Myoelectric Leg for Transfemoral Amputee

Kirtan P. Parekh[1] Jignesh B. Vyas[2]
[1,2]Department of Biomedical Engineering
[1, 2] Government Engineering College, Gandhinagar, Gujarat, India

Abstract-- This paper will review the works on Surface Electromyography (SEMG) signal acquisition and controlling as well as the uses of SEMG signals analysis for Transfemoral amputee's people. In the beginning, this paper will briefly go through the basic theory of myoelectric signal generation. Next, the signal acquisition & filtering techniques applied for SEMG signal will be explained. Then after this EMG signal control or actuate the myoelectric leg who was suffering from Transfemoral amputee using microcontroller. This paper gives the better controlling SEMG signal and also very smooth and easy controlling of the Prosthetic leg motor using Myoelectric Controller.

Key Words: Myoelectric Controller, Transfemoral Amputee, Electromyography (SEMG), Knee Angle, Flexion, Extension.

I. INTRODUCTION

The electric signal produced during muscle activation, known as the myoelectric signal, is produced from small electrical currents generated by the exchange of ions across the muscle membranes and detected with the help of electrodes. Electromyography is used to evaluate and record the electrical activity produced by muscles of a human body. The instrument from which we obtain the EMG signal is known as electromyograph and the resultant record obtained is known as electromyogram [1]. The nervous system always controls the muscle activity (contraction/relaxation). Hence, the EMG signal is a complicated signal, which is controlled by the nervous system and is dependent on the anatomical and physiological properties of muscles. Figure 1 shows the typical EMG signal.

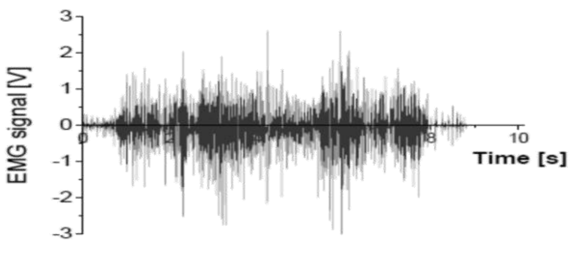

Fig. 1: EMG Signal

II. ORIGIN OF MYOELECTRIC SIGNAL

The nervous system is both the controlling and communications system of the body. This system consists of a large number of excitable connected cells called neurons that communicate with different parts of the body by means of electrical signals, which are rapid and specific. The nervous system consists of three main parts: the brain, the spinal cord and the peripheral nerves. The neurons are the basic structural unit of the nervous system and vary considerably in size and shape.

Neurons are highly specialized cells that conduct messages in the form of nerve impulses from one part of the body to another. A muscle is composed of bundles of specialized cells capable of contraction and relaxation. The primary function of these specialized cells is to generate forces, movements and the ability to communicate such as speech or writing or other modes of expression. Muscle tissue has extensibility and elasticity. It has the ability to receive and respond to stimuli and can be shortened or contracted. Muscle tissue has four key functions: producing motion, moving substance within the body, providing stabilization, and generating heat.

Three types of muscle tissue can be identified on the basis of structure, contractile properties, and control mechanisms: (i) skeletal muscle, (ii) smooth muscle, and (iii) cardiac muscle. The EMG is applied to the study of skeletal muscle. The skeletal muscle tissue is attached to the bone and its contraction is responsible for supporting and moving the skeleton. The contraction of skeletal muscle is initiated by impulses in the neurons to the muscle and is usually under voluntary control. Skeletal muscle fibers are well-supplied with neurons for its contraction. This particular type of neuron is called a "motor neuron" and it approaches close to muscle tissue, but is not actually connected to it. One motor neuron usually supplies stimulation to many muscle fibers. Figure 2 shows the motor unit.

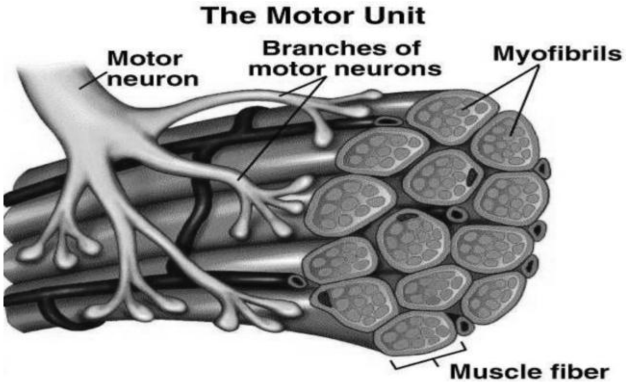

Fig. 2: A motor unit consist of one motor neuron and all the muscles fibre it stimulates.

