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DEVELOPMENT OF EMG AMPLIFICATION CIRCUIT

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“ I hereby declare that I have read through this report entitle “Development of EMG Amplification Circuit” and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Mechatronic)”

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DEVELOPMENT OF EMG AMPLIFICATION CIRCUIT

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A report submitted in partial fulfillment of the requirements for the degree of Bachelor of Mechatronic Engineering

Faculty of Electrical Engineering

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“ I declare that this report entitle “Development Of EMG Amplification Circuit” is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree”

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ABSTRAK

Satu litar penguat signal electromyogram (EMG) direka dan diterjemahkan dalam kajian ini. Input litar penguat ini merupakan isyarat EMG yang diukur dari permukaan kulit menggunakan elektrod konfigurasi bipolar yang membolehkan pengukuran isyarat daripada otot yang terlibat dengan cara yang cekap. EMG boleh ditakrifkan sebagai potensi elektrik dihasilkan disebabkan oleh penguncupan otot. Walau bagaimanapun, amplitud isyarat EMG adalah lemah dan sangat kecil yang berada di antara 0 hingga 5mV. Objektif kajian ini adalah untuk mereka bentuk, membina dan mengesahkan litar penguatan EMG yang direka. Litar EMG tersebut terdiri daripada sensor, penghawa isyarat dan memaparkan data. Dalam kajian ini isyarat EMG akan diekstrak daripada otot tangan manusia untuk aktiviti cengkaman pelbagai tangan. Signal output yang dihasilkan menggunakan rekaan litar penguat EMG dijangka menunjukkan pelbagai corak EMG isyarat dihasilkan berdasarkan kuasa yang berbeza genggaman tangan digunakan.

ABSTRACT

An electromyogram (EMG) amplification device is designed and presented in this research. The designed amplifier circuit is fed with EMG signals measured from surface of the skin using bipolar electrodes configuration which enables the measurement of the signal from muscle interest in an efficient manner. EMG can be defined as the electrical po tential produced due to the contraction of muscle. It can be picked from the residual portion of muscles of an amputee. However, the amplitude of EMG signal is weak and very small which is between of 0 to 5mV. The objectives of this research are to design, construct and validate the designed EMG amplification circuit. The EMG measuring system consists of sensor, signal conditioning and display data. In this research the EMG signal will be extracted from human hand muscle for various hand grip activity. The designed EMG amplification is expected to show various pattern of EMG signal produced based on different hand grip force applied.

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CHAPTER 1

INTRODUCTION

1.0 BACKGROUND STUDY

Around the world, there are large number of persons with limb loss due to war, disease and accidents. For example, peoples who involved in tragic accidents will cause paralysis or an amputation which will make they face many difficulties in daily life. Therefore, the disabled individuals need to be assisted with modern technologies such as cybernetic prosthesis in order to improve their quality life. A cybernetic prosthesis is a type of robotic device which consist of a combination of joints, link, servo motors and control algorithm that are put together to resemble the gripping function of human hand [1]. The main objective of prosthetic device is to allow the amputee to grasp objects. By measuring and using the tiny voltage generated by the activity of muscle known as Electromyogram (EMG), the motion of cybernetic prosthesis can be controlled indirectly [1]. This voltage is amplified first and processed so that the actuators on the prosthesis move according to the desired motion when user flexes related muscle.

An approach used for recording, measuring and analysing the EMG signal were investigated by H. Piper for the first time using galvanometer in 1912 and followed by Gasser and Erlanger in 1924 with the assist of oscilloscope [2][3]. For the first time application of EMG signal for controlling powered upper limb prosthesis was applied during 1940s [4]. Then, the development of EMG field was increase rapidly throughout 1960s, 1970s and 1980s [5]. The study of EMG is related to the industry of Biomedical

Engineering and Biomechatronics field for prosthesis that apply EMG signal. In biomechanics field, EMG signal is use as an indicator for the beginning of muscle activation, its relationship towards the force produced by a muscle and use as index of the fatigue processes occurring within a muscle. In Biomedical application, EMG signal provide a way of sensing normal human being and classifying different movement of body effectively [6][7].

