Medical Device Concept
Electromyogram

1st Stephanie Chinenye Okosa
Interecative Systems Engineering II
Electronic engineering department
Hochscule Hamm Lippstadt University
Lippstadt, Germany
stephanie-chinenye.okosa@stud.hshl.de

Abstract— **Electromyography is a technique used to detect, monitor electrical signals of muscle activities, and diagnose nerve disorders. The electric signal obtained, can be used in clinical or biomedical application. The process of acquiring the signal require advanced methods for detecting, decomposing, and processing. This document intends to model an electromyogram device, with a focus on the hardware components, the function of the device, its users as well as its future direction.**

Keywords—electric, signal, muscle, activity, electromyography

I. INTRODUCTION

Electromyography also known as EMG is a procedure carried out to diagnose the health of muscles and the nerve cells that control them. Electrical current is generated in the muscle during muscle contraction as a result of muscle stimulation. EMG measure the electrical signals that are generated because of physiological variations in the electrical behaviour of muscle fibre membranes. EMG technology is relatively new in the field biomedical engineering and there are various limitations in detecting and analysing electrical signals. This signal acquires noise while traveling through different tissues, thus the need to develop a precise device for analysing muscle activity.

A. Purpose

Muscles are used in different forms, in order to allow movement of the skeleton, maintain stability and much more. When a patient complains or shows signs of muscle numbness, pain, tingling or weakness in limbs, the EMG is used to measures muscle response or electrical activity in response to a nerve's stimulation of the muscle. This signal can be translated into graphs and electrical pulses of the muscle is monitored through a speaker, aiding the doctor to make diagnosis and detect neuromuscular abnormalities.

B. Scope

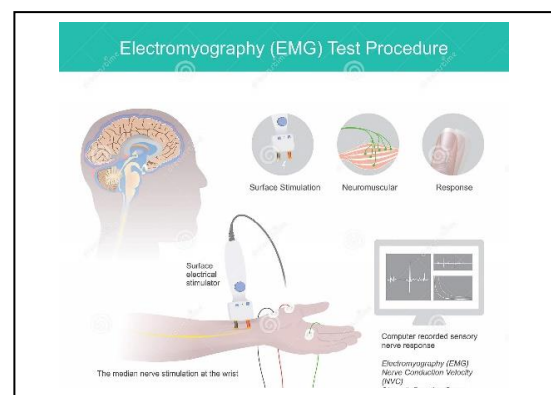EMG tests can be carried out with:
1) Surface electrodes:

Figure 1: Surface electrode [19]

They are used for nerve conduction velocity test, to detect true nerve disorders or conditions whereby muscles are affected by nerve injury. They are small sensors which are placed over the skin to check the nerve response to electrical signals.
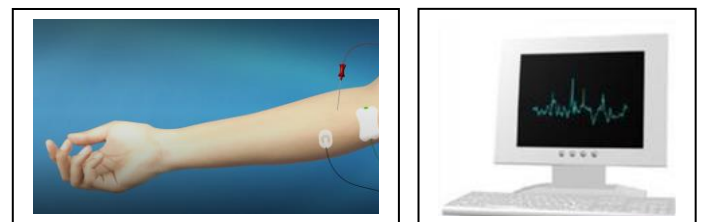
2) Needle Electrodes:

Figure 2: Needle electrode [18]

The electrical activity is detected by a needle which serves as an electrode. A needle is inserted through the skin into the muscle tissue to evaluate muscle activity when at rest and when contracted.

C. Definitions and Abbreviations

- Electrical signals: These are action potentials that transmit information from one neuron to another.
- Noise: Electrical signals that are not part of the desired EMG signal.
- Stimulator: simulate electric signals.
- EMG: Electromyogram
- ECG: Electrocardiography
- AF: Audio frequency

D. Overview

This document contains a detailed explanation of the purpose of an EMG, pictorial illustrations of the device, how it functions using system modelling diagrams to show the hardware components, critical-based parts of the system and user interface. Also, a discussion about the concept is explained, the problem it solves, improvements made on the system and finally, a summary and future directions of the system is given.

