GNG2101

Design Project User and Product Manual

Communication Pointer Mounting Device

Submitted by:

Fraymers (Group C1.1)

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March 26, 2023

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Table 1. Acronyms

Acronym	Definition
USB	Universal Serial Bus
3D	3 Dimensional
CAD	Computer Aided Design
PLA	PolyLactic Acid (Plastic filament material in 3D printing)
BOM	Bill of Materials
STL	STereoLithography File Format Family (File type for 3D printing)
SD	Secure Digital (Flash memory card)
MDF	Medium Density Fibreboard
SVG	Scalable Vector Graphics File Format (File type for laser cutting)
VCC	Voltage at Common Collector
GND	Ground
SDA	Data Line
SCL	Clock Line
IDE	Integrated Development Environment
LED	Light Emitting Diode

A comprehensive list of all components and their explanation already exists in Table 2. As such, to reduce redundant information, a separate table of glossary will not be included in this section. Please refer to Table 2 should you require assistance with the nomenclature used throughout this document.

1 Introduction

This document serves as both a user manual and a product manual for the communication pointer device that we developed for GNG2101 during the Winter 2023 term. Our product Fraymes exists to allow users with limited hand mobility to interface with Bliss-Boards more effectively using their head. This is done by utilizing a laser that can be mounted on the user's glasses or headband, which will allow them to simply look at the element that they wish to point towards. In addition, our product is powered by a rechargeable battery and includes a motion activated switch. For further details on our product and Bliss-Board, please refer to Section 2.

The user manual portion of this document consists of Sections 2, 3, 4 and 5. The user manual aims to inform the user on what the product is, how to use the product and what steps to take should an issue arise. This section is mainly written in an informal manner by directly addressing the user. This was done in an attempt to make the user manual more approachable.

The product manual portion of this consists of section 6. The product manual aims to document the whole design process to enable the more tech savvy individuals to replicate our product should they wish to do so. This includes a list of parts required and detailed steps on how to build and assemble the several components into one cohesive product.

In addition, section 6.4 outlines our own design process that we followed to ensure that the final product meets the standards that we set out to achieve. This is done by documenting all our prototypes and their test results. To summarize, our product met all critical target specifications. However, Section 7 contains further details on how to improve some of the non-critical target specifications that were not met.

This project was a great learning experience for us as a team, and we hope this document proves to be useful to you as well.

2 Overview

It is estimated that 16% of the world's population experiences significant disability [1]. Although society is getting better at accommodating such individuals, more can, and should, be done. That is why our product Fraymes exist. We wanted to develop a way to improve our user's communication method that would be both effective and emancipatory.

Our user is an individual who uses Bliss-Board to communicate. Bliss-Board is a low-tech communication tool that is commonly utilized by non-verbal or speech impaired people. It involves pointing to various elements, which can be either simple images or complex words, that are printed on the board. Unfortunately, Bliss-Board requires precise hand movements, which is something our user struggles with due to their limited hand mobility. As such, if our user wants to communicate more effectively, they will require an alternate way to interface with the board.

Fraymes aims to do just that. Instead of using their hands, our user can use their head to point at the various elements on the Bliss-Board with the help of our battery-powered, head-mountable laser source. It is a cheaper, and a better, alternative to existing products in the market [2] [3]. Some of the improvements over our competition include:

- Uses a rechargeable battery: Not only is the battery rechargeable, but it can be charged using a USB-A phone charger, thus streamlining the charging process.
- Includes a head-motion activated switch: Having a process to shut-off the laser when no movement is detected allows our product to be more emancipatory than its counterparts.

Our product is organized into two subsystems: the head-mounted subsystem and the hip-mounted subsystem. The blue casing in Figure 1 makes up the head-mounted subsystem. The brown casing is a main component of the hip-mounted subsystem.

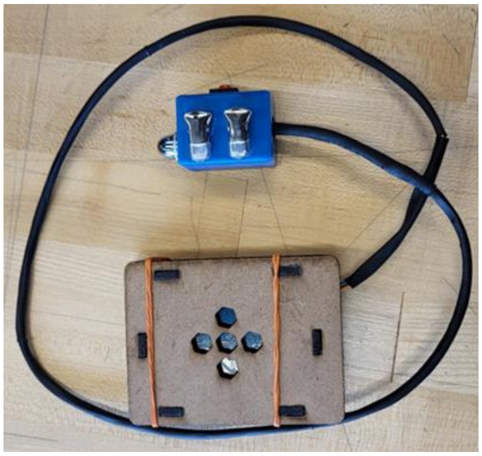


Figure 1 Final Product without Add-ons

In an effort to reduce redundant information, the two subsystems will only be summarized briefly here. For more information on the elements of each subsystem, please refer to Section 2.1.

The head-mounted subsystem has two functions. It allows the user to point the laser using their head. It also allows the product to take in input from the user via a tilt-sensor (gyroscope) and a kill switch. For more information on this subsystem, please refer to Section 3.4.1.

The hip-mounted subsystem houses the remaining components of the product. Among those is the hip-mountable casing, which houses the Arduino Uno. Arduino Uno is responsible for determining whether the laser should be toggled on or off based on the input from head-mounted subsystem. For more information on this subsystem, please refer to Section 3.4.2.

Figure 2 visualises a simplified block diagram that showcases a very high-level view of the architecture of our product.

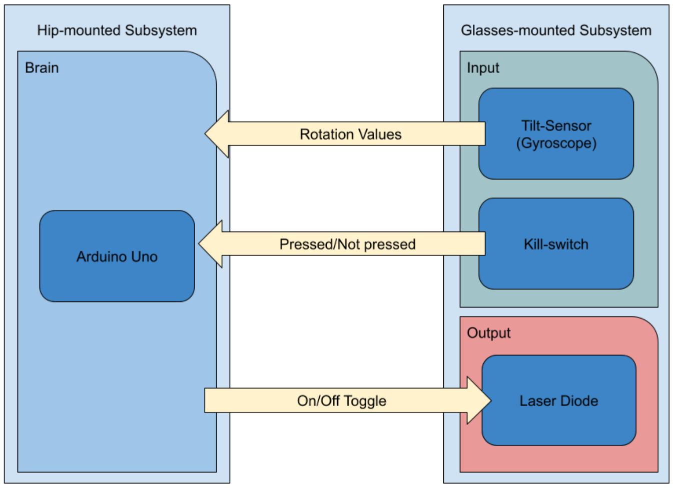
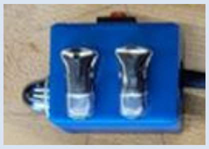


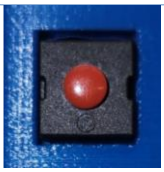
Figure 2 Simplified Block Diagram of Product's Architecture

2.1 Conventions

This section of the user manual contains a table to enumerate all parts that make up the final product. Each entry will be accompanied with a picture for reference. Please familiarize yourself with the terminology used in this table as the conventions established here will be used throughout the rest of the user manual.

Table 2 List of Terminology

Part	Definition	Reference Image
Head-mounted subsystem	Head-mounted subsystem refers to the blue casing and all its contents. For a short description, please refer to Section 2. Synonym: Glasses mounted component	

Kill-Switch	Kill-switch refers to the red button located on top of the head-mounted subsystem. It is used to completely turn of the operation of the laser. *Synonyms*: Button; Master-Switch	
Tilt-Sensor	Tilt-Sensor refers to the sensor that is responsible for detecting movement. It is used to turn on the laser when required. Note that the sensor is not visible to the user as it is inside the blue casing. *Synonyms*: Gyroscope	
Clips	Clips refer to the two grip-clips attached to the side of the blue casing. It is used to attach the head-mounted subsystem to the frame of the user's glasses.	
Hip-mounted Subsystem	Hip-mounted subsystem refers to the pouch and all its contents. For a short description, please refer to Section 2. *Synonyms*: Pouch Subsystem, Hip mounted component	
Pouch	Pouch refers to the black hip-mounted pouch that holds the holds the hip-mountable casing and battery. It is to be attached to a belt during operation.	
Battery	Battery refers to the potable power bank that powers the whole product. It can be charged using the USB-C charging cable that is included in the product.	
Hip-mountable casing	Hip-mountable casing refers to the brown casing that houses the Arduino Uno. The top of the casing is detachable for easy access to the Arduino Uno. *Synonym*: Arduino casing, Brown casing	
Arduino Uno	Arduino Uno is the microcontroller used in this product. It acts as the brains of the system by when the laser needs to be turned on or off. *Synonym*: Microcontroller	
Power Cable	Power cable refers to the cable that powers the whole system. It does so by connecting the battery (USB Type A head) to the Arduino Uno (Micro Type B head). *Synonym*: Blue cable	
Cable	Cable refers to the black cable that connects the head-mounted subsystem to the Arduino Uno. Since the cable is permanently attached, do not attempt to remove it. *Synonym*: Black cable	

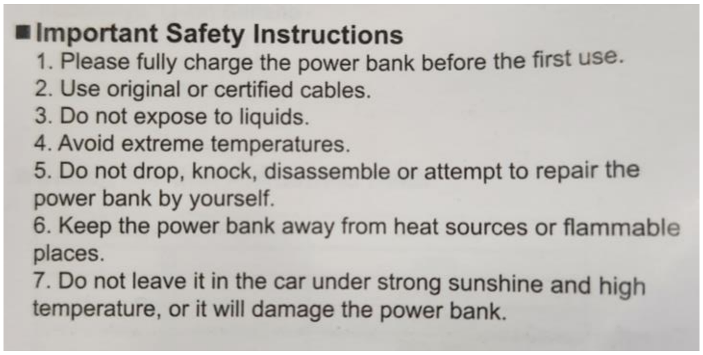
2.2 Cautions & Warnings

This section of the user manual contains all relevant cautions and warnings that you should know about before using the product. Please study this section carefully to minimize the risk of injury.

