Chirality: Smart Glove

Winter Quarter Design Review

Development Team

- Diego Jerez
- Ananth Pilaka
- Jonathan Wilcox
- Phil Wang
- Yusheng Su

The Problem

- Smart gloves exist in various capacities, but are either not accurate or overly specialized
- Controls using hand gestures and motions are intuitive, but no good interface to fully capture them exists
- Solution: Smart Glove as a Universal Remote
  - Glove can capture hand orientation, finger orientation and finger bend within 1° of error
  - Data can be sent to any host application via Bluetooth

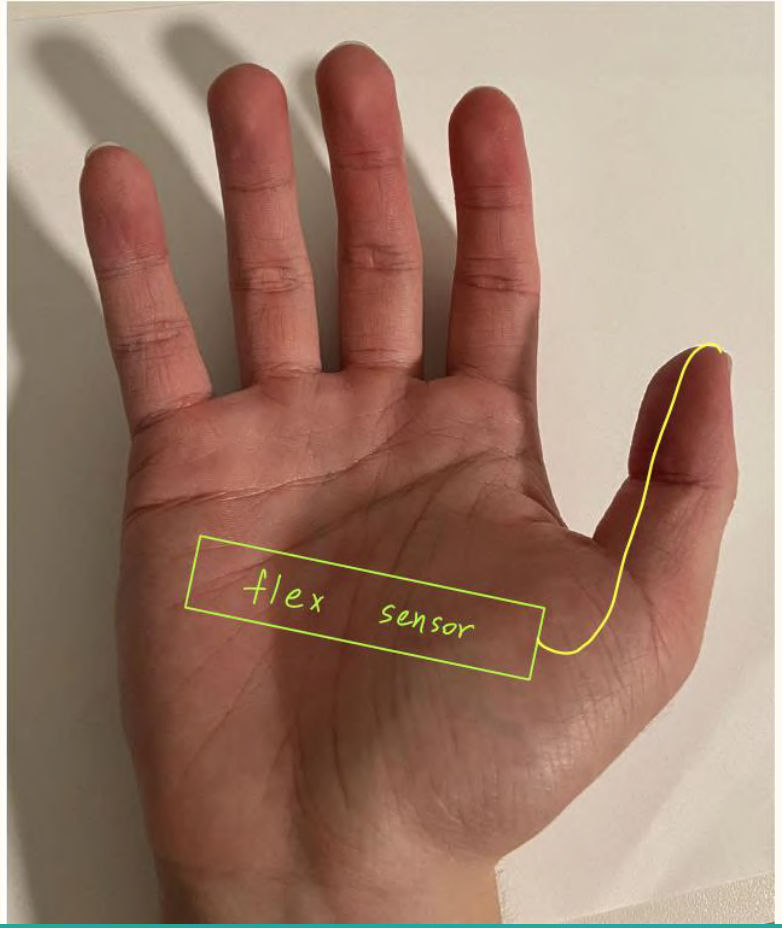
Possible Applications

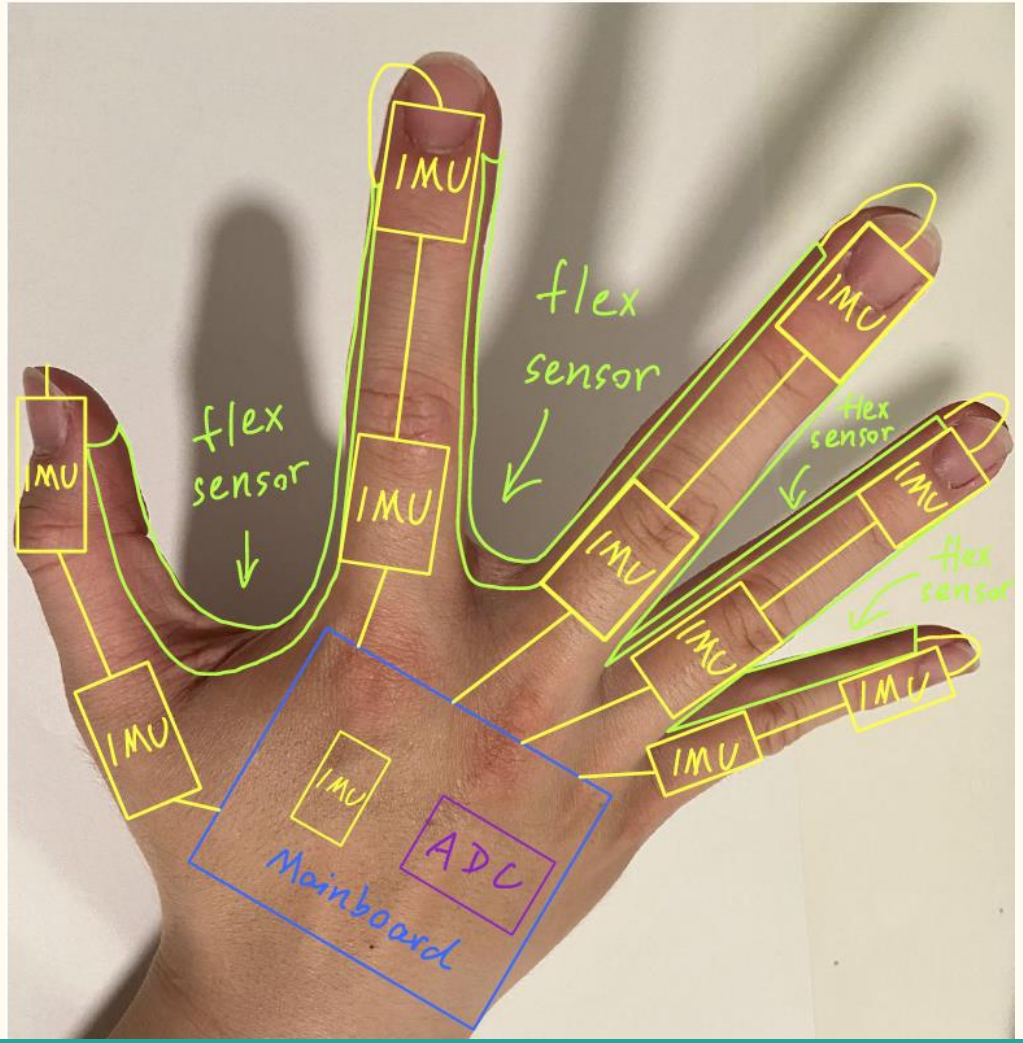
- Virtual reality
  - Glove can feed VR applications accurate hand data to render user hands in virtual space
- Automated System Control
  - Glove would enable intuitive control schemes using hand movements and gestures to be created
- Teaching Sign Language
  - A host application can interpret glove data to read and correct sign language gestures made by a user

