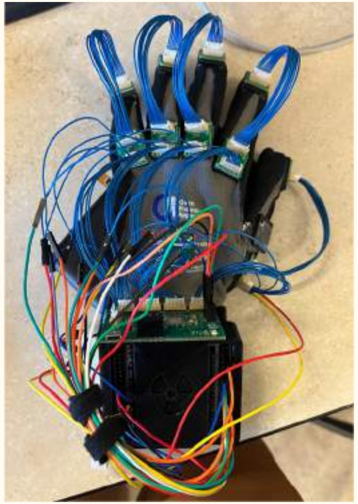
Chirality: Smart Glove

The Problem



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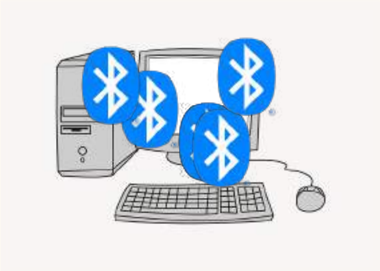
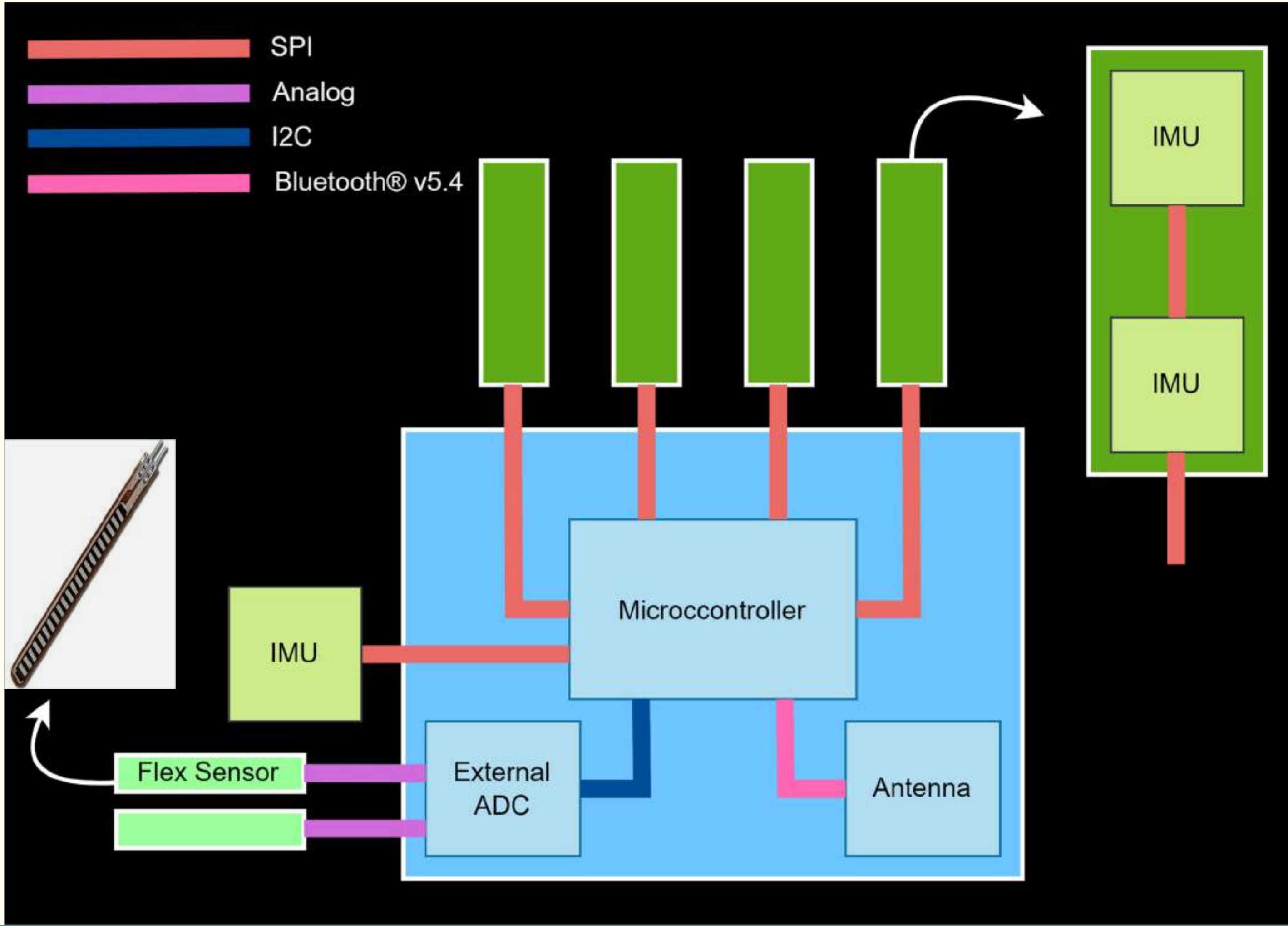
Possible Applications

Behavioral Spec

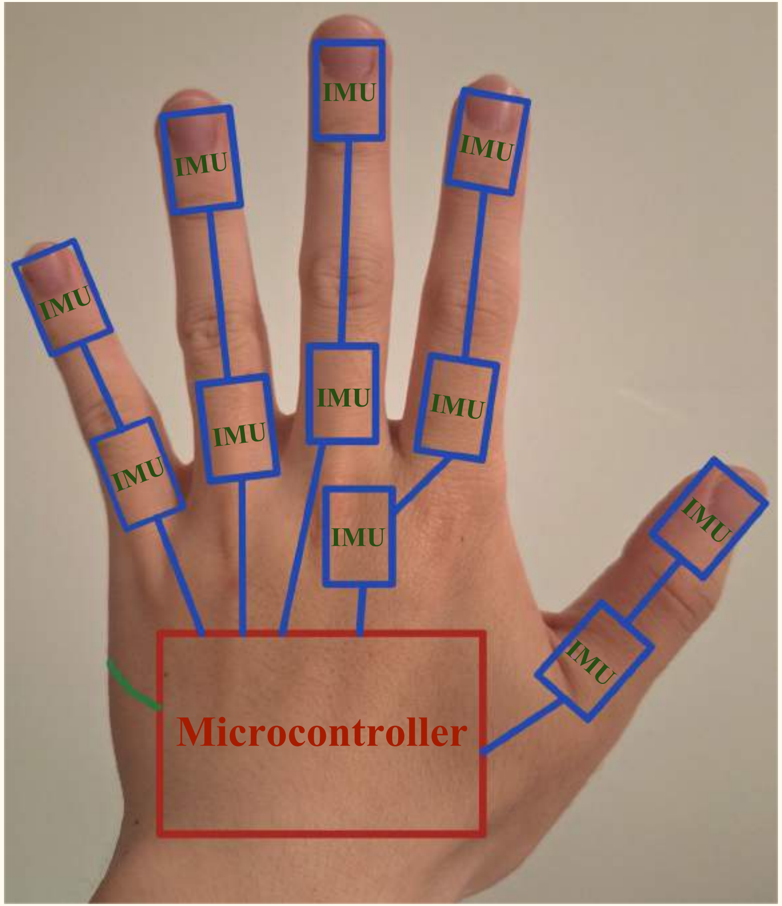
- Measure rotational position of each finger within 1° of error
- Communicate this data at high frequency via Bluetooth



