

Deliverable C: Problem Definition and Concept Design

Group C1.1

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1 Introduction

For the project of developing a communication pointer, this document addresses the customer feedback to implement the final design. The need statements as well as the target specifications are revised to address the customer's critique. The document then covers the bill of materials, as well as the detailed design and how each component fits together.

2 Client Feedback

During the second client meeting, the client revealed that they preferred the hip-mounted design concept over the all-integrated design concept. As such the team decided to proceed with the hip-mounted design as our primary concept. However, based on the feedback from the client, it was apparent that some changes needed to be made to the final design concepts.

The client revealed the customer cannot move their head too fast due to their disability. In fact, the customer rarely moves their head at all. As such, the acceleration based shut off option for the laser that was suggested cannot be used in the final design concepts. After ideating with the client, we decided on implementing a button that will act as a kill switch for the laser. This button will be operated by the caregivers of the customer. In addition, a timer based shut off option will be used to conserve battery while the laser is in use.

Secondly, the client was okay with part of the device being semi-permanently attached to the glasses frame given that said part was small and light enough. As such, the need statements will need to be revised to account for that.

2.1 Need Statements Revision

Based on the feedback from section 2, some of the need statements had to be revised. Table 1 contains all need statements that were altered. The unchanged need statements will not be reiterated, and instead can be found in Deliverable B Report.

Table 1: Revised Client Need Statements

Number	Old Need Statement	Old Importance	New Need Statement	New Importance
2	The laser can be reliably turned on and off without the use of arms and hands.	5	The laser can be reliably turned on and off without the use of arms, hands, and head motion.	5
5	The product is lightweight.	3	The product mounted on the glasses frame is lightweight.	5
6	The product is small in size.	2	The product mounted on the glasses frame is small in size.	5
18	The mount is easily detachable from the glasses frame.	5	The mount is easily detachable from the glasses frame.	2

2.2 Target Specifications Revision

Based on the need statements from section 2.1, some of the target specification had to be revised. Table 2 contains all target specifications that were altered. The unchanged target specifications will not be reiterated, and instead can be found in Deliverable B Report.

Table 2: Revised Target Specifications

Number	Metric	Old Target	New Target	Unit
2	Product mass on frames	20	12	g
3	Time to mount	30	300	s
8	Product size	2x1x1	6x3x3	cm
16	Time to detach	30	300	s

3 Critical Product Assumptions

Even with the clarifications from client meeting 2, there are still some ambiguities that prevent us from moving forward with the detailed design. As such, some critical assumptions will be made about the product in this stage as follows:

- User's head motion is incompatible with acceleration-based switches: While our client did say that the user did not move their head too fast, no exact acceleration limits were given. It could be that the acceleration is slower than the average human, but still fast enough to support acceleration-based switches. Since we have no way of verifying said sentence however, we will be assuming that the user's head motion is incompatible with acceleration-based switches.
- User's range of head motion is incompatible with position-based switches: Like the previous statement, the exact range of motion for the user's head is currently not known. As such, we will be assuming that the user's range of head motion is incompatible with position-based switches.
- User's glasses are thick and bulky (has its frame cross section dimension between 3x3mm to 5x10mm): While our client assured us that the glasses that the user uses are thick and bulky, they have not confirmed the exact dimensions for us yet. As such, we have assumed a range that we think will capture most glasses that are thick and bulky.
- The bliss board will always be at most 2m away from the user: While talking about the specifications of the bliss board, the client always referred to it generally. Since we have no way to confirm if the general case applies to the user regarding the distance between user and bliss board, we will assume that it does.

The client mentioned that they will have more information ready for us by client meeting 3. With the added information, we plan on reviewing said assumptions to ensure that they are all valid.

4 Detailed Design

The overall system includes a glass mounted part and a hip mounted part as seen in Figure 1. A glass mounted casing will hold the laser, accelerometer, and power button. A hip mounted pack will carry a battery and Arduino. A wire will be configured to connect them both.

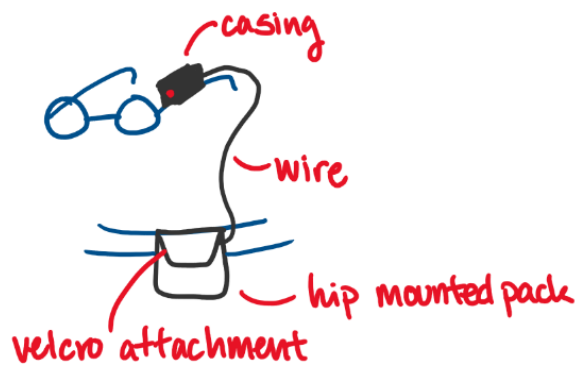


Figure 1 System Design

While the overall design stayed true to what was proposed in Deliverable B, the subsystems themselves had to be modified severely. As such, each subsystem will be covered again from scratch in the following sections.

4.1 Laser Hardware Detailed Design

This subsection will rely on a battery-powered Arduino to control and power a laser diode and an accelerometer. In addition, the subsystem will be connected to a kill switch for convenience. The Arduino and battery will be hip mounted, while the accelerometer, laser diode and the kill switch will be mounted on glasses frames. Once all components are connected, the final circuit diagram will match Figure 2. Note that a breadboard is only used to convey the electrical connections more clearly and does not represent the final product.

