ECE 445: Senior Design Laboratory
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Automatic Pill Dispenser

Design Document

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1. Introduction

1.1. Objective

Our product will help those who have medications and vitamins that they need to take on a daily basis. It can be quite difficult to remember what pills to take when and how much the correct dosage is. To overcome this difficulty, the pill sorter will be able to take in a full month's worth of several pills, sort them into the correct dosage, and dispense them at the correct interval. This takes the potential for error each day and moves it upstream to a single task: correctly inputting the prescription information into the pill sorter. Now instead of 30 or 31 opportunities for a mistake to be made, there is one. This method decreases the opportunity for error and makes it easier for the end user because all they have to do is open their hand and the correct medication will be dispensed.

This problem has been tackled in the past. However, the solution that others have come up with tends to resemble an alarmed box, still requiring manual sorting by the user, or a bulky countertop box without a direct user interface, requiring a somewhat high technical knowledge to operate. Our solution will overcome both of these common pitfalls with an intuitive user interface so even those with limited computer and technical knowledge can fully utilize the system and a simple design that avoids oversized motors, actuators, and containers. The end product will be a low-cost solution to an everyday problem [1].

1.2. Background

According to a study by NPR, 119 million Americans take prescription drugs. In addition to that group, our target population includes any person who takes over the counter allergy medication, pain relievers, and vitamins routinely. As figures 1 and 2 show below, there is a significant population between the ages of 0-18 and 65+ years old that take both prescription and over the counter medicines routinely. The Kaiser Family Foundation found that on average those who are 0-18 years old purchase medication 4.3 times each year and for those who are over 65 years old, that number jumps to 23.9 times per year in the United States. People between the ages of 19 and 64 purchase 12.7 medications annually. We are gearing towards helping those between 0 and 18 and over 65 because these are the age groups that typically require extra help whether it be from parents, guardians, or caretakers. Removing the task of counting out and alerting these groups to take their medication could preserve the autonomy of aging users and give children a sense of autonomy as they are able to take their medication without having a parent watching over them once the dispenser is programmed [2].

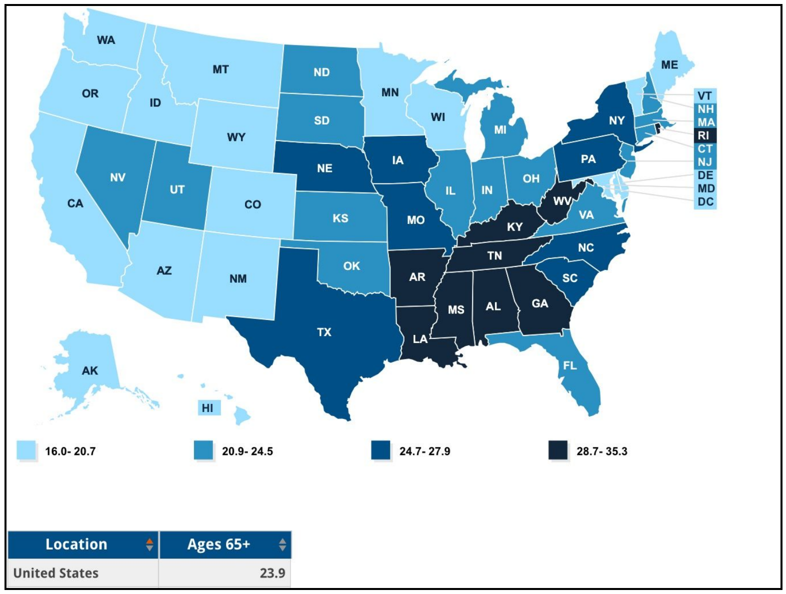

Figure 1: Retail Prescription Drugs Filled at Pharmacies (Annual per Capita Ages 65 and Up) [2]

