GNG2101

Design Project User and Product Manual

PILL DROP

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Table 1. Acronyms

Acronym	Definition
IR	Infrared
ADHD	Attention Deficit Hyperactive Disorder
UPM	User and Product Manual
LED	Light Emitting Diode

Provide clear and concise definitions for terms used in this document that may be unfamiliar to readers of the document. Terms are to be listed in alphabetical order.

Table 2. Glossary

Term	Acronym	Definition

1 Introduction

The objective of this project is to design a medication dispenser device that aims to enhance the quality of life for those that suffer from attention deficit hyperactivity (ADHD) disorder, and is required to take medication daily. A smart pill case has been designed to ease the pill taking process by organizing, and giving reminders, all while being economically advantageous to similar products on the market. The medication dispenser device created by the GNG2101 Engineering student design team, CHILL PILLZ5, is called the Pill Drop.

This document will feature an overview of our design, followed by conventions, cautions, and warnings associated with the use of the product. It will also highlight how to set-up and use the device, with the proper considerations and system access and navigation that is required. Moreover, a breakdown of the systems sub-functions and features will be elaborated in further detail, ensuring that the user is provided with the fully functioning capabilities of the medication dispenser. Troubleshooting and supporting references will also be provided and how to fix errors that may be encountered while using the device. Lastly, a bill of materials, equipment list, instructions, as well as the conducted testing and validation will be provided for potential designers that wish to elaborate on this given design. The overall purpose of this document is to provide users with as much informative detail on the device in order to use or alter it effectively.

The main features of the device that will be further discussed are the functionality of the button press to dispense the medication, the anti-jamming system, low battery mode, LED configurations and signals, malfunction notification system, and more. This User and Product Manual (UPM) provides the information necessary for those with disabilities associated with

memory loss or attention deficiency to effectively use the Pill Drop device and for prototype documentation. It is also intended for caregivers to those with associated attention and memory deficiencies.

2 Overview

The Pill Drop pill dispenser is designed to provide, for those who have memory retention and attention difficulties, as well as muscular or skeletal conditions, a smart pill case that safely eases the pill taking process by organizing the medication, and giving reminders all while being economically advantageous to similar products on the market. This is important because millions of Canadians are affected by these conditions and require a solution so that their health can be taken care of safely.

The user of Pill Drop pill dispenser has ADHD as well as hyper mobile joints and required a pill dispenser that would dispense pills if they had not yet been taken that day, and prevent dispensing if they had. The dispenser is also required to be quiet, no light on while the machine not in operation, and require little physical power to operate.

Compared to other products on the market, Pill Drop dispenser does not require opening a different compartment everyday, and also allows the user to fill the machine all at once when their prescription has been refilled. If medication has already been taken that day, feedback is given through the use of a red LED and no medication will be dispensed. This prevents taking more medication than is prescribed.

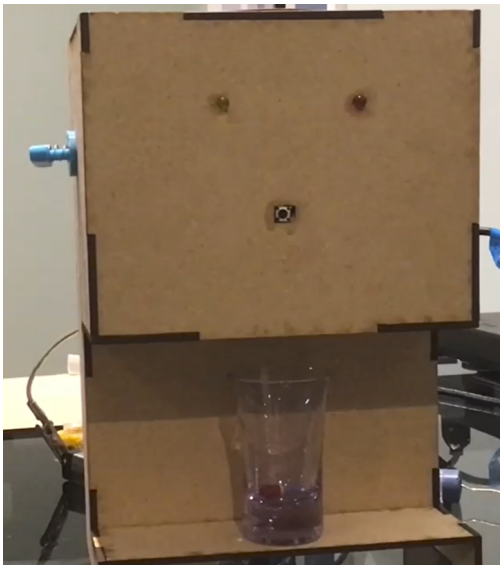

Figure 1: Dispenser Front

2.1 Conventions

- NOTE: important notes to consider when carrying out an action
- ACTION: Indicates when an action is required by the user

2.2 Cautions & Warnings

- Do not leave pill dispenser in direct sunlight
- Pill dispenser is not water resistant
- Electrical components are sensitive to static discharge
- Keep hands out of hopper while in operation to avoid cuts or bruises
-

3 Getting started

The Pill drop pill dispenser is a design which allows medication to be dispensed every day without the need for opening and closing the pill bottle everyday. The system function by first having the user remove the lid from the top of the dispenser and pour the correct medication into the hopper. When medication is desired, the button of the front of the machine is pressed. This sends a signal to a microcontroller which directs a stepper motor connected to the rotating disk to perform a rotation of 720 degrees which will dispense two pills. The pills are dispensed by removing a pill with the rotating disk from one side of the hopper and dropping it from the bottom other side of the hopper. It then falls through a shoot into the dispensing cup at the front of the machine.

