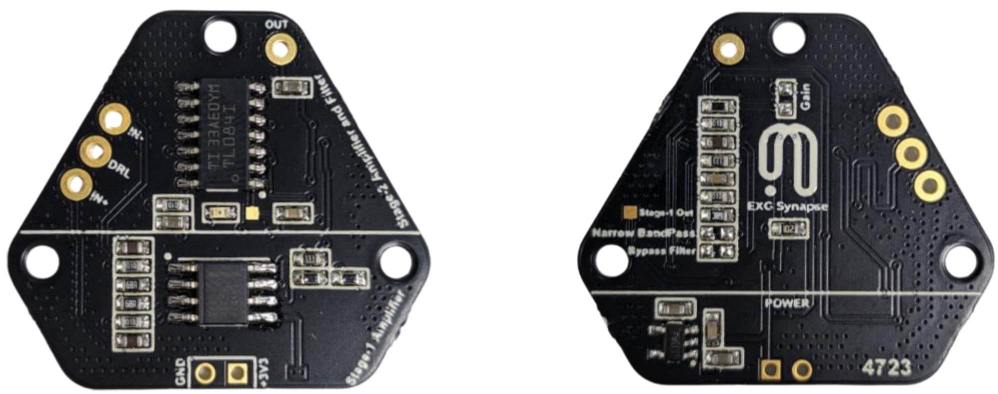
Product Reference Manual



Introduction

Neuphony EXG Synapse is an innovative, hexagon-shaped chip designed for recording high-quality biopotential signals from various regions of the body, including the heart (ECG), brain (EEG), eyes (EOG), and muscles (EMG). Serving as a robust analog-front-end (AFE) biopotential signal-acquisition board, the Neuphony EXG Synapse can seamlessly integrate with a range of microcontroller units (MCUs) or single-board computers (SBCs) equipped with an analog-to-digital converter (ADC). Compatible platforms include popular options such as Arduino UNO & Nano, Espressif ESP32 and more.

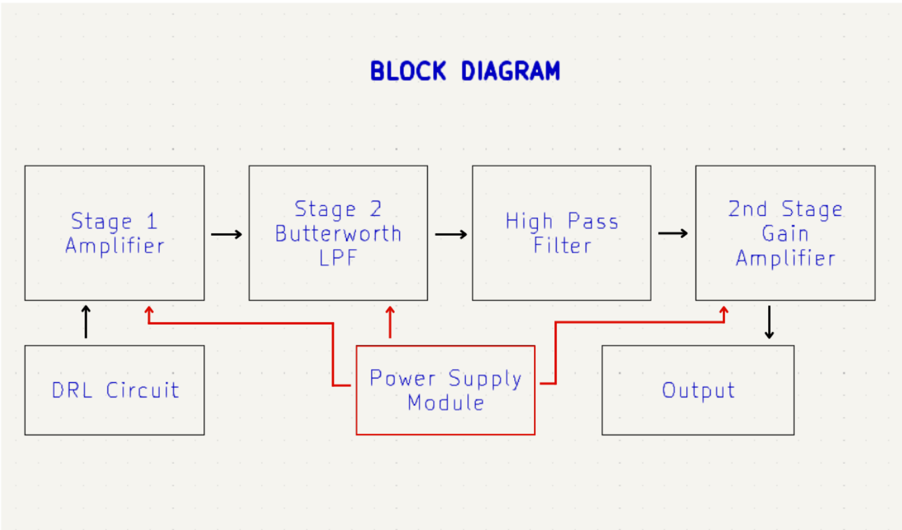
This versatile device also interfaces effortlessly with dedicated ADCs like the Texas Instruments ADS1115 and ADS131M0x, expanding its compatibility and flexibility for diverse applications. The Neuphony EXG Synapse empowers users to explore and capture publication-grade biopotential signals, making it a valuable tool for researchers, developers, and enthusiasts in the field of bioelectronics and health monitoring.

CONTENTS

1 Features

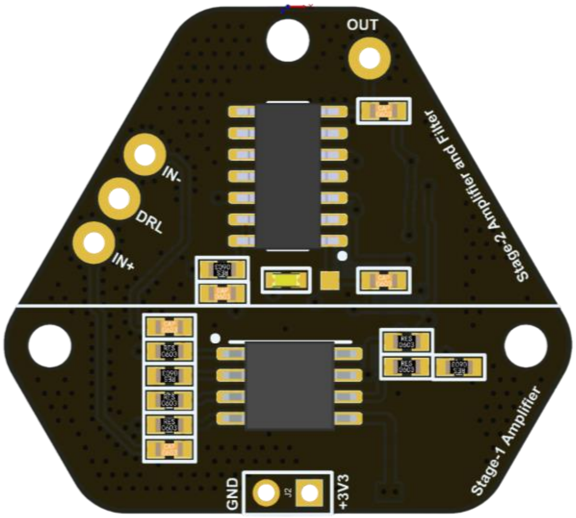
1. Comprehensive biopotential signal compatibility, covering ECG, EEG, EOG, and EMG, ensures a versatile solution for various physiological monitoring applications.
2. Neuphony EXG Synapse offers customizable gain and filter bandwidth settings for precise signal configuration.
3. Enjoy flexibility with an optional bypass of the bandpass filter, allowing tailored signal output for diverse analysis.
4. Seamlessly pairs with any MCU featuring ADC, expanding compatibility across platforms like Arduino, ESP32, STM32, and more.
5. Seamless Python/LSL compatibility

2 Block Diagram

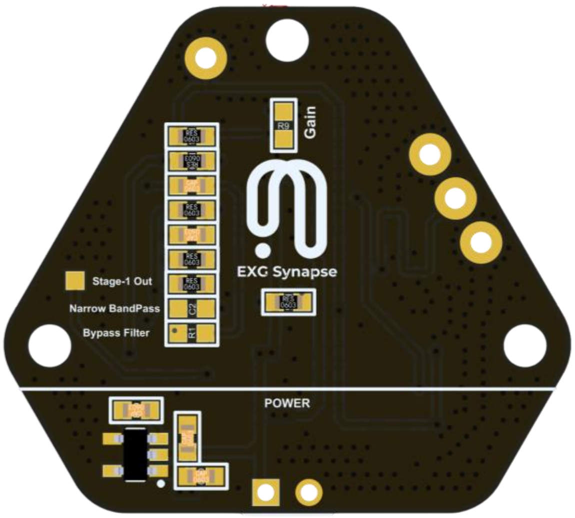


3 The Board

3.1 Top View



2.1 Bottom View



4 Specifications

1. **Input Voltage:** 3.3V
2. **Input Impedance:** 20 GΩ
3. **No. of channels**: 1
4. **Electrodes**: 3
5. **Compatible Hardware:** Any ADC input
6. **Biopotentials:** ECG EMG, EOG, or EEG (configurable bandpass)

   By default configured for a highpass cutoff of 1.6Hz and a lowpass cutoff of 47Hz and Gain 50
7. **Dimensions**: 30.0 x 33.0 mm

