Automatic Solder Dispenser

Final Project Report

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Executive Summary

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 30-40cm 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.

In response to this problem, we have created an automatic solder dispenser. This dispenser holds up to four rolls of solder, and allows access to students at all hours.

Requirements Specification

This system is functional for two groups of users. The first group is the students, who are able to interact with a touch screen display and safely receive an acceptable amount of solder. The second group is the administrators, who are able to interact with the touch screen to perform maintenance.

When a student accesses the machine via a student ID swipe, they are greeted with a display. This display allows the student to choose what solder type to dispense, as well as the length of the solder. When selecting the solder type, descriptions are provided that assist the student in helping choose the best solder for the desired application. In order to prevent the student from harming themselves or the system, the machine cuts the solder in an area that is unreachable to students.

Administrators can gain special access via their ID card. When an administrator changes a solder roll, he or she can inform the machine that a new roll has been added. Emails will be sent to ETG when the machine encounters power loss or when a solder roll level is below 5% remaining. The requirements can be summed up as followed:

Functional Requirements

- Users must be able to choose between four different types of solder
- A university ID card is required to receive solder
- After receiving solder, the user cannot receive more for 20 minutes
- An email should be sent to ETG when a solder roll has 5-10% remaining

Non-Functional Requirements

- The system should fit in an enclosure with similar dimensions to a shoe box
- The approximate budget should be around $400
- Part of the enclosure should be clear (So students can see the process inside)

System Design & Development

Design Plan

In order to complete the project, the work was divided into three categories: electrical work, programming work, and mechanical work. More information regarding these three categories can read in the following paragraphs.

Electrical Work

The electrical work oversaw the power requirements for the dispenser, determined which microcontroller is best, designed and created a PCB circuit board containing drivers, and determined 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 the client, it was decided that 2 standard servos were to be used for cutting the solder, and 4 stepper motors were to be used for pulling the solder off of the roll. Each of the 4 stepper motors would control its own extruder. Each extruder would control the solder removal from a spool.

The printed circuit board has four Adafruit TB6612 stepper motor drivers, one for each stepper motor. It also contains pins for power and servo motors. All of these pins are placed on the board for organizational purposes. It is best to keep all electrical connections on the board. This makes it easier for troubleshooting when testing, and it will also help others to understand the project. The first revision of this board is shown below.

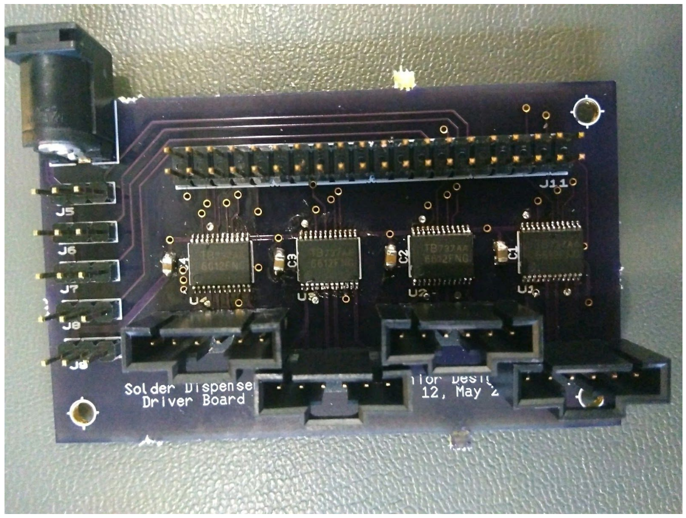

Figure 1: Driver Board Revision 1

This board had issues with Driver #3 that were most likely due to a bad solder connection. Driver #4 was wired incorrectly which caused the motor to spin in the opposite direction. We did not realize this until Revision 2. Also, the cutter seemed weak, and our advisor suggested we change the voltage to 6V.

We created a second revision, which took in 6V in order to give power to the stepper motors, drivers, and servos. It is then regulated to 5V to run the screen, PI, and sensors.

