NEUROEMPATHY - A SELF PHYSIOTHERAPY DEVICE FOR STROKE PATIENTS

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CERTIFICATE OF CORRECTNESS AND APPROVAL

Certified that work contained in this thesis titled "**NEURO EMPATHY – A self-physiotherapy device for stroke patients**", was carried out by Ahsan Mumtaz Chattha, Muhammad Hamid Noor, Arslan Ahmed and Jawaad Iqbal under the supervision of Col. Dr. Abdul Ghafoor and Lec. Narmeen Shafqat for partial fulfillment of Degree of Bachelors of Electrical Telecommunication Engineering is correct and approved. The plagiarism of the document is ____ %.

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ABSTRACT

World Health Organization's stats shows that 15 million people worldwide suffer stroke each year, of which five million are left permanently disabled due to lack of physiotherapy. These precious lives can be saved since stroke is curable. However, self-physiotherapy devices are not readily available in the market.

The project, **Neuro Empathy**, presents a wearable device that can help stroke patients perform self-physiotherapy and enables them to perform routine work by removing the barrier of disability. Our project makes use of a novel technique called Functional Electric Stimulation (FES). The project includes an EMG circuit to acquire the EMG (Electromyography) signals and a FES Stimulator that artificially generates body movements.

Our device can help paralyzed patients retrain voluntary motor functions such as grasping and reaching by promoting neuroplasticity (rewiring of brain). These activities help the brain to reorganize itself, both in structure and how it functions overtime by forming new neural connections throughout the life.

DECLARATION

No portion of work presented in this thesis has been submitted in support of another award or qualification either in this institution or anywhere else.

In The Name of Allah, the Most Benevolent, the Most Merciful.

DEDICATION

This dissertation is lovingly dedicated to our parents, teachers and well-wishers.

ACKNOWLEDGEMENTS

We are grateful to Allah Almighty for providing us strength to tread on despite many difficulties.

We are very grateful to our Project Supervisors Col. Dr. Abdul Ghafoor and Lec. Narmeen Shafqat who supervised the project in a very encouraging and helpful manner. As supervisors, their support and guidance has always been valuable assets for our project.

Also, the team NeuroEmpathy acknowledges the support and guidance extended by Famous Neurologists; Brig. Dr Waseem Alamgir (MH) and Maj Dr. Waseem (AFIRM) in carrying out feasibility study and designing of the device for stroke patients.

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LIST OF ABBREVIATIONS

EMG	Electromyography
FES	Functional Electric Stimulation
PIC	Programming Interface Controller
PCB	Printed Circuit Board

Chapter 1: Introduction

1.1. Project Overview

The project aims to design and develop a device that enables paralyzed patients, in particular stroke patients, help perform self-physiotherapy at the comfort of their homes. The project includes an EMG acquisition circuit, a micro controller and a Functional Electric Stimulator (FES) that artificially generates body movements. The proposed device is capable of helping paralyzed patients retrain voluntary motor functions such as grasping and reaching. These activities eventually help the brain to reorganize itself, both in structure and how it functions overtime, by forming new neural connections throughout life.

1.2. Problem Statement

World Health Organization's stats shows that 15 million people worldwide suffer stroke each year of which five million are left permanently disabled due to lack of physiotherapy. These precious lives can be saved since stroke is curable. But self-physiotherapy devices are not readily available in the market. The world expects more of health devices from engineering disciplines and this is the reason that a lot of research is being carried out in the bio-medical field. The use of this device will enable the patients to perform physiotherapy sessions at the comfort of their homes with the following advantages:

i. Paralyzed patients would not have to go to hospitals for therapy sessions.

ii. With the hospital barrier removed, there will be no need for therapy appointments with long waits.

iii. EMG signals characterizing different movements remain same for 90% of the time and hence a single FES circuit would be able to cater for different types of paralysed patients.

iv. Due to the use of EMG signals, FES therapy is more natural and helps the brain perform neuroplasticity thus restoring the voluntary movements over time.

v. This setup is portable and can be carried around.

vi. The study of EMG signals could also be used to diagnose neurological diseases.

1.3. Approach

The proposed project consists of an EMG acquisition circuit, Surface electrodes, Microcontroller and Functional Electrical Stimulator (FES). EMG signals are acquired using the surface electrodes. The acquired EMG signals are then filtered and amplified. These processed signals are fed to the FES using microcontroller. FES will generate pulses of varying current and frequency on the basis of signals received from microcontroller. Then these pulses will be applied to muscles using surface electrodes to move hand of the paralyzed person.

1.4. Objectives

The project is aimed at providing a pragmatic solution towards people who suffer from some kind of disability. People with disabilities have trouble performing daily chores. The project proposes to help such people perform self-physiotherapy so that they can have their physiotherapy sessions with ease in their homes. The device will use the EMG signals acquired from the healthy side and pass it to the paralyzed part through FES.

The main objectives of the project are as below:

Objective 1

Detection of EMG signals from healthy side through surface electrodes, amplification and noise removal.

Objective 2

Designing a Functional Electrical Stimulator (FES) that successfully replicates the predefined movements.

Objective 3

Developing a code for the controller that passes EMG signals to the FES for sending to the paralyzed parts.

1.5. Scope of the project

The project is solely for stroke patients. Since we are stimulating the nerves and muscles to generate the movement, therefore it cannot be used for paralyzed patient whose nerves or muscles are damaged.

1.6. Organization of thesis

Chapter1 It includes summary and the details of the approach/method used for the accomplishment of the mentioned objectives.

Chapter2 Deals with the literature review carried over the months.

Chapter3 It includes the technological requirements and detail of components used in this project.

Chapter4 It includes the hardware designing and system interface.

At the end of the document is the appendix giving additional relevant details about code.

Chapter 2: Literature Review

The communication between neurons within the brain is the root of all our thoughts, emotions and behaviors. When masses of neurons synchronize and communicate with each other electrical pulses are generated. Electromyography is the technique of measuring electrical activity of the muscles from electrodes.

2.1 Muscles:

A muscle is composed of groups of particular cells that provide for contraction and relaxation. The main function of these group of cells is to generate forces, movements and to provide the ability to speak and write. A muscle tissue is both extensible and elastic along with the ability to produce response to different stimuli and resultantly can be contracted or shortened. Muscle tissue primarily performs 4 key functions:

- Produces motion
- Generating heat
- Helps in substance movement within the body
- Provides stabilization.

The types of muscle tissues can be identified based on contractile properties, control mechanisms and structure:

1. Cardiac muscle
2. Skeletal muscle

3. Smooth muscle

Electromyography (EMG) signals are acquired through skeletal muscles. The skeletal muscle tissue is in direct contact with the bone and its contraction and relaxation is responsible for providing support and movement to the human skeleton.

Both, the excitability of muscle tissue and the excitability of neural tissue, share several similarities. Like a single neuron, for any stimulus electric impulse that is below a certain threshold level, no response is produced by a single muscle fiber. For the production of a single twitch or some contraction the single stimulus electric impulse should be above a certain threshold.

A muscle twitch usually is a combination of 3 different phases:

- The latent period
- The contraction period
- The relaxation period

The first phase called latent period refers to the initial indications of contraction in the muscle from the time when the stimulus is delivered. The second phase called contraction period, is defined as the time taken to reach peak contraction after the latent period. The third phase called the relaxation period is the time taken by the muscle takes to fall to resting tension after it has reached peak contraction.

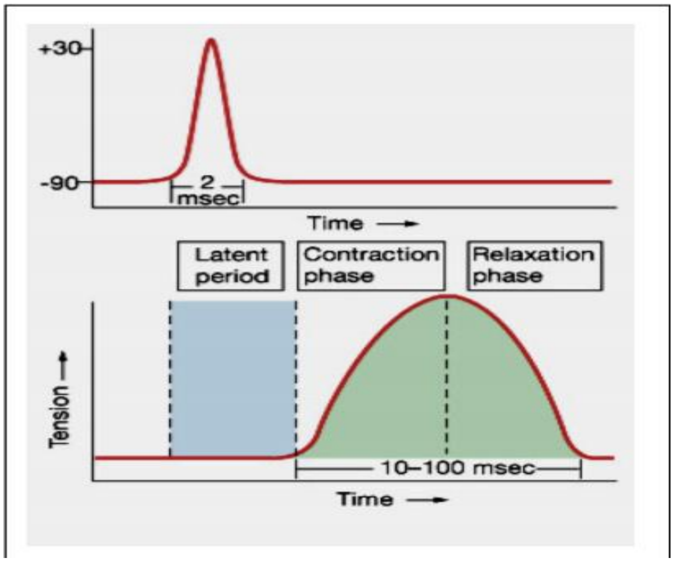

Figure 1: A Single Twitch: An Action Potential on Muscle Fiber followed by Contraction

Muscles rely on two physiological phenomena to produce motion: **recruitment** and **summation**. An increase in the number of motor units that are producing response to a single stimulus, results in an increase in tension in the whole muscle. This whole process is called Recruitment. On the other hand, the time between twitches, that results in increasing tension in the muscle fibers is known as Summation. The overlapping of individual twitches produces a continuous, smooth, contraction of highly increasing strength. The recruitment process requires a gradual increase in the stimulus amplitude till it crosses the lower threshold stimulus limit to produce a response from the muscles. With the increasing stimulus amplitude only the muscle fibers that cross the lower threshold limit respond and contract. Similarly, with the increase in the number of motor units that are recruited, the stimulus amplitude also increases and resultantly the tension and contraction of the muscles also increases. After a certain time, when all the motor units have been recruited, increasing the stimulus amplitude produces no effect on the tension/contraction of the muscles. Consequently, a weak, intermediate or strong muscle contraction solely depends on the number of motor units that are recruited.