2.2.1 Battery Warnings

Since the product uses a portable power bank, it is important to follow all warning pertaining to batteries. To specify, do not attempt to open the casing due to risk of explosion and injury. In addition, do not dismantle, crush, puncture, short circuit or tamper the battery. Do not expose it to liquids, fire, or environments where the temperature is above 60 °C. Store the battery in a cool, dry place away from direct sunlight and other heat sources. Finally, keep battery out of reach of children and pets.

Note that the information above was summarized from the user manual of the battery, which has been included in the pouch for convenience. For more information on battery safety, please consult said user manual.



■ **Important Safety Instructions**

1. Please fully charge the power bank before the first use.
2. Use original or certified cables.
3. Do not expose to liquids.
4. Avoid extreme temperatures.
5. Do not drop, knock, disassemble or attempt to repair the power bank by yourself.
6. Keep the power bank away from heat sources or flammable places.
7. Do not leave it in the car under strong sunshine and high temperature, or it will damage the power bank.

Figure 3 Snippet from Battery's User Manual

2.2.2 Laser Warnings

Note that the laser used in this product is a Class 2 laser. Class 2 lasers are relatively weak and generally safe to use under normal conditions [4]. However, it is still important to follow general guidelines to minimize the risk of injury. To specify, do not directly stare into the laser beam or point it directly into anyone’s eye. Always turn off the laser when not in use. Finally, keep laser out of reach of children and pets.

2.2.3 Mounting Caution

Note that the clips used in the product are not fully coated in rubber. As such, exercise extra precaution when mounting the product to a glasses’ frames to ensure that only the rubberized grip is in contact with the frames. Doing so will prevent any cosmetic damage on the frames caused by the metal clips scratching against the frames.

3 Getting started

This section of the user manual exists to provide a general walkthrough of the system from setup through exit. Note that the terminology used in this section is consistent with the ones defined in section 2.1. As such, please review all relevant information to avoid confusion when following along the instructions.

3.1 Configuration Considerations

First, ensure that battery is fully charged before setting up the device. Doing so will maximize the number of hours the product will be operational for. The petal-shaped indicator will have all four bars lit when the battery is fully charged as shown in Figure 4.

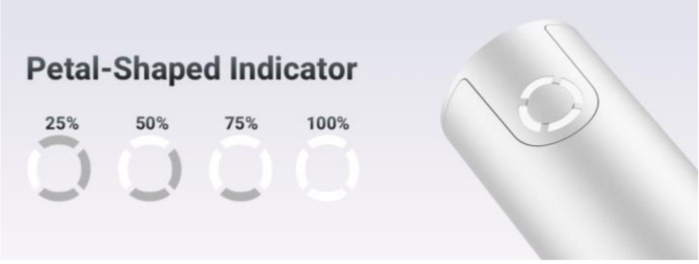


Figure 4 Petal-Shaped Battery Life Indicator

Next, ensure that you are wearing a belt before setting up the product. While mounting on a belt loop can work, it is advised to attach the hip-mounting system to a belt for maximum stability. Also ensure that you are wearing glasses or headband. It is essential to do so since the head-mounted subsystem needs to be mounted on something during operation.

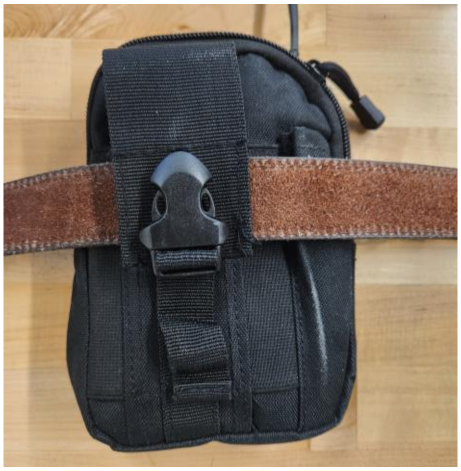


Figure 5 Pouch mounted on Belt using Buckle

Finally, ensure that all components that make up the product is within reach before setting up the device. This includes the head-mounted subsystem, the hip-mountable casing, the battery, and the pouch. Everything mentioned in the list will be required to set up the product completely.

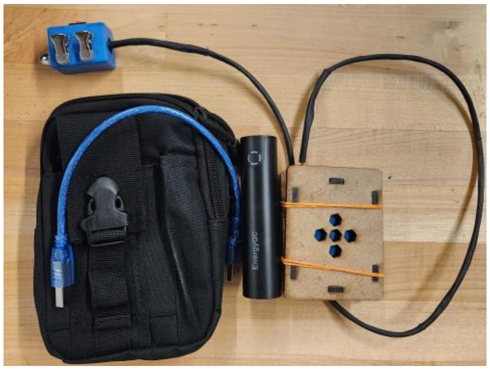


Figure 6 Components Required for Setup

3.2 User Access Considerations

Since the product was made with a specific user in mind, the length of the cable is customized to fit their needs. As such, special attention should be paid when the product is used by someone else. If the person is too tall, the hip-mounted subsystem should not be mounted on the belt. Doing so can damage and eventually destroy the cable. As such, the hip-mounted subsystem should be carried on a backpack or something similar instead.

3.3 Accessing/setting up the System

To ensure that the product is fully set up first attach the Arduino Uno to the battery using the blue cable. The Arduino Uno should turn on at this point, which is indicated by a yellow light shining inside the hip-mountable casing. If the yellow light does not turn on, please refer to Section 5.1.1 for troubleshooting assistance.

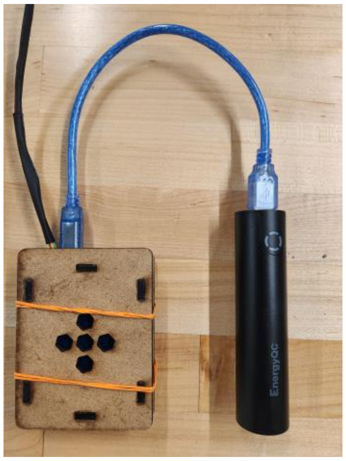


Figure 7 Blue Power Cable Attached

Next, ensure that the kill-switch is turned off before putting on the glasses. To achieve this, move the glasses around and observe the laser. If the head-mounted subsystem is producing a laser dot, then press the button to turn the laser off. This is done to ensure that the laser is not accidentally pointed at someone's eye during set up. For more information about laser safety, please refer to Section 2.2.2.

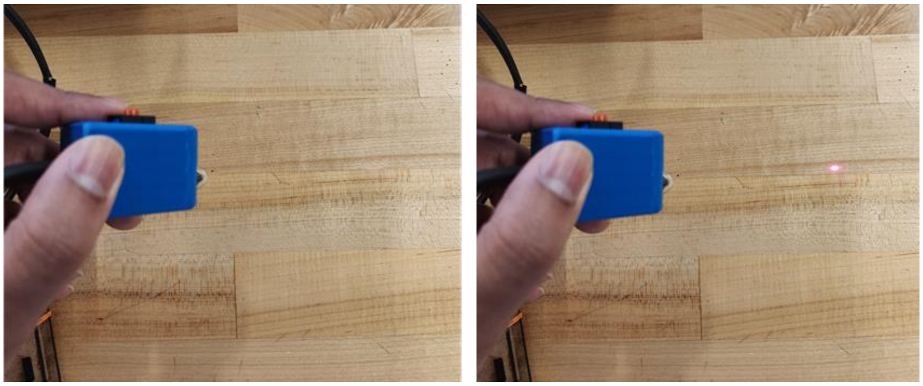


Figure 8 Laser Turned Off vs Laser Turned On

Afterwards, attach the clips on the head-mounted subsystem to your glasses' frame. Ensure that the head-mounted subsystem is facing away from the glasses' lens as failing to do so will make the glasses unusable. Please refer to the instructions in Section 2.2.3 to prevent any cosmetic damage on your glasses' frame.

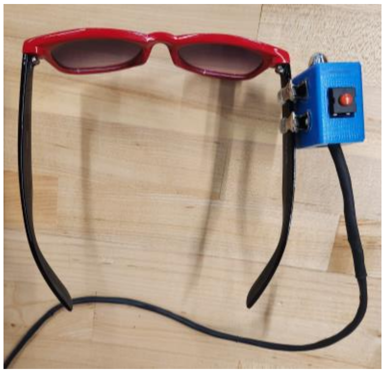


Figure 9 Head-Mounted Subsystem Attached to Frame

Finally, place the hip-mountable casing and the battery inside the pouch and attach said pouch on your belt using the buckle clip. Please ensure that the pouch is attach to the same side of the body as the head-mounted subsystem. The setup is now complete!

