

# Human–Computer Interface Controlling Devices Through Brain Signals Using Bio Amp Technology

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**Abstract**—The Brain–Computer Interface (BCI) enables direct communication between the brain and external devices without physical movement. This project develops a low-cost, portable BCI system using BioAmp technology to capture and amplify EEG signals. The signals are filtered, digitized, and analyzed to detect user intent. The processed output controls applications such as cursor movement or simple electronic devices. This system shows how affordable hardware and open-source tools can make BCI technology accessible for education, research, and assistive use.

## I. INTRODUCTION

This mini project focuses on measuring and visualizing human bio potential signals using the BioAmp EXG Pill and the Maker UNO microcontroller. Bio potential signals such as ECG, EMG, and EEG are essential for understanding the electrical activity of the heart, muscles, and brain. In this project, the BioAmp EXG Pill serves as a compact analog front-end module that amplifies and filters these weak physiological signals, while the Maker UNO captures the conditioned output and sends it to a computer for display using tools like ArduinoIDE and Spike Recorder. Through this work, we gained practical experience in sensor interfacing, biomedical signal acquisition, electrode placement, skin preparation, noise reduction, and analog to-digital conversion. Overall, the project provides a simple, low-cost, and effective approach to learning biomedical instrumentation and understanding real human physiological signals.

The amplified output from the BioAmp is then connected to a Maker UNO board, which acts as the data-acquisition unit. The UNO receives the analog

signal through its A0 pin and converts it into digital values using its built-in ADC. These digital samples are then sent to a computer using a USB connection. With the help of visualization tools like the Arduino Serial Plotter, Spike Recorder, or other software, the ECG or EMG waveform can be observed in real time. This simple circuit setup provides an easy and safe method to study bio signals without using complex medical equipment. By using the BioAmp and Maker UNO together, students and beginners can understand the basic principles of biomedical electronics, human body signal measurement, and digital signal processing. This project forms a strong foundation for advanced health-monitoring applications.

Brain–Computer Interface (BCI) and bio-signal processing techniques have opened new possibilities in this field. Electroencephalography (EEG) captures electrical activity generated by the brain, while Electromyography (EMG) measures electrical signals produced by muscle contractions. Both signals provide valuable information that can be used to control external devices such as wheelchairs, robotic arms, and home automation systems. However, systems based solely on EEG may suffer from signal noise and slow response time, whereas EMG-based systems depend on the presence of muscle activity and may not be suitable for completely paralyzed patients.

Moreover, with the advancement of microcontrollers such as Arduino and ESP32, it has become possible to develop portable and cost-effective assistive solutions. This project proposes a Brain and Muscle Controlled Assistive Device that integrates EEG and EMG signals using a bio-signal acquisition module and a microcontroller platform. The system aims to enable hands-free control of electronic devices and mobility

aids, thereby enhancing independence and improving the quality of life for physically challenged individuals.

## II. RELATEDWORK

IoT and biomedical signal processing have emerged as significant paradigms in assistive healthcare technologies. Numerous research studies have explored Brain Computer Interface (BCI) and Electromyography (EMG) based systems to assist physically challenged individuals in interacting with their environment. Several works focus on EEG-based device control for mobility assistance and rehabilitation.

In [1], researchers developed an EEG-based wheelchair control system that interprets brainwave patterns to assist paralyzed patients in navigation. The system successfully detected attention levels; however, it required high-cost medical-grade equipment, limiting accessibility. Another study in [2] proposed a low-cost EMG-based robotic arm controlled through muscle contractions. Although effective for limb assistance, the system lacked integration with brain signals for users with severe paralysis.

A hybrid EEG-EMG control system was presented in [3], where both neural and muscle signals were processed using a microcontroller to operate assistive devices. The study demonstrated improved accuracy compared to single-signal systems, but it did not include real-time adaptive filtering for noise reduction. In [4], authors implemented a Raspberry Pi-based BCI system capable of controlling home appliances via brainwave detection. While the system enabled remote monitoring, it suffered from signal instability and required extensive calibration.

Recent advancements incorporate machine learning techniques for better signal classification. In [5], convolutional neural networks (CNN) were used to classify EEG signals for prosthetic control. Although accuracy improved significantly, computational complexity increased, making real-time implementation challenging for low-power microcontrollers. Similarly, [6] proposed a cloud-based neuro-monitoring system that transmitted EEG data to remote servers for processing. However, reliance on continuous internet connectivity reduced system reliability.