II. OVERALL DESCRIPTION

The forces generated by the skeletal muscle due to contraction is as a result of electrical activity in the nervous system. Tiny electrical impulses which carry the message to contract are transmitted along motor nerves towards the muscle. When an impulse arrives towards a nerve ending, the message is passed on and electrical activity spreads towards the muscle fibers. During an EMG test, surface electrodes are placed on the body or needle are inserted into the skin. This test could have a duration of 30 to 60 minutes depending on how many nerves are being tested. EMG electrical signal output can be affected by the amount of muscle contraction which is generated by the individual during test duration. Also, electric noise signals which can be generated from power supply and environmental factors can also have an effect which can be eliminated using differential amplifiers.

A. Product perspective

EMG is used to visualize the electrical signals of the muscle activity when the muscle cells are activated. It is made up of electrodes, attached to cable wires that connects the electrodes to a signal amplifier, a speaker which outputs the sound produced from the electric signals, a computer screen to monitors and save the signals. Below is a block diagrammatic representation of the major EMG components, interconnections, and external interfaces.
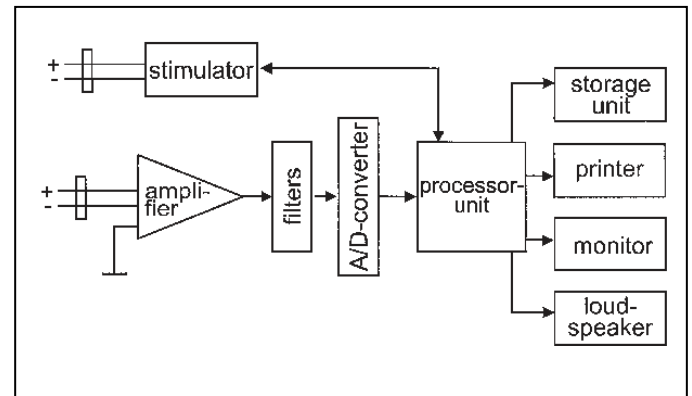

Figure 3: Block Diagram [17]

B. Product function

An EMG records and measures electrical signals caused by muscle activity. The EMG can be used to detect electrical activities of the muscle, monitor muscle pulses, and detect any nerve disorder. Below are diagram representations of how an EMG test is conducted and its major functions.
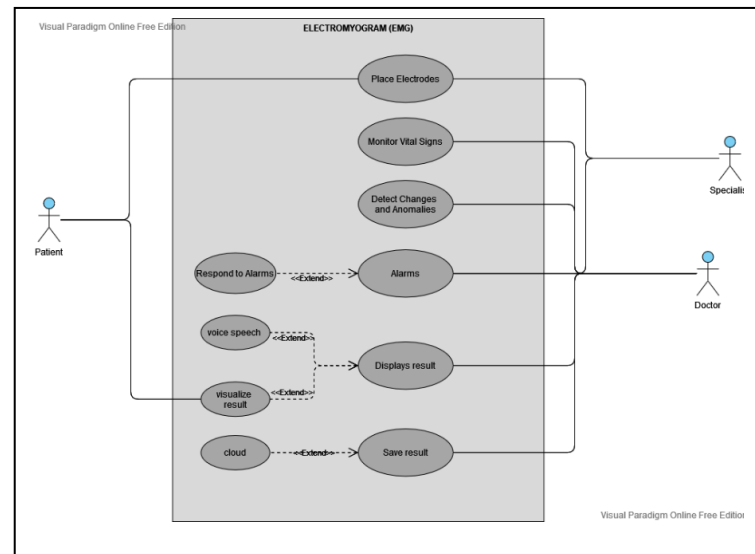

Figure 4: Use case Diagram
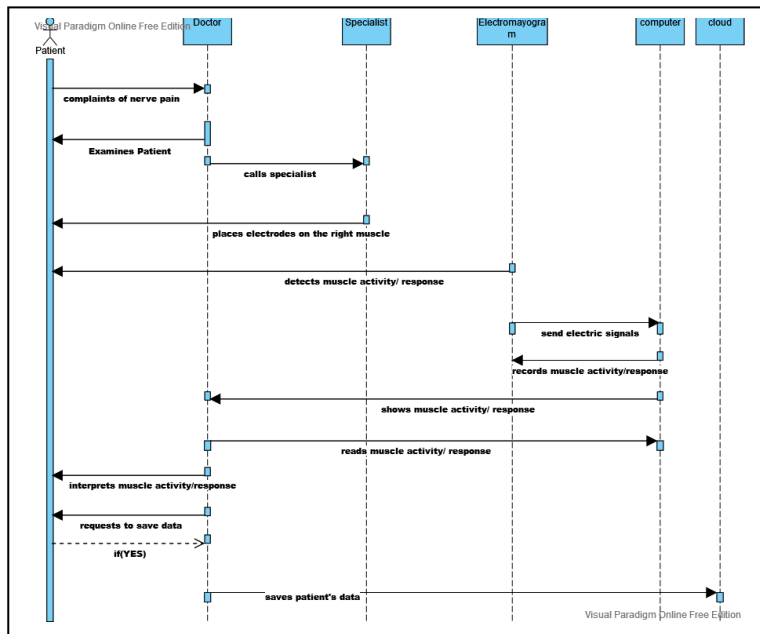*Shows the overall functions of the EMG with repect to its users.*

