ESCUELA POLITÉCNICA NACIONAL

Laboratorio de Investigación en Inteligencia y Visión Artificial "ALAN TURING"

PROSTHESIS EPN v2

Assembly Manual

Denis Araque

July 2023

Contents

Table of Figures

1 Introduction

A prototype of myoelectric prothesis for the right hand will be built with 4 degrees of freedom and will be able to imitate a whole-hand grasping movement. This prototype will be based on an opensource design and will be built using 3D printing.

2 Required Materials

2.1 List of materials

The table below contains all the items (excluding tools) required for building a complete prosthesis.

Table 1: List of materials

Item	Description	Vendor	Link	QTY	Cost/Item	Ext. Cost
DC Motor (Index, Middle, Thumb)	298:1 Micro Metal Gearmotor HPCB 12V with Extended Motor Shaft	POLOLU	https://www.pololu.com/product/3056	3	$ 23.45	$ 70.35
DC Motor (Ring, Little)	1000:1 Micro Metal Gearmotor HPCB 12V with Extended Motor Shaft	POLOLU	https://www.pololu.com/product/3057	1	$ 31.95	$ 31.95
Encoder	magnetic, incremental, extended shaft	POLOLU	https://www.pololu.com/product/3081	2	$7.95	$15.9
Wire motor connector	6-Pin Single-Ended Female JST SH-Style Cable 30cm	POLOLU	https://www.pololu.com/product/4763	4	$ 1.89	$ 7.56
Microcontroller	Wemos D1 R32	AMAZON	https://www.amazon.com/Bluetooth-Module-CH340G-Development-Arduino/dp/B0BZWSJR6Z/ref=sr_1_10?keywords=D1+R32&s=electronics&sr=1-10	1	$ 29	$ 29
Motor driver	4 motors, L293d	AMAZON	https://www.amazon.com/DEVMO-Shield-Expansion-Arduino-Duemilanove/dp/B07S39BCZ6/ref=sr_1_1_sspa?crid=2752LYAKRPURR&keywords=M%C3%B3dulo+Shield+L293d+L293+Controlador+De+Motores+Arduino&qid=1688761751&sprefix=m%C3%B3dulo+shield+l293d+l293+controlador+de+motores+arduino%2Caps%2C132&sr=8-1-spons&sp_csd=d2lkZ2V0TmFtZT1zcF9hdGY&psc=1	1	$ 11.99	$ 11.99
Battery	Lipo 7.4v 2S, 800mAh	AMAZON	https://www.amazon.com/sea-jump-Battery-Compatible-Aircraft/dp/B0C3TH4CZD/ref=sr_1_4?crid=8KK9N4PQD1W1&keywords	1	$ 22.99	$22.99

			=Lipo+7.4v+2S+800mAh&qid=1689021159&sprefix=lipo+7.4v+2s+800mah%2Caps%2C147&sr=8-4			
Usb cable	Usb-A micro, >=1.5m	AMAZON	https://www.amazon.com/Amazon-Basics-Charging-Transfer-Gold-Plated/dp/B07232M876/ref=sr_1_8?keywords=usb+micro+cable+1.5m&sr=8-8	1	$ 7.49	$ 7.49
Nylon string	0.6mm diammeter	AMAZON	https://www.amazon.com/LUTER-Crystal-Stretchy-Bracelet-Necklace/dp/B08CK6G7HV/ref=sr_1_7?crid=3R13BQRCSQ6TF&keywords=Hilo+nylon+plastico+0.6mm&qid=1689018626&sprefix=hilo+nylon+plastico+0.6m%2Caps%2C172&sr=8-7	1	$ 6.39	$ 6.39
TPU Filament	1.75mm, 750 g	AMAZON	https://www.amazon.com/Polymaker-Filament-Flexible-1-75mm-Cardboard/dp/B09KL2FXNJ/ref=sr_1_7?crid=2C54Y1GZN5Y89&keywords=Rollo+TPU+impresion&qid=1688764520&sprefix=rollo+tpu+impresion+%2Caps%2C145&sr=8-7	1	$ 29.99	$ 29.99
PLA Filament	1.75mm, 1kg	AMAZON	https://www.amazon.com/SUNLU-Filament-Toughness-Clogging-Dimensional/dp/B0B1ZV6CJM/ref=sr_1_6?crid=3E838PDT5A4LH&keywords=Rollo+PLA&qid=1688764560&sprefix=rollo+pla%2Caps%2C178&sr=8-6	1	$ 20.99	$ 20.99
LIPO battery charnger	25W, 2S-3S	AMAZON	https://www.amazon.com/SUPULSE-Battery-Charger-Balance-7-4-11-1V/dp/B08L7VCBXG/ref=sr_1_2_sspa?crid=IEKCAKWPUJTC&keywords=charger+Lipo+7.4v+2S%2C+1100mAh&qid=1688764029&sprefix=charger+lipo+7.4v+2s%2C+1100mah%2Caps%2C150&sr=8-2-spons&sp_csd=d2lkZ2V0TmFtZT1zcF9hdGY&psc=1	1	$ 19.99	$ 19.99
Connectors Dupont kit	Male pin header, Housing Female 1x1, Housing Female 2x1, Housing Female 3x1, Right angle header	AMAZON	https://www.amazon.com/IWISS-1550PCS-Connector-Headers-Balancer/dp/B08X6C7PZM/ref=d_m_crc_dp_lf_d_t1_sccl_3_1/138-2424123-6724857?content-id=amzn1.sym.5d471845-5073-424b-b27b-c0676f48a016&pd_rd_i=B08X6C7PZM&psc=1	1	$ 14.99	$ 14.99
Extra-Long Strip	Straight angle header	AMAZON	https://www.amazon.com/Adafruit-Extra-Long-Break-Away-16-pin-	1	$ 6.72	$ 6.72