Behavioral Spec

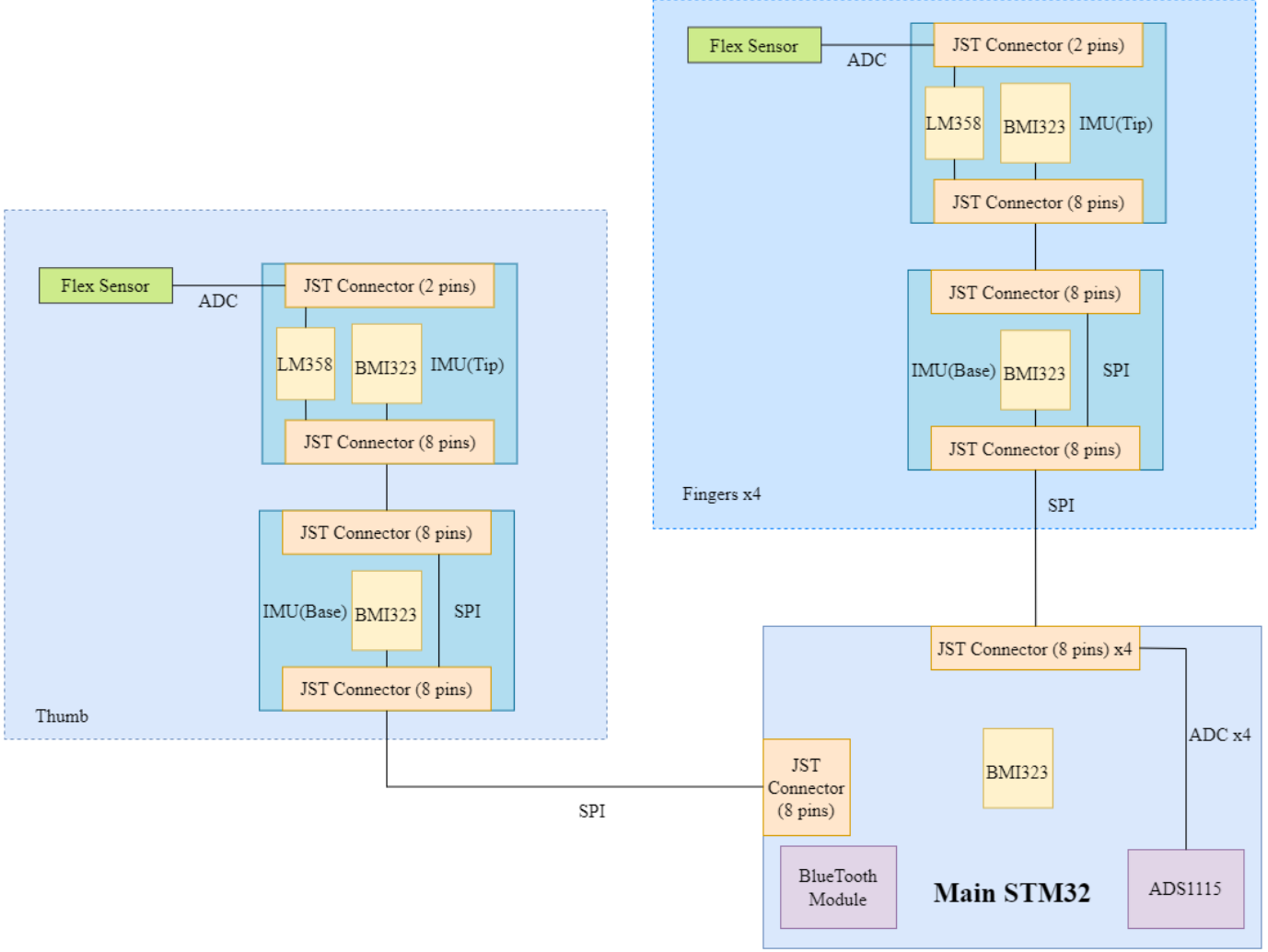
- We will utilize a configuration of high-accuracy sensors to position each finger in 3D space
  - Inertial Measurement Units (IMUs) are capable of measuring rotational position within 1° of error
  - Each IMU reports rotational position of key joints on fingers
  - IMU on palm tracks positional reference for each of 2 IMUs on finger
- Placing 2 IMUs on each finger, and supplementing with flex sensors in-between each finger, we aim to capture 3 axes of rotation for each finger
  - Motivated by the fact that all possible movements of the hand are superpositions of rotational movement around wrist and finger joints

