Herbert Wertheim College of Engineering
UNIVERSITY *of* FLORIDA

Global Grip Solutions™

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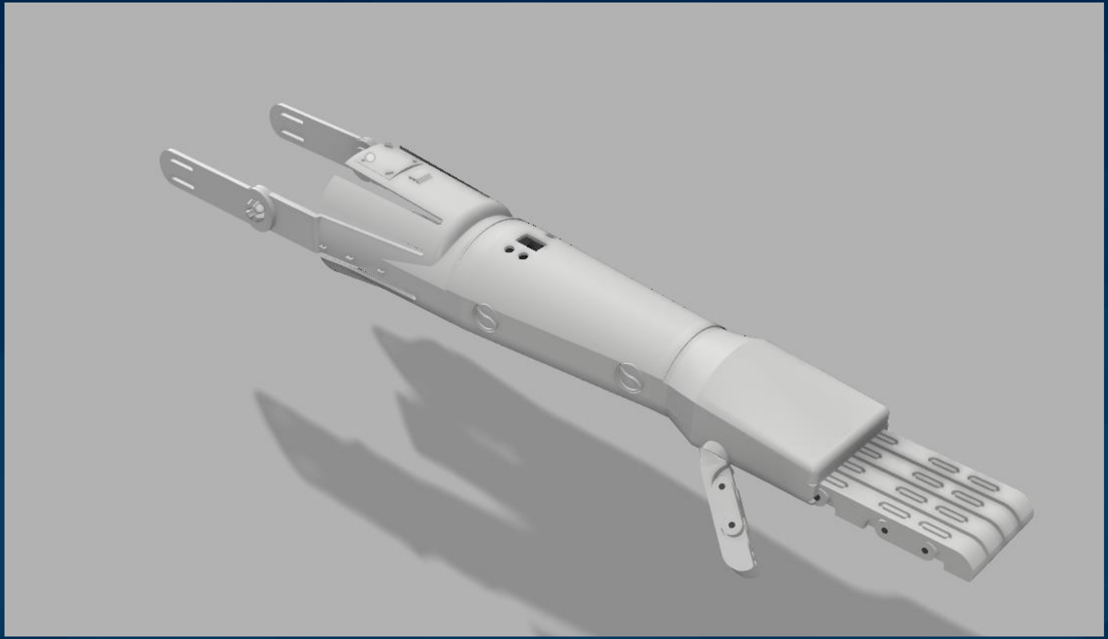


Presentation Outline

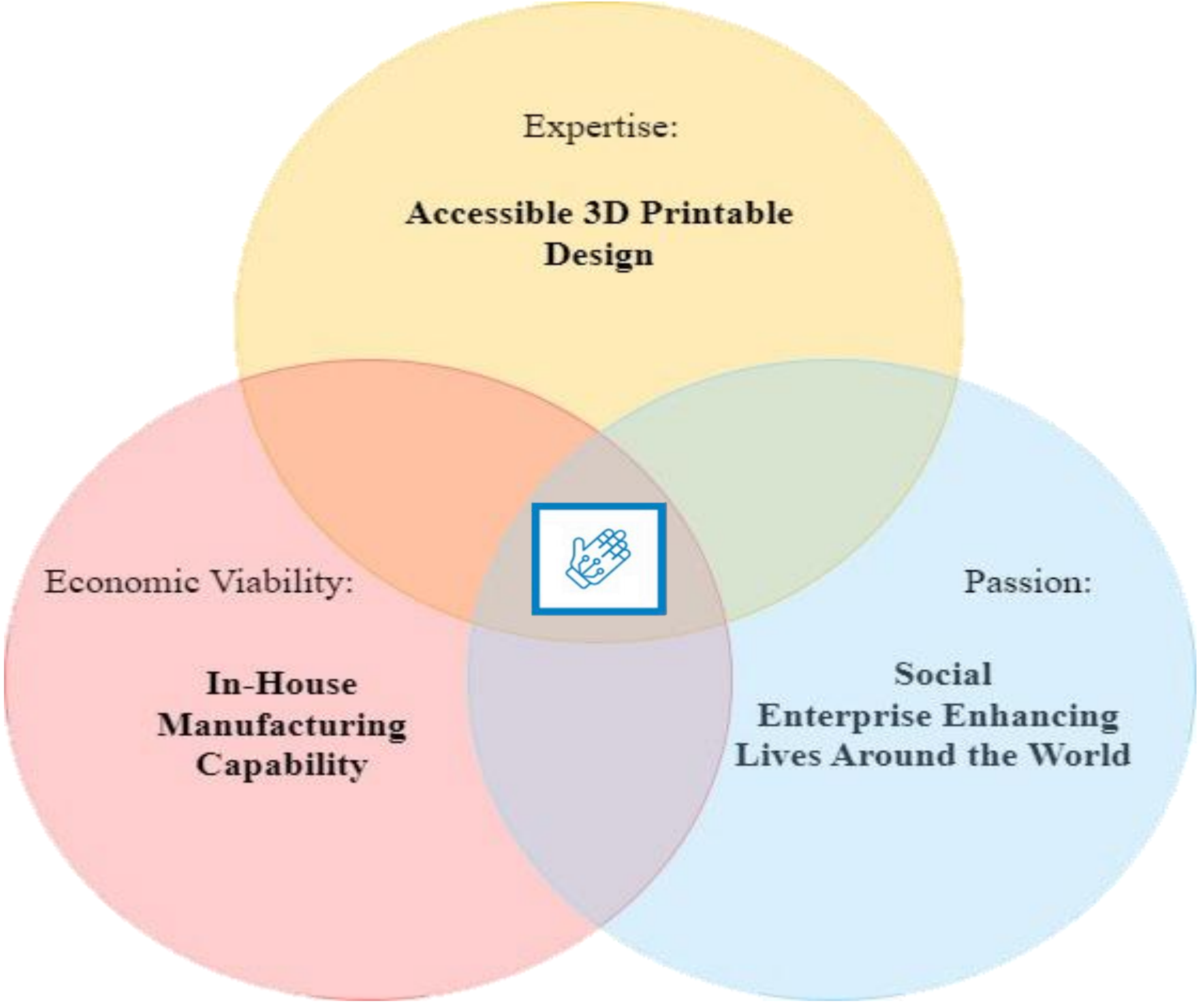
- Customer Needs
- Our Hedgehog Concept
- Evolution of Product
- Product Specifications
- Product Features
- Electrical Diagram and Layout
- Software Overview
- Test Protocols and Results
- Cost Overview
- Potential Improvements

Customer Needs

- Affordable
- Functional
- Easy to use
- Long-lasting
- Accessible
- Universal
- Customizable
- Smart-feature
- Safe to use
- Potential AI Implementation

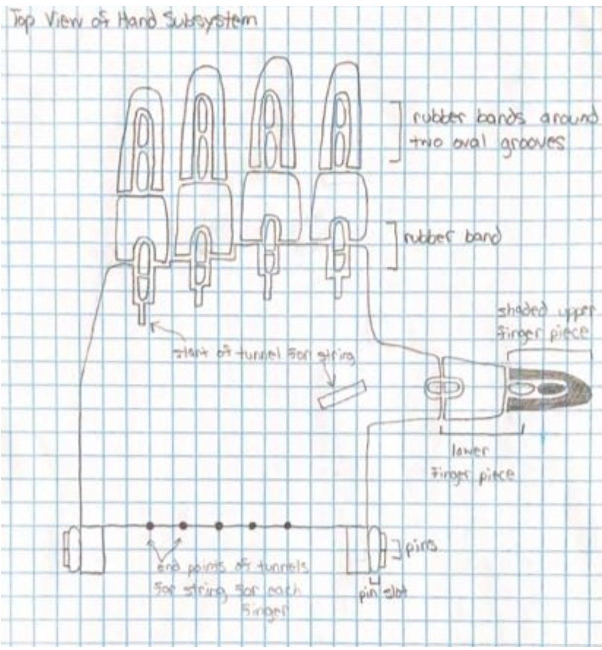
Hedgehog Concept

By designing our product to be majority 3D printed and allowing for in-house manufacturing in developing countries, we are improving the lives of people who would otherwise be forced to struggle every day with below-elbow deformities.

