Project Documentation 3

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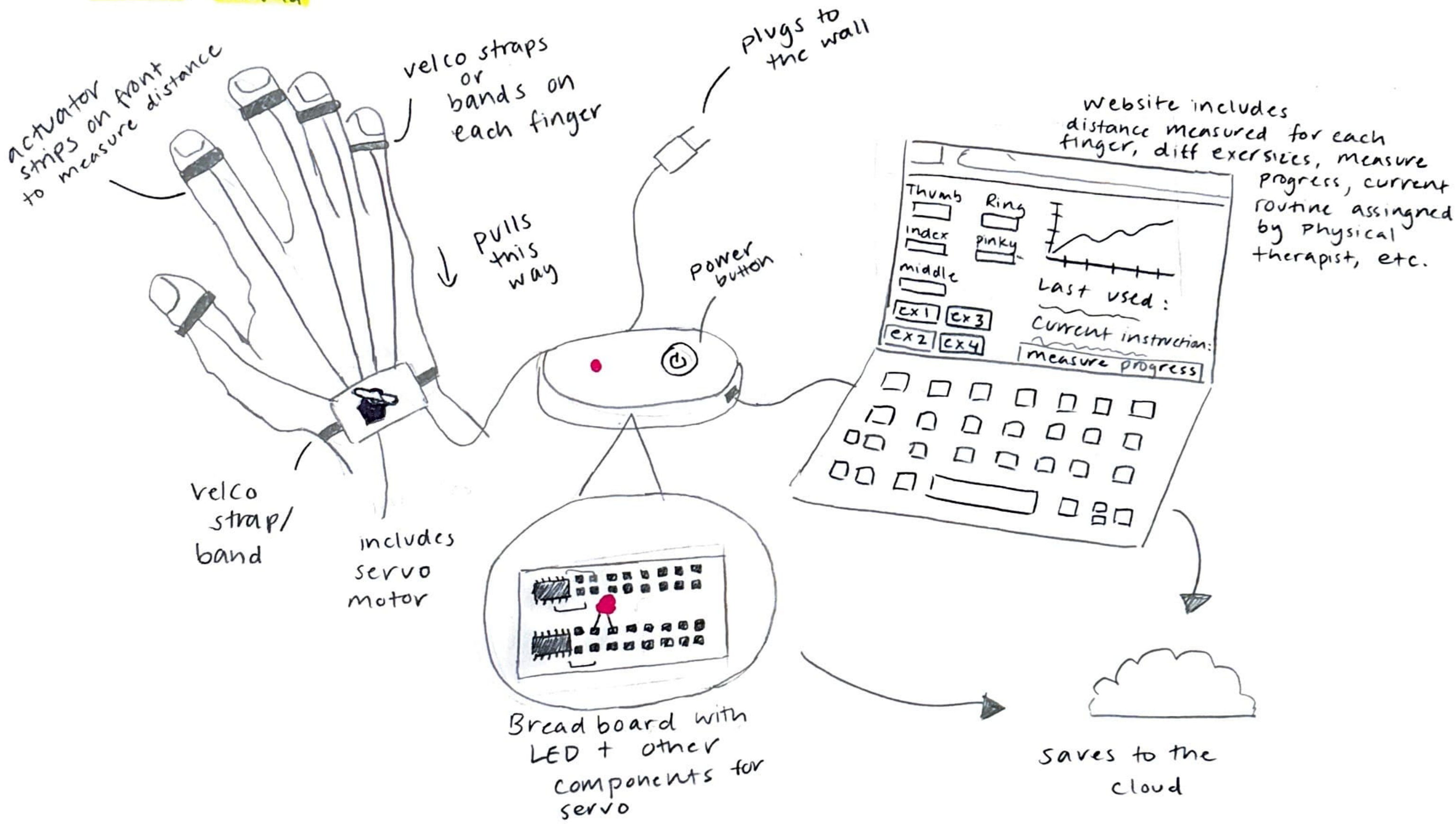
Github

