

Electromyography Sensing Circuit for Detection of Neuromuscular activity

Rohini Chavan¹, Sai Trisha N², Snehal Shinde³, Swayam Gurnule⁴ and Shantanu Neve⁵

¹⁻⁵Vishwakarma Institute of Information Technology, Electronics & Telecomm. Dept., Pune, India.

Email: rohini.chavan@viit.ac.in, saitrisha.22311719@viit.ac.in, snehal.22310781@viit.ac.in, swayam.22310762@viit.ac.in, shantanu.22310605@viit.ac.in.

Abstract— This research is focused on developing an EMG circuit for detecting electromyography (EMG) signals from muscles, utilizing self-adhesive surface electrodes that are applied to capture signals from skeletal muscles. This technology is essential for understanding neuromuscular function. Two of the electrodes are placed on the flexor carpi radialis and the flexor carpi ulnaris muscles. The third electrode is placed on the Humero-radial joint as a reference. The captured signals undergo a series of processing stages, including amplification, filtering, and rectification. Due to the low amplitude of myoelectric signals (ranging from microvolts to millivolts), an instrumentation amplifier is crucial for enhancing signal strength and minimizing noise interference during data acquisition. The output signal obtained through these stages demonstrates improved quality and reliability. Current EMG devices face several challenges, including high costs, slow response times susceptibility to noise, limited amplitude sensitivity, and bulkiness. This paper proposes a compact and affordable EMG sensor that offers a promising solution for both clinical and research applications, making EMG technology more accessible and effective.

Keywords— Electromyography (EMG), Surface electrodes, Signal quality, cost-effective.

I. INTRODUCTION

The aim of the project is to build EMG sensing circuit for measuring muscle activity movement. Electromyography (EMG) is the subject which deals with the detection, analysis and utilization of electrical signals emanating from skeletal muscle [1]. Myoelectric signals are generated from the motor neurons which are a part of the Central Nervous System (CNS). EMG signal arises due to neuromuscular activity. Due to very small range (uV to mV) of muscle signal, an instrumentation amplifier is vitally needed to amplify the signal as to avoid signal lost due to excessive noise build-up during data acquisition [2]. Furthermore, the signals obtained from the muscle can vary significantly, presenting a challenge due to the instability of the signal information. Consequently, designing and analysing an accurate amplification circuitry is essential to ensure reliable performance and consistency in signal processing. Digital Oscilloscope (DSO) is used to monitor and record the EMG signals generated by muscle contractions, which can be challenging to observe and analyze with the naked eye. The basic components of the EMG sensor are the Instrumentation amplifier, Band pass filter, rectifier and the non-inverting amplifier. In order to receive the signals from muscles, surface electrodes are used. Surface electrodes use non-invasive technology to measure and capture the EMG signals.

Surface electrodes operate based on the principle of chemical equilibrium, detecting changes between the skin's surface and the underlying tissue through electrolytic conduction.

Despite advancements, many commercial EMG systems are expensive and a reliable device with fast response times and affordability is crucial. Our project work presents a newly developed EMG sensor offering high sensitivity, improved signal-to-noise ratio (SNR), higher common mode rejection ratio (CMRR) and quicker response time