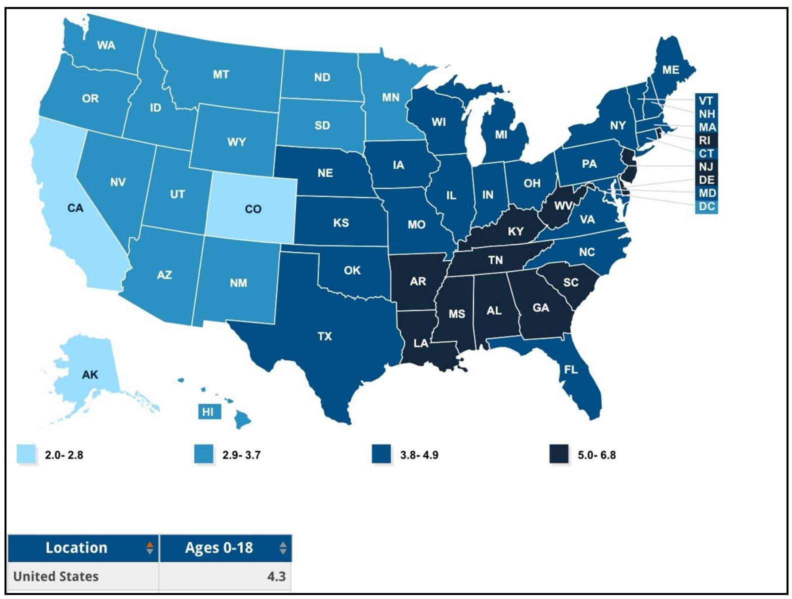

Figure 2: Retail Prescription Drugs Filled at Pharmacies (Annual per Capita ages 0-18) [2]

1.3. High-level Requirements

1. The machine will sort and properly dispense one pill at a time for any given pill.
2. The machine will be able to dispense medication at specified times.
3. The machine will audibly alert the user that it is time to take medication.

2. Design

2.1. Block Diagram

Our dispenser will require five separate sections: a power supply which will turn the 120 VAC 60 Hz to 5 VDC; a control unit featuring a microcontroller and sensors to properly alert and dispense medication; a user interface to program the proper dosage; three motors (one per type of medication) to dispense a single pill; and most importantly, a system of alerts so the user knows that it is time to take their medication. The block requirements are laid out below.

- Power Supply - convert an incoming 120 VAC signal into a 5 VDC supply.

- Sensing and Control - Detect when a single pill has been passed. Alert user if the wrong dosage has been passed. Turn motors on and off individually. Turn on LED and speaker when medication is dispensed. Turn off LED and speaker when medicine is removed from the machine. Pass the incoming 5 VDC supply to each component. Accept user input from the buttons and reprogram itself as commanded.

- User Interface - Allow the user to see what pill they are setting a dispensing schedule for. Allow the user to change days that the pill will be dispensed. Allow the user to change the time that the pill will be dispensed.

- Dispensing Motors - Turn on and off as commanded by the microcontroller.

- Alerting Components - Turn on and off as commanded by the microcontroller.

