OcuFeel

Midway Design Review

Team 17

Team Intro

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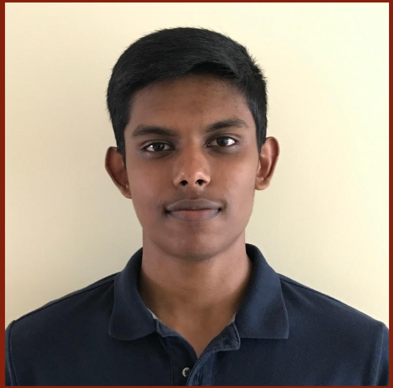


Pradeep Manivannan
(EE)

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 objects off the ground	Can detect objects within 16cm
Response Time	Less than 500 ms from sensor reading to waistband motor output	
Range	8 meters	For objects on the same plane as the lidar
Haptic motor angular resolution	27 degree intervals over 12 motors.	270 degree range around the user, not including 90 degrees behind the user
Battery Life	Greater than 3 hours	
Battery Management	Rechargeable and replaceable	System informs user of low battery
Weight	Less than 500 grams	
Error checking	Loss of bluetooth communication, system malfunction, data corruption	Malfunction consists of any system compromising faults, like sensor malfunctions or microcontroller crashes

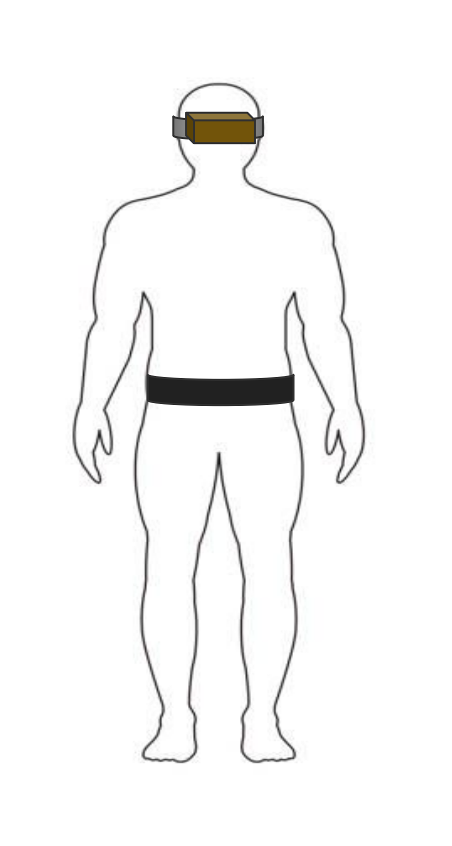
Design Overview

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.

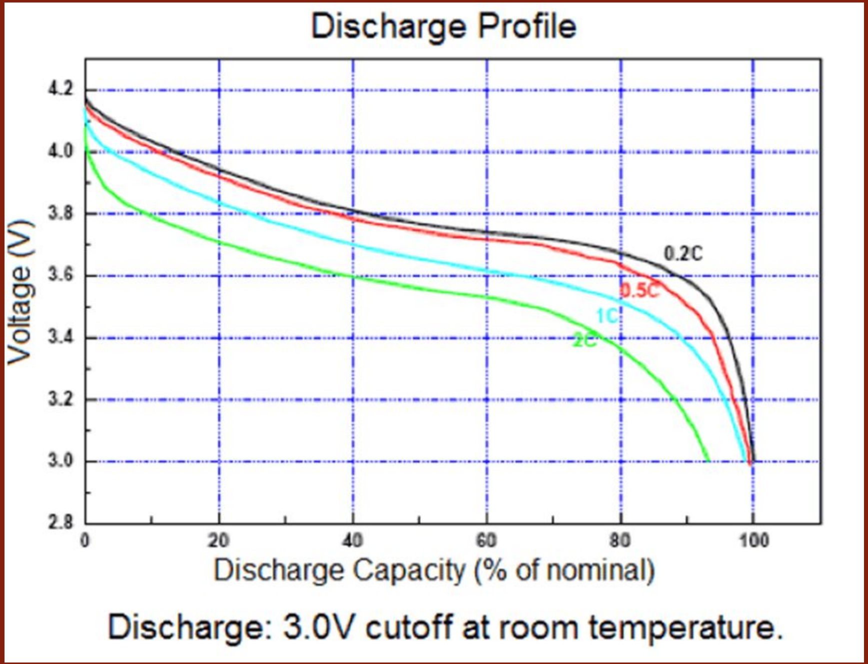
-Both of these subsystems are battery powered, and communicate via Bluetooth (Low Energy).



Outline

- **Battery Deliverable**
- Haptic Waistband Deliverable
- Headset Deliverable

MDR Deliverable: Battery



Reference of Graph used to Calculate Battery performance of 3.7V LiPobattery

Part	Current Consumption (mA)
Lidar 1	112
Lidar 2	112
Short IR	30
Long IR	30
Powerbooster	5
Speaker	70
Accel/Gyro	0.5

Total	**359.5 mA**
Battery Capacity	**2500 mA**
C Rate	**0.1438**

Deliverable: Present data for tests on the battery life of the headset

MDR Deliverable: Battery

By adding the microcontroller and the bluetooth power consumption, we can safely round the total current consumption to 500mAh in the worst case scenario, which leads to a 0.2C rate.

With a 0.2C rate the following calculations can be used in our system with a 3.7V battery with a 2500mAh capacity:

- Low Battery: When there is an 80% discharge, the voltage capacity shall be 3.69V
- Critical Battery: When there is an 90% discharge, the voltage capacity shall be 3.60V

```
#Grab Voltage value directly thru the BAT pin from the powerbooster
if Battery_Voltage <= 3.69 and played_20percent_Audio == False:
    Audio_Controller.Low_Battery()
    played_20percent_Audio = True

if Battery_Voltage <= 3.60 and played_10percent_Audio == False:
    Audio_Controller.Critical_Battery()
    played_10percent_Audio = True
```

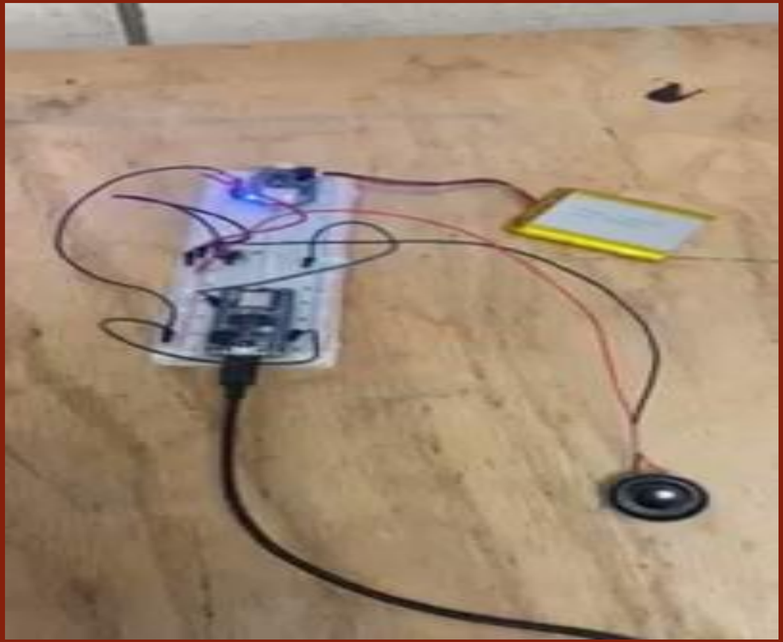
Output of reading BAT pin

```
14:06:26.484 -> 3.97
14:06:26.993 -> 3.97
14:06:27.507 -> 3.97
14:06:27.974 -> 3.98
14:06:28.487 -> 3.97
14:06:28.996 -> 3.98
14:06:29.508 -> 3.98
14:06:30.018 -> 3.98
14:06:30.484 -> 3.98
14:06:30.998 -> 3.97
14:06:31.509 -> 3.97
14:06:31.974 -> 3.98
14:06:32.486 -> 3.97
14:06:32.998 -> 3.97
14:06:33.507 -> 3.97
14:06:34.015 -> 3.98
14:06:34.478 -> 3.97
14:06:34.986 -> 3.97
```

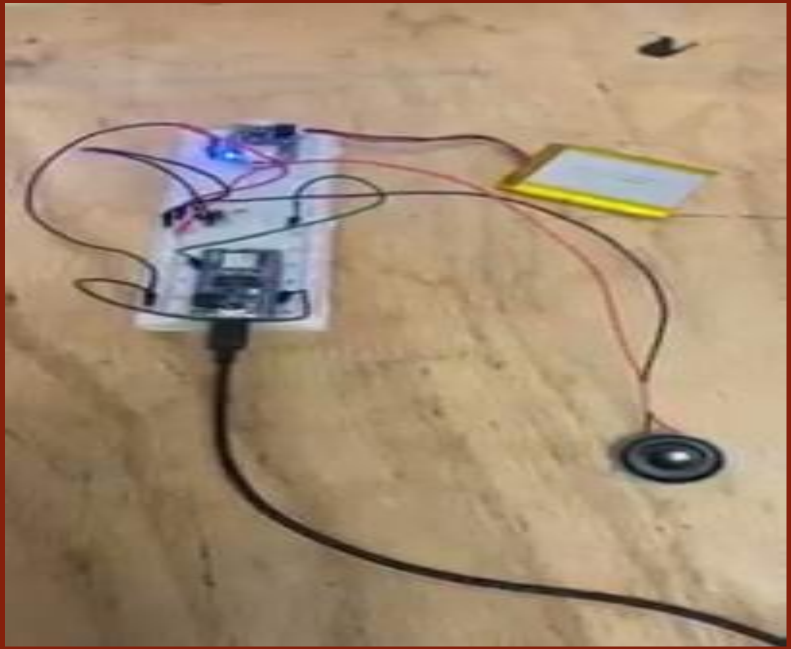
MDR Deliverable: Battery

Deliverable: Demonstrate the headset subsystem is able to determine when the battery is at 20% and 10% of maximum capacity and give audio feedback when these events occur.

