Final Report
ECE 445 - SENIOR DESIGN

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Abstract

Our project was motivated by designing low-cost user-friendly programmable pill dispenser. Such general purpose dispenser would have more intuitive interface and cost a fraction of different products that are currently offered by the market. Using our gained knowledge of electrical engineering and using creativity we came up with a unique mechanical design for the pill dispensing algorithm. Based on the algorithm we collected and assembled necessary hardware into a prototype. Our prototype still needs several enhancements to become marketable but we laid out the foundations necessary for massive adoption.

Contents

1. Introduction

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].

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 [1]. 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 [2]. 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].

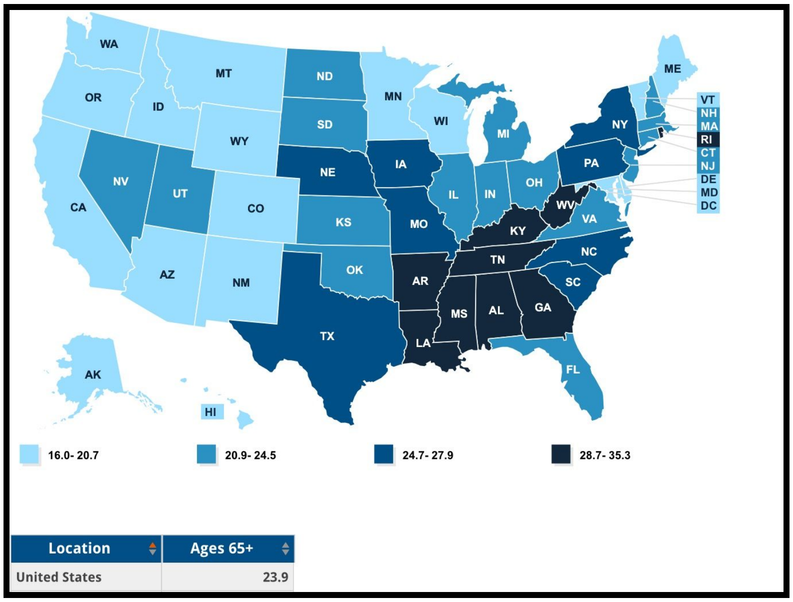

Figure 1: Retail Prescription Drugs Filled at Pharmacies (Annual per Capita Ages 65 and Up) [2]

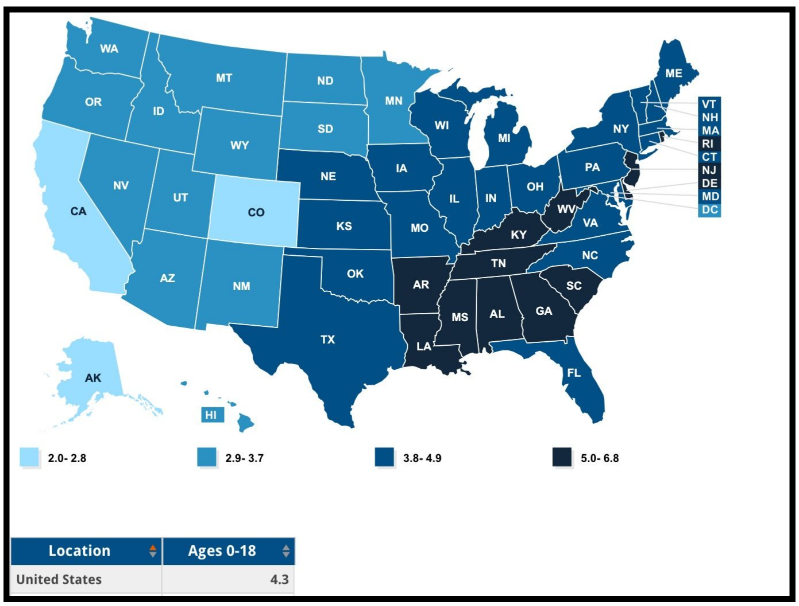

Figure 2: Retail Prescription Drugs Filled at Pharmacies (Annual per Capita ages 0-18) [2]

2. Project Design

2.1 Introduction

We sought for our design to be able to allow a user to set times and days for either one or two pills to be dispensed. This system would allow a caretaker or parent to set the weekly routine once and then leave it for as long as they want the medicine to be taken. This is ideal for young children and aging adults as it can be difficult for them to determine the right dosage, remember to take the medication, and take it at the correct times. The software layout and hardware user interface creates an intuitive process that any user can follow to create a weekly schedule. The design and creation of these is detailed below.

2.2 Design

2.2.1 Block Diagram and High Level Verifications

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. Pass the incoming 5 VDC supply to each component.
- IR Break Beam Sensing and Control - Detect when a single pill has been dispensed . Alert user if the wrong dosage has been passed. Turn motors on and off individually.
- User Alerts - Turn on LED and speaker when medication is dispensed. Turn off LED and speaker when medicine is removed from the machine.
- User Interface - Display which pill the user is 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 - Dispense indicated quantity of pills at programmed time. Rotate 90 degrees forwards and 90 degrees backwards to starting position.

