Dexterity - Midterm Design Review

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Dexterity: Overview

Background

- Researchers handle hazardous contents in labs frequently ➔ risky predicament
  - i.e. preparing virus samples or handling poisonous substances
- Robotic handling systems are expensive
  - Barriers of entry for smaller labs

Objectives

- Provide researchers and labs with a safe, cost-effective approach to hazardous material manipulation, which can be used for their lab-specific needs

Dexterity: Deliverables

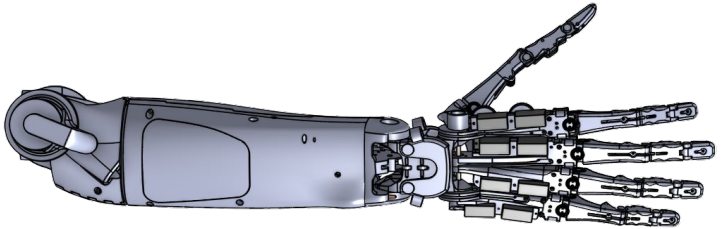
Control Glove

- Hall effect sensors and IMUs track hand motion to drive the robotic armature
- Linear actuators provide haptic pulses for touch feedback from the robotic arm

Control Glove Prototype

Robotic Armature

- CAD based off the open-source Dexhand project
- Pressure sensors on each fingertip to drive linear actuators on control glove

