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EMG Based Nerve Weakness Detection System

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Abstract- The nerve weakness detection system is a portable system for detecting nerve and muscle weakness using an EMG sensor, Bluetooth moduleHC-05 , Mobile/System application and ESP32. Conditions such as Peripheral Neuropathy can be identified by analyzing muscle activity signals. The person with peripheral Neuropathy suffers by hand and leg pain and numbness due to the weakness. The EMG sensor captures a raw analog bioelectrical signals from muscles, which are converted into digital form using the ESP32's built-in signal conversion module(ADC). These signals are processed to evaluate muscle strength and detect abnormalities. The processed data is transmitted to a mobile application via Bluetooth or Wi- Fi, where a weakness index is calculated and displayed in real time using a Mobile/System application. Based on predefined ranges, the system classifies the severity of weakness. This low-cost and user-friendly solution enables early detection, continuous monitoring, and supports rehabilitation, especially in remote healthcare settings.

Keywords- Electromyography, Peripheral Neuropathy, ESP32, Muscle Activity Monitoring, Nerve Weakness Detection.

I. INTRODUCTION

Muscle movement is controlled by nerves. The brain sends electrical signals through nerves to muscles, causing them to contract and relax. If the nerve signal is weak or damaged, the muscle cannot contract properly, leading to weakness as seen in Peripheral Neuropathy.

A muscle is made up of small units called sarcomeres containing actin and myosin. During contraction, these filaments slide over each other (sliding filament theory). The I band (only actin) becomes shorter, and the H band (only myosin) disappears during contraction, showing that the muscle is actively working.When a muscle contracts, it produces electrical signals. These signals are measured using an EMG sensor. Strong muscles produce high-amplitude signals, while weak muscles produce low-amplitude signals. During relaxation, the signal is very low or absent.

Pheripheral Neuropathy is a condition that occurs when the pheripheral nerves, which connect the brain and spinal cord to the rest of the body become damaged. This condition is commonly caused by diabetes, vitamin deficiency, infections, injuries or certain medications. It leads to symptoms such as numbness, tingling sensation, pain and muscle weakness, especially in the hands and feet. It can determined by both clinical and diagnostic methods. In addition, diagnostic test like Electromyography(EMG) are used to measure the electrical activity of the muscles, where reduced or abnormal signal indicate muscle weakness or nerve damage. In modern digital systems, sensors such as

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EMG sensors captures muscle signals, convert them from analog to digital form, and analyze their strength and pattern to identify weakness accurately.

PROBLEM STATEMENT

The problem addressed in this project is the need for a low-cost, portable, and hardware-based EMG nerve weakness detection system. Existing clinical EMG systems are expensive and confined to hospitals, making early detection difficult for many patients. There is a need for a simplified embedded biomedical device that can capture muscle electrical signals, process them efficiently, and provide immediate indication of nerve weakness. The objective of this project is to design and implement a compact EMGbased nerve monitoring system using microcontroller technology, signal conditioning circuits, and display units to ensure early diagnosis, reduced hospital dependency, and improved healthcare accessibility.

OBJECTIVES

- To acquire muscle electrical signals using EMG sensors.
- To convert analog EMG signals into digital form using ADC.
- To analyze the strength of muscle activity from EMG signals.
- To detect and classify different levels of muscle weakness.
- To develop a real-time monitoring system for muscle condition.
- To reduce noise and improve signal accuracy using filtering techniques.
- To display the muscle activity on a digital platform (Mobile or PC).
- To store patient data for future analysis.

II. LITERATURE SURVEY

Various Biomedical Researchers -Surface Electromyography for Neuromuscular Assessment (2023)

Surface Electromyography (sEMG) is a widely used non- invasive technique for evaluating the electrical activity produced by skeletal muscles. In recent years, researchers have focused on improving the efficiency and portability of EMG- based monitoring systems to assist in the diagnosis and rehabilitation of neuromuscular disorders. Surface EMG sensors are placed on the skin over the muscle to detect electrical signals generated during muscle contraction and relaxation.

