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Method for Monitoring Rapid Eye Movement in Hospital Patients

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Background & Motivation

What is REM and Why does it matter?

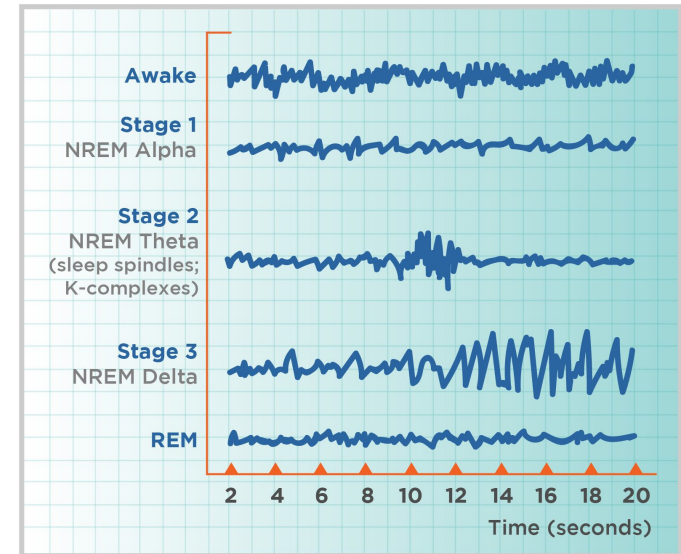
Rapid Eye Movement (REM) is a stage of sleep in which there is an increase in eye movement and and paralyzation of the body

The rapid movement is quantifiable by amplitude, frequency, and duration of the eye's rotation

REM is one of the most important metrics for a person's health

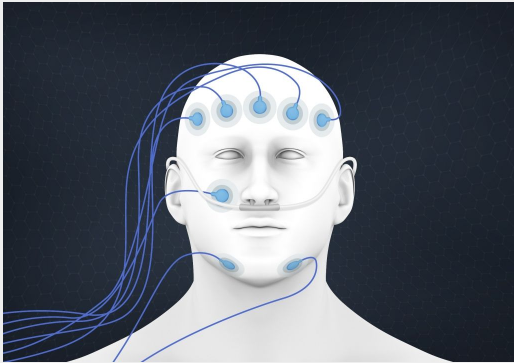
- Research brain activity/development
- Identify emotional/mental state
- Track patient recovery

EKG RECORDINGS DURING SLEEP



Current Sleep Monitoring Methods Do Not Suit Hospital Need

Polysomnography “PSG” Tests



The **Gold Standard** method but is **expensive and impractical** for general ward setting

FitBits/Smart Watches



While **affordable**, they only report **correlations to REM** sleep unfit for patient care standards

Dream2 Headband



An **accurate** option that is **not commercially available** for purchase as it is a stage 2 FDA research device



An improved REM monitoring system is needed to detect the amplitude, velocity, and rotation of eyeball movement. The system must be easy to use and accurate for the duration of patient sleep.



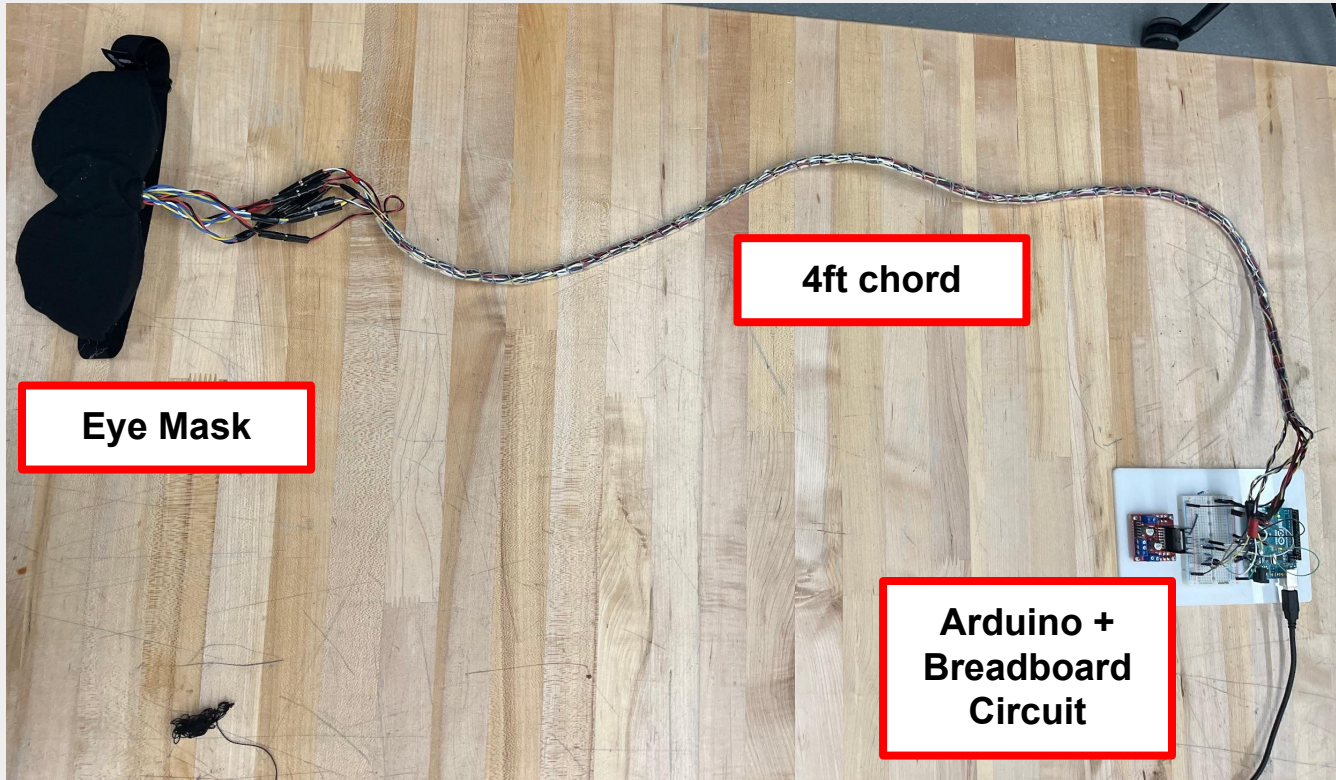
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Requirements & Version 1 Prototype