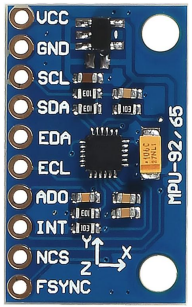


DexHand Robotic Armature

Design

Hall Effect Sensor

IMU



CONTROL GLOVE ELECTRICAL BLOCK DIAGRAM

16 Hall Effect Sensors

DC-DC Converter to 3.3V

1 Li-ion 18650 Cell 4.2V Maximum

Analog Multiplexer

5 LRA Haptic Modules

DC-DC Converter to 6V

2 IMUs

I2C Multiplexer

ESP32S3 DevkitC

5 Digital Servos for Kinematic Feedback

Data Packets with Pressure Sensor Data

Data Packets with Finger Angle and IMU Data

Legend

VCC/GND

ESP-NOW

Analog

I2C

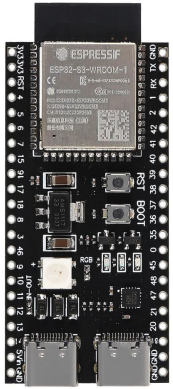
Digital

18650 Battery

LRA Haptic Module

Pressure Sensor

ESP32



ROBOTIC ARM ELECTRICAL BLOCK DIAGRAM

DC-DC Converter to 3.3V

2 Li-ion 18650 Cells in Series 8.4V Maximum

5 Pressure Sensors

5 Serial Servos for Wrist, Forearm, and Elbow Movement

DC-DC Converter to 6V

2 IMUs

Feetech TTL Linker

ESP32S3 DevkitC

16 Digital Servos for Finger Movement

Data Packets with Pressure Sensor Data