Smaller delay and higher frequency correlates to lower battery life

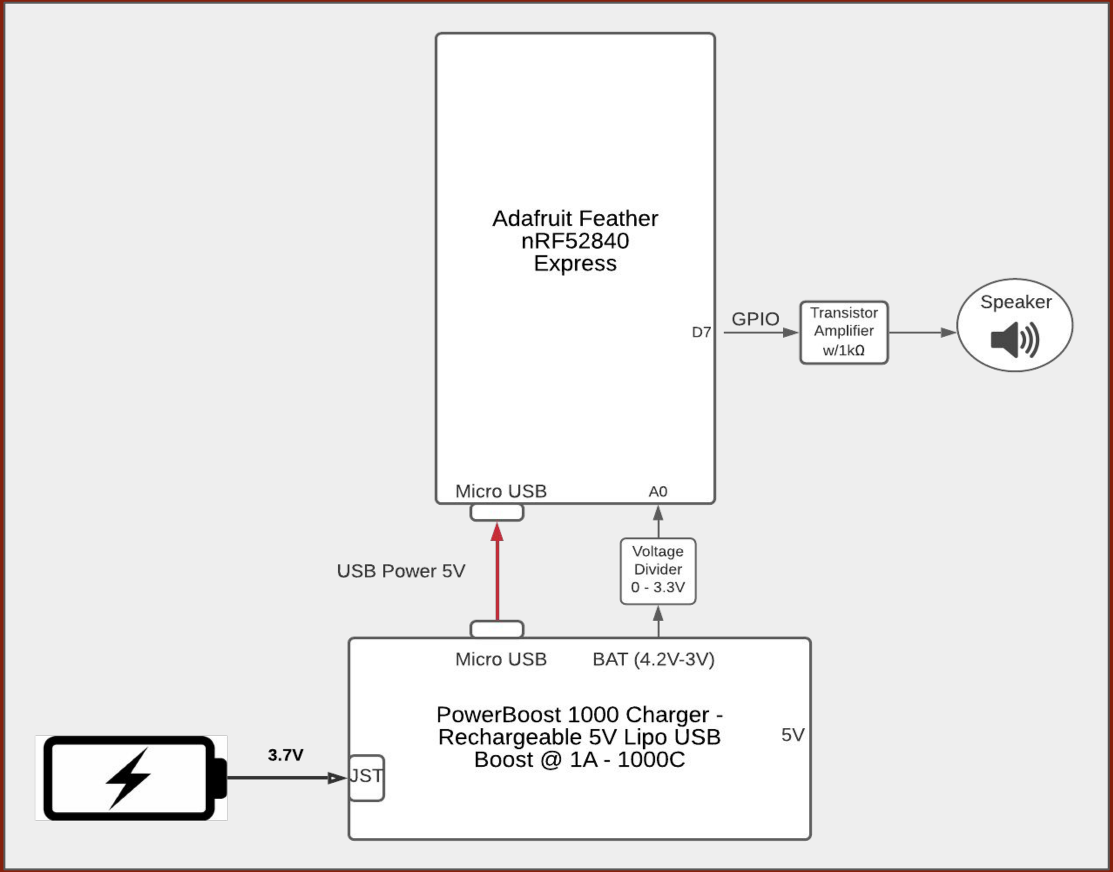


Low Battery



Critical Battery

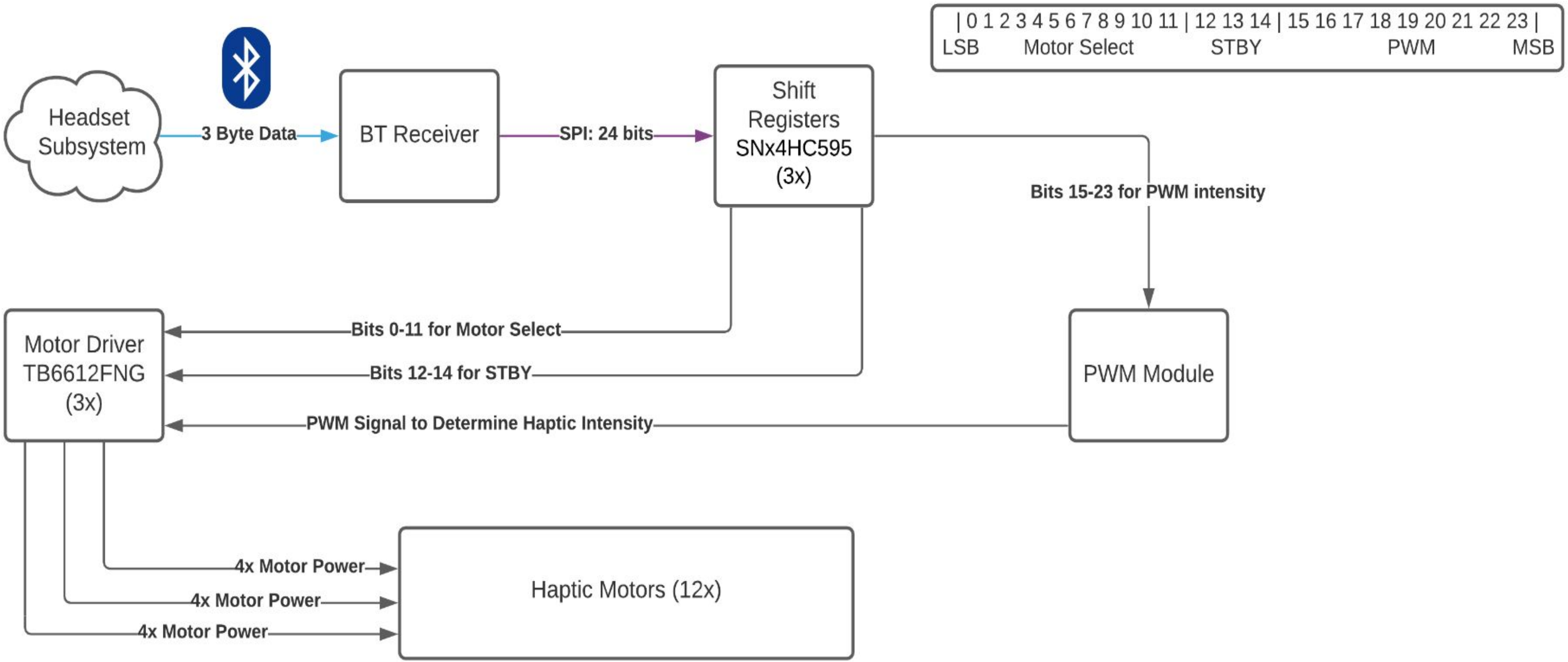
Current Speaker Block Diagram



Outline

- Battery Deliverable
- **Haptic Waistband Deliverable**
- Headset Deliverable

Haptic Waistband Hardware Block Diagram



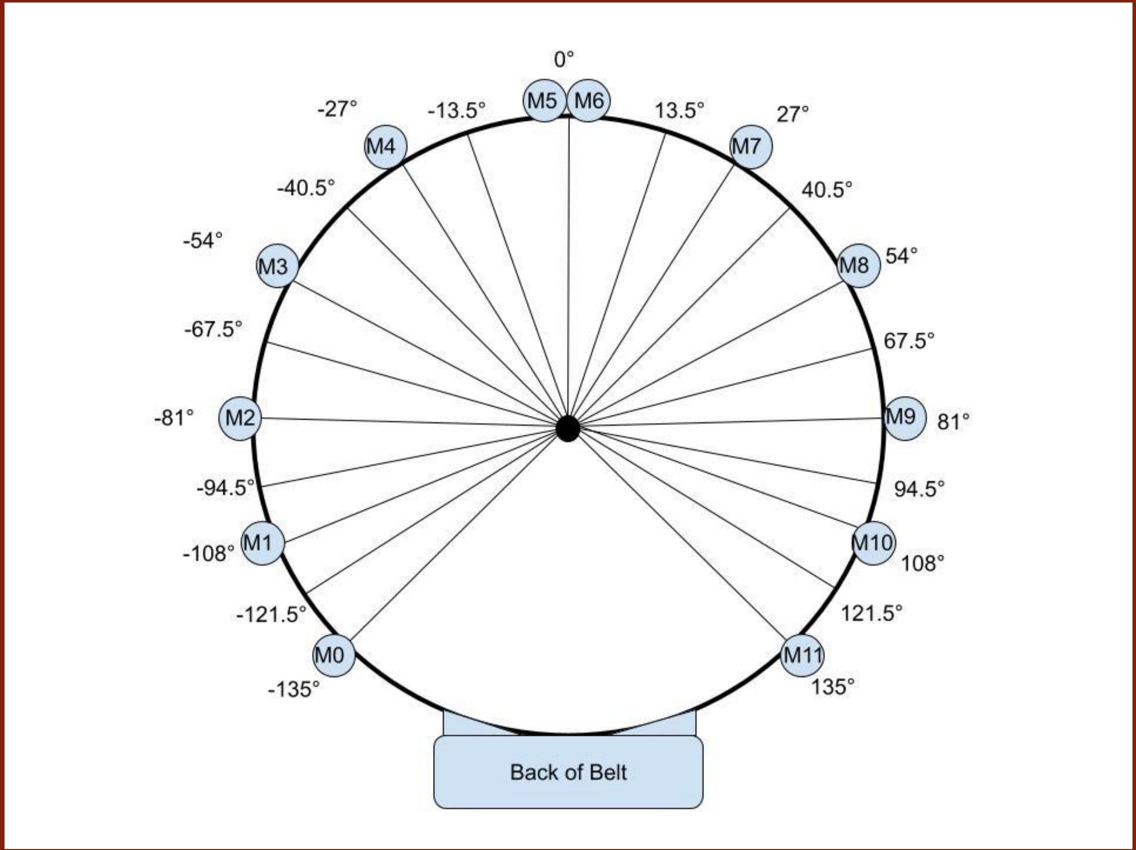
Haptic Waistband Input Data Breakdown

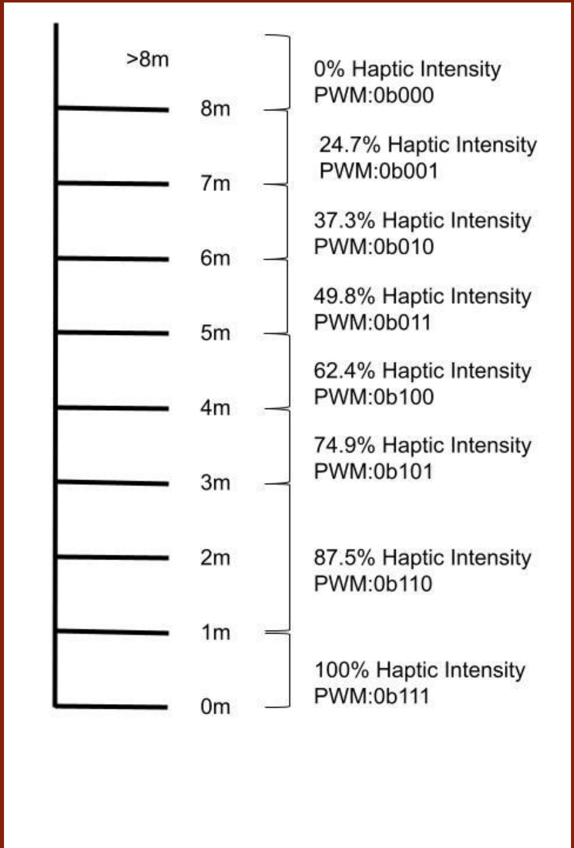
Bit Input: 0b**000000000000**000**000000000**

Bit	0	1	2	3	4	5	6	7	8	9	10	11
Function	M0 Select	M1 Select	M2 Select	M3 Select	M4 Select	M5 Select	M6 Select	M7 Select	M8 Select	M9 Select	M10 Select	M11 Select

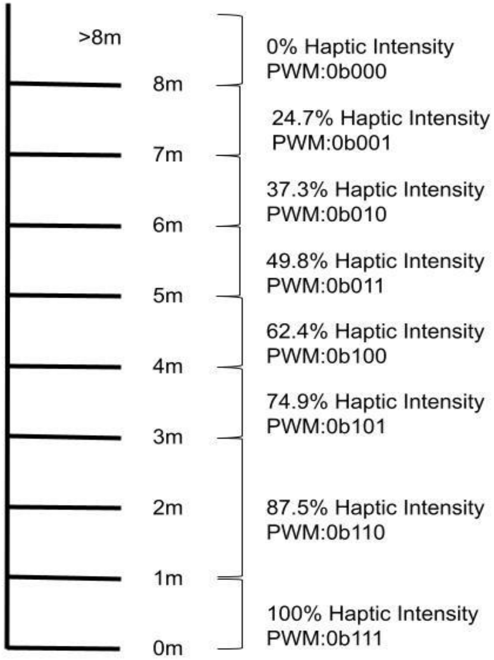
Bit	12	13	14	15	26	27	28	29	20	21	22	23
Function	Driver 1 STBY	Driver 2 STBY	Driver 3 STBY	PWM 1 Strength Data			PWM 2 Strength Data			PWM 3 Strength Data		

