FUNCTIONAL MUSCULAR STIMULATION THROUGH GESTURE RECOGNITION FOR PLEGIC PATIENTS

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Abstract— This paper presents an amalgamation of the methods Electromyography (EMG) and Functional Electrical Stimulation (FES) to develop a device which is used for recovery of the patients suffering from strokes, spinal cord injuries and other neural disorders. This approach replaces physiotherapy sessions, which makes it economical and thus, accessible to all individuals. In this mechanism, EMG signals generated by the movement of muscles in the hand are acquired by the usage of surface electrodes. Acquired signals are then amplified, filtered and conditioned. Further, this conditioned signal is transmitted to a microcontroller wirelessly. On reception of this signal, the microcontroller enables the FES circuit via a switching circuit. The stimulus provided by the FES circuit is of a specified frequency and current intensity and is applied for a certain period of time. Accurate placement of stimulation electrodes ensures replication of the movement of the reference hand on to the imitation hand.

Index Terms— APB, EMG, FES, Muscle Stimulator.

I. INTRODUCTION

The number of neural disorder cases is recorded to be increasing every year. Rehabilitation, customarily besides being a long and arduous process, is also an expensive deal, which makes it beyond reach for the ordinary people. The motive is to design an economical device that is compact and easy to use and decreases the tedious and long duration of the recovery period.

Identification and analysis of electromyographic signals involve a detailed process of steps that have to be followed to allow for optimum reception of muscle activity signals. In Webster's textbook for medical instrumentation [1], specific descriptions as to properties of EMG, ECG etc, and the type of surface electrodes used on the muscular areas have been given. Also, placement of electrodes as well as the care required in applying and using the electrodes has been mentioned in it. A lot of care has to be taken while designing a signal conditioning circuit for the detection and amplification of the electromyographic signals. Jingpeng Wang and team [2] have outlined a basic EMG signal conditioning setup with small size amplification and filter series, also highlighting the importance of eliminating the power line frequency. These guidelines have been followed in most other conditioning circuits as well [3][4]. In Raurale's work, EMG signals have been acquiesced and analysed for prosthetic hand control, while Ahsan and team have achieved similar applications using Artificial Neural Networks as a classification for different hand motions [5]. Some of the more conventional circuits are re-examined and developed on in Marzhan's work [6] and a more suitable circuit in terms of design size and power consumption are also referred. Along with the EMG detection circuit, a crucial component to this project is the design and functioning of the Functional Electrical Stimulation circuits and electrodes. Haibin Wang's paper [7] gives a basic introduction of FES and its stimulation waveform and its corresponding parameters. The parameters addressed in it are also mentioned in Amelia Azman's project [8] for designing a suitable FES circuit for non-invasive (skin surface) electrode stimulation. The heart of the FES circuit consists of the 555 timer and the isolation transformer, like mentioned in Anirudha and team's paper [9] even though they have executed it for lower limb activation. In these papers, FES has been defined as an expensive but effective muscle injury and paralysis reliever, something which has scientifically been backed up by the research conducted by Mirbagheri and team [10] which suggests that FES assisted treatment has highly therapeutic affects specially in case of SCI (Spinal Cord Injury) patients. Combining the two processes of FES and EMG is an idea that was developed as a response to Rekimoto Lab's Possessed Hand [11].

II. METHODOLOGY

This paper has been divided into two sections.

- Gesture Recognition: This section is concerned with the acquisition and processing of the EMG signals from the reference hand when muscle activity is recorded.
- Functional Muscular Stimulation: This section focuses on replicating the movement caused by the reference hand and replicating this movement on the imitation hand through muscle stimulation.

