Automatic Solder Dispenser

PROJECT PLAN

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Table of Contents

List of Figures

List of Tables

List of Definitions

ETG: Electronics and Technology Group

ISU: Iowa State University

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

PLC: Programmable Logic Controller

HMI: Human Machine Interface

ID: Identification

1 Introductory Material

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 Proposed Approach and Statement of Work

2.1 Objective of the Task

The objective of this project is to design and create and automatic solder dispenser. This machine can be used by anyone with an Iowa State University ID card to obtain solder. Designs will be included for future scaling purposes, as ETG may wish to create more machines.

2.2 Functional Requirements

The functional requirements are broken up as follows for student and administrator users:

Students

- Display screen will inform students about solder types
- Display screen will allow students to pick a type of solder
- Box will dispense 12-18" of solder from the specified roll
- Box will cut solder piece off before student receives it

- Box will sense if a solder jam has occurred.

Administrators

- Administrators can view solder levels for each roll
- Administrators can inform machine of a changed roll
- Machine will send periodic emails of usage rates and levels
- Machine will send an email when roll has approximately 5% remaining
- Machine will send an email when a jam has occurred

2.3 Constraints Considerations

The total cost of the box should be less than $400. This constraint will limit what components and enclosures we use. The box should be approximately the same size as a standard shoe box, and should have a clear top for students to see inside and understand what is going on inside the dispenser. The user screen should display information about the different solder types available and students should have no issues figuring out how to use the dispenser. None of our practices should be considered unethical, and all code will be neatly written and follow standard coding practices.

2.4 Previous Work And Literature

Leland Harker, our client, had already drawn up and created several mechanical designs, including a solder extruder and servo cutting system. He gave us the assembled Inventor drawings, extruder, and cutter, and we now have to ensure that each will work as intended, as well as designing the other components to integrate seamlessly with it.

An automatic solder dispenser has not been created by anyone in the past. The solution that comes closest is a vending machine used for dispensing electrical components. Our machine is different in that it is free and operates from ISU ID’s. It will also have a completely different inside component design, as the vending machine shown (Figure 1) is a standard snack vending machine while our design is specifically made for solder.

Figure 1: Electronic Parts Vending Machine (Bell, 2018)

Although this project is much different than the vending machine in Figure 1, some features will be similar. For example, in order to show students what is going on inside the dispenser, one of the sides of the enclosure will have a clear surface. More specifically, one side of the enclosure will act as a window that will allow the user to see all of the mechanical and electrical parts functioning together. Allowing the user to see the functionality of the device is similar to how a vending machine has a clear window. All of the electrical parts in the vending machine are visible to the user. Also, the user gets to watch the machine dispense the item that he or she wants. This common feature of vending machines will be implemented in the solder dispenser design as well.

Another feature in vending machines that will also be implemented in the design of the solder dispenser is a mechanism that prohibits the user from reaching in and taking items that he or she did not pay for. In the scope of this project, students should not be able to reach into the solder dispenser and pull more solder from the roll during any part of the process. A common vending machine has a door that the user can open to retrieve the items that he or she paid for. The door, in this case, is designed so that the user cannot reach upwards to take more items. Similarly, the solder dispenser will not allow students to reach into the machine and take more solder than is allowed. The student will only be able to retrieve the solder that the machine dispenses.

Vending machines also require a form of payment before a user can receive an item that he or she wants. This project will implement a similar feature, but instead of using currency to receive the solder, students will swipe their ISU IDs. Additionally, each student can receive solder once every 20 minutes.

Another machine that shares some basic ideas with our project is an automatic paper towel dispenser. When a user waves their hand under the sensor, a specified length of paper towel is dispensed. When the paper towel roll runs out, it must be replaced, and the system must avoid jams as much as possible.

2.5 Proposed Design

We divided this project into three main categories: electrical work, programming, and mechanical work.

Electrical Work

The electrical work will oversee the power requirements for the dispenser, determine which microcontroller is best, design and create a PCB circuit board containing drivers, and determine 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 will be used for cutting the solder, and 4 stepper motors will be used for pulling the solder off of the roll. Each of the 4 stepper motors will control its own extruder. Each extruder will 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, servos, and jam detection sensors. 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 will also help others to understand the project. The board we created is shown below.