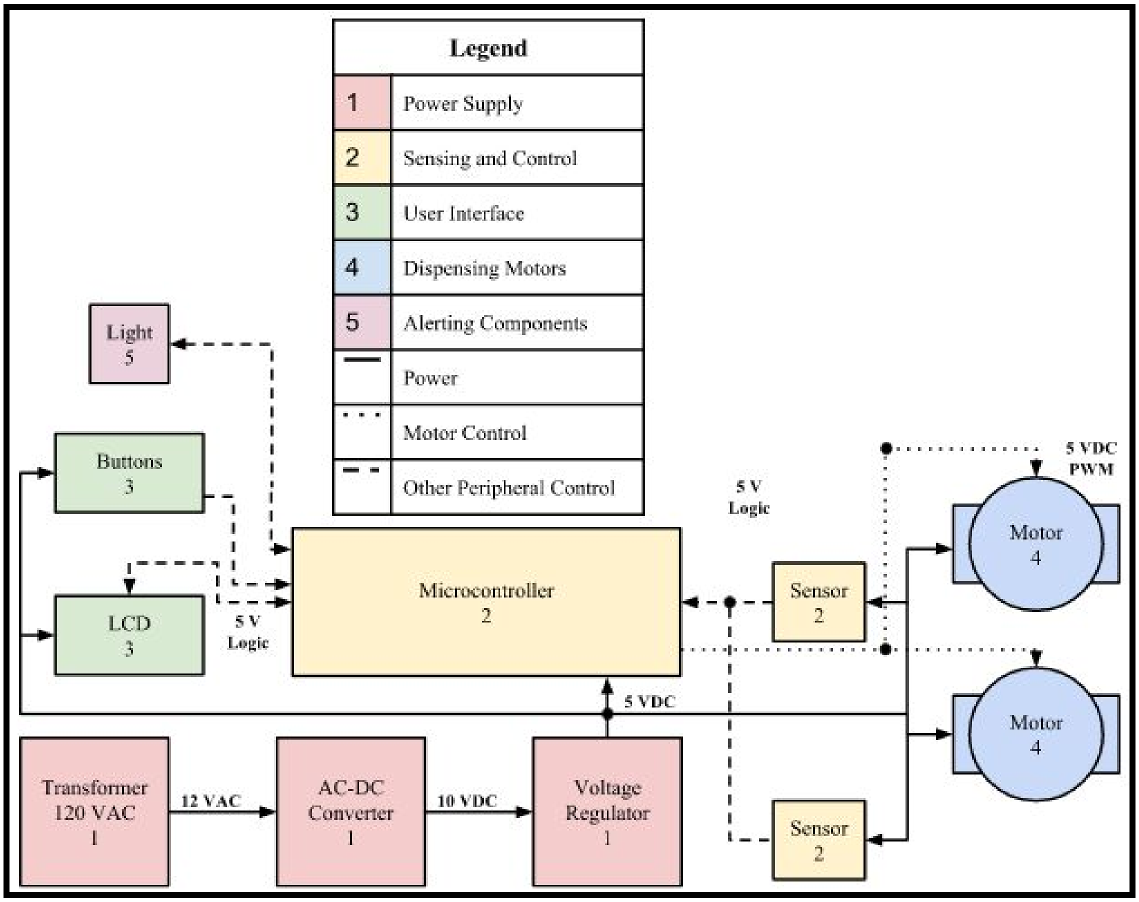

Figure 3: Block Diagram

2.2.2 Laser Cutter Drawings

The design for the enclosure was handled with Creo. The outside dimensions of the box were determined based upon estimates of the sizes of the components. The holes for components were dimensioned directly from measuring those components. The gears were made to have a one-to-one gear ratio since higher or lower shaft revolutions per motor revolution were not necessary. The front of the box is shown in Figure 4.

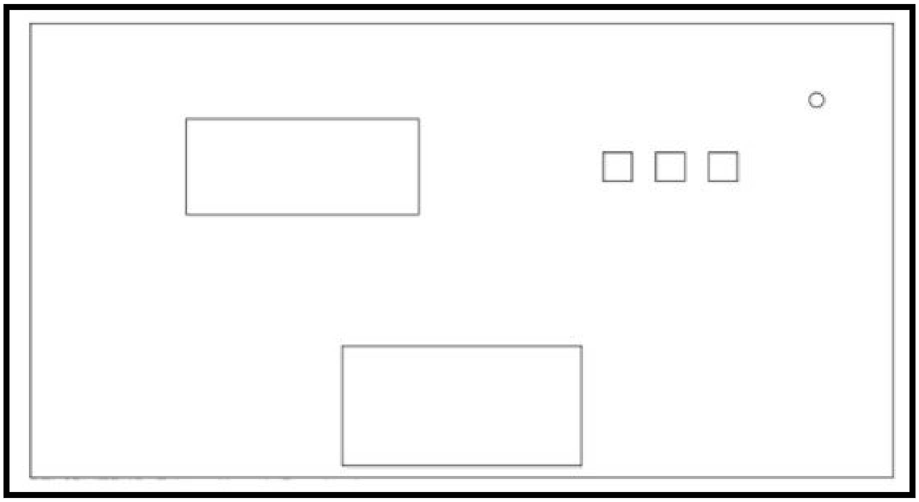

Figure 4: Enclosure Front

The sorting disk design changed several times throughout the duration of the project. The final design in shown below in Figure 5. The center hole is for the shaft, the larger hole is for the pill, and the radial cut is to ensure that the disks do not break the IR sensor’s beam. We created the gap necessary to make it so only one pill can sit in the aperture by stacking two eighth inch disks on top of each other.

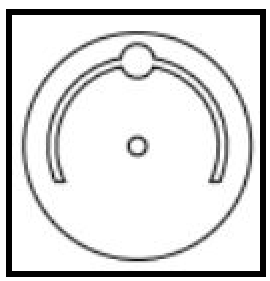

Figure 5: Sorting Disk

Figure 6 shows the bottom stationary disk. The center hole is for the shaft, the larger hole is for the pill to fall through, and the small hole is where the IR sensor sits.

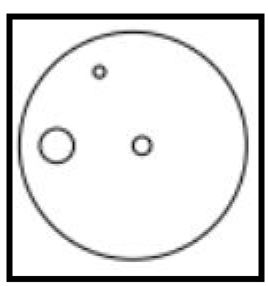

Figure 6: Bottom Disk

Figure 7 shows the gears that were attached the the motors and shafts.

