Muscle BioAmp Shield

Upside Down Labs

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CHAPTER

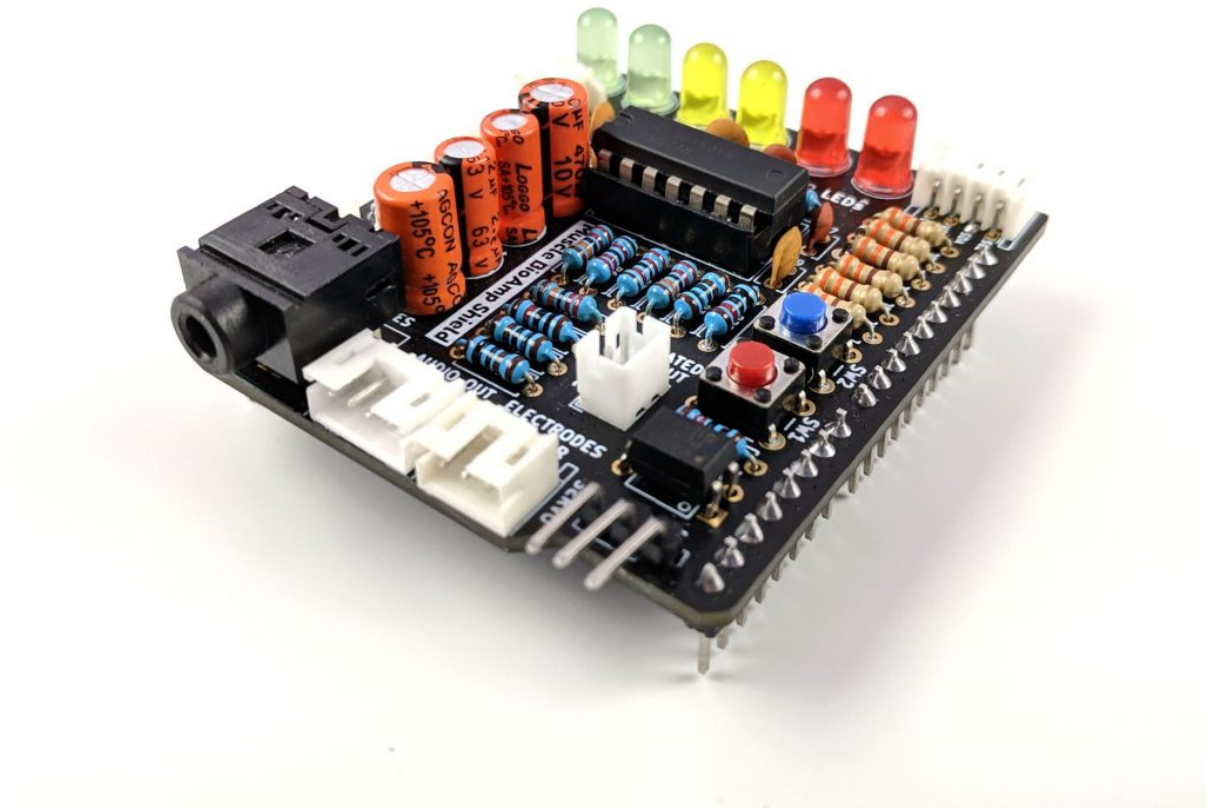
ONE

MUSCLE BIOAMP SHIELD

v0.3

1.1 Overview

Muscle BioAmp Shield is an all-in-one Arduino Uno ElectroMyography (EMG) shield for learning neuroscience with ease which is inspired from BackYard Brains (BYB) Muscle Spiker shield and provides similar features like hobby servo output, user buttons, LED Bar, Audio output, and battery input. It is perfect for beginners as they can easily stack it on top of Arduino Uno to record, visualize and listen to their muscle signals to make amazing projects in the domain of Human-Computer Interface (HCI).



1.2 Features & Specifications

Muscle BioAmp Shield comes with various plug-and-play options so you can connect hundreds of extension boards like OLED screens, character displays, accelerometers, and servo controllers to name just a few using the STEMMA I2C interface. You also get STEMMA digital and STEMMA analog ports. On STEMMA analog port you can connect additional BioAmp EXG Pill or any other sensor with analog output. On STEMMA digital port you can connect any digital sensor or actuator of your choice.

Input Voltage	5V
Input Impedance	10^11 ohm
Fixed Gain	x2420
Bandpass filter	72 – 720 Hz
Compatible Hardware	Arduino UNO
BioPotentials	EMG (Electromyography)
No. of channels	1
Electrodes	3 (Positive, Negative, and Reference)
Dimensions	6.0 x 5.3 cm
Open Source	Hardware + Software

1.3 Hardware

Images below shows a quick overview of the hardware design.

