UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

Smart Insole

Group 41

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April 30, 2024

Background

Problem: Hikers have no way to track advanced analytics about their hike.

Current Alternatives:

- Ski boot analytics devices
- Gait trackers (industrial and $$$)
- Nothing hiking related

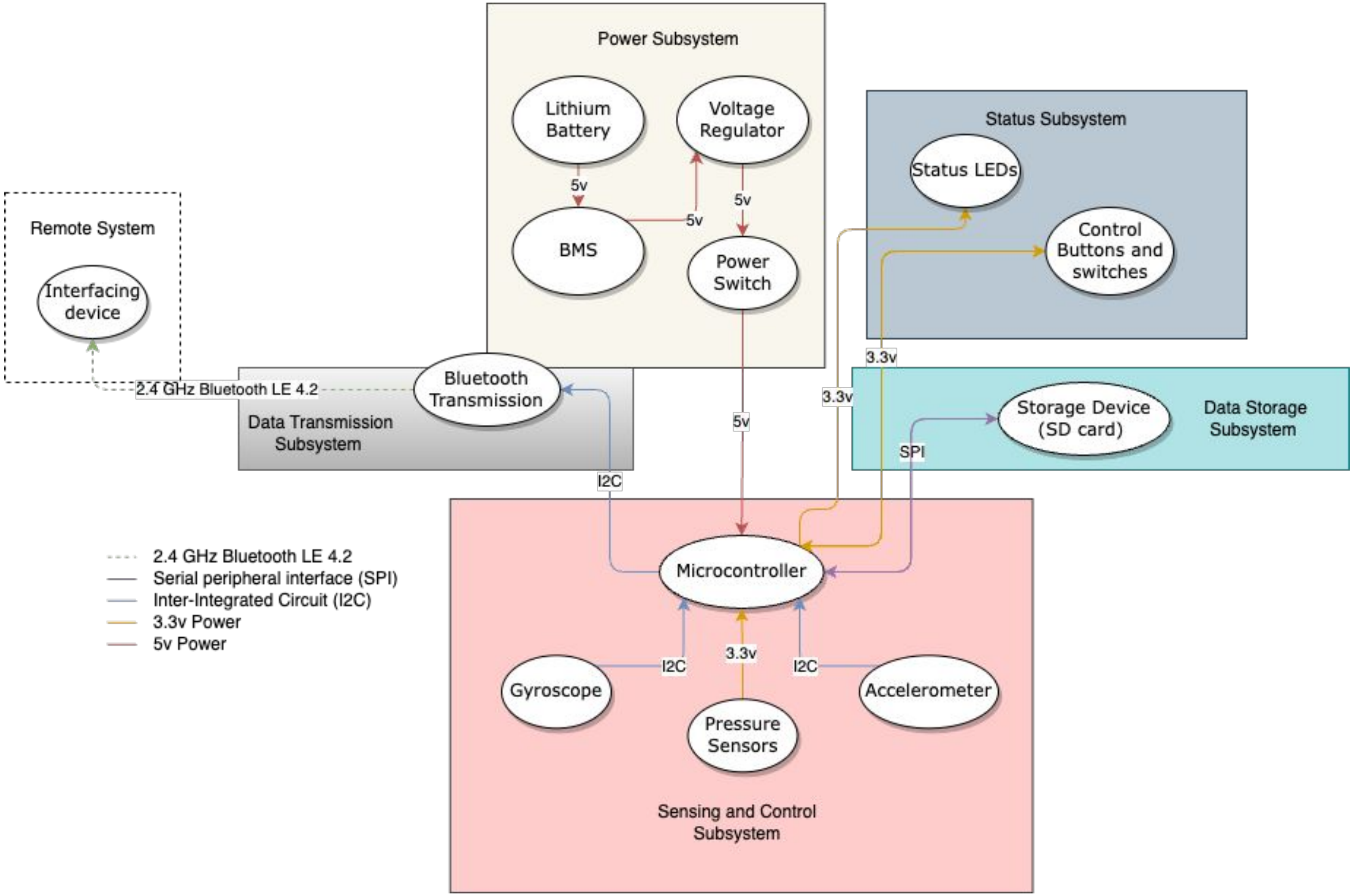
High Level Requirements

1. **Accurate Analytics**: Track granular pressure changes and extract valuable inertial movement information. Each pressure area < 3 inches squared and sensor readings to be within 10%.

2. **Accurate and Intuitive Data Integration**: Allow users to easily track their stats in the medium that they choose, either in real time or via upload after the hike. Latency less than 0.5 seconds.

3. **Wearable/Modular Physical Implementation**: Easy to implement into existing hiking regiment for all types of hikers, should not detract from the nature experience or physically constrain the hiker at all. 100% range of motion.

Block Diagram



Block Diagram for our Smart Insole Device

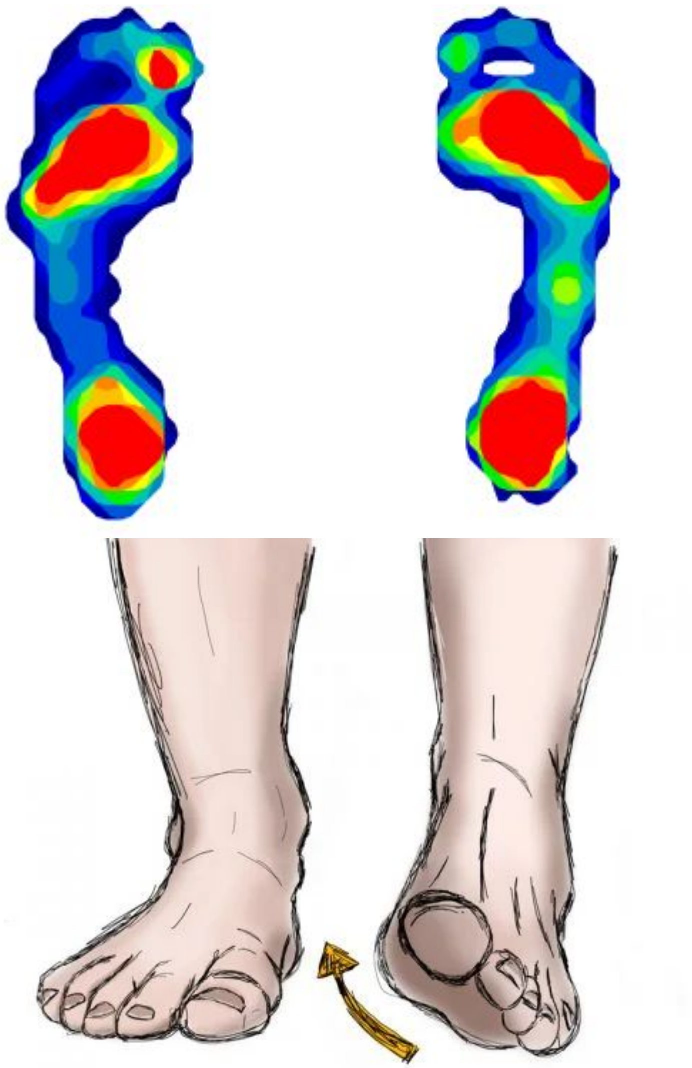
Requirements and Verification Per Subsystem (Demo)