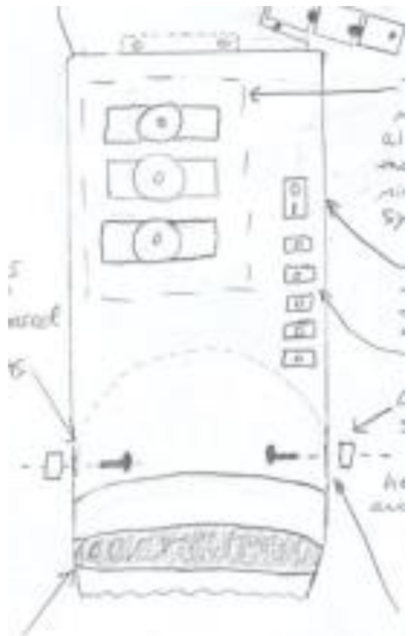


Evolution of Our Product

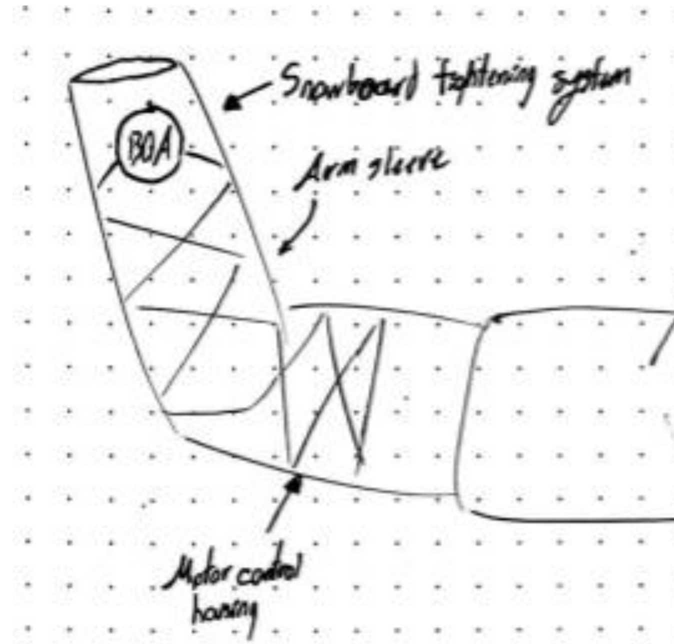
- Started off design concept with individual design sketches by each group member
- Used binary trade study to select best overall design



Hand Articulation Sketch



Forearm Sketch



Limb Attachment Sketch

Evolution of Our Product

Hand							
Cost	Aesthetically Pleasing	Functionality	Ease of Repair	Reliability	Ease of Use	Durability	Weight
A	B	C	A	E	F	A	A
	B	C	B	E	F	G	B
		C	C	C	C	C	C
			D	E	F	G	H
				E	E	E	E
					F	G	F
						G	G
							H

Metric	Count	Weight
Cost	3	0.11
Aesthetically Pleasing	3	0.11
Functionality	7	0.25
Ease of Repair	0	0.00
Reliability	6	0.21
Ease of Use	4	0.14
Durability	4	0.14
Weight	1	0.04

Hand							
Cost	Aesthetically Pleasing	Functionality	Ease of Repair	Reliability	Ease of Use	Durability	Weight
A	A	A	A	E	A	G	A
	B	C	D	E	F	G	H
		C	C	C	F	G	C
			D	E	D	G	D
				E	E	E	E
					F	F	F
						G	G
							H

Metric	Count	Weight
Cost	5	0.18
Aesthetically Pleasing	0	0.00
Functionality	4	0.14
Ease of Repair	3	0.11
Reliability	6	0.21
Ease of Use	4	0.14
Durability	5	0.18
Weight	1	0.04

Hand							
Cost	Aesthetically Pleasing	Functionality	Ease of Repair	Reliability	Ease of Use	Durability	Weight
A	A	C	A	E	F	G	H
	B	C	B	E	F	G	H
		C	C	C	C	C	C
			D	E	F	G	H
				E	E	E	E
					F	G	F
						G	H
							H

Metric	Count	Weight
Cost	2	0.07
Aesthetically Pleasing	1	0.04
Functionality	7	0.25
Ease of Repair	0	0.00
Reliability	6	0.21
Ease of Use	4	0.14
Durability	4	0.14
Weight	4	0.14

Hand Articulation Binary Trade Study

Evolution of Our Product

- Initial design prototypes

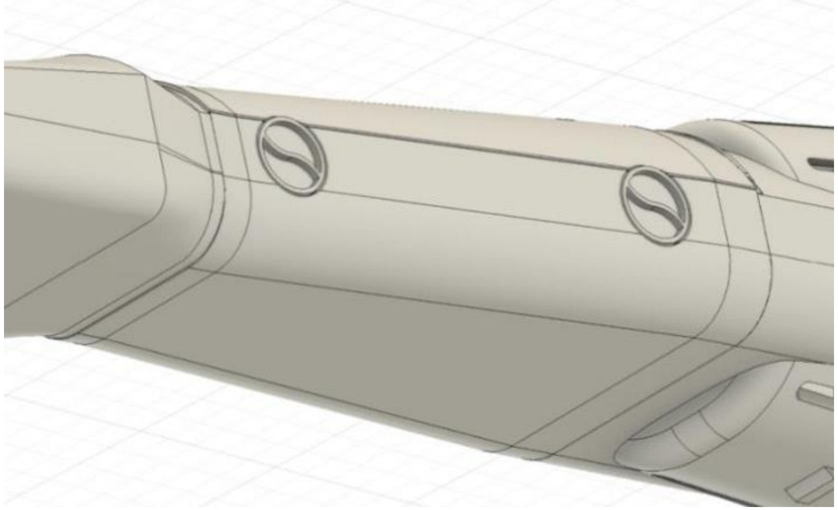
Cardboard Prosthetic Assembly Prototype

Initial CAD Prototype

Evolution of the Forearm Housing

- Original design
  - 6 OTS screws to close the forearm housing

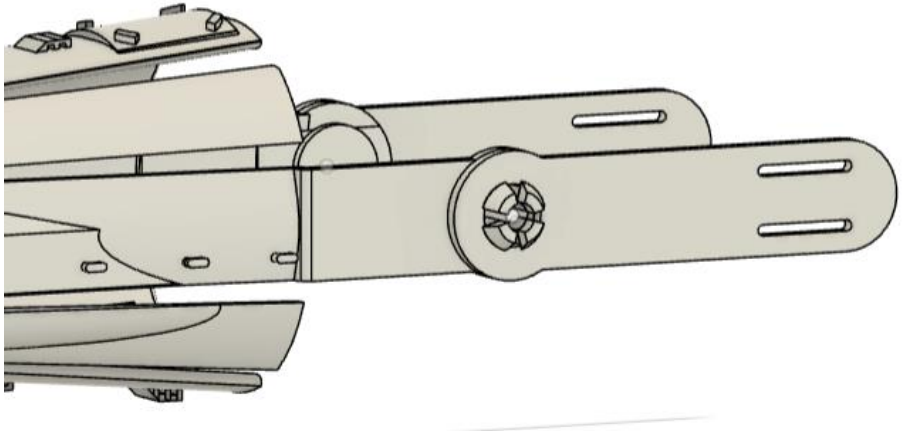
- Updated design
  - 4 3D-printed shrink cap fasteners to close the forearm housing
  - Closed forearm attaches palm and limb attachment



Evolution of the Limb Attachment

- Original design
  - 2 OTS screws fasten limb attachment to Velcro arm attachment

- Updated design
  - 2 3D-printed snap-fasteners attach limb attachment to Velcro arm attachment
  - Provides 360-degree rotation for elbow bending



