ROBOT ARM CONTROLLED BY MUSCLE TENSION BASED ON ELECTROMYOGRAPHY AND PIC18F4550

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Abstract—*Along with the progress of time, the application of science of robotics is also growing and starting to get the shares in many fields, especially the biomedical field that will be very beneficial to mankind's survival.*

In this thesis the writer will discuss the design and application of electromyography or more commonly known as gauges muscle tension to move the robot arm with the aid of a microcontroller PIC18F4550, with this final project the writer transforms muscles signals that are usually presented in the form of graphs or audio into physical form of movement using a robot arm.

Keyword: Electromyography , PIC18F4550 , Rectifier , Servo , Robotic Arm , Amplifier.

I. PRELIMINARY

Today's modern technological development has been growing very rapidly and play an important role in the daily basis on human life, including the mechanics and electro medical sector, both of those knowledge could help people with disabilities such as who has lost their motoric function and then replaced with electronic motor in the form of robot arm.

One of the options that can be used to be utilized by electro-medical system is a muscle, the muscle still can be utilized by reading the state when it's contracted for when someone has lost their arm due to amputation. The left over muscle from an amputated arm can be used to move the robot arm by some processing invloved.

By the time the muscle contracts, it will generate impulse signals that can be read by electrodes which can then be amplified and later on processed though a microcontroller for controlling robot arm with servo motors.

II. THEORETICAL BASIS

Before going any further into the discussion of how the design are made, the first thing to be understood is the origin of the voltage signal which is to be read by the electrodes attached to the skin surface, this voltage signal occurs by the process of polarization and depolarization of two most important Ion in the muscle cells, these ions are sodium (Na +) and potassium (K +), the occurring process of voltage is divided into 3 parts, namely Polarization (flexing), Depolarization (muscle relaxation), and Resting condition[1].

The following is an explanation of each phase and the impact on the readout signal voltage:

- Resting Phase : In this phase occurs a balanced circulation between sodium (Na+) and potassium (K+) ions and in the theory, muscle cells produces -80mV.
- Depolarization : In this phase the muscle contracts and the sodium ion displace the potassium ion from outside into the muscle cells in a larger portion in compared with the release of potassium ion from the inside of a muscle cells, During this displacement process of the ions through the cell membrane of a muscle, there are voltage fluctuations on the muscle cells by 120mV.
- Polarization : In this phase occurs relaxation of the muscles resulting a displacement of sodium ions to the outside of muscle cells with greater proportions than potassium ions that enter the muscle cells, in theory this process gradually decrease the voltage back to -80mV.

With the above theory, then a simple flow chart was made to illustrate a simple signal processing process to be easy to work with the microcontroller.

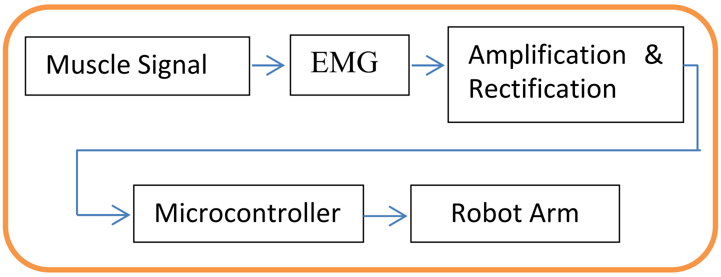

Figure 2.1 Block diagram of the system.

From the figure 2.1 above it can be figured how the system functioned and the components needed in the design process according each part of the stage.

The signal from the Electromyography system does not directly processed by a microcontroller, but it's amplified beforehand because the signal that were generated by electromyography system was too small to read by the microcontroller, other than amplified, the signal is also rectified because it's an AC signal that cannot be directly processed by a microcontroller and by rectifying it also simplifies the processing inside the microcontroller.

A. Electrode

In this final project proposal, electrode is an important factor for this measurement, because it acts as an gateway for the signal to be read by this tool, in this testing the writer use the gel type electrode.

Gel type electrode composed of Electrolyte Gel as a chemically linked bond between the skin and part of the metal electrode. Oxidative and reductive chemical reactions occur on the surface between the metal and the gel, the main composition of the metal part of the electrode is Silver Chloride[2][4]. The silver chloride part easily facilitate the current flow passing through the bend between the electrolyte and the metal parts of the electrodes, Gel type Electrodes were used during the measurements because the noise goes far less compared with the silver chloride type.

Figure 2.2 Gel type electrode

B. Servo Motor

Servo motor is a DC motor that equipped with a control circuitry. This control circuitry will provide feedback on the motor's rotational position from 0 to 90 degrees and -90 degrees. Besides, this motor also has a relatively strong torque.

Figure 2.3 Exhibit of a servo motor.

