# KANTIPUR ENGINEERING COLLEGE

**(Affiliated to Tribhuvan University)**

**Dhapakhel, Lalitpur**

**[Subject Code: EX755]**

**A FINAL YEAR PROJECT REPORT ON**

# "BIO-ROBOTIC ARM"


**Submitted by**

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**A MAJOR PROJECT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE OF BACHELOR IN ELECTRONICS & COMMUNICATION ENGINEERING**

**Submitted to:**

**Department of Computer and Electronics Engineering**

**August, 2017**

# BIO-ROBOTIC ARM


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**Supervised by:**

**Er. Sachin Shrestha**

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**KANTIPUR ENGINEERING COLLEGE**

**DEPARTMENT OF COMPUTER AND ELECTRONICS ENGINEERING**

# APPROVAL LETTER

The undersigned certify that they have read and recommended to the Institute of Engineering for acceptance, a project report entitled “BIO-ROBOTIC ARM” submitted by Bipul Ranjitkar, Prabindra Pradhan and Sahaj Shakya in partial fulfillment for the degree of Bachelor of Engineering in Electronics & Communication Engineering.

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# ACKNOWLDGEMENT

We would like to express our gratitude to the “**Department of Computer and Electronics Engineering**”, Kantipur Engineering College for granting us the permission to undertake this final year major project entitled: "**Bio-Robotic Arm**". We are also grateful to our project coordinator **Er. Sujin Gwachha** for his diligent guidance and encouragement. We are sincerely thankful to **Er. Bibhu Sharma** for his guidance in designing the Mechanical components. And we would like to thank all our teachers for their knowledge imparted, guidance and cooperation. Further we are grateful to the KEC electronics lab, KEC workshop, KEC store and the KEC library for offering us the flexibility of various research and build material to advance this project.

We are sincerely grateful to our Supervisor, **Er. Sachin Shrestha**, for his continuous guidance, suggestions and continuous supervision during this project. We would very much like to thank Robotic Association of Nepal (RAN) for providing crucial build materials required for completing this project.

Lastly, we would like to express our sincere thanks to all our friends, seniors and all others who helped us directly or indirectly in completion of this project.

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# ABSTRACT

Amputee and Archeiropody patients often use an artificial hand or other types of prosthetics to regain part of the lost functions. However the advanced robotic prosthesis is economically out of reach of many patients. In this project, we have described a low cost system that operates from the low dimensional surface EMG signal derived from the arm of the human body to control a robotic arm. We developed an EMG sensing circuit that works with surface bio-electrodes and a hand and arm mechanism actuated by servo-motors. Our system uses the low dimensional EMG data and map specific patterns to derive the action of the robotic arm as a form of prosthetic arm with movements similar to a human arm. The system is controlled with an Arduino Uno board that uses microcontroller Atmega328.


Keywords: EMG, robotic arm

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# ABBREBIATIONS

**A**

1. ADC : Analog to Digital Converter

**C**

2. CAD : Computer Aided Design
3. CNC : Computer Numeric Control

**D**

4. DARPA : Defence Advanced Research Project Agency
5. DRL : Driven Right Leg

**E**

6. ECG : Electrocardiography
7. EDA : European Defence Agency
8. EEG : Electroencephalography
9. EMG : Electromyography

**I**

10. IDE : Integrated Development Environment
11. IDLE : Integrated Development and Learning Environment
12. iEEG : intracranial Electroencephalography

**M**

13. MAV : Mean Amplitude Value
14. MEG : Magneto encephalography
15. MU : Muscles Unit

**R**

16. RAM : Random Access Memory
17. RISC : Reduced Instruction Set Computer
18. ROM : Read Only Memory

# CHAPTER 1: INTRODUCTION

## 1.1 Introduction

This project “Bio-Robotic arm” is project based on a biofeedback mechanical arm that uses a low dimensional input derived from EMG (electromyography) data. The work involves creating a system that allows signals recorded directly from a human body to allow control of a part of a robotic arm.

