RERC: Accessible Pill Dispenser/Cutter

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Abstract

Currently, errors in medication administration and compliance are persistent problems in home medication. There are many medication organization systems on the market that aim to minimize errors; however, they often prove to be inadequate or expensive. Another concern is the rising cost of prescriptions. Pill cutting is becoming a more widely accepted as a method to decrease prescription costs; however, no medication organizer currently incorporates an automated cutting mechanism. The goal of our project was to create an accessible pill dispenser and cutter capable of administering set dosages of pills and half pills on a preprogrammed schedule. Over the course of a semester, we have designed and built one module of our pill dispenser. Much future work will need to be done to produce a final working prototype that is programmable, has a quality control mechanism, and can accommodate up to four different pill types.

I. Background Information

Motivation

Numerous people have a difficult time taking their set dosage of pills on time. Whether it's forgetfulness, other priorities, a decision to omit dosage, or a physical and or emotional handicap (1), people do not regularly adhere to their daily regimens of pill consumption. Adherence is described as the consistency in consumption of physician prescribed medicine at a specified time. In the United States, reported average adherence rates for patients receiving treatment for chronic conditions were between 43%-78% (2). In addition to patients who suffer from chronic illnesses, the elderly population has a difficult time with adherence. Estimates suggest that only 25%-60% of the elderly population has close to perfect adherence. One main reason there is such a low adherence rate is due to the amount of pills that are taken. One study suggests that 25% of the elderly population takes at least three pills a day, and in hospital settings, up to eight pills a day (3). Also, doctors often have a hard time monitoring the adherence of their patients. Methods such as monitoring blood levels for medicine, recording the number of refills, and patient self-reports are often expensive, time-consuming, and unreliable. A pill dispenser that can automatically distribute a dosage of pills at a set period in time could drastically raise the adherence level of patients who have difficulty maintaining a consistent dosage regimen. Furthermore, pill dispensers can be built with the capability to record dosages that were distributed, giving doctors a better estimate of adherence level of patients.

Physical and mental handicaps often prevent people from taking their medicine on time. It is therefore in the best interest of the patient to construct a pill dispenser that is as universal as possible. The goal of the pill dispenser design is to overcome limitations in strength, coordination, sight, and hearing apparent in many users. A pill dispenser that has the capability to cut a pill in half is necessary for patients who do not have the full use of their hands. Visible and audio alarms are necessary for people suffering from visual or audio impairment and a user-friendly interface complete with a large touch screen is imperative for personal use of all intellectual capacities. Here is a hypothetical client base that may benefit from a pill dispenser with these capabilities.

<u>John Smith</u>

Problem: John has recently been involved in a tragic car accident that left him with an amputated left arm. He also has very little use in his right hand due to severe trauma to his peripheral sensory neurons. John must take a variety of pain medications to combat the phantom pain caused by neuromas that formed from injured nerve endings at the stump site which continue to fire action potentials (4).

Solution: John can benefit from a pill dispenser that has the ability to dispense multiple medications for his pain. Also, John may be instructed to start at reduced level of medication so that his body becomes use to the dosage. If this is the case, John will not be able to cut his own pills. A pill dispenser that can automatically cut his pills may prove to be beneficial. Due to the emotional stress caused by the accident, John may take too many pain-killers at one time, leading to an increased risk of overdosing. A pill dispenser can help regulate the set amount of dosage administered to John at one time.

<u>Ann Johnson</u>

Problem: Ann suffers from a genetic disorder known as Huntington's Disease. Huntington's Disease results from genetically programmed degeneration of neurons in certain areas of the brain. This degeneration causes uncontrolled movements, loss of intellectual faculties, and emotional disturbance (5). Although her condition is mild, the illness occasionally disrupts her coordination and causes tremors (6). Ann must take medication to suppress the disease. Side effects of the medication include fatigue and restlessness.

Solution: Ann could benefit from a pill dispensing device with an interface that is physically easy to use with large buttons which require little coordination to use. Also, a simple interface that requires little input from the user may benefit Ann because of her increased restlessness and inability to concentrate for extend periods of time. Furthermore, a device with a loud alarm indicating scheduled dosage times could potentially help if Ann is feeling drowsy. An automated pill cutter may also assist Ann with obtaining half pill dosages.

Lu Yang

Problem: Lu suffers from Anterograde amnesia as a result of a motorcycle accident at age 25. Anterograde amnesia is a form of amnesia where new events are not transferred to the person's long-term memory. People who suffer from this illness remember memories of events before the accident but cannot form any new memories. Lu severely injured his hippocampus in the accident, the long-term memory center in the brain (7). As a result of the accident, Lu cannot remember to take his daily dosage of medication. Other than this condition, Lu is in fine health.

Solution: Lu could benefit from a pill dispenser that can be set on a monthly schedule to deliver his daily set dosage of pills. With visual and audio reminders, Lu will be informed every day that he does in fact take medication. Furthermore, a pill dispenser that has the ability to contact off-site caregivers once dosages are running out can help caregivers assist in refilling medications for Lu.

Gretchen Ramsel

Problem: Gretchen is a 74 year old grandmother that spends the majority of her time house-sitting for her widowed granddaughter's children. Gretchen is lively and in relatively good health. She does, however, take medication for her high blood pressure and limited arthritis in her fingers. She also takes a calcium tablet each day to strengthen her bones. Gretchen lives a hurried life-style which is centered around her grandchildren, and she often forgets to take her necessary medication. She also is farsighted which gives her trouble making out small print.

Solution: Gretchen could benefit from a pill dispenser with audible and visual alarms to remind her when to take her set dosage of pills each day. Moreover, Gretchen could benefit from an interface with large fonts and easy-to-press buttons so that she has no problem reading and programming the pill dispenser. With her arthritic fingers, cutting pills may prove to be a challenge. A pill dispenser capable of automatically cutting pills could save Gretchen a lot of pain, frustration, and time.