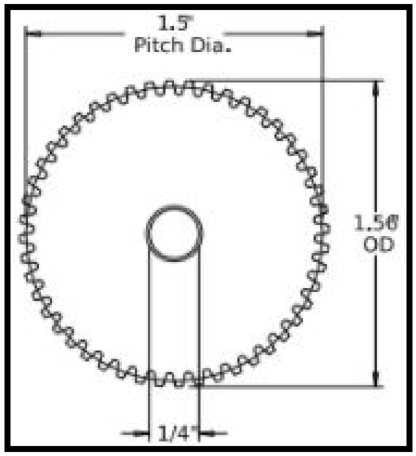

Figure 7: Gear

2.2.3 Microcontroller Pin Layout

The biggest problem our group ran into has been the limited number of pins on the microcontroller. We did not anticipate this problem in our idea generation phase and had to make a few changes because of it. The number of available pins on the microcontroller is 19 [3]. We needed 24 pins according to accomodate our initial design. Table 1 shows the pin breakdown. In order to reduce the number of necessary pins we decided to remove two of the buttons and then change the connections on the motors. Since the motors each take four pins to work, we were able to change the order of the connections and use only four pins to connect both motors. Table 2 shows the order in which the motors were wired. This worked because the motor is essentially two inductors that get signals from the microcontroller. So if the order is changed, then no current or voltage difference is induced across the inductor. This means that the motor will not turn. This simple rearrangement allowed us to refrain from making further reductions to our design, while still having the ability to reach all goals we had set forth.

Table 1: Number of Pins

Component (Quantity)	Number of Pins
IR Sensors (2)	2
Motors (2)	8
LCD	6
Buttons (5)	5
LED	1
Time Unit	2

Table 2: Motor Connections

Microcontroller Pin	Motor 1	Motor 2
Digital 8	1	4
Digital 9	2	2
Digital 10	3	1
Digital 11	4	3

2.2.4 PCBs

Figure 8 shows the eagle schematic created in order to make the power supply board layout shown in Figure 12. Figure 10 shows the eagle schematic created in order to make the microcontroller board layout shown in Figure 14. These were designed according to the guidelines supplied by the ECE Shop even though the PCBs were not ordered through the ECE Shop. This decision was made because they have more limited machinery so if their constraints were met then our online source, PCBWay, would be able to make them without any concerns. The design requirements are shown in Table 3.