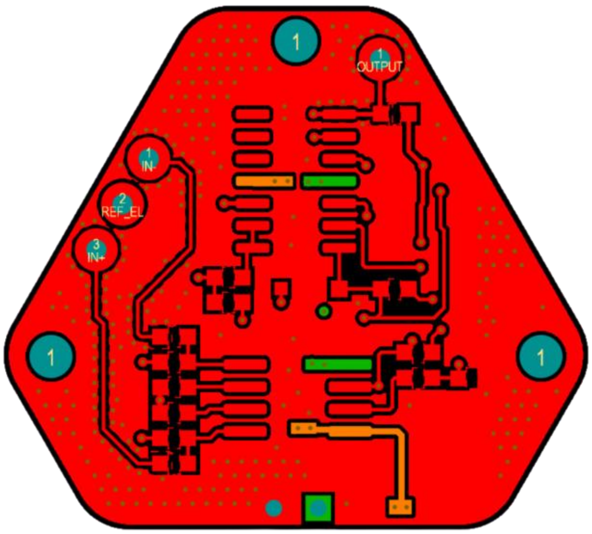
5 Absolute Maximum Ratings

Description	Min	Typ	Max	Unit
Input voltage from 3V3 pad	1.8	3.3	5.5	V
Operating Temperature	-40	25	85	°C

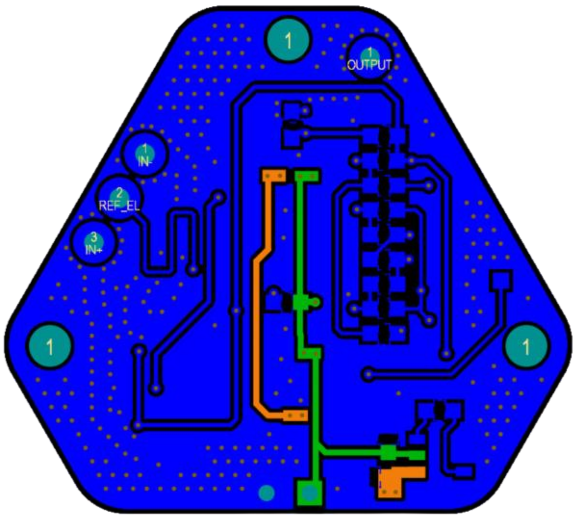
Recommended Operating Conditions for Neuphony EXG Synapse's input voltage is 3.3V

6 Board Topology / Layers

6.1 Top Layer



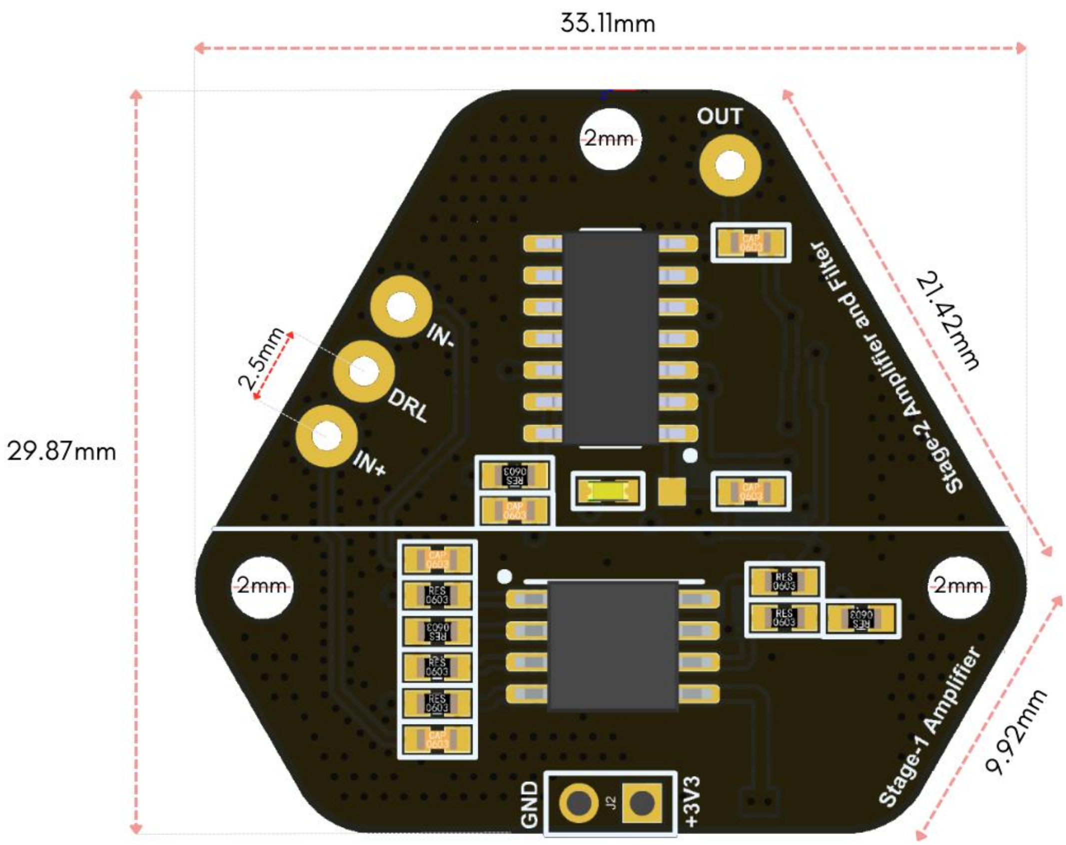
6.2 Bottom Layer



6.3 Layer Stack-Up

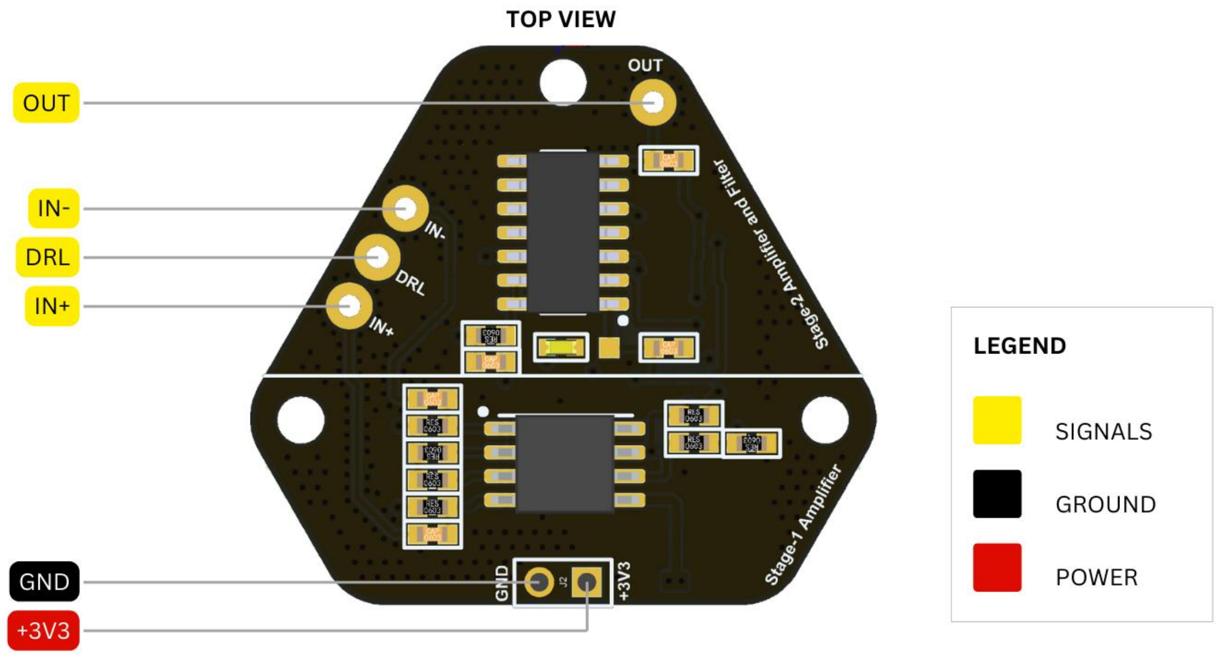
Layer	Name	Material	Thickness	Constant	Board Layer Stack
	Top Overlay				
	Top Solder	Solder Resist	0.010mm	3.5	
1	TOP	CF-004	0.035mm		
	Dielectric1	Core-042	0.500mm	4.8	
2	BOTTOM	CF-004	0.035mm		
	Bottom Solder	Solder Resist	0.010mm	3.5	
	Bottom Overlay				
Total board thickness:			0.590mm		

