EMG Signal Feature Extraction for Designing the Calf Stimulator

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Abstract— **From past years, Bio-medical domain has great advantage in emerging technology. Nowadays the road accidents have increased tremendously, and in accidents mostly the spinal cord gets injured badly. Due to spinal cord injury person suffer from the paraplegia that is paralysis of different parts of body. Walking inability is often viewed as the major and most painful outcome of spinal cord injury(SCI).When people get paralyzed then they can't do their work independently. Every time they need help from others so the electrical stimulator concept has introduced to maintain and restore the movements of upper and lower limbs of paralyzed person. Stimulating the lower limb with electrodes can awaken the circuitry and gets functioning without instruction from brain. Feature extraction of EMG signal and design of stimulator is the main aim of the project. This paper will describe the analysis of EMG signal in Matlab and also design stimulator with the help of microcontroller. Activation of the stimulator will be based on the extracted signal using different parameters and setting the threshold value.**

Keywords— Electromyogram signal, Electrodes, Feature extraction, Electric Stimulator.

I. INTRODUCTION

Bio-medical domain is the widely emerging technology from past recent years. During past years, a number of digital stimulator have been developed and successfully implemented. This research work describes the methodology of collecting EMG signal and hardware and software approach to drive the stimulator. For designing the stimulator, firstly we have to collect the EMG signals. Biological signals are called EMG signals which are electrical signals produced by the activation of the muscles motor unit. EMG signals are picked from the surface and the time domain features associated with the intended motion are extracted using suitable technique. These signals are non-stationary, non-liner, complexity and have large variation. This nature creates difficulty in analyzing EMG signal. There are two techniques for data collection of EMG signal which includes surface method and intramuscular method. In this experiment we have used surface method for data collection. Common EMG signals strength can range from uV to few mV.

These surface EMG signals normally are of low amplitude. The signal acquisition system has protection against interference effects to facilitate the identification of the intention of the user from weak signals.

The proposed system developed an electric calf stimulator for ankle movement. Electric stimulation means to influence the natural bio-electric process within the body, i.e., creating action potentials that are conducted along the excitable cells. It uses el electric current to cause a single muscle or nerve or group of muscle/nerve to contract. Using this stimulator person can do ankle movement like dorsal flexion and plantar flexion so that they can walk and live independently.

II. LITERATURE ON RELATED WORKS

There are different types of stimulators that are used to restore the muscle in rehabilitation treatment of paralyzed person like Transcutaenus Electric Nerve Stimulation (TENS), Functional Electrical Stimulation (FES), Galvanic Stimulation (GS), Electric Nerve Stimulation (ENS), etc. Nowadays, the electric portable stimulator plays the important role in clinical studies. There are different types of stimulators that are used to restore the muscle in rehabilitation treatment of paralyzed person like Transcutaenus Electric Nerve Stimulation (TENS), Functional Electrical Stimulation (FES), Galvanic Stimulation (GS), Electric Nerve Stimulation (ENS), etc. Recently clinical studies demonstrates the recovery of functionality of paralyzed portion that contributed by electrical stimulation of different nerves that generates missing function of upper limb due to spinal cord injury. A portable, programmable, battery operated stimulator is designed which can be used for stimulation of minor muscles defect as well as critical muscle defect [1].FES shows walking after paralysis by activating the muscles of lower extremities with the help of stimulations [2].There are normally two non-parametric approaches in feature extraction. Temporal and Spectral Approach are the two non- parametric parameters for feature extraction of EMG signal [3]. The comparative study of multi-purpose Functional Electric Stimulation (FES) that is used to store the movements of spinal cord injury patients by applying low level current to the paralyzed muscle of the patients to function, activate [7].The proposed stimulator has closed loop stimulation which is more suitable for various FES application that are used for both experimental and clinical studies.[9]. There are various types of electrodes like needle, disk, surface electrodes used in FES system but they prefer skin surface electrodes. Here, an FES system has been defines actively as an application of suitable electric current to muscle fibers to restore the control function of body and proposed low cost FES system that as targeted person which suffered from hemiplegic stroke condition. The skin surface electrodes have been chosen due to its simplicity which can be easily available for clinical settings [10].