Male Header (80 pieces)			Header/dp/B09G5RF3H6/ref=sr_1_24?keywords=long+straight+angle+header&s=industrial&sr=1-24			
M2 screws, nuts kit	M2 screws	AMAZON	https://www.amazon.com/HVAZI-Metric-Stainless-Button-Assortment/dp/B07DVLLKZ3/ref=sr_1_3?keywords=tornillos%2Bm2%2B15mm&qid=1688766714&sr=8-3&th=1	1	$ 10.99	$ 10.99
Hex Brass Spacers Standoffs kit	Female female standoffs M3 screws	AMAZON	https://www.amazon.com/M2-M2-5-M3-Motherboard-Male-Female/dp/B06Y5TJXY1/ref=d_m_crc_dp_lf_d_t1_sccl_3_4/138-2424123-6724857?content-id=amzn1.sym.5d471845-5073-424b-b27b-c0676f48a016&pd_rd_i=B0BP6P37QY&th=1	1	$ 13.88	$ 13.88
					TOTAL:	$ 321.17

NOTE: *Delivery costs not included*

2.2 3D Printed Parts

The 3D printed parts are designed to be printed in PLA (palm and forearm) with support material and rafts. The flexible and soft material which is used for the fabrication of the fingers is TPU.

All files required for 3D printing can be accessed via https://github.com/laboratorioAI/prosthesis_v2. The suggested print specifications for each part are found in Table 2.

Table 2: 3D printed parts

Part Name	**Print Specifications**	**Estimated Print Time**	**Est. Material Weight**
Right Palm	Default, Print with supports and raft	29h 16min	108.1 g
Forearm	Default, Print with supports and raft	41h 51min	152.7 g
Thumb	Default	6h 20min	23.5 g
Index	Default	3h 43min	13.1 g
Middle	Default	3h 37min	13.0 g
Ring	Default	3h 2min	10.8 g
Little	Default	2h 34min	9.1 g
Servo Spool Full Set	Default	0h 40min	2.1g
Forearm support	Default	3h 37min	13.9 g
Fingernail Full Set	Default	0h 11min	0.6g
	TOTAL:	94h 51min	346.9 g

3 Material Preparation

3.1 3D Printed Parts (94h 51m)