Figure 5: Sequence Diagram
Explains the whole process in order to carry out an EMG test.

C. User Interface

Muscle activity of the specified part of the body is displayed visually on a computer screen and is also detected audibly with a speaker. The presence, size, and shape of the wave form produced on the oscilloscope provides information about the ability of the muscle to respond to nervous stimulation. An illustration of the user Interface is displayed below:
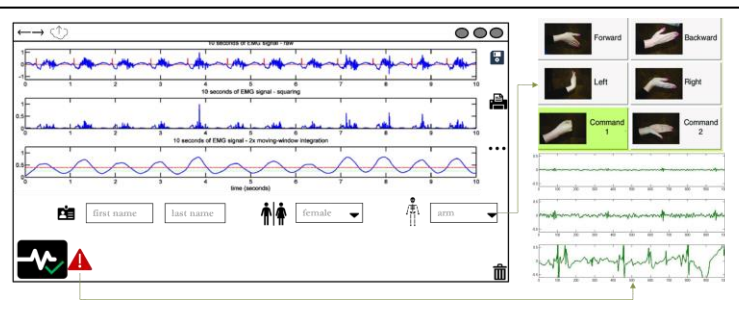

Figure 6: User Interface
The Electrical signals is displayed on the monitor. The wave forms appears from contraction of muscles of the patient. When the mucle is at rest, there are no contractions. The doctor is required to fill the personal information of the patient print, delete or save result on the hard disk and cloud. When there is abnormality in the muscle, the alarm goes off and the doctor diagnosis the patient. Also, the alarm goes off when the electrode is not placed properly.

D. User Characteristics

The EMG can be used by a doctor who has specialized in nerve and muscle disorder or a hospital technician on a patient. For a doctor to carry out an EMG test, the patient may have shown symptoms of nerve pain, tingling, weakness, or loss of muscle strength.

E. Hardware Interfaces

- Fine wire electrodes: Detects electric activity generated by muscle contraction. It is made of stainless steel with nylon coated wires placed inside its hollow shaft. It is mostly used because it can be easily withdrawn from the body without causing pain. It is preferred for EMG test because it can evaluate electric activity more precisely than the surface electrodes.

Figure 7: Fine wire electrode [3]

- EMG detector: This is a sensor which can detect and gather the small muscle signals.
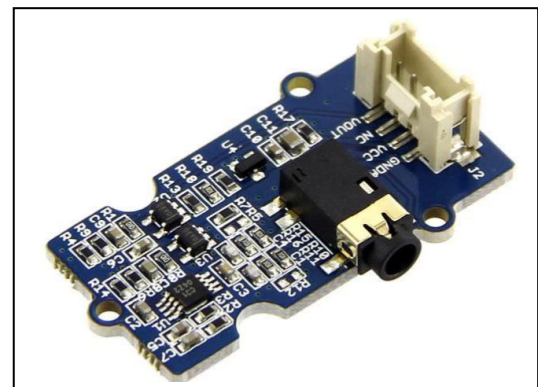

Figure 8: EMG sensor v1.1 [7]

- Simulator: Fully functional prototype for outputting electrical signal generated accurately and precisely.
- Amplifier: Used to amplify electric signals obtained from EMG electrodes. Electrical noise can be generated from power supply
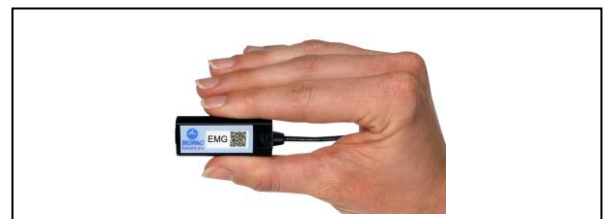

Figure 9: BIOPAC EMG100D [11]
It is a smart amplifier that improves performance by amplifying signal close to the subject and reduces noise artifact. It is also designed for great data acquisition.

and environmental factors. This can be eliminated by using differential recording.

