OcuFeel

Final Project Review

Team 17

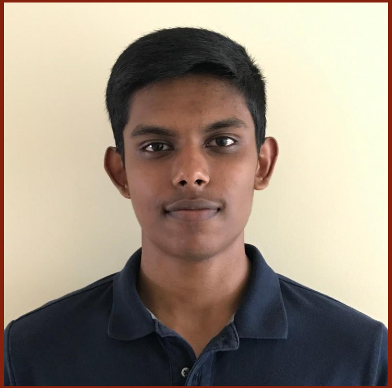
Team Intro

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

Pradeep Manivannan

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

Callum Little

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

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 600 grams.

Technical Specifications

Specification	**Threshold**	**Note**
Detect low clearing hazards	50 cm away from headset for above objects	Successful
Detect Tripping Hazards	5 cm tall obstacle off the ground	Successful
Response Time	Less than 500 ms from sensor reading to waistband motor output	Successful - Measured response t = 34ms
Range	8 meters	Successful
Haptic motor angular resolution	27 degree intervals over 10 motors.	**Motors Good, PWM PCB Line Fail. Two motors changed for trip & height hazard**
Battery Life	Greater than 3 hours	Successful - Calculations confirm this
Battery Management	Rechargeable and replaceable	Implemented
Weight	Less than 600 grams	Successful - Weight = 522g
Error checking	Loss of bluetooth communication, system malfunction, data corruption	Malfunction consists of any system compromising faults, like sensor malfunctions or microcontroller crashes

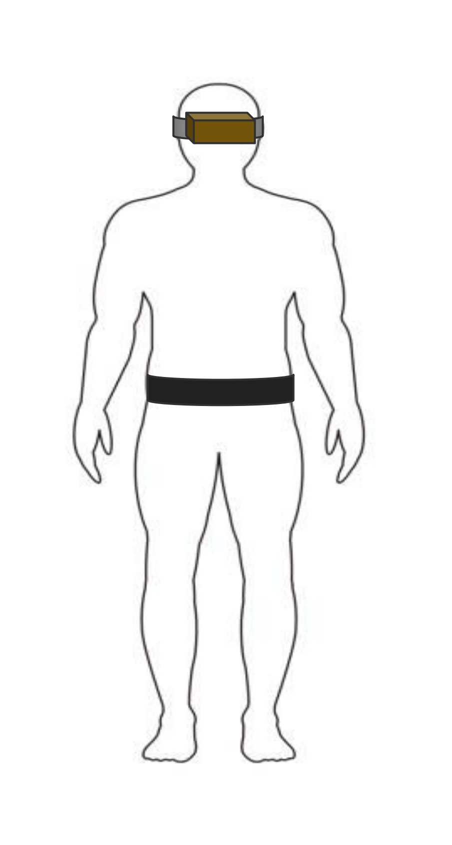
Design Overview

Overall system consists of two major subsystems:

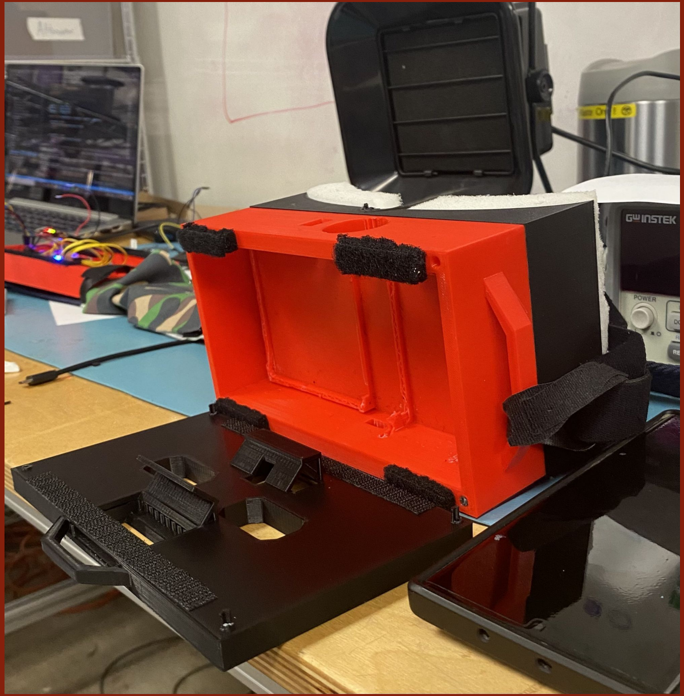
- A headset containing various sensors for range finding in front, below, and above it. Detects obstacles and hazards for the user.

- 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).