1 Design for Manufacture and Assembly

FRONT VIEW

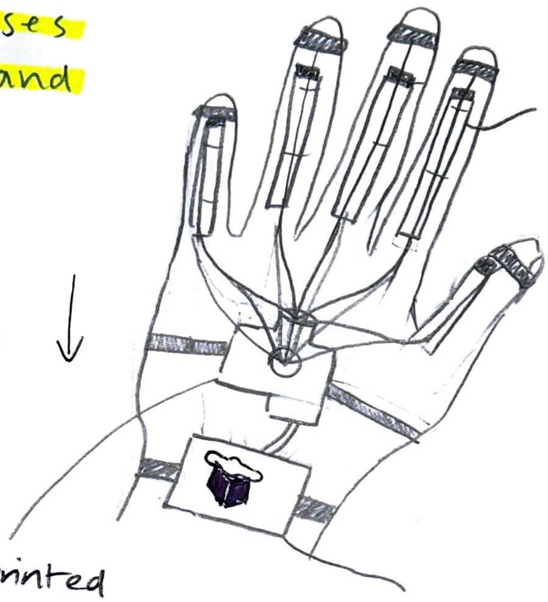
opens hand



BACK VIEW

-Attaches the same way as front view

closes hand



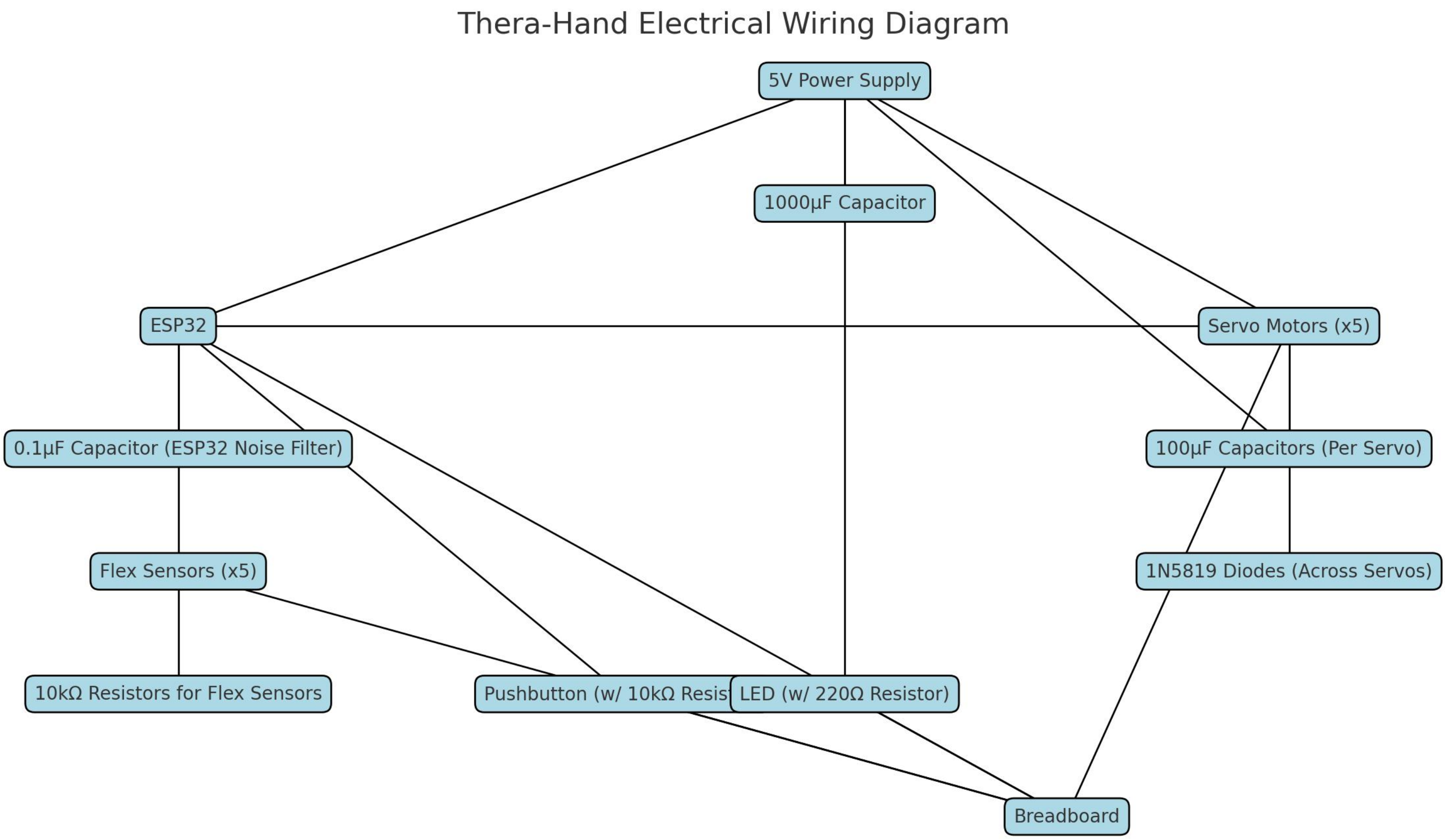
actuator strips attached using double-sided 3M VHB tape/velcro Placed first to be underneath strings.

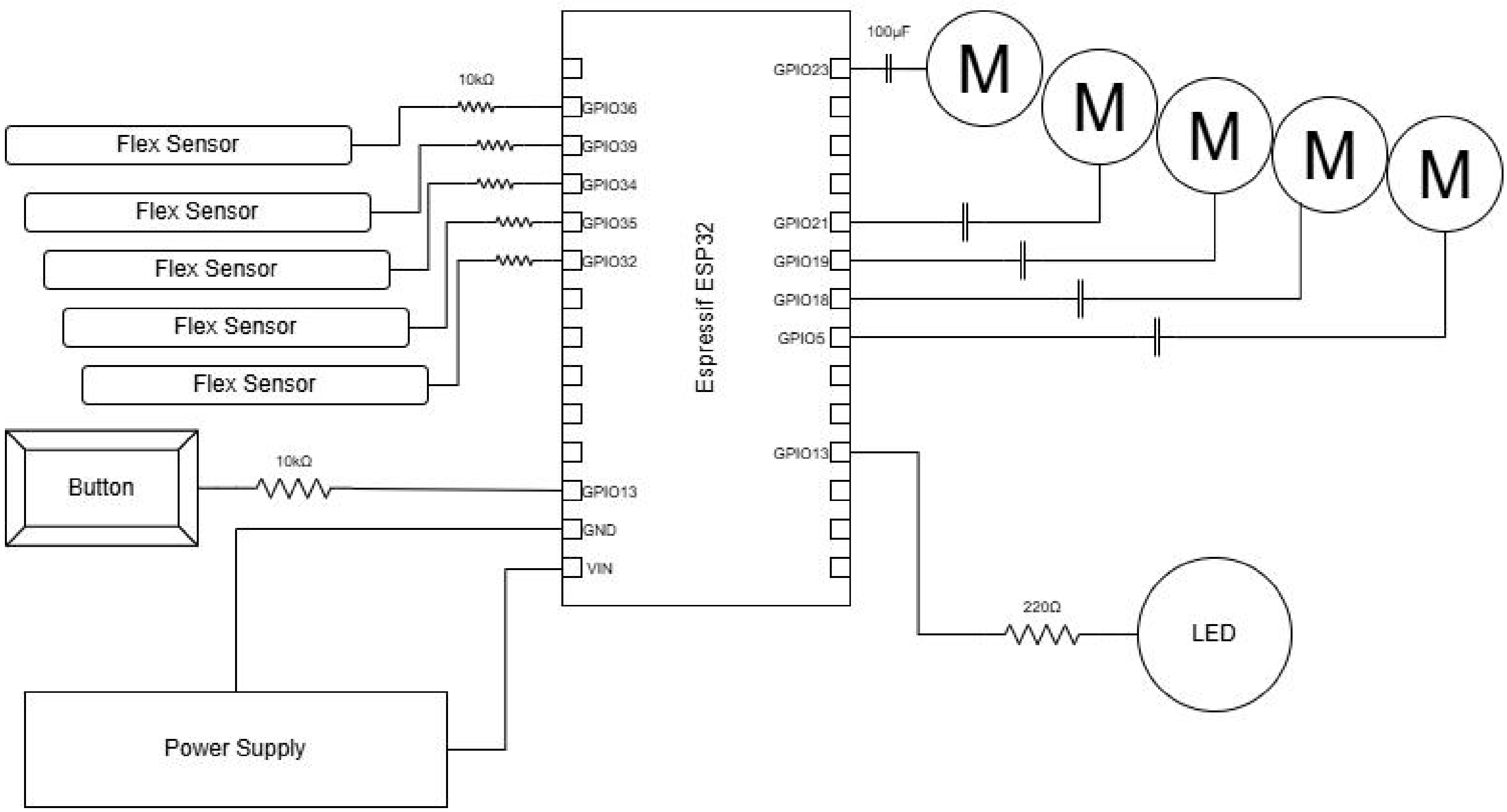
considering glove design for easier + quicker user assemble

