Electronic Design Lab

Exoskeleton Glove

Milestone-1

Real-Time Hand Tracking

- **Virtual Reality :** Realistic games can be built using precise hand tracking for Immersive VR.
- **Medical Robotics:** Precision tracking prevents surgical errors.
- **Rehabilitation:** Accurate motion aids stroke recovery & prosthetics.

Why do we need an Exoskeleton Glove?

- **IMU Limitations:** Suffer from drift over time, leading to inaccurate tracking and requiring frequent recalibration.
- **Camera Challenges:** Struggle with occlusion, varying lighting conditions, and depth perception, reducing tracking reliability.

How do we tackle this?

We are also incorporating force sensors to enable the ability to measure the amount of force being applied.

Rotary Encoder-Based Tracking

1. Unlike IMUs, which suffer from drift and calibration issues, rotary encoders provide absolute, high-precision joint angle measurements

2. No occlusion issues like camera-based tracking

Full Finger Movement Mapping

3. Using 19 rotary encoders & FSRs, we track every joint in each finger, capturing detailed hand movements with near-zero error.

4. Tracks hand movement without lag and replicates it accurately in Unity 3D

Multiple options which we looked at :

Flex Sensors

- Multiple positions can give the same output signal
- Difficult to position multiple sensors on a single finger

Multiple options which we looked at :

Inertial Motion Units (IMUs)

- Difficult to position multiple units along a single finger
- Requires four wires (power and I2C), leading to excessive wiring and noise issues
- I2C multiplexing reduces microcontroller connections but requires additional hardware
- Prone to noise and drift, requiring filtering and precise calibration for accuracy

Multiple options which we looked at :

Rotary Potentiometers

- Chosen for compact fit along a single finger
- Each sensor requires three connections (two for power, one for signal)
- Shared power connections reduce microcontroller pin usage
- Provides sufficiently stable and reliable output

Optimal Sensing Mechanism for Exoskeleton Glove

Parameters for consideration	Flex Sensor (Spectra Symbol Flex Sensor-FS-L-055-253-MP 80mm Male Pins connector)	IMU (MPU 6050)	Rotary Potentiometer (3382G-1-103G BOURNS)
Accuracy	✗ (Non-linear response)	✓ (Good with fusion)	✓✓ (Very precise)
Response Time	✓ (Fast) {~70ms}	✓ (Fast, but needs filtering) {~5ms}	✓✓ (Instantaneous) {~2ms}
Drift Issues	✓ (Minimal)	✗ (Significant over time)	✓✓ (No drift)
Power Consumption	✓✓ (Very low)	✗ (High, needs constant correction)	✓ (Low)

Conclusion

We conclude that going ahead with the rotary potentiometers seems to be the best option as for now

Why We Chose Rotary Potentiometers

- Compact & Scalable: Multiple units fit easily on a single finger.
- Efficient Wiring: Shared connections reduce microcontroller pin usage.
- Stable Output: Provides consistent and reliable readings.
- Comprehensive Sensing: Supports up to 19 sensors for full finger tracking.