1. Remote Interface: SATISFIED
2. Data Transmission: SATISFIED
3. Data Storage: SATISFIED
4. Sensing: SATISFIED (only partially on PCB)
5. Status: SATISFIED
6. Power Delivery: SATISFIED

Plan:

1. Demonstrate working sensors on PCB
2. Demonstrate remaining working sensors on breadboard

Design Changes



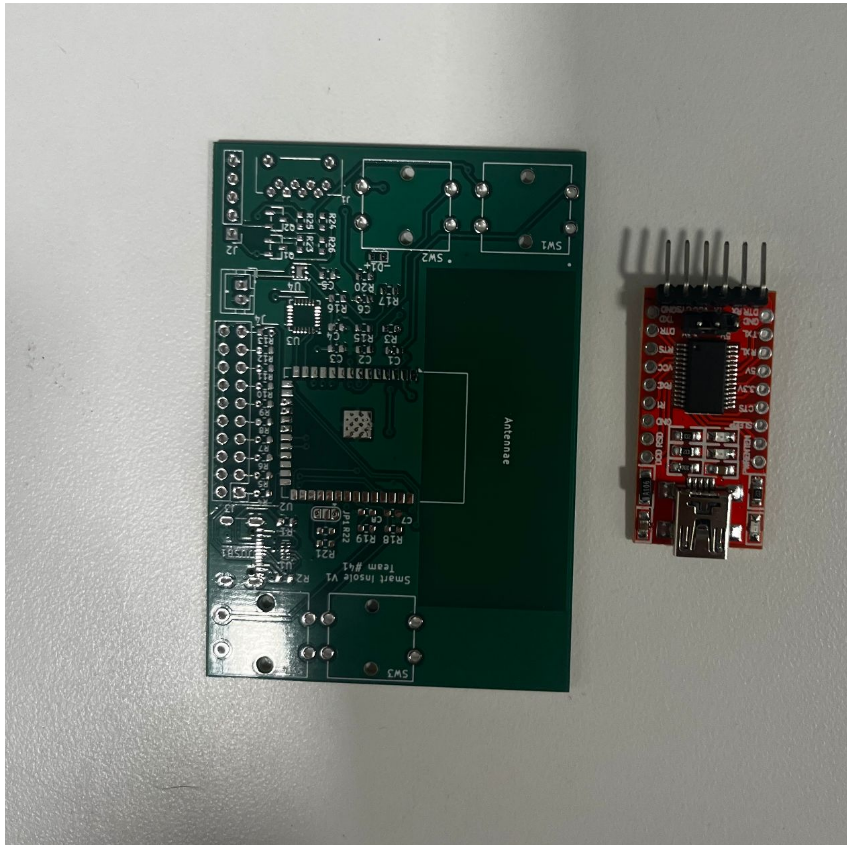
Pressure

wanted to track where users exert the most pressure on their foot

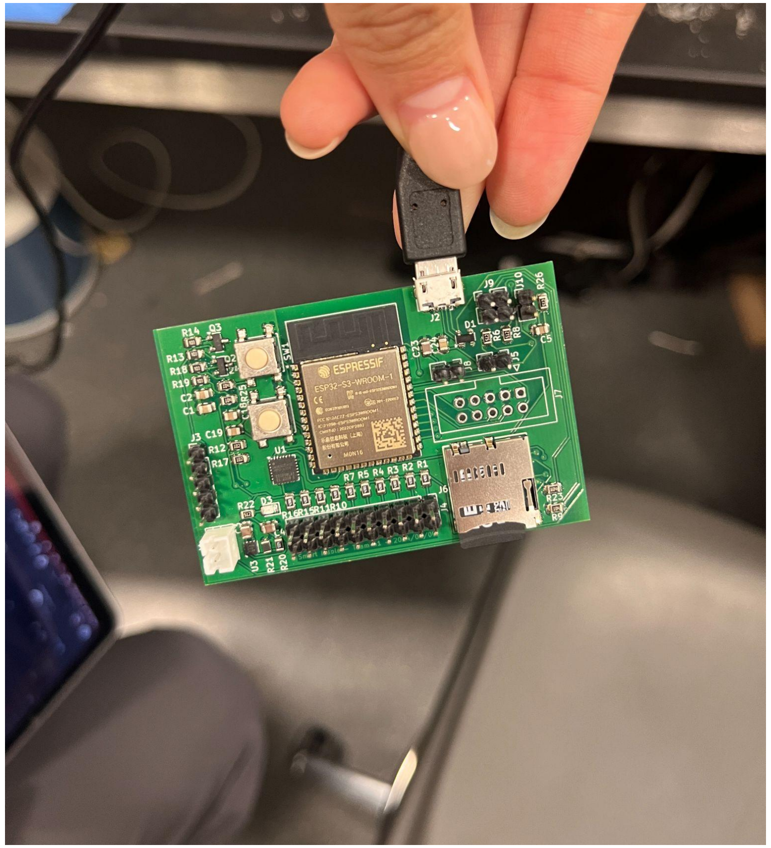
Movement + Orientation