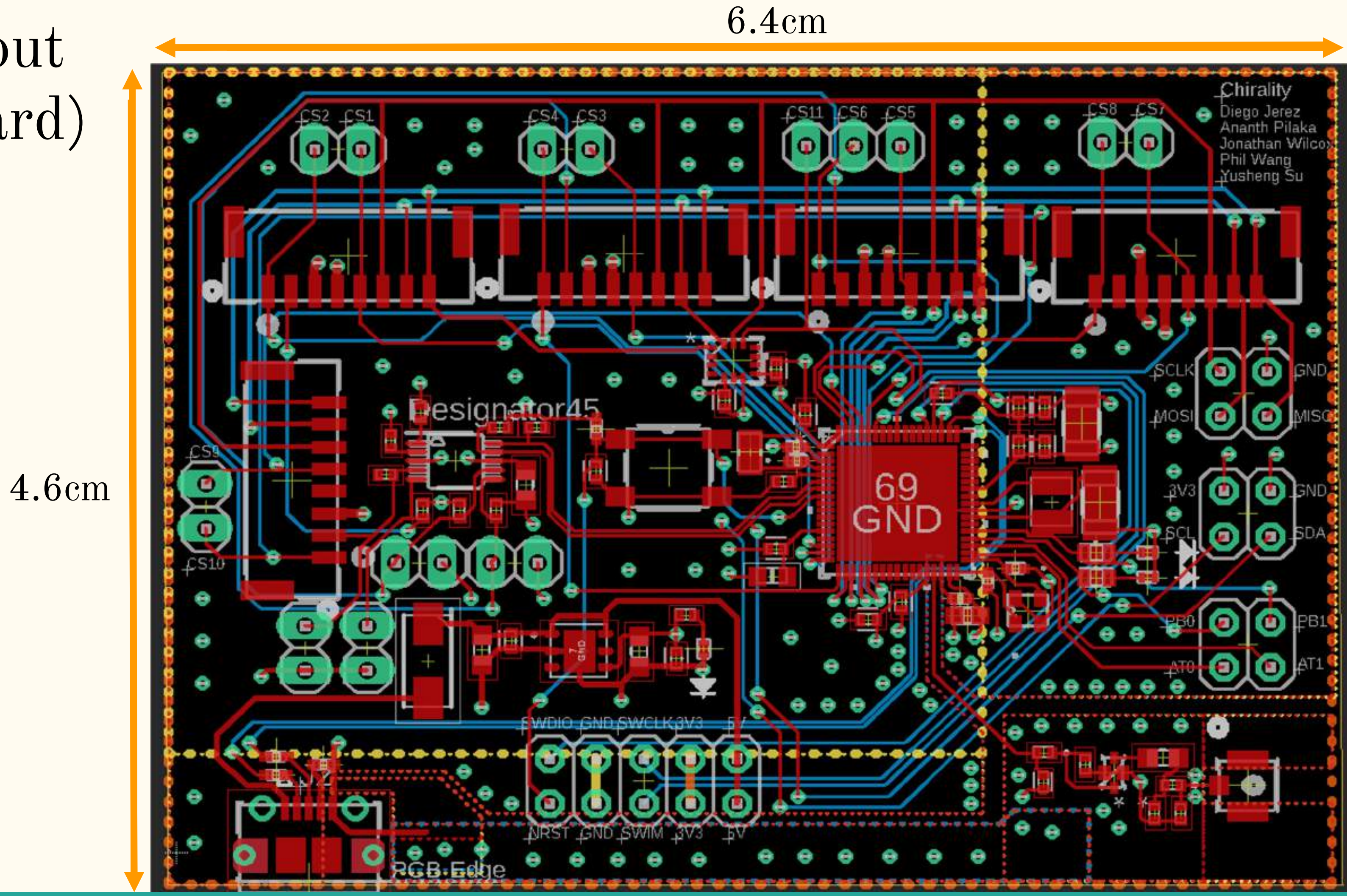
Block Diagram



Parts on Hand



PCB Layout (Main Board)



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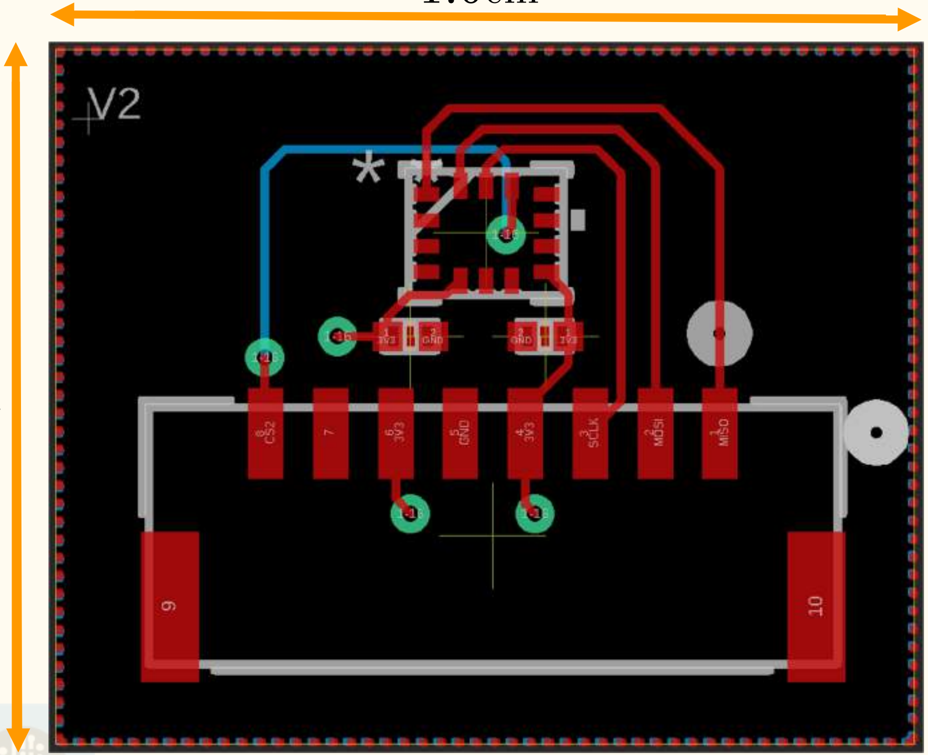
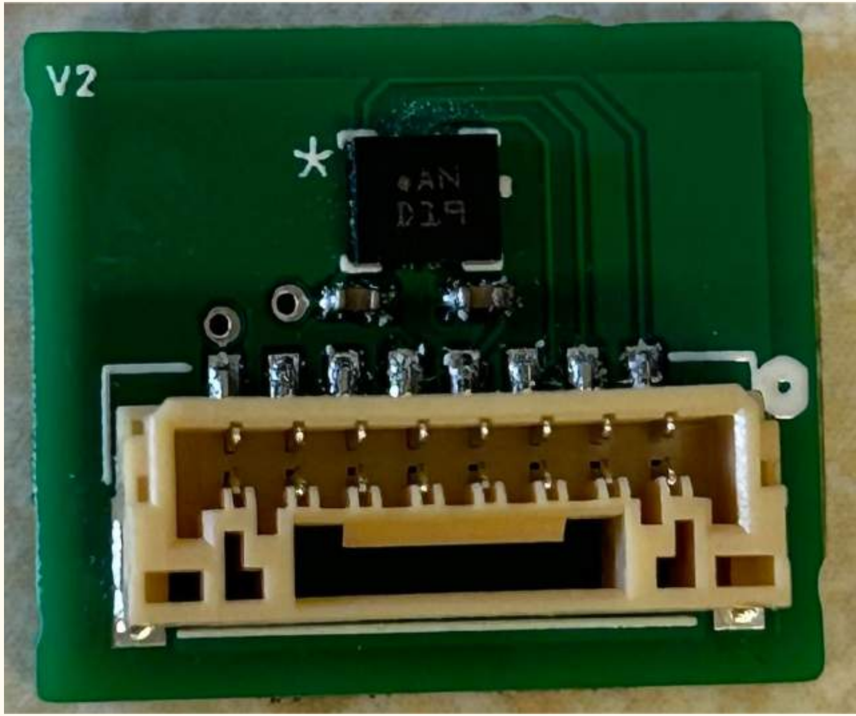
PCB Layout (IMU_TIP)