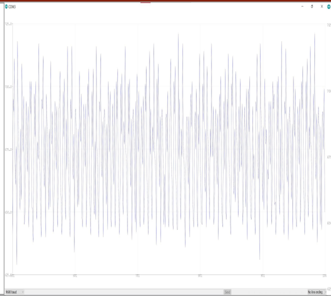
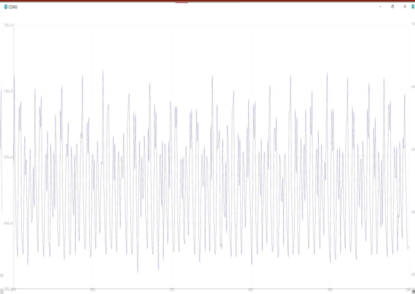
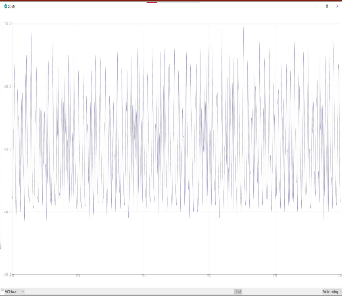
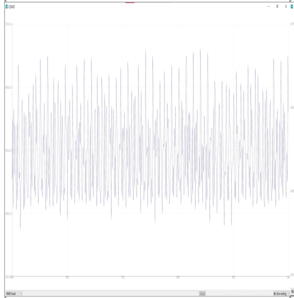
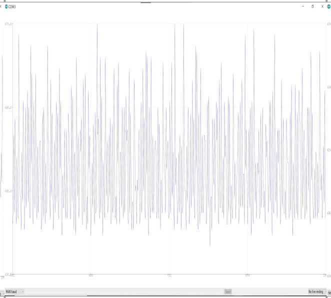
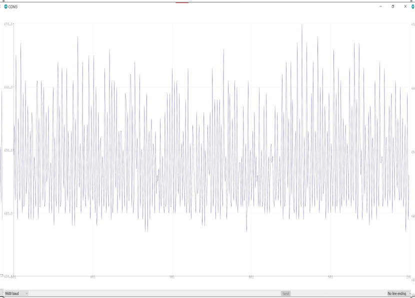
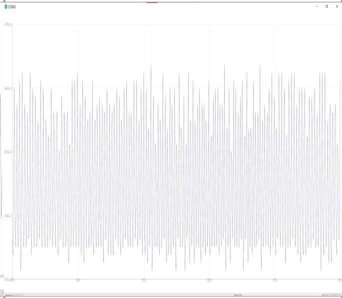
Haptic Waistband Angle and Distance Breakdown



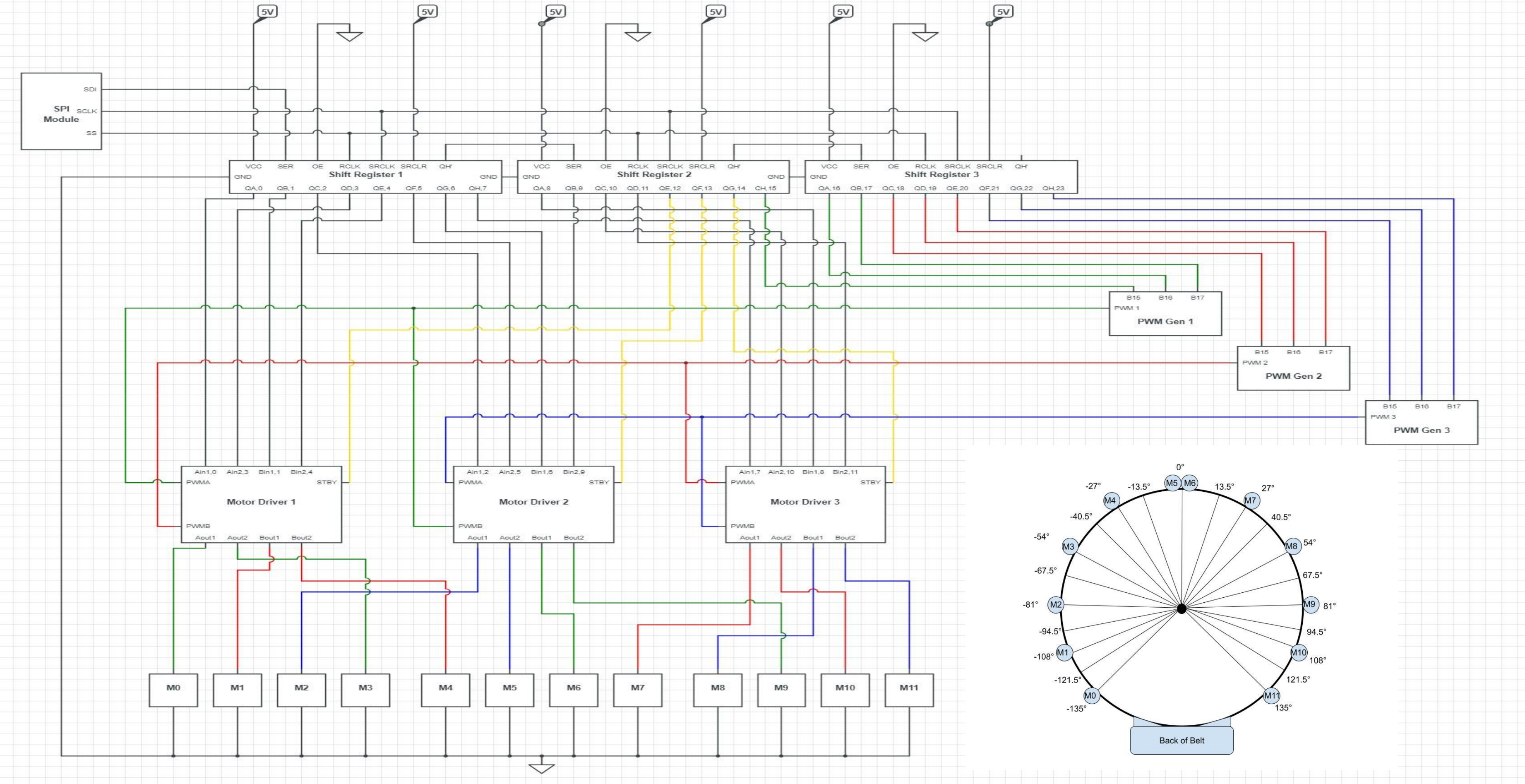


Haptic Waistband Intensity Measured with Accelerometer



Plots of Changing Frequencies			
Haptic Intensity Percentage:	24.7%	37.3%	49.8%
			
62.4%	74.9%	87.5%	100%

Haptic Waistband Schematic

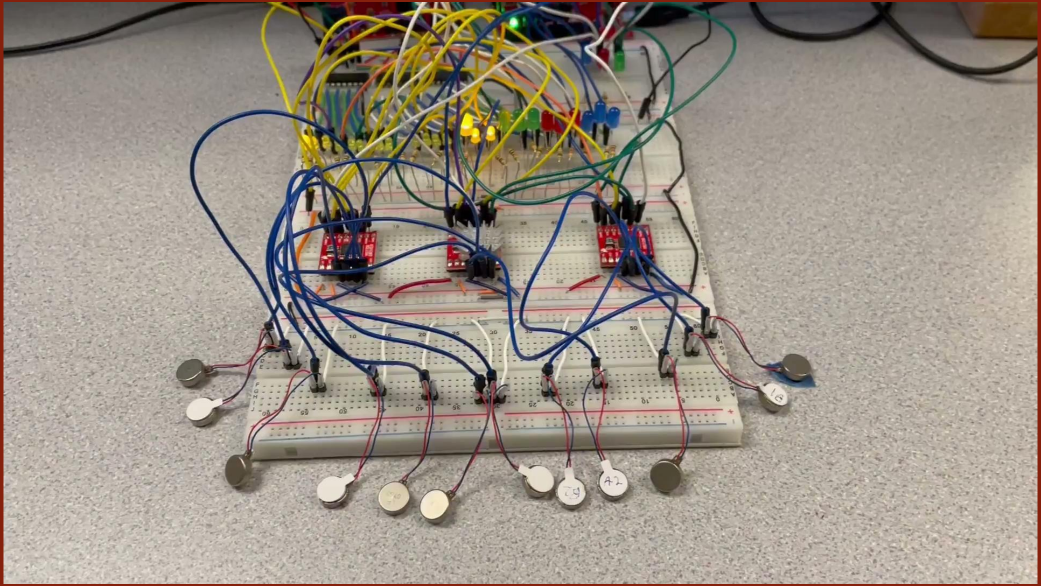


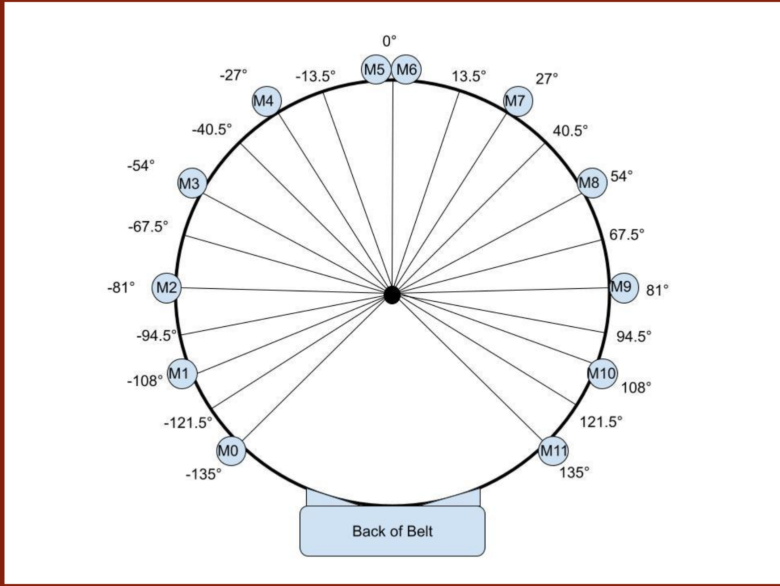
Haptic Waistband Custom PCB

- Everything “above” motors will be included on custom PCB excluding BT receiver module.
- Routing will be based on this schematic.
- PWM IC currently simulated by an Arduino.
  - Will be dedicated IC on PCB.
  - Or Adafruit ItsyBitsy nRF52840 Express - Bluetooth LE Ada 4481 is most likely candidate.
- SPI Module currently simulated by an Arduino
  - Will be replaced with dedicated hardware that is BT capable and has an SPI output.
  - Or Adafruit ItsyBitsy nRF52840 Express - Bluetooth LE Ada 4481 is most likely candidate.
- Shift Registers will need SMT for PCB
- Motor drivers currently on breakout board.
  - Will need SMT chip-only version for PCB
  - TB6612FNG
- Routing from drivers to motors will take place external to PCB
  - Wires will need to be neatly routed around the belt.
  - Groundline throughout belt

Haptic Waistband Deliverable

- Demonstrate haptic response based on simulated data input.
  - Simulated data input will be created from various scenarios of object distance and location based on the potential output of the headset.
  - Simulated data input will include objects at a distance up to 8 meters and across the 270 degree angular field.

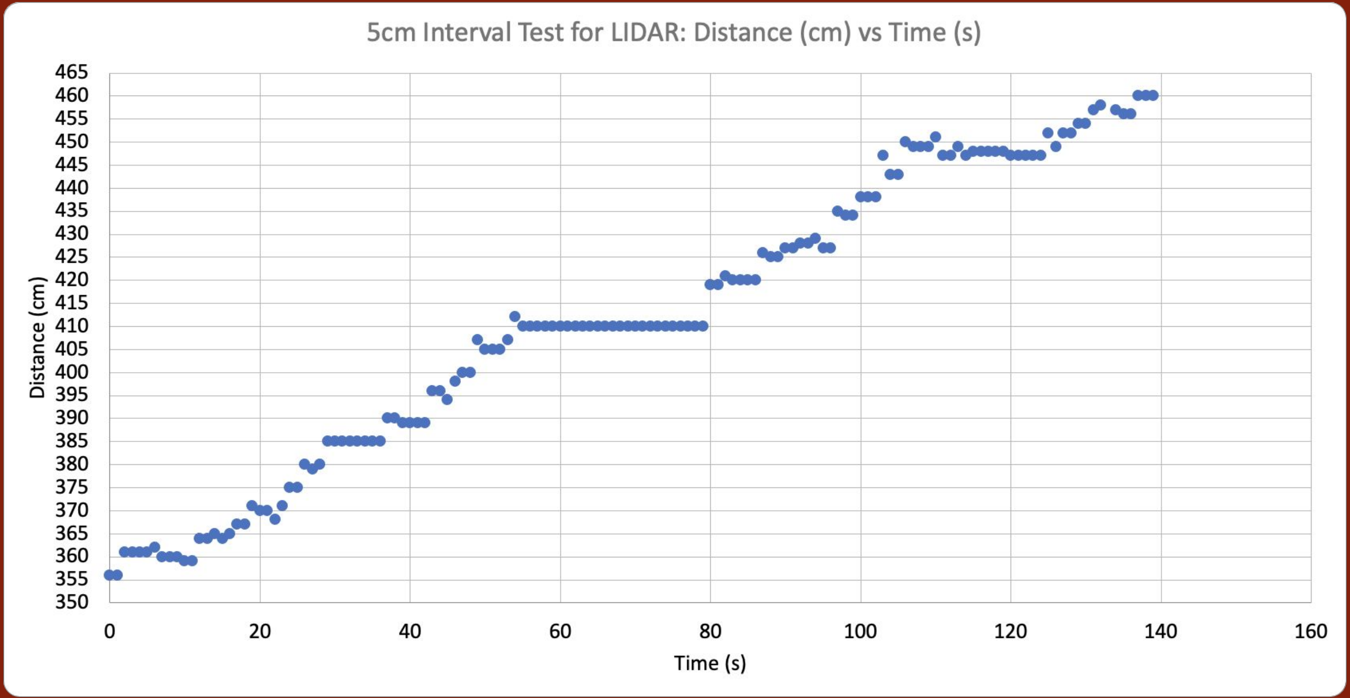




Outline

- Battery Deliverable
- Haptic Waistband Deliverable
- **Headset Deliverable**

LIDAR Data: Interval Test



Tested over mid-range distances (355-460cm)