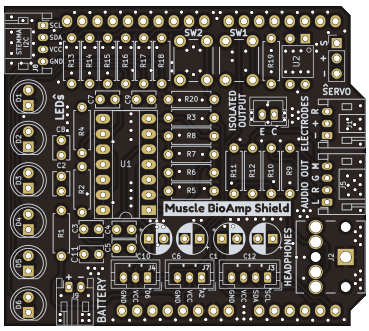


Fig. 1: *PCB Front*

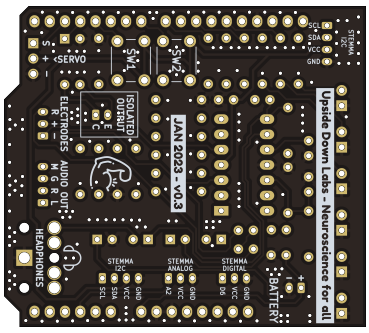


Fig. 2: *PCB Back*

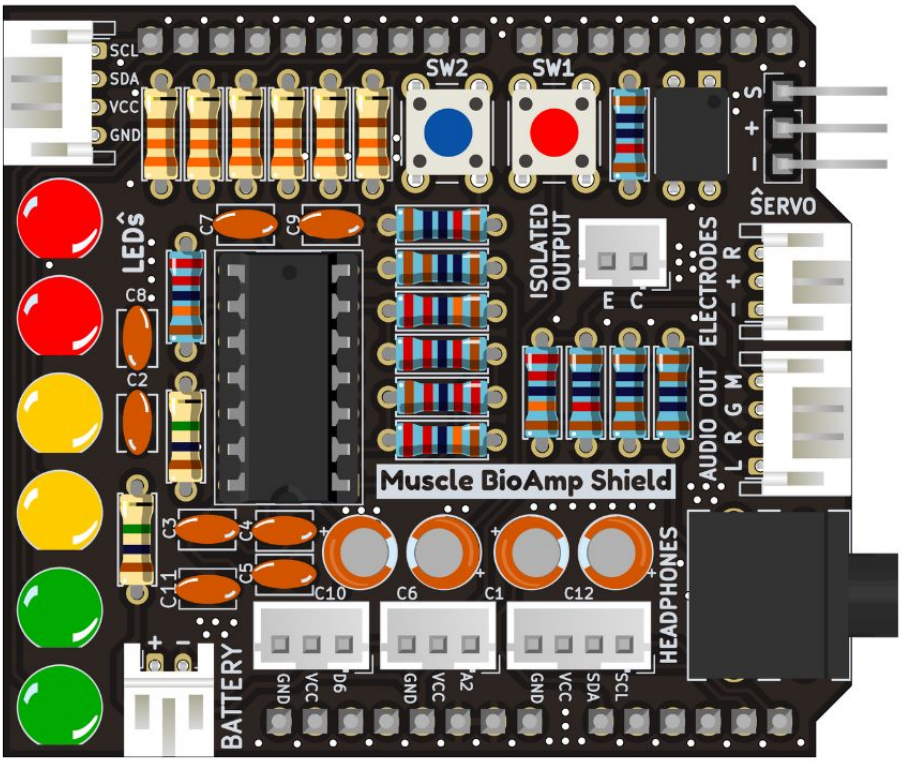


Fig. 3: *Assembled PCB*

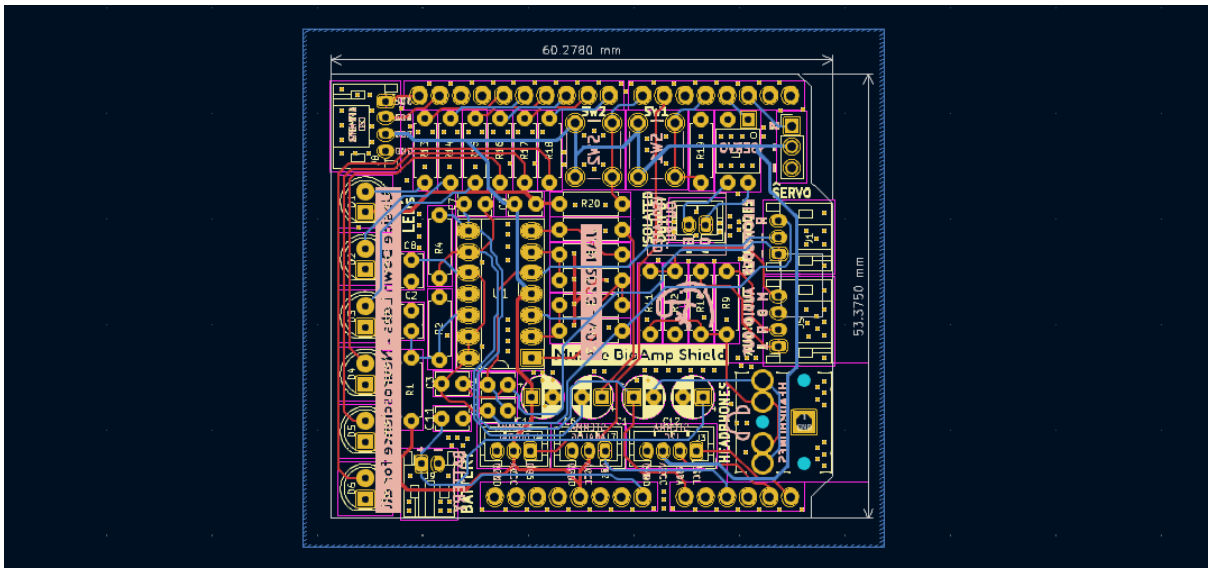


Fig. 4: *PCB Layout*

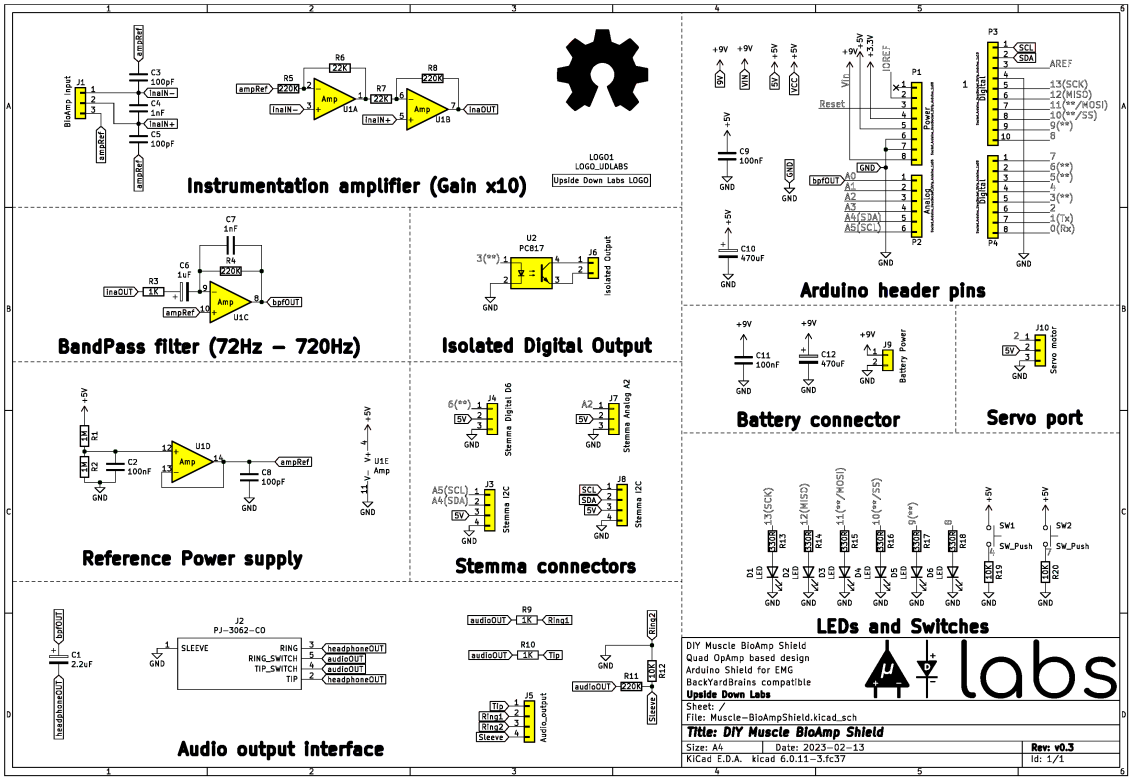


Fig. 5: *Schematic Diagram*

1.4 Contents of the kit

There are 2 variants available for Muscle BioAmp Shield v0.3 kit - one comes with the shield assembled and the other one contains bare PCB of the sensor and the components separately which you can assemble pretty easily.

Click on the link below to see the unboxing of the kit:

https://youtu.be/w8yw12SUe6Q

1.5 Software requirements

Before you start using the kit, please download Arduino IDE v1.8.19 (legacy IDE). Using this you'll be able to upload the arduino sketches on your development board and visualise the data on your laptop.