Pill Dispensers/Organizers

Individuals taking multiple medications require clear-cut organization of pills and strict adherence to an appropriate medication schedule. The most basic organization product on the market today is a weekly medication organizer. Weekly organizers are most commonly recognized in the form of *Figure 1* where one plastic container has seven separated compartments for pills (8). In addition to only holding a week's worth of medication, these organizers also require self-loading of pills by the patient and do not provide any alerts to remind users to take their medication. The simplicity of this product allows for a low market price ranging from $5 - $60 (8). Prices increase considerably for

Figure 1: Weekly pill organizer

Figure 2: Automatic pill dispenser/organizer

more complex pill organizers with added features such as automated pill dispersal and alert systems that monitor a patient's adherence to medication regimens. At the appropriate time, products such as those shown in *Figure 2*, will sound an alarm to alert a user that it is time to take their medication (8). Many of these products are fairly new to the market and despite being more effective than earlier organizers, they still require self-loading of medication and demand prices upwards of $1500.

Pill Cutting

Current pill organizers have not integrated the ability to split pills. Pill cutters make up an entirely separate market. There are multiple reasons why pill cutters are utilized. Some drugs are produced in doses that fail to meet patients' medication regimens; therefore, these drugs must be cut in half. Furthermore, increasing prices of medication prescriptions is an issue causing many patients to turn toward pill cutting. Often the same medication of two different sizes has the same co-pay. To avoid the extra cost of paying multiple co-pays for low dose prescriptions, people often opt to cut pills. Most pill cutters are handheld devices, small in size and operable by dexterous persons. *Figures 3 & 4* depict current pill cutters that share similar designs and are priced under $20 (8). Pill cutters generally consist of a holding area for one medication and an area in which the patient positions the pill under a cutting apparatus. The cutting area is usually a surface with a high coefficient of friction, such as rubber, to prevent the pill from slipping. Most cutting mechanisms use a thin razor blade and rely on the user's own strength to raise and lower the blade for cutting. A unique feature to be considered in possible designs is a tapered blade that applies varying pressure on the pill during cutting to alleviate stress concentrations and provide a cleaner cut.

Figures 3 & 4: Conventional pill cutters

Even and accurate cuts are essential requirements for pill splitting devices. Many pills are scored for cutting purposes with a depressed line across the middle. However, the material of pills does not always ensure the pill will separate into two equal halves. Some pills are not made to be cut at all, and therefore should not be subjected to a blade at any time. Another element of pill cutting to be considered is the residue left behind after a cut. If too much is lost to residue, the "halves" may not contain enough medication to be effective. Using a rotating blade, despite possibly making a cleaner cut, is not feasible. Mixing pill residues could also have harmful effects on patients, and separate blades in isolated cutting containers should be used to cut different medications. One blade could be used if a cleaning mechanism was integrated, but any such mechanism should completely remove all residues and not leave behind any trace of cleaning substances.

II. Design Considerations

Problem Statement

Medication administration regimens cause significant dispensing and adherence issues for many individuals, often compounded by the necessity of slicing pills in half. In order to improve the living conditions of those suffering from these ailments, we aim to build a pill cap that will dispense a set dosage of pills. Specifically, the cap should be able to dispense the same dosage of half, one, or two pills at appropriate time intervals, as specified by the pharmacist. Additionally, the device should automatically alert the client when to take a pill, and not release any pills except during the set dosing period.

Design Constraints

Based on the design problem outline by the RERC a list of Product Design Specification (PDS) was developed (*Appendix 1*). The PDS has served as a template for addressing the different functionalities that our device must incorporate.

First, our design must be able to organize multiple medications, thus separate compartments for storage of numerous medications should be included. These storage compartments should also preserve the integrity of the medication. Our device must also be able to accurately deliver a single pill of a specific medication. The ability to dispense a single pill should not be hindered by differences in pill sizes and shapes. The mechanism utilized to dispense pills should be gentle and non-damaging to the medication. Lastly, the device must include a mechanism that is capable of accurately splitting pills in half. Additional design considerations need to be set forth for the pill cutting portion of our device. First, our device must reliably split pills in half, as deviations may cause patients the have adverse reactions to the medication. Any debris that has been created while cutting must be removed from the system. This will ensure that the functionality of the moving components within the device are not hindered and cross contamination of medications does not occur. Pill halves should also not be wasted; thus a storage compartment for pill halves must also be included to house half pills, after they have been cut.

In addition to providing the basic functionalities of storage, cutting, and dispensing our device must be accessible to all individuals. The accessibility design constraints for our project can be found in the following section.

Accessibility

Accessibility is a key design constraint considered to ensure our device can reach a diverse population of medical patients, particularly older patients and users with disabilities or activity limitations. Regardless of the disability it is essential that all users are able to perceive the information presented by the product, successfully operate the device, understand the device and its outputs, and be able to navigate the product (4). Moreover to achieve accessibility, the design should strictly adhere to ADA specifications and follow these recommendations (9):

To accommodate users who may be blind or have visual impairments:

Recommendations

a. Sans Serif font should be used
b. Text should be larger and have broad lettering
c. Both upper and lower case lettering should be used

d. Sufficient spacing between letters, words, and lines of text should be provided
e. Screens should have high contrast and resolution
f. Supplementary auditory information should be provided
g. Glare on screen should be minimized
h. Tactile indicators should further aid those with visual impairments

Users may be blind or have uncorrectable limitations including loss of visual field or temporary visual impairments such as low lighting or an obstructed line of sight (10). Thus, optimizing the visual components of the device is essential for increasing clarity and visibility for those with visual impairments. It is also recommended that the device is not overly dependent on visual information. Instead, redundancies either auditory or tactile indicators should be incorporated to provide the user the same information as displayed in text.