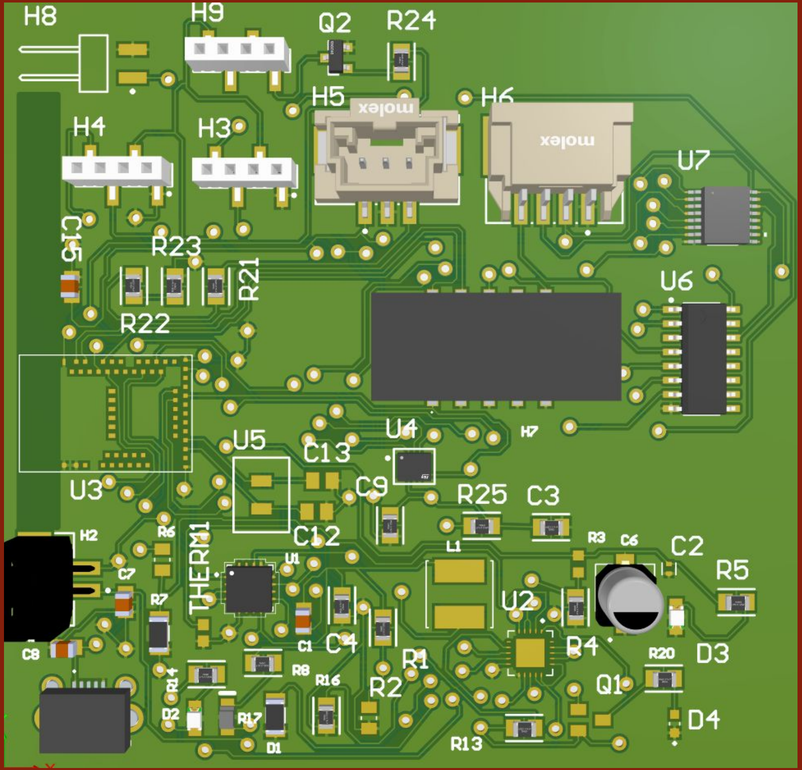


Physical Headset Design

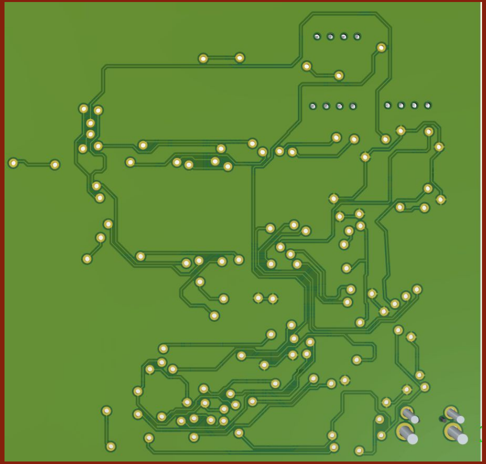


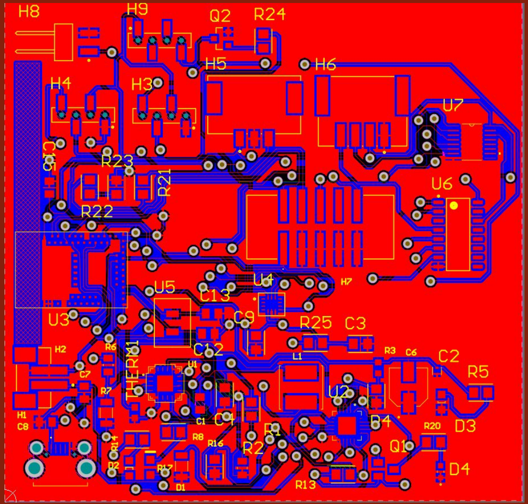
Headset Board Layout

3D Top View - 71x69 mm



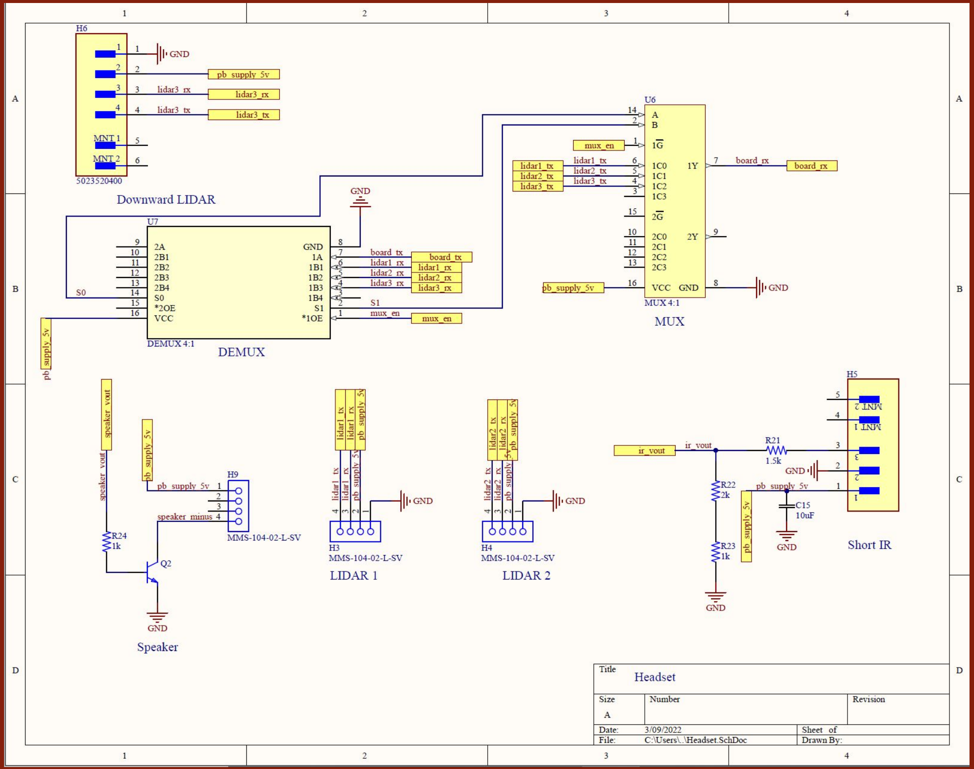
3D Back View



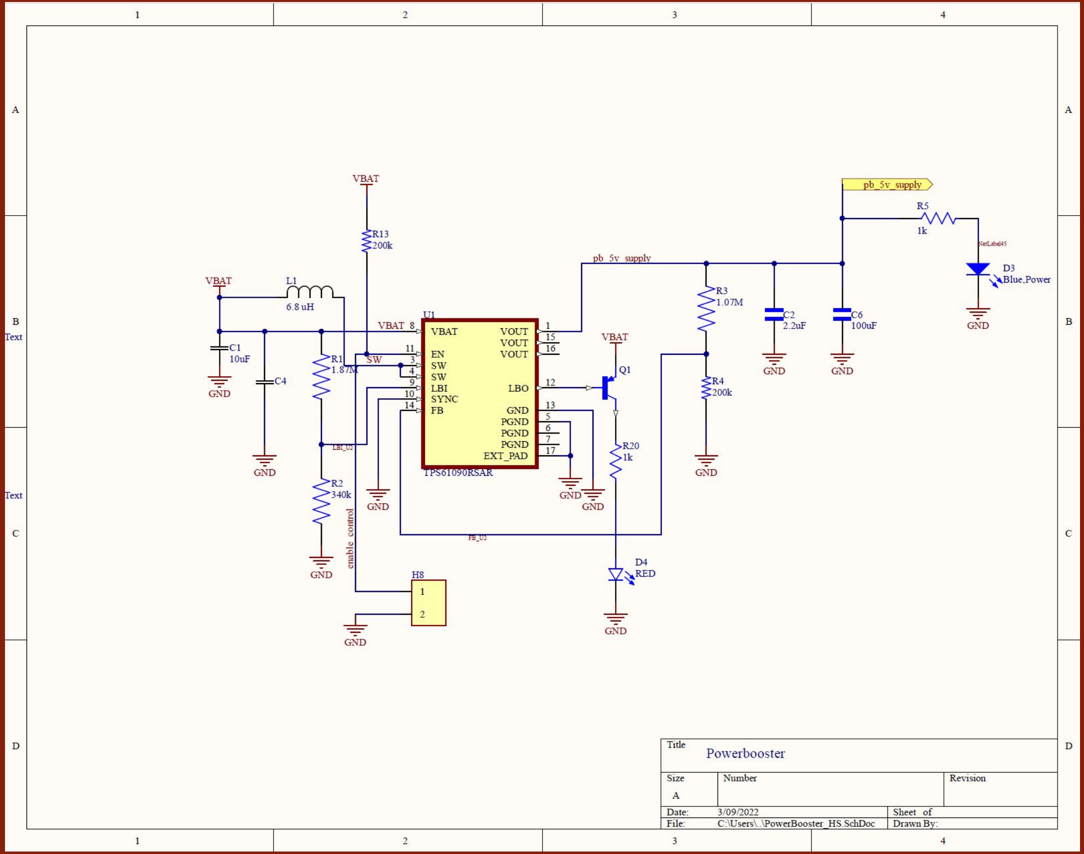