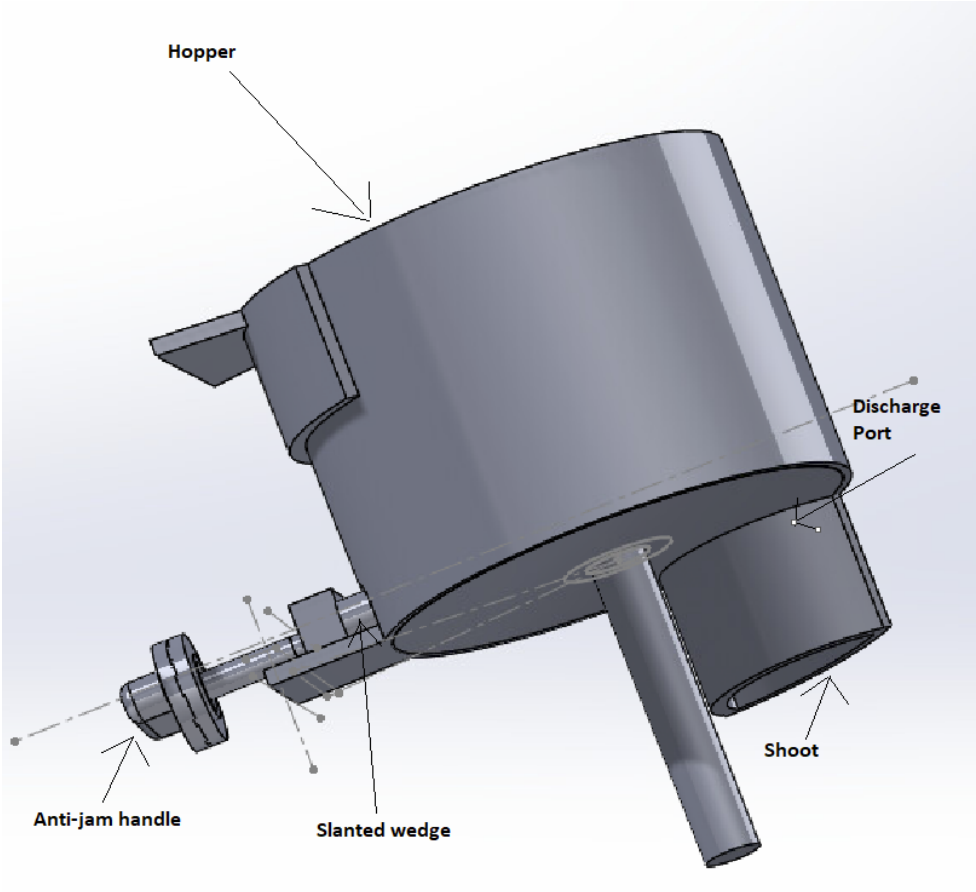

Figure 2: Mechanical Assembly

When the button is pressed to dispense medication, the program first checks to see if the medication had been dispensed less than 20 hours ago. If not, the pills are dispensed as stated above. If it has been less than 20 hours the pills will not be dispensed and a red LED will be illuminated on the front of the dispenser indicating that pills had already been taken. The solid yellow LED on the front of the dispenser indicates that a jam has occurred and the anti-jammer mechanism must be used. A flashing yellow light indicates a low battery.

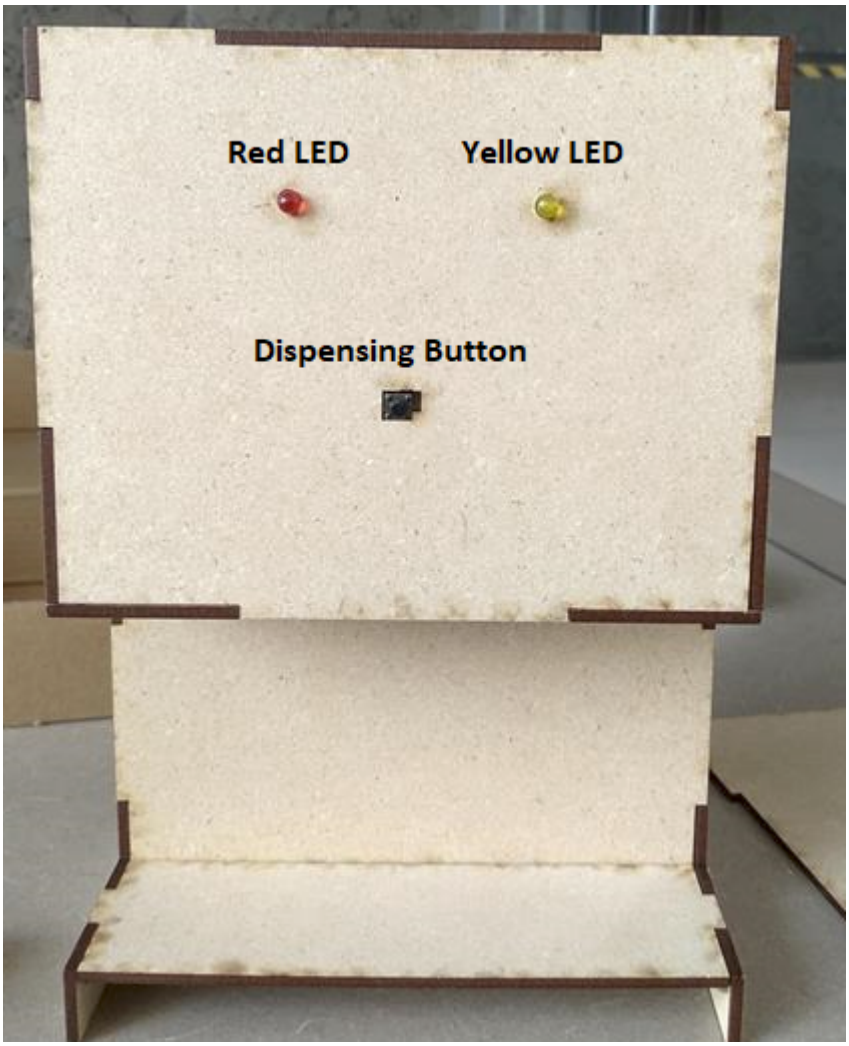

Figure 3: Dispenser Front Labels

When a jam does occur, the anti-jammer is pushed inward toward the device which causes the jammed pills to be cleared from the notch in the rotating disk. The indication of a jam resets the counter in the program so that pills may be dispensed again directly after. There is also an LED and IR receiver in the shoot which will see a pill drop by and verify two pills have been dispensed. If not the disk will rotate an additional 360 degrees to drop one more pill. This IR function is currently not functional as the sensor burnt out and we were unable to retest.