To accommodate users who may be deaf or hard of hearing:

Recommendations

a. Audio outputs should be have incremental controls
b. Auditory default volume should be reasonably loud
c. Redundant visual and tactile information for auditory content should be provided

Users may be deaf or hard of hearing. The most common approach for addressing this issue is incorporating redundant visual and tactile information for audio content. Alarms for the device could provide an adjustable audible tone, a flashing visual display, and a vibrating mechanism to insure the user is successfully alerted (10).

To accommodate users who may have fine motor impairments, limited reach, strength, or control:

Recommendations

a. Device should be operable with one hand
b. Device should be operable with either right or left hand
c. Force required to activate controls should be minimized

d. Controls should require general motion, rather than precise motions
e. Users should not easily be able to accidentally activate functions

Users may have motor disabilities that can affect their interactions with a device. These disabilities could include decreased fine motor controls, decreased grip strength, inability to exert force, and inability to perform two-handed tasks (9). The design of the device should minimize the motor demands of the device and allow for alternative voice activated controls.

To accommodate users who may have cognitive or memory impairments:

Recommendations

a. Prompts should be provided for user
b. Language should be simple
c. Redundant labels should clearly communicate function
d. User should be able to recover from errors
e. User should be able to easily navigate the produce

Users may have cognitive or memory impairments; thus, alarms and alerts should be incorporated so that minimal memory is required.

Universal Design

Pills come in different shapes and sizes based on the kind of pill and set amount of dosage. When designing a pill dispenser, it is therefore necessary to build a device that is capable of selecting and cutting a variety of pill shapes and sizes. In an interview with Ken O'neill of the UW-Pharmacy department, several questions were asked about the relative size and frequency of pills that are commonly cut (11). The answers to the questions are provided below.

What is the most common smallest pill to cut?

The smallest pill to effectively cut would be either Atenolol 25mg or 25 mg hydrothroclorizide. The size of these pills is similar to over-the-counter Claritin

What is the largest pill that would typically be dispensed?

Potassium Chloride pill. Similar in size to Centrum.

What are your thoughts on the pill cutters that are currently used?

Currently, pill cutters often crush pills instead of splitting which is a limitation. However, using a guillotine approach, less product is lost because the blade does not saw through but merely splits pills into two halves.

How common is it for individuals to be prescribed a larger pill to cut instead of single smaller pills?

This can depend on the marketing of the pill, if an effective higher dose has been approved and the patient has run out, it may not be cost effective to produce a smaller pill. However a physician may wish to prescribe a lower dosage and thus the individual has no choice but to cut the pill. People who are more cost conscious also often split pills.

From the interview, a range of sizes of pills can be roughly estimated. Using these values loosely, we can design our pill cutter to effectively position and cut the necessary sizes of pills. It is still necessary, however, to consider all sizes of pills that customers may take in order to create a pill dispenser capable of selecting any size pill for delivery.

Ethics

The reliability of this device must be a major concern in the design project. If pills fail to dispense or are dispensed in incorrect dosages our device may inadvertently present harm to users. Failure to adhere to medication regimens set by medical professionals leads to 10% of hospital visits which result in nearly 125,000 deaths annually in the USA (8). In order to prevent non-adherence, safeguards must be incorporated into all aspects of the design including locks that prevent unauthorized access to pills and safety alerts that immediately inform medical personnel that dosages have been missed or errors have occurred in dispensing medication.

III. Alternative Designs

Manual Measuring Device

Overview

The manual measuring device (*Figure 5*) is set up to gauge the dimensions of each medication in order to generate a dispensing device that properly aligns pills for cutting and dispensing. Before loading the entire prescription into the pill holding funnel, the first pill is set onto the measuring platform. The platform mounting panels are then adjusted by the user to touch each edge of the pill. These mounting panels are mechanically linked to the dispensing tube which would adjust so that pills are only capable of falling in the desired vertical orientation. Additionally, the height of each pill is known from loading on the measuring platform which adjusts the height of the cutting blade to half of the total pill height.

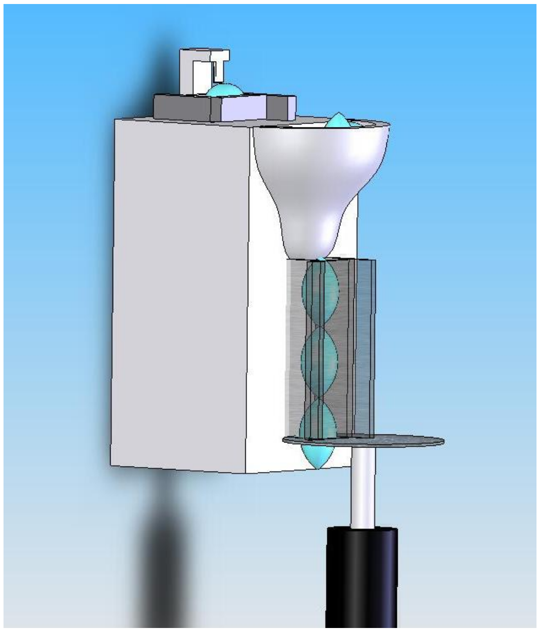

Figure 5: Manual measurement design

Pros

Manual measurement allows for precise cutting of a large variety of pills due to the initial pill height measurement. Additionally, this device would not require a large amount of counter space in home usage due to the vertical orientation of each unit.

Cons

Although the device can be adjusted to multiple pill shapes and sizes it is labor intensive for users and requires understanding of how the measuring platform is used which is not completely intuitive. Furthermore, it would be difficult to prevent pills from jamming within the tight fitting dispensing tube which could prevent pills from be dispensed.