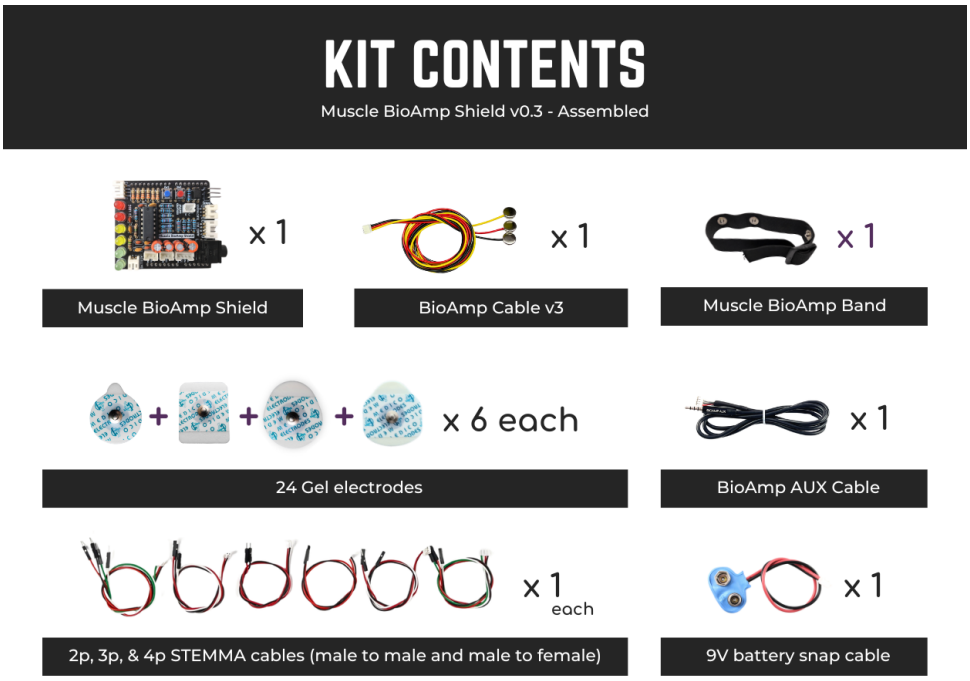


Fig. 6: *Assembled Muscle BioAmp Shield kit content*

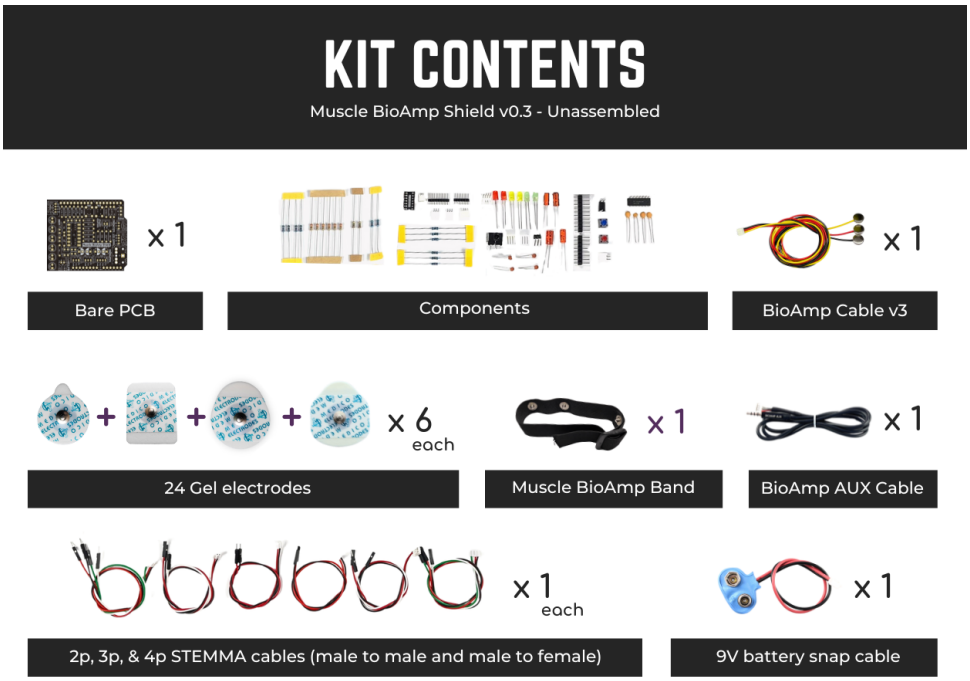


Fig. 7: *Unassembled Muscle BioAmp Shield kit content*

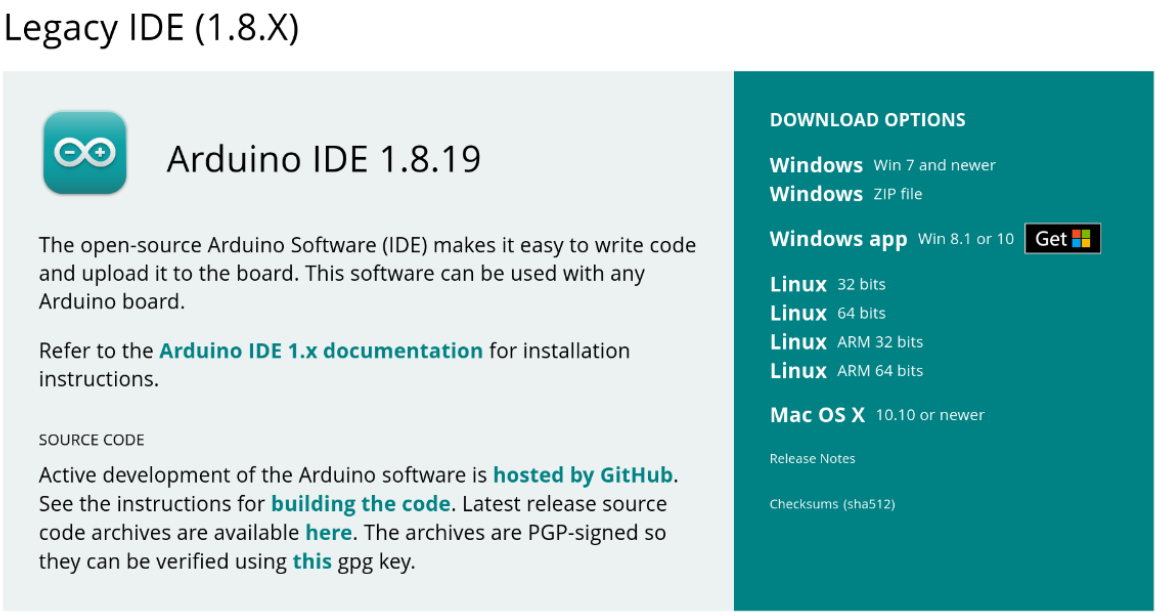
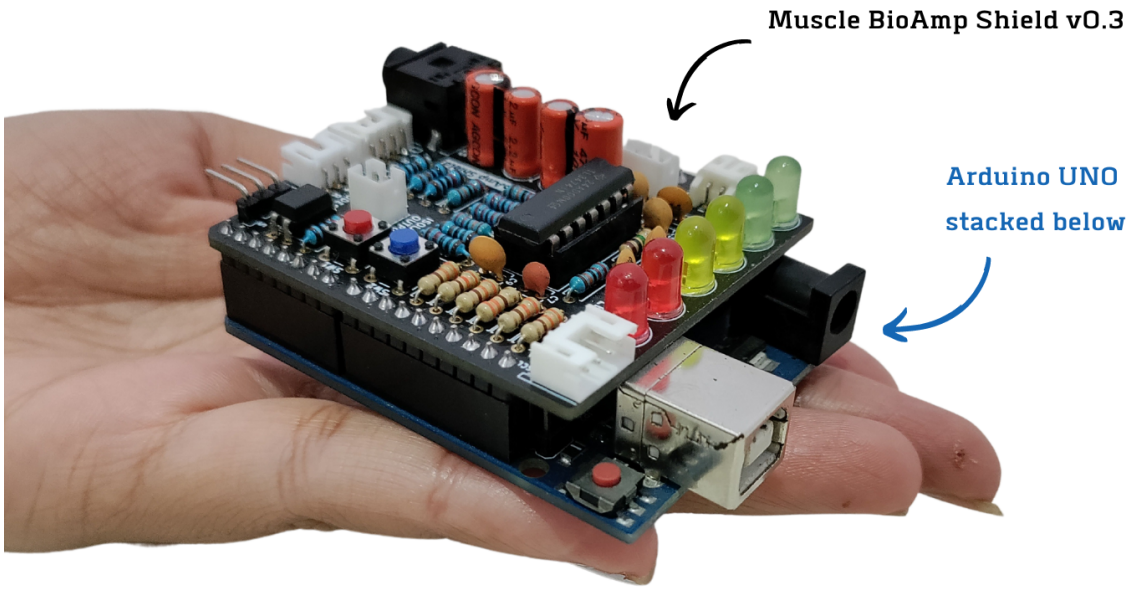


Fig. 8: Download Arduino IDE v1.8.19

1.6 Using the Sensor

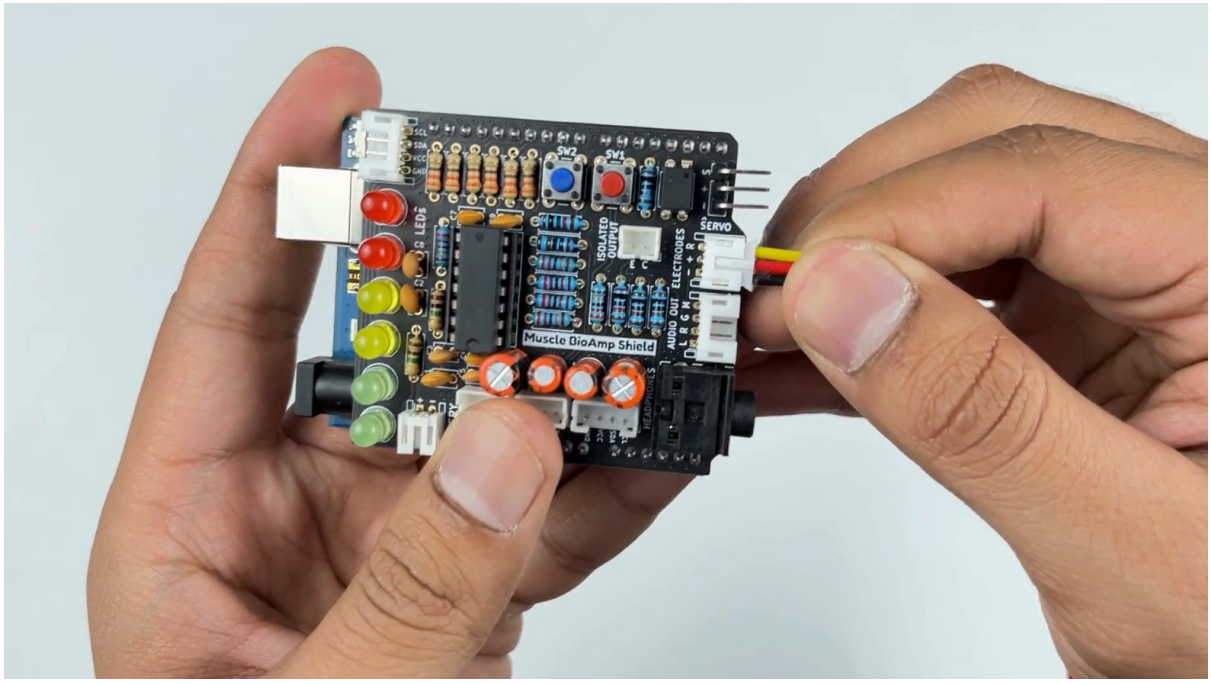
1.6.1 Step 1: Stack on Arduino Uno

Stack the Muscle BioAmp Shield on top of Arduino Uno properly.



1.6.2 Step 2: Connecting Electrode Cable

Connect the BioAmp Cable to Muscle BioAmp Shield as shown.



1.6.3 Step 3: Skin Preparation

Apply Nuprep Skin Preparation Gel on the skin surface where electrodes would be placed to remove dead skin cells and clean the skin from dirt. After rubbing the skin surface thoroughly, clean it with an alcohol wipe or a wet wipe.

For more information, please check out detailed step by step *Skin Preparation Guide*.

1.6.4 Step 4: Electrode Placements

We have 2 options to measure the EMG signals, either using the gel electrodes or using dry electrode based Muscle BioAmp Band. You can try both of them one by one.

Using gel electrodes

1. Connect the BioAmp cable to gel electrodes,
2. Peel the plastic backing from electrodes
3. Place the IN+ and IN- cables on the arm near the ulnar nerve & REF (reference) at the back of your hand as shown in the connection diagram.

