Medical Device Concept
Electromyogram

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***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 requires advanced methods for detecting, decomposing, and processing. This document intends to model an electromyogram device concept, 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 measures the electrical signals that are generated because of physiological variations in the electrical behaviour of muscle fibre membranes [5]. There are various limitations in detecting and analysing electrical signals. These signals acquire noise while traveling through different tissues, thus the need to develop a precise device for analysing muscle activity.

A. *Purpose*

Muscles have different functions in the human body such as allowing movement of the skeleton, maintaining 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 measure muscle responses or electrical activity in response to a nerve's stimulation of the muscle. This signal can then be translated into graphs and the electrical pulses of the muscle are 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:*

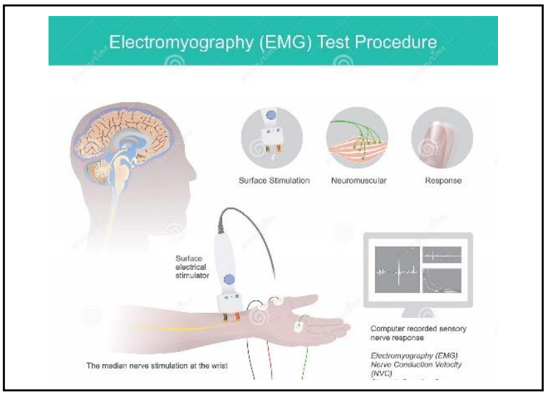

Figure 1: Surface electrode [17]

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 nerve responses to electrical signals.

2) *Needle Electrodes:*

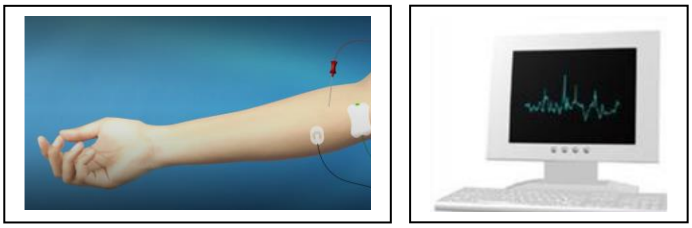

Figure 2: Needle electrode [16]

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: Stimulate electric current to the muscles.
- Muscles: A body tissue consisting of long cells that contract when stimulated and produces motion [3].
- EMG: Electromyogram
- ECG: Electrocardiography
- AF: Audio frequency
- VLSI: Very-large-scale Integration.

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 parts of the system and user interface. Also, the concept of the EMG is explained, the problem it solves, assumptions and dependencies of the system and finally, a summary and future directions of the system are 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 or physiological factors can 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 them to a signal amplifier, a speaker; which outputs the sound produced from the electric signals, a computer screen to monitor and save the signals. Below is a block diagrammatic representation of the major EMG components, interconnections, and external interfaces.

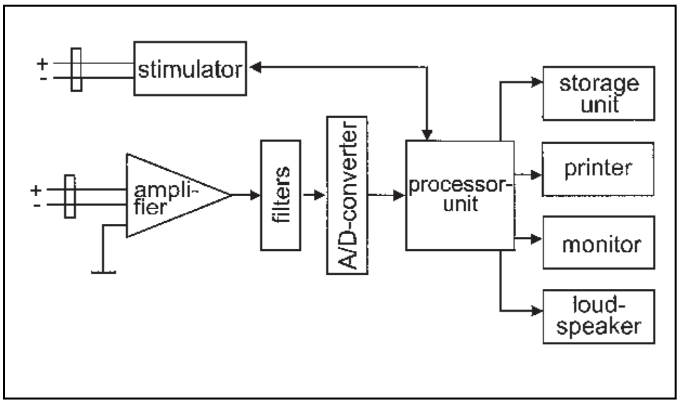

Figure 3: Block Diagram [15]

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.

