OcuFeel

Comprehensive Design Review

Team 17

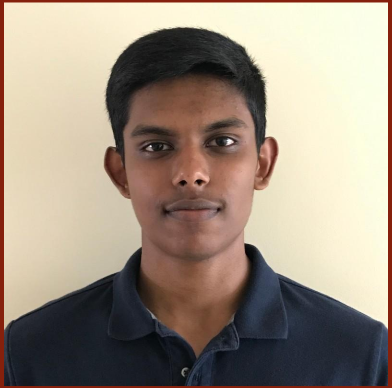
Team Intro

Advisor: Professor Zink

Matthew Corcoran
(CompE)

Callum Little
(EE)

Jon McDonald
(CompE)



Pradeep Manivannan
(EE)

Spring Semester Team Responsibilities

Matthew Corcoran

- Team Manager
- Headset Software Lead
- Haptic Response Assist

Callum Little

- Haptic Response Lead
- Waistband PCB Design
- Headset Design Assist
- Budget Manager

Pradeep Manivannan

- Headset PCB Design
- Headset Design Lead
- Headset Software Assist

Jon McDonald

- Headset Software Assist
- Battery Power Lead
- Audio Response Lead

Problem Statement

The blind and visually impaired predominantly utilize the white cane, a device that allows the user to detect objects in front of them and allow them to navigate the world. However, this tool does not have the ability to help detect distance (outside the length of the white cane),depth of objects in the environment without physical contact, and objects in motion.

Project Goal

Create a system that will help the visually impaired and blind navigate the environment around them.

- The system should be light weight and not impede motor function
- Give effective feedback to the user to make appropriate decisions on movement

Specifications

1. Will assist a user in navigating around typical obstacles located in an indoor setting, all without the use of their vision. Objects larger than **5cm off of the floor** will be considered obstacles.
2. Will be able to make distance and orientation measurements of objects in the environment, and provide feedback within a <500ms period.
3. Provides feedback to the user regarding the distance and direction of objects in the environment with a centimeter distance accuracy and 30 degree angular resolution.
4. Informs the user of any errors that affect the functionality of the system.
5. Supplies enough power to operate for at least 3 hours.
6. Provides clear feedback regarding the remaining amount of power.
7. Power source is rechargeable/interchangeable.
8. Will not impede the user's innate motor functions and the distance detection system will not weigh more than 500 grams.

Technical Specifications

Specification	Threshold	Note
Detect low clearing hazards	50 cm away from headset for above objects	Successfully detects object within 50 cm threshold.
Detect Tripping Hazards	5 cm tall obstacle off the ground	Successfully detects objects 5cm off the floor
Response Time	Less than 500 ms from sensor reading to waistband motor output	Currently measured response time of 34ms so specification is met
Range	8 meters	Successfully detects objects within 8m
Haptic motor angular resolution	27 degree intervals over 12 motors.	Successful demonstration, need to improve accuracy
Battery Life	Greater than 3 hours	Calculations confirm this specification
Battery Management	Rechargeable and replaceable	System informs user of low battery.
Weight	Less than 500 grams	Yet to be confirmed
Error checking	Loss of bluetooth communication, system malfunction, data corruption	Malfunction consists of any system compromising faults, like sensor malfunctions or microcontroller crashes

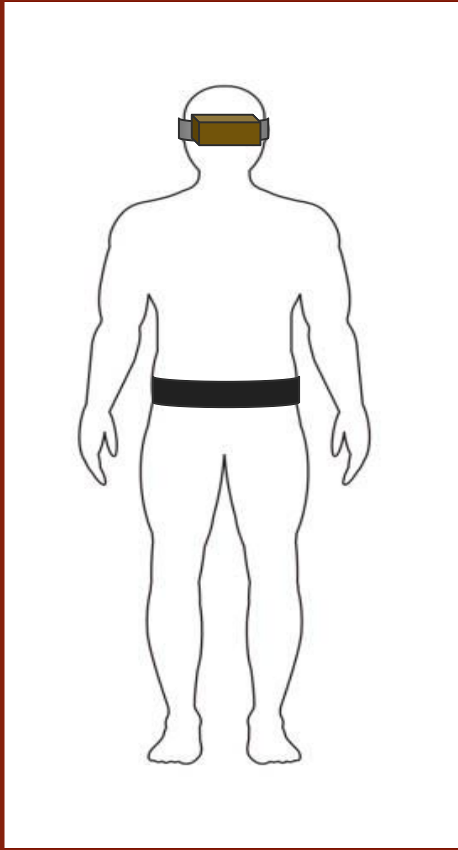
Design Overview

Overall system consists of two major subsystems:

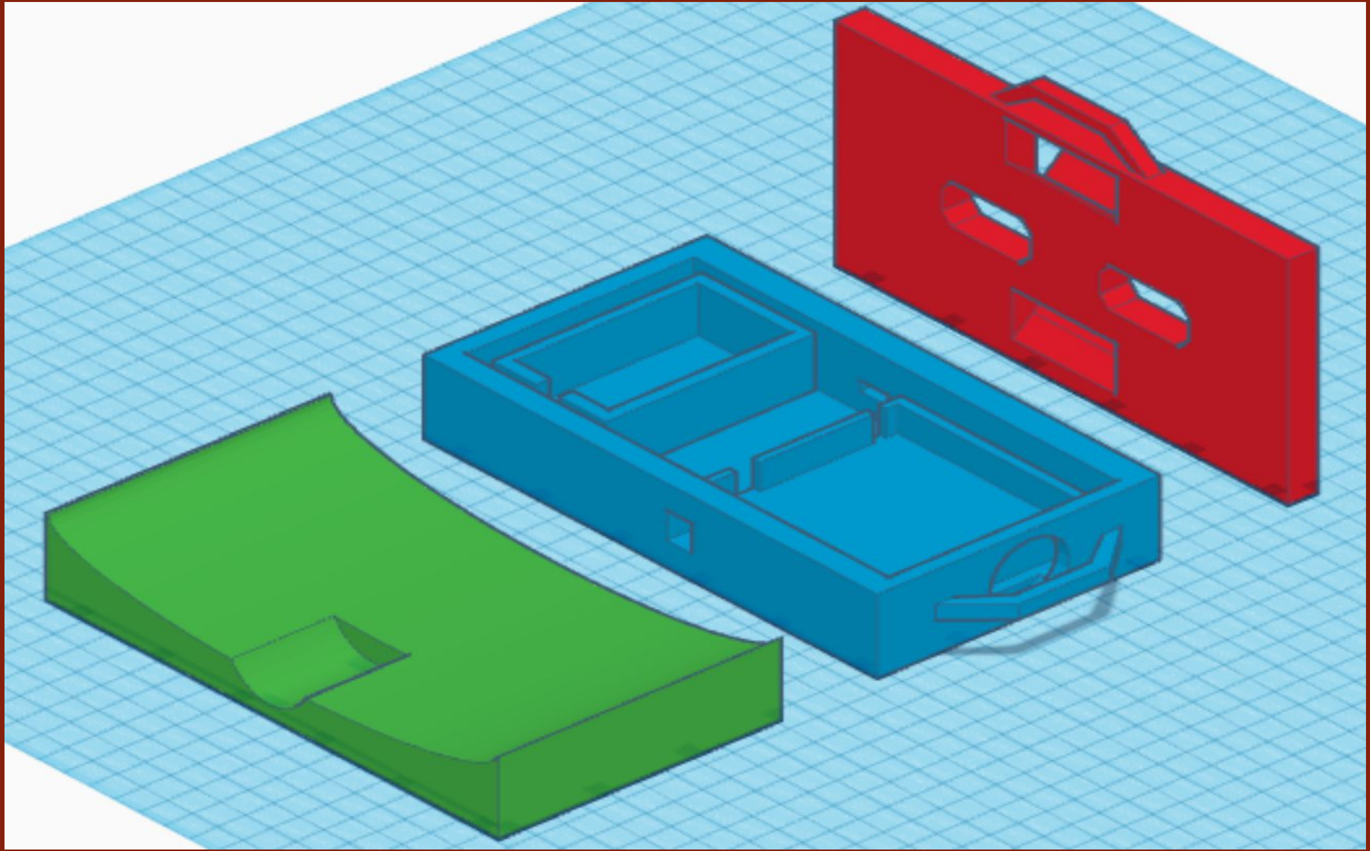
- A headset containing various sensors for range finding in front, below, and above it. Detects obstacles and hazards for the user.

- A waistband that has a series of haptic motors, each corresponding to a particular direction and can output different strengths to indicate distance.

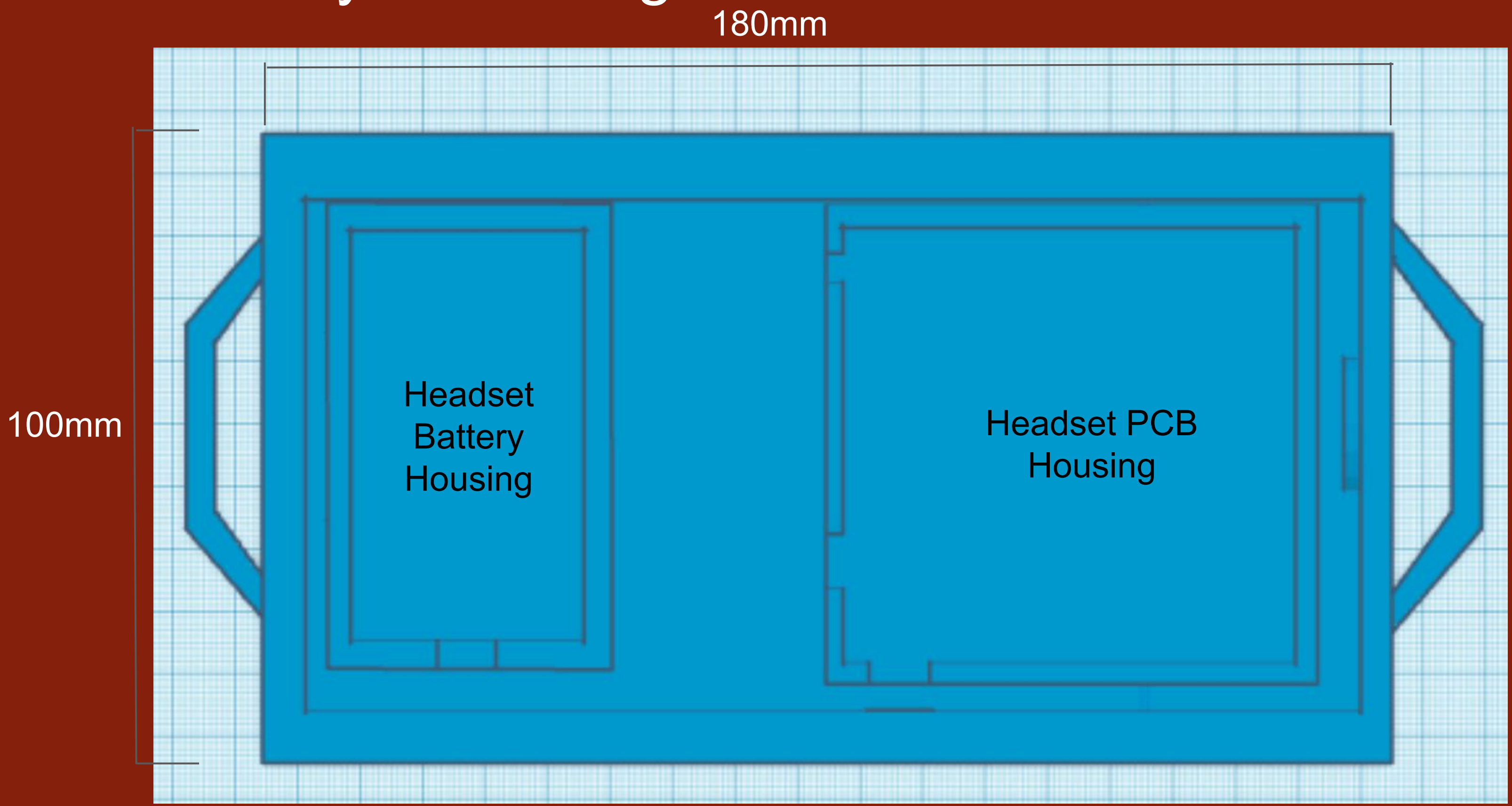
-Both of these subsystems are battery powered, and communicate via Bluetooth (Low Energy).