III.PROPOSED SYSTEM ARCHITECTURE

The proposed work is to implement Electrical stimulator.Electrical stimulator is a device that is used to maintain or restore the muscle activity of lower extremity of paralyzed patients.The work will reflect the study of Myoelectric signal (MES)/EMG signal which will be obtained from skeletal muscles of surface of calf and extracting required features which are further used to classify different kind of ankle movements.Using that extracted features from calf muscle, the nerve and muscle stimulator will be designed with current source having low frequency and amplitude faradic/ galvanic currents.

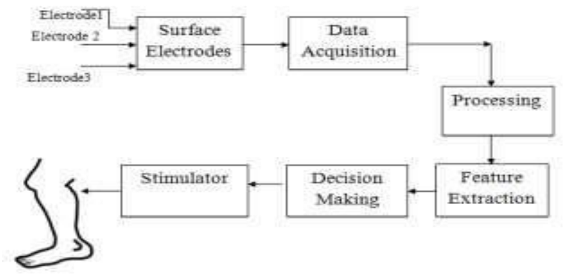

Fig.1 Block Diagram of proposed system

In this proposed system, database of standard EMG signal has been collected from normal person according to the condition for comparison purpose.EMG signal has been acquired using NI DAQ 6009 Card with the help of surface and disk electrodes. Further processing of EMG signal is done to remove unwanted part using signal conditioning. Preprocessing on the acquired EMG signal will be carried out to extract the time domain features.

A.Hardware Evaluation-

1. Instrumentation amplifier (INA106)-

An instrumentation amplifier is a type of differential amplifier which includes very low DC offset, low drift, low noise very high open loop gain very high common mode rejection ratio and very high input impedance. Instrumentation amplifiers are used where great accuracy and stability of the circuit both short- and long-term are required.

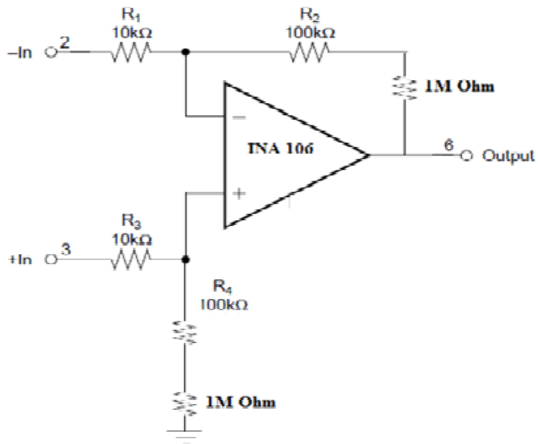

Fig.2 Design of Instrumentation amplifier

For the INA106 to adjust the gain accordingly there is facility to add the resistor in feedback that is resistor RA. So to adjust the gain I have connected the 1M ohm resistor between pin no 5 and pin no 6 that is in between inverting input and output.

2. Design of Filter

a) High Pass Filter:

The second order high pass filter circuit is shown in fig 3.

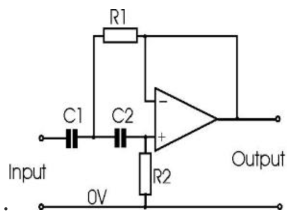

Fig.3 Operational amplifier two pole high pass filter

The calculation for the circuit is shown below. The formula for cut-off frequency is Fc = 0.707 /2 π, RC2=50Hz.

Where

R1=R2=6.8Kohm,C1=0.22uF,C2=2C1=0.44uF.

b) Low Pass Filter:

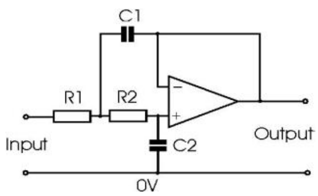

Fig.4 Operational amplifier two pole low pass filter

The formula for cut-off frequency is Fc=0.707/2π RC2=150Hz

where,R1=R2=6.8Kohm,C2=0.11uF,C1=2C2=0.22uF.

Using the two-pole low-pass active filter and two-pole high pass active filter the second order Butterworth band pass filter is designed. The cut off frequency for band pass filter is Fc1 50Hz and Fc2 150Hz.