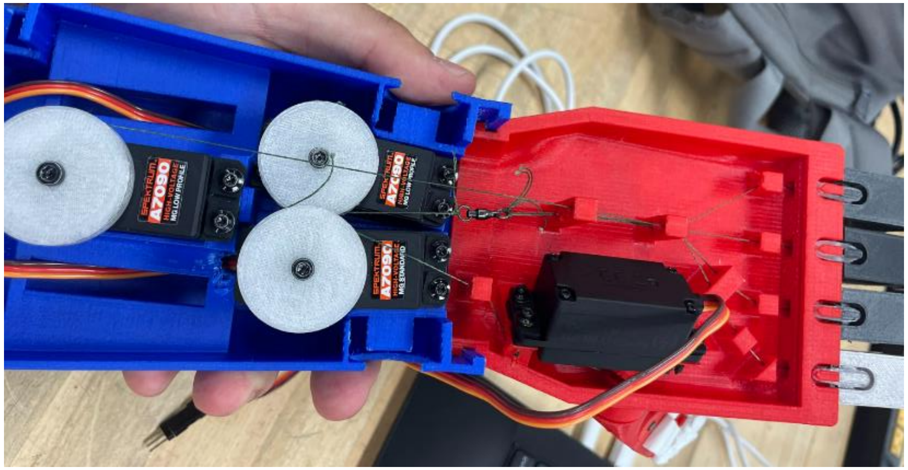
Key Product Specifications

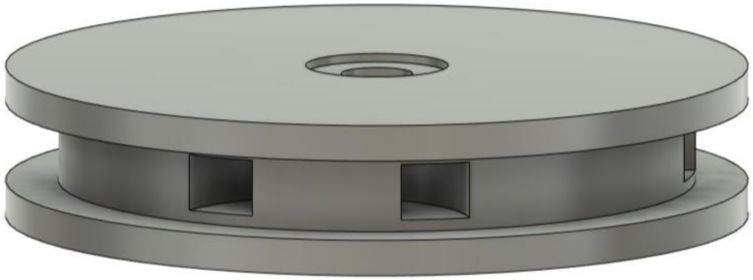
- Weight – 1.93 lbs.
- Motors (x4) – 18.0 kg-cm (15.62 lb-in)
- Batteries (x3) – 1800 mAh | 9V
- Battery life: 4+ hours
- Recharge time: 2 hours
- Structural load sustained: 60+ lbs.
- Material: 3D-printed PETG

Motor Spool Diameter Calculations

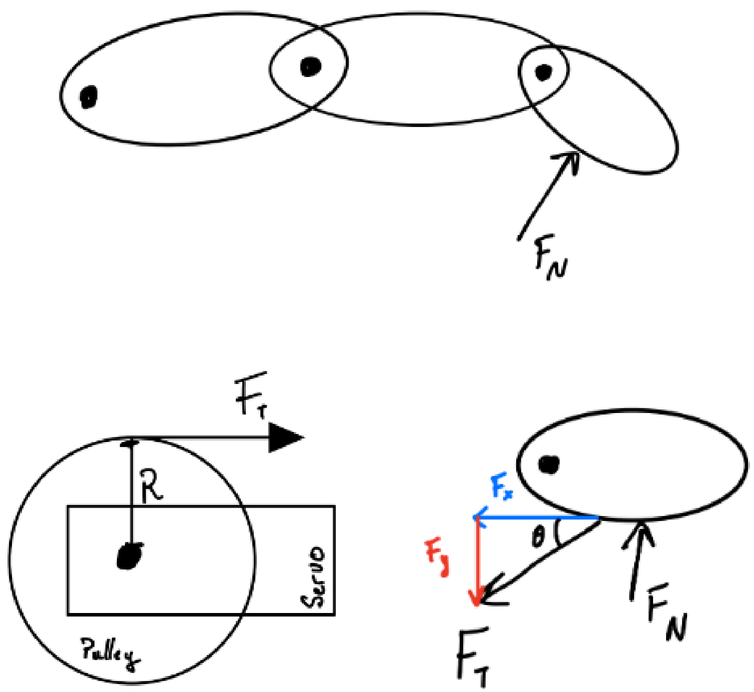
- Distance line must be pulled for full finger actuation: 1.1 inches
- Motor rotation: 120 degrees
- Diameter necessary for finger actuation: 1.05 inches

$$D = \frac{1.1\ in}{\left(\frac{120°}{360°}\right)}\left(\frac{1}{\pi}\right) = 1.05\ in$$





Motor Torque Determination



$$F_T = \frac{F_N}{\sin\theta} + F_E + F_\mu = String\ Tension$$

$$F_N = 10\text{lbs} = Grip\ Strength \qquad \theta = 30^\circ$$

$$F_E = 3 \times 0.41\ lbs\ (\text{tension of rubber bands}) = 1.2\ lbs$$

$$F_\mu = (N \times \mu) \times 3 = (10lbs \times 0.25) \times 3 = 7.5lbs$$

$$F_T = 20l\text{bs} + 1.2l\text{bs} + 7.5l\text{bs} = 28.7l\text{bs}$$

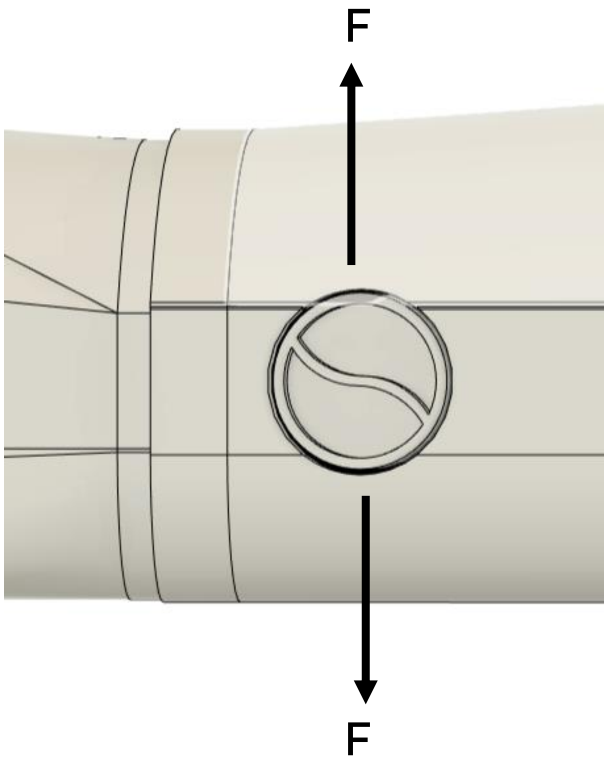
$$T_s = Servo\ Torque = F_T \times R = 28.7lbs \times 0.525in$$
$$= 15.06lbs - in\ or\ 17.35kg - cm$$

Free Body Diagram of the Finger Motor Pairing

Motor Requirements vs. Actual Motor Specifications

Factor of Safety

- Assuming 20 lbs. impact to forearm fastener
- The actual force the fastener can withstand is 67.5 lbs.
  - Based on testing from performance evaluation 2



$$F_i = 20\ lbs$$

$$F_a = 67.5\ lbs$$

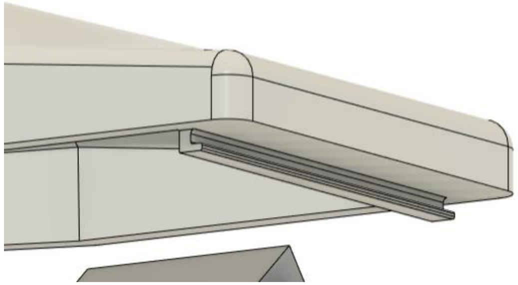
$$FOS = \frac{67.5\ lbs}{20\ lbs} = 3.4$$