II. LITERATURE SURVEY

- Author- Ismail Saad et al. [1] proposed a system for the effective analysis of electromyogram (EMG) signal processing aimed at evaluating muscle strength, specifically for rehabilitation applications. The study involves the acquisition of single-channel EMG signals from human muscles using non-invasive electrodes. A signal acquisition circuit is designed to amplify the small EMG signals, which typically range from microvolts to millivolts, using high-precision instrumentation amplifiers. This amplification is crucial to minimize noise during data collection. After amplification, the EMG signals are digitized using an analog-to-digital converter (ADC). The processing is managed by a microcontroller (ATmega328), which ensures accurate interpretation of the EMG signals. The processed EMG signals are categorized into six different levels to display the user's muscle strength, aiding in rehabilitation for individuals with reduced muscle strength or the elderly.
- Author- Shilpi Singh et al [3] proposed a system that focuses on identifying electromyography (EMG) signals associated with muscle activation, crucial for diagnosing neuromuscular disorders. EMG signals, collected from healthy, myopathic, and neuropathic subjects using surface electrodes, are complex and often corrupted by noise. The study employs wavelet transforms to analyze these signals, extracting various time and frequency domain features, such as duration and mean frequency, to classify the different types of EMG signals. The paper describes the methodology for signal acquisition and noise reduction, highlighting two main noise sources: ambient noise and transducer noise. A detailed procedure for signal processing is outlined, which includes filtering the raw EMG signals with high-pass, low-pass, and notch filters, followed by wavelet decomposition to enhance the signals. The results demonstrate effective classification of motor unit action potentials from the collected EMG data, making the findings beneficial for clinical testing and diagnostics in neuromuscular disorders. Key techniques used in the analysis include feature extraction methods like root mean square and autoregressive coefficients.
- Author- H.M. Desa et al [4] proposed development of an electromyography (EMG) circuit designed to detect muscle activity from the quadriceps during knee extension. Using self-adhesive surface electrodes placed on the rectus femoris, the study involved five healthy male subjects with varying leg dominance. The circuit incorporates several stages including amplification, filtering, and rectification to process the EMG signals effectively. Key components include the INA106 differential amplifier for noise cancellation and a TL072 low-noise JFET operational amplifier for further signal processing. The methodology involved capturing the EMG signals via an oscilloscope during controlled knee extension movements. Results indicated that the circuit successfully amplified and processed the EMG signals, showing a significant voltage difference during knee extension compared to the resting state. The average voltage difference across subjects was found to be 3.298V. This circuit is expected to be beneficial for further applications, such as analyzing muscle function in clinical settings for stroke or paralysis patients. Future research may focus on investigating signals from the hamstring for knee flexion and expanding the application of the EMG circuit in motor control systems.
- Author- Xiangxin Zou [5] proposed a project that focuses on using an Electromyography (EMG) sensor to detect muscle movement, modifying the signal through a connected circuit, and presenting the output in audiovisual formats. The circuit comprises an instrumentation amplifier to boost the EMG signal, filters to eliminate DC offset and noise, a rectifier to convert the signal to a positive swing, and an envelope detector to smooth the output. The design was simulated using Multisim and implemented on a breadboard. The EMG sensor employs a 1p coin as an electrode, leveraging its conductivity. The system is powered by a microcontroller (Arduino) to display muscle activity both visually (via an LED bar) and audibly (through a speaker), making it accessible for users with hearing or visual disabilities. Experimental results showed stable amplification and filtering of the EMG signal, although challenges like noise interference and unstable output were noted. Future improvements include using conductive gel for better electrode-skin contact and optimizing circuit design to minimize noise. The project successfully demonstrates how EMG technology can provide meaningful feedback on muscle activity, enhancing accessibility for diverse users.

- Author- A. Prakash et al [6] proposed a compact and affordable myoelectric sensor designed for prosthetic applications, addressing limitations of current EMG devices such as high cost, slow response time, and noise susceptibility. It features a single-package design that includes an electrode interface, signal conditioning, and power supply. The performance of dry electrodes was compared with conventional Ag/AgCl electrodes, showing satisfactory results. The sensor employs an envelope detection technique that improves signal smoothness and response consistency, resulting in a 1.4 times greater signal-to-noise ratio (SNR) and 45% higher sensitivity than commercial devices, along with a 57% faster response time. Tested on amputees, the sensor successfully controlled a 3D-printed prosthetic hand with proportional grip strength based on EMG signals, demonstrating its effectiveness in real-world applications.

III. METHODOLOGY

Electromyography (EMG) is an technique for evaluating muscle function. Accurate EMG signal acquisition requires careful design of the sensing circuit to minimize noise and maximize signal acquisition. This methodology outlines the steps taken to build an effective EMG sensing circuit.