Several low-cost assistive systems using Arduino

platforms have also been proposed. In [7], an EMG-controlled home automation system was designed for individuals with partial mobility. The system could control lights and fans but did not support combined EEG input for patients with minimal muscular activity. Another approach in [8] integrated attention-based EEG detection with relay modules for appliance control, yet lacked rehabilitation-focused feedback mechanisms.

From the literature, it is evident that while many systems focus on either EEG or EMG-based control, few integrate both signals effectively in a cost-efficient and portable manner. Additionally, existing solutions often face limitations related to high cost, complex setup, signal noise, limited adaptability, and absence of user-friendly implementation for real-world assistive scenarios.

Therefore, our proposed Brain and Muscle Controlled Device integrates both EEG and EMG signals using a BioAmp EXG module and Arduino/ESP32 platform to provide a low-cost, portable, and reliable assistive solution. The system enables hands-free control of electronic devices and mobility aids, aiming to enhance independence and improve quality of life for physically challenged individuals.

From the literature, it is evident that while many systems focus on either EEG-based brain signal control or EMG-based muscle signal control, very few studies effectively integrate both modalities into a single unified assistive framework. Most existing solutions rely on high-cost medical-grade EEG headsets, complex computational models, or continuous cloud connectivity, which limits affordability and practical implementation for everyday users. Furthermore, several systems suffer from signal noise, calibration complexity, delayed response time, and limited adaptability to users with severe paralysis who may have minimal muscle activity.

Another important limitation observed in prior research is the lack of portability and real-time standalone processing. Many proposed models depend on external servers, advanced processors, or high-power embedded platforms, making them unsuitable for low-resource environments. In addition, although machine learning and deep learning approaches improve classification accuracy, they increase hardware complexity and computational burden, thereby affecting real-time performance and cost

efficiency. Several EMG-based systems are effective for patients with partial mobility; however, they cannot assist individuals who rely primarily on neural signals due to extreme muscular limitations. Similarly, EEG-only systems may face accuracy challenges without additional confirmation from muscular input. Therefore, there exists a need for a low-cost, portable, hybrid assistive system that integrates both EEG and EMG signals while maintaining simplicity, reliability, and real-time responsiveness. Our proposed Brain and Muscle Controlled Device addresses these gaps by combining neural and muscle signal acquisition using the BioAmp EXG module with Arduino/ESP32-based embedded processing. The system performs signal amplification, filtering, and threshold-based decision making locally, eliminating dependency on continuous internet connectivity or expensive computational resources.

Unlike many previous approaches, the proposed system is designed with affordability and accessibility as primary objectives. It enables hands-free control of home appliances, assistive devices, and mobility aids through intentional focus or minimal muscle activity. The dual-signal integration improves reliability by allowing cross-verification of commands, thereby reducing false triggering caused by noise or unintended movements. Moreover, the modular design allows future integration of advanced signal classification techniques, wireless communication modules, and rehabilitation-focused feedback mechanisms.

In comparison with earlier systems, our proposed solution emphasizes cost-effectiveness, portability, ease of implementation, and real-world applicability for physically challenged individuals. By bridging neuroscience and embedded systems technology in a simplified yet efficient manner, the project contributes toward the development of practical assistive solutions that enhance independence, dignity, and quality of life for individuals with limited mobility. From the literature, it is evident that while numerous research efforts have focused on EEG-based or EMG-based assistive systems, only a limited number of studies successfully integrate both brain and muscle signals into a unified, low-cost, real-time control framework. Most existing EEG-based systems rely heavily on sophisticated signal processing algorithms, medical-grade acquisition devices, and computationally intensive classification models. Although such

approaches improve accuracy, they significantly increase system complexity, cost, and power consumption. This makes large-scale deployment difficult, particularly in low-resource environments where affordable assistive technologies are most needed.

Similarly, EMG-based systems have demonstrated reliable performance in detecting voluntary muscle contractions for prosthetic or appliance control. However, these systems primarily benefit individuals with partial muscular mobility and are less effective for patients suffering from severe paralysis or neurodegenerative conditions where muscle activity is minimal or inconsistent. In addition, many EMG-only systems lack adaptive threshold mechanisms, leading to false triggering due to involuntary muscle movements or external electrical noise.