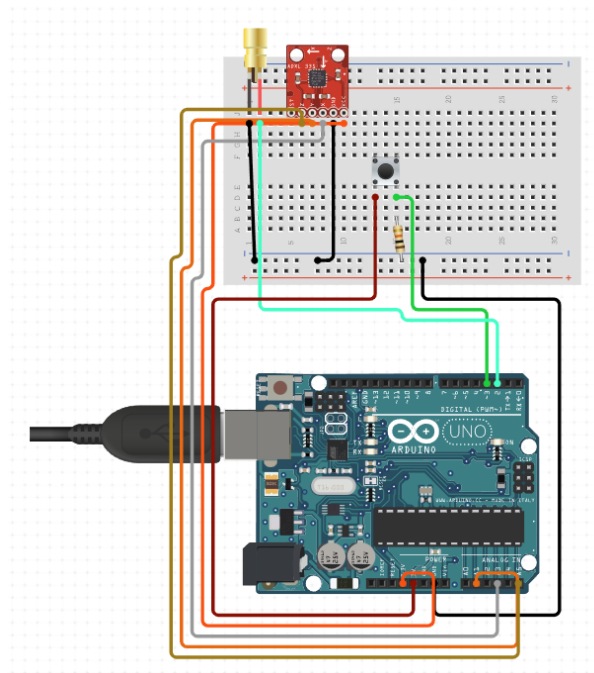


Figure 2: Overall Laser Hardware Circuit Diagram

4.1.1 Power Source

The battery used in this subsystem is a small 5000mAh Mini Power Bank [1]. This power bank was chosen since it can deliver 5V DC power over USB directly to the Arduino. The power bank will be connected to the Arduino using the serial power port on the board as shown in Figure 3.

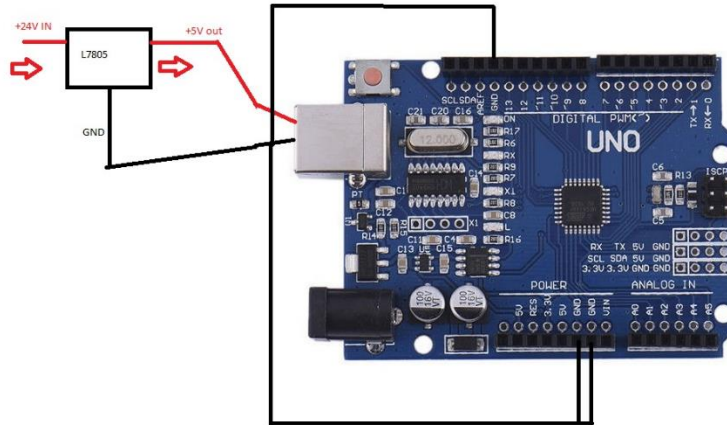


Figure 3: Battery Pack Circuit Diagram

4.1.2 Laser

The laser used in this subsystem is a simple cat toy 5mW red dot laser. This laser was chosen since it is the most cost effective while matching requirements. The laser will be connected to the Arduino as shown in Figure 4.

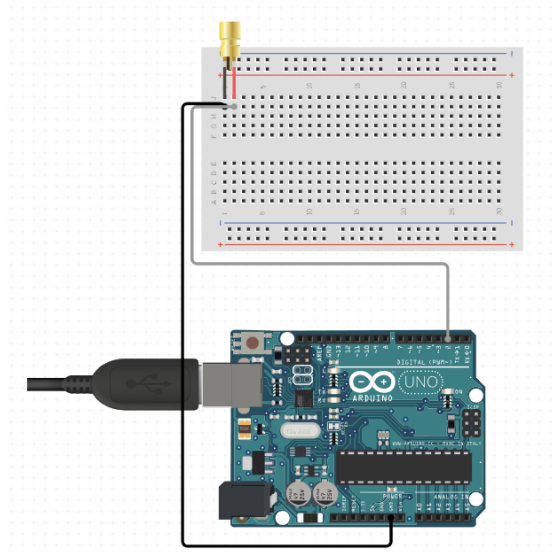


Figure 4: Laser Circuit Diagram

The laser will be operated using the digital pin that will be controlled by the software in section 4.2.

4.1.3 Accelerometer

The accelerometer used in this subsystem is a MPU-6050 [2]. This accelerometer was chosen since it is the most popular accelerometer that can be directly interfaced with the Arduino. The accelerometer will be connected to the Arduino using various pins as shown in Figure 5.