PCB View

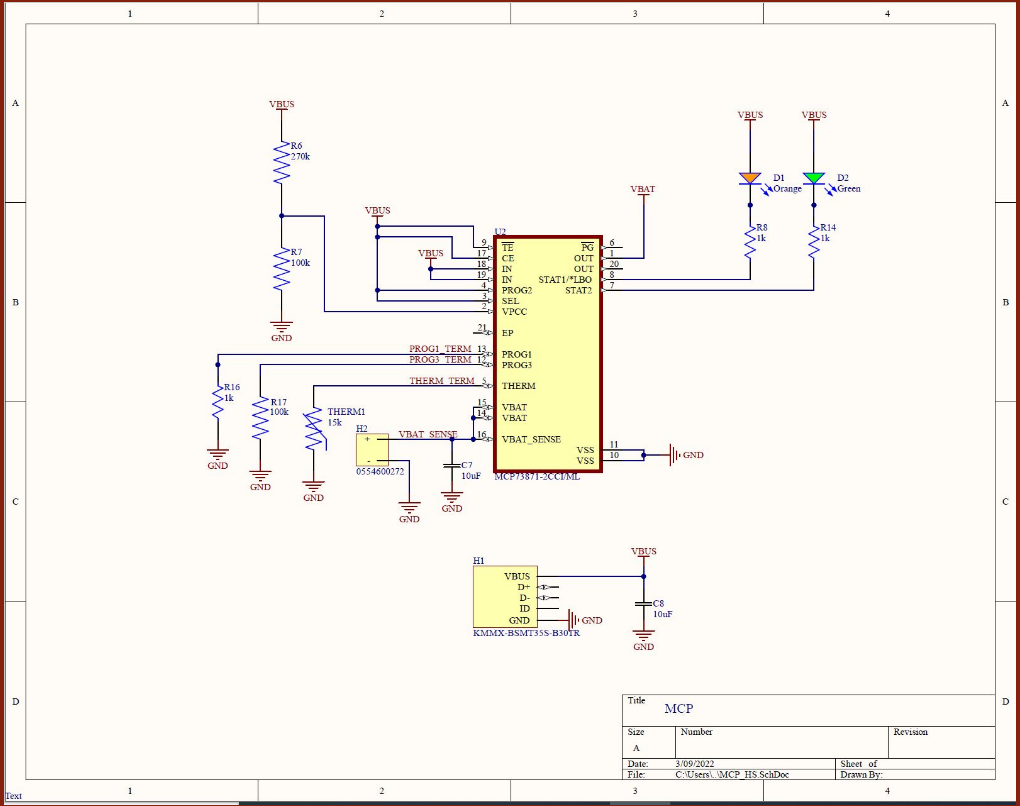
Headset PCB Schematic - Headset



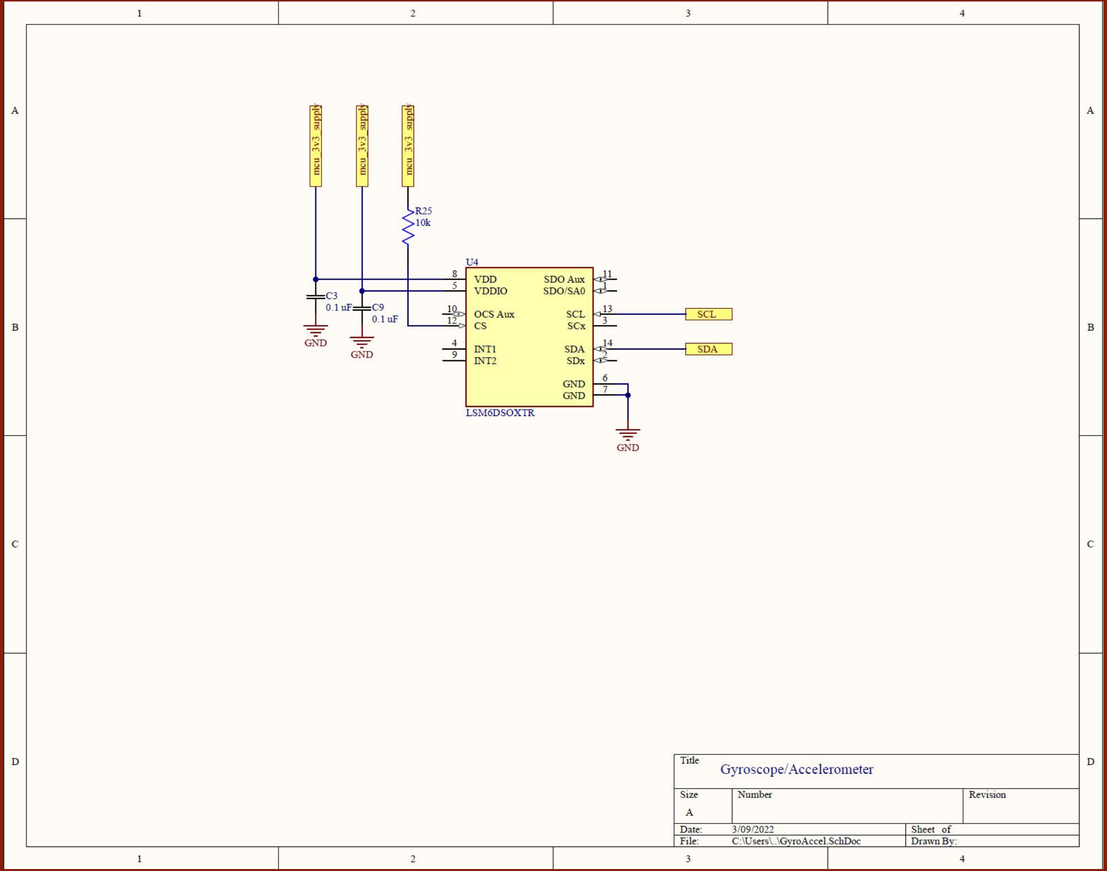
Headset PCB Schematic - Power-Booster



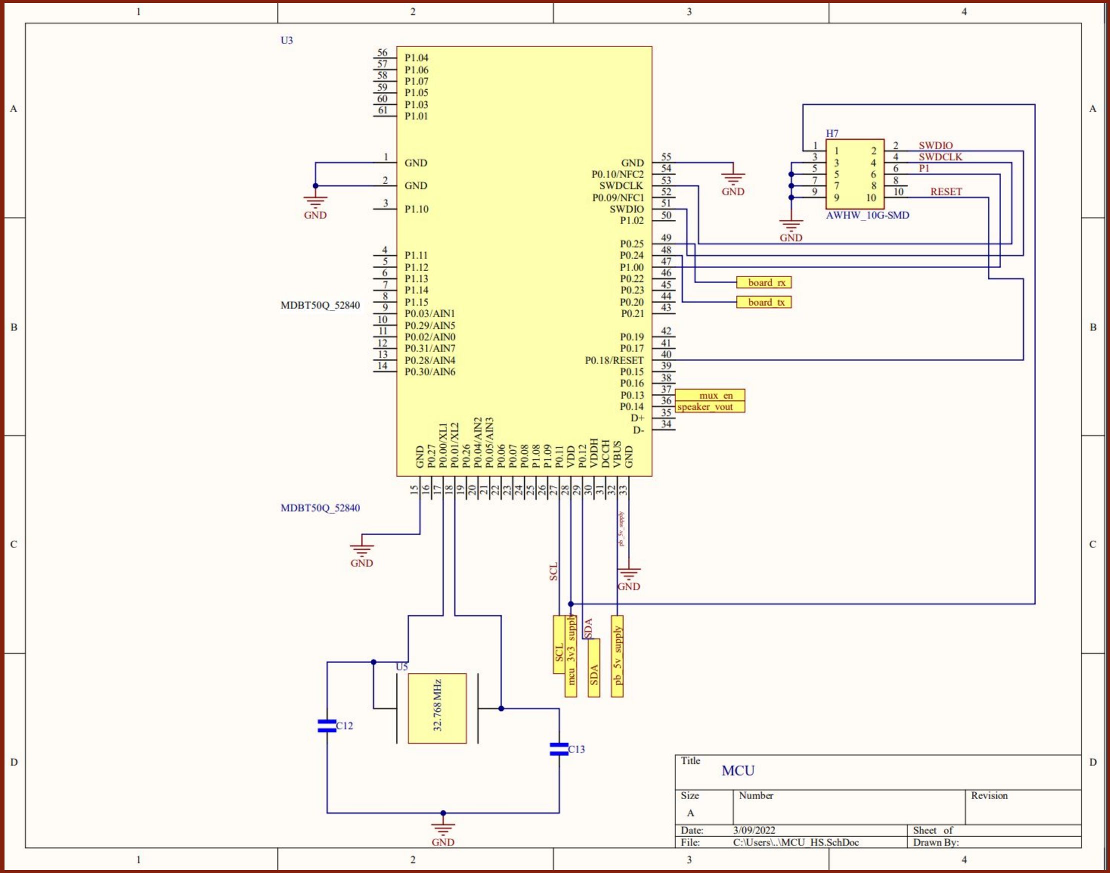
Headset PCB Schematic - MCP Battery Charge Manager