To supply emergency power, we added two supercapacitors. This allows the Raspberry Pi to send an email to ETG regarding main power loss. It also allows the Raspberry Pi to safely shut down. The PI has approximately 5 seconds to send this email after sensing power loss. A picture of this revision is shown below. As mentioned, motor #4 spun backwards, and the footprints for the 26mV forward-drop diodes were too small. The logic voltage of the driver was 6V, and the maximum specified in the datasheet was 5V. While this did not seem to affect the performance of the drivers, we fixed this error on Revision #3.

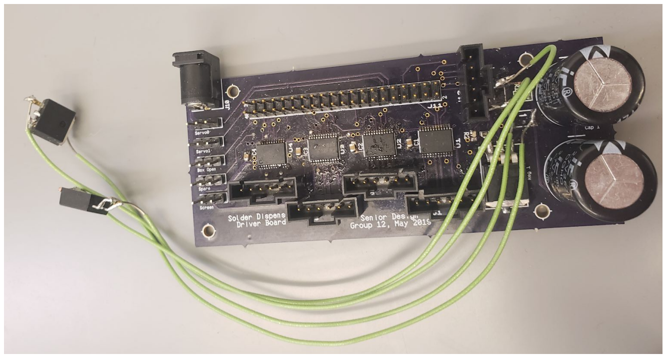

Figure 2: Driver Board Revision 2

The final revision (Revision #3) had all errors fixed, and looked aesthetically pleasing compared to the second revision. The large heat sink on this board is necessary as the regulator gets very hot. It dissipates approximately 1W of power.

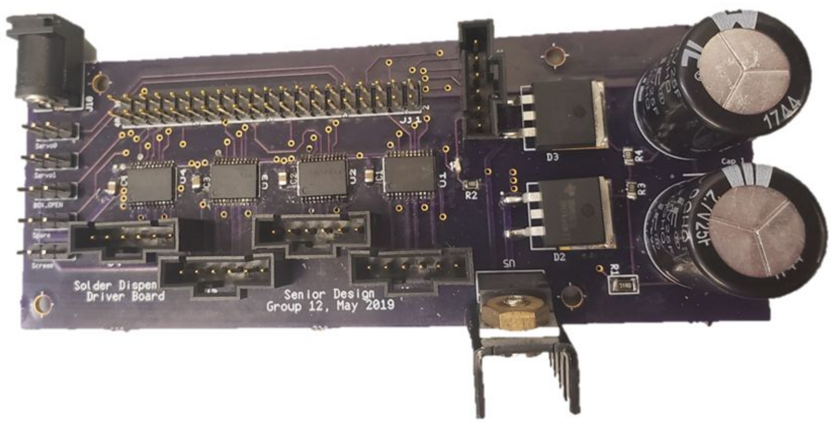

Figure 3: Driver Board Revision 3

Detecting jams would be beneficial. We tried to capture the process that the solder would go through while being dispensed and evaluate if it was present when expected. Any variation would be considered an aberrant state that we could consider a “jam”. We attempted two different types of sensors: A photoresistor/diode combination and an OEM opto-interrupter schematic.

Figure 4: Photoresistor/Diode Solder Detection

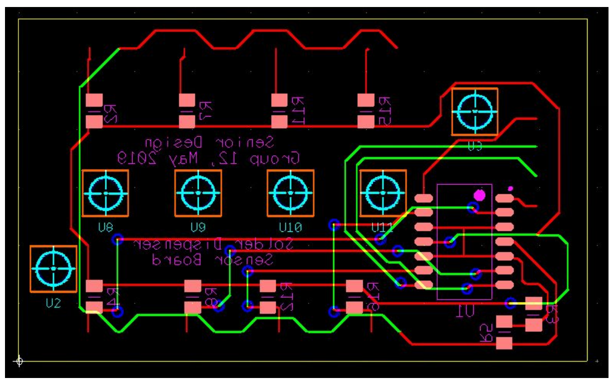

Figure 5: Photoresistor/Diode Solder Detection Layout

This photoresistor/diode combination sensor makes use of a difference amplifier circuit to determine when the stream of light is or isn't blocked. We fabricated a black Delrin "Isolation block", which helps to reduce light-pollution from affecting the sensitive photoresistors. When testing this sensor, two of the four channels worked well, and the other two were intermittent. We ensured that the LEDs being used had maximum current, ensuring that the channel would not be too dim. Depending on the exact location of the photoresistors, the tube, and the solder, the two intermittent channels would sometimes work as expected. Since this design did not seem reproducible or robust, we looked for a new solution.