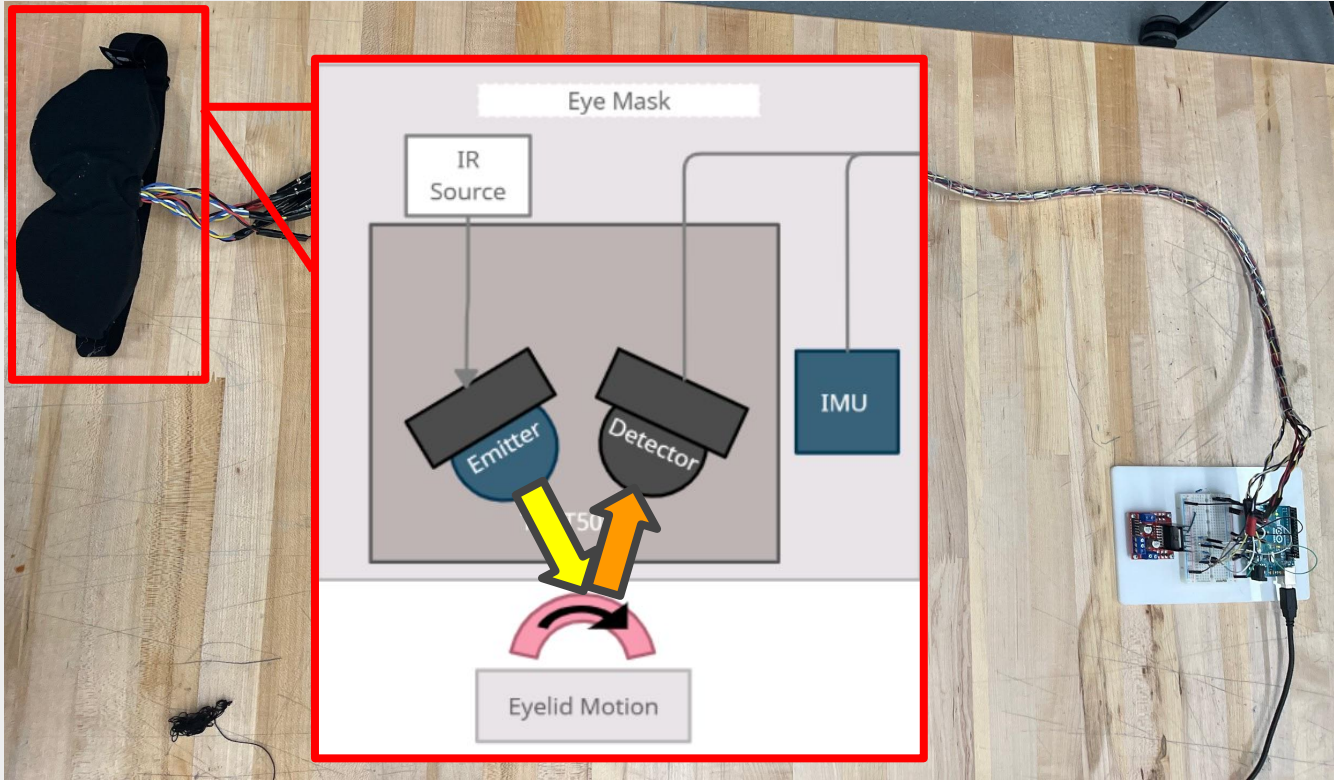
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Requirement	Specification	Verification Status in Dec 2022
Device must monitor the duration of REM sleep	Continuous REM movement > 1 hr Continous Eye movement for 10 hours	not tested not tested
System must quantify sleep characteristics	Eyeball Rotation: 0.5-13.5 degrees Eyeball Velocity: 120 degrees/sec Sampling Rate > 40 Hz	13.5 degrees met, 0.5 degrees not met, minimum 6 degrees detected 120 degrees/sec met, verified for 900 degrees/sec system samples at 220 Hz
System must be able to differentiate head from eye movement	exclude head movements > 20 degrees/sec	not tested
Device must be capable of data storage and output	report data in 1s, 5s, 10s, 20s intervals	data post processing filters in range of any size
Device must not be affected by electrical noise	Filter noise > 500 Hz	data post processing utilizes digital low pass filter
Device must be safe to use and operate	IEC 60601 and ISO 14971	not tested
Device should fit a variety of head sizes	weigh < 5lbs breadths: 147.6 to 167.1 mm lengths: 169.6 - 193.2 mm circumference 541.1 - 605.8 mm	final device weighs 0.25 lbs breadths from 142.24 - 246.38 mm lengths from 101.6 - 203.2 mm circumference range of 401.32- 701.04 mm
Device must be easy to use	Device set up time for medical staff < 5 min Device set up for at home use < 10 min	not tested not tested
Device must be suitable for diverse populations	patient age > 18 years old adjustable for pupil distance 54 - 77 mm	met automatically not met
Device must be comfortable during use	sleep disturbance less than control non invasive	not tested final device does not enter patient's body
Product should be environmentally sustainable	ISO 1135 - reusability ISO 11607 - material toxicity rechargeable batteries	not tested not tested not met

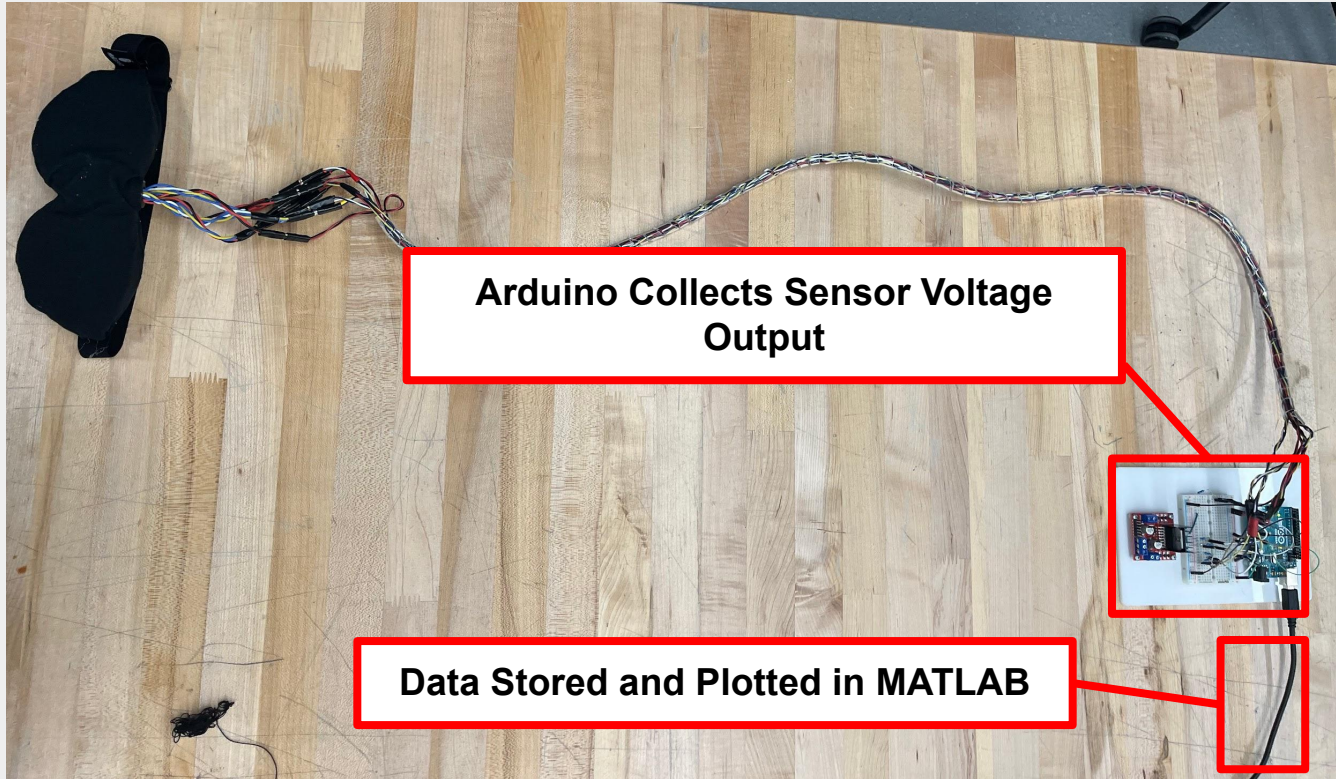
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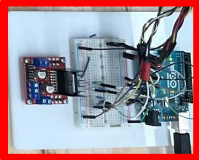
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Arduino Collects Sensor Voltage Output



Data Stored and Plotted in MATLAB





Completed Requirements

- System must quantify sleep characteristics
- System must differentiate head from eye motion
- Device must be capable of data storage and output
- Device should fit a variety of head sizes
- Device must not be affected by electrical noise

Unmet Requirements

- Device must be comfortable during use
- Device must measure the duration of continuous eye movement
- Device must be easy to use
- Data must isolate head from eye motion



ME490 Tasks to Meet the Three Requirements

Device must be comfortable during use

- All hardware self contained in the mask (area less than 240 mm x 35 mm)
- Device is cordless