2.2 Neuron:

A neuron is a nerve cell that is an integral and essential part of the nervous system that carried electrical impulses. A neuron is composed of a cell body and nerve fibres (axon and dendrites) and axon terminal. However, all neurons may differ in shape, size and characteristics as these attributes are dependent on the function and role of the neuron. Neurons, although similar to other cells in the human body, inherit one key difference. Neurons are specialized to transmit information to other nerve cells, muscle or gland cells throughout the body. The process of communicating information by these highly specialized nerve cells is carried out in both electrical and chemical forms.

Neurons help perform 5 important functions:

- Neurons receive transmitting signals arriving from the neighbouring neurons.
- Neurons perform the integration of these signals.
- Neurons, resultantly, give rise to nerve pulses.
- These pulses undergo conduction by the Neurons.
- Finally, these pulses are transmitted to other neurons.

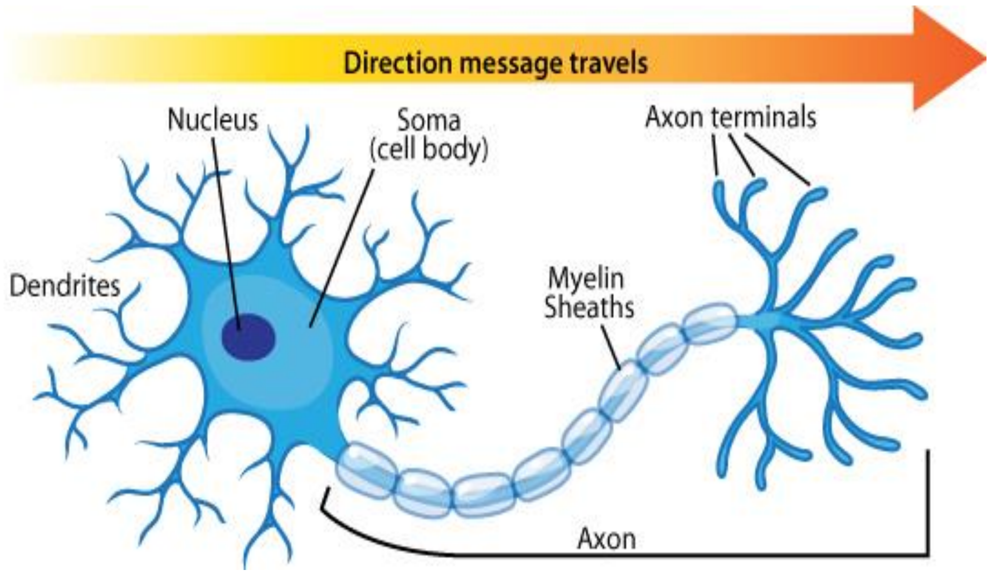

Figure 1: Neuron Biological Structure

Period of Latent Summation is a short time interval required by the neurons to respond to the total aggregated inputs. A pulse response is generated by the neuron and is sent to the axon only if the total potential of its membrane crosses certain defined threshold for firing. However, for a neuron to generate some response the total potential of its membrane must reach a certain defined level i.e. the neuron generates a pulse response and sends it to its axon only if the optimal conditions for firing are fulfilled. The difference in charge between the inside and outside of the cell is paramount to generating an electrical impulse by the neuron.

Incoming impulses can either be excitatory (a cause of firing incoming pulses) or inhibitory (a cause of hindering the firing response). When a nerve impulse generates, a neuron's potential changes from an internal negative charge to a positive charge thus resulting in a dramatic reversal in the electrical potential occurring on the cell's membrane. This reversal produces an action potential which travels at speeds reaching several hundred miles per hour, along the axon's membrane. In this way, a neuron is made able to fire impulses multiple times every second.

2.3 EMG:

Electromyography is an electro-symptomatic procedure for assessing the wellbeing state of muscles and the nerve cells controlling them. There are two sorts of EMG in far reaching use: surface electromyography (EMG) and intramuscular (needle and fine-wire) electromyography (EMG). Intramuscular electromyography (EMG) can be performed by inserting a needle cathode or a needle containing two fine-wire anodes into the muscle tissue to assess muscle movement both very still and contracted positions. The subsequent electrical action is then watched. Intramuscular EMG might be considered excessively intrusive so surface EMG is favored over it.

The attributes of the flag are as per the following criteria:

- Amplitude: 0-10 mV (peak to peak) or 1.5 mV (RMS)
- Frequency: 0-500 Hz (Usable) & 50-150 (Dominant)

Signals with energy above the electrical noise level are considered usable.

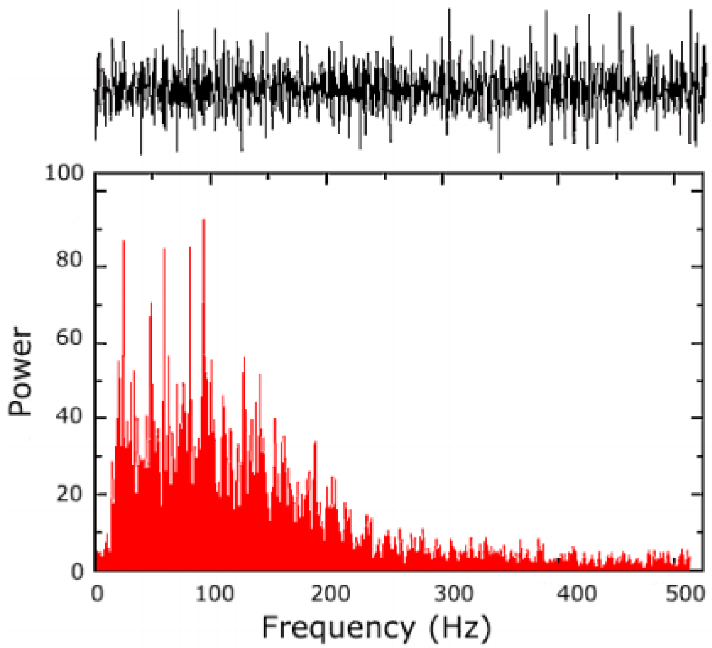

Figure 3: Frequency spectrum of the EMG signal

2.3.1 Detection of EMG Signals:

EMG signals are identified utilizing surface cathodes. Two anodes are utilized for recording of EMG motion from the muscles alongside a third terminal which is a reference cathode and ought to be set on the zones which are electrically latent, for example, wrist, elbow or lower leg if there should arise an occurrence of lower limits. These terminals will be associated with Muscle Sensor. Muscle Sensor utilizes EMG (electromyography) to quantify the electrical movement of muscles. Regularly, the surface EMG signals are inside the scope of +/ - 5000 microvolts, and the scopes of recurrence content are from 6 Hz to 600 Hz, in which the predominant recurrence extend is from 20 Hz to 150 Hz.

2.3.2 Noises in EMG Signals:

One of the greatest difficulties in utilizing EMG is the specific little flag to-commotion proportion of the signs that we are endeavoring to watch, coupled by the wide assortment of clamor sources. Three general methodologies are utilized to manage the issue of clamor in EMG recording and examination, each with their own particular focal points, difficulties and impediments: end of commotion sources, averaging, dismissal of uproarious information, and commotion evacuation.

The noise affecting the EMG signal includes:

• **Inherent noise in the electronics components in the detection and recording equipment** - Electrical noise is generated in all electronics components. The frequency range of this is from 0 Hz to several thousand Hz.

• **Ambient noise** – The noise originated due to electromagnetic radiation, such as radio and television transmission, electrical-power wires, light bulbs, fluorescent lamps, etc. is ambient noise.