Embedded Systems Research Group- Low-Cost EMG Monitoring System Using Arduino (2022)

This research paper presents the design and development of a low-cost Electromyography (EMG) monitoring system using an Arduino microcontroller. The main objective of the study is to provide an affordable solution for monitoring muscle activity, especially for educational, research, and basic medical applications. EMG signals are generated when muscles contract and relax, and these electrical signals can be measured to analyze muscle performance and detect possible neuromuscular issues.

Biomedical Signal Processing Researchers - Signal Conditioning Techniques for EMG Applications (2021) EMG signals generated by skeletal muscles are extremely weak, typically in the microvolt to millivolt range, and are highly susceptible to noise and interference from external sources such as power lines, motion artifacts, and electronic equipment. Therefore, proper signal conditioning is essential for accurate signal acquisition and analysis.

Medical Electronics Researchers -EMG-Based Muscle Weakness Detection System (2020)

The research highlights that threshold-based analysis is a simple and efficient method for identifying muscle weakness in real time. The system can be used in rehabilitation centers, physiotherapy clinics, and medical monitoring environments to evaluate patient muscle performance and track recovery progress after injuries or neurological disorders.

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Healthcare Technology Research Team -Embedded Systems in Biomedical Instrumentation (2019)
This research discusses the integration of microcontrollers in biomedical devices. It explains how embedded systems improve real-time monitoring and reduce equipment size and cost. The study supports the development of portable medical diagnostic tools.

Jabeena.A, Shivam Kumar- smart EMG based nerve monitoring system (2018)
Neuromuscular disorders are rapidly increasing across all age groups due to lifestyle changes, injuries, diabetes, and neurological conditions. One of the major challenges in healthcare is the delayed identification of muscle weakness caused by nerve dysfunction. Early symptoms are often ignored because they are mild and not easily noticeable without clinical testing.

Agarwal Isha Sanjay, Kulkarni Radhika Ravindranath, Chawandke Manasi Prashant - EMBEDDED EMG SIGNAL ANALYSIS SYSTEM (2017)
This paper presents the design and implementation of a hardware-based embedded system for monitoring muscle activity using Electromyography (EMG) signals. The system utilizes an EMG sensor module connected to a microcontroller for real-time signal acquisition and analysis. When muscles contract, small electrical signals are generated. These signals are detected by surface electrodes, amplified using signal conditioning circuits, and processed through a microcontroller.

Vishal Tank, Sushmita Warrier, Nishant Jakhiya. - EMG Monitoring System Using Arduino Controller(2017)
This project demonstrates the development of an EMGbased monitoring prototype using Arduino as the main processing unit. The EMG sensor captures muscle electrical activity and sends analog signals to the microcontroller for analysis.The microcontroller converts the analog signal into digital data and compares it with predefined threshold values to determine muscle strength levels. Based on the signal intensity, the system categorizes muscle condition as normal, weak, or inactive

Manikandan T, Mohammed Aejaz M.A, Nithin Krishna N.M, Mohan Kumar A.P, Manigandan R- ADVANCED EMBEDDED BIOMEDICAL SIGNAL MONITORING SYSTEM (2016)
This proposed method introduces an embedded biomedical monitoring system that automates the detection and analysis of physiological signals such as muscle activity. The system integrates EMG electrodes, signal conditioning circuits, microcontroller processing, and LCD display modules. The EMG sensor detects bioelectric signals generated during muscle contraction. These weak signals are amplified, filtered, and processed to determine muscle performance. The system also includes alert mechanisms such as buzzers for abnormal signal detection.

III. EXISTING SYSTEM

The existing system for nerve weakness detection primarily consists of clinical EMG machines used in hospitals and diagnostic laboratories. These systems are designed to measure muscle electrical activity with high precision. Traditional EMG machines require multiple electrodes, advanced amplification circuits, computer-based analysis software, and trained medical personnel to interpret the results. While highly accurate, these machines are bulky, expensive, and not suitable for continuous home monitoring. The setup process is complex and requires controlled clinical environments. Therefore, accessibility remains limited, especially in rural or resource-constrained areas.