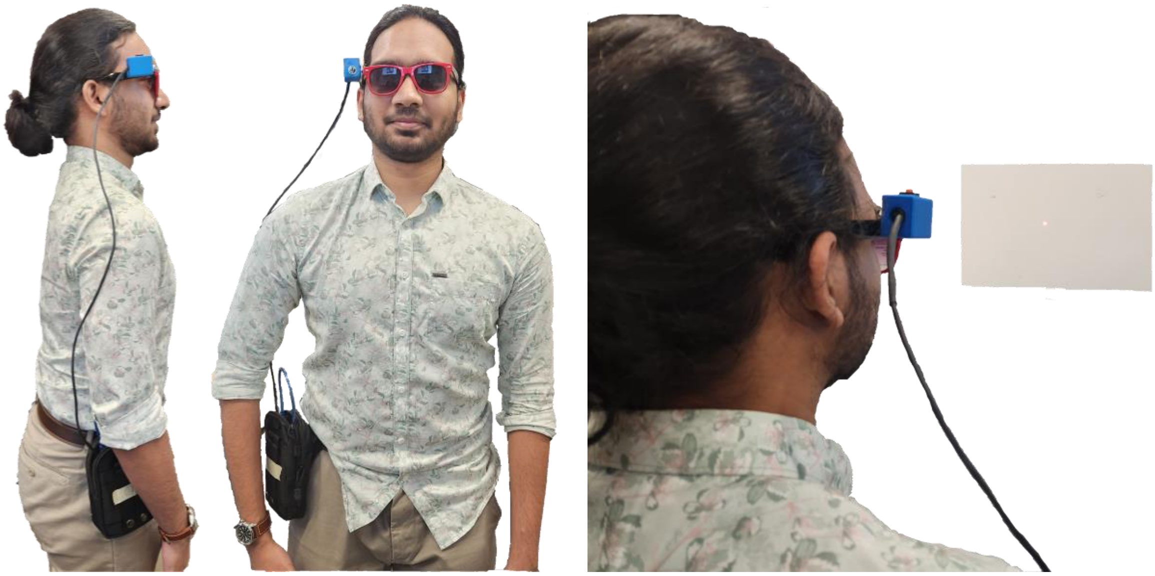


Figure 10 Final Setup View

3.4 System Organization & Navigation

The product is organized into two subsystems: the head-mounted subsystem and the hip-mounted subsystem. This section aims to document the main features of both the subsystems. Figure 2 visualises a simplified block diagram that showcases a very high-level view of the architecture of our product.

3.4.1 Head-Mounted Subsystem

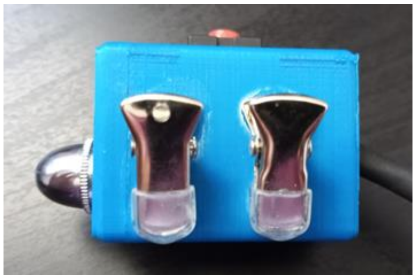


Figure 11 Head-Mounted Subsystem

The blue casing is the part that attaches to the frame and is thus called the head-mounted subsystem. It contains the laser, tilt-sensor (gyroscope), and the kill-switch. The tilt-sensor and kill-switch act as the input to our product while the laser acts as the output. This means that the tilt-sensor and kill-switch are both used to determine whether the laser should be on or off. The actual mechanism of how this is determined can be found in Section 6.3.

3.4.2 Hip-Mounted Subsystem

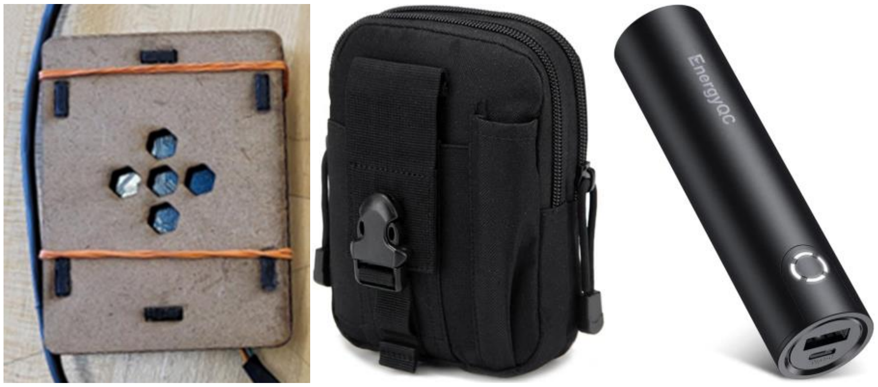


Figure 12 Hip-Mounted Subsystem

The hip-mounted subsystem consists of the pouch, the battery, and the hip-mountable casing.

The hip-mountable casing is the brown casing in Figure 12 and it houses the Arduino Uno, which acts as the brain of our product. This means trying to decide on whether to keep the laser on or not using the information from the head-mounted subsystem. The actual mechanism of how this is determined can be found in Section 6.3.

In addition, the hip-mounted subsystem also contains a battery that powers the whole product. Both the battery and the hip-mountable casing is placed in the pouch during operation and storage. Attaching this pouch to yourself will allow you to be mobile while using our product.

3.5 Exiting the System

When you have finished using the product, the follow the upcoming steps to ensure safe and proper storage of the product. First, turn off the laser using the kill switch. This is done to ensure that the laser is not accidentally pointed at someone’s eye during cleanup.

Next. detach the head-mounted subsystem from your glasses using the handles on the clips. Do not use excessive force as it should easily come off. Using excessive force can lead to cosmetic defects on the glasses’ frames.

Finally, unplug the power cable that connects the hip-mountable subsystem with the battery. This will prevent the battery from draining unnecessarily while the product is not being used, thus preserving battery life. It is important to recharge the battery periodically as the product can only be used for 2 days on a full charge. This will ensure that the product is ready for use when you need it.

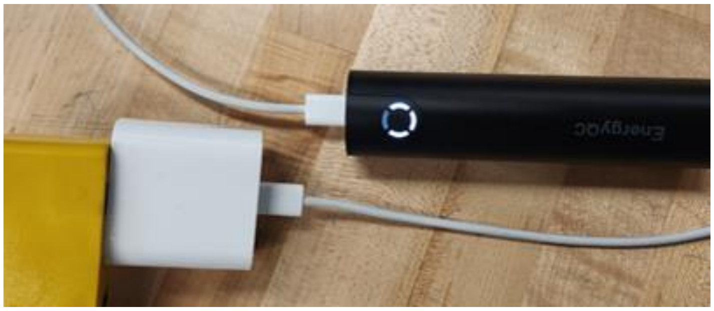


Figure 13 Recharging the Battery using Phone Charger

In addition, it is recommended that you keep all the components within the provided pouch for storage. This will help keep the components organized for next use. Furthermore, it will protect the product against bumps and dust, thus increasing the longevity of your product.

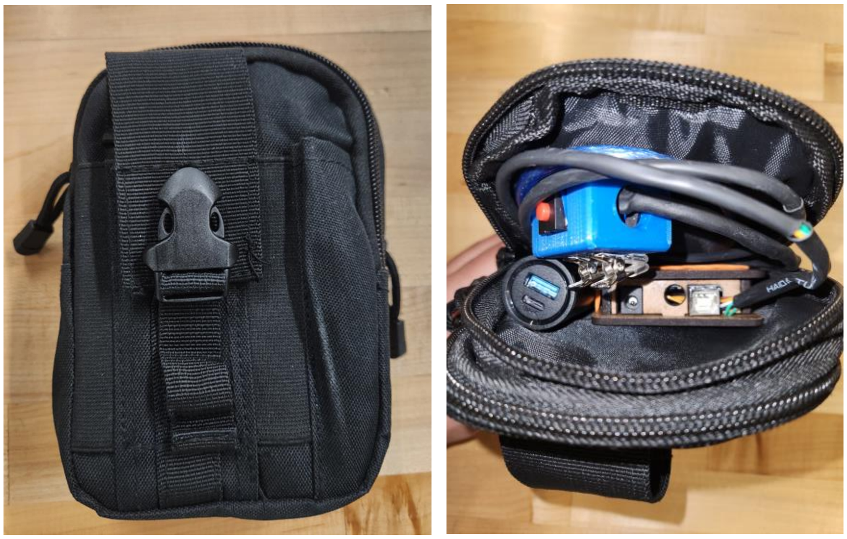


Figure 14 Product Storage in Pouch

4 Using the System

The following sub-sections provide detailed, step-by-step instructions on how to use the various functions or features of the product Fraymes.

4.1 Kill-Switch

As mentioned in Section 2.1, the kill-switch is responsible for controlling the operation of the laser. As such it has two operations: activating and deactivating the laser. The following sections will elaborate on the two operations.

4.1.1 Activating the Laser

To activate the laser, simply move the head-mounted subsystem around and observe its output. If the laser dot is observed on a flat surface as shown in Figure 15, then the laser is already activated. If not, then press the kill-switch to activate the laser. Please consult Section 5.1.1 if the laser still fails to activate.

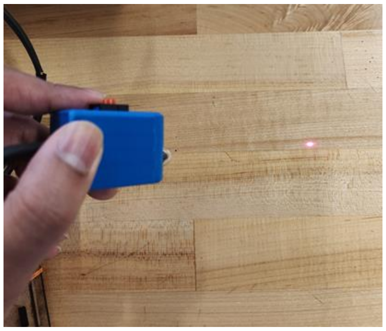


Figure 15 Activating the Laser

4.1.2 Deactivating the Laser

To deactivate the laser, simply move the head-mounted subsystem around and observe its output. If no laser dot is observed on a flat surface as shown in Figure 16, then the laser is already deactivated. If not, then press the kill-switch to deactivate the laser.