• **Motion artifacts** – Motion artifacts have two main sources: one from the interface between surface electrodes and the skin, second from the movement of cable which connects electrodes to the amplifier.

• **Inherent instability of the signal** - EMG signals are instable because their amplitude is quasi-random in nature. The frequency components ranging from 0 to 20 Hz are usually unstable.

2.3.3 Elimination of Noise Sources:

Possibly the best way of dealing with noise is to not have any in the first place. The simplest wellsprings of commotion to manage are outer, natural wellsprings of clamor that are unavoidable in all situations. Cases incorporate line impedance from transmission lines, bright lights and a huge cluster of electronic gear.

Another tractable wellspring of commotion in EEG recording is physiological clamor that starts from tissues other than muscles that create electrical signs. Basic cases of such commotion are visual flag caused by eyeball development (EOG), cardiovascular flag (electrocardiogram, ECG) and development antiquities caused by muscle withdrawal (electromyogram, EMG).

2.3.4 EOG Noise:

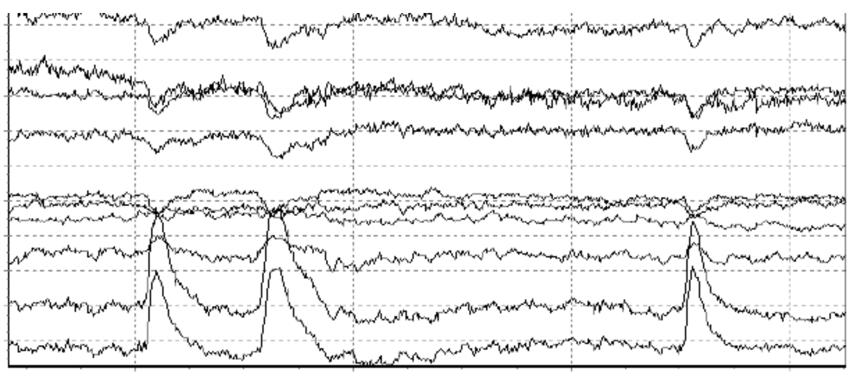

Figure 4: Noise Because of Eye Blinking

2.3.5 Sweat Glands Noise:

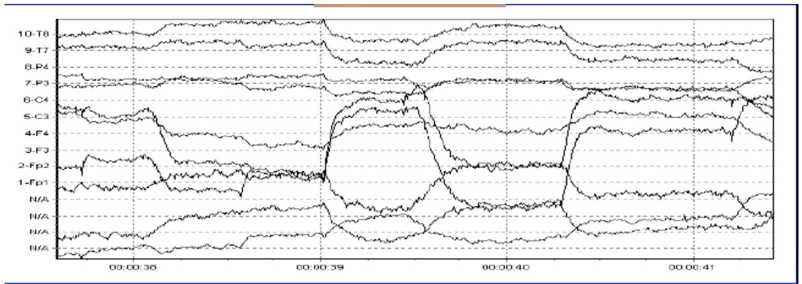

Figure 5: Noise Because of Sweat Glands

2.3.6 Signals Averaging:

Signal averaging is a way to deal with noise in data. It is assumed that noise in signals is random in nature whereas signal of interest is stable. EMG signal is recorded over an interval of time which gives the noise at each point of time, reduces the signal at some point and increases at some but on average cancel itself out, in result gives us the stable EMG signal.

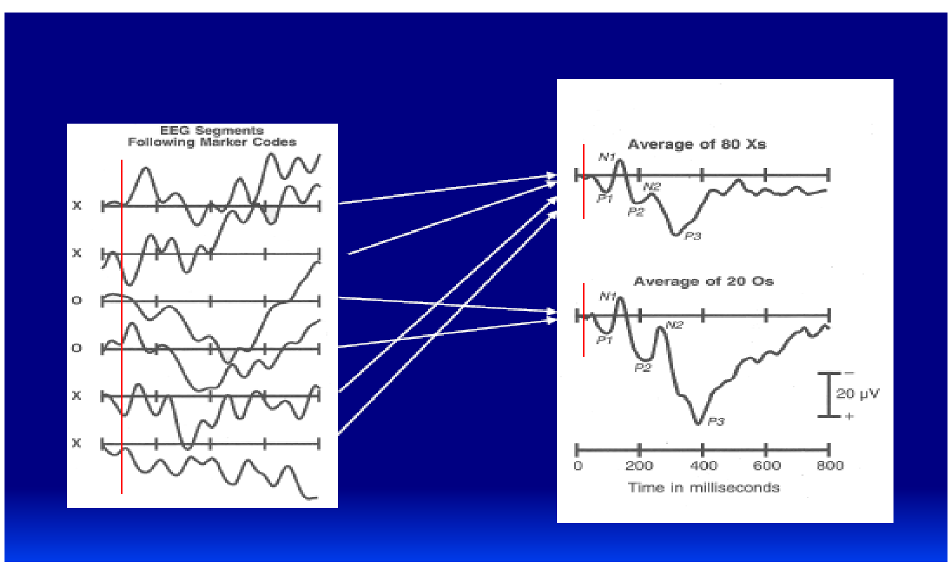

Figure 6 Signals Averaging

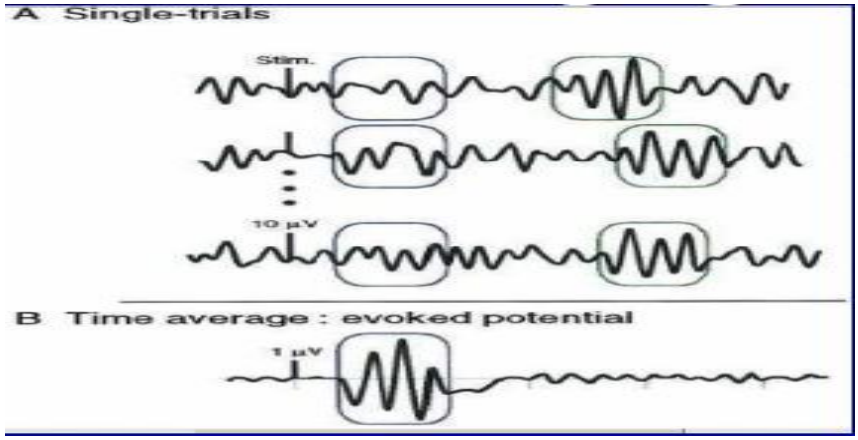

Figure 7: Averaging of Values That Comes at Different Times

2.3.7 Limitation of Signal Averaging:

- Signal averaging cannot be used when signal of interest is variable and when studying rare events which are not bounded to a specific point of time.
- The only noise which is symmetric and random in nature can be removed by signal averaging. The noise which is limited to event of interest is added with the signal of interest because it cannot be averaged out.
- The noise which is not symmetric leads to increase or decrease of the averaged signal because average is not zero across time.

2.4 Amplification and Filtering:

Differential amplifier is utilized as a part of the initial step of processing; its advantage is that the components which are same in the contributions of the two electrodes are subtracted from each other by this differential amplifier. Ambient commotion is removed at this very first stage.

If inter electrode distance (IED) held small, noisy signals noted by both electrodes are nearly alike. Conversely, distinction between the voltages of both electrodes are decreased. Therefore, it’s a trade-off when the common-mode rejection (CMRR) upsurges, gain reduces. differential amplifier that has high CMRR can be used for an improved CMRR. Differential amplifier deducts reading of two electrodes and formerly increases the difference acquired. Hence signals acquired by two electrodes, these signals are overwhelmed having similar values. Cause for alike value of the two signals might be electromagnetic devices, EMG signals and power sources because of muscles that are remote. CMRR tells ability of amplifier circuitry to overwhelm the signals, which mutual inputs, phase and frequency of both are alike as compared to GND voltage. As a guiding rule maybe peak CMRR is required.

Motion artifacts yield components with low frequency, which are less than 10 Hz, therefore we can remove it by allowing signal to pass from High Passing Filter whose bandwidth is alike. Similarly, to eliminate effects caused by aliasing, components with frequency of high value also desired to be eradicated, hence signal now needs to be passed from Low passing filter. Beforehand elimination of noise is obtained by notch filter. Nevertheless, EMG signal does great signal influences about that frequency, therefore we had loss of signal when we used notch filter, hence as universal rule we should not use notch filter, instead we should use a band pass filter.