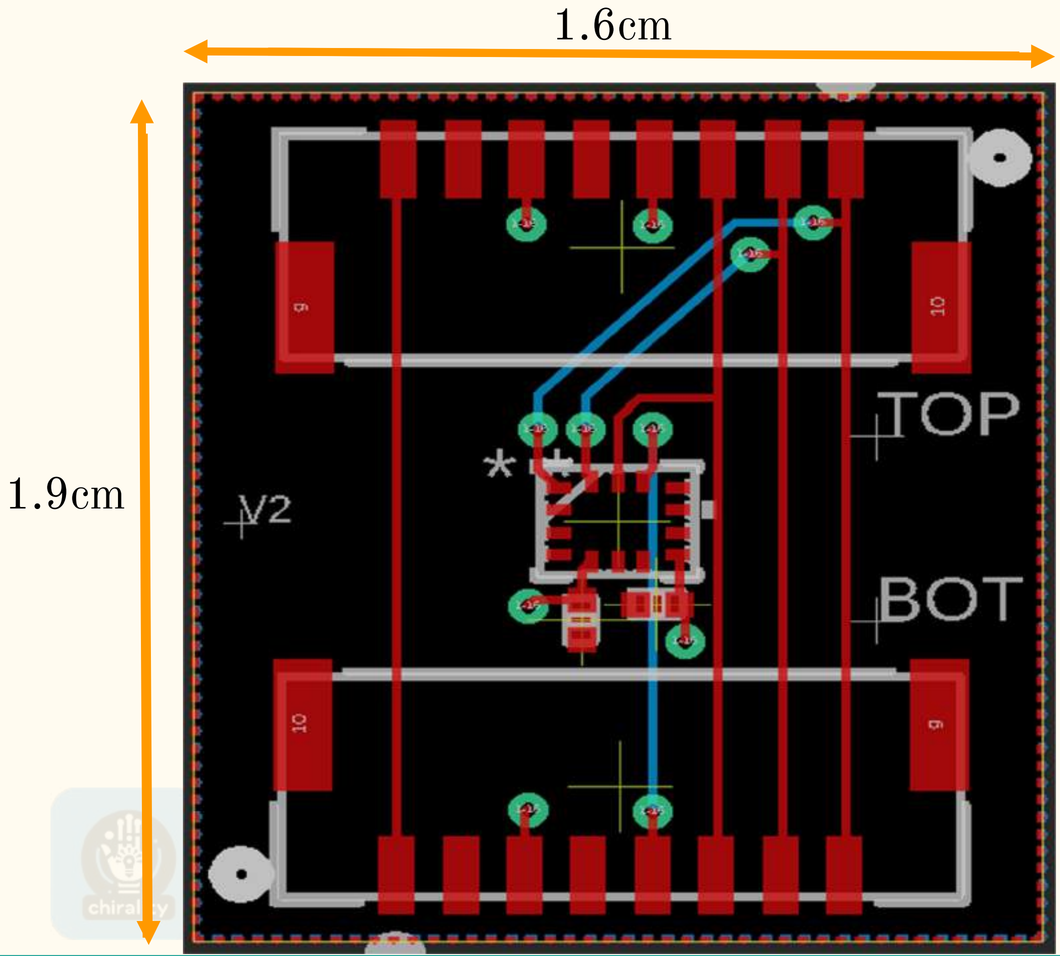
1.6cm

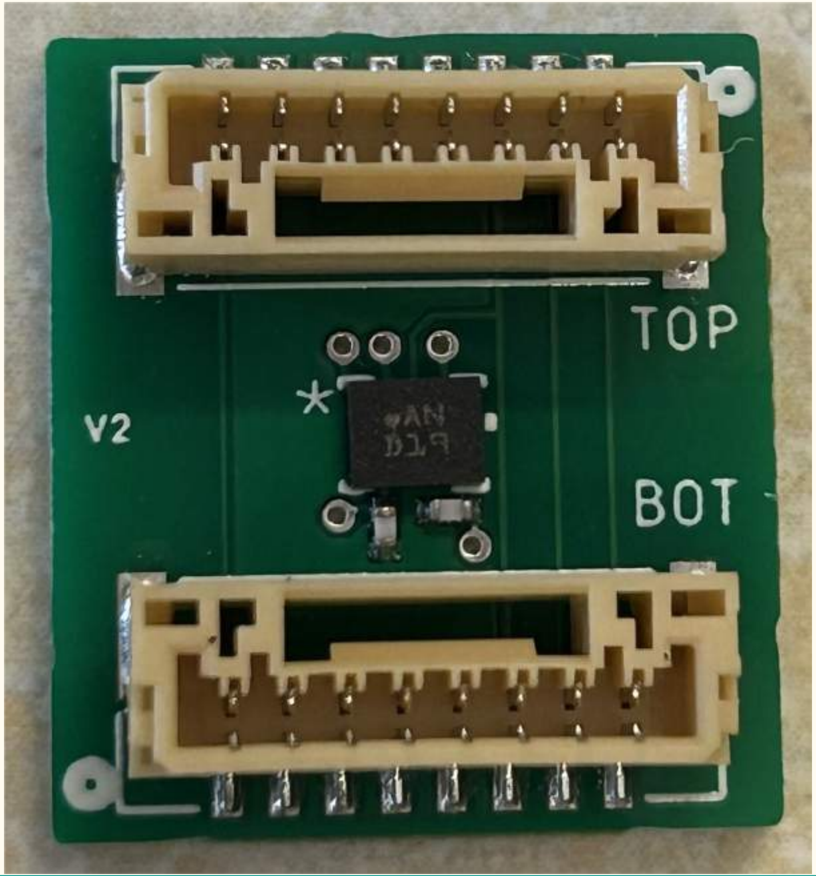
1.3cm





PCB Layout (IMU_BASE)