PEZ® Pill Dispenser Device

Overview

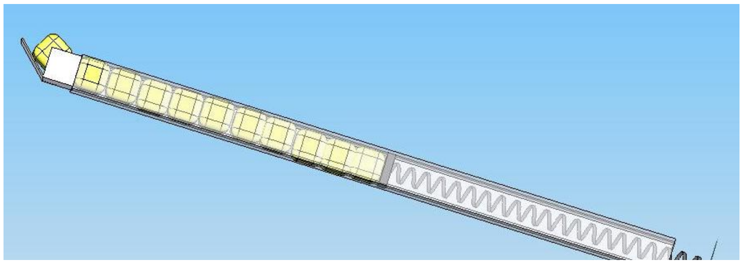

Figure 6: PEZ dispenser design

Pills of known size can be loaded and dispensed similar to the mechanism of a PEZ® dispenser (*Figure 6*). Instead of needing a variety of pill dispensing holders for the various sizes and shapes of pills, this universal holding mechanism was designed. *Figure 7* is a schematic of the pill holder looking longitudinally down the pill holding shaft. The pill **(1)** is first placed up against the back stop **(2)**. The blocking arms **(3)** extend the full length of holding shaft can and can be adjusted in the directions shown by the arrows. Once the pill is fitted, the arms then lock into place at their respective positions. Various sizes of pills can use the same holders instead of making separate holders for each different pill. Pills are packed into the holding shaft, which is then placed into one of four loading docks in the pill dispensing console. At the end of each loading dock a small spring that will be used to advance one pill at a time.

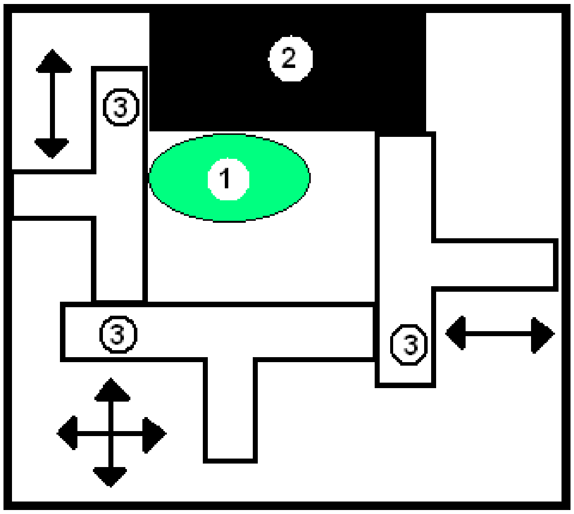

Figure 7: Longitudinal view of PEZ dispenser design

Pros

The PEZ® pill dispenser design could effectively distribute one pill at a time which is an important component of the overall design. This deign also makes it possible to add multiple PEZ® pill dispenser shafts for different kinds of pills. Each holder acts independently from the other holders, so the whole pill dispensing device can be set up for multiple PEZ® pill dispenser holding shafts. Also, with the use of arm blockers, the PEZ® pill dispenser is able to accommodate any size pill that needs to be dispensed. This is an important attribute to the overall design because it eliminates the need for custom-designed holders for each individual pill type.

Cons

One problem is the overall complexity of the design. The mechanical arm blockers will all need to be machined and then placed on tracks for movement. Furthermore, the pushing mechanism that advances the pill will some need to accommodate different pill sizes. A cutting mechanism is not incorporated into the PEZ® pill dispensing design at this time. Finally, this design involves extensive interaction between the care-giver and the device. Individually loading pills may take a considerable amount of time. If our device is to complicated, it may require extra training for the care-giver to use our design.

Previous BME 400 Dispensing Design

Overview

A previous BME 400 design team utilized a toothpick-type dispensing mechanism. This device uses a rotating pill drum that has been cut on one edge to the shape of the pill being dispensed. The pill drum is mounted to a stepper motor which is rotated below the outlet of a pill funneling component designed to position pills to drop into the pill drum as shown in *Figure 8*. Multiple interchangeable pill drums were created to facilitate the dispensing of a variety of pill shapes and sizes (15).

Figure 8: Previous BME 400 design

Pros

A clear advantage of a toothpick-mechanism is the testing performed by the previous group that demonstrated individual pills are regularly dispensed within three rotations of the pill drum. Additionally, the interchangeable pill drums increased the universality of the design to work with numerous types of medication. Finally, the computer code for rotating the drum can be easily written and executed using a BASIC STAMP 2 microcontroller.

Cons

While the previous design team's dispensing mechanism has been shown to adequately dispense pills, there is no component for pill cutting that is a major component of our design specifications. Additionally, use of interchangeable pill drums requires the user to remove and replace the drum onto the motor that may lead to problems with alignment. Since there is no consideration for pill cutting, the design lacks concern for pill residue after cutting and mechanisms for cleaning or replacing cutting blades to prevent contamination.

Evaluation

While each design has advantages and it is difficult to predict which would generate the best end prototype to meet our design criteria, our final design is the continuation with modification to the previous BME 400 project. Each device presented many mechanical challenges which must be overcome but the pill drum mechanism has been shown to successfully dispense individual pills (15). Interchangeable inserts for each pill size are more feasible and intuitive for inexperienced users to successfully load medication as opposed to measuring each medication and setting up each module for a different pill. With a proven mechanism to dispense individual pills, increased attention can be directed towards a mechanism for pill cutting which is an important component of the design criteria not addressed by the previous pill drum design.

IV. Final Design

Pill Drum & Inserts

The shape, weight, and size of different medications are not currently standardized. Creating a pill dispensing mechanism that can accommodate the variety of shapes and size of pills on the market is essential. Another major necessity for a pill dispensing mechanism is that it needs to accurately dispense one pill at a time. To address both of these concerns, we have developed a pill drum that has interchangeable inserts that can accommodate a variety of pills and can deliver one pill with each rotation.

The core pill drum (*Figure 9*) is constructed from an acrylic cylinder and has been machined to incorporate a 1x1.5x0.75 inch hole where interchangeable inserts will be placed. The inserts can be fastened to the pill drum via a friction clasp. Additionally, since pills will be cut while in a pill drum a fine cut exactly one inch down through the width of the pill drum was made so that the blade could easily pass through. A hole has been drilled and taped through the face of the cylinder so that the motor can be easily attached via the connector made from welding together a shaft collar and half inch bolt.