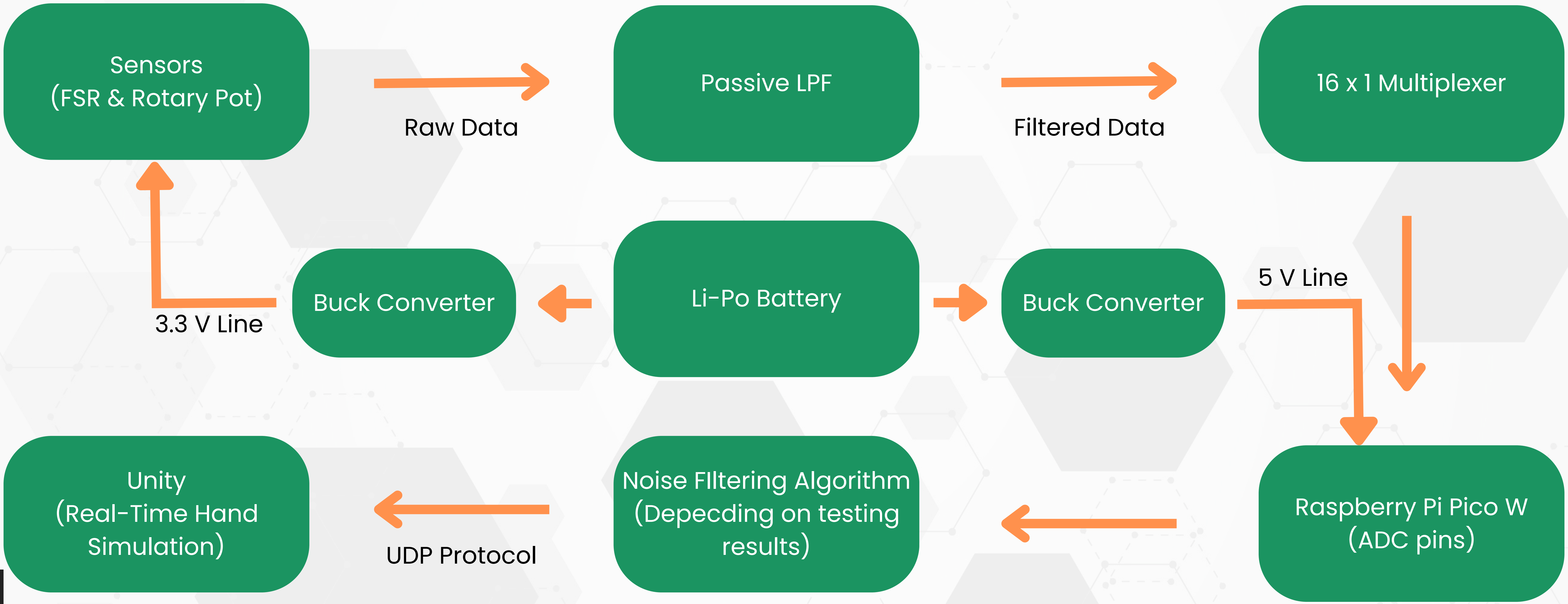
Why We Rejected Flex Sensors

- Ambiguity in Output: Multiple finger positions can give the same signal.