Components - List

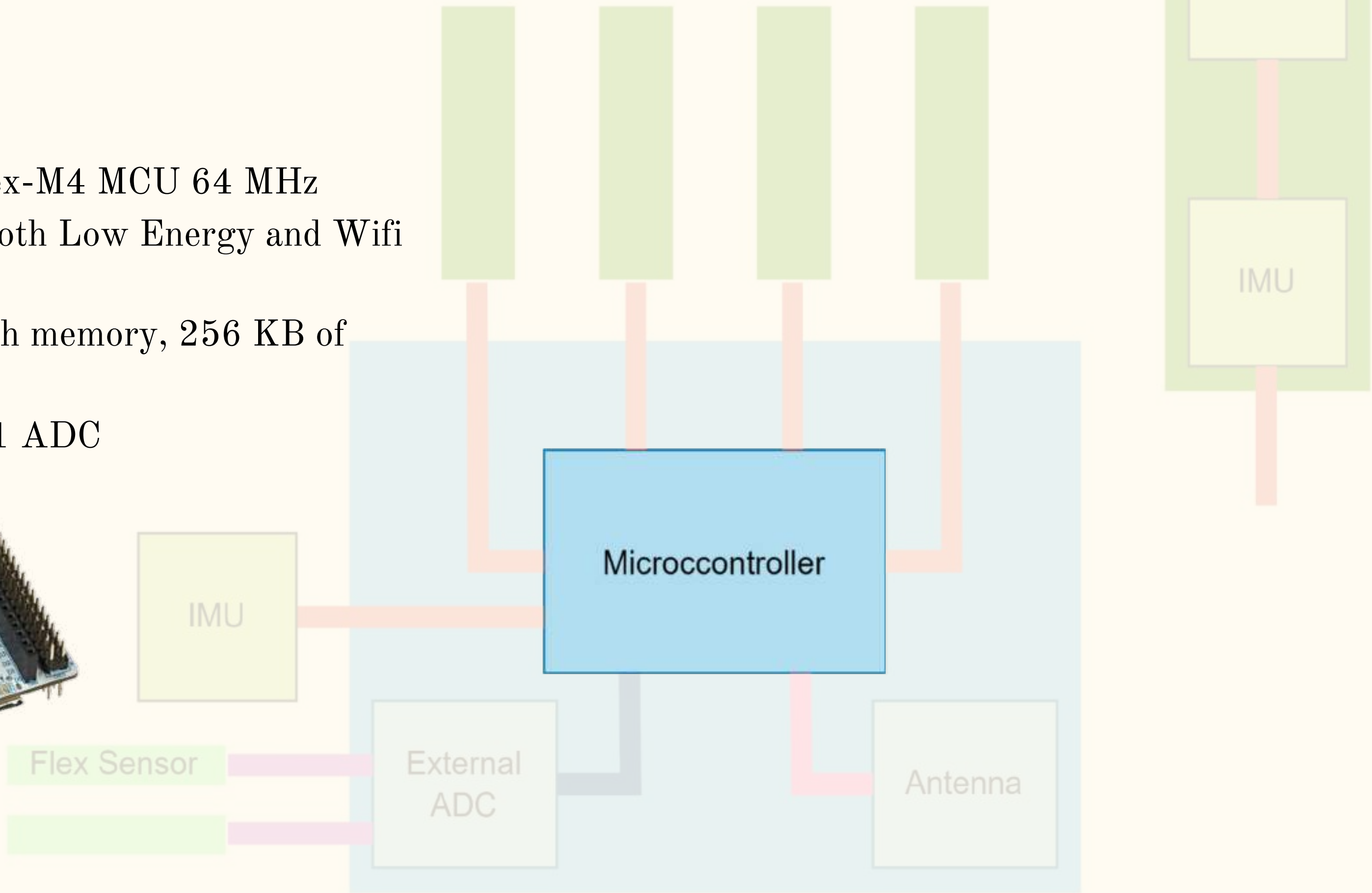
- Bosch BMI323 IMU
- Spectra Symbol Flex Sensor
- NUCLEO-WB55RG STM32 Board
  - STM325WB55RG
- Texas Instruments ADS1115 external ADC
- Antistatic Glove



Components - Microcontroller

STM32WB55RG

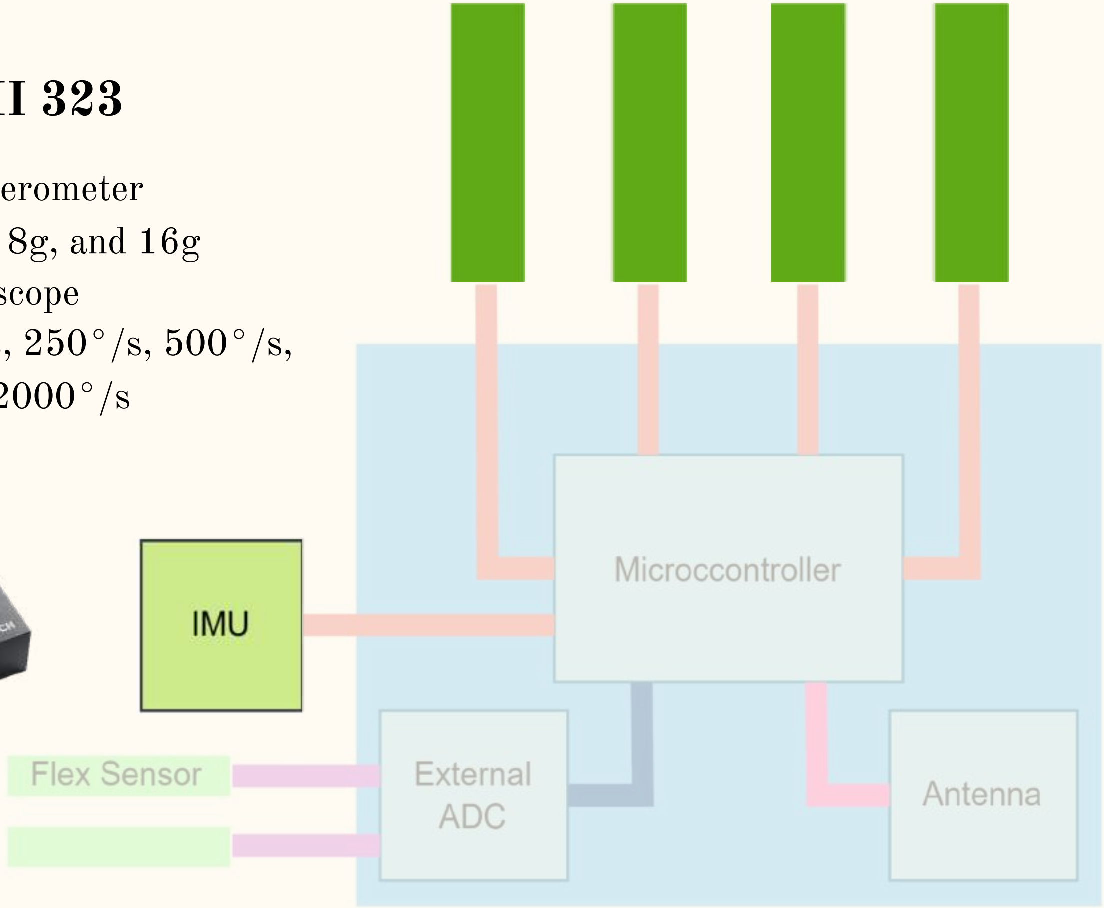
- Dual core Arm Cortex-M4 MCU 64 MHz
  - Built-in Bluetooth Low Energy and Wifi stack
  - 1 Mbyte of flash memory, 256 KB of SRAM
  - 2 SPI, 2 I2C, 1 ADC