The Input of servo motor consists of three parts, namely Vcc, Gnd, and Control (PWM = Pulse Width Modulation).Giving PWM to the servo motor will make the servo move in a certain position and then stops to maintain its position if the signal is given periodically afterwards.

Here is an example of some of the signals used to control the servo motors along with the position of its movement.

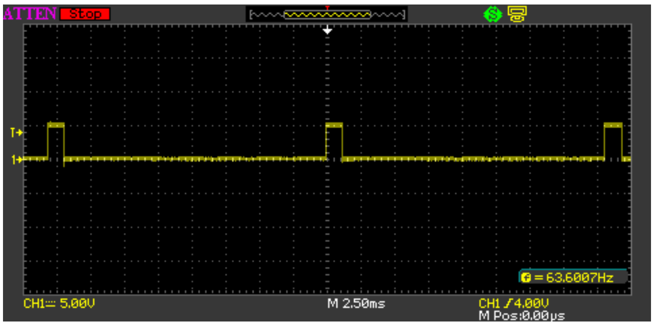

Figure 2.4 Control signal pulse for 0° Position (Centre).

C. Operational Amplifier

Operational amplifiers (Op-Amp) is an electronic component which is a series of transistor and other electronic component packed into an integrated circuit (IC) which has two inputs inverting and non-inverting with an output terminal. Feedback circuit can then be added to control the overall response characteristics of the operational amplifier (Op-Amp) itself.[6] To summarize operational amplifier (Op-Amp) is a differential amplifier that has two inputs and one output. Op-amp is used to form linear functions or other various kinds of operations, it’s often referred to as the basic linear integrated circuits. Operational Amplifiers (Op-Amp) is an analog electronics component that serves as a multipurpose amplifier in integrated circuit form and have a symbol as follows:

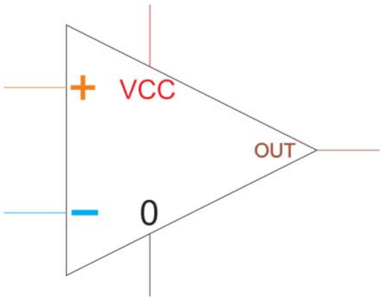

Figure 2.5 OP-AMP Symbol

D. Envelope Detector

Envelope detector is a circuit consisting of a diode, a resistor and a capacitor. The purpose of this circuit in the EMG system is to maintain each peak value[6] that has been produced by the previous stage amplification of the muscle signal itself.

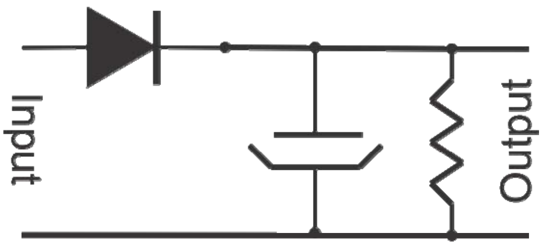

Figure 2.6 A simple envelope Detector

The figure below shows the output of an envelope detector corresponding to the given input signal.

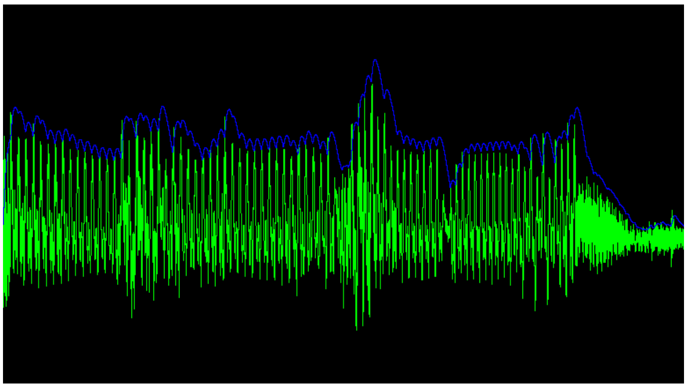

Figure 2.7 Input Signal (Green) Output signal (Blue) of the Envelope detector

III. *HARDWARE & SOFTWARE DESIGN*

This setup uses two circuits , namely analog circuits such as operational amplifiers and digital circuits in the form of a microcontroller.

Analog circuits that are in use on this final project consists of three operational amplifiers, the instrumentation amplifier AD620 is used specifically because of it's main purpose in EMG field, the function of the instrumentation amplifier itself is to amplify the muscle signals obtained from the skin surface. Selection of instrumentation amplifier AD620 was based by the principal applications in the product datasheet.