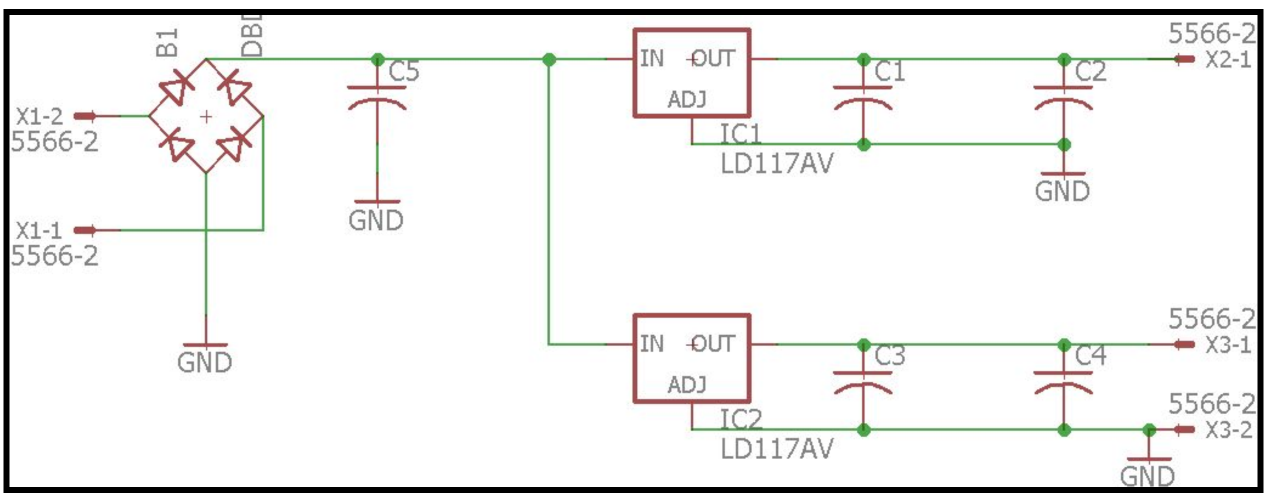

Figure 8: Power Supply Schematic

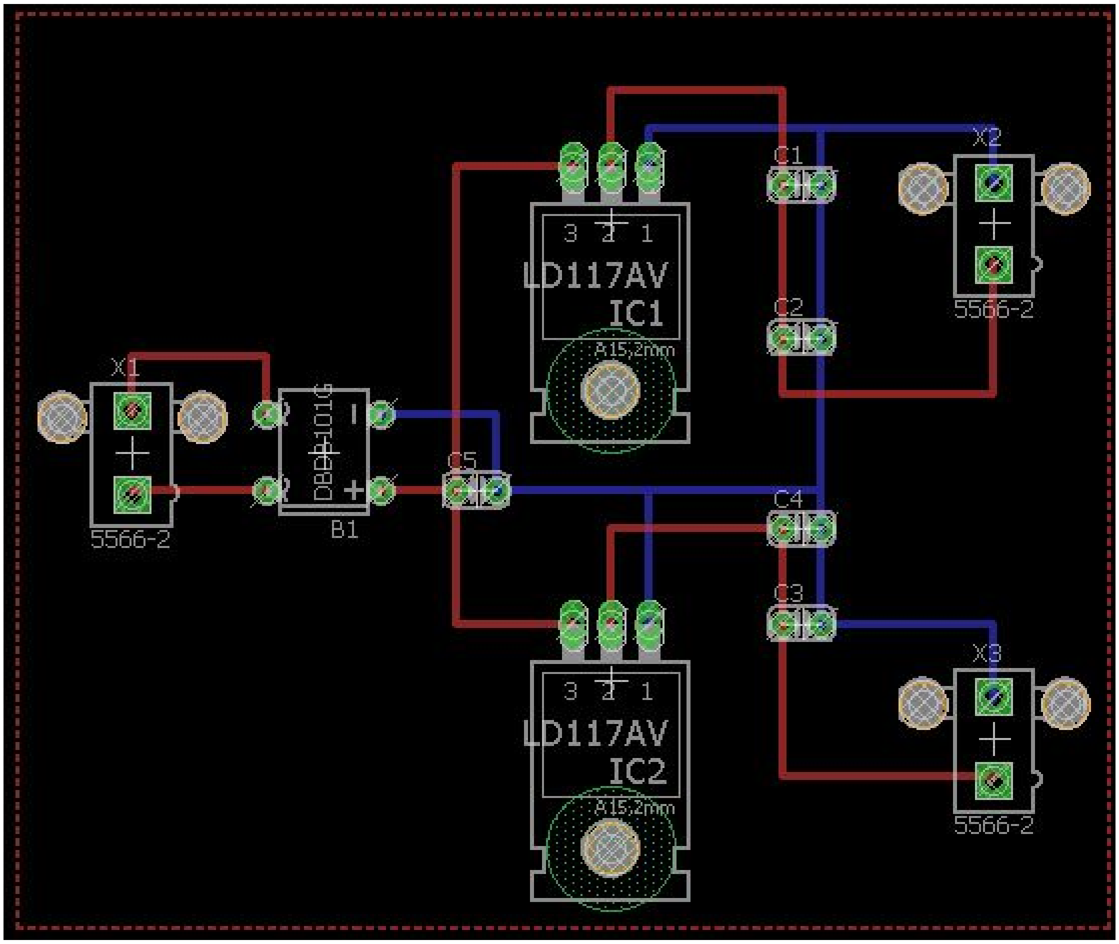

Figure 9: Power Supply Board Layout

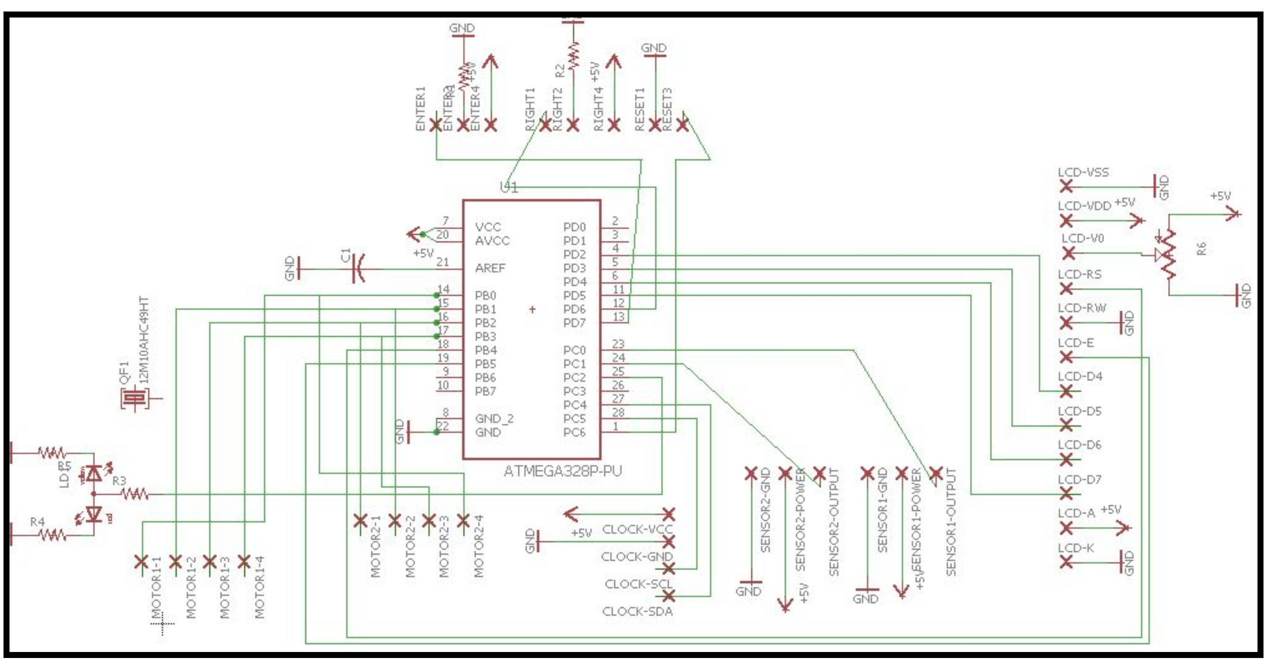

Figure 10: Microcontroller Schematic

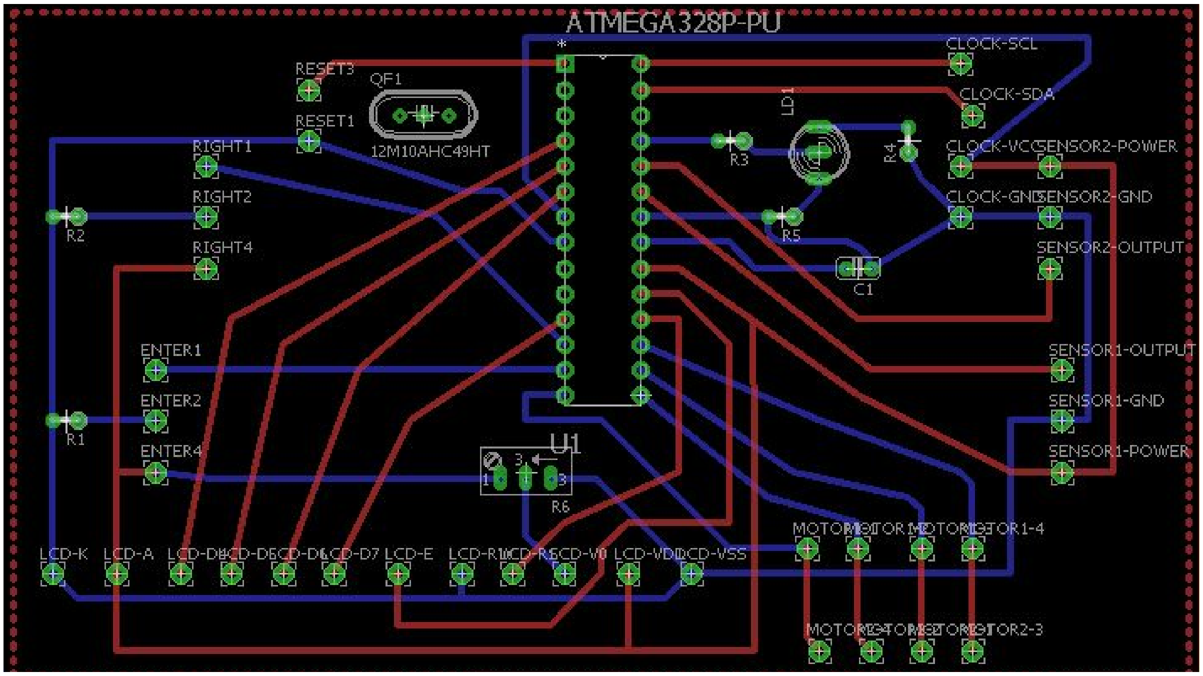

Figure 11: Microcontroller Board Layout

Table 3: PCB Design Requirements

Design Requirement	Met for PCB?
Two side maximum	Yes
Vias not sitting under components	Yes
Background plane is ground	Yes
Trace dimensions 0.024 – 0.032 mil	Yes
Isolation set to at least 50 mil	Yes
Trace width set to 30 – 50 mil (decided based upon our current throughout system)	Yes
Vias able to be hand soldered wires	Yes

Our boards came in as they were designed and without any manufacturing flaws. There were a few errors in their design though. The power supply board had the wrong footprint for the bridge rectifier and had the voltage regulator pins wired incorrectly. The microcontroller board did not have any input holes for the incoming 5 VDC from the power supply and the quartz crystal did not have any connections to it. We were able to make both boards work as we received them with little to no modification. The boards are shown below in Figure 12 and Figure 14. The power supply output is shown in Figure 13.