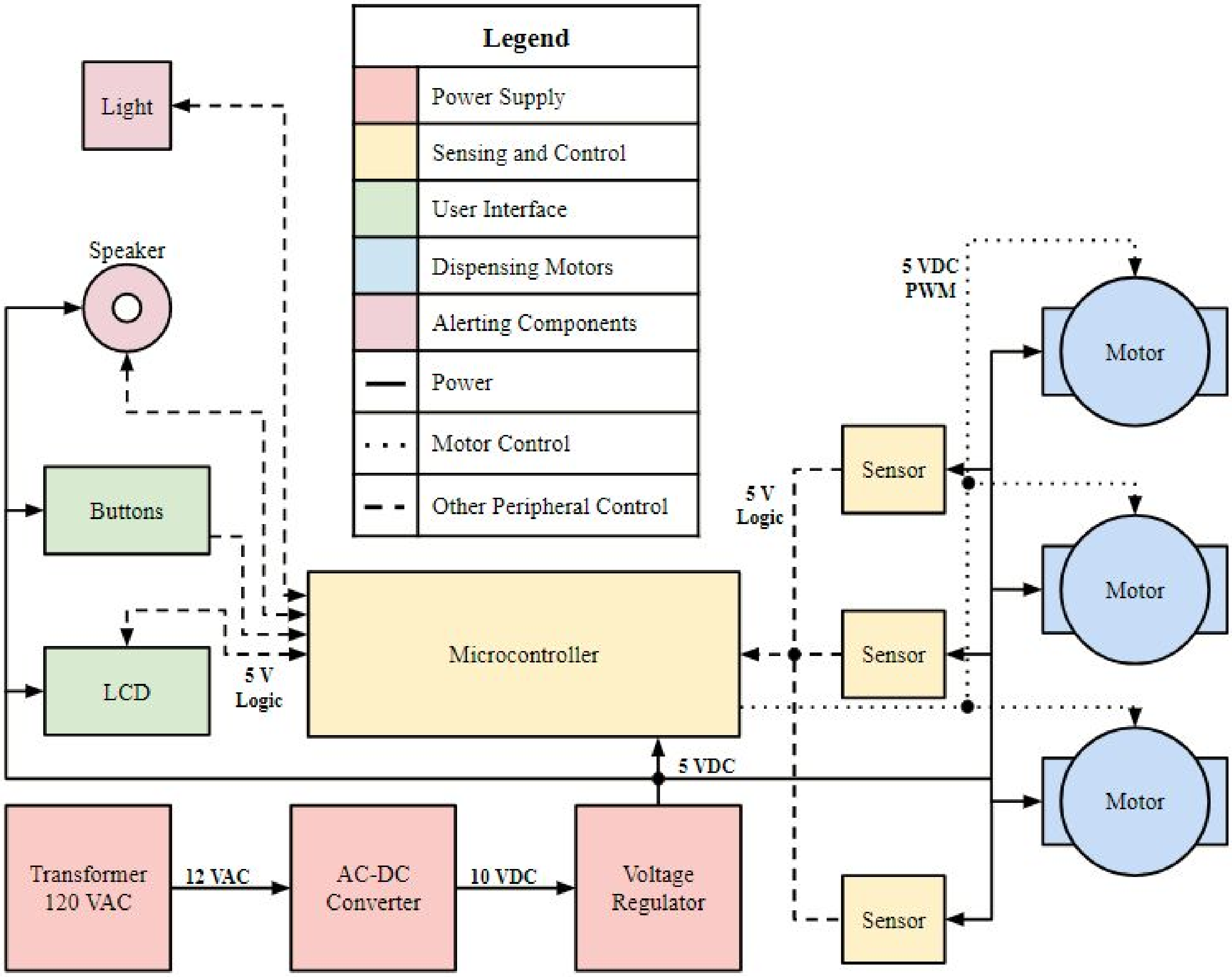

Figure 3: Block diagram

2.2. Functional Overview

The part numbers, vendors, part details, datasheet links, and purchasing links are all summarized in a separate document. A screen capture of the parts list document can be seen below in Figure 4.

2.2.1. Transformer

A transformer is the first of the three power supply components. Our board needs a reliable DC voltage supply to power the dispenser's circuit components, however, we desire this device to plug into the wall for accessibility. As a result, our circuit requires a transformer to step down the wall voltage of 120 VAC to 12 VAC.

Table 1: Transformer Requirements and Planned Verifications

Requirements	Verifications
1. Steps down 120 VAC to 12 VAC	1. Oscilloscope measurements taken to

2.2.2. AC-DC Converter

The second piece of the power supply is a bridge rectifier for full wave rectification of the incoming 12 VAC coming in from the transformer. This full-wave rectified signal will be smoothed out with a capacitor and then passed to two parallel voltage regulators.

Table 2: AC-DC Converter Requirements and Planned Verifications

Requirements	Verifications
1. Fully rectifies incoming 12 VAC 2. Capacitor effectively smooths AC signal so voltage stays within 1 V of 12 V	1. Oscilloscope measurements taken 2. Oscilloscope measurements taken

2.2.3. Voltage Regulator

The final part of the power supply is the voltage regulator. Our voltage regulator will buck the 12 VDC input to a steady 5 VDC input; this constant direct current is critical to supplying the digital components the power they need.