Print parts as specified in section 2.2

Figure 1: Palm side view

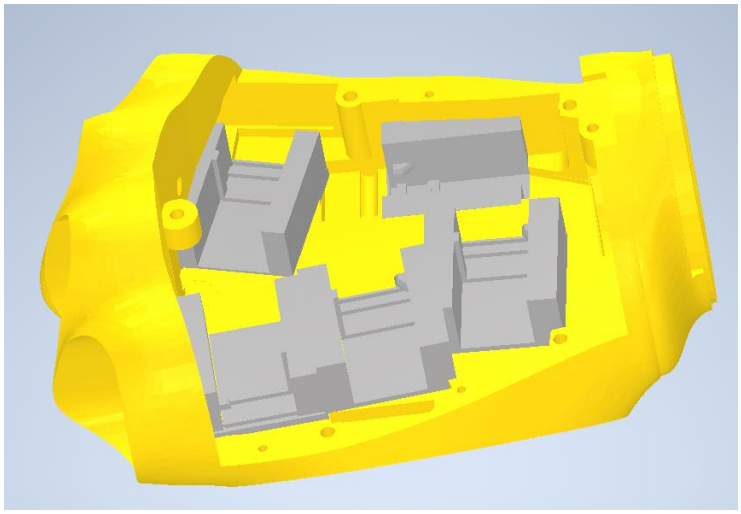


Figure 2: Palm back view (socket connector)

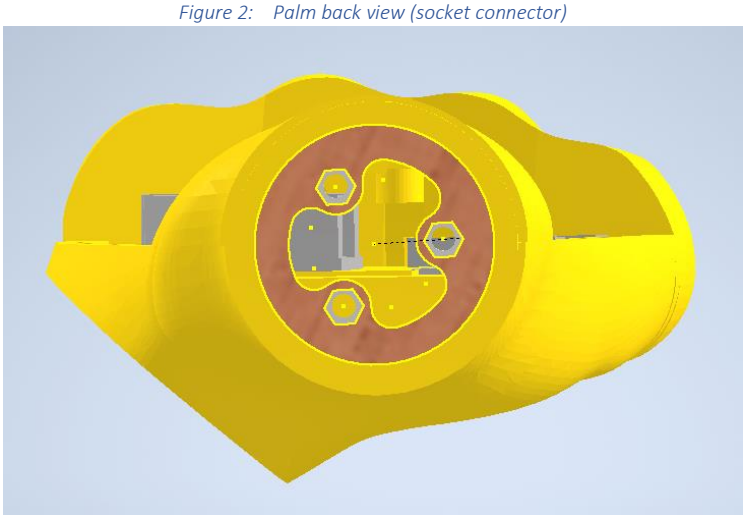


Figure 3: Forearm side view

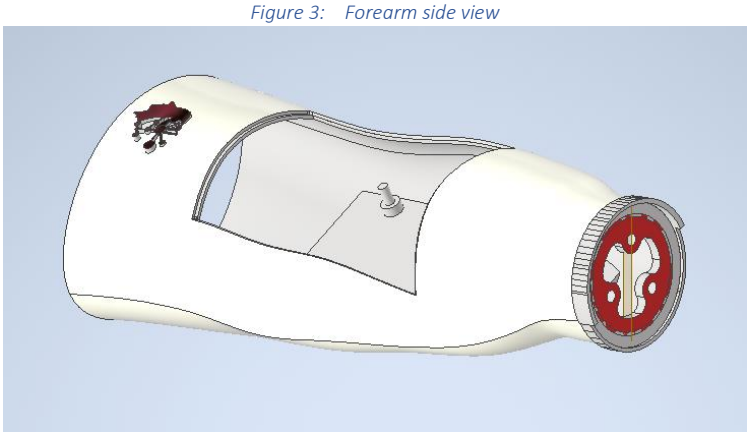


Figure 4: Forearm bottom view (holes for base)