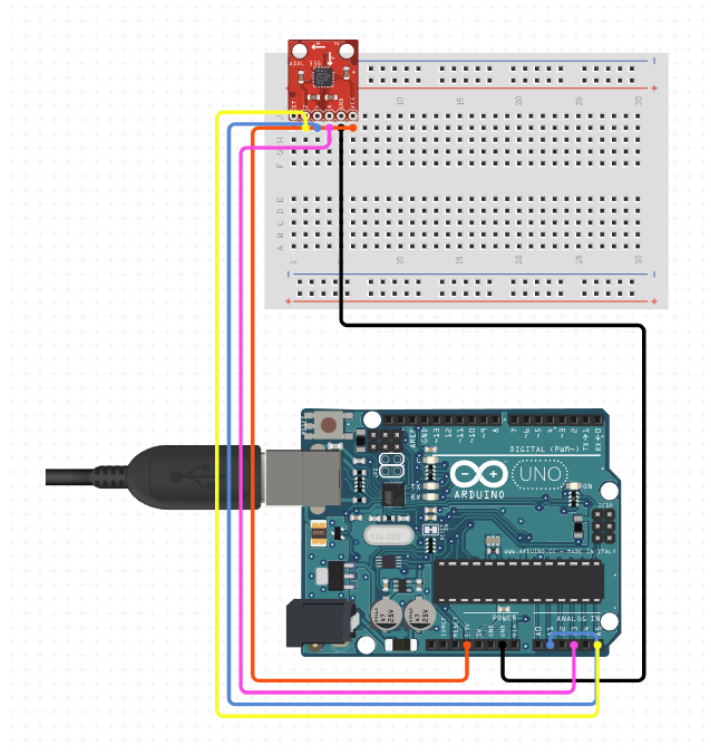


Figure 5: Accelerometer Circuit Diagram

Figure 5 shows the following connections:

- Power for the accelerometer (V_{CC}) is connected to the 5-volt pin of the Arduino,
- X, Y, and Z output ports are connected to the analog pin which sends the data to the Arduino to be processed and,
- the ground pin is connected to the Arduino's ground.

The accelerometer will allow the user to turn on the laser for 4 minutes after their first head movement. For more information on how this is achieved, please consult section 4.2 (software design section).

4.1.4 Kill Switch

The kill switch used in this subsystem is a tactile button [3]. A standard button was chosen since the kill switch will be operated by the caretaker of the customer, who is assumed to be an able-bodied person. The button will be connected to the Arduino with the help of a pull-up resistor as shown in Figure 6.

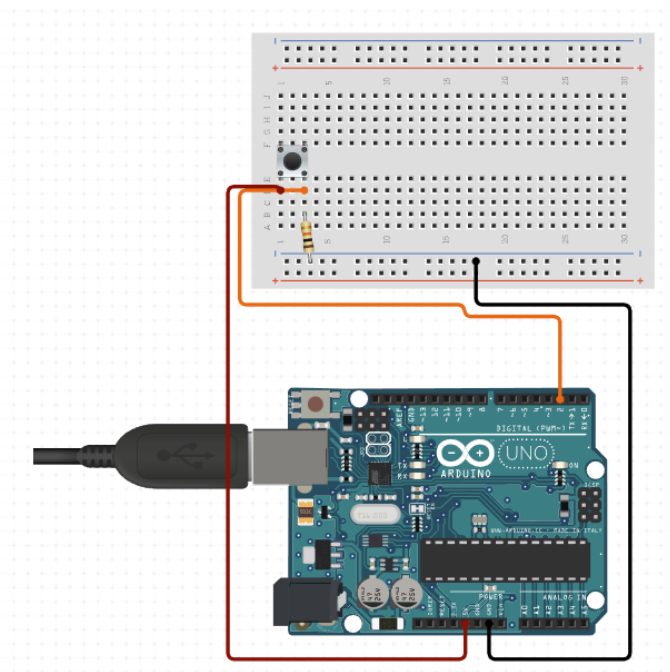


Figure 6: Tactile Button Circuit Diagram

The kill switch will act as a digital master switch which will allow it to disable the operation of the laser using motion. For more information on how this is achieved, please consult section 4.2 (software design section).

It is important to note that this circuit design relies on the pull up resistor to allow the button to act as if it is in the high state when the button is not pressed. The circuit is simply the power connected to the 5V data pin of the Arduino, the digital pin and the ground connected to ground closing the circuit.

4.2 Laser Software Detailed Design

This subsection will be responsible for controlling the operation of the laser and will consist of purely software. The software will be handling the on-off feature for the laser by polling inputs from both the accelerometer and the kill switch.

Once movement is detected by the accelerometer, the program will turn on the laser for 4 minutes after the last movement (provided that the kill switch is disabled). This will be achieved by using a 4-minute timer that will shut off the laser after 4 minutes. If movement is detected after the laser shuts down, the timer will reset, and this cycle will repeat indefinitely.

If the kill switch is pressed at any point during the process mentioned above, an interrupt will occur which will stop all loops and turn off the laser if necessary. Pressing the kill switch again will restart the loop.

The whole process of events is visualized in Figure 7 with the help of an activity diagram. All activity inside the blue dotted rectangle is controlled by the accelerometer and all activity outside the blue dotted rectangle is controlled by the kill switch.