Device must measure the duration of continuous eye movement

- Device is powered continuously for 8 hours

Device must be easy to use

- Completed instructional manual for user-testing

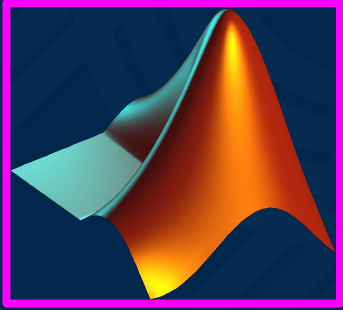


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Version 2 Prototype

MECHENG 490 Work

Data Storage



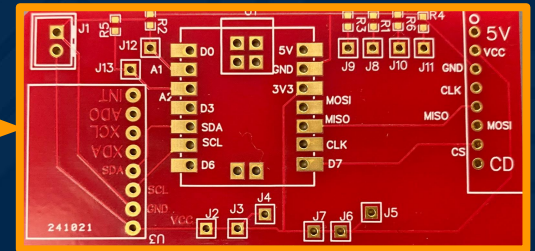
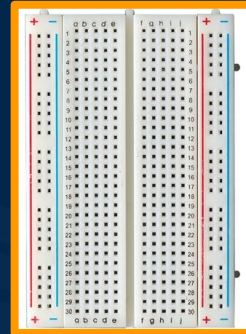
Power Supply



Microprocessor

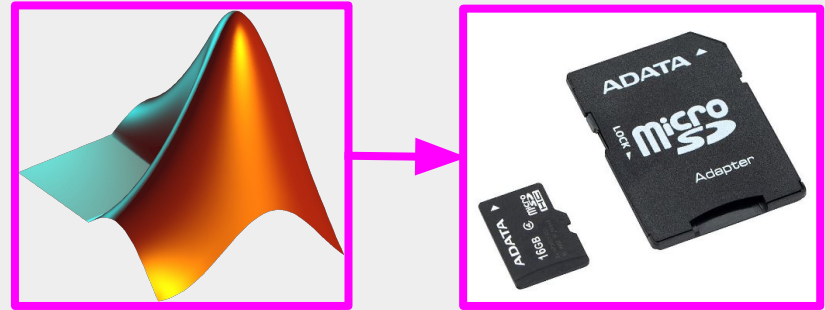


Circuit Construction



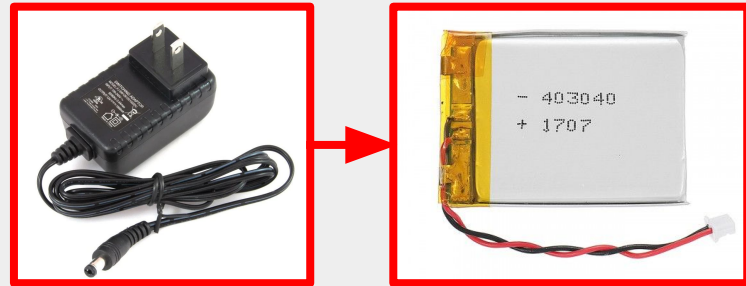
Data Storage: SD Card

- Saves Data
 - Matches MATLAB at 220 Hz
 - Writes to txt file
 - Names files differently per patient
- Contains Minimal Limitations
 - SD card is write protected - no files can be deleted off SD card
 - A new 128 GB card will need to be purchased after 3000 eight hour trials



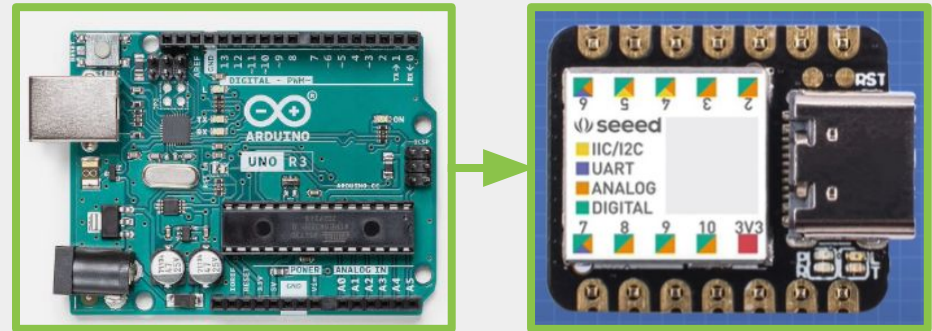
Power Supply: Rechargeable Battery

- Powered V1 Prototype at 3.3 V
 - Sample rate was unaffected
- Determined the minimum power requirement for device to monitor for 8 hrs using a Source Meter
 - 4.7 Ahr for an active SD card
 - 2.3 Ahr for a passive SD card
- Researched thin, light, rechargeable LiPo Batteries
 - 3.7 V MIKROE-4475 6 Ahr (67 x 99 x 8.1 mm)
 - 3.7 V MIKROE-4474 3 Ahr (57 x 63 x 8.1 mm)



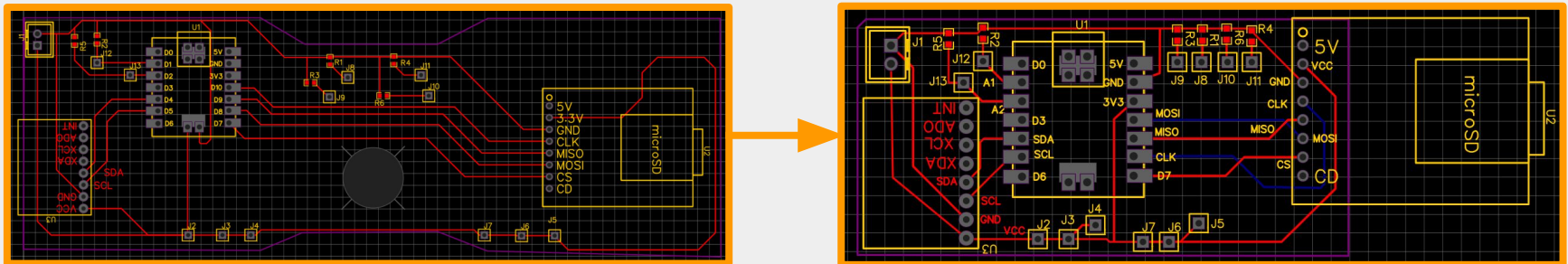
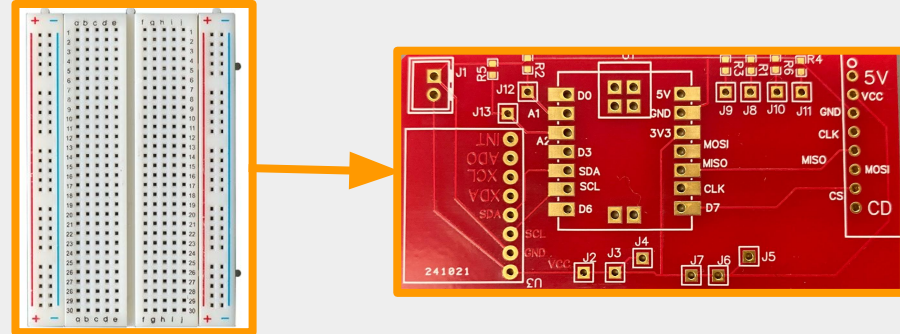
Microprocessor: Seeeduino XIAO

- Meets all Pin Requirements
 - 2 Analog Inputs for Optical Sensors
 - I2C communication for IMU
 - SPI communication for SD card
- Operates at 3.7 V
- Interfaces with Arduino IDE
- Decreases area to one-ninth size



