Automatic Solder Dispenser

DESIGN DOCUMENT

Team: sdmay19-12
Client: Leland Harker
Adviser: Leland Harker

Team Members
Samuel Willford
Jason Austin
Justin Wheeler
Zachary Bumstead
Kevin Carlson
Trenton Allison

sdmay19-12@iastate.edu
sdmay19-12.sd.ece.iastate.edu

Revised: December 2, 2018

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ETG: Electronics and Technology Group

ISU: Iowa State University

Coover Hall: The dedicated electrical and computer engineering hall at Iowa State University

ID: Identification

1 Introduction

1.1 Acknowledgement

The team would like to thank the Coover Hall ETG Department at Iowa State University. Without their assistance, this project would not be possible. We would like to specifically thank Leland Harker, our client and advisor. He has a great passion for engineering and is more than willing to share his knowledge and resources with us.

1.2 Problem Statement

ETG has seen an increase in solder use in Coover Hall. Students will come to ETG asking for solder, but often don't know which kind they should be using. An ETG employee would then explain the different types of solder, help the student decide which one is best for their unique situation, and give them approximately 12-18 inches of the requested solder. This is a very frequent and repetitive occurrence. ETG has requested that we automate this process to allow more efficient allocation of ETG employee time.

ETG has tried placing solder spools in labs, but found that the spools would quickly disappear. It is also difficult for students to track down the location of a solder spool throughout the many labs in Coover. Ultimately ETG would like to know where the spools of solder are located and ensure that students cannot "borrow" or steal the solder spools.

Lastly, ETG is closed during the night hours and on weekends, which means students do not have access to solder. This is not ideal as many students are working in labs at all hours of the night and need access to solder.

1.3 Operating Environment

The automatic solder dispenser will be located in various labs in Coover Hall. The dispenser must be strong and enduring, because malicious engineering students may hit and tilt the machine, trying to obtain more solder. Special care must be taken to ensure that the machine is not easily damageable and that normal wear will not interfere with its functionality. The dispenser must be easily moveable to other lab locations. There will not be any harsh precipitation or temperature changes, and the labs are generally kept clean.

1.4 Intended Users and Intended Uses

The automatic solder dispenser will have two main users: students and administrators. Students will be in need of solder throughout the semester, and this machine needs to be easily accessible for those in need of solder. Students will swipe their ISU ID, navigate through the solder descriptions, decide which solder type is best for them, and select it.

Students will benefit from this machine due to it being accessible at all hours, every day. Currently, if a student is working on a project late at night and needs solder, the student would be out of luck because ETG would be closed.

Administrators will care for the machine and replace solder rolls when needed. The administrators will be ETG employees, and they will receive emails when the machine jams or needs a roll replaced. They can then swipe their ISU ID card into the machine and gain access to the administrator page on the touchscreen. Here they can view usage rates and errors, as well as notify the machine when a solder roll has been replaced.

1.5 Assumptions and Limitations

Assumptions:

- Multiple solder dispensers will eventually be created using our designs.
- If multiple dispensers are made, students will only be locked out of the individual machine they used for 20 minutes.
- Multiple rolls of the same type of solder will not be placed in one machine.
- 120V AC will be available for the dispenser to use.
- A stand or table will be available for the dispenser to sit on in order to be at customer level.

Limitations:

- Each student will need their ISU ID card present when needing solder.
- The cost of each solder dispenser should be kept under $400.
- Changing the structure of emails or programming will be difficult for those unfamiliar with the software.
- The size of the dispenser should be approximately shoe-box sized.
- The dispenser should be completed and tested by May 2019

1.6 Expected End Product and Other Deliverables

The final deliverables for this project will include one fully-working solder dispenser machine, as well as the necessary designs needed to create additional dispensers in the future. The solder dispenser will be fully operational and tested by actual students to ensure it functions as expected. The dispenser should be completed and ready to be tested by March 25, 2019. The final version with any corrected pieces or parts should be completed by April 29, 2019. The finished project will be able to function correctly for both students and administrators. Other deliverables include documentation for the recreation of mechanical, electrical, and software that the solder dispenser requires.

The main user for the solder dispenser is students. The process for student use can be summarized in a few steps. First, the student will swipe his or her student ID. Then, the student will use the touch screen to select what type of solder he or she would like. The machine will then cut a piece of solder for the student and not allow him or her to get more solder for 20 minutes.