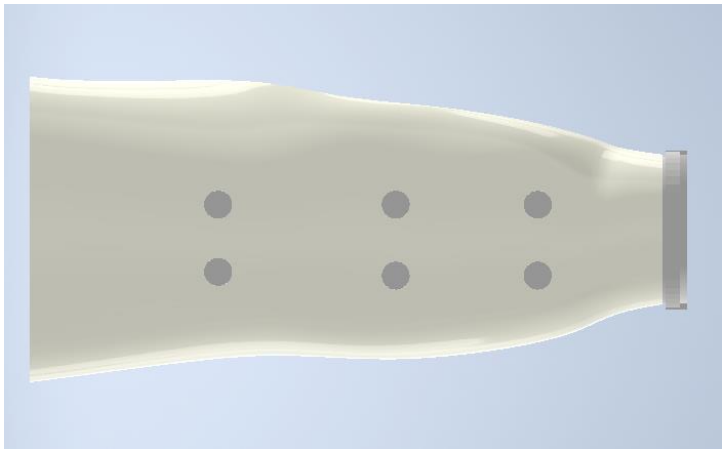


Figure 5: Thumb, index, middle, ring and little

Figure 6: Servo spool side view

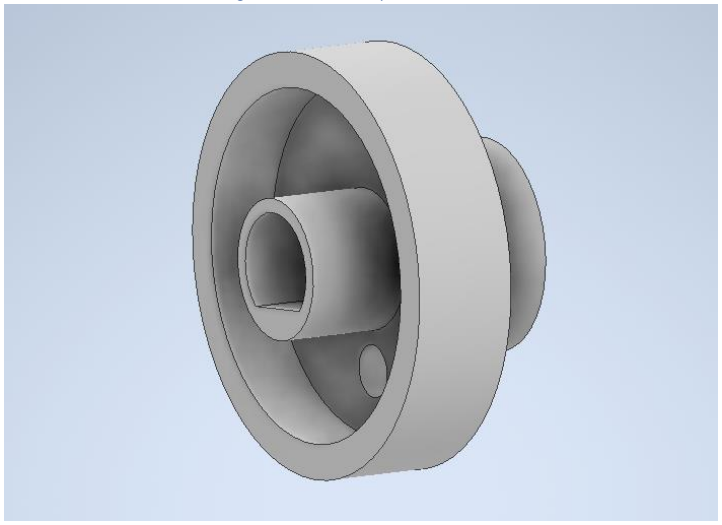


Figure 7: Base side view

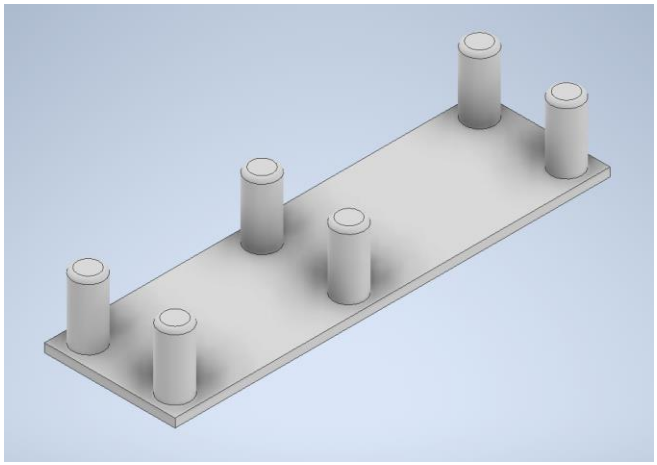
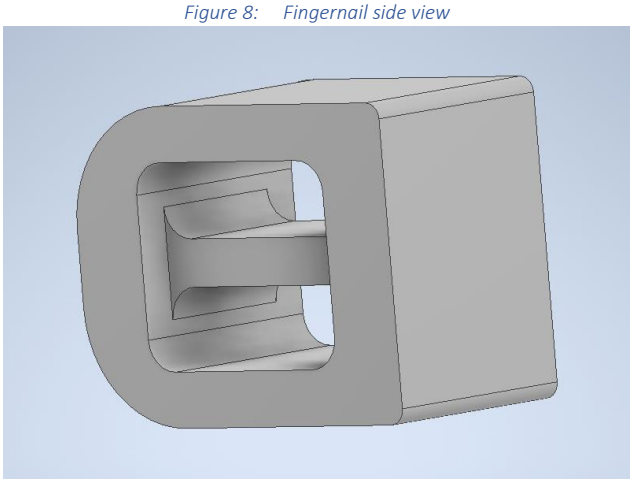


Figure 8: Fingernail side view



4 Hand Assembly

4.1 Tension Mechanism

Pass the 0.6 mm nylon string through the holes that have the fingers. To facilitate the task, use a thin wire that serves as a guide for the nylon string.