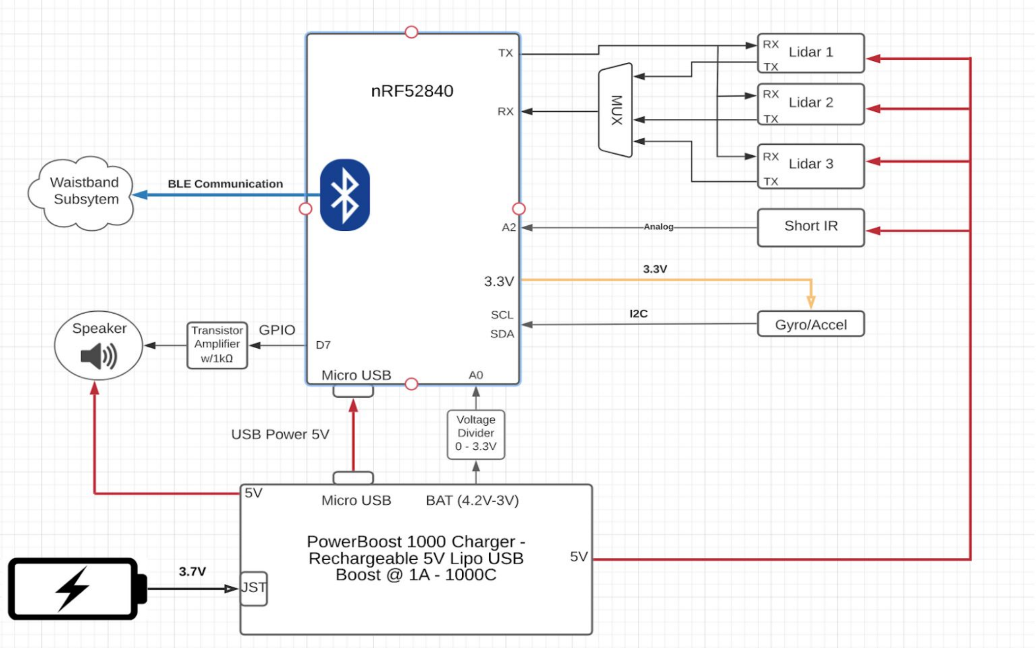
Headset PCB Schematic - Gyroscope/Accelerometer



Headset PCB Schematic - MCU

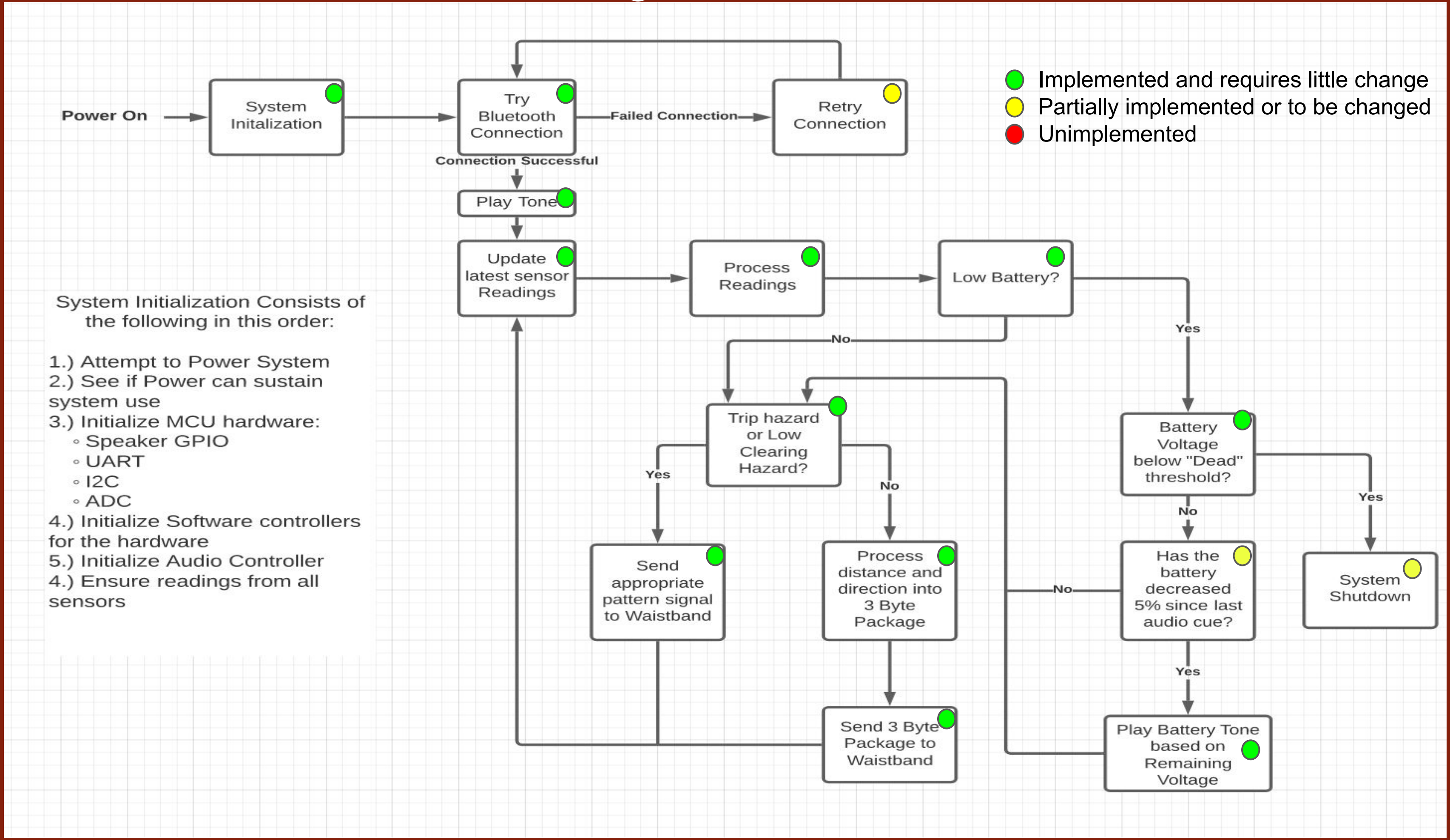


Headset Board Design

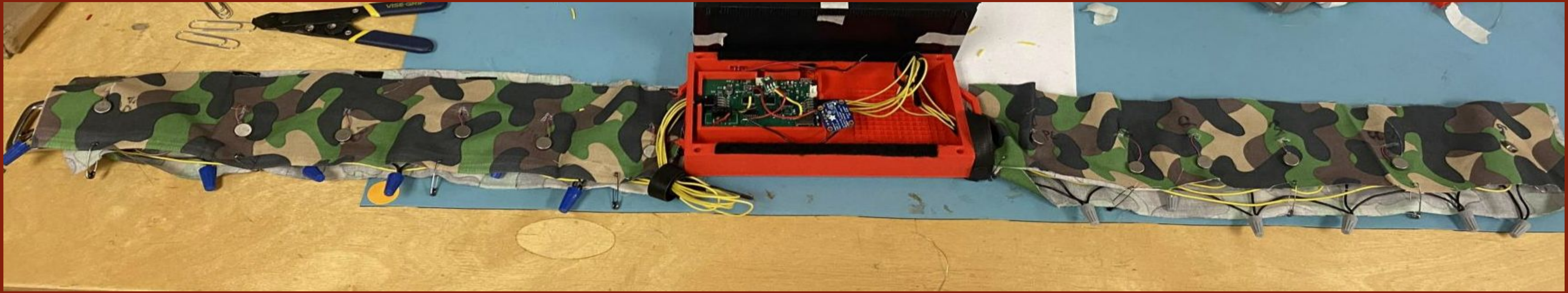


- Since the PCB ran into problems with the power booster section which was a replica of the breakout we moved to a protoboard
- Consists of all the same components but MCU, powerbooster, and gyroscope are on breakouts
- All components are soldered to board

