tw
Nov 01, 2015

Dr.Andrew Rawicz
School of Engineering Science
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Burnaby, British Columbia
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Re: ENSC 440 Design Specification for a Medicine Dispensing System

Dear Dr. Rawicz

The document attached *Design Specification for The PillMaster System* explicitly discusses the system design of our product. The goal of our company is to make the medication system in nursing homes more efficient with high reliability by tackling the errors at dispensing and administration stages. We are designing a medicine dispenser that will allow users to take the pill on time and split the pill as needed for elderly.

This document outlines the design specifications that will meet the functional specifications of The *PillMaster*. Also, it includes test plans for each unit to verify and evaluate the design against the desired criteria for our product.

Our company, DGMasters Inc., is composed of six engineers: Jasmine Liu, Tony Lu, Chris Xiao, Daniel Lan, Ritchie Kieu and Jose Mendoza. This is an enthusiastic and diverse team with background in several fields of engineering including electronics, computer, systems and biomedical engineering. If you have any question or concern about this document, please feel free to contact me by email at zyl2@sfu.ca.

Sincerely,

Jasmine Liu
CEO
DGmasters

Enclosure: *DesignSpecifications for a Medicine Dispensing System*

Design Specification

The *PillMaster*

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Executive Summary

The probability of an elderly person to die due to being exposed to an error of the medication system is up to 80% [1]. These errors occur in all of the 4 stages of the system [2]. DGMasters Incorporated is targeting to correct errors in dispensing and administering stages [2]. With our product the *PillMaster*, errors such as wrong time of dispensing and wrong dosage of dispensing will be corrected. In addition, our product will provide a cut functionality that will allow the user to control the dosage further. This document will discuss the design specifications and plans of the *PillMaster* automated dispenser, which includes specifications for the software, mechanical and electrical systems. The purpose of this document is to explain, in detail, DGMasters Inc.'s approach in designing these systems for the final prototype.

The software system will consist of:

- The clock timer - which is responsible for timekeeping.
- The microcontroller- which is responsible for timing when to activate the motors involved in pill dispensing and cutting. In addition, it will interpret the data input by the user and the data from the pressure sensors.
- The LCD and the Keypad- which are responsible for user input and information display

The mechanical system will consist of motors, sensors, rotating shafts, and their structural frames. These components will be the building blocks for the following mechanical stages:

- The dispensing mechanism - which is responsible for automated the pill dispensing of several sizes
- The pill splitting mechanism - which is responsible for automating pill cutting of several sizes
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The electrical system consists of an AC to DC power converter used to power the microcontroller and one motor in the system. This document will discuss, in more detail, these systems in their own respective sections, outlining their specific design, function, and implementation. Here, we will show that the functional requirements are met as mentioned in the functional specifications, while noting that some functions are mainly proof of concept. These design specifications will also discuss the test plans for the software and mechanical systems integration as well as the components of which these systems consist.

The test plan will consist of a series of tests that will verify certain subsystems separately. The descriptions for each test will include the test conditions and the expected results.

DGMasters Inc.

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Glossary

Just-In-Time Design Method: This method of designing requires to verify the conceptual functionalities of a feature via informal testing and prototyping. If the engineer is satisfied with the quality of the feature's performance, then the feature can be added to the design[4].

PWM: It stands for pulse width modulation. It is a type of signal used to make certain actuators perform work. The signal consists of a pulse with a certain width which is fed into the actuator at a certain frequency [5].

Servomotor: Is a type of actuator consisting of a DC motor and the circuitry used to encode its position. It moves using pwm signals [5].

Microcontroller: It is a CPU system on a chip. It is usually paired with a mechanical system to provide it with control signals [5].

RTC: Stands for Real Time Clock. It is a piece of hardware use to keep track of the calendar time [5].

1 Introduction

DGMaster's *PillMaster* medicine dispensing machine is a device that can help nurse, care giver, senior and guardian managing themselves or their patients' daily medicine schedule and dosage. With programmable schedule, categorized medicine containers and automatic dosage control users can enter their schedule and dosage to setup PillMaster. The device can cut a pill if user needs to take half dosage or have swallowing difficulty. *PillMaster's* target audience is not only patients, but also individual who want to take their medicine on time. DGMasters Incorporated use the just-in-time design principle. This concept will allow the team to do preliminary informal testing and prototyping before it is considered a final design. The specifications discussed in this documents are only the ones that have passed the preliminary testing and will be implemented in the final prototype.