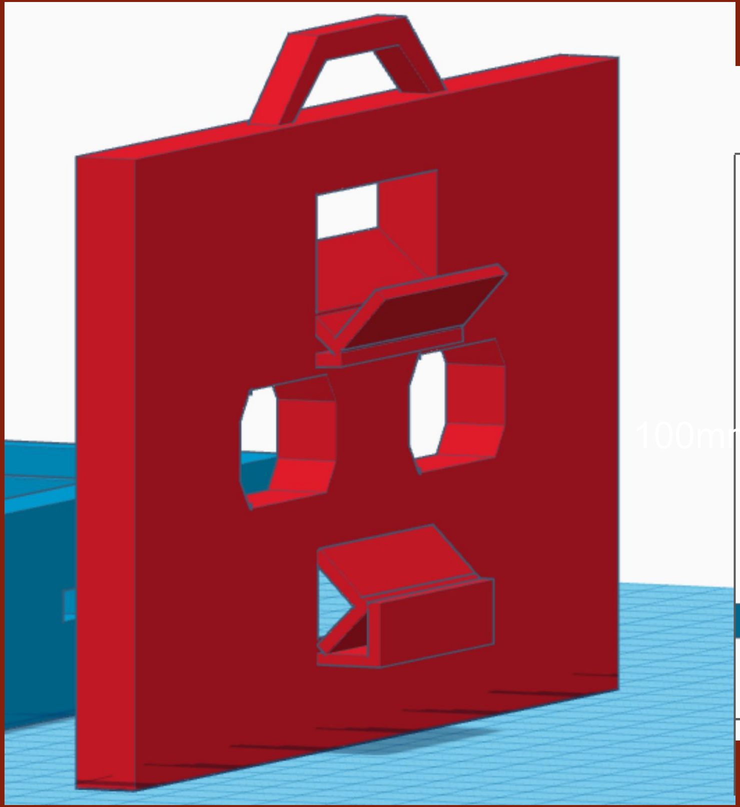
Headset Physical Design

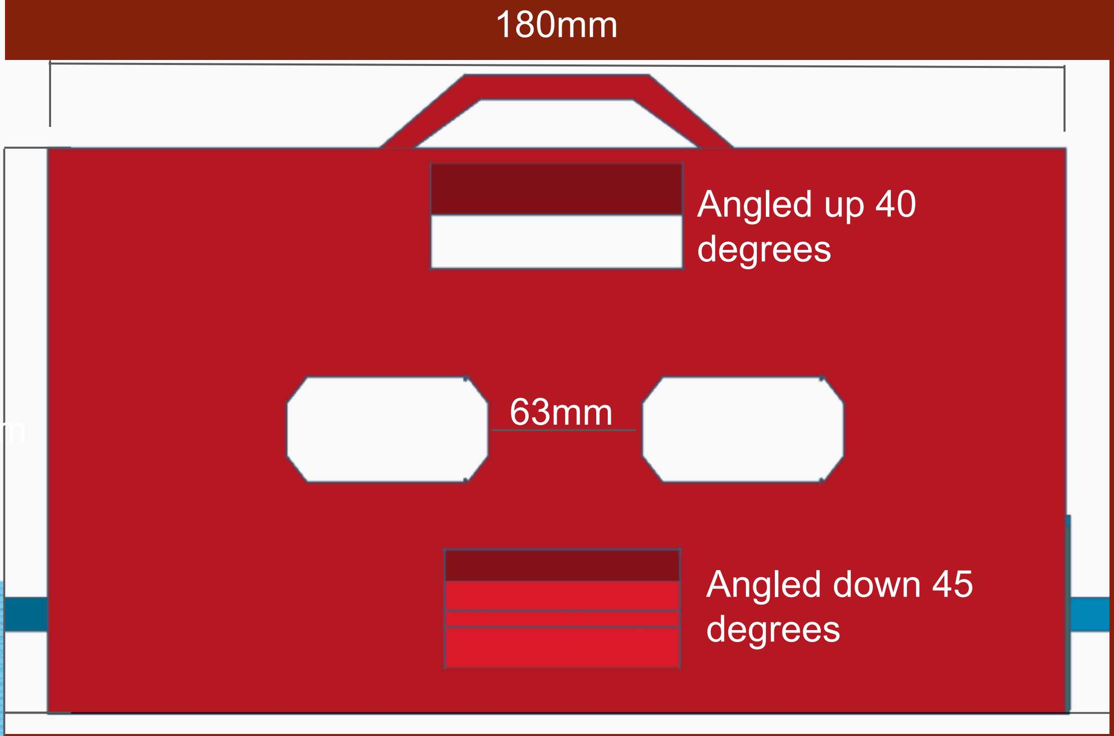


Headset Physical Design

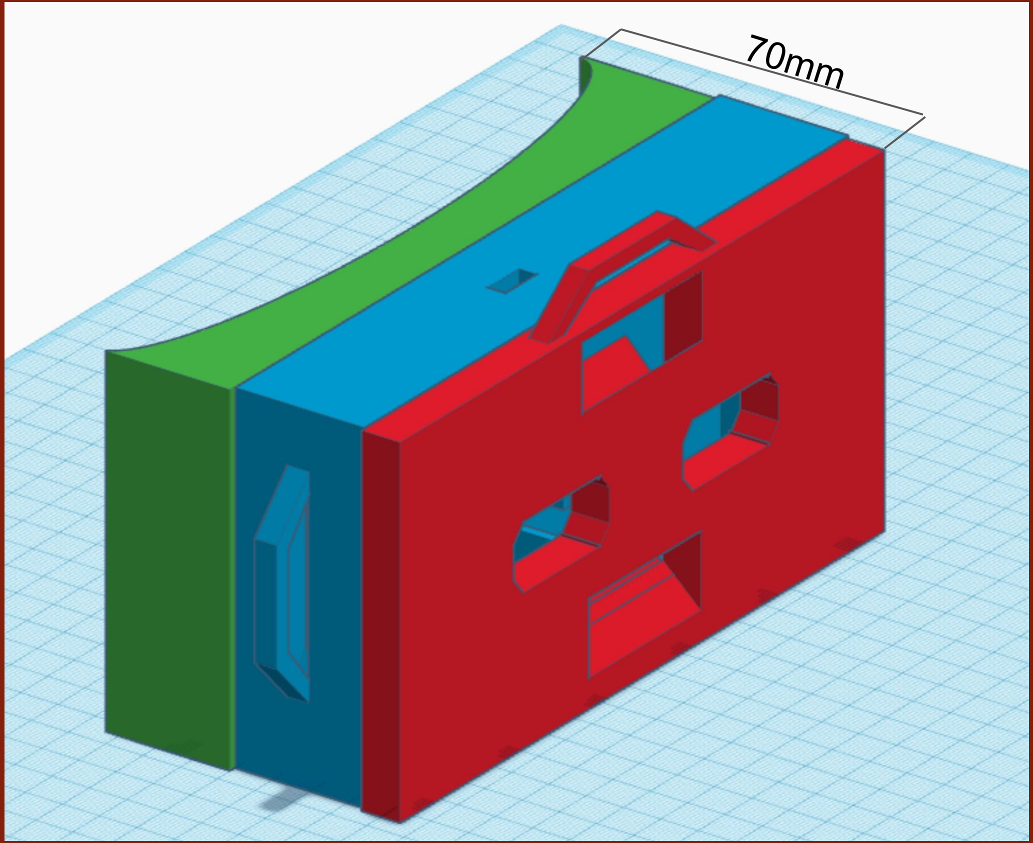


Headset Physical Design





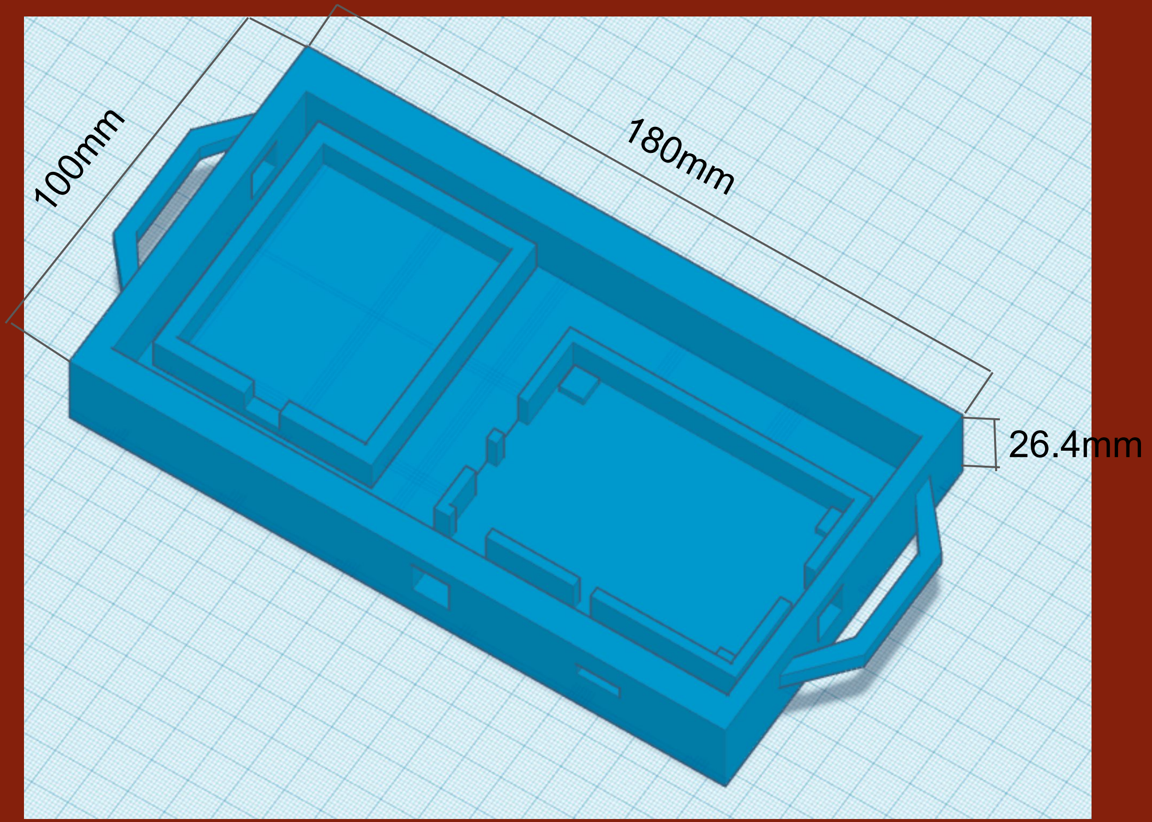
Headset Physical Design



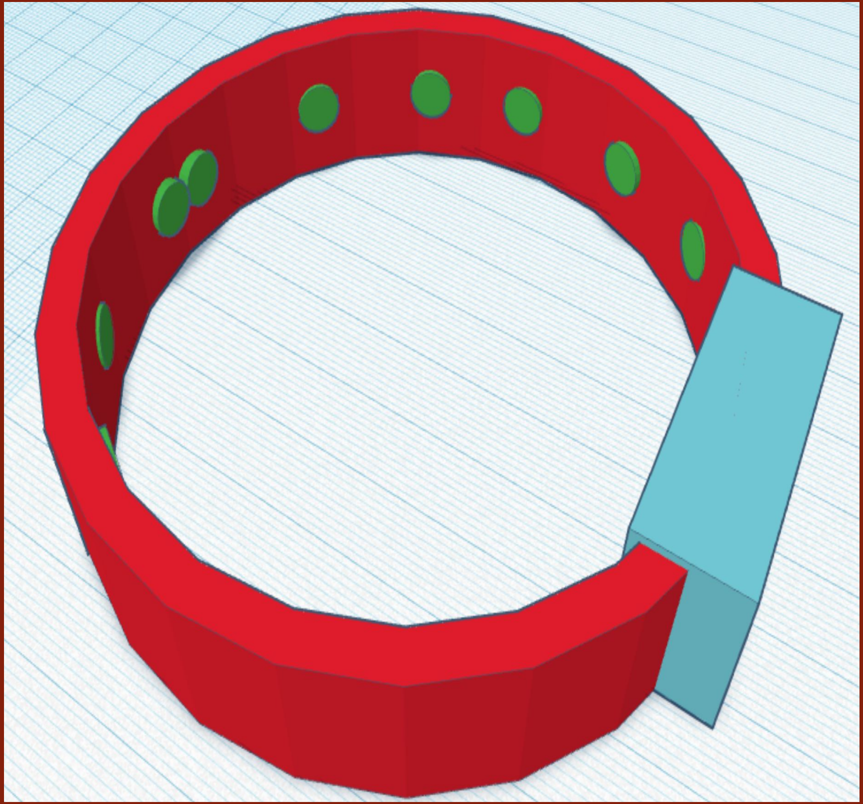
Specification weight < 500g

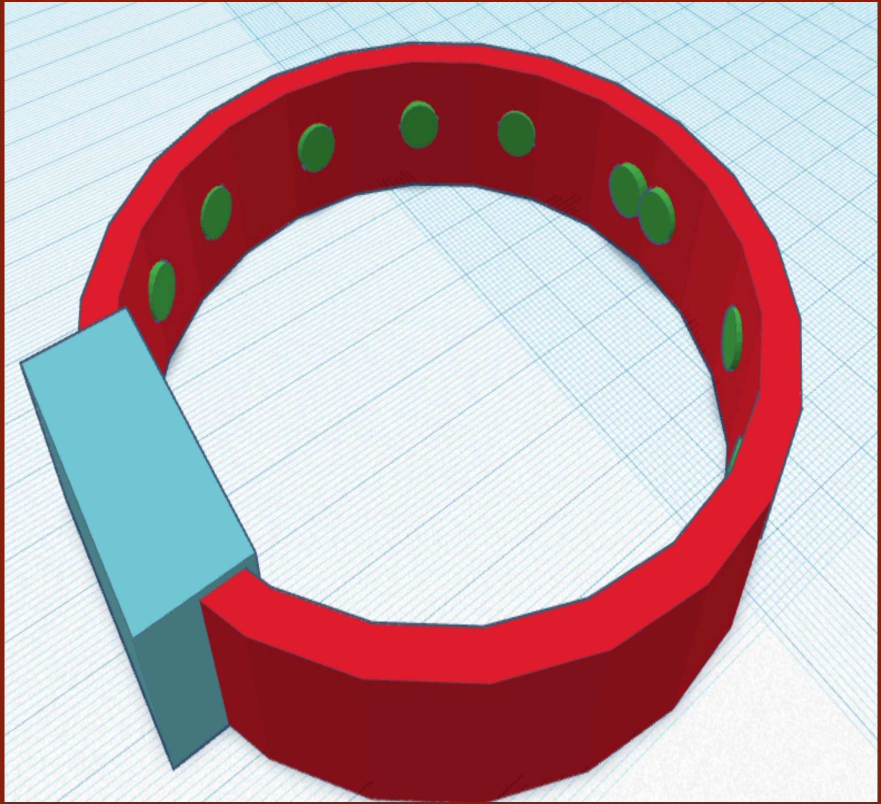
- Achieved by adjusting design to hollow format to decrease plastic weight.
- Also accommodate for weight of PCB, sensors, battery.