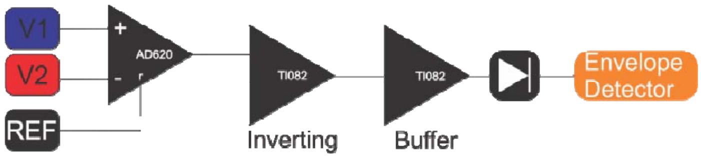

Figure 3.1 Signal Processing Flow

The second operational amplifier IC is a Dual Op-Amp that configured as an Inverting and Buffer amplifier, Meanwhile the second Op-Amp was configured in inverting amplifier mode and the feedback resistor was substituted with a variable resistor for variable gains, the aim is to simplify the adjustment of amplitude of the output signal which generated from the input amplification, then the signal is put into Buffer Amplifier on the third op-amp which given diode and Envelope Detector at the output, the purpose of rectification process and filtering is to average the signals of muscle that has been amplified into a DC signal that can be read by the ADC of the PIC18F4550 microcontroller.

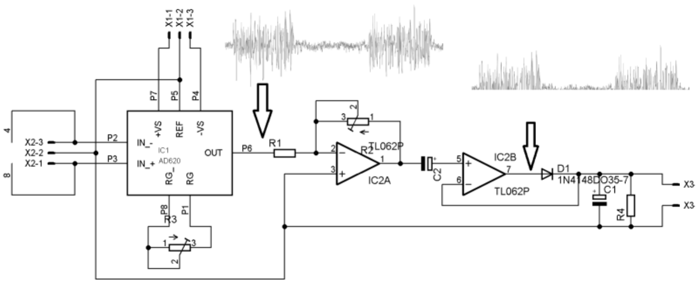

Figure 3.2 Schematic diagram & Signal

From Figure 3.2 it can be simply concluded how the muscle signal readout works and each part of the circuit can be separately described.

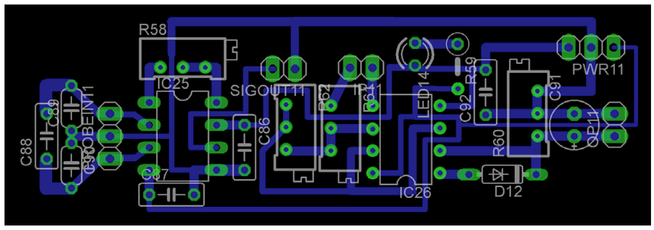

Figure 3.3 Layout & component placement of the EMG PCB

A. Instrumentation Amplifier

A specific operational amplifier is needed because a certain criteria has to be met in the design process, which is small physical footprint, low external component count, and optimized for EMG purpose.

AD620 is specifically built IC for use in EMG signals applications and ECG readings other than that the usage is relatively much more easier in comparison with any other Op-Amp circuit.

By simply adding only a resistor to set the value of amplification on the Op-Amp, the circuit in use can be made throughout as minimalistic as possible.

AD620 is minimalistic because it only requires only one resistor to determine the gain values, the formula for determining the value of the resistor that is used and the resulting gains are as follows:

$$R_G = \frac{49.4k\Omega}{G-1} \tag{1}$$

Note:
RG = Desired Gain Resistor Value

G = Desired Gain Value

In this thesis, the author used 275.9 for the gain value, so the resistor that is used by the author is 180Ω, this value of resistor is considered as the most accessible on the market and generating enough gain for processing at a later stage.

B. General Purpose High Impedance Dual Op-Amp TL062

The Selection of TL062 Op-Amp is based over the high input impedance of the op-amp because it has a JFET Front End and this component can be easily bought in the market.

In this application, TL061 is used in two different modes, namely the inverting amplifier and Buffer mode, Inverting amplifier Mode is used to set the second signal amplification which is derived from AD620. The reason for second amplification after AD620 is to reduce excessive noise from single stage amplification.

Since the output signal from the previous stage amplifier was still in the form of impulses, Buffer Mode is used in conjunction with a diode on the output stage and envelope detector, the objective of this setup is to rectify the output signal that has been previously amplified and maintain a stable DC signal over the signal peaks to further read by the microcontroller's ADC.

C. Microcontroller

The microcontroller which used in this final project is PIC18F4550, This microcontroller is chosen because the author has already familiar with it alongside that it has many ports that can be used as input or output and it also has quite a lot of ADC input, which are 13 channel inputs.

In its use microcontroller has to be programmed in order to process data from in the input, in this final project PIC18F4550 microcontroller was programmed to convert values from the ADC input into servo motors control signal to move the robot arm.