Table 3: Voltage Regulator Requirements and Planned Verifications

Requirements	Verifications
1. Voltage output stays within 4.5-5.5 V	1. Oscilloscope measurements taken

2.2.4. Microcontroller

A microcontroller (MCU) is necessary for our circuit to function, for we have multiple control input and output peripherals. This MCU will have to accept the user's designated medication time while properly keeping track of the current time. That way, the controller can then control the motors to dispense the pills while sensing whether one came out. We will be using the ATmega328P MCU to control our board. This microcontroller operates around the 5 V level and has a CPU which runs at 16 MHz.

Table 4: Microcontroller Requirements and Planned Verifications

Requirements	Verifications
Operating Voltage: 1.8 - 5.5V	1. Verifying Voltage Regulator should ensure incoming Microcontroller Voltage

2.2.5. Sensors

These sensors will work in tandem with the microcontroller to sense the proper dispensing of the pills; meaning, only the desired number of pills are administered. We will be using IR break-beam sensors. This will allow detection of whether or not a pill has passed through the sorting mechanism. The response time is less than 2 ms so these are able to take in data fast enough to be able to detect if more than one pill has been passed through with the intended dosage.

Table 5: Sensors Requirements and Planned Verifications

Requirements	Verifications
1. Sensors turn on between 4.5 V and 5.5 V 2. Sensors send signal out when beam is broken 3. Broken beam signals are distinguishable	1. Voltage applied to sensors measured with multimeter 2. Sensor output signal measured with multimeter 3. Successive output signals shown and measured with oscilloscope

2.2.6. LCD

The LCD chosen can display two 8-character lines. This was chosen so that the user can see which of the three tubes they are setting a time for on the top line with the second line showing the desired days to have the medicine dispensed. After the days are selected, the top line will remain the same while the second line will show the time for the medicine to be dispensed so that the user can set it.

Table 6: LCD Requirements and Planned Verifications

Requirements	Verifications
1. LCD turns on with voltage between 4.5 V and 5.5 V 2. LCD displays text input from microcontroller	1. Voltage applied to LCD measured with multimeter 2. Test text input is shown

2.2.7. Buttons

These buttons will allow the user to enter information. There will be four directional buttons and an enter button. Allowing the user to fully program the machine without any need for a computer.

Table 7: Button Requirements and Planned Verifications

Requirements	Verifications
1. Buttons are on with voltage between 4.5 V and 5.5 V 2. Buttons send signal out when pressed	1. Voltage applied to buttons measured with multimeter 2. Buttons output signal measured with multimeter

2.2.8. Dispensing Motors

We will be using compact stepper motors to precisely turn the pill dispensing tumbler. The motors must be finely controlled so that the correct dosage of medication is dispensed. The motors will be powered by their own voltage regulator out of the power supply and will accept incoming commands from the software through the microcontroller.

Table 8: Motor Requirements and Planned Verifications

Requirements	Verifications
1. Proper dosage dispensing	1. Multiple different sized pills placed into dispenser

2.2.9. Alerting Components (Audio/Visual)

An LED light and a small speaker will be used to alert the user when to take their medication. The light will flash and the speaker will emit a sound starting at the time the medication is dispensed and ending when the receptacle is removed from the enclosure. These will be powered through the microcontroller and will be turned on and off as told by the software through commands sent from the microcontroller.