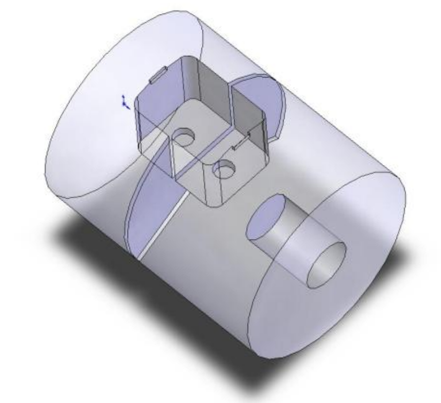

Figure 9: Pill drum

Acrylic inserts that are the same shape and size as the hole in the pill drum were also made (*Figure 10*). The bottom of the insert was milled so that the friction clips could be easily attached to the bottom of each insert. These friction clips were attached to the inserts so that the inserts can then be securely fastened to the pill drum for a temporary period of time. Each insert features a different pill cutout and was split down the middle so that the blade could easily pass through.

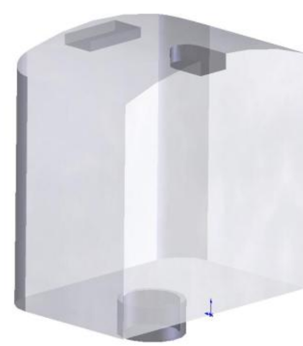

Figure 10: Pill drum insert

The ability to both cut and dispense pills is not addressed by other pill dispenser designs. To improve upon past designs, we have incorporated a cutting mechanism into our design. For pills to be accurately cut in half, it is important that the pill be held securely. Cutting the pill while it is in the drum appears to be the most practical option, because it is being held securely. In addition to adding the fine cut through the drum, it was necessary to account for all confounding effects of cutting the pill. The force exerted by the blade has the potential to dislodge for the pill halves from the pill drum. Thus we have designed a shield that surrounds the entire pill drum that will keep the halves contained in the drum.   The shield contains cuts outs that were made to insure all other functionalities of the drum were retained.

Motors

A stepper motor is being used to generate rotation of the pill drum. A permanent magnet, called a rotor, located at the center of the motor is rotated by a series of on and off inputs which excite stationary coils located around the circumference of the motor. Depending on the pattern and rate-of-change of those inputs, precise motion can be achieved (13). *Figure 11* shows a simplified schematic of a stepper motor as each coil (1-4) is excited.

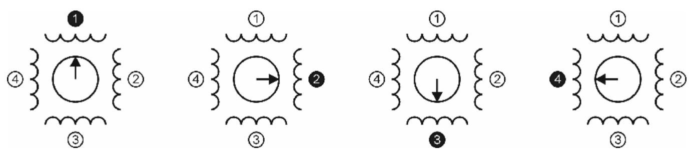

Figure 11: Stepper motor

In actuality, multiple series of these coils are arranged inside a single motor. Each phase (4-phase in this case) advances the rotor a single step. The stepper motor that is used in our prototype has a step of 7.5 degrees, or a total of 48 steps per revolution.

The selection of a stepper motor for our prototype was based on its intrinsic characteristics. Stepper motors can hold any defined position as well as rotate either forward or in reverse. Using Basic stamp 2 microcontroller, we were able to write a program that allowed the stepper motor to stop and position our pill drum at set points in the revolution.   Stepper motors are also very accurate. This characteristic ensures correct orientation for sensing as well as cutting of pills. Also, stepper motors draw less power from a microcontroller than a servo motor. Servo motors require constant input from a controller whether the motor is a stationary position or in motion. This draws a substantial amount of power away from the circuit. Stepper motors, however, only require input that is necessary to position the motor at a certain point; once positioned, the input ceases. At this point, only the coil that is holding the rotor in place is excited. This property allows us to use multiple stepper motors with the same Basic stamp 2 microcontroller (12).

Specifications of the Mitsumi® stepper motor used:

- Rated Voltage: 12 VDC
- Rated Current/Phase: 259 mA
- No. of Phase: 4
- DC Coil Resistance: 50 Ω/ phase ±7% (100 Ω / coil)
- Step Angle: 7.5° / phase
- Excitation Method: 2-2 phase (unipolar)

Figure 12 shows exact dimensions of the stepper motor:

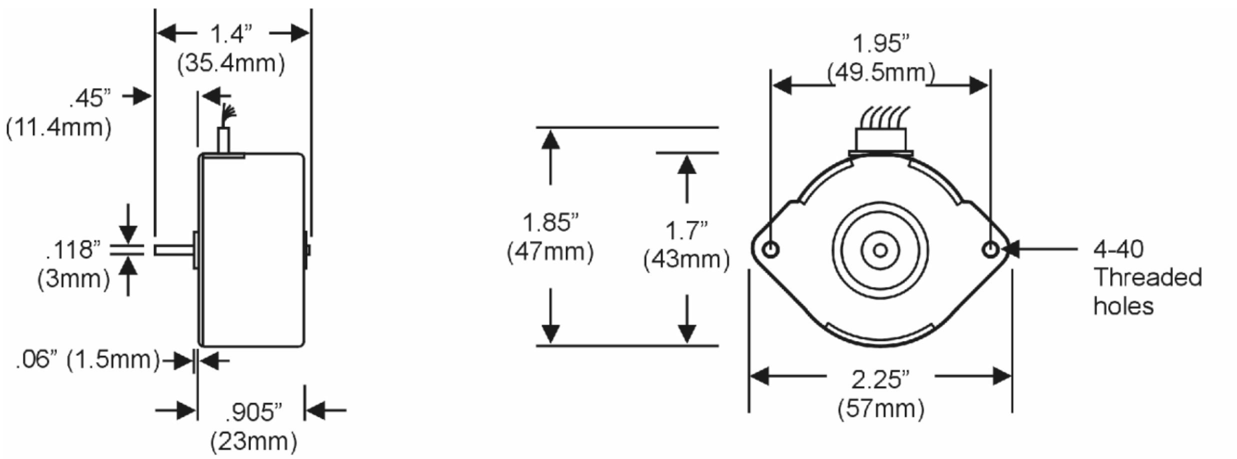

Figure 12: Dimensions of stepper motor

With the help of the Basic stamp 2 microcontroller, we were able to achieve full control of our stepper motor. The schematic of the circuit setup can be seen in *Figure 13* Pins 4-7 from the Basic stamp 2 microcontroller board are directly connected to a ULN2803A Darlington transistor switch. The function of the switch is to boosts the Stamp's current-switching capability (12). Then a wire for each phase of the stepper motor is connected to the transistor. We also need an external 12 volt source to run the motor.