Waistband System Physical Design

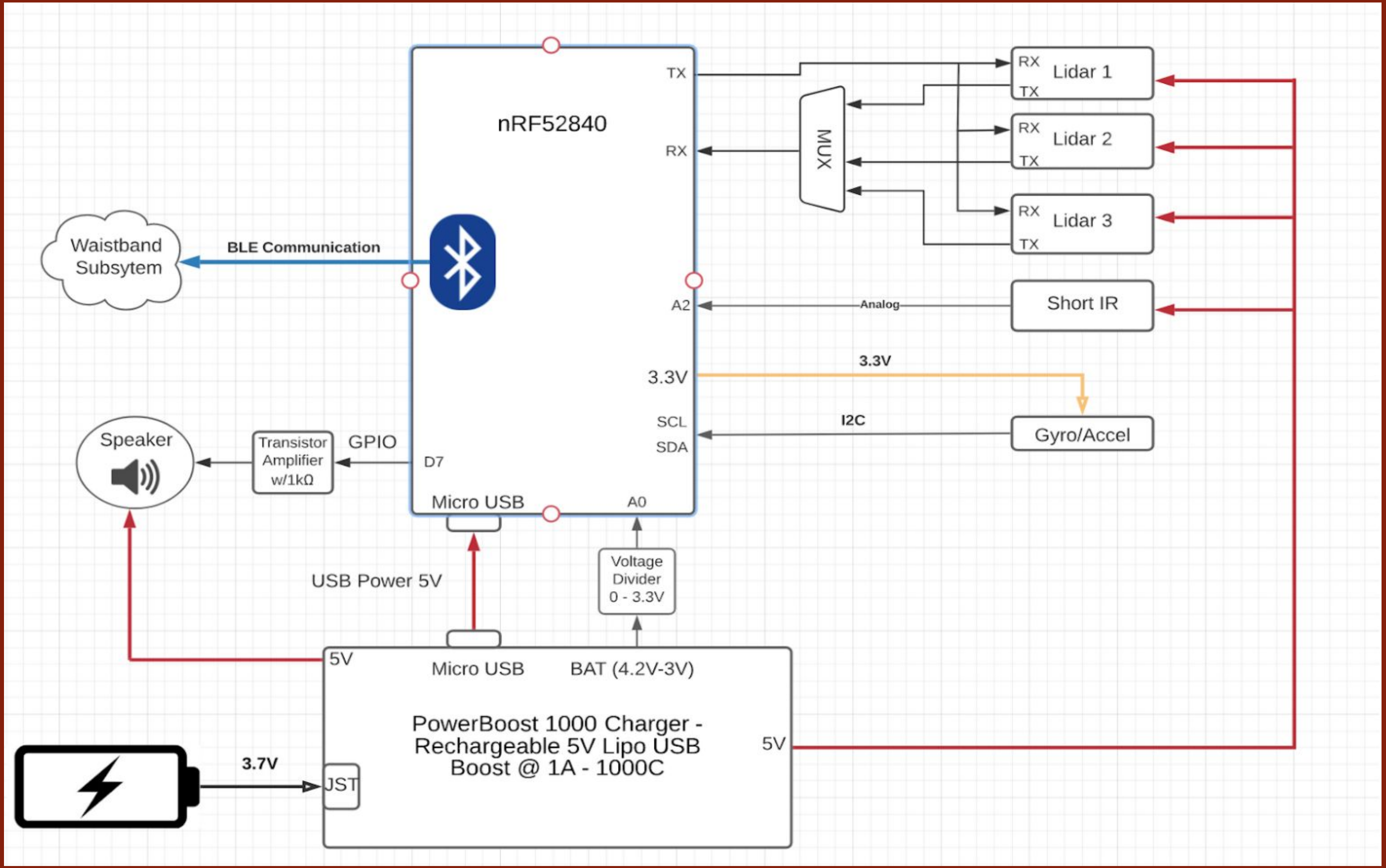


Waistband System Physical Design

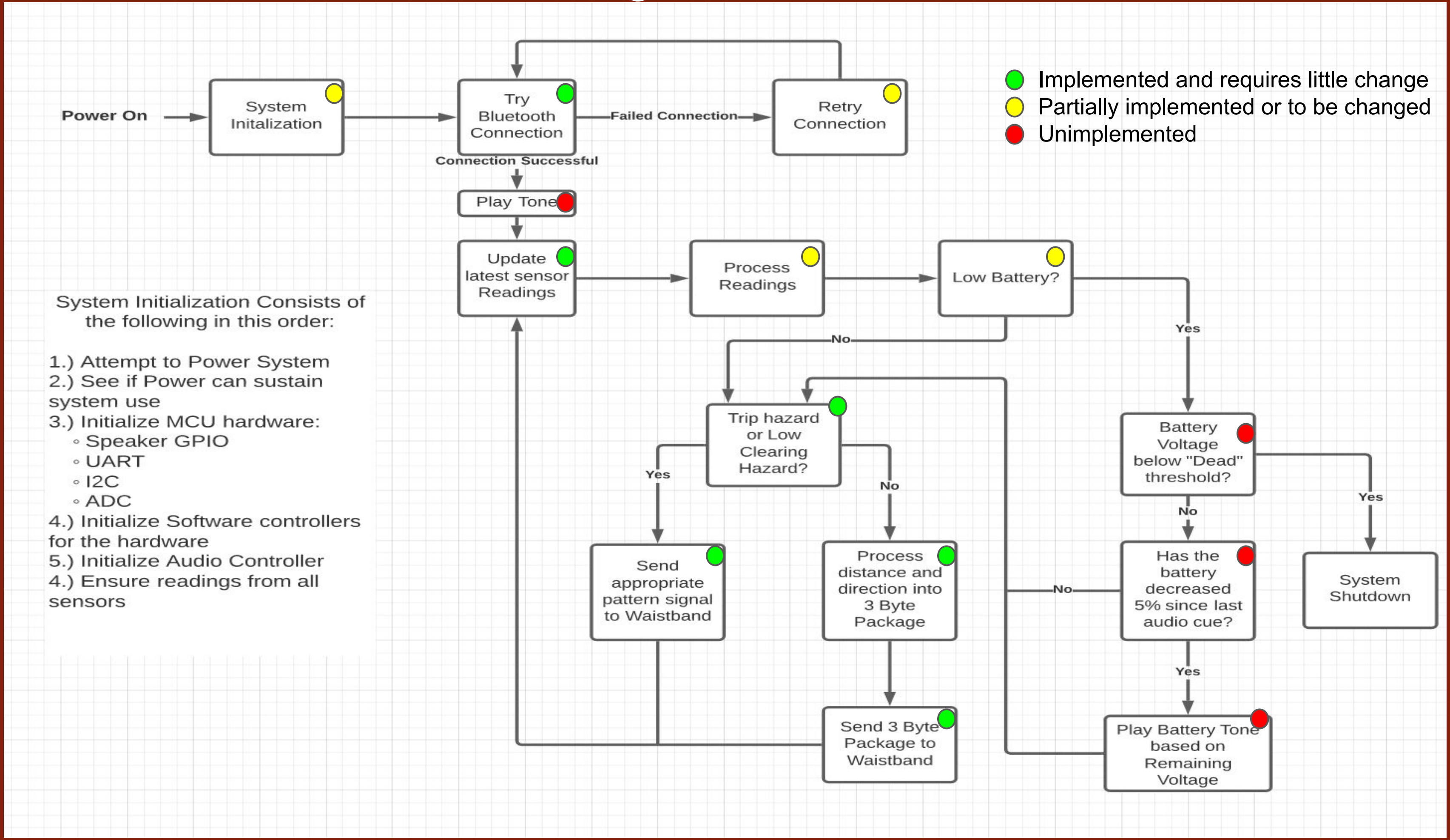




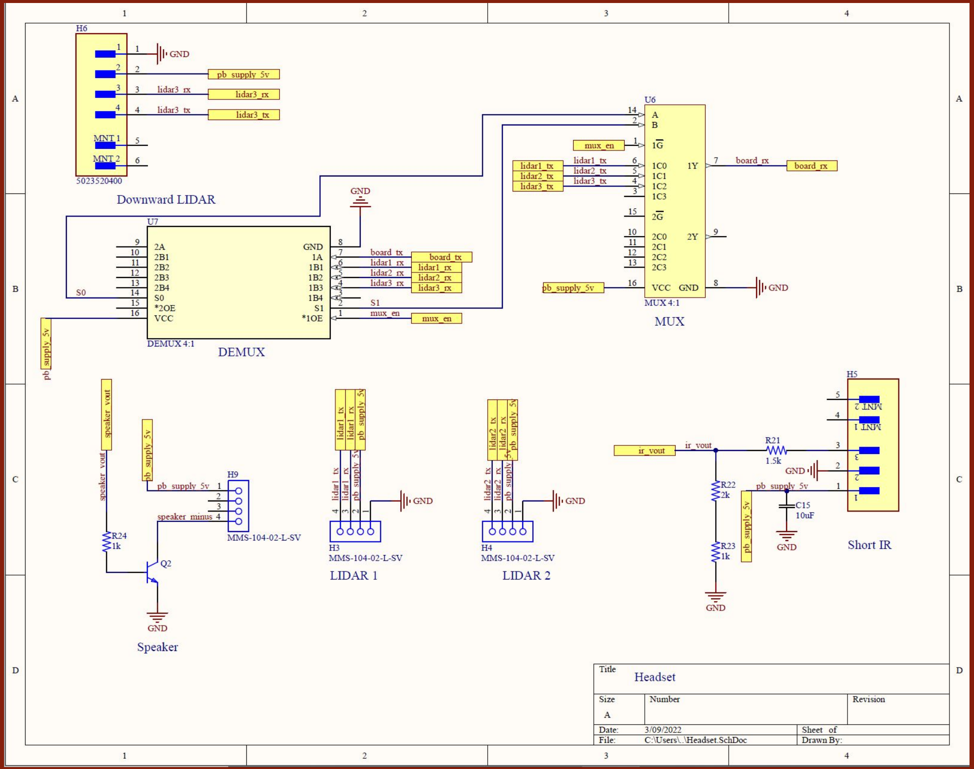
Headset Hardware Block Diagram



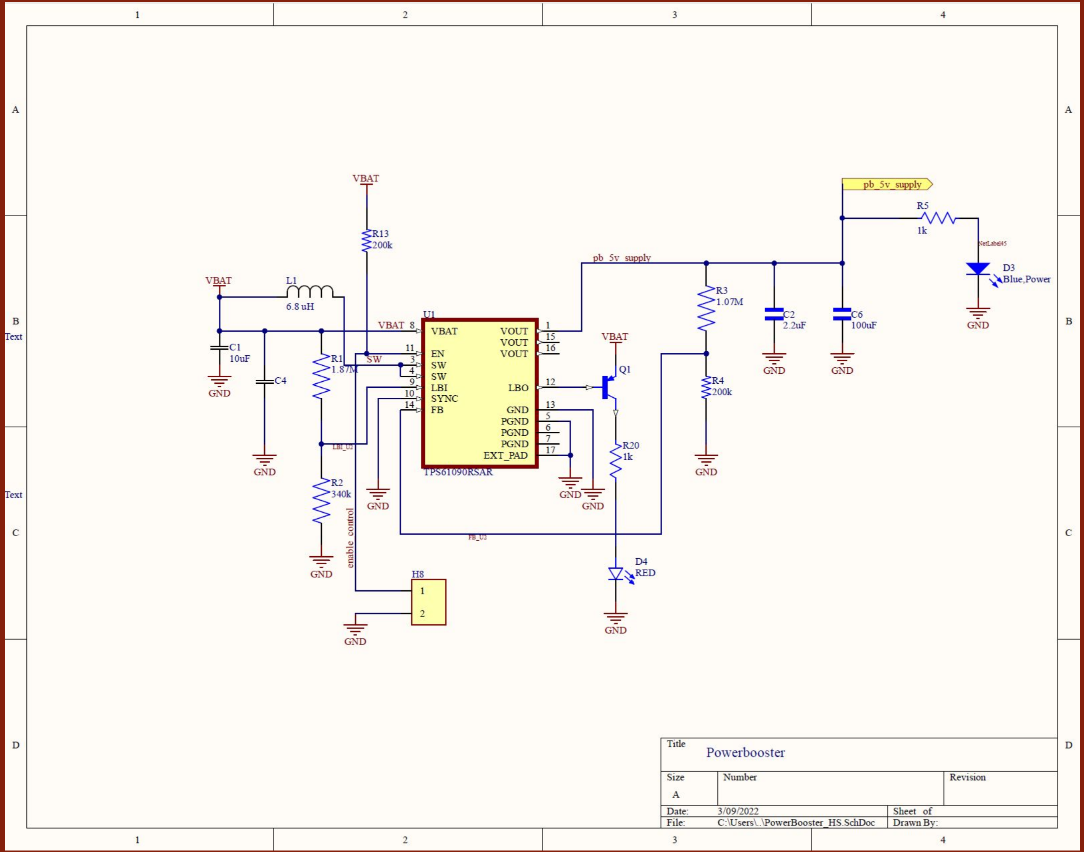