Table 9: Alerting Component Requirements and Planned Verifications

Requirements	Verifications
1. LED turns on between 4.5 V and 5.5 V 2. Speaker turns on between 4.5 V and 5.5 V 3. Speaker emits sound when turned on	1. Voltage applied to LED measured with multimeter 2. Voltage applied to speaker measured with multimeter 3. Sound is audible to human ear

Table 10: Parts List and Cost

	Name	Details	Manufacturer/ Distributor	Part Number	Datasheet	Link		Market	Price Per Unit	Quantity	Total Price
1	Transformer	120/240/480 to 24 V transformer	Mars Motors and Armitures	50354 - 40Va	datasheet	purchase		Amazon	14.97	1.00	14.97
2	6800uF capacitor	16V 6800uF	NTE electronics	VHT6800M16	datasheet	purchase		Amazon	3.44	2.00	6.88
3	100nF capacitor	100V .1uF	NTE electronics	CML104M50	Datasheet	purchase		NTE parts diect	0.31	2.00	0.62
4	1uF capacitor	100V 1uF	NTE electronics	NPR1M100	datasheet	purchase		Newark	0.22	2.00	0.44
5	Voltage Regulator	5V Output	Bestsupplier	L7805	Datasheet			Amazon	0.30	2.00	0.60
6	Full wave bridge rectifier	200V and 50A max	NTE Electronics	NTE53016	datasheet	purchase		Amazon	5.35	1.00	5.35
7	Microcontroller	8-Bit with Flash Memory	Atmel	ATmega328-PU	datasheet			Amazon	4.83	1.00	4.83
8	IR Break Beam Sensor	3mm LEDS	Adafruit	2167	Datasheet			Amazon	3.99	3.00	11.97
9	Ocsillator	16 MHz	Uxcell	HC-49S	datasheet			Amazon	0.50	1.00	0.50
10	22 pF Cap	50 V, 22 pF	Uxcell					Amazon	0.11	2.00	0.22
11	LCD	20x4	RioRand		Datasheet			Amazon	7.99	1.00	7.99
12	Buttons	Tactile Push Button	Uctronics	B3F-4055	datasheet			Amazon	0.17	5.00	0.85
13	Stepper Motor	DC 5 V	Uxcell	28BYJ-48	datasheet			Amazon	3.31	3.00	9.93
14	Motor Drive Board	Inverter driver	Uxcell	ULN2003	datasheet			Amazon	3.31	3.00	9.93
15	Buzzer	12 mm, 5 V	Uxcell	ux	none	purchase		Sparkfun	1.95	1.00	1.95
16	Transistor	200mA 40V	Digikey	2N3904	Datasheet	purchase		Digikey	0.40	1.00	0.40
17	Resistor	500 ohm			datasheet	purchase		Digikey	0.88	1.00	0.88
18	LED	3-6V Red LED			none	purchase		Amazon	1.00	7.09	7.09
									Project Total Price		85.40

2.3. Physical Design

Our device will use precisely controlled motors to spin a hopper. When desired, the pills will trickle down into a common tube and out to the medication cup. Figures 5 and 6 show a digital rendering of our projected final design. The three orange cylinders on top are where the user will pour their pill bottles into. The power supply, sorting mechanisms, microcontroller, break beam sensors, and motors will all be hidden from the user's line of sight within the enclosure. The LCD screen and buttons will be on the front left of the enclosure. The purple box is what the pills will be dropped into after they are sorted and dispensed.