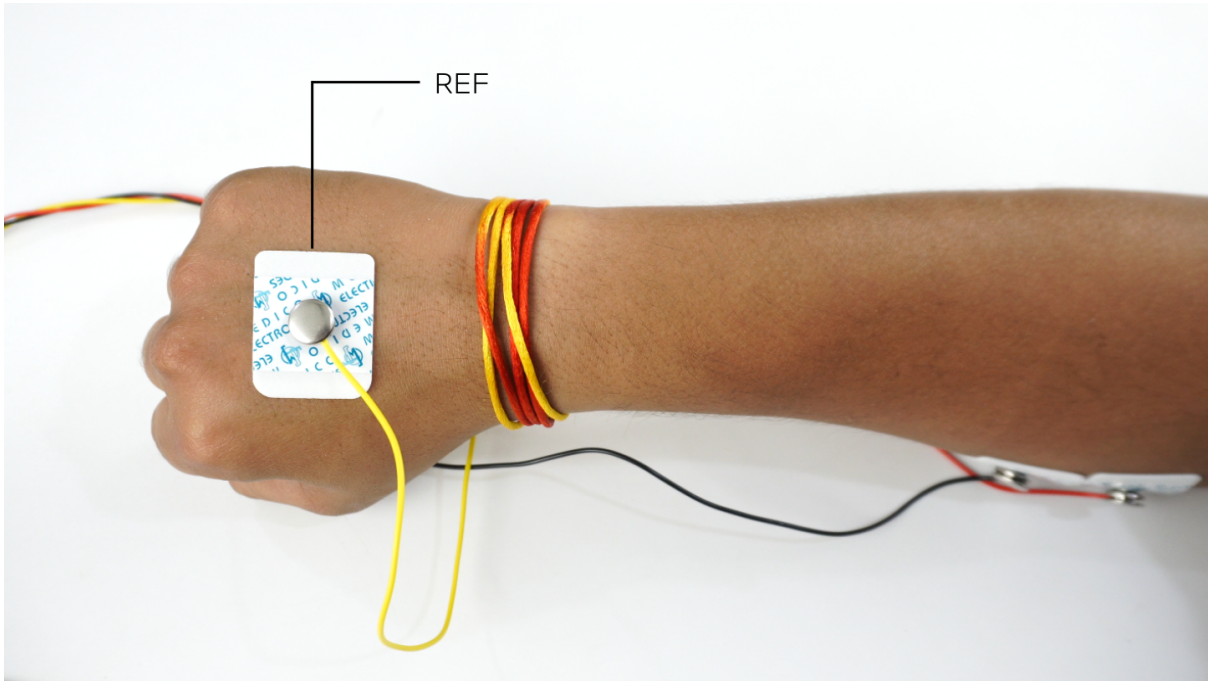


Fig. 9: *Electrode placement for REF cable*

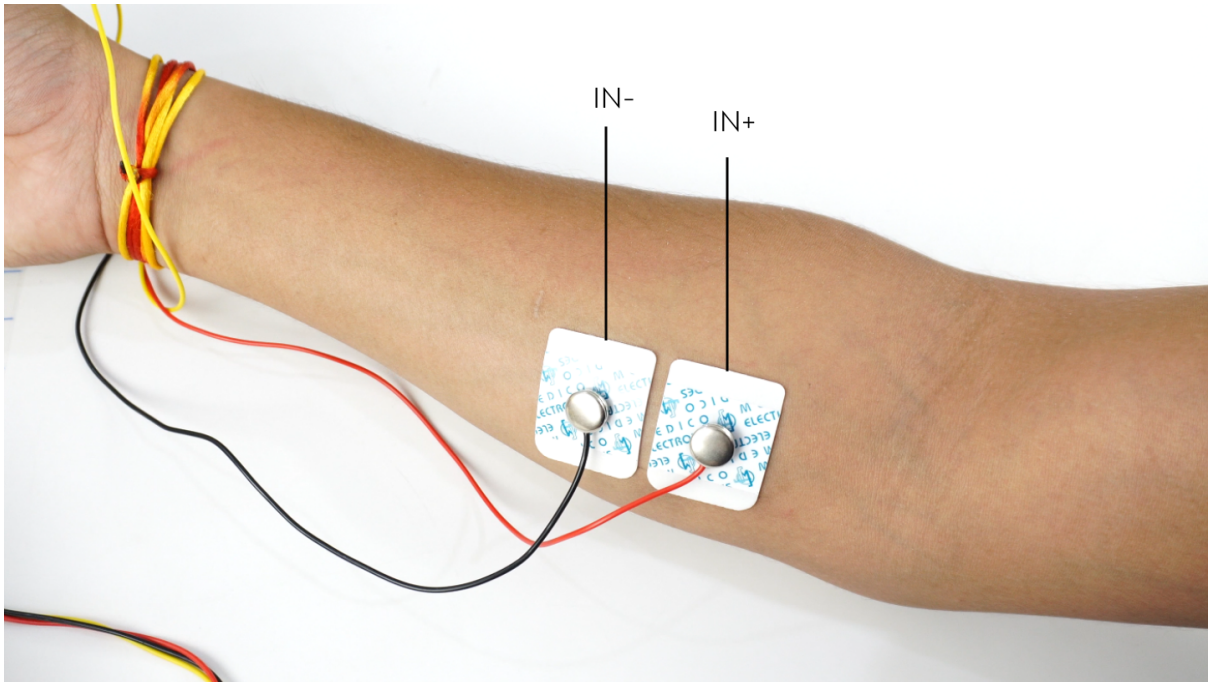


Fig. 10: *Electrode placement for IN+, IN- cables*

Using Muscle BioAmp Band

1. Connect the BioAmp cable to Muscle BioAmp Band in a way such that IN+ and IN- are placed on the arm near the ulnar nerve & REF (reference) on the far side of the band.
2. Now put a small drop of electrode gel between the skin and metallic part of BioAmp cable to get the best results.

Tip: Visit the complete documentation on how to assemble and use the BioAmp Bands or follow the youtube video given below.

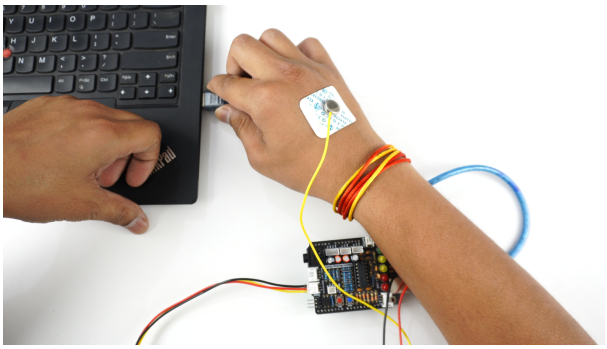
Tutorial on how to use the band:

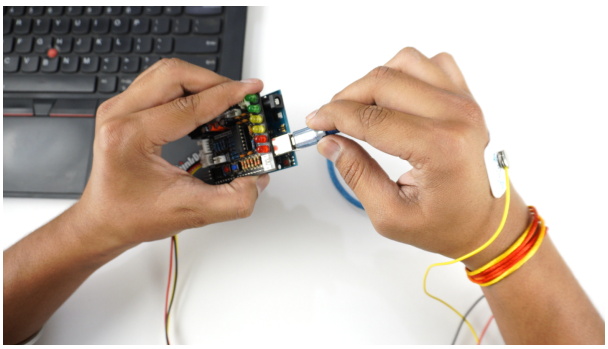
https://youtu.be/xYZdw0aesa0

Note: In this demonstration we are recording EMG signals from the ulnar nerve, but you can record EMG from other areas as well (biceps, triceps, legs, jaw etc) as per your project requirements. Just make sure to place the IN+, IN- electrodes on the targeted muscle and REF on a bony part.

1.6.5 Step 5: Connect Arduino UNO to your laptop

Connect your Arduino UNO R3 to your laptop using the USB cable (Type A to Type B).





Warning: Make sure your laptop is not connected to a charger and sit 5m away from any AC appliances for best signal acquisition.

1.6.6 Step 6: Visualise EMG signals on laptop

Copy paste any one of the arduino sketches given below in Arduino IDE v1.8.19 that you downloaded earlier:

EMG Filter

EMG Envelope

Go to `tools` from the menu bar, select `board` option then select Arduino UNO. In the same menu, select the COM port on which your Arduino Uno is connected. To find out the right COM port, disconnect your board and reopen the menu. The entry that disappears should be the right COM port. Now upload the code, & open the serial plotter from the `tools` menu to visualize the EMG signals.

After opening the serial plotter make sure to select the baud rate to 115200.

Now flex your arm to visualize the muscle signals in real time on your laptop.

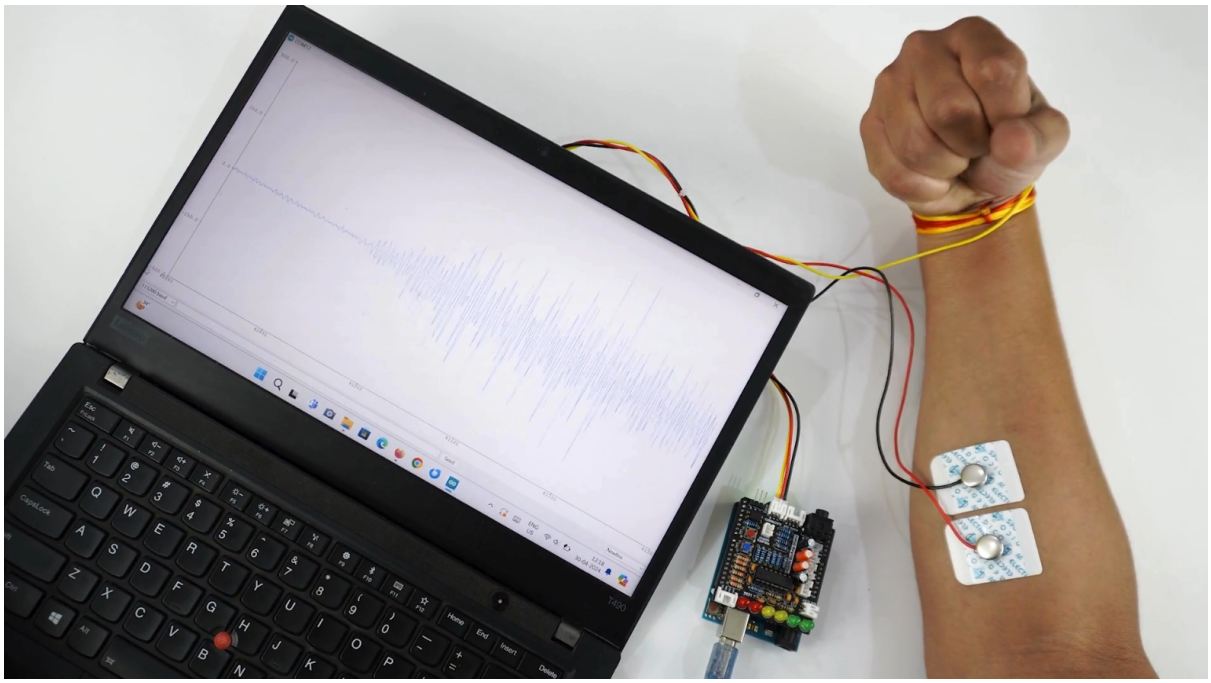


Fig. 11: *Visualise EMG signals on laptop*

1.6.7 Step 7: Visualise EMG signals on LEDs

Copy paste the Arduino Sketch given below in Arduino IDE:

LED Bar Graph

Make sure you have selected the right board and COM port. Now upload the code, and flex your arm. You'll see the LED bar going up. More strength you apply, more the LED bar goes up.

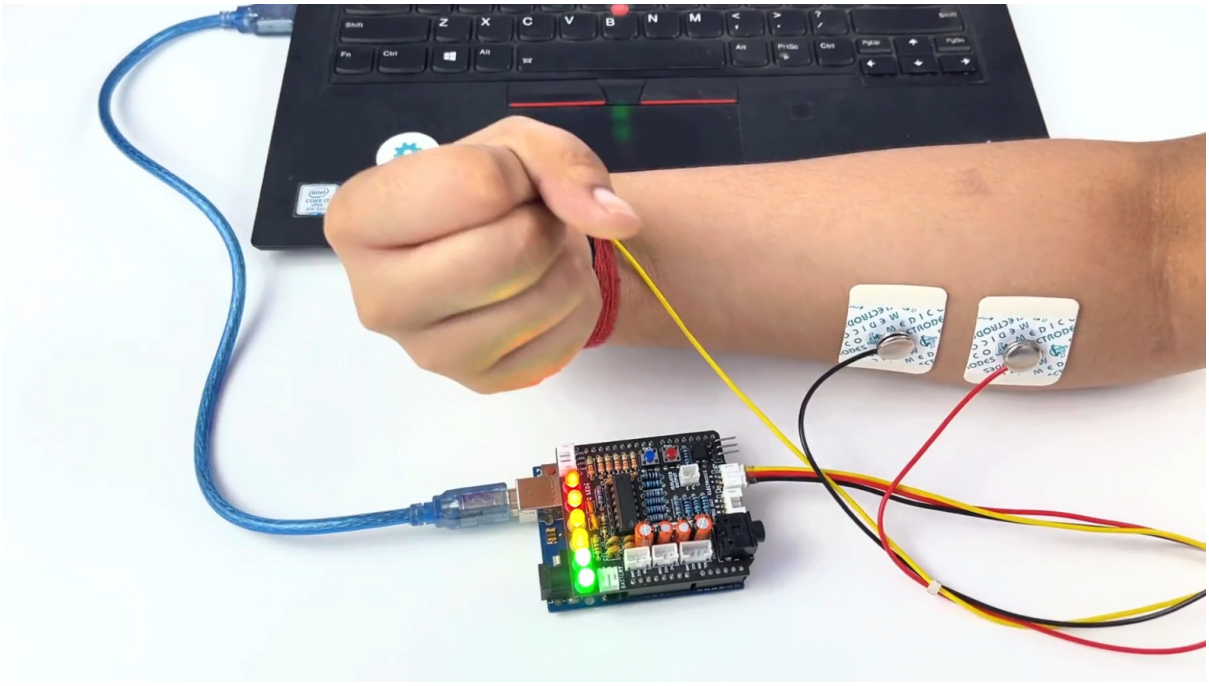


Fig. 12: *Visualise EMG signals on LEDs*

1.6.8 Step 8: Listen to your EMG signals

You can either listen to the muscle signals (EMG) on a speaker or wired earphones/headphones. Let's try both of them.