- o Redundancy: An AF amplifier is used to differentiate the pulse of a normal muscle activity from an abnormal pulse. When the muscle is at rest, the sound does not undergo large variation but under abnormal conditions and spontaneous activities, there is a sudden change in sound.


Figure 10: TCA9140 Amplifier [9]
A monolithic integrated circuit with up to 10W output power. It provides all the advantages of integrated AF amplifiers. Also, it is protected from overheating, supply over voltage and short circuit.

- Filter: Used to filter out electrical noise. A bandpass filter between 20Hz and 500Hz and a notch filter at 50Hz to 60Hz needs to be implemented because EMG signal frequency ranges from 0Hz to 500Hz while other forms of electrical noise such as ECG and power line noise range from 0Hz to 20Hz.
- Diode: rectifies amplified and filtered EMG signals to remove the negative part of the signal.
- A/D converter: Samples electric signal and converts digital signal into an analog signal for data acquisition. A BIOPAC M160 is used for data acquisition because it has software with specialized abilities for analysis system. supports a wide range of

amplifiers, it is ethernet ready and includes Acqknowledge
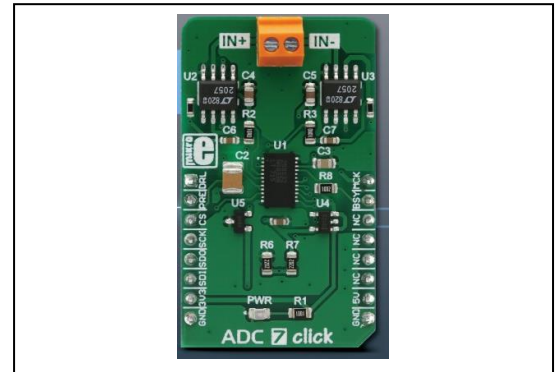
Uses the LTC2500-32 oversampling successive approximation register ADC which has a very low noise on the output, a high dynamic range of 148DB and more.

- Microcontroller: Reads and processes signal from ADC.
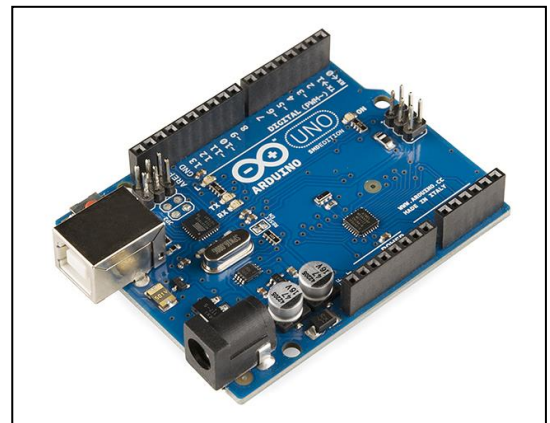
- Raspberry Pi: Hosts the intelligence components for preprocessing and classification.
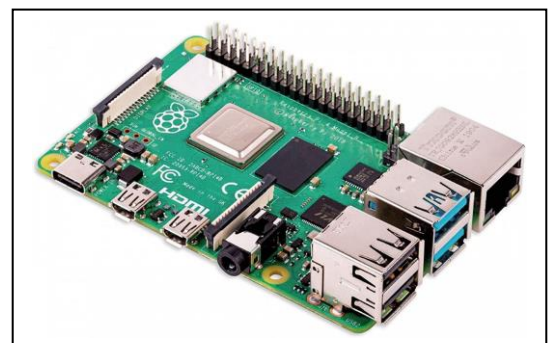

Figure 13: Raspberry Pi 4 [20]
Uses USART communication protocol to communicate with the Arduino to exchange information via USB ports. It also

- Loudspeaker: The Electrical pulses of the muscle are monitored through a speaker.
- Screen: Displays electrical signal.
- Storage Unit: A cloud storage space is made available 5Terra bytes and an internal memory space of 8 Gigabytes.
  - Redundancy in storage space.