Another key limitation observed in prior research is the dependency on cloud-based processing or continuous internet connectivity. Several proposed models transmit EEG or EMG data to remote servers for classification using machine learning or deep learning techniques. While cloud integration enhances analytical capability, it introduces latency, privacy concerns, network dependency, and increased operational cost. For critical assistive applications such as wheelchair control or emergency communication, delays in response time may reduce system reliability and user safety.

Furthermore, many existing systems require complex calibration procedures before operation. EEG signals are highly sensitive to electrode placement, motion artifacts, and environmental interference. Without proper filtering and amplification, signal quality deteriorates, affecting classification accuracy. Although advanced filtering algorithms and convolutional neural networks have been proposed to address these issues, they demand high computational resources that are not always feasible for compact embedded systems such as Arduino or low-power microcontrollers.

Portability and user comfort are also challenges identified in earlier solutions. Bulky hardware configurations, wired setups, and heavy processing units reduce user convenience and limit real-world applicability. In assistive healthcare systems, simplicity, ease of use, and comfort are critical parameters that directly influence user acceptance and long-term usability.

Therefore, there remains a significant research gap in developing a cost-effective, portable, and hybrid assistive system that integrates both EEG and EMG signals while maintaining real-time responsiveness and simplified hardware architecture. A dual-signal approach improves reliability by enabling cross-verification of detected commands. For instance, brainwave-based attention detection can be combined with a minor muscle contraction to confirm user intent, thereby minimizing false positives and enhancing control accuracy.

Our proposed Brain and Muscle Controlled Device addresses these limitations by employing the BioAmp EXG module for high-quality bio signal acquisition and amplification, integrated with an Arduino/ESP32 microcontroller for real-time embedded processing. The system performs local filtering, threshold analysis, and command execution without reliance on cloud infrastructure. This ensures low latency, improved privacy, and operational independence from network availability.

Unlike many previous approaches, the proposed system emphasizes affordability and modularity. The use of open-source hardware platforms and readily available components significantly reduces implementation cost, making the solution accessible to a broader population. The design supports hands-free control of household appliances, assistive tools, and mobility aids, thereby enhancing independence for individuals with limited physical capabilities.

Moreover, the modular architecture allows future integration of advanced signal classification algorithms, wireless communication modules, machine learning enhancements, and rehabilitation-oriented feedback mechanisms. The system can also be expanded to support prosthetic control, smart home integration, and IoT-enabled healthcare monitoring.

In comparison with earlier systems, our approach offers a balanced trade-off between performance, cost, portability, and simplicity. By combining neural and muscular signal processing within a compact embedded framework, the proposed system contributes toward the advancement of practical and scalable assistive technologies. Ultimately, it aims to improve quality of life, promote self-reliance, and restore a sense of control and dignity for physically challenged individuals.

### III. PROPOSEDWORK

In the previous section, an extensive literature review was conducted to identify the limitations of existing EEG- and EMG-based assistive systems. Based on the identified research gaps, a Brain and Muscle Controlled Device is proposed in this work. The proposed system integrates bio signal acquisition, embedded processing, and real-time device control to provide an affordable and portable assistive solution for physically challenged individuals. Our methodology is divided into four parts: methodology, system component selection, system design, and implementation.

#### System Component Selection

In this section, the hardware and software components used to design and implement the proposed system are discussed.

#### Hardware Components

In this work, an Arduino/ESP32 microcontroller is used to process the data obtained from EEG and EMG sensors. The BioAmp EXG module acts as the signal acquisition and amplification unit, serving as the primary interface between the human body and the controller. The hardware components included in the proposed system are as follows:

- i. Arduino Uno / ESP32
- ii. BioAmp EXG Pill (EEG/EMG acquisition module)
- iii. EEG electrodes
- iv. EMG electrodes
- v. Relay module
- vi. LED / DC motor / appliance load
- vii. Jumper wires
- viii. Power supply unit
- ix. Electrode gel (NuPrep)
- x. Connecting cables

#### Software Components

The software components are used to interface biosensors with the controller and execute signal processing operations. The analog signals received from the BioAmp module are converted into digital signals and analyzed for threshold detection.

- i. Arduino IDE
- ii. Embedded C / C++ programming
- iii. Serial monitor for signal visualization

#### Communication Platforms

The communication platform is responsible for enabling signal interpretation and device control. The system can operate in standalone mode or can be extended to wireless communication.

- i. Embedded processing unit (Arduino/ESP32)
- ii. Optional IoT interface for remote monitoring (future scope)

#### System Design and Architecture

This section provides details of the system design and architecture. Unlike traditional assistive systems that rely solely on mechanical switches or caregiver assistance, the proposed system enables hands-free control using neural and muscular signals. The design focuses on portability, simplicity, and cost-effectiveness.