Through the BASIC code, we set up the output pins 4-7 to correspond with the 4 phases of the stepper motor. By sequencing these 4 pins, and therefore phases, we were able to control the motor both in a forward and a reverse direction. The precise position of the motor is limited to the magnitude of the step. The step size of our motor is 7.5

degrees; this means that we were only able to position the motor at 7.5 degree increments. Also, we were able to hold a motor at a certain position for a known time by adding pauses into our code. This provided us a way to hold the stepper at a certain position for a known period of time while sensing and cutting pills. The complete code used for our design can be seen in *Appendix 2.*

Figure 13 shows a schematic of how the stepper motor is connected to the Basic Stamp 2.

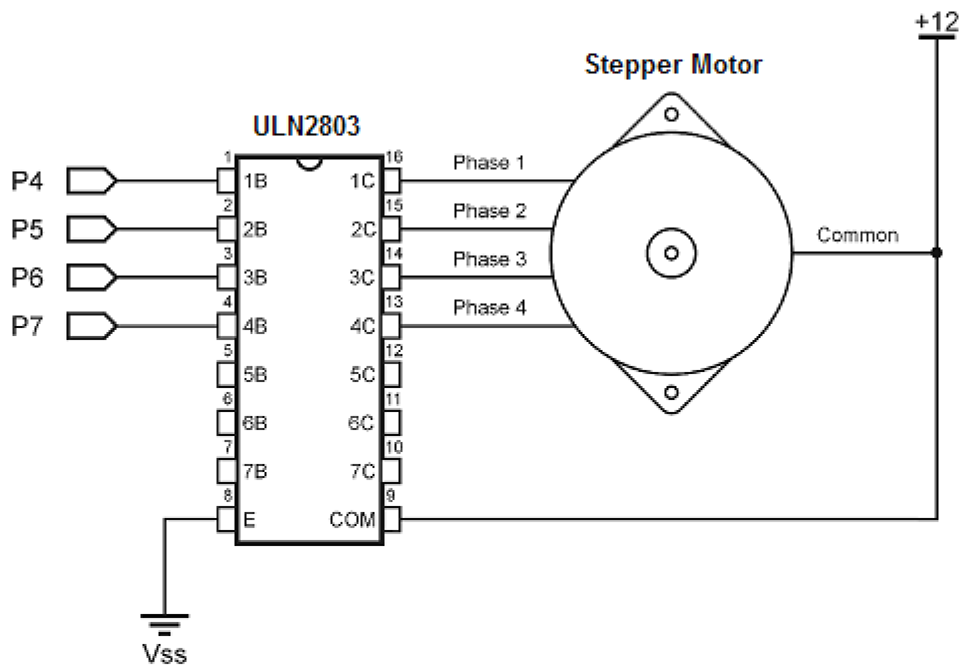

Figure 13: Circuit schematic of stepper motor connection

Testing

In order to get an idea of the strength of various types of pills on the market, a force test was conducted using a standard hand-held pill cutter (*Figure 14*). By applying increasing amount of weight to the end of the pill cutter, we were able to find the resultant cutting weight of each type of pill. Knowing the correct position of the pill relative the applied force, we were able to use similar triangle geometry to find the resultant force required to cut each pill. *Table 1* shows the results of the experiment.

Pill Type	**Shape**	**Pill Position**	**Applied Force (lbs.)**	**Resultant Force (lbs.)**

Calcium Antacid Tablet	Circular	2	2.5	4.64
Glucosamine Chondrotin	Elliptical	2	5	9.29
Naproxen Sodium	Circular	1	2.5	5.41
SunVite	Elliptical	2	5	9.29
Calcium 500 + D	Elliptical	3	2.5	4.06
Advil (glossy coating)	Circular	1	5	10.8
Walgreens Multivitamin	Circular	1	1.25	2.71
Target Acetaminophen	Elliptical	2	5	9.29
Tylenol (ES)	Circular	1	5	10.8

Table 1: Pill force tests

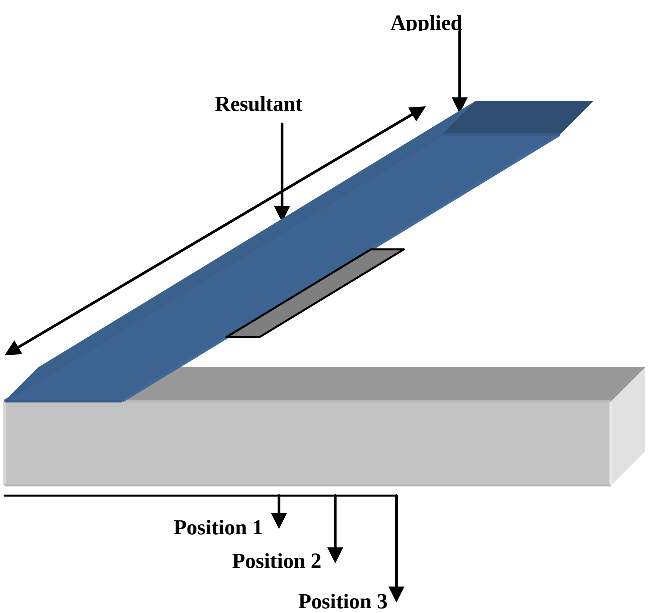

Figure 14: Pill force tests set-up

The resultant forces applied to the pill range from 2.71 lbs (Walgreens Multivitamin) of force to 10.8 lbs (Advil and Tylenol) of force. The average force was found to be 7.37 lbs. Using this information, we are able to set a rough upper limit on the amount of force we will need to generate from our pill cutter. However, this data is done under static loading and does not take into account the momentum generated by a moving blade so actual values of applied force will be less.