Parts on Hand

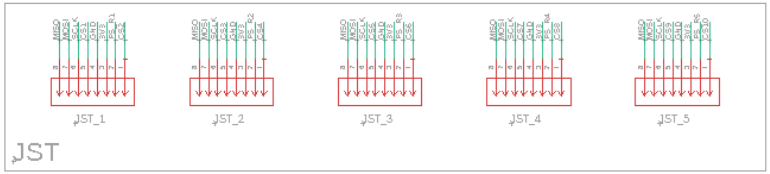


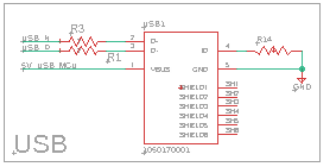


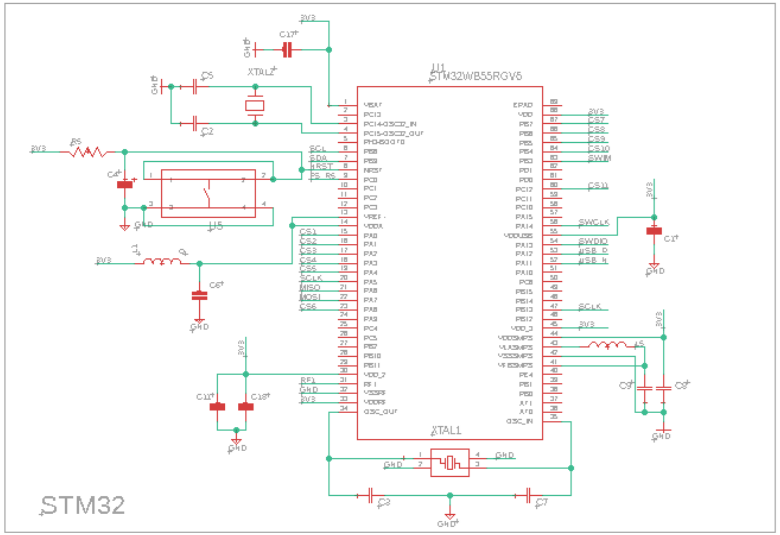
Block Diagram

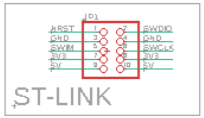


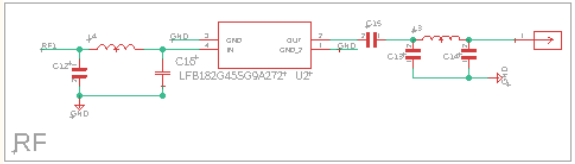
Schematic (Main Board)