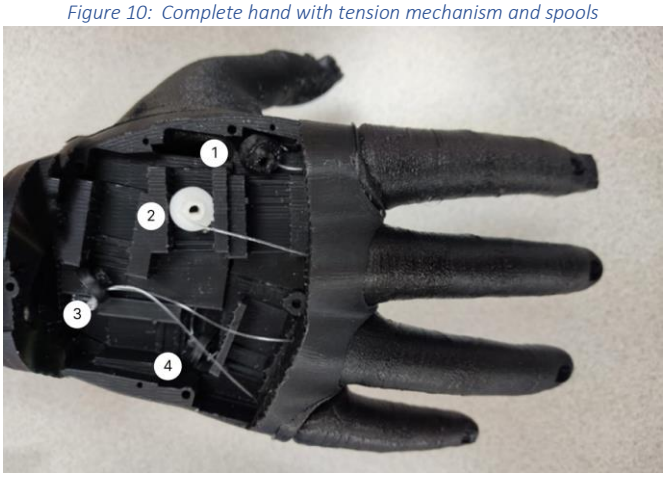
Figure 9: Internal structure of the fingers (duct for nylon string)

The nylon string will have the function of making the fingers stay flexed by the force of the DC motor that will pull the string so that the hand closes. It is important to place the fingernails (figure 8) at the ends of the nylon string to prevent the string from entering the fingers due to the pulling force generated by the motor.

4.2 Palm-finger assembly

Once all the fingers are with the tension mechanism, the next step is to glue the fingers to the palm for which we will use an ultra-strong glue to prevent the fingers from detaching over time. Place the spools (figure 6) at the end of each string as shown in figure 10, considering the position in which each motor is to be placed.

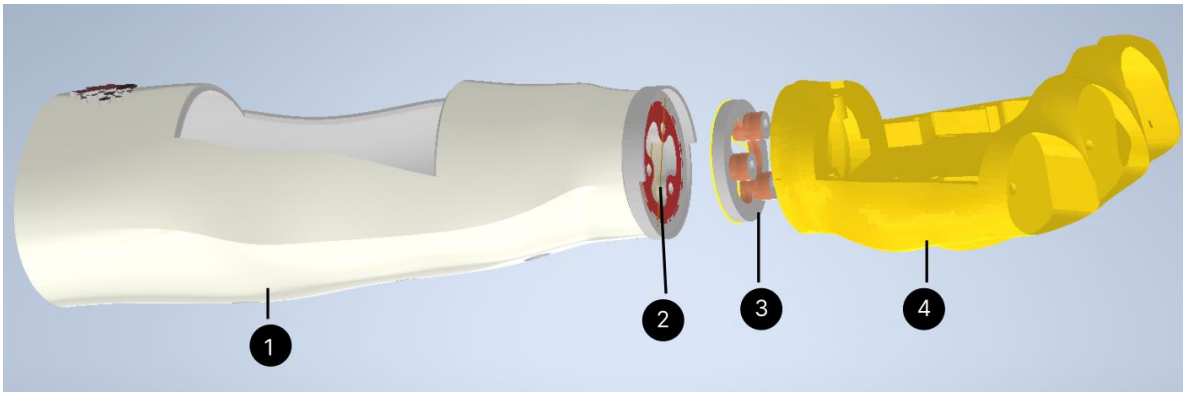
Figure 10: Complete hand with tension mechanism and spools



For this model, the ring finger and the little finger will be pulled by the same motor (1000:1) by the nylon strings of both fingers, which will go to a single spool as seen in figure 10. The next step is to connect the forearm with the entire hand, to join these pieces, 3 Hex Brass Spacers Standoffs (Figure 11) will be used that will fit into the socket connector found on the palm and on the forearm (see Figure 12), then they will be screwed on both sides.

Figure 11: Hex Brass Spacers Standoffs

Figure 12: Assembly diagram



1. Forearm
2. Socket extension
3. Socket connector
4. Palm

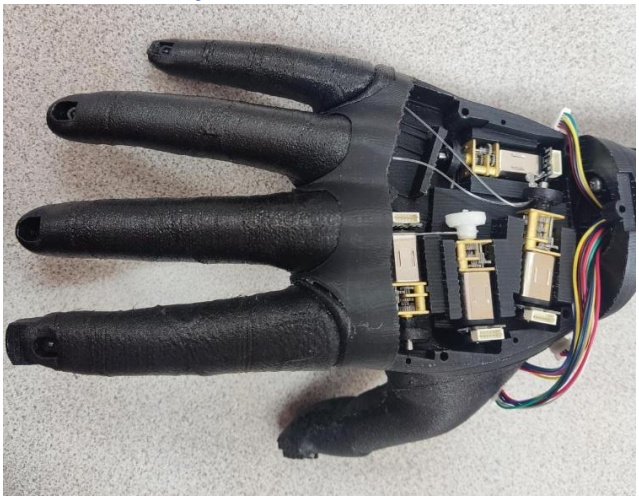
5 Motors Installation

Magnetic encoders will be soldered onto the DC motors (see Figure 13). The magnetic encoders will be used to determine the position of the fingers.