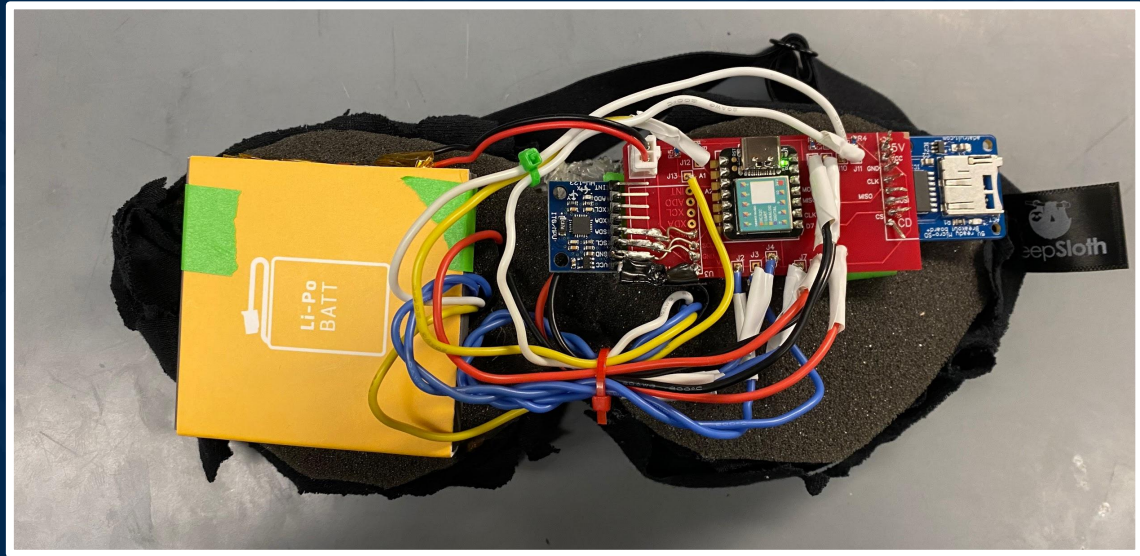
Circuit Construction: Custom Printed Circuit Board

- Minimizes wires needed and length
- Contains all electronics on face of mask
- Iterated Designs
 - First design mimicked mask
 - Second design minimized area