7 Dimensions



8 Pinout

8.1 Pinout Diagram



Pinout for Neuphony EXG Synapse

8.1 Pin Description

Pin	Type	Description
OUT	ANALOG	Anlog output
IN-	ANALOG	Negative analog input
DRL	ANALOG	Right Leg Drive
IN+	ANALOG	Positive analog input
GND	POWER	Ground
+3V3	POWER	+3V3 Power Rail

Pin description for Neuphony EXG Synapse

9 Default Frequency Range

Default Frequency Range for input signals.

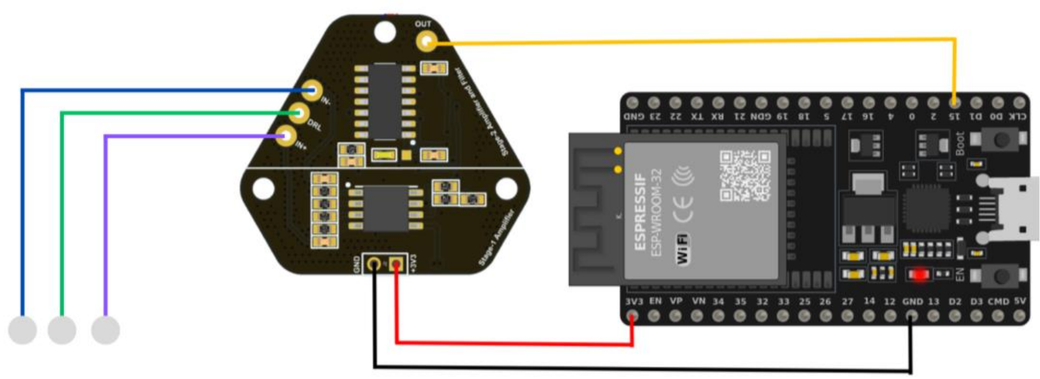
1. ECG Frequency Range: 0.5 - 40Hz
2. EMG Frequency Range: 75 - 150 Hz
3. EEG Frequency Range: 0.5 - 47.5 Hz
4. EOG Frequency Range: 0.5 - 15 Hz

10 Getting Started

- **Requirements**
  Hardware: EXG Synapse, DOIT-ESP32-DEVKIT-V1, Jumper Wires
  Software: Arduino IDE

- **PCB Configuration:** EXG Synapse has configuration options in terms of gain and bandpass filter bandwidth. The user can modify these values depending on the use case. Here is an image showing the resistor pad R9(for gain) and capacitor pad C2(for filter bandwidth).

- **Connection with ESP32** EXG Synapse requires only three wires to connect to any MCU. 3V3 connects to the 3V3 pin on the ESP32 and GND to GND pin on the ESP32. The Output of EXG Synapse can be connected to any ADC pin of ESP32 and configured as an analog input to read the data.



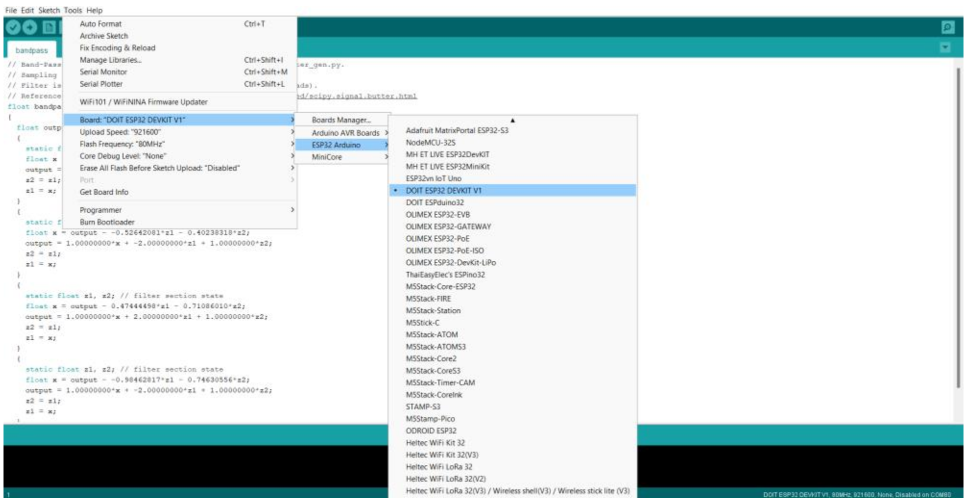
- **Installing the Library:** We have developed a library intended for integration into your code, facilitating the acquisition of EXG signals. Install the required library available on our [Github repository.]

- **Flashing Code on ESP32:** To flash the required code on ESP32, you need to install Arduino IDE and setup for flashing to an ESP32. You can follow [this guide] if you don't find your board listed in Arduino. Once your board is added to Arduino, you can go to [our GitHub repository], here you will find all the necessary files for acquiring the data using EXG Synapse.