Figure 13: DC Motor Assembled Magnetic Encoder

Once the four motors are equipped with their respective encoders, spools should be placed on the motor shafts. Afterward, the motors should be positioned within the palm spaces (see Figure 14).

Figure 14: Hand with DC Motors

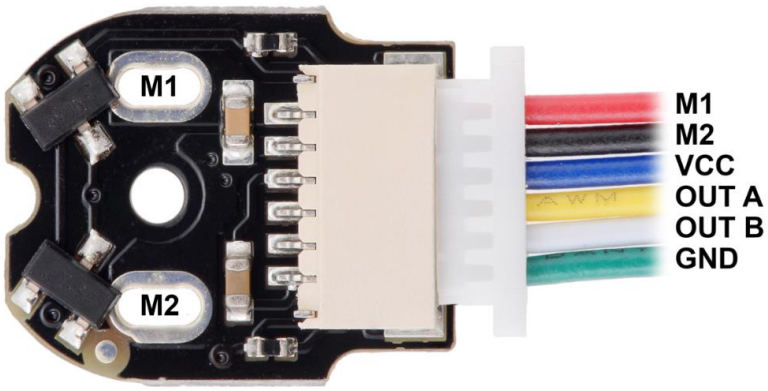


6 Electronic Connection

6.1 Encoder

To start with the electrical connection, it is important to know the outputs of encoder (figure 15) and to crimp the DuPont connectors to the other end of the cable depending on the need.

Figure 15: Encoder pinout



1. M1: Motor positive pin
2. M2: Motor negative pin
3. VCC: VCC
4. OUT A: Encoder signal
5. OUT B: Encoder signal
6. GND: Ground

The encoder board senses the rotation of the magnetic disc and provides a resolution of 12 counts per revolution. It has dual-channel Hall effect sensor boards and two 6-pole magnetic discs.

Control of the motors is achieved using the Adafruit Motor Shield V1, which is a motor controller capable of controlling four DC motors. For the connection of the motors to the Adafruit Motor Shield V1, you must follow the diagram (see figure 18).

6.2 Adafruit Motor Shield V1 Modifications

Before assembling the components to work with the Adafruit Motor Shield V1, you need to make the following modifications to the board to ensure proper functionality:

Note: Take caution while making modifications to avoid damage to the components.

1. **Extend Pin 13:**
   - Locate pin 13 on the Adafruit Motor Shield V1 board.
   - Carefully extend the pin or solder a male pin header to it.
   - This extended pin will be used to connect the first encoder signal.
2. **Extend Pin 2:**
   - Locate pin 2 on the Adafruit Motor Shield V1 board.
   - Similar to the previous step, extend the pin or solder a male pin header to its parallel pin.
   - This extended pin will be used to connect the second encoder signal.
3. **Extend 3.3V Pin:**
   - Locate the 3.3V pin on the Adafruit Motor Shield V1 board.
   - Extend this pin to connect to the encoders' Vcc (power supply).

- Additionally, you will need a 5-channel pin bar. Short circuit this pin bar to the 3.3V pin.

4. **Solder Male Pins for A0-A5:**
   - Identify the spaces on the Adafruit Motor Shield V1 board designated for A0 to A5.
   - Solder male pins into these spaces to create the necessary analog input connections.
   - These connections will be used for specific sensor inputs or other analog components.
5. **Solder Male Pins for GNDs:**
   - Locate the spaces on the Adafruit Motor Shield V1 board designated for Ground (GND) connections.
   - Solder male pins into these spaces to provide ground connections for various components.
   - Ground connections are crucial for completing electrical circuits and ensuring proper functioning.

After completing these hardware modifications, your Adafruit Motor Shield V1 board will be ready to work with the required components for controlling the motors of the prosthesis. Be sure to double-check your connections and ensure everything is securely soldered to avoid any loose connections during use.

Please note that these modifications are specific to adapting the board for the described purpose. Follow the instructions carefully and cross-check with the provided diagrams and illustrations to ensure accuracy and successful assembly.