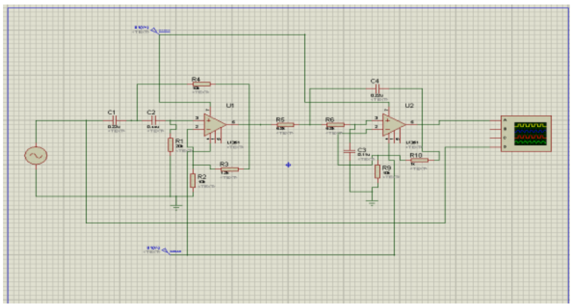

Fig. 1 Design of Butterworth Band pass filter

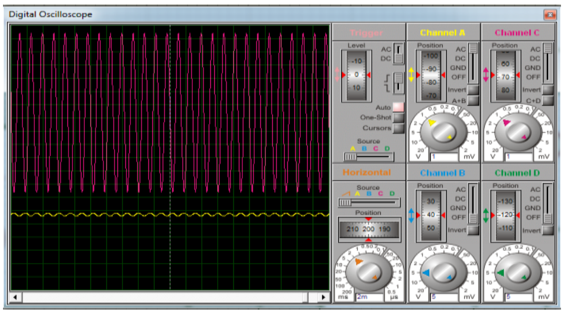

Fig. 2 Filter Simulation

B. *Software Evaluation-*

In proposed work, the signal acquired from the surface of body is to be processed for finding the time domain features like-

A] Mean Absolute Value (MAV): MAV and IEMG both are very much similar. This is used for onset index which detects the activity of muscle. MAV is the average of the absolute value of EMG signal amplitude.MAV is a popular feature used in EMG ankle or leg movement.

$$\text{MAV}=\frac{1}{N}\sum_{n=1}^{N}|X_n|$$

B] Integrated EMG (IEMG): IEMG is same as MAV that is normally used for onset detection index that is related to Myoelectric or EMG signal. IEMG is the summation of absolute value of MES signal amplitude, and given as,

$$\text{IEMG}=\frac{1}{N}|X_n|$$

C] Root Mean Square (RMS): RMS is mostly related to non-fatiguing contraction and constant force. Generally it is similar to Standard deviation (SD) and expressed as,

$$\text{RMS}=\sqrt{\frac{1}{N}\sum_{n=1}^{N}|X_n^2|}$$

D] Simple Square Integral (SS1): SSI is used to capture the energy of EMG signal. It is given as

$$\text{SSI}=\sum_{n=1}^{N}|X_n|^2$$

F] Maximum voltage:

C. Flow chart:

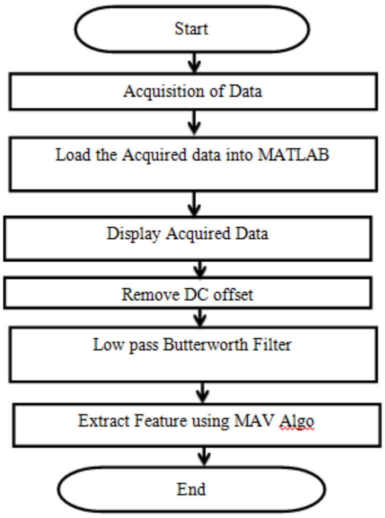

Fig.7 Flowchart for MES Feature extraction

D.Design of Stimulator:

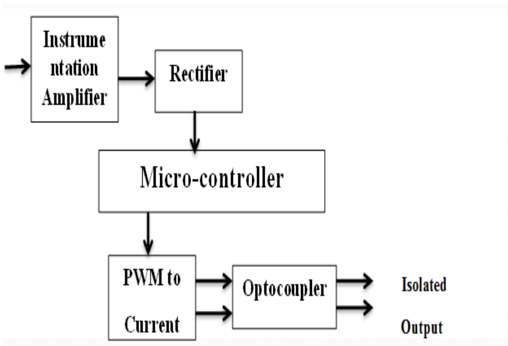

Fig.8 General Functional block diagram of Stimulator

Fig.8.Illustrate the general functional block diagram of electrical stimulator. It is functionally divided into 3 blocks input stage, a controller stage and a driving stage. In the input stage the rectified EMG is given to the microcontroller. Then according to the threshold parameters micro-controller generates the PWM output, and in driving stage the output is converted into current which is given to the patients through electrodes. The PWM wave is generated by PIC Microcontroller, the frequency of the PWM is 3125Hz which is fixed. At the output of controller, the voltage is converted into current then one Optocoupler is used to isolate the output.