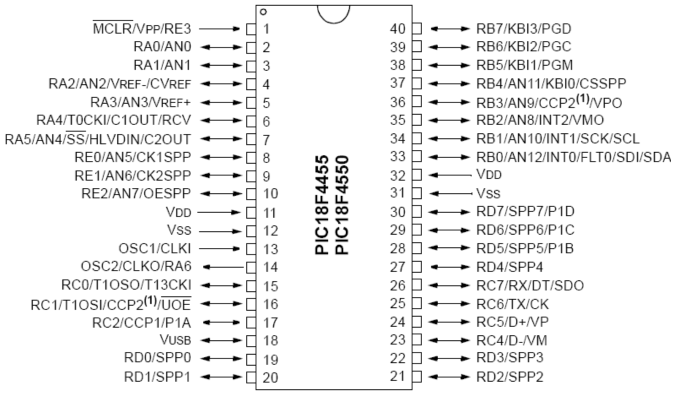

Figure 3.4 Pin-out of PIC18F4550

D. ADC

ADC in PIC18F4550 has 10bit resolution which means that if the analog value of 5 volt given to the input and converted to digital value, it will generate value of 1023, this digital value which then will be converted into a signal that can be used to control a servo motor.

E. Program

In this sub-chapter briefly described the algorithm that has been used in the program for driving the servo motor based on the output voltage of the EMG circuit.

F. Program Algorithm

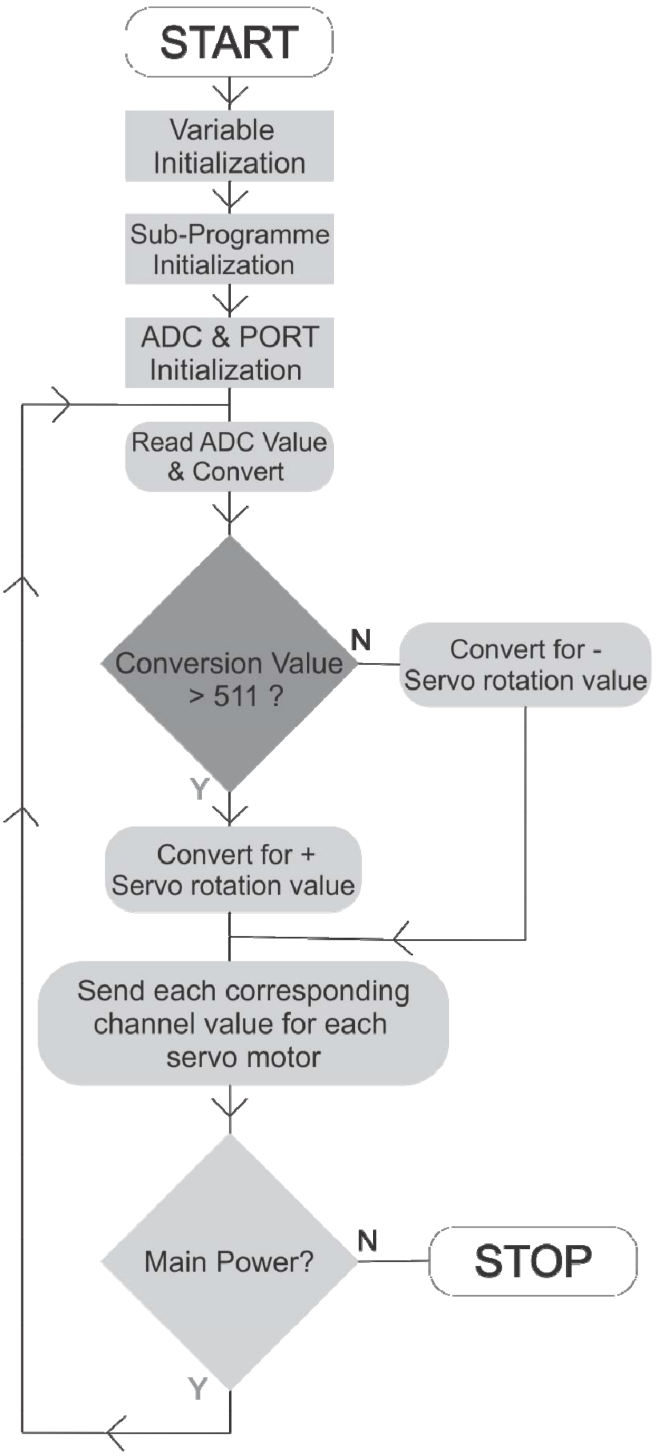

Figure 3.12 Program Algorithm

IV. *CONCLUSION*

Based on the experimental results and observations have been conducted in the laboratory, it can be concluded that:

1. The simple EMG circuit that was made has worked well in reading and amplifying the muscle signals obtained from the skin surface using gel-based electrodes.

2. The robot arm program code that was made has been running well according to design after calibration with certain the type of muscle and can be used to drive 2 servo motors or more according to the number of input signals, while the program response according to muscle signal is nearly real time.

3. The prototype of EMG circuit, Program code, and the robot arm that has been made in according to its initial design is working.

V. BIBLIOGRAPHY

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