Pill Cutting

Solenoid

As previously explained, a non-rotating razor blade should be used for cutting pills in half. Lining up the blade with the center of pills is easiest when the motion of the blade stays in a constant linear plane. A linear push solenoid moves straight in one direction when excited by an electrical current. The solenoid (*Figure 15*) is a "modified electromagnet" that consists of two major parts, a central core or armature and a coil of wire that surrounds the armature (14). Sending current through the wire coil creates a magnetic field with strength directly related to the number of wire coils. More wire coils create a stronger magnetic field. The magnetic field generates force that pushes the central core up through the solenoid. The distance the armature travels is referred to as the solenoid's stroke and generally ranges from 0.5" to 1.5". Once the wire coil is excited by the current and the armature pushes forward in a linear motion, it will remain at its excited position until the current source is turned off. Switching off the current allows the solenoid's armature to fall back down to its original position which is normally regulated by a spring mechanism.

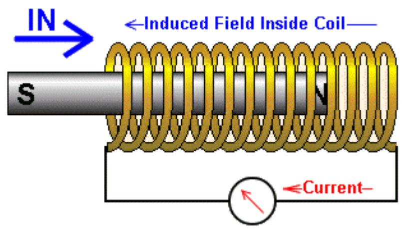

Figure 15: Solenoid

Sealed solenoids are enclosed in durable casing to protect the wire coils from the external environment which extends the life of the solenoid. With a 1" stroke the solenoid is able to generate 80 oz. or 5 pounds of force. Connecting a blade to the tip of the solenoid's armature behind this force should be sufficient to cut in half test pills for demonstration purposes. The specific solenoid uses a 12 volt DC source that can provide more than 1.2 Amps to excite the current of the wire coil and create a strong enough magnetic field to drive the armature. Parallax Basic Stamp 2 microcontrollers are unable to sources the1.2 Amps that is required for a solenoid so a relay switch must be used (12). Relays are switches that can handle large amounts of current running through an internal coil. The relay switch controls whether a circuit is complete or not and is activated or switched on by very low voltages. Since the microcontroller is only a 5 volt source, a 5 volt relay must be used. The current needed to excite the relay's internal coil, thus exciting the solenoid's coil, is 89 milliamps. One I/O pin on the microcontroller can source a maximum of 50 milliamps, so 2 pins must be used to provide sufficient current to the relay. Running the solenoid from the microcontroller allows for simple on/off control. Exciting the appropriate pins excites the relay creating a closed circuit and activating the solenoid's linear stroke. Conversely, turning the same pins off switches the relay again, making the solenoid circuit incomplete and allowing the armature to return to its resting position.

V. Future Work

Much needs to be done to successfully address all of the design constraints. First, improvements must be made to better integrate the pill drum components with the different motors. Moreover, we will need to look into the addition of sensors that can reliably determine whether or not a pill has been captured by the pill drum and has been successfully administered to the patient. Sensors and their corresponding program will serve as a quality control mechanism for our product. We will also need to create a more compact set up which contains at least four different pill dispenser modules. Once the four different modules are put together, we will need to create an accessible interface that can be programmed for different medication administration regimens. This interface will also incorporate the necessary alarms to alert the patient to take their medications or alerts that can inform off-site medical personal notifying that pills have not been taken at the appropriate time.

Once our final prototype is constructed testing must also be done to ensure our design is both reliable and effective for home use. Reliability of our design can be assessed by running tests on the different individual components of our design i.e. pill cutting, pill sensing, and pill dispensing. Tests should also be run when all of the components are together to make sure that their interactions do not hinder each other's ability to function properly.

Other tests that are focused on the user should be conducted to ensure that our device is accessible to a variety of individuals. To perform this type of assessment, an IRB would be required and enlisting a sample population that is representative of our projected user base would be necessary. To obtain an IRB we would need to create a protocol that informs our participants and maximizes their safety. Both quantitative data on the dispenser's performance and qualitative data focused on overall accessibility of the dispenser could provide insight into both the benefits and shortcomings of our design.

VI. References

(1) Osterberg, Lars, and Terrence Blaschke. "Adherence to Medication" *Drug Therapy* 353: 487-497.
(2) Smith, D., Compliance Packaging: A Patient Education Tool, American Pharmacy, Vol. NS29, No 2 February 1989.
(3) Salzman, C. "Medication Compliance in the Elderly." *J Clin Psychiatry* 56 (1995): 18-22.
(4) 4 Ramachandran, V. S. & Hirstein, William (2008), "The Perception of Phantom Limbs: The D. O. Hebb Lecture", *Brain* **121** (1): 1603-1630.
(5) http://www.ninds.nih.gov/disorders/huntington/huntington.html.
(6) http://www.mayoclinic.com/health/huntingtons-disease.
(7) http://neurology.health-cares.net/anterograde-amnesia.php.
(8) "E-pill Medication Reminders". <http://www.epill.com>. 2004.
(9) "Americans with Disabilities Act Homepage". <http://www.ada.gov/>. Oct 2, 2007.
(10) "Accessibility". <http://www.ahrq.gov/accessibility.htm>. Oct 4, 2007.
(11) Personal Interview with Ken Oneill (UW-Pharmacy) October 25, 2007.
(12)http://www.parallax.com/Portals/0/Downloads/docs/cols/nv/vol1/col/nv6.pdfColumn #6: Silicon Steroids for the Stamp Help Your Projects Heft Big Loads 1995

(13)http://www.parallax.com/Portals/0/Downloads/docs/prod/motors/Stepper_Motor_27964.pdf.