This document describes details and technical specifications of the component and software in the device. Product requirements will describe what conditions will the components meet and unit test plan will specify how each component will be tested and the expected result.

1.1 Scope

This document will cover all the design specifications for The *PillMaster* system. Furthermore, this document describes how the design meets the system's functional requirements provided in The *PillMaster* function specs [3]. In terms of the product's development stage, only the design specifications pertaining to the prototype and proof of concept stages will be explicitly discussed. Refer to section 8 of the function specs document to have the list of the requirements that will are not targeted by the design. Flow charts and schematics will be used to aid in the description of the design.

1.2 Intended Audience

The content of this document is targeted towards the mechanical, electrical and software engineers who are part of the DGMasters Incorporated. Any company engineer who has access to this document has basic knowledge of just-in-time design cycles, servomotors, microcontroller programming, and circuitry design. In addition, the engineer has to understand the design evaluation through testing. Furthermore, the engineer has to be comfortable working with the metric system's unit conventions.

1.3 Classification

The design specifications of The *PillMaster* will be divided into the following sections: System design, mechanical design, and electrical design and software requirements. Similar to the function specs, document the design name or enumeration will follow format: **DX.#-%**.In this format "**D**" stands will design and will be a constant for all the design specification enumerated. "**X**" will have the following convention: "**M**" to denote the mechanical system, "**E**" to denote the electrical system, "**S** to denote the software system. "**#**" will denote the primary design number. The number will match the functional requirement the design specification is intended to meet. "**%**" will denote the secondary design number. It will be used to communicate if more than one specification is used to meet one functional requirement.

The test plan to evaluate and verify that the design meets its functional requirements will have the following enumeration format: **T.#**. "**T**" is a constant for all tests. "**#**" will denote the test number.

2 System Design

In essence, The *PillMaster* is a programmable and automatic pill dispenser. The elderly nurse staff user will be able to program at the time the pill will be dispensed, how many they want to be dispensed and if they want it to be cut. The system will be able to deliver the pill as specified by the user automatically. In order for these requirements to be always true, the design specifications in Table 1 will be implemented. The relationships between all those specifications can be seen in Figure 1.

Name	Design Specification	Justification
DU.1-1	The *PillMaster* will be driven by a computer program written in C language on an embedded Arduino microcontroller.	The software will be able to process the user's input and control the path of the pill in the system's main body. An embedded microcontroller is ideal because the software will manage a mechanical system. The code is written in C language

		because the microcontroller we chose is compatible with it by default [13]. This way the pill delivery will be automatic.
DU.2-1	The *PillMaster* will have a cylindrical shaft has a length of 10 cm and a radius of 5 cm.	The shaft will serve as a connection between the load containers and the rest of the pill path. Furthermore, it will serve as a stopper to the pill when the system is idle. Its dimensions were chosen to ensure quick modification in case the system fails certain tests.
DU.2-2	The shaft will contain a hole along its length. The radius of this circular hole will be 1.0 cm or 1.5 cm.	This specification serves as a means to prove that our design allows only one pill to be dropped at a time. The two sizes are to fit two different sizes of pills which will aid to get data on the effectiveness of our product with different pills.
DU.3-1	The *PillMaster* will be driven by an embedded Arduino microcontroller with a processing speed of 16MHz [5].	Having the software system performing 16000000 instructions per second will ensure that the system has less than a 2 minute delay of delivering the pill from the loading container to the patient.
DU.4-1	The *PillMaster* will have a metallic saw with a radius of 3 cm.	The saw has to be big enough to cut the biggest pill we will be using for the proof of concept. The biggest pill has a length of 1.5 cm.
DU.5-1	The *PillMaster* will have embedded memory of 256 kb [13].	This amount of memory will allow the system to save the input from the user. In addition, the system will read from this memory to manage the behavior of the pill path. This will allow the system to perform all the actions as specified by the user.