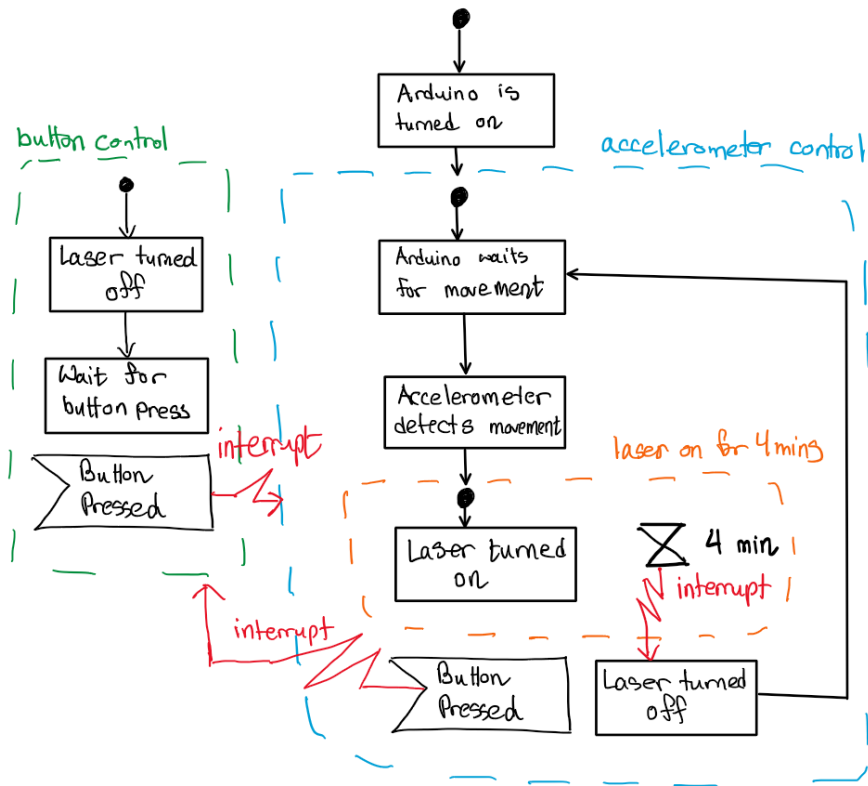


Figure 7: Laser Software State Machine

4.3 Glasses Mounted Casing Detailed Design

This subsystem will allow the user to point with a laser using their head and consist of a casing that will be mounted to one temple of the user's glasses. This casing will hold the laser, accelerometer, and power button. In addition, the casing must contain any necessary wiring between the three parts. It is to note that since the components will be wired to a hip mounted battery pack, the casing must have an opening to allow the wire to run externally. The general design includes a front side from which the laser light will point, a top side where the button will be placed, the back side from where the wire will be fed out of the casing, and a chosen (right/left) side on which the mounting clips will be attached (Figure 8).

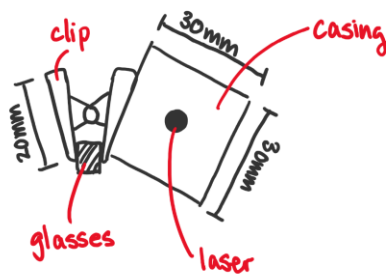


Figure 8. Front view of glasses mount

The casing will be 3D printed to allow for its specific detailed design and low cost. The outer dimensions of the final assembled casing will be 55mm x 30mm x 30mm. To allow for assembly, the casing will be printed in two parts, a hollow rectangular prism open at one end, and a similar piece of shorter length (Figure 9). The first piece will have outer dimensions of 45mm x 30mm x 30mm and the second will have dimensions of 10mm x 30mm x 30mm. The thickness of the walls of both of these parts will be 5mm. These two parts will be glued together after the accelerometer and wiring is completed as the inside will not have to be accessed after assembly.

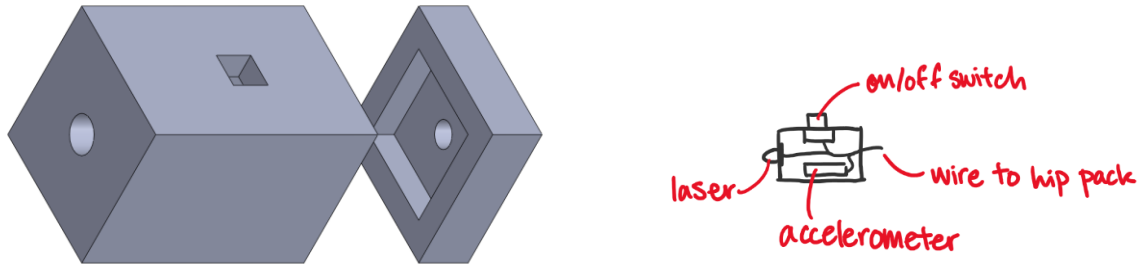


Figure 9. Top Casing

The first piece will act as the frontal piece as seen in Figure 10. The front side (end of rectangular prism) of the casing will be designed to have a circular opening of 6.5mm in which the laser will be placed. If budget allows, this hole may be increased to approximately 8mm to insert a rubber gasket between the laser and casing. This would allow for dampening of some of the expected laser vibrations and allow for secure attachment. The top side will also have a square opening of 7mm x 7mm in which the power button will be inserted. The second piece will act as the back cap of the casing as seen in Figure 11. The inner dimensions of this piece must allow the accelerometer to be inserted and have clearance for wiring. A 5mm diameter hole will be designed at the back of the casing for the wires to be fed out of the casing.