Listening EMG on speakers

1. Connect the BioAmp AUX cable on a bluetooth speaker that have 3.5mm jack support.
2. Switch on the speaker and turn the volume to maximum.
3. Flex and listen to your muscles.

Listening EMG on a wired earphones/headphones

1. Plug your wired earphones or headphones on the 3.5mm jack of BioAmp v1.5.
2. Plug it in your ears.
3. Flex and listen to your muscles.

1.6.9 Step 9: Controlling a servo motor

Connect the servo claw to Muscle BioAmp Shield.

Copy paste the Arduino Sketch given below in Arduino IDE:

Servo Controller

Make sure you have selected the right board and COM port. Now upload the code, and flex your arm to control the servo claw in real time.

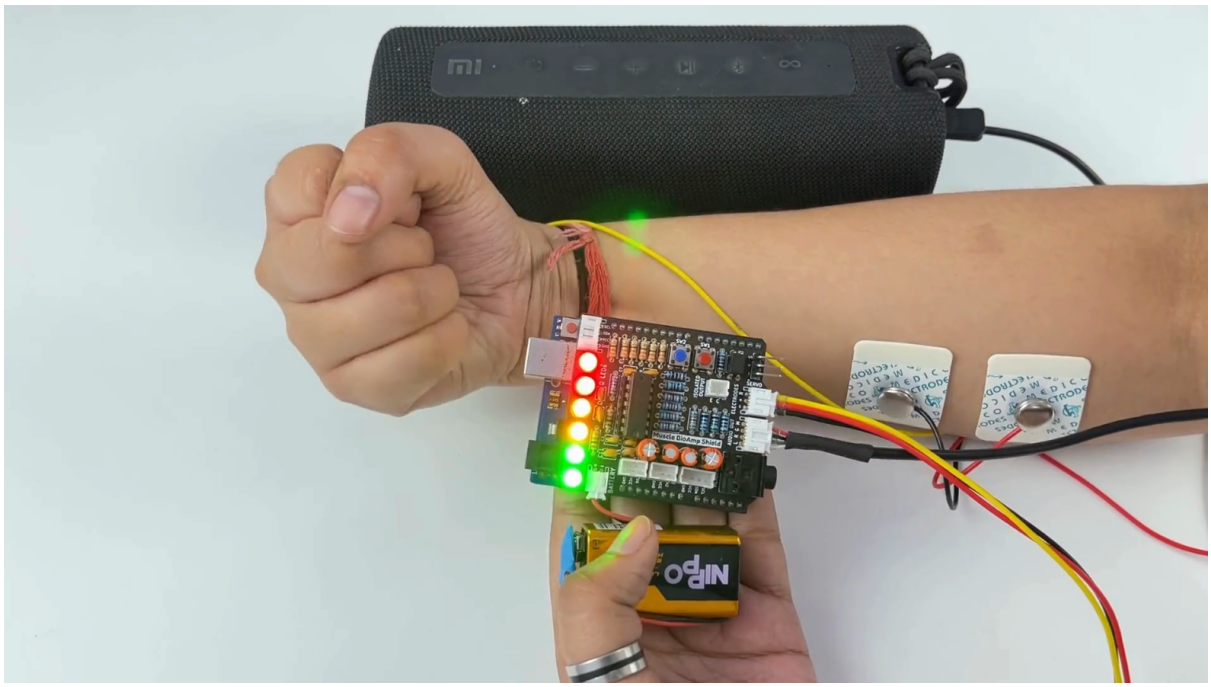


Fig. 13: Listening EMG on speakers

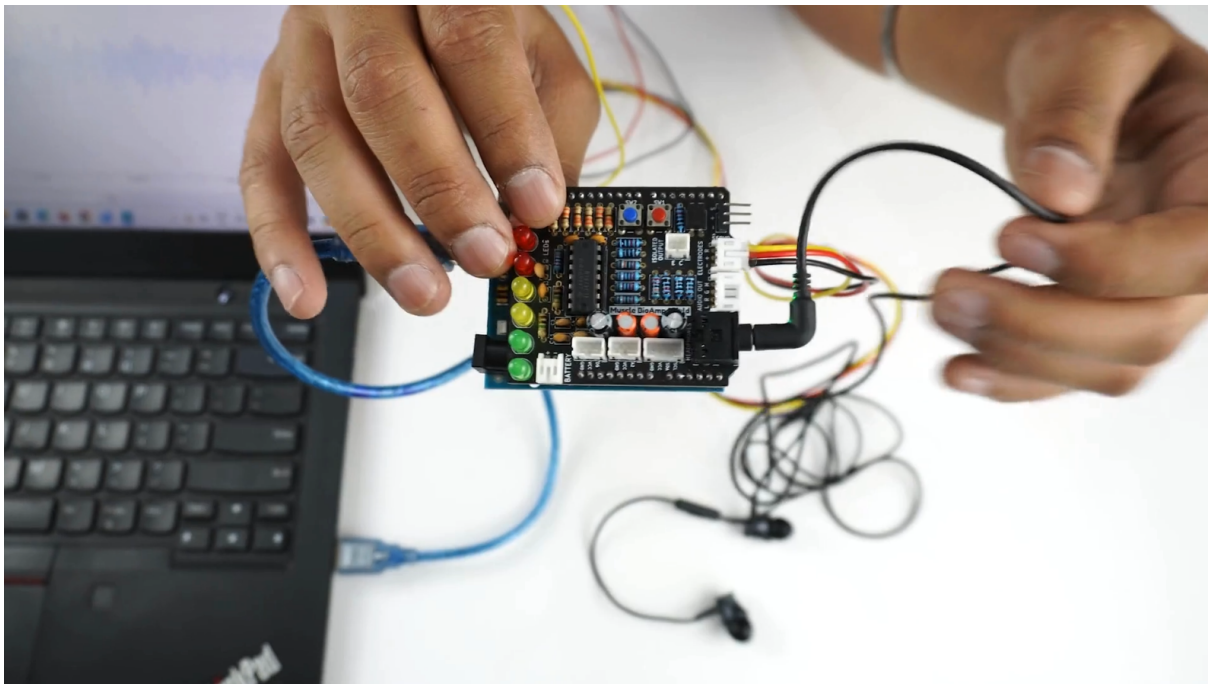


Fig. 14: *Listening EMG on a wired earphones/headphones*

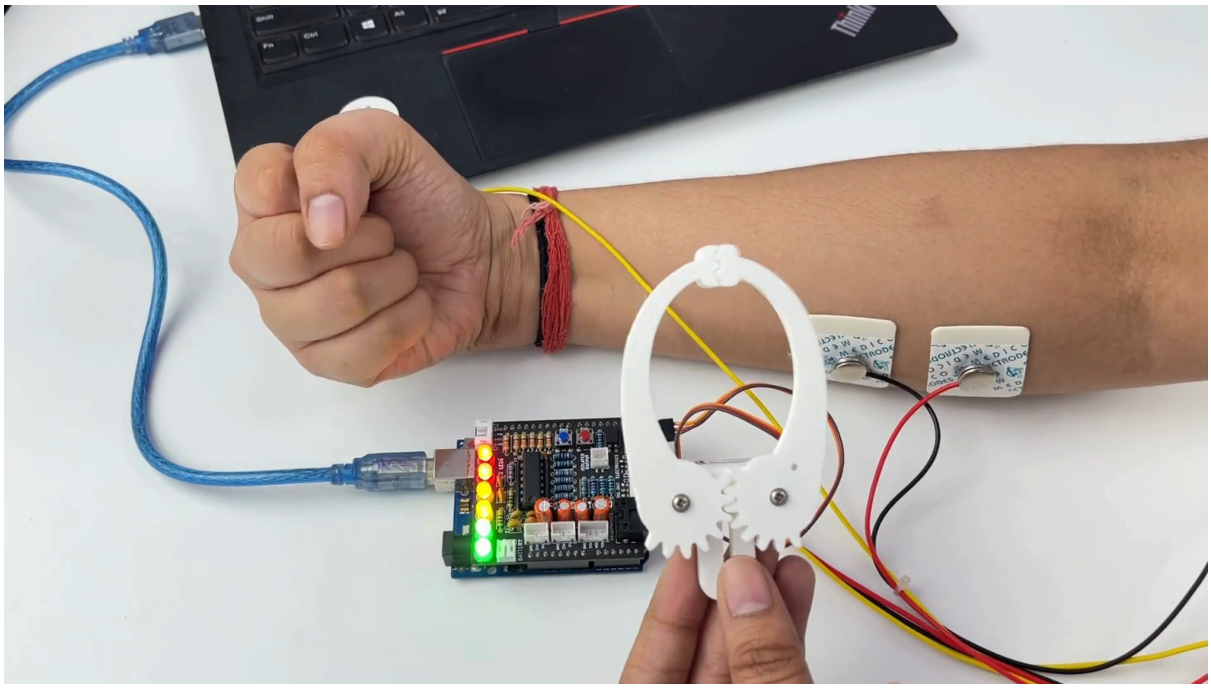
1.6.10 Step 10: Controlling a servo claw

Connect the servo claw to Muscle BioAmp Shield.