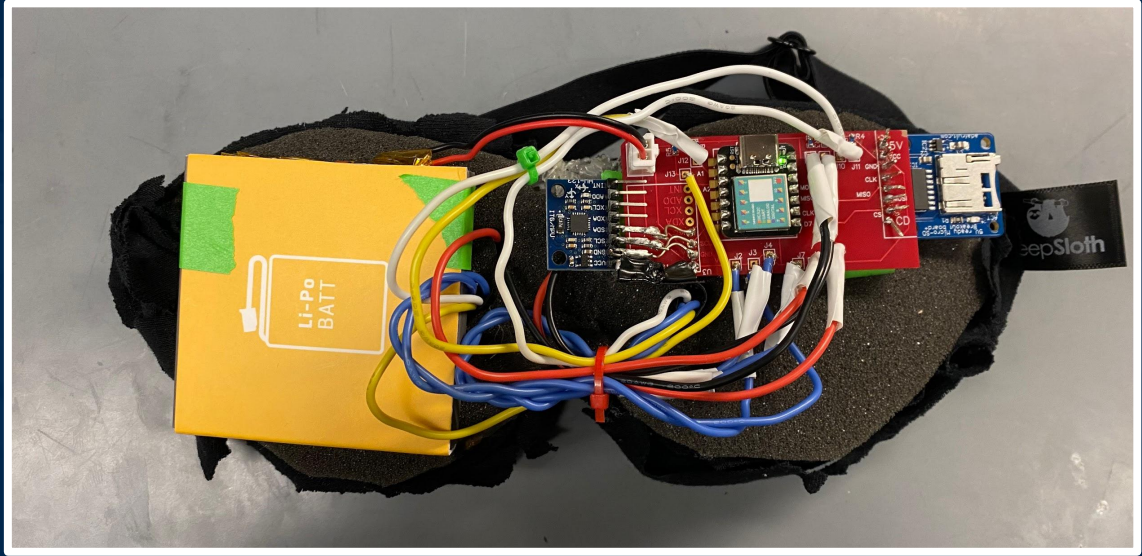


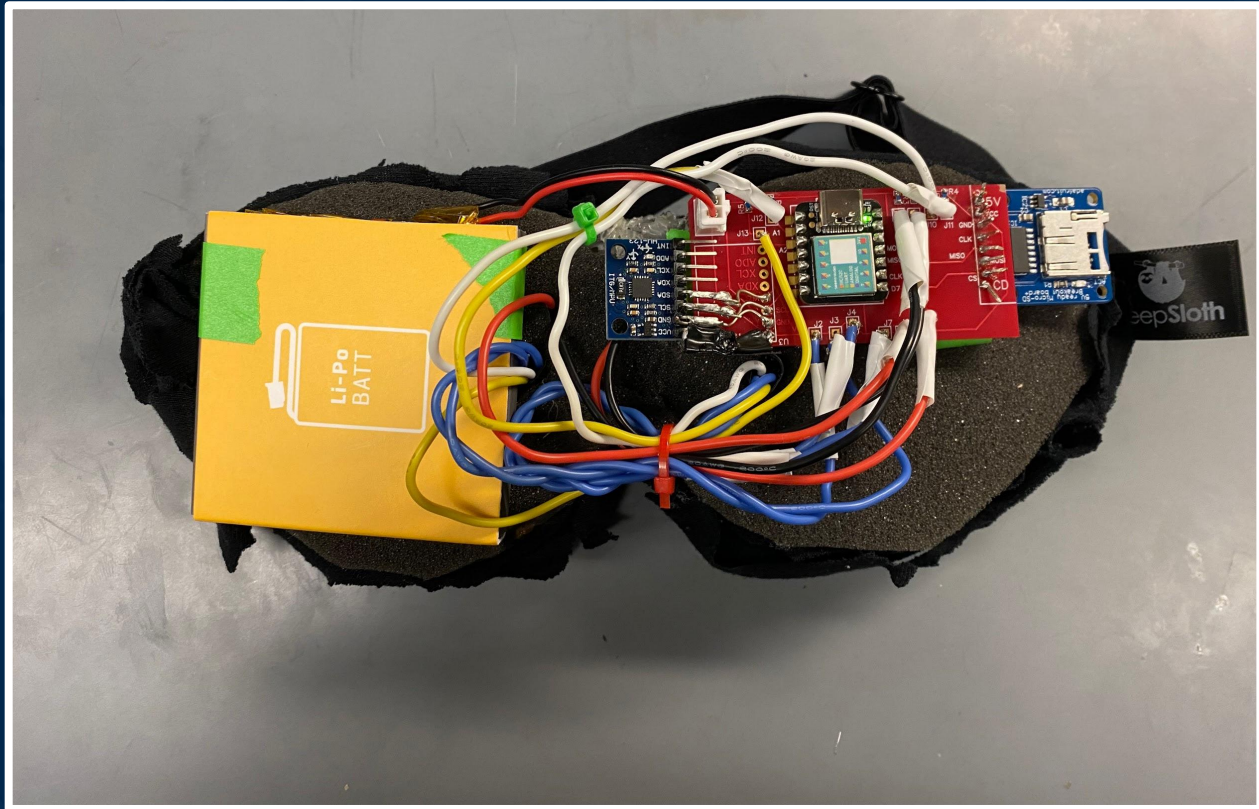


Inside

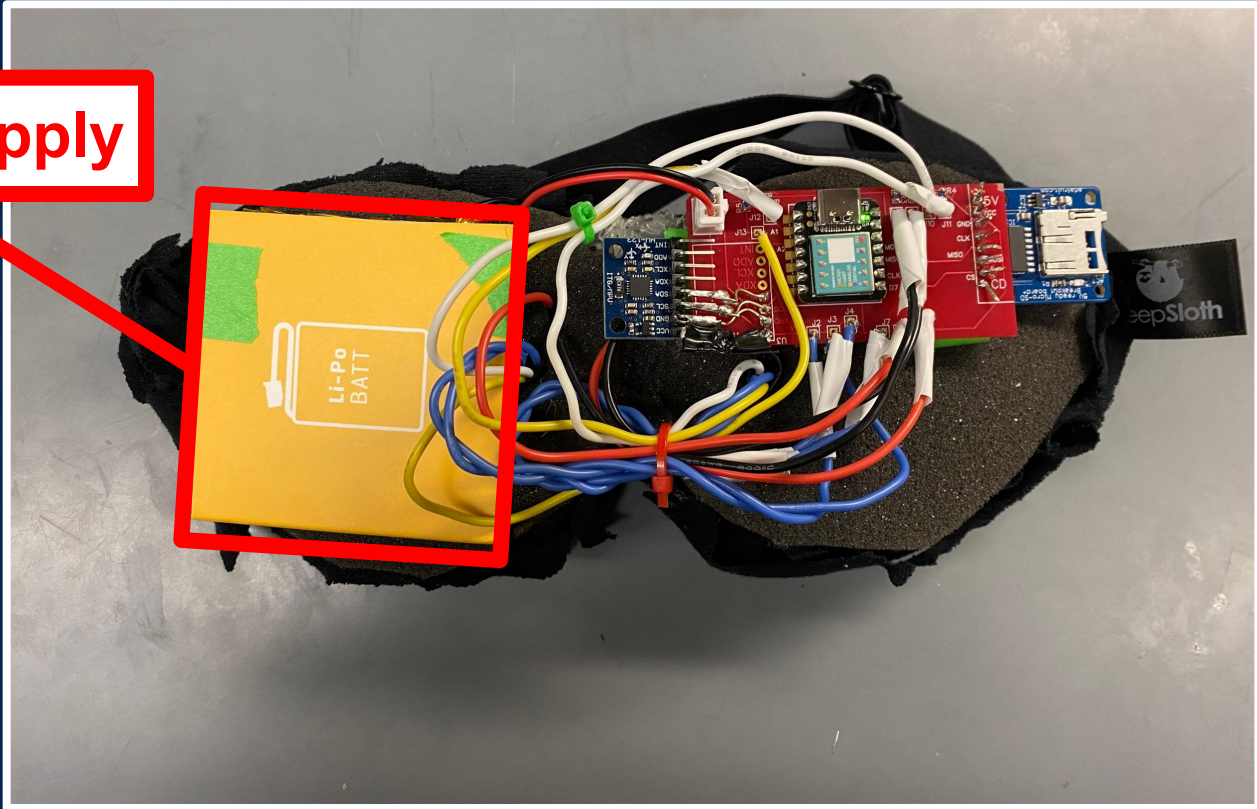


Outside





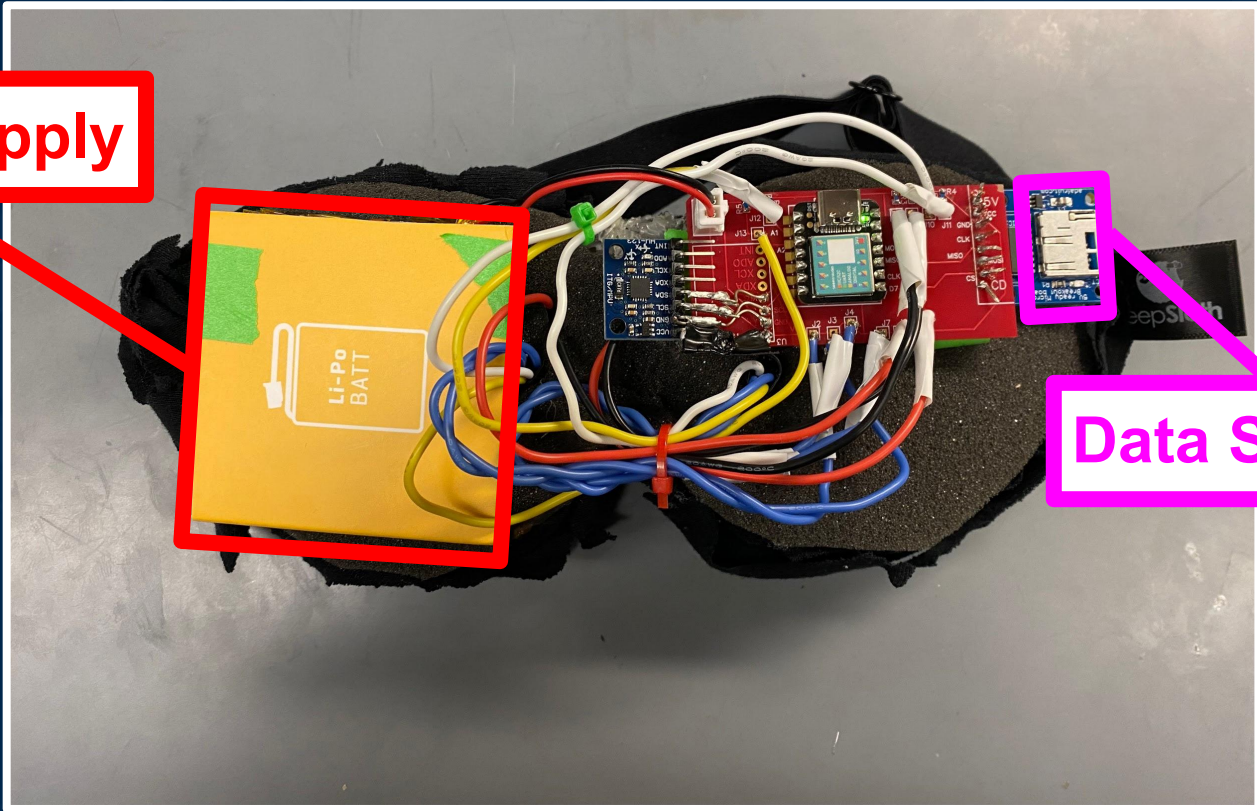
Power Supply



Power Supply



Data Storage

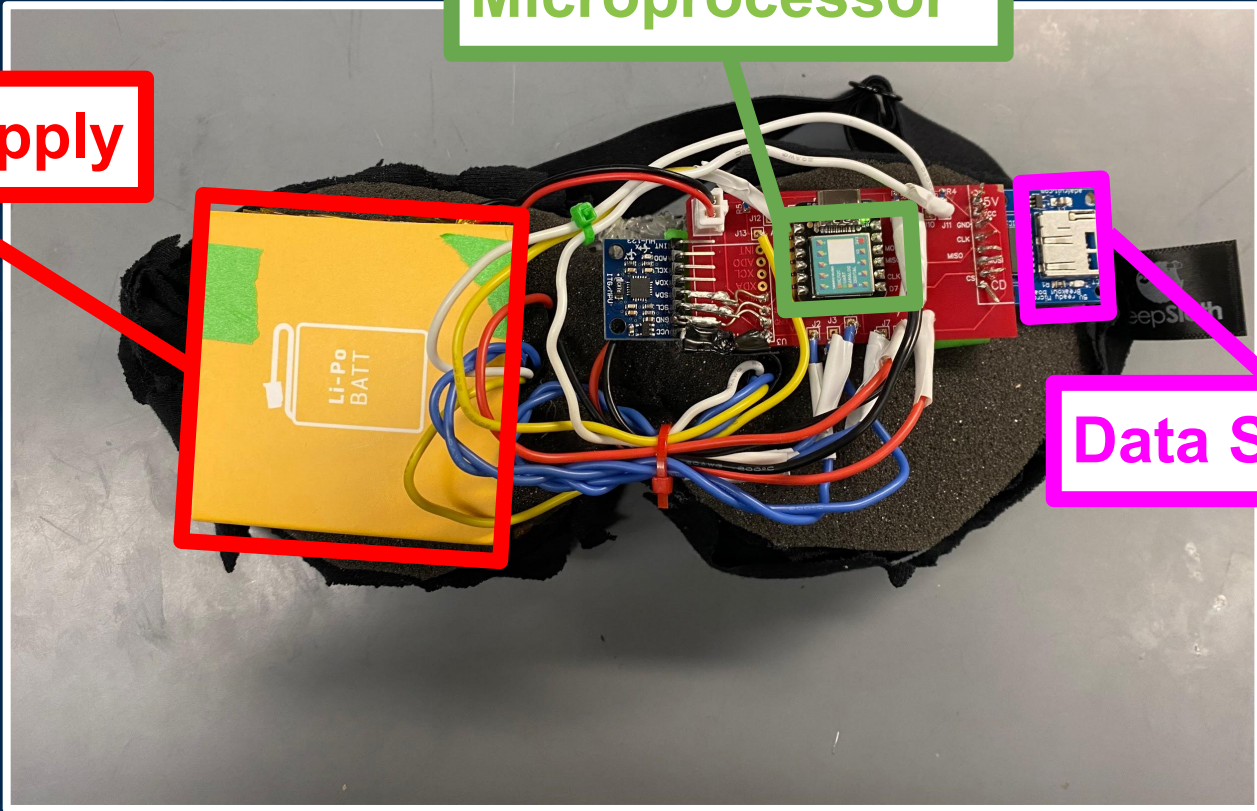