The human body as a whole is electrically neutral; it has the same number of positive and negative charges. But in the resting state, the nerve cell membrane is polarized due to differences in the concentrations and ionic composition across the plasma membrane. A potential difference exists between the intra-cellular and extracellular fluids of the cell.

In response to a stimulus from the neuron, a muscle fiber depolarizes as the signal propagates along its surface and the fiber twitches. This depolarization, accompanied by a movement of ions, generates an electric field near each muscle fiber. An EMG signal is the train of Motor Unit Action Potential (MUAP) showing the muscle response to neural stimulation. The EMG signal appears random in nature and is generally modeled as a filtered impulse process where the MUAP is the filter and the impulse process stands for the neuron pulses, often modeled as a Poisson process [2].

III. PROPOSED SYSTEM

Aimed at improving the quality of life for amputees, this paper is providing the development of EMG sensor for Transfemoral amputation as well as to make myoelectric controller which is explain below. Two channels of MES are collected from the thigh using gelled surface electrodes. Electrodes are placed equidistant at thigh for knee flexors and knee extensors.

The two MES channels are fed through instrumentation amplifier (AD620), with the limited gain. Outputs of the pre-amplifiers are fed into amplifiers with limited bandwidth set at 50 Hz to 1 kHz. These filtered signals are than rectified and these rectified signals send to the separator comparator for flexion and extension movement. After these signals are also fed to the microcontroller which are send to the motor driving circuit and this motor driving circuit consist of separate relay for flexion and extension movement and after these relay signals send to the motor which is attached on prosthetic leg.

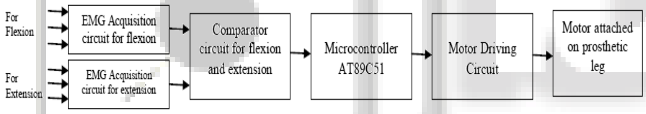

Fig. 3: Generalized Block Diagram of Myoelectric controller

A. *Electrode Placement*

There are two types of electrodes for obtaining EMG signals, inserted (invasive) electrodes and surface (non-invasive) electrodes. The ease of use of surface electrodes makes their implementation for this project preferable. Surface electrodes come in many varieties, with most characterized by the number of contacts. Some different types of surface electrodes are monopolar, bipolar, tripolar and multipolar, all of whose geometry is described by their name. For the purpose of this paper a multichannel bipolar electrodes are used along with a reference electrode in order to implement the differential amplifier.

Here to mimic the natural leg movement myoelectric signals are collected from knee flexor and extensor since these muscle groups are directly responsible for the knee movement of interest. Two differential myoelectric signal channels were recorded using surface electrodes. One channels were used to record potentials for flexors and the other one are used to record for extensor. The desired position for electrodes is on the belly of the muscle and not on the outer edge of the muscle where other muscles could interfere with the muscle under examination.

Here, we were taking EMG in four places in patient's body. This four muscle names are: Rectus Femoris and vastus medialis are responsible for the extensor movement while other two are biceps Femoris (Short head) and are responsible for Extensor movement.

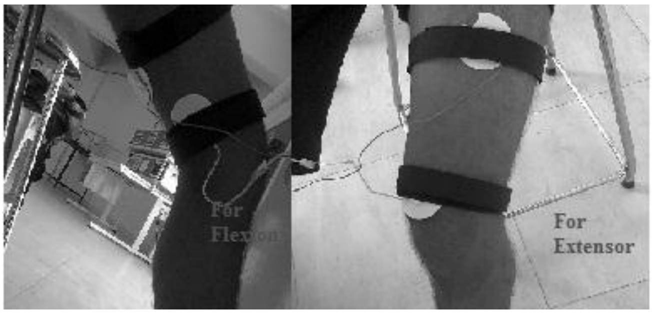

Fig. 4: Electrode Placement

B. *Signal acquisition & filtering Technique*

In this section consist of the Instrumentation amplifier, Bandpass filter, Notch filter, Non-inverting Differential amplifier and Bridge rectifier. The preferred method of amplification for this application is differential amplification using a bipolar electrode and instrumentation amplifier. It is this methods ability to remove electromagnetic noise that the body has picked up that make it the most attractive for this application.