Updated Headset Software Diagram



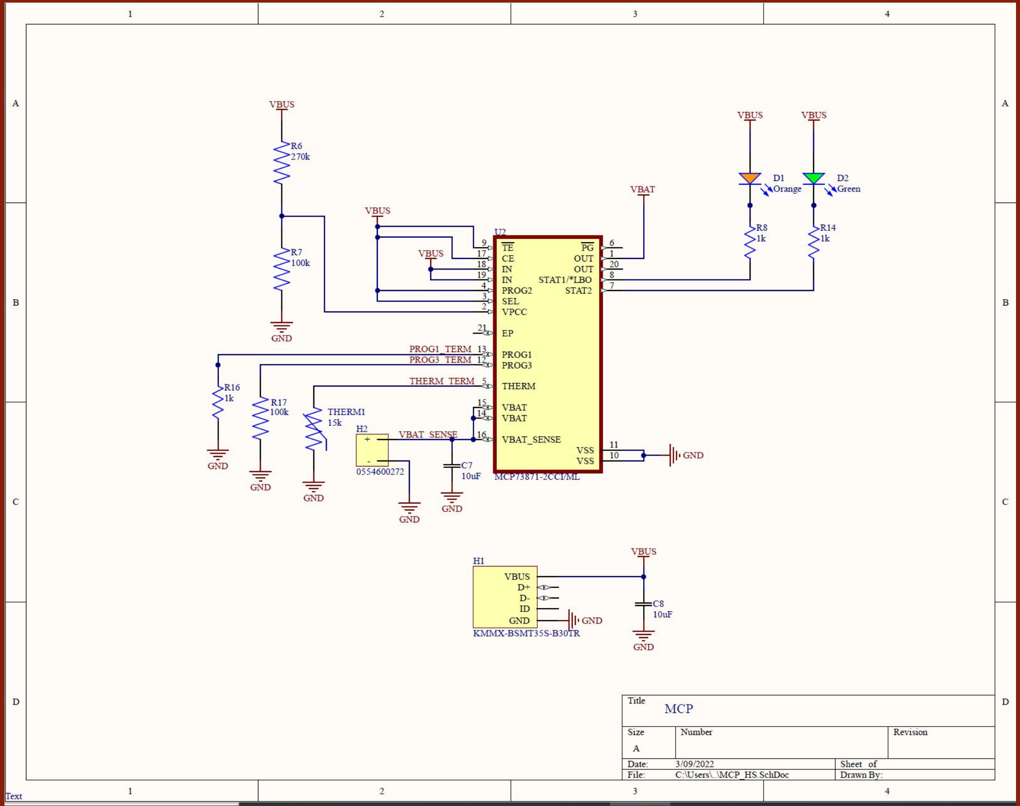
Headset PCB Schematic - Headset



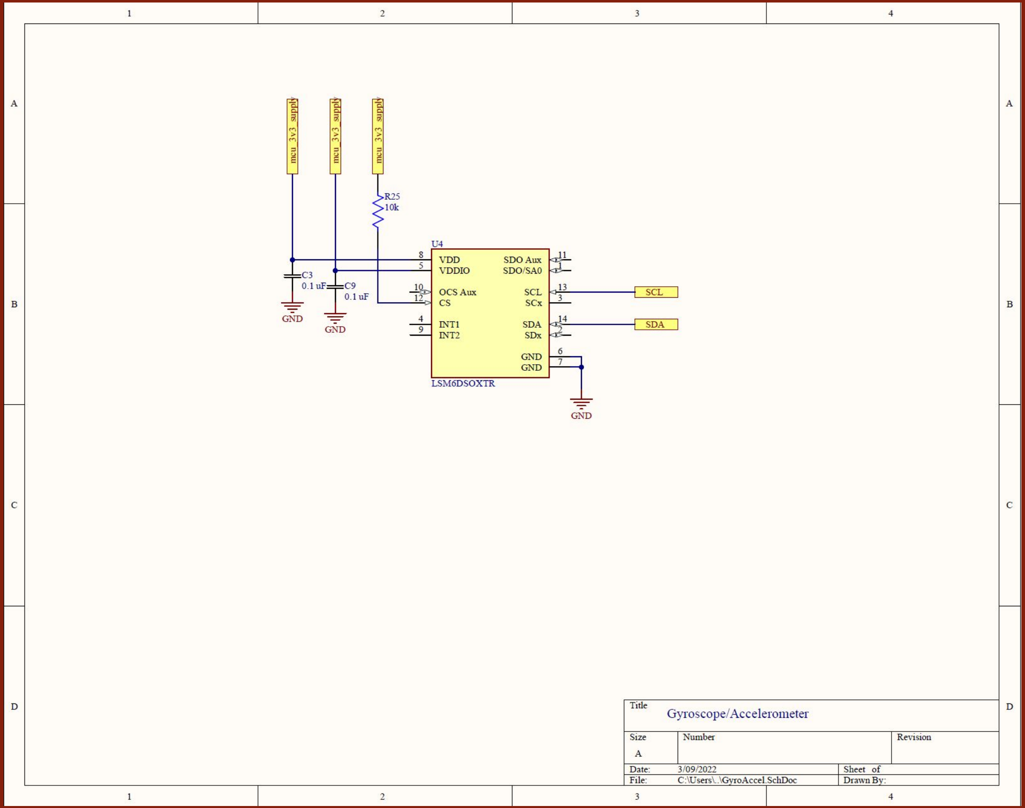
Headset PCB Schematic - Power-Booster



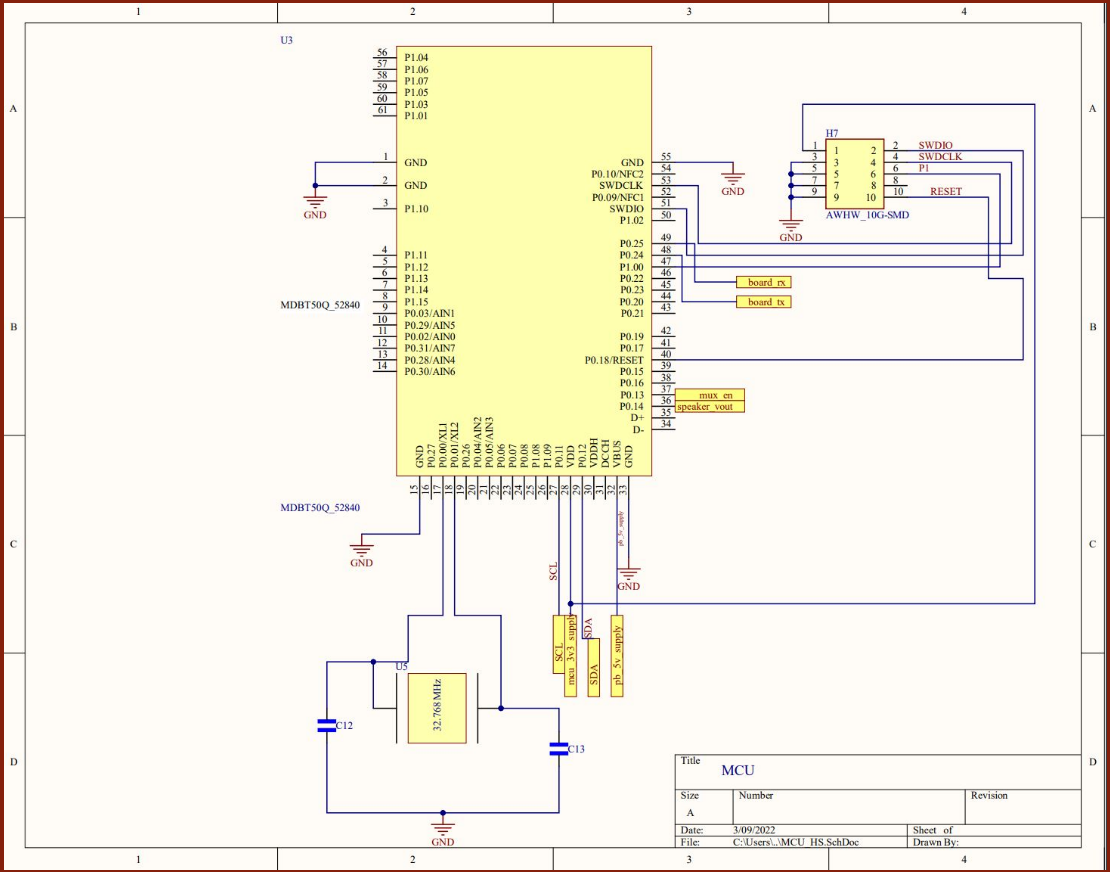
Headset PCB Schematic - MCP Battery Charge Manager