1. Analog to Digital design-

The microcontroller consists of built in Analog- to- Digital (ADC) converters. These enable the conversion of our analog inputs into quantized values. The voltage from the rectifier is fed to one ADC pin (AN0). The ADC of the microcontroller divides these analog inputs into 1024 quantized levels. These values are 0 (for 0V input) and

1023 (for 5V input). In this way, rectified EMG voltage sensing is achieved.

2. Pulse Width Modulation-

To adjust the period of stimulating pulse the pulse width modulator is used. By changing the duty cycle of PWM waveform the pulse duration adjustment is achieved. The duty cycle like the ADC, must be divided into digital outputs. .The duty cycle of the PWM pin is set with a quantized value which is 0 for minimum (0%) duty cycle and 255 for maximum (100%) duty cycle. The simulation for this is shown in Fig 9, and output of PWM is shown in Fig.10.

3. Current Source-

At the output of the PWM, the amplifier is connected to increase the voltage of the PWM. Then that voltage is converted into the current using voltage to current converter with grounding load. To adjust the amplitude of the PWM the 10K log plot is used at the output of controller. The simulation for this is shown in Fig 9, and output of PWM is shown in Fig.10.

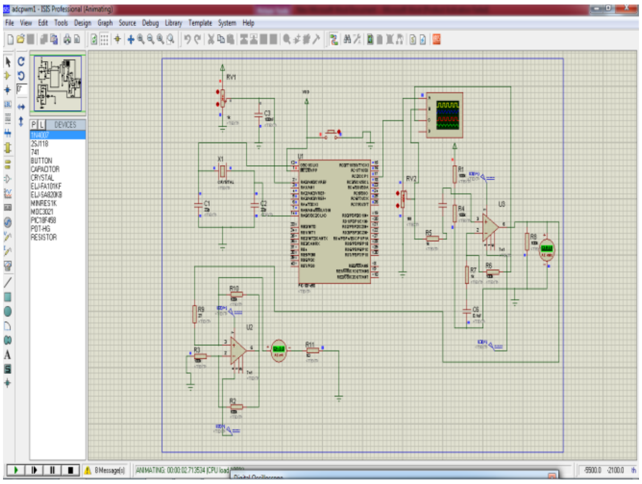

Fig.9 Simulation of PWM and current source

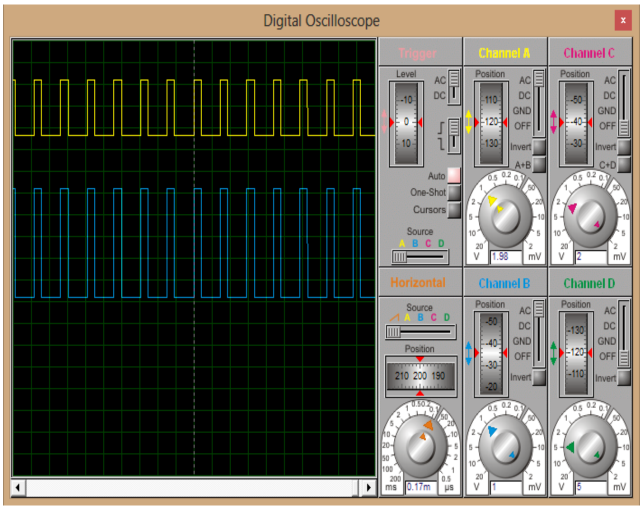

Fig.10 Output of simulation of PWM for continuous pulses

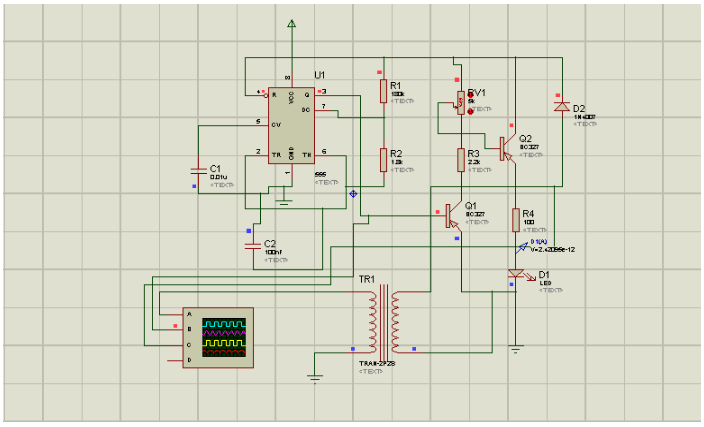

Fig.11 Simulation of PWM and voltage sources

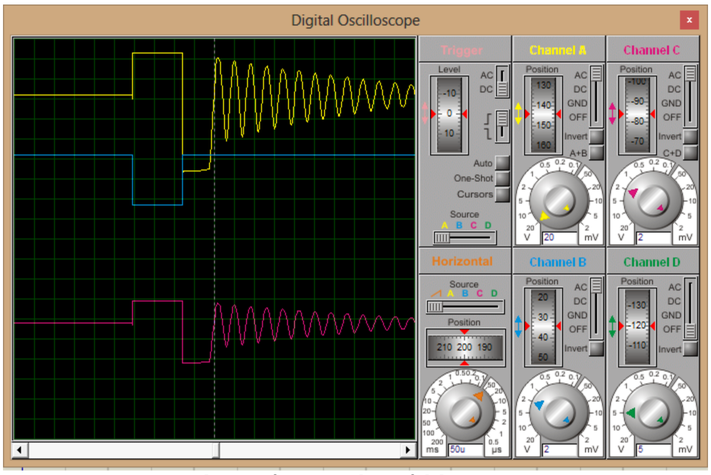

Fig.12 Simulation of PWM pulses of delay 5sec

IV RESULTS & OBSERVATIONS