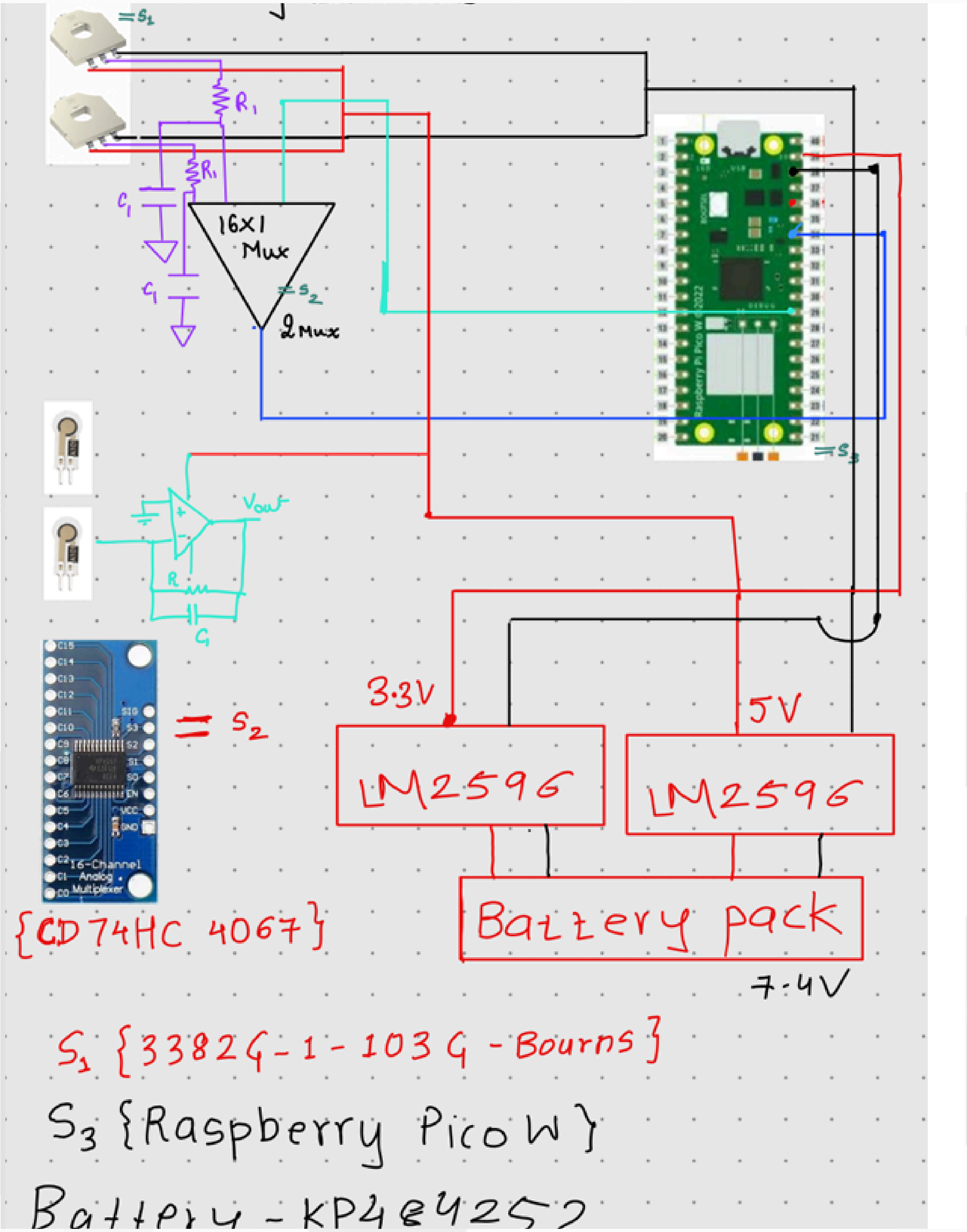
Why We Rejected IMUs

- I2C Limitations: Challenging to position multiple units on a finger.
- Excessive Wiring: Each sensor requires four wires, leading to complexity and noise issues.
- Hardware Overhead: I2C multiplexing needs extra components.
- Prone to Drift: Requires frequent recalibration and filtering.