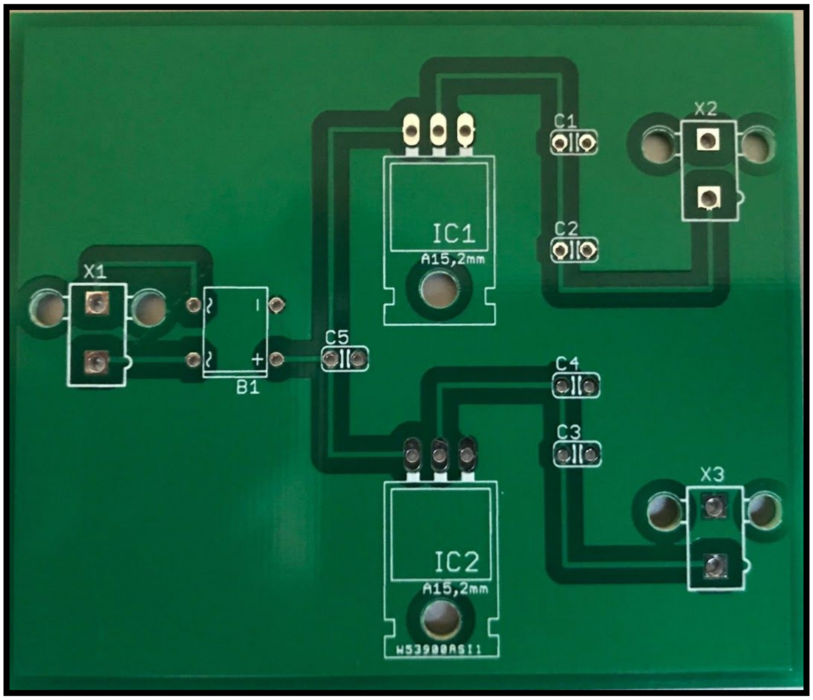

Figure 12: Power Supply Board

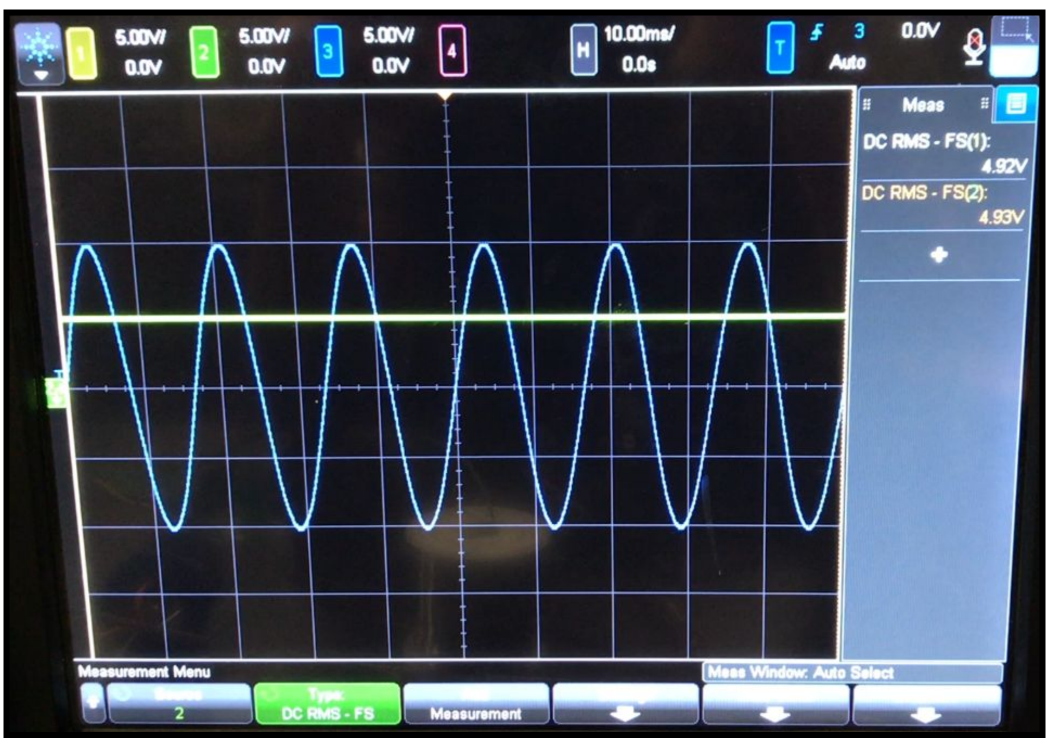

Figure 13: Power Supply Output

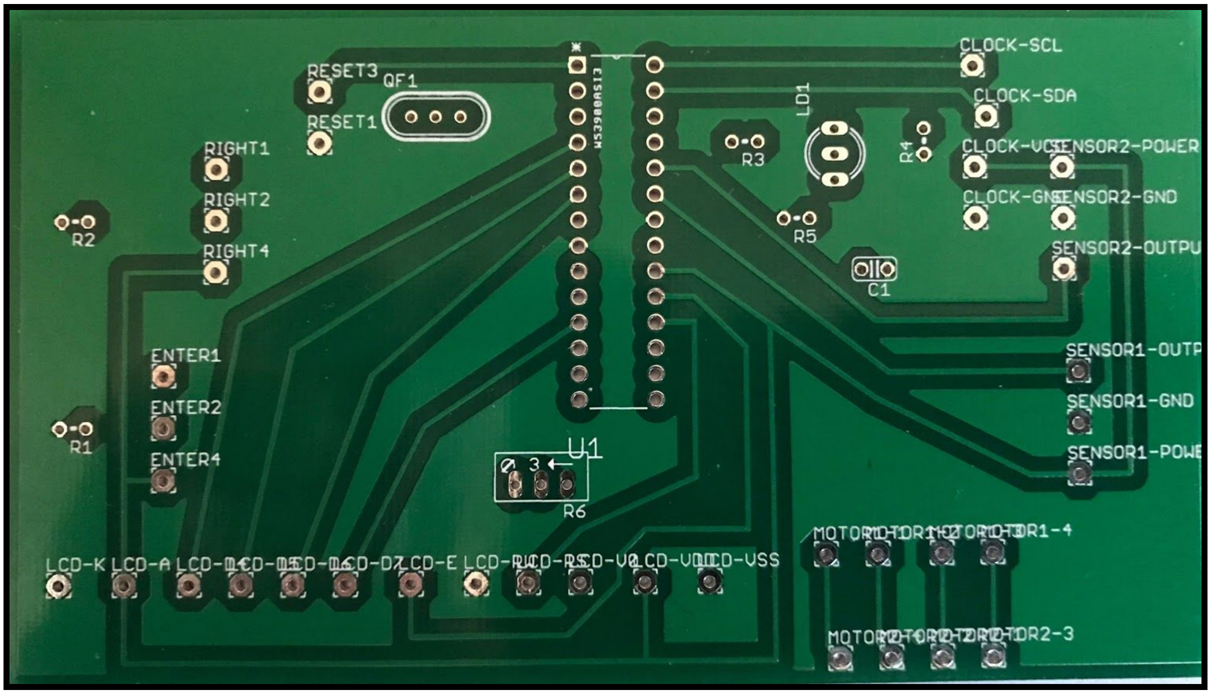

Figure 14: Microcontroller Board

2.2.5 Software

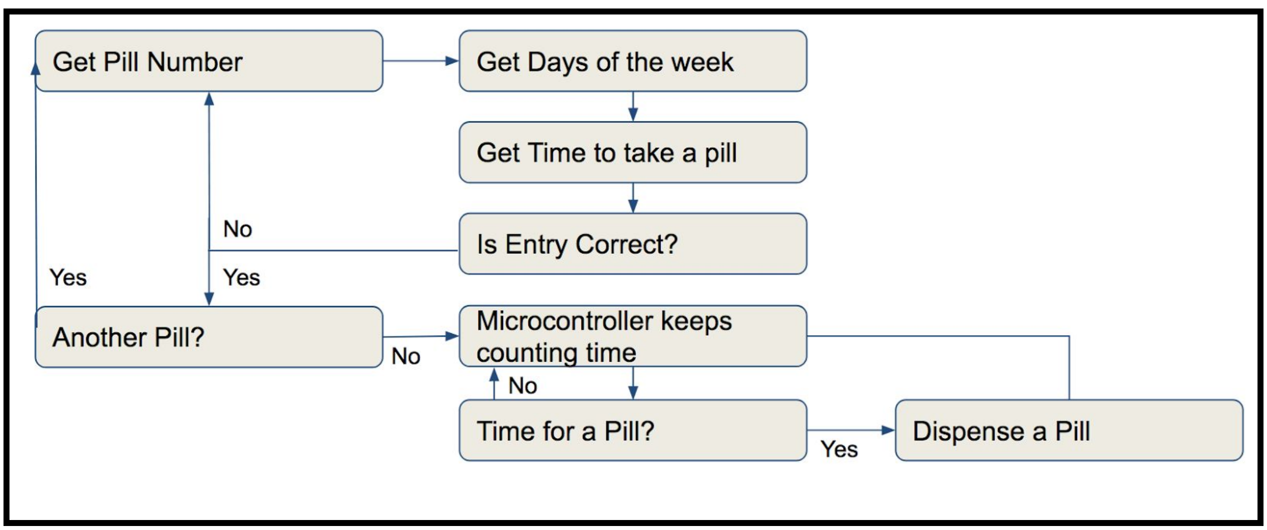

Figure 15: Operations Flowchart

Figure 15 illustrates software steps that we implemented for our pill dispenser. At each step microcontroller needs to take into account of any combination of user input consisting of navigation button, enter button, and reset button. This is implemented using recursion. Depending on user input microcontroller needs to save user provided information and give appropriate instructions for output devices. User instructions can be found in section 4.

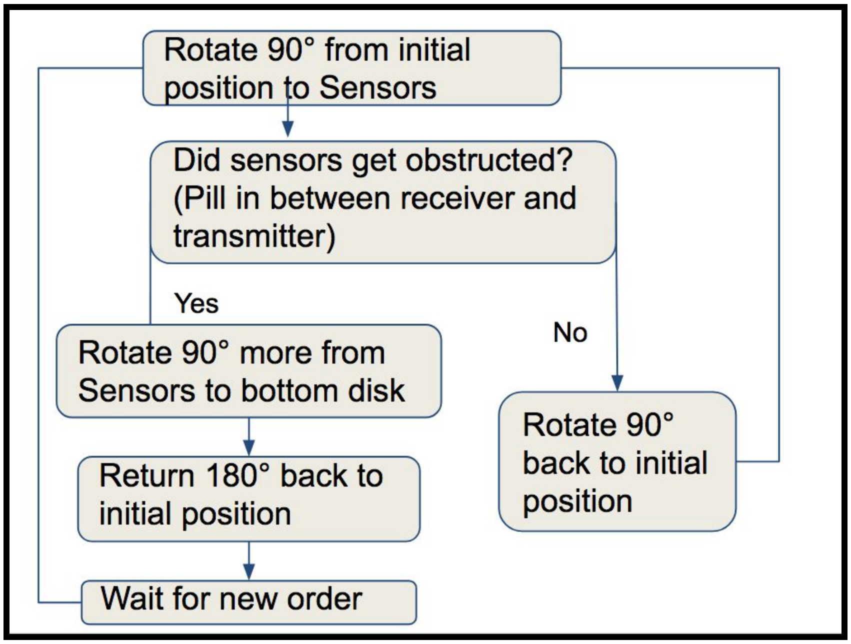

Figure 16: Pill dispensing algorithm

Figure 16 is implementation of the Pill dispensing algorithm based on the hardware design we implemented. It rotates to sensors passing the region of the pill container. By mechanical design only one pill or no pill can be inside the larger hole of the sorting disk. If a pill fell into a disk, it verifies that the pill is fallen, rotates more to dispense it and return to initial position. Otherwise, no pill has fallen, so it will go back to initial position. It takes into account possibility of pill not falling and ensures that one pill falls by being in a feedback loop with sensors.

2.3 Verifications

2.3.1 Component Verifications

We applied modular testing for all hardware components. For the motor sensor interaction we tested to ensure that the motor turned the correct amount and in the correct direction when the sensor was obstructed. Since the motors were commanded and powered by the same pins, we determined appropriate driving combination to make them rotate independently. Then we tested the time unit to make sure it had the correct date and time as well as keeping functionality when the main circuit was powered off. We similarly tested the LCD, buttons, LED, and power supply.

After our code for each component was working with the arduino, we integrated it into one fully working program. We then worked out the bugs that came up from combining the component codes. Once we had the full code working with the arduino, we burned the program into a microcontroller. From there were gradually moved each component from the arduino to the microcontroller PCB. We tested our hardware by adding each component into microcontroller circuit one by one. The modular testing simplified our design debugging as we were able to see exactly what caused problems since we limited the number of changes with each iteration.

2.3.2 Module Verifications

Each of the steps in our pseudocode from the design document was separately tested to make sure it output the correct result. For example in step 1, which is the "Select Pill" state, the right button press needs to switch the cursor to the right and record its new pill number by adjusting the position. For step 2, which is "Select Days of the week" when we press enter it shows the day was selected and if we press enter again it gets deselected. If we press the right button it navigates to the next day until we navigate and press enter. We tested each code unit by giving our custom input and comparing the output of the system with what we expected. Each of the steps was individually tested and after all modules behaved as expected we integrated all the modules. Below is the full requirements and verifications table that we created as a way to verify if we had met all of the necessary parts of our project.