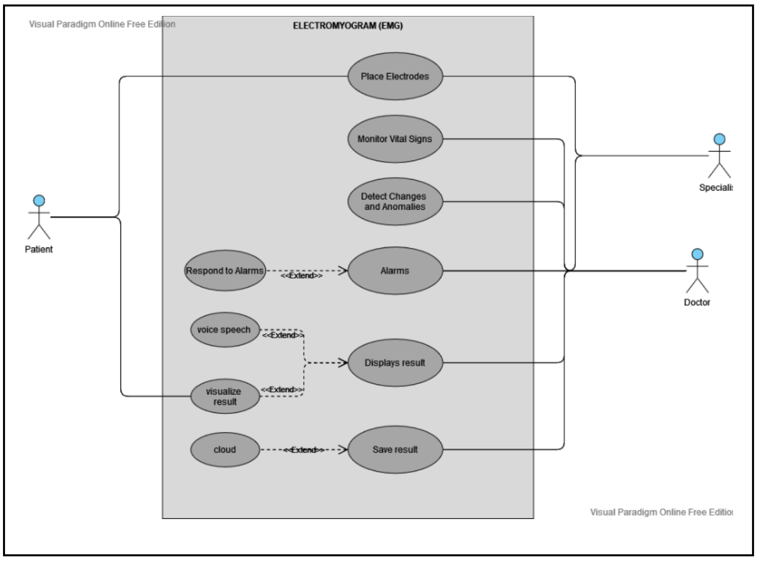

Figure 4: Use case Diagram

Shows the overall functions of the EMG with repect to its users.

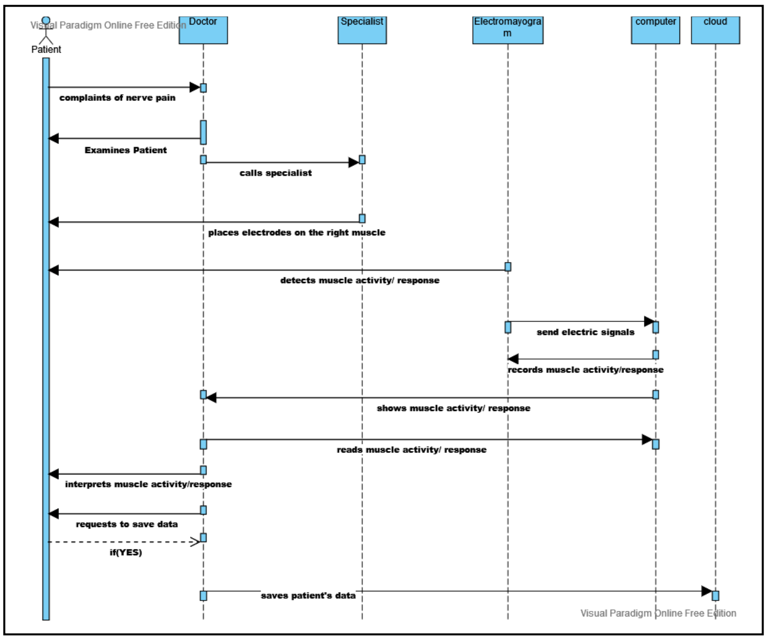

Figure 5: Sequence Diagram
Explains the whole process in order to carry out an EMG test.

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 screen provides information about the ability of the muscle to respond to nervous stimulation. An illustration of the user interface is displayed below:

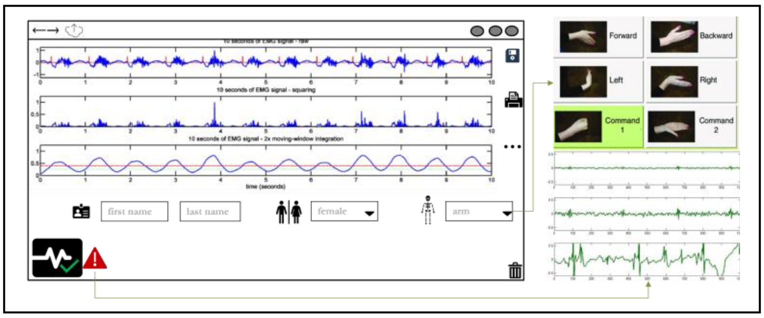

Figure 6: User Interface
The Electrical signals is displayed on the monitor. The wave forms appears from contraction of muscles of the patient. When the mucle is at rest, there are no contractions. The doctor is required to fill the personal information of the patient, print, delete or save result on 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 on a patient by a doctor who is specialized in nerve and muscle disorder or a hospital technician. 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. Patients of all age group can carry out this procedure because it is of low risk and complications are rare.

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 [5]. It is preferred for EMG test because it can allow more precise evaluation of electric activity than the surface electrodes.

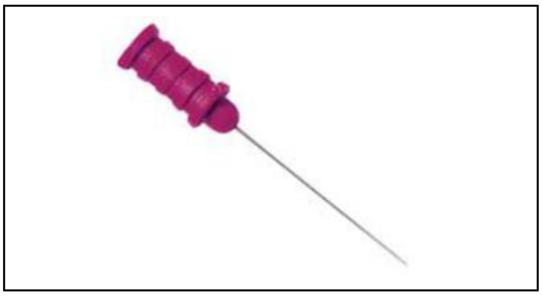

Figure 7: Fine wire electrode [2]

- EMG detector: This is a sensor which can detect and gather the small muscle signals [4].