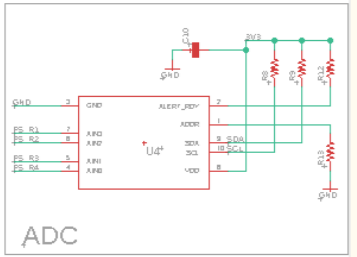


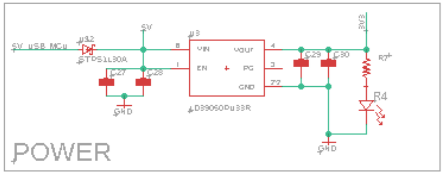


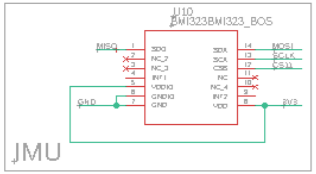




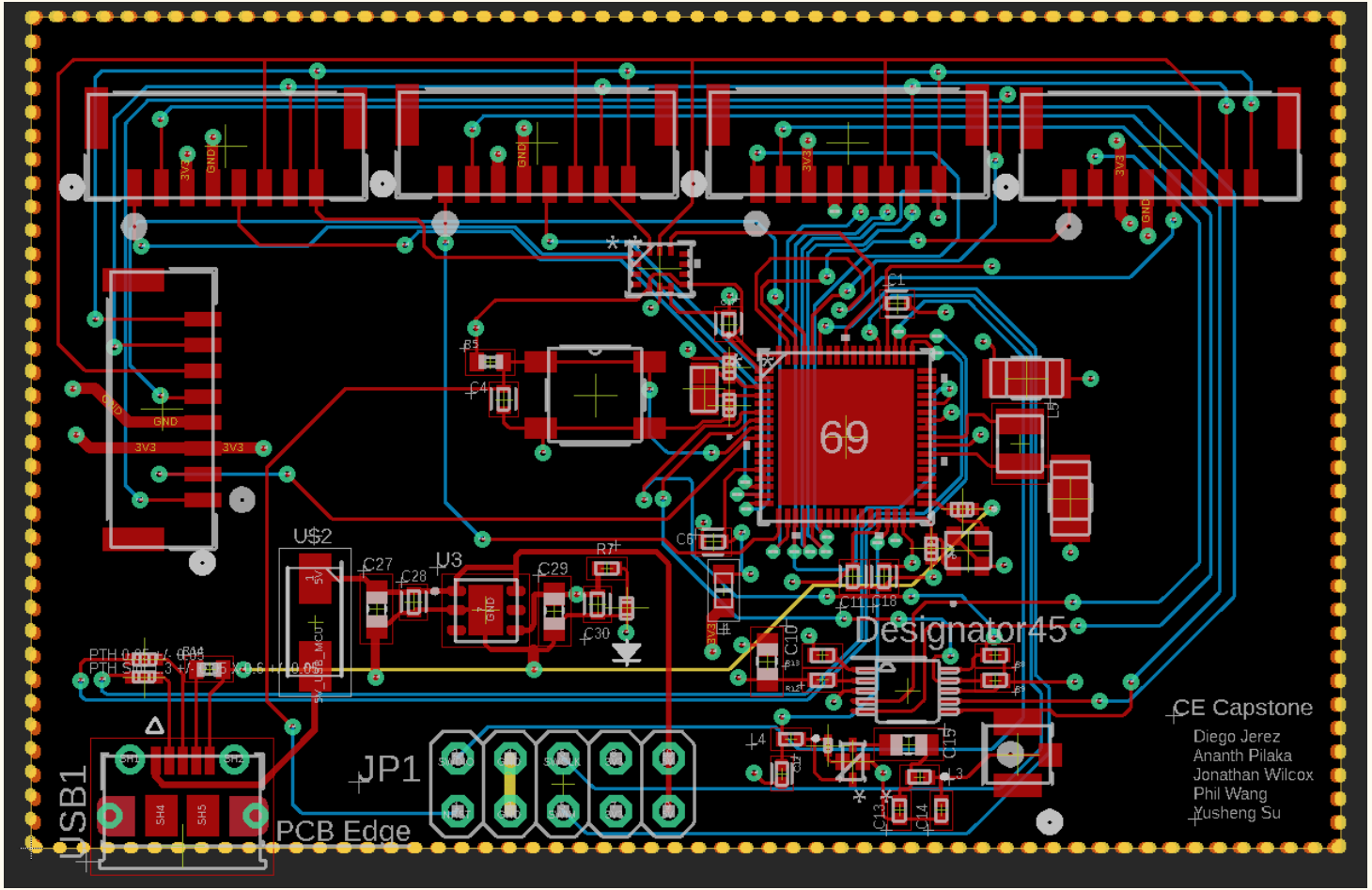




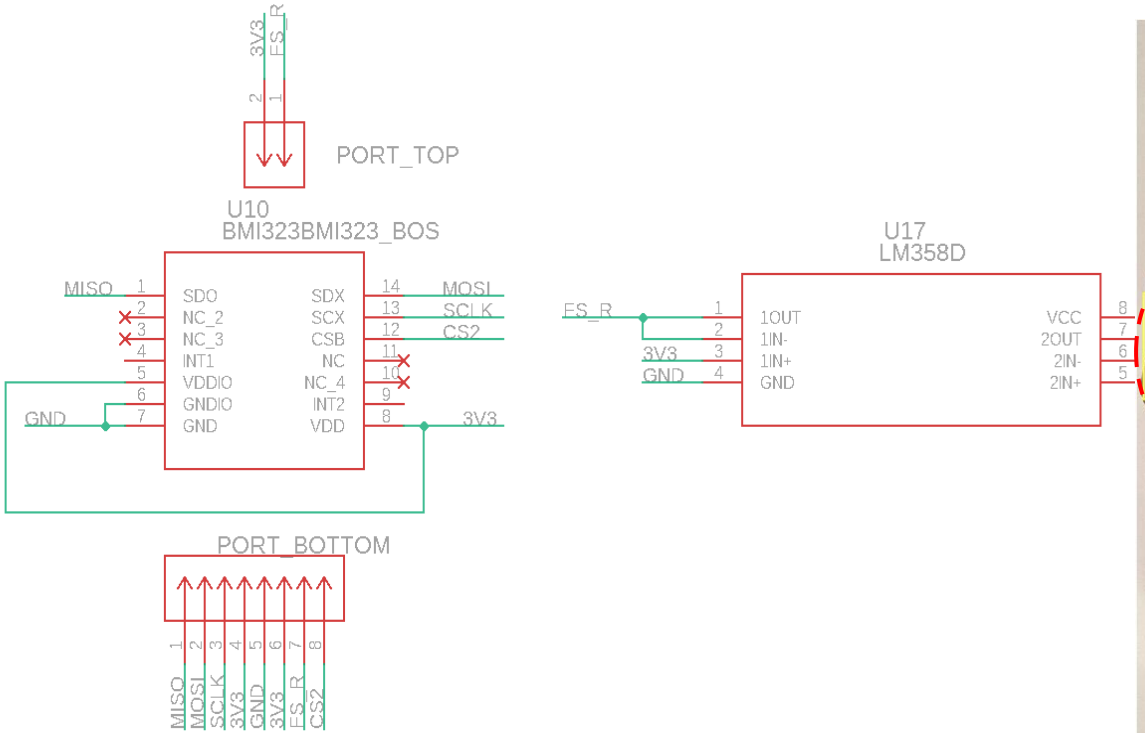


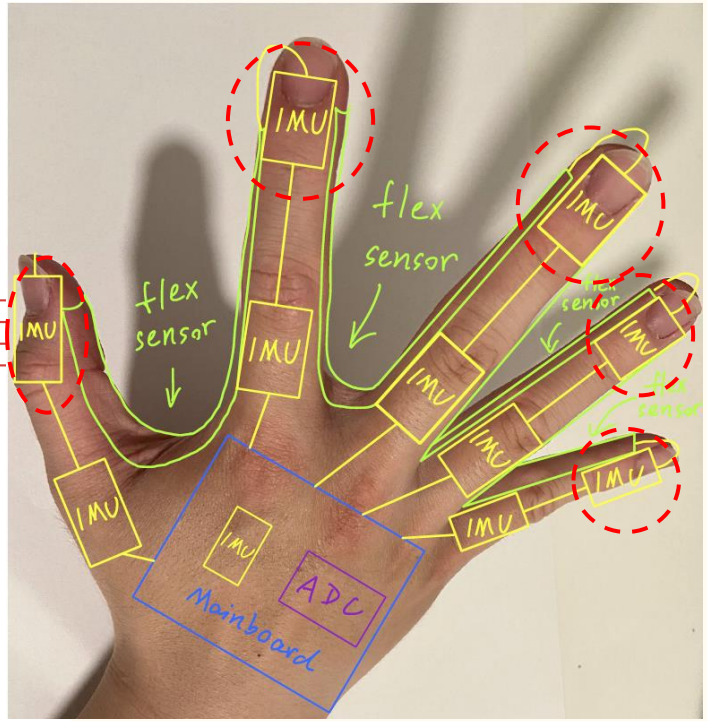


PCB Layout (Main Board)



Schematic (IMU_TIP)