Updated Headset Software Diagram

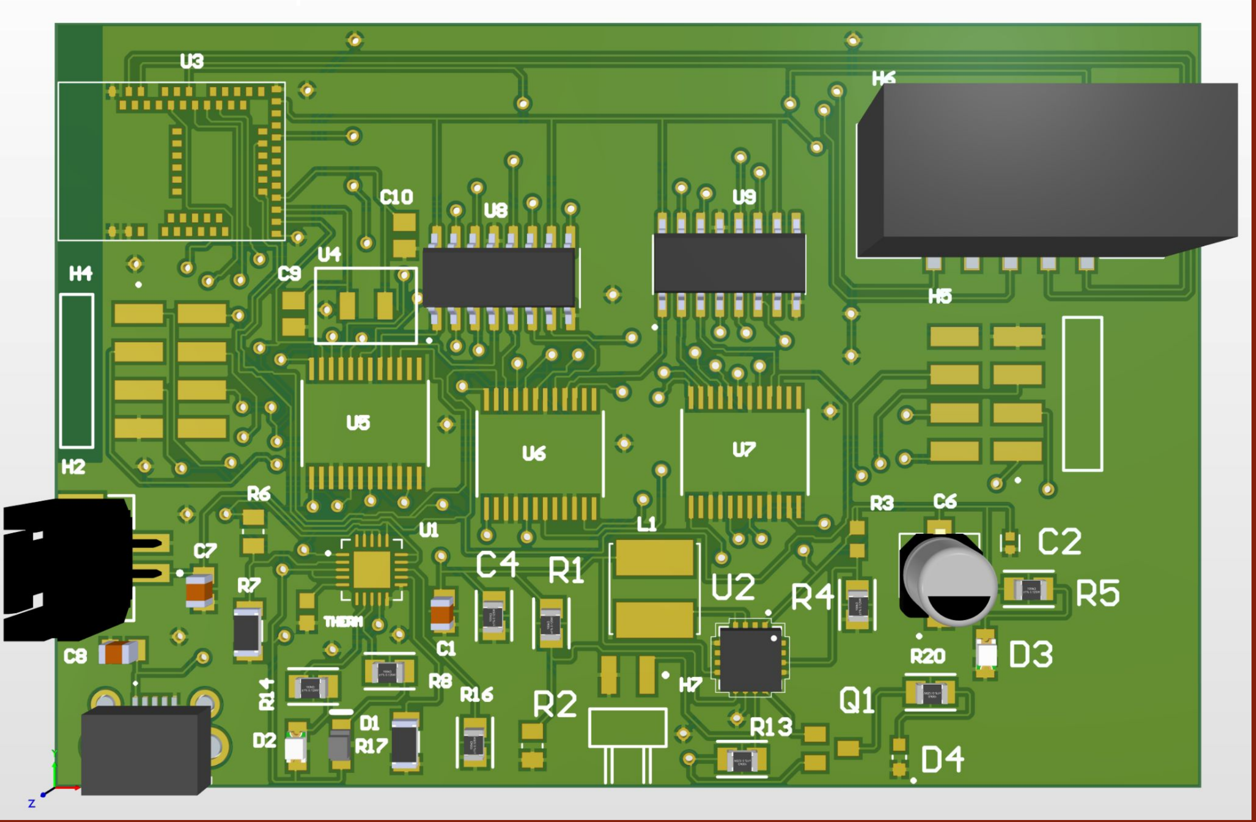


Physical Waistband Design

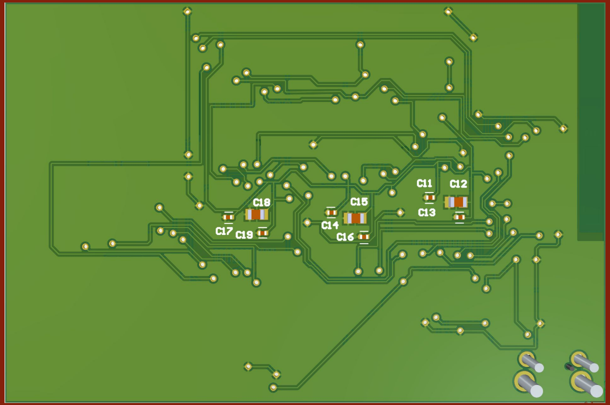


Waistband Board Layout

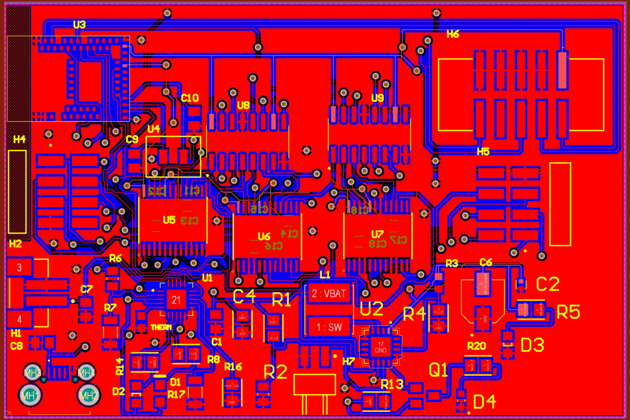
Top - 3D View - 2x3in - 50.8x76.2mm



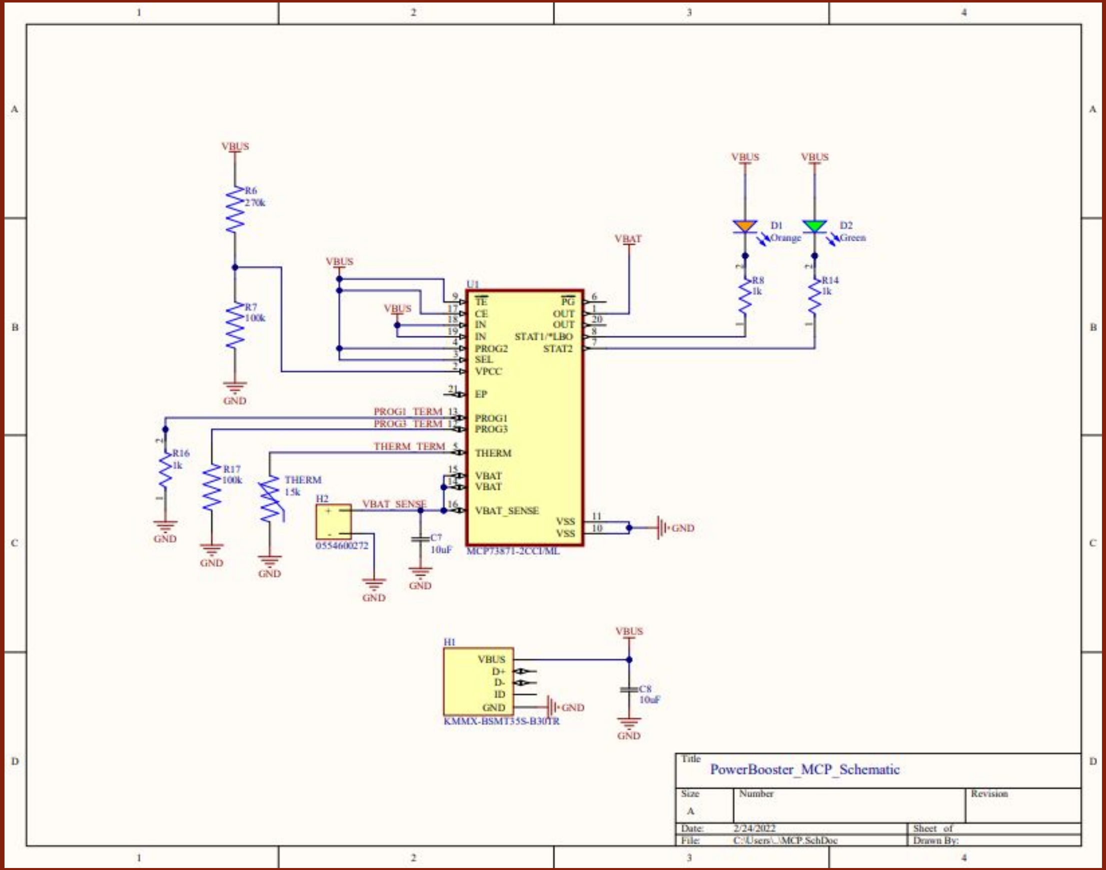
Bottom - 3D View



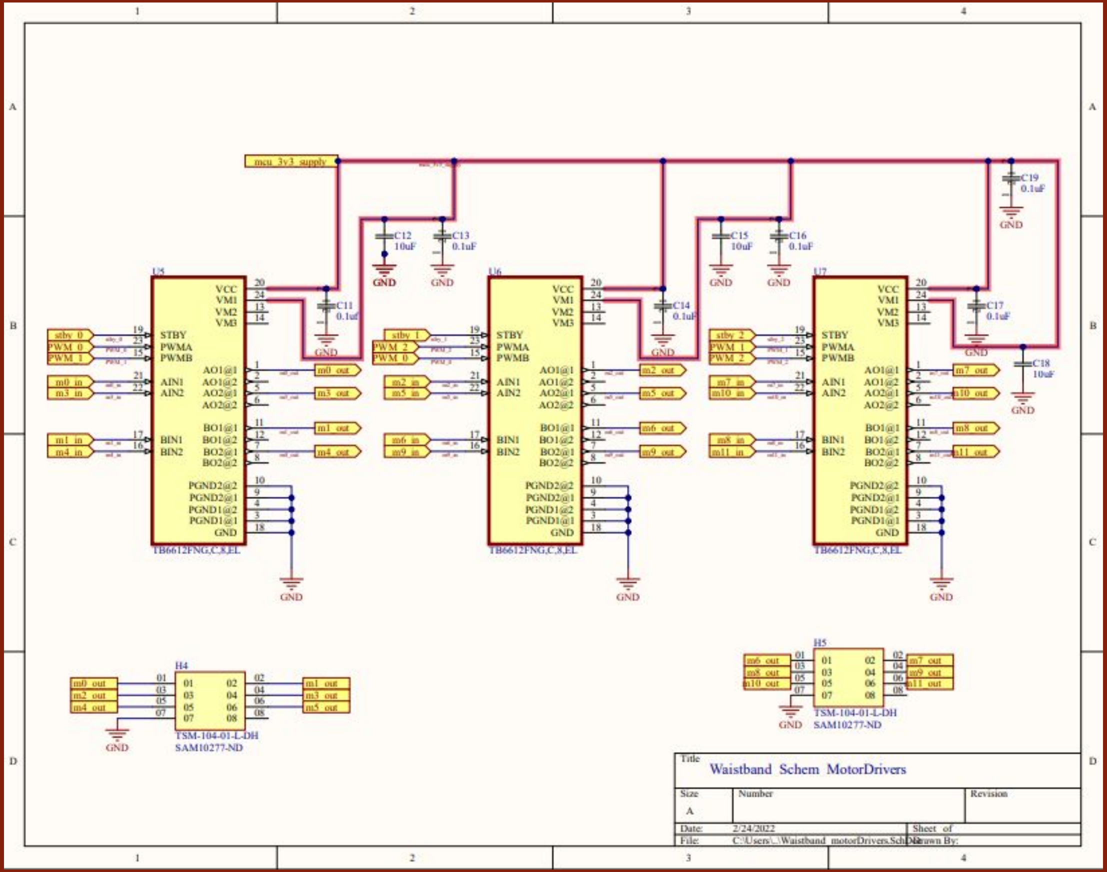
Top - PCB Design View



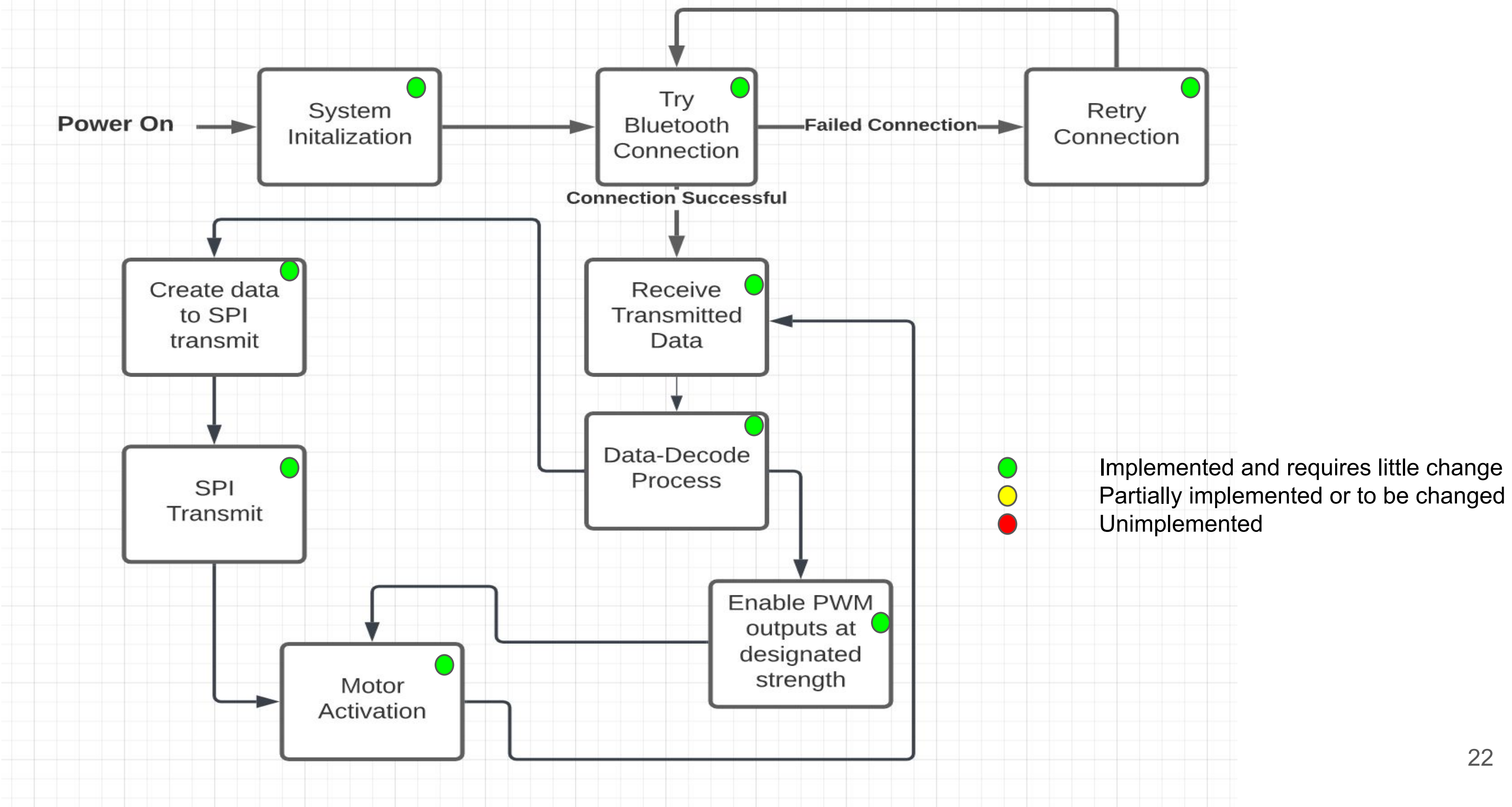
Waistband PCB Schematic - MCP Battery Charge Manager



Waistband PCB Schematic - Motor Drivers