(14) http://mechanical-components.globalspec.com/.

(15)www.theamdd.com.

VII. APPENDIX

PDS

Dec 12, 2007

Product Design Specifications

Title: Accessible Pill Cap Dispensing/Cutting Device

Team:
Max Michalski- Team Leader
Ashley Huth- Communicator
Joseph Ferris- BSAC
Bryan Fondrie- BWIG

Function: Dispensing set doses of medication from half to double doses of pills based on the programmed schedule. In order to administer half doses, the pill cap design will be capable of cutting pills in half mechanically. Additionally, the dispenser will automatically alert patients when to take pills and inform personnel offsite if doses have been missed.

Client requirements: The automated pill cap device should be easy to use by clients with diverse capabilities and safely assist with dispensing a single dosage during the prescribed interval. The prototype should be able to dispense any of 1/2, 1 or 2 pills at a time and be able to cut pills in half if required for 1/2 pill dosage. It should remind users to take their medications, record what medications have already been dispensed, provide multi-modal indicators of current status, and only dispense the pills within the specified time windows each day. The device should alert someone offsite if a dose is missed. The prototype can be larger than a normal pill cap for demonstration purposes.

Design requirements:

1. **Physical and Operational Characteristics**

    a. *Performance requirements*
    Pill cap must be capable of accurately dispensing set doses at designated time. The device will only dispense at given time intervals and inhibit patient access to medication at non-designated times. The design must incorporate a cutting device which halves a variety of pill shapes and sizes. The pill cap must also promptly inform medical personnel when doses have been missed by the patient.

    b. *Safety*

The mechanical pill slicer must accurately cut pills in half so as to administer correct doses of medication. Additionally, the cutting device must be contained within the pill cap.

c. *Accuracy and Reliability*
   The dispenser must administer the appropriate dosage of medication at the programmed time interval.

d. *Life in Service*
   Multiple years and the dispenser can be reprogrammable for a different medication regimen.

e. *Shelf Life*
   The mechanical pill slicer must safely contain pills for the duration of the prescription.

f. *Operating Environment*
   This device could be used in a variety of settings including, but not limited to, homes, hospitals, and nursing homes.

g. *Size*
   The device should be of minimal size; however the final prototype may be larger for demonstration purposes. Moreover, the device may be scaleable to handle both large and small medication regimens and pill bottle sizes.

h. *Material*
   Plastic materials which are easily sterilized to allow for repeated usage.

i. *Aesthetics, Appearance, and Finish*
   The device should be aesthetically pleasing.

2. Production Characteristics

a. *Quantity*
   One large-scale working prototype.

b. *Target Product Cost*
   The total cost of the project may be no more than $2000 but minimal cost is desired to allow access for patients of all economic classes.

3. Miscellaneous

a. *Standards and Specification*
   Must be FDA approved in order to put into service.

b. *Customer*

Individuals that have numerous medications, or individuals who have trouble complying with their recommended medication regimen.

c. *Patient-related concerns*
Dispensing the appropriate dosage of medication at the scheduled time and not allowing patient to access medication at non-scheduled times.

d. *Competition*
Other devices are on the market that addresses medication regimen compliance by reminding the individual to take their pills.

Sample Code

```
' {$STAMP BS2}

' {$PBASIC 2.5}

' -----[ Variables ]-------------------------------------------------------

Phase          VAR     OUTB                   ' phase control outputs

idx            VAR     Byte                   ' loop counter

stpIdx         VAR     Nib                    ' step pointer

stpDelay       VAR     Byte                   ' delay for speed control

counter        VAR     Byte

' -----[ EEPROM Data ]-----------------------------------------------------

Steps          DATA    %0011, %0110, %1100, %100

' -----[ Initialization ]--------------------------------------------------

Setup:

  DIRB = %1111                                ' make P4..P7 outputs

  stpDelay = 30                               ' set step delay

' -----[ Program Code ]----------------------------------------------------

Main:

FOR counter = 1 TO 4                          ' runs loop 4 times

  FOR idx = 1 TO 12

    GOSUB Step_Fwd                            ' rotate clockwise 90 degrees

  NEXT

  PAUSE 2000

  FOR idx = 1 TO 7                            ' rotates clockwise 90 degress

    GOSUB Step_Fwd
```

```
  NEXT                                 ' pause 2 seconds
  PAUSE 2000                             ' deactivates solenoid
  FOR idx = 1 TO 29                        ' rotates clockwise 180 degrees
    GOSUB Step_Fwd
  NEXT
  PAUSE 2000                              ' pause 2 seconds
NEXT

FOR idx = 1 TO 12
GOSUB Step_Fwd
NEXT
PAUSE 1000
HIGH 14
HIGH 12
PAUSE 2000
LOW 14
LOW 12
PAUSE 1000
   FOR idx = 1 TO 7                        ' rotates clockwise 90 degress
    GOSUB Step_Fwd
  NEXT                                 ' pause 2 seconds
  PAUSE 2000                             ' deactivates solenoid
  FOR idx = 1 TO 29                        ' rotates clockwise 180 degrees
    GOSUB Step_Fwd
  NEXT
  PAUSE 2000

DEBUG "Enjoy your pills!"
END                                    'end program

' -----[ Subroutines ]-----------------------------------------------------
' Turn stepper clockwise
Step_Fwd:
  stpIdx = stpIdx + 3 // 4                  ' point to next step
  GOTO Do_Step

' Read new step data and output to pins


Do_Step:
```

```
READ (Steps + stpIdx), Phase          ' output new phase data
PAUSE stpDelay                        ' pause between steps
RETURN
```