Data Packets with Finger Angle and IMU Data

Legend

VCC/GND — ESP-NOW

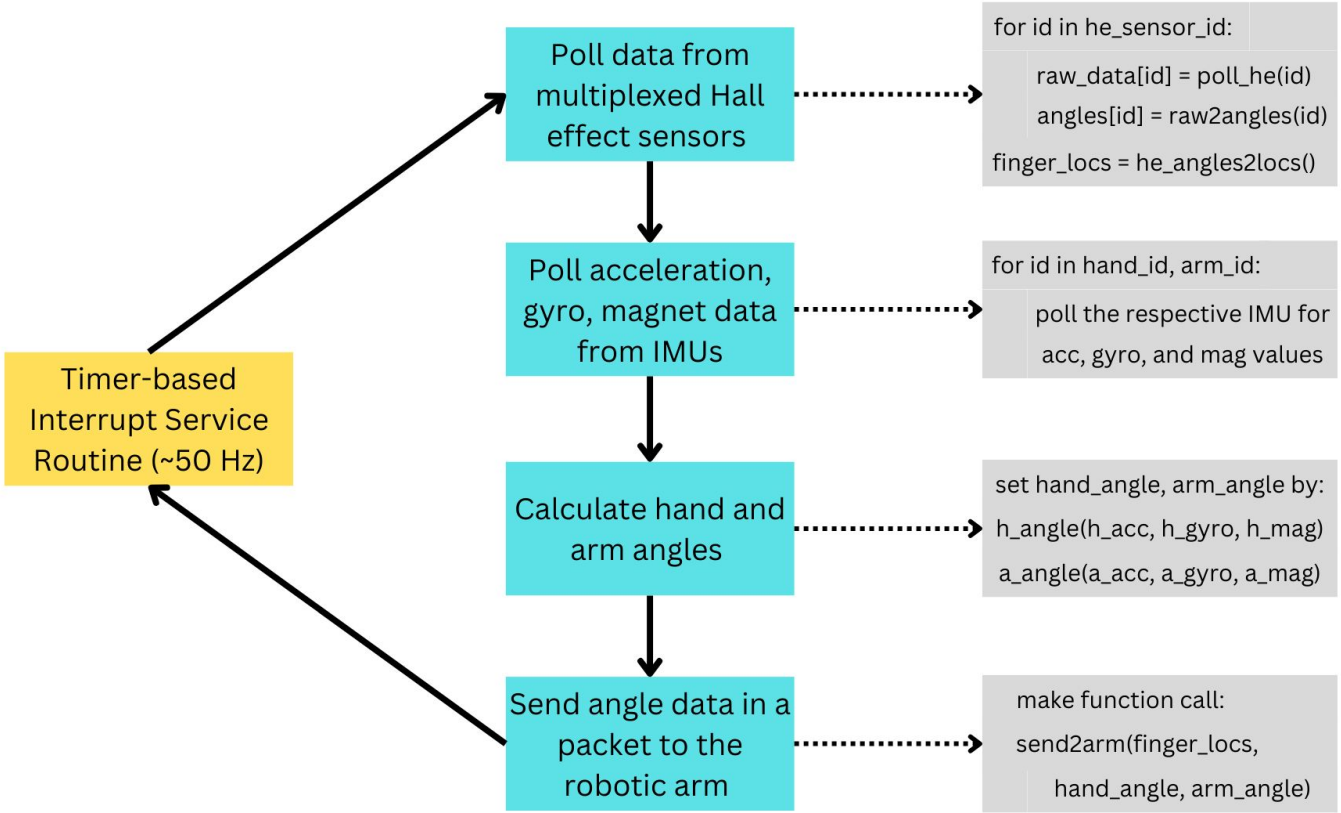
Analog — I2C

Digital — Serial

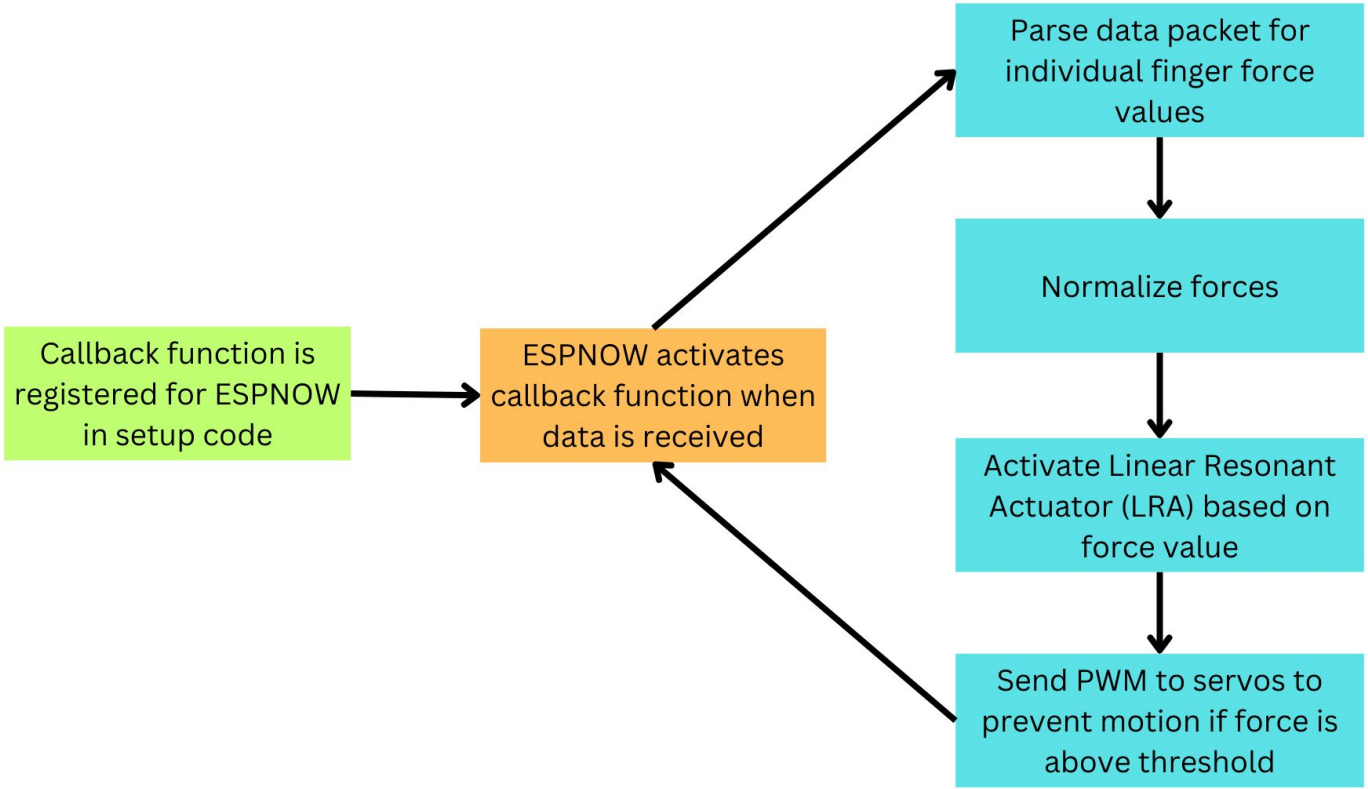
Finger Servos

Forearm and Elbow Servos

Glove Sensor Processing Software Flowchart

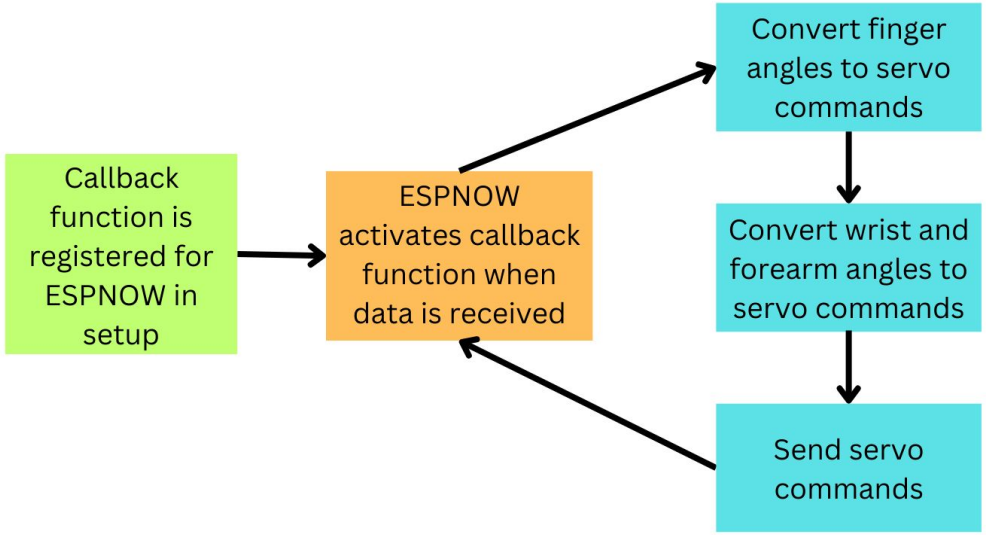


Glove Haptic Data Processing + Control Software

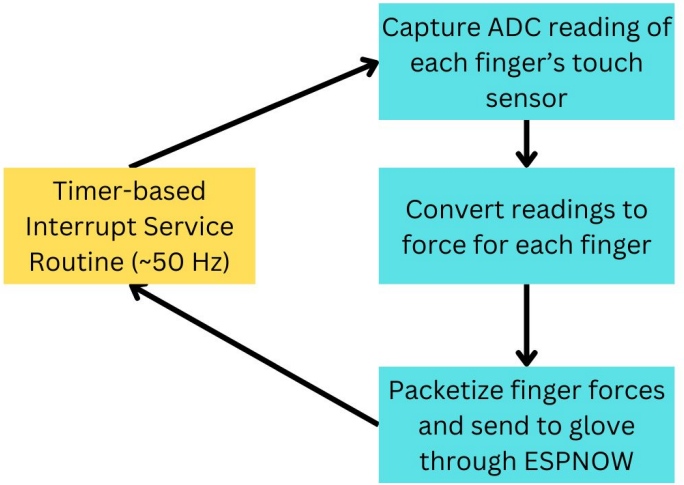


Robotic Arm Software

Movement Command Callback

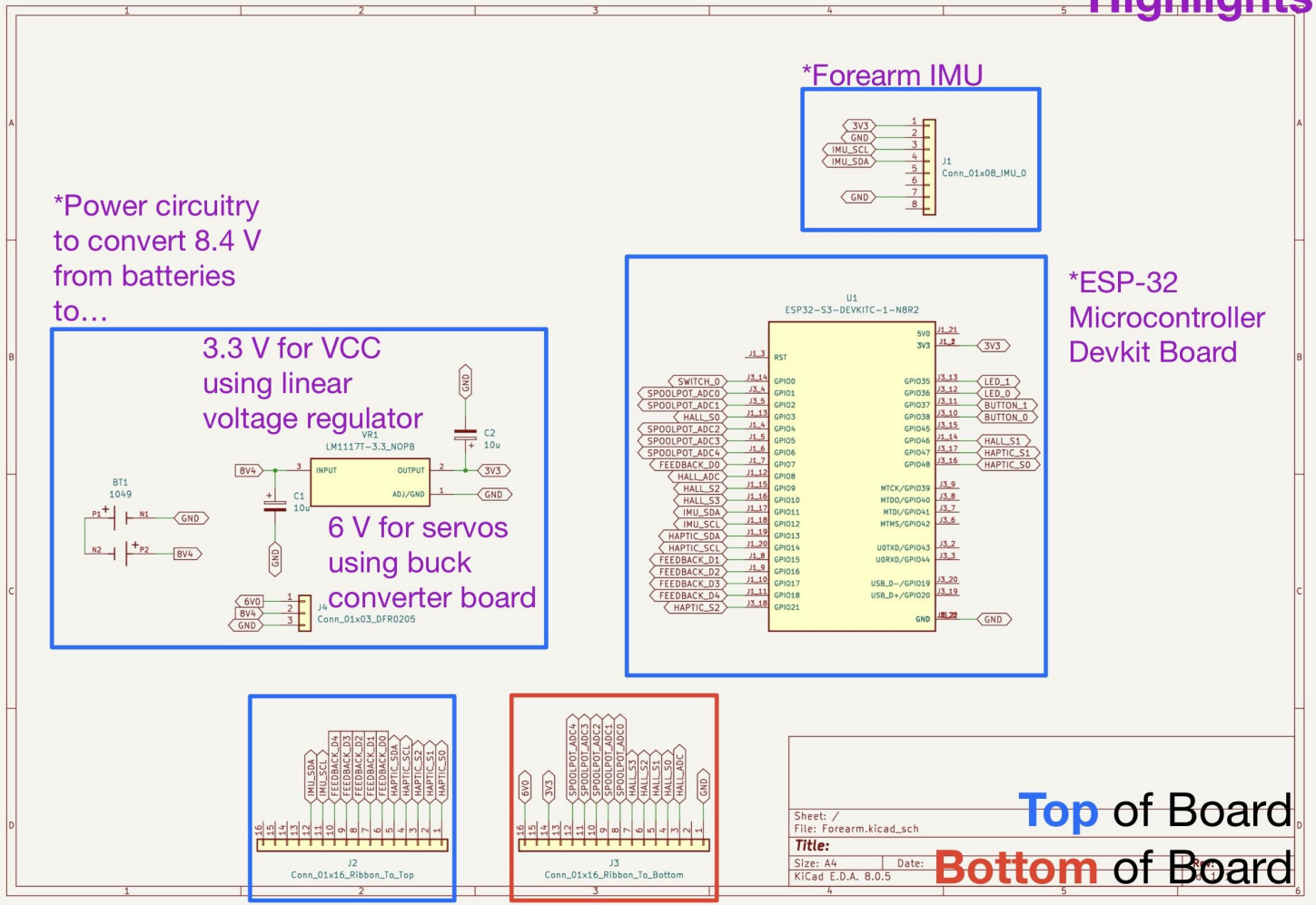