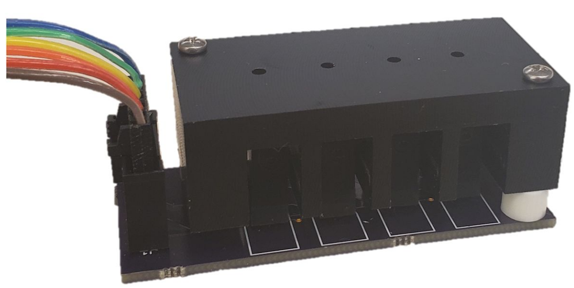

Figure 6: Opto-Interrupter Solder Detection

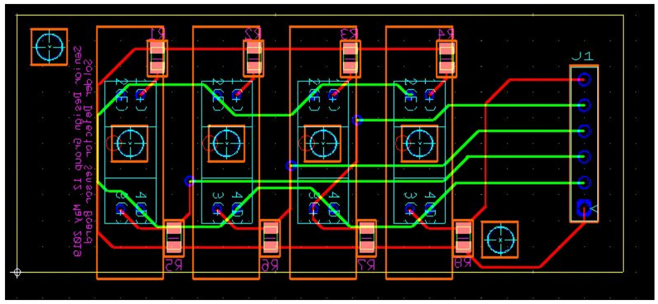

Figure 7: Opto-Interrupter Solder Detection Layout

For our second version of the sensor, we used OEM opto-interrupters. A slightly different isolation block was created. In the spirit of making use of all of our resources, this block was cut using the CNC mill, and it is also made of Delrin and serves the same purpose as the previous block. Moving to CNC manufacturing increased the precision of this component greatly. Unfortunately, it was still not precise enough to make up for the small diameter of the solder moving parallel to the device. The reliability of the sensors was highly dependent on the position of the tube and the direction of its bend radius with respect to the direction of the opto-interrupter's sensor.

Since both sensors were less reliable than the dispenser system itself, we decided not to incorporate either design into the final system.

Programming

Having selected a Raspberry Pi as the control board, python is the natural choice to build the application. The GUI TK library was leveraged to create a basic interface for user interactions. SQLite provides the database for long term storage of data.

A database was created to store the ISU card numbers of users, which are read from a USB magnetic stripe reader. By using the database, the dispenser is able to prohibit users from getting more solder within the next 20 minutes even if the device loses power. The program also controls both the stepper and servo motors. A stepper motor can be rotated a specific number of steps, which will allow us to dispense a given length of solder. The servo motors are used to cut the solder.

We are using a 7" touchscreen display with the Raspberry Pi, which provides a GUI for a student to operate the dispenser and with which administrators can replace spools and manage settings. The GUI consists of three main views; the access screen, selection screen, and admin config panel.

The access screen functions provide students and admin an access point to the device. Swiping an ISU ID will tell the system to verify that the individual has access, either because they are an admin, or because they have not gotten solder within the last 20 minutes.

The selection screen gives a user the option between 4 solder spools, and each has its own set of properties that will be displayed if selected. A slider allows the user to select how much solder they wish to have dispensed, the programmed limits allow for lengths between 30 and 40 cm. Pressing the dispense button will log the user's access in the database, starting their cooldown. Then the device will dispense the requested length before cutting the solder.

The admin panel provides access to device configurations, including the properties of each solder spool, the email settings, and options to add new admin, or clear all other admin from the database.