Wanted to design our device to track users movements and orientation

Design Changes

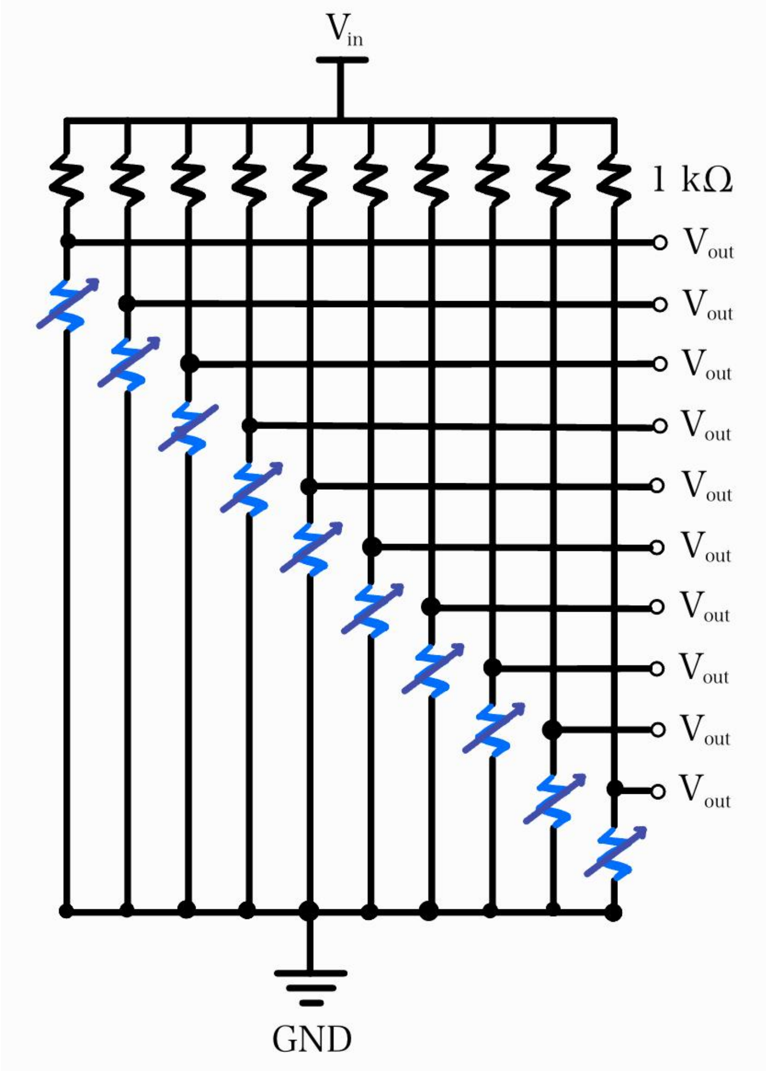


~ 8 cm x 5 cm



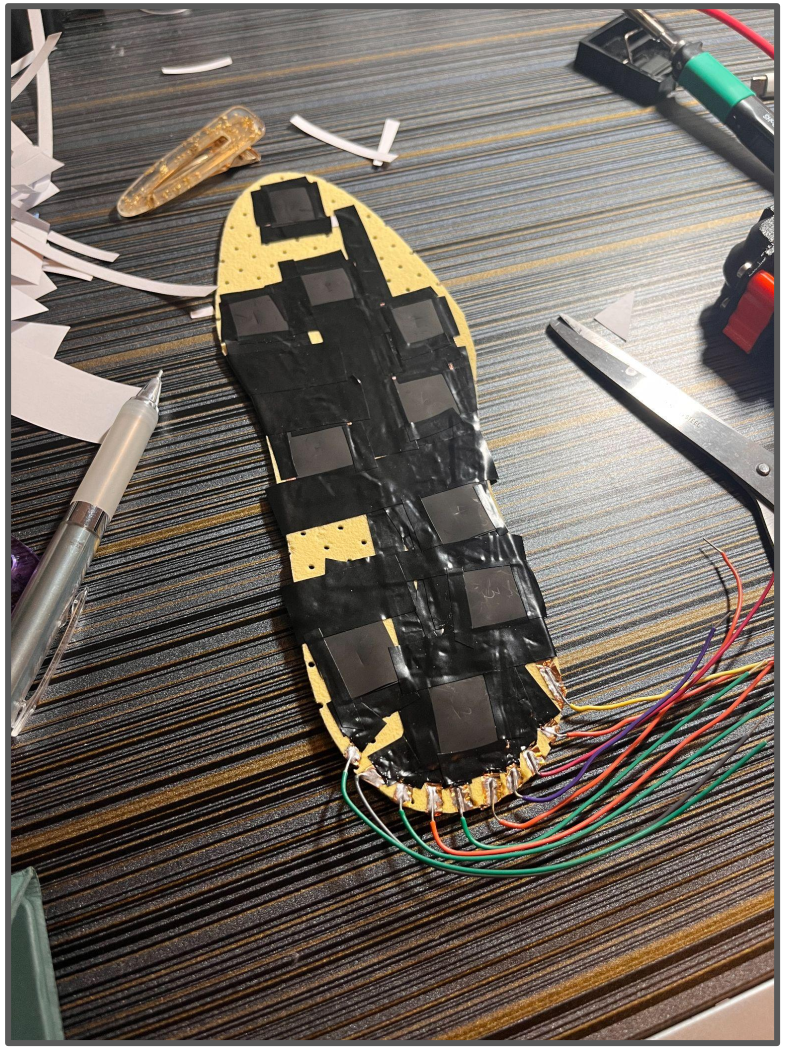
~ 6 cm x 4 cm

Insole design

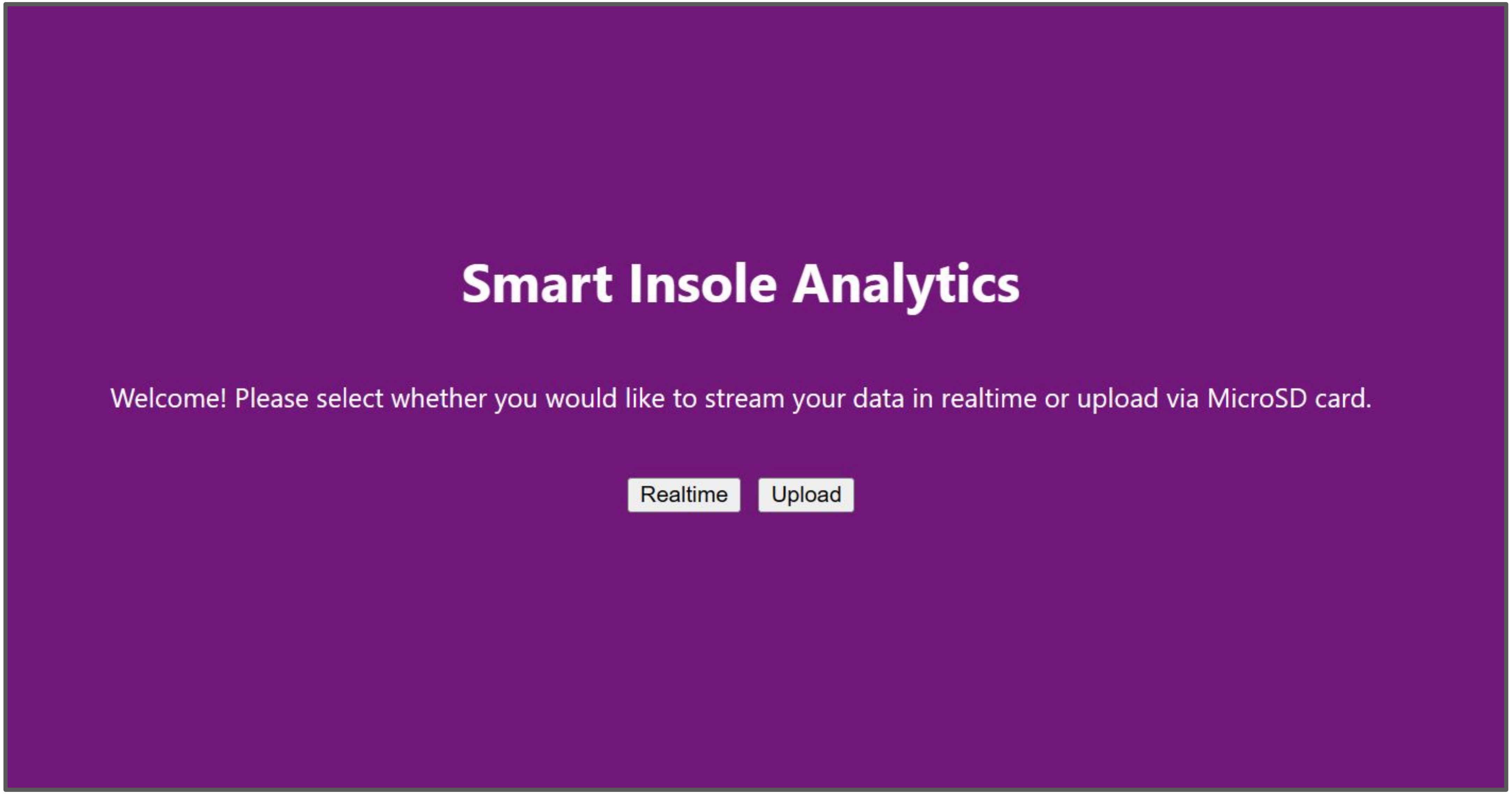


- The insole uses pressure-sensitive material called velostat, which increases resistance when pressure is applied
- Using a simple voltage divider circuit, we can pair voltage across the velostat with different pressures applied