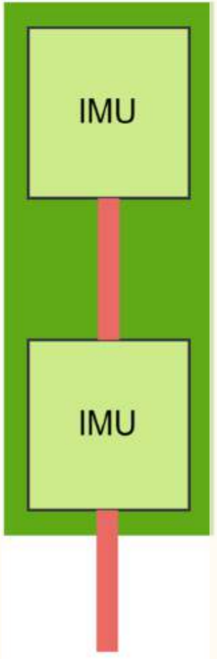


Components - Inertial Measurement Unit

Bosch Sensortec BMI 323

- 16-bit Triaxial Accelerometer
  - Range: 2g, 4g, 8g, and 16g
- 16-bit Triaxial Gyroscope
  - Range: 125°/s, 250°/s, 500°/s, 1000°/s, and 2000°/s

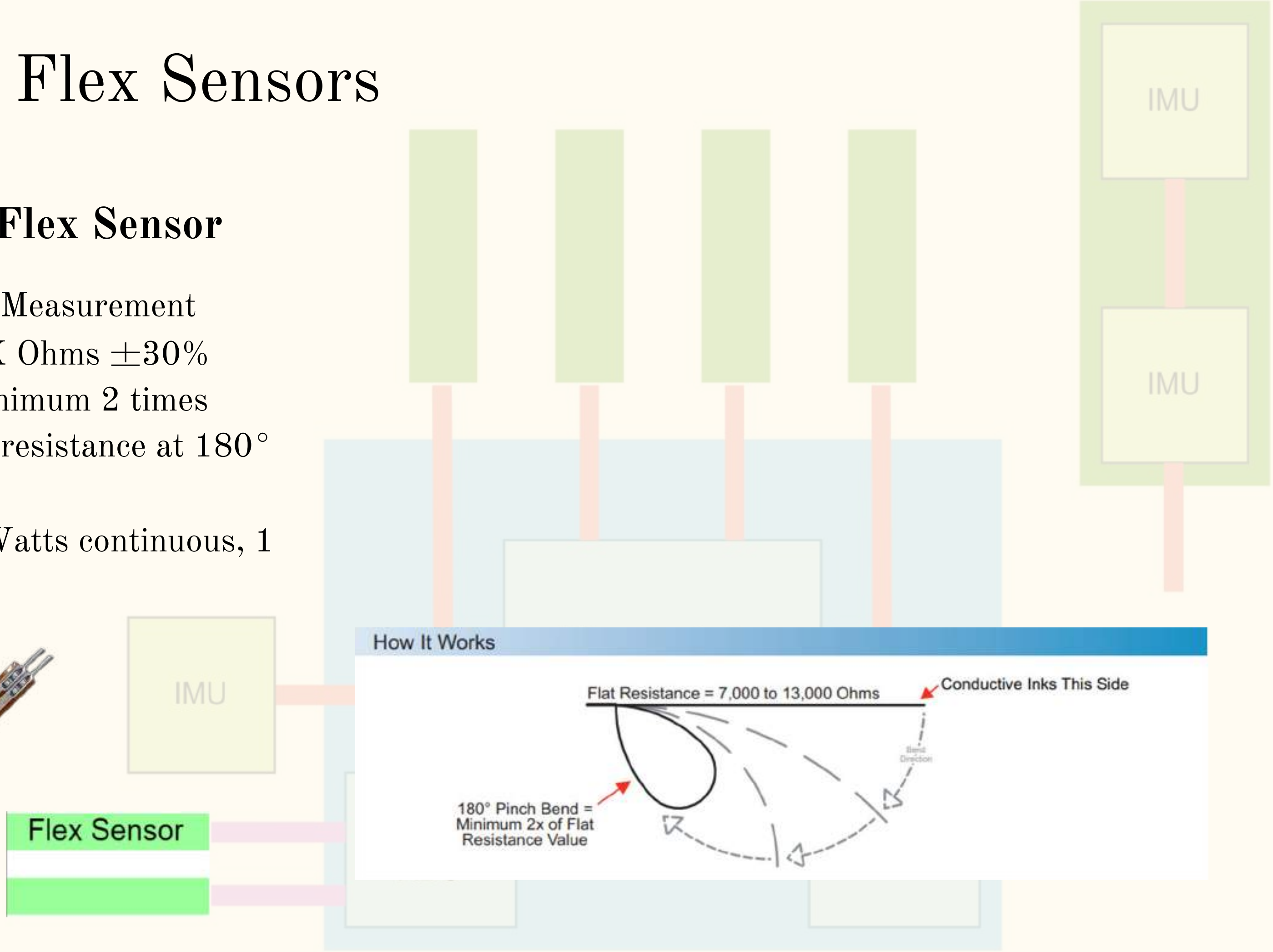




Components - Flex Sensors

FS-L-055-253-MP Flex Sensor

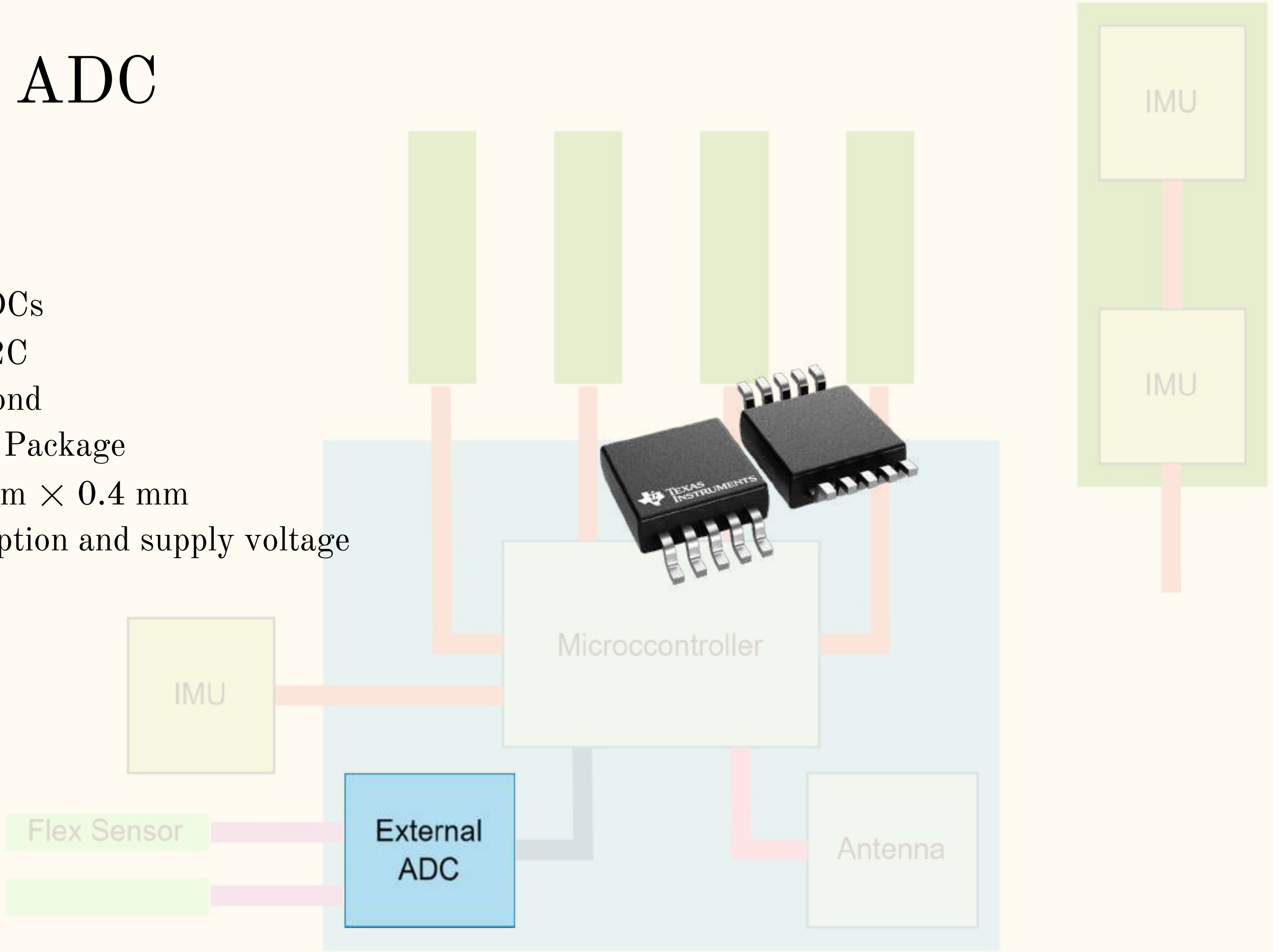
- Angle Displacement Measurement
- Flat Resistance: 10K Ohms ±30%