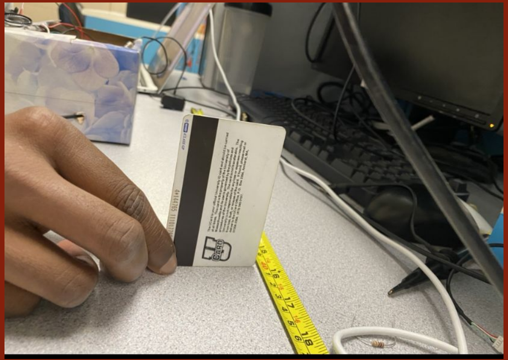
Able to accurately determine the distance of an object

Deviations from true value caused by human error (object not placed exactly on marking, hand movement)

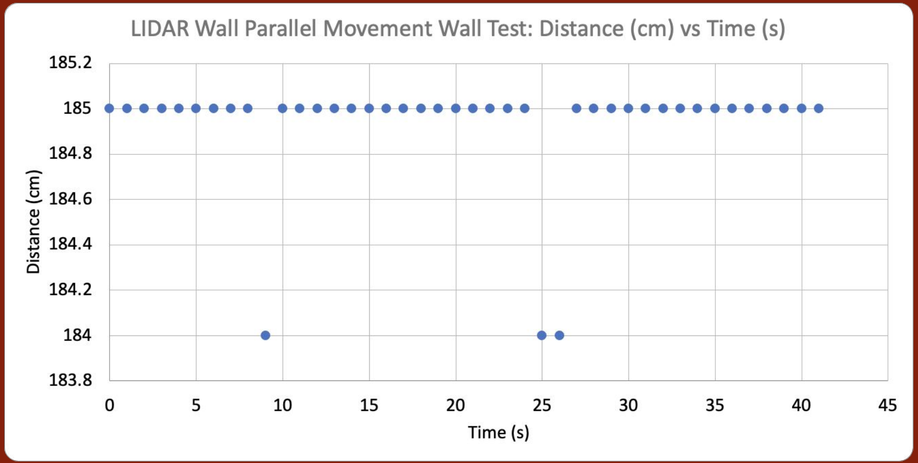
LIDAR Data: Precision Test

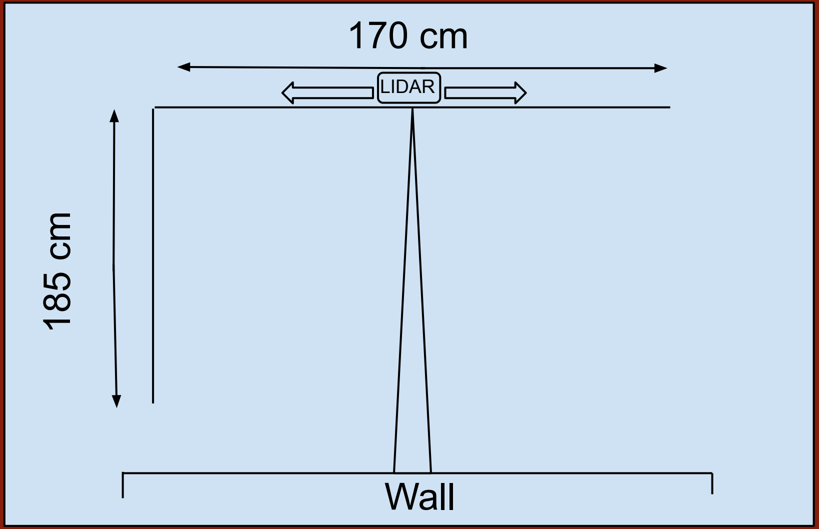
Distance Intervals (mm)	Avg. Distance (mm)	St. Dev (mm)
200	198.9736842	1.237042765
	...	
300	304.6216216	1.523358786
	...	
400	403.9722222	2.843399486
	...	
505	505.2105263	1.685854461
510	510.6666667	0.887625365
	...	
600	603.0196078	1.870723882
	...	
705	705.9491525	1.718911689

- Setup intervals between 200mm and 705mm and increased distance in 5 mm intervals
- Error due to imprecise mm markings as well as moving in between intervals



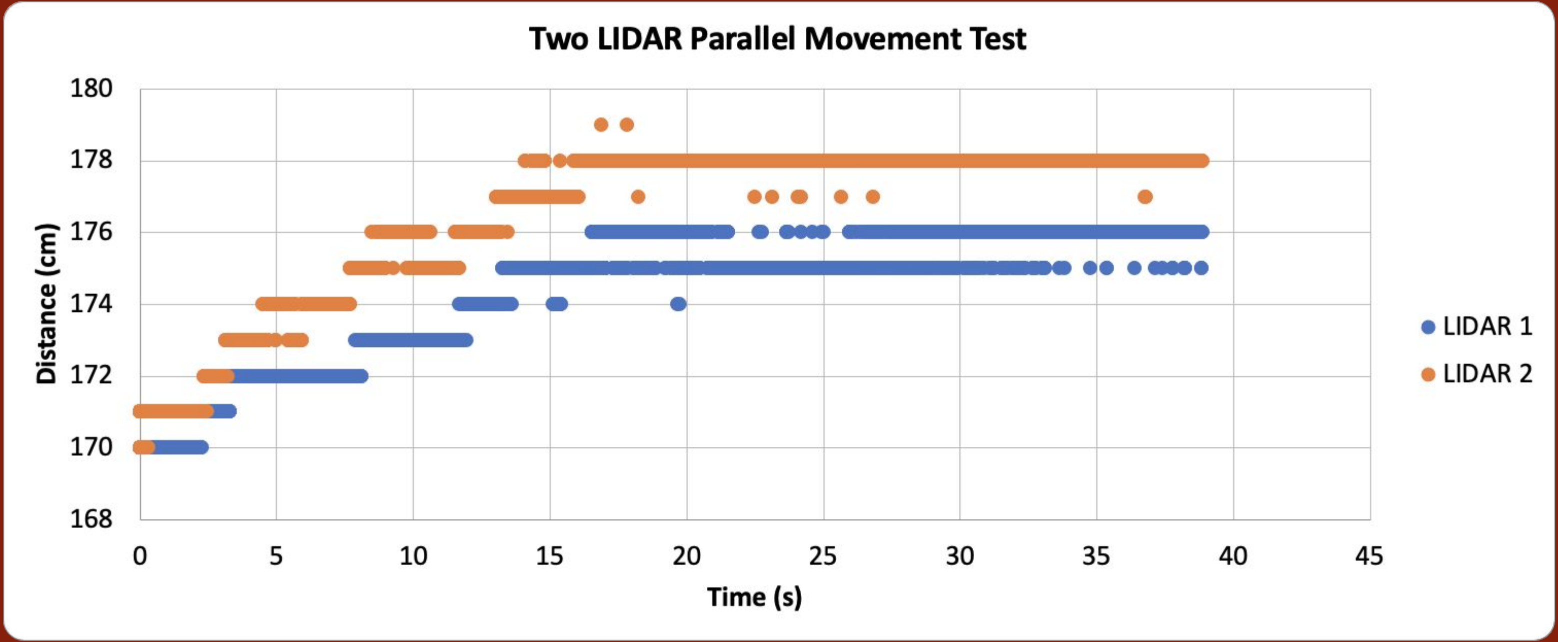
LIDAR Data: Parallel Movement Test





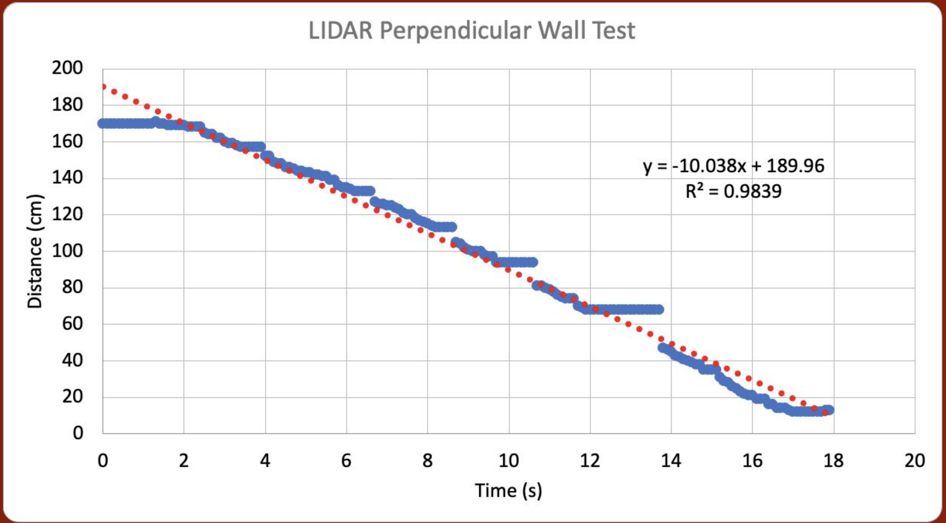
- LIDAR is mounted to chair pointed at wall 185cm away
- Chair is slid 170cm in one direction and distance to the wall is output
- Error caused by chair not being moved in a straight line

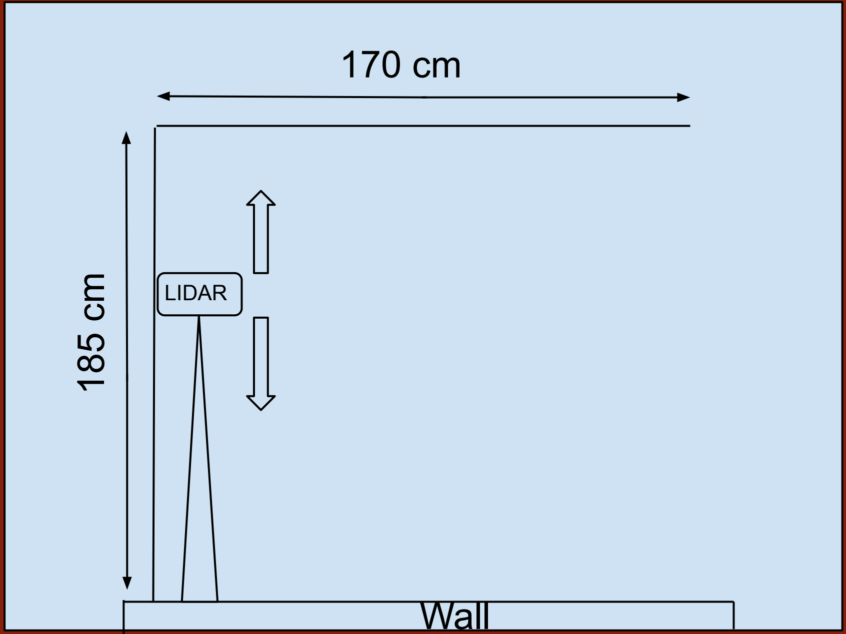
LIDAR Data: Two LIDAR Parallel Movement Test



** same setup as individual LIDAR parallel movement test
*** constant difference between LIDAR 1 and LIDAR 2 ensures accuracy of sensors