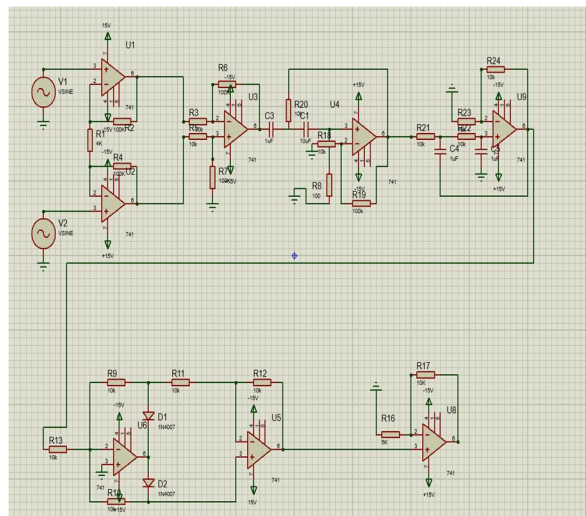


Figure1. Block simulation Diagram of EMG sensing circuit

A raw EMG signal is obtained from the electrodes. Three surface self -adhesive electrodes are used to capture the EMG signals. Two of the electrodes are placed on the flexor carpi radialis and the flexor carpi ulnaris muscles. The third electrode is placed on the Humero- radial joint as a reference.

Due to small range signal received from the muscle, high precision instrumentation amplifiers are required to amplify the signal. Selected gain is required to amplify the signal to avoid the information signal being eliminated for the next stage of the signal processing. Noise filtering is important in this signal processing to remove the noise [6]. Band pass filter is used to reduce noise and avoid offset voltage. Precision full wave rectifier circuit is used to lower the ripple factor

The stages involved include:

A. The Instrumentation amplifier circuit

CONNECTION DIAGRAM

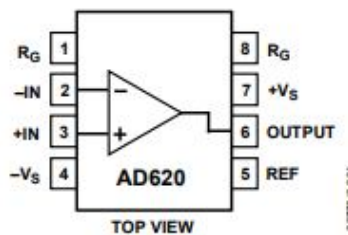


Figure 2: Pin-out of IC AD620

Instrumentation amplifier is used as a pre-amplifier to acquire EMG signal from muscle through the non-invasive electrodes [7]. AD620 is used as instrumentation amplifier in the circuit. The AD620 is a low cost, high accuracy instrumentation amplifier that requires only one external resistor to set gains of 1 to 10,000.

It provides high common mode rejection ratio, high input impedance and adjustable gain along with stability and accuracy. The AD620 offers improved performance over the three op amp IA designs, along with smaller size, fewer components, and $10 \times$ lower supplies current.

The gain of the instrumentation amplifier is calculated through the formula:

$$R_G = \frac{49.4k\Omega}{G-1}$$

R_G is set to 100 ohm in the circuit resulting in a gain of 495.

B. Band pass filter

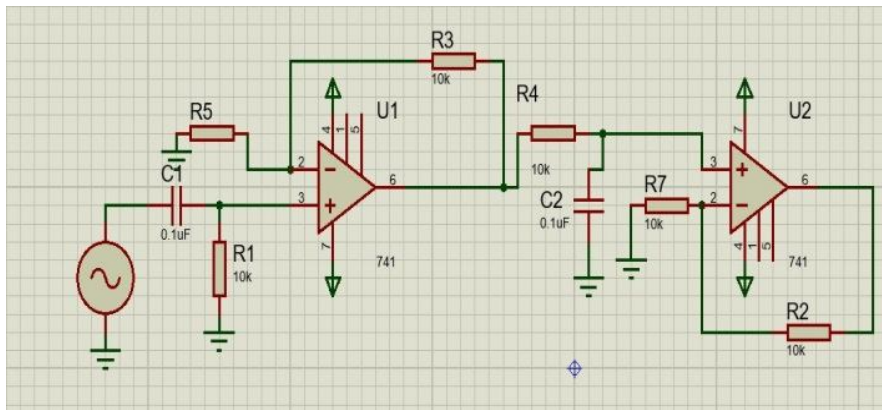


Figure 3: Band – pass filter

First order Butterworth filters are used with a lower cut-off frequency of 19.4 Hz and higher cut-off frequency of 492 Hz which is the typical frequency range of EMG signals.

First order Butterworth filters provide good frequency response (-20dB/decade), and enhanced noise reduction with minimal phase distortion.

The cut-off frequency is calculated through the formula:

$$f_{\text{cutoff}} = \frac{1}{2\pi RC}$$

The value of capacitance C and resistance R is chosen to be 0.01uF and 82Kohm respectively for the lower cut-off frequency (fL) and 0.01uF and 3.3Kohm respectively for the higher cut-off frequency (fH). The gain of the band pass filter is set to 2.