Copy paste the Arduino Sketch given below in Arduino IDE:

Claw Controller

Make sure you have selected the right board and COM port. Now upload the code, and flex your arm to control the servo claw in real time.



1.6.11 Step 11: Connecting 9V battery

Till now, the power for the EMG system was coming from the laptop via USB cable of Arduino Uno but there can be 2 ways in which you can make the system portable:

- **Using 9V battery:** Directly connect a 9V battery to Muscle BioAmp Shield using a 9V snap cable.
- **Using Power Bank:** Instead of connecting the USB cable of Arduino Uno to laptop, you can directly connect it to power bank.

Note: Do not use 9V battery while controlling a servo claw using Muscle BioAmp Shield. Instead connect the Arduino UNO to a power bank or directly to your laptop.

1.6.12 Step 12: Other functionalities you can explore

Using I2C ports

There are 2 I2C ports available on Muscle BioAmp Shield and you can connect hundreds of devices having I2C compatibility using the 4-pin JST PH 2.0 mm STEMMA cables provided.

Some of the examples are: `OLED screens`, `character displays`, `temperature sensors`, `accelerometers`, `gyroscopes`, `light sensors`, `BioAmp Hardware`, etc.

Using STEMMA Digital port

Connect Arduino Uno's D6 digital I/O pins using STEMMA digital connectors.

Using STEMMA Analog port

Connect Arduino Uno's A2 analog input pins using STEMMA analog connectors.

Using user buttons

Program the 2 user buttons according to your project requirements.

CHAPTER

TWO

SKIN PREPARATION GUIDE

2.1 Why skin preparation is important?

Proper skin preparation is crucial before recording any biopotential signal be it Electrocardiography (ECG), Electromyography (EMG), Electroencephalography (EEG), or Electrooculography (EOG).

- `Clean skin surface:` Removes dead skin cells, oils, & other substances that increases skin impedance.
- `Improve impedance:` Improves the conduction of electrical signals from the body to the recording equipment and minimizes impedance.
- `Electrode-skin contact:` Ensures optimal contact between the electrodes and the skin surface.
- `Signal quality:` Enhances the overall quality of recorded signals, providing clear & reliable data for analysis & improves the ability to capture subtle variations in biopotential signals.
- `Consistency in recordings:` Reduces variability in signal quality, making it easier to make any Human-Computer Interface (HCI), Brain-Computer Interface (BCI) project or a real-world application.
- `Long term adhesion:` Facilitates long-term adhesion & stable placement of electrodes to the skin during extended signal monitoring.

2.2 Kit Contents

Nuprep gel	Mildly abrasive, highly conductive gel that should be applied before placing the electrodes on the skin to improve signal quality & enhances the performance of monitoring electrodes.
Electrode Gel	Highly conductive gel that acts as a coupling agent between dry electrodes and the skin to aid the transmission of biopotential signals like ECG, EMG, EOG, or EEG.
Ten20 paste	Contains the right balance of adhesiveness and conductivity, enabling the dry electrodes to remain in place while allowing the transmittance of biopotential signals.
Alcohol Swabs/Wet wipes	Soft & non-woven pads that helps in cleaning the skin surface and does not leave any residue.
Cotton Swabs	Useful while applying nuprep gel or ten20 paste.

2.3 Steps to follow

You can follow the steps given below to do the skin preparation properly:

2.3.1 Step 1: Identify the targeted area

Identify the target area where the gel electrodes or BioAmp Bands will be placed for recording the biopotential signals.

2.3.2 Step 2: Apply NuPrep gel

Take a small amount of NuPrep gel using a cotton swab and apply it on your targeted area.

2.3.3 Step 3: Clean the skin surface

Use gentle, circular motions to rub the gel on the skin surface. This removes all the dead skin cells & improves conductivity.

> **Warning:** Do not rub the gel for too long as it has abrasive properties and may cause skin redness and irritation.