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3.1 Set-up Considerations

Pills are placed into hopper before operation is able to begin. Ensure unit has power through batteries or AC adaptor if necessary. Press button located on the front of dispenser to begin dispensing. Follow direction as set out in Section 3 as needed.

3.2 User Access Considerations

The pill dispenser is capable of being used by anyone, however it was designed specifically for those with memory impairments, as well as those with muscular or skeletal conditions. There are no restrictions on the operation of the system, however if the user wishes to change the amount of pills dispensed at one time they would need some basic programming skills. The pill dispenser is designed so that pills are dispensed with the press of a button and therefore makes it possible for those with muscular or skeletal conditions to easily access their medication with minimal physical effort. The design is currently only able to dispense one type of medication at a time as there is no mechanical device capable of sorting different pill sizes incorporated.

3.3 Accessing the System

3.3.1 Adding Medication

Step 1: Remove lid from top of dispenser

Step 2: Add medication to hopper (will be visible when lid removed)

Step 3: Replace lid on hopper (must be done to prevent ingress of dust and debris)

3.3.2 Power On

3.3.2.1 Battery Operation:

Step 1: Ensure the AC adapter is not plugged in.

Step 2: Press exposed power button located on the bottom of the dispenser

3.3.2.2 AC Operation:

Step 1: Ensure the exposed power button on the bottom of the dispenser is in the off position. This can be made apparent by pressing the main dispensing button twice, if the power button is in the off position no LED's will illuminate.

Step 2: Plug in the AC adapter to a wall outlet

Step 3: Plug the barrel end of the AC adapter into the inversely shaped receptacle on the rear of the pill dispense

3.4 System Organization & Navigation

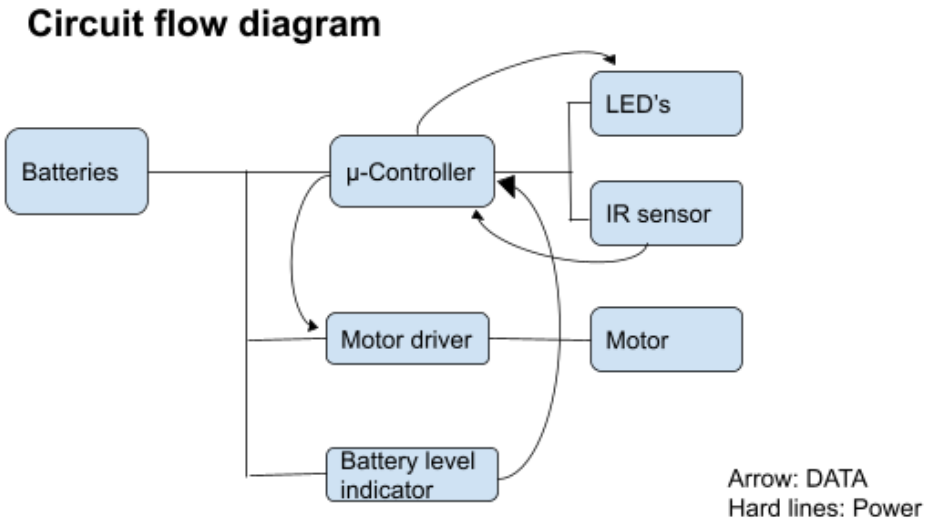

Figure 4 : Circuit Flow Diagram

The system is organized into modes which are navigated via sensor readings, system states, and button presses. The high level diagram of the system's organization and navigation can be seen

below

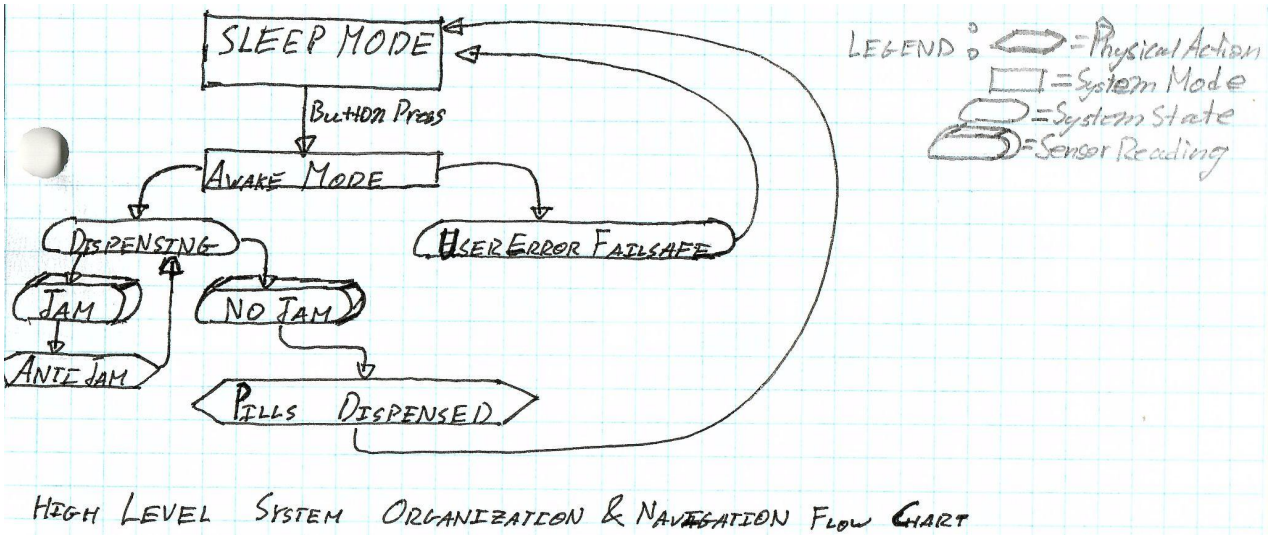

Figure 5: High Level System Organization & Flow Chart

The following is a brief description of each element displayed in the flow chart.