Table 3: The *PillMaster* System Design Specifications

Figure 1 shows the interaction between the most important components of the system. The thin arrows indicate the data path. The user sends data to the system about pill dispensing parameters which are the following: the time in which the pill will be dispensed, how many pills will be dispensed, and if the pill needs to be cut. All of these options will be displayed on the LCD display which will be sent from the microcontroller.

When the microcontroller decides to dispense the pill, it will send signals to move the motors one by one. In addition, pressure sensors will tell the microcontroller the position of the pill.

The thick arrow represent the pill path. It is loaded into the top of the mechanical system and the system itself delivers the pill to the patient. The mechanical system will follow the parameters entered by the user.

The solid arrow represents the power given from the power converter to the microcontroller.

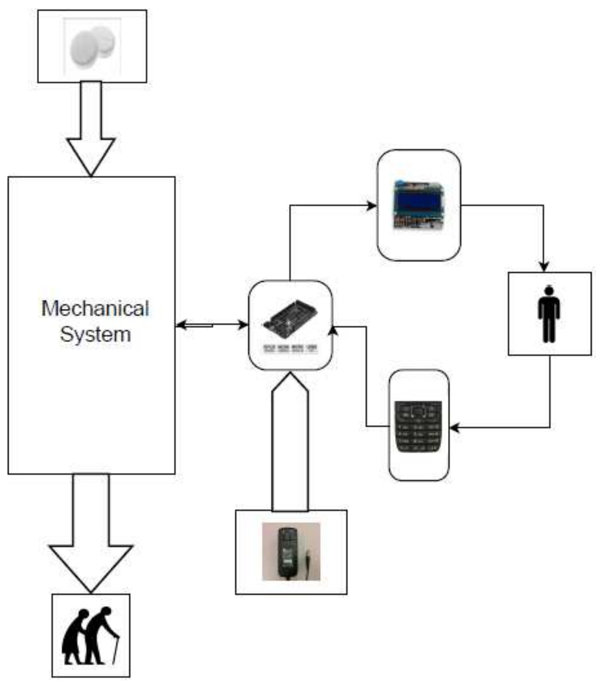

Figure 3: Block Diagram of The *PillMaster* System [6, 7, 8, 9, 10, 11]

3 Software System Design

Our software system includes a microcontroller, a timer, a LCD, and keypad. The software design specifications of the system are outlined in Table 2. The microcontroller that will be embedded is the OSEPP Mega 2560 R3 Plus. Our choice of LCD is the OSEPP 16x2 LCD with keypad shield. Finally, our timer choice is the Mini RLC DS3231.

Specification Number	Specification Description	Specification Justification
DS.1-1 DS.2-1	The microcontroller will have 256kb of memory [13].	This amount of memory will be necessary to store the instruction and data information.
DS.3-1 DS.4-1	The microcontroller will have 12 digital inputs and 12 digital outputs [13].	This specification will allow to the microcontroller to communicate with the LCD, Keypad and timer modules. These two components rely on digital communication.
DS.5-1 DS.6-1	The microcontroller will have 12 analogue inputs and 12 analogue outputs [13].	This specification will let the microcontroller to communicate with the servomotors and the pressure sensors.
DS.6-2	The analogue outputs will be used for pwm communication.	The servomotors that will be used rely on pwm communication in order to decide which position to rotate.
DS.7-1 DS.8-1	The microcontroller will have a 5V pin and a ground pin.	This specification will allow power to the servomotors and pressure sensors
DS.10-1 DS.11-1 DS.12-1	The keypad will have 10 digit buttons from 0 to 9.In addition, It will have 3 more non-digit functions [14].	This specification will allow the user to enter digits from 0 to 9 in order to specify time of pill dispensing. The 3 extra buttons are reserved to implement an “Accept”, “Cancel” and
DS.13-1	The LCD will display 32 characters on the screen at a time [15].	The guide questions that the system will ask the user will have 20 characters on average.
DS.16-1 DS.17-1 DS.18-1	The timer will be of the RTC kind. It will have a resolution in the order of seconds. Furthermore, it can monitor the time of the day and pass the information to the microcontroller digitally.	The timer was chosen with this specification to ensure that the system monitors the current time constantly. This way the *PillMaster* can deliver the pill at the appropriate time. Having hardware performing the time reporting allows the microcontroller to have a decrease work load.