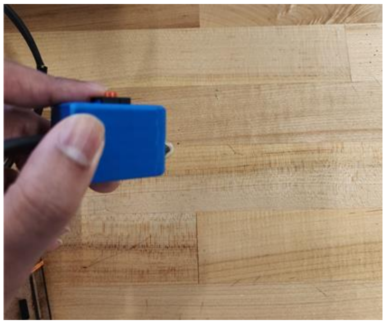


Figure 16 Deactivating the Laser

4.2 Laser

As mentioned in Section 2.1, the laser is used to interface with a Bliss-Board using your head. The exact mechanism to achieve this will be explained in the following section.

4.2.1 Laser Operation

To physically operate the laser, please aim your head at the element on the Bliss-Board that you want to select. The Bliss-Board in Figure 17 works by stringing together elements to form complete sentences. You can see how the laser was used instead of a finger to operate the Bliss-Board. Note that the operation of the Bliss-Board will be different for each individual board. Please consult your Bliss-Board manual and follow its specific instructions for optimal results.

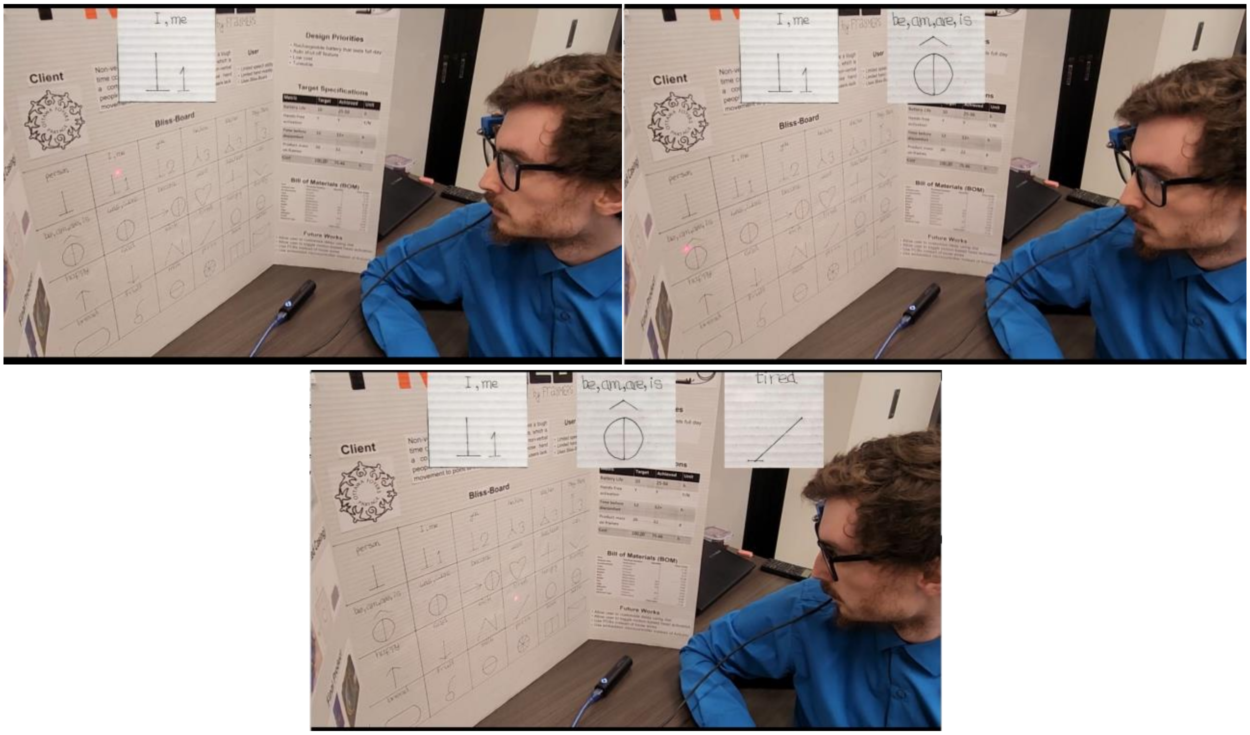


Figure 17 Operating Laser on Bliss-Board

5 Troubleshooting & Support

This section documents all known technical difficulties and issues that may arise during the use of our products and how to go about solving said issues. Most of the solutions suggested can be performed without any additional tools and from the comforts of your home.

5.1 Error Messages or Behaviors

5.1.1 Product Not Powering On

Here are some steps that you can follow should your product not turn on. If one step does not work, please move on to the next step until your issue has been resolved.

- Check Kill-Switch to ensure that the product is indeed turned on. Refer to Section 4.1.1 for more information on how to achieve that.
- Check the battery's charge to ensure that it is not empty. This can be done by pressing button inside ring and observing how many segments light up as shown in Figure 18. Figure 4 depicts how to properly interpret the ring indicator. Should the battery be at 0%, please try again after charging the battery.

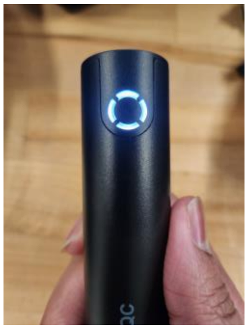


Figure 18 Battery Life Display on Battery

- Ensure USB cable from battery to Arduino is plugged in. There should be an orange light emitting from the Arduino as shown in Figure 19. If that is not the case, then please proceed with the troubleshooting process.

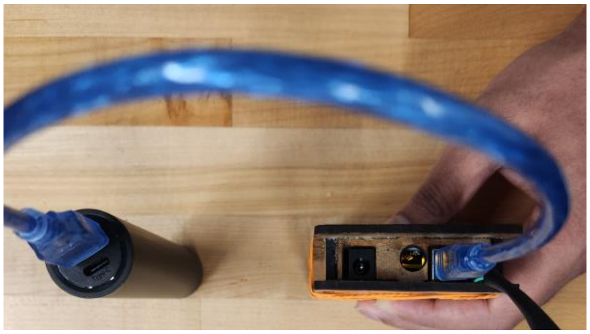


Figure 19 Proper Power Connection Between Battery and Arduino Uno

- Ensure that the Arduino Uno is functional by troubleshooting it with another battery/wall power and a spare wire. If the yellow light is still not turning on, then your Arduino Uno is not functional and needs to be replaced. Contact support and they will provide you more information on how to achieve that.
- Ensure that the wire is functional by troubleshooting it with devices that can make the proper connections. Should the wire be non-functional, please contact support and they will provide you more information on how to replace said wire.
- Ensure that the battery is functional by troubleshooting it with another device, like smartphone, and a spare wire. If the battery cannot deliver power to the other device, then your battery is not functional and needs to be replaced. Contact support and they will provide you more information on how to achieve that.

5.1.2 Laser Auto-Shutoff Not Functional

Here are some steps that you can follow should your laser auto-shutoff stop functioning. If one step does not work, please move on to the next step until your issue has been resolved.

- Ensure that the laser is not moving. The auto-shutoff feature requires total lack of movement. If device is mounted on your head, either remove the glasses or stop moving your head.
- If all else fails shut off device completely, by unplugging battery. Then restart the device by plugging back the battery in.

5.2 Special Considerations

5.2.1 Device Exposed to Moisture/Water

Should the device get wet, turn off the device completely. Unplug the power cable from battery to microcontroller. Place all components in a bag of rice for 2 days. Then, attempt to power the device back on. If this process does not work, please contact support.

5.3 Maintenance

5.3.1 Battery Health

- To maintain a long-lasting battery, it is best to charge the battery only when it is near 0% battery left.
- Avoid leaving the battery plugged in for extended periods of time without use.
- Ensure that the device is used at least once every 6 months.

5.3.2 Device Health

- Ensure the device is stored in at room temperature around 15 °C to 35 °C.

- Ensure the device is stored in relative humidity percentage of 30% to 60 %.
- Dust off device every 6 months to avoid static build up.

5.4 Support

Should you require any assistance first determine the type of problem you have be it an electrical, mechanical one or any other problem with the product. Then once you have an idea what the issue is use the information below to determine who the best individual is to contact.

5.4.1 Electrical Support

Contact electrical support members should you have any issue regarding the battery, the microcontroller, or the laser. Their contacts are as follows:

- Aidan Charles achar209@uottawa.ca
- Isaac Soward isowa064@uottawa.ca

5.4.2 Mechanical Support

Contact mechanical support should you have any issue with the head-mounted casing, the hip-mountable casing for microcontroller or the pouch. Their contacts are as follows:

- Ena Piercy epier072@uottawa.ca
- Marie Nelly Mbungu mmbun032@uottawa.ca

5.4.3 General Support

Contact general support should you have any issue that does not fall under the previous two sections. Their contact is as follows:

- Symoom Saad ssaad049@uottawa.ca

6 Product Documentation

This section aims to allow the reproduction of the final product. It describes the design considerations and the importance of each subsystem. The final prototype can be separated into three main subsystems: the mechanical, electrical, and software systems. The mechanical subsystem may be further separated into two parts: the glasses mounted component and the hip mounted component. The manufacturing method and instructions of each subsystem is described in this section.

6.1 Mechanical System

Instructions on how to manufacture the mechanical system are provided in detail in this section. The mechanical system has been separated into two components (the glasses mounted housing and the hip mounted component) for simplicity.