Unlike conventional assistive devices that depend on manual switches or caregiver assistance, the proposed system allows users to control electronic devices through neural and muscular intent. The architecture is designed to minimize complexity while ensuring reliability and responsiveness.

The system operates in real time, continuously monitoring biosignals and comparing them against predefined thresholds. The architecture supports both single-signal operation (EEG or EMG independently) and hybrid dual-signal verification to enhance accuracy.

#### Device Design

The Brain and Muscle Controlled Device is designed to be compact and user-friendly. EEG electrodes are placed on the scalp to measure brainwave activity, while EMG electrodes are attached to specific muscle regions such as the forearm or jaw to detect muscle contractions. The electrodes are connected to the BioAmp EXG module, which amplifies and filters the low-amplitude biosignals.

The processed analog signals are transmitted to the Arduino/ESP32 microcontroller. A relay module is connected to the controller to operate external devices such as lights, fans, or motors. The device assembly is compact and portable, enabling real-world application in home environments. The modular structure allows integration with additional assistive devices such as wheelchairs or robotic arms.

The device is designed to be lightweight, portable, and user-friendly. EEG electrodes are placed on the scalp in positions that capture attention-related brainwave

patterns. EMG electrodes are positioned on muscle regions capable of voluntary contraction. The electrodes are connected to the BioAmp module, which performs amplification and filtering. The output of the BioAmp is transmitted to the microcontroller's analog input pins.

A relay module is connected to the digital output pins of the microcontroller. External devices such as LEDs, fans, or assistive motors are interfaced through the relay. The entire system is assembled on a compact board structure to ensure portability and ease of installation in home environments.

The modular design allows integration with additional assistive technologies such as smart home systems, prosthetic devices, or mobility aids.

#### Architectural Details

The control architecture consists of three main stages: signal acquisition, signal processing, and command execution. The EEG and EMG signals are first captured using surface electrodes. Since biosignals are extremely weak and susceptible to noise, the BioAmp module performs amplification and filtering to improve signal quality.

The amplified signals are then fed into the microcontroller's analog input pins. The embedded program continuously monitors signal values and compares them with predefined threshold levels. When a specific attention level or intentional muscle contraction is detected, the controller interprets it as a valid command. The corresponding output pin is activated, which triggers the relay module and controls the connected device.

The system operates in real time without requiring internet connectivity or cloud-based computation. This reduces latency and enhances reliability for assistive applications. The design also supports dual-signal verification, where EEG and EMG inputs can be combined to improve accuracy and reduce false triggering.

The control architecture of the proposed system consists of three primary layers:

##### 1. Signal Acquisition Layer

EEG and EMG electrodes capture electrical signals generated by neural and muscular activity. Since these signals are extremely weak and susceptible to environmental interference, proper electrode placement and skin preparation are essential.

### 2. Signal Conditioning and Processing Layer

The BioAmp EXG module amplifies and filters the acquired biosignals. The conditioned signals are then fed into the microcontroller. The embedded program continuously monitors signal amplitudes and performs threshold-based analysis to detect intentional activity. Noise reduction techniques and baseline calibration procedures are implemented to improve reliability. Dual-signal integration allows the system to validate commands by combining EEG and EMG inputs, thereby minimizing false positives.

### 3. Command Execution Layer

Once a valid signal is detected, the microcontroller generates a digital output signal that activates the relay module. The relay controls external devices such as household appliances or mobility aids. The execution is immediate, ensuring real-time responsiveness.

The system is designed to function without cloud dependency, reducing latency and ensuring operational reliability even in areas without internet connectivity. The architecture supports scalability and future integration of wireless modules, machine learning-based signal classification, and IoT connectivity

### 3.2.3. System Monitoring Features:

The proposed system provides the following key features:

- (i) Brain signal detection: The EEG electrodes continuously monitor brainwave activity. When a specific focus or attention threshold is reached, the system recognizes it as an intentional command.
- (ii) Muscle signal detection: The EMG sensors detect voluntary muscle contractions such as blinking or jaw clenching to trigger device operation.
- (iii) Dual-signal integration: The system can combine EEG and EMG inputs for improved reliability and reduced noise interference.
- (iv) Device control: The microcontroller activates connected loads such as LEDs, fans, or motors through a relay module.
- (v) Real-time response: The embedded system ensures immediate action without reliance on cloud processing.
- (vi) Assistive application: The device enables physically challenged individuals to control household appliances or mobility aids independently.

