and the doctors/guardians have no way to know. Also, this product is not able to improve the drug abusers' performances.

Different from their ideas, we give higher priority to the doctors/guardians. The performance of the user of our pillsafe cap is presented to the authority accounts for supervision. Especially when the separation detector works, the authorities will know right away and stop the false actions.

To help the user improve their resistance to overusing pills, we purposely make the dispenser small and only can dispense a few pills each time. We also design a counter to show users that their pills left are decreasing. The LED lights are also used to notify users. The RED led lights and "000" shown on the LCD will create psychological hints to users that they should stop dispensing immediately. This is better than dispensing all allowed at once, since it helps the patients to improve their patience and performances.

More importantly, our product is only a cap and it can be placed on any pill bottles. So it is extremely cost-friendly.

2.4 Tolerance Analysis

One important factor to success of our project is that we can count the exact number pills being dispensed with high accuracy (need to be close to 100%) in real time. We need to determine the margin of error of our design. In order to measure the margin of error on pill count, we find our photoelectric sensor has two different kinds of placing: from both sides and from top and bottom. Below are the pictures of their trigger points vs displacement graphs.

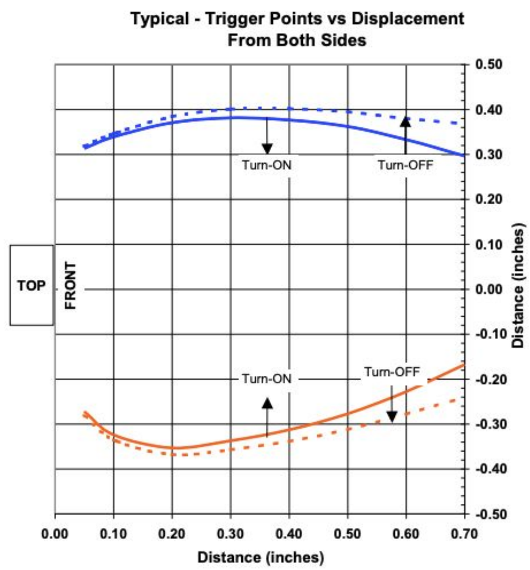

Figure 6: Trigger point vs displacement of PE sensor from both sides

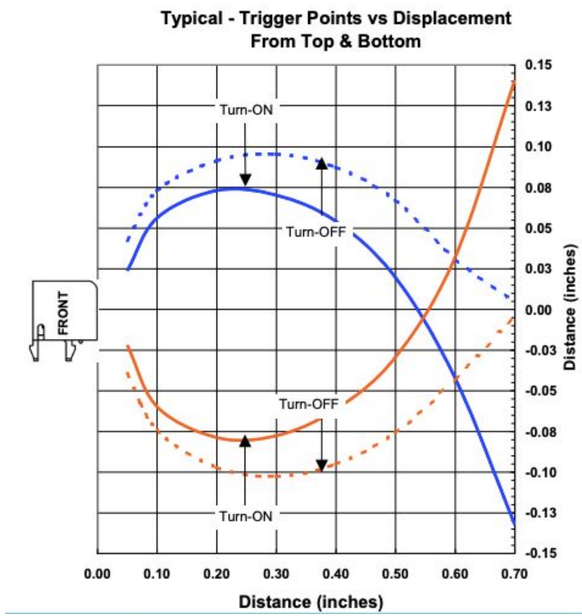

Figure 7: Trigger point vs displacement of PE sensor from top & bottom

From the graphs Figure 6 and Figure 7, we can clearly see that there is a different pattern of how the photoelectric sensor is triggered in these two kinds of placement. With the first placement of the sensor, it is easy to detect that one pill is being pulled out when the pill is near the surface of the bottle. With the second placement of the sensor, it is easy to detect that one pill is being pulled out when the pill is near the center of the bottle. Since we add a moveable gear that can control the size of the leak mouth and a cushion with a cut on the center set under the leak mouth to prevent dumping too many pills at one time. We will choose the second placement which is From top and bottom to achieve higher accuracy on counting the pills.

In order to measure the margin of error on latency, we can use the fact that the time scale for the microcontroller is about 2us/division, so the reaction time from external input to ISR output is about 3 microseconds [4]. Also, the average latency for WiFi networks is about 1-3 microseconds [5]. We take the average as 2 ms for our WiFi latency. The average network latency for our app is about 100ms. So the speed of our app updating the pill count is important.