6.1.1 Glasses Mounted Housing

The glasses mounted casing houses the laser and gyroscope/accelerometer used in the product. The physical button is mounted on the outside of the housing for ease of access. The housing is needed to protect the laser and gyroscope/accelerometer from potential damage, to allow ease of mounting, and for aesthetic purposes. A 3D printed housing was chosen due to its low cost, lightweight properties, and its customizability. PLA was chosen as the printing material due to its ease of access and low cost. Lanyard grip clips were used for their ease of mounting, strength, and secure mounting. The chosen clips allow for a steady laser pointer, which is one very important aspect of the product.

The housing is designed using SolidWorks (CAD software). A hollow rectangular shape is used for simplicity in design. Two holes on either end of the rectangular prism are designed; one that is fitted to the laser diameter and another to allow the wires out the back end of the housing. On the top of the housing, a cavity is designed to allow the button to be mounted on the outside of the housing. A hole is designed within this cavity to the inside of the casing, allowing for the needed electrical connections of the button. A flange and indent were added to the inside of the two parts to aid in placement of the two parts during assembly. Finally, all edges were filleted (rounded) to prevent sharp edges that could potentially be a safety hazard. The housing was designed as two parts as seen in the figures below:

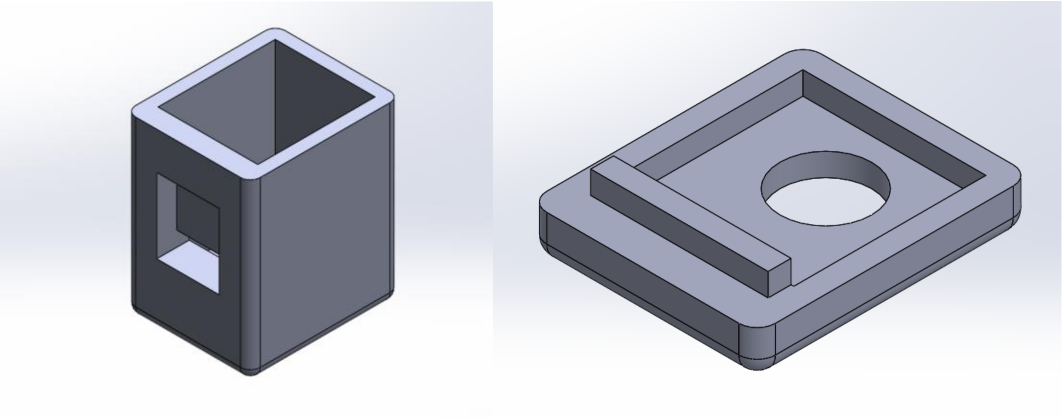


Figure 20 Left Diagram: Part1; Right Diagram: Part2

6.1.1.1 BOM (Bill of Materials)

The table below outlines the BOM of the glasses mounted component. Electrical components that are housed within the casing are included in the BOM of the electrical system (Table 5). The number of clips is designated to be 2+ since two are used on the casing but more may be used as desired to keep wiring in place (to clip on clothes, etc.). Although any adhesive can be used in assembly, Gorilla super glue was used in the mechanical assembly.

Table 3 BOM for Glasses Mounted Housing

Item #	Item	Purchase location	Quantity	Link	Price (CAD)
1	PLA	Makerspace	N/A	N/A	0
2	Grip clips	Amazon	2+	https://www.amazon.ca/ONLYKXY-Non-Slip-Alligator-Lanyards-Accessories/dp/B08LGGBDGY	14.29/30 pieces
3	Adhesive	Makerspace	N/A	N/A	0
				Total =	$14.29

6.1.1.2 Equipment list

- SolidWorks (or equivalent CAD software)
- Ultimaker 2+ 3D printer; 0.4mm nozzle (or another comparable 3D printer)
- Ultimaker Cura Software
- SD card

6.1.1.3 Instructions

6.1.1.3.1 3D Printed Casing

The instructions for printing the 3D printed casing are described in this section. For additional assistance in 3D printing at MakerSpace, consult: https://en.wiki.makerepo.com/wiki/Digital_technologies/3D_printing/3D_printing-_Beginner/3D_printing_in_our_Makerspace.

1. Open SolidWorks design files provided on MakerRepo (Part1fin2.SLDPRT and Part2.SLDPRT). The assembly file Assem12.SLDASM is provided for viewing the final assembly.

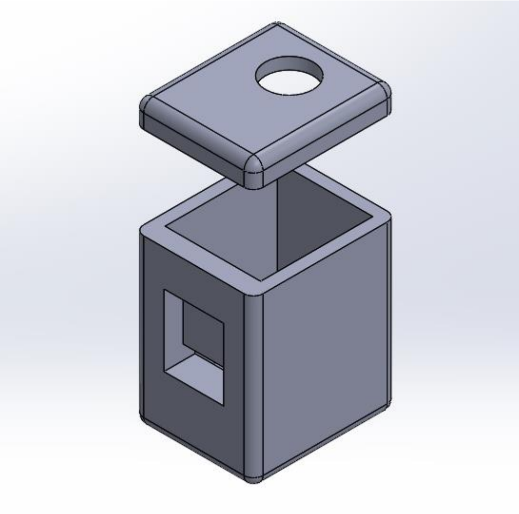


Figure 21 Glasses Mounted Housing Assembly

2. Edit housing as needed. (Skip this step if original design is used).
3. Save part files as STL files.
4. Open the STL files on Ultimaker Cura. Ensure that the orientation of the parts is as seen in Figure 20 to eliminate as much use of support as possible.
    a. Select Generic PLA for material used.
    b. Select 0.4mm nozzle size.
    c. Resolution 0.1mm.
    d. 20% infill.
    e. Adhesion.
    f. (Support is recommended for Part 1 – due to the button cavity).
5. Slice and save the file to the external SD card drive.
6. Insert SD card into 3D printer.
7. Start print. Part 1 will take approximately 3 hours while the Part 2 will take approximately 1 hour.

6.1.1.3.2 Assembly

Assembly of the glasses mounted housing may not be completed without some assembly of the electrical system. In fact, it is recommended to start this section only after the electrical components in this housing has been assembled. Refer to section 6.2.3.2 for assembly of the electrical system.

1. Complete electrical assemble of components that are to be housed (Section 6.2.3.2, Steps 1-9).
2. Place button in the top cavity of Part 1 of the housing. Align the button to allow the bottom to sit on the countersunk surface and the pins to pass through the hole to the inside of the casing. Use adhesive on the bottom of the button to secure the button in place.

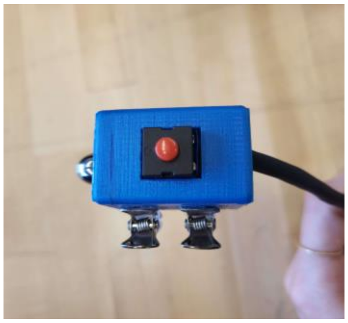


Figure 22 Glasses Mounted Housing Assemble: Step 2 Completed

3. Insert the laser into the opening of Part 1. Use adhesive if necessary.

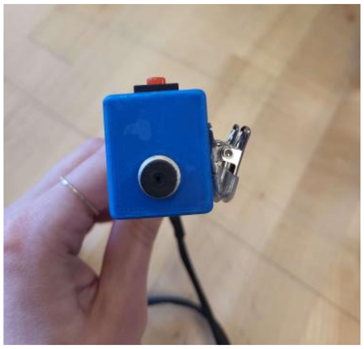


Figure 23 Glasses Mounted Housing Assemble: Step 3 Completed

4. Twist the cap of the laser on the part of the laser protruding from the housing.
5. Secure the accelerometer/gyroscope on the inside of the housing using adhesive. The accelerometer/gyroscope can be fitted on a side wall, with the length parallel to the length of the housing.

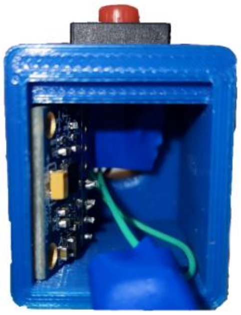


Figure 24 Glasses Mounted Housing Assemble: Step 5 Completed

6. Pass wire through the back opening of Part 2 of the housing.

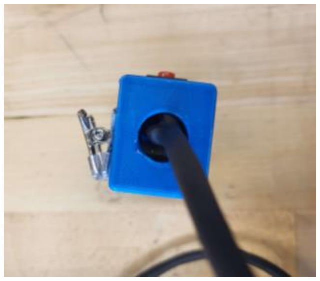


Figure 25 Glasses Mounted Housing Assemble: Step 6 Completed

7. Secure the two parts of the housing with adhesive.
    a. Align the ledge/flange of Part 2 with the inner indent of Part 2. Adhesive can be added on this flange to allow increased attached surface area.
8. Use adhesive to secure clips on the desired side of the casing (the clips can be mounted on the left or right side of the glasses/head)

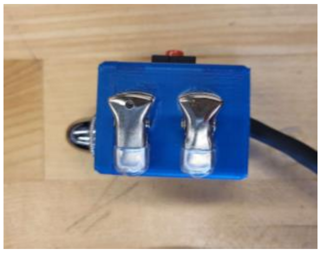


Figure 26 Glasses Mounted Housing Assemble: Step 8 Completed

A photo of the final assembly is provided below.