DS.19-1 DS.20-1 DS.21-1 DS.22-1	The C code used to instruct the microcontroller will be able to transmit pre-written text to the LCD. The code will also be able to read the button inputs of the user.	This specification will allow the system to ask the user a series of pre-written questions. The answer to these questions will determine how the microcontroller will manage the system. The list of questions can be found in the function specs document [3].
DS.23-1 DS.24-1	The C code will allow the microcontroller to produce pwm analogue signals of multiple pulse lengths and convert voltage signals into pressure units.	A code like this will be able to communicate with the servomotors via pwm signals and read the pressure via the voltage conversion function.

Table 4: Software System Design Specifications

The code used to describe the microcontroller's behavior can be seen in Figure 2. The code will render the microcontroller in a normal state in which it will wait to dispense the pill and display the calendar time in the LCD. Once the user wants to start the programming, the code will detect the signal and go into the programming state. In this state, the program will ask the user questions about the pill delivery. It will store this information in the microcontroller's memory and use it to manipulate the pill path. The information input by the user will be stored until the user presses the reset button. The pill path manipulation state has not been designed because the mechanical design construction has not passed preliminary testing yet. These states also affect how the microcontroller interacts with the system.

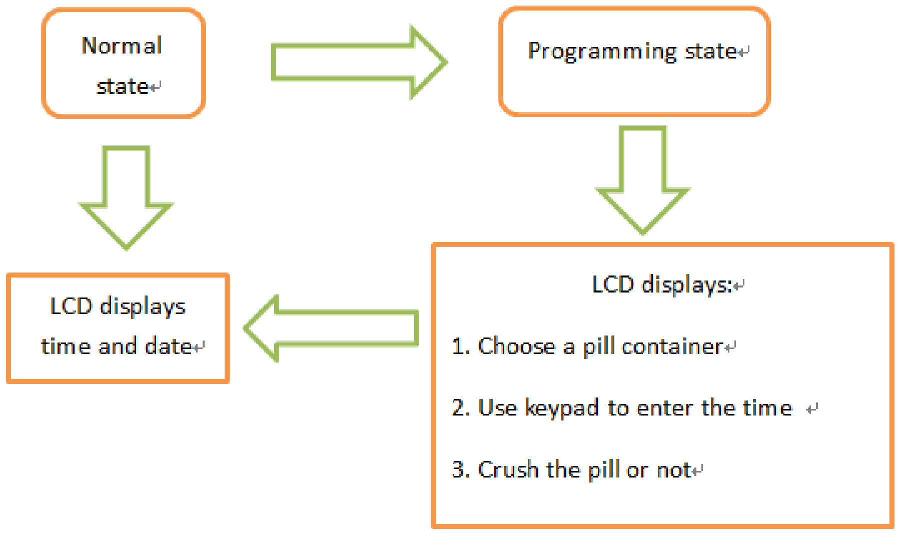

Figure 4: Diagram of the current C code version

Figure 3 shows the interaction diagram between components. The Mega 2560 will serve as the interpreter between the user and the mechanical system. It will relay information to the user via the LCD and will receive input to the user via the Nokia keypad. This will be done in the programming stage. During the normal state, the DS3231 will provide the microcontroller with information about the time. If the microcontroller detects that it is time to detect the pill, then it will coordinate and communicate with the mechanical system to deliver the pill as per the user's specifications.

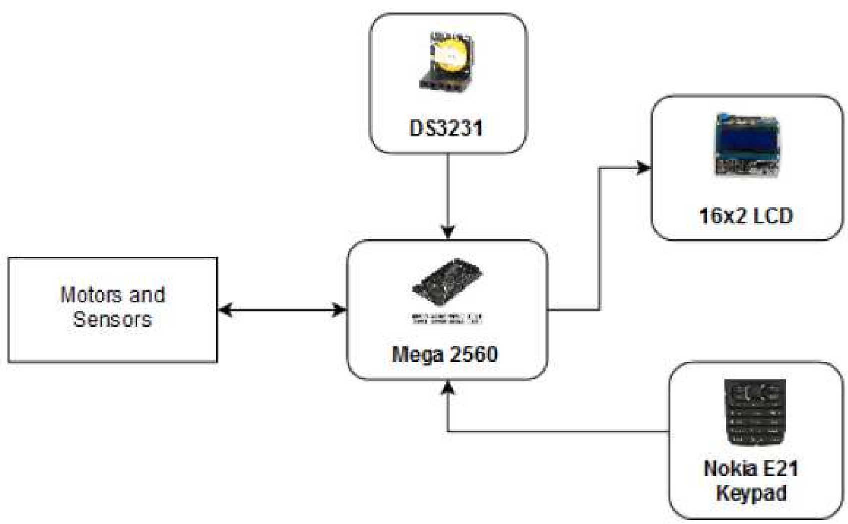

Figure 3: Diagram of the Software System's Data Distribution [9, 10, 11, 12]