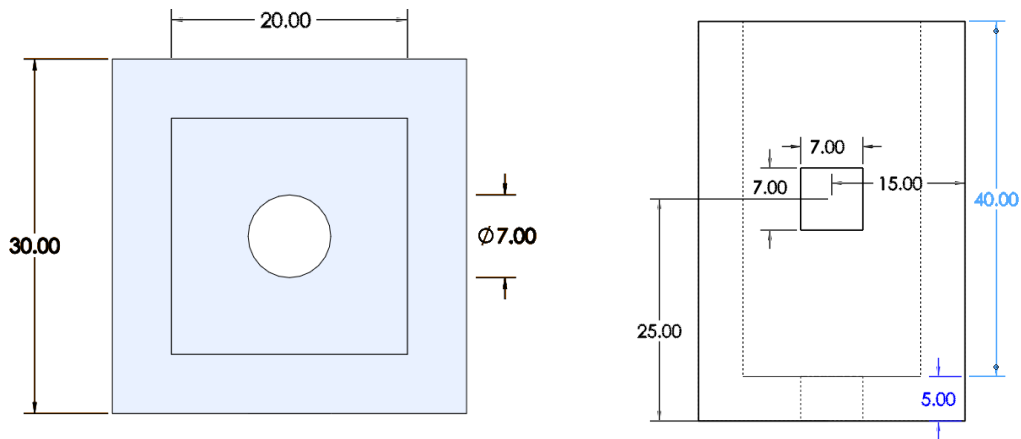


Figure 10 Top piece 1 dimensions

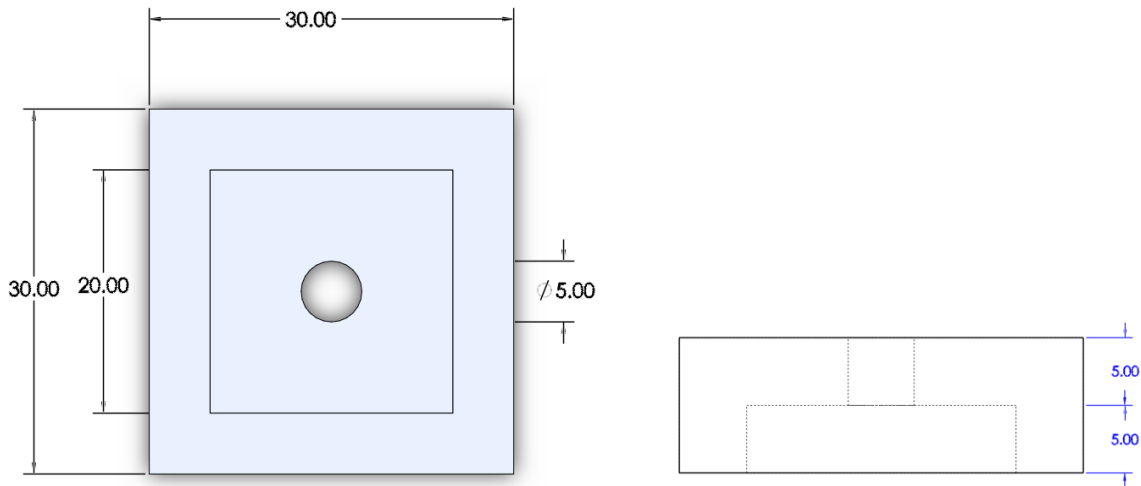


Figure 11 Top piece 2 dimensions

Since everything contained in this design of the glasses mounted casing is lightweight, clips with grip may be used to mount the casing to the glasses. These clips will be fixed to a chosen side of the rectangular prism (right or left) with the use of available appropriate adhesive. Preferably, 3 clips of 6mm width will be used. Additional clips may be used to secure the wires into place along the glasses and on clothes. This will prevent wobbling of the laser if a wire is tensioned during user movement.

4.4 Hip Mounted Detailed Design

This subsystem will reduce the weight on the glasses and will consist of a pouch that will be mounted on one's hip. The pouch will hold a rechargeable battery pack and an Arduino. The pouch will be purchased as is and will include a belt hoop to allow mounting to the hip. It may also be placed elsewhere if desired.

A hard casing will be required to protect the Arduino from damage. Therefore, a simple 3D printed casing will be designed as seen in Figure 12, Figure 13, and Figure 14. The casing will be a hollow rectangular prism in which the Arduino may be inserted. The casing will be mounted in two parts according to the design pictured in Figure 12 [4]. This design will allow removal of the Arduino if necessary. The design will be adapted to include an opening of 15mm x 15mm to allow the power cable out of the casing as seen in Figure 12. The placing and size of this opening is in accordance with the dimensions of an Arduino Uno's [5]. The dimensions of the whole casing are 70mm x 90mm. Dimensions in the initial designs may easily be changed to account for clearances.