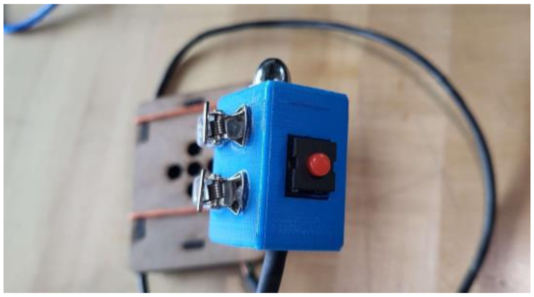


Figure 27 Final Assembly of Glasses Mounted Component

6.1.2 Hip Mounted Component

The hip mounted component is used to carry the battery and Arduino used in the product. A hip mount was chosen to minimize the weight and size of the housing on the glasses. A purchased pouch is used to carry the battery and Arduino as well as to mount these parts to a belt (or preferred location). A purchased pouch was chosen for the product to allow for increased ease of use, ease of attachment, and to save manufacturing time.

A laser cut casing was made to protect the Arduino from potential damages within the pouch. MDF was chosen as the casing material due to its lightweight properties and ease of assembly. A 3D printed casing was originally considered, however, printing a casing of the size of an Arduino is time consuming. In addition, making a lid that can open and close adds complexity. Laser cutting was chosen due to its speed and precision of cutting sheets of MDF.

6.1.2.1 BOM (Bill of Materials)

Although the battery and Arduino Uno are housed within the hip mounted component, these components are included in the electrical system BOM (Table 5, Section 6.2.1).

Table 4 BOM for Hip Mounted Component

Item #	Item	Purchase location	Quantity	Link	Price (CAD)
1	MDF	MakerStore	1	https://makerstore.ca/shop/ols/products/mdf/v/M003-1-8-18-NCH	3.00/piece of 1/8” x 18” x 24”
2	Adhesive	Makerspace	N/A	N/A	0
3	Pouch	Amazon	1	https://www.amazon.ca/Azarxis-Tactical-Smartphone-Cellphone-Attachment/dp/B09D7Q64QF	14.99/piece
				Total =	$17.99

6.1.2.2 Equipment list

- Inkscape
- Epilog Laser Cutter
- Epilog Laser Cutter Software

6.1.2.3 Instructions

Instructions to design and laser cut the Arduino casing is described in this section.

6.1.2.3.1 Laser Cut Arduino Casing

The instructions for laser cutting the Arduino casing are described in this section. For additional assistance in laser cutting at MakerSpace, consult:
https://en.wiki.makerepo.com/wiki/Digital_technologies/Laser_cutting/Laser_cutting-_Beginner

1. Open the SVG design file provided on MakerRepo (ArduinoCase.svg 0000) using Inkscape.
2. Save the file as a pdf on an external drive.
3. Open the pdf on a device with Epilog Software installed.
4. Turn on the laser cutter and follow instructions for setting up the laser cutter as found in the following link. Use settings for MDF 1/8” thickness.
    - https://en.wiki.makerepo.com/wiki/Digital_technologies/Laser_cutting/Laser_cutting-_Beginner
5. Enter the settings needed in Epilog for laser cutting with MDF.
    - Since no engravings are required, all cuts will be set to cut all the way through the material.
6. Print the file.
7. Assemble the bottom panel and 4 sides of the housing (5/6 panels). Note that orientation of pieces is of importance for correct fit.
8. Use adhesive to secure the 5 pieces together. The top (6th) piece may be left unsecured for later access to the Arduino.

A photo of the final assemble has been provided below.

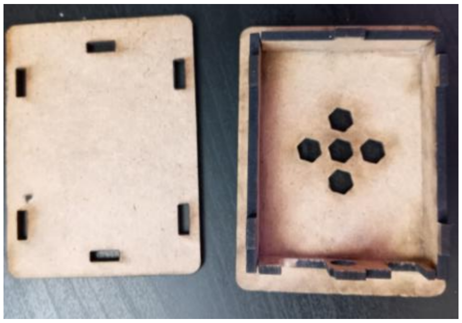


Figure 28 Final Assembly of Laser Cut Casing

6.1.2.3.2 Assembly

Once again, the assembly of the hip mounted component may not be completed without some assembly of the electrical system. It is recommended to start this section only after the electrical components in this housing has been assembled. The prerequisites for this section include Section 6.2.3.3 and Section 6.2.3.4.

1. Complete Section 6.2.3.3 to protect the loose wiring with heat shrink tubing.
2. Solder the wires to the Arduino as instructed in Section 6.2.3.4.

3. Place the Arduino into the laser cut Arduino casing. Store any excess wire within the casing.
4. Place the top of the casing onto the casing. An elastic band may be used to keep the casing in place.

A photo of the final assemble has been provided below.

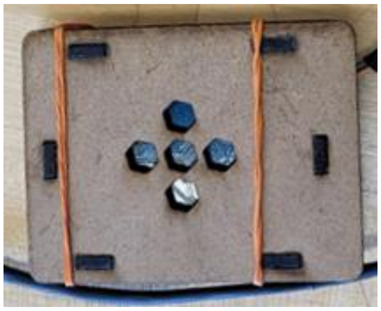


Figure 29 Final Assembly of Hip Mounted Component

6.2 Electrical System

The electrical system consists of all the electronic parts such as the gyroscope, the laser, the button, and the Arduino Uno. This section will document the process of procuring, preparing, and assembling the aforementioned list of components so that it is ready to be used as the final product. Note that both the glasses mounted casing from Section 6.1.1 and the hip mounted component from Section 6.1.2 will be required to complete the assembly process.

6.2.1 BOM (Bill of Materials)

Although the Arduino Uno is a core part of the electrical system, it will be instead included in the software system BOM (Table 6, Section 6.3.1).

Table 5 BOM for Electrical System

Item #	Item	Purchase location	Quantity	Link	Price (CAD)
1	3 axis gyroscope	Amazon	1	https://www.amazon.ca/Gikfun-MPU-6050-Accelerometer-Gyroscope-EK1091x3C/dp/B07JPK26X2	15.89/3 pieces
2	Laser	Canadian Tire	1	https://www.canadiantire.ca/en/pdp/autotrends-laser-pointer-keychain-0375029p.html?loc=plp	9.99/piece

3	Button	MakerStore	1	https://makerstore.ca/shop/ols/products/on-off-power-button-pushbutton-toggle-switch	2.25
4	Wire	Makerspace	N/A	N/A	0
5	Solder	Makerspace	N/A	N/A	0
6	Arduino Uno	MakerStore	1	https://makerstore.ca/shop/ols/products/arduino-Uno-r3	17.00/piece
7	Battery	Amazon	1	https://www.amazon.ca/EnergyQC-Portable-Charging-External-Compatible/dp/B0B117KWXZ/	22.99/piece
8	Adhesive	Makerspace	N/A	N/A	0
9	Shrink wrap	Makerspace	N/A	N/A	0

6.2.2 Equipment list

- Soldering Iron
- Heat Gun
- Wire cutters
- Pliers
- Metal shears

6.2.3 Instructions

Instructions to assemble the parts into the final electrical product is described in this section. The instructions are divided into subsections to help organize the information better. These subsections should be followed chronologically for optimal results.

6.2.3.1 Removing the laser

1. Use the metal shears to cut into the laser casing.
2. Use the pliers to strip the outer casing from the inner electrical components of the laser. This is done to remove the laser diode from its encasing.

6.2.3.2 Mount Wiring and Assembly

1. Solder 2 sections of wire to the laser; one to the positive (5 cm of wire) and the other to the negative terminals (60 to 70 cm of wire).
2. Feed the positive terminal wire through the button hole of the mount casing.
3. Solder the positive terminal to one terminal of the button.
4. On the other terminal of the button solder a length of wire that will connect to the Arduino (60 to 70 cm).
5. Tape connections to insulate on both the button and laser.
6. Feed button terminals through holes with wires.
7. Feed wires out the back of the casing.
8. 4 lengths of wire (60 to 70 cm) need to be cut to solder to the gyroscope (4 different colours are recommended).
9. Solder said wires to the gyroscope board on the following pins (VCC, GND, SDA, SCL).
10. Follow the glasses mounted component assembly (Section 6.1.1.3.2) to complete the assembly of this component.

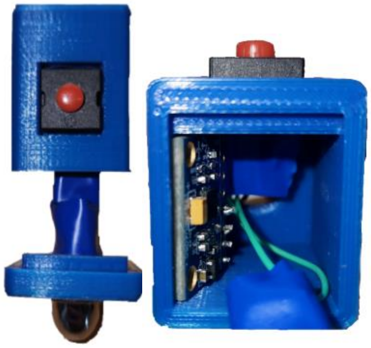


Figure 30 Electrical Components Inside Mount

6.2.3.3 Wire Cable

1. Feed wires through tubes of shrink wrap up to casing or previous tube.
2. Using the heat gun, shrink the heat shrink wrap.
3. Repeat until most of the wire is covered.

6.2.3.4 Arduino Soldering

1. Feed wires though wire hole in Arduino casing.
2. Solder the negative laser wire and gyroscope GND to GND on Arduino board.
3. Solder gyroscope VCC to 5 V.
4. Solder SCL to SCL.
5. Solder SDA to SDA.
6. Solder laser positive to Arduino digital port 13.

7. Follow the hip mounted component assembly (Section 6.1.2.3.2) to complete the assembly of this component.

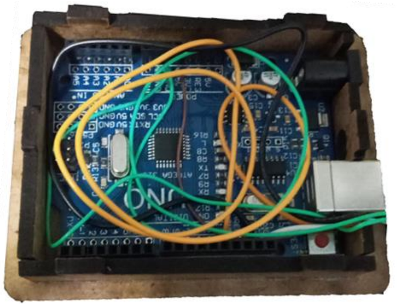


Figure 31 Fully Wired Arduino in Casing

6.2.3.5 Battery to Arduino

1. Connect the USB to battery and Arduino.

6.3 Software Design

The software system consists of the code that controls the head-motion activated switch. It runs on the Arduino Uno and requires input from the gyroscope and the button. In addition, it outputs the result on the laser. As such, to properly run the code provided in Appendix 10, both the mechanical system (Section 6.1) and electrical system (Section 6.2) must be assembled in advance.