4 Electrical System Design

The electrical system consists of an AC to DC Nokia cellphone converter. It will connect the power rails in the wall to the microcontroller only. The other components were purchased to be compatible with the power pins provided by the OSEPP Mega 2560 R3 Plus. The specifications of the power converter are listed in Table 3.

Figure 3 shows the power converter that will be used. It has a plug to connect to the wall power rails. At the end it has a coaxial connector to plug into the Mega 2560.

Specification Number	Specification Description	Justification
DE.1-1	Power from the wall will be converted to a 12 V DC to AC power converter. The converter is 1.80 m long and can provide up to 1.5A	A purchased power converter is the best way to ensure a safe converter. Furthermore, it already comes with circuitry that ensures power stability. 12V will be used to power the Mega 2560 microcontroller. Most of the current will be used in moving the motors which will take about 0.3 A. Having a maximum of 1.5 A is sufficient.
DE.2-1		
DE.3-1		
DE.4-1		

Table 3: Electrical Design Specifications

Figure 4: AC to DC Power Converter

5 Mechanical System Design

The mechanical system consists of motors, sensors, mechanical frame which guide the path of the pill. The specifications for the components are listed in Table 3. For the motors, we chose the SG90-Micro Servo Motors to rotate the shaft and the HD-1501MG Servo Motor plus a 6.3W DC Motor to cut the pill. For the sensors, we chose SF09376.The frame will be a structure made of FDA approved plastic and wood, as proof of concept. It is intended to contain the motor and sensors. The design of the frame has not been finalized yet.

Specification Number	Specification description	Specification Justification
DM.1-1	The mechanical system will have 3 cylindrical containers with a length of 20 cm and a radius of 10 cm.	The team compromised in the dimension because it will allow the user to load it with more than 10 pills.

DM.2-1	The mechanical system will have 3 cylindrical shaft has a length of 10 cm and a radius of 5 cm.	The shaft will serve as a connection between the load containers and the rest of the pill path. Furthermore, it will serve as a stopper to the pill when the system is idle. Its dimensions were chosen to ensure quick modification in case the system fails certain tests. 1 shaft per container
DM4-1		
DM.3-1	The servomotors rotating the shaft and the servomotor plus DC motor moving the saw will be able to operate with a voltage between 1 and 12V [16 17 18].	This specification allows the motors to be powered by the microcontroller's 5V pins. If that is insufficient, the power can be provided from the power converter.
DM.5-1	The pressure sensors in the containers, the platform of the cutting mechanism and in the outside tray will output an analog voltage signal [19].	The analog output will be ideal to communicate with the microcontroller quickly. Having a large impedance of 1 MΩ guarantees no damage due to current leakage.
DM.5-2	The sensor will have a maximum impedance of 1 MΩ when sensing no pressure [19].	
DM.6-1	The tubes in which the pills will travel will have a radius of 1.7 cm.	The maximum size of a pill is approximately 1.5 cm. a 1.7 cm tube will guarantee that the pill will not get stuck.
DM.7-1	The servomotors rotating the shafts will have the capacity to move a maximum load of 17.0 kgcm [16].	The servomotors will rotate a shaft that will have a load of 3.32 kgcm.
DM.8-1	The motors in charge of the pill cutting system will be able to rotate a load of maximum load of 6.25 gcm [17, 18].	The servomotors will rotate a saw that will have a load of 4.73 gcm.
DM.9-1	The saw in charge of cutting the pill in half will be made out of metal and have a radius of 3 cm.	The saw will cut the pill through the middle; therefore, it has to be larger than 1.5 cm.
DM.10-1	The frame will be made of wood bolted together with metallic nuts and nails.	Wood is easy to cut and shape. Metallic nails and bolts are easily available.
DM.11-1	The servomotors rotating the shaft will be held in 3 positions: 0 which will be the idle position, 90 which will be the picking position	This coding will allow the microcontroller to manage the position of the shaft