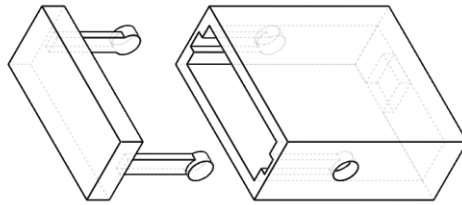


Figure 12 Arduino casing

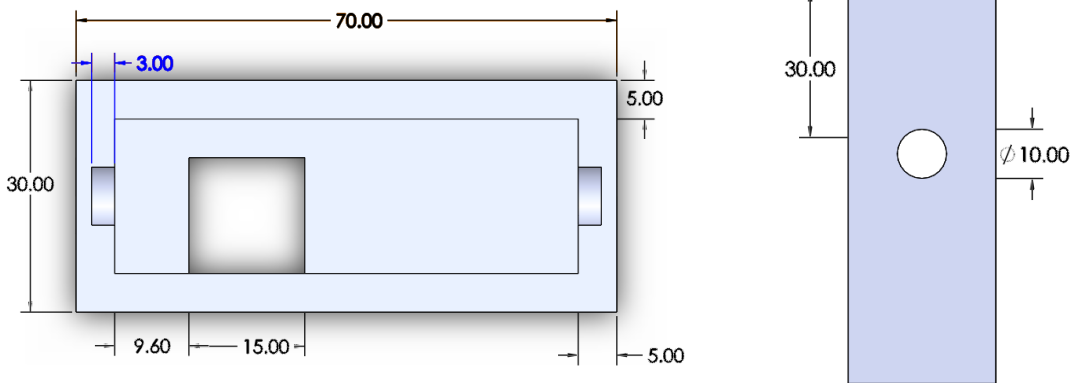


Figure 13 Arduino casing piece 1

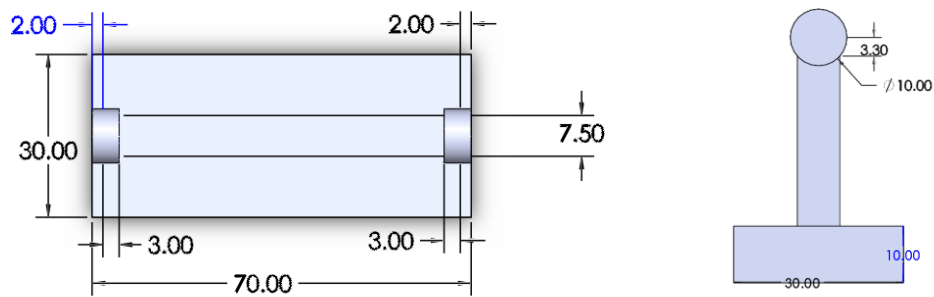


Figure 14 Arduino casing piece 2

5 Implementation Process

In this section, a crude plan was constructed to help ensure that the project is completed in time. To help with this, a list of all the skills and resources needed was aggregated in section

5.1. Next, an outline of the three prototypes was presented in section 5.2. Finally, the project plan is presented using a Grant chart in section 5.3.

5.1 Prerequisites

This section contains a list of skills and resources that will be required to make the final product.

5.1.1 Laser Hardware Development

Table 3: Laser Hardware Skills and Resources checklist

Skills		
Name	Assigned To	Currently Achievable
Soldering	Issac Soward	Yes
Wiring	Issac Soward	Yes
Resources		
Item	Current Status	
Arduino Uno	Approval Pending	
Power Bank	Approval Pending	
Accelerometer	Approval Pending	
Laser	Approval Pending	
Tactile Button	Approval Pending	
Soldering Station	Obtained (MakerSpace)	

5.1.2 Laser Software Development

Table 4: Laser Software Skills and Resources checklist

Skills		
Name	Assigned To	Currently Achievable
Arduino Simulations	Symoom Saad	Yes
Arduino Coding	Aidan Charles	Yes
Resources		
Item	Current Status	
Simulation Software	Obtained (TinkerCAD)	
Arduino Uno	Approval Pending	

5.1.3 Glasses Mounted Casing Development

Table 5: Glasses Mounted Casing Skills and Resources checklist

Skills		
Name	Assigned To	Currently Achievable
3D Modeling	Ena Piercy	Yes
Assembling 3D printed parts	Ena Piercy	Yes
Resources		
Item	Current Status	
Grip Clip	Approval Pending	
3D Modeling Software	Obtained (SolidWorks)	
3D Printer	Obtained (MakerSpace)	

PLA	Obtained (MakerSpace)
Adhesive	Obtained (MakerSpace)

5.1.4 Hip Mounted Subsystem Development

Table 6: Hip Mounted Subsystem Skills and Resources checklist

Skills		
Name	Assigned To	Currently Achievable
3D Modeling	Marie Nelly Mbungu	Yes
Assembling 3D printed parts	Marie Nelly Mbungu	Yes
Resources		
Item	Current Status	
Pouch	Approval Pending	
Power Bank	Approval Pending	
3D Modeling Software	Obtained (SolidWorks)	
3D Printer	Obtained (MakerSpace)	
PLA	Obtained (MakerSpace)	

5.1.5 Reflection on Skills and Resources available

On the electrical and coding side both Isaac and Aidan have knowledge of both circuit construction and Arduino based projects. In particular, Aidan has made multiple projects using Arduinos and Isaac has designed and soldered various circuits for personal projects. Furthermore, Symoom has used tools like TinkerCad and other Arduino simulation software, so he is able to rapidly test the design of the product perform physical prototypes start. As for the resources, we have access to the maker lab as well as personal electrical equipment like multimeters, wires, Arduino components etc.

To manufacture the casings of the product, 3D printing is required. This requires a CAD model and a 3D printer. The two mechanical engineering members have experience with CAD, specifically SolidWorks, which will allow for the design of the casings. In addition, 3D printers and the needed materials (PLA) are available for use at Makerspace and MakerLab.