Microprocessor

Power Supply



Data Storage

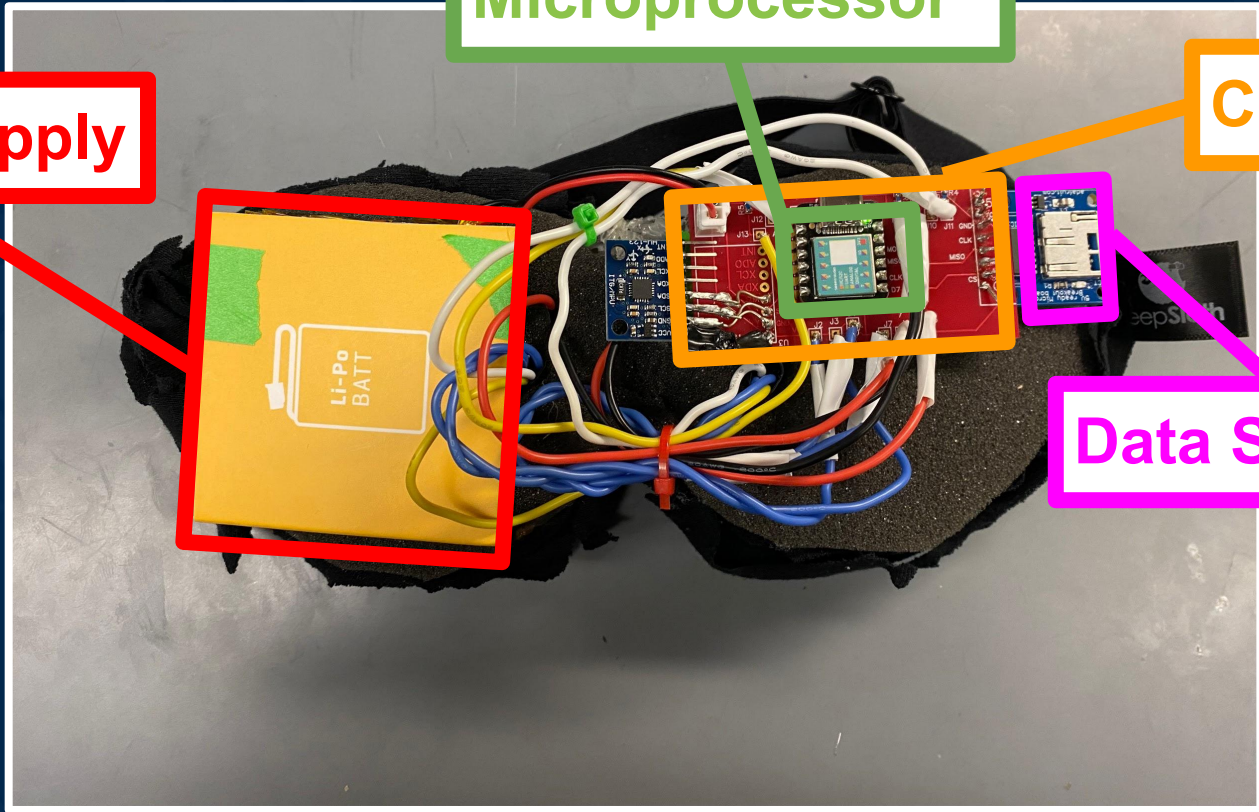


Microprocessor

Power Supply

Circuit

Data Storage

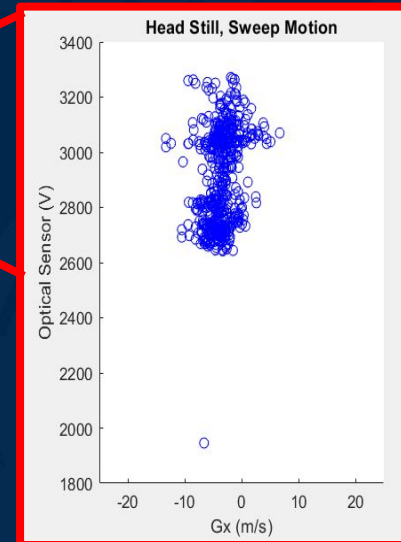
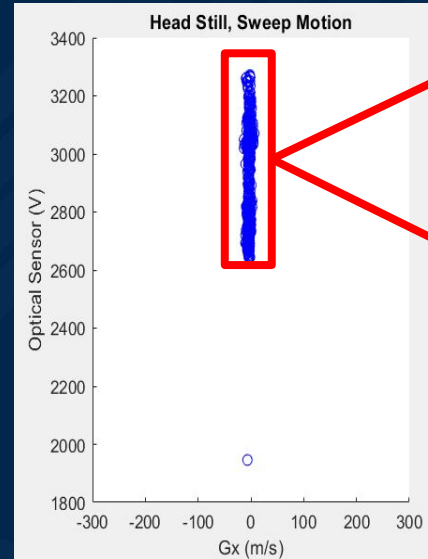
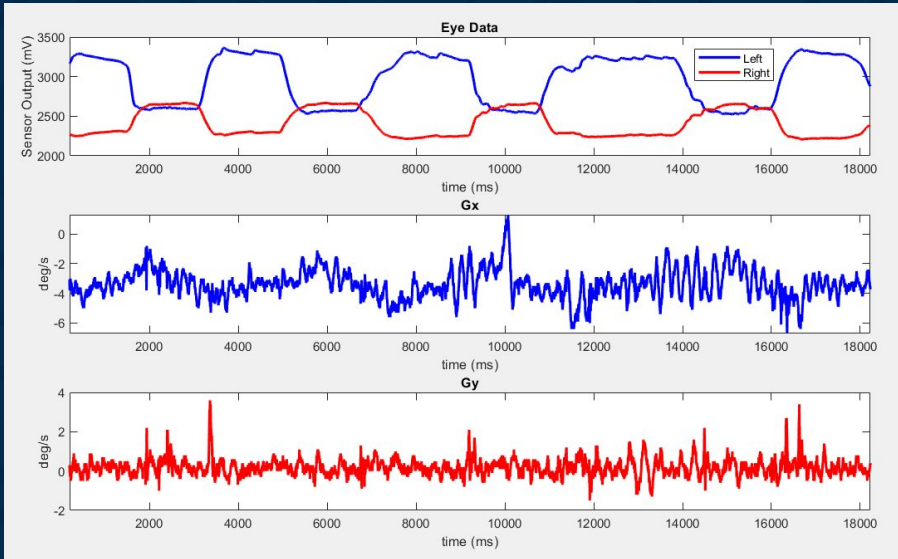