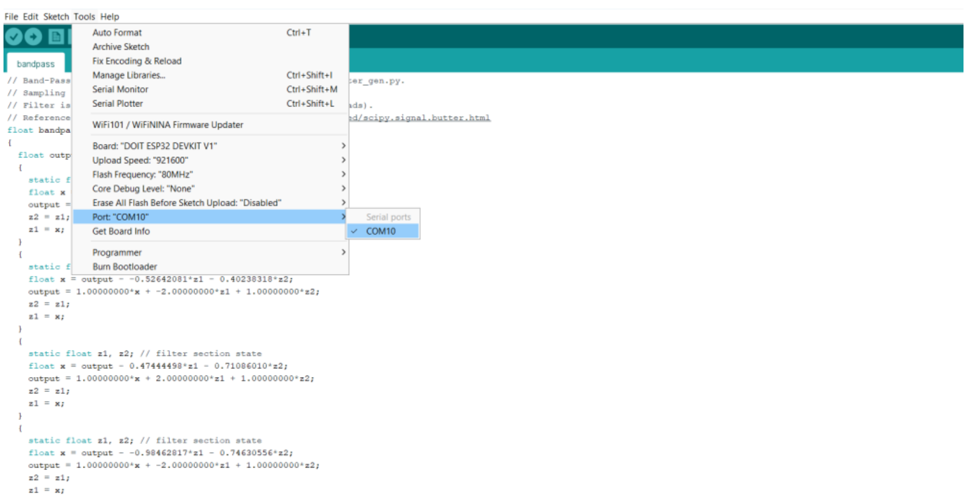
Navigate to the folder of your choice (serial or BLE), and download the required .ino (EEG, ECG, EMG, EOG). Now compile and upload the code on your board.

Please follow the screenshots given below.

Board Selection:



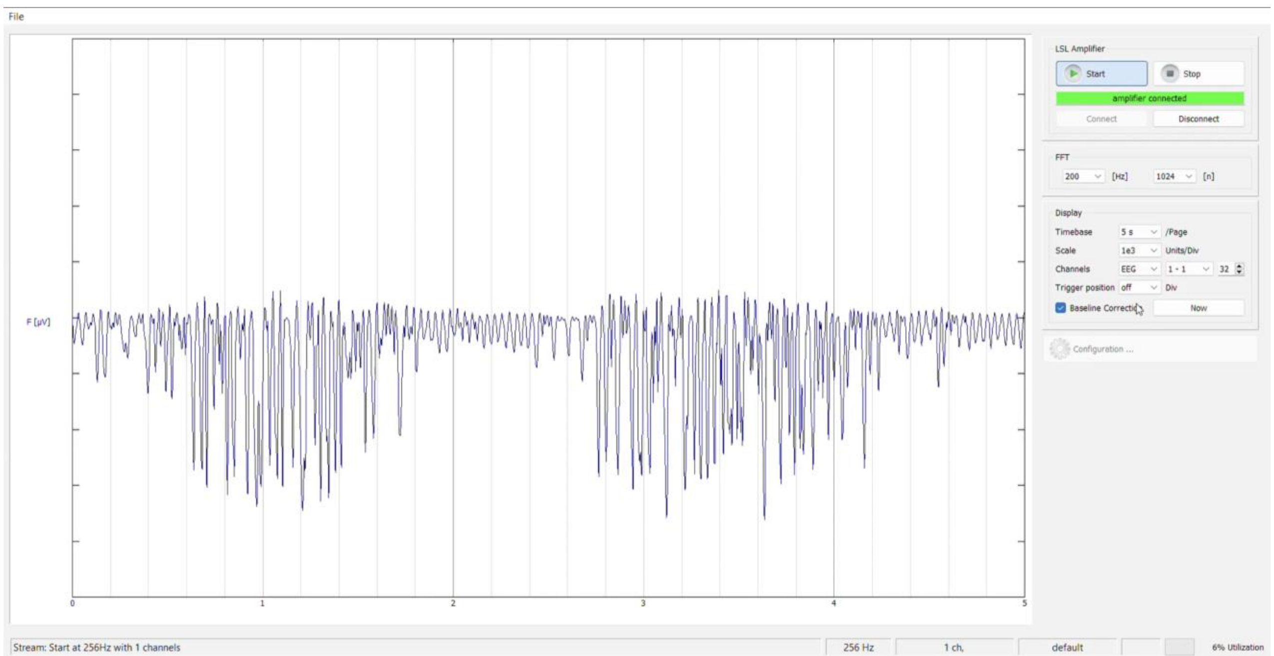
COM Port Selection:



- **Skin Preparation:** Before placing the electrode, skin surface must be cleaned with an alcohol based wet wipe and then Nuprep Gel can be used to enhance the signal quality as it reduces the skin impedance. You can follow [this] guide on how to use Nuprep Gel while preparing for data acquisition.

- **Data Visualization: Serial**: The Lab Streaming Layer (LSL) is a system designed for real-time data streaming and recording. We have provided a python script located in the GitHub repository used to read the data from serial and create an LSL stream. The stream created by the script can be easily visualized using a LSL-compatible software such as **BrainVision LSL Viewer**. It can be downloaded for free using this link.

  BLE: If flashed with the code provided under software\Arduino\ble, ESP32 will stream data continously over BLE. You can create a client-side interface to read this data and use it for further applications.

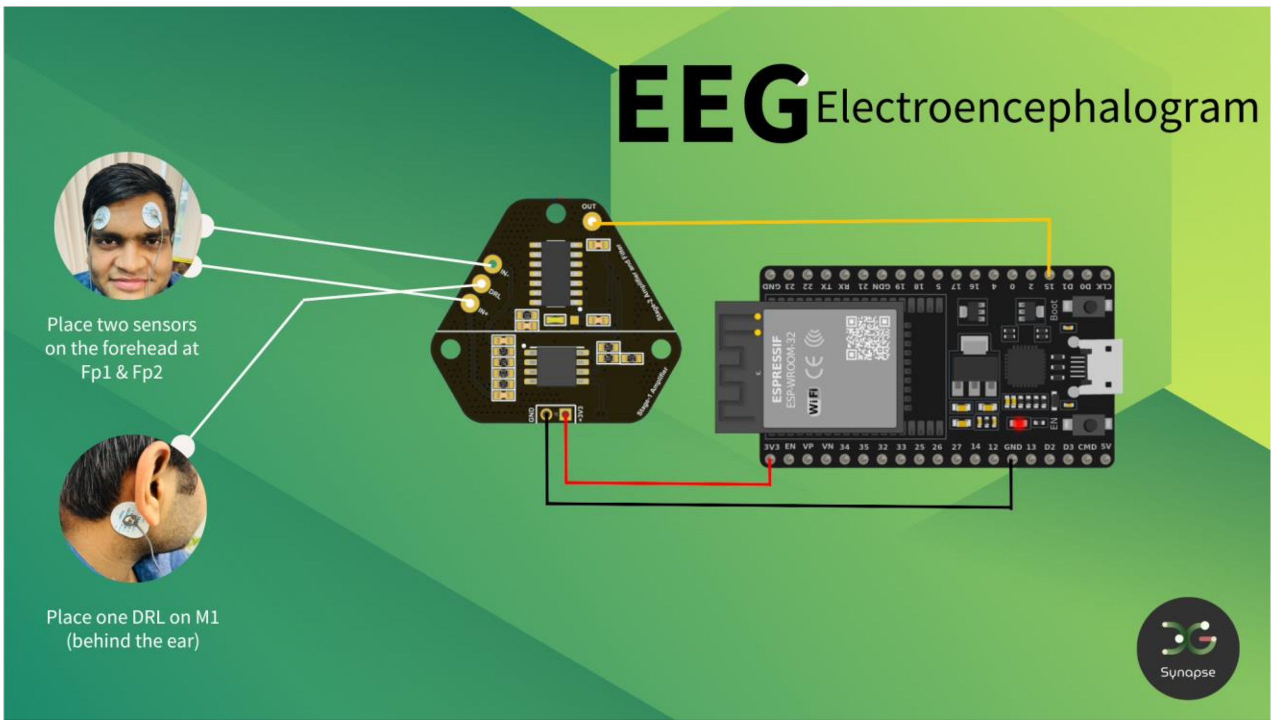


11 EXG Circuits

11.1 EEG

What is EEG:

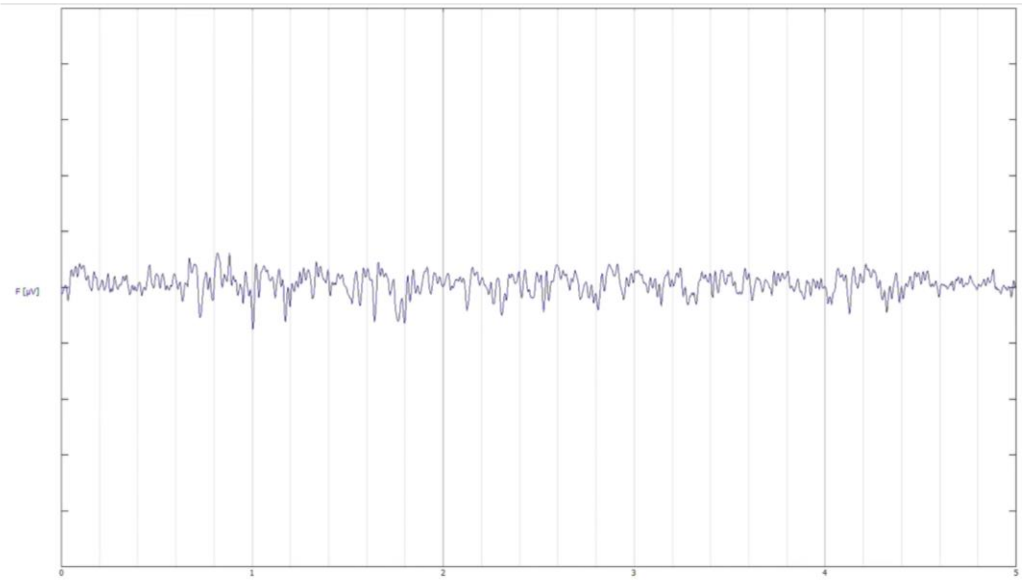
EEG stands for electroencephalography, which is a non-invasive technique used to measure and record electrical activity in the brain. It involves placing electrodes on the scalp to detect and amplify the electrical signals produced by the brain. These signals, known as brainwaves, can provide insights into brain function and activity.



Electrode Placement: Check above image for correct electrode placement

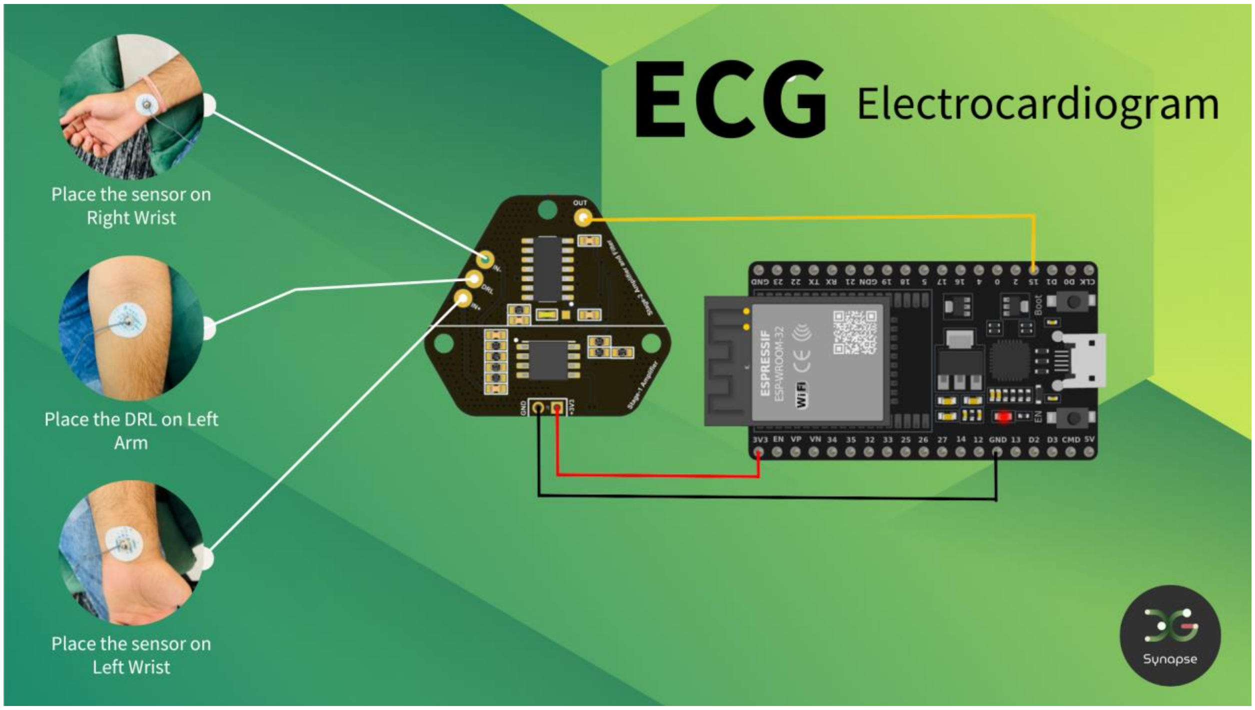
Data Visualization:

The Lab Streaming Layer (LSL) is a system designed for real-time data streaming and recording. We have provided a python script for **EEG** located in the [GitHub repository] used to read the data from serial and create an LSL stream. Following is a screenshot of EEG data captured with Synapse.


F [µV]
0
1
2
3
4
5

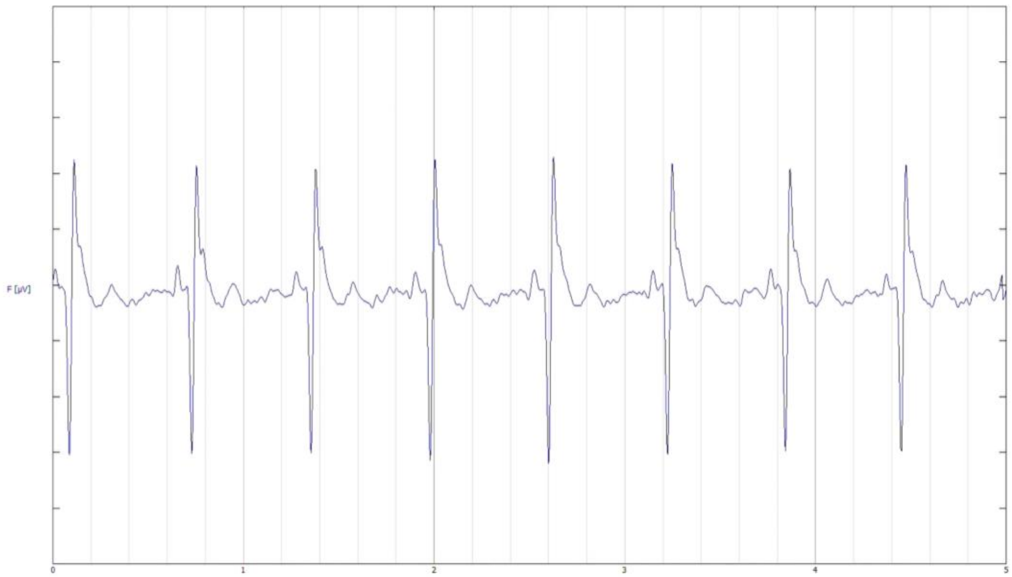
11.2 ECG

What is ECG:
ECG stands for Electrocardiogram. It is a medical test that measures and records the electrical activity of the heart. The ECG helps in diagnosing various heart conditions and evaluating the heart's overall health.