The other intended user is an administrator. The finished project will function differently for administrators than for students. After the administrator swipes his or her ID, he or she will be allowed to view usage statistics or perform maintenance on the machine. The finished project will also be expected to communicate with administrators as well. Errors such as jams and warnings about low solder rolls with be emailed to administrators from ETG.

Besides the expected functionality of the product, the designs for the dispenser will also be delivered. The designs to be included in the final project will consist of circuit schematics, layout designs, software codes, and a bill of materials. The layout designs will include an assembled layout of the box and individual models. Using this information, more dispensers can be created in the future.

2. Specifications and Analysis

2.1 Proposed Design and Design Specifications

Our design can be broken into three main categories: electrical, programming, and mechanical work. Each of the following will be discussed. An overview of how these categories correspond to each other is shown in figure 1.

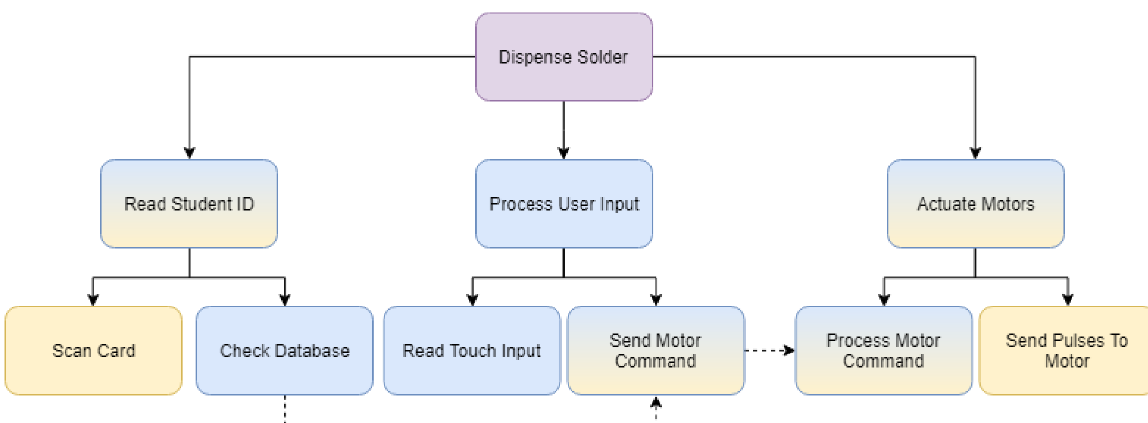

Figure 1: Category Overview

Electrical Work

The electrical work includes the power requirements for the dispenser, determining which microcontroller is best, designing and creating a PCB circuit board containing drivers, and determining which servos and motors to use. The electrical team decided to use a Raspberry Pi for the microcontroller, which uses 5V for power. From previous designs and input from our client, it was decided that 2 standard servos will be used for cutting the solder, and 4 stepper motors will be used for pulling the solder off of the roll.

The PCB has four Adafruit TB6612 stepper motor drivers, one for each stepper motor. It also contains pins for power, servos, and future sensors. Future sensors may be implemented to inform administrators when the box is opened, as well as determining when a jam has occurred.

Programming

On the programming side, a database has been created to store the ISU card numbers of users, which is read from a USB magnetic stripe reader. By using the database, the dispenser can prohibit users from getting more solder within the next 20 minutes. The program will be written to control both the stepper and servo motors. The stepper motor can be rotated a specific number of degrees, which will allow us to dispense a preset length of solder. The servo motors will be used to cut the solder.

We are using a 7" touchscreen display with the Raspberry Pi, which will be programmed so that users can operate the dispenser and administrators can replace spools and view status reports.

Mechanical Work

The mechanical work includes determining what designs have already been created, as well as determining if the designs work correctly and are optimal. Four extruders will be created, which will each connect to a stepper motor, and each motor will control the solder on a spool. The extruder has a spring mechanism in order to keep tension on the solder at all times.

After the extruder, a collector piece will be connected. The collector will combine the outputs of all four extruders into one single output. In order to have only one cutter, all four different solder spools must end up going to the same place, no matter which type is chosen. The collector could be as simple as connecting the four extruders together via four separate flexible tubes if this does not cause jamming issues. Designs will be created accordingly.