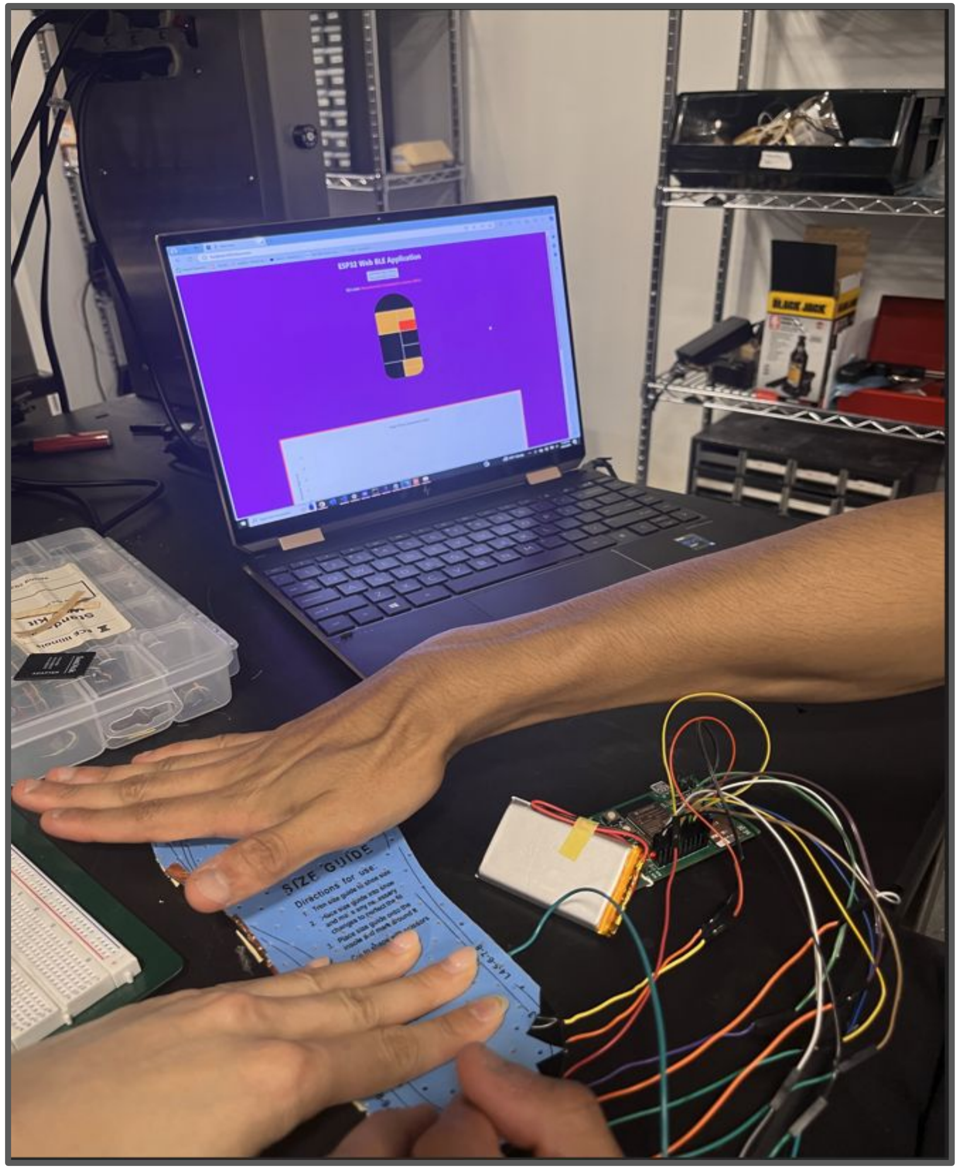
Insole design

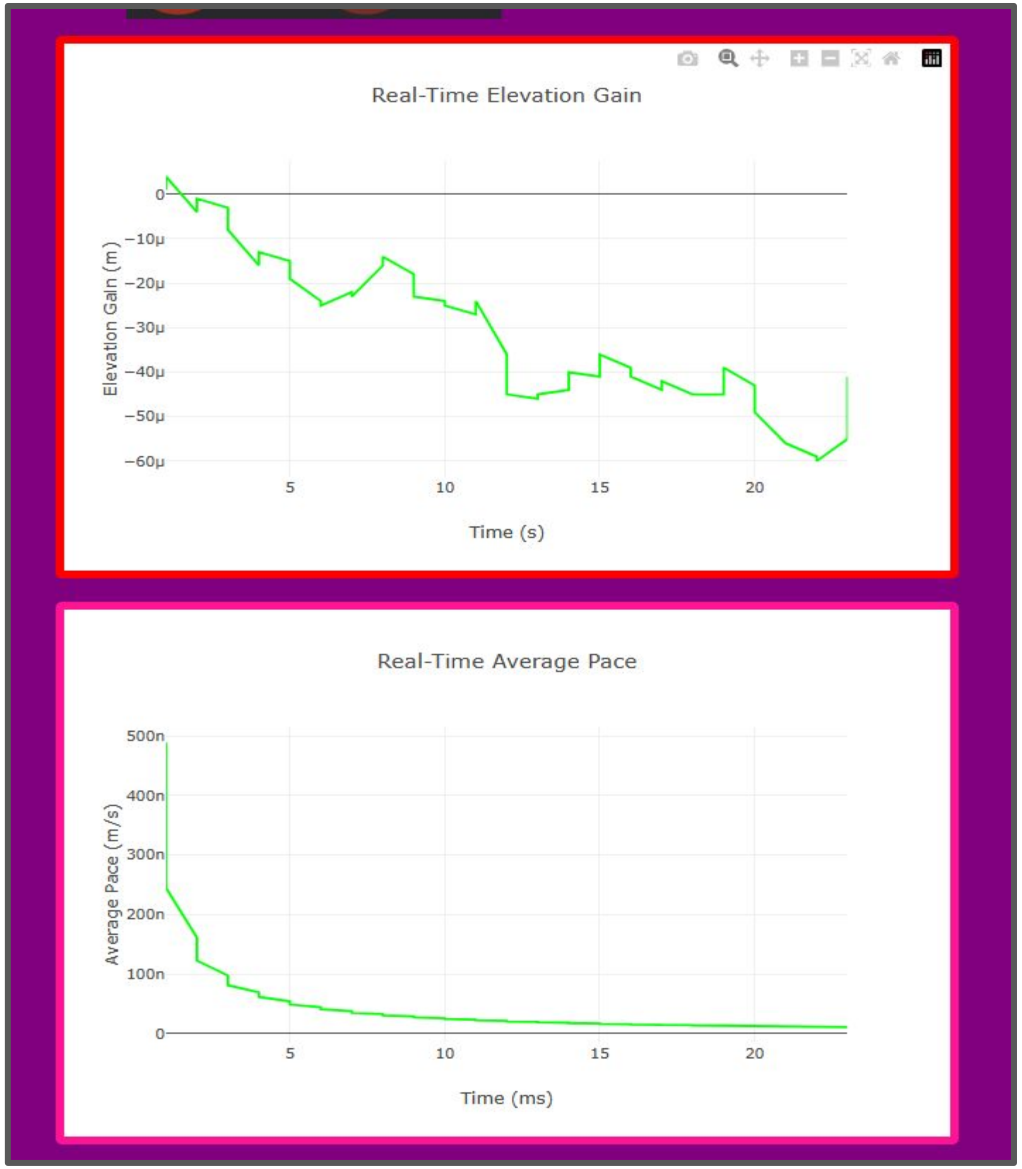


Web Interface



Web Interface: Real Time





Web Interface: Upload

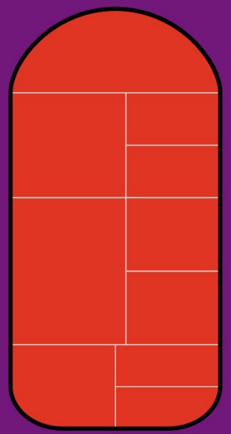
Averages:

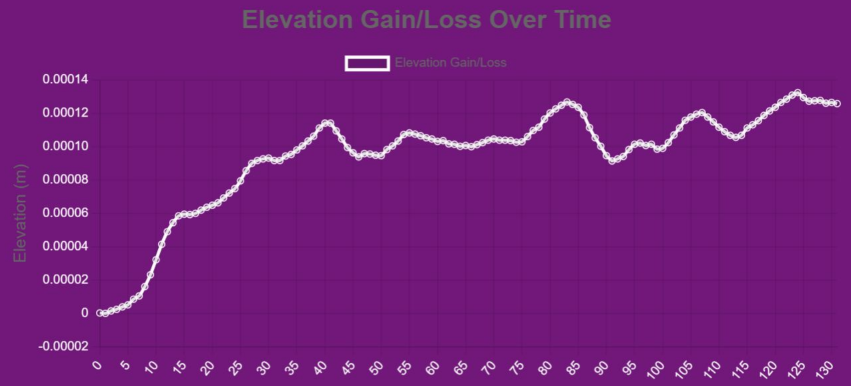
Accelerometer: -0.619, -0.220, 9.477

Gyroscope: -0.041, 0.020, -0.027

Pressure Sensor: 0.000, 0.000, 0.000, 0.000, 0.000, 0.000, 0.000, 0.000, 0.000, 1.125