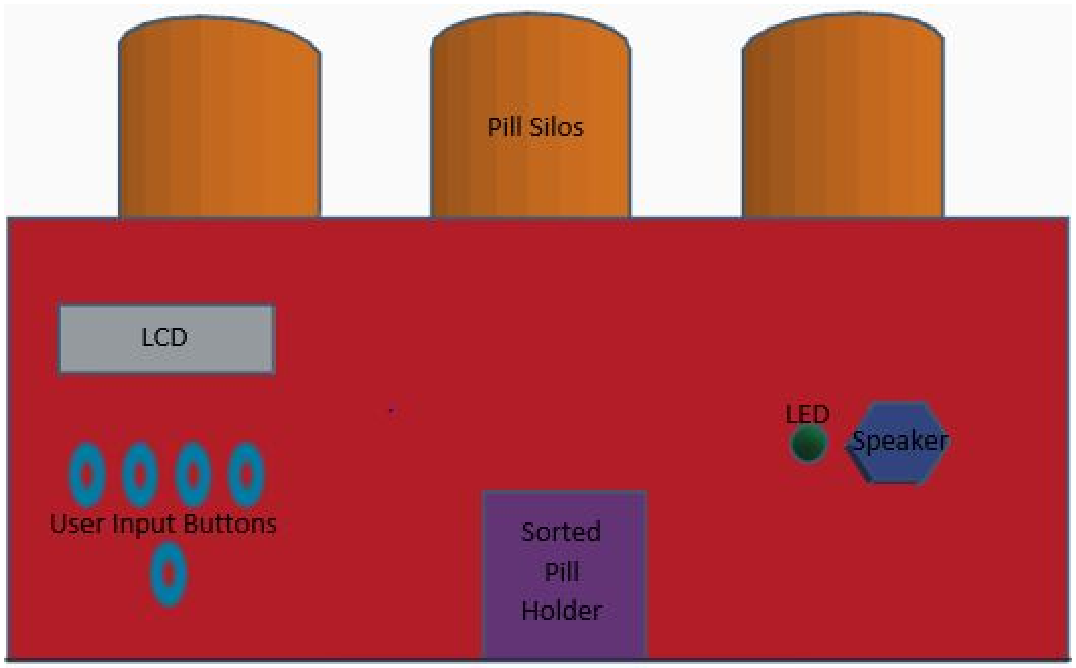

Figure 4: Front View of Physical Design

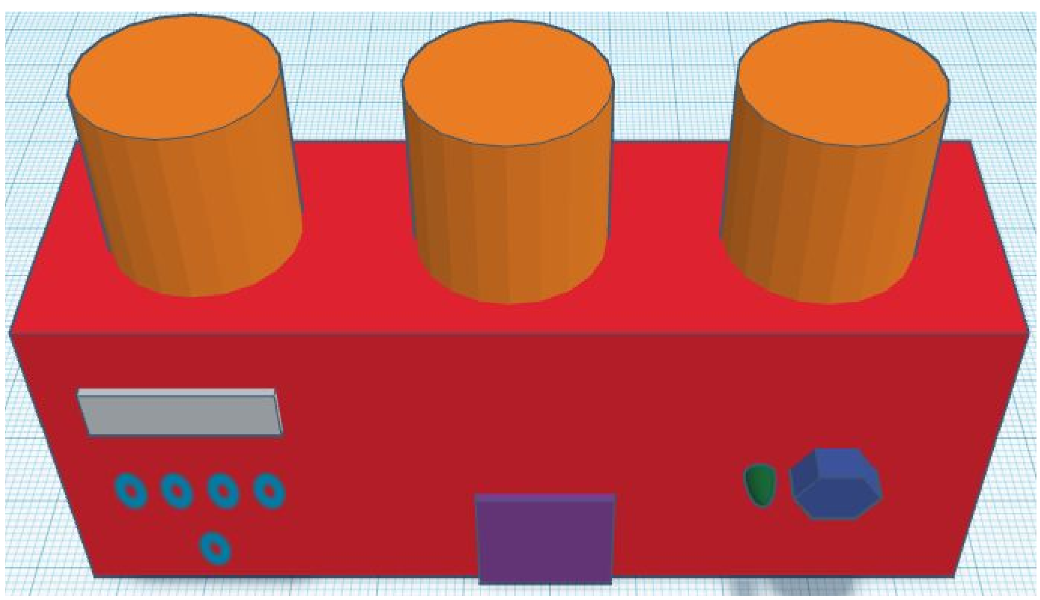

Figure 5: Aerial View of Physical Design

2.4. Safety and Risk Analysis

The main concern we have while thinking about and designing this circuit is the improper dispensing of medication by the machine. We must assure that only the proper dosage will be administered. Additionally, we assure that our machine will alert and dispense the medication at the correct time. Currently, we have one faux pas; we cannot assure who takes the medication. In our design, we only have one user. We may implement a keycode to enter a PIN number, and definitely will if we have extra time and expand the number of users.

When building a circuit to be in the center of someone's home, one needs to make sure the circuit is safe and stable. A faulty circuit risks starting on fire. We must ensure that our circuit and housing come together to create a reliably safe device.