Haptic Waistband Software Diagram



User Wearing Full System

FPR - Deliverables (From CDR)

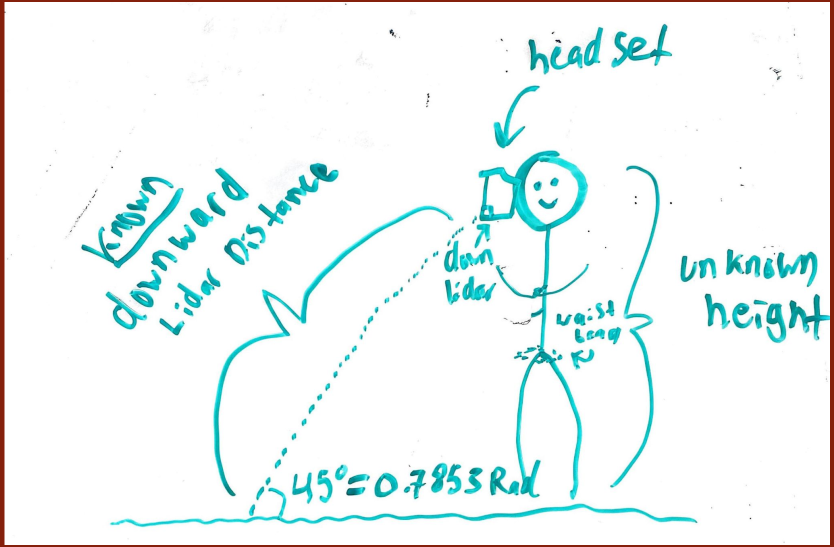
- Full system demonstration
  - 3D printed physical design will be worn by user.
  - An "obstacle course" will be set up for the user to navigate through solely using the feedback provided by the OcuFeel system.
  - As the system will be worn, both systems will solely rely on battery power.
- Performed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