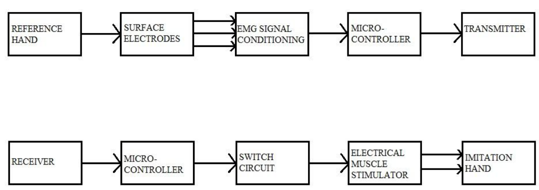

Fig 1: Block Diagram

A. *Placement of electrodes*
The correct placement of electrodes is vital as it is a crucial step in acquisition of the EMG signals.

i. Skin preparation:

Quality EMG signals can only be obtained with proper application of the sensors. The skin barrier poses an impediment to the detection of the electric fields from its surface. The impact of the skin in attenuating and possibly distorting these signals can be minimized by ensuring that it is free from extraneous matter which can include hair, oils and dry dermis. Thus before the placement of electrodes /sensors excessive hair in the muscle site is removed. A brisk wipe using an alcohol swab is done to effectively remove surface oils and other contaminants.

ii. Surface electrodes:

Two types of surface electrodes are commonly used those are dry electrodes which are in direct contact with the skin and gelled electrodes using an electrolytic gel as a chemical interface between the skin and the metallic part of the electrode. In this project/mechanism high quality disposable electrodes are used to detect and acquire EMG signals as they adhere well to the skin and hygienic to use.

iii. Location of the electrode:

The signal acquisition EMG cable comprises of three surface electrodes namely reference electrode, active electrode and ground electrode which are placed on the muscle/motor point. The electrode should be placed between a motor point and the tendon insertion or between two motor points, and along the longitudinal midline of the muscle. The longitudinal axis of the electrode (which passes through both detection surfaces) should be aligned parallel to the length of the muscle fibers. As the muscle fibers approach the fibers of the tendon, the muscle fibers become thinner and fewer in number, reducing the amplitude of the EMG signal. Also in this region the physical dimension of the muscle is considerably reduced rendering it difficult to properly locate the electrode, and making the detection of the signal. Thus, correct placement of the electrode becomes crucial.

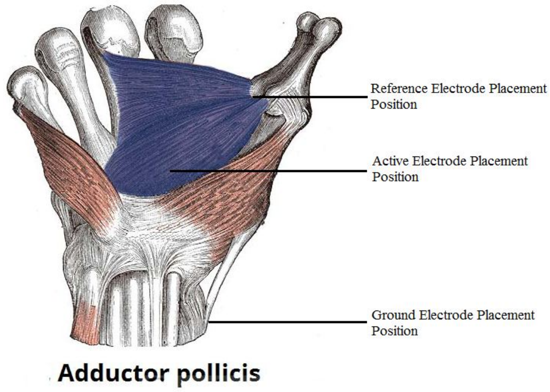

Fig 2: Placement of Electrode on APB muscle

B. *Signal Conditioning*
It is well accepted that the amplitude of the EMG signal is within the range of μV to low mV. The energetic distribution of EMG signal is basically within the 0 to 500 Hz range in frequency domain, with the dominant components in the 50-150 Hz range. Such low amplitude signals contain a lot of noise and are very difficult to work on. Outside the 0-500 Hz frequency range, signals with energy less than electrical noise level are unusable. Four primary types of noise sources contribute to the process of EMG signal acquisition, i.e. the inherent noise of electronic parts inside the signal detection and recording instrument, the ambient noise from the electromagnetic radiation in the environment, the motion artifacts with electrical signals mainly in the frequency 0-20 Hz range from the electrode-skin interface and from movement of the cable connecting the electrode to the amplifier. Therefore, EMG signal is fairly weak and with unwanted noises. It has to be carefully processed before using it for any health care applications. Signal amplification and filtering thus plays a critical role in EMG practical application systems.