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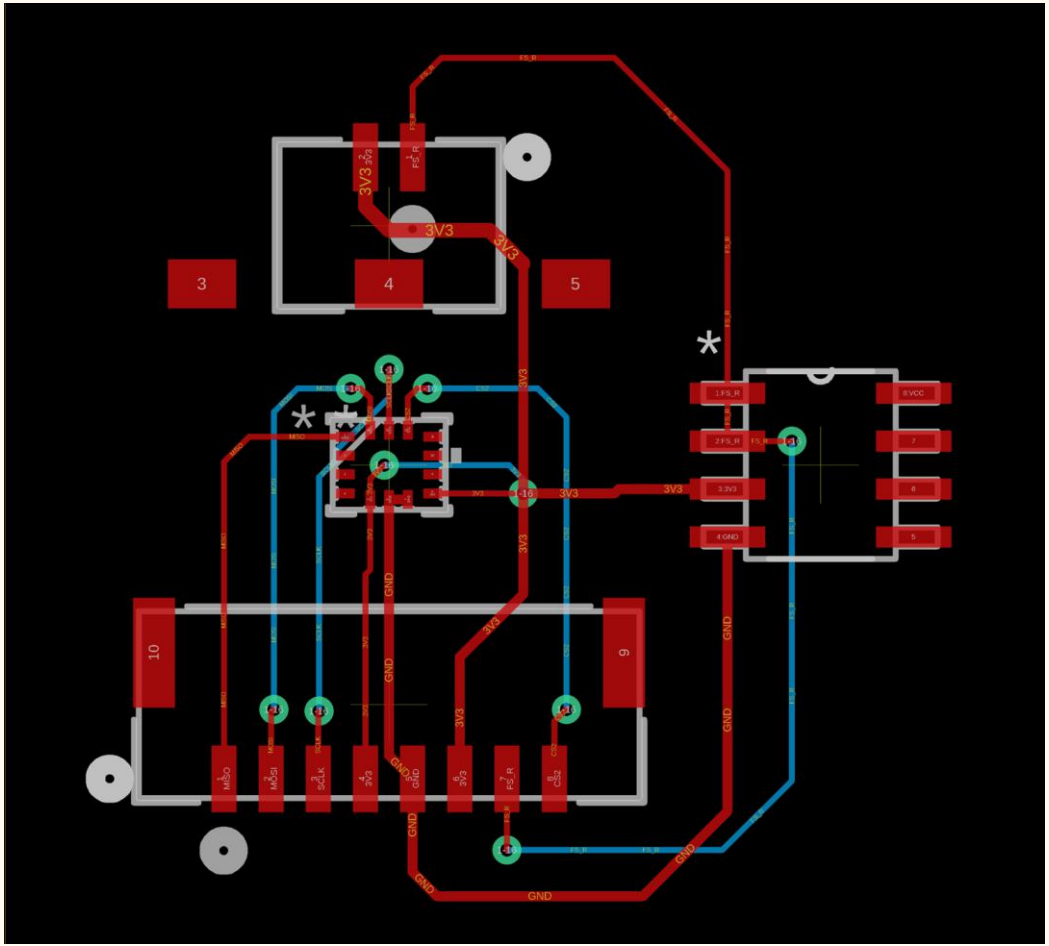
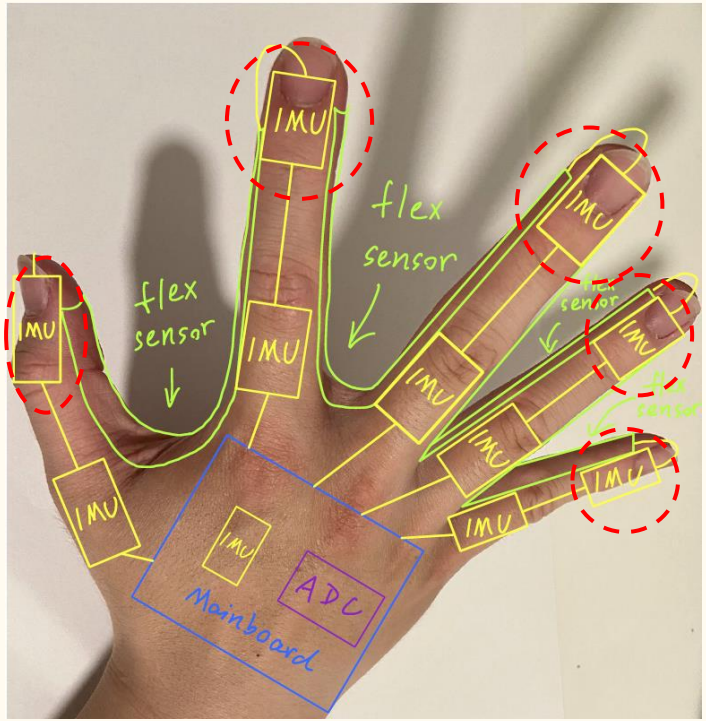
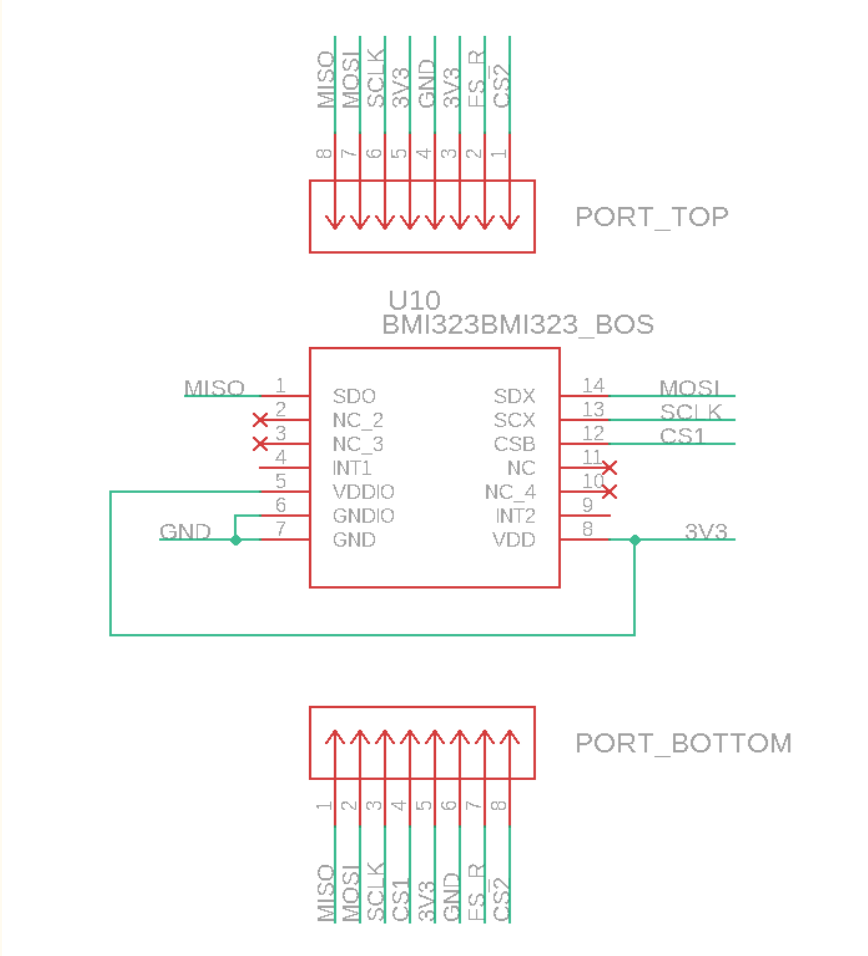
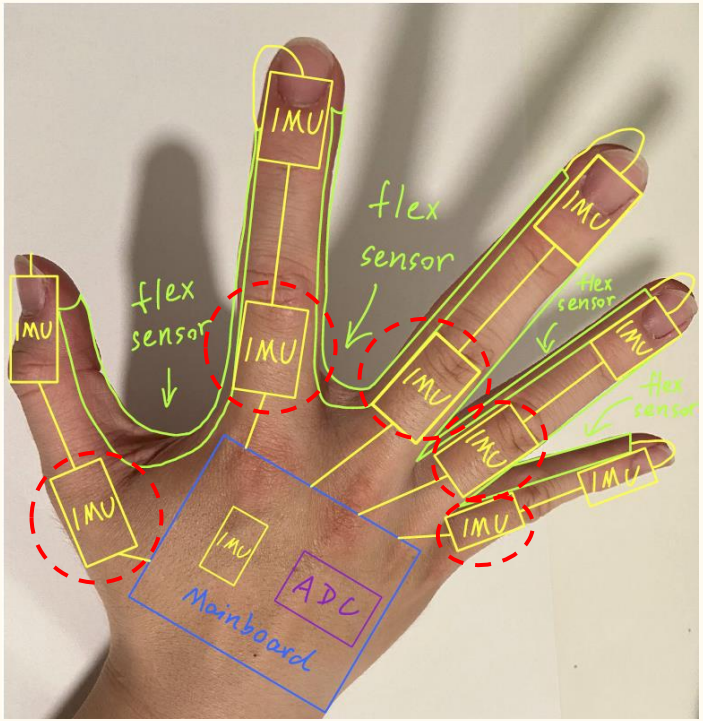