Average Pressure Sensor Distribution on Foot



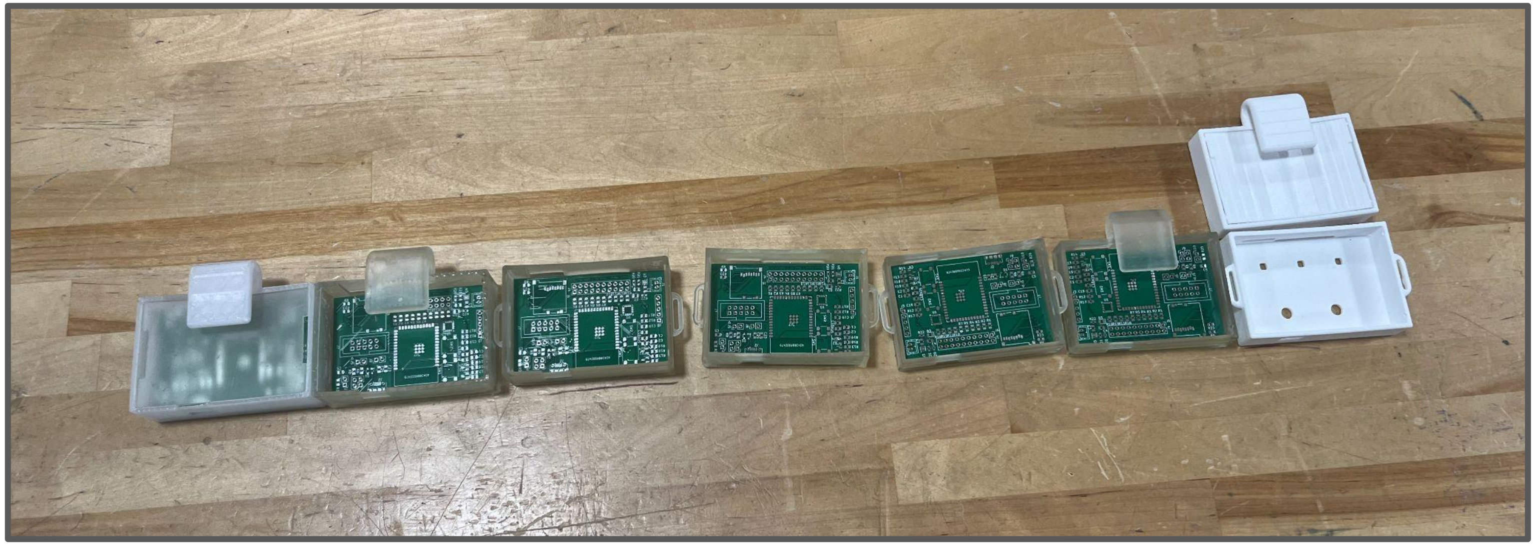


Accelerometer: -0.619, -0.220, 9.477

Gyroscope: -0.041, 0.020, -0.027

Pressure Sensor: 0.000, 0.000, 0.000, 0.000, 0.000, 0.000, 0.000, 0.000, 0.000, 1.125

Wearable/Modular Design



Demo: Putting it all together

DEMO VIDEO

Requirements and Verification: Data Transmission Subsystem – SATISFIED

- Data can be transmitted to another device - SATISFIED
  - Microcontroller -> Web App
- Information not lost when transferring from sensor -> microcontroller -> bluetooth - SATISFIED
  - Currently polled at 64Hz and all data is captured in SD card and an averaged value is sent over BLE.

Requirements and Verification: Power Subsystem

- Consistent power delivery - SATISFIED
  - 3.3v + or - 3%
- Rechargeability - SATISFIED
  - Lipo can be charged with Lipo charger
- Last all hike - SATISFIED
  - 5 hours

Requirements and Verification: Status Subsystem

- Users can tell status of device - SATISFIED
    - Two LEDs, one to indicate bluetooth connection, and another to indicate whether data is being recorded
- Start and end hike button - SATISFIED

Requirements and Verification: Remote Interface Subsystem

- Receive data transmitted from data transmission subsystem - SATISFIED
- Display data to users - SATISFIED
- Low latency - SATISFIED
    - Sent within milliseconds. Set to 64Hz – 0.015 seconds.

Requirements and Verification: Data Storage Subsystem

- Data can be stored on device - SATISFIED
  - Micro SD card
- Data can be read off device - SATISFIED
  - Micro SD card
- Data storage is large enough to store multiple full hikes - SATISFIED
  - 16gb

Requirements and Verification: Sensing Subsystem

- Accelerometer can track velocity and acceleration - SATISFIED
- Pressure sensors can track pressure in relation to each other accurately - SATISFIED
- Gyroscope can track direction - SATISFIED
- Processing delay can keep up with sensor read rate - SATISFIED

Accelerometer: -0.619, -0.220, 9.477

Gyroscope: -0.041, 0.020, -0.027

Pressure Sensor: 0.000, 0.000, 0.000, 0.000, 0.000, 0.000, 0.000, 0.000, 0.000, 1.125

Max Ambient Temperature

Calculation for max ambient temperature our device can be in

$$TA(MAX) = 125°C – 80.3°C/W × (5\ V – 3.3\ V) × (0.25\ A) = 90.87°C$$

$$TA(MAX) = 125°C – 80.3°C/W × (5\ V – 3.3\ V) × (0.5\ A) = 56.74°C$$

$$TA(MAX) = 125°C – 80.3°C/W × (5\ V – 3.3\ V) × (0.6\ A) = 43.09°C$$

Max Time On Battery Power

Calculation for max time on battery power with 2000 mAh battery

- Gyro + SD not measured with PCB but with breadboard
  - Gyro: 1.73v over 1k ohm - .0017 A
  - SD : 0.159v over 1k ohm - 0.000159 A

PCB Power Draw - 400mA → 2000mAh / 400mA = ~5 hours

Ethics

Privacy

- Clear user interface + LEDs indicate when the device is recording data
- Physical buttons to control when and if data is recoding
- comply with the IEEE standards on data privacy

Data

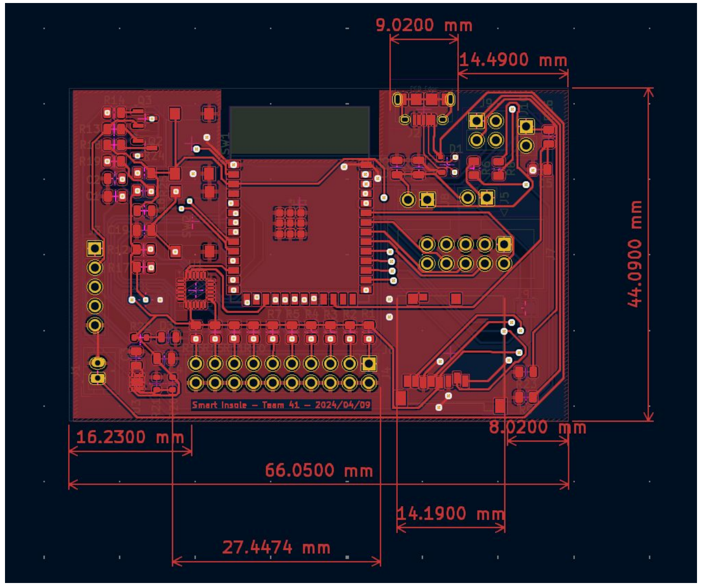
- Data not tracked when device not in operation
- no location tracking with our device as gyroscope is relative to foot.
- Compliant with the IEEE standards on wearable electronics

```
New sensor data notified to BLE client.
New sensor data notified to BLE client.
Starting the hike!
1
Time Elapsed (SD Write): 64750 milliseconds
New sensor data notified to BLE client.
Time Elapsed (SD Write): 125 milliseconds
```

IEEE Privacy Policy." IEEE, www.ieee.org/security-privacy.html.