The proposed Brain and Muscle Controlled Device offers a low-cost, portable, and efficient assistive solution compared to many existing systems. By integrating neuroscience and embedded system design, the system enhances independence, promotes self-reliance, and improves quality of life for individuals with limited mobility

## IV. SYSTEM IMPLEMENTATION

The implementation details of the proposed Brain and Muscle Controlled Device are divided into three primary modules: biosignal acquisition and controller interfacing, signal processing and decision-making module, and the assistive device control module. The overall methodology adopted in this research is represented in the form of a systematic flow beginning from neural and muscular signal detection to real-time device activation.

Implementing a bio-signal-based assistive control system using Arduino/ESP32 and BioAmp EXG module involves careful integration of hardware and software components. The following outline describes the step-by-step approach adopted in this work:

### 1. Bio signal Sensor Selection

The first step in implementation involves selecting appropriate biosignal acquisition components. EEG

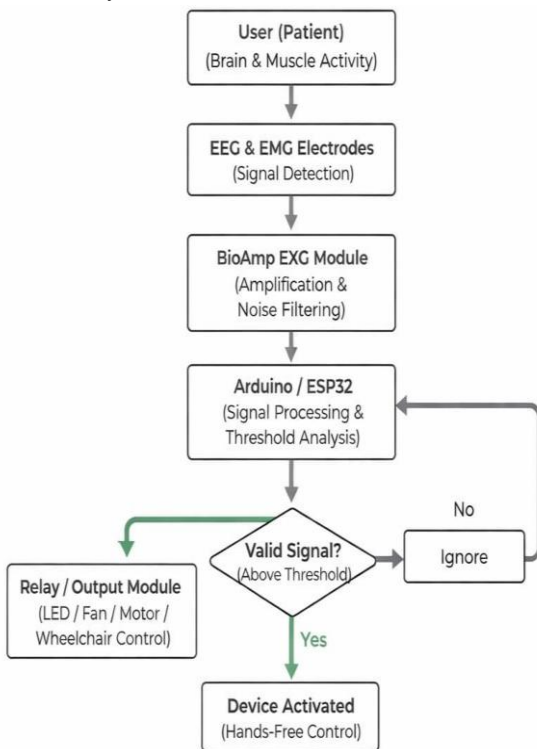


Fig 1(a): Working Flow Diagram of the Proposed Assistive Control System

electrodes are chosen to monitor brainwave activity related to focus and attention levels. EMG electrodes are selected to detect voluntary muscle contractions from specific muscle groups such as the forearm or jaw. Since these signals are extremely weak and highly sensitive to noise, a BioAmp EXG module is incorporated to amplify and filter the acquired signals before processing.

## 2. Microcontroller Setup

The Arduino Uno / ESP32 microcontroller is configured as the central processing unit of the system. The controller is programmed using the Arduino IDE with embedded C/C++ code. Analog input pins are assigned to receive conditioned EEG and EMG signals from the BioAmp module. Digital output pins are connected to a relay module for device control. The microcontroller continuously monitors the incoming signals and executes decision-making logic in real time.

## 3. Data Acquisition

The EEG and EMG electrodes capture electrical activity from the human body. These raw signals are transmitted to the BioAmp module, where amplification and filtering take place. The amplified analog signals are then forwarded to the microcontroller's analog input channels. Data is sampled at regular intervals to ensure accurate representation of neural and muscular activity. Baseline calibration is performed during initial setup to determine the resting signal values of the user. This calibration phase helps in setting appropriate threshold levels to differentiate between intentional commands and background noise.

## 4. Signal Processing and Analysis

The acquired biosignals are processed using threshold-based and pattern recognition techniques implemented within the microcontroller. Since EEG signals represent varying attention levels and EMG signals indicate muscle contraction intensity, the system compares real-time readings against predefined thresholds.

If the EEG signal exceeds the attention threshold, it is interpreted as a valid cognitive command. Similarly, when EMG signal amplitude crosses the muscular activation threshold, it is considered an intentional physical command. Dual-signal verification can also be enabled to enhance reliability by requiring confirmation from both EEG and EMG signals before execution.

Noise filtering and smoothing techniques are

implemented in software to reduce fluctuations caused by environmental interference or involuntary movements. This ensures stable and accurate command detection.