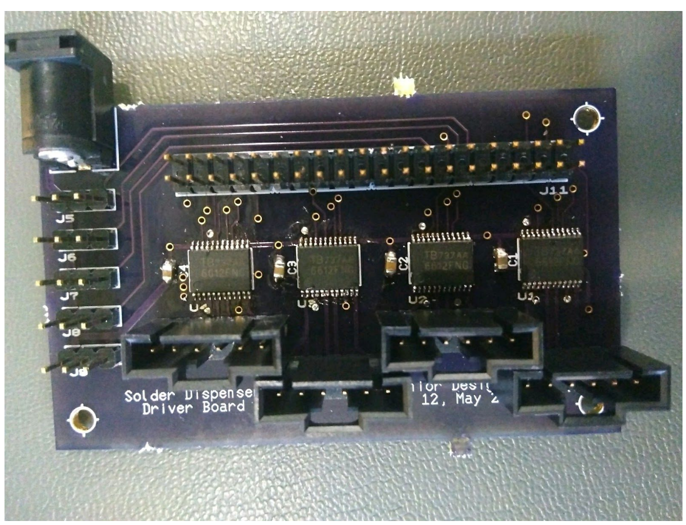

Figure 2: Our Printed Circuit Board

Besides pins for power and servos, the board has pins for future sensors. These 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 will be created to store the ISU card numbers of users, which will be 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 also control both the stepper and servo motors. A 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 team will determine 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 extruder will control the solder on a spool. The extruder has a spring mechanism in order to keep tension on the solder at all times.

Connecting the outputs to the extruders are thin, flexible tubes, 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 do not want the user to have access to the solder until after it is cut. The cutter is made up of two servos, with a design very similar to a cigar cutter (Figure 2).

Figure 3: Guillotine Cigar Cutter (Amazon.co.uk, 2018)

After being cut, the solder will fall into a position that is accessible to the user. 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.

2.6 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.

2.7 Safety Considerations

Safety is important to consider for our dispenser. We have a sharp cutter in motion that could easily do significant damage to appendages if used improperly. To ensure that no user is injured from use or curiousity, the cutter should be inside the box and out of reach.

In order to avoid the safety hassles of dealing with 120V AC, we are using an adapter to bring the voltage down to 5V DC before entering the dispenser.

2.8 Task Approach

Our team discussed a plan of action and created the flowchart seen in figure 3.

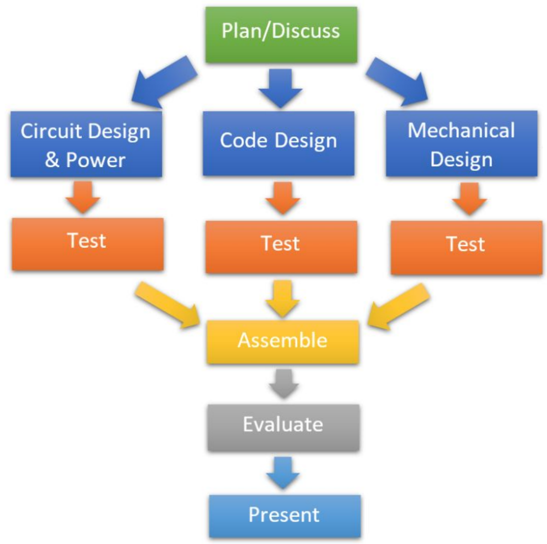

Figure 4: Flowchart of Action

As you can see, we will first go through a planning and brainstorming phase. This will include defining the problem and narrowing down possible solutions. Next we will design the necessary circuits, codes, and mechanical pieces that our solution needs. We will test each section, assemble the pieces together, and evaluate the final product as a whole. If needed we will return to the design process and re-iterate until we have a final product that works as required. Finally, we will present our results.

2.9 Possible Risks And Risk Management

Implementing jam detection for our dispenser could be a challenge. Given our budget of $400, finding a sensor that can accurately determine if a solder stream is present could be tricky. To manage this risk, we are looking at possible mechanical solutions to this issue, as well as electrical sensors.