Here the instrumentation amplifier AD620 of Analog Devices is selected for this design due to its high CMRR at high gain. The AD620 is a low cost, high accuracy instrumentation amplifier that requires only one external resistor to set gains of 1 to 10,000.Here Limited gain of approximately 25 is designed as we don't want to amplify noise with the signal.

After, we are use Bandpass filter reject common-mode signals using differential amplifiers, a Bandpass filter are required to increase the signal-to-noise ratio and reject other physiological signals, such as the electrocardiogram (ECG) signal and axon action potential (AAP). A filter is a device designed to attenuate specific ranges of frequencies, while allowing others to pass, and in so doing limit in some fashion the frequency spectrum of a signal. The frequency range(s) which is attenuated is called the Stop band, and the range which is transmitted is called the Pass band. The EMG signal falls within the audio frequency range 10 Hz to 5 KHz. The prominent frequency range from 40 Hz to 1 kHz has to be isolated to be then processed. Hence, filters play a vital role in signal conditioning part of this project.

Notch filter is basically a narrow band reject filter and is commonly used for the rejection of power line frequency hum. Here we have used the notch filter with twin-T network. One T-network is made up of two resistors, and a capacitor, while the other uses two capacitors and a registers. Raw EMG signal contains noise and its amplitude is in microvolt range. At the pre amplifier stage we had set limited gain as signal contains noise so we need further amplification of filtered signal. So output of the notch filter is given to differential amplifier. After we use Bridge Rectifier all negative signals are converted in to the positive signal.

C. Myoelectric controller

In order to successfully achieve prosthesis, an effective control technique is very important in order to drive the electric motors in the mechanism. With the advent of modern microcontroller technology, the control options available today have never been so effective. For implementing the desired control to the motors, the amplified EMG signal in analog form has to be converted into digital format because microcontroller only understand digital signal (0 and 1). After this, the motors are driven with the help of a microcontroller through the thresholding technique. These techniques will be discussed in detail in this section. In this section, we discuss Comparator, microcontroller and motor driving circuit.

1) Comparator

Microcontroller only understands the digital signal, so first we are convert the EMG signal to the digital form. Here, we should use comparator for converting the ANALOG signal into the digital format. A comparator compares a signal voltage applied at the input of an op-amp with a known reference DC voltage V_{ref} given at the other input. It is an open-loop operation, i.e., there is no feedback path in the case of a comparator. Comparators can be classified into two types, namely non-inverting and inverting. Here, Inverting comparator is used.

The signal input is given to the inverting input terminal and the reference voltage is given to the non-inverting input terminal. When the input voltage is greater than the reference voltage that time output of the comparator goes negative V_{sat} pulse. When input signal is less than V_{ref} output becomes positive V_{sat}. Here we set reference voltage according to our EMG signal amplitude or our thresholding voltage. Here, we used separate comparator for flexion and extension and V_{ref} of the comparator are different.

2) Microcontroller

A Micro-controller is simply a “Computer on a Chip”. A CMOS-based 8-bit Atmel AT89C51 single-chip serves as the microcontroller of the system; it accepts the digitized EMG signals and is programmed to control the Geared DC motor. The use of micro controller in the proposed design is to distinguish the different signals results from the different movements of the limb. We make use of the microcontroller in our design because of advantages of microcontroller from our prospective as follow:

1) Programming is Easy and can be used for multipurpose use. Classification of the signals for different movement control can be implemented easily and it can also be used to control the prosthesis via the Geared DC motor.

2) The Product is of a small size so consumes less space. The prosthetic device used is not only function well but also cosmetically good and consume less weight with less space. So this advantage makes the design more stressful.

3) The system designed with very little effort and is easy to troubleshoot and maintain.