## 5. Control and Execution Module

Once a valid signal is detected, the microcontroller activates the corresponding output pin connected to the relay module. The relay functions as an electrically controlled switch, enabling the system to operate external appliances such as lights, fans, motors, or assistive mobility devices.

For demonstration purposes, LEDs and DC motors are used to represent real-world loads. The execution process occurs instantly, ensuring minimal delay between user intention and device activation. The system is designed to operate independently without the need for internet connectivity, making it suitable for real-time assistive applications.

### Bio signal Classification and Decision Logic

The core functionality of the proposed system lies in its ability to interpret human intent from bio signals. Unlike complex machine learning-based systems that require cloud computing resources, this work focuses on efficient embedded signal interpretation.

The implementation process can be divided into three phases:

### Phase 1: Signal Detection

EEG and EMG signals are captured through surface electrodes and transmitted to the BioAmp module. The signals are amplified and filtered to remove unwanted noise.

### Phase 2: Feature Extraction and Threshold Evaluation

The microcontroller reads analog values and extracts relevant features such as signal amplitude and variation patterns. These features are compared against calibrated threshold values to detect intentional activity.

### Phase 3: Command Classification and Execution

If the detected signal meets predefined criteria, it is classified as a control command. The system then activates the corresponding output device. If the signal does not satisfy threshold conditions, it is ignored to prevent false triggering.

This structured decision-making mechanism ensures accurate and responsive control.

### Assistive Application and User Interaction

The proposed system is primarily designed to empower physically challenged individuals by enabling hands-free control of their environment. The user only needs to focus mentally or perform a minimal muscle movement to trigger device activation.

The system can be extended to include wireless modules such as Bluetooth or Wi-Fi for remote monitoring and control through a mobile application. However, in its current implementation, the device operates as a standalone embedded system to ensure reliability and low latency.

Visual feedback can be provided through LEDs or serial monitoring to indicate successful signal detection and device activation. This feedback mechanism helps users understand system responses and enhances usability.

The implemented Brain and Muscle Controlled Device demonstrates that bio signals can be effectively translated into actionable control commands using low-cost embedded hardware. The modular implementation ensures scalability, allowing future integration of advanced signal classification algorithms, IoT connectivity, and rehabilitation-focused features.

By combining neuroscience principles with embedded system engineering, the proposed implementation provides a practical, affordable, and real-time assistive solution aimed at improving independence and quality of life for individuals with limited mobility

## V. RESULT

In this section, the experimental results of the proposed Brain and Muscle Controlled Device are presented.

Various experiments were conducted to evaluate the feasibility, accuracy, and real-time performance of the system. The primary objective of testing was to verify proper bio signal acquisition, signal processing reliability, and successful device control through EEG and EMG inputs.

Initially, all hardware components including the EEG electrodes, EMG electrodes, BioAmp EXG module, Arduino/ESP32 microcontroller, and relay module were successfully interfaced and tested. Proper electrode placement and skin preparation were ensured to obtain stable signal acquisition. The analog bio signals amplified by the BioAmp module were continuously monitored using the serial interface in the Arduino IDE. The real-time signal values were

displayed to verify signal fluctuations corresponding to neural focus and voluntary muscle contractions.

To evaluate EEG-based control, experiments were conducted by asking the user to maintain focused attention for a fixed duration. It was observed that the EEG signal amplitude increased beyond the calibrated threshold during concentration. When the threshold value was exceeded, the microcontroller successfully triggered the connected output device. The LED and DC motor connected through the relay module were activated immediately upon detection of a valid EEG signal. The response time between signal detection and device activation was minimal, confirming real-time operation.

Similarly, EMG-based control experiments were performed by instructing the user to perform intentional muscle contractions such as jaw clenching or forearm tightening. The EMG signal amplitude showed a significant rise compared to baseline readings. Once the amplitude crossed the predefined threshold, the system classified the input as a valid muscular command and activated the corresponding output device. The relay module switched successfully without false triggering during resting conditions.

To improve reliability, dual-signal verification testing was conducted. In this experiment, both EEG attention signals and EMG muscle signals were required to exceed their respective thresholds before device activation. This approach significantly reduced unintended activations caused by environmental noise or involuntary muscle movements. The hybrid signal integration demonstrated improved accuracy compared to single-signal operation.

Noise resilience testing was also performed by introducing minor external disturbances such as hand movements and ambient electrical interference. The filtering mechanism of the BioAmp module effectively reduced signal noise, and the system maintained stable operation. Baseline calibration ensured that minor fluctuations did not result in false positives.