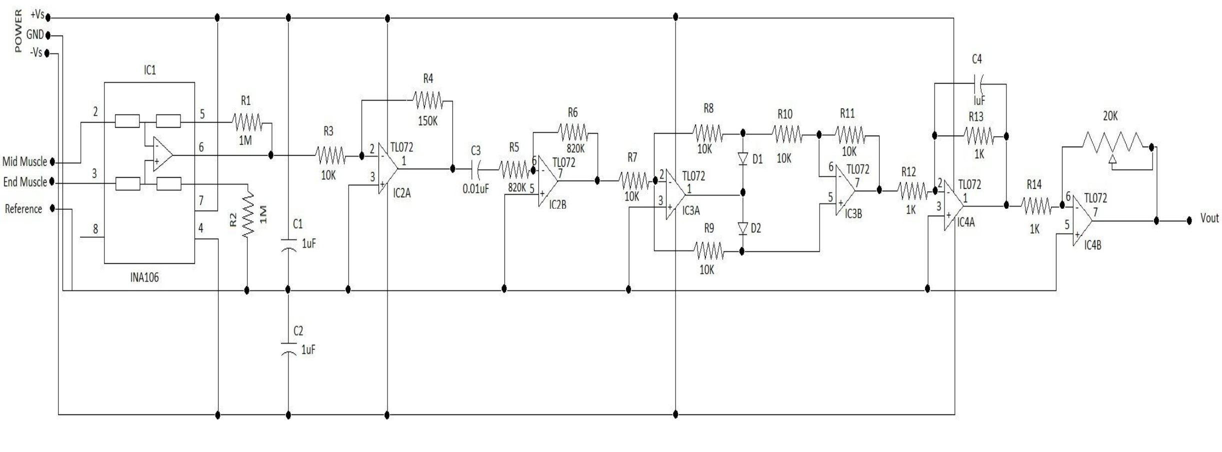

Fig 3: Signal Conditioning Circuit [4]

The circuit comprises of the following stages:

i. INA106 is a difference amplifier, used as a preamplifier in the design, with a gain of 110. It takes the difference of the two signals obtained from the active electrode and the reference electrode and amplifies it. The high CMRR offered by the IC rejects most of the power line frequency of 50-60 Hz.
ii. An inverting amplifier of gain -15 has been used to amplify the signal further using IC TL072.
iii. In order to reject the low frequency noise interfering with the input signal, an active, first order HPF of unity gain has been used with a cut off frequency of 110Hz, allowing signals only above this frequency.
iv. A full wave rectifier is used to turn all the negative portion of the signal into positive voltage region.
v. Low Pass Filter (LPF) In order to eliminate high frequencies that lie beyond the dominant range of EMG signals (as specified above), an active, first order LPF is designed with a cut off frequency of 2 Hz.
vi. Inverting Amplifier with variable gain: As the LPF of the previous stage inverts the signal, an inverter has been used again in the last stage to flip the signal. A potentiometer offers the flexibility of adjusting the final gain, as per the requirement.

C. Transceiver and Processing

At the heart of the system is the micro-controller that receives the signals from the signal conditioning circuit of the muscle. The inputs have been connected to the analog ports of the first Arduino Uno. The purpose of using Arduino Uno is to allow for easy and fast prototyping. The initial testing phase for the signal acquisition was conducted on the Arduino IDE serial monitor, where the analog readings were observed. A snippet of the code used for reading and setting resolution is shown below.

```
int sensorValue=analogRead(A0);

float voltage=sensorValue*(5.0/1023.0);

serial.println(voltage);
```

This gives an analog reading for the signal activity on a scale of 0-5. This reading is used to help detect peaks. As continuous values are generated, a twitch in the muscle jumps the value by at least 0.3 units. As soon as a spike in the value is detected, the nRF24L01 module transmits a message to its counterpart. The main purpose of using a transceiver is to broaden the range of use, as multiple receiver hands can also be set up for a more general use. One controller is for the EMG acquisition and the other for the FES activation. Once the flag is set on the Arduino, a tunnel of communication is set between both the Transceiver sets, and the message about the muscle activation is passed through. This is immediately picked up by the receiver Arduino and that begins the process for stimulating the muscles using the stimulator. An output is sent only on encountering a peak in the signal obtained which arises when there is a movement in the finger. All the communication and control pass through these micro-controllers.