- Bend Resistance: minimum 2 times greater than the flat resistance at 180° pinch bend
- Power Rating: 0.5 Watts continuous, 1 Watt Peak



Components - ADC

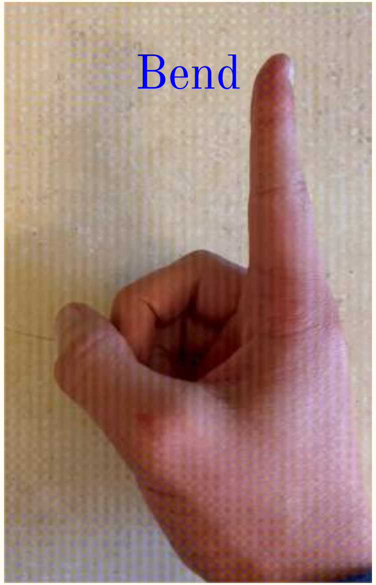
ADS1115

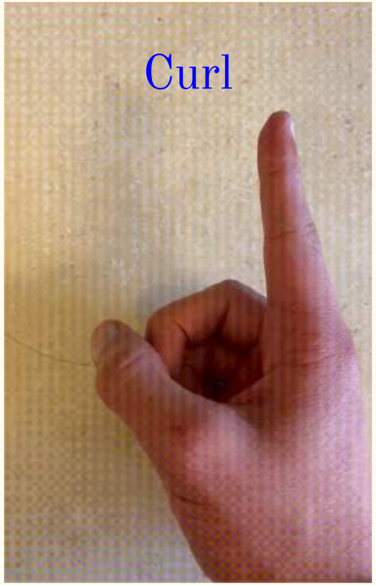
- Delta-sigma (ΔΣ) ADCs
- 4-Channel, 16-bit, I2C
- 860 samples per second
- Ultra-Small X2QFN Package
  - 2 mm × 1.5 mm × 0.4 mm
- Low current consumption and supply voltage
  - 2V, 150µA