Methodology

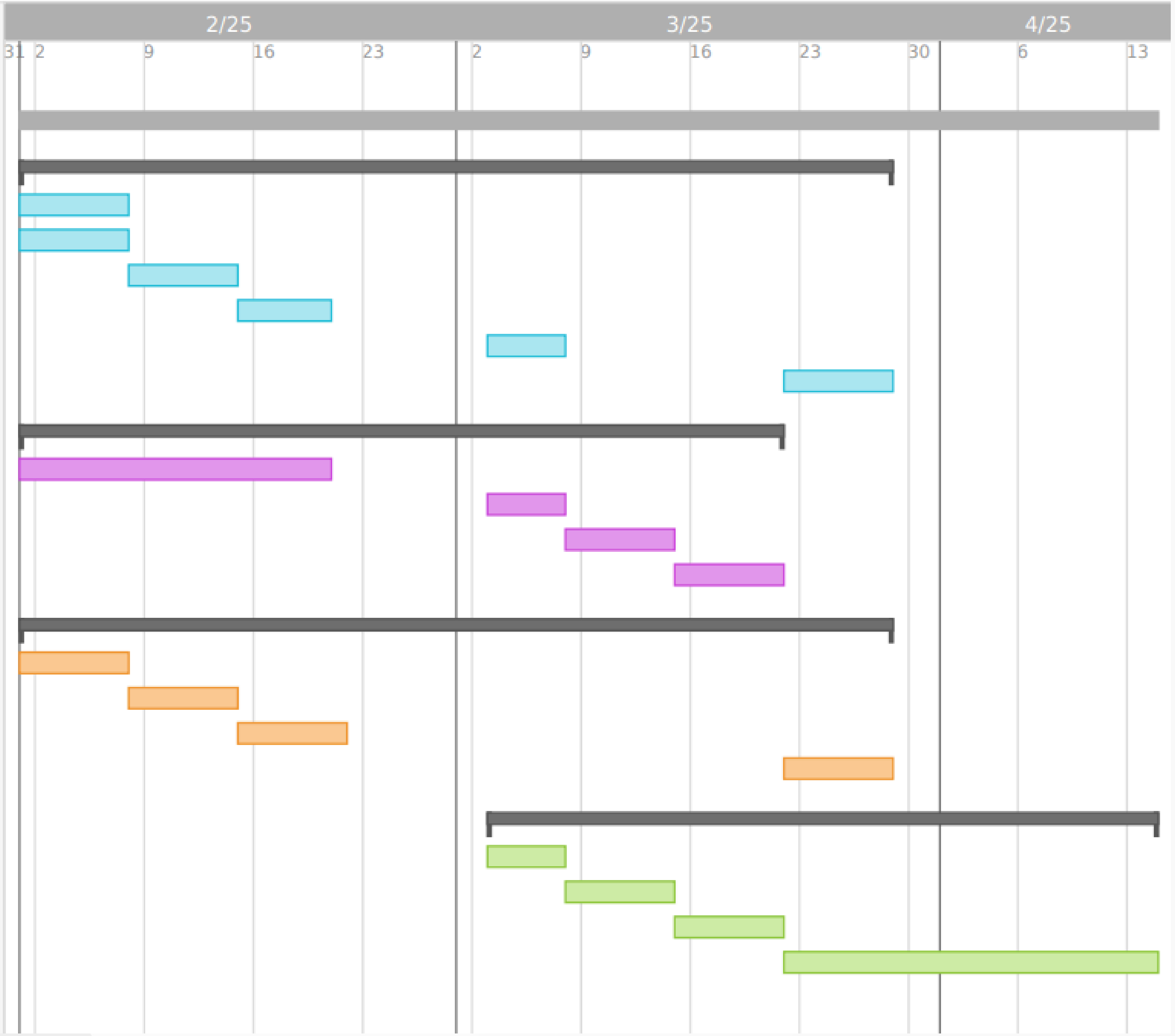


Sensor-Controller Interface



Gantt Chart

EDL-Exoskeleton Glove	**0h**	**0%**
Hardware	**0h**	**0%**
Procure multiplexers, rotatory potent...	0	0%
Set-up Rpi pico W	0	0%
Design PCB layout (for Rpi + filters ...	0	0%
Fabricate PCB, soldering, integrate s...	0	0%
Integrate multplexers with Rpi pico ...	0	0%
Integrate force sensors (if time permi...	0	0%
Software	**0h**	**0%**
Learn unity	0	0%
Finalize making glove	0	0%
Communication between Rpi and Uni...	0	0%
Final debugging and refinement	0	0%
Mechanical (CADing and 3D printin...	**0h**	**0%**
Practice 3D modelling	0	0%
Model the required components	0	0%
Print components and assemble	0	0%
Extra parts for final furnished look	0	0%
Testing	**0h**	**0%**
Individual testing	0	0%
System integrated testing	0	0%
Final testing and precision	0	0%
Test, improve, fine tune, try other th...	0	0%



Work Distribution among Team members

Nishant Bhave:

- CAD modeling and 3D printing of the exoskeleton glove.
- PCB design and sensor integration.
- Testing and debugging of the system.

Prajwal Nayak

- 3D hand simulation development in Unity.
- Integration of Unity with Raspberry Pi Pico W for real-time data input.
- Debugging and refinement of the Unity simulation.

Work Distribution among Team members

Reeyansh Shah:

- 3D hand simulation development in Unity.
- ADC setup and data transmission testing.
- Debugging and refinement of the Unity simulation.

Shikhar Moondra:

- CAD modeling and 3D printing of the exoskeleton glove.
- Glove assembly and sensor integration.
- Testing and debugging of the system.

Siddick Khatri:

- Procurement of components and PCB design/fabrication.
- Raspberry Pi Pico W setup and ADC integration.
- Sensor functionality testing and data transmission.

Risks and Mitigation Strategies

Hardware Risks

- **Sensor Noise:** Due to wires, Electro-magnetic interference
  Solution: Passive RC filter and proper insulation

- **Power:** High current drawn by sensors and R Pi, low battery life
  Solution: High capacity battery (2500 mAH) and low-quiescent buck converter

- **Wire routing:** Lot of wires from sensors
  Solution: Proper bundling of wires with an extra layer of glove on top

Risks and Mitigation Strategies

Mechanical Risks

- **Compatibility with all users:** May cause sensor misalignment
  Solution: Ring-based flexible mechanism to adapt to users’ finger sizes

Risks and Mitigation Strategies

Software Risks

- **Signal latency:** Due to wireless transmission
  Solution: Using UDP protocol to transmit data from R Pi to Laptop

- **Calibration drifts:** With time and use the sensor outputs may drift because of the mechanical wear of potentiometers
  Solution: Recalibrate before every use to make sure accurate replication

Deliverables

- An external exoskeleton attachment to be worn by the user
- Wireless data transmission to the computer for simulation
- Low latency simulation of arm on unity based software

Thank You