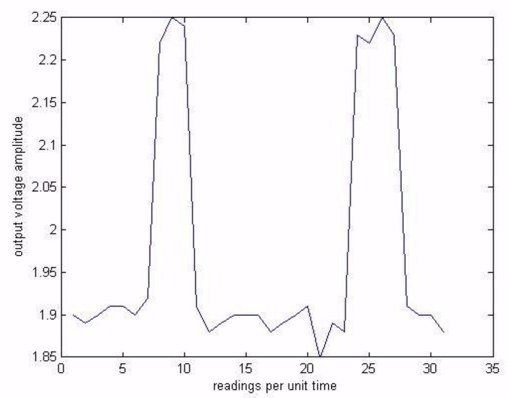

Fig 4: Peak detection

D. Channel Selector and Stimulator

The muscle activity on the reference hand can occur at any motor point (here limited to only fingers), it becomes a challenge to recognize the muscle activity site on the patient hand/imitation hand on which movement is imitated. This is because the entire process needs to be carried out with human intervention. The solution is to employ a simple channel selection system using a basic NPN transistor as shown in below diagram. Muscle activity points are directly controlled by the microcontroller; if muscle activity was sensed at a particular point, the spike in values is detected by the Arduino and it starts the procedure to stimulate the appropriate muscle on the receiving end. Since we have created the setup for only 1 set of muscles (APB) as of now, we have directly connected the Arduino Uno output to the FES stimulation circuit. Suppose a spike is detected for the APB muscle, the analog output (Pin 6 in this case) of the Uno switches to high, and it completes the circuit which is bridged by the transistor (BC 557). This activates the 12V battery and powers the circuit, which in turn provides a electric pulse across the electrode. The duration of the pulse is comparably same as the duration of the spike. This process can be extended to two channels (APB and ODM muscles) which can get activated at the same time as well, as long as spikes are detected on the EMG signals of both the APB and the ODM muscle signals.

The pulse trigger circuit is isolated from the Arduino microcontroller, though it connected across the BC 557 transistor. A brief schematic of the circuit is shown in the Fig. 5. The major component of the circuit is a 555 timer circuit in astable multivibrator mode, from where the pulse wave is generated. We also use Darlington pair transistors (T1 and T2 in the diagram) to amplify the pulse. The transistors are connected to a potentiometer which can be varied to change current amplitude, as current required to stimulate the muscles changes from person to person.

As shown in the diagram, it is also essential to use an isolation transformer for safety reasons, as electric pulses are directly passed on to the human skin.

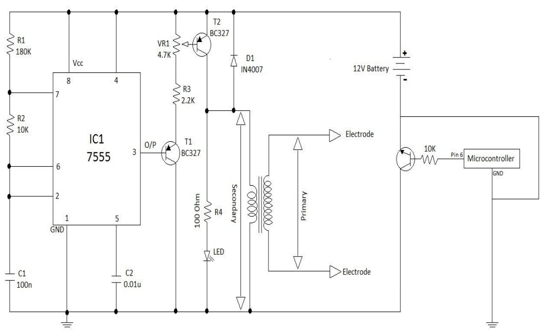

Fig 5: Functional Electrical Stimulation circuit

CONCLUSION

A set-up that has the potential to detect the EMG signal of the muscle movement in a normal/reference hand and replicate that motion (with degree of freedom, intensity and direction) to another set of hand muscles which are incapable of moving themselves, for reasons such as paralysis, has been constructed. Series of experiments on numb and virile and hands have shown that muscle stimulation is accurately reproduced from reference hand to experimented hand. The set-up uses radio frequency communication between the reference set to the receiver set which can also be extended to multiple receiver sets. This method is highly advantageous and can be practically applied in medical areas and hospitals. Further research is recommended to identify methods for optimum use of the project for more accurate finger and joint replication.

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