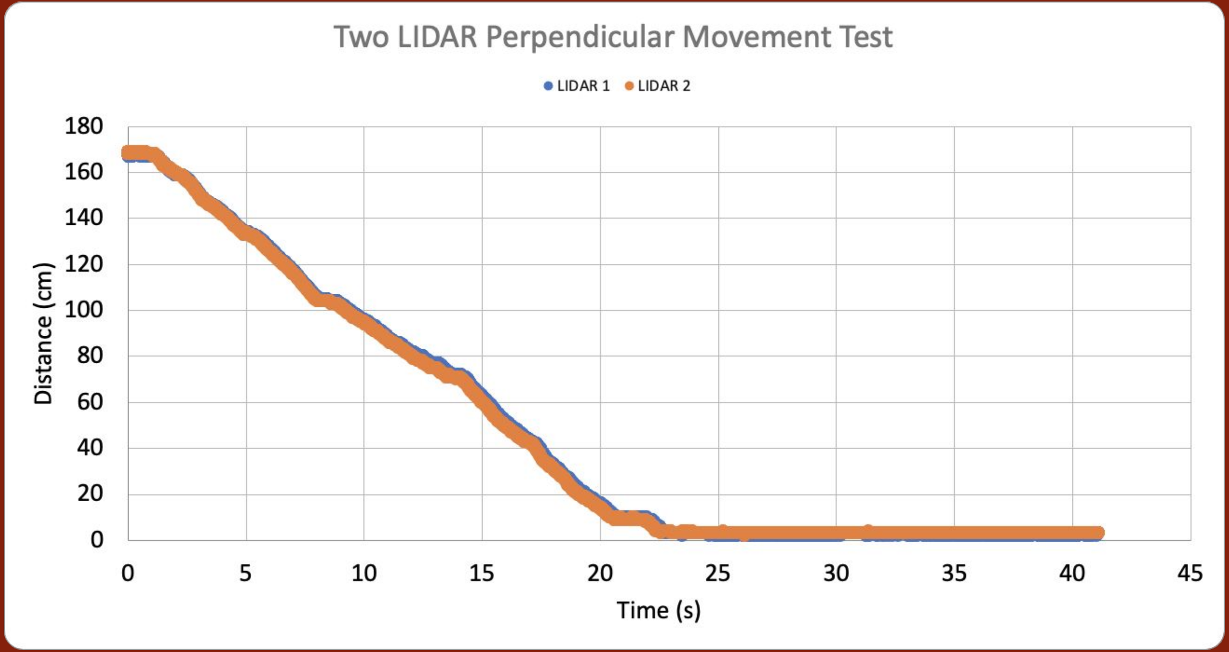
LIDAR Data: Perpendicular Movement





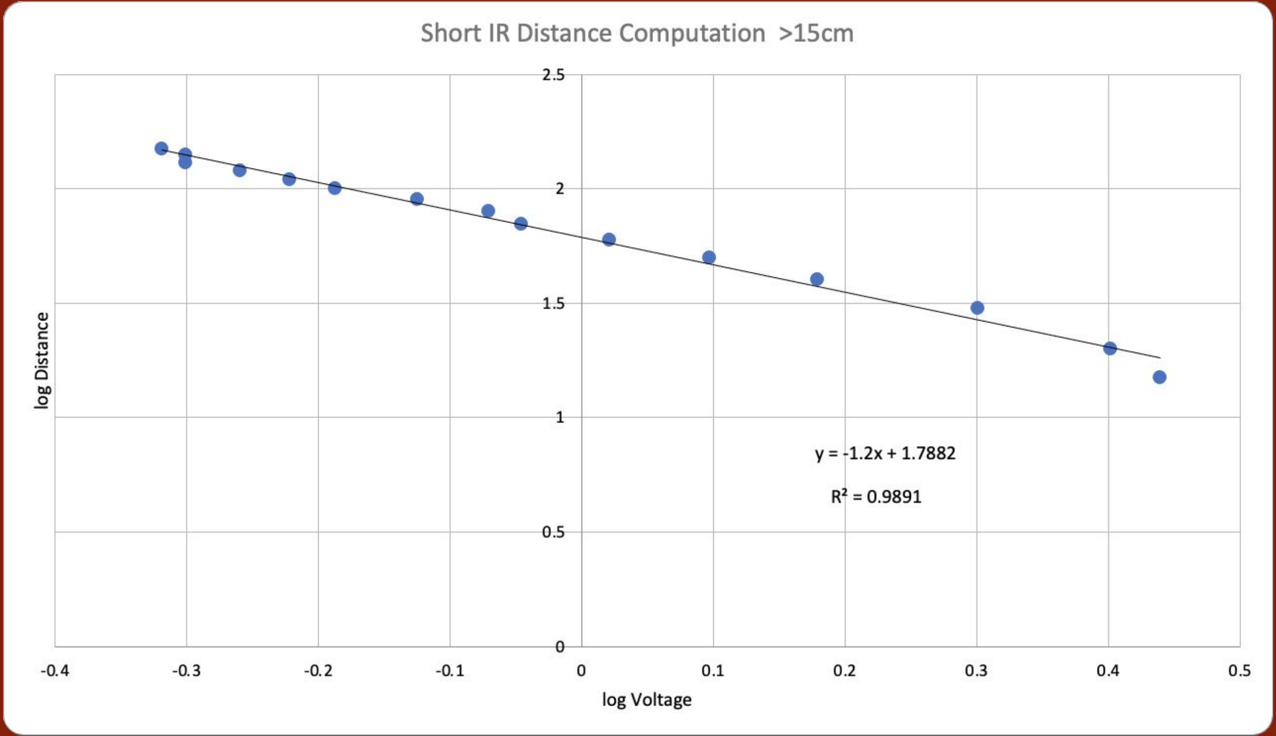
- LIDAR mounted to chair pointing to single spot on the wall 185 cm away.
- Chair is pushed toward the wall at constant rate in straight line. Distance to wall is output
- Error when chair is pushed too fast or not straight

LIDAR Data: Two LIDAR Perpendicular Movement Test



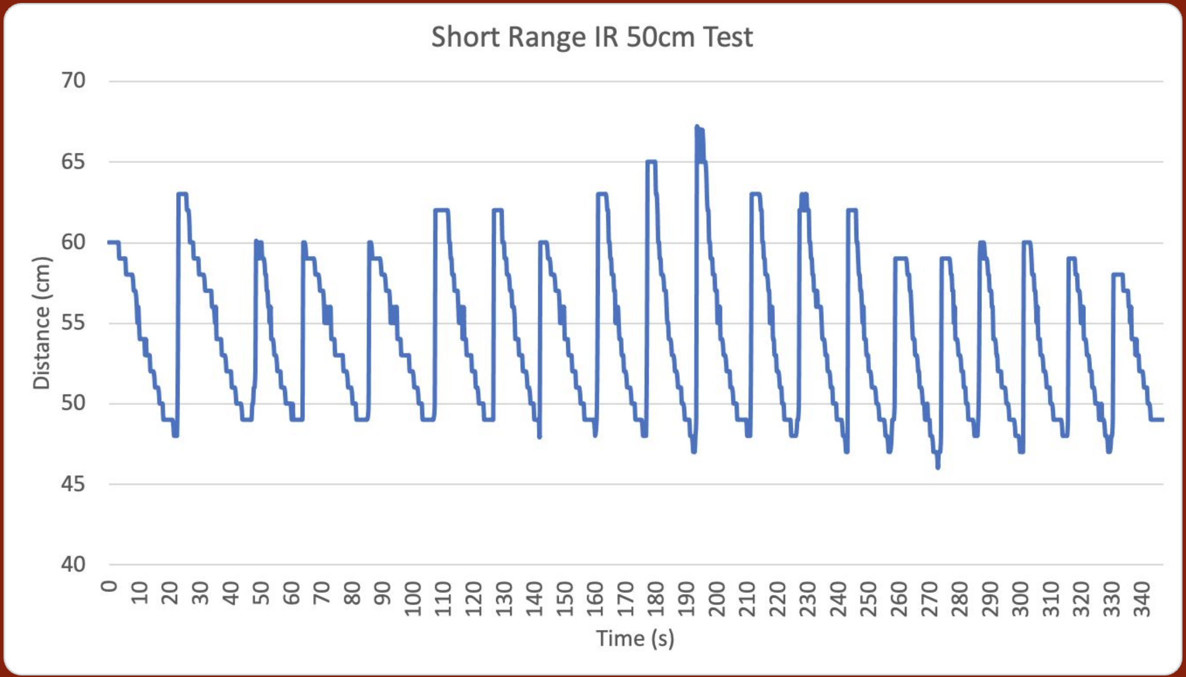
** same setup as individual LIDAR perpendicular movement test

Short IR Data: Distance Characteristic



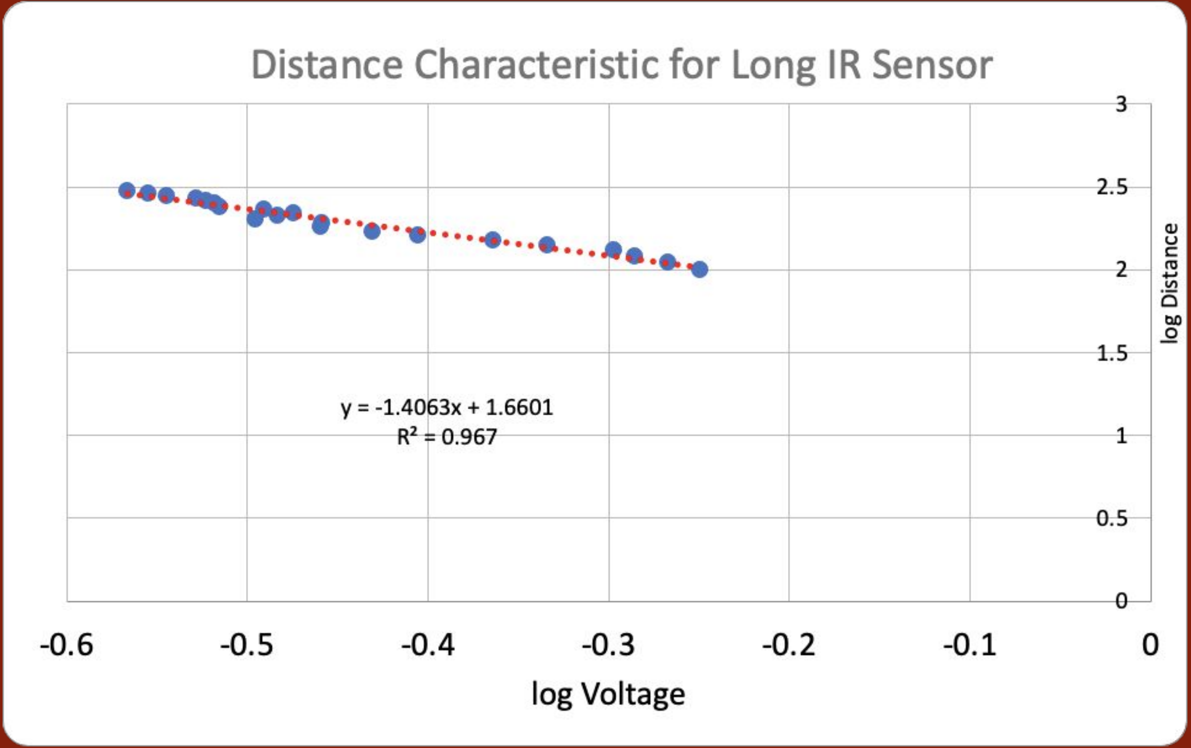
- Distance characteristic was reconstructed based on data from the datasheet