The overall system performance was evaluated based on responsiveness, accuracy, and stability. The experimental observations confirm that the proposed system successfully converts neural and muscular activity into actionable control commands. The relay-controlled devices such as LEDs and DC motors responded consistently to valid bio signal inputs.

The proposed Brain and Muscle Controlled Device

demonstrates reliable real-time assistive functionality without reliance on cloud computing or internet connectivity. The experimental results validate that the system can be effectively used for hands-free control

of electronic appliances and mobility aids. These results highlight the feasibility of implementing a low-cost, portable, and efficient assistive technology solution for physically challenged individuals.

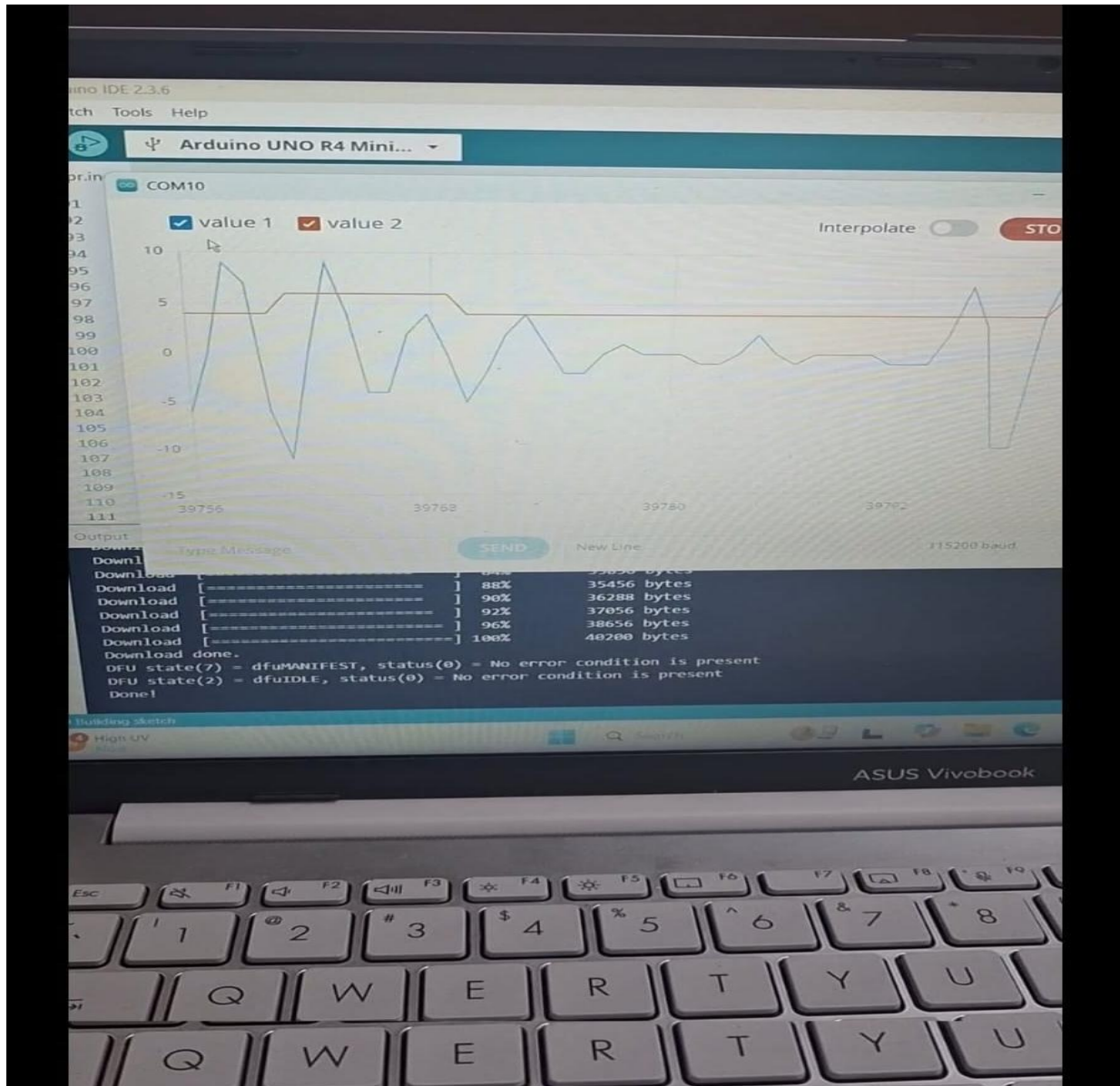


Fig 2(a) : Serial Plotter Output of Hand EMG Signals

#### CONCLUSION AND FUTUREWORK

Assisting physically challenged individuals in performing daily activities remains a significant challenge in modern healthcare and rehabilitation engineering. Continuous dependence on caregivers for basic tasks such as switching on appliances,