Table 4: Requirements and Verifications Table

Component	Requirement	Verification	Status	Points
Transformer	1. Steps down 120 VAC to 12+-1 VAC	1. Steps down 120 VAC to 12+-1 VAC	1. Verified	1. 2
AC-DC Converter	1. Fully rectifies incoming 12 VAC 2. Capacitor effectively smooths AC signal so voltage stays within 12+-1 V	1. Oscilloscope measurements taken verify rectification occurs. 2. Oscilloscope measurements taken verify voltage stays within 1 V.	1. Verified 2. Verified	1. 2 2. 2
Voltage Regulator	1. Voltage output stays 5+-0.5 V	1. Oscilloscope measurements taken to verify voltage is between 4.5 V and 5.5 V.	1. Verified	1. 8
Microcontroller	1. Operating Voltage: 1.8 - 5.5V and Temperature: -40C - 85C 2. Microcontroller follow flowchart defined in the Design Document	1. Verifying Voltage Regulator should ensure incoming Microcontroller Voltage 2. Verify all steps by testing different inputs	1. Verified 2. Verified	1. 2 2. 20
Sensors	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 make motors turn to release pill	1. Voltage applied to sensors measured with multimeter 2. Sensor output signal measured with multimeter 3. Second turn is observed after beam is broken	1. Verified 2. Verified 3. Verified	1. 2 2. 2 3. 3

LCD	1. LCD turns on with voltage between 4.5 V and 5.5 V 2. LCD displays text input from microcontroller 3. LCD outputs text around 500ms of button press	1. Voltage applied to LCD measured with multimeter 2. Test text input is shown 3. Can be measured with timer	1. Verified 2. Verified 3. Verified	1. 2 2. 10 3. 2
Buttons	1. Buttons are on with voltage between 4.5 V and 5.5 V 2. Buttons send signal out when pressed 3. Reset button resets the whole program any time	1. Voltage applied to buttons measured with multimeter 2. Buttons output signal measured with multimeter 3. Press reset at any time	1. Verified 2. Verified 3. Verified	1. 2 2. 2 3. 2
Motors	1. Proper dosage dispensing 2. Has 64 steps per revolution 3. Work independent of each other 4. Dispense at the specified time	1. Multiple different sized pills placed into dispenser 2. Will be counted with controlled input signals. 3. While one motor operates check the other one 4. Compare the real and dispensed time	1. Verified 2. Verified 3. Verified 4. Verified	1. 10 2. 2 3. 5 4. 10
LEDs	1. LED turns on between 4.5 V and 5.5 V 2. LED turns on when it is time to take a pill	1. Voltage applied to LED measured with multimeter 2. Check the LED brightness	1. Verified 2. Verified	1. 2 2. 2
Time Unit	1. The time displayed on the LCD is within 35 seconds of the real time 2. The time keeps synchronized even after power is off	1. Compare time on LCD with real time 2. Turn power off, wait some time, turn it back on and check displayed time	1. Verified 2. Verified	1. 2 2. 4

3. Cost and Schedule

Our components cost was 85$ for one unit we produced. Our projected labor cost was $14,625. We used 195 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:

$$Total\ labor\ Cost\ =\ Hourly\ Rate\ *\ 2.5\ *\ Hours\ Worked \qquad \{1\}$$

The real schedule was a slightly condensed version of our projected schedule, so most tasks were allocated the proper amount of time. Total cost is $14,710.

4. User Instructions

4.1 User Interface

- Yellow button moves cursor to the right
- Blue button is select
- Red button is restart entry
- LCD will display the current step information
- LED will light up when a pill is dispensed

4.2 Step 1

- Use the right and enter buttons to select the pill you want to set a time for. Pill 1 is on the left. Pill 2 is on the right.
- Select enter once you have chosen the pill(s)

4.3 Step 2

- Choose the days the pill should be dispensed by navigating right and hitting select.
- Deselect by pressing select again.
- Select enter once you have chosen the days.

4.4 Step 3

- Select the time to dispense at by pressing enter to alter the corresponding to cursor number.
- Select the meridiem to A.M. or P.M.
- Select enter once you have chosen the time.

4.5 Step 4

- Confirm entry for Steps 1-3.
- If yes is selected the settings will be saved.
- If no is selected the settings will be deleted and you will be redirected to Step 1.

4.6 Step 5

- Select if another pill is to be dispensed.
- If yes is selected you will be redirected to Step 1.
- If no is selected the date and time will be displayed on the LCD and the pill will be dispensed as programmed

5. Conclusion

5.1 Accomplishments

We were able to successfully complete the project on time and with all of the features that we set out to include. As expected, we learned many things throughout the work during the semester and came up with several ways to improve our design.

5.2 Uncertainties

We powered our motors from the power supply because our motors were just vibrating without rotating and needed more than 5V given by the datasheet to operate from the same pins. We believe that this problem could have been solved using 10V voltage regulator. We also were uncertain with the operation of the time unit battery. At some point the led signal on the time unit was very blink and time wasn't displayed. We guess that this happened because during one of our testing experiments we accidentally applied too much voltage for a short period of time and after a while the time unit stopped working. Luckily, we had a back-up time unit.

5.3 Ethical Considerations

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" [4] as per IEEE Code of Ethics, #1. With the mechanical design adaptable for pill size and double checking, these mistakes could be avoided with our system. Also, our multi layer design of power supply is a standard practice intended to minimize any chance of fire hazards [5]. 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" [4]. 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. 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 verified that all components are functioning as intended. We verified that parts are not damaged, are within tolerance, and working together.

5.4 Future Work

The biggest improvements we thought of were:

- To improve the mechanical design will make it more stable and robust
- Reduce the size of the unit will make it more portable
- Letting the user choose different numbers of the same pill at the same time will allow more flexible dosage
- Adding more pill options than just two for increased functionality
- Having a speaker to alert the user that it was time to take medication for additional alarm

6. 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: 12- Dec- 2017].

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