F. Assumptions and dependencies

Before an EMG test is initiated, the needle electrode is assumed to be new and not expired. Also, it is assumed that the patient's muscles are at rest, and electrical activity is commenced at muscle contraction. The larger the amount of weight held during muscle contraction, the larger the amplitude of electrical signal. Various factors can have effect on the EMG results. These may include:

- The length of the cable wires: short cable wires minimize electrical noise.
- Electrical noise signals generated.
- Electrode structure and placement.
- Location of electrode with respect to the motor points in the muscle.
- Other factors could be biological or physiological such as a patient that has been administered anesthetics or muscle relaxants or has some implanted device such as a pacemaker.

III. SPECIFIC REQUIREMENT

The primary aim of the EMG is to detect, measure and visualize electrical signals generated by muscle activity during test. Below is a diagrammatic representation of its functional and non-functional requirements.
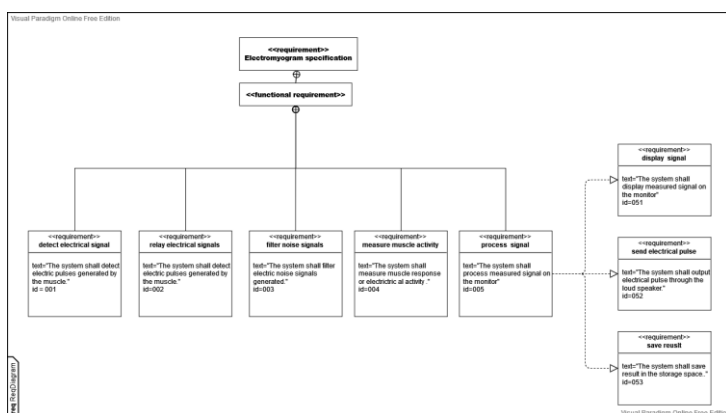
Figure 14: Functional requirement Diagram
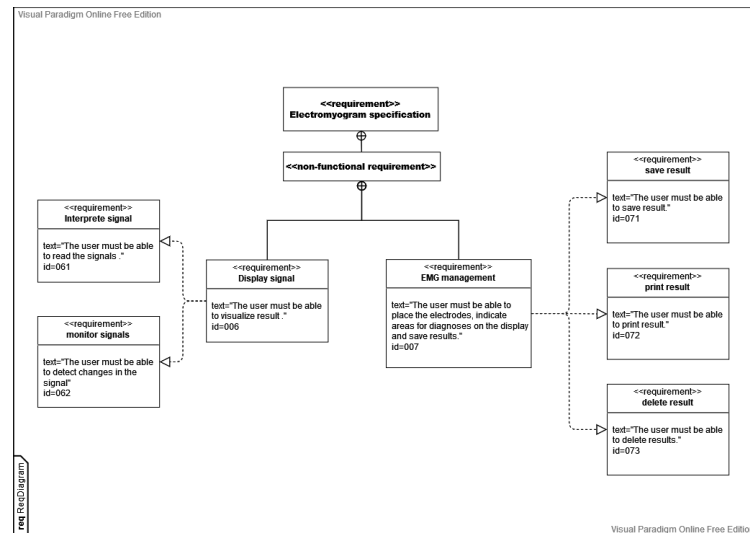*This shows the functions the system is required to perform.*

Figure 15: Nonfunctional requirement
This shows the functions the system is required to allow the user to perform.

A. System Attributes

1) Reliability: The system is reliable if all the dependencies that c

2) Availability: The system is available at any point needed.

3) Portability: Hardware components of the system are portable with each other.

4) Maintainabilty. The hardwarde components can easily be replaced when damaged or serviced.

5) Safety: Based on the material and the function of the the device, It is safe for the doctors and patients use.

6) Security: There is high level of data protection by the using a secure cloud service. Eg. Tresorit.

IV. CONCLUSION

EMG signals have so many biomedical applications. These signals are very useful in detecting neuromuscular abnormalities. We can observe how electric noise is a major concern in mind while recording electrical signals from the muscles. Therefore, we create a concept of an EMG device that measures and detects electric activity in muscle and tries to minimize electric noise signal.

A. Future direction

Advanced EMG for signal detection would be possible soon due to VLSI technology that would enable detection of fine movements rather than taking signals from the entire muscle. More advanced algorithms with high data quality and accuracy would help solve the problem of

pattern recognition. Future steps in the direction of eliminating electric signal noise is being investigated.

REFERENCES

[1] *IEEE Recommended Practice for Software Requirements Specifications*. 1998.