Considering that the casings have relatively simple geometries, the CAD design will not require excessive time. A few hours maximum will be sufficient. Since the 3D printed parts are relatively small and hollow, the printing time is estimated to be 4 hours total. It is assumed that Makerspace has all required printing material and the 3D printers available.

5.2 Procedure

This section will cover the procedure that will be followed to develop a working final product. This will be done with the help of the three different prototypes to test the various target specifications our product has to obtain.

5.2.1 Prototype 1 (Electrical)

As there is no budget for this prototype, it makes sense to purely conduct this prototype using simulations. Since the results of an electrical simulation is more meaningful than a mechanical one for our product, our first prototype will test the electrical characteristics of our laser hardware and software subsystem.

This prototype will test the power consumption of the laser software subsystem to ensure that our target specification for battery life is met. Since the target specification is 10 hours of operation, we will need to ensure that the battery chosen for this project is indeed the correct one. This will be done by using the voltmeter and ammeter in the simulation to calculate the power required by the subsystems and extrapolating that information to 10 hours.

This prototype will be built and simulated on TinkerCAD. A primary reason for this is that TinkerCAD is free and has the ability to simulate Arduino code as well, which are both requirements for this prototype.

5.2.2 Prototype 2 (Mechanical)

For this prototype, we will be manufacturing and testing tolerance of the glasses mounted casing and the Arduino casing. Since we will need to wait for the BOM to be approved and the components to be shipped before we can start working on this prototype, it makes sense to delay this prototype to be the second one.

This prototype will test the following metrics:

- Product mass on frame: This can be done by weighing the assembled product and ensuring that it is under 12g. There are weighing machines in MakerSpace that can be used to achieve this.
- Glasses mounted casing size: This can be done by measuring the dimensions of the assembled product and ensuring that it is under 2cm x 1cm x 1cm. There are vernier calipers in MakerSpace that can be used to achieve this.
- Arduino casing size: This can be done by measuring the dimensions of the assembled product and ensuring that it is under 8cm x 9cm x 4cm. There are vernier calipers in MakerSpace that can be used to achieve this.
- Water Resistance: This can be done by modifying a well-documented testing procedure to fit the equipment available to us and ensuring that it reaches IPX-1 [6].
- Time to recharge batteries: This can be done by taking the average of all attempts at recharging the battery and ensuring that it is under 120s.

5.2.3 Prototype 3 (Integration)

For this prototype, we will be integrating all subsystem to form a high-fidelity final prototype. Since this prototype will be completed close to Design Day, it makes sense to conduct a high-fidelity prototype to ensure that everything works as intended and made adjustments if required.

This prototype will test the following metrics:

- Laser stability: This can be done by measuring the delta between target and deviation of pointing operations and ensuring that it is under 5 cm.
- Activation sensitivity (error rate): This can be done by taking the average of how many times the laser failed to activate when required and ensuring that it stays within 15%
- Time to mount and Time to detach: This can be done by taking the average time of all attempts at mounting and detaching the casing form the frame and ensuring that it is under 300 s.
- Time before discomfort: This can be done by performing various everyday tasks with and without the product on and noticing if/how the product hampers said operations. Since it is unreasonable for someone to test for 12 straight hours, the tests will be limited to 10 minutes. The results of these test will then be extrapolated to give us a conclusive answer.

5.3 Project Management

This section contains a snapshot of the procedure we will try to follow from the creation of prototype 1 to creation of the final product. Note that the dates are subject to change as they are highly dependent external factors such as BOM approval, shipping dates and availability of MakerSpace.

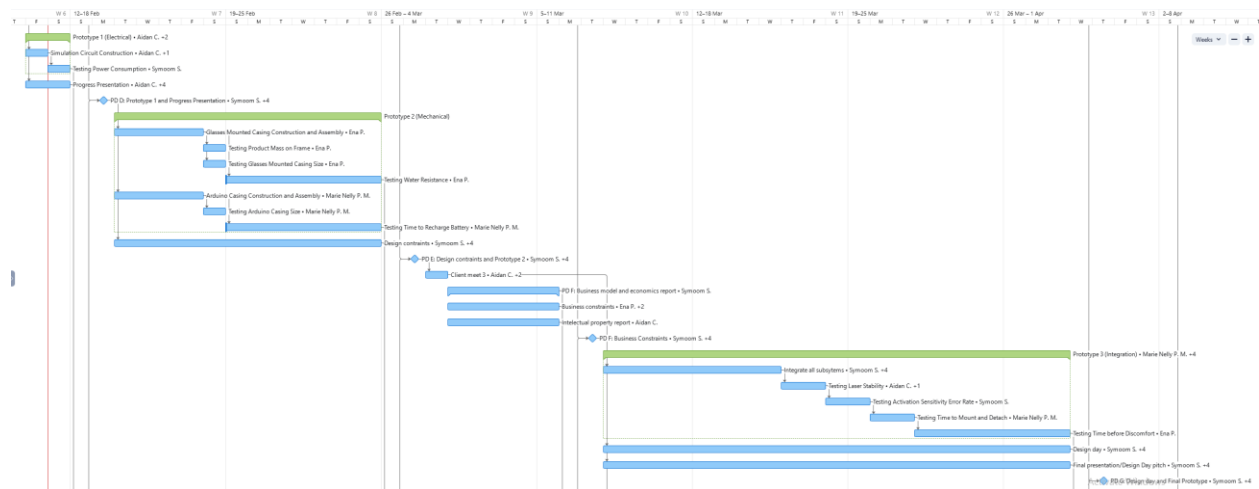


Figure 15: Proposed Project Plan

The snapshot was taken from the Gantt chart view of our project plan from Wrike. The prototype parent tasks have a different (green) color to increase readability.

