Design and Development of a Low Cost EMG Signal Acquisition System Using Surface EMG Electrode

T. S. POO[#1], K. Sundaraj[#2]

[#]School of Mechatronic Engineering,
Universiti Malaysia Perlis (UniMAP),
Kompleks Ulu Pauh,
02600 Arau,
Perlis.Malaysia.
[1]john_poo@hotmail.com

Abstract— **Electromyogram or EMG signal is a very small signal; it requires a system to enhance for display purpose or for further analysis process. This paper presents the development of low cost physiotherapy EMG signal acquisition system with two channel input. In the acquisition system, both input signals are amplified with a differential amplifier and undergo signal pre-processing to obtain the linear envelope of EMG signal. Obtained EMG signal is then digitalized and sent to the computer to be plotted.**

Keywords— **Electromyogram, Surface EMG Electrode, Linear Envelope, Acquisition System, Differential Amplifier.**

I. INTRODUCTION

Human body is an electrical conductor. Chemical reaction in human body will produce a small electrical change. In addition, the characteristics of the electrical signal in the muscle change while electromyograms signal also known as EMG signal is detected [1]. Electromyography (EMG) is a method for evaluating and recording the activation signal of muscle. Electromyography is conducted using an instrument to produce a record called electromyogram. The instrument is used to record the activation signal generated by muscle which is very difficult to interpret and analyse by bare eyes.

The first basic of EMG concept is discovered by Francesco Redi's in 1666 during his study on the insect. Redi discovered a highly specialized muscle of the electric ray fish (Electric Eel) that can generate electricity. In 1792, a publication entitled "De Viribus Electricitatis in Motu Musculari Commentarius" appeared, written by Luigi Galvani, in which the author demonstrated that electricity could initiate muscle contractions. Six decades later, in 1849, Dubios Raymond discovered that it was also possible to record electrical activity during a voluntary muscle contraction. The first actual recording of this activity was made by Marey in 1890, who also introduced the term electromyography [2]. In 1922, Gasser and Erlanger used an oscilloscope to show the electrical signals from muscles. Because of the stochastic nature of the myoelectric signal, only rough information could be obtained from the observation. The capability of detecting electromyography signals improved steadily from the 1930s through the 1950s, and researchers began to use improved electrodes more widely for the study of muscles. Clinical use of surface EMG (sEMG) for the treatment of more specific disorders began in the 1960s. Hardyck and his researchers were the first (1966) practitioners to use sEMG. In the early 1980s, Cram and Steger introduced a clinical method for scanning a variety of muscles using an EMG sensing device [3] [4].

Motor unit is a group of impulse signals and the fundamental of generating an EMG signal. It is generated when the brain is making decision to move the arm. The nerve impulses that stimulate contraction are carried in nerve by bundles of wire-like motor neuron from brain to muscle [5]. As motor neuron going near a muscle, it divides into several branches called axon terminals, each serving different muscle fiber. [6].

Nerves conduct impulses through a travelling wave of depolarization along their axon. Axon is the peripheral extension of the proximally located nerve cell body. At rest, the axon has an intracellular potential that is negative in relation to the extracellular potential. When an axon is conducting an impulse, voltage dependent channels open and allow influx sodium (Na+) ions. This influx of positive ions depolarizes the axon, changes the resting potential further down the axon, causing those channels to open and thus creates a wave of depolarization [7]. During the electrical process of nerve stimulation along its course, waves of depolarization will travel in the both direction from that point. Nerve conduction can be measured in physiological direction of nerve conduction or its opposite direction. Motor and sensory nerve action potential can be measured through skin electrodes if the nerve is sufficiently superficial.

The exchange of ions across the muscle fibres innervated by the recruited motor unit result in small electrical current, which combined for particular motor unit, is known as the motor unit action potential (MUAP) [8]. The aggregate electric signal generated from all of the MUAPs in a detected area is referred as the myoelectric signal, which is also called electromyogram (EMG). The signal propagation precedes muscle movement by around 10 to 100 ms [9].

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Electromyography (EMG) signal is stochastic in nature. The pattern of the EMG signal can be reasonably represented by a Gaussian distribution function. Amplitude of EMG signals can be ranged from 0 to 1.5 mV (rms) while its usable energy is between 0 to 500Hz frequencies and is dominant in 50 to 150 Hz range [10].