Touch Sensor Processing



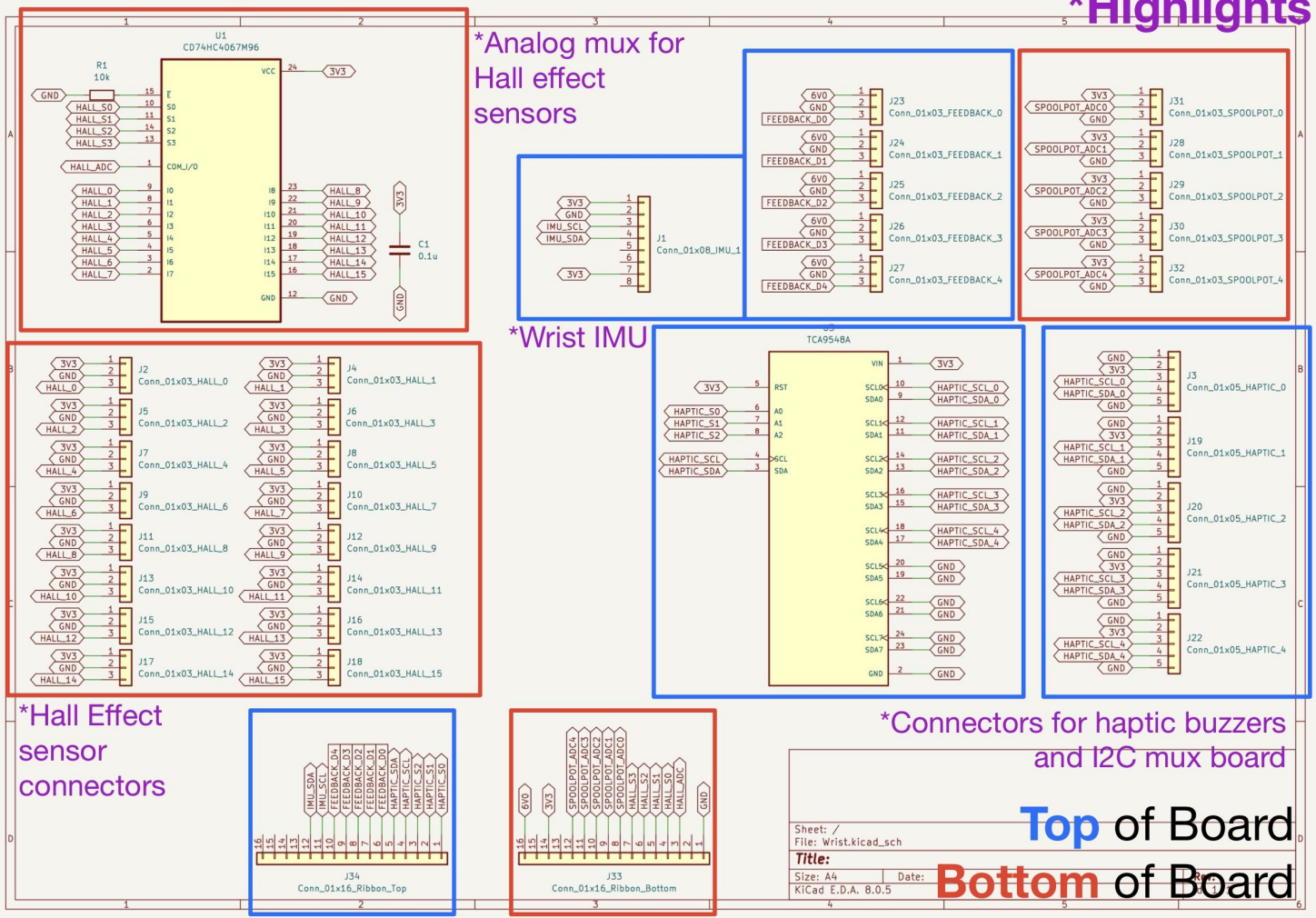
Control Glove Circuit Schematic “Forearm”

*Highlights



Control Glove Circuit Schematic

"Wrist" (Back of Hand)



Test Plan

Robotic Arm Testing

After assembling the finger and thumb assemblies:

- Test 3 Degrees of Freedom (DOF) for each finger to ensure each joint can move independently and with the correct range of motion.
- Test 4 DOF for the thumb to confirm full movement, including opposability.