The head-motion detection software works by detecting change in tilt in any direction of the gyroscope with an accuracy of 0.25 units, at which point the laser will turn on. It will automatically turn off the laser after after 12 seconds. If movement is detected after the 12 seconds have passed, the laser will turn on again. This change happens so fast that it is undetectable to the human eye.

6.3.1 BOM (Bill of Materials)

The table below outlines the BOM of the software system. Since the software only needs a microcontroller to run, only Arduino Uno is required for this system.

Table 6 BOM for Software System

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

6.3.2 Equipment list

- Laptop
- Arduino IDE
- USB connector cable

6.3.3 Instructions

1. Go to https://makerepo.com/Marllyyy/1508.fraymes and download the Arduino code.
2. Open Arduino IDE.
3. Open the downloaded Arduino code in the Arduino IDE.
4. Select Arduino Board and the appropriate Serial Port.
5. Click Compile button on Arduino IDE to compile code on laptop.
6. Click Upload button on Arduino IDE to upload code to Arduino Uno.
7. Test the code by using the product as intended (Section 4).

6.4 Testing & Validation

This section contains all major prototypes that were created to validate and test our detailed design. The following subsections are presented in the chronological order in which they were carried out in.

6.4.1 Software System (Prototype 1)

Prototype 1 was a low-fidelity analytical prototype modeling the electrical systems of the final prototype. A simulation was created in TinkerCAD. Data that would be provided by the gyroscope was provided by a potentiometer and the laser was replaced by an LED due to software limitations. Our code was also uploaded to test how it would function, along with power draw calculations.

Table 7 Target Specifications and Test Results for Prototype 1

Metric #	Metric	Target	Results	Unit	Pass/Fail
12	Hands-free activation	Y	Y	Y/N	Pass
10	Battery life	>10	>25	h	Pass

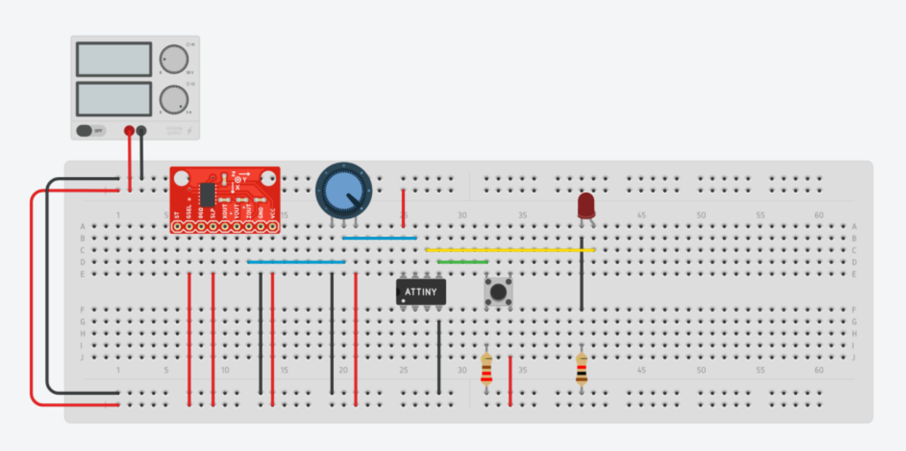


Figure 32 Prototype 1 Simulation Diagram

6.4.2 Mechanical System (Prototype 2)

Prototype 2 was a mechanical prototype that tested the glasses mounted casing. A housing was designed on SolidWorks and 3D printed to test the feasibility of the housing using this method of manufacturing. The clips were also tested for mountability. A figure of this prototype is found below.

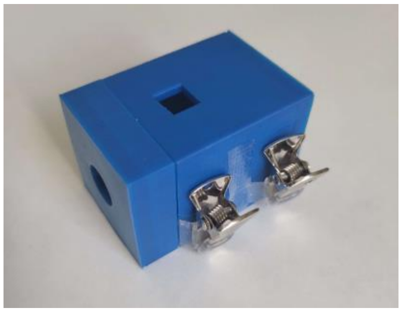


Figure 33 Prototype 2

The mass on the frames, the product size, the time to dismount, and the aesthetics were tested in this prototype. A summary of the results is given in the table below.

Table 8 Target Specifications and Test Results for Prototype 2

Metric #	Metric	Target	Results	Unit	Pass/Fail
2	Product mass on frames	20	17 (with clips; without accelerometer, laser, button, wiring mass)	g	Pass

3	Time to mount	30	1	s	Pass
8	Product size	2 x 1 x 1	4.5 x 3 x 3	cm x cm x cm	Fail
16	Time to detach	30	2	s	Pass
17	Aesthetically pleasing (Uniform color)	Y	Y	Y/N	Pass

With the results of the tests performed on this prototype, it was found that a 3D printed casing for the glasses mounted component was feasible. In addition, the clips were able to withstand the mass of the housing, even without permanent attachment to the housing. As a result of the testing and observation of the prototype, the housing was designed to be smaller, to include a button ledge, and to have rounded edges in the final prototype.

6.4.3 Final Prototype

As the final prototype was built to be fully functional, the product was able to be tested against all the original target specifications. The product was used in multiple locations with different glasses frames to test the criteria. A summary of the target specifications and results is seen in Table 9 below.

Table 9 Target Specifications and Test Results for Final Prototype

Metric #	Metric	Target	Result	Unit	Pass/Fail
1	Time to place battery in charge	<120	<60	s	Pass
2	Product mass on frames	<20	22	g	Fail
3	Time to mount	<30	3	s	Pass
4	Laser stability	<5	<1	cm	Pass
5	Laser beam range	>2	2.5+	m	Pass
6	Laser safety grade	Class II	Class II	class	Pass
7	Manufacturing cost	<100	105.05	CAD	Fail
8	Product size:	l x w x h	l x w x h	cm x cm x cm	

	• Glasses mounted casing	2 x 1 x 1	2.5x3x4		• Fail
	• Hip mount case	8 x 9 x 4	17.5 x 11 x 6		• Fail
9	Mount compatibility with frames (Frame cross section dimensions)	3x3 to 5x10	6x2 to 10x3.5	mm	Fail
10	Battery life	>10	>20	h	Pass
11	Laser beam visibility	2m indoors	2m+ in various lighting indoors	# of environments	Pass
12	Hands-free activation	Y	Y	Y/N	Pass
13	Activation sensitivity (error rate)	<15	0 (When tested 10 times)	%	Pass
14	Time before discomfort	<12	12+	h	Pass
15	Water Resistant	Y	N	Y/N	Fail
16	Time to detach	<30	3	s	Pass
17	Aesthetically pleasing	Y	Y	Y/N	Pass

The tests to test the target specification and the results of these tests are described in more detail below.

6.4.3.1 Time to Place Battery in Charge

Since the rechargeable battery was placed in a relatively easy-to-access location within the pouch, it was easy to retrieve the battery place it in charge using the included wire. Our tests revealed that most test subjects could easily do this within 1 minute, which leads us to pass this target specification.

6.4.3.2 Product Mass on Frames

The product mass on the frames was tested by weighing the glasses mounted component (without glasses). The final mass was measured to be 22g. Although this mass is 2g above the target mass, the 2g was not felt significantly when the prototype was being used by a user. Discomfort was not felt, and the glasses did not slide or tilt.

6.4.3.3 Time to Mount

The time to mount was tested by mounting the final prototype onto multiple pairs of glasses. Although time to mount at first was difficult, a well-practiced user was found to be able to mount the product within 3s. The main reason behind the difficulty in mounting was due to the two clips having to be pressed at once. Adding a bar or equivalent to attach the two clip handles to allow for only one contact point to open both clips may be useful in the future. However, this would increase the product mass, which is a more critical target specification and client need. In addition, not only would mounting be less than the target of 30s regardless, as aforementioned, once the user is well practiced, the mounting only takes 3s. Finally, since the client stated that the product may be left semi-permanently on the user’s glasses, the mounting and dismounting time is not as important.

6.4.3.4 Laser Stability

The laser stability was tested by using the final prototype onto a flat, vertical white surface. A test subject mounted the product to their glasses and kept their head level 2m away from the surface. The approximate range of error distance due to magnified minimal head vibration was measured on the target surface of the laser. This error was less than 1cm. In addition, the product was also tested with a Bliss-Board with 8x8cm grids. The laser and product showed a much higher accuracy than what is needed for a 5x5cm grid.

6.4.3.5 Laser Beam Range

The laser beam range was tested by pointing the laser toward a surface and slowly increasing the distance between the laser and the surface. Although the laser was able to point to farther distances, for the use and accuracy needed for a Bliss-Board with small grids, a distance of 2.5m was found to be the maximum distance. After this point, vibrations of the laser point increased, the laser point appeared dimmer (in regular indoor lighting), and the laser point grew larger. However, 2.5m is greater than the target specification of 2m and Bliss-Boards are not regularly used at distances greater than 1-1.5m maximum.