Connected to the output of the collector is 12-18 inches of tubing, which will be formed into a tight spiral. when the solder is pushed through the tubing, it will keep its spiral shape. This is optimal for dispensing, since we don't want the user to have access to the solder until after it is cut. The spiral will allow the solder to remain inside the box while being cut. The cutter is made up of two servos, with a design very similar to a cigar cutter (shown in figure 2).

Figure 2: Guillotine Cigar Cutter (Amazon.co.uk, 2018)

After being cut, the solder will fall into a position either inside or outside of the box that is accessible to the user. It is important that the solder is cut first in order to ensure that users cannot pull out more solder directly from the spool.

2.2 Design Analysis

The team has made designs for the hardware, software, and mechanical areas of the project. The team started by addressing the types of designs that each area needed. The electrical portion of the project requires the connection of different hardware elements, including the microcontroller, stepper motor, motor drivers, and servo motors. These elements will then be connected inside the enclosure. Before the entire electrical system can be built and tested, a printed circuit board must be designed so that all the hardware can be connected. Once the specific hardware elements were selected, we focused on designing the printed circuit board.

For the software side of the project, the designated lead began working on the user interface for the administrators, and the database for student IDs. When designing the user interface, we had to choose a GUI library that worked best for the application of our project.

In terms of the mechanical work, we chose an enclosure and designed, tuned, and tested several parts. We have designed a simple collector and made improvements to the existing extruder and solder-cutter models. Plastic, bendable tubing is used to let solder flow from each mechanical device. For the enclosure, a size was chosen that fits all of our components and the team has selected where the components will be placed so that the space is optimized. The following sections discuss our designs, how they are working, and ideas on how to improve them.

Electrical Designs

Once we selected which motor drivers to use, we began working on the circuit design. We began by using a variety of components: MOSFET transistors, diodes, and resistors. We decided to remove those components and mainly feature the motor drivers in order to simplify the board. After testing the motor drivers, we started the printed circuit board layout. The board has motor drivers, capacitors, and connectors such as terminal blocks and header pins. Besides the components, the board also has power connection pins for other hardware like the LCD screen and the microcontroller. We sent our PCB file for manufacturing, and soldered the components onto the board when it arrived.

After testing, it was confirmed that 3 out of the 4 motor drivers worked. The one that had an issue was most likely due to a soldering problem, but unfortunately the pads broke off the board when attempting to fix it. A new board will be made at a later time that will include sensor pins. Testing a basic software program proved that the motors were able to rotate when connected through the board. The board design is shown below.

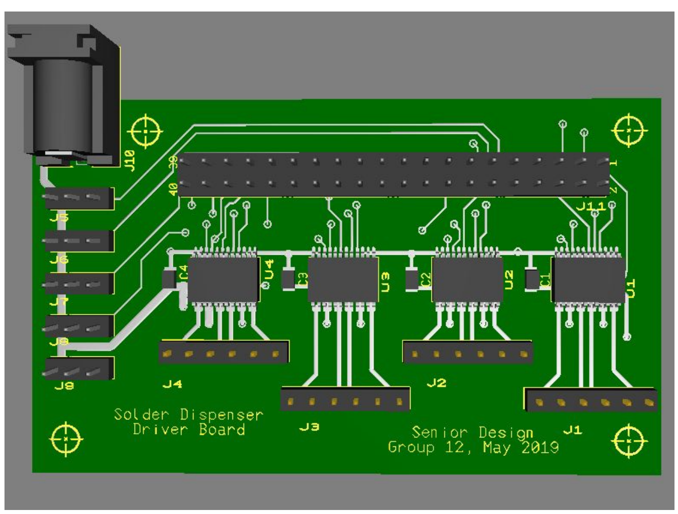

Figure 3: PCB Design

Software Designs

Our strategy for designing the software was to break it up in parts, working on one software feature at a time. The software lead designed the user interface for the administrators and the database for student ID information. When a student swipes his card, the ID is stored in the database. The database keeps track of how much time has passed since the student last received solder, which allows us to enforce the 20 minutes waiting time. The card reader and motors have been incorporated into the code, and a test program has been created. Stepper motors and servo motors each have their own class with code in order to keep the main program neat.

When an ISU ID is swiped through the card reader, the display allows a user to dispense a specified length of solder and choose which type of solder they need, and runs the extruder and cutter accordingly. It has been confirmed that this program works correctly.