- Sleep Mode: keeps system in low power state until button press
- Awake Mode: Comprised of the following system states:
    - Dispensing: system state that results in pills dispensed and occurs twice per button press.
        - Jam: sensor reading given if a Jam occurs while dispensing, results in a physical action required
            - Anti Jam: physical action required by the user to unjam the dispensing mechanism, also turns on a yellow LED to notify the user of a jam. Returns to the dispensing state.
        - No Jam: sensor reading given if no Jam occurs while dispensing, leads to pills being dispensed

        - Pills Dispensed: physical action by the dispensing mechanism that results in pills being dispensed. Returns to Sleep Mode
    - User Error Failsafe: System state entered if user tries to dispense more than two pills per day cycle (results in illumination of red LED) or if battery is low (results in flashing of yellow LED). Returns to Sleep Mode.

3.5 Exiting the System

Upon dispensing completion the system automatically attempts to enter sleep mode. Fully powering off the device can be done manually.

3.5.1 Battery Operation Mode

ACTION: To fully power off the device all batteries must be removed.

NOTE: Powering off the device will result in a system reset. For proper use please follow actions in section 3.3. when attempting to turn on the device.

3.5.2 AC Operation Mode

ACTION: To fully power off the device the AC adapter must be unplugged.

NOTE: Powering off the device will result in a system reset. For proper use please follow actions in section 3.3. when attempting to turn on the device.

4 Using the System

Dispensing Pills:

In order to dispense two pills the machine must first be turned on (section 3.3). The user must then press the dispense button on the front of the dispenser (figure…). Under nominal operation this will result in two pills being dispensed. If any errors are encountered see section 5.1 for troubleshooting and next steps.

5 Troubleshooting & Support

The chance of three pills getting stuck in the notch is extremely small (around 1 case in 50 tests). However, if it happens, the first step the user needs to do in order to clear the jam is to open the top lid. Then use tweezers to gently move the jammed capsule and clamp it out. After that, press the button placed on the front side of the dispenser to calibrate the notch and the anti-jammer, and then press the anti-jammer to clean the remaining two clogged capsules. If the above method still fails to clear the clogged capsule, the user can choose to take out the hopper to facilitate cleaning. For the user's safety, the user must turn off the equipment and remove the battery before disassembling the hopper. To disassemble the hopper, the user will gently lift the hopper upwards to detach it from the card slot of the motor's shaft, and then pull the hopper towards the rear cover and take it out. System failures may also be caused by insufficient battery power, resulting in inadequate motor torque to dispense medicines properly. Since the battery life of this product is five days, when the yellow LED indicator lights up, please replace the battery in time to make the device work normally.

5.1 Error Messages or Behaviors

If the yellow LED is flashing after dispensing it means that the battery level is low and requires changing.

If the yellow LED is solid there is a jam in the system. Please allow the anti-jamming procedure to take place and use the anti jamming tool to undo the jam.

If the red LED turns on after the button press it means you have taken your medication in the past 20 hours.

5.2 Special Considerations

1. To reduce the risk of electric shock, please do not place the device near the water, or and other liquids.
2. Do not place the device on a heated surface or near the oven.
3. Before loading the medication, please be aware of the expiration date of the medicine.
4. In order to prevent the corrosion of internal electronic components and to extend the life-span of the dispenser, please do not spray directly to the device, and keep the device away from the moisture environment.

5. Please place the device on a flat and firm surface to prevent the device from being damaged by falling
6. If there is a malfunction, please check the battery usage first. If disassembly is required, be sure to turn off the power in advance.

5.3 Maintenance

In order to ensure the proper functioning of the dispenser, the equipment should be placed in a dry and clean environment. If cleaning is required, please make sure to disconnect the power of the equipment in advance to prevent damage to the electronic components in the device. For exterior cleaning, slightly moisten the soft cloth with water or all-purpose cleaner, and then gently wipe the surface. Please do not use any abrasive cleaner or detergent, and please do not spray the equipment directly for cleaning.

5.4 Support

If any information or service is needed, do not hesitate to contact us by calling 613-333-3333. A representative will be available to help you 24/7.

6 Product Documentation

6.1 Subsystem 1 Mechanical

The mechanical components of the pill dispenser include the pill dispensing mechanism, the anti-jammer mechanism, the body of the dispenser, as well as the supports required internally to hold everything in place.

The pill dispensing component is constructed of three parts which are a hopper with and integrated, slanted divider, a rotating disk with a notch cut along the outside edge, and a bottom cap which keeps these components in place.