pulls this way

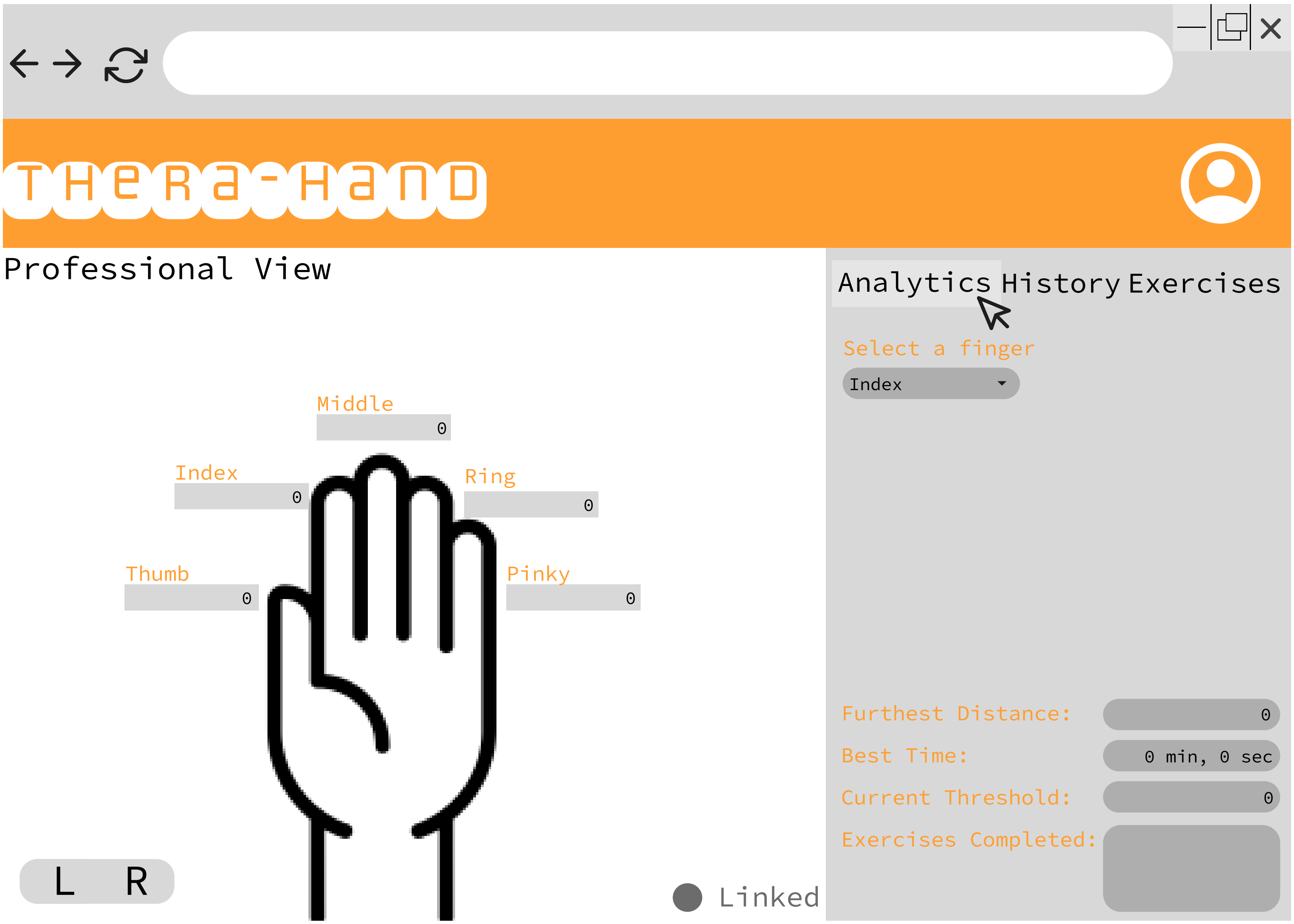
3D printed box for palm feeding the string for better range of motion so hand can curl / clench