6.4.3.6 Laser Safety Grade

The laser purchased has a safety grade of Class II. This is equivalent to the Class II grade that was targeted.

6.4.3.7 Manufacturing Cost

The cost of the product was 105.05 CAD$. Although this cost is higher than the target cost of 100 CAD$, if parts were purchased by piece and not by bulk, the cost would be 77.47 CAD$ which is below the target cost.

6.4.3.8 Product Size

The product size was tested by measuring the product dimensions and comparing the results to the target specifications. In regard to the glasses mounted housing, the dimensions were measured to be 4.5 x 3 x 2.5 cm. This is greater than the targeted 2 x 2 x 1 cm. This was due to the assumption that a laser diode would be used in place of a store-bought laser. In addition, it was determined to use 2.5mm walls for the 3D printed casing to increase sturdiness. Finally, clearance for wires was added within the housing itself. Although the size was greater than originally anticipated, the product did not affect the user in the tests and was still lightweight. Due to the additional clearance in the current housing design, the product size may be reduced and still be functional.

The product size of the hip mounted part (the pouch) was measured to be 17.5 x 11 x 6 cm. This is much greater than the target specification of 8 x 9 x 4 cm. However, as the hip mounted part is being mounted on a belt strap or placed in a bag, the size is not a critical target specification. In addition, the additional room in within the pouch may be used to store the whole product or carry other necessities.

6.4.3.9 Mount Compatibility with Frames (Frame Cross Section Dimensions)

The compatibility of the mount with frames was tested on 3 pairs of glasses. The cross-section dimensions of these glasses' arms are 2 x 6 mm, 3 x 8 mm, and 3.5 x 10 mm. Although the full range of 3 x 3 mm to 5 x 10 mm was not tested, the mount was fully functional (provided needed stability) at a glasses arm width smaller than the target specification. In order to test the mounting, the product was tested for usual use on the glasses as well as shaken for 2s. In both cases, the product did not move on the frames.

6.4.3.10 Battery Life

The battery life was tested by moderately using the product for 10 minutes. The power drawn from the battery was measured using a digital oscilloscope. This result was then extrapolated to find the total battery life for an average user. This was found to be 20 hours. If more or less time is needed, a different battery may always be used to increase the life of the product in a single charge.

6.4.3.11 Laser Beam Visibility

The laser beam visibility was tested to ensure that the laser was visible in as many environments as possible. The product was tested in three indoor lighting situations and was fully visible in all three environments by multiple testers. Considering that the product will be mostly used indoors in similar lighting, this test is adequate for this product.

6.4.3.12 Hands-Free Activation

The hands-free activation was tested multiple times on different occasions and in different environments by several different users. A simple shake of the product after turning the power on or simple movements such as picking up the product activated the head-motion activated switch.

In addition, hands free deactivation was also tested. The product was found to power off the laser after movement was not detected for 20 seconds. This was achieved by either putting the product down on stable surface or by the user stilling their head for 20 seconds.

Although not included in the target specifications due to the client's later additional need of a physical kill switch, a kill switch was implemented and tested in the final prototype. The kill switch was tested by pressing the button and ensuring that the laser turned off and on when it was pressed.

6.4.3.13 Activation Sensitivity (Error Rate)

The error rate was tested simply by counting the times the hands-free movement detection activation functioned to turn on the product. Out of the 10 times that it was tested and additional uses of the product, the activation never failed, resulting in a 0% error rate. This is ideal and less than the 15% target error rate. Although the failure rate was tested to be 0%, more occurrences of usage may increase this error rate. However, the 0% error rate suggests a smaller error rate than 15% over time and appears to be insignificant in use.

6.4.3.14 Time before Discomfort

The time before discomfort was tested by using and wearing the product for a long period of time. Note that the product was not tested for the full 12 hours. Instead, it was tested for 1 hour, and since no discomfort was noticed by several users, it suggested that discomfort would be negligible when the product is mounted.

6.4.3.15 Water Resistant

Although the product was not tested to be water resistant, due to its assembly method and materials used, it is clear that the product is not water resistant. In the glasses mounted component, gaps into the casing that would allow water into the electrical components exist and the Arduino casing is made of a non water-resistant material (MDF). In addition, non permanent electrical connections between the battery and Arduino are accessible to the outside for regular use.

6.4.3.16 Time to Detach

The time to detach the glasses mounted component was tested with a similar method to the test the time to mount. Similarly, to the time to mount, the time to detach was also tested to take approximately 3 seconds. A time significantly less than the target specification of 30 seconds was achieved.

6.4.3.17 Aesthetically Pleasing

The criteria for aesthetics were tested by the symmetry of and color as described in Deliverable E. The glasses mounted component due to its uniform color and symmetry was determined to be aesthetically pleasing. However, improvements may be made to this area. One way to extend this would be to extend the uniformity of color scheme to both casings in future iterations. However, since the hip mounted casing is hidden within the pouch during the operation of product, our team did not find it necessary to paint the hip mounted casing blue for the current iteration.

7 Conclusions and Recommendations for Future Work

Overall, our product lived up to expectations. It functioned as expected and had most features we were looking to implement. The best ways to improve our product is likely to try and reduce its size and weight. These improvements can be accomplished by integrating all components in the head mount onto a PCB. Integrating all head components will remove the need for extra wire room in the casing, this will allow for a smaller case reducing the total weight. Additionally, the Arduino Uno used was more powerful than was required meaning a smaller less powerful microcontroller could be used to improve the battery life and size of the pouch. The product achieved all functional requirements thus, these quality-of-life features could be improved to make the product better.

Alternatively, the product can be improved by making it more versatile. Making our product more versatile requires having proper gesture activation in addition to existing features. This improvement can be accompanied by numerous other features originally ruled out for this specific application. Examples include making the timer and sensitivity more tunable for less technical users with the help of preprogrammed buttons or dials. Generally, increasing the suite of features will allow our product to be marketable to more clients.

8 Bibliography

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[3] "LaserWriter (Eyeglass Mounted)," Low Tech Solutions, [Online]. Available: https://store.lowtechsolutions.org/laserwriter-eyeglass-mounted/.

[4] "Laser safety in the workplace," Ontario, [Online]. Available: https://www.ontario.ca/page/laser-safety-workplace.

[5] b_r_a_v_e, "Arduino Uno Case (laser cut)," Thingiverse, [Online]. Available: https://www.thingiverse.com/thing:4224797.

APPENDICES

9 APPENDIX I: Design Files

This section contains all design files that will be required to fully build the product from scratch. To specify, it contains the glasses mounted housing, the laser cut Arduino casing and the Arduino code that is required for head-motion activation. Note that the Arduino casing was inspired by an online design file that can be found in the linked source [5]. The design was modified to include a hole to thread the wires through and fix the misalignment of the power port hole.

Table 10 Referenced Documents

Document Name	Document Location and/or URL	Issuance Date
Part1fin2.SLDPRT	https://makerepo.com/Marllyyy/1508.fraymes	April 6, 2023
Part2.SLDPRT	https://makerepo.com/Marllyyy/1508.fraymes	April 6, 2023
ArduinoCase.svg	https://makerepo.com/Marllyyy/1508.fraymes	April 6, 2023
Laserpointer.ino	https://makerepo.com/Marllyyy/1508.fraymes	April 6, 2023

10 APPENDIX II: Laser Code

```
#include <Adafruit_MPU6050.h>

#include <Adafruit_Sensor.h>

#include <Wire.h>



Adafruit_MPU6050 mpu;

bool check =false;



void setup(void) {

  Serial.begin(115200);

  pinMode(13, OUTPUT);

//digitalWrite(13, LOW);

        // Try to initialize!

        if (!mpu.begin()) {

          Serial.println("Failed to find MPU6050 chip");

          while (1) {

            delay(10);

          }

    Serial.println("FaiadsfPU6050 chip");

        }

        Serial.println("MPU6050 Found!");



        // set accelerometer range to +-8G

        mpu.setAccelerometerRange(MPU6050_RANGE_2_G);

  mpu.setGyroRange(MPU6050_RANGE_500_DEG);






        // set filter bandwidth to 21 Hz

        mpu.setFilterBandwidth(MPU6050_BAND_21_HZ);
```

```
 delay(100);
}


void loop() {
	/* Get new sensor events with the readings */
	sensors_event_t a, g, temp;
//if the laser moved turn on for 12 sec
 if (check == true){
    delay(0.2* 60 * 1000);//test for now
    check=false; //check for motion
    digitalWrite(13, LOW);


  }
  //main code loop
	while(check== false){
    mpu.getEvent(&a, &g, &temp);
    if (abs(g.gyro.x)>0.25 || abs(g.gyro.y)>0.25 || abs(g.gyro.z)>0.25){ //changing these values will change the sensitivity of device
      digitalWrite(13, HIGH);
      check= true; //once motion is detected change to true and exit loop
      break;


    }
    delay(10);


  }
  //diagnostic print to computer monitor
	Serial.print("Acceleration X: ");
	Serial.print(a.acceleration.x);
	Serial.print(", Y: ");
	Serial.print(a.acceleration.y);
```

```
              Serial.print(", Z: ");
              Serial.print(a.acceleration.z);
              Serial.println(" m/s^2");

  Serial.print("Rotation X: ");
  Serial.print(g.gyro.x);
  Serial.print(", Y: ");
  Serial.print(g.gyro.y);
  Serial.print(", Z: ");
  Serial.print(g.gyro.z);
  Serial.println(" rad/s");

Serial.println("");

              }
```