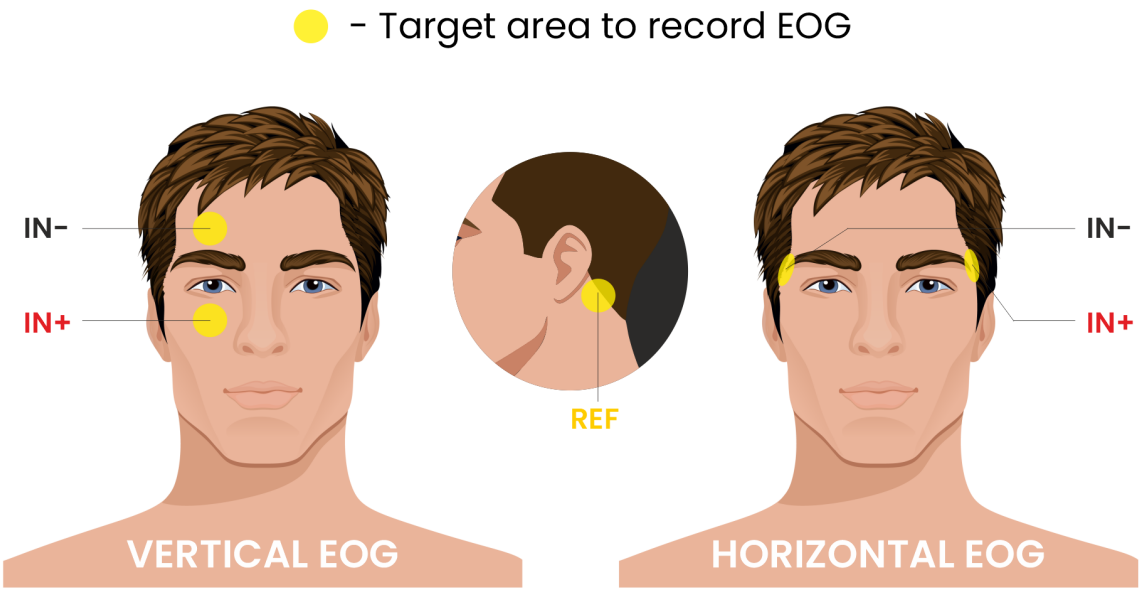


Fig. 1: Target area to record EOG

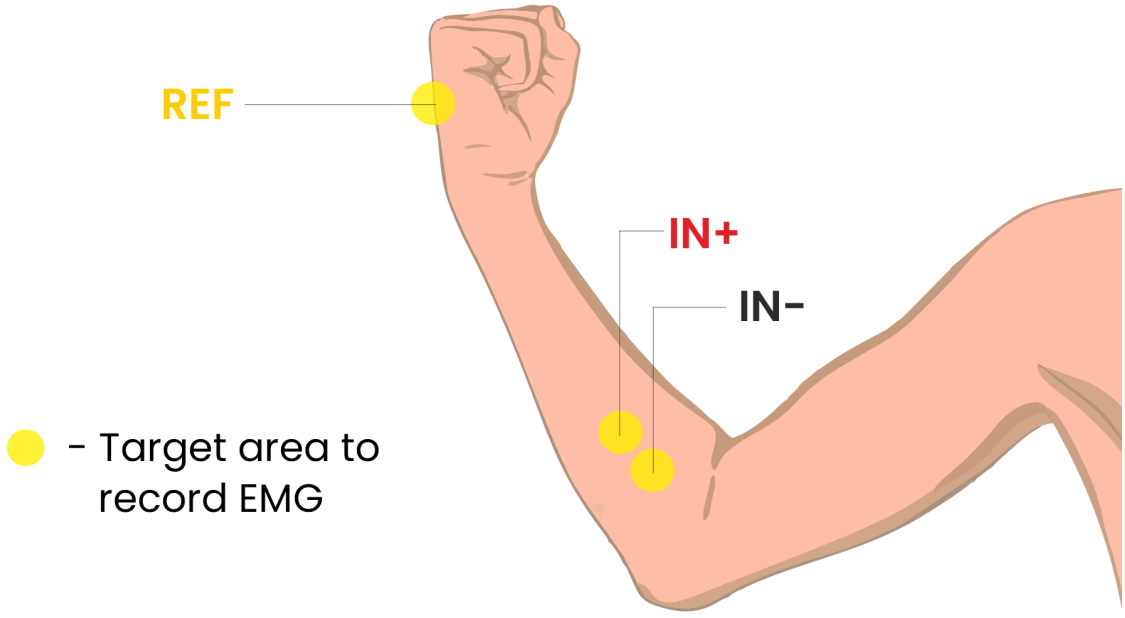


Fig. 2: Target area to record EMG

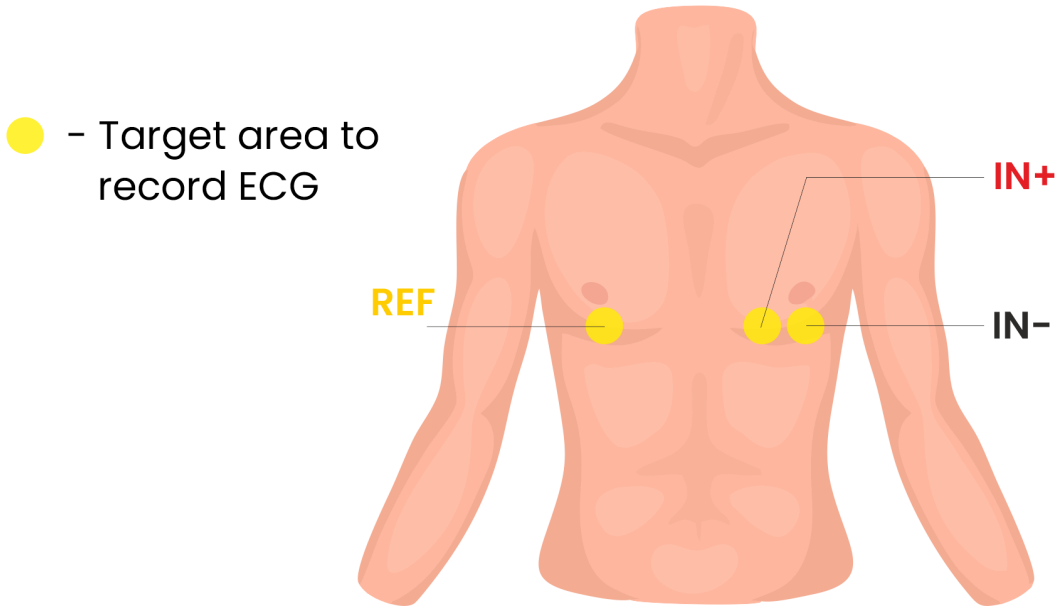


Fig. 3: Target area to record ECG

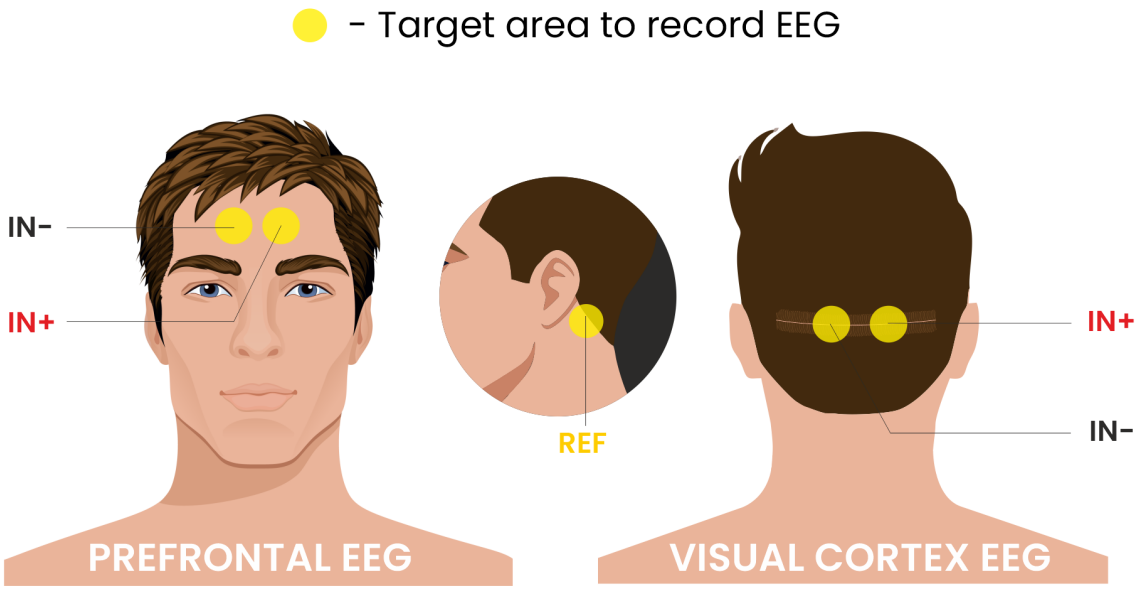


Fig. 4: Target area to record EEG

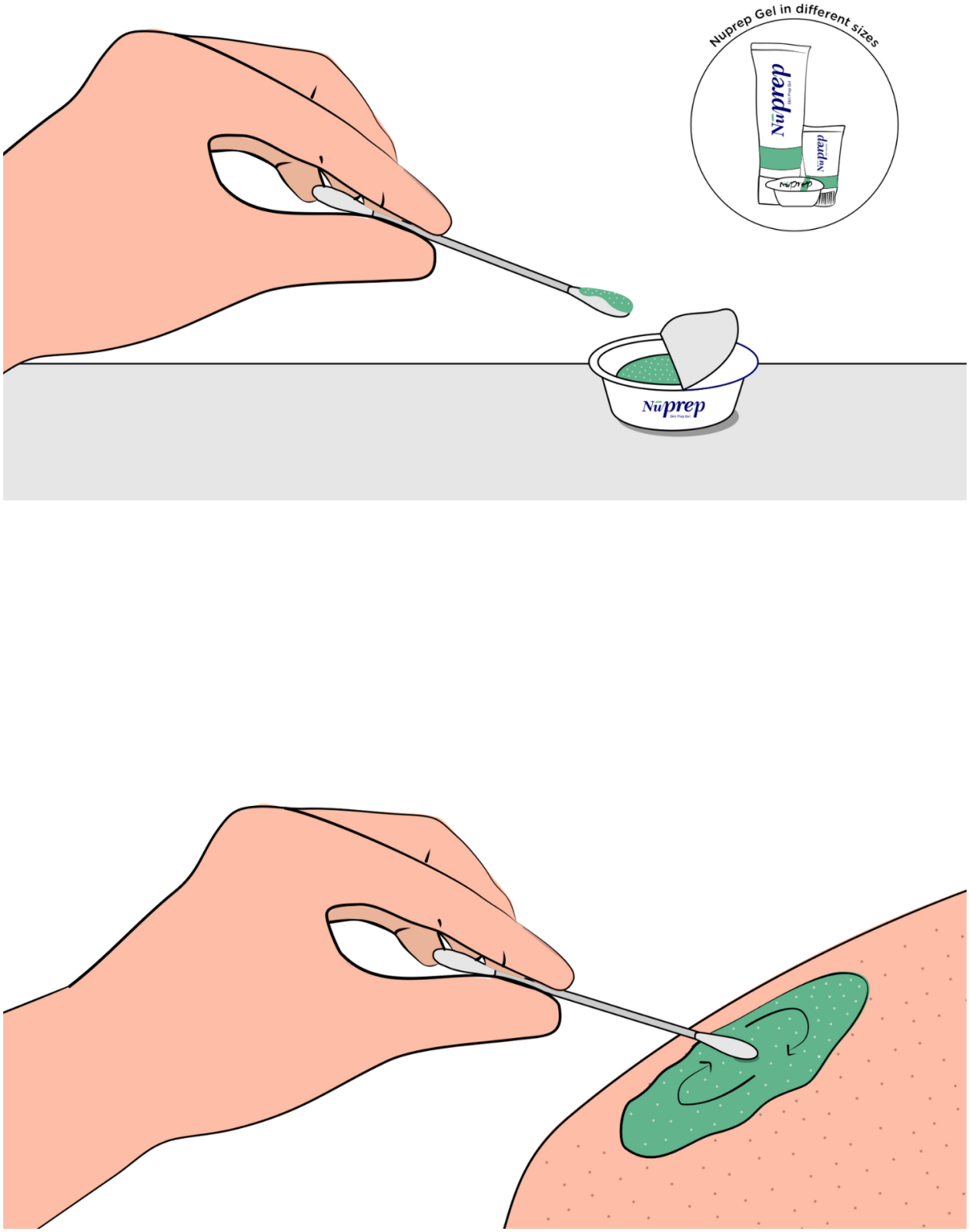


Fig. 5: Rub the gel gently using the cotton swab

2.3.4 Step 4: Wipe off the gel

Wipe away excess gel with alcohol swabs or wet wipes.

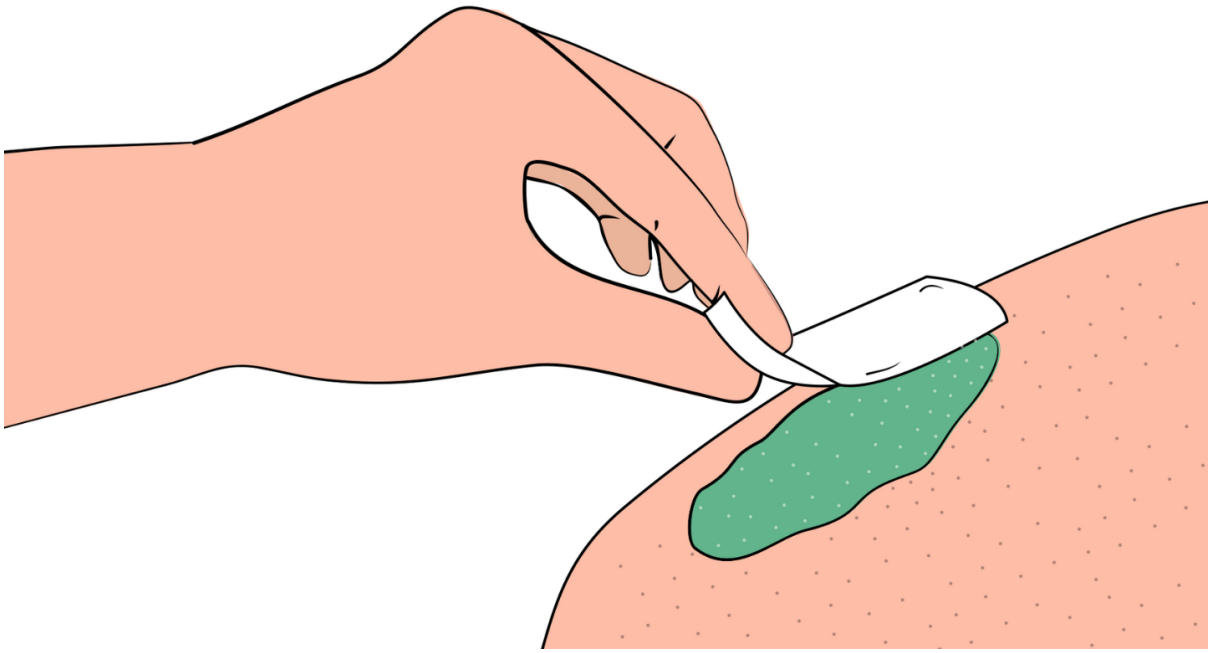


Fig. 6: Wipe away access gel

Warning:

- Using alcohol swabs can dry out the skin, so don't use them if your skin is already dry.
- Close your eyes while using the alcohol swabs for EOG recording else it may cause eye redness & irritation.