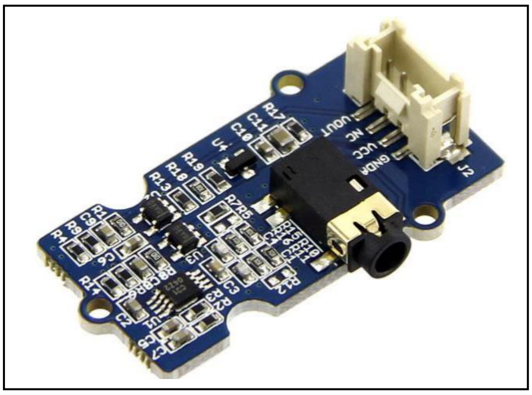

Figure 8: EMG sensor v1.1 [4]

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

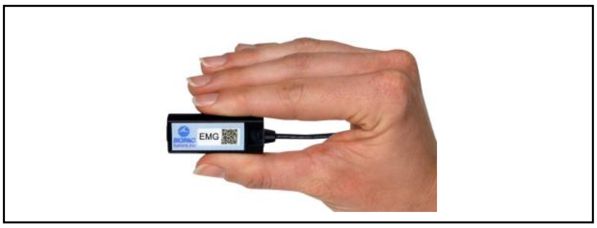

Figure 9: BIOPAC EMG100D [9]
It is a smart amplifier that improves performance by amplifying signal close to the subject and reduces noise artifact. It is also designed for great data acquisition.

   - Redundancy: An audio frequency (AF) amplifier is used to differentiate the pulse of a normal muscle activity from an abnormal pulse [10]. 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.

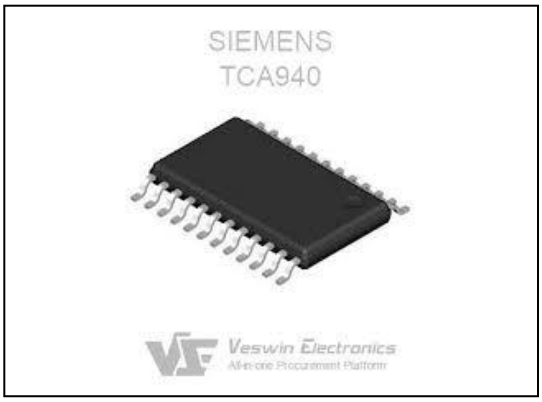

Figure 10: TCA9140 Amplifier [6]
A monolithic integrated circuit with up to 10W output power. It provides all the advantages of integrated AF amplifiers. Also, it is protected from overheating, supply over voltage and short circuit.

- 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 software [8] with specialized analysis capabilities.

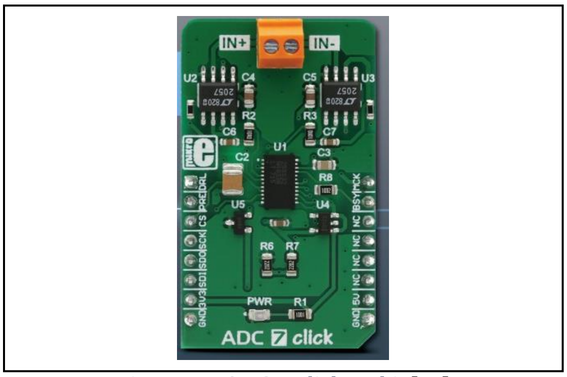

Figure 11: ADC 7 click 32-bit [11]
Uses the LTC2500-32 oversampling successive approximation register ADC which has a very low noise on the output, a high dynamic range of 148DB and more.

- Microcontroller: Reads and processes signal from ADC.

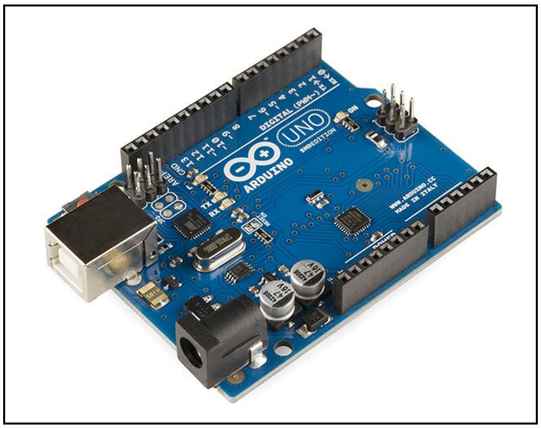

Figure 12: Arduino Uno [12]

- Raspberry Pi: Hosts the intelligence components for preprocessing and classification.