Notice that even though the individual tests are not dependent on each other, they must be done in series. This is because we will be constructing only one of each prototype and as such the availability of said prototype was accounted for in our project plan.

6 Bill of Materials (BOM)

A List of Parts and Bill of Materials for both a fully functional prototype and a proof-of-concept prototype is shown below in Table 7 and Table 8. The fully functional prototype BOM includes all needed parts for a prototype that the client can use immediately while the proof of concept BOM does not include the pouch or the battery pack. This is because the product would still function without the pouch and a different power source may be used for simply testing the product.

Table 7 BOM: Fully Functional Prototype

Item #	Item	Purchase location	Quantity	Link	Price (CAD)
1	Arduino Uno	MakerStore	1	https://makerstore.ca/shop/ols/products/arduino-uno-r3	17.00/piece
2	Accelerometer	Amazon	1	https://www.amazon.ca/Gikfun-MPU-6050-Accelerometer-Gyroscope-EK1091x3C/dp/B07JPK26X2	15.89/3 pieces
3	Laser	Petsmart	1	https://www.petsmart.ca/cat/toys/interactive-and-electronic/whisker-city-laser-cat-toy-5305543.html	5.99/piece
4	Battery	Amazon	1	https://www.amazon.ca/EnergyQ-C-Portable-Charging-External-Compatible/dp/B0B117KWXZ/	22.99/piece
5	Button	MakerStore	1	https://makerstore.ca/shop/ols/products/tactile-button-switch-6mm-x-20-pack	5.00/20 pieces
6	Wire	Makerspace	N/A	N/A	0
7	Solder	Makerspace	N/A	N/A	0
8	PLA	Makerspace	N/A	N/A	0
9	Clips	Amazon	5+	https://www.amazon.ca/ONLYKXY-Non-Slip-Alligator-Lanyards-Accessories/dp/B08LGGBDGY	14.29/30 pieces
10	Adhesive	Makerspace	N/A	N/A	0
11	Pouch	Amazon	1	https://www.amazon.ca/Azarxis-Tactical-Smartphone-Cellphone-Attachment/dp/B09D7Q64QF	14.99/piece
Total cost=					96.15 + tax
Total cost by piece =					68.90 + tax

Table 8 BOM: Proof of Concept Prototype

Item #	Item	Purchase location	Quantity	Link	Price (CAD)
1	Arduino Uno	MakerStore	1	https://makerstore.ca/shop/ols/products/arduino-uno-r3	17.00/piece

2	Accelerometer	Amazon	1	https://www.amazon.ca/Gikfun-MPU-6050-Accelerometer-Gyroscope-EK1091x3C/dp/B07JPK26X2	15.89/3 pieces
3	Laser	Petsmart	1	https://www.petsmart.ca/cat/toys/interactive-and-electronic/whisker-city-laser-cat-toy-5305543.html	5.99/piece
5	Button	MakerStore	1	https://makerstore.ca/shop/ols/products/tactile-button-switch-6mm-x-20-pack	5.00/20 pieces
6	Wire	Makerspace	N/A	N/A	0
7	Solder	Makerspace	N/A	N/A	0
8	PLA	Makerspace	N/A	N/A	0
9	Clips	Amazon	5+	https://www.amazon.ca/ONLYKXY-Non-Slip-Alligator-Lanyards-Accessories/dp/B08LGGBDGY/	14.29/30 pieces
10	Adhesive	Makerspace	N/A	N/A	0
Total cost=					58.17 +tax

In Table 7, the total cost is calculated as purchased as well as per piece which does not include the cost of the unneeded parts that are bought in bulk. As can be seen in Table 7, the total price is much greater than the 50 CAD budget for this project. However, it is requested to increase this budget due to the portable battery pack that is crucial to the client and the bulk components that are increasing the cost. A great effort was made to find parts of lower cost; however, these were not available in the time frame needed for this course. In addition, the use of Makerspace materials was also incorporated to decrease the total cost. It is therefore needed to increase the budget to allow for the addition of the pouch and the battery pack to allow for portability and for the client to be able to use the product comfortably.

7 Conclusion

This deliverable outlined the changes in the project based off client interaction, reassessment of needs and specifications, and provides a detailed design along with anticipated costs. Using feedback related to preferred design options presented to the client and discussing more about feasible abilities of the user a final detailed design was created. This added functions such as the on/off switch that impacts all aspects of the project. However, with this new information a complete 3D model of casings could be created, circuits could be designed, and the functionality of software could be modeled. Added to this detailed design we could judge what skills and tasks would be required to create the final prototype and determine whether team members had enough skills to complete them. Further, a list of necessary materials and purchase locations give a rough estimate of final development costs. With this information on hand a outline of planned prototypes was created to test our final design.

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