2.5 Functional Electrical Stimulator:

Functional electrical stimulation FES is a type of medical healing treatment which uses transcutaneous current to start shrinkages in muscles and is frequently used for those individuals who have injuries of spinal cord and stroke. It is used to assist movement of upper and lower limb, improve functioning of respiratory system, reestablish the functioning of bowel and bladder, reestablish sexual functions of males, and to help and treat secondary problems such as muscle waste, spasticity and bone demineralization. In FES an electrical signal for controlled movement is given to nerves to cause muscle contraction which can help in restoring functional movements of paralyzed part. Different type of FES devices that have microprocessor/microcontroller have been industrialized to recover lower and upper limb functions in individuals after SCI/stroke. The systems that are proposed have almost a fizzed design and don't have an open architecture.

Our designed stimulator consists of a 555 timer, Darlington transistor and a step up transformer. 555 timer generates the pulses of few mV and uA. Darlington transistor acts as an array and add these pulses to increase the current from uA to mA. Then the step up transformer increase the voltage up to 100V. The voltage ranges from 0-100V, current ranges from 0-20mA and frequency from 50-150HZ.

To vary the characteristics of these pulses two potentiometers are used which are set to generate the pulses that are required to stimulate the paralyzed part.

Table 1: Specifications of FES

Parameters	Values
Frequency	0-150hz
Voltage	0-80V
Current	0-20mA

2.6 Applications:

- Spinal cord injury
- Walking in spinal cord injury
- Stroke and upper limb recovery
- Drop foot
- Stroke
- Multiple sclerosis
- Cerebral palsy

2.7. Shortcomings/issues with existing solutions

Already available devices do not promote neuroplasticity. Neuroplasticity is the natural rewiring of brain. This helps the brain to reorganize itself, both in structure and how it functions overtime, by forming new neural connections throughout life. Existing devices like Transcutaneous Electric Neuro Stimulator (TENS) generate pulses but do not innervate muscles, hence fail to promote neuroplasticity.

2.8. Issues addressed by the proposed project

The proposed project helps stroke patients to overcome the barrier of disability by enabling them to perform self-physiotherapy at ease in their homes. Stroke patients would not have to make expensive appointments at hospitals

2.9. Core Features of Neuro Empathy

The core features of the project are:

- A precise EMG Acquisition Circuit
- Wearable (portable) Device
- HW/SW Integrated System
- Easily affordable
- Utilizes novel technique of Neuroplasticity

Chapter 3: Technological Requirements

This chapter provides an overview of the technological requirements.

3.1 Hardware Requirements:

The Hardware required for the implementation of the project includes:

3.1.1 EMG Surface Electrodes:

Surface electrodes are positioned on skin/mucosa and do not infiltrate surface. These are made of a metallic polymer disc that has 5–30 mm diameter. This disc is conductive. It is attached to skin on experimental muscle using some adhesives. Surface electrodes have two types they can be either dry or floating. Dry electrodes are directly connected with the skin and there is nothing in-between, however floating electrodes have electrolytic gel. This gel acts as a chemical interface between the skin and the metallic part of the electrode.

Figure 8: Surface electrodes

3.1.2 Arduino Microcontroller Board:

Its main component is ATmega328P. It would be used for the interfacing of all the modules mentioned above. It contains 14 digital input/output pins, 6 analog inputs, 16 MHz quartz crystal, USB connector and a reset button. It has all things that are required to assist the microcontroller; you can easily attach it to the computer by using a USB cable.

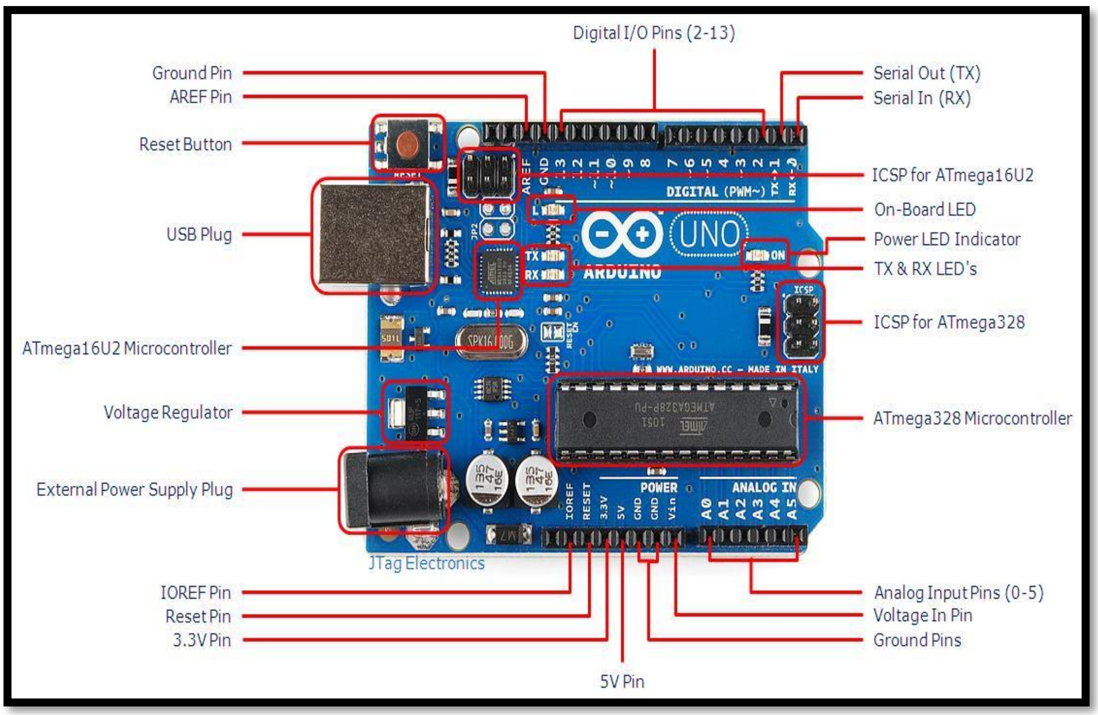

Figure 9: Arduino Micro Controller Board

3.1.3 PIC:

PIC microcontrollers are world's tiniest microcontrollers which can be programmed to perform variety of tasks. Many electronic devices use these microcontrollers these devices include computer control systems, phones etc. There are many types of these, but GENIE range of programmable microcontrollers has best ones.

Its structure comprises of various registers/stack where registers function as Random Access Memory (RAM) and stack keeps returning addresses. Key features of PIC microcontrollers are EEPROM, RAM, Timers/Counters, flash memory, I/O Ports, CCP (Capture/Compare/PWM module), ICSP and LCD (in circuit serial programming). The 8-bit microcontroller has four kinds on base of the internal design such as Base Line PIC, Enhanced Mid-Range PIC and PIC18

Figure 10: Programmable Interface Controller

The basic pin configuration of PIC controller is shown below

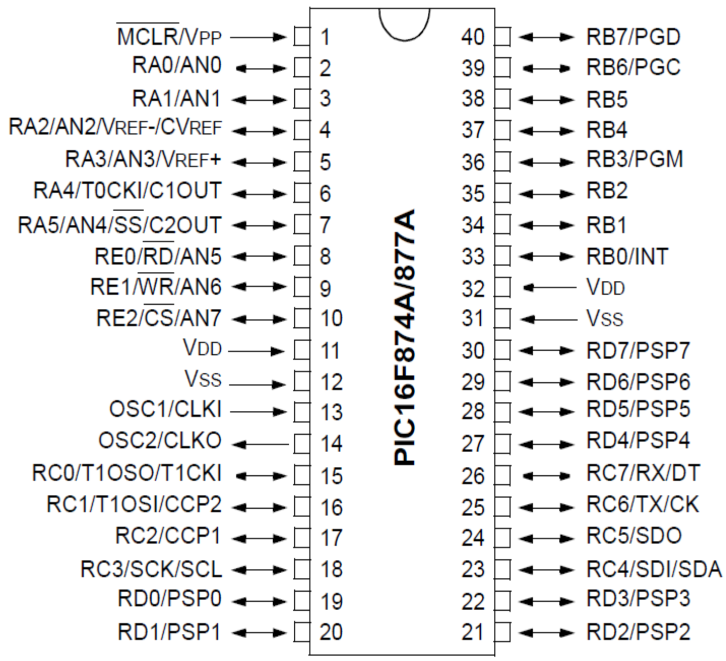

Figure 11: Pin configuration of PIC

The key features of PIC16f72A are given in table below taken from data sheet

Table 2: Feature of PIC 16f72A

Key Features	PIC16F877A
Operating Frequency	DC – 20 MHz
Resets (and Delays)	POR, BOR (PWRT, OST)
Flash Program Memory (14-bit words)	8K
Data Memory (bytes)	368
EEPROM Data Memory (bytes)	256
Interrupts	15
I/O Ports	Ports A, B, C, D, E
Timers	3
Capture/Compare/PWM modules	2
Serial Communications	MSSP, USART
Parallel Communications	PSP
10-bit Analog-to-Digital Module	8 input channels
Analog Comparators	2
Instruction Set	35 Instructions
Packages	40-pin PDIP 44-pin PLCC 44-pin TQFP 44-pin QFN

3.1.4 Differential Amplifier INA128:

INA128 is an amplifier that consumes small power it is used for general purpose instrumentation and it has a very good accuracy. The small size of this amplifier and its multipurpose 3-op amp structure makes it perfect for many uses. Input circuitry that has feedback of current provides large range of frequency even at high gain (200 kHz at G = 100). An exterior resistor sets the gain of it from 1 to 10,000. It has a gain equation which is industry standard. It is laser-trimmed to provide small offset voltage (50 µV), high common mode rejection (120 dB at G ≥ 100) and drift (0.5 µV/°C). It operates with very low power supplies ±2.25 V, current is only 700 µA, perfect for systems that are ran using batteries. It has internal input defense that can tolerate till ±40 V without any damage.