Mechanical Designs

The mechanical area of our project requires the creation of new designs as well as making improvements to existing designs supplied by our client. First, the proper enclosure was chosen that will fit all of our components in the arrangement that we desire. The original enclosure that was suggested would only fit 80% of our components, which would not be acceptable. It was carefully decided where the components would be placed inside the enclosure in order to optimize the space given. The current design for our enclosure and the arrangement of the parts can be seen in Figure 4 below.

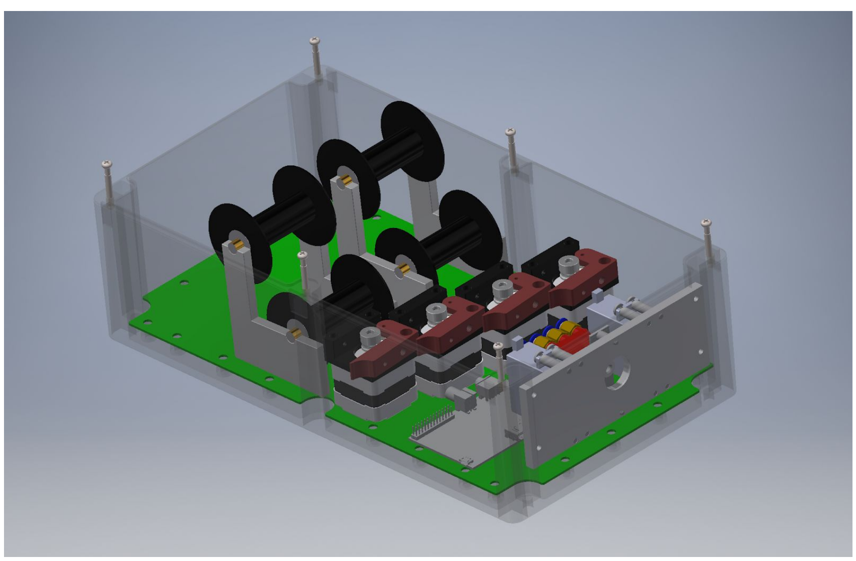

Figure 4: Assembly of Enclosure

Our client provided us with designs for the cutter and extruder, and we are currently working on improving the extruder model. Our goal is to make changes to the design in order minimize both the complexity of the model and the cost to create it, as well as ensuring it will function as desired. New extruders have been made out of aluminum, which should last much longer than the previous plastic pieces. An assembled view of an extruder is shown in figure 5.

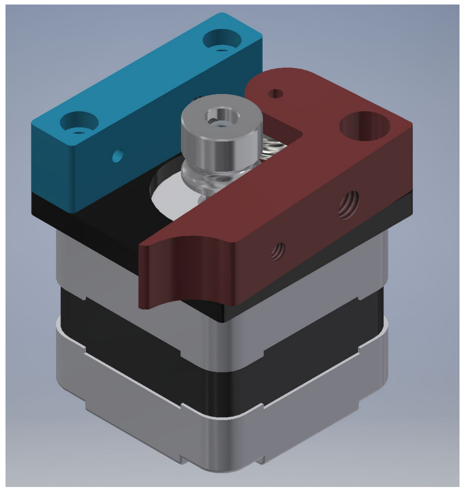

Figure 5: Extruder Assembly

The cutter prototype has been tested with the software code as previously mentioned, and the system has been tuned for a perfect solder cut. The designs for the collector are still in the beginning stages, as we may find that a collector is not needed, or a very simple design will suffice. Lastly, we need to design a feature that will hold onto the solder until the cutting is finished, in order to ensure students can't pull solder directly from the spool. Our initial idea for this was a tail-like tube that will keep the user from pulling the solder out until the cutting is finished. We believe that a better device could be used in this instance, and are in the process of coming up with new ideas for this feature.

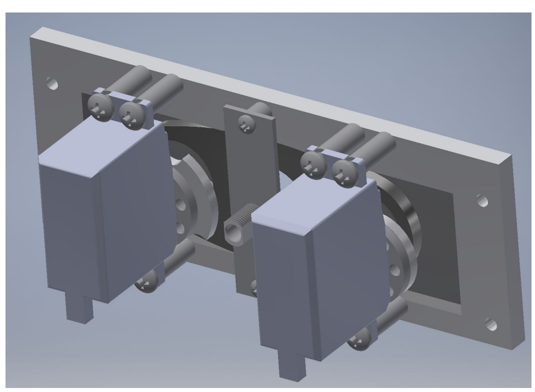

Figure 6: Cutter Assembly

3 Testing and Implementation

3.1 Functional Testing

To test the machine's overall functionality, we will repeatedly iterate through the process that a user will experience. We will vigorously test the touchscreen functionality as well as the ability to accurately distribute solder, determine when jams occur, keep track of how much solder is left on each roll, and email ETG staff when a roll is empty or a jam occurred.