	and -90 which will be the dropping position.	using pwm signals.
DM.12-1	The motors in charge of the pill cutting will move continuously counter clockwise.	This type of motion will allow the microcontroller to predict the behavior of the cutting mechanism accurately.
DM.13-1	The cutting platform will have 2 usable holes. One with a radius of 1.0 cm and the other with a radius of 1.5 cm.	This specification will accommodate the size of the pills that can be picked up by the rotating shafts.

Table 4: Mechanical System Design Specifications

Figure 4 shows a conceptual division of the mechanical system. It indicates that the system can be divided in the dispensing portion and the cutting portion. The dispensing portion is the first contact that the pill has with the *PillMaster*. The user will load the pills into the container. The pills will be stopped by the shaft until the microcontroller sends the pwm signal to rotate the shaft into "picking" position and then to the dropping position. The pill will fall into the cutting portion which can be seen in Figure 6. It will fall into one of the usable slots (so far only the 1.0 cm and 1.5 cm holes will be used). If the user specified for the pill to be cut, then the motors will proceed to move the saw blade to cut the pill. There will also be a safety enclosure box that will surround the cutting mechanism, such that use of the saw blade is made as safe as possible.

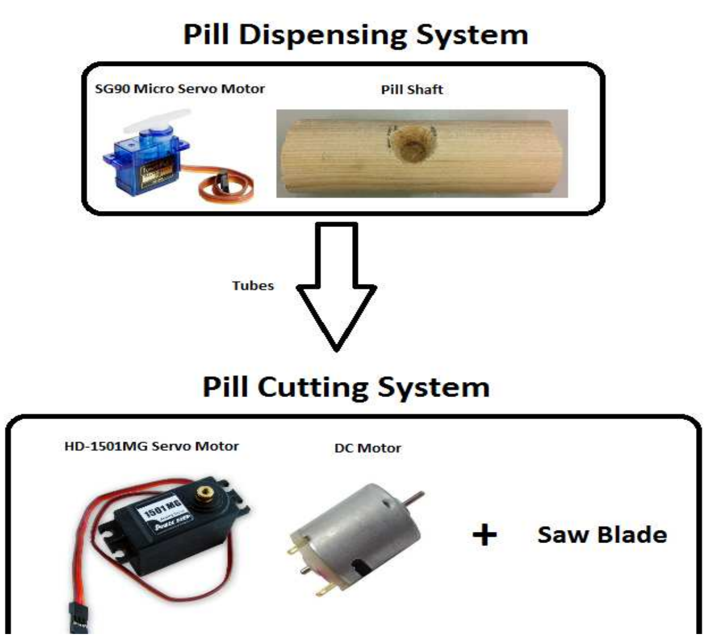

Figure 5: Pill Path Diagram [19, 20, 21]

Once the pill passes through the cutting mechanism it will be dispensed into a tray with a cup on it. The tray has yet to pass preliminary testing. Furthermore, the cutting mechanism will have a movable stopper module to hold the pill in place; however, it has yet to pass the preliminary testing. In the case of the sensors, how they will placed in their respective locations have yet to be decided. Nevertheless, it is a fact that these pressure sensors will be used to tell the microcontroller where the pill is in the mechanical system.