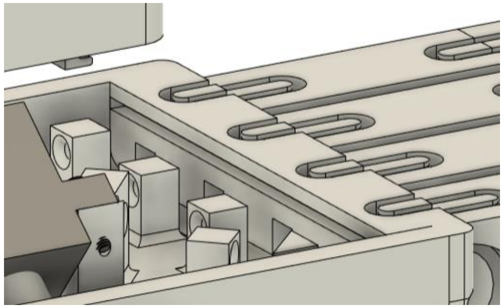
Key Product Features

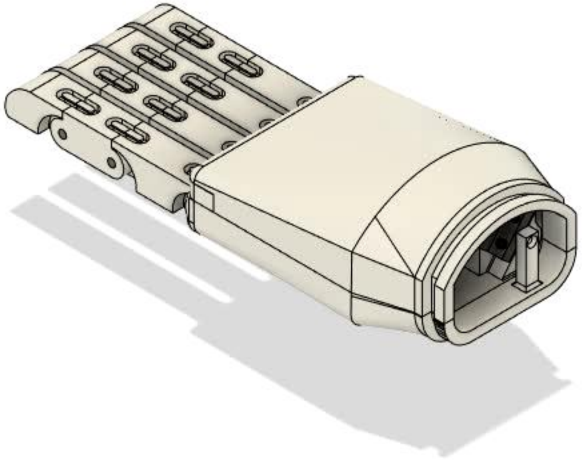
- 3 subsystems
- 3D printed parts replaced OTS parts
  - Easy manufacturability & more accessibility
- BOA Lacing system
  - Ease of use & wide range of fit
- Myoelectric sensors (EMG)
  - Allows for intuitive user control
  - Later AI implementation
- Rotating Thumb
  - Allows for functionality
- Rechargeable batteries
- Manual override buttons
- On/Off Switch

Hand Subassembly - Overview

- Fingers are attached to palm with press fit rod
- Thumb is attached with press fit to motor shaft
- Top of palm slides into slot on the bottom palm
  - Forearm attaches over the palm holding it in place without fasteners

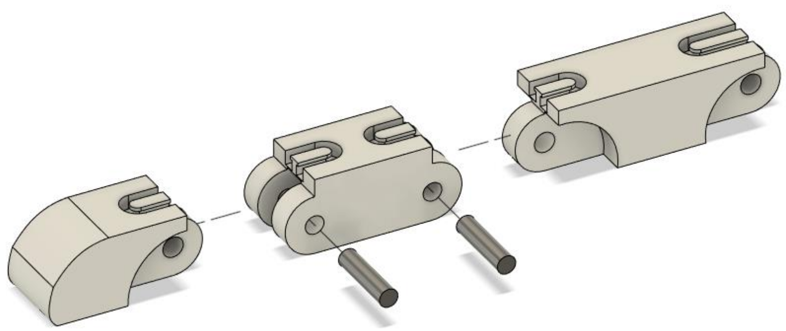


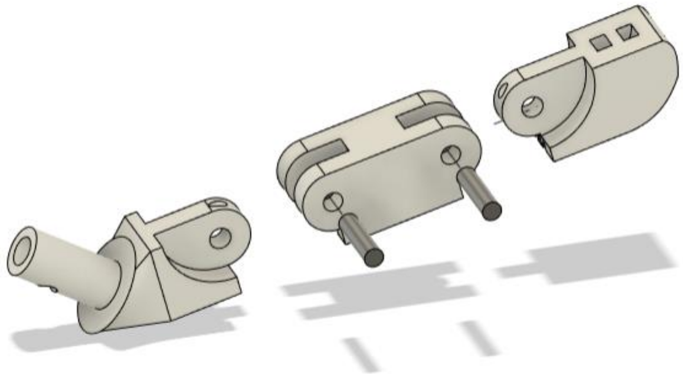




Hand Subassembly - Finger and Thumb

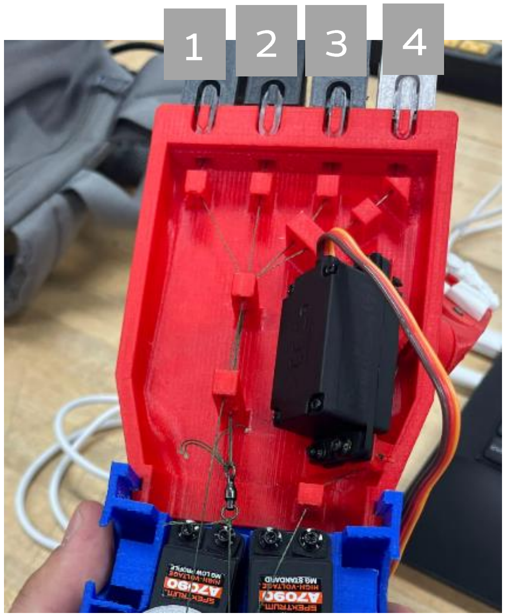
- Opening/closing is powered by tendon driven system
  - Fishing line is tied at the fingertip
  - Line is strung through channels on the bottom side of fingers
  - Rubber bands are placed in channels on the top side of the fingers
- Steel pins are used as joints
  - Press fit between the pin and the middle 3D-printed finger piece

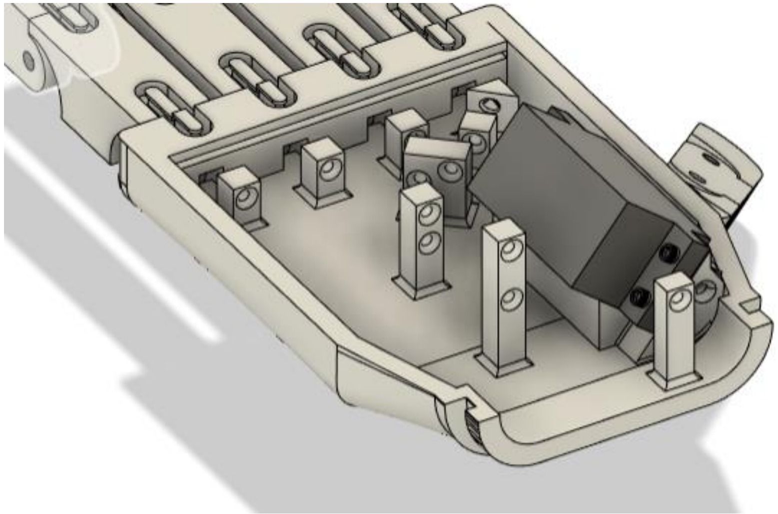


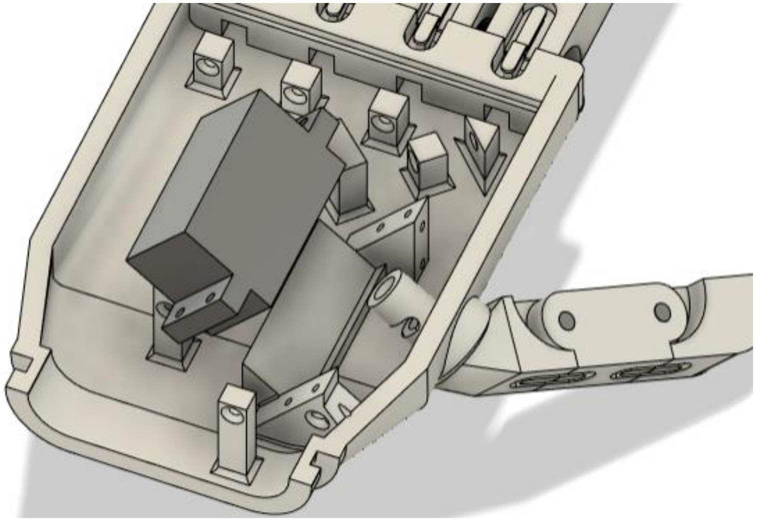


Hand Subassembly - Palm Interior

- Raised guides are extruded off the base of the palm
  - Guides for the fishing line
  - Swivel attaches fingers 1-3 together
  - Finger 4 actuated by 1 motor
  - Thumb actuated by 2 motors
- Angled platform for the motor
  - Motor connects to thumb to actuate thumb rotation