another servo motor for back side of hand

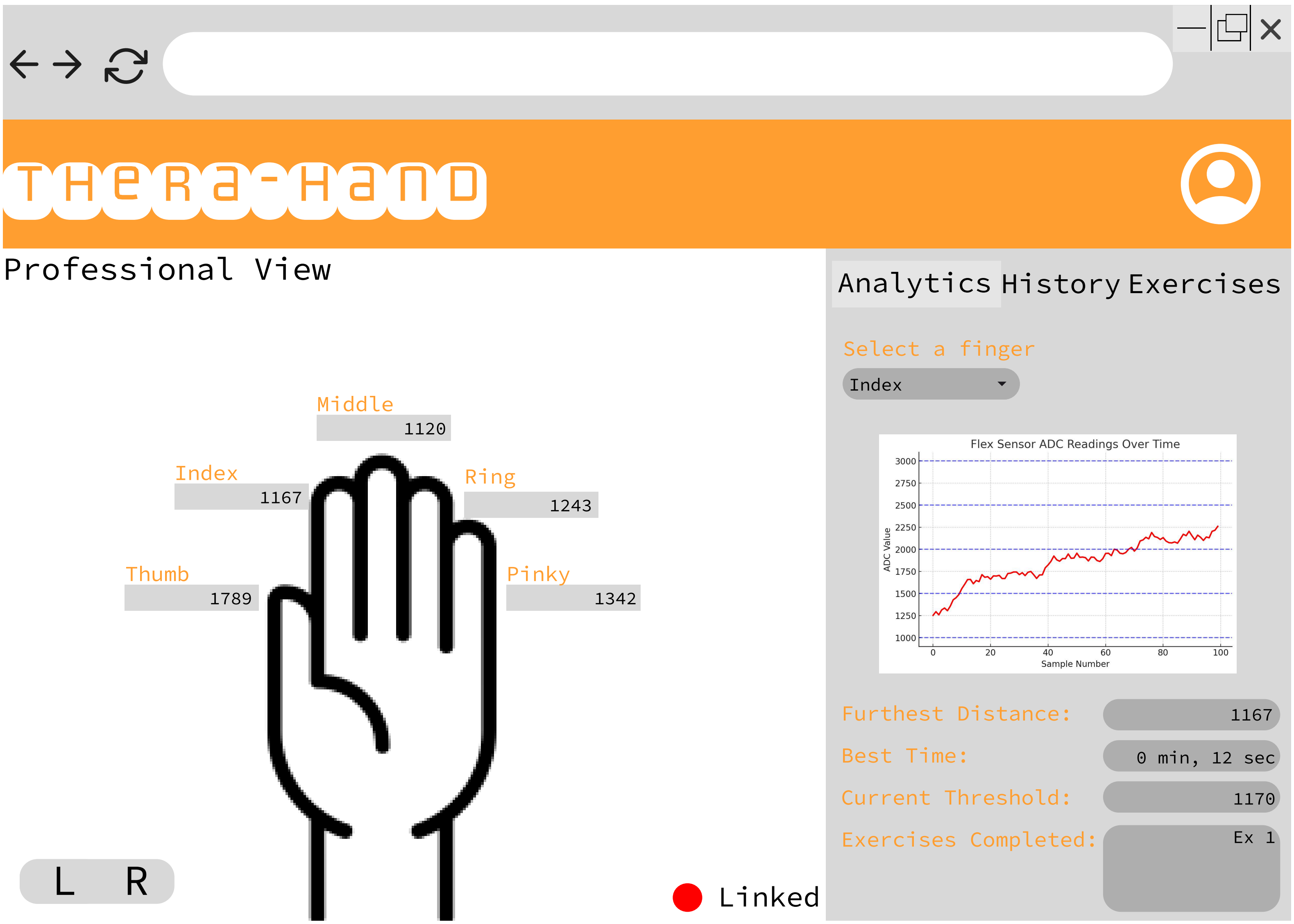

Thera-Hand Electrical Wiring Diagram
5V Power Supply
1000µF Capacitor
ESP32
Servo Motors (x5)
0.1µF Capacitor (ESP32 Noise Filter)
100µF Capacitors (Per Servo)
Flex Sensors (x5)
1N5819 Diodes (Across Servos)
10kΩ Resistors for Flex Sensors
LED (w/ 220Ω Resistor)
Breadboard