Height Determination Method

We attempt to optimize the lidar resolution by robustly setting the users height based on distance from the lidar on the users head to the ground

```
user_height = calculate_user_height(0.7853, Downward_Lidar); // 0.7853 is 45 degrees in rad
```

```
int OcuFeel_Headset::calculate_user_height(float angle_rad, TF_mini *lidar_ptr){
    return ((int) (lidar_ptr->getDistance())*cos(angle_rad));
}
```



Updated Gyroscope Test

- Implemented Complementary Filter
  - Using gyroscope and accelerometer readings
  - Angle outputs shift over time ~0.267dps
  - Difference between start and end measurements are constant
  - System resets itself frequently mitigating large drifts

Motor	Theoretical Degree Measurement	Calculated Degree Measurement	Percent Error
M5/M6	26	26.48	1.85%
M7	26	26.38	1.46%
M8	53	53.57	1.08%
M9	80	81.13	1.41%
M10	107	105.87	-1.06%

Board Processing Power Consumption

Nordic created their own profiler which allows you to set your board parameters to evaluate the expected current consumption

Test setup	
Chip	nRF52840 QIAAC0
Softdevice	s140 6.1.0
Voltage	3.3 V
Regulator	DCDC
BLE event details	
Interval	105.00 ms
Length	3.69 ms
Data transmission	
On air data rate	1 Mbps

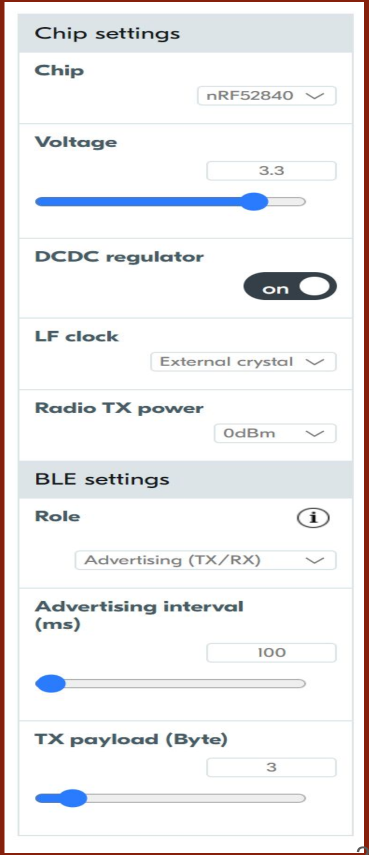
Current consumption	
BLE event total charge	9.69 µC
Idle current	2.7 µA
Total average current	95 µA

We are sending a 3 byte signal

| 0 1 2 3 4 5 6 7 8 9 10 11 | 12 13 14 | 15 16 17 18 19 20 21 22 23 |

LSB Motor Select STBY PWM MSB

Headset Parameters



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	0.095
Total	**469.6 mA**
Battery Capacity	**4400 m**
C Rate	**0.1067 OR ~9.3 hour battery life**

Waistband Subsystem

Part	Current Consumption (mA)
Board Processing	0.06
Powerbooster	5
Motor Drivers 3x	1.8 + 1.8 + 1.8
Shift Registers 2x	35 + 35
Total	**80.46 mA**
Battery Capacity	**2500 mA**
C Rate	**0.0322 OR ~31 hour battery life**

Note

Spec # 5 Met with flying colors!

No battery life decrease since CDR Calculations

Weight Specification Check

We aimed for our designs weight to be similar to VR headsets so we aimed for for a headset weight below 600 grams.

Our final design came out to be 522 grams on a digital weight scale

<u>Note</u>
Spec # 8
Proved

FPR Hardware

Waistband

- Custom PCB with nrf52840 module and associating ICs
  - Shift Registers
  - Motor Drivers
  - Breakout components
    - USB-C 5V Adapter
    - 5v-3.3v Regulator
- Haptic Motors 12x
- Portable USB Battery Pack

Headset	Purpose
PCB with receiver module & Charger	Processing
TFMini Plus Lidar 2x	Forward Det.
Short IR	Above Det.
TF Mini S Lida r	Trip Det.
Accelerometer/Gyroscope	Orientation
Speaker 2W 8 Ω	Audio Cue
Rechargeable Li-Po with 3.7V 4400 mAh Battery Capacity	Power

Current Cost

Project Expenditures

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
CDR → FPR Additional Headers: 14.03 + 45.88	------------	------------	$59.91
Total Parts	------------	---------------	**$485.2**

Total: $485 + $personal = $650

Waistband Subsystem Performance

- MCU, Shift Register, Motor Driver, Motor System, works on regular testing.
  - Consistently runs into issues regarding shift register output.
  - PWM_1 signal - Crosstalk and signal integrity issues, due to trace layout.
- Power Booster System
  - As mentioned for the headset, attempted to replicate PowerBooster design onto PCB, was successful to begin with but eventually failed
  - Waistband system can still be powered wirelessly with a USB portable battery pack and a USB-C 5v adapter we implemented. This system along with a 5v-3.3v regulator allows us to control and power your board.
- The shift register “standby” output is the root of most of our problems. With an unknown cause - our shift registers fail to enable our motor drivers.
  - Continue work to SDP Demo Day