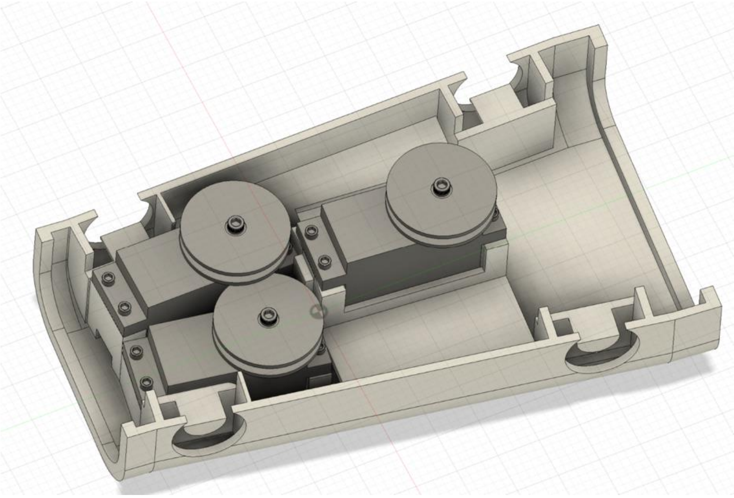


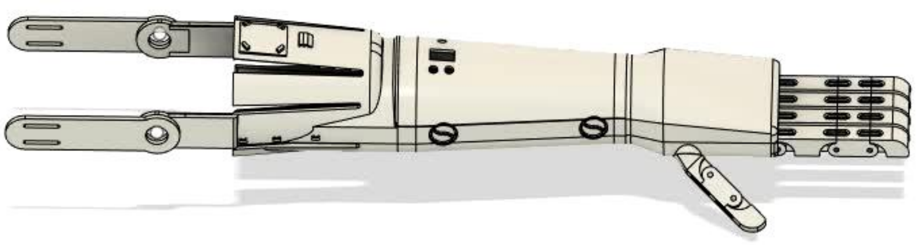




Forearm Housing - Overview

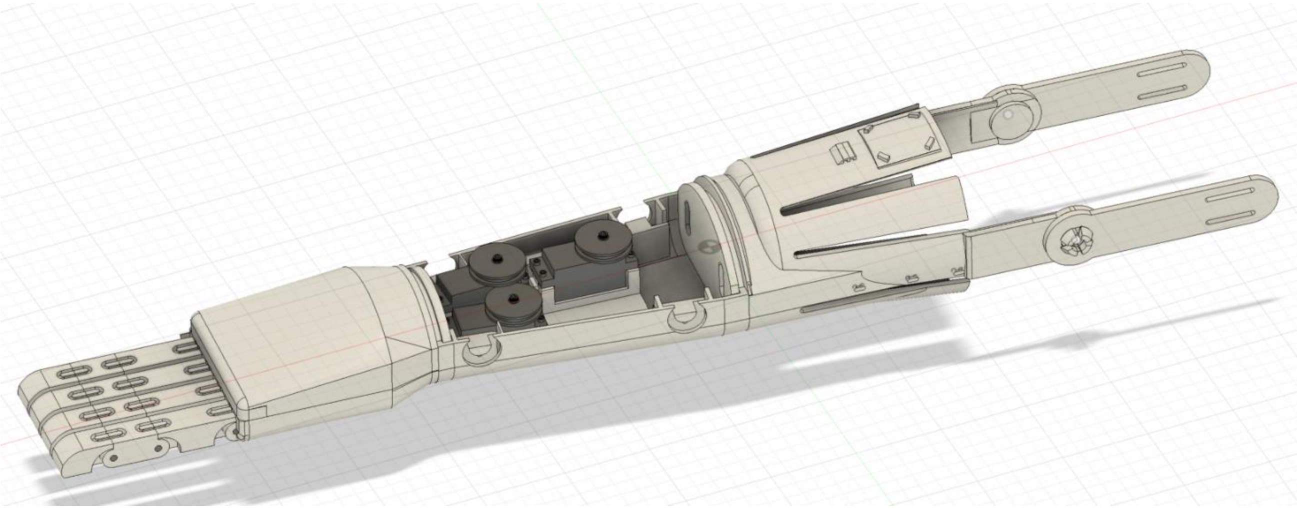
- Houses almost all electronics and mechanical components
- Fishing line tied through to motor spools
- Top and bottom of housing close over the hand and limb attachment

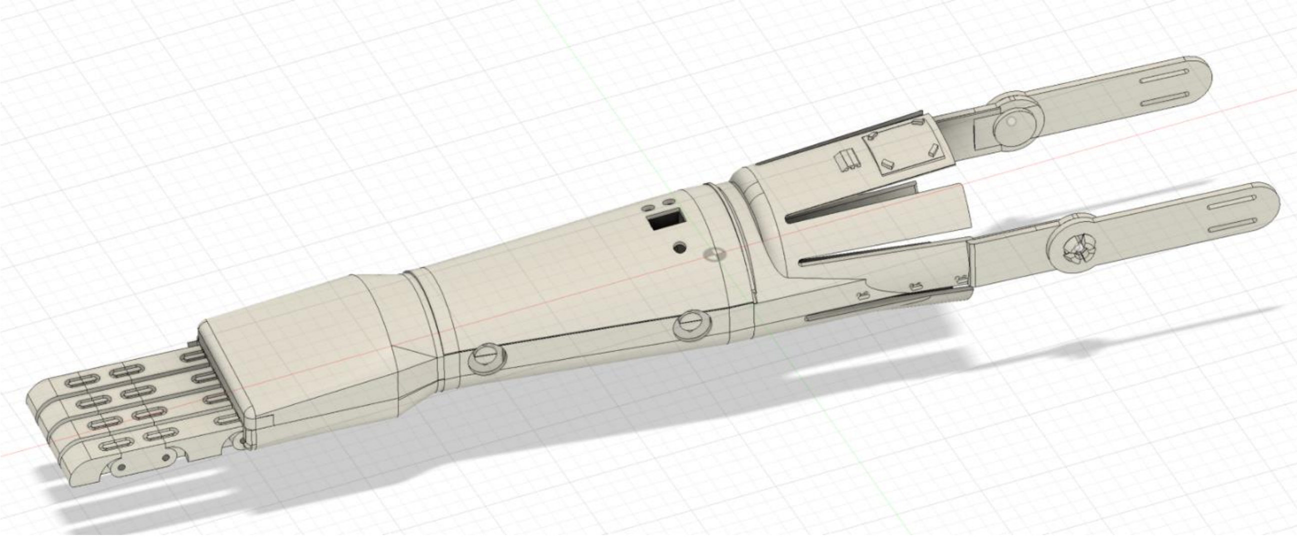




Forearm Housing – Subassembly Fastening

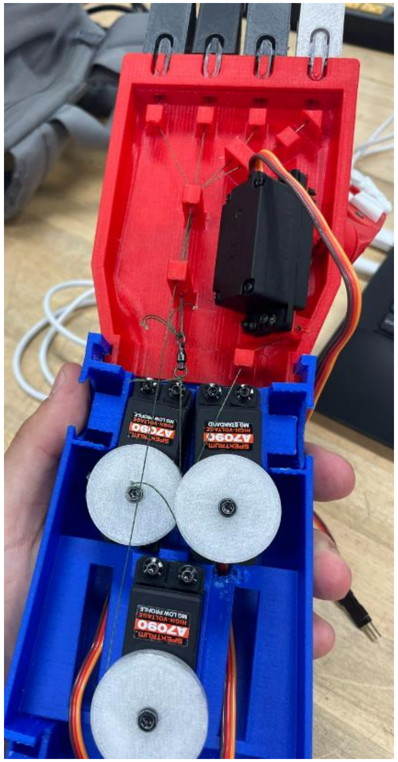
- 3D-printed fasteners secure limb attachment and palm in place
- Dust and water-resistant casing
- Manual controls mounted on forearm top





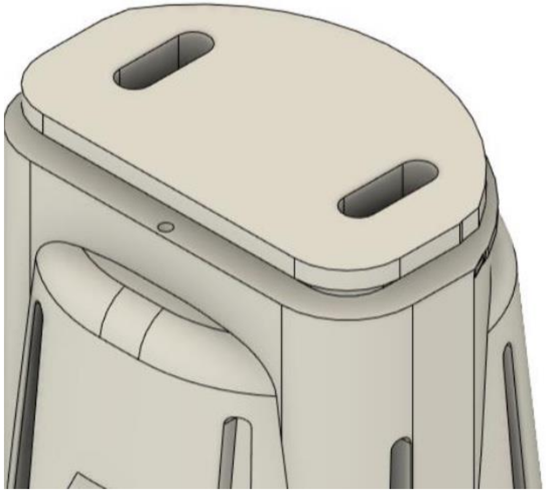
Motor Selection and Electrical Component Placement