In this study, EMG signals are measured indirectly from muscle while the subject grips hand at fixed force but different wrist angle. The FDS (Flexor Digitorum Superficialis) muscle is selected because it is forearm muscle responsible for extension and flexion of hand. In daily life situation, most of human hand motion required both of hand force and joint wrist simultaneously such as to turn the knob to open a door. Data relating of hand grip strength at various wrist angle is very useful to be used as control algorithm to control hand motion of a cybernetic prosthetic hand. Currently, one of the regular methods to measure hand grip force and wrist angle is to use hand dynamometers. This device can provide accurate measurement of hand force applied at varying wrist angle [8].

Electromyogram is well known as EMG which is one of electrophysiological signal and it is extracted from skeletal muscle activity. Skeletal muscle produces electrical activity among muscle fibre caused by the nerve impulses that send from brain during contraction and relaxation of muscle. When muscle fibres contract, there is an exchange of ions in the muscle fibre membranes, this flow of ions generate an electrical current [8]. A pair of electrode made up from Silver Chloride (AgCl) is placed on surface of the skin in order to measure the flow of ions and convert into electron flow [9]. Typically, this signal is too tiny within the range (0-5mV) while the range of frequency is from (6-600Hz), which the dominant frequency range is from (20-150Hz) [10]. Therefore, it required a specifically design amplifier that will assist to amplify the signal. There are few amplification stage are required before the signal can be displayed since to eliminate the noises which interface the EMG signal.

1.1 PROBLEM STATEMENT AND MOTIVATION

Limb loss is not only growing problem in Malaysia but including the rest of the country due to the increasing number of accidents, diseases and serious crimes. After a tragic incident resulting in an amputation, the disabled individual needs to be assisted with all possible modern technological in order to improve his quality of life. A cybernetic prosthesis is a device which can greatly assist individuals with hand disabilities by enabling them to have some of the hand capabilities of an able bodied individual [11].

In war-torn countries such as Cambodia, Iraq, and Afghanistan, 80 to 85 percent of amputees are land mine survivors [12]. Due to the increasing rate of amputations, there is an ever-growing demand for cybernetic prosthesis. Thus, it is very costly for the amputees to afford it since not all the amputees have high rate income. Furthermore, importing components from industrialized countries is expensive. In order to reduce the price is by cutting the production cost to develop the device. One of the important parts of cybernetic prosthesis is EMG amplification device. Therefore, to develop a low cost EMG amplifier device is needed for reducing the price of cybernetic prosthesis.

EMG signal is useful to be used for cybernetic prosthesis. For example, EMG signal based on the hand grip force can be used as part of the control algorithm for cybernetic prosthesis in order to control the strength gripping [13]. Generally, the surface EMG signals are weak and too tiny within the range of 0-5mV. Thus, it is a necessary to boost up this signal with an amplifier which is specifically designed to measure the signal. With the assist of designed and simulation of amplification circuit by using Multisim software, EMG signal can be measure and record for further process.

EMG signals are commonly analysed in a few techniques, basically in terms of the signal's amplitude, frequency content and phase information that relatives to the reference signal. Interface instrumentation will be design which consists of required electronic circuitry to measure EMG signals from the human skin surface and the necessary software to record, display and process these raw EMG. It consists of instrumentation for EMG measurement, the surface electrodes that work as EMG sensor and the EMG signal conditioning circuits to amplify the signals, hand dynamometer that measures the hand grip, the data acquisition device (DAQ), digital oscilloscope and computer to display, record and process the EMG signals obtained experimentally.

1.2 OBJECTIVE OF STUDY

The objectives of this project are listed :

1. To design and simulate the EMG amplification circuit by using Multisim software.
2. To construct the designed EMG amplification circuit.
3. To validate the designed and constructed EMG amplification circuit through extraction of signal from human skin surface.