If the update with a relatively fast speed(100ms):
Total latency = 3+2+100=105ms > 100ms

If the update with a relatively moderate speed(200ms):
Total latency = 3+2+100=105ms < 200ms

If the update with a relatively slow speed(1min):
Total latency = 3+2+100=105ms < 1min

Based on the calculation above, we can clearly see that we need a proper speed for updating the pill count on the app. With a relatively fast speed, it is even shorter than the total latency of receiving the data. With this speed, we will update the incorrect information. With a moderate speed, we can update the pill count on the app on time and don't need to worry about updating the wrong data. With a relatively slow speed, it is okay but sometimes we will miss some crucial information. So we will choose the update speed to be 200ms in order to provide safer guidance for the patient.

2.5 COVID-19 Contingency Planning

If this course goes all online, we will add more complex functionalities in the software part. We would add more data analysis functions and personal design to our App. People can react differently to the same drug based on their various absorptions to the medicine and their age variance. Based on the patient's age and his/her history of taking medicine, our app will be able to provide scientific data analysis and suggestions on his/her future drug using.

3. Cost and Schedule

Type	Manufacture	Part Number	Quantity	Unit Cost	Total Cost
Battery	Energizer-Eveready	LIR2032	2	$1.495	$2.99
Microcontroller	Microchip	ATmega328	1	$2.08	$2.08
PE Sensor	TT Electronics	OPB715Z	1	$6.84	$6.84
LED	CHINA YOUNG SUN LED TECHNOLOGY CO., LTD.	YSL-R1047CR4G 3BW-F8	1	$2.05	$2.05
LCD	Lumex Opto/Components Inc.	LCD-S301C31TR	1	$2.35	$2.35
Trigger Switch	Interlink Electronics	FSR 402	1	$6.95	$6.95

Wifi Module	Espressif Systems	ESP8266	1	$10.00	$10.00
Total cost	**$33.26**				

Table 3: Component Cost

Week	Yanxi	Boyuan	Zijin
Week 1: 09/28/2020	Work on the design document. Work on tolerance analysis.	Work on the design document. Work on R&V table.	Work on the design document. Work on software design.
Week 2: 10/05/2020	PCB design Help with order parts	Schematic design and simulation Place order for parts	Writing code for the app and controller
Week 3: 10/12/2020	3D-printing the cap Test Mechanism	Solder part on PCB	Writing code for the app and controller
Week 4: 10/19/2020	Test sensors and displays	Test power units and circuits	Writing code for the app and controller
Week 5: 10/26/2020	Testing and make adjustment		
Week 6: 11/02/2020	Prepare for mock demo		
Week 7: 11/06/2020	Final integration and testing for both software and hardware		
Week 8: 11/16/2020	Prepare for final presentation and final report submission		

Table 4: Schedule

4. Ethics and Safety

It is important to consider possible ethical and safety issues involved with a technical project. Since our app is able to get first hand information about users' drug habits, we are responsible to protect our users' privacy. To protect our users' privacy, we designed a password protected login system and every user is required to sign a privacy agreement for other users when they sign up. Also, our project is designed for public health. Every feature in our project is designed to prevent drug misuse. These are implement of #1 of IEEE code of Ethics: "to hold paramount the safety, health, … , to protect the privacy of others, ... [6]"

Despite the facts talking above, we should also consider the user's individual/personal rights. Since this application will give the absolute control to the doctor/provider side, there might exists discrimination, financial or sexual orientations which violating #8 of IEEE code of Ethics [6]. Even though we are not able to control the behavior on the administrator side, we will give users/patients the right to stop the program under emergency situations.

We will guarantee our device is safe for our users. To accomplish that, we will pay close attention to points that can possibly cause safety issues to users later. Firstly, we need to be careful of the voltage we apply to the battery, since the battery could explode and cause danger if an overcharge happened. Secondly, since we do not give patients the right to turn off the switch unreasonably, the circuits are being powered consistently. Thus, the entire application must work under little power supply. Lastly, the smart cap contains mechanical parts for the user interface module. We would make sure that these mechanical parts are safe to physical bodies. These are another implement of #1 of IEEE code of Ethics: "to hold paramount the safety, health, ... [6]"

5. References

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