2.10 Project Proposed Milestones and Evaluation Criteria

Our project can be broken down into the following milestones:

Milestone #1: Decide microcontroller, box, and motors

Projected date finished: 9/18/2018

The first task for this project is to determine which microcontroller to use, what type of box to use, and what motors are needed. This is basic information that is needed to start the heavy engineering work, and we completed it on September 18, 2018. To test the box, designs were created that included estimate sizes of each component needed. We found the smallest box available that could still fit all of our required components. We tested stepper motors and servos with the Raspberry Pi, and ensured each type of motor would work.

Milestone #2: Design and Create PCB Board

Projected date finished: 11/23/2018

The next milestone was designing the necessary drivers for the stepper motors and designing one PCB board that contained all of the electrical devices needed. After designing the PCB board, we soldered the components to it, and tested it. A few minor revisions need to be made, but we were able to run 3 stepper motors through the PCB. Further evaluation will be continued once jam sensors are detected.

Milestone #3: Complete Mechanical Design and Creation

Projected date finished: 12/21/2018

The mechanical design and creation process includes the extruder, cutter, and mounting pieces. These can be tested by hand in many cases, as well as with basic programmed code on the Raspberry Pi. An aluminum extruder is nearly finished, and the cutting device has been tested and confirmed to work. Mounting brackets have been cut from aluminum also. When testing the cutter, solder should be cut cleanly without sticking to the blade. The extruder should pump the solder without damaging it.

Milestone #4: Complete Programming Code

Projected date finished: 2/8/2019

The software with the screens and Raspberry Pi will be testable with the stepper motors and mechanical pieces we will have created by this time. The touchscreen can be tested largely on its own. The projected finish date is February 8, 2019. A basic outline of the program has been created already, and it can control the stepper motors and servos. In order to test the software, we will ensure that each motor and servo is controlled correctly and the administrator functions all work as expected.

Milestone #5: Integrate All Parts, Place in Box

Projected date finished: 3/22/2019

After finishing the other milestones, the last step is to integrate all of the parts together and place them in the box. The entire dispenser will be tested as a whole, and refinements will be made if needed. To test the dispenser, the box will be placed on display where students can operate and use it, giving feedback for improvements afterwards.

2.11 Project Tracking Procedures

Our group has a timesheet that keeps track of weekly goals and success. At the beginning of the week, all members state their goals for what they want to accomplish during the week. They strive to accomplish that goal, and they return to the timesheet at the end of the week. They state what they accomplished, how many hours they worked, and what they need from other members in order to accomplish their next task.

When writing reports, this tracking system makes the process smoother by having detailed information all in one place.

2.12 Expected Results and Validation

Our desired outcome is an automatic solder dispenser that works, does not jam often, and is easy to use. When a rare jam does occur, the machine would be able to realize the jam occurred, and send an appropriate email to ETG. New administrators would be easy to add to the database, and spools would be easy to change and replace. This would be a full turnkey solution, and students would not have issues figuring out how to use the machine. Our validation will come from our client, students, and users.

2.13 Test Plan

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

While the software and mechanical designs are still being completed, simple testing with the motors and servos will be performed to make sure that they will function within the system. When mechanical designs are finished and the parts are made, they can be tested with the electrical components. Testing this will verify 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. Once the programming is complete, the entire system can be integrated and tested. Here, the software will control the system, and we will test the functionality for both sets of users.

Once a successful prototype is built and tested, we will test the dispenser in a real world application. The plan to test the dispenser is to allow users to operate it for several weeks. We will place the dispenser in a popular, public area (For example: TLA in Coover Hall), where students can test the functionality and try to “trick” our machine. Feedback from the students will be recorded in order to improve the dispenser. Any issues will then be fixed. After making improvements to the design, more testing will be done.

Since this dispenser will be used by humans, the best test bench will be a human. If students can easily operate the dispenser without breaking it and without it jamming continuously, this project will be a success.

In short, we will use basic test code to test the extruder and cutter. When those are proven to work, they will be connected through the PCB and re-tested, which will confirm that the PCB works. Lastly the code will be refined and tuned and re-tested. When each component is confirmed to work, the mechanisms will all be integrated together and tested with the final program code.

3 Project Timeline, Estimated Resources, and Challenges

3.1 Project Timeline

Our detailed project timeline is shown in tables 1 and 2. Table 1 shows our fall semester timeline, which includes selecting initial parts, designing the PCB board, completing a majority of the programming work, and designing most of the mechanical pieces. Our goal is to complete as much of this project as possible early on. Since most projects tend to take longer than expected, we figure allocating extra time will greatly help us if we fall behind.