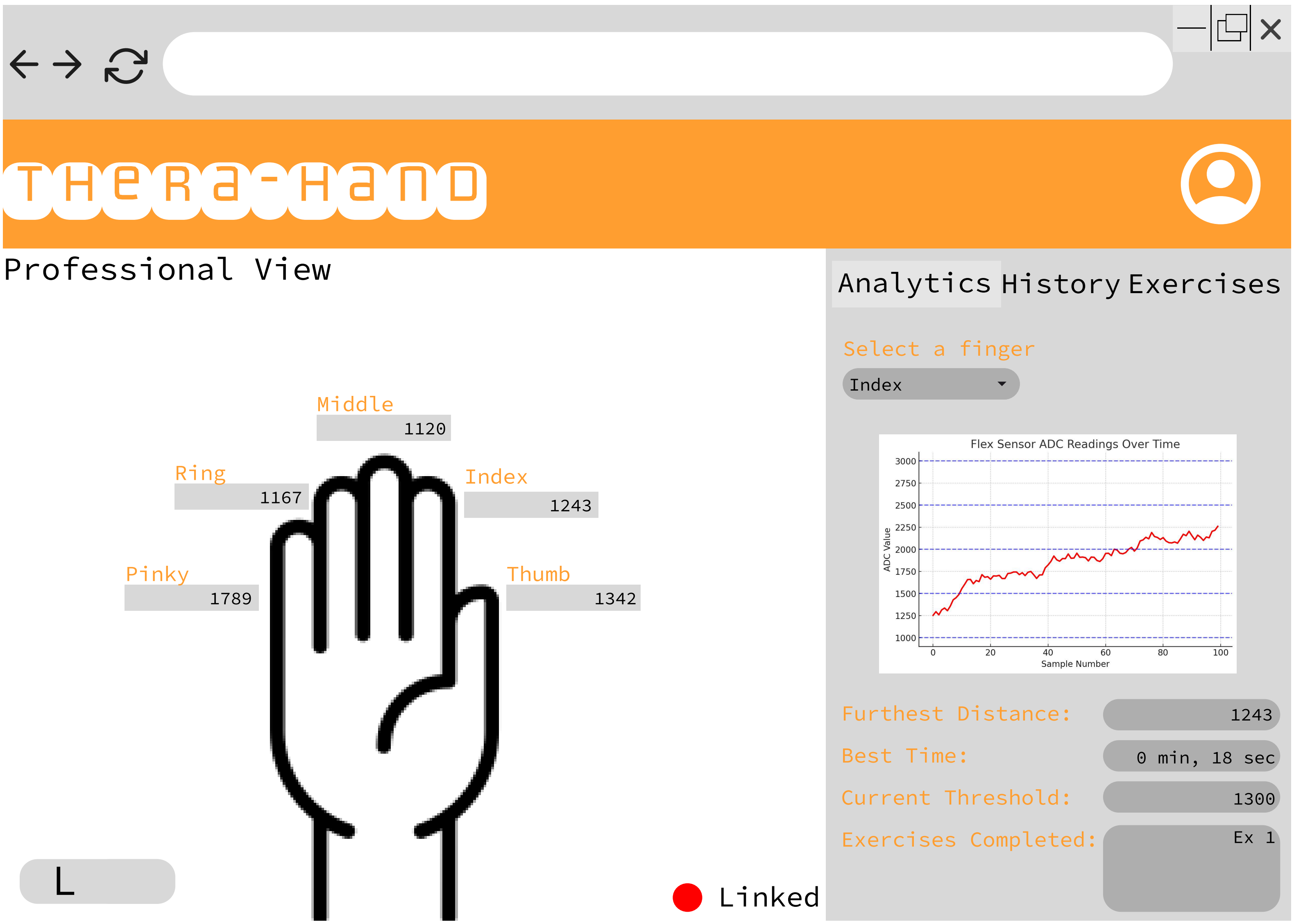


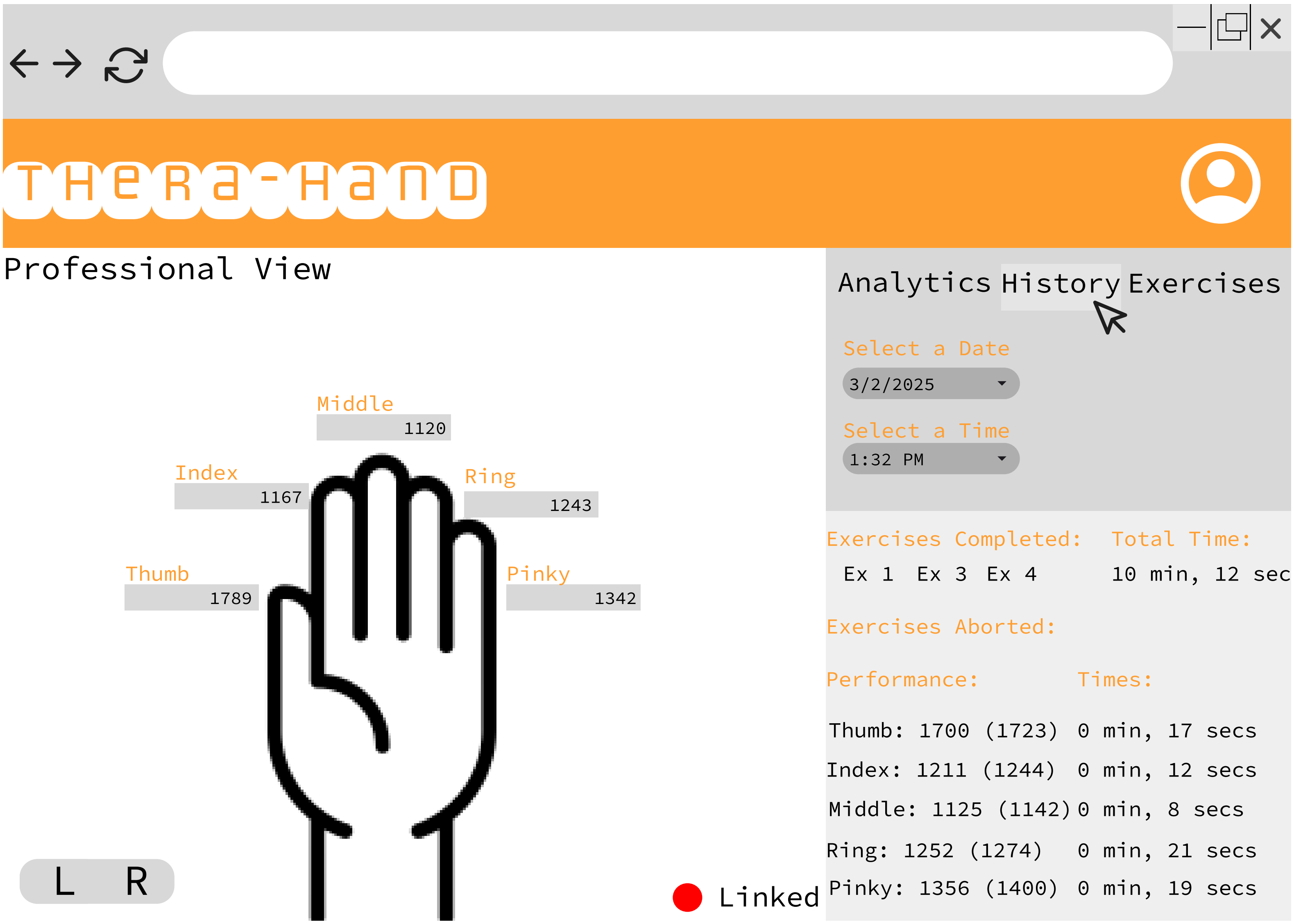
Flex Sensor
Flex Sensor
Flex Sensor
Flex Sensor
Flex Sensor
10kΩ
GPIO36
GPIO39
GPIO34
GPIO35
GPIO32
Button
10kΩ
GPIO13
GND
VIN
Power Supply
Espressif ESP32
100μF
GPIO23
GPIO21
GPIO19
GPIO18
GPIO5
GPIO13
M
M
M
M
M
220Ω
LED