Disadvantages Of Existing System

- **High Cost:** Clinical EMG machines are expensive and not affordable for small clinics or individuals.
- **Lack of Portability:** The equipment is bulky and designed mainly for hospital use.

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- **Skilled Operation Required**: Requires trained technicians for signal acquisition and interpretation.
- **Complex Setup**: Multiple electrodes and calibration steps increase operational complexity.
- **Limited Accessibility**: Not easily available in remote or rural healthcare centers.

IV. PROPOSED SYSTEM

The proposed system is a hardware-based EMG (Electromyography) Nerve Weakness Detection System designed to monitor muscle electrical activity and identify abnormalities that may indicate nerve dysfunction. The system leverages EMG sensor technology, signal conditioning circuits, and a microcontroller-based embedded system to provide real-time monitoring of muscle activity.
The operation begins when surface EMG electrodes are placed on the target muscle area of the patient. When the muscle contracts, it generates small electrical signals (bioelectric potentials). These signals are extremely weak (in millivolts) and require amplification and filtering before processing.

The EMG sensor module captures these signals and performs:
- Signal amplification
- Noise filtering
- Rectification

The conditioned analog signal is then sent to the ESP32, which converts the analog signal into digital data using its built-in ADC (Analog-toDigital Converter).

Based on predefined threshold values programmed into the microcontroller:
- If signal strength is within normal range (< 50 µv) → LCD displays
- "Muscle Activity Normal"
- If signal strength is below threshold (50-150 µv)→ LCD displays
- "Possible Nerve Weakness"
- If signal strength is above threshold (> 150 µv) → LCD displays "Severe Nerve Weakness"
- If no signal detected → LCD displays "No Muscle Activity"

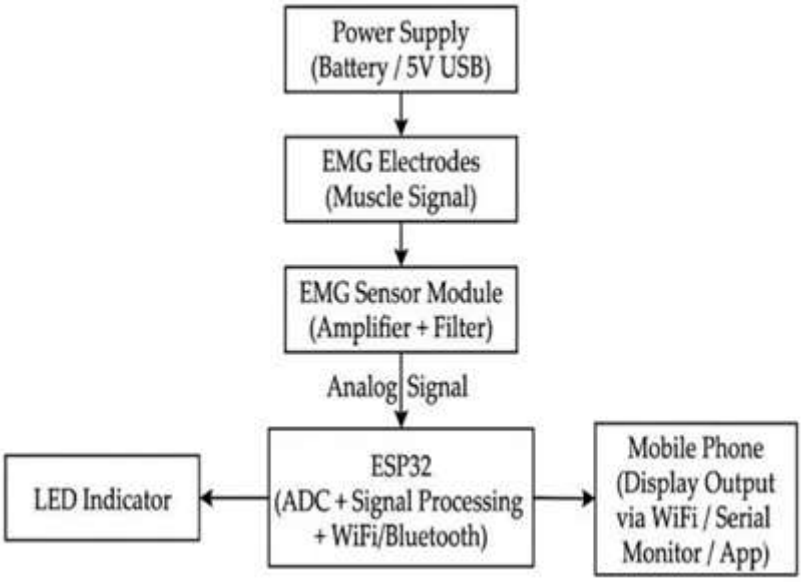

Fig. BLOCK DIAGRAM

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V. METHODOLOGY

The development of the proposed EMG-Based Nerve Weakness Detection System follows a systematic and structured approach. The methodology is divided into several key phases to ensure accurate biomedical signal acquisition, processing, and wireless output display.

Requirement Analysis
In this phase ,system requirements are identified and appropriate hardware components are selected.