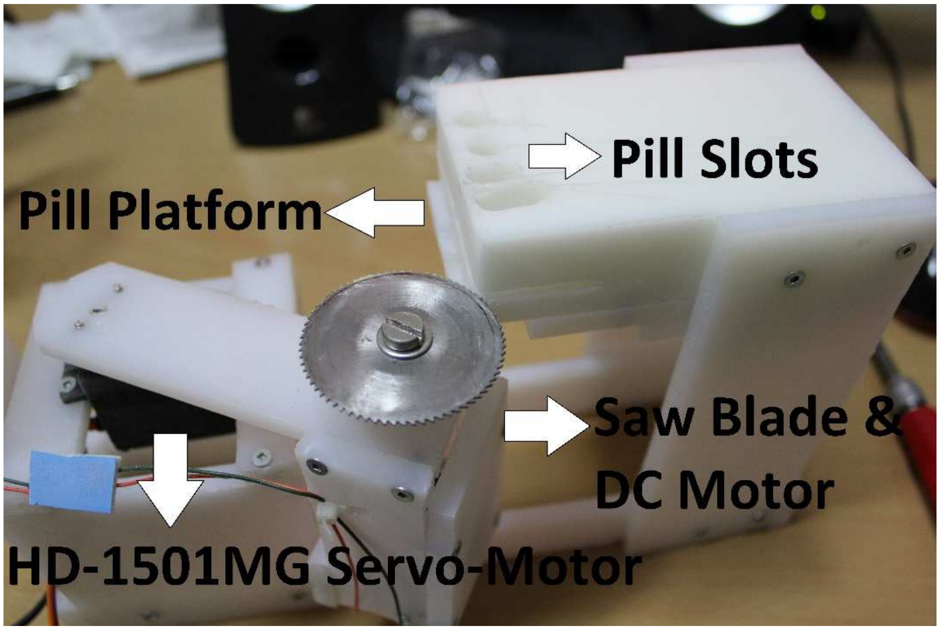

Figure 6: Mechanical System's Cutting Module

6 Test Plan

The test plan is listed in Table 4. The plan intends to test the integration of each component. The team will focus on results that provide an insight on the integrations of the parts into the whole system. Furthermore, the tests express focus on repeated trials in order to provide some reliability from the components themselves. The number of trials were arbitrarily chosen.

Test Number	Test Description	Conditions	Expected Results
T.1	Plug the power converter into 5 different wall plugs. Measure its voltage for 30 seconds	The power converter must be not passing any current.	In every plug, the voltage measured has to be 12.0 V for the whole 30 seconds.
T.2	Display the time in the LCD from what is read in the timer. Check the time displayed after an hour. Do this test 5 times.	N/A. The test is to verify software.	The LCD has to display the correct time of Vancouver in the hh:mm:ss format. Furthermore, the time displayed should be synchronized after an hour
T.3	Take power away from the Timer. Wait for 5 minutes and turn it on again. Check the value displayed in the LCD. Do this test 5 times.	N/A. The test is to verify software.	The timer has to have measured the passing of the 5 minutes it was disconnected from the system. This result has to be true in every trial.
T.4	Use the keypad to write the number “1991”. Do this test 10 times.	The LCD must be connected to the microcontroller.	The LCD has to display the characters “1991” as they are being typed in every trial.
T.5	Make the wooden shaft drop 15 pills from the container.	The motor has to be connected to an external power supply.	The shaft has to drop the 15 pills without breaking or stalling. The movement has to smooth without any jerky movements throughout the whole test.
T.6	Program the microcontroller with a version of the *PillMaster* software that initializes with displaying the word “HELLO” on the LCD upon initialization. Turn off and on the system. Do this 5 times.	N/A. This test is to verify software.	For all the 5 times, the LCD has to display the word “HELLO” upon initialization.
T.7	Drop 15 pills into the cutter module’s slots.	N/A. Nothing will be powered.	For all the trials the pill has to fall with its longest side in the vertical direction with respect to the earth.

T.8	Make the cutting system split 10 pills in half.	The cutter needs to be powered by an external power supply.	All the pills have be cut in half. The pieces have to be completely separated.
T.9	Try to insert hands into the cutting mechanism safety enclosure.	The DC motor and saw blade are inactive.	Hands cannot be inserted into the safety enclosure without intentionally unscrewing the safety enclosure box.

Table 5: Electrical Systems Requirements List

7 Conclusion

The document clearly states the design specification of PillMaster. The functional specifications have served as a guideline for the design considerations. This document describes the process and purpose behind each decision for both hardware and software of the system. The PillMaster should have four main components: container, shaft, cutter and microcontroller. PillMaster allows users to request an order of specific dose of pills by using the keypad, then the system will dispense the required amount of pill automatically. The test plan will be followed to ensure all the functions of the system meets the original expectation outlined in the functional specification document. Further improvements and expansions of functionalities will be considered. In addition, the design is still incomplete and will be continued to be developed or changed. The expected completion date for our prototype is early December 10, 2015.

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