Headset PCB Schematic - Gyroscope/Accelerometer

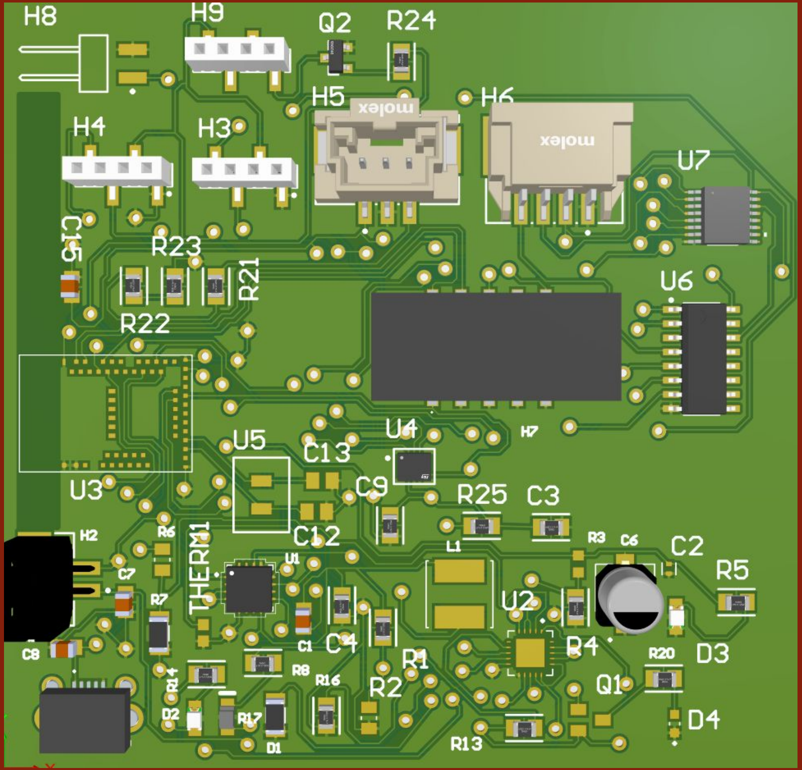


Headset PCB Schematic - MCU

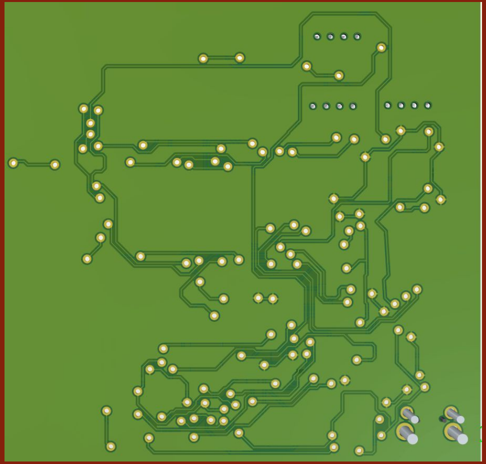


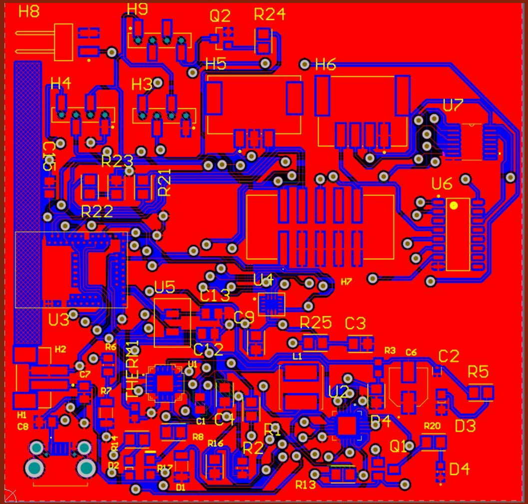
Headset Board Layout

3D Top View - 71x69 mm



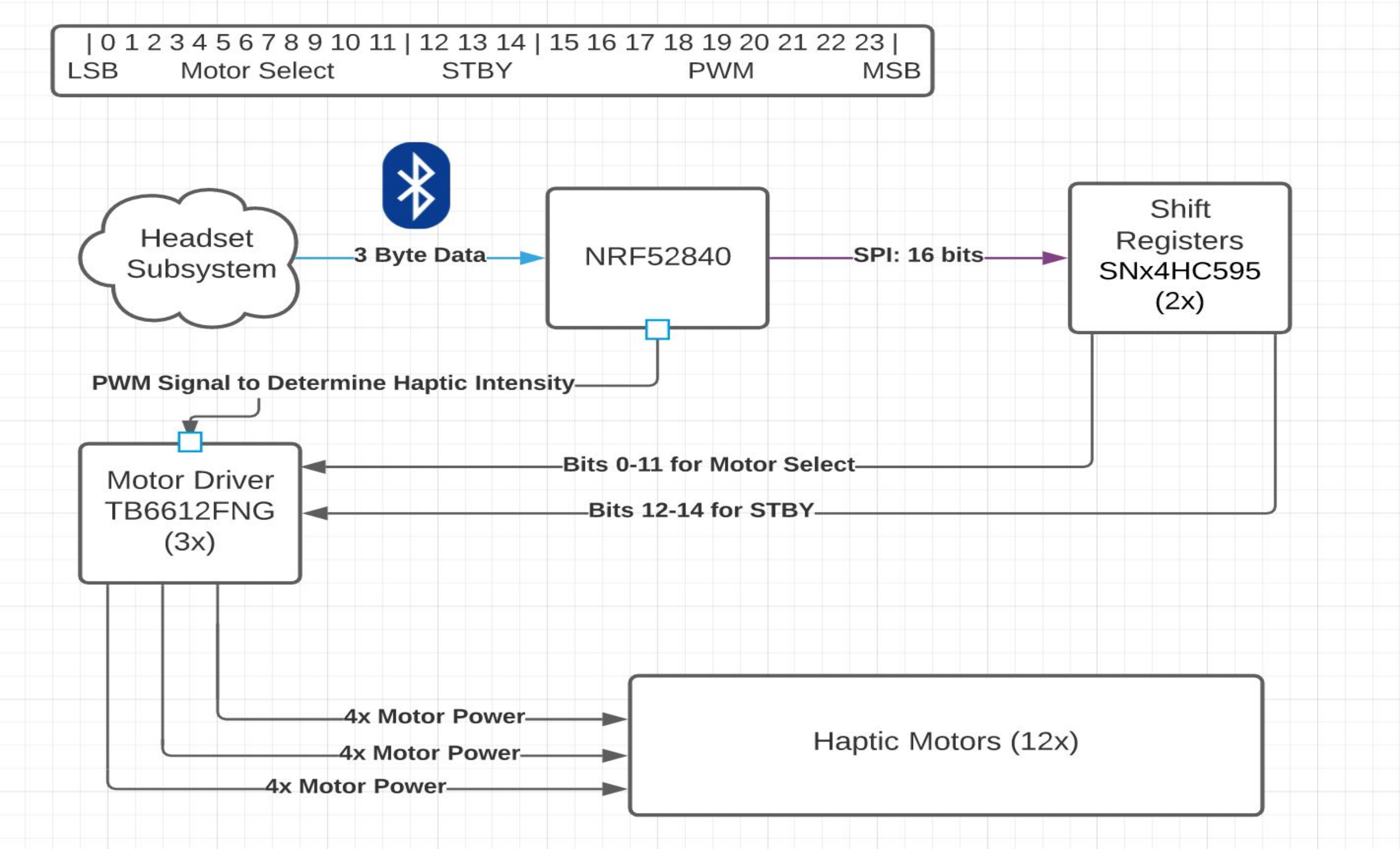
3D Back View



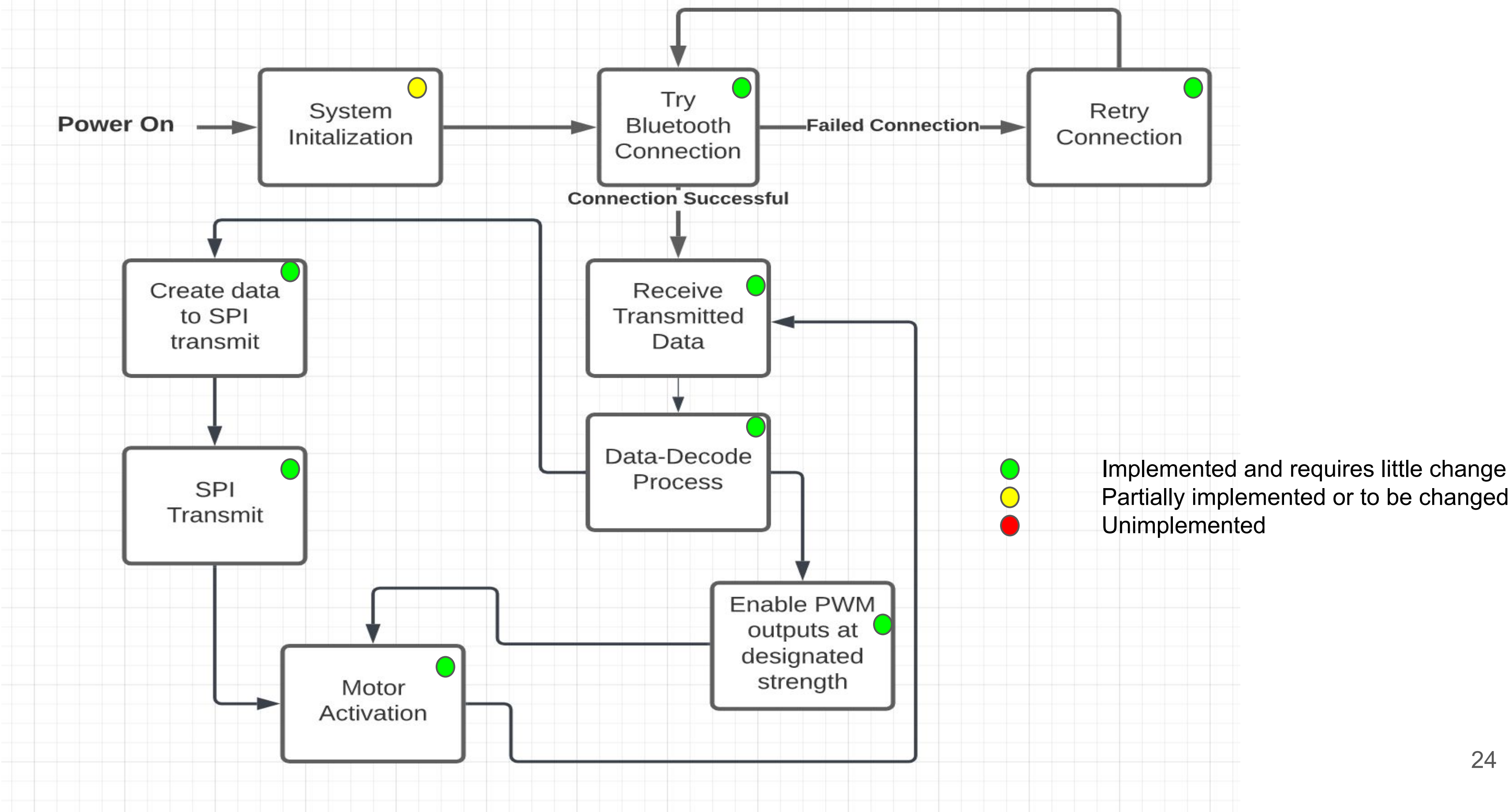


PCB View

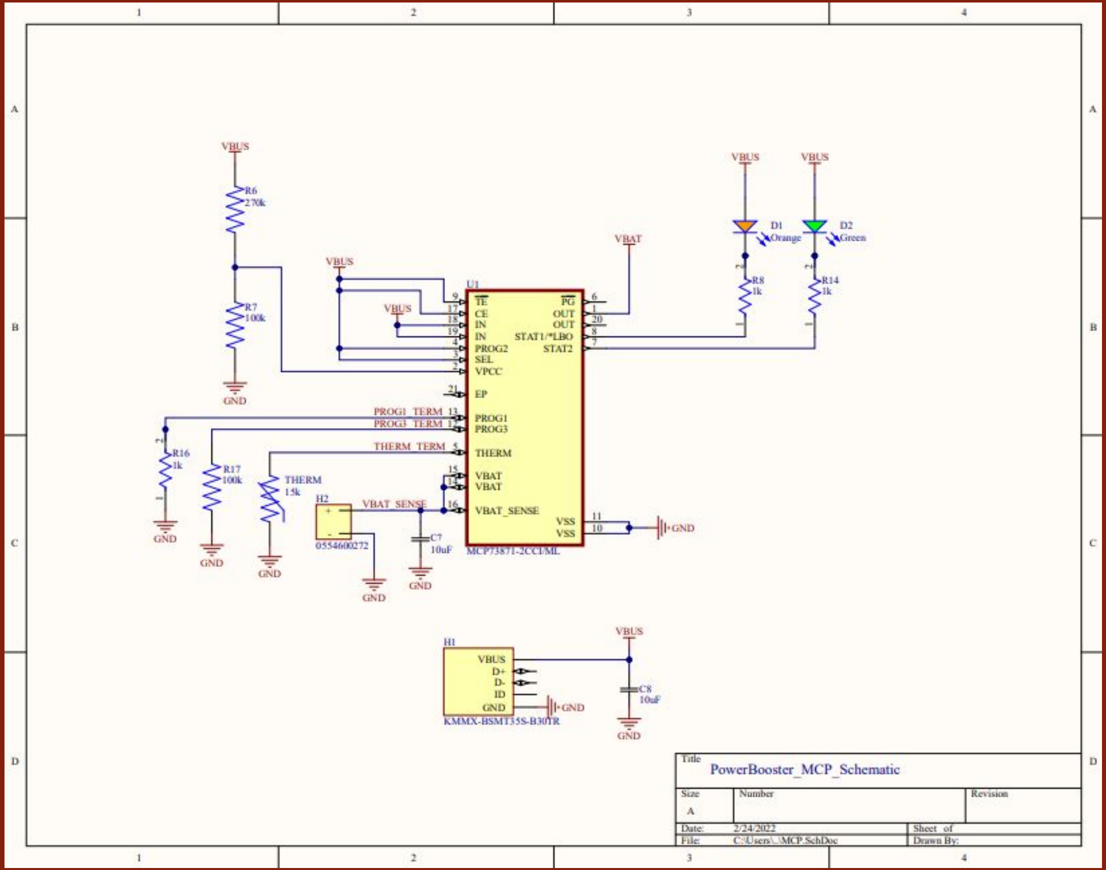
Haptic Waistband Hardware Block Diagram



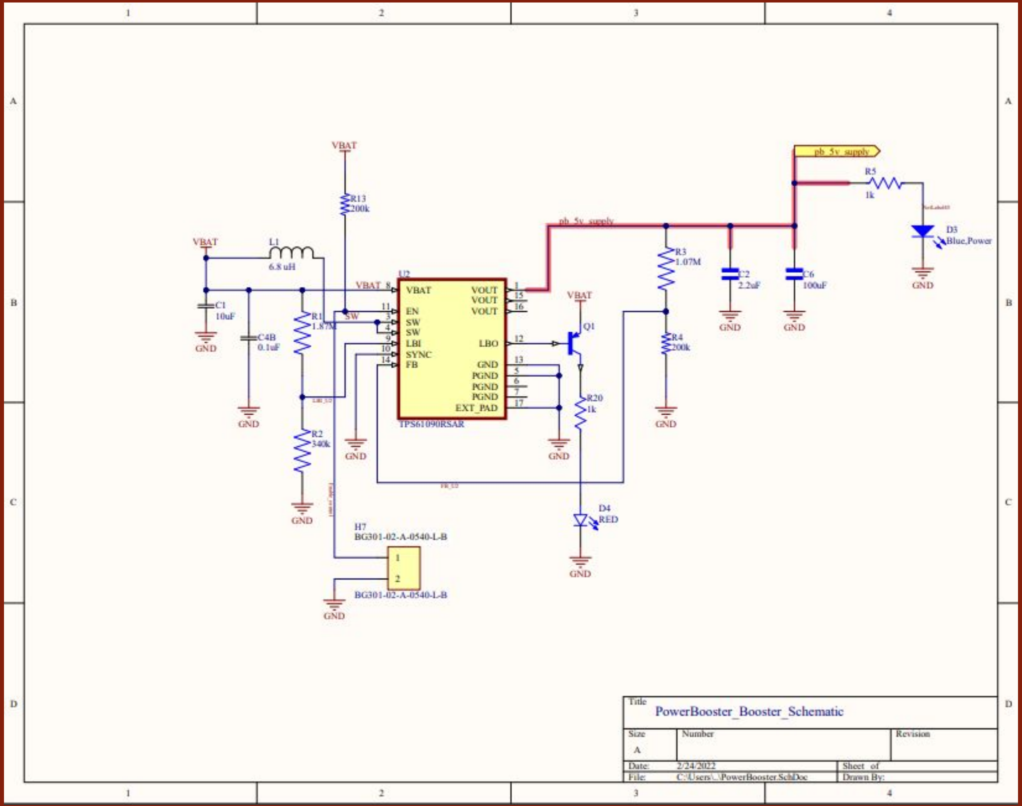
Haptic Waistband Software Diagram



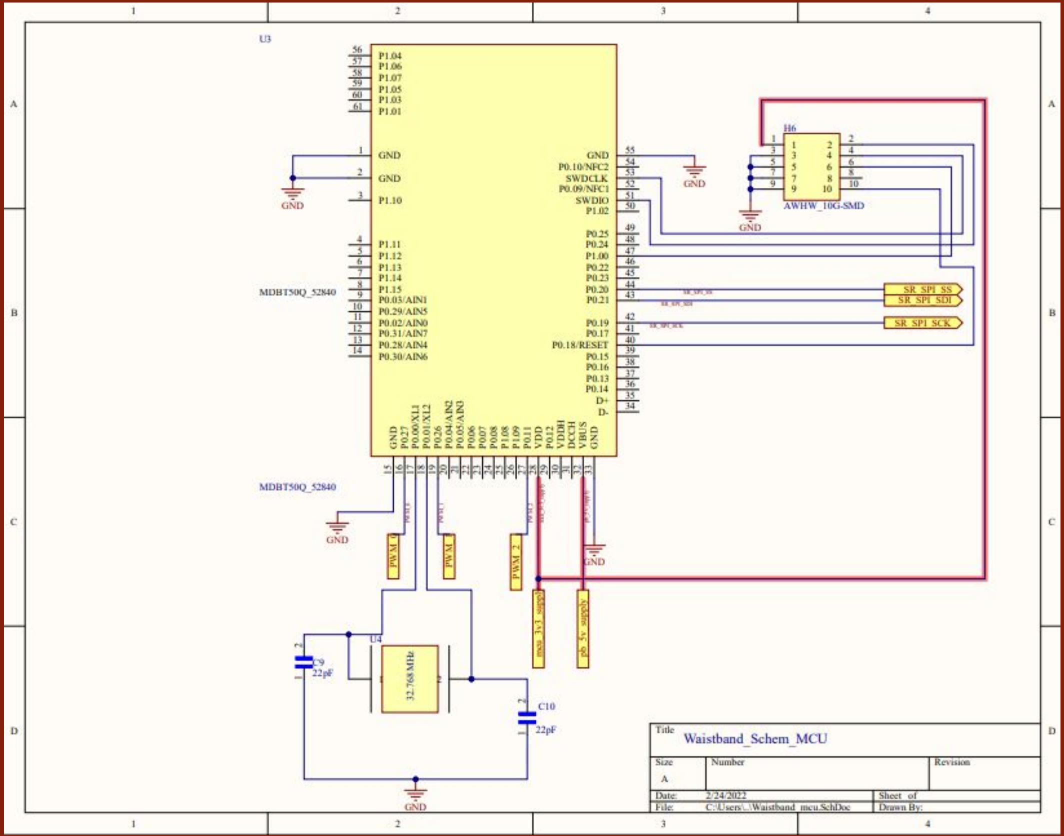
Waistband PCB Schematic - MCP Battery Charge Manager