- Servo motors used for finger actuation and thumb rotation
  - A7090 Brushless Low Profile Metal Gear HV Servo
- Torque chosen based on force necessary to pull fishing line
  - 18 kg-cm (15.62 lb-in)
- 3D-printed spools
  - Lines are connected to spools
  - Reel in line when motor is on
- Wired to back of forearm, connected to Arduino



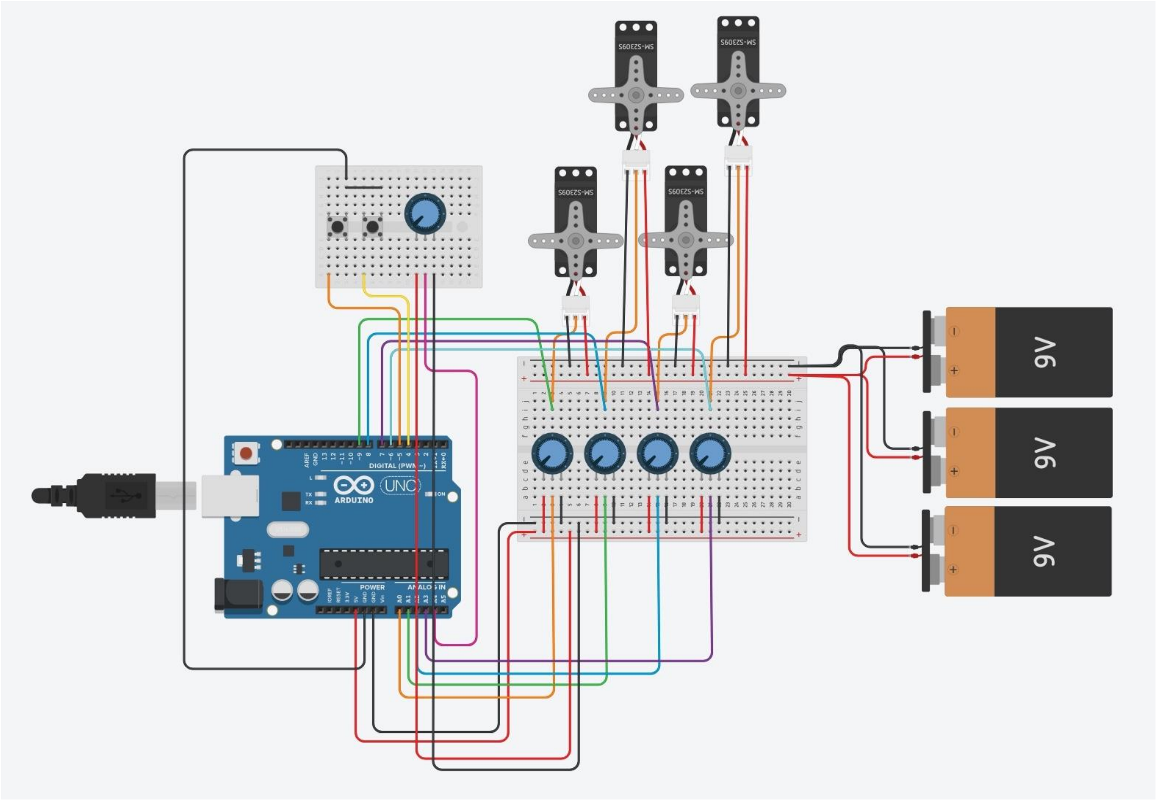
Limb Attachment - Overview

- Flexible PETG geometry
- BOA Fit System for tightening
- Internal foam adhesive padding for comfort
- 3D-printed hinges
- Velcro strap for upper-arm support
- Openings for myoelectric cables

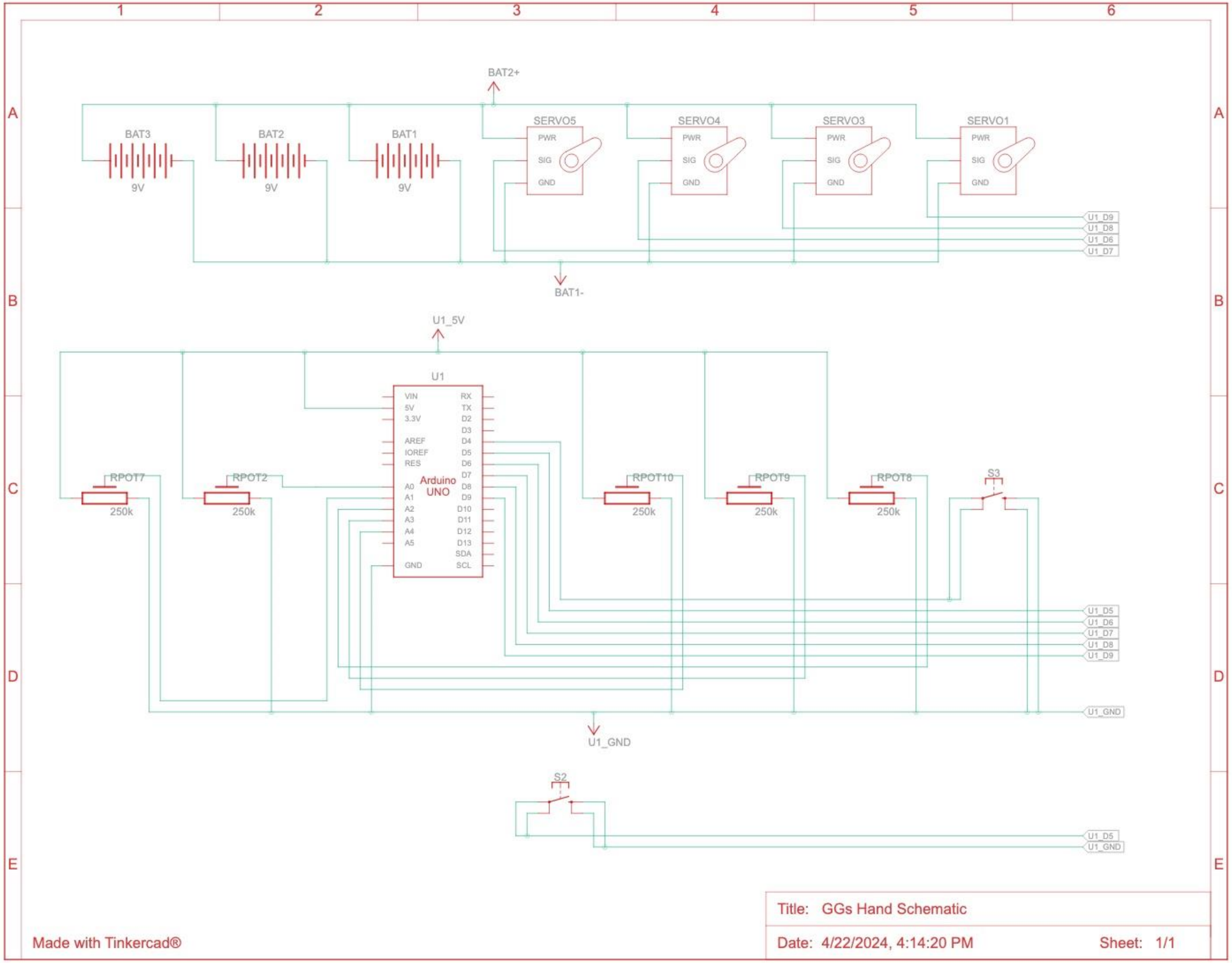


Electrical Layout

- Three 9V Batteries powering Arduino and motors
- 4 myoelectric sensors, analog inputs
  - Represented as potentiometers
- Manual controls
  - On/Off Switch
  - 2 push buttons – open and close grip
  - Potentiometer – cycle through grip presets