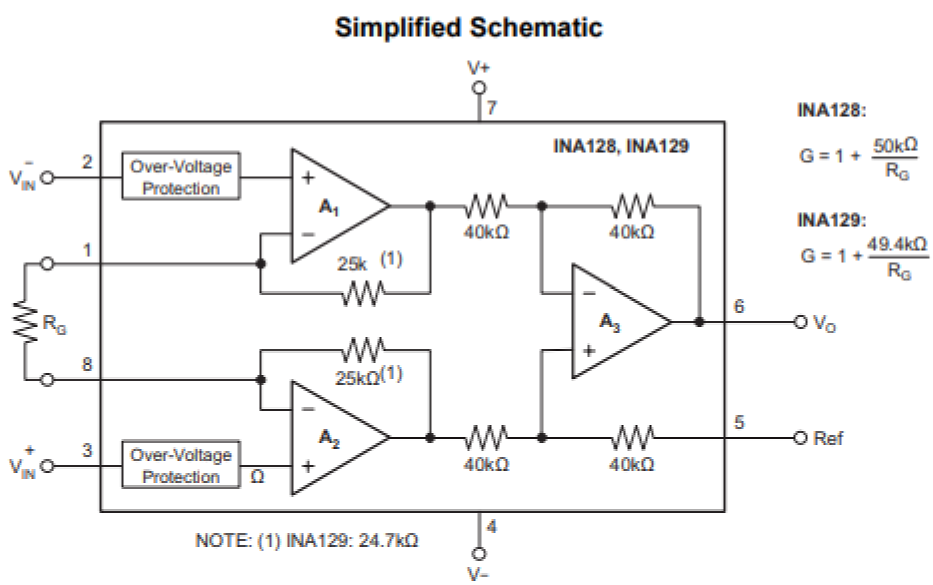

Figure 12: INA128

3.1.5 Voltage Regulator LM7805:

LM7805 is a voltage regulator of +5v and gives regulated output current of 1A. Since they are designed to give fixed voltage but can be used with other components to deliver adjustable current and voltage.

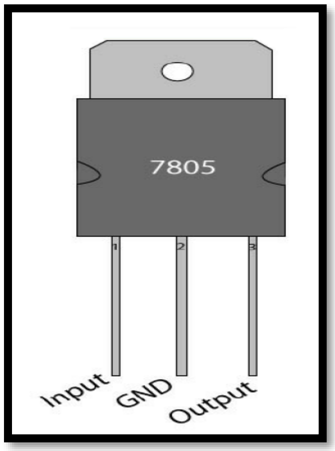

Figure 13: Voltage Regulator

Main features of LM-7805 IC are given below taken from data sheet.

Table 3: LM-7805 Features

Input Voltage	10V
Output Voltage	5V
Dropout Voltage	2V
Number of Outputs	1
Number of Pins	3
Output Current	500mA
Case Style	TO-220
Temperature Range	0°C to +150°C
Base Number	7805

IC Number	7805
Maximum Input Voltage	35V
Minimum Input Voltage	7V
Maximum Temperature	150°C
Minimum Temperature	0°C
Tolerance +	4%
Maximum Current	1.5A
Voltage Regulator Type	Positive Fixed

.

3.1.6 Darlington Transistor ULN2003A:

The ULN2003A is Darlington transistor array having high-voltage, high-current. It is made up of seven pairs of NPN Darlington that give outputs of high voltage, it also has diodes that have common cathode to give switching of the loads that are inductive. One pair has a collector current value of 500 mA. To increase their capability of current these pairs can be connected in parallel with each other. These pair have lot of uses like in hammer drivers, relay drivers, display drivers and lamp drivers. ULN2003A device is made especially for their use for 14-V to 25-V PMOS device. In this device every input contains a resistor in series and Zener diode for keeping input current to an inoffensive value. ULN2003A contain 2.7-kΩ resistor in series for every pair to operate with TTL or 5-V CMOS devices.

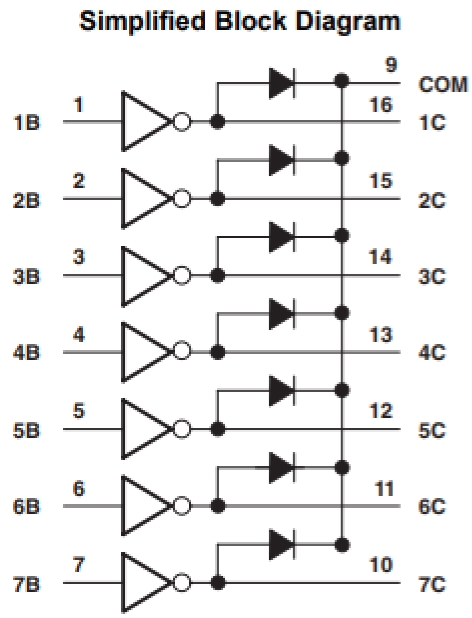

Figure 14: ULN2003A

Chapter 4: Hardware Design

This chapter describes the hardware working, schematic and proteus designing and system interface.

4.1 System Block Diagram

System block diagram gives the general overview that how the signals from healthy side will be transmitted to the paralyzed arm. First EMG signal are acquired using surface electrodes and some signal processing is performed on them. Then these signals are interfaced with FES using microcontroller.

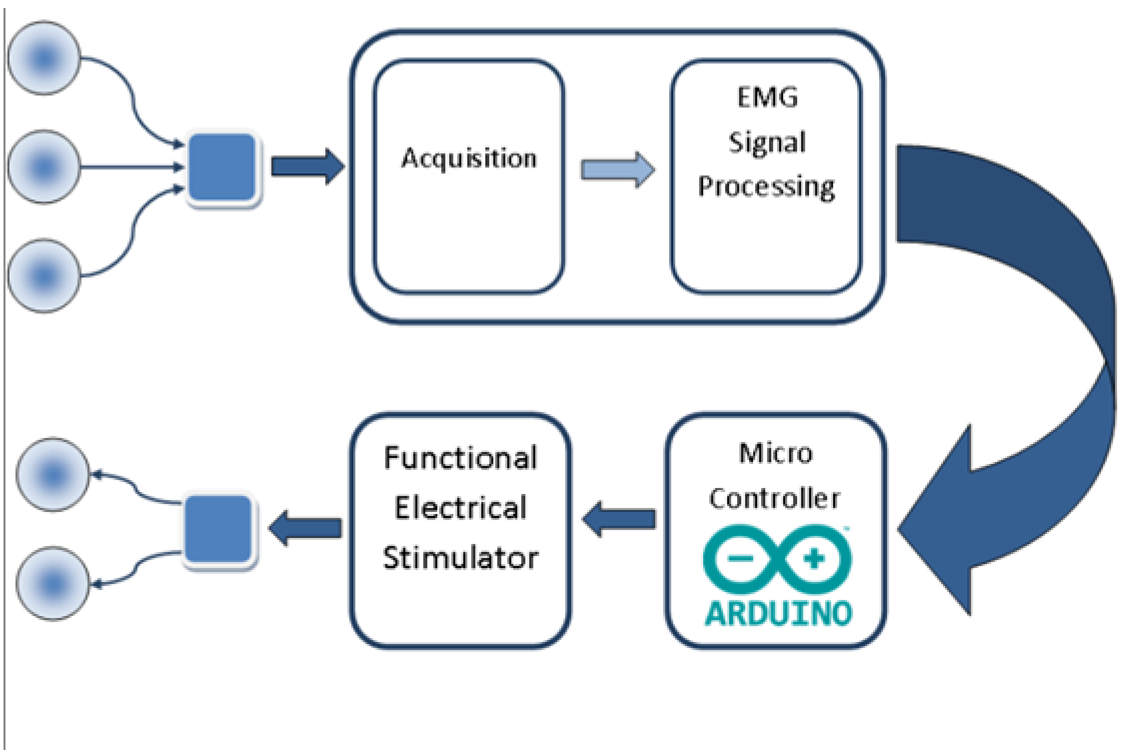

Figure 15: Block diagram

4.2 System Flow Diagram

A flow diagram is a graphical representation of a system in relation to its sequence of functions (as distinct from the data it processes).