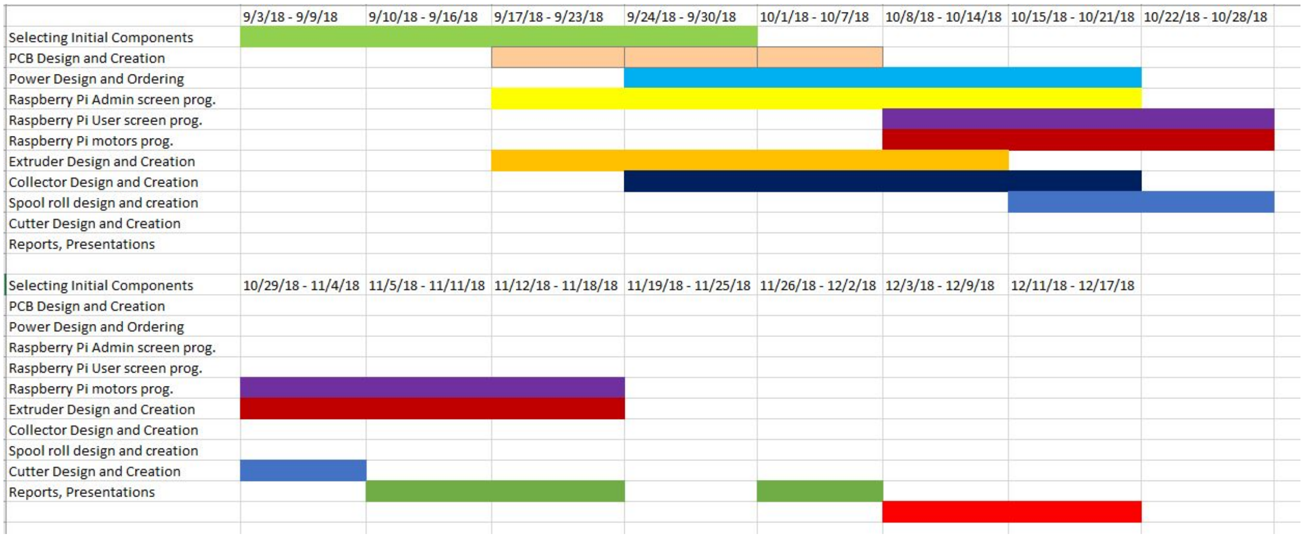

Figure 5: Schedule for Fall Semester

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

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

The spring semester (shown in figure 4) will wrap up the programming and mechanical work. We will then spend several weeks evaluating and publicly testing the dispensing machine. If any parts break or wear out we will re-design and test again until the system works well. Finally, we will spend the last couple weeks working on our final presentations and reports.