Mechanical Work

Cutter and extruder designs were passed down from our client/advisor, Lee Harker. Initially our team tested the existing design using 3D printed plastic. We quickly determined that this part required tolerances that we couldn't achieve with our 3D printer, and moved on to metal.

The aluminum extruder design shown in Figure 8 was designed with ease of manufacture in mind. The piece highlighted in blue and the piece highlighted in red come from the same thickness of standard stock, making ordering easier. The third piece is of a second stock thickness. The major profiles of these parts were cut out with a waterjet cutter on campus which is free, and the finer-toleranced features were made in Coover with the CNC mill.

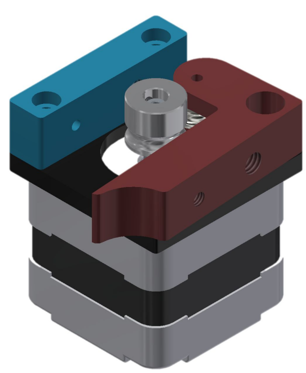

Figure 8: Initial Extruder Design

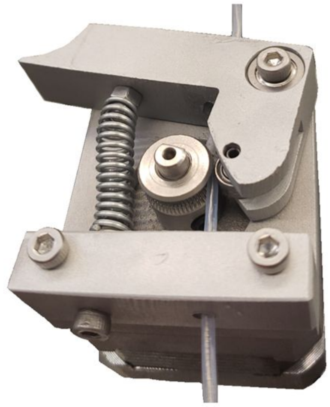

Figure 9: Initial Extruder Created

Four extruders were created, and each were connected to a stepper motor.

While this extruder design worked well when holding the tubes straight, we found that it often jammed when integrated with the rest of the system. We designed a new extruder that held the tubes in-line. This design is shown below.

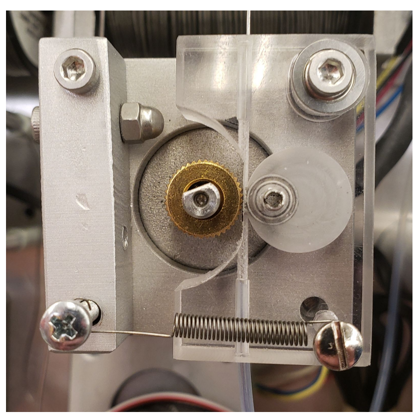

Figure 10: Revised Extruder Created

The cutter is made up of two servos that operate blades, creating a shearing force (Figure 11). We kept the original design given to us, adding some updated servo horns which made the sub-system slightly more robust. We did find that running the servos at

5V did not give the system enough power to cut accurately. Changing the voltage to 6V improved this cutting ability immensely.

Figure 11: Guillotine Cigar Cutter (Amazon.co.uk, 2018)

Figure 12: Cutter

After being cut, the solder falls into a long tube that is accessible to the user at the end of the tube. It is important that the solder is cut before being accessible in order to ensure that users cannot pull out more solder directly from the spool.

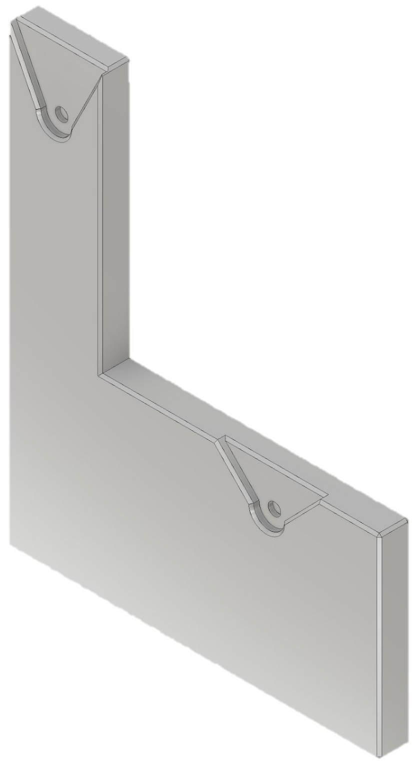

Figure 13: Spool Bracket

To hold the spools of solder in place we made two sets of spool brackets. These were waterjet cut and two pockets were milled out in each bracket to support the spools. These were simply cut down from Delrin round stock. A spring-plunger pin was set centered in each end of the spools. These pins allow ETG techs to quickly remove old spools and replace them. We eventually had to update these spool brackets with right-angle pieces of aluminum, bracing them more securely to the mounting plate. This could be avoided by precisely tapping the holes on the bottom of the spool brackets, or by increasing the stock thickness they are cut from to accommodate a larger size of machine screw.