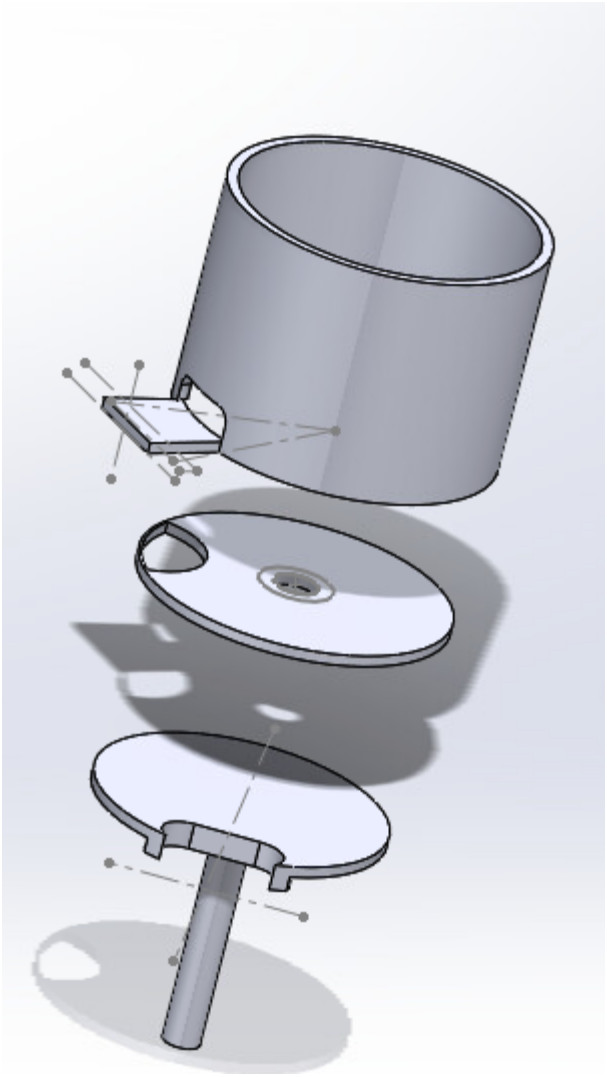

Figure 6: Dispenser Assembly

The medication is put into the hopper which is 6 cm high with a diameter of 8 cm. Taking the other internal components into account, the hopper has a volume of 250 cm^2 which will easily hold 1 months worth of medication. The medication is directed to the opening in the rotating disk by way of a slanted divider which also works to keep the pill storage and outlet ports separate. When the medication is required to be dispensed, the rotating disk will rotate 720 degrees which will cause two pills to be extracted from the hopper and directed to the dispensing cup.

Adjustments had to be made to get the notch cut in the rotating disk properly sized for the clients medication as well as changing the slope of the divider. Medication was more likely to jam in the dispenser when the divider had a greater slope because it does not allow the pills to lay flat and increases the chances of more than one pill partially getting into the port. The components were all constructed through the use of 3D printing with PLA filament. No other materials were considered due to the limited time and resources available for the prototype.

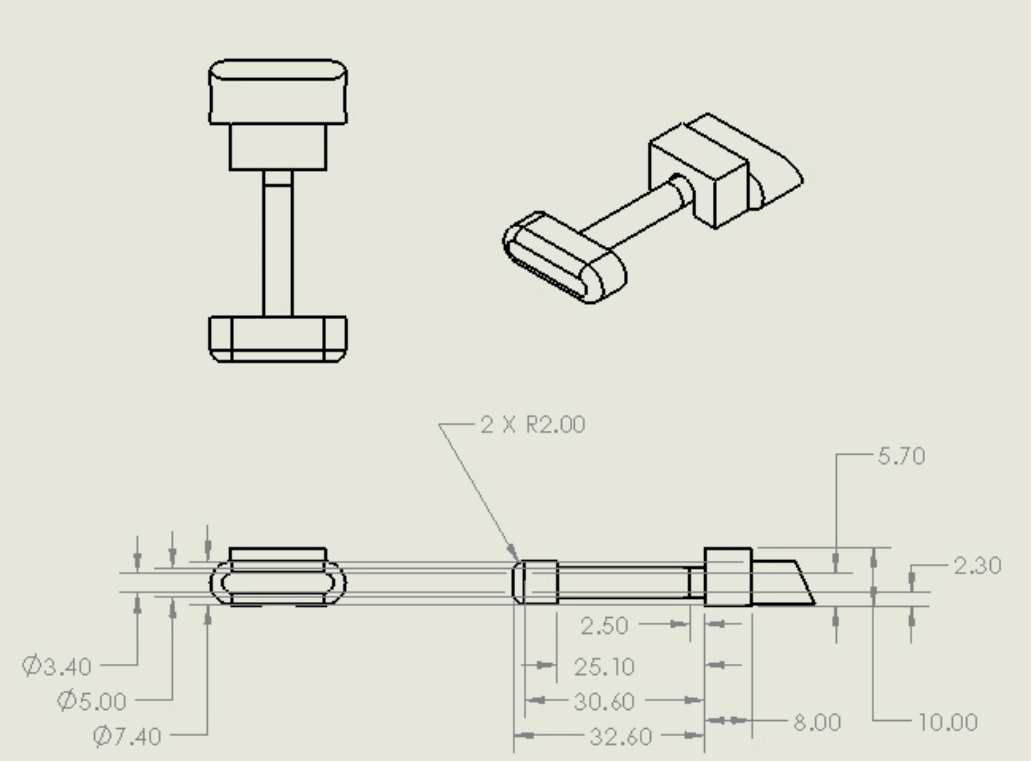

Figure 7: Anti-jam Mechanism

The anti- jamming component consists of several pieces whose combined purpose is to clear any jams that may take place within the dispenser. The anti-jammer sits in the housing so that it blocks the opening cut into the side of the hopper. A spring keeps it in the correct position

so that it stays in place when it is not needed, and is able to be inserted when a jam occurs. The components involved in this section include a slanted wedge shown on the bottom right, a stopper pressed up against the back to keep it in the correct position, a shaft, and the knob at the opposite end which extends through the side of the dispenser. The slanted wedge must be sized properly so that it blocks the hole in the hopper when not in use and is able to slide into the notch of the rotating disk when needed to clear a jam. The location it gets inserted is in the hopper directly next to where the slanted divider stops and the exposed rotating disk begins. This is because through the testing process we determined that that was the only location where jams occured. The components were all constructed through the use of 3D printing with PLA filament. No other materials were considered due to the limited time and resources available for the prototype. The internal structural components were also created through 3D printing with PLA filament for the same reasons.