The two components that pose the greatest risk to successful completion of the project are the microcontroller and the software. These two things pose the greatest risk because they are the pieces that we as a group have the least familiarity with. The proper selection of a microcontroller that can perform the tasks we need is a crucial and time heavy task. As a group of electrical engineering majors, the software provides another obstacle similar to those that we have faced in previous computer engineering focused classes.

2.5. Tolerance Stack Analysis

The first tolerance stack we analyzed was the high end of all component tolerances. The values used for each piece can be found in the requirements and verifications for each part in section 2.2. As shown the circuit will still function under these conditions.

The second tolerance analysis we analyzed was for the low end of all component tolerances. Again, the values used for this analysis can be found in section 2.2 in the requirements and verifications table. As shown the circuit will still function under these conditions.

3. Cost and Schedule

3.1. Cost

Our projected cost for parts is \$85.40. We came to this number by finding sources for all of the electrical parts and components we will be buying. The itemized list can be seen below in Figure 8. Our projected labor cost is \$13,500. We have allotted 180 hours at a rate of \$30 per hour which translates to a salary of \$62,400. The total labor cost is calculated with the following equation:

$$Total\ labor\ Cost\ =\ Hourly\ Rate\ *\ 2.5\ *\ Hours\ Worked$$

The total project cost is the summation of parts and labor. This comes out to $13585.40. Itemized Costs list can be found in Figure 4.

In addition to these structured costs we have the costs of lab equipment. This is a different category from the other two spends because they are one time use. The parts will be used in this project and will remain in the prototype. The man hours will be used up and not recoverable as well. The lab equipment will be usable for other projects and future needs. The lab equipment cost is approximately $14,438.90. The breakdown of individual costs can be seen in Figure 8.

Table 11: Lab Equipment Costs

Oscilloscope	Soldering Iron	Multimeter	Power Supply	Waveform Generator	Pulse Generator
$8,276	$179.90	$1,094	$1,437	$2,657	$795

3.2. Schedule

Figure 9 lays out the individual responsibilities of each team member for each week. This will be used to drive successful and on-time completion of tasks. Priorities have been given to long lead time aspects of the project and to items that will hold up to the rest of the project until they are finished. In addition to this table, there is a google calendar that holds all important dates and deadlines.

Table 12: Schedule and Individual Responsibilities

	Project Goals	**Christopher K.**	**Matt C.**	**Iskandar A.**
9/10 - 9/16	Obtain Approval	Project Approval		
9/17 - 9/23	Have Idea of Parts	Brainstorm Project Parts		
9/24 - 9/30	Completed Parts Lists	Research Individual Components		
10/1 - 10/7	Parts Purchased and Delivered	Sensor Validation	Power Supply Validation	Motor Validation
10/8 - 10/14	Parts Tested and Validated	Microcontroller Validation	Buttons and LCD Validation	Light and Speaker Validation

10/15 - 10/21	Hardware Build Completed	Sensors and Microcontroller Mounted	Power Supply, Buttons, and LCD Mounted	Motors, Light, and Speaker Mounted
10/22 - 10/28	Software Build Started	Sensor and Microcontroller Modules Completed	Power Supply, Buttons, and LCD Modules Completed	Motors, Light, and Speaker Modules Completed
10/29 - 11/4	Software Debugging Completed	Sensor and Microcontroller Modules Debugged	Power Supply, Buttons, and LCD Modules Debugged	Motors, Light, and Speaker Modules Debugged
11/5 - 11/11	Software Merged with Hardware	Sensor and Microcontroller Hardware and Software Communicates	Power Supply, Buttons, and LCD Hardware and Software Communicates	Motors, Light, and Speaker Hardware and Software Communicates
11/12 - 11/18	Hardware Enclosure Built and Merged with Hardware	Sensor and Microcontroller Enclosure Completed	Power Supply, Buttons, and LCD Enclosure Completed	Motors, Light, and Speaker Enclosure Completed
11/19 - 11/25 (Break)	Final Paper Underway	Sensor and Microcontroller Sections	Power Supply, Buttons, and LCD Sections	Motors, Light, and Speaker Sections
11/26 - 12/2	Mock Demo Bugs Fixed	Sensor and Microcontroller Modules Debugged	Power Supply, Buttons, and LCD Modules Debugged	Motors, Light, and Speaker Modules Debugged
12/3 - 12/9	All Design Documents Finalized	Sensor and Microcontroller Sections	Power Supply, Buttons, and LCD Sections	Motors, Light, and Speaker Sections
12/10 - 12/16	Project Completed	Presentation, Final Paper, Lab Checkout, and Lab Notebook Due		