Another middling problem we tried to solve was the large size of the output tube from the dispenser. For safety constraints the tube must be longer than a person's finger so it cannot be caught in the cutter. It must also be long enough to prevent the user from reaching solder as it is being dispensed. (They shouldn't be able to pull out as much as they want). As a result of this the output tube is over 20 inches long. We tried several designs to remedy this.

The central idea of everything we tried was to take the straight solder that comes from the extruders and make it helical and therefore shorter. All of the designs we tried were

3D printed. The first one, shown in Figure 14, was very basic but illustrated that the concept worked.

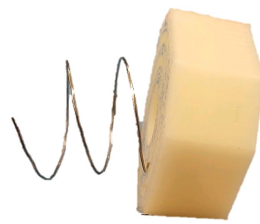

Figure 14: Coiler Initial Prototype

Later versions of the coiler are shown in Figure 15 and represent several changes in philosophy. The first iteration added mounting points and featured two wide coils for solder instead of four narrow ones. The next iteration was thicker and was manufactured in two parts to make fitting the tubing easier.

Figure 15: Coiler Design Progression

Since all of the designs we tried ultimately increased the occurrence of jamming, we decided to tradeoff the aesthetics of the box for successful dispensing.

Implementation

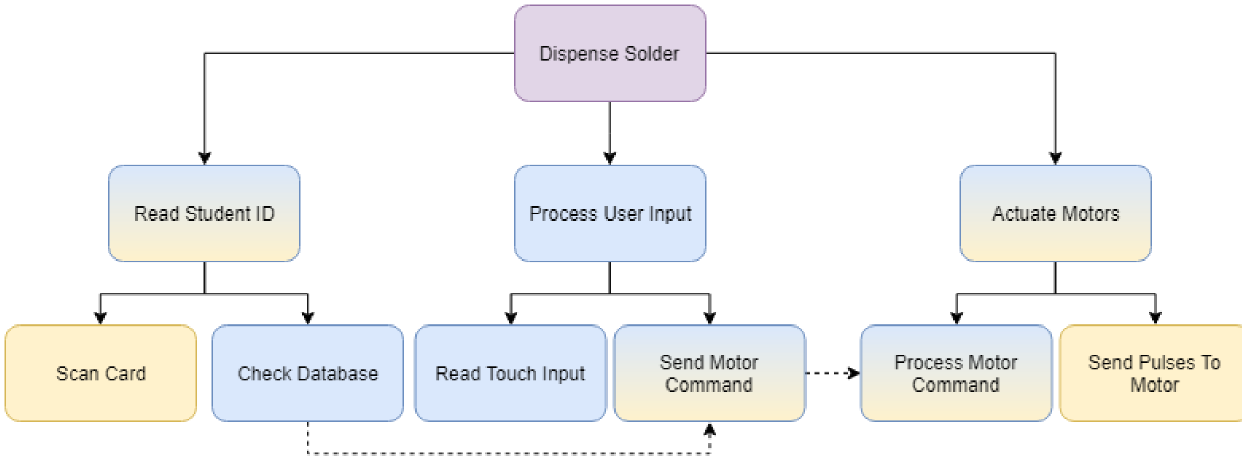

Figure 16: Functional Decomposition

Technology Considerations

When first confronted with this project, our initial design included a PLC and HMI combination. We have several members in the group with PLC and HMI programming experience, but we found that the cost of buying a quality PLC and HMI would exceed our entire budget. Instead, the Raspberry Pi can provide the same function for a fraction of the price, and one of our members has experience programming with it. We also used a 7" display because we need the users to interact with the dispenser. Since the interaction is somewhat complex, a touchscreen display seemed appropriate.