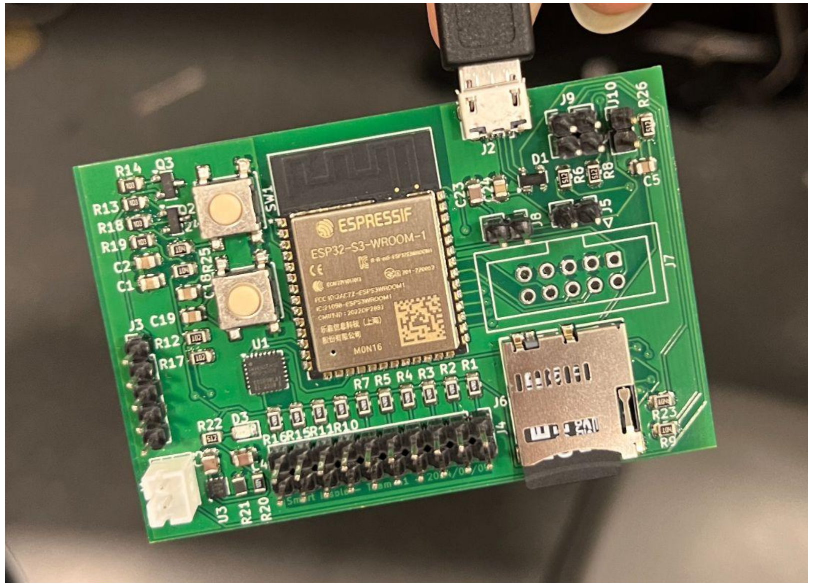
Capabilities

- Can upload programs to the ESP-32 and run them accordingly
- Connected our pressure sensors to the PCB and updated our heat map accordingly over Bluetooth on the webapp