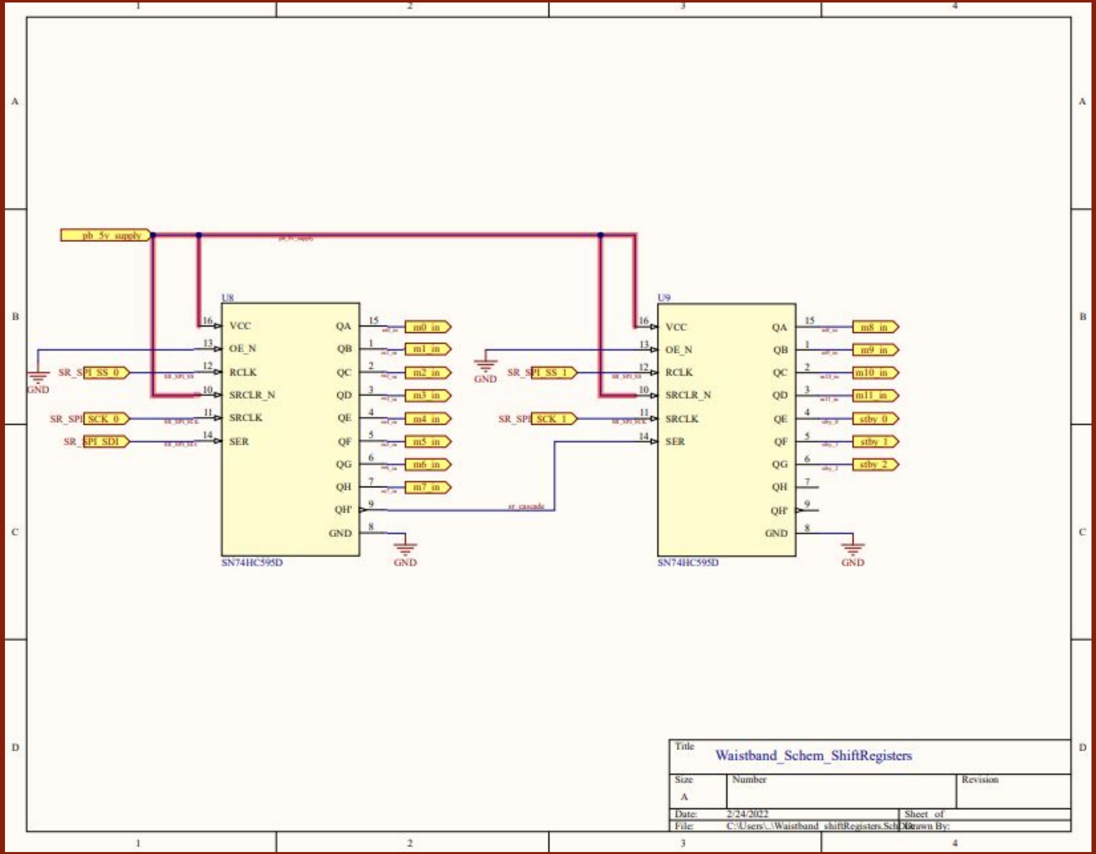
Waistband PCB Schematic - Power Booster



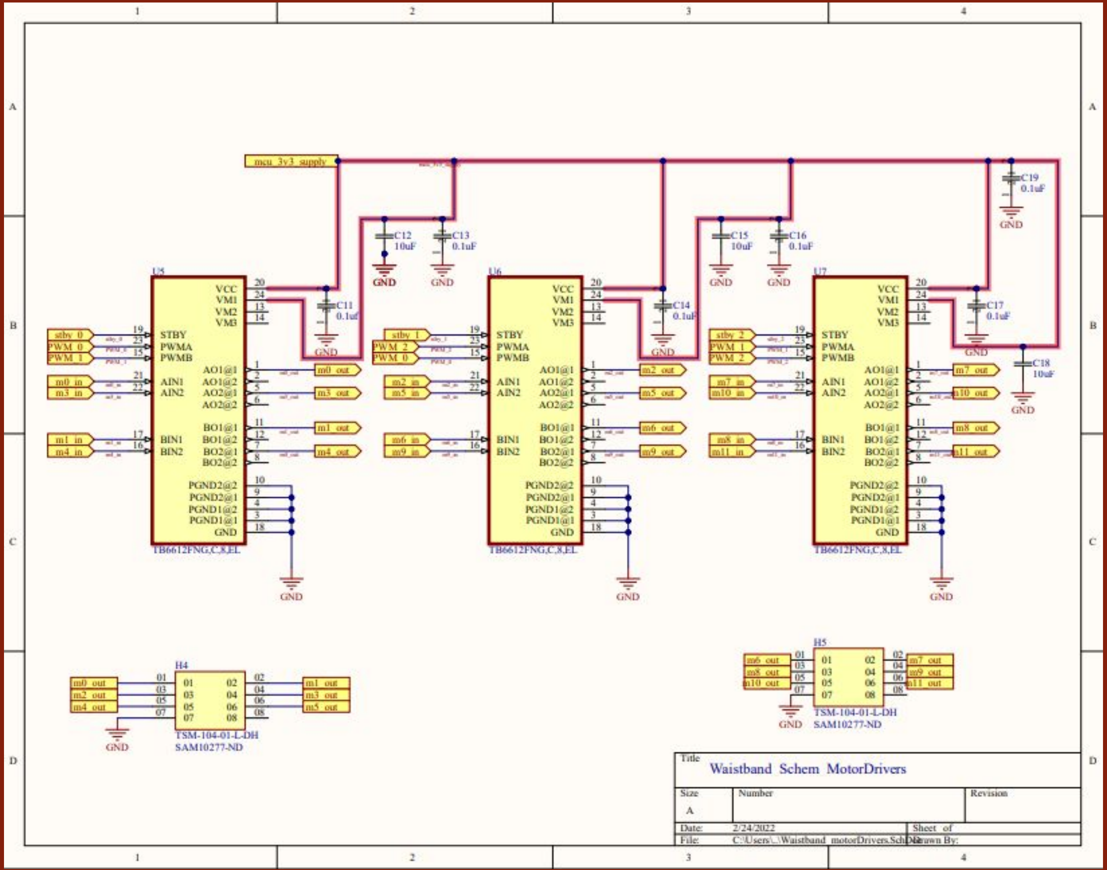
Waistband PCB Schematic - MCU



Waistband PCB Schematic - Shift Registers

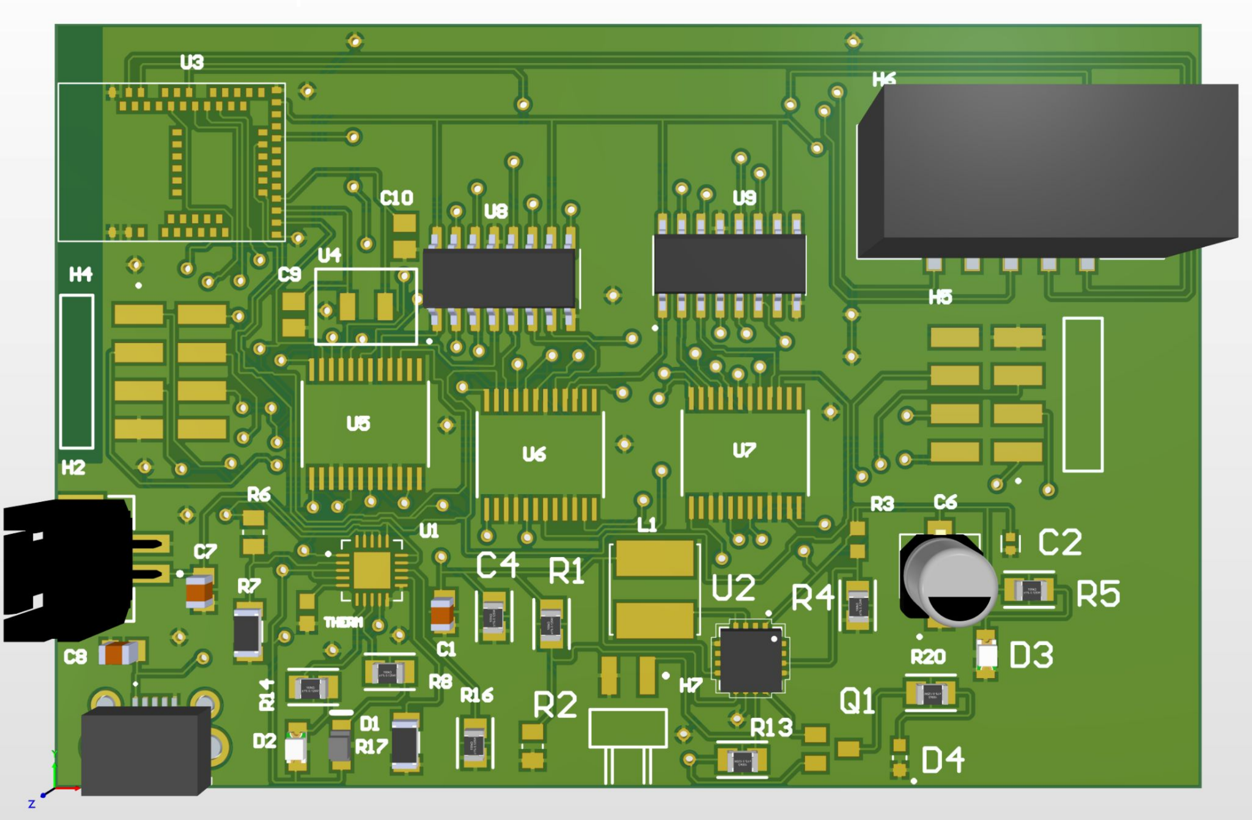


Waistband PCB Schematic - Motor Drivers

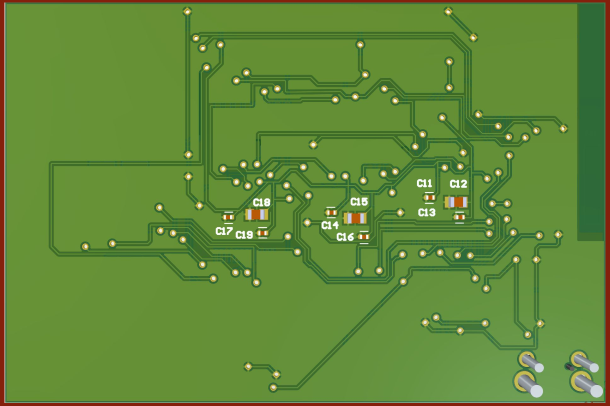


Waistband Board Layout

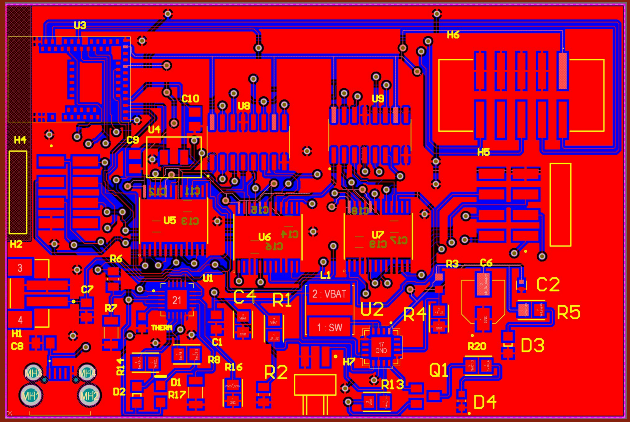
Top - 3D View - 2x3in - 50.8x76.2mm



Bottom - 3D View



Top - PCB Design View



PCB Status

In Production

W202202242300695
Estimated Finish Time: 2022-02-27 12:00:00

2022-03-09 22:35:21 — SO12202246046-3973261A completed production, ready to send to shipping center. Estimated arrival time: 2022-03-11 11:35:21

2022-03-08 22:04:11 — SO12202246046-3973261A is producing in Factory JLCPCB Factory 3. Estimated finish time: 2022-02-27 12:00:00, view progress

2022-03-08 22:04:11 — SO12202246046-3973261A manufacturing data finished.

2022-02-28 06:59:48 — Y1-3973261A completed production, ready to send to shipping center. Estimated arrival time: 2022-03-01 19:59:48

2022-02-26 02:43:29 — SO12202246046-3973261A confirmation pending, please check your email for details and reply us asap.

Unexpected delay in first PCB shipment delay

- Problem with stencil, updated status states that it is in transit

Due to this some of our systems are still on breakouts.

- Power-Booster
- MCU's
- Motor Drivers
    - Example on adapter
- Gyroscope

Project Expenditures

Current Cost

Part	Price per Unit	Quantity	Total Price
Vibration Motor	$2.15	12	$25.80
SparkFun Triple Axis Accelerometer Breakout - ADXL335	$14.95	1	$14.95
TFMini Plus Lidar	$50.00	2	$100.00
Adafruit Feather nRF52840 Express	$24.95	1	$24.95
SHARP Long Range IR (100-550cm)	$9.85	1	$9.85
SparkFun 6 Degrees of Freedom Breakout - LSM6DSO (Qwiic)	$11.95	1	$11.95
Breadboard to JST-ZHR Cable - 5-pin x 1.5mm Pitch	$2.95	1	$2.95
JST to Breadboard Jumper (3-pin) (basic 2mm pitch)	$1.50	1	$1.50
5V 2.5A Switching Power Supply with 20AWG MicroUSB Cable	$8.25	1	$8.25
Lithium Ion Polymer Battery - 3.7v 2500mAh	$14.95	1	$14.95
Waistband PCB Rev 1	$15.10	1	$37.20
Waistband PCB Assembly Rev 1	$50.46	1	$67.85
PCB Headset Materials : Revision 1	$15.11	1	$35.47
Total Parts	------------	---------------	**$425.29**

Future Costs

Expected Parts	Expected Price
PCB Headset Rev 2	$40
Headset Material	$15
PCB Waistband Rev 2	$40
Waistband Material	$15
Total PCB	**$110**

Expected total : $425.29 + $110 = $535.29

CDR Hardware

Waistband

- Nordic nrf52840 (Receiver)
- Motors 12x
- Shift registers 3x
- Motor Drivers 3x
- PowerBoost 1000 Charger - Amplifier for 5V and 1 Amp, allows battery connection and charging
- Rechargeable Li-Po with 3.7V 2500 mAh Battery Capacity

Headset

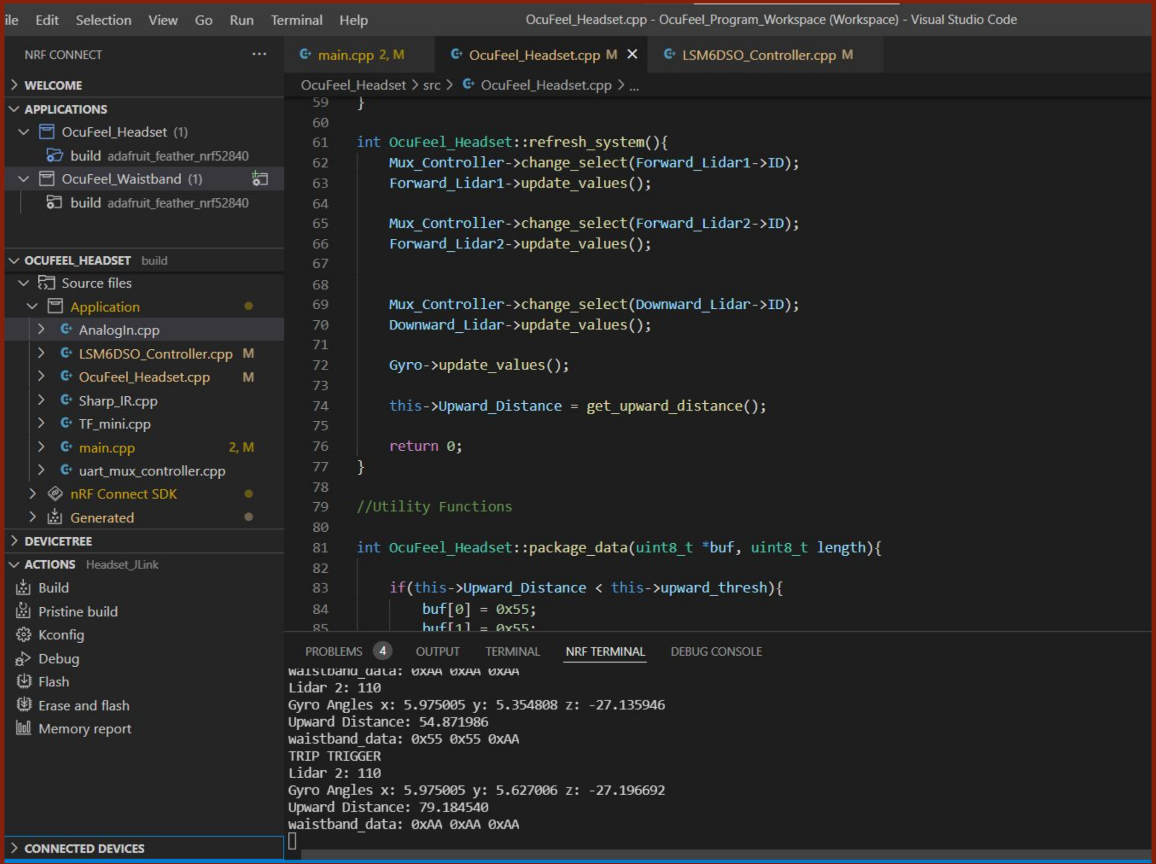
- Nordic nrf52840 (Transceiver)
- TFMini Plus Lidar 2x - Forward facing ranging
- Short IR - Low Clearing detection
- TF Mini S Lidar - Trip hazard detection
- Accelerometer/Gyroscope
- Speaker 2W 8 Ω - Audio cues
- PowerBoost 1000 Charger - Amplifier for 5V and 1 Amp, allows battery connection and charging
- Rechargeable Li-Po with 3.7V 4400 mAh Battery Capacity

Software

Headset takes an Object-Oriented approach (C++) while the Waistband is still procedural.

Modular approach allows for quick testing changes and debugging.

Waistband software using C.



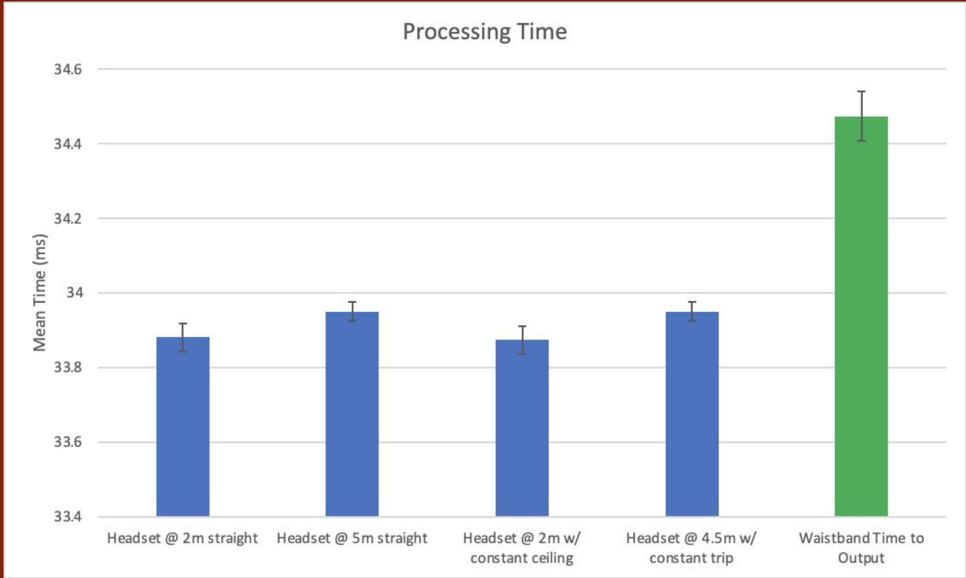
Snippet of the Headset system class and a list of source files.