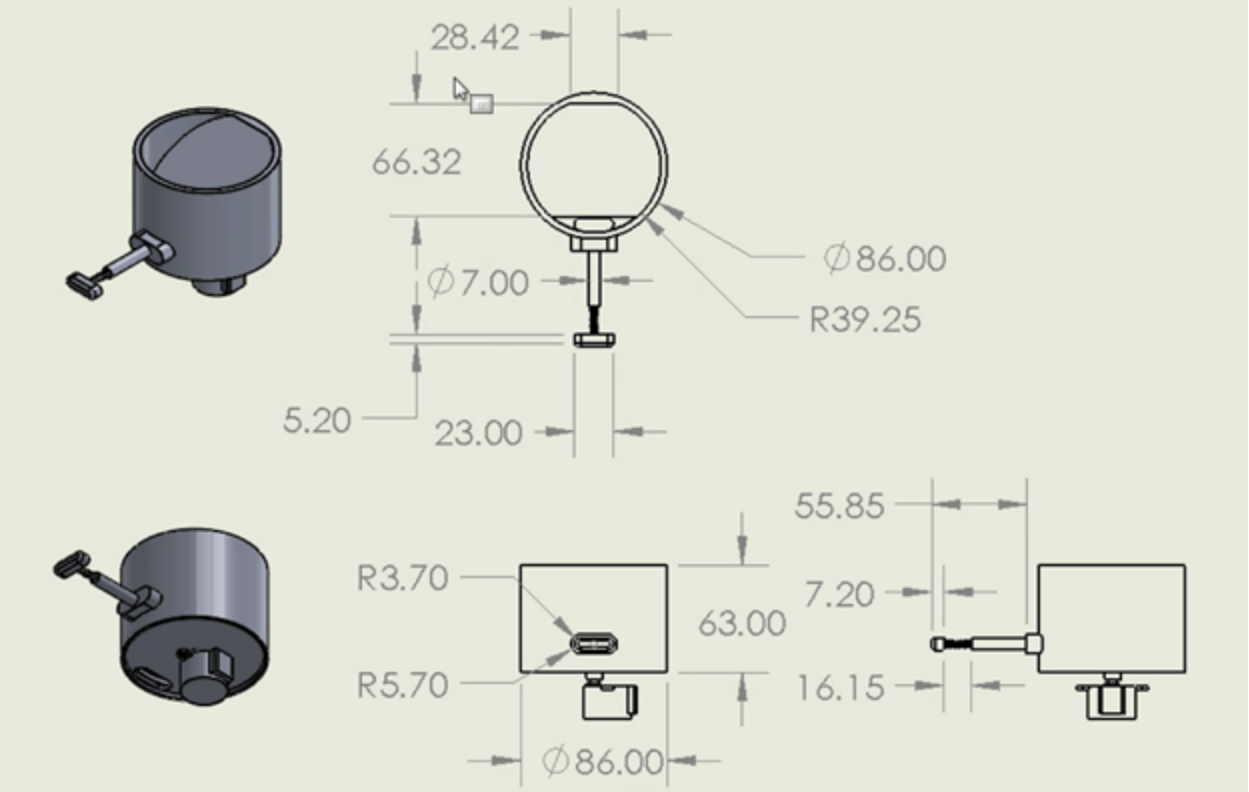

Figure 8: Anti-jammer and Hopper combined

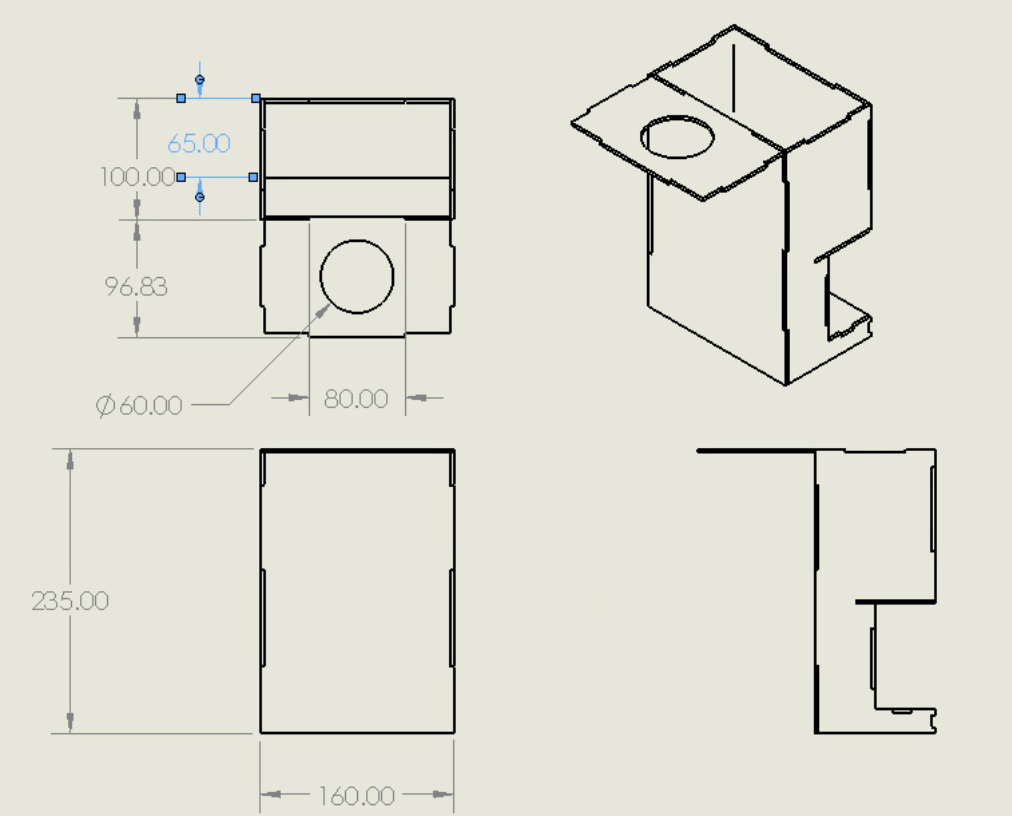

Figure 9: External Body

The external components of the pill dispenser were manufactured with the use of a laser cutter and ⅛” MDF board. The dimensions of the outer housing were created using the SolidWorks 3D modeling software which allowed overall dimensions to be changed relatively easily. The components were connected together by applying hot glue along the internal seams. In the future a better option may be using a material such as a plastic so that cleaning and maintenance is easier. Originally there was a design created using PLA filament and the 3D printer however the time needed to print the exterior in that way would have taken to much time.