C. Precision Full wave rectifier circuits

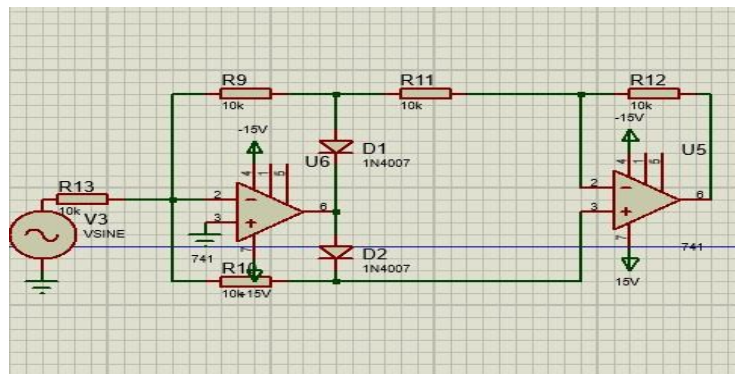


Figure 4: Precision Full wave rectifier

Precision rectifier is used instead of the normal rectifier. If the normal rectifier is used, the EMG signal across the diode is affected due to 0.7V forward bias voltage drop. The EMG signal fluctuates between positive and negative value during the muscle movement. Thus signal smoothing is obtained after rectification. All the resistors are set to 10K in the circuit to provide unity gain.

D. Final amplification

A non – inverting amplifier is used for the final gain. Enhanced signal strength is produced, making it easier for the signal to be analysed and processed. The gain of the final amplification is set to 101.

IV. IMPLEMENTATION

The circuit is first tested through simulation on Proteus. Proper calculations are needed to ensure that the circuit works properly. Next, the components are arranged on the breadboard according to Figure 1. A DC power supply of +15V and -15V is given to the circuit. Each stage is tested individually before the cascaded circuit is constructed. Three surface self -adhesive electrodes are used to capture the EMG signals. Two of the electrodes are placed on the flexor carpi radialis and the flexor carpi ulnaris muscles. The third electrode is placed on the Humero- radial joint as a reference. The output voltage from the circuit is then fed into the Digital Oscilloscope (DSO) for analysis. Figure 5 depicts the EMG sensing circuit setup.

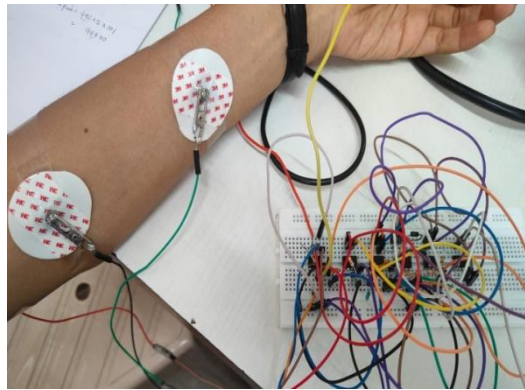


Figure 5: EMG sensing circuit setup

V. RESULTS AND DISCUSSIONS

This section presents the results obtained from the developed EMG circuit, as illustrated in Figure 5. The circuit operates using a DC power supply from batteries, while the output is connected to an oscilloscope to capture the waveform at each stage of the process. Resultant output from every stage is captured according to block diagram of EMG acquisition circuit. The circuit is tested on four healthy individuals.

The typical output of the EMG waves is unfiltered and exhibits significant distortion and noise, as shown in the figure 6.

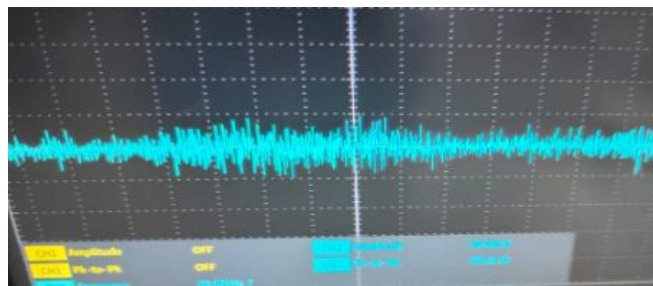


Figure 6: Output of typical unfiltered EMG signals

The instrumentation amplifier amplifies the weak EMG signals from the electrodes while rejecting noise and interference. This enables accurate detection of muscle activity. The output of the instrumentation amplifier is shown in figure 7. In the circuit the instrumentation amplifier is set at a gain of 495. The voltage observed during hand extension is 640mV.