Software Processing Time

Current iteration:

- Headset processing and packet sending averaged ≅34 ms
- Total System averaged: ≅35 ms

Well below our <500ms specification

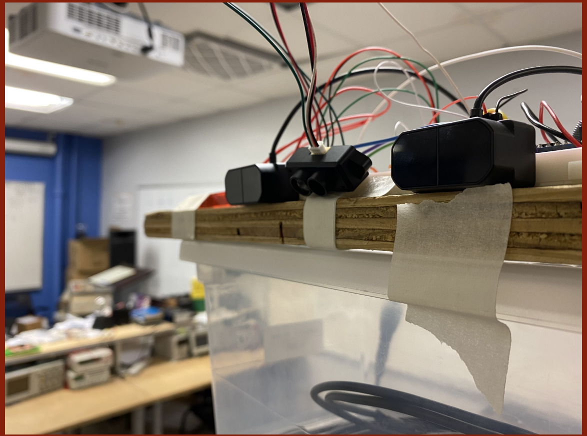


Test	Mean Time (ms)	Std. Dev (ms)	95% Confidence Interval (ms)
Headset @ 2m straight	33.88039867	0.325035137	0.036780512
Headset @ 5m straight	33.95016611	0.217964001	0.024664495
Headset @ 2m w/ constant ceiling	33.87375415	0.332679314	0.037645517
Headset @ 4.5m w/ constant trip	33.95016611	0.217964001	0.024664495
Waistband Time to Output	34.47333333	0.586317419	0.066346843

Trip Detection

- Using TFmini-S ToF LIDAR (12m range)

Mean Distance from Object (cm)	Avg. of Mean Detection Distance (cm)	Calculated Change in Height (cm)	Measured Change in Height (cm)	Percent Error
255.1	247.957037	7	7.142962963	2.04%



Testing Gyroscope

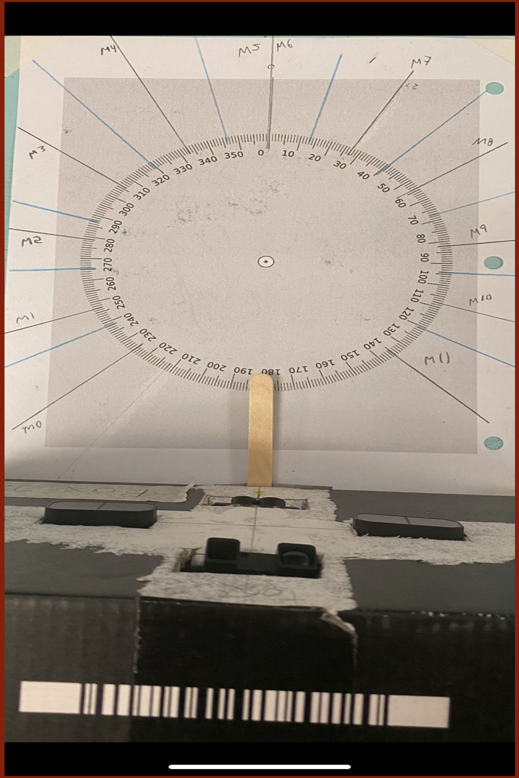
User goes between designated motor range & then outside

- Example: M1 haptic is between 94.5° & 121.5°

Testing Criteria Based On:

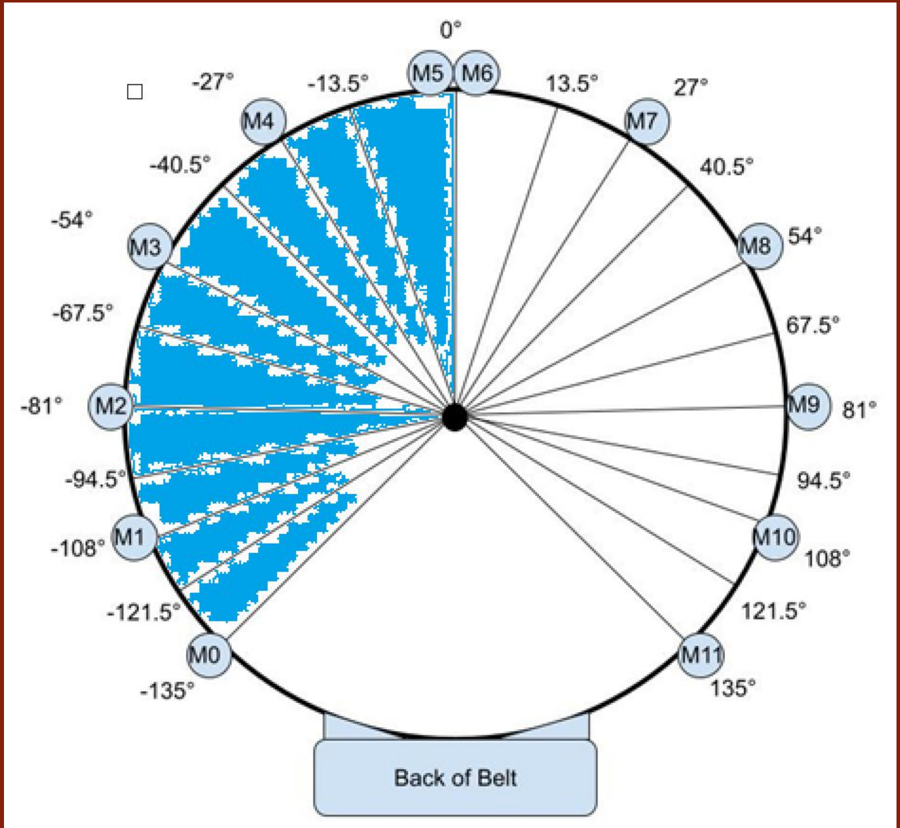
- Hit: angle of Gyro Z axis within the acceptable range
- Miss: angle of Gyro Z axis not within the acceptable range

Note: Will do more specific accuracy tests into FPR



Gyroscope Test Data

	Motor					
Trial	M0	M1	M2	M3	M4	M5
1	y	y	y	y	y	y
2	y	y	y	y	y	y
3	y	y	y	y	y	y
4	y	y	y	y	y	y
5	y	y	y	y	y	y
6	y	n	y	y	y	y
7	y	y	y	y	y	y
8	y	n	y	y	y	y
9	y	y	y	y	y	y
10	y	y	y	n	y	y



Updated Battery Life Breakdown

Headset Subsystem

Part	Avg Current Consumption (mA)
Lidar 1&2 (Plus)	112 + 112
Lidar 3 (S)	140
Short IR	30
Powerbooster	5
Speaker	70
Accel/Gyro	0.5
Board Processing	*To be Calculated*
Total	**469.5 mA**
Battery Capacity	**4400 mA**
C Rate	**0.1067 OR ~9.3 hour battery life**

Waistband Subsystem

Part	Current Consumption (mA)
Board Processing	*To be Calculated*
Powerbooster	5
Motor Drivers 3x	1.8 + 1.8 + 1.8
Shift Registers 2x	35 + 35
Total	**80.4 mA**
Battery Capacity	**2500 mA**
C Rate	**0.0322 OR ~31 hour battery life**

Note:
Can’t calculate final values until full PCB implementation

Next Steps - Hardware

- **Headset**
    - Assemble PCB and transfer software onto Headset PCB MCU - nRF52840
    - Test PCB version of system
    - Finalize and print physical design of headset
    - Implement system into physical design
    - System test in final physical design
- **Waistband**
    - Assemble PCB and transfer software on Waistband PCB MCU - nRF52840
    - Test PCB version of system
    - Finalize and print physical design of waistband
    - Implement system into physical design
    - System test in final physical design

Next Steps - Software

Headset

- Cleaning up sensor readings
  - In particular, the gyro filtering and processing needs to be expanded upon
  - IR sensor is accurate, but would require some processing to stabilize data
- Battery life and Speaker modules
- More reliable ESB service
  - If necessary or deemed appropriate, switch to a different BLE service

Waistband

- Battery life detection
- Sending subsystem information back to the headset

FPR - Deliverables

- Full system demonstration
  - 3D printed physical design will be worn by user.
  - An “obstacle course” will be set up for the user to navigate through solely using the feedback provided by the OcuFeel system.
  - As the system will be worn, both systems will solely rely on battery power.
- Performed tests
  - Ensure system is rechargeable.
  - Detailed gyroscope analysis to ensure angular accuracy.
  - Adaptable trip detection depending on users height.
  - User survey test and analysis

Responsibilities into FPR & Demo Day

Matt -

- System Validation & Software Improvements

Callum -

- Waistband PCB assembly and implementation.
- Full System Physical Design

Jon -

- System Validation & Sensor Improvements through software
- Implement Audio Cues for System
- System Testing

Pradeep -

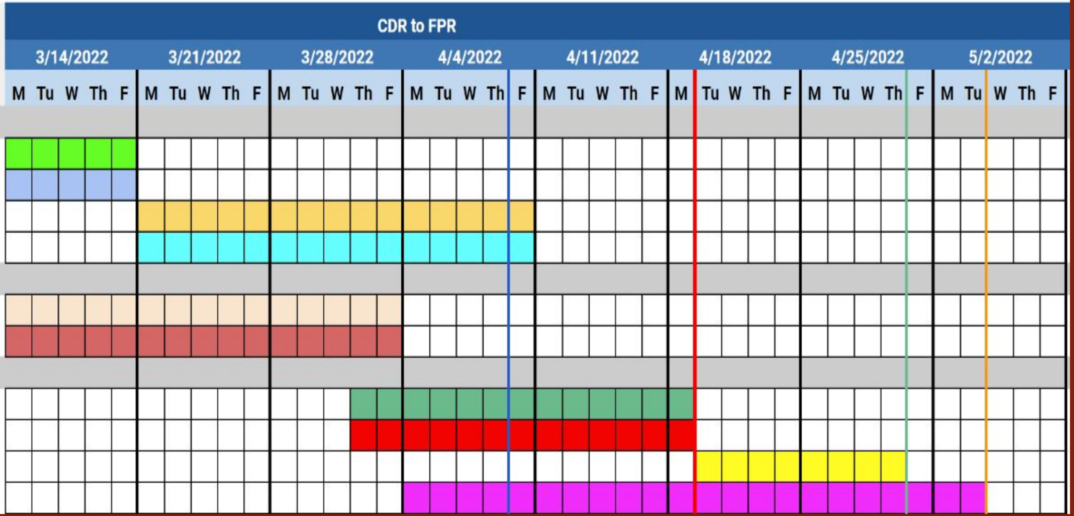
- Headset PCB assembly and implementation
- System Testing

Gantt Chart - Between 3/14/22 & 4/19/22

OcuFeel Gannt Chart	**Group**	Jon McDonald, Pradeep Manivannan, Callum Little, Matthew Corcoran
Project Manager: Matthew Corcoran	**DATE**	3/14/22 - 4/19/22

Draft SDP Report = Blue   FPR=Red line   Demo Day = Green   Final SDP Report = Orange

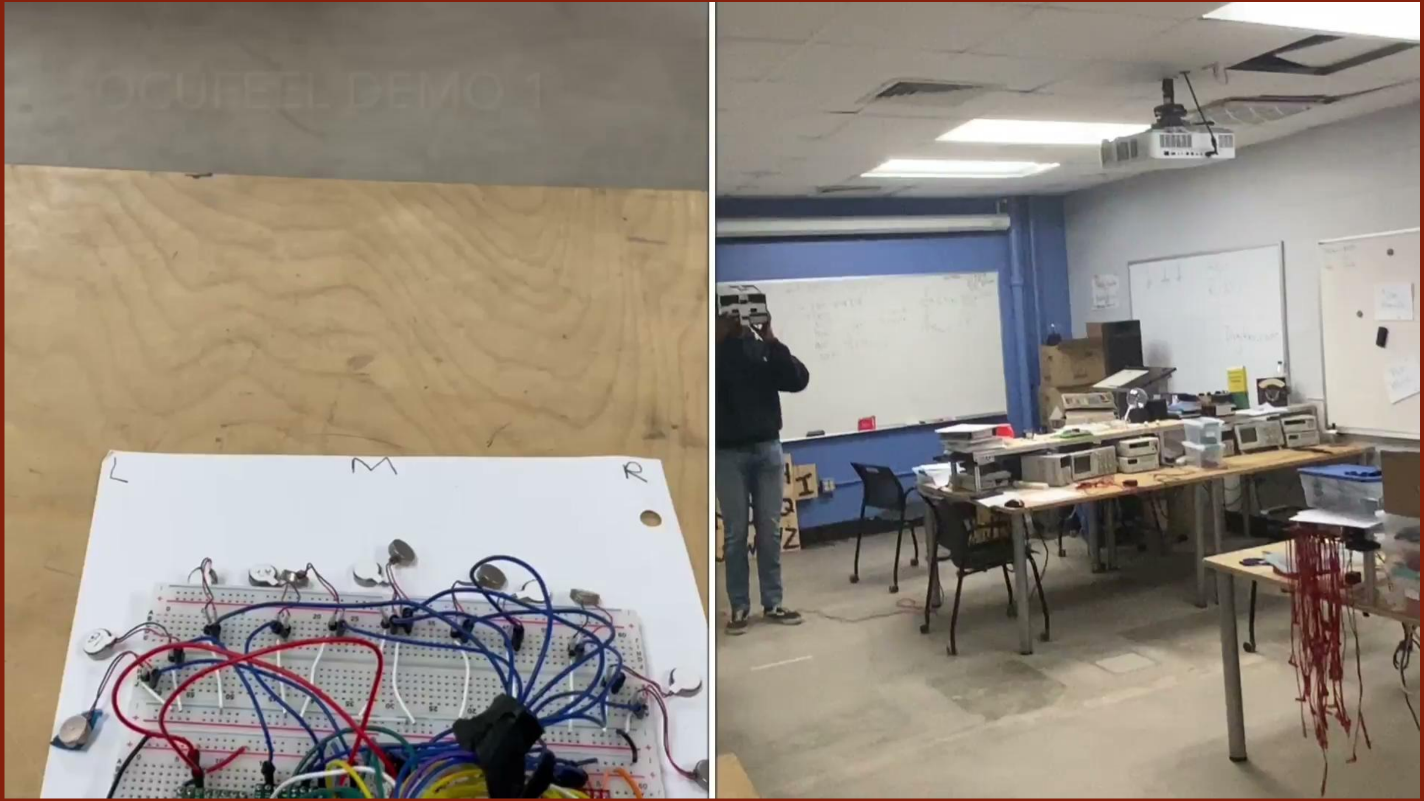
TASK TITLE	TASK OWNER	START DATE	DUE DATE	EST. DURATION
Hardware				
Headset PCB Revision	CL,PM	3/14/2022	3/20/2022	6
Waistband PCB Revision	PM,CL	3/14/2022	3/20/2022	6
Waistband Design & Build	CL,MC	3/21/2022	4/8/2022	18
Headset Design & Build	PM,JM	3/21/2022	4/8/2022	18
Software				
Test cases to Validate Block Diagram	MC,JM	3/14/2022	4/1/2022	18
Clean Up Code Warnings	MC,JM	3/14/2022	4/1/2022	18
Final Design				
System Poster	CL,PM,MC,JM	3/31/2022	4/19/2022	19
Website	CL,PM,MC,JM	3/31/2022	4/19/2022	19
Demo Prep	CL,PM,MC,JM	4/19/2022	4/29/2022	10
SDP Report	CL,PM,MC,JM	4/4/2022	5/4/2022	30