1.3 SCOPES OF STUDY

1. The experiment will perform with 5 healthy subject within the age range of 20-30 years on their dominant hand.
2. The surface EMG signal by using bipolar electrode configuration is extracted from Flexor Digitorum Superficialis (FDS) muscle.
3. The amplification device will be test by measuring EMG signal with 3 different level of hand grip strength (20N, 40N, 60N) and 3 different wrist angle position (90, 60, 120) degrees by using hand dynamometer.
4. The amplitude of EMG signal from 0-5mV will be amplified to transistor-transistor logic (TTL) ranges of 0-5 V.

CHAPTER II

LITERATURE REVIEW

2.0 INTRODUCTION

This chapter discusses projects and paper works related to this project. These related works have been reviewed carefully in order to improve the quality and reliability of this project. By reviewing the previous projects of other researchers, the gap analysis can be performed. The recommendation of their project can be taken into consideration as improvement of this project. Moreover, there are some useful ideas that can be implemented in this project from other similar projects. Therefore, literature review process extended right from the start until the end of the project. By reviewing the previous works, a proper plan on how this project can be conducted and the features that have to be added in order to make this project reliable and marketable are enlightened. Besides that, there are some findings sources added from internet and books which are very contributive to this project. Throughout the analysis at the beginning of the project the special feature in this project is determined and the components used in this project are decided. In addition, the function and the concept are well understood.

2.2 OVERVIEW OF EMG AMPLIFICATION SYSTEM

In order to develop an EMG amplification device, 5 research paper review to study the concept, methodology, and analysis technique and to make the best comparison and before implemented in this project research.

Sharul N.S. *et al* (2012) present measurement system for EMG signal extract from forearm muscle. The objective of this study is about to investigate the relationship between forearm EMG signal and hand wrist position at different hand grip strength. The system is divided into 4 parts. First part is EMG circuit that used to measure EMG signal from 3 forearm muscles. Second part is hand dynamometer which is required to measure the hand grip force and wrist angle and third part is a data acquisition (DAQ) hardware. The function of DAQ for this study is process data from EMG circuit and inputting data into a laptop for processing. Finally a laptop to record, process and display the EMG signal and force signal. Three muscles were selected which are Flexor Carpi Radialis (FCR), Flexor Digitorium Superficialis (FDS) and Extensor Digitorum Communis (FDC). All these muscle related to the hand and wrist motion. The EMG signal from these muscles is measure using 3 channel EMG circuit. The EMG circuit consists of instrumentation amplifier, high pass filter, low pass filter and galvanic isolation. At instrumentation stage, differential amplifier (Burr-Brown INA128P) is selected which has high common mode ratio (120dB) and gain is set as 20. To reduce unused frequency a high pass filter with 50Hz cut off frequency and a low pass filter with 500Hz cut off frequency were selected. A labVIEW 1V code was written to record both the EMG and hand grip force signals. In this study, left arm from one subject was chosen and asked to perform force level at 1N, 2N, 3N, 4N, 5N and 6N by gripping the hand dynamometer at 3 different angles (60^o, 90^o, and 120^o). Based on the result can be conclude that, the pattern EMG waveform produced from 3 muscle are similar even with different force apply and the 3 muscle can be differentiate by apply different angle of wrist.

Sharul N. S *et al* (2011), present development of EMG circuit in order to investigate the relationship between muscular efforts of the flexor muscle in forearm and hand grip strength. The FDS muscle was chosen since it is responsible for finger flexion during hand gripping. Basically, this experiment is about designing EMG circuit in order to measure EMG signal from the FDS muscle. By using bipolar electrode configuration, AgCl electrode is placed on the FDS muscle to detect the EMG signal. The input signal is amplified with gain 26 by using Burr-Brown INA128P which is one of instrumentation amplifier with high CMRR (120dB). Then the amplified signal is feed into band pass filter which is created by Sallen Key high pass filter with 20Hz cut off frequency and cascaded with Sallen Key low pass filter with 500Hz cut off frequency. When the input signal is filtered it is amplified again with inverting amplifier with gain 100. For safety of the user, galvanic isolation is applied using isolation amplifier. The TDS 1002B digital oscilloscope is used to record the amplified EMG signal. For the force measurement set up, the subject is required to grip the hand gripper with three different forces according to gripper coil deflection. 10% degree deflection represents minimum grip strength, 50% degree deflection represent for intermediate grip strength and 100% degree deflection for maximum grip strength. The result from the experiment showed that the EMG signal frequency is increasing as the hand grip strength increase.