Schematic (IMU_BASE)





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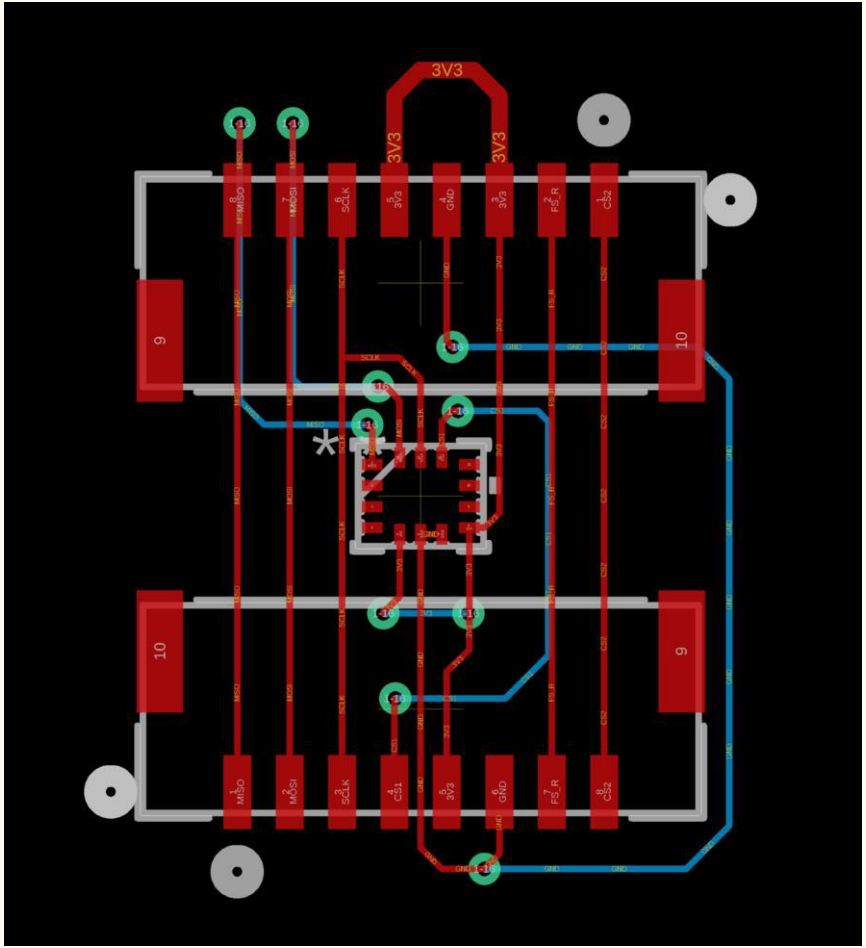
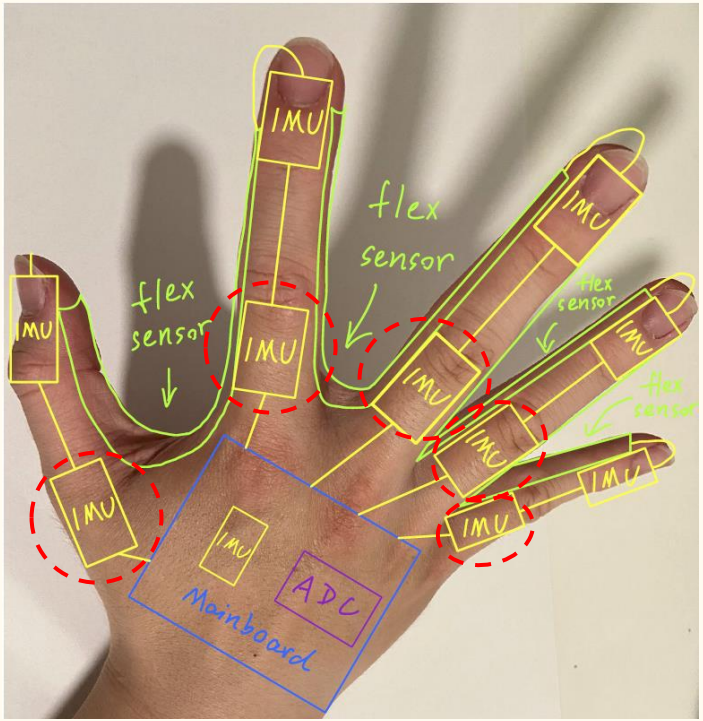