Short IR Data: Overhead Object Detection



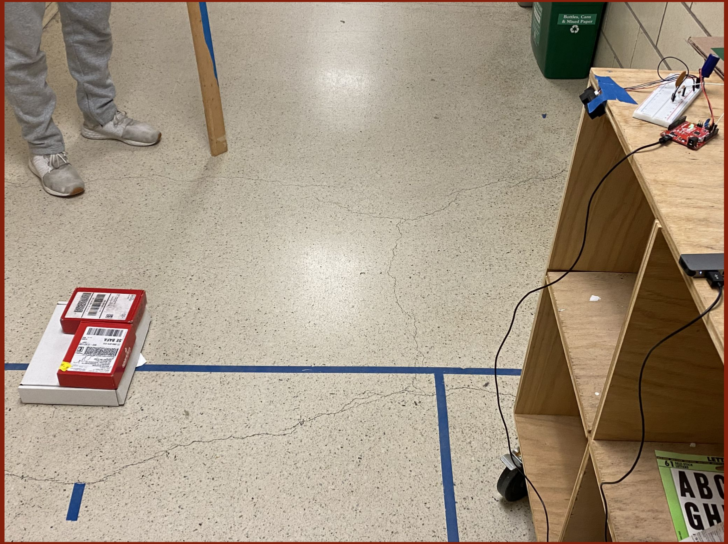
- Headset is placed with object >50cm from sensor
- Object is moved closer than 50cm, the test is successful
- Ran for 20 trials, succeeded 20 times

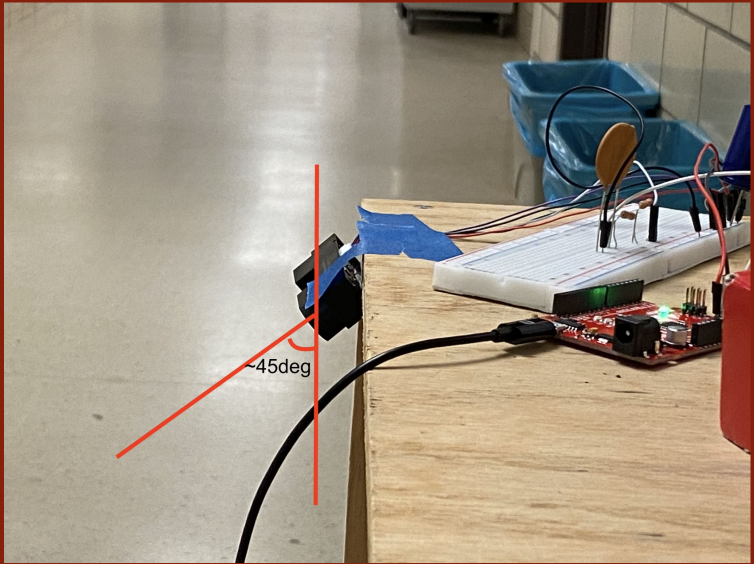
Long IR Data: Distance Characteristic



- Output voltage was read as object was moved in 10 cm intervals from 1m-3m
- Plot of distance as a function of voltage was created and linearized which was then implemented in the software to get distance readings

Long IR Data: 10cm Detection Test





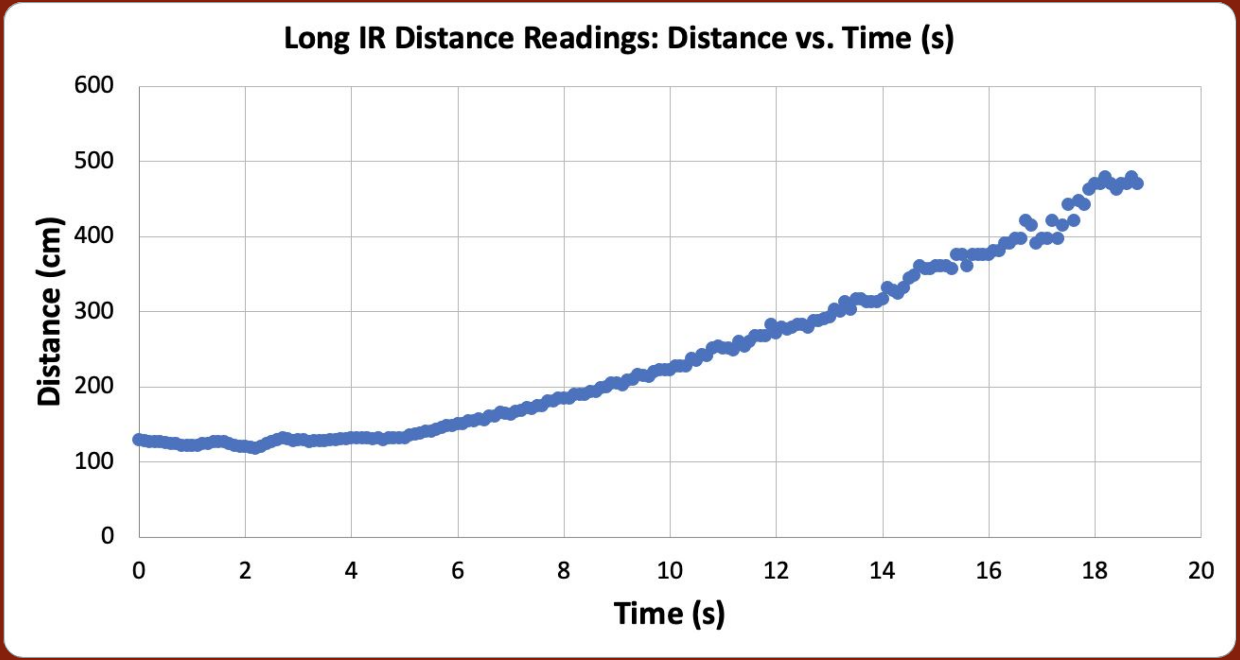
- Distance from sensor to object is 135 ± 1cm

- Sensor makes 45 deg angle from vertical
- 10cm change in the vertical is 7cm change on sensor output

Long IR Data: 10cm Detection Test

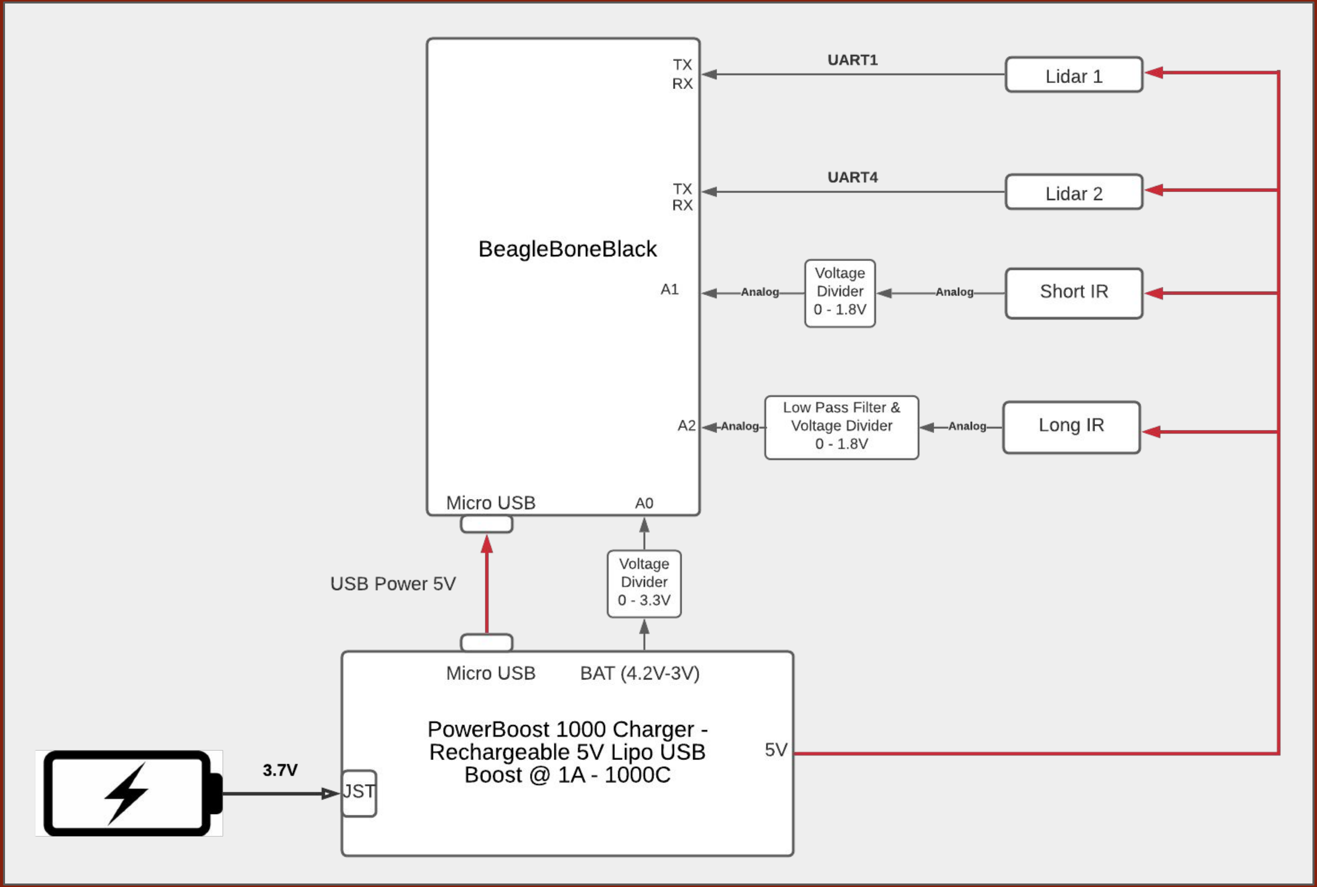
Test Number	1	2	3	4	5
Initial Distance (cm)	134.24	134.61	134.11	133.88	134.23
Avg. Detection Distance (cm)	121.82	119.98	118.79	118.63	118.82
Difference (cm)	12.43	14.63	15.32	15.25	15.42
Test Number	6	7	8	9	10
Initial Distance (cm)	132.32	132.70	130.12	134.16	134.29
Avg. Detection Distance (cm)	120.23	121.08	118.78	121.19	118.67
Difference (cm)	12.09	11.62	11.34	12.97	15.62
Test Number	11	12	13	14	15
Initial Distance (cm)	134.19	134.15	133.85	133.61	134.00
Avg. Detection Distance (cm)	118.62	121.05	118.70	118.22	122.57
Difference (cm)	15.57	13.10	15.15	15.38	11.43
Test Number	16	17	18	19	20
Initial Distance (cm)	134.15	134.37	134.54	134.14	134.16
Avg. Detection Distance (cm)	117.35	120.45	119.11	119.00	120.68
Difference (cm)	16.81	13.92	15.43	15.14	13.48