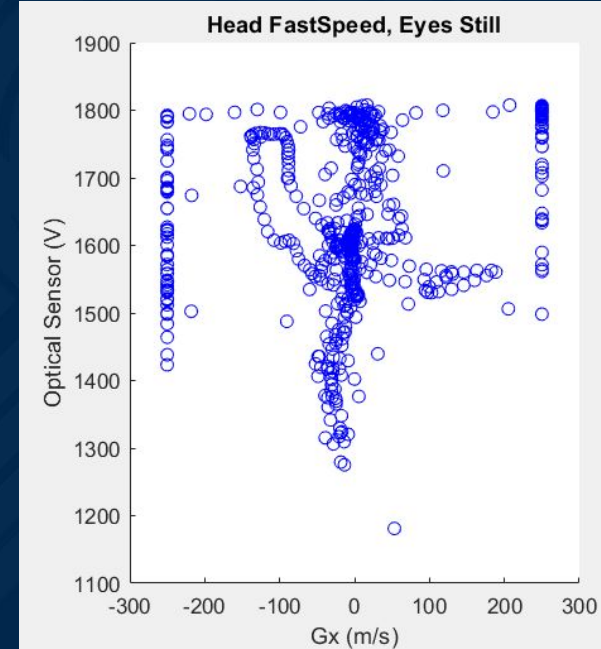
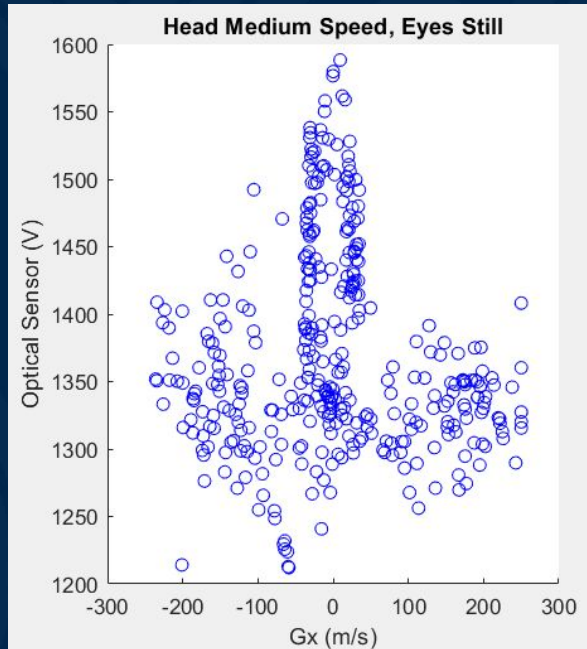
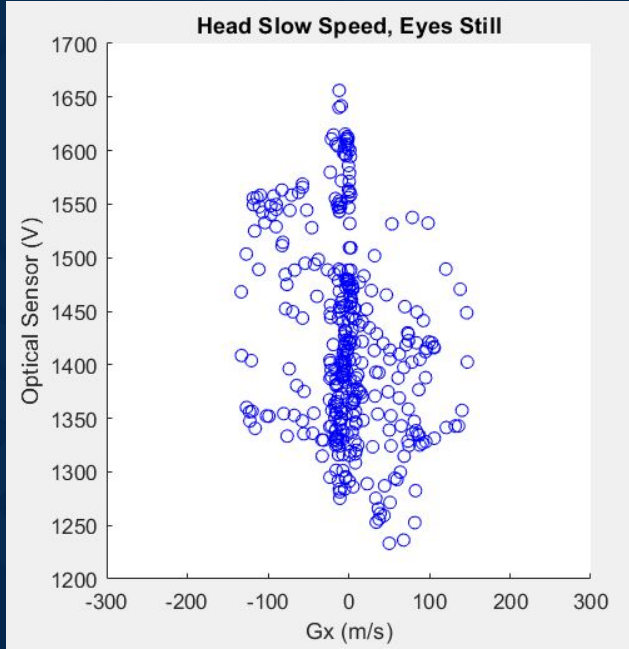
Results

Version 1 and Version 2 Prototype

Version 1: System Differentiated Head and Eye Movement



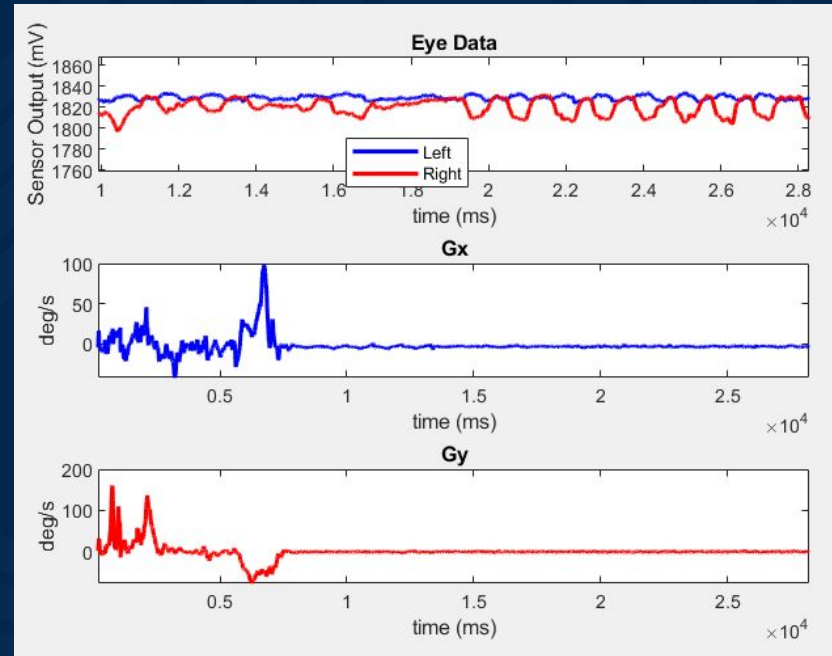
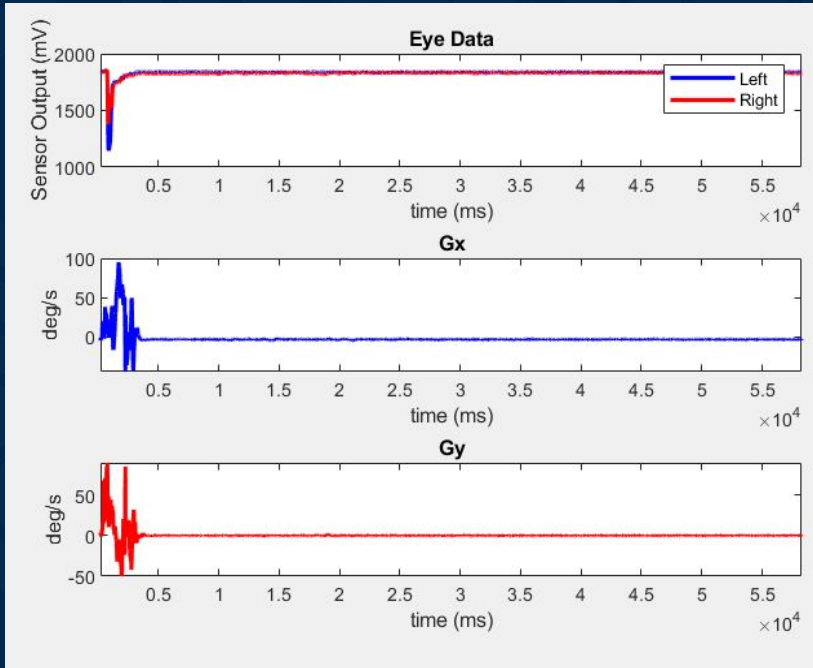
Speed of Head Rotation Can Impact Optical Change



Concern: Mask Fit Could Impact Detected Movement

Loose Mask

Tight Mask







Version 2: IMU communication not connected

- SD card collects optical sensor data perfectly fine on PCB, battery powered
- IMU communication is unrecognized by Seeeduino on PCB
 - IMU was recognized by Seeeduino on breadboard before soldering
 - Separate Seeeduino breadboard & IMU set up is now also unrecognized