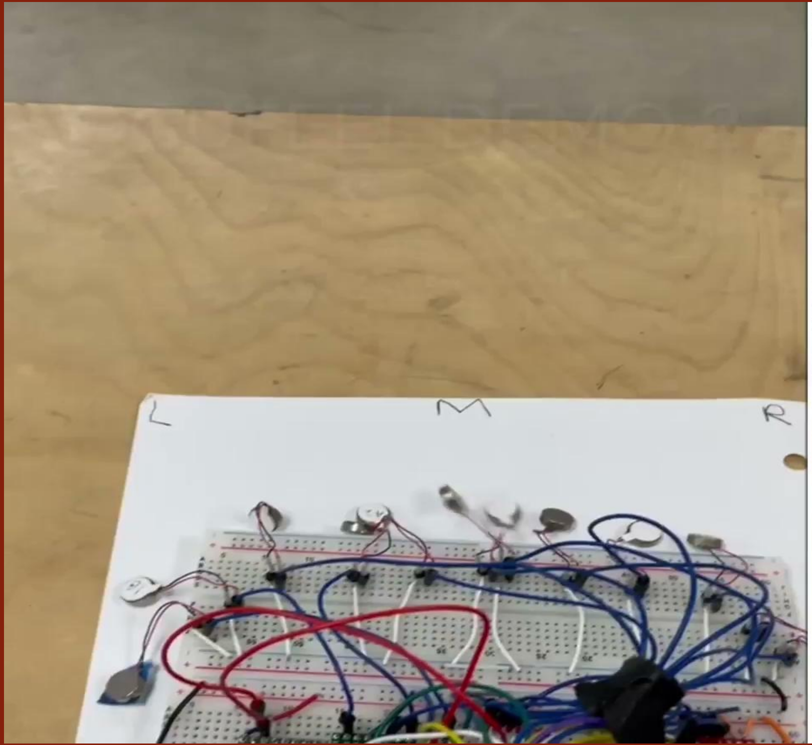
Legend

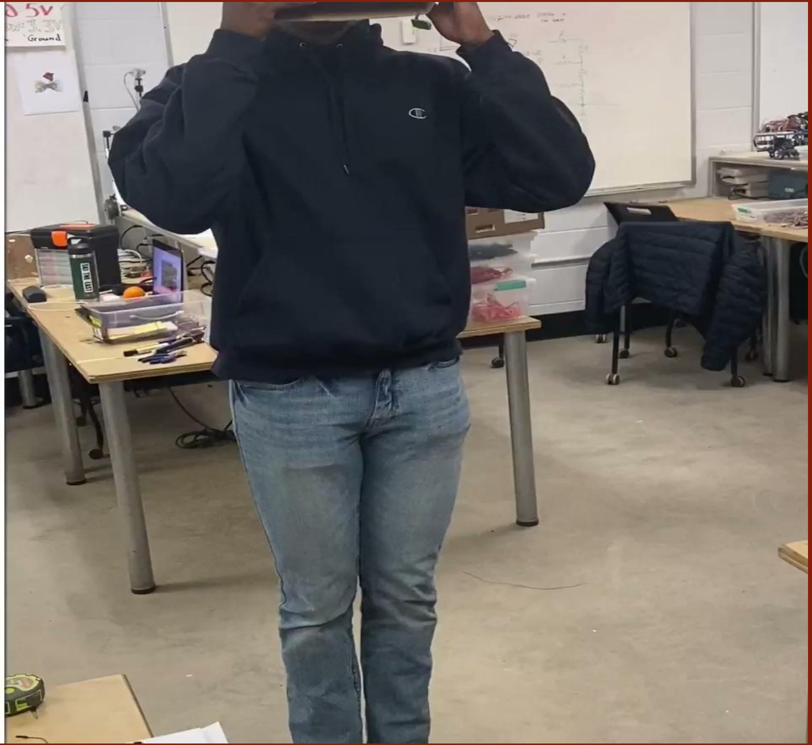
Jon McDonald - JM
Pradeep Manivannan - PM
Callum Little - CL
Matt Corcoran - MC

Demonstration Videos
Demo 1: Lidar distance and corresponding haptic response

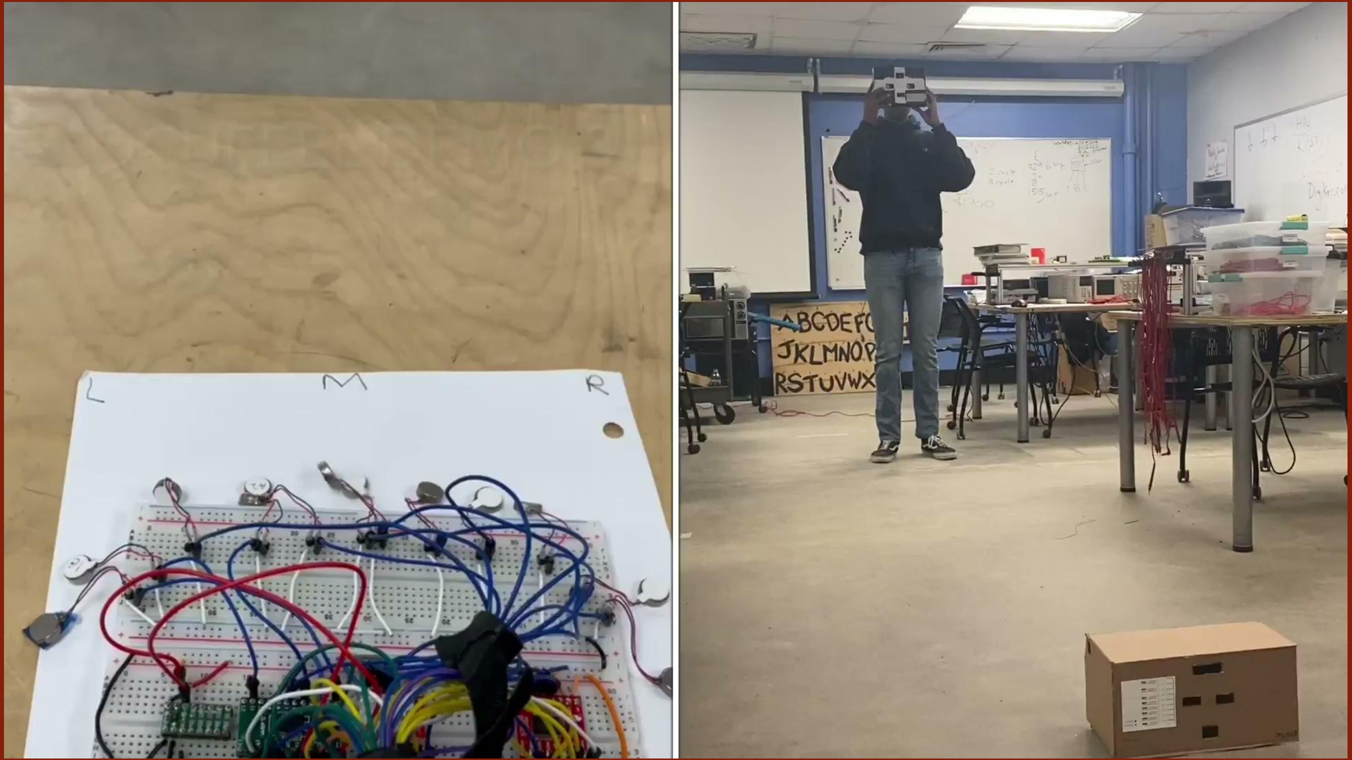


Demonstration Videos
Demo 2: Overhead obstacle detection and corresponding haptic response

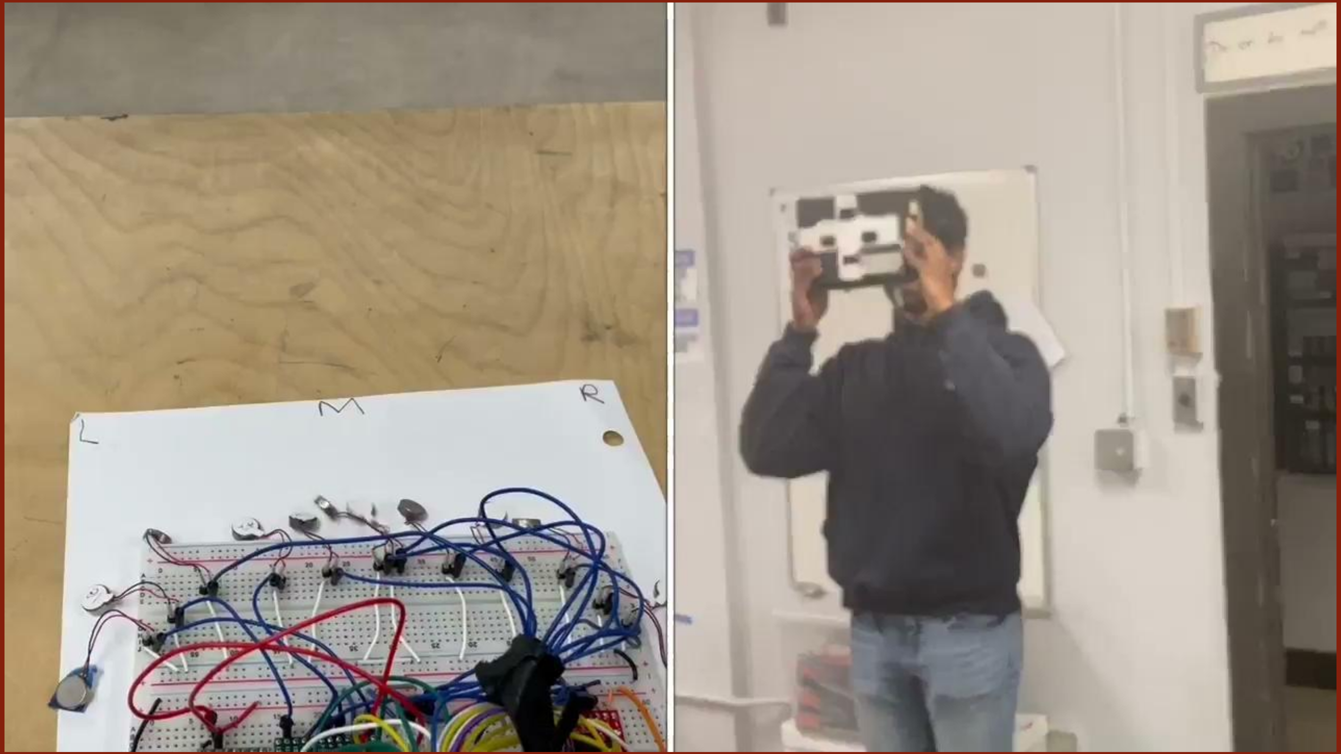




Demonstration Videos
Demo 3: Tripping hazard detection and corresponding haptic response



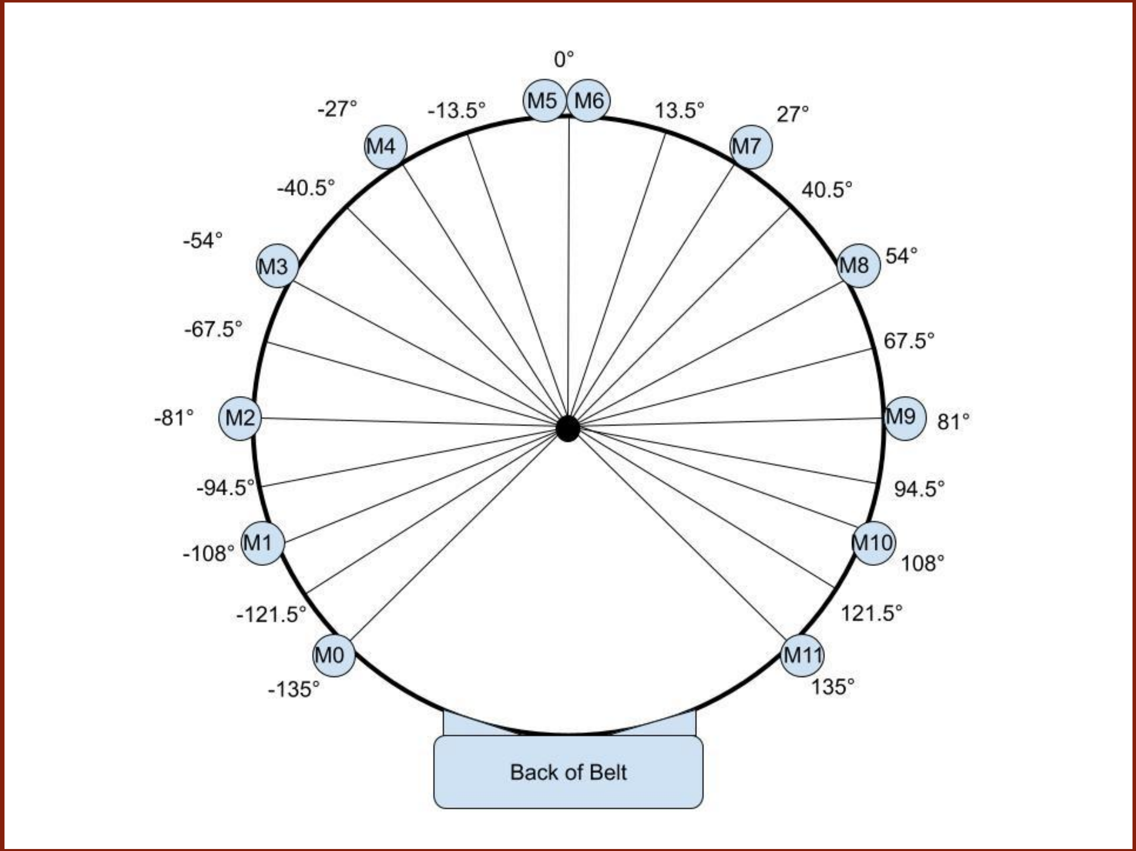
Demonstration Videos
Demo 4: Angle change detection and corresponding haptic response

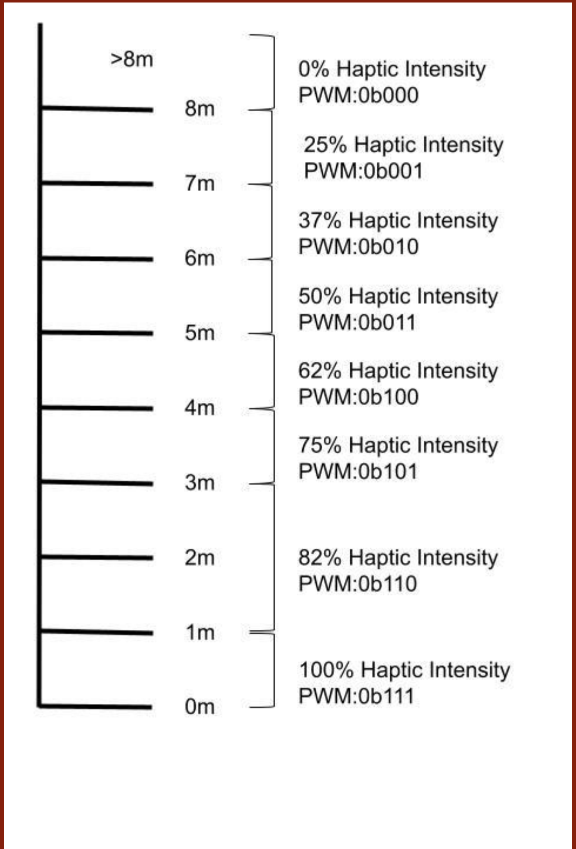


Demonstration Videos
Demo 5: Full system demo going through each detection scenario

Live Demo of System!

Haptic Waistband Angle and Distance Breakdown





Questions?

Thank you.