4. Ethics and Safety

The potential costs of delivering incorrect doses or medications from the dispenser are extremely high. It would not be outlandish for this error to result in a hospital visit or death. Therefore, we take responsibility in "in making decisions consistent with the safety, health, and welfare of the public" [3] as per IEEE Code of Ethics, #1. With the correct automation and double checking, these mistakes could be avoided with our system. As spoken about above, if used correctly this product takes 30 potential opportunities for error each month and shrinks it into one step. Also, our multi layer design of power supply is a standard practice intended to minimize any chance of fire hazards [4].

When making design decisions we take responsibility into making our design implementation of all components and peripherals user-friendly for different demographics of users, as per requirements of the IEEE Code of Ethics, #5: "To improve the understanding of technology; its appropriate application, and potential consequences" [3]. While there is more importance put on the programming of the machine, it is much easier for a parent, guardian, or caretaker to set aside the proper amount of time once to set the correct dosage and timing information than it is for them to set daily reminders to set up, count out, and provide medication to the patient.

We intend to set up some sort of identification system to verify that it is actually the intended patient receiving the medication. Our current methods are a simple four-digit PIN number, a typed password, or RFID sensor. These can all be added as a peripheral to the central sorting and dispensing mechanism so our design will not be affected should these methods not work. As a whole, the proper use of this system does not cross any IEEE and/or ACM ethics codes as its intended use will streamline the lives of those taking multiple medications each day.

When we first took on this project we researched many previous attempts at delivering a similar item. What will set us apart from the others is our project's ability to take in full bottles of pills without manual sorting. The other projects have been closer to alarmed safety boxes than automated pill dispenser. This is because they still require the user to manually sort the days pills into a silo; so each silo is only good for one day. Then the machine rotates or makes the pills available to the user at the right time and alerts the user in some fashion. This does not reduce the risk for error and is no better than using a plastic monthly sorter in combination with a cell phone alarm or alarm clock. While our project has a similar goal to these others, there is a large improvement in user interface, simplicity, and error minimization that only comes with ours.

High importance has been set for the handling of all electrical components that will be included in our design. We have sourced from reputable businesses, clearly defined the parameters we need each part to meet, verified through testing that our requirements have been met, set up failure detection for the dispensers, and will verify that all components are functioning as intended. Performing our due diligence to ensure that parts are not damaged, are within tolerance, and working together will ensure the delivery of a quality product.

References

[1] R. Harris, "Federal Survey Finds 119 Million Americans Use Prescription Drugs", *NPR.org*, 2017. [Online]. Available: http://www.npr.org/2016/09/08/493157917/federal-survey-finds-119-million-americans-use-prescription-drugs. [Accessed: 22- Sep- 2017].

[2] "Retail Prescription Drugs Filled at Pharmacies (Annual per Capita by Age)", *The Henry J. Kaiser Family Foundation*, 2017. [Online]. Available: http://www.kff.org/other/state-indicator/retail-rx-drugs-by-age/?activeTab=map&currentTimeframe=. [Accessed: 22- Sep- 2017].

[3] Ieee.org, "IEEE IEEE Code of Ethics", 2016. [Online]. Available: http://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed: 02-Oct-2017].

[4] Bob Mammano and Lal Bahra, "Safety Considerations in Power Supply Design," TI Literature No. SLUP227. Available: https://www.ieee.li/pdf/essay/safety_considerations_in_power_supply_design.pdf. [Accessed: 02-Oct-2017].