3) Thresholding and Motor Driving Circuit

The control of prosthesis leg is provided through the thresholding technique [3]. Once the signal is received from comparator, taking all necessary considerations as described before, a suitable threshold is applied to that particular output of the EMG signal. Before applying the threshold, output of the EMG signal is to be observed properly. A threshold value should then set be accordingly. It is recommended to set the threshold value to a point which is less than half the output of the EMG signal.

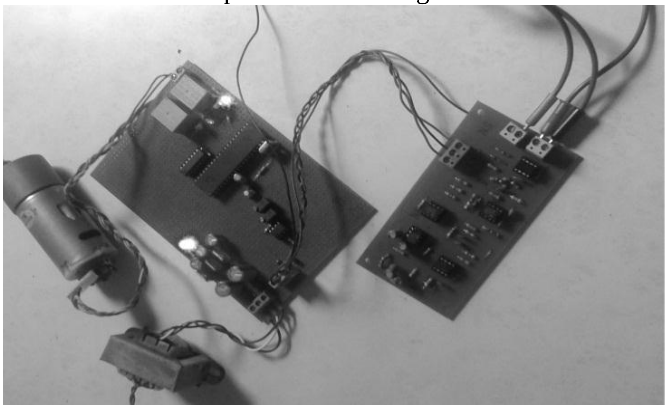

Fig. 5: Hardware of Myoelectric controller

When the output signal of the EMG exceeds this threshold, the microcontroller should set an output pin to ’1’ and ‘0’ otherwise [3]. E.g. if the maximum value of the output of the EMG signal is 2.24V then we can set a threshold of 0.90V. This signal is forwarded to a motor relay driver in order to drive the respective electric motors of a prosthetic mechanism. The motor driver should be designed or selected according to our requirements of electric motor. Usually a motor driver which can drive a 12V motor and handle up to 4A current can adequately meet requirements for a prosthetic leg.

Here, we use the relay based motor driving circuit which is easily drive the Geared DC motor on prosthetic leg. When the flexion signal comes then relay 1 is actuate and Motor run on clockwise direction and if the extension signal comes then relay 2 is actuate and motor run on Anti clockwise direction. Here, we are use Geared DC motor which has 230 rpm at 12 V supply and its gives 30Kg/cm torque which easily convenient for the prosthetic leg.

IV. RESULTS AND CONCLUSIONS

A useful way of acquiring EMG signals and motor drive has been explained in this paper. Modern microelectronics and controllers have enabled us to develop efficient control of prosthetic robotic mechanisms.

As an earlier, we discuss the control of a myoelectric leg. There are two primary motions of the human knee leg, flexing and extending. For flexion, electrode should be placed on Flexor biceps Femoris (Short head) and for extension; the electrode should be placed on Extensor Rectus Femoris. As both muscles exhibit different signal patterns, therefore, a multi-channel input scheme should be employed, so that both signals are gathered independently. Both signals should be observed carefully and a suitable threshold should be set after filtering and amplification. The same procedure is to be followed in order to develop control of all other movement of leg i.e. by placing EMG electrodes on specific muscles which control them, allowing us to classify different motions of the leg [4]. The signal observed from a subject with a moderate built is shown in Table 1. Table 1 provides the EMG signal response from each of the subject's knee joint muscles after amplification and threshold set for their control [3].

When a human uses a prosthetic, he desires to use his natural limb movements to control the mechanism. In order to achieve this, EMG provides the perfect assistance to allow a subject to make normal movements using a prosthetic apparatus, hence, efficient controllers and improved algorithms are essential for enhanced control of the device. Given the fact that EMG was introduced more than 30 years ago, the research community has a come a long way in coming up with innovative techniques, hardware solutions and advanced procedures to design, control and utilize these signals to produce resourceful prosthetic means to tackle disabilities and amputations effectively.

Sr.. No.	**Knee/Leg**	**Muscle Name**	**Peak voltage Reading before contracting (V)**	**Peak voltage Reading after contracting (V)**	**Threshold Set (V)**
1	Knee (Flexing)	Biceps Femoris (Short head)	0.12	1.82	0.60
2	Knee (Flexing)	Semimembranosus	0.20	1.98	0.70
3	Knee (Extending)	Rectus Femoris	0.44	2.12	0.84
4	Knee (Extending)	vastus medialis	0.40	2.62	1.00

Table 1: EMG signals observed and the threshold in terms of voltage

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