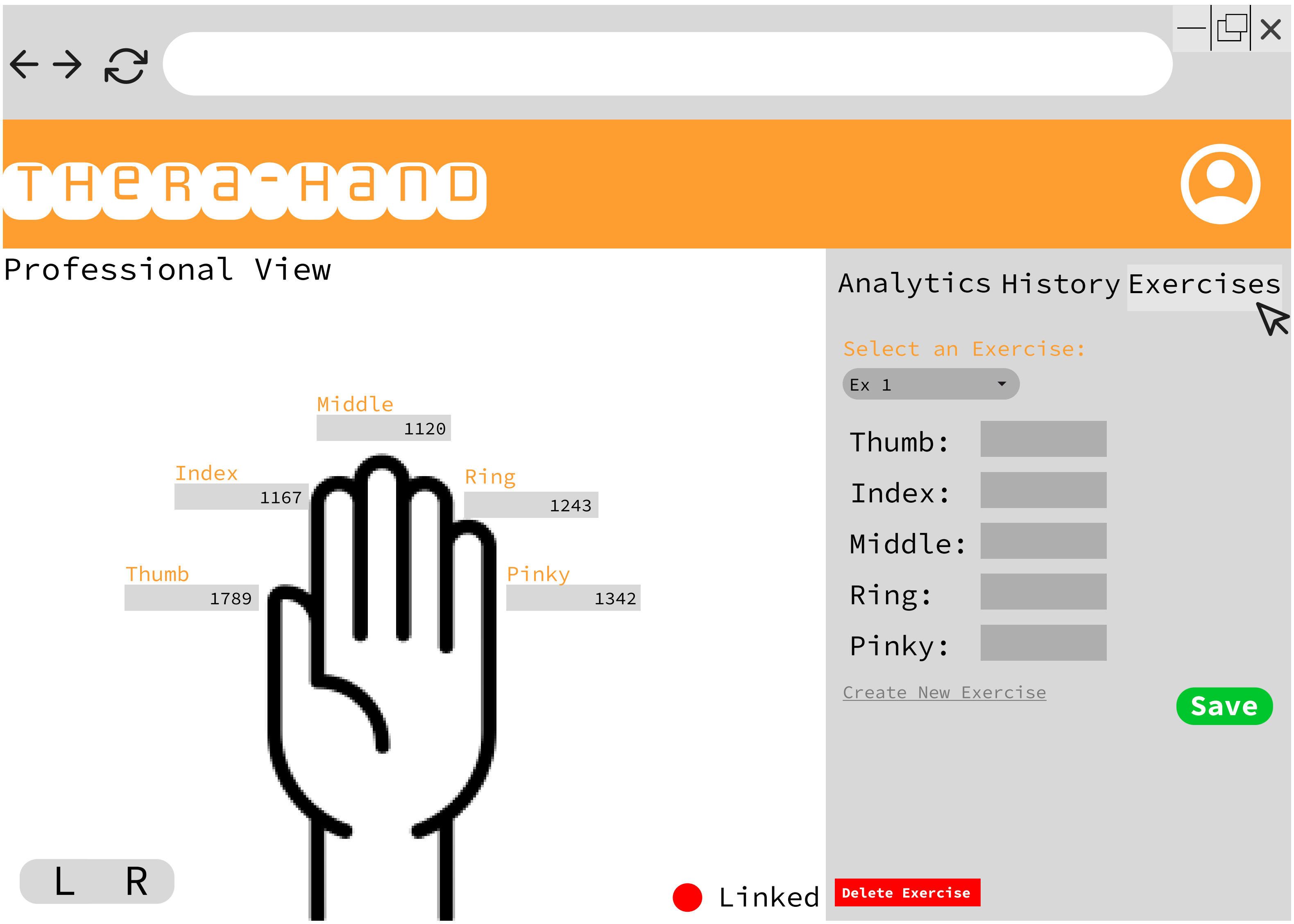


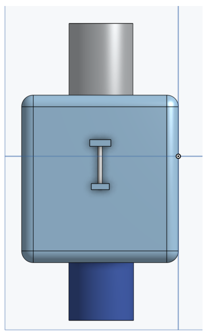
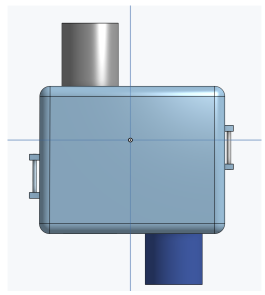
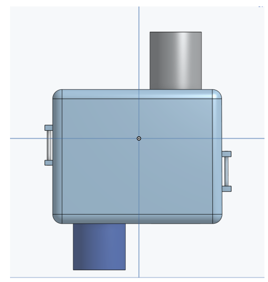
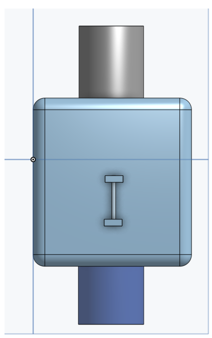
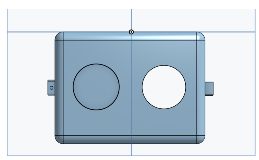
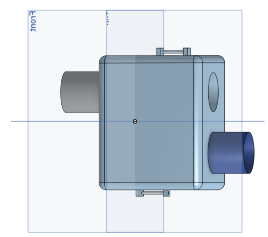
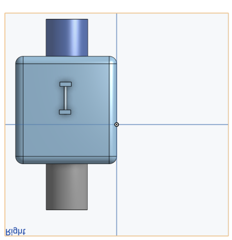
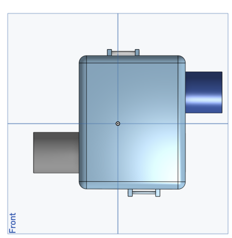
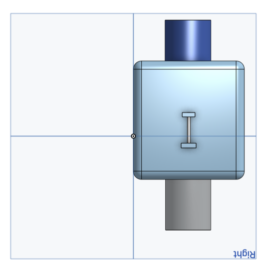
THERA-HAND
Professional View
Analytics
History
Exercises
Select a finger
Index
Middle
0
Index
0
Ring
0
Thumb
0
Pinky
0
Furthest Distance:
0
Best Time:
0 min, 0 sec
Current Threshold:
0
Exercises Completed:
L
R
Linked


THERA-HAND
Professional View
Analytics
History
Exercises
Select a finger
Index
Flex Sensor ADC Readings Over Time
ADC Value
Sample Number
Middle
1120
Index
1167
Ring
1243
Thumb
1789
Pinky
1342
L R
Linked
Furthest Distance:
1167
Best Time:
0 min, 12 sec
Current Threshold:
1170
Exercises Completed:
Ex 1


THERA-HAND
Professional View
Analytics
History
Exercises
Select a finger
Index
Flex Sensor ADC Readings Over Time
ADC Value
Sample Number
Middle
1120
Ring
1167
Index
1243
Pinky
1789
Thumb
1342
Furthest Distance:
1243
Best Time:
0 min, 18 sec
Current Threshold:
1300
Exercises Completed:
Ex 1
L
Linked


THERA-HAND
Professional View
Analytics History Exercises
Select a Date
3/2/2025
Select a Time
1:32 PM
Middle
1120
Index
1167
Ring
1243
Thumb
1789
Pinky
1342
Exercises Completed:
Ex 1 Ex 3 Ex 4
Total Time:
10 min, 12 sec
Exercises Aborted:
Performance:
Times:
Thumb: 1700 (1723) 0 min, 17 secs
Index: 1211 (1244) 0 min, 12 secs
Middle: 1125 (1142) 0 min, 8 secs
Ring: 1252 (1274) 0 min, 21 secs
Pinky: 1356 (1400) 0 min, 19 secs
L R
Linked


THERA-HAND
Professional View
Analytics
History
Exercises
Select an Exercise:
Ex 1
Thumb:
Index:
Middle:
Ring:
Pinky:
Create New Exercise
Save
Middle
1120
Index
1167
Ring
1243
Thumb
1789
Pinky
1342
L
R
Linked
Delete Exercise

2 Ethics Statement

We reference: The Code of Ethics for the Physical Therapist

With our physical therapy hand device we aim to address treatment for those who would benefit from remote commitment to treatment[2][3], adapting to modern trends to benefit therapists[6] and clients[7] and serving those without consistent access to therapy[8].

- Principle 2: Physical therapists shall be trustworthy and compassionate in addressing the rights and needs of patients and clients.
- Principle 3: Physical therapists shall be accountable for making sound professional judgments.
- Principle 6: Physical therapists shall enhance their expertise through the lifelong acquisition and refinement of knowledge, skills, abilities, and professional behaviors.
- Principle 7: Physical therapists shall promote organizational behaviors and business practices that benefit patients and clients and society.
- Principle 8: Physical therapists shall participate in efforts to meet the health needs of people locally, nationally, or globally.