Long IR Data: Distance Readings

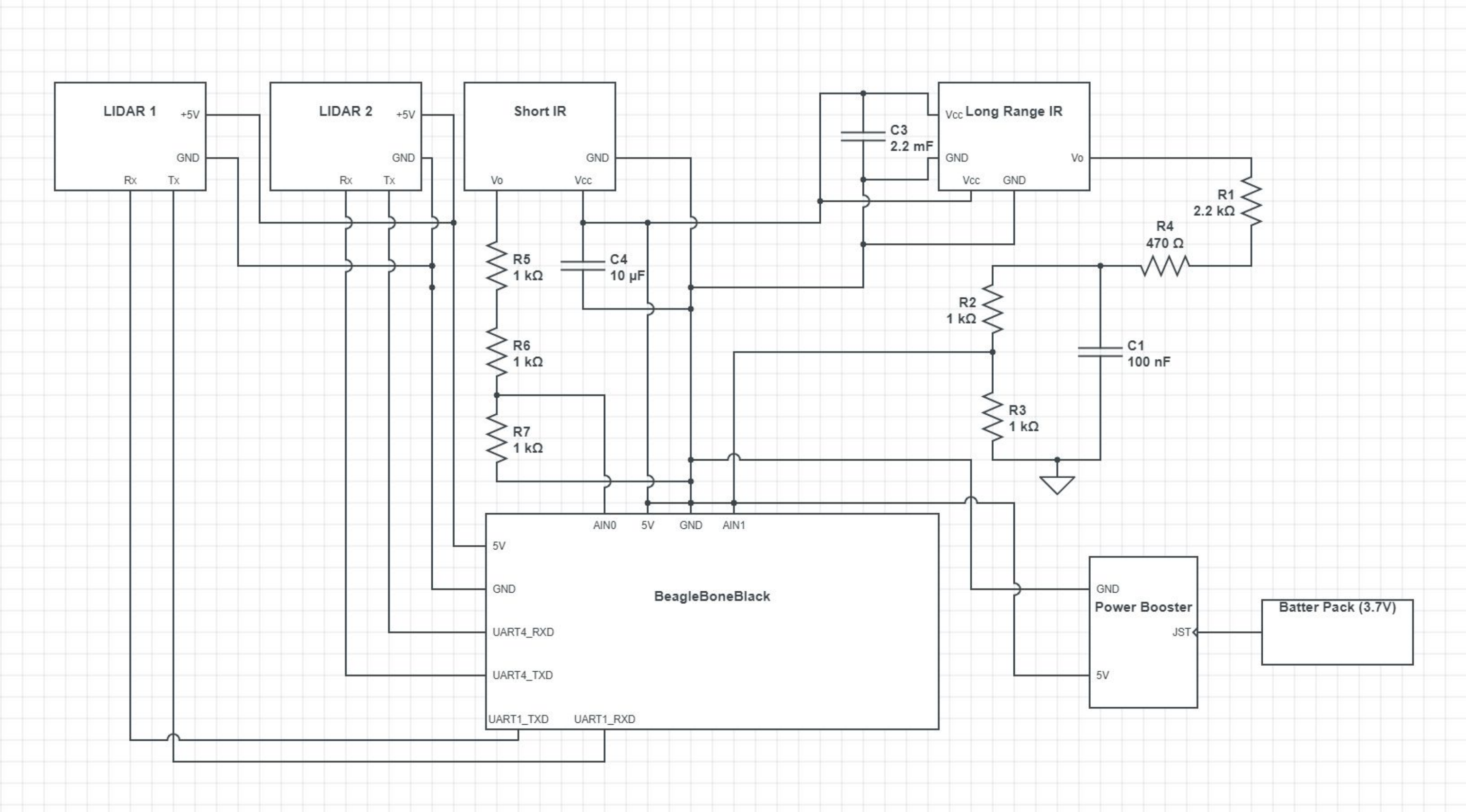


- Object placed 1m away then moved away to 5m
- Using Arduino and Sharp Arduino library
- 10-bit to 12-bit ADC conversion

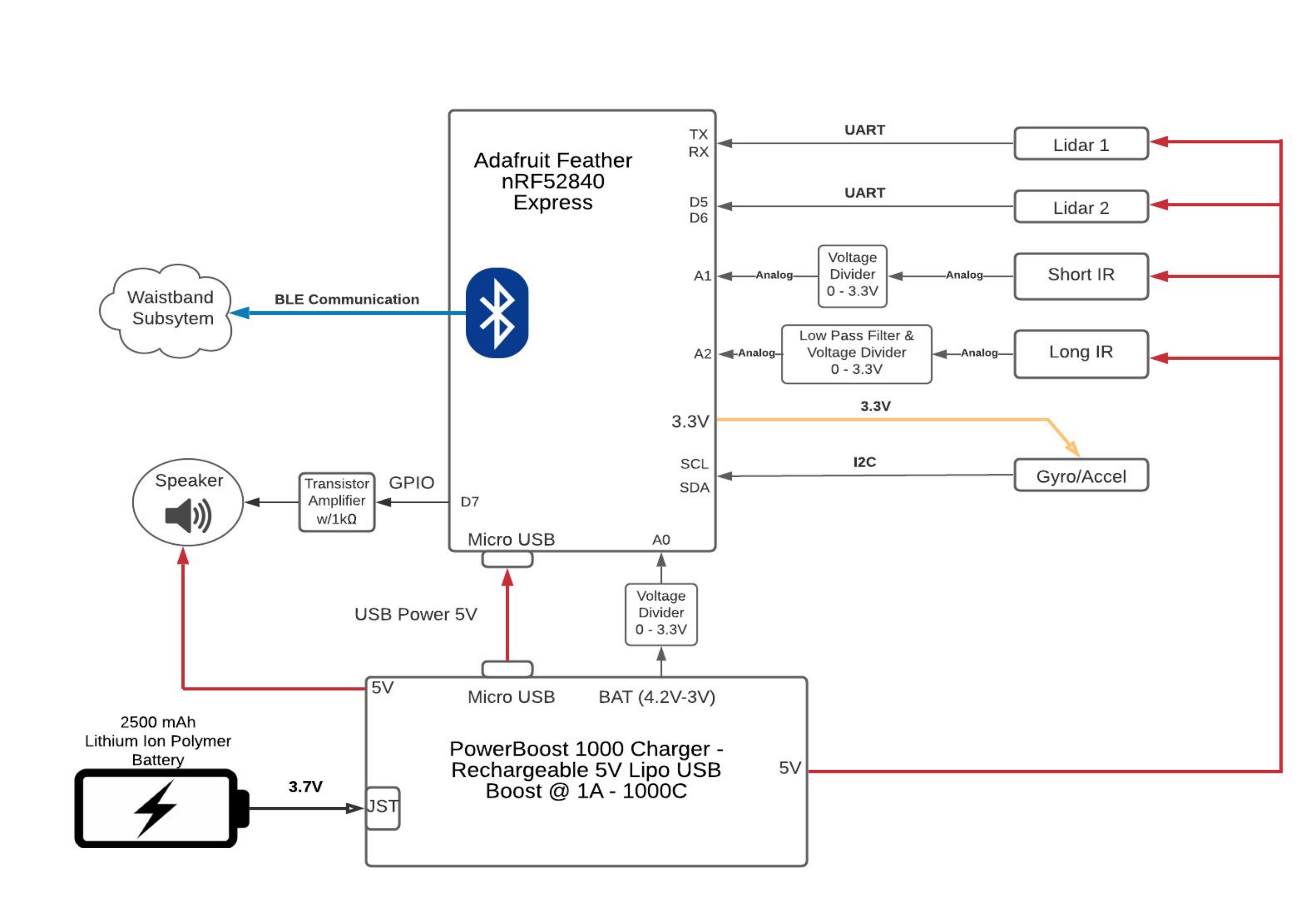
Current Sensor Block Diagram



MDR Headset Schematic



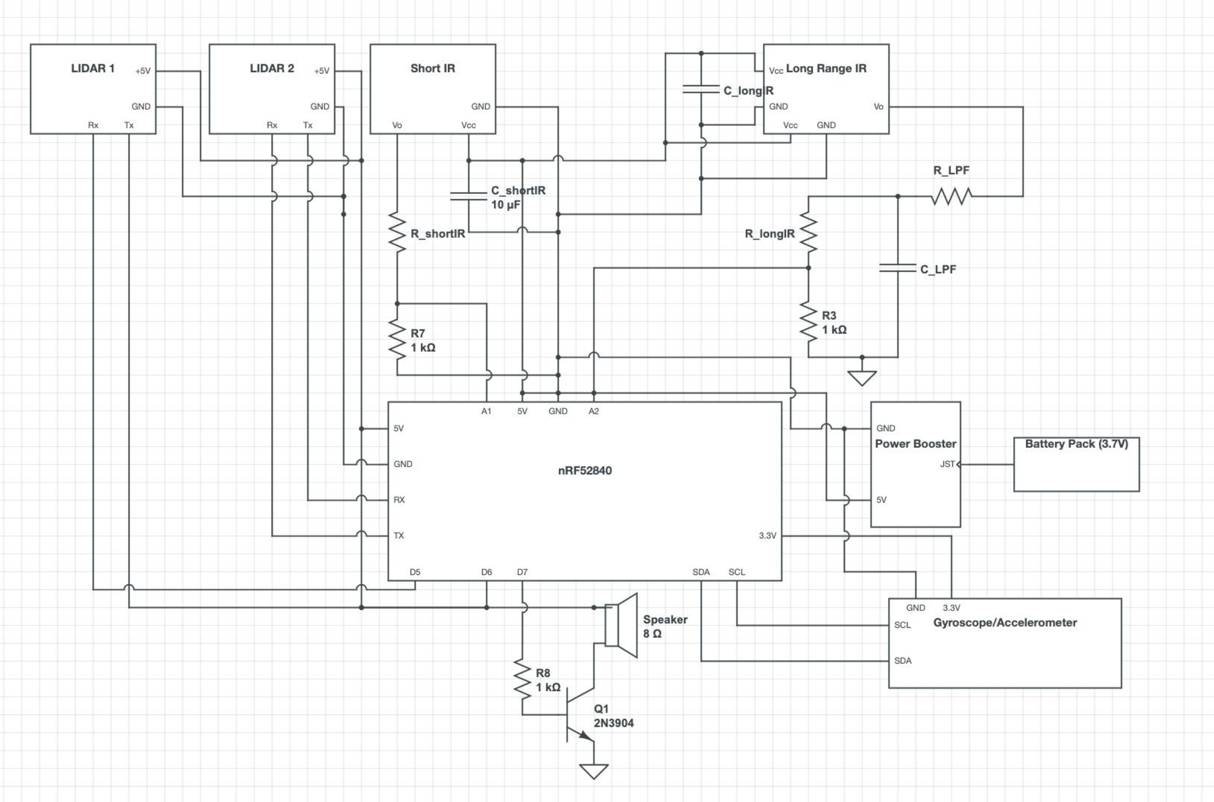
Proposed Headset Hardware Block Diagram



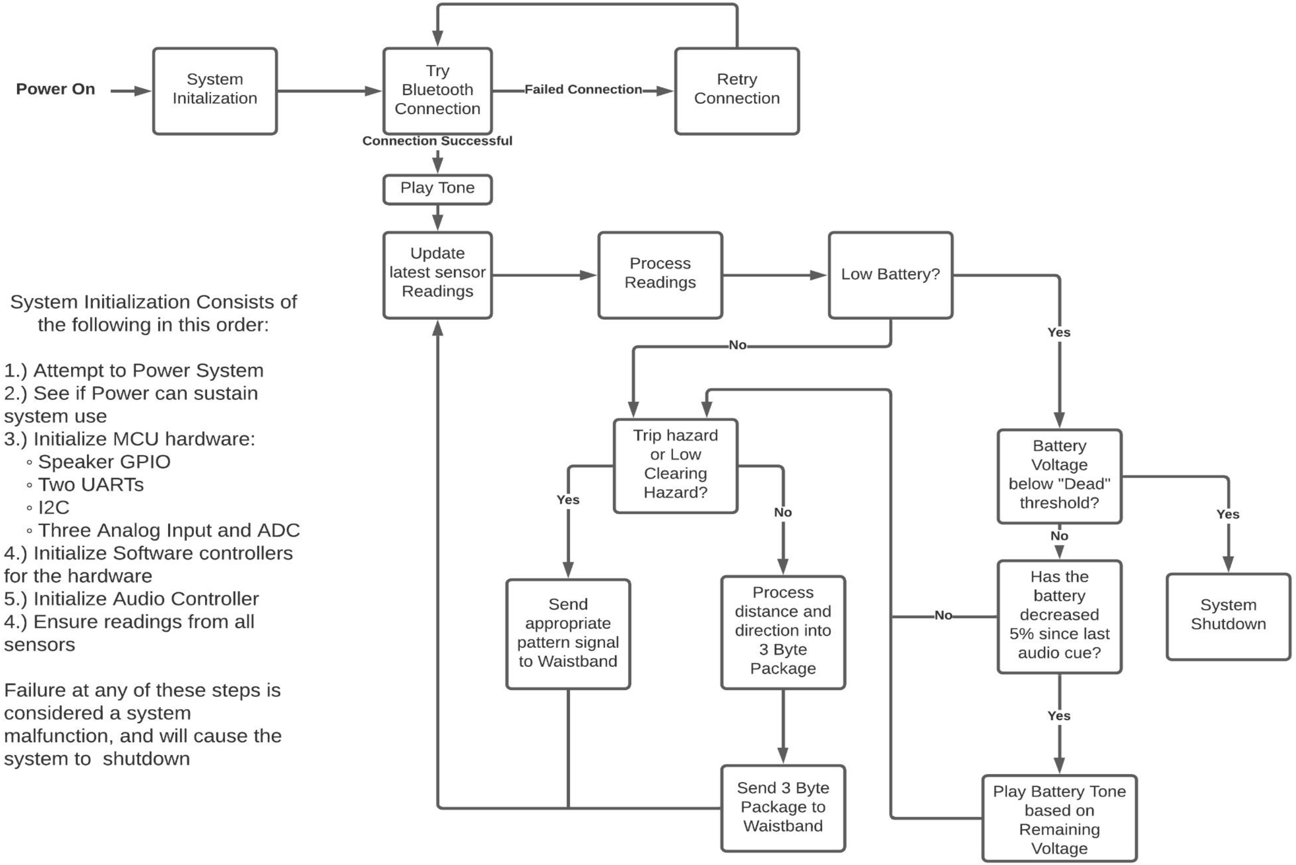
Proposed Headset PCB Design

- PCB will be based on headset schematic
- Microcontroller will change to Adafruit Feather
- Add through-hole connections for the MCU, power controller, sensors
- Resistor values in the step voltage divider will change according to the corresponding voltage on the Feather
- Bypass capacitor will have to decrease significantly to find suitable SMT version for the long range IR
    - Possibly get new sensor due to noisy outputs even after filtering