With this system we have extracted the time domain features to design the calf stimulator. The filtered EMG signals of different persons are collected using Daq-Card, and different features of EMG signals are extracted using MATLAB tool. The different features extracted are (MAV) Mean absolute value, (RMS) Root mean square, Maximum amplitude, Minimum amplitude, Average level. The Mean absolute value of the EMG signal is related to the muscle contraction level of that muscle of the person. RMS value of EMG signal is directly proportional to the contraction force applied on that muscle to contract.

Table 1. describes the calculated MAV , RMS and MAX value for ankle movement of normal person

Normal Person No	**MAV**	**RMS**	**MAX**
1	1.5480e-06	0.0564	0.0038
2	1.6504e-06	0.0569	0.0030
3	3.8704e-06	0.1256	0.0047
4	1.0561e-06	0.1029	0.0032
5	1.6941e-06	0.0556	0.0036
6	1.7618e-06	0.1569	0.0042
7	1.7319e-06	0.1563	0.0027

8	1.7623e-06	0.1992	0.0056
9	1.6732e-06	0.1231	0.0045
10	2.3767e-06	0.1524	0.0040
Average	**1.9124e-06**	**0.1185**	**0.0393**

Table 2. Describes the calculated MAV, RMS and MAX value for ankle movement of Patients

Patients No	**MAV**	**RMS**	**MAX**
1	2.8481e-07	0.1120	0.0003
2	2.8451e-07	0.2310	0.0524
3	3.1458e-07	0.0567	0.0070
4	2.7891e-07	0.1014	0.0021
5	2.8881e-07	0.0254	0.0001
6	3.8121e-07	0.0123	0.0002
7	2.3242e-07	0.0561	0.0018
8	4.1456e-07	0.1345	0.0080
9	2.4574e-07	0.0125	0.0001
10	3.4561e-07	0.0127	0.0034
Average	**3.0716e-07**	**0.0754**	**0.0075**

From the above two tables it is observed that the normal persons MAV , RMS value and MAX value are greater than the patients MAV , RMS value and MAX value respectively. Hence we can say that normal persons muscle contraction level and the muscle force acting on the muscle is higher than the paralysed patients. Hence using this database one program is developed in the MATLAB to bifurcate the signals of normal person and patient by calculating average of the values.The threshold voltage level to drive the stimulator is calculated from the average and peak voltages before and after RF contraction. The current value for the stimulator is set between 1 mA to 50 mA. The different current levels will be given to the patient according to the patient’s response for certain period of time.