After assembling the wrist and forearm:

- Test 2 Degrees of Freedom for wrist
- Test 2 Degrees of Freedom for forearm

Control Glove Testing

1. Hall Effect Sensor
- Test the 16 hall effect sensors on a breadboard to ensure they are reading magnetic field changes accurately

2. Finger Linkage Assembly
- Test that the 16 hall effect sensors still work after assembly, ensuring no mechanical interference

3. IMU Accuracy
- Test both IMUs to verify that they provide accurate orientation data post-assembly

4. Communication
- Test sending and receiving packets between ESP32 microcontrollers to verify reliable wireless data exchange

Complete System Testing

1. Communication
- Test that packets are successfully sent and received between both ESP32 microcontrollers in complete system

2. Control
- Test controlling 1 finger with the control glove
- Test controlling all 5 fingers with the control glove
- Test controlling wrist movement using IMU data
- Test controlling forearm and elbow movement using IMU data

3. Haptic Feedback
- Test the haptic response of all 5 fingers to confirm uniform and reliable feedback across all fingers

4. Calibration
- Test the calibration of the control glove to the robotic arm to ensure that hand movements and forces are accurately translated to the robotic system

Timeline

Task	Person	Status	Sept 9 - 15	Sept 16 - 22	Sept 23 - 29	Sept 30 - Oct 7	Oct 7 - 13	Oct 14 - 20	Oct 21 - 27	Oct 28 - Nov 4	Nov 4 - 10	Nov 11 - 17	Nov 18 - 24	Nov 25 - Dec 1	Dec 2 - 8	Dec 9 - 15
Deliverables																
Proposal	All	Due 9/20		All												
Poster	All	Due 9/27			All											
Poster Session	All	Due 10/4				All										
Initial PCB Design (Review)	All	Due 10/14						All								
Midterm Design Review	All	Due 10/15						All								
Integration Testing	All	Due 12/5												All	All	
Final Report	All	Due 12/5													All	
Final Video	All	Due 12/5													All	
Demo	All	Due 12/9														All
Robot Hand Mechanical:																
Full Robot Armature Assembly	Max, Bhargav	Due 10/20						Max, Bharg	Max, Bharg	Max, Bhargav						
Full Robot Hand Assembly	Max	Due 9/29	Max	Max	Max	Max	Max									
CAD of elbow base	Max	Due 10/6						Max								
Integration of IMUs	Bhargav	Due 10/6							Bhargav							
Testing of Robot Hand Mechanical Function	Max, Bhargav	Due 11/24									Max, Bharg	Max, Bharg	Max, Bhargav			
Robot Hand Control:																
Single finger movement	Alex, Jacob	Due 10/13				Alex, Jacob	Alex, Jacob	Alex, Jacob								
All Finger movement	Alex, Jacob	Due 10/27							Alex, Jacob	Alex, Jacob						
Wrist and Forearm movement	Alex, Jacob	Due 11/17									Alex, Jacob	Alex, Jacob				
Control Algorithm Dev.	Alex, Jacob	Due 10/6		Alex, Jacob	Alex, Jacob	Alex, Jacob										
Inter-uC Communication	Alex, Jacob	Due 10/6	Alex	Alex	Alex	Alex, Jacob										
Pressure sensor communication	Jacob	Due 10/27						Jacob	Jacob							
Haptic feedback	Alex, Jacob	Due 10/17								Alex, Jacob	Alex, Jacob	Alex, Jacob				
Testing of Control Algorithms w/ Robot Hand	Alex, Jacob	Due 11/24										Alex, Jacob	Alex, Jacob			
Glove Mechanical:																
Full Haptic Glove	Max, Bhargav	Due 11/24								Max, Bharg	Max, Bharg	Max, Bhargav				
Single Haptic finger with angle sensors	Max	Due 10/27						Max								
CAD design of wrist and back of hand housing	Max	Due 11/3							Max							
Testing of Mechanical Function	Max, Bhargav	Due 11/24										Max, Bharg	Max, Bhargav			
Glove Electrical:																
Haptic Module Development	Bhargav	Due 10/20	Bhargav	Bhargav	Bhargav	Bhargav	Bhargav	Bhargav								
IMU Design	Jackson	Due 9/29	Jackson	Jackson	Jackson											
IMU Communication	Jackson	Due 9/29			Jackson											
Intial Glove PCB	Jackson	Due 10/13			Jackson	Jackson	Jackson									
Final Glove PCB	Jackson	Due 11/3						Jackson	Jackson	Jackson						
Sensor Signal Processing Dev.	Jacob	Due 9/29	Jacob	Jacob	Jacob											
PCB Testing	Jackson	Due 11/17								Jackson	Jackson	Jackson				
Testing of Glove Electrical Function	Bhargav	Due 11/24										Bhargav	Bhargav			

Questions?