6.1.1 BOM (Bill of Materials)

Item Number	Part Name	Description	Quantity	Unit Cost	Extended Cost
1	Battery	AAA	6	$ 0.99	$ 5.94
2	Microcontroller	A-star 328 pb micro	1	$ 6.35	$ 6.35
3	Stepper Motor	28BYJ-48	1	$ 3.65	$ 3.65
4	PLA filament	1.75mm, precision +-0.05mm	100 g	$0.02/gram	$ 2.00
5	Wire	Jumper wire	3 m	$ 3.83	$ 3.83
6	IR LED and receiver	Used as motion Sensor	1	$ 2.79	$ 2.79
7	Led light	1.8-2.0V	2	$ 0.07	$ 0.14
8	MDF	Laser cutting material	1 panel (216 in^2)	$ 9.88	$ 9.88
9	Miscellaneous components	-	-	$ 5	$ 5
Total					**$ 46.57**

Table 3: Bill of Materials

6.1.2 Equipment list

- 6X AAA batteries and a holder for the batteries
- 28BYJ-48 stepper motor
- IR LED and Receiver
- 2X LED lights (yellow and red)
- Pololu A-star 328 pb
- Laser cutter (+ cutting materials)
- 3D printer (+ Filament)
- A button
- 2X 100 Ohm resistor
- 180 Ohm resistor

- ⅛” MDF

6.1.3 Instructions

- Step 1: Download the following files from the maker repo : A,B,C
- Step 2: Laser cut the A file, and 3D print the B file
- Step 3: Set up the circuit
- Step 4: Copy the code from the note document of file C
- Step 5: Upload the code to the microcontroller
- Step 6: Put the components in the housing

6.2 Testing & Validation

Our product had 3 main concerns that needed to be tested throughout our prototypes. The first concern being the anti jamming mechanism, followed by the pill collection method, and finally the power budget.

Mechanically, tests were done on the sorting and anti-jamming mechanism to determine how often the pills jammed in the sorting mechanism, as well as if the anti-jammer was able to clear the obstruction. Tests were also done to verify hopper size, that the disk spun freely, and that it could be dropped from a height of 60 cm. The following table indicates the mechanical tests completed, the results, and actions we took to ensure the dispenser met all of the required metrics.

Metric #	Results	Action Required
1	Approximate volume available= $(\pi * r^2 * h) / 2$ $= (\pi * 4^2 * 6) / 2$ $= 150.8\ cm^3 > 47\ cm^3$	No action required
2	1st attempt with 5 pills: no error 2nd attempt with 5 pills: last 2 pills jammed	Reoriented divider so that slope was reduced.

	1st attempt with 10 pills: 1 jam 2nd attempt with 10 pills: 2 jams 1st attempt with 15 pills:1 jam 2nd attempt with 15 pills:1 jam	Adjusted pill port size.
3	Pills separated as required	No action required
4	Pills directed as required.	Direction good but the divider was reoriented to help with jamming.
5	Disk spins as required	No action required
6	All three components withstood a drop of 60 cm. Bottom plate disconnected at drop of 60 cm when components were connected	Structurally sound with use of hot glue and super glue.

Table 4: Mechanical tests and results

Metric #1 was tested by measuring the internal dimensions of the hopper. Only one set of measurements, followed by a second set for verification was needed to prove acceptable volume. For metric #2 varying amounts of pills were placed in the hopper and dispensing was done to see how many, if any, pills became jammed while in operation. The results list how many jams occurred. The results of the anti-jam function were not recorded however when jams occurred they were able to be cleared. Metrics #3 and #4 were verified while performing the test for Metric #2. Metric #5 was confirmed one hopper was assembled and it was found to move freely. Metric #6 was not tested due to not wanting to break any components once it was assembled.

6.3 Subsystem 2 Electrical

The electrical components of the pill dispenser are the microcontroller, button, IR light/receiver, motor controller, battery, stepper motor, red LED, and a Yellow LED (BOM, sec 6.1.1).

6.3.1 Code Path Overview/Considerations

The diagram below outlines the detailed code path followed by the microcontroller and is organized via functions. The following subsections serve to give a detailed description of each function, as well as considerations made during prototyping.