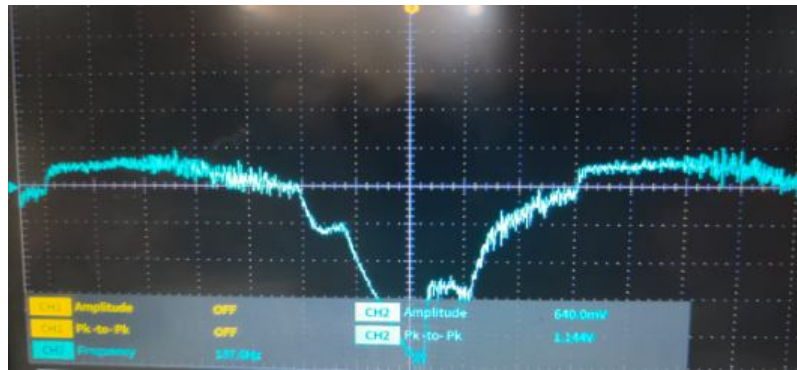


Figure 7: Output of instrumentation amplifier

Next, the signal is passed through the band-pass filter which isolates the desired frequency range of the EMG signals while attenuating frequencies outside this range. This helps to eliminate noise and interference ensuring that only relevant muscle activity signals are processed. By allowing frequencies typically between 20 Hz and 500 Hz to pass, the filter enhances the quality and reliability of the detected EMG signals. The filtered signal is free from DC offset and exhibits reduced frequency noise compared to the output from the instrumentation amplifier. The maximum voltage during hand extension reaches 960mV. The frequency of the EMG signals is observed to be around 50 Hz. This signal is then directed to the rectification stages for additional processing.

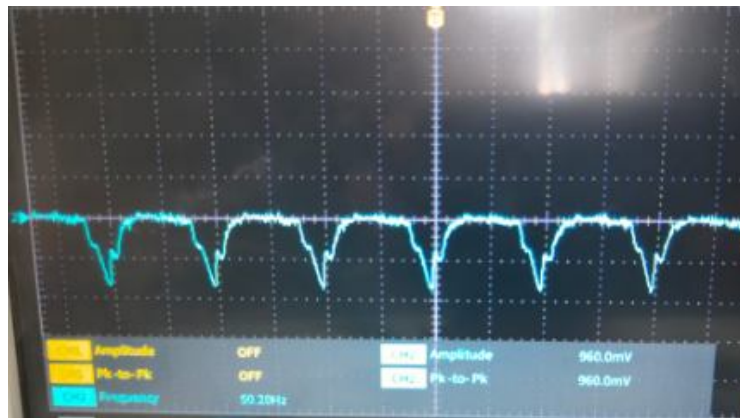


Figure 8: Output of the band – pass filter

In the rectification stage, the signal is passed through the precision – full wave rectifier which converts the amplified AC EMG signal into a unidirectional (DC) signal. This allows for accurate representation of the signal's magnitude, capturing both positive and negative halves of the waveform. By using operational amplifiers, it ensures minimal voltage drop and high accuracy, providing a smooth output that reflects the envelope of the EMG signal. The final amplitude of voltage is observed to be 1V during hand extension. Figure 9 illustrates the output of the rectifier circuit followed by further amplification of the signal.