The extruder and cutter devices were tested with a basic Raspberry Pi code. This code controlled the stepper motors and servos in each device, and we were able to fine tune each appropriately. The extruder code was tuned to ensure the length of soldered dispensed is accurate, and the servo code was tuned to turn the correct number of degrees for a precise and clean cut. Both of these tests proved successful.

The PCB was tested next. The motors were connected through the PCB to the Raspberry Pi in order to test the PCB itself. The motors still worked as they did previously, which meant the board operated correctly.

3.2 Non-Functional Testing

In order to test the usability of our soldering dispenser, we will allow a trial period where people can use it. During this time we will ask for feedback from users, as well as ensuring that our dispenser is secure, fool-proof, and safe. Unplugging the machine should not cause the database to be cleared, and the box should be durable.

3.3 Interface Specifications

The overall dispenser will be tested by humans over time, however individual pieces of the project will be tested before integrating all of the components together. The extruder was tested with the Raspberry Pi. A generic test code was written to command the stepper motor in the extruder to spin. After the successful testing of the extruder, the cutter was also tested using the Raspberry Pi, again with a test code. We were able to test the PCB by connecting the stepper motors and servos for the extruder and cutter respectively. Again, using a test code, a signal was sent through the PCB to activate the motors and prove that our design was successful.

3.4 Hardware/Software Platforms Used

The Raspberry Pi 3+ uses python for coding. We chose this language because the Raspberry Pi was designed to work closely with it. Python has many built in libraries that make building applications and interfacing with GPIO pins much easier than other languages.

When designing the PCB, it was decided that MultiSIM would be best, due to two of our team members having experience with it. An alternative was Eagle, but our team had little experience with this software.

3.5 Modeling and Simulation

Modeling of the extruder and supporting brackets for the solder spools were created in Inventor. Inventor has a nice assembly feature that allows users to input multiple drawings and create an overall assembly, which we used to model the enclosure and all of the mechanisms inside (shown earlier in figure 4).

MultiSIM was used for simulating the PCB design. The design schematic is shown in figure 7.

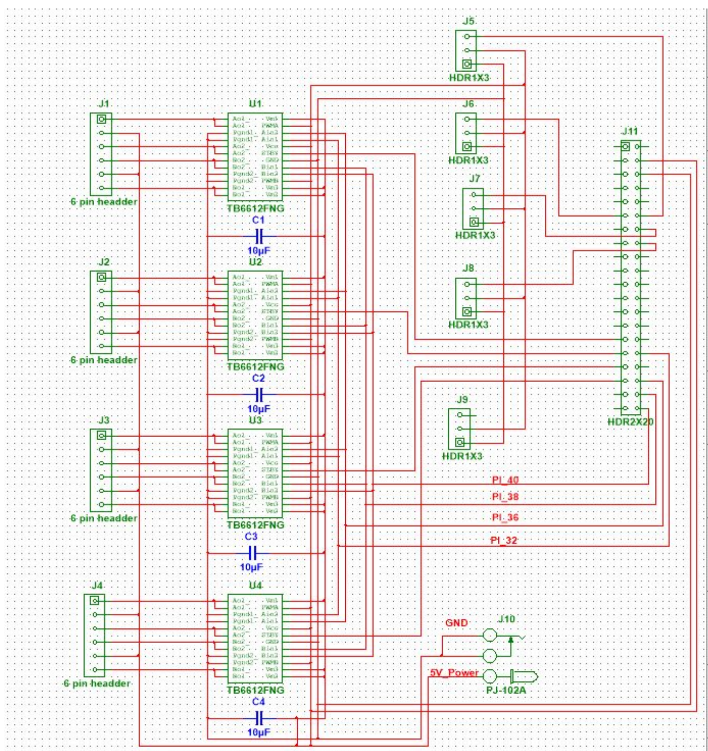

Figure 7: Driver PCB Board Schematic

3.6 Implementation Issues and Challenges

One issue we have discussed is the process of which solder goes from the cutter into the possession of the student. A long tube protruding from the box was presented as a possible solution, although many team members believe this approach would not be aesthetically pleasing and could possibly be damaged. The solution would prevent students from being able to pull the solder directly off the spool by only allowing them access to the solder after it has been cut. More solutions may be brainstormed in the future.