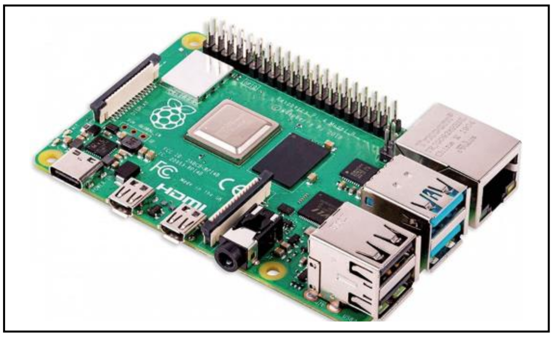

Figure 13: Raspberry Pi 4 [18]
Uses USART communication protocol to communicate with the Arduino to exchange information via USB ports [7].

- 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, not expired, biocompatible and presented sterile as they are considered invasive devices. 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 such as electromagnetic disturbances.
- Electrical noise signals generated from other devices and environmental factors such as power sources.
- 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.

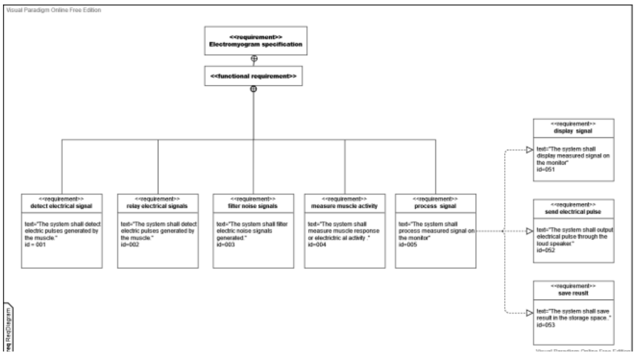

Figure 14: Functional requirement Diagram
This shows the functions the system is required to perform.

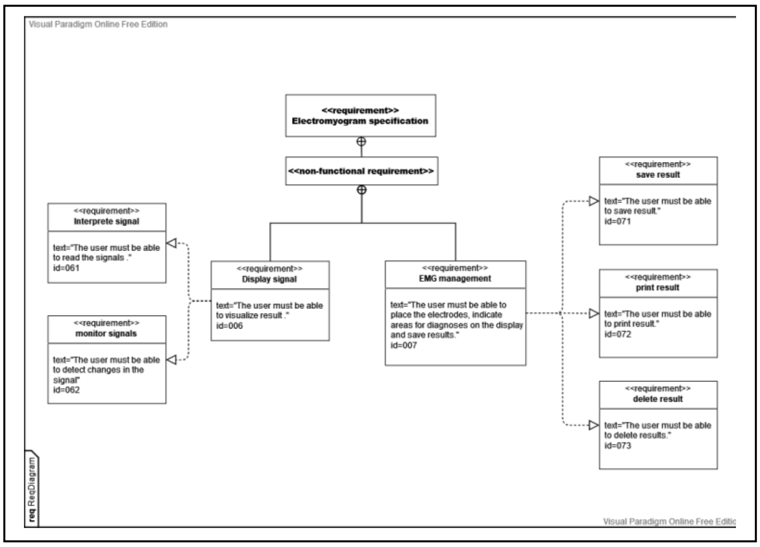

Figure 15: Nonfunctional requirement
This shows the functions the system is required to allow the user to perform.

A. *System Attributes*

1) *Reliability:* The system is reliable if all the dependencies are constant.

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

3) *Portability:* The EMG can be easily moved and placed at any specified location.

4) *Maintainabilty.* The hardware 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 both doctors and patients. Physiological and biological considerations are observed when setting the stimulation intensity.

6) *Security:* There is high level of data protection by using a secure cloud service. eg. AWS.

IV. CONCLUSION

EMG signals have so many biomedical applications. These signals are very useful in detecting neuromuscular abnormalities. Electric noise is seen to be a major concern in while recording electrical signals from the muscles. Therefore, creating a concept of an EMG device that measures and detects electric activity in muscle and tries to minimize electric noise signal would be effective.

A. *Future direction*

Advanced EMG for signal detection would soon be possible due to very large-scale integration (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.

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