6.3 Wemos D1 R32 Modifications

The Wemos D1 R32 board requires specific modifications to ensure compatibility with the encoder. Follow the steps below to perform the necessary modifications:

Figure 16: Wemos D1 R32 Before Modification

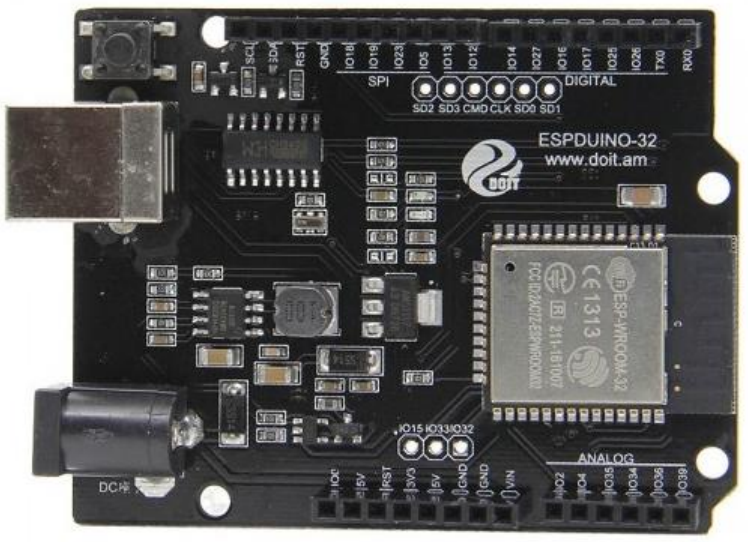
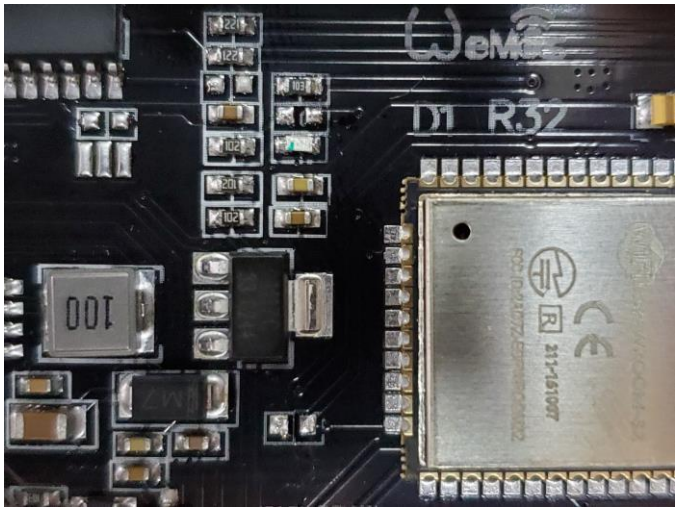


Figure 17: Wemos D1 R32 After Modification



Required Modifications:

1. **Desolder Pull-Down Resistors of GPIO2:**
   - Locate the pull-down resistors associated with GPIO2 on the Wemos D1 R32 board.
   - Using a desoldering tool, carefully remove these resistors.
   - This step is crucial to avoid interference with the encoder signals on GPIO2.
2. **Desolder Built-in LED of GPIO2:**
   - Locate the built-in LED connected to GPIO2 on the Wemos D1 R32 board.
   - Carefully desolder the LED to prevent any conflicting signals with the encoder.
   - Removing the LED ensures a clean and uninterrupted connection for the encoder.

Important Notes:

- When debugging in serial, ensure that the line endings are set to "NL" (New Line) or "LF" (Line Feed).
- Be aware that the silk labeling on the Wemos D1 R32 board may contain errors, including mislabeled pins.
- If you encounter bootloading issues with the shield connected, try disconnecting only the motor index and attempt bootloading again.
- If removing the motor index still results in bootloading failure, try disconnecting all other motor connectors.
- Note that the paulstoffregen/Encoder library is not compatible with ESP32. Instead, use the madhephaestus/ESP32Encoder library for proper functionality.

After completing these modifications, the Wemos D1 R32 board will be compatible with the encoder and ready for use in controlling the motors of the prosthesis. Ensure all connections are secure and verify that the modifications have been carried out accurately before proceeding with further assembly and testing.

Figure 18: Diagram to connect the motors to the Adafruit Motor Shield V1