II. ACQUISITION SYSTEM PROCESS FLOW

EMG signal is collected from an arm muscle which is known as biceps. Two snap type surface EMG electrodes from Medi-Trace miniseries electrode are attached to the center of biceps muscle. The acquired EMG signal from the electrode is feed into the amplification stage. In amplification stage, the acquired EMG signal is amplified for two different amplifiers. An instrument amplifier is used as the first amplification with the gain of 100. Meanwhile, normal operational amplifier with gain of 20 is used for the second amplification. This is due to the amplitude of raw EMG signal is very small and hardly observed by bare eyes. Therefore, amplification on the EMG signal is required.

A filter is used to eliminate the noise contained in the signal after the signal is amplified. In this acquisition system, notch filter is used to filter out the 50Hz noise in the signal which is being generated in every power source. The notch filter reduces the amplitude of the input signal as the frequency of the input signal comes to 50 Hz [11]. Fig. 1 shows the changing of amplitude with respect to frequency. Input signal amplitude will increase back to original amplitude as signal frequency increases away from the filter frequency.

Amplified and filtered EMG signal is rectified by a single diode to remove the negative part of the EMG signal. Rectification of acquired EMG signal is because of the symmetrical in the EMG signal. As the interest of this study is on the positive part of the signal, thus, the negative part of the EMG signal is eliminated by a diode.

Low pass filter will obtain the outer envelope of the EMG signal before being digitalized by analogue-to-digital converter. Low pass filter is designed to eliminate the 3 Hz frequency in the EMG signal. Linear envelope of EMG signal is obtained after low pass filter. Then, the filtered signal is fed into an analogue-to-digital converter circuit. A signal conditioning analogue-to-digital converter (ADC) is used to sample the signal into 24bit data. AD7710 is a charge balancing ADC and able to output up to 24bit data with no missing code [12]. Output of the ADC is sent to a Programmable Integrated Chip (PIC) to buffer for sending a digitalised signal data into computer through RX232. Received data will be plotted with plotter software. Summarized process flow of the acquisition system is shown in Fig. 2.

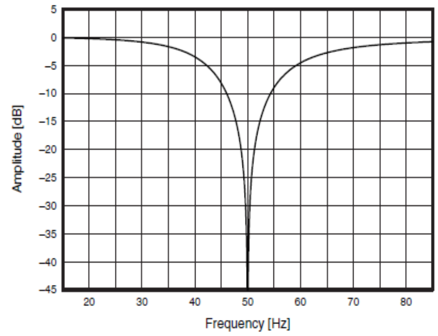

Fig. 1: Change of amplitude of input signal with respect to change of frequency of input signal.

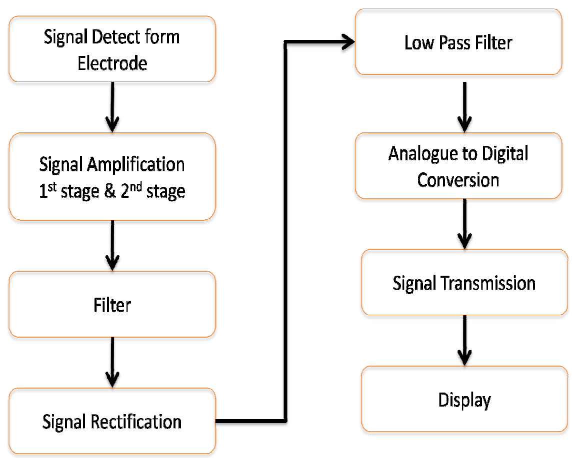

Fig. 2: Process flow of acquisition system.

III. COMPONENT IN THE ACQUISITION SYSTEM

Input EMG signal detected is fed into acquisition system with some signal pre-processing component as shown in Fig. 3 below. In Fig. 3, input electrode cable is connected to the high pass filter in order to remove the effect of motion artifact before input to the instrument amplifier.