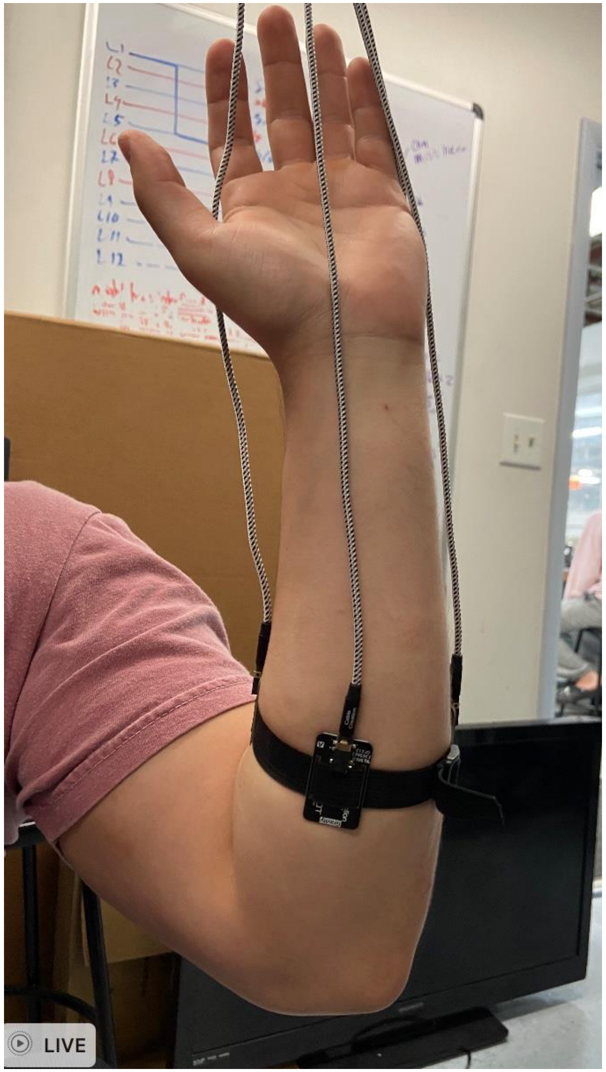


Electrical Schematic



Myoelectric Sensors (EMG Control)

- Reads electric pulses inside muscles
- Provides analog input to Arduino
- 4 different locations provides more data
- Placed along residual limb
- Wired through limb attachment
- Flex inner arm for close grip
- Flex outer arm for open grip



Myoelectric Sensors Improvements

- Noise filtering
  - Current data is jumpy
  - Need to filter input for consistent grip

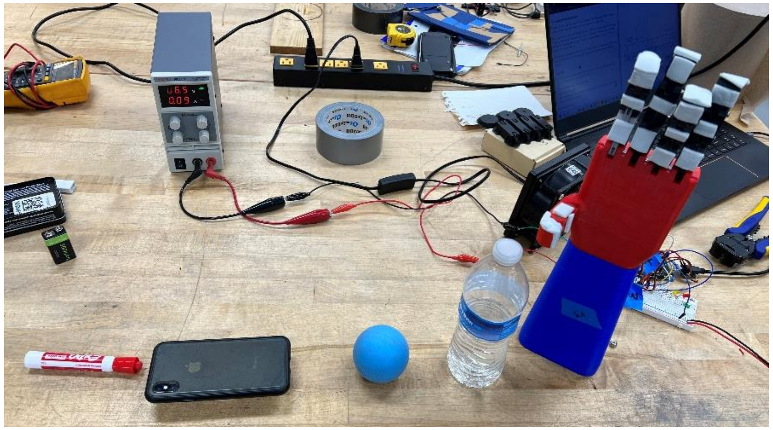
- Artificial Intelligence Implementation
  - Can identify user's desired grip
  - Filters EMG inputs intelligently
  - Outputs desired grip configuration

- Inconsistency with sensor placement
  - Varies from user to user
  - Can change values of inputs

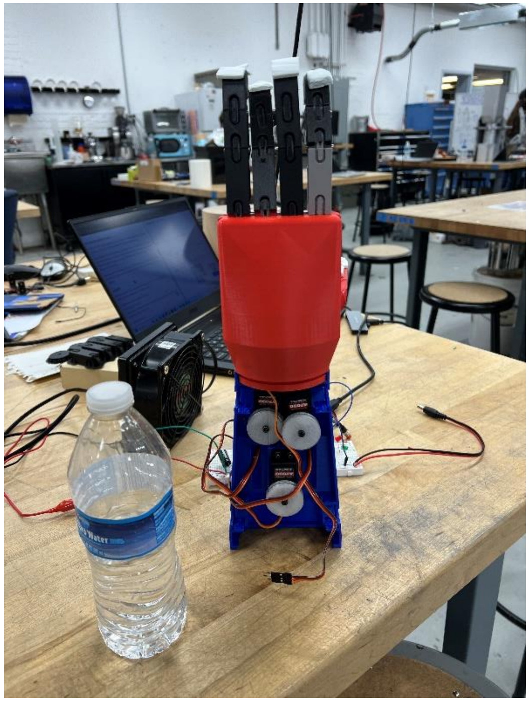
Current Code Structure

- Initialization sets threshold values
- Potentiometer selects desired grip
- Myoelectric sensor data is filtered (low-pass and high-pass)
- Inner arm flex closes grip
- Outer arm flex opens grip
- Output grip depends on potentiometer position
- Open/Close override buttons
- On/off switch to disconnect circuit

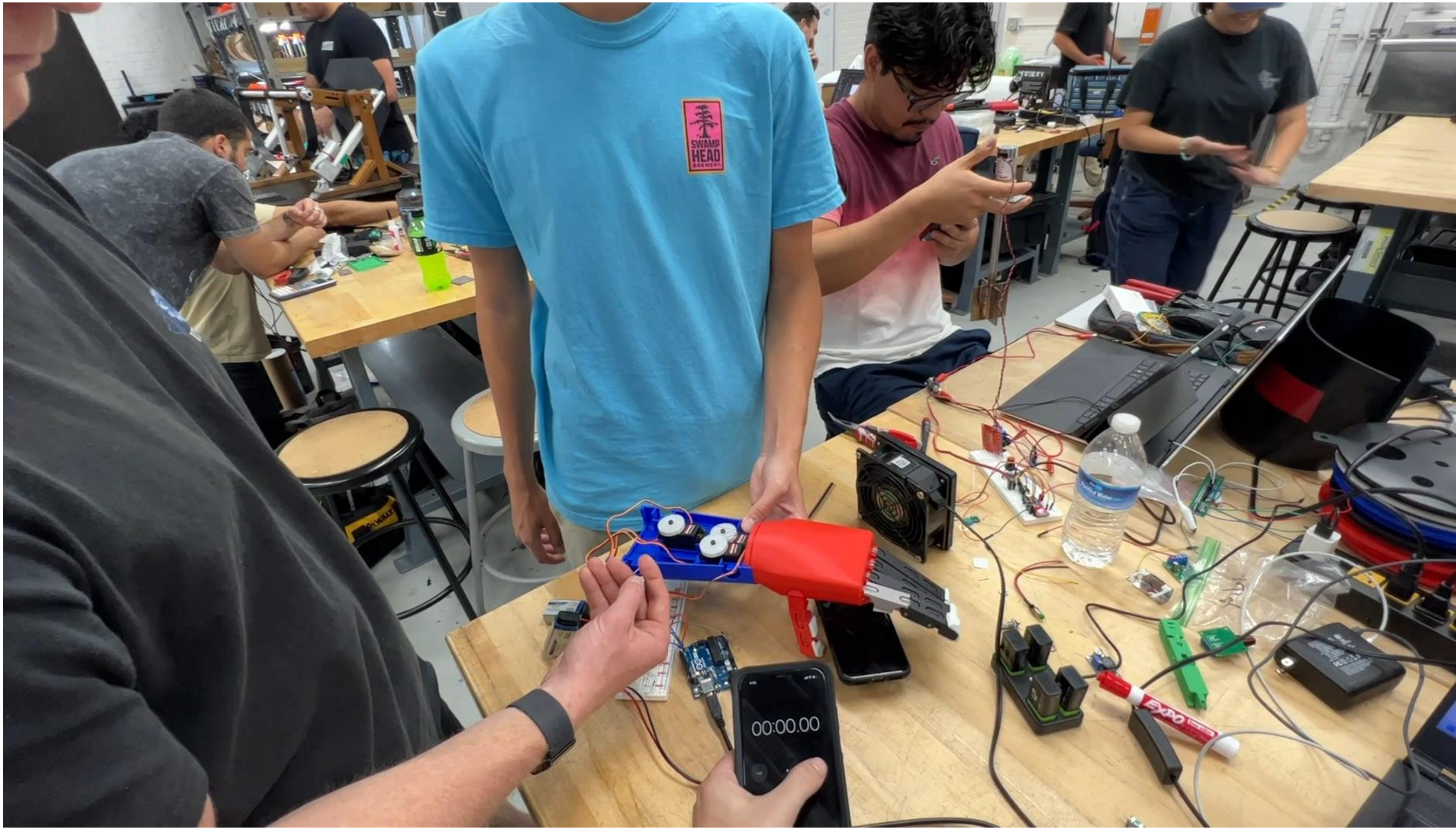
Performance Evaluation 1



- Customer need #6
  - Achieve as many hand grasps as possible
  - Ability to handle variety of everyday objects
- The test was broken up into 3 sections
  - Gripping Success Test
  - Rotation Test
  - Shake Test
- 4 unique objects tested
  - Water bottle, Expo marker, lacrosse ball, and phone
- 98% success rate