2.3.5 Step 5: Measuring the signals

Now you can either use gel electrodes or BioAmp bands for the signal recording.

Using gel electrodes

Connect the BioAmp cable to gel electrodes, peel the plastic backing from electrodes and place the IN+, IN-, REF cables according to your specific biopotential recording.

Note: While placing the gel electrodes on the skin, make sure to place the non-sticky tab of the electrode in the direction opposite to your hair growth. This allows you to remove the electrodes easily without pulling off much body hair.

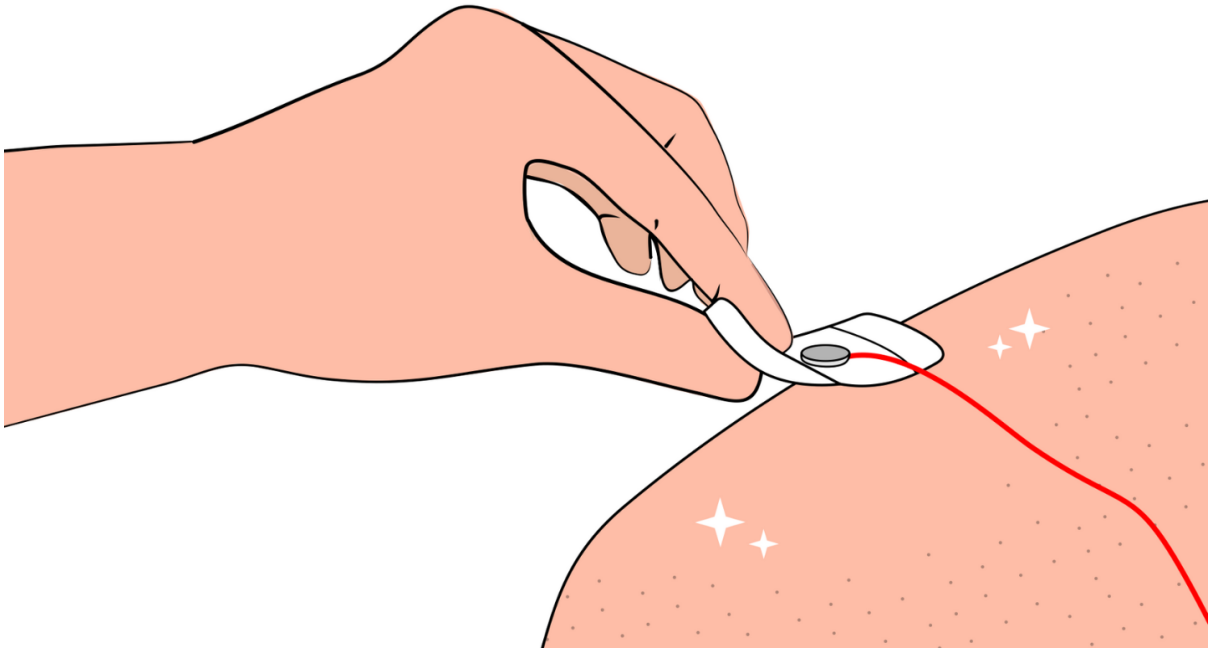


Fig. 7: Placing gel electrodes on skin surface

Using BioAmp bands

Connect the BioAmp cable to your BioAmp band. Now apply a small amount of `electrode gel` or `Ten20 conductive paste` on the dry electrodes between the skin and metallic part of BioAmp cable. This improves the signal conductivity, enhancing overall signal quality.

Note: The above graphics demonstrates the use of electrode gel/Ten20 paste with Muscle BioAmp Band. Similarly you can use Brain BioAmp Band and Heart BioAmp Band. Refer to using-bioamp-bands guide to assemble and use all the BioAmp Bands correctly.

Now you are all set! Make all the connections correctly and start recording your biopotential signals.

Warning: NuPrep gel, Ten20 paste and the alcohol swabs shouldn't be used if you have a history of skin allergies to lotions and cosmetics.

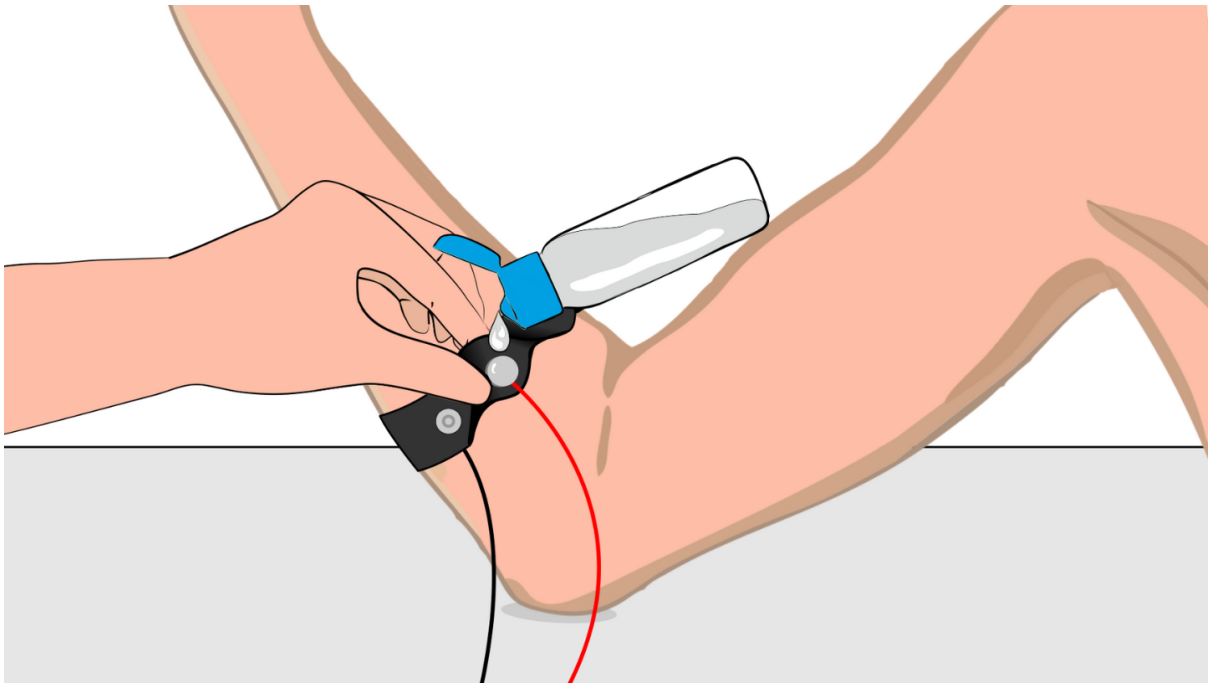


Fig. 8: Method 1: Using Electrode gel

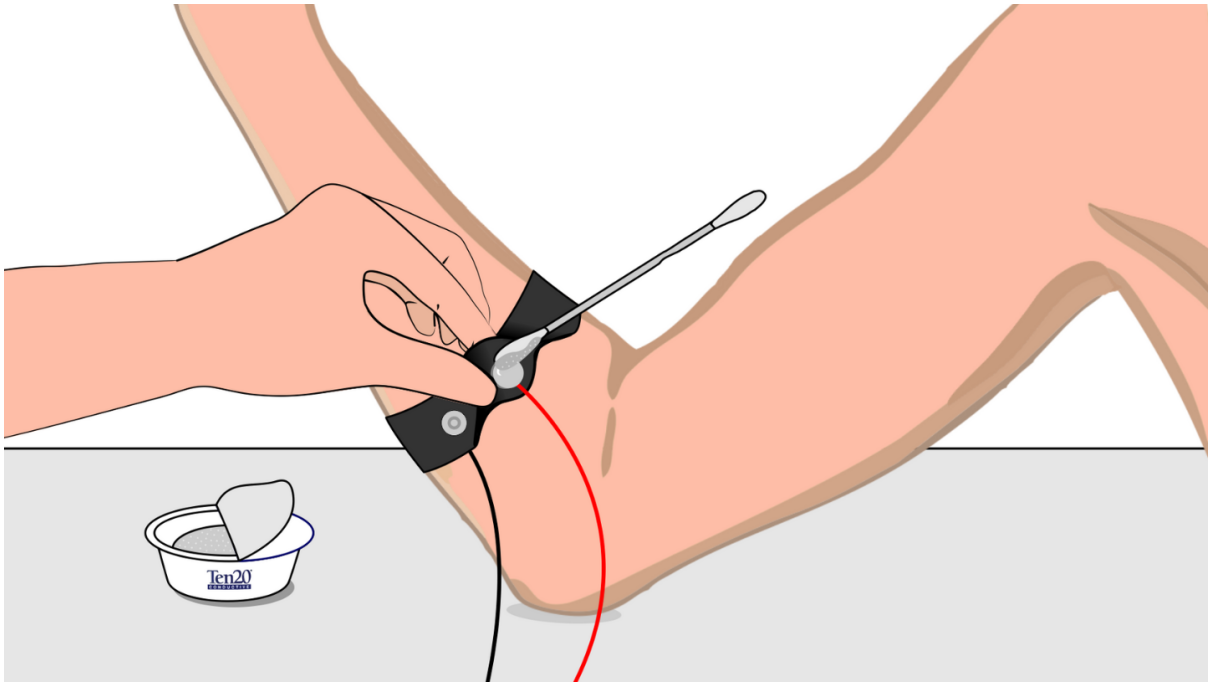


Fig. 9: Method 2: Using Ten20 paste