When it came to the solder sensors, we tried to build our own. We tried using LEDs, photoresistors, and a 3D printed housing that we designed. Unfortunately, our design did not work as well as hoped. This could be due to inconsistencies in the 3D-printed housing. These deformities may have obstructed some of the light from the LEDs, and did not allow the photoresistors to detect the light consistently. Also, we attempted to use opto-interrupters that were recommended to us by our advisor. These sensors functioned exactly like the sensor we tried to build, but these devices were already premade and functioned more consistently. Even though this new idea functioned better, we could not get the sensor to work at a higher rate than the overall system.

The open-box sensor is a simple magnetic reed switch. We decided this would work better than a push button switch because the reed switch would not have to align perfectly. As long as the two magnetic ends are within a couple centimeters, the box will not trigger an "open-box" alarm email.

Our best practices include commenting code thoroughly, labelling PCBs in descriptive and appropriate ways, and setting target goals early. We followed standard coding conventions of indenting and prioritizing readability.

Testing, Validation, and Evaluation

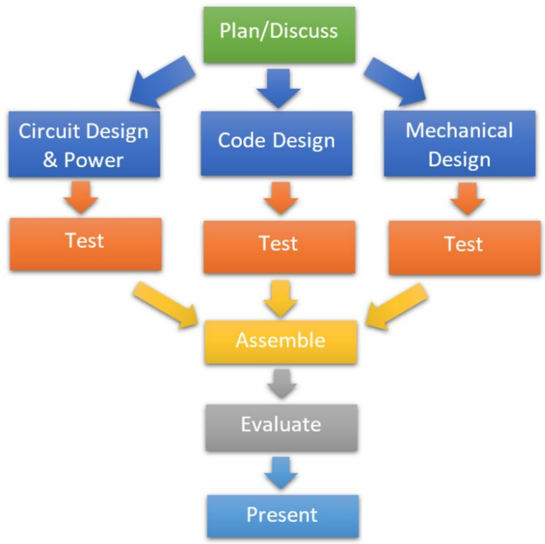

Figure 17: Flowchart of Action

Test Plan

Once all of the designs are completed for each of the three areas in the project, testing began. At Milestone #2, the PCB was finished, meaning the electrical side of the project is ready to be tested. When testing the PCB, it was connected to the microcontroller, motors, and servos, and LCD screen. Power was connected from the PCB to each component one at a time. This is done in order to ensure that each component can turn on.

Next, simple testing with the motors and servos was performed to make sure that they would function within the system. Then the mechanical designs were finished and we tested them with the electrical components. This testing verified that the system can work at a basic level. The goal at this testing stage is to see if the system can extrude and cut a piece of solder of sufficient length. After the programming was completed, the entire system was integrated and tested. Here, the software controlled the system, and we tested the functionality for both sets of users.

After each component was confirmed to work, the mechanisms were integrated together and tested with the final program code.

Driver Board Testing

When testing the driver board, we noticed that the servos were not cutting solder consistently. We decided to change our power supply to 6V at 3A. This ensured that the servo motors had enough power to consistently cut the solder. Since we are using a different power supply, we still needed to ensure that other components, such as the Raspberry Pi, received 5V input. To accomplish this, we added a 5V regulator to the schematic design. Upon further testing, we found that the regulator was getting very hot, and too much heat could damage other components on the board. Adding a heat sink to the regulator solved this problem.

Sensor Board Testing

Testing with the sensor board was a bit difficult. Although the devices themselves worked well, the positioning of the solder tubes with respect to the light emitters and detectors on the sensors caused the data from the sensors to vary. We found that the tubes needed to be positioned so that the sensors could correctly detect whether solder was present.

