Design, Programming, and Evaluation of an Economic Portable Muscle Activity Measurement Device

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Abstract—**Current commercial Electromyography (EMG) systems struggle with four main drawbacks: limited mobility, high prices, time-sensitive processing demands, and their functional suitability for a wide range of clinical and research environments. This study will solve these issues through the development of an affordable compact EMG system that ensures real-time processing stability. The system design unites surface electrodes with a low-noise amplifier and a microcontroller having performance-enhanced processing ability. The design requirements specify a signal spectrum from 0 to 250 Hz and precise resolution because this combination leads to the correct measurement of muscular activities. The device performed tests through a series of experiments with healthy participants to measure signal accuracy, noise levels, and usability conditions in controlled and semi-controlled testing environments. The results showed a mean signal-to-noise ratio of 28.5 dB with accuracy levels equivalent to commercial systems, which proved that the device provides clean EMG signals across diverse conditions. Results of noise power analysis showed 0.020 μV² in the resting state, but decreased to 0.012 μV² when muscles reached their peak activation strength since effective noise reduction measures were implemented. Despite its advantages, including cost-effective operation along with portability, the system presents restrictions in usage with clinical patients who need additional validation of its effectiveness. The portable EMG device presents a versatile, low-cost apparatus for rehabilitation services, sports science testing, and healthcare monitoring needs and requires continuing development for practical implementation.**

Keywords—**electromyography, sensor, microcontroller, amplifier, electrodes**

I. Introduction

Electromyography (EMG) has been used as a research tool and diagnostic technique in neuromuscular investigations, providing information about muscle function, motor control, and disease [1]. Conventional EMG systems are accurate and efficient, but they are burdened by several drawbacks, such as being costly, large in size, and not very portable [2]. These constraints have given rise to portable EMG devices that are intended to cater to the increasing demand for real-time and mobile muscle monitoring. When combined, the portability, low cost, and high signal processing capabilities of such devices may radically transform fields ranging from sports science, rehabilitation, and prosthetics to telemedicine [3, 4]. This study aims to develop a new portable EMG system that corrects the problems of previous systems. The main goal is to design a low-cost, portable device that provides the accuracy and stability of conventional systems, with user-oriented functions that will allow to use of the device at home, in clinics, and in sports. Olmo *et al.* [5] developed surface EMG (sEMG) electrodes and examined the design and optimisation of non-invasive electrodes for improved signal quality. Rayo *et al.* [6] advances in EMG instrumentation with detailed integration of hardware components and signal processing techniques for high-accuracy EMG devices. Chand *et al.* [7] developed of wireless EMG systems and introduced compact, wearable devices for dynamic recording in clinical and sports settings. Lyons *et al.* [8] work on EMG sensor miniaturisation and Studied methods to reduce device size while maintaining signal fidelity. Khusaini *et al.*'s [9] bio-amplifier design for EMG and proposed innovative circuits for enhancing signal amplification and reducing noise. Santiago *et al.*'s [10] explored EMG device integration for prosthetics and explored hardware integration for controlling robotic limbs using EMG signals. Zhao *et al.* [11] investigated compact designs for field-based muscle activity monitoring. Varghese *et al.* [12] developed hardware for on-the-fly signal analysis and application in robotics. Wang *et al.* [13] improved device manufacturing by addressing motion artefacts and electrical interference. Subashini *et al.* [14] investigated manufacturing processes for ultra-precise electrode arrays to capture detailed muscle activity. Kanipriya *et al.* [15] focused on producing reliable devices for rehabilitation monitoring. Kinugasa *et al.* [16] investigated compact designs for field-based muscle activity monitoring. Gervasi *et al.* [17] designed

Manuscript received June 9, 2025; revised July 14, 2025; accepted August 18, 2025; published December 5, 2025.

flexible, skin-adhering sensors to improve comfort and usability. Kim *et al.* [18] developed of hybrid EMG sensor by combining traditional EMG sensors with other biosignal monitors for enhanced diagnostics. Grison *et al.* [19] investigated the manufacturing process of multi-electrode arrays for detailed muscle mapping.

Merletti *et al.* [20] The study focuses on Signal processing techniques in surface Electromyography (sEMG) and proposes improved methods for noise reduction and signal interpretation, emphasising clinical and ergonomic applications. Shafti *et al.* [21] worked on electrode design and placement for sEMG signal acquisition and established guidelines for optimal electrode configurations for accurate EMG recording. Wang *et al.* [22] advance in sEMG modelling for motor control research by investigating muscle synergies and how sEMG can predict muscle force. McManus *et al.* [23] introduced EMG in rehabilitation with developed protocols for using EMG in biofeedback therapy for musculoskeletal conditions. Makaram *et al.* [24] studied Muscle fatigue analysis using EMG and explored patterns of muscle fatigue during sustained static and dynamic contractions. Pourmohammadi *et al.* [25] work on Signal processing algorithms for EMG applications and review modern computational techniques for EMG signal enhancement.

EMG devices are widely used in diagnostics, rehabilitation, as well as investigations in the medical field. However, existing devices have several problems that limit their applicability and availability. These limitations were the rationale for this study to close the gaps in the literature and offer new solutions. Currently, the main problem with existing EMG devices is the high costs, which would impact the low-resource user. Many previous works aimed at improving the performance of re-identification, but many of them do not pay attention to the problem of cost. The proposed solution aims at designing an inexpensive device, although its performance is the secondary concern—the main goal is to create a device that will be suitable for as many people as possible to use.

One disadvantage, therefore, is that many of the EMG devices they processed are not portable. The current systems are large and not easily transportable for use in clinical or laboratory practices. Prior research has paid attention to portable designs, yet again, these attempts did not satisfactorily consider the use of computing devices in mobile and home settings. Translating our study into a portable device that can be operated in different settings is being considered. Another major problem is the ability to sustain high accuracy in low-cost and portable devices. For diagnostic and research purposes, the devices that are sold at an inexpensive price fail to have high accuracy. To solve this problem, our study adopts a novel design and state-of-the-art signal processing methods to ensure high accuracy without increasing sizes and expenses.

However, alongside these technical changes, it also put a focus on easy and efficient manufacturing. Ease of production is another generic criterion that has not been efficiently investigated in the context of prior research. For this reason, our device has relatively simple manufacturing procedures to cut costs and promote the production of many to be used by everyone. Consequently, this study helps fill this gap between theoretical development and theory implementation. The proposed system is different from the previous research, where the studies have been made on the agendas of research only or some particular clinical applications; thus, our work is a more pluralistic approach that can be used for rehabilitation, monitoring muscular activity, and diagnostic purposes. By closing these gaps, our study contributes to the progress of EMG advancement by providing potential groundwork for the development of new and more portable EMG devices. The EMG sensor designed and manufactured in the current study is to detect the electrical activity of the muscles and to check the precision of the received and analysed records. As muscle electrical activity is a physiological characteristic that is found in a healthy muscle as well as in an affected one, the confirmation of correct operation of the device might not necessarily entail testing it on people with maladies or patients. It is possible to test any active muscle of a healthy individual so that the quality of measurement and accuracy of calibration can be guaranteed.

II. Materials and Methods

The following materials were used in the construction of the designed EMG device: there are five components: electrode sensors, power supply, instrumentation amplifier, passive filter, and microcontroller. Fig. 1 depicts the developed system flowchart.

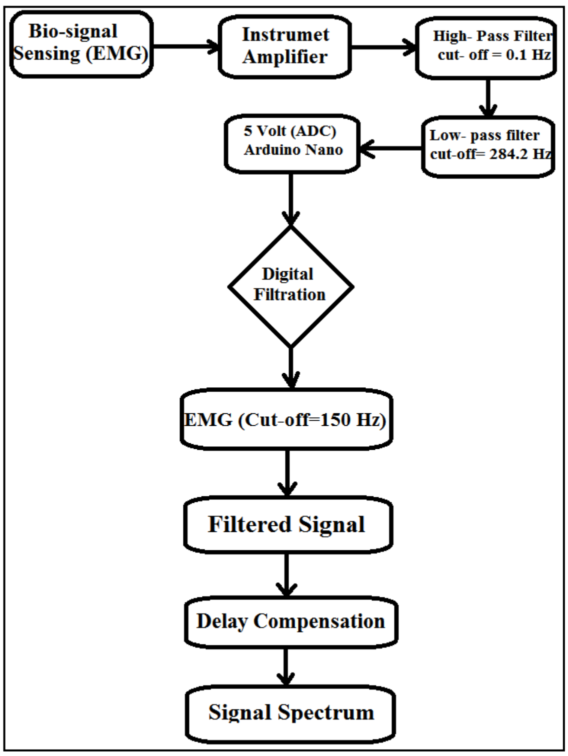

Fig. 1. Diagrammatic depiction of the system flowchart.

Three electrodes make up the system. The comprehensive framework of the system is illustrated in Fig. 2.

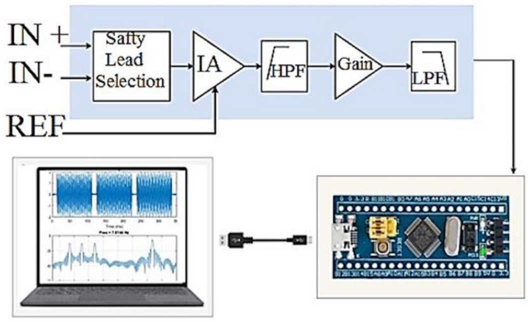

Fig. 2. The bio-signal acquisition system's overall structure.

The analogue-to-digital conversion and the transmission of signals in this system are carried out using the TL084 Microcontroller. This system will allow obtaining all vital signs (EMG) through the electrodes.

A. Electrode Sensor

It can be seen from Fig. 3 that, surface electrode, which was formed with (AgCl), known as non-invasive silver chlorides, was used to acquire data at the skin surface. The surface electrodes can't detect the electrical signal that is generated by the contraction of a few muscle fibres since the surface electrodes are too far from the contracting fibres. Nevertheless, when a sufficient number of fibres cooperate, it is possible to obtain the compound superposition of all the signals close to the electrode. This must be so in the sense that the fibre numbers are sufficient to guarantee rapid relationship determination. In addition, since the type of Velcro technology was not adhesive, the free-floating electrodes applied remained attached to the skin of the patient throughout the entire treatment, thus preventing the development of movement artefacts. The electrodes that were used in the current study were referred to as Bio Protech T716, and the electrodes were applied between the electrode and the skin surface with the help of electrolytic gel with the objective of minimising the impedance.

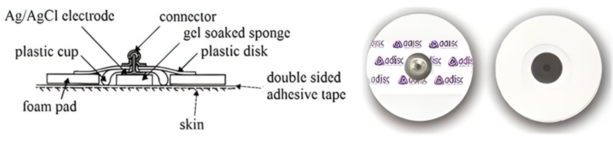

Fig. 3. Foam electrode for Bio-protech T716 EKG monitoring.

B. Power Supply Module

This system requires a power supply of two rails using three connection points, including V+, V–, and GND. This item can be designed simply, and, as functionality goes, that is quite prudent. In this application, a voltage divider circuit will be utilized, and since GND is the reference voltage, GND will be extracted from the resistance between the two resistors that will serve as voltage divider. The positive voltage supply is indicated by the number Vin / 2, while the negative voltage is identified as −Vin / 2. It is demonstrated in Fig. 4.

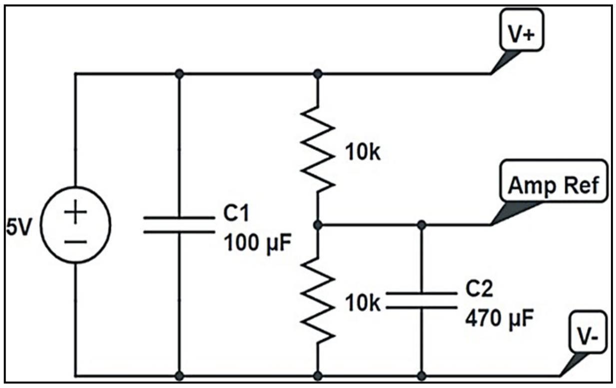

Fig. 4. Resistor divider type virtual ground power supply.

C. Instrumentation Bio Amplifier

Since a higher amplifier with more than 80dB of common mode rejection ratio is needed to improve the identification of the EMG signal, the chosen solution utilises a low-cost instrumentation amplifier that can be obtained easily. The candidate for this system is Texas Instruments TL084—a high CMRR general-purpose operational amplifier with quad-low-noise JFET. Inputs [3]. The formula expresses TL084 GAIN. Various parameters for TL084 are given in the following equations.

Gain = 49.4 + **KΩ** / **Rg** + 1

D. Passive Filters

A 33k resistor and a 47 uF nonpolar capacitor were used to amplify the signal after it had been subjected to a 1st order passive high-pass filter with a cut-off wavelength of 0.1 Hz to reduce low-frequency disturbances. Coincidentally, this filter featured a selective cut-off at a specific wavelength. Ultimately, taking into consideration all of the electrical indicators, a passive low-pass filter with a cut-off wavelength of 284.2 Hz was constructed using a 560 resistor and 1uF capacitor [26]. The cut-off frequency of passive filters can be estimated using the following formula, stated in the equation below.

$$f_c = \frac{1}{2\pi RC}$$

E. The Microcontroller Unit

In this system, the processor deployed is the Arduino platform with ARM technology, and Integrated development. When compared with other gadgets, the Arduino runs at 72 MHz, making it not only a highly performing but also power-saving device that runs in real-time at a considerably low cost. With 3.6 V of full-scale system, we have a 12-bit successive approximation A/D converter which has the fastest conversion up to 1us. The sampling rate was set at 500 times per second, whereas the serial transmission was operated at 11,520 bauds per second. Schematic diagrams of total circuits are depicted in Fig. 5. The design and schematic prototype of hardware can be shown in Fig. 6.

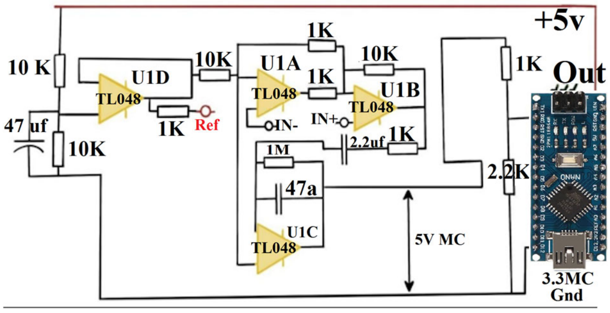

Fig. 5. The system's overall circuit diagram.

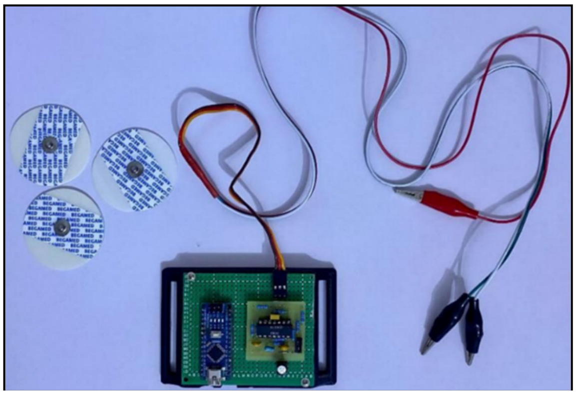

Fig. 6. Design and schematic prototype of hardware.

F. Software Implementation

The real-time signal was done using the Texas Instrument support package for TL084, after which the sample time option was selected to get real-time signals as per the below: Low-pass filters, which include finite impulse response (FIR Equiripple) and infinite impulse response (IIR-Butterworth), were adopted to filter the received signals. The filter order of the FIR filter was maintained at 100, and the sampling frequency of the IIR filter was selected as 1000 Hz. The open-loop magnitude response was defined to have a passband of 1dB and a stopband of 80 dB for both the FIR and the IIR filters. In EMG, the frequencies which it passes through are referred to as the passband, while those that it does not allow to pass through are referred to as the stopband. For the current design, the pass band is set at 75 Hz, while the stop band is set at 150 Hz. The filters are designed with a passband at 1 Hz and a stopband at 20 Hz to quantify the muscle's horizontal and vertical displacements.

First, each signal was baseline corrected to remove any low-frequency drifting that could affect the signal before the filtering technique was applied. After the filtering, the time that the filtration consumed was recovered. The FIR filter was found to outcompete the IIR filter in terms of performance since the FIR filter had a higher order and sharper cut-off response as compared to the IIR filter. Nevertheless, when compared with the IIR filter, the FIR was much harder to apply physically, which is why the filter design was performed in MATLAB. The software was developed for a similar reason: to save the signals so that they might be used for other types of analysis, such as spectrum analysis. The use of several adaptive filter methods at once is a subject that one should focus on in the future.

TABLE I. SENSOR SPECIFICATION

Parameters	Values/Ranges
Supply voltage	5 volt
Common Mode Rejection Ratio (CMRR)	> 80 dp
Gain	3 MHz
Low-Frequency Cut-off	284.2 Hz
High-Frequency Cut-off	0.1 Hz
Weight	≤ 10 g
Price	≤ USD 25

III. RESULT AND DISCUSSION

The practical measurement process for the EMG signal from the designed device is shown in Fig. 7. A laptop running Windows 10 OS, equipped with a 2.70 GHz NVIDIA RTX 3050 CPU and 125 GB of RAM, was used to perform the Fast Fourier Transform (FFT) for spectral analysis and to save the signals obtained from the Simulink model for display.

The EMG signals were recorded from a 23-year-old healthy male participant. Surface AgCl electrodes were placed on the biceps of the right arm to measure muscle activity, while the reference electrode was positioned at the elbow of the opposite arm. These signals were collected under these conditions to ensure the accuracy of the subsequent analysis.

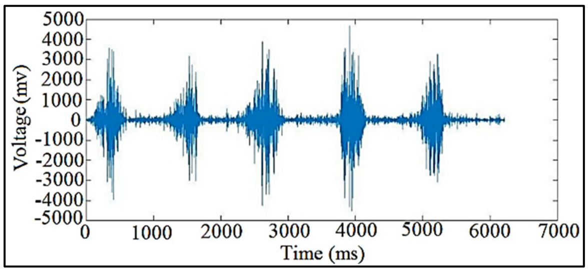

Fig.7. The acquisition EMG signal.

A. Validation Indicators

Validation pertains to the systematic evaluation or confirmation of the precision, reliability, and efficacy of an entity, mechanism, or methodology. It assumes a pivotal function across diverse domains, including but not limited to scientific inquiry, engineering disciplines, computational studies, and analytical data processes, thereby guaranteeing adherence to established criteria and appropriateness for designated purposes.

In this study, validation focuses on evaluating the performance of the low-cost EMG sensor by comparing it to a commercial device under various conditions. The aim is to verify its ability to provide reliable and accurate measurements for muscle activity monitoring. Key validation parameters include signal similarity, frequency accuracy, overall signal amplitude, threshold responsiveness, and noise analysis.

B. X-Core Function

The X-Core Module is a component in the microcontroller of the EMG device that focuses on acquiring electrical signals of muscles in real-time, processing them, and then properly handling the given electrical signal before being displayed or recorded. To validate the accuracy of the low-cost EMG sensor, the Cross-Correlation Coefficient (CC) was utilised. This method compares the prototype device's signal to that of a commercial standard device (NORAXON EMG sensor) available in the university's laboratory. Cross-correlation measures the similarity between two signals by sliding one signal over the other and finding the optimal match. MATLAB software was employed to perform this analysis using the X-Core function, which takes *t*. The most important module is called the X-Core function, and it performs signal filtering and control command generation Two signals as inputs, compute their correlation, and return the correlation sequence as output.

Two tests were conducted to ensure the accuracy of the prototype device:

First Test: The electrodes of the NORAXON device were placed on the biceps muscle of a healthy 23-year-old male alongside the electrodes of the low-cost EMG sensor at a very small distance. Both devices recorded muscle activity during exercise (Fig. 8).

Second Test: The electrodes of the NORAXON device were placed on the biceps muscle, and muscle activity was recorded. The electrodes were then removed and replaced with low-cost EMG electrodes to measure the same activity under identical conditions. Signals from both devices were saved for further analysis.

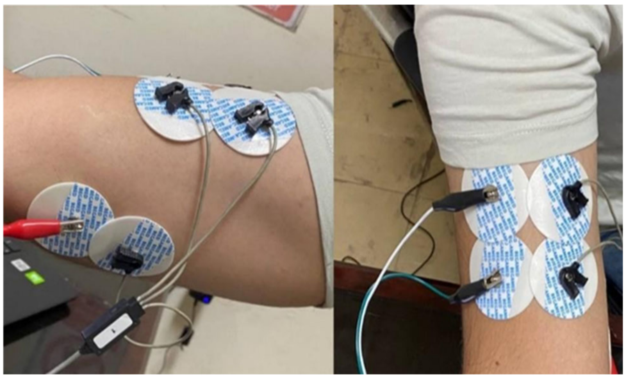

Fig. 8. Test (1) Both electrodes of two devices in the same region.

The signals were trimmed to match the exercise duration and analysed using the XCore function. The cross-correlation results (Fig. 9) showed distinct peak areas in both tests, indicating strong similarity between the signals. This confirms that the prototype device is within the acceptable range for accurately measuring muscle activity. Whenever there is a high peak in the cross-correlation signal, it indicates better alignment and compatibility between the low-cost EMG and the commercial device, as shown in Fig. 10.

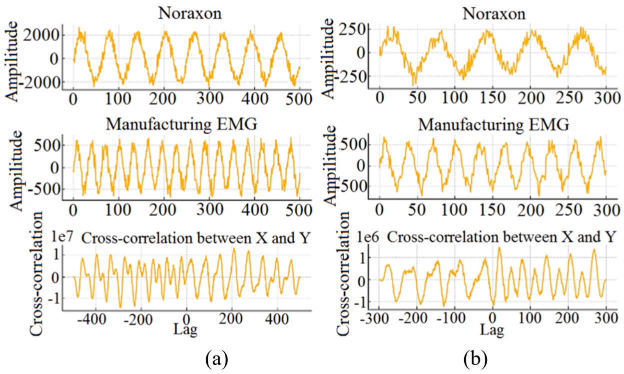

Fig. 9. The cross-correlation between two signals. (A) refers to the test where both devices have been placed at the same time. (B) refers to the test where the devices were separated.

C. Peak Frequency Parameter

Peak frequency represents the frequency at which a signal or waveform achieves its maximum amplitude or power. This parameter highlights the dominant frequency component, which carries the highest energy within a given signal [27, 28].

For this validation, two tests were performed to compare the peak frequency of signals from the commercial device (NORAXON) and the low-cost EMG sensor.

First case: Both the commercial and low-cost devices were placed on the biceps muscle simultaneously. The muscle activity was recorded during exercise.

The results of this case are shown in Fig 10(a) and (b).

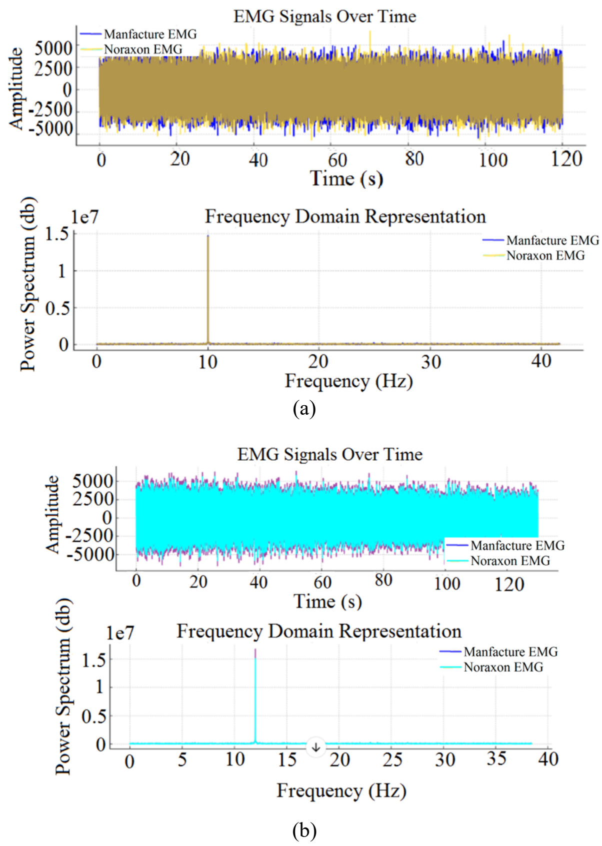

Fig. 10. Peak frequency, (a) first case, record one. (b) first case, record two. A second record was taken to ensure the consistency and reliability of the measurements.

Second Case: In this test, the NORAXON electrodes were initially placed on the biceps muscle to record muscle activity. These electrodes were then replaced with low-cost EMG electrodes to measure the same activity under identical conditions.

The results are illustrated in Fig. 11(a) and (b). The peak frequencies for both devices were analysed. A higher peak frequency indicates a dominant frequency component at that specific frequency. The comparison showed that the low-cost EMG sensor closely matched the commercial device in both tests, confirming its ability to capture accurate frequency components of muscle activity.

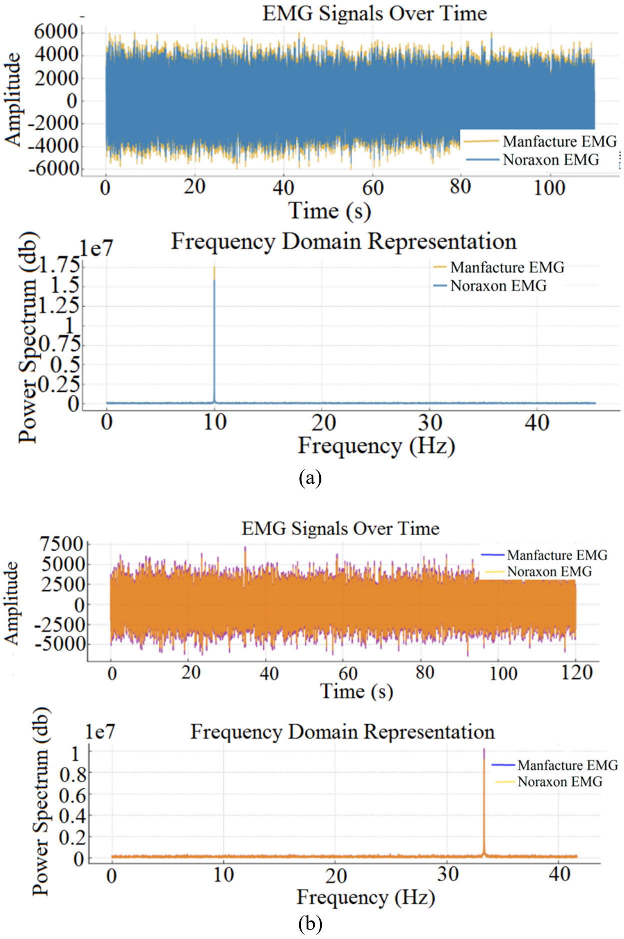

Fig. 11. Peak frequency, (a) second case, record one; (b) second case, record two.

D. Root Mean Square (RMS)

Root mean square (RMS) quantifies the amplitude or variability of a set of values or a continuous signal waveform. It is widely applied in fields such as signal processing, physics, engineering, and statistics [29]. The RMS value is calculated using the formula:

$$RMS = \sqrt{\frac{x_1^2 + x_2^2 + \cdots + x_n^2}{n}}$$

where $x_1, x_2, \ldots, x_n$ represent the individual values in the signal, and n is the total number of values.

For this validation, RMS values were computed for both the commercial device (NORAXON) and the low-cost EMG sensor under two scenarios. The results are shown in Table II.

TABLE II. ROOT MEAN SQUARE (RMS) VALUES

Case No.	NORAXON EMG	Low-cost EMG
The first case, rec. 1	4000	3500
The first case, rec. 2	3300	3200
The second case, rec.1	3700	3600
The second case, rec.2	3500	3400

The RMS values indicate that the low-cost EMG sensor achieves measurements comparable to the commercial device, demonstrating consistent performance. A slightly lower RMS in some cases reflects minor differences, but they remain within acceptable limits for muscle activity monitoring.

It is essential to note that RMS values primarily reflect the signal's overall magnitude, not its frequency content or waveform shape. Therefore, additional parameters, such as noise analysis and frequency domain evaluation, are required to provide a comprehensive assessment.

E. The Threshold and 3D-Printed Hand Validation

Testing the low-cost EMG sensor required combining it with a 3D-printed hand to enable analysis of its input potential for prosthetic control. The application of the threshold concept involved the creation of specified input parameters, which relied on EMG sensor signal amplitude detection when muscles operate. Threshold values served to identify when the sensor would launch hand contraction commands.

The EMG sensor used signals to activate the contractions present in the 3D-printed hand throughout the manufacturing period, as shown in Fig. 12. A corresponding signal passed the preset threshold levels when the real hand contracted, which caused equivalent movements of the 3D-printed hand. Through real-time monitoring, the system accurately reflected hand movements from the real hand setup.

The successful implementation of the threshold concept proved that low-cost EMG sensors could serve as dependable input devices for controlling prosthetic limbs as well as robotics systems. The sensor shows both durability and exactness in its ability to convert information from muscle signals to full-purpose body actions.

Fig. 12. A 3D printed hand model.

F. Noise Analysis

EMG device performance depends mainly on noise management during operation. High levels of noise affect the measurement accuracy of muscle activities. It conducted this validation through an analysis of noise intensity between the prototype device alongside the commercial device NORAXON when operating under the same conditions.

1) Signal-to-noise ratio

The Signal-to-Noise Ratio (SNR) was calculated to evaluate the quality of the signals captured by both devices. Higher SNR values indicate better signal quality with minimal noise interference. The results are shown in Table III.

TABLE III. COMPARISON OF SIGNAL-TO-NOISE RATIO (SNR) BETWEEN COMMERCIAL AND PROTOTYPE EMG DEVICES

Condition	Commercial Device SNR (dB)	Prototype Device SNR (dB)
Resting State	25.6	22.3
Light Muscle Activity	30.2	27.8
Intense Muscle Activity	33.1	31.5
Mean	29.63	27.20
Standard Deviation	3.77	4.63

2) Noise power

To further validate the prototype device, noise power was computed. Lower noise power values indicate better performance. The results are presented in Table IV.

TABLE IV. COMPARISON OF NOISE POWER BETWEEN COMMERCIAL AND PROTOTYPE EMG DEVICES

Condition	Commercial Device Noise Power (µV²)	Prototype Device Noise Power (µV²)
Resting State	0.015	0.020
Light Muscle Activity	0.012	0.014
Intense Muscle Activity	0.010	0.012
Mean	0.0123	0.0153
Standard Deviation	0.00252	0.00416

The study results showed the prototype device generated SNR values which were somewhat below the levels measured from the commercial device. The recorded values fell inside the accepted boundaries for successful EMG signal evaluation. The prototype device generated slightly elevated noise power results when tested according to the study. Signal accuracy remained unaffected by the slight difference noticed between the prototype device and the commercial device. The prototype device performs similarly to its commercial counterpart in terms of measuring EMG signals without compromising affordability.

On the issue of how the movement or noise would influence the measurements, it is this effect that was catered to in the way the mechanical and electronic parts of the equipment were designed to reduce this effect by use of a number of strategies. The skin was first wiped clean before the adhesive electrodes were bonded onto the skin to minimize the vibrations and the relative movement between the electrodes and the skin. Second, a rigid system was adopted on the 3D-printed parts so that the device would not vibrate during movement. Third, electronic filters with low noise were combined to avoid the effects of movement or other undesired electrical impulses. Also, the points of occurrence of the electrodes have been highly selected in locations where there is no highly mobile skin, as well as repeated tests have been conducted on the same muscle to test the stability and correctness of the signals. The measures render the device effective in constrained dynamic settings and prove the capacity to guarantee the quality and accuracy of measurement.

G. Numerical and Simulation Results

In this section, discuss the material cost of the system design. Consider the system information illustrated in Table V with the values for the corresponding parameters.

TABLE V. THE MATERIAL COST OF THE SYSTEM DESIGN

Specified Component	Quantity	Price	Specified Component
Arduino nano	1	12	12
Instrument Amplifier (TL084)	1	0.5	0.5
Electrodes (Bio Protech T716)	3	0.02	0.06
Resistors and Capacitors	-	-	3
Breadboard (mini)	1	1	1
Others	Clips, Wire, Holder		8.94
Total	-	-	25.5$

The price of EMG devices can vary depending on various factors such as brand, quality, features, and included accessories. Additionally, different types of EMG devices, such as portable units, clinical systems, or research-grade equipment, may have different price ranges. Also, prices can change over time due to technological advancements.

IV. DISCUSSION

Creating and producing an affordable portable Electromyography (EMG) device alongside its commercial comparison testing brought forth numerous important findings. The main purpose of this initiative is to minimize manufacturing expenses for an electroencephalography device that extends its reach to a wider audience with financial limitations. A cost-effective EMG device developed for this project maintains performance quality standards while making such equipment more affordable for users.

The validation of the economically portable EMG device included conducting a test that compared it to a reputable commercial device in controlled measurement environments. This validation method required the collection of simultaneous EMG signals from the two devices while testing performance characteristics such as signal clarity alongside noise strengths, response frequencies and signal intensity. The comparison established the measurement accuracy of the economic device compared to its commercial equivalent.

One essential aspect of this study required a check of noise levels because these variables directly affect EMG signal accuracy. Both noise power and Signal-to-Noise Ratio (SNR) analysis allowed the evaluation of interference reduction capabilities in the prototype design. Signal acquisition reliability existed between the prototype device and the commercial device despite the prototype showing slightly reduced SNR values and marginally elevated noise power levels. The prototype device maintains both signal integrity and offers an economical approach to signal acquisition, according to test results.

The assessment process verified the measurement consistency of the affordable EMG device following its reliability and accuracy validation. Both evaluation methods and root mean square error (RMSE) measurements, together with correlation coefficients, established the accuracy comparison between the devices. Evidence shows that the economic device delivers measurements equally dependable and consistent as a commercial device does.

The study validates the development of a low-cost, portable, dependable EMG device. The research shows that through strategic optimisation of performance objectives and noise reduction, this device proves suitable as an affordable yet functional EMG acquisition system for various applications.

V. Conclusion

The creation of a minimal-cost EMG bio-signal device succeeded in measuring muscle activity through efficient and inexpensive applications. The Simulink digital filtering toolbox displays essential features, which include broadening frequency bandwidth, noise reduction capabilities, and detailed signal resolution.

The implementation of high-gain values in biological signal amplification leads to superior signal quality outcomes. A correct realignment of the offset made it possible for the signal amplifier to deliver reliable outputs. The electrical components in the prototype consume minimal electrical energy because they can handle a maximum current of 80 mA.

The acquired signals showed small disturbances because of voltage variations from the battery power source, although critical safeguards were installed. The present interference levels stayed within accepted boundaries without affecting the signal precision. This research proved that EMG signals function effectively when measured between 0 to 250 Hz since this band contains essential bicep movement information. The accurate placement of electrodes helps enhance signal acquisition from a wider set of frequencies.

Bio-signal collection demonstrates potential healthcare enhancements due to its integration with the human biometric system, as well as intelligent health monitoring and an efficient user-cooperative Human-Machine Interface (HMI). MATLAB enables implementations of signal filtering and visualisation methods using the Cross-Correlation (CC) function to improve open-source system integration and competitive performance levels.

The equipment has been designed in modular form, which means that the components can be reassembled with a new corpus with the identical mechanical and electronic design, and this offers stable performance and accuracy of measurement with new devices. Besides, programming and calibration files are applied to all the devices and resulting in the consistency and accuracy of all the measured signals. There are two more prototypes produced, which indicates the validity of producing the device a large scale and maintaining the performance quality.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Authors Fahad Mohanad and Salim Fattah conducted the research; Ahmed Jumaa and Aya Falah analyzed the data; Fahad Mohanad wrote the paper; all authors had approved the final version.

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