Another challenge we will have is sensing when a solder jam has occurred. The team decided that using a photoresistor is the best approach, as 100mV swings could be created when testing in a lab. The photoresistor will ensure that in each iteration of use, solder appears in the tubing, then disappears. In this way the program will know that solder was moved through the cutter and dispensed. If the photoresistor works consistently well, the problem will be solved. If not, more sensors will be tested.

3.7 Process

Figure 8 shows our design process. We iterate through a sequence of planning, designing, testing, and evaluating until we reach an acceptable outcome. As you can see, each subsection (circuit design, coding, and mechanical designs) was tested separately, as well as evaluated after being assembled together.

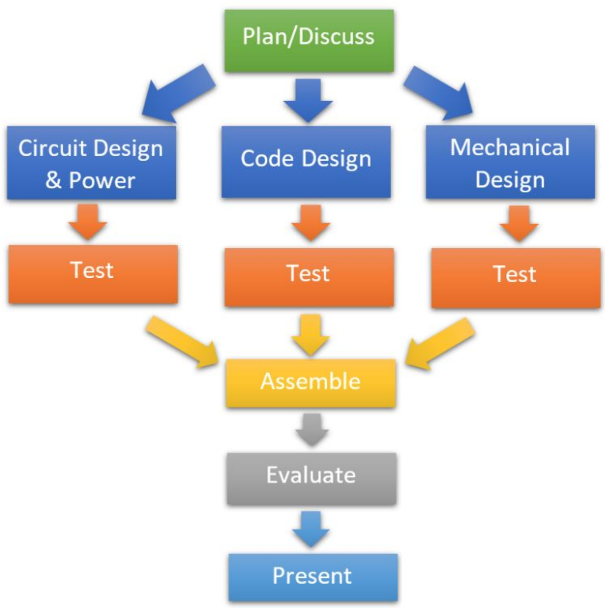

Figure 8: Flow Diagram of Design Process

The PCB circuit board that contains stepper motor drivers was tested after creation. We used the Raspberry Pi to test each driver, and ensure that each stepper motor moves correctly. We also tested the power supplies, ensuring that each driver and motor can be operated without exceeding the ratings of the power supply.

We tested the code in different sections. The code that controls the motors was tested with the PCB board and stepper motors. The code that implemented the database was tested with the cardreader. Each user and administrator screen was carefully tested to ensure that no dead-ends occur during use, and all functions are executing as expected.

Each mechanical design, including the extruder and cutter, was tested separately. The extruder was tested using the stepper motors, a driver, and voltage generator. The cutter was tested using the Raspberry Pi, where it controlled both servos moving in opposite directions. We discussed using different lubricants for the cutter, in order to help it glide better and not wear as fast. A lubricant may be decided on in the future if wear patterns or performance issues indicate a need for it. A new cam design for the cutter allowed four bolts to connect the servos to the cutting device, instead of two bolts with the old design. This resulted in the servos being much more stable.

3.8 Results

When we tested the solder cutting device, we tried running both servos on the same PWM signal. This created problems because it was hard to calibrate the two blades just right. Having two separate signals allows more controllability, and therefore more accuracy.

When we first decided on a driver, we ordered one from Amazon in order to test its functionality. We successfully operated the stepper motor with the driver, and decided to use the driver design in our PCB board design.

4 Closing Material

4.1 Conclusion

Our solder dispenser design is simple, inexpensive, yet durable. We have carefully thought about each piece of hardware and software, and have discussed alternatives and modifications to ensure the best solution is incorporated. Our goal is to create a solder dispenser that users can access 24/7. A student can swipe his or her ID, select from 4 different solder types, and receive 12” of that solder.

So far we have decided on what microcontroller and motors to use. We have also created the database needed to store students ID numbers, and we designed the PCB containing drivers for the stepper motors. On the mechanical side, we have taken the designs previously made by our client, discussed any changes that are necessary, and began creating the physical components. A layout has also been made that shows where each component will go inside the box. We have a plan in place and are currently working on designing and completing the work.

4.2 References

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