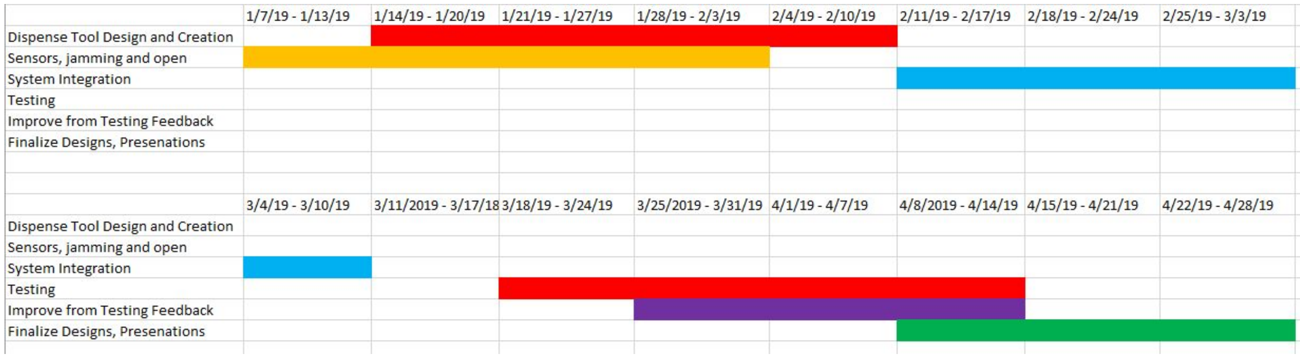

Figure 6: Schedule for Spring Semester

To kick off the second semester, sensors will be implemented to help detect when jams occur. Once the sensors are implemented into the design, the whole system can be integrated. Integrating the system means combining the electronics, software, and mechanical systems in order to form a functioning prototype. When all sections of the project are integrated, testing of the prototype can be performed. After all testing stages are complete, any final refinements can be made. When the team is satisfied with the performance and functionality of the system, the final presentation will be created.

3.2 Feasibility Assessment

We are expected to deliver a fully functioning automatic solder dispenser by the end of the year. The design does not seem too difficult at first glance, but realistically we will likely find that the mechanical side of the project may cause problems. Getting the solder to move smoothly through the dispenser without jamming could be quite a challenge. Then, detecting when a jam has occurred could also present some difficulties. We have considered using a light sensor to determine if the solder physically came out of the dispenser, but that may not work as well as we imagine. Time will be spent on overcoming this challenge once the first mechanical designs are finished.

Figuring out how much solder is left in a roll could also present some challenges. We plan on using a stepper motor and calculating how much solder has been displaced since the roll was installed. Once the roll gets down to approximately 5% of its original length, an email would be sent out to ETG explaining which roll needs changed. We may have to do some slight tuning for this, as we may find that our calculations are slightly off due to slack in the solder. Overcoming this potential issue can be worked on after the PCB is finished. Although the software controls the system and is not yet completed, simple programing can be written to figure out how to detect low solder amounts. When the method for overcoming this issue is finalized, it will then be shared with the programing lead so that it can be implemented with the rest of the software.

Overall the project will likely present some unseen problems, but if we plan ahead and stay on schedule we should be able to handle each one. We should be able to finish this project.

3.3 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	15	Kevin
Spool Roll Design and Creation	15	Justin
Cutter Design and Creation	15	Justin
End of Semester Reports, Presentations	25	Sam
Dispense Tool Design and Creation	30	Kevin
Sensors: Jamming and Opening	20	Trent
System Integration	25	Justin
Testing	8	Zach

Improve from Testing Feedback	30	Jason
Finalize Designs, Presentations	35	Sam

Table 1: Approximation of Time Allocation

Table 1 is only an estimation. As we continue with the project we will likely find that some tasks require much more time while others do not require as much as we suspected.

3.4 Other Resource Requirements

Other than financial resources, our project will need the use of ETG's milling machines for the extruder pieces. We will need aluminum for these parts, as well as a human resource that can operate the mill. We also need a Raspberry Pi and a 7" touchscreen display, which ETG has given us already, along with other miscellaneous parts.

We need all of the mechanical designs and prior attempts of extruders, collectors, and cutters that have been made by members of ETG, along with the proper human resources to help us understand the designs.

We will need access to the proper tools for drilling and screwing our box and components together. Most importantly, we need time allocated from our client and advisor to give insights and clarify issues.

3.5 Financial Requirements

To create the solder dispenser, we will need financial resources for the box, PCB board, magnetic card reader, power supplies, and various sensors, cables, and tubes. The approximate box cost will be $100, the Raspberry Pi $40, and the display screen $20. The waterjet and milling work for the aluminum mechanical parts is free. The other miscellaneous supply costs are unknown at this time, however, our client gave us an approximate budget of $400.

4 Closure Materials

4.1 Conclusion

In conclusion, our project is to create a machine that dispenses 12-18" of solder for university students. This project is important because students are often working in labs late at night when ETG is closed. If they are need of solder, they must wait until the next morning to receive some from the ETG department. Installing a soldering dispenser machine would ensure that students can receive solder at all hours of the day without entire rolls being wasted or stolen.

Our goal is to complete the dispenser, test it, and tune it to where it works with minimal errors. We will then ensure our designs are clear enough that future solder dispenser machines can be created. We will follow our weekly project plan carefully to ensure we stay on schedule and avoid gridlocking each other's work. The machine will have a clear top, and students will be able to see the mechanical and electrical parts, and understand how the machine operates.

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

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

4.2 References

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