Results and Validation

Our desired outcome was an automatic solder dispenser that works, does not jam often, and is easy to use. New administrators are easy to add to the database, and spools can be simply changed and replaced. This was a full turnkey solution, and students will not have issues figuring out how to use the machine. While improvements can always be made, the solder dispenser does seem to meet all of the requirements.

Project and Risk Management

Personnel Effort Requirements

After meeting as a group, we estimated the number of hours needed for each task and placed the estimations in Table 1. The person mentioned for being responsible is not the sole member responsible and/or working on a the given task.

Task	Total Man Hours Needed	Main Person Responsible
Selecting Initial Components	20	Sam
PCB Design and Creation	30	Trent
Power Design and Ordering	10	Zach
Raspberry PI Admin Screen Programming	25	Jason
Raspberry PI User Screen Programming	25	Jason
Raspberry PI Motors Programming	20	Jason
Extruder Design and Creation	30	Justin
Spool Roll Design and Creation	15	Kevin
Cutter Design and Creation	15	Justin
End of Semester Reports, Presentations	20	Sam
Dispense Tool Design and Creation	30	Kevin
Sensors: Jamming and Opening	20	Trent
System Integration	25	All
Testing	8	All
Improve from Testing Feedback	30	Justin, Jason
Finalize Designs, Presentations	20	Sam

Table 1: Approximation of Time Allocation

Project Timeline

Our detailed project timelines are shown below. The first shows our fall semester timeline, which included selecting initial parts, designing the PCB board, completing a majority of the programming work, and designing most of the mechanical pieces. Our goal was to complete as much of this project as possible early on. Since most projects tend to take longer than expected, we figured allocating extra time will greatly help us if we fall behind.

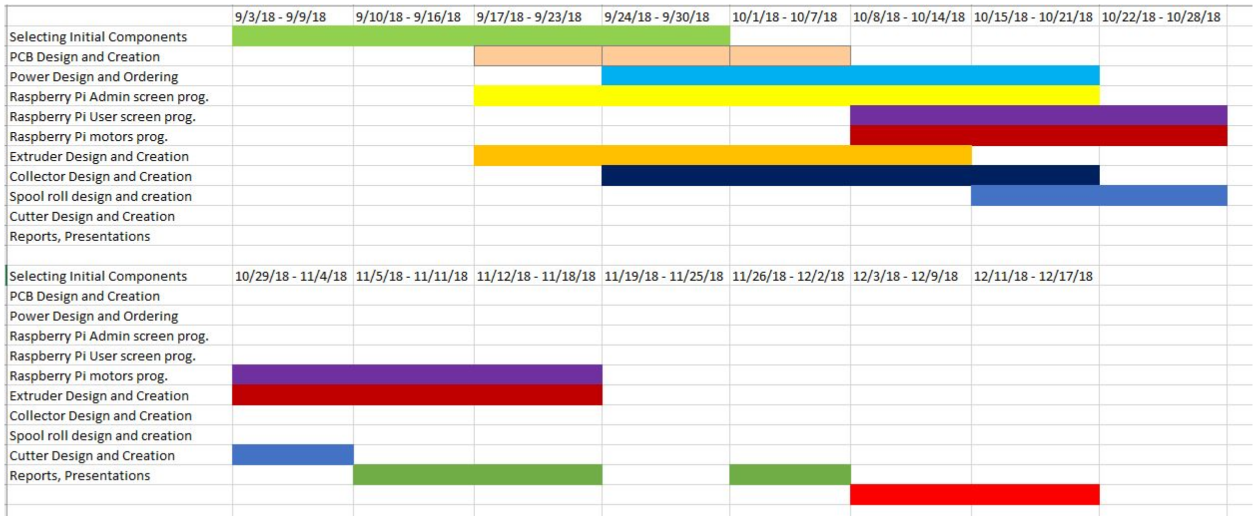

Figure 18: Schedule for Fall Semester

First, initial components were selected and ordered. While mechanical parts were still being selected, the designs for the PCB were made. The PCB was designed using MultiSim and Ultiboard, and when the PCB design was finished, the design file was fabricated.