V.CONCLUSION AND FUTURE IMPROVEMENT

The proposed work is to develop Electrical Calf Stimulator. Electrical stimulator uses electric current of 0-50 mA to cause single nerve/muscle or group of muscles/nerves to contract and by contracting these muscles/nerves helps to strengthen the affected muscle. It is used to maintain or restore the muscle activity of lower extremity. The work reflects the study of Electromyogram (EMG) signal acquired from the surface of the body by specially design surface electrode are to be processed for finding the time domain features which can be further used to design the stimulator.

REFERENCES

[1] Debabrata Sarddar, Madhurendra Kumar, Sikdar, “*Functional Electric Stimulation using PIC Microcontroller*, “International Journal of Computer Application,vol.44,issue no.12,April 2012,pp31-35.

[2] Anirban Dutta and Rudi Kobetic, “*Walking after partial paralysis assisted with EMG-triggered or switch-triggered Functional Electric Stimulation-two case studies”*, IEEE International Conference on Rehabilitation Robotics, July 2011,pp 1-6..

[3] Sijiang Du and Marko Vuskovic presented, *“Temporal Vs Spectral Approach to Feature Extraction from Prehensile EMG Signals”*, IEEE International Conference, ,November 2004,pp 344-350.

[4] Thomas C.Bulea,Rudi Kobetic, Musa L. Audu, John R.Schnellenberger and Ronald J.Triolo, *“Finite State Control of a Variable Impedance Hybrid Neuroprosthesis for Locomotion after Paralysis”*, IEEE transaction on Neural System and Rehabilitation Engineering,vol.21, issue no.1,January 2013,pp 141-151.

[5] Cheryl L.Lynch, Milos R.Popovic, *“ A Comparison of Closed-Loop Control Algorithms for Regulating Electrically Stimulated Knee Movements in Individual with Spinal Cord Injury”*,IEEE transaction on Neural System and Rehabilitation Engineering,vol.20,issue no.4,July 2012,pp 539-548.

[6] Ryan J. Farris, Hugo A. Quintero and Michael Goldfarb “*Preliminary Evaluation of a Powered Lower Limb Orthosis to Aid Walking in Paraplegic Individuals”*IEEE transaction on Neural System and Rehabilitation Engineering,vol.19,issue no.6,December 2011,pp 652-659.

[7] Aizan Masdar,B.S.K.Ibrahim, M.Mahadi Abdul Jamil, Dirman Hanafi, M.K.I.Ahmad and K.A.A.Rahman”*Current Source with Low Voltage Controlled for Surface Electrical Stimulation”,IEEE 9th International Colloquium on Signal Processing* and its Application,2013,Kuala Lumpur,Malaysia.

[8] Matthew A. Schiefer, Ronald J. Triolo and Dustin J. Tyler, *“Model of Selective Activation of the Femoral Nerve with a Flat Interface Nerve Electrode for a Lower Extremity Neuroprosthesis”*, IEEE transaction on Neural System and Rehabilitation Engineering,vol.16,issue no.2,2008,pp 195-205.

[9] Qi Xu Tao Huang, Jiping He Yizhao Wang Haulun Zhou,*”A Programmable Multi-channel Stimulator for Array Electrodes in Transcutaenus Electrical Stimulation”,* Proceedings of the IEEE/ICME International Conference Medical Engineering, Harbin, China, 2011,pp 652-656.

[10] Amelia W. Azman, Jannatu Naeem, Yasir Mohd, Mustafah”*The Design of Non-Invasive Functional Electrical Stimulation (FES) for Restoration of Muscle Function* “International Conference on Computer and Communication Engineering, 2012, pp 612-616.

[11] Ming, Ding Yaun, Yanan Li, Minpeng Xu, Weijie Wang, Rami Abboud “*Neuroprosthesis System for Lower Limbs Action Based on Functional Electrical Stimulation* “, International Conference on Electrical and Control Engineering,2011 pp 4583-4586.

[12] Emily Watlz Photography by Greg ,“Electrical Stimulation of the Spinal Cord could let Paralyzed People move again”.

[13] ara