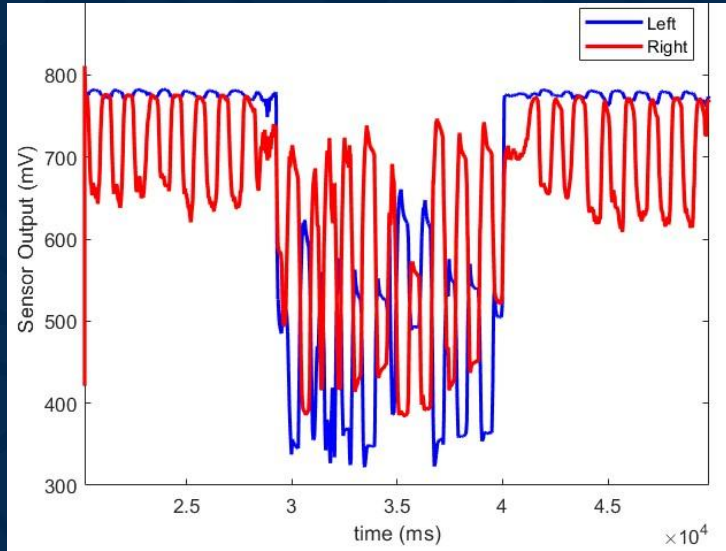
Most Likely Cause for IMU is software related

- Difference in MCU architectures has slight changes with interaction to Arduino IDE scripts
 - Version 1 Arduino is ATmega328P
 - Seeeduino XIAO uses SAMD21
- <Wire.h> library should work for SAMD21 but unclear if <MPU6050.h> sublibrary can work too
- Recommendation: rewrite IMU code without MPU6050 library

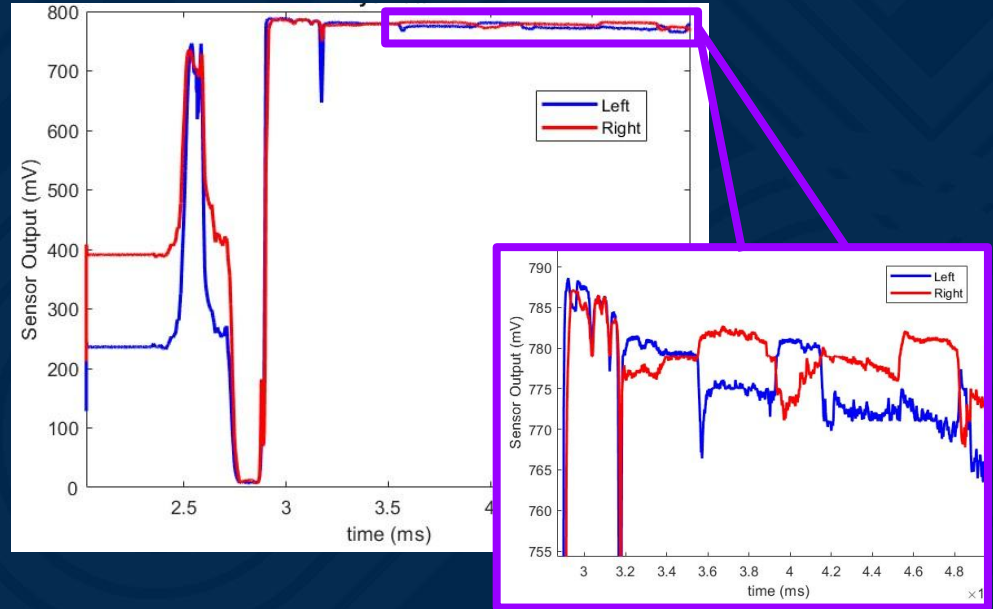
```
void setup() {  
  
  Wire.begin();  // initialize I2C bus (1  
  Serial.begin(19200);  
  delay(3000);  
  Serial.println("Starting");// initialize serial  
  // initialize MPU6050 sensor module  
  
  // Verify module connection  
  Wire.beginTransmission(0x68);  
  Serial.print("MPU6050 module connection ");  
  mpu6050.initialize();   
  Serial.println(mpu6050.testConnection() ? "suc
```

Version 2: Sweep and Static Eye Motion Detected

Sweep



Static

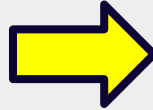




Conclusions

Device is comfortable during use

- Device operates without cords
- All hardware is on the eye mask



Future Work

Improve form factor security

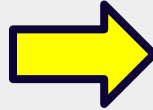
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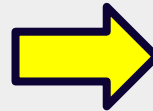
- Device operates without cords
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Device must measure the duration of continuous eye movement

- Device can supply power between 5.5-10 hours



Improve form factor security



Report data collection in UTC time

Future Work

Conclusions

Device is comfortable during use

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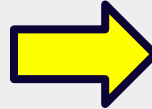
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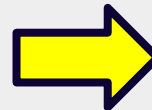
System must differentiate head from eye movement

- IMU currently uncommunicative

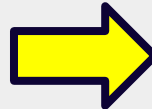
Future Work



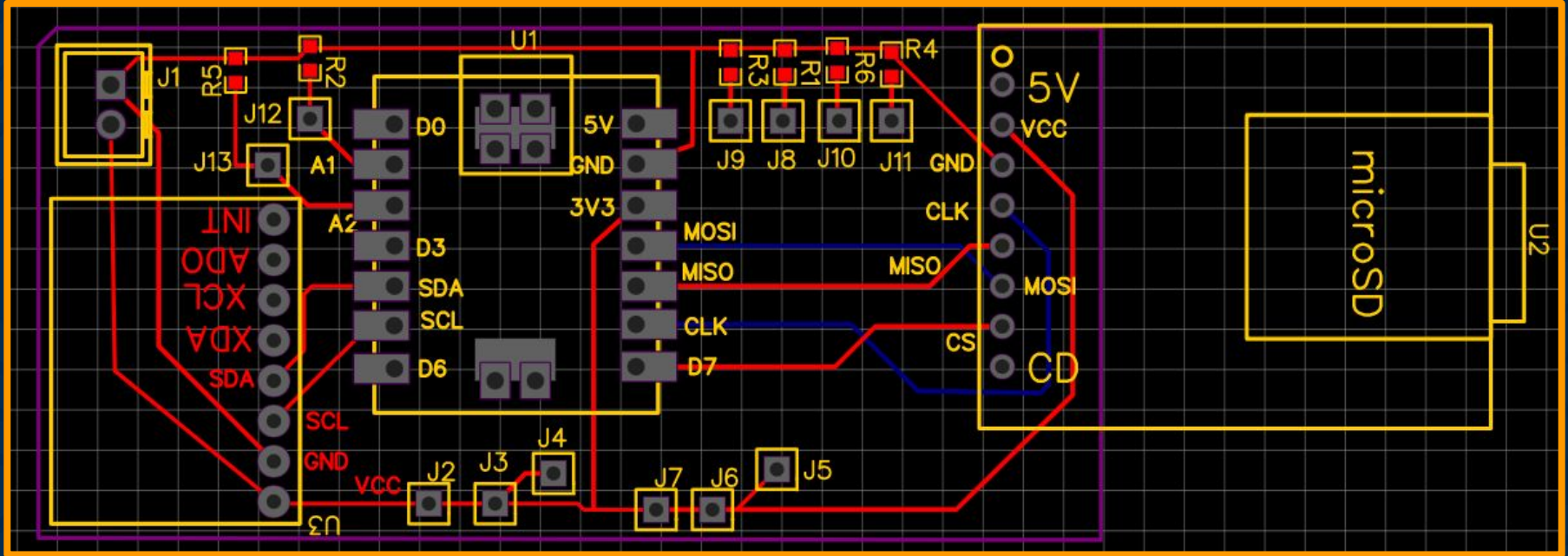
Improve form factor security



Report data collection in UTC time



Rewrite IMU code



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