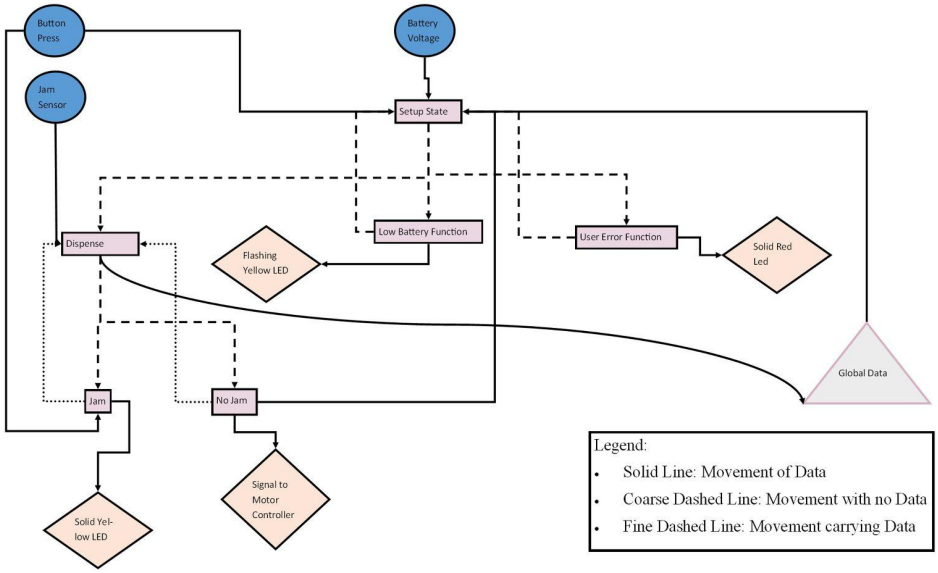

Figure 10: Code Path Overview

6.3.1.1 Setup State

This is the state in which the system will power on and thus initiates the start of the day cycle timer. The state evaluates the battery voltage and any button presses in order to direct the microcontroller to 1 of 3 functions. If the battery voltage is low this leads to the Low Battery Function, if the button has been pressed and the day cycle has already passed or the device is under first time setup it leads to the Dispense function, if the button has been pressed and the day cycle has not passed it leads to the User Error function.

Initially, when the code was in its infancy, all functions were part of the setup state, however, this proved to grow complicated as the complexity of each function increased, leading to the separation of functions.

6.3.1.1.1 Dispense Function

Serves to attempt to dispense pills while simultaneously checking for jams, if a jam has been sensed it will lead to the Jam function, otherwise it will lead to the No Jam function. The function also contains a counter for the number of pills dispensed and stores this data in Global Variables. Once pills have been dispensed this function returns to the Setup State.

When developing this function data was initially passed back via the return command, however this proved to be unnecessarily complicated, and was simplified at no expense to the performance by storage in global variables.

6.3.1.1.1.1 Jam Function

This function turns on the yellow LED until the user has pressed the dispense button for 3 seconds, and serves as a method to notify the user to press the anti jamming plunger. This function then returns to the Dispense function with the data that the anti jamming plunger has been depressed.

6.3.1.1.1.2 No Jam Function

Outputs a signal to the motor controller, which communicates with the motor and results in a pill being dispensed. The function then returns to the Dispense function.

6.3.1.1.2 Low Battery Function

This function flashes the yellow LED in the case of a low battery, this will continue until the battery has been replaced.

6.3.1.1.3 User Error Function

This function served to illuminate the red LED to notify the user of the user error described in 6.3.1.1

6.3.2 Power Analysis Overview, Calculations & considerations

To ensure the continuous operation of the pill dispenser under battery operation met our criteria, a power analysis was performed under normal use case assumptions and can be seen in the table below. Under the proposed battery the power analysis showed a total life of approximately 8 days.

Component	**Ton [Hours/ Day]**	**Voltage**	**Current**		**Watts*H ours/Day**		**NOTES**
Motor	3.47E-04	9.00E+00	2.50E-01		7.81E-04		Motor runs for 30 seconds per day
Battery level indicator	2.40E+01	9.00E+00	4.10E-06		8.86E-04		Always on measuring battery level
LED 1 (Low battery/jam)	0.00E+00	5.00E+00	2.00E-02		0.00E+00		Flashes when battery low, on solid when jammed
LED 2 (Pill already taken)	3.47E-04	5.00E+00	2.00E-02		3.47E-05		
LED 3	0.00E+00	5.00E+00	2.00E-02		0.00E+00		Not used
Sensor					0.00E+00		Header

IR LED	1.39E-03	1.20E+00	1.00E-01		1.67E-04		
IR Receiver	1.39E-03	5.50E+00	4.50E-04		3.44E-06		
µ-Controller	2.40E+01	5.00E+00	5.00E-03		6.00E-01		
				TOTAL	6.02E-01		

Table 5: Power Analysis

Due to underwhelming real world battery performance, an AC adapter was added for use as a secondary power source in order to give the user the opportunity to have an extended runtime.

7 Conclusions and Recommendations for Future Work

To conclude, through our client meetings and feedback, our team was able to design a medication dispensing device that eases the pill taking process, all while providing reminders and being economically advantageous. Our team was able to learn how to coordinate together as a team and communicate effectively, all while working in a remote environment during this pandemic. In our previous design deliverables, we updated our design based on the clients feedback, predicting the critical assumption of the design, prototyping to make the assumption a reality, and creating a bill of materials. For our final prototype, we were able to integrate our client feedback and learn how to incorporate new features that we had no prior experience with. For instance, arduino coding low battery functions, malfunction detection, and laser cutting. The most important lesson we learned was the importance of proper communication. Not only does effective communication help in solving problems that arise faster, but it also equally divides the workloads. Another drawback we had was spending lots of time perfecting the components (mechanical, electrical, code, etc) separately, but when it came time to incorporate the pieces together, issues would arise such as the battery not being powerful enough. This has taught us the importance of troubleshooting issues early, so that if a problem were to arise, we would have time to order a new piece of equipment, or figure out an alternative solution. If we had more time to work on this project, we would use a more efficient power supply, laser cut the external case in acrylic for a more aesthetically pleasing look, and perform more testing on the sensitivity of the malfunction or anti-jam detection. We also recommend users to practice their understanding of the Arduino software by reading sample codes available, and learning how to incorporate robotics and electronics.

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APPENDICES

9 APPENDIX I: Design Files

Table 3. Referenced Documents

Document Name	Document Location and/or URL	Issuance Date

10 APPENDIX II: Other Appendices