Electrode Placement: Check above image for correct electrode placement

Data Visualization:
The Lab Streaming Layer (LSL) is a system designed for real-time data streaming and recording. We have provided a python script for **ECG** located in the [GitHub repository]() used to read the data from serial and create an LSL stream. Following is a screenshot of ECG data captured with Synapse.

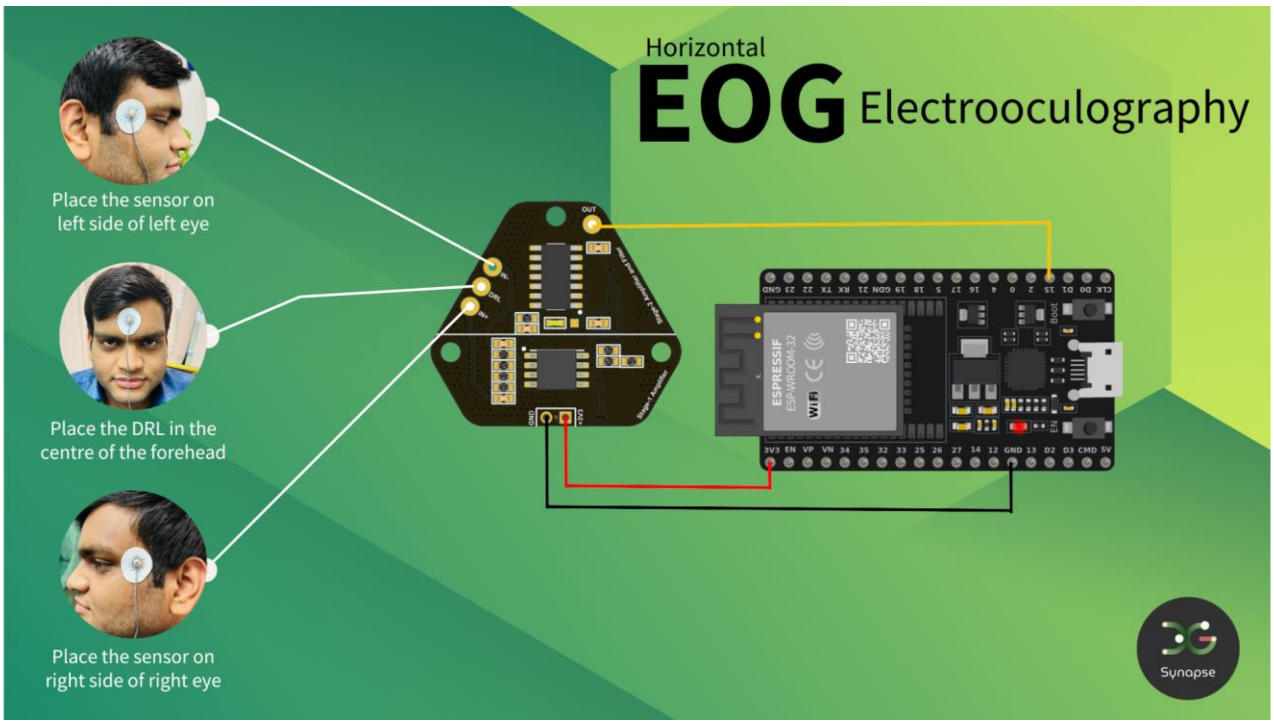

F [µV]
0
1
2
3
4
5

11.3 EOG

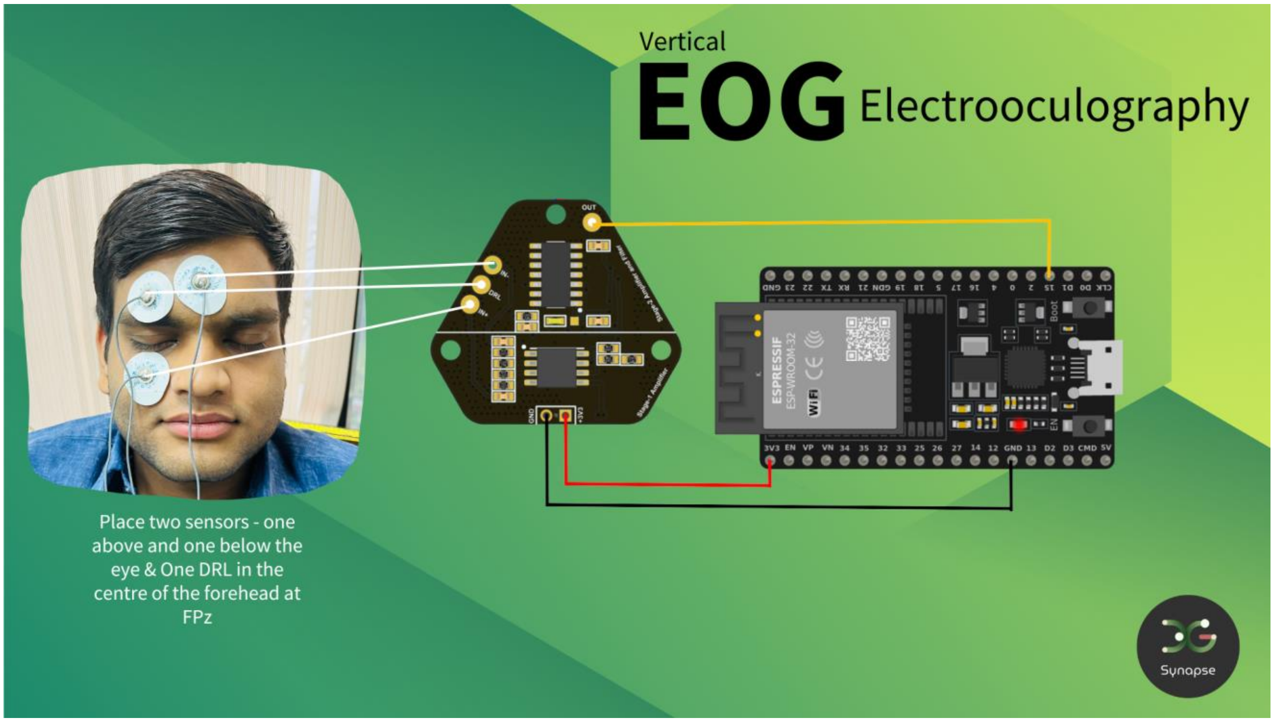
What is EOG:

EOG stands for "Electrooculography." It refers to a technique used to measure and record the electrical activity of the muscles that control eye movements. This technique is often used in medical and research settings to study eye movements and diagnose certain eye disorders.