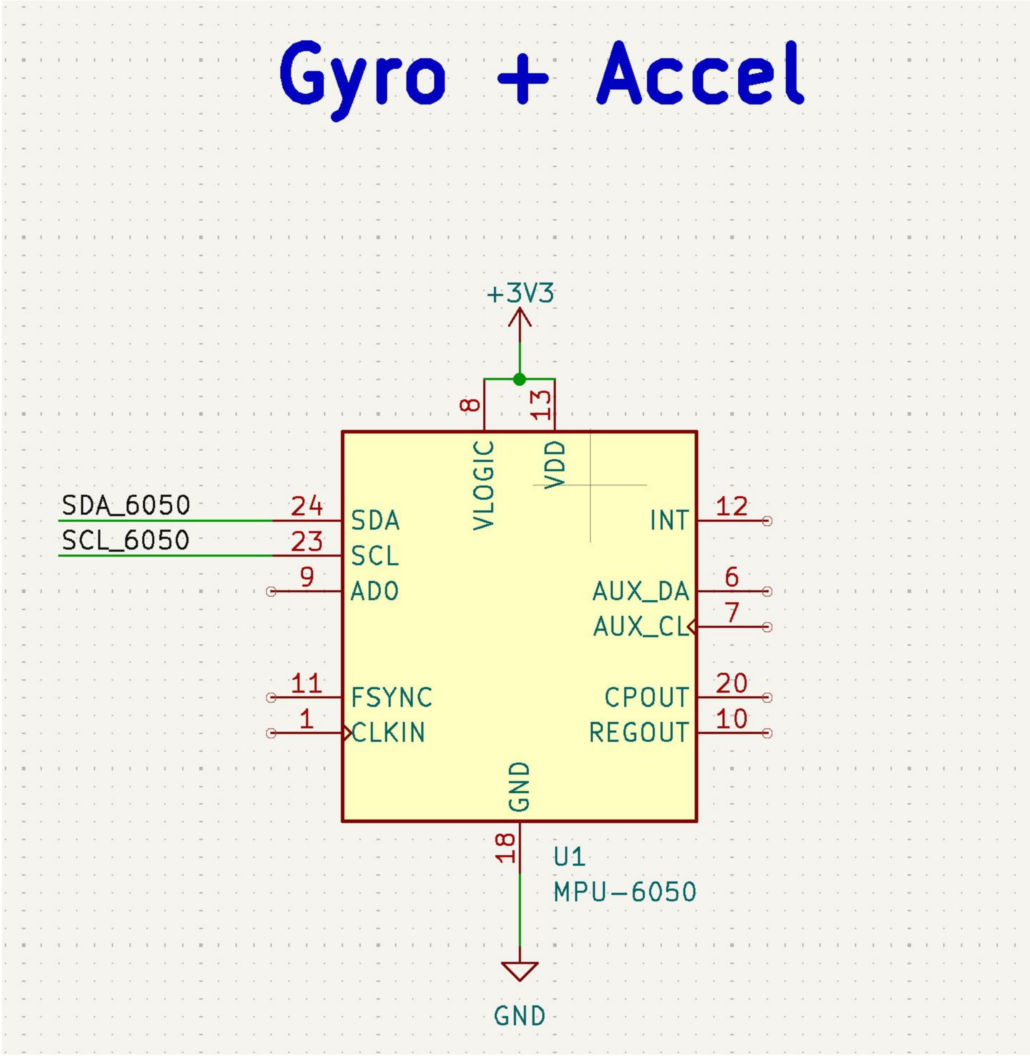


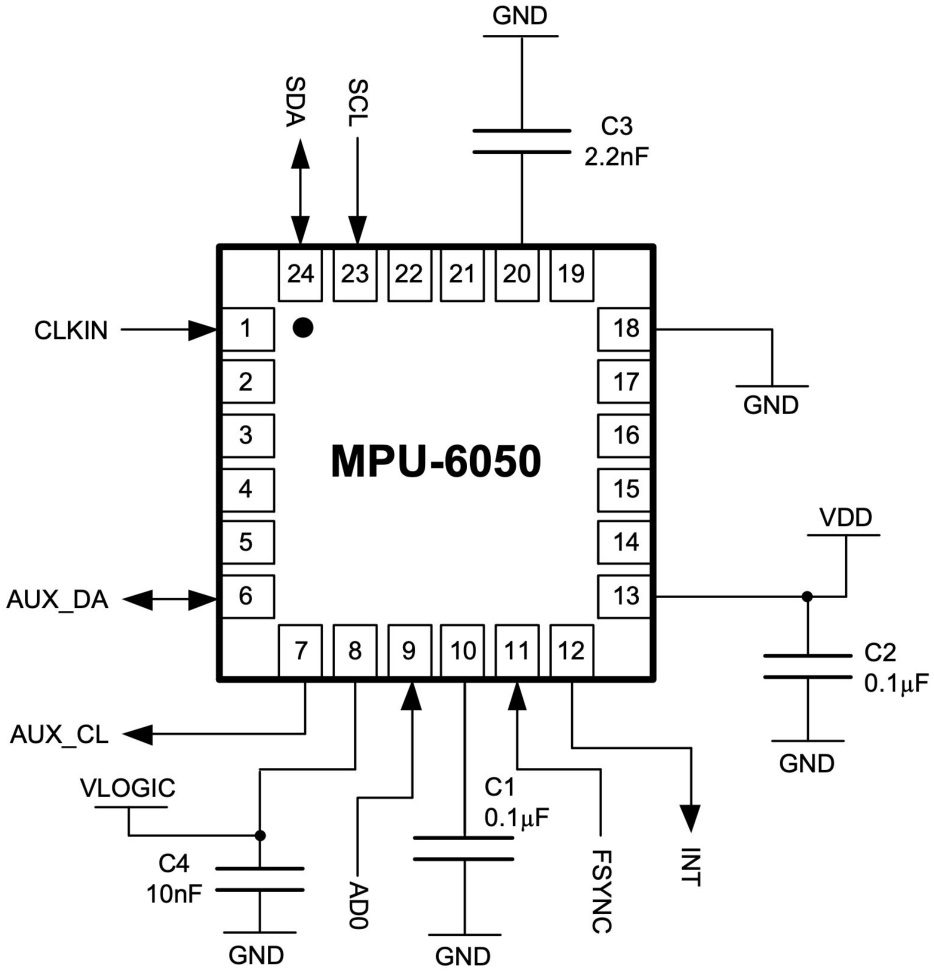
Errors

- The MPU6050 accelerometer required more connections than previously intended
- The microSD card connections were mistaken for SD card connections
- Diagrams for both next



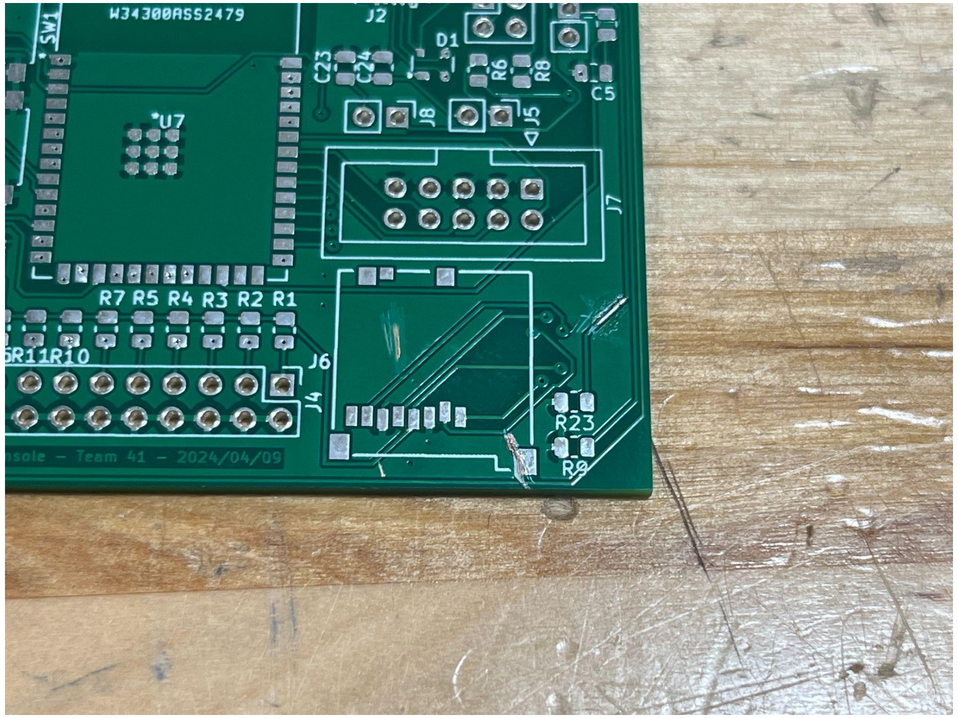
MPU PCB Error

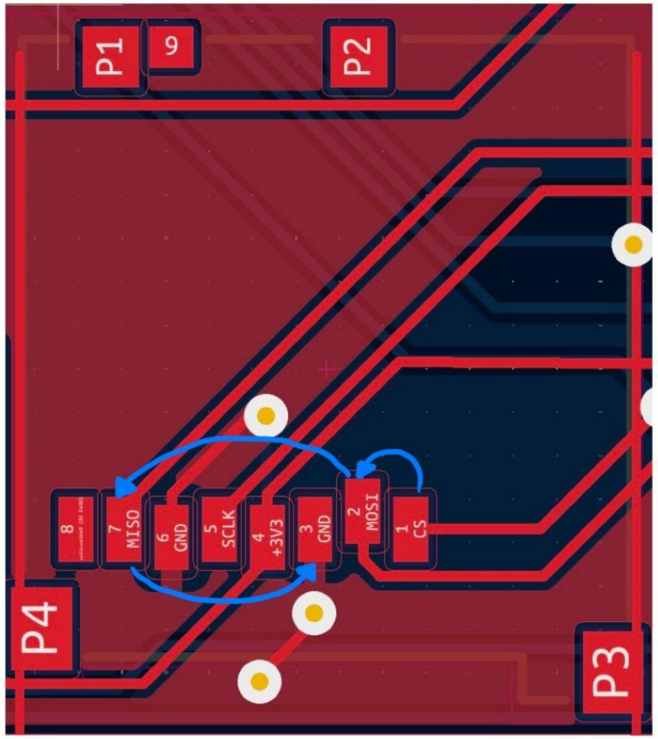


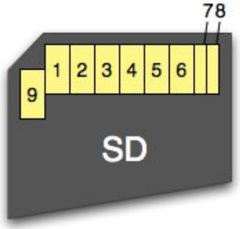


SD Card Read PCB Error

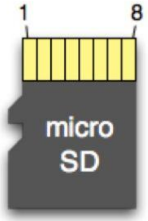
Connected our pins on the PCB according to a SD card schematic and not a micro SD card







Pin	SD	SPI
1	CD/DAT3	CS
2	CMD	DI
3	VSS1	VSS1
4	VDD	VDD
5	CLK	SCLK
6	VSS2	VSS2
7	DAT0	DO
8	DAT1	X
9	DAT2	X



Pin	SD	SPI	
1	DAT2	X	
2	CD/DAT3	CS	
3	CMD	DI	= MISO
4	VDD	VDD	
5	CLK	SCLK	
6	VSS	VSS	
7	DAT0	DO	= MOSI
8	DAT1	X	

What We Learned

- Work with the ESP32 Chip
- How to design a PCB and get it ordered
- Work with the Arduino IDE and code in C++
- Code with the React framework
- Data manipulation

Recommendations for further work

- Fix PCB design
  - Fix SD card connections
  - Fix IMU connections
- Solder on wires instead of using pin headers to allow PCB to fit in enclosure
- Allow for users to turn on and off bluetooth capabilities
- Add more useful charts for users to visualize data

Overall

- Fully and successfully built on a breadboard. **100% functionality on a breadboard**
- Know exactly what went wrong with the PCB and given another order/extra time without order delay we could get the last two working. **80% functionality on PCB.**

THANK YOU!

The Grainger College of Engineering

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(Keep this text simple and short on one or two lines.)

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