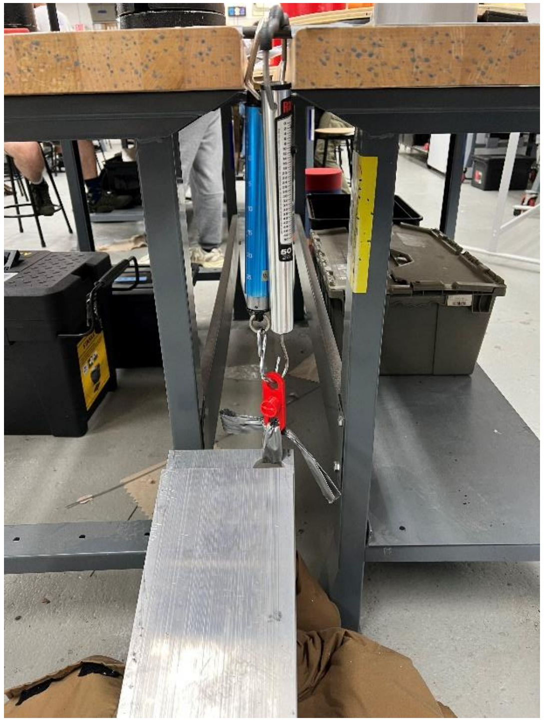


Performance Evaluation 1



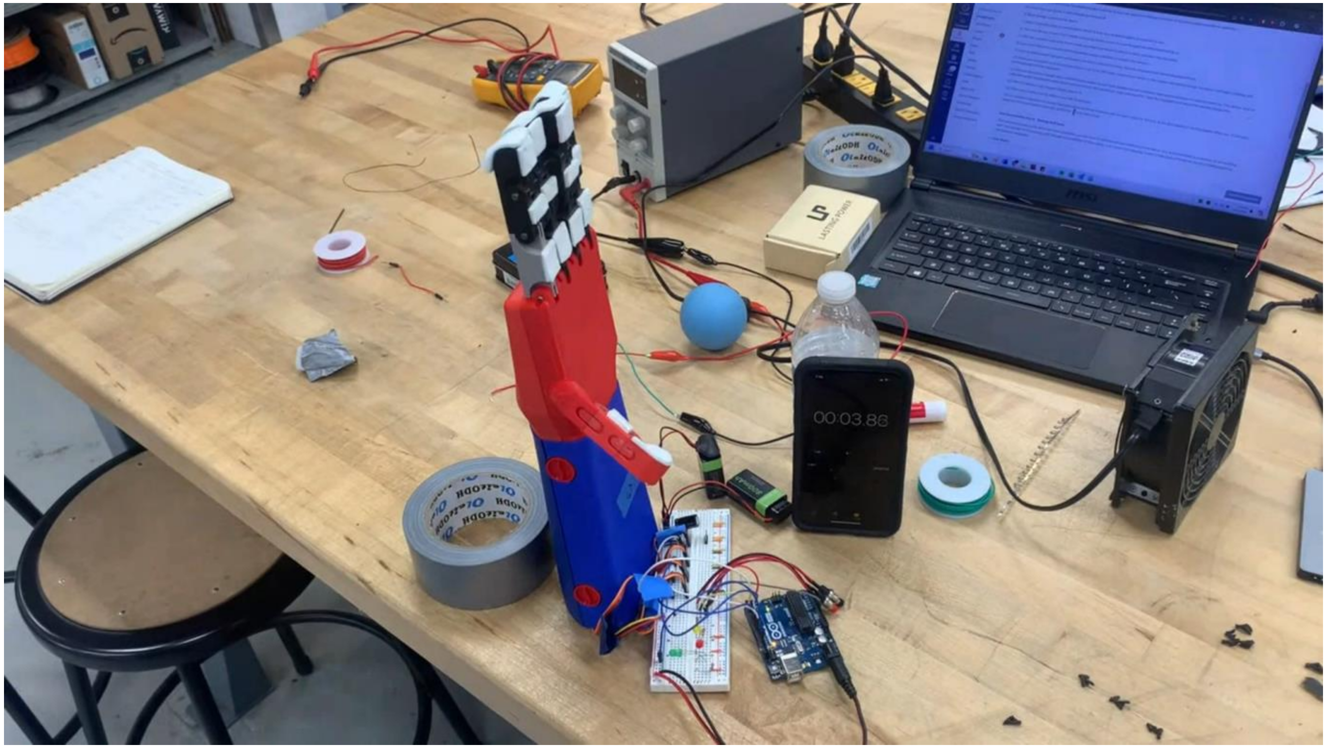
Performance Evaluation 2

- Customer need #23
  - Resistant to recurring impact
- Tested strength of 3D-printed fasteners
- Fasteners achieve ultimate failure at ~67.5 pounds



Performance Evaluation 3

- Customer need #15
  - 3 hours of heavy use between recharges
- Tested lifespan while cycling through grip configurations
- Battery lifespan of 4 hours and 35 minutes



Product Demonstration

Cost Table Summary

- The total cost to produce one prototype was **$779.58**. This is safely below the $1500 limit set for developing a prototype R&D artifact.
- The total cost for a representative batch manufacturing run was **$695.52**. It can be seen that the per-unit batch cost is less than the cost associated with developing a single prosthetic arm prototype ($779.58).

Prototype Cost

Cost Description	Qty	Unit	Unit Price	Subtotal
OTS Parts	-	Total Packs	$766.22	$766.22
3D Printing	-	-	$12.78	$12.78
Energy	3.44 kWh	$/kWh	0.17	$0.58
Assembly Cost	-	-	-	$0.00
			Total Cost	**$779.58**

Per-Unit Batch Cost

Cost Description	Qty	Unit	Unit Price	Subtotal
OTS Parts	-	Total Individual Parts	$679.91	$679.91
3D Printing (10% discount applied)	-	-	$11.50	$11.50
Energy	3.44 kWh	$/kWh	0.17	$0.58
Assembly Cost	0.06 h	$/h	56.74	$3.53
			Total Cost	**$695.52**

Future Potential

Global Grip Solutions'™ design should be integrated into future EML4502 students' projects because of the following:

- Working prototype
- Unique Hedgehog Concept
- Creative features
  - BOA Fit System
  - Foam padding
  - 3D-printed fasteners
  - Myoelectric sensors
- Potential for AI Implementation

Looking Forward

- AI Neural Network Implementation
- AI Training by GGS™ rather than the user
- Tactile Sensor Feature Addition
- Human-like aesthetics and contouring
- Thumb redesign for higher functionality
- Consider wear of motor spools
- Fishing line and elastic rubber bands replacement

Conclusion

- Functional, affordable, and highly accessible for a wide range of users
- Utilizes 3D printing, myoelectric sensors, and the potential for artificial intelligence implementation
- Fits users of different sizes and residual limb geometries and is color-customizable
- Value proposition focuses on intuitive functionality and high accessibility, built to be fully 3D-printed in developing countries
- Protected by trademark and IP protection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