[2] A. Palumbo, P. Vizza, B. Calabrese and N. Ielpo, "Biopotential Signal Monitoring Systems in Rehabilitation: A Review", *Sensors*, vol. 21, no. 21, p. 7172, 2021. Available: 10.3390/s21217172 [Accessed 8 June 2022].

[3] M. Zahak, "Signal Acquisition Using Surface EMG and Circuit Design Considerations for Robotic Prosthesis", *Computational Intelligence in Electromyography Analysis - A Perspective on Current Applications and Future Challenges*, 2012. Available: 10.5772/52556 [Accessed 4 June 2022].

[5] D. Holger, "DESIGN AND CONSTRUCTION OF AN EMG MULTICHANNEL ACQUISITION SYSTEM PROTOTYPE", Master, POLITECNICO DI TORINO, 2012 52556 [Accessed 4 June 2022].

[6] S. Jung, J. Meklenburg and S. Patrick, "Surface Electromyogram Simulator for Myoelectric Prosthesis Testing", 2010 [Accessed 5 June 2022].

[7] J. Ghosh, "Electromyography (EMG) signal acquisition and processing by using surface electrodes", 2019. Available: https://www.researchgate.net/publication/3331185 71. [Accessed 4 June 2022].

[8] T. Rudroff, *Kinesiological Fine Wire EMG*. U.S.A, Noraxon U.S.A. Inc., 2008[Accessed 5 June 2022].

[9]"TCA940 Datasheet | Thomson Components - Datasheetspdf.com", *Datasheetspdf.com*, 2022. [Online]. Available: https://datasheetspdf.com/datasheet/TCA940.html [Accessed: 10- Jun- 2022].

[10]"MP160 Starter Systems | BIOPAC", *BIOPAC Systems, Inc.*, 2022. [Online]. Available: https://www.biopac.com/product category/research/systems/mp150-starter-systems/. [Accessed: 10- Jun- 2022].

[11]"EMG Smart Amplifier | EMG100D | Research | BIOPAC", *BIOPAC Systems, Inc.*, 2022. [Online]. Available: https://www.biopac.com/product/emg-smart-amplifier/. [Accessed: 10- Jun- 2022].

[12]"EMG Block Diagram Explanation", *Electronics and Communications*, 2022. [Online]. Available: https://www.electronicsandcommunications.com/2018/04/emg-block-diagram-explanation.html. [Accessed: 10- Jun- 2022].

[13]"ADC 7 Click | Mikroelektronika", *MIKROE*, 2022. [Online]. Available: https://www.mikroe.com/adc-7-click. [Accessed: 10- Jun- 2022].

[14]"Arduino Uno - Wikipedia", *En.wikipedia.org*, 2022. [Online]. Available: https://en.wikipedia.org/wiki/Arduino_Uno. [Accessed: 11- Jun- 2022].

[15] M. Reaz, M. Hussain and F. Mohd-Yasin, "Techniques of EMG signal analysis: detection, processing, classification and applications", *Biological Procedures Online*, vol. 8, no. 1, pp. 11-35, 2006. Available: 10.1251/bpo115 [Accessed 4 June 2022].

[16]"Electromyography (EMG): Purpose, Procedure, and Results", *Healthline*, 2022. [Online]. Available: https://www.healthline.com/health/electromyography#risk-factors. [Accessed: 04- Jun- 2022].

[17]"Chapter 4.2 Standards of instrumentation of EMG", *D3i71xaburhd42.cloudfront.net*, 2022. [Online]. Available: https://d3i71xaburhd42.cloudfront.net/7be421219b8a4f247e20bc2664eddda288a901b9/2-Figure1-1.png. [Accessed: 06- Jun- 2022].

[18]"Electromyography (EMG)", *Hopkinsmedicine.org*, 2022. [Online]. Available: https://www.hopkinsmedicine.org/health/treatment-tests-and-therapies/electromyography-emg. [Accessed: 30- May- 2022].

[19] *Thumbs.dreamstime.com*, 2022. [Online]. Available: https://thumbs.dreamstime.com/z/electromyography-test-procedure-illustrate-explain-use-medical-electrical-tools-to-checking-neuromuscular-disease-155497820.jpg. [Accessed: 30- Jun- 2022].

[20] *Welectron.com*, 2022. [Online]. Available: https://www.welectron.com/media/image/product/20929/md/raspberry-pi-4-modell-b-8-gb-ram~3.jpg. [Accessed: 10- Jun- 2022].