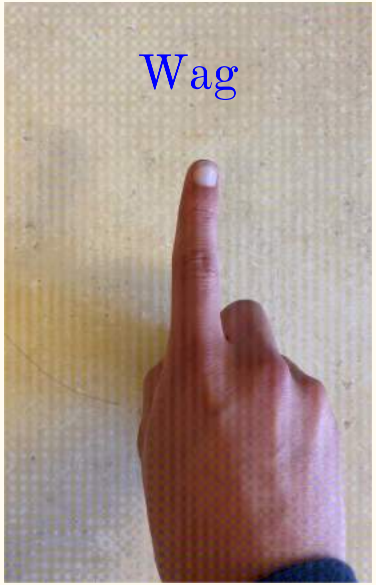


Software Development

- Represent finger with bend, curl, wag angles

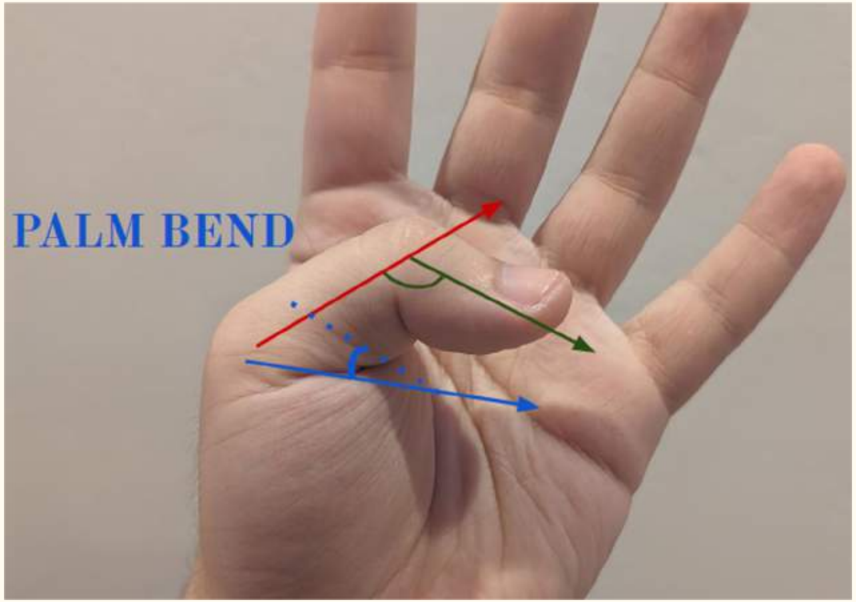






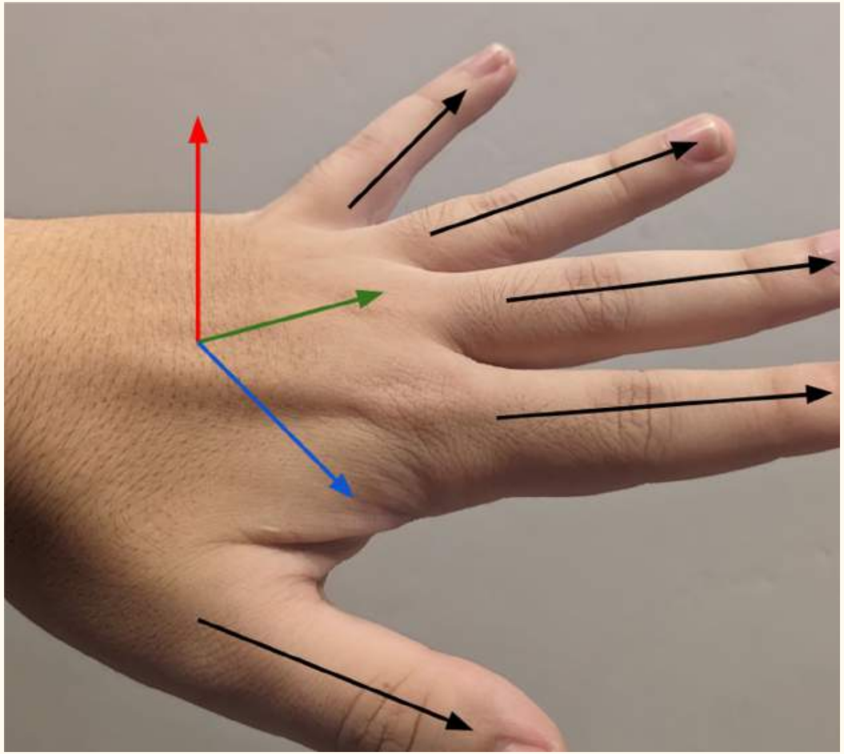
Software Development

- Represent finger with bend, curl, wag angles
- Thumb is same as a finger, but with palm bend as bend



Software Development

- Represent finger with bend, curl, wag angles
- Thumb is same as a finger, but with palm bend as bend
- Hand is collection of fingers and thumb
- Use BLE stack to send real-time data



Data Sources

Gyroscope:

Pros:

- 3-axis rotation data
- Accurate regardless of motion

Cons:

- Rate data → discrete integral → positional drift

Accelerometer:

Pros:

- Accurate positional data based on gravity

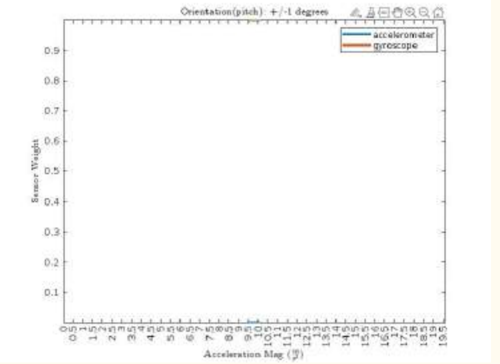
Cons:

- Can only give 2-axis rotation data
- Less accurate for rotation during movement

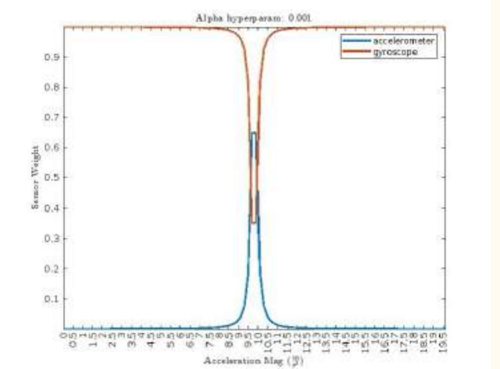
Sensor Fusion

- Derive rotation data from gyroscope and accelerometer
- Combine gyroscope and accelerometer rotation with dynamically weighted average
- Three tunable hyperparameters:
  - Peak constant
  - Gyroscope bias
  - Gravity magnitude offset (set to 9.8)

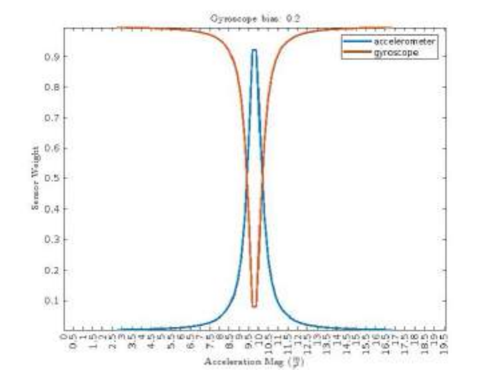
Orientation factor:



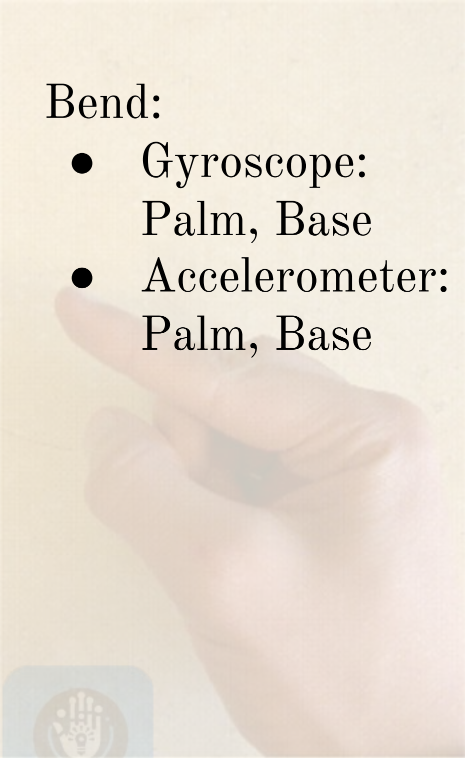
Peak constant:



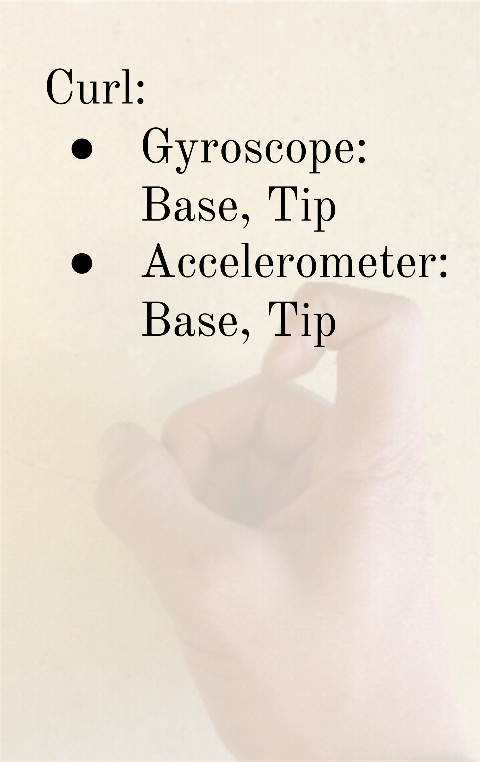
Gyroscope bias:



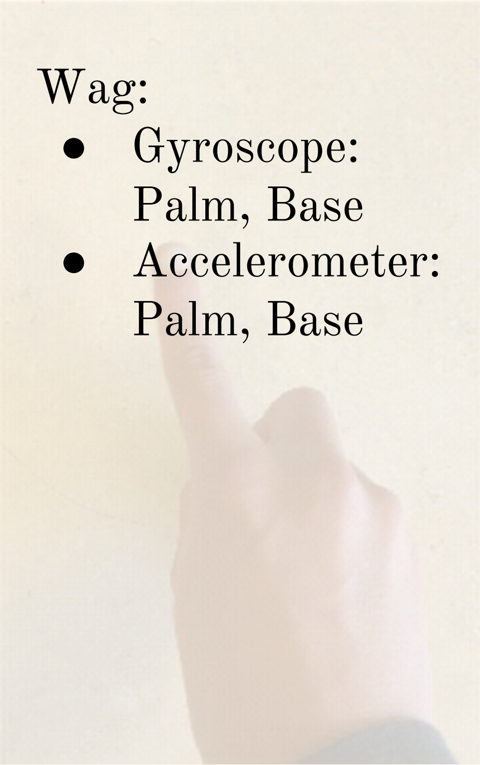
Relevant Finger Data



Bend:
- Gyroscope: Palm, Base
- Accelerometer: Palm, Base

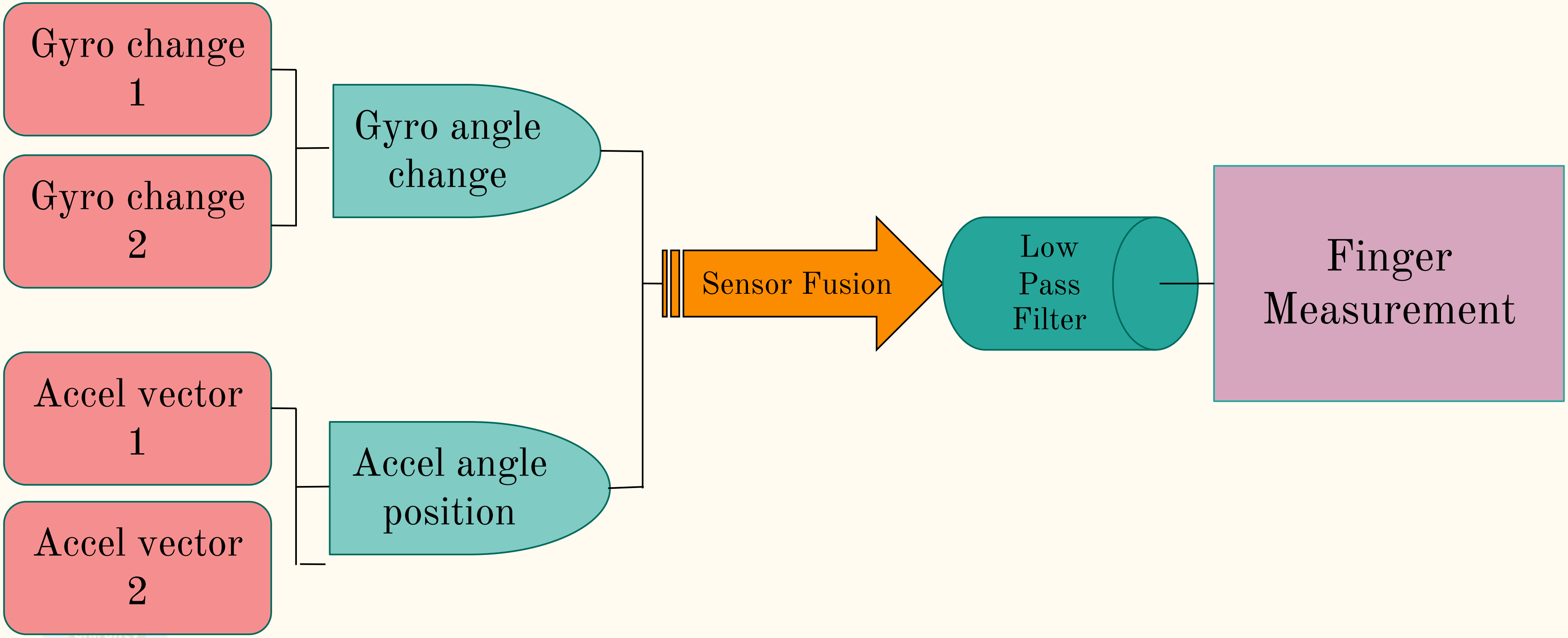


Curl:
- Gyroscope: Base, Tip
- Accelerometer: Base, Tip

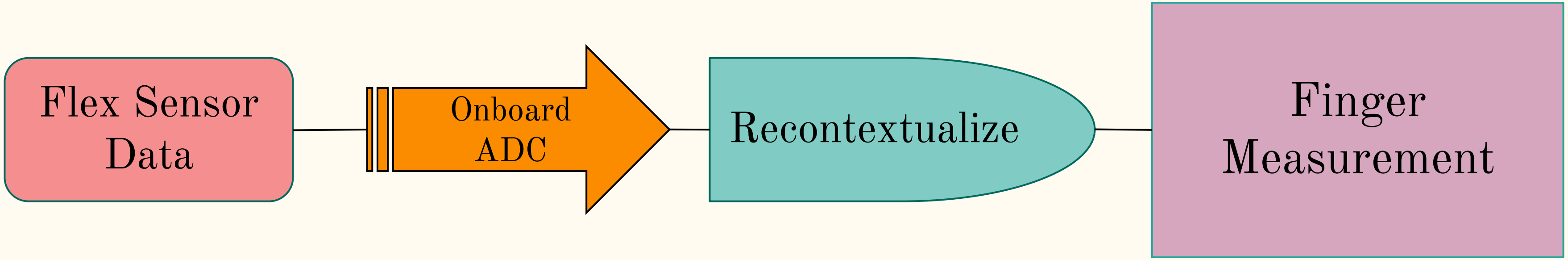


Wag:
- Gyroscope: Palm, Base
- Accelerometer: Palm, Base

Software Flow (Finger Measurement)



Software Flow (Thumb Bend)

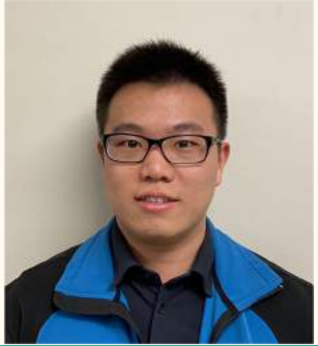


Application Development

- Virtual Model rendered from real-time positional data generated by smart glove
- Each joint in virtual model utilizes relative rotational data from nearby IMU and its reference position given by IMU on palm.

Development Team

- Diego Jerez
  - Team Lead
  - Data Parsing & Hardware Processing
- Ananth Pilaka
  - Software Development & Visualization
- Jonathan Wilcox
  - Bluetooth & Communication Protocol Development
- Phil Wang
  - Hardware Testing & PCB Development
- Yusheng Su
  - Hardware Testing & PCB Development



Demo Video

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Acknowledgements

Special thanks to:

- Dr. Yogananda Isukapalli, CE Capstone Project Instructor
- Eric Hsieh, Lead TA
- Alex Lai, TA
- Brian Li, TA

Thank you

Q&A