controlling mobility aids, or interacting with the environment can affect confidence and quality of life. To address this issue, a Brain and Muscle Controlled Device has been designed and implemented as an affordable and practical assistive solution. The proposed system integrates EEG and EMG bio signal acquisition using the BioAmp EXG module

with Arduino/ESP32-based embedded processing. The system is capable of detecting neural attention levels and voluntary muscle contractions, amplifying and filtering these signals, and converting them into actionable control commands. The microcontroller processes the incoming analog signals in real time and activates external devices through a relay module when predefined threshold conditions are satisfied.

The prototype was tested under various experimental conditions. EEG-based control was validated by monitoring focused attention levels, while EMG-based control was tested using intentional muscle contractions such as jaw clenching and forearm tightening. The system successfully activated connected devices such as LEDs and DC motors upon detection of valid signals. Dual-signal verification further enhanced reliability by reducing false triggering caused by environmental noise or involuntary movements.

The proposed system operates without reliance on cloud computing or continuous internet connectivity, ensuring low latency and improved privacy. Its modular and portable design makes it suitable for real-world assistive applications. The results demonstrate that neural and muscular signals can be effectively translated into hands-free device control, offering independence and improved interaction with the surrounding environment.

Overall, the proposed Brain and Muscle Controlled Device provides a low-cost, efficient, and real-time assistive technology solution aimed at enhancing mobility, autonomy, and dignity for individuals with limited physical capabilities.

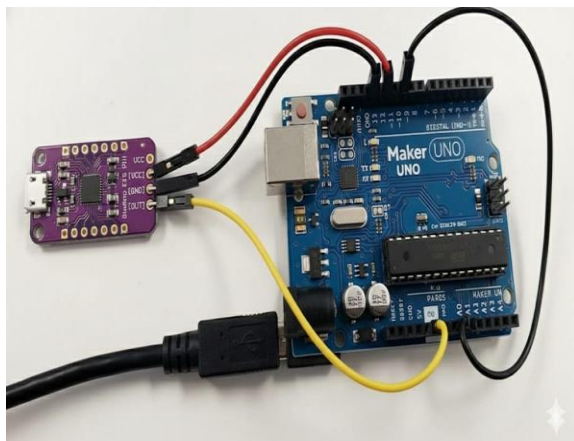


Fig 3(a): Circuit Connections of BioAmp EXG Module with Arduino UNO

#### Future Work:

Although the proposed system demonstrates promising results, several improvements can be made to enhance performance, scalability, and usability.

In the future, system complexity can be reduced by integrating advanced signal processing techniques within a single high-performance microcontroller, eliminating the need for additional modules. Power optimization strategies can also be implemented to develop a fully portable battery-operated version of the device.

Further enhancements can include the integration of machine learning algorithms for more accurate classification of EEG and EMG signals. Instead of simple threshold-based detection, advanced models such as Support Vector Machines (SVM), Artificial Neural Networks (ANN), or lightweight deep learning techniques can be implemented to improve command recognition accuracy and adaptability across different users.

Wireless communication modules such as Bluetooth, Wi-Fi, or IoT-based cloud platforms can be incorporated to enable remote monitoring and smart home integration. A dedicated mobile or desktop application with a customized dashboard can be developed to provide real-time visualization of biosignal activity and device status.

Additionally, the system can be expanded to support advanced assistive applications such as wheelchair navigation, robotic arm control, prosthetic limb operation, and rehabilitation monitoring. Integration with wearable health sensors could further enhance functionality by combining neural control with physiological monitoring.

Future research may also focus on improving electrode design for enhanced comfort and long-term usability, as well as implementing adaptive calibration techniques to automatically adjust thresholds based on user-specific signal variations.

The current work demonstrates the feasibility of translating brain and muscle signals into device control. With further refinement and integration of intelligent algorithms, the system can evolve into a comprehensive assistive platform that significantly improves independence and quality of life for physically challenged individuals.

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