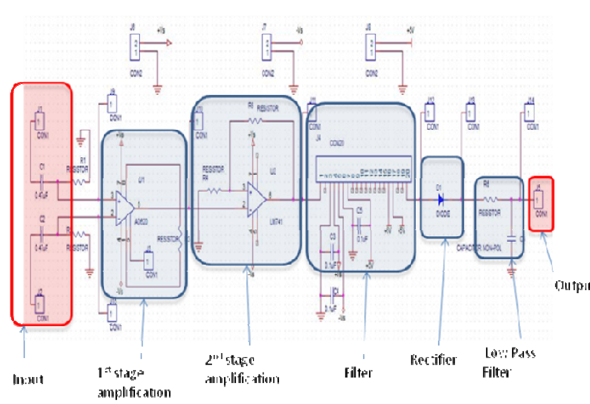

Fig. 3: Circuit diagram of low cost EMG acquisition platform.

Two input signals are fed into the low cost instrument amplifier which the gain of the amplifier can be set with a single resistor. This instrument amplifier is involved in first stage amplification and connected in a way of differential amplifier where two input signals of the amplifier are compared by the instrument amplifier. Both input signals with the common component will be removed and the difference between the input signals is being amplified. Hence, common noise in both input signal is being removed to obtain the EMG signal as illustrated in Fig. 4. This differential amplification technique is applied to eliminate the potentially much greater noise signal from power line sources in the circuit.

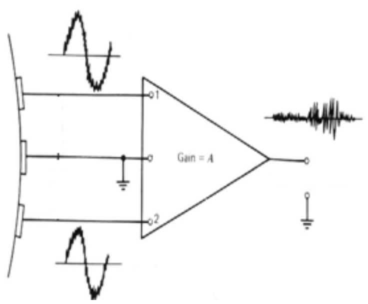

Fig. 4: Differential amplifier rejects the common signal by subtracting the common signal that is present at equal amplitude at each active terminal.

First stage amplifier gain is set to 100 while 20 for second stage amplifier. Therefore, total gain of 2000 is used to amplify the EMG signal from first stage amplification and second amplification. Formula of first stage amplifier gain and second amplifier gain is shown in equation (1) and equation (2). Total gain of the amplification is the product of both first and second amplifier gain as in equation (3).

$$G_1 = \frac{49.4k\Omega}{R_G} + 1 \qquad (1)$$

$$G_2 = \frac{R_2}{R_1} + 1 \qquad (2)$$

$$G_T = G_1 \times G_2 \qquad (3)$$

Where: G1 = First stage amplifier gain.
G_2 = Second stage amplifier gain.
G_T =Total amplification gain.
R_G, R_1, R_2 = Resistor Gain for amplifier.

Single chip filter is used to filter the 50 Hz which can be found in every power source. After filtered, 50 Hz component in the EMG signal is removed. Linear envelope of EMG signal is obtained after the signal undergoes half wave rectification and low pass filter. Rectification of EMG signal is done with one diode to remove the negative part of the signal. Gained linear envelope of EMG signal is digitalized with ADC circuit as shown in Fig. 5. The EMG signal is digitalized to 24bit data, which will send to PIC for transfering the digitalized signal to the computer.

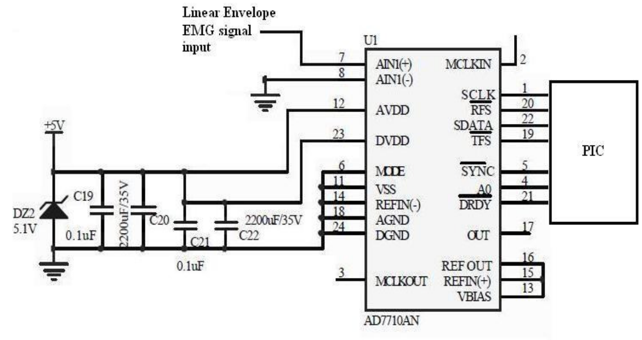

Fig. 5: Analogue to digital converter circuit which convert EMG signal into digital form.

ADC used to convert the EMG signal is programmable. It needs to be programmed every time power up. Therefore, a programmable integrated chip is connected to the ADC. The calibration setting for programmable ADC is burned into the PIC. Consequently, ADC will be programmed once powered up the circuit.