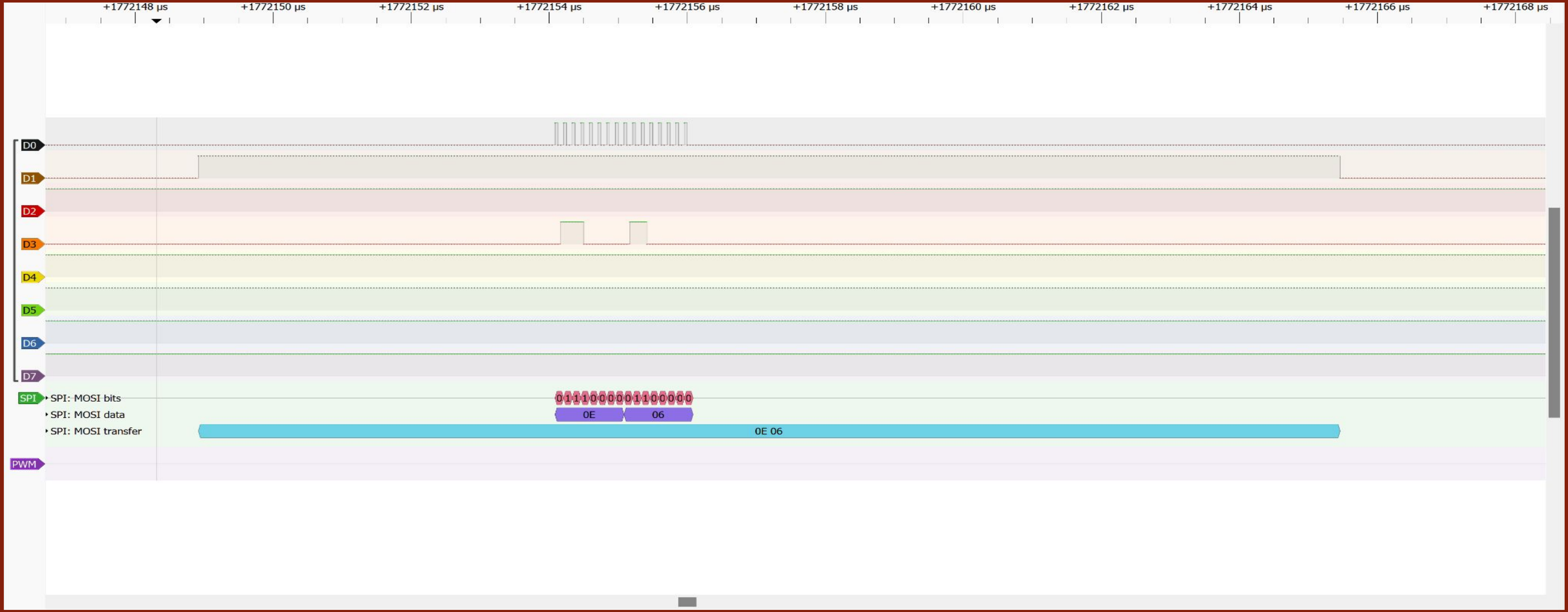
Waistband Subsystem Performance

RTT viewer read from waistband MCU. Input data is taken from received data from headset system.

Registers what the PWM strength should be and what motor should be activated. This corresponds with SPI data on next slide.

```
00> @ motor num= 5 ,  raw_data = 060e
00> PWM0: 6
00> PWM1: 6
00> PWM2: 6
00> END WHILE BUT BEFORE SLEEP
00> END WHILE 209
00> START WHILE
00> GOT RX
00> Input Data: 06 0f b6
00>
00> @ motor num= 6 ,  raw_data = 060e
00> PWM0: 6
00> PWM1: 6
00> PWM2: 6
00> END WHILE BUT BEFORE SLEEP
00> END WHILE 210
00> START WHILE
00> GOT RX
00> Input Data: 06 0f b6
00>
00> @ motor num= 7 ,  raw_data = 060e
00> PWM0: 6
00> PWM1: 6
00> PWM2: 6
00> END WHILE BUT BEFORE SLEEP
00> END WHILE 211
00> START WHILE
00> GOT RX
00> Input Data: 06 0f b6
00>
```

Waistband Subsystem Performance



SPI Output from PCB MCU - Matches Bluetooth input taken in by MCU from Headset System

Demonstration

Headset system using sensors to collect data and sending that data to waistband system.

Waistband PCB receives data and data will be shown using RTT viewer connected to the PCB MCU.

```
00> @ motor num= 5 ,  raw_data = 060e
00> PWM0: 6
00> PWM1: 6
00> PWM2: 6
00> END WHILE BUT BEFORE SLEEP
00> END WHILE 209
00> START WHILE
00> GOT RX
00> Input Data: 06 0f b6
00>
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00> END WHILE BUT BEFORE SLEEP
00> END WHILE 210
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00> END WHILE BUT BEFORE SLEEP
00> END WHILE 211
00> START WHILE
00> GOT RX
00> Input Data: 06 0f b6
00>
```
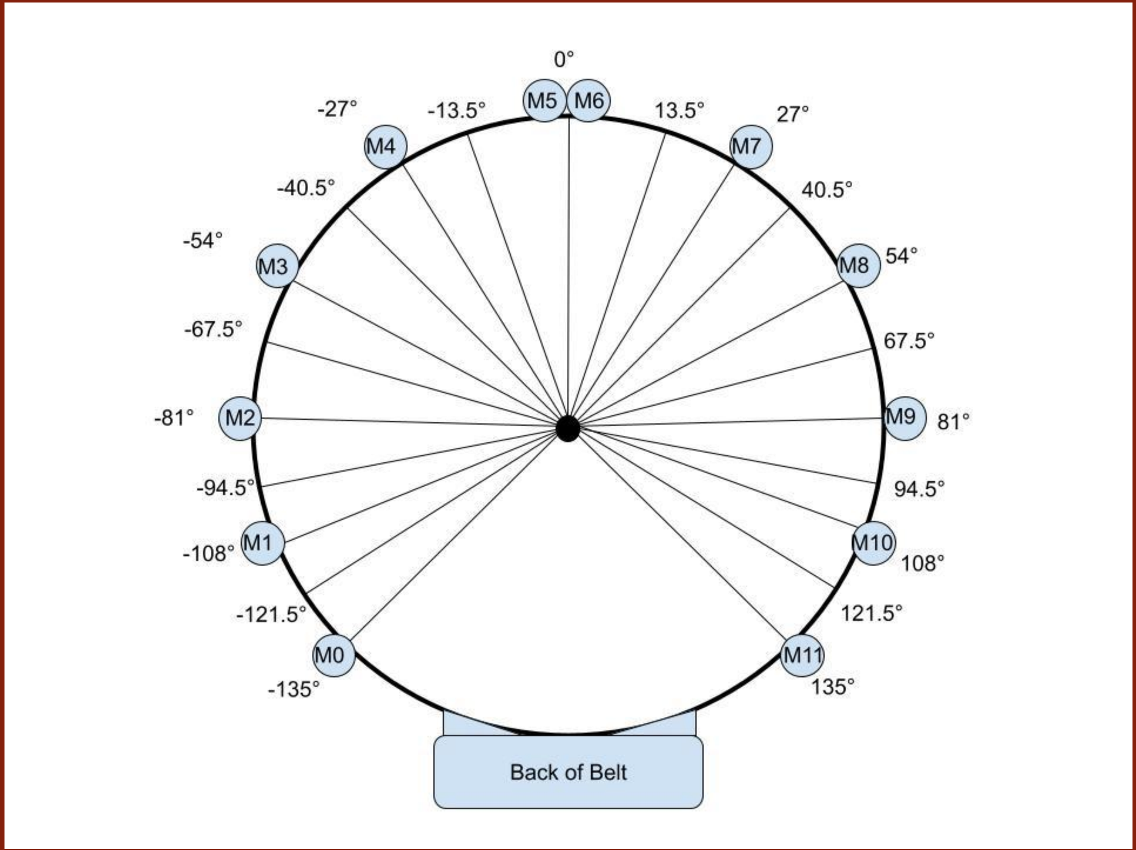
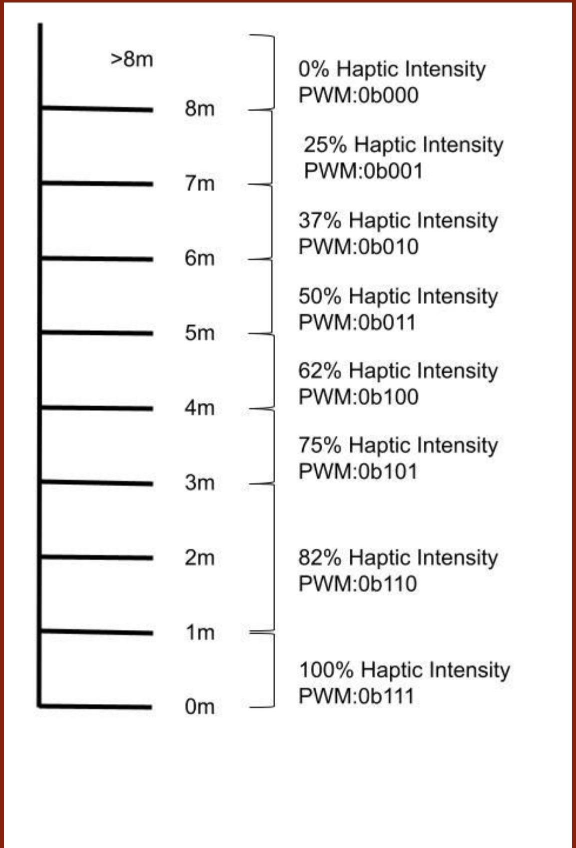

Haptic Waistband Angle and Distance Breakdown





Questions?

Thank you!