At the same time that the PCB was being designed, software coding had started, and the mechanical parts were designed. The first software to be written was the functionality for the administrator. While the code was being written, the extruder was designed. The next software piece written was for the functionality of the user and the touch screen. Programming for the motors was also done during this time. While this was being done, the cutter and spool rolls were designed, as well as mounting brackets. Once the PCB, software, and mechanical parts were finished, the semester was closed out by working on presentations.

The spring semester (shown below) wrapped up the programming and mechanical work. We then spent several weeks evaluating and testing the machine. We had to re-design the extruder and driver board again, re-testing until the system worked well. Finally, we spent the week working on our final presentations and reports.

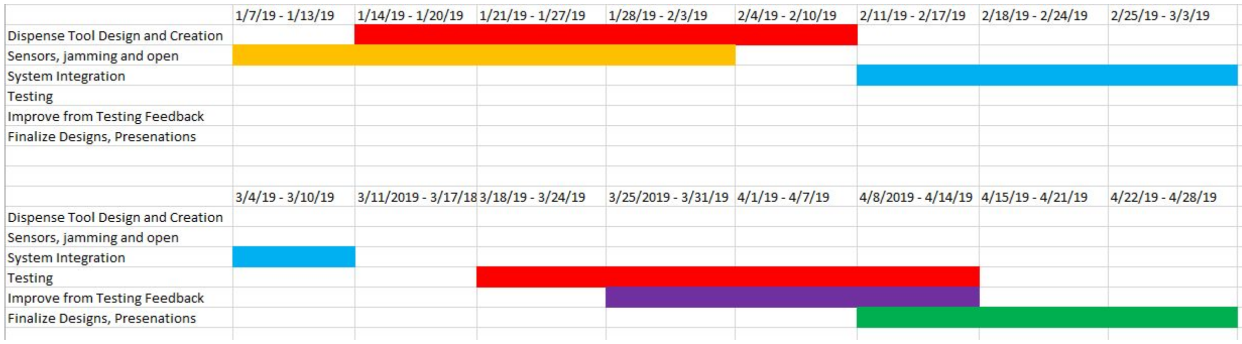

Figure 19: Schedule for Spring Semester

Possible Risks And Risk Management

A few potential risks that we were concerned with was students reaching in box to pull out more solder, injury due to cutter, and students opening the box. These risks were mitigated by creating a tube designed to make reaching into the box impossible. We also implemented an "open-box" sensor that will immediately email ETG that it has been opened.

- Primary Risks
  - Bodily Harm
    - Structure of Output Tube
    - Box-Open Sensor
  - Damage to Device
    - Box-Open Sensor
    - Polycarbonate Enclosure
  - Unauthorized Use
    - Card Scanner
    - Structure of Output Tube

Lessons Learned

We learned much about PCB design and creation, managing time, and fabrication of mechanical components. Below are some of the lessons we learned from this project:

- Triple check PCBs before ordering to save time and money
- The first 80% of the project takes 20% of the total time, the last 20% takes 80% of the time
- Keep designs and codes simple

Conclusion

In conclusion, our project was to create a machine that dispenses approximately 30-40cm of solder for university students. This project was important because students are often working in labs late at night when ETG is closed. If they need solder, they must wait until the next morning to receive some from the ETG department. Installing a solder dispenser machine ensures that students can receive solder at all hours of the day without entire rolls being wasted or stolen.

Our goal was to complete the dispenser, test it, and tune it to where it works with minimal errors. The machine has a clear top, and students are able to see the mechanical and electrical parts, and understand how the machine operates.

We used a Raspberry Pi controller with a 7” touchscreen display to control and extrude solder from the user-selected roll. Four different kinds of solder are present in the machine, and students can decide which type of solder they need based on the information given on the touchscreen.

This project was a learning opportunity for all, and will result in a much-needed machine.

Potential improvements that could be made in the future include jam detection, a coil block, and aesthetic improvements to the dispenser and software.

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