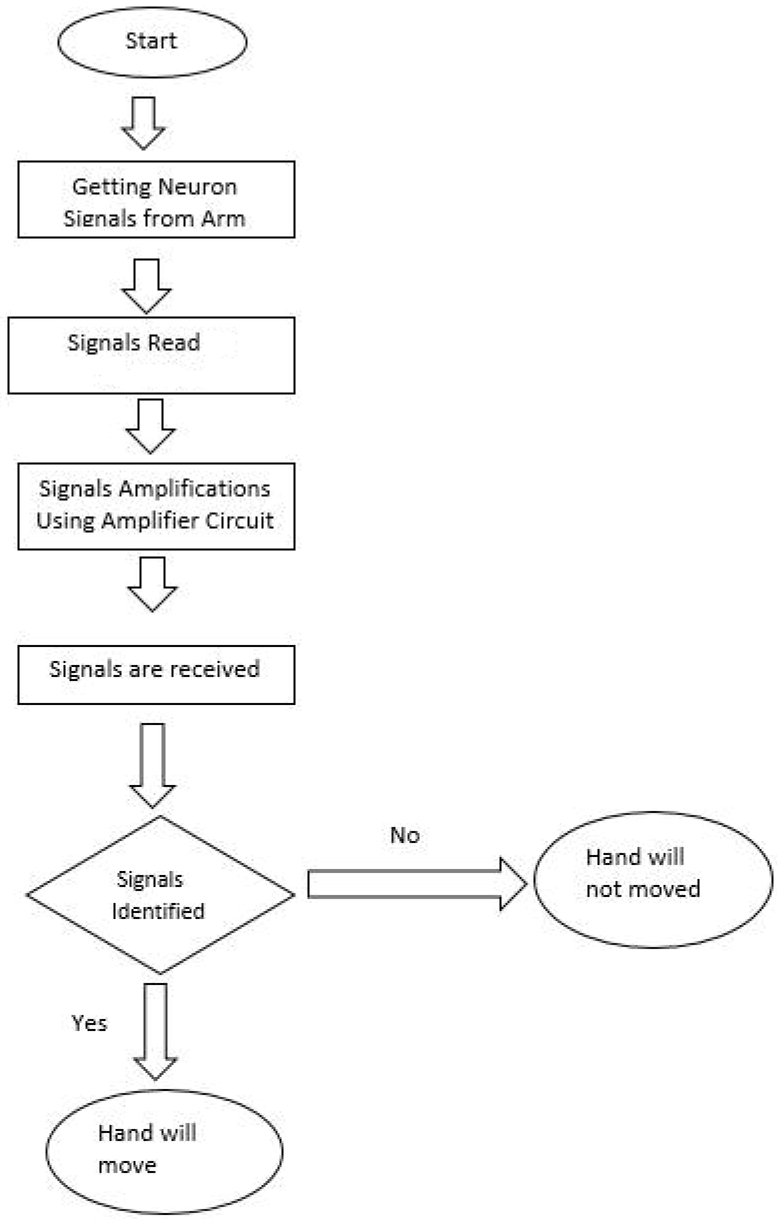

Figure 16: Flow diagram

First, the electrodes attached to the arm of sender sense the signals which are taken by EMG acquisition circuit. Here this circuit acts as both as an amplifier and noise removal. This gives the amplified signals. Then these signals are sent to FES using PIC controller. At the end the paralysed hand will move which is the main purpose of our project.

4.3 Hardware Designing:

The hardware designing includes Circuit, PCB preparation, Code dumping and interface.

4.3.1 Circuit design

The circuit for our device consists of an EMG acquisition and FES. EMG signals are acquired from start and end of a muscle then their common signals are rejected and amplified using a differential amplifier. These amplified signals are transferred to micro controller. Micro controller sends these signals to the FES and FES generates controlled pulses. The figure below is the EMG acquisition circuit. This is immediately followed by the FES interfacing with EMG acquisition circuit. This later figure is the complete circuit of our device.

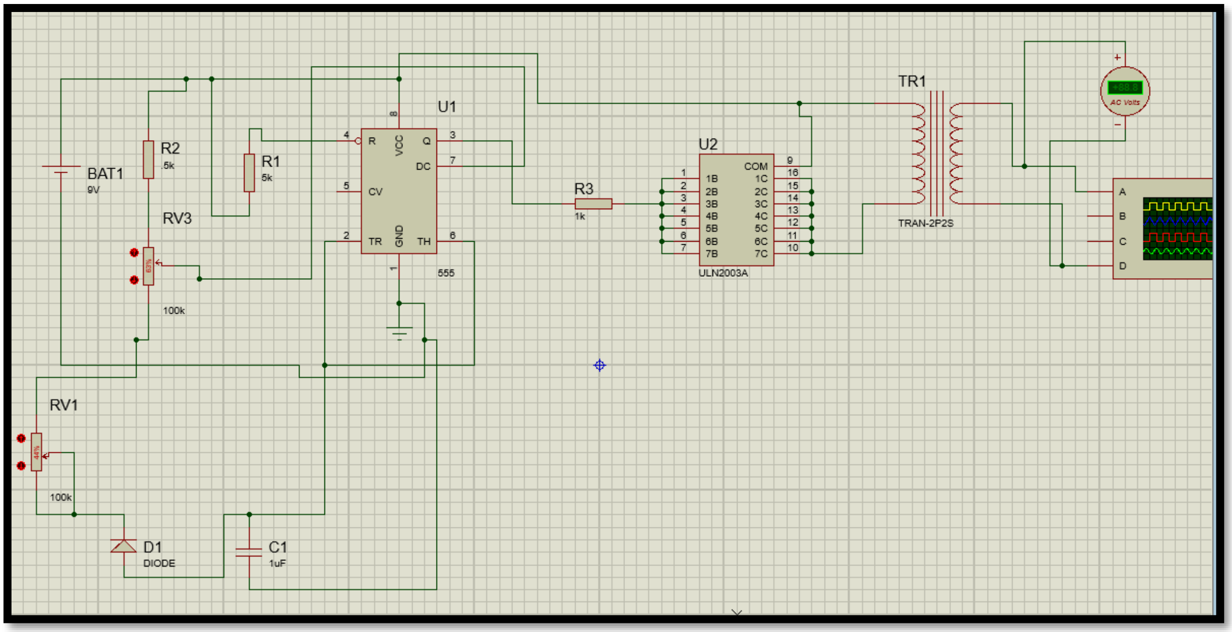

Figure 17: EMG Acquisition Circuit

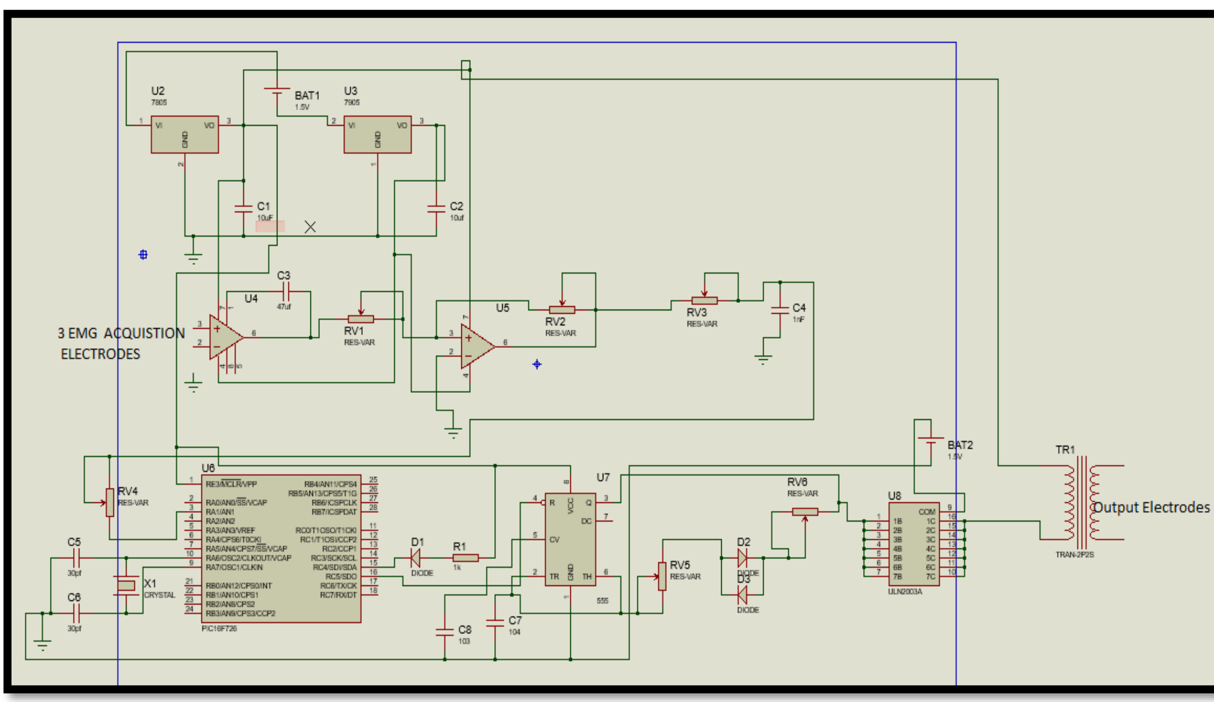

Figure 18: Circuit Diagram

4.3.2 PCB Preparation

The PCB preparation involves the following steps:

1. Designing of schematics on proteus software.
2. Print this schematic on the copper board using iron.
3. Ferric chloride is used to remove the copper from the board except the black lines.
4. Drill the board to make place for components.
5. Solder the components on the board and PCB is ready.

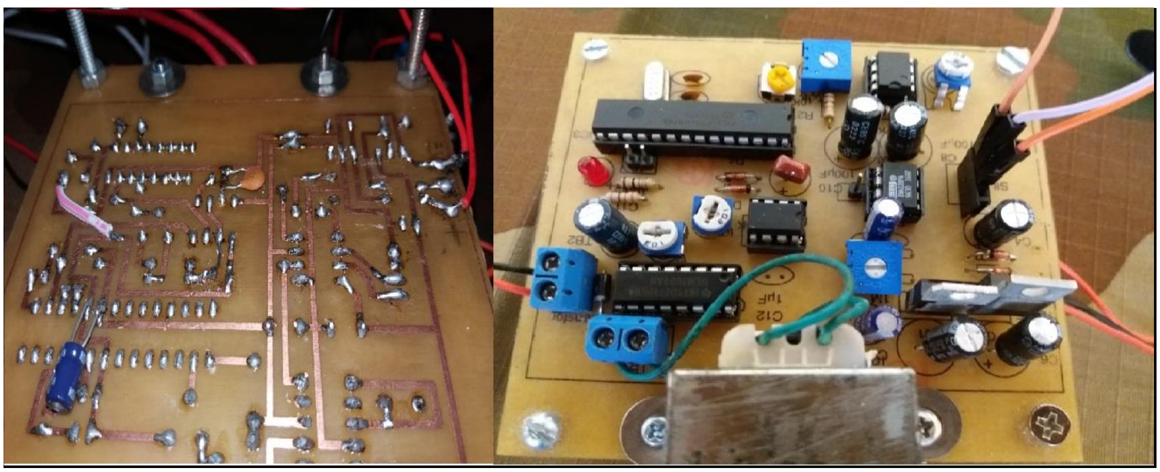

Figure 19: Printed Circuit Board

4.3.2 Program the PIC:

To program PIC microcontroller, software named 'MP-Lab' is used.

1. First install the software.
2. Then open the software window.
3. From Menu bar, select project.
4. Then select wired project.

5. Select ‘PIC16f72’.
6. Select the compiler ‘CCS C’, then select the path location.
7. Give name “Neuro Empathy” to the project.

4.3.3 Loading Code to PIC:

The microcontroller’s code loading process is called dumping. The microcontrollers understand only the machine level language, which contains ‘0 or 1s’. So we need to load the hex code into the microcontroller. There is software PICFLSH which is used for dumping. The programmer kit along with software is used with the hardware kit. The process, in which code is loaded in microcontrollers, is called dumping. Here are the steps for dumping.

- Install the software.
- Connect the hardware using a serial cable.
- Place the microcontroller in the kit. Then press the lock button.
- Open the software.
- To open and load the code select the option from the menu.

Figure 20: Code Dumping Device

4.3.4 Working:

First, we connect the 9V batteries with the circuit to make the circuit functional. Voltage regulation from 9V to 5V, which is required for some ICs which operate at 5V, is done through LM7805.

We put on three adhesive surface electrodes on the healthy arm of a stroke patient or a healthy person in case the stroke patient has paralysis on both sides. Two electrodes are placed on muscles for capturing muscle activity and one electrode is placed on a bone for reference signal. The orientation of these electrodes depends upon the desired movement. We connect these electrodes through wire connectors to the circuit.

We put on two adhesive EMS stimulating electrodes, having larger conducting area due to conducting gel, on the paralyzed arm of that stroke patient. The position of these electrodes depends upon the desired movement. We connect these electrodes through wire connectors to the circuit.

Now, our circuit is ready to function.

The patient attempts to move both arms. Muscle activity of intact arm is very much stronger than that of paralyzed arm. That's why the healthy arm moves and paralyzed arm stays immovable.

When the healthy arm moves, EMG signals are acquired through surface electrodes from the muscle activity. EMG signals are basically the measurement of electrical activity of the muscles. These signals are fed to the circuit through connectors. These raw EMG signals have the characteristic voltage of 0mV-10mV, current of 0mA-10mA and frequency of 0Hz-500Hz

Reference signal is fed to the ground of the signal to make the EMG signals synchronous to the circuit. The other two signals, which are the actual signals of the muscle activity, are directly fed to the instrumentational amplifier INA128. Common Mode Rejection (CMR) is done here by removing the difference of these two signals and amplifying the other component parts of the signals. Two potentiometers are also attached to this amplifier to adjust the CMR ratio. We use instrumentational amplifier here EMG signals when acquired are of the micro volts and no common amplifier can even detect these signals.

The output signal of this instrumentational amplifier is then fed to a band pass filter which is a combination of resistors and capacitors. This band pass filter discards the signal having frequency components of lower than 50Hz and higher than 150Hz and EMG signal of frequency 50Hz-150Hz is achieved. Band pass filtering is done because most of the information about EMG signal lies in the frequency range of 50Hz-150Hz. Moreover, EMG signal components having frequency less than 50Hz are very much difficult to detect and components having frequency greater than 150Hz are considered as noise when we talk about EMG signals.

The output signal of this band pass filter is fed to the other amplifier UA741 which simply amplifies the signal. Two potentiometers are also attached to this amplifier to adjust the gain of the amplifier. These processed (amplified and filtered) EMG signals have the characteristic voltage of 0V-5V, current of 0mA-100mA and frequency of 50Hz-150Hz

Now the filtered and amplified signal is fed to the microcontroller. Microcontroller is used here for the interfacing of EMG signals and the stimulator. Here PIC16F72 microcontroller is used. PIC microcontroller is preferable to use while dealing with EMG signals because we can program it to its register level which removes the barrier of delay which we usually face while using Arduino or Raspberry Pi. These high level microcontroller computers slow down when they take EMG signals as input and cannot operate in the time span of microseconds. EMG signals vary its voltage and within a microsecond. To cater this problem a low level microcontroller is used.

Microcontroller PIC16F72 takes EMG signals as input. It reads input EMG signal after every 10 milliseconds. It converts the analog EMG signal to digital EMG signal as it has a built-in Analog-Digital Converter for digitization of input signals. Now, microcontroller works as a comparator which does the On-Off Keying. It reads EMG signal voltage value and compares it with the threshold of the voltage. If the EMG voltage is less than that of threshold, then it sends a '0' (low voltage) to its output pin. If the EMG voltage is greater than that of threshold, then it sends a '1' (high voltage) to its output pin. Whenever it sends 'o' or '1' to the output pin, the voltage (low or high) at output pin is sustained for 1 second. After that time span, microcontroller compares the voltage values again.

The output signal (low or high) of the microcontroller is fed to a mono-stable multi-vibrator 555 timer. When the output signal of the microcontroller is '0' (low voltage), 555 timer remains off. When the output signal of the microcontroller is '1' (high voltage), 555 timer generates square pulses. This square wave signal is fed to a pair of resistor and capacitor which is used to clipping of the square waves. Square waves signal is converted to a faradic wave signal.

This signal from 555 timers is then fed to ULN2003 through a combination of potentiometers. These potentiometers are used to adjust the voltage and current of this stimulating signal. ULN2003 is a transistor-array of Darlington transistors. This array of 7 Darlington transistors is used to enhance the current value of the stimulating signal. All 7 Darlington transistors are combined in the parallel pattern to enhance the efficiency of this array 7 times.