3 Budget for Prototype

Item	**Quantity**	**Vendor**	**Price per Unit ($)**	**Total Cost ($)**
Flex Sensors	5	[Spectra Symbol]	10.85	54.25
Microcontroller (ESP32)	1	[AITRIP]	15.99	15.99
Glove	1	[LYDTICK]	16.99	16.99
Wiring & Connectors	1 (pack)	[Spark Fun]	5.97	5.97
Battery Pack	1	[Raion Group]	29.95	29.95
3D Print Filament	1	[AMOLEN]	29.99	29.99
Actuator (Micro-Servos)	1 (10 pack)	[Smraza]	18.99	18.99
Server Cost (Monthly)	N/A	[AWS]	Free Tier	Free
Velcro	1	[ULINE]	20.00	20.00
TOTAL				**192.13**

4 Life Cycle Assessment

4.1 Goal and Scope Definition

4.1.1 Objective

The LCA aims to assess the environmental footprint of the Thera-Hand rehabilitation device, considering its:

- Energy consumption (power supply, servos, ESP32).
- Material usage (PLA, rubber, fishing line, sensors).
- Manufacturing and transportation impact.
- End-of-life disposal/recycling feasibility.

4.1.2 Functional Unit

A single Thera-Hand device is assumed to be used for 2 years before replacement.

4.1.3 System Boundaries

This LCA includes:

- Raw Material Extraction – Plastics, rubber, and electronics production.
- Manufacturing and Assembly – 3D printing, PCB production, servo motor production.
- Transportation – From manufacturing to users.
- Use Phase – Power consumption during operation.
- End of Life – Disposal, recycling, or potential reuse.

4.2 Inventory Analysis

4.2.1 Material Composition and Impact

Component	**Material**	**Environmental Impact**
Frame & Housing	PLA (3D printed)	Low-carbon footprint, biodegradable under specific conditions
Sensors	Flexible PCB, resistive materials	Electronic waste, difficult to recycle
Actuators (Servos)	Plastic, copper wiring	High-energy manufacturing, limited recyclability
Power Supply	Electronic components, metal	Requires responsible e-waste disposal
Wiring & Fishing Line	Copper wiring, nylon	Small footprint, but non-biodegradable

4.2.2 Energy Consumption(Use Phase)

Based on prior power consumption estimates:

Component	Power Consumption (W)	Usage per day (hours)	Annual Energy (kWh)
ESP32	1.25W	2	0.91 kWh
5 SG90 Servos	6.25W (idle) / 16.25W (peak)	1	5.93 kWh
Sensors & LED	0.15W	2	0.11 kWh
Total Estimate	$\approx$ 7.65W - 17.65W	-	6-7 kWh/year

Table 1: Comparison: This is equivalent to a low-power LED bulb running for 3 months.

4.3 Impact Assessment (Environmental)

4.3.1 Manufacturing:

- Electronics production (ESP32, sensors, servos) has the highest carbon footprint.
- 3D printing (PLA) requires energy but has a relatively low impact compared to metals.

4.3.2 Use Phase:

- Low electricity consumption (6-7 kWh/year) makes it energy-efficient.

4.3.3 End-of-Life Considerations:

- PLA parts are biodegradable in industrial composting but not in landfills.
- Servos, wiring, and PCBs require responsible e-waste recycling.

4.4 Interpretation and Recommendations

4.4.1 Key Findings

- Low Energy Consumption: Thera-Hand is energy-efficient in use.
- Minimal Carbon Footprint for PLA: The frame is eco-friendly, but plastics must be disposed of properly.
- E-Waste Challenge: Sensors, servos, and the ESP32 must be recycled properly.
- Transportation Impact: If shipped globally, the CO_2 footprint increases.

4.4.2 Recommendations

- Optimize 3D Printing Material: Use recycled PLA or biodegradable TPU to reduce waste.
- E-Waste Collection Plan: Offer a recycling take-back program for electronics.

- Reduce Servo Impact: Use low-power or energy-efficient servos if possible.
- Sustainable Packaging: Use biodegradable or recycled materials for packaging.

4.5 Conclusion

- Thera-Hand is a low-energy, partially sustainable device.
- The biggest environmental concern is e-waste disposal of sensors and servos.
- Efforts to recycle electronic components and use sustainable materials can improve its eco-friendliness.

5 Test Plan

5.1 Ability to be turned on/off

The device should have the ability to be turned off separately from being unplugged.

5.1.1 Goal

The Device should be able to be turned on and off while still connected to a direct power source.

5.1.2 External Factors

Make sure the power connection is stable and not underloaded.

5.1.3 Equipment

Hand device with external bank, Power Source.

5.1.4 Steps

1. The device should not be connected to any person.
2. The device should be plugged into an AC stable power supply of at least 120V. A common wall socket is preferred.
3. Load any basic exercise and wait longer than 10 seconds.
4. Turn off the device by pressing the power button on the box connected to the wall. Make sure to press the power button before the exercise has finished.
5. Observe and measure the time it takes for the device to stop movement.
6. Repeat steps 3-5 multiple times with differing exercises.

5.2 Ability to download/save metrics

Data should be stored and sent remotely after each exercise is completed.

5.2.1 Goal

The Device should be able to remotely send data to an external device that can store data.

5.2.2 External Factors

Unstable power supply, unstable internet connection, and connectivity issues.

5.2.3 Equipment

Hand device with external bank, Power Source, Separate device connected to internet and connected to device.

5.2.4 Steps

1. Plug the device into a stable 120V AC power supply, preferably a wall outlet.
2. Load the exercise onto the device and begin the workout. Preferably a short workout routine.
3. Connect the therapist's device to a stable internet connection.
4. Pair the device to a therapist's computer, allowing it to download and store the device's workout data.
5. Start the workout and wait for it to finish.
6. Observe the download of the device

5.3 Weight

Determine the weight of the device that is worn on the hand. Under two pounds.

5.3.1 Goal

The device should weigh under 2 lbs or 1kg.

5.3.2 External Factors

The scale should be accurate enough to detect under five pounds and should be zeroed before use.

5.3.3 Equipment

Hand device without external bank, small scale.

5.3.4 Steps

1. Unplug the device from the power bank and computer.
2. Place the device on the scale. The glove should be dry and empty. Strings should be attached from servos to fingers.

5.4 Accuracy of repetition counting

The device should be tested to report as many repetitions as are being performed. We need to know the degree of error of our data.

5.4.1 Goal

The device should count the repetitions performed ideally with perfect accuracy.

5.4.2 External factors

The device should be properly calibrated to recognize when a full range of motion repetition has occurred.

5.4.3 Equipment

Hand device with external bank, Power Source, Separate device connected to the internet and connected to the device.