Horizontal Eye Movements



Vertical Eye Movements

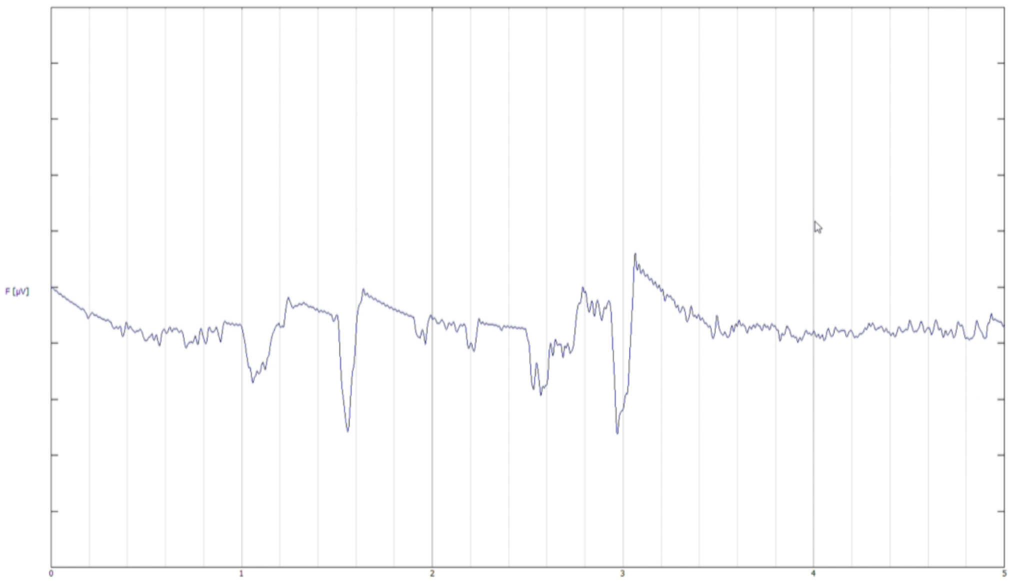


Electrode Placement: Check above image for correct electrode placement

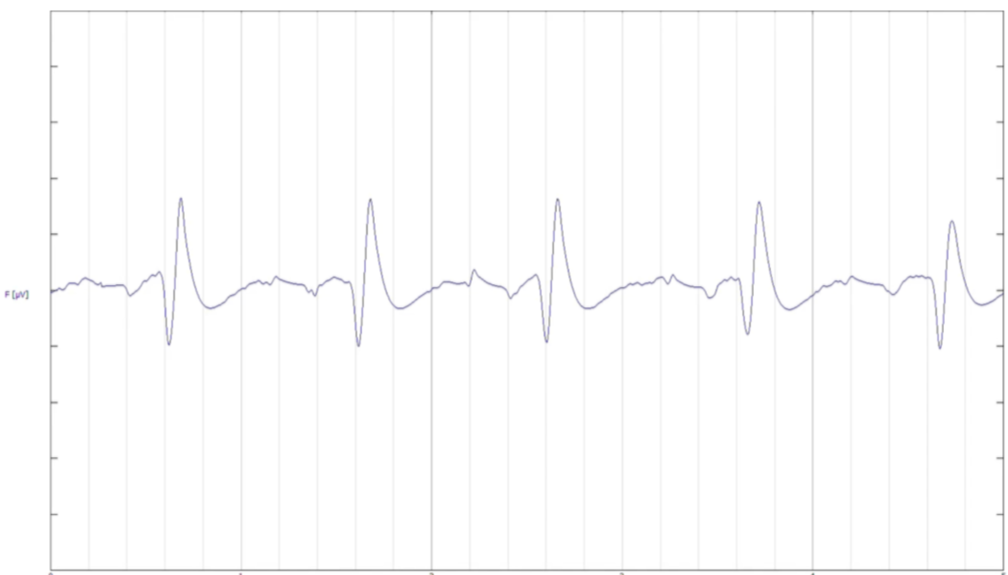
Data Visualization:

The Lab Streaming Layer (LSL) is a system designed for real-time data streaming and recording. We have provided a python script for **EOG** located in the [GitHub repository]() used to read the data from serial and create an LSL stream. Following is a screenshot of ECG data captured with Synapse.

Horizontal EOG Data:

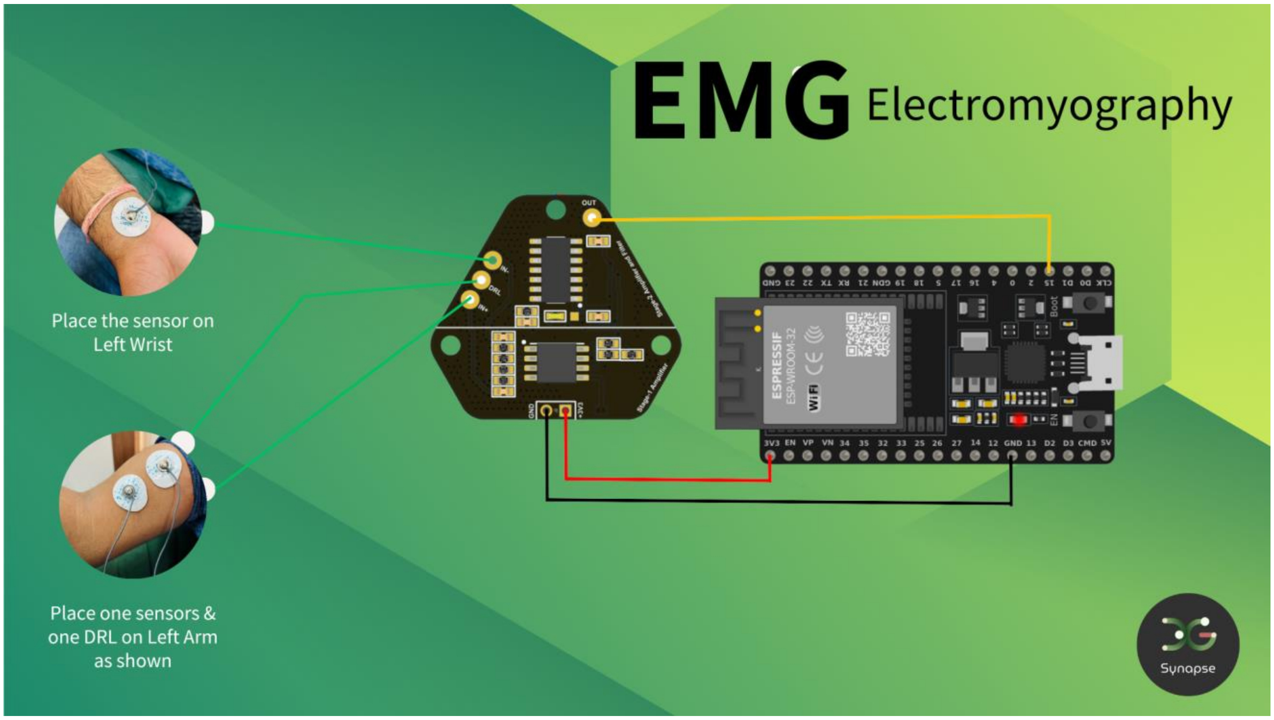


Vertical EOG Data:



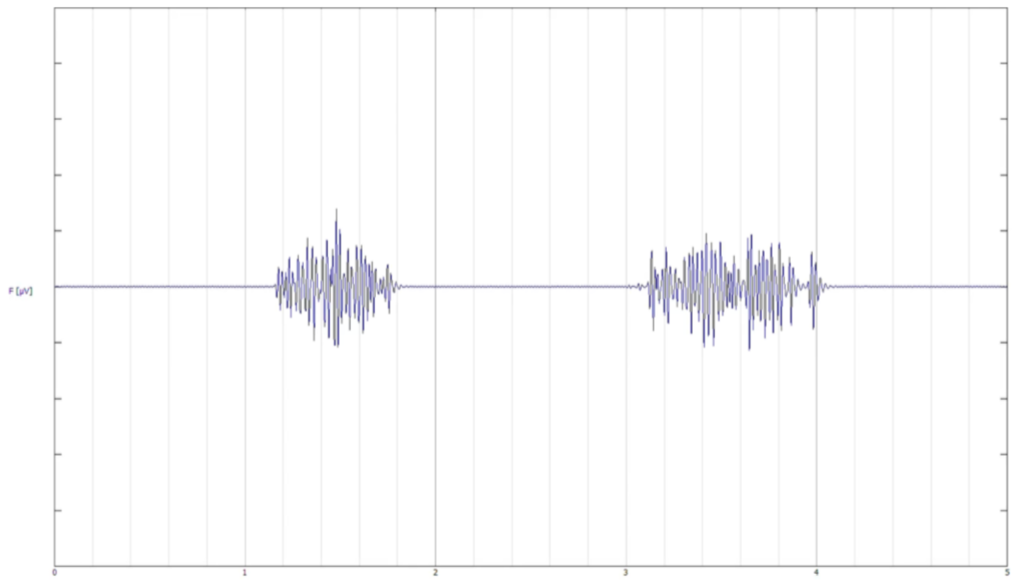
11.4 EMG

What is EMG: EMG stands for Electromyography. It is a technique used to measure and record the electrical activity produced by skeletal muscles. This information can be useful in various applications, such as studying muscle function, diagnosing neuromuscular disorders, and monitoring muscle activity during physical therapy or athletic training.



Electrode Placement: Check above image for correct electrode placement

Data Visualization: The Lab Streaming Layer (LSL) is a system designed for real-time data streaming and recording. We have provided a python script for **EMG** located in the [GitHub repository]() used to read the data from serial and create an LSL stream. Following is a screenshot of ECG data captured with Synapse.



12 Possible Configurations

12.1 Configurable Gain

Default Gain Configuration: The default gain in the first stage amplification is set to 50. This value is established to provide a baseline performance in typical use cases.

User-Configurable Gain: To accommodate diverse application scenarios, users have the flexibility to configure the gain according to their specific requirements. This customization is achieved by placing a desired resistance at the designated location, R9.

Gain Formula: The gain (G) is determined by the following formula: G = R9/10k
Where:

- *G* is the gain of the amplification stage.
- *R*9 is the resistance value placed at the configurable location.
- 10*k* is the resistance at the inverting input.

By manipulating the value of *R*9, users can finely tune the amplification gain to suit the unique demands of their intended application. This level of customization ensures optimal performance and versatility in the amplification process.

13.2 Bandpass Filters Bandwidth

Default Bandpass Filter Configuration: The bandpass filter is implemented as a 2nd order Butterworth filter, offering a default high pass frequency of 1.6Hz and a default low pass frequency of 48.228Hz. These preset values are selected to cover a wide range of applications effectively.

User-Configurable Low Pass Frequency: For users desiring customization, the bandpass filter allows the adjustment of the low pass frequency. This is accomplished by manipulating the capacitance of C2, a capacitor placed in parallel with C3.

Capacitance Options: To simplify user adjustments, a set of capacitances is provided: 0.5uF, 3nF, 0.2uF, and 0.1uF. Each of these capacitances results in a specific low pass cutoff frequency when combined with C3 in parallel.

- A capacitance of 0.5uF yields a low pass cutoff frequency of 19.6Hz.
- A capacitance of 3nF results in a low pass cutoff frequency of 47.52Hz.
- A capacitance of 0.2uF leads to a low pass cutoff frequency of 27.84Hz.
- A capacitance of 0.1uF produces a low pass cutoff frequency of 34.10Hz.

The bandpass filter design employs the characteristics of a 2nd order Butterworth filter, ensuring a smooth frequency response within the specified range

12.3 Bypass Bandpass Filter

Bypass Option for Direct Data Access: For enhanced flexibility, users have the option to bypass the bandpass filter and access data directly. This bypass feature allows users to streamline their signal processing by circumventing the filtering stage when it is not required for their specific application.

Activation of Bypass: To enable direct data access without bandpass filtering, users can engage the bypass option. This can be achieved through a designated control or switch in the circuit.

Streamlined Signal Path: By choosing to bypass the bandpass filter, users can obtain raw data without undergoing the frequency filtering process. This is particularly useful when a specific application demands unaltered or unfiltered signal information.

Versatile Integration: The bypass capability is designed to seamlessly integrate with the bandpass filter circuit, offering users the flexibility to tailor the signal processing approach based on their unique requirements. Whether opting for the bandpass filter or the direct data path, users can adapt the system to suit the demands of their specific applications.

13 Reference Documents

Ref	Link
Synapse Github Repository	https://github.com/Neuphony/EXG-Synapse
ESP32 Installation Guide	https://espressif-docs.readthedocs-hosted.com/projects/arduino-esp32/en/latest/installing.html\
Nuprep Gel Application Demo	https://www.youtube.com/watch?v=qQSClWIYUwM&t=76s
BrainVision LSL Viewer	https://pressrelease.brainproducts.com/lsl-viewer/
Download BrainVision	https://www.brainproducts.com/downloads/more-software/#utilities

14 Certification

14.3 Certification

OSHWA Certification is currently under process

14.3 Licenses

Item	ID
Hardware	CERN-OHL-S2.0
Software	MIT
Documentation	CC BY-SA 4.0

15 Company Information

Company Name	Address
Pankhtech India Pvt Ltd	Company ID: U33309DL2020PTC371693 A-545, Urbtech Trade Centre, Sector 132, Noida, 201303, India GSTIN 07AAJCB3585D1ZO

16 Change Log

Date	Revision	Changes
1/12/2023	1	First Release