The following components are used in the proposed system:
- EMG Sensor Module (for detecting muscle electrical signals)
- Surface Electrodes (for capturing bioelectric muscle activity)
- ESP32 Microcontroller (for signal processing and wireless communication)
- LED Indicator (for visual alert)
- Mobile Phone Interface (for displaying EMG signal data)

Hardware Setup
In this phase, all hardware components are connected to form the complete system.
- Surface electrodes are placed on the muscle to detect electrical activity generated during muscle contraction.
- The EMG Sensor Module amplifies and filters the weak muscle signals.
- The processed analog EMG signal is sent to the ESP32 analog input pin.
- The ESP32 microcontroller processes the EMG signal data.
- The system is powered using a regulated 5V USB power supply to ensure stable operation.

Software Development
The ESP32 microcontroller is programmed using the Arduino IDE. The software performs the following tasks:
- Reads analog EMG signals from the sensor using the built-in ADC
- Converts analog signals into digital values
- Processes the signal and compares it with predefined threshold values
- Controls LED indicators to show muscle activity condition
- Sends EMG signal data to a mobile phone via WiFi or Bluetooth

The program ensures real-time monitoring of muscle activity and early detection of possible nerve weakness.

System Integration and Testing
In this phase:
- All hardware components and software modules are integrated.
- EMG signals are tested under different muscle conditions such as rest, normal contraction, and weak contraction.
- Threshold values are adjusted for accurate detection.
- LED indications and mobile phone output are verified for correctness. The system performance is evaluated based on signal accuracy, reliability, and response time.

Validation and Deployment
The final system is validated to ensure:
- Accurate detection of muscle electrical activity
- Stable operation with minimal signal noise
- Correct LED indication for muscle condition
- Proper display of EMG data on the mobile phone

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After successful validation, the system is optimized for compact and portable design. The proposed system can be used for physiotherapy monitoring, muscle activity analysis, and early detection of nerve weakness.

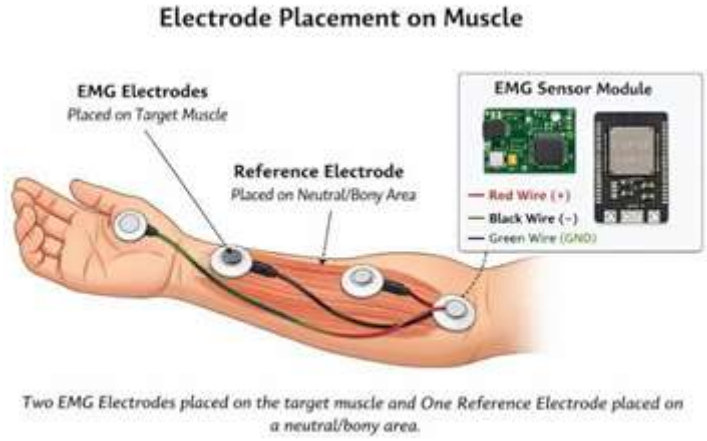

Fig.Electrode Placement in Muscle

VI. RESULT

The EMG Based Nerve Weakness Detection System was successfully designed and implemented using surface electrodes, EMG sensor module, ESP32 microcontroller, LED indicator system, and a mobile monitoring interface.

Surface electrodes were placed on the forearm muscle to measure electrical activity during the following conditions:

- Muscle at rest
- Normal muscle contraction
- Weak muscle contraction

The EMG signals generated by muscle activity were detected by the electrodes and sent to the EMG sensor module. The sensor module amplified and filtered the weak bioelectrical signals and produced an analog output.

The ESP32 microcontroller read the analog EMG signal through its analog input pin and processed the data. Based on the predefined threshold value, the system identified whether the muscle activity was normal or weak.

The system successfully demonstrated the ability to detect variations in muscle electrical activity and provide immediate feedback, which can help in identifying possible nerve weakness conditions

RANGE	AMPLITUDE(µv)	WEAKNESS
LOW	< 50 µv	Low Weakness
MEDIUM	50 µv-150 µv	Moderate Weakness
HIGH	>150 µv	Severe Weakness

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Fig. Output Of Measuring Weakness By Mobile Application

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