Headset Custom PCB



Updated Headset Software Diagram



System Initialization Consists of the following in this order:

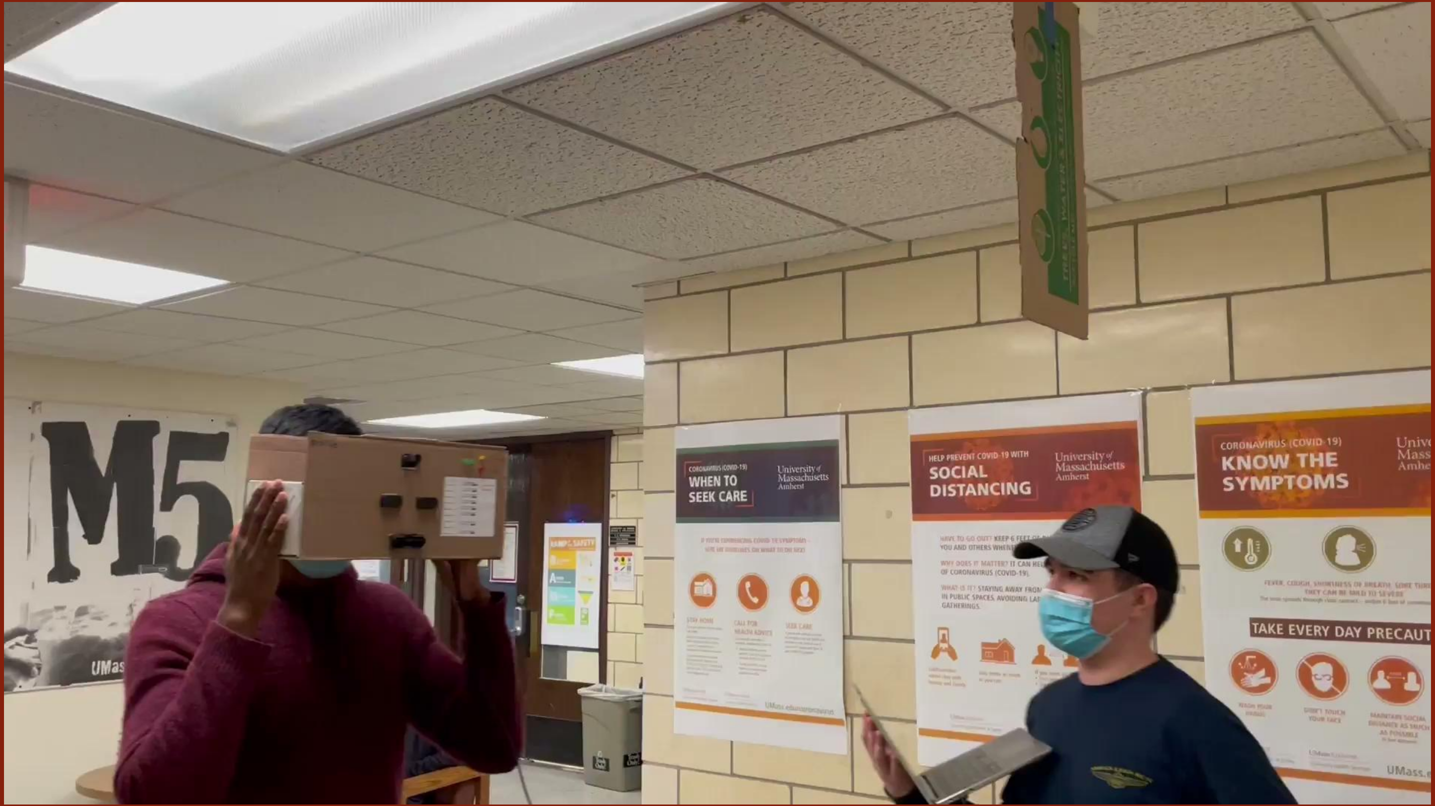
1.) Attempt to Power System
2.) See if Power can sustain system use
3.) Initialize MCU hardware:
- Speaker GPIO
- Two UARTs
- I2C
- Three Analog Input and ADC

4.) Initialize Software controllers for the hardware
5.) Initialize Audio Controller
4.) Ensure readings from all sensors

Failure at any of these steps is considered a system malfunction, and will cause the system to shutdown

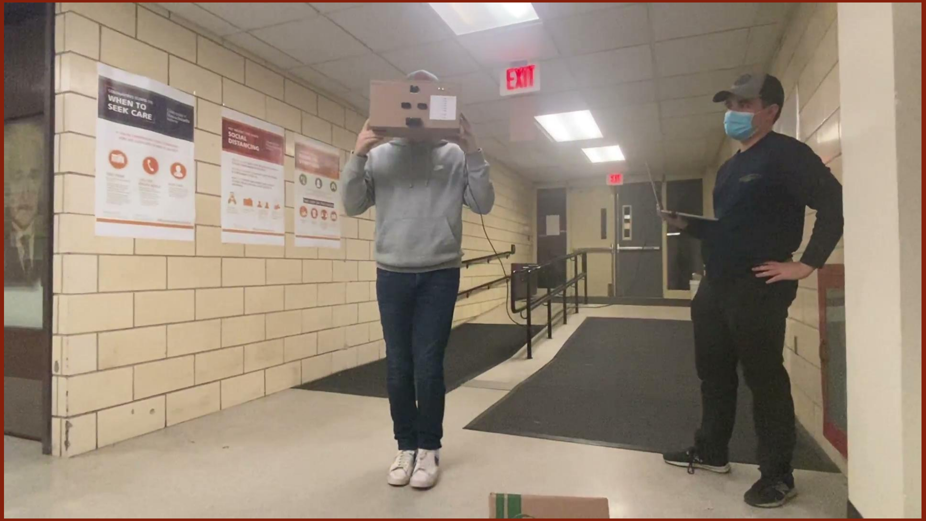
Headset - LIDAR Demonstration

Headset - Short IR Demonstration



Headset: Long IR Demonstration

14x12 inch box (Height x Width)



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
Total Parts	**----------------------**	**---------------**	**$214.2**

Shipping : $69.8
Current total : $214.2 + $69.8 = $284

Future Costs

Part	Expected Price
PCB Headset	75
Headset Material	25
PCB Waistband	90
Waistband Material	25
Total PCB	**215**

Expected total :
$284 + $215 = $499

Contingency Microcontroller for MDR:
BeagleBone Black

MDR Hardware

Waistband

SparkFun RedBoard 2x - Arduinos

Accelerometer - Testing and data collection for motors

Motors 12x -

Shift registers 3x

Motor Drivers 3x

Resistors & LEDs used for visual reference

Headset

Lidar 2x - Forward facing ranging

Short IR - Low Clearing detection

Long IR - Trip hazard detection

Adafruit Feather nrf52840 Express - Battery testing

BeagleBone Black - For MDR* System prototype

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 2500 mAh Battery Capacity

5V 2.5A Power Supply Wall Adapter - For MDR* Beaglebone power supply

Resistors & LEDs used for visual reference

MDR Software

CircuitPython - nrf52840 Express

- Object class for TF Mini Plus and IR developed by Matt
- Audio controller object class developed by Jon

Python 2.7 - Beaglebone Black

- Adafruit_BBIO library for various hardware setup and controlling on the Beaglebone
- Python math libraries
- Similar to CircuitPython, TF Mini Plus also had a object class developed

Arduino Script - Waistband modules

- Native PWM functions

Next Steps

- Headset
  - Headset movement accounted for using Gyroscope/Accelerometer mechanism
  - Transmit at least 3 bytes of data per system cycle to waistband via bluetooth
  - Design headset PCB
- Waistband
  - Receive at least 3 bytes of data from headset via bluetooth
    - Error detection/correction
  - Haptic feedback responds in real time to sensor information
  - Design waistband PCB
- Power
  - A shutdown safety measure for when the battery voltage can not safely support the system
  - An on and off switch to provide power
  - Battery to power the waistband system per specification

Spring Semester Team Responsibilities

Matthew Corcoran

- Team Manager
- Headset Software Lead
- Haptic Response Assist

Pradeep Manivannan

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

Callum Little

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

Jon McDonald

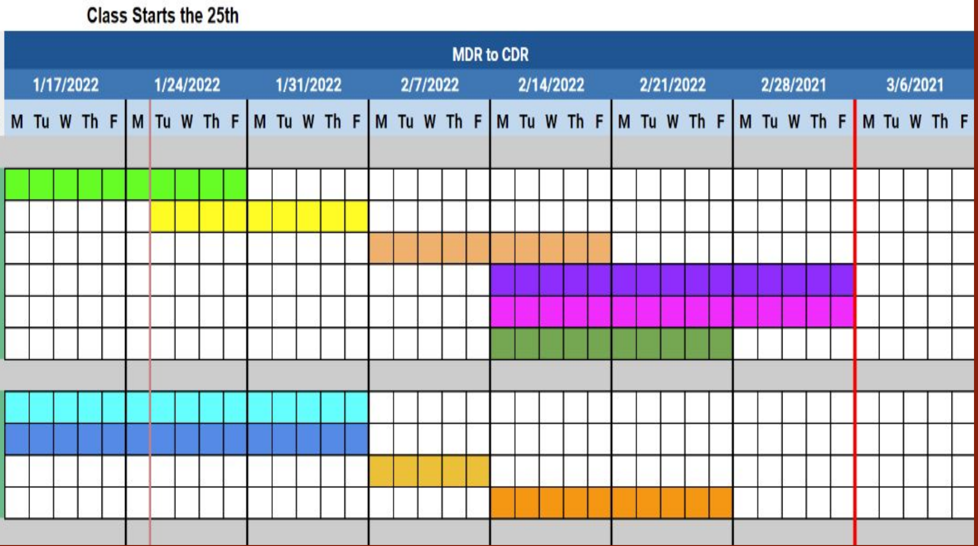
- Battery Power Lead
- Audio Response Lead
- Headset Software Assist

Gantt Chart - Between 1/17/22 & 3/7/22

OcuFeel Gannt Chart | **Group** | Jon McDonald, Pradeep Manivannan, Callum Little, Matthew Corcoran

Project Manager: Matthew Corcoran | **DATE** | 1/17/22 - 3/7/22

TASK TITLE	TASK OWNER	START DATE	DUE DATE	EST. DURATION	PCT OF TASK COMPLETE
Hardware					
PCB Design and Order	CL,PM	1/17/2022	1/28/2022	11	0%
Battery On/Off Delay Switch	JM,PM,MC	1/25/2022	2/4/2022	9	0%
PCB Revision(s)	CL,PM	2/7/2022	2/18/2022	11	0%
Headset Design	JM,PM,CL	2/14/2022	3/4/2022	20	0%
Belt Design	CL,MC	2/14/2022	3/4/2022	20	0%
Low Voltage Shut Down System	MC,JM	2/14/2022	2/25/2022	11	0%
Software					
Data Packaging & Bluetooth Transmission	JM,MC	1/17/2022	2/4/2022	17	0%
Bluetooth Receiving	JM,MC	1/17/2022	2/4/2022	17	0%
Account for movement with Accel/Gyro	CL,MC	2/7/2022	2/11/2022	4	0%
System Shut Down Cases	PM,JM	2/14/2022	2/25/2022	11	0%



Legend

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

Live Demo of System!

Questions?

Thank you.