5.4.4 Steps

1. Plug the device into a 120V AC outlet.
2. Turn the device on and begin basic squeeze exercises, where fingertips must touch, for 10 seconds.
3. While the device records repetitions, manually count how many repetitions occur until the time is over.
4. Compare the number of repetitions the device reports to the number of repetitions observed.

5.5 Individual controllability

Each finger should be able to operate independently of any other finger.

5.5.1 Goal

Verify that each finger is independently programmable and movable.

5.5.2 External factors

Individual anatomy and flexibility of those being tested.

5.5.3 Equipment

Hand device with external bank, Power Source, Separate device connected to the internet and connected to the device.

5.5.4 Steps

1. Plug the device into a 120V AC outlet.
2. Turn the device on and verify each finger individually can be pulled in individually.
3. Verify each finger individually can be extended back out.

5.6 Resting state

The device should return to a resting state after the completion of each exercise.

5.6.1 Goal

The device should be verified to return to a neutral state after each exercise is completed.

5.6.2 External factors

Someone's anatomy or flexibility may prevent a typical "neutral" resting state.

5.6.3 Equipment

Hand device with external bank, Power Source, Separate device connected to the internet and connected to the device.

5.6.4 Steps

1. Plug the device into a 120V AC outlet.
2. Turn the device on and begin an exercise.
3. After completion of the exercise, verify that the device has returned to its neutral resting state.

5.7 Full Range of Motion on each finger

The device should be able to move in the full range of motion for each finger. Determine through flex sensor data in the amount of flexion (degrees).

5.7.1 Goal

The device should demonstrate flexion within the expected biomechanical range (0-90 for DIP, 0-100 for PIP, 0-90 for MCP, depending on finger). Deviation beyond 2.5% of standard human range to be flagged for recalibration. If the device does not meet the expected range, adjustments in control algorithms and mechanical design may be necessary.

5.7.2 External factors

Ambient temperature variations, Device vibrations and mechanical inconsistencies, Any potential latency in response times.

5.7.3 Equipment

Glove with integrated flex sensors, Voltage divider circuit with known resistor (? ohms), Arduino, Computer for data logging and visualization

5.7.4 Steps

1. Mount the device securely and ensure proper calibration of flex sensors.
2. Record natural rest position of each finger.
3. Actuate each finger from full extension to full flexion.
4. Record flex sensor data at key points of movement (0, 45, 90, etc.).
5. Repeat the process for each finger, ensuring consistency.

5.8 Ability to fit on a common hand

The device should be able to fit securely and comfortably on common hand sizes, using straps for adjust-ability.

5.8.1 Goal

The device should securely fit common hand sizes without excessive gaps or pressure points. The adjustable straps should allow for a customized fit without discomfort. If fit issues arise, modifications to strap length, padding, or buckle placement may be necessary.

5.8.2 External factors

Impact of movement on strap security. Any noticeable discomfort due to prolonged wear.

5.8.3 Equipment

Robotic/assistive hand device with straps for adjustability. 3D hand model (male/female). Measuring tools for assessing gaps and pressure points (ruler, measuring tape, etc.). User feedback for qualitative comfortability assessment.

5.8.4 Steps

1. Prepare the hand models and device with adjustable straps. Ensure straps are at their default adjustment before each trial.
2. Measure the circumference of each hand model at the middle of the hand and forearm.
3. Place the device on each hand model and secure it using the straps. Adjust the straps for a snug but comfortable fit.
4. Record strap tension using measuring tape and pressure sensors.
5. Conduct subjective assessment for comfort and stability.

5.9 Durability of the device

5.9.1 Goal

The device should maintain functional integrity for at least 100,000 flexion cycles without significant degradation. The structural components should withstand typical impact forces without catastrophic failure. Environmental exposure should not lead to material breakdown or loss of functionality. If durability issues arise, material selection, mechanical design, or protective coatings may need revision.

5.9.2 External factors

Effects of prolonged use on mechanical performance. Environmental factors leading to premature material failure.

5.9.3 Equipment

Robotic/assistive hand device. Mechanical testing rig for repeated flexion cycles. Load cell sensors to measure stress and strain. Environmental chamber for temperature and humidity variations. Impact testing apparatus for drop and shock resistance.

5.9.4 Steps

1. Mount the device on a mechanical testing rig.
2. Calibrate sensors to measure force, stress, and performance degradation.

3. Record initial material integrity and functionality metrics.
4. Subject each finger mechanism to repeated flexion cycles (minimum 100,000 cycles).
5. Monitor for signs of wear, stiffness, or failure.
6. Drop the device from various heights onto different surfaces.
7. Assess structural damage and continued operability.
8. Expose the device to temperature fluctuations (-10C to 50C) and high humidity.
9. Evaluate material degradation and operational stability.

Name(s)	**Date and Location**
Test 1: Did the power turn off? (Yes/No)	
Test 2: Was data remotely sent? (Yes/No)	
Test 3: Weight: (kg/lbs)	
Test 4: What accuracy were the repetitions counted to? (%)	
Test 5: How many fingers were individually controllable? (0-5)	
Test 6: Did the device return to a resting state? (Yes/No)	
Test 7: Full Range of Motion on each finger? (Yes/No)	
Test 8: Ability to fit on common hand? (Yes/No)	
Test 9: Device Durability acceptable? (Yes/No)	

Table 2: Test Log

6 Updates

6.1 Need Statement

Physical therapy for hand rehabilitation is a time and cost-intensive process that has limited at-home alternative options available.

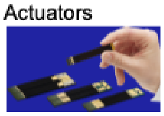
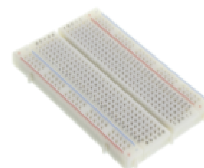
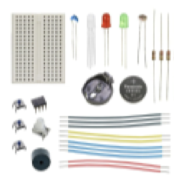
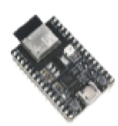
6.2 Goal Statement

We aim to reduce physical therapy visits by up to 50%, subsequently reducing insurance costs.

6.3 Design Objective

Design a cost-effective solution that is both user-friendly and streamlines the-hand rehabilitation process.

6.4 Morphological Chart

Frame	Mechanics	Materials	Design Superficial
Velcro straps 	Rotor pulley 	Fishing line 	wsl/ubuntu ubuntu
Gloves cloth 	Actuators 	Bowden Cable 	Neoprene (rubber) 
Gloves leather 	Air tubes 	Raspberry pi 	Breadboard 
Plastic (PLA) 	Servos 	Arduino 	Circuit components 
	LED 	Esp32c3 	

6.5 Gantt Chart