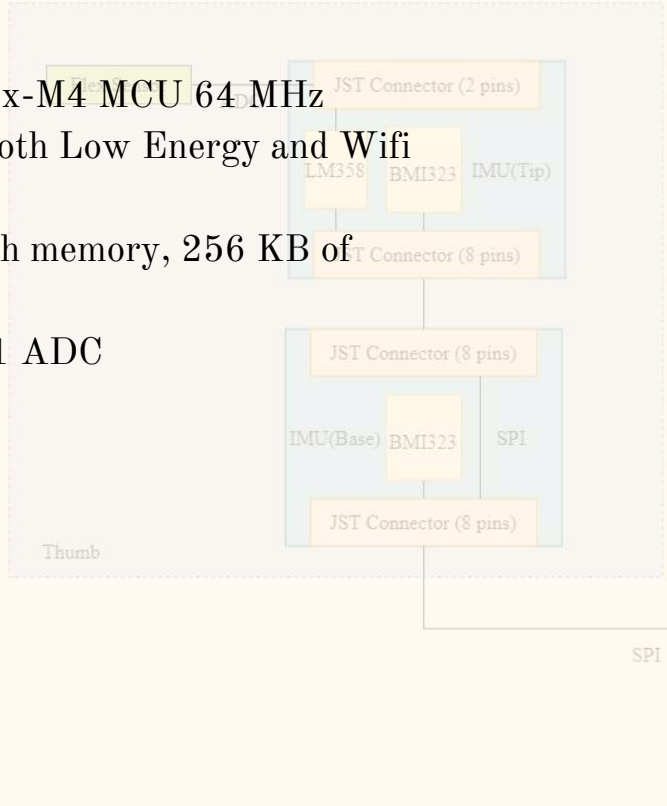
Components - List

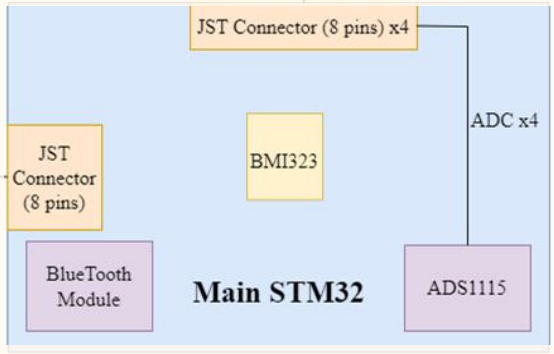
- Bosch BMI323 IMU
- Spectra Symbol Flex Sensor
- NUCLEO-WB55RG STM32 Board
  - STM325WB55RG
- Texas Instruments ADS1115 external ADC
- Glove

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

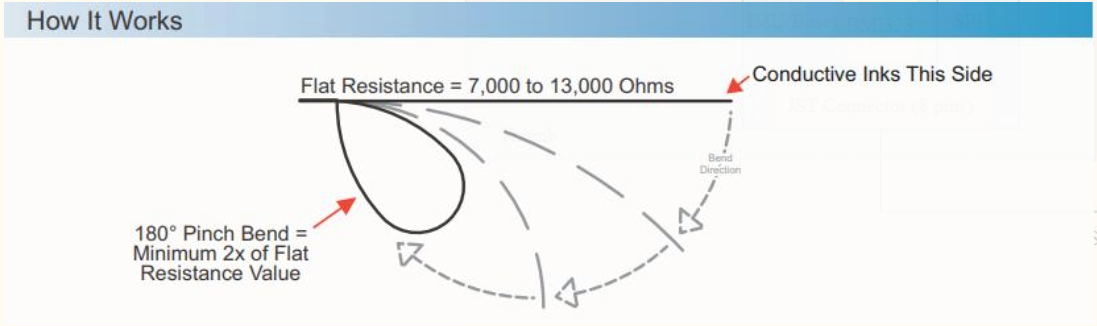
Bosch Sensortec BMI 323

- 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

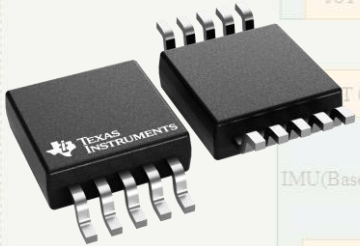
- Angle Displacement Measurement
- Flat Resistance: 10K Ohms ±30%
- Bend Resistance: minimum 2 times greater than the flat resistance at 180° pinch bend
- Power Rating: 0.5 Watts continuous, 1 Watt Peak