A robotic arm is controlled using the EMG signal acquired from the electrodes attached to the human arm. The EMG signals are acquired from three different muscle groups of the upper forearm. Considering the EMG signal be very noisy and of the order of micro volts, appropriate filters and amplifiers can be used to provide a valid data. The signals recorded directly from a human body is amplified and filtered to allow control of a portion of a robot arm. The purposed system is designed to use these low dimensional data and map specific patterns to resulting actions of a robot arm [5]. The system can be used as a Bio-Robotic arm for Archeiropody patients (congenital defect, meaning you are born with this condition), amputation (traumatic or surgical condition for removal of body parts). Industrial purpose such equipment movement in normal as well as shied areas, Military purpose for bomb defusing and so-on.

## 1.2 Background

Currently, successful autonomous completion of complex, high-level strategies by a robot relies heavily on human input for control. The unpredictability and density of information provided by the environment surrounding a robot, combined with inaccuracies in sensor measurements make these tasks difficult for a robot to complete. Human brain and human body, on the other hand, are capable of processing large amounts of information and are better at making rational decisions based on these data than current autonomous systems [5].

In some cases, robotic motions and behaviors can be pre-recorded so that the operator only needs to satisfy a simple condition to trigger playback of the action.

While this might work in static cases but in dynamic cases, situations may arise where a pre-determined movement may not be appropriate or possible [7]. In such cases, a human to robot relationship needs to be established for better outcomes rather than an autonomous system [1].

## 1.3 Rationale

Generally, prosthetic arm is not capable of functioning like a human arm. External movement from another or same user needs to be applied. A Prosthetic arm is incapable of movement, placement and pointing objects. Similarly, successful autonomous completion of complex, high-level strategies by a robot relies heavily on external human input for control. In order for robots to do all but the simplest of tasks, such as obstacle avoidance or color segmentation, human intervention and guidance play a major role. Even tasks as simple as moving through a doorway can be surprisingly tough for an autonomous robot.

Our purpose system is capable of perform the above task without any external users input. The system basically relies on the input from the user itself. The input signal is taken by using a low dimensional bio-medical sensor that is further amplified and filtered followed by sampling and analysis. The raw data is converted to feedback signal which incorporated with the motor rotation for the movement of the arm.

## 1.4 Objectives

i. To design a robotic arm.
ii. To utilize biomedical signals in Robotics.

## 1.5 Features

i. The system movements based on human muscle activation.
ii. The system is capable of transition and rotational movements.
iii. The user can monitors its bio-signal patterns and muscular movements.

## 1.6 Feasibility Analysis

### 1.6.1 Economic Feasibility

All the components are easily available in local Electronics Market and College. The main components used for the expected system are easily available in local electronics market and inside college and the cost of all the components are reasonably cheap.

### 1.6.2 Technical Feasibility

Microcontroller provides real time clock and it helps in signal analysis. The EMG sensor provides raw data. Low dimensional and noisy bio-medical input signals are derived from the sensors which is further filtered out and amplified by using proper electronic devices and algorithms. The raw data signals are processed and analyzed. These processed signals are compared with the raw data for feedback bio signals. The feedback signals are used for controlling the motors using the microcontrollers. The signals incorporates with the motor rotations for the movement of the robotic arm.

# CHAPTER 2: LITERATURE REVIEW

## 2.1 Literature review

Until recently, robots were mainly used in factories for automating production processes. In the 1970s, the appearance of factory robots led to much debate on their influence on employment. Mass unemployment was feared. Although this did not come to pass, robots have radically changed the way work is done in countless factories. This article focuses on how the use of robotics outside the factory will change our lives over the coming decades. New robotics no longer concerns only factory applications, but also the use of robotics in a more complex and unstructured outside world, that is, the automation of numerous human activities, such as caring for the sick, driving a car and killing people. New robotics is driven by two long-term engineering ambitions. Firstly, there is the engineering dream of building machines that can move and act autonomously in complex and unstructured environments i.e. Static cases. Secondly, there is the dream of building machines that are capable of social behavior and have the capacity for moral decision making i.e. dynamic cases. New robotics offers numerous possibilities for making human life more pleasant, but it also raises countless difficult societal and ethical issues.