The stimulating signal from the array of Darlington transistors is then fed to a step-up transformer. This step-up transformer is used to enhance the voltage of the stimulating signal because 555 timer generate pulses of very low voltage. The transformer is modified such that it converts a maximum of 5V to 90V.

The output signal from the transformer is the actual stimulating signal which has the characteristic voltage of 0V-90V, current of 0mA-50mA and frequency of 50Hz-150Hz. This stimulating signal is fed to the adhesive EMS stimulating electrodes through connectors. This signal then stimulates the corresponding muscles of the paralyzed arm which artificially generates the movement in that paralyzed arm.

In a nutshell, when the stroke patient attempts to move both arm his healthy arm moves naturally and his paralyzed arm moves artificially simultaneously.

4.3.5 Output of FES:

Functional electrical stimulator is designed to generate pulses according to the parameter set by us. Its output waveform on the oscilloscope is shown in figure below.

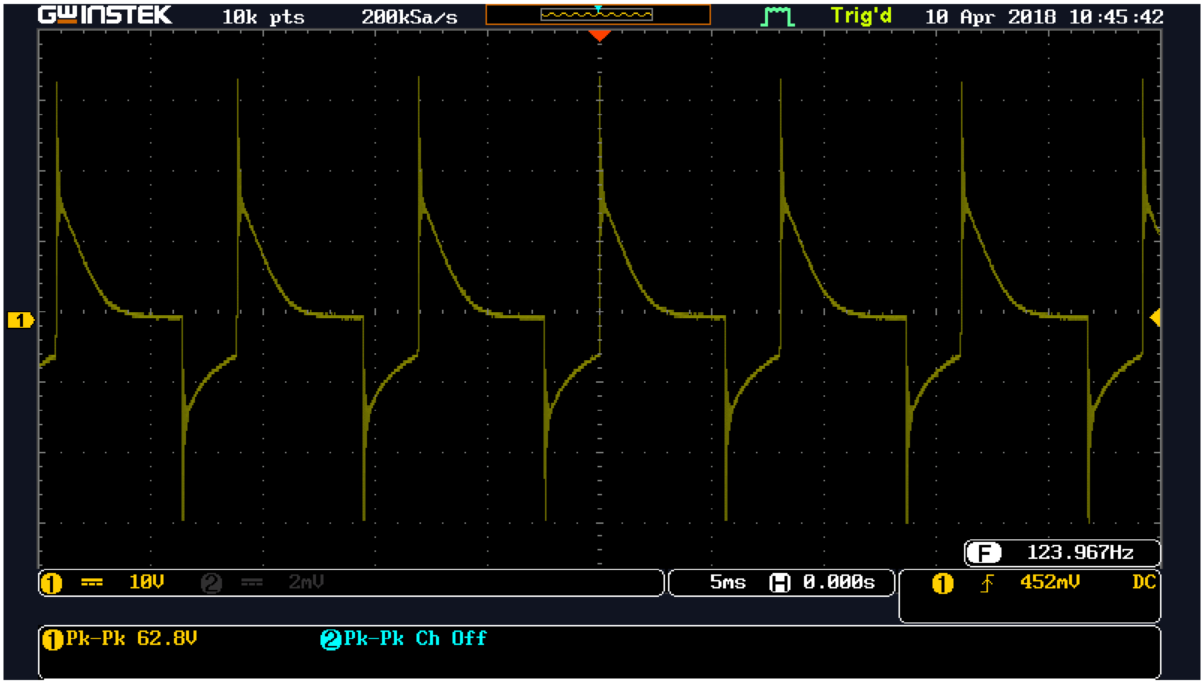

Figure 21: Output Waveform

4.4 System Interface:

Our interface uses surface electrodes to detect EMG signal of a movement from healthy arm and generates the movement in the paralyzed arm corresponding to information received using the designed device.

The interface for our proposed system is given below

Figure 22: System setup

4.4.1 User Characteristics:

User of our product need to be technically aware of how to apply electrodes in the body. Minimal knowledge is enough. There is no need of any technical professionals. Once device is programmed to transmit the signals then all u do is just move your hands and then see the spontaneous movement of your partner hands. Our product is complete for the use of common persons.

4.5 Functional Requirements:

The main functional Requirements of our System are as follow:

- The main function of proposed project is to detect movement through EMG electrodes.
- Get movement signal from the healthy arm and then apply algorithm for amplification and noise removal.
- The signals from sender after amplification and noise removal are transferred to receiver by FES.
- Once movement stimuli signals are identified our system will transmit it to the other end and generate movement.
- Our main target is to get the stimuli of movement with high accuracy
- For detection of Signals from sender, LED will also Blink which means that signals are acquired successfully from the sender using muscle sensor.

4.5 Non-Functional Requirements:

4.5.1 Performance

The system is a real time system and requires rapid action when stimulus is received. As soon as Signals are received, Receiver hands must be movable. The response time should be ideal to avoid any issue.

4.5.2 Availability

Availability is a major issue if a very important and critical system is depending just on your movement. Then it should be always available there to provide you services. For example, you cannot compromise a negligence in detecting if a Sensor or Micro controller don’t Work properly.

4.5.3 Maintainability

We need to maintain this because as the technology changes we should also make this newer and advanced by using advanced version of Micro controller, Electrodes and Muscle Sensor.

4.5.4 User interfaces

User interface of application will be easy to use as it can be use by lay man. User only heed to attach the electrodes on its proper position

4.5.5 Portability

Our system include electrodes and small hardware are all portable so it can easily move from one place to another.

4.6 Dependencies:

- Depends on hardware and requires power supply otherwise our system will not provide efficient result.
- The Hardware on which our system lies is FES. Without stimulator, we cannot generate movement.
- Another dependency of our system is the PIC controller which sends the signals to FES.

Future Work

Many different test and experiments have been left as future work due to lack of time (i.e. it is difficult to simulate experiments concerning different muscles since experiments with real data are time consuming and require a detailed study of human anatomy for each muscle involved). Future work concerns deeper analysis of EMG signals, simulation of different muscles with multi-movements to achieve actual replication and the use of device in treatment of diseases other than stroke.

This thesis has been mainly focused on the treatment of stroke patients. However, there are some ideas that we would have liked to incorporate in our existing product. This includes:

1. Use of multi electrode placement on involved muscles to simulate movements that replicate exactly the movement of the stimulus.
2. Use of Machine Learning algorithms to train the device, to include only those muscles every time, which have been stimulated while not including other muscles to produce more accurate results.
3. The device can be used to acquire EMG signals to provide for human actuated devices that find uses in rehabilitation and bio-mimetic technology.
4. The non-invasive measurement technique allows for quantifying the motor impairment in Parkinson's disease (PD).

Conclusion

The proposed framework will concentrate on controlling and exchanging the development signal from healthy arm to the paralyzed arm by utilizing EMG, Amplifier circuit, PIC and FES. Primary center will be on getting the voltage signals from healthy arm precisely and after that applying further preparing on it to create the sign at the less than desirable end.

The fundamental capacity that involves our undertaking incorporates stroke patient with electrodes on his healthy arm can send a Signal to paralyzed side. A small scale controller detects that the individual accomplished something that signs "yes." From there, the sign is sent to an attractive loop (Electrode)s altered to a paralyzed hand. At the point when that attractive sign is gotten by the other side, it considers it to be a blaze: the sign that a "yes" has been sent. And after that he moves his hands same as the signs got from the sender.

The correspondence between neurons inside the mind is the base of every one of our contemplations, feelings and practices. At the point when masses of neurons synchronize and speak with each other electrical heartbeats are created. Electromyography is the method of measuring electrical action of the muscles from terminals set on the skin.

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Appendix A

PIC Code

```
#include <16F72.h>


#FUSES HS,NOWDT,PUT,NOPROTECT,NOBROWNOUT

#use delay(clock=16000000)

int i = 0;

int16 Ch1 = 0;

int16 temp = 0;


void main()

{

output_high(PIN_C4);

output_low(PIN_C5);


for(i = 0; i < 5; i++)

{

output_low(PIN_C4);

delay_ms(100);

output_high(PIN_C4);

delay_ms(100);

}

 while(1)
```

```
 {
set_adc_channel(0);
delay_ms(100);
Ch1 = Read_ADC();

if(Ch1  > (temp + 70))
{
output_low(PIN_C4);
output_high(PIN_C5);
delay_ms(1000);
output_high(PIN_C4);
output_low(PIN_C5);
}
else
{
temp = Ch1;
}
 }
}
```

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