IV. RESULT

EMG signal is collected by using surface EMG electrode placed on the skin of muscle of interest. Fig. 6 shows the placement of two EMG electrodes on the biceps and one for the reference. Reference electrode is placed on the wrist, which is the bony area of hand. This wrist is chose because fewer muscles contain at this area which will generate no EMG signal. Before placing the electrode, subject skin is cleaned to reduce the resistance of the outer layer of skin and ensure good electrical contact. Distance between two electrodes is 2 to 5 cm apart and aligned with the long axis marked on the skin overlaying the belly of the biceps muscle.

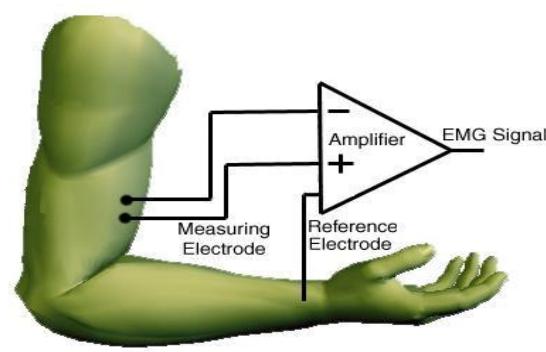

Fig. 6: shows the placement of two EMG electrodes on the biceps and one for the reference.

The acquired EMG is fed into the acquisition system while a subject performs a muscle contraction task. The EMG signal is observed stage by stage in order to monitor the changes in the acquired EMG signal. Oscilloscope is connected to the test point that allocated after first and second stage of amplifier, filter, ratification and low pass filter. Fig. 7 shows the changes of EMG signal on the acquisition system stage by stage. Linear envelope obtained from the output of low pass filter is digitalized and sent into a computer. Plotter software is used to plot the linear envelope EMG signal in the computer as shown in Fig. 8.

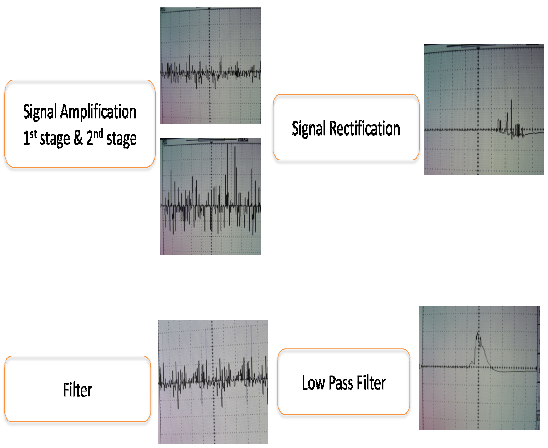

Fig. 7: Stage by stage output of show on oscilloscope.

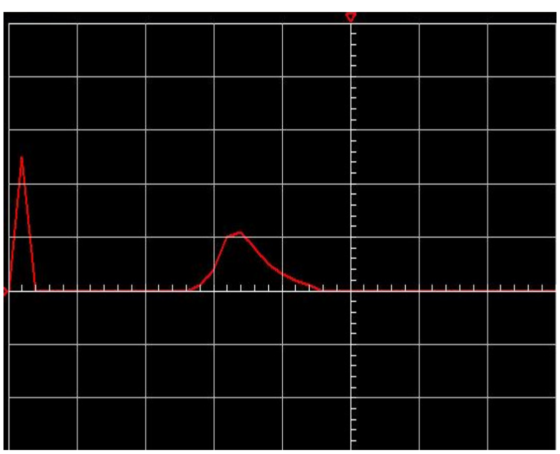

Fig. 8: Linear envelope EMG signal plot in the computer by plotter software.

V. Conclusion

Developed low cost EMG acquisition system is able to detect EMG signal from biceps muscle and obtain linear envelope EMG signal form the output. Besides, linear envelope of EMG signal is successfully digitalized and sent into the computer through a serial communication. The linear envelope of EMG signal is re-plotted with plotter software which can read the digitalized signal from the ADC. In future, more efforts are needed to enhance the communication between acquisitions circuit and computer for faster data transfer. Moreover, multiple types signal input need to be added in future work to enhance the variability of signal monitoring.

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