A robotic arm is a type of mechanical arm, usually programmable, with similar functions to a human arm; the arm may be the sum total of the mechanism or may be part of a more complex robot [2]. The links of such a manipulator are connected by joints allowing either rotational motion (such as in an articulated robot) or translational (linear) displacement [3]. The first prototype, Unimate, was produced in 1961 and installed in GM's factory for die casting handling and spot welding. It cost $65,000 to produce yet was sold for $18,000. After that, GM installed 66 more Unimates and Ford became interested as well. The industrial robot future was certain to be bright with all of the automotive interest and investment. Modern industrial robot arms continued to evolve in the 1960's and 70's around the globe. In 1963, the six-jointed Rancho Arm was created to assist handicapped. This was followed by the tentacle arm, designed by Marvin Minsky in 1968. It was able to lift a person and had 12 joints. So, in 1969 the Standford Arm eventually led to commercial arm production. The Stanford Arm was one of the first electronically powered, computer-controlled arms. The Stanford Arm was followed by the Silver Arm in 1974. The Silver Arm was created by MIT's David Silver to perform precise assembly using touch and pressure sensors and a microcomputer. By the middle of the 1970s, industrial robots had boomed and were expected to grow at rates around 30% per year. The industrial robotic industry officially took off and never looked back. It wasn't until recently that the robotics industry has regained mid-1980 revenue levels. By 2014, there was a 29% increase in robot sales across the globe.

Similarly, Electromyography (EMG) is a diagnostic procedure to assess the health of muscles and the nerve cells that control those (motor neurons) [4]. An EMG uses tiny devices called electrodes to transmit or detect electrical signals. The introduction of the first commercially available electromyography (EMG) system was from 1950. From 1950 to 1973 was the era of the analog EMG systems: EMG signals were recorded, and subsequent analyses were carried out manually on film or paper. From 1973 to 1982, the first modular digital EMG systems were introduced. Dedicated analysis modules were introduced, but detailed analysis was still done on paper. In 1982, the first system controlled by a microprocessor was introduced. From 1982 to 1993, many new ways of analyzing EMG signals and basic reporting features were implemented in the EMG systems. Since 1993, personal computer technology has been used in EMG systems. Standard software and hardware components are used to record, analyze, and document EMG examinations. Since 1950, many people have influenced the development of new features in commercial EMG systems [6].

The history of EEG is detailed by Barbara E. Swartz in Electroencephalography and Clinical Neurophysiology. In 1912, Ukrainian physiologist Vladimir Vladimirovich Pravdich-Neminsky published the first animal EEG and the evoked potential of the mammalian (dog).In 1914, Napoleon Cybulski and Jelenska-Macieszyna photographed EEG recordings of experimentally induced seizures. German physiologist and psychiatrist Hans Berger (1873–1941) recorded the first human EEG in 1924 [1]. Since then the research on EEG has grown rapidly. Research on BCIs began in the 1970s at the University of California, Los Angeles (UCLA) under a grant from the National Science Foundation, followed by a contract from DARPA. The papers published after this research also mark the first appearance of the expression brain–computer interface in scientific literature. In 1998 Doctors implanted electrodes on the brain of a paralyzed person to control cursor into the computer. By 2014 Ohio Doctors were able to control the body parts by inserting electrode and microchips into the brain.

Brain and Muscles computer interface is a research field been studied since middle of 70s in diverse areas of knowledge such as neuroscience, biomedicine, automation and control engineering and computer science. “The Thought Experiment” was performed in 2014 in which a paralyzed person controlled his limbs using brain computing based EEG signals. “SIMTK” is a free research project hosting platform that is currently researching in biomedical signals. Similarly, “Neuromorphic Lab” is a research based area which studies biological intelligence to develop adaptive Neuromorphic brains, muscles and robots. Controlling of bio-mechanical arm is currently under studied by Washington University Computer Science and Engineering Research department which is able to perform 2 degree motion movement of the arm using human signal such as EMG, EEG, iEEG, MEG, ECG and so-on. “Ryan Mintz”, “University of Toronto” has made a robotic arm using Emotiv EPOC headset, a laptop, and a robot arm supplied by the university. The headset captures electromyographic (EMG) signals [5]. The electrical currents given off by nerves in skeletal muscles and their homebrew software then processes the signal into a numerical value from zero to five that corresponds with a movement the arm can make. This means that clenching your jaw and winking your eyes in sequence can direct the arm to perform a task like picking up an object.

The purpose system works on similar principle as a mechanical