Hao Lin, *et. al*. (2010) present a research and design on surface EMG amplifier. The objective of this study is to analyze the major noise and to design the parameter about surface EMG amplifier, then simulates by using Multisim2001. EMG circuit design consist of bipolar electrodes to pick up the EMG signal from surface body, a differential amplifier Burr-Brown's INA128 to pre-zoom the EMG signal and INA137 is used for reference level. In order to reduce the low frequency noise, a Sallen-Key high pass filter circuit with 10Hz cut off frequency is connected to the INA128. While, 50Hz frequency noise impact is overcome by using the 50Hz notch filter. Burr-Brown UAF42 was used to compose the T notch by using software CAD-FILTER42 from Burr-Brown. The parameters and Notch center frequency was set to be 49.8Hz and 50.2Hz. Next, the input signal is amplified for the second time by using the 100K resistance potentiometer as variable gain amplifier. The amplified signal is cascaded to Sallen-Key low pass filter with 100Hz cut-off frequency. The filter has simple structure, easily and fast adjusted. After that, the EMG signal is put into Analog-Device' AD536 in order to change the RMS to DC. The advantages are, it has excellent performance, can calculate any complex waveforms. The Canadian Interactive Image's Multisim2001 simulation software was used to simulate the hardware design. It is convenient, fast to simulate and easily to choose equipment and replace components.

Zahak Jamal *et al*.(2011). present a research relates to a method for detecting electromyography signals from the extension and relaxation of hand muscles. It is successfully demonstrated with simple DC motor for the two hand motion. In this study, two kinds of surface EMG electrodes were used for signal acquisition Delsys 2.1 single differential and Delsys 3.1 double differential active electrodes and simple disposable EMG electrodes. While, for the reference electrodes is 3M Red Dot Resting EKG Electrode. In addition, the EMG system used is the Delsys-Bagnoli portable EMG system which has two channels and also can amplify the signal up to 100, 1000, or 10000 times. The position of the electrodes is very importance as to distinguish all the five finger movements based on its reflective muscles. In order to drive the motor for a prosthetic hand, a differential amplification technique is used for signal acquisition. In this experiment, the IC INA121 was used as an instrumentation amplifier. It can give a gain up to 10000 times. After amplification, the analog signal needs to be converted to digital signal by using Analog-to-Digital Converter (ADC). A 10-bit ADC which came as peripheral with ATMEGA8 microcontroller was selected. The control for the motor is provided with help of thresholding method. When the digital output crosses this threshold, the microcontroller sets an output pin to '1' and forwarded to a motor drive circuitry in order to drive a motor. It was observed that the motion of fingers gave a set of pattern when their muscles were contracted.

Samir B, *et al.*(2007). The present invention related to develop a low cost grip transducer based on Hall Effect component to quantify the fingertip touch force. The aim of this research is to investigate how the fingertip force grasping affects the adductive motion of the thumb. The EMG amplifier design consists of three AgCl electrodes, a differential amplification of AD524 with gain 1000 to zoom the EMG signal. Then, the signal is feed to band pass filter which is made by 2^{nd} order Butterworth high pass filter with cut off frequency 0.05Hz and cascaded with 4^{th} order Butterworth low pass filter, 500Hz cut off frequency. Both outputs signal from EMG amplifier and from fingertip transducer are feed into commercial National Instrument (DaqBoard 1005) which has 20KHz sampling rate with 16bits resolution. A preliminary experimental test has been carried out for fingertip force grasping according to the AdP muscle for controlling the adductive motion of the thumb. The intensive activities can be observed during contact acting. The experimental results show that the changes of dynamic fingertip force affects the intensity of AdP EMG of the thumb and the acquired signals are satisfactory and present a high immunity to interferences particularly against the power source.