Components - ADC

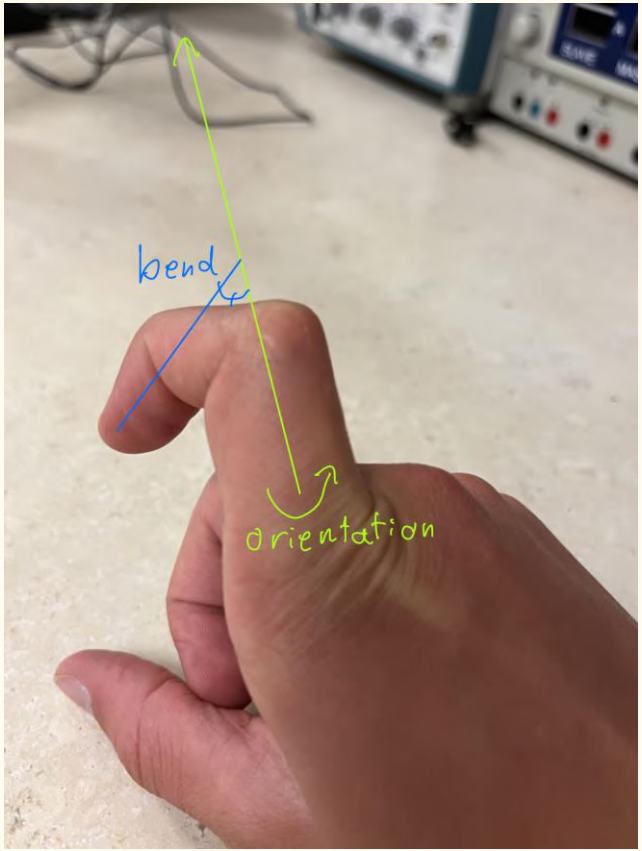
ADS1115

- 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



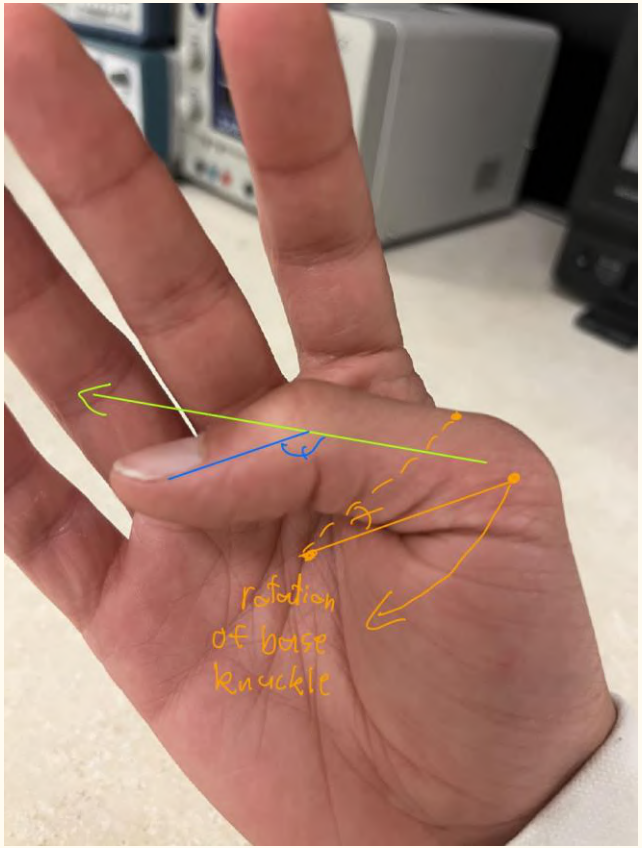
Software Development

- Internal Representation
  - Represent fingers with a rotational direction and bend amount



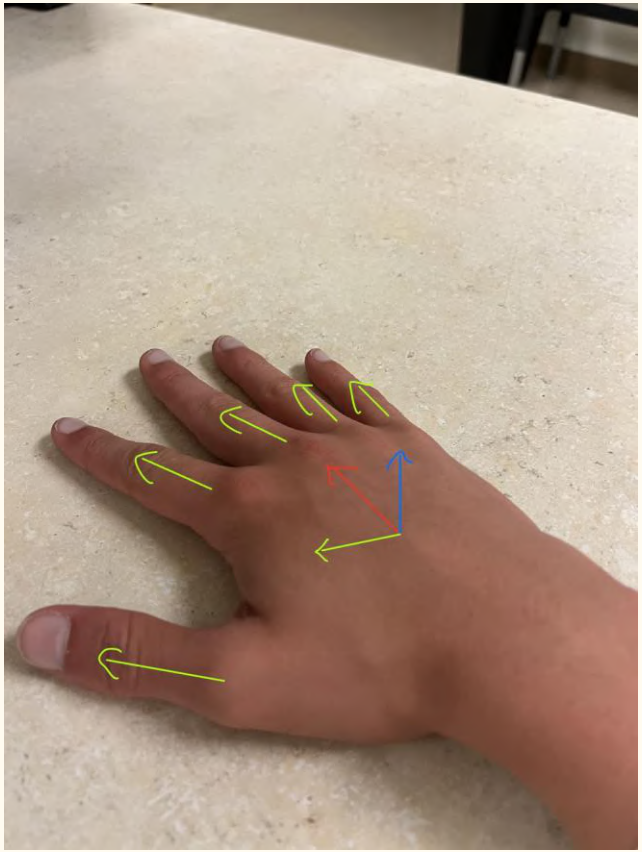
Software Development

- Internal Representation
  - Represent fingers with a rotational direction and bend amount
  - Represent palm bend with rotation of the base thumb knuckle around center of palm



Software Development

- Internal Representation
  - Represent fingers with a rotational direction and bend amount
  - Represent palm bend with rotation of the base thumb knuckle around center of palm
  - Use hand basis for finger position vectors
  - Represent hand as collection of fingers and thumb
  - Initialize the notification characteristic on the 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:

- Positional data based on gravity

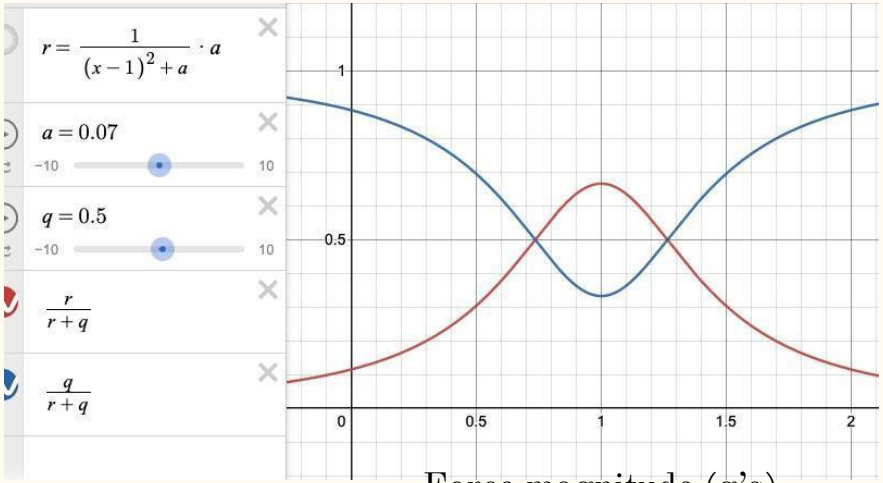
Cons:

- 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
- Accelerometer rotation weighted higher during periods of slower movement
- Gyroscope data weighted more with faster movement

Sensor weight



Force magnitude (g's)

Software Development

- Application
  - 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.

Current Progress

- Tested flex sensors with ADCs
- Implemented positional calculations using IMUs
- Finalized 3D virtual hand model
- Tested BLE stack on MCU using IMU data
- Designed PCB schematic and layout

Schedule

- End of Winter 2024:
  - Finalize the design of PCB and order it
  - Begin assembling parts onto the glove for prototype testing
  - Interface between the application and microcontroller wirelessly
- Spring 2024:
  - Finalize hardware and software development
  - Test and debug
- Reach Goal: Universal Remote

Acknowledgements

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- Eric Hsieh, Lead TA
- Alex Lai, TA
- Brian Li, TA

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
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Thank you

Q&A