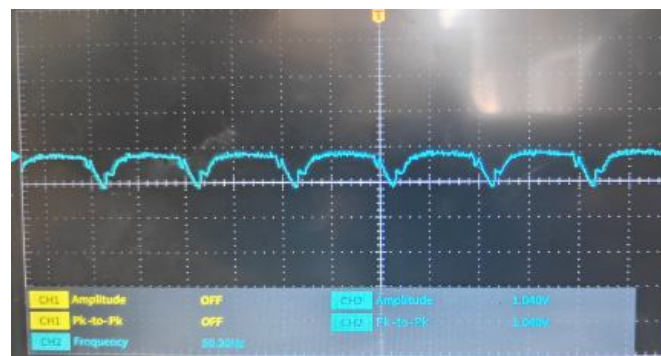


Figure 9: Final output of the circuit after rectification and amplification

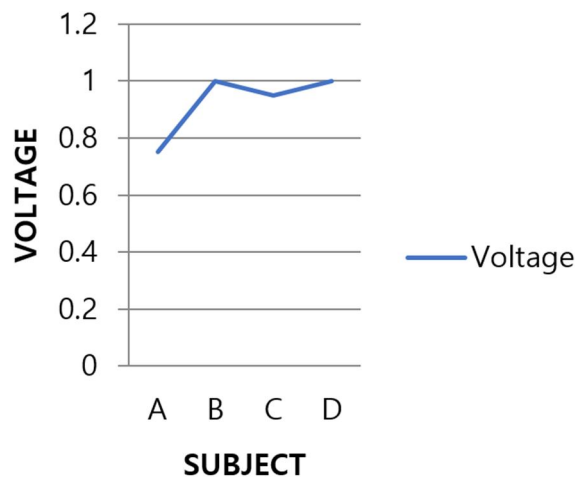


Figure 10: Hand extension output graph

VI. CONCLUSION AND FUTURE SCOPE

The EMG sensing circuit, incorporating an instrumentation amplifier, band pass filter and precision rectifier, demonstrates significant potential in accurately capturing and analysing bioelectric signals. The instrumentation amplifier enhances signal amplification while maintaining excellent common-mode rejection, which is critical for isolating weak EMG signals from noise. The rectifier converts the AC signals into a unidirectional format, enabling effective analysis of muscle activity intensity. Additionally, the band pass filter efficiently isolates the relevant frequency components, typically within the 20 Hz to 500 Hz range, thereby improving signal integrity and minimizing noise interference. Despite these advantages, challenges such as noise interference, electrode placement, and skin impedance require careful calibration and signal conditioning.

Looking ahead, there are promising opportunities for integrating this technology into wearable devices, employing advanced signal processing techniques, and exploring multi-modal sensing for comprehensive health monitoring. Integrating EMG sensing technology into remote monitoring systems can provide valuable insights into patient progress outside clinical settings. This could lead to more proactive management of conditions and better patient outcomes. EMG technology has significant implications for rehabilitation, particularly in physical therapy. By providing real-time feedback on muscle activation, therapists can tailor rehabilitation programs to individual needs, optimizing recovery. By analysing patterns and anomalies in muscle activity, the technology can assist in diagnosing conditions such as amyotrophic lateral sclerosis (ALS), multiple sclerosis (MS), and other muscle disorders.

REFERENCES

- [1] Ismail Saad, Nur Husna Bais., Bun Seng C., Mohd. Zuhir H., N. Bolong, 2015. "Electromyogram (EMG) Signal Processing Analysis for Clinical Rehabilitation Application", Third International Conference on Artificial Intelligence, Modelling and Simulation, 2015, pp. 123-128, DOI: 10.1109.
- [2] Hao, L., Shan, X., Peng, Y., Chen, L, 2010. "A Research and Design on Surface EMG Amplifier". IEEE 2010 Int. Conf. Measuring Technology and Mechatronic Automation, Tian Jin, 13-14 March 2010, 306-309.
- [3] S. Singh, B. Mishra, and A. K. Wadhwani, " Electromyography (EMG) based signal processing and their Feature Selection using Wavelet Transform," "International Journal of Applied Engineering Research", vol. 14, no. 2, pp. 2019.
- [4] H. M. Desa, M. S. Zuber, R. Jailani, and N. M. Tahir, "Development of EMG Circuit for Detection of Leg Movement," in "Proc. 2016 IEEE Symp. Computer Applications & Industrial Electronics (ISCAIE)", Shah Alam, Malaysia, May 2016, pp. 1-5. Doi : 10.1109.
- [5] Xiangxin Zou, "The Design of the Electromyography Sensor with the Modifying Circuit", Journal of Physics: Conference Series, vol. 1693, no. 1, pp. 012189, 2020.
- [6] A. Prakash, S. Sharma, and N. Sharma, "A compact-sized surface EMG sensor for myoelectric hand prosthesis" , "Biomedical Engineering Letters", vol. 9, no. 4, pp. 467-479, Aug. 2019.
- [7] Chan Bun Seng, Farrah Wong, 2012 "Myogram Circuit for On-OFF Control", Processing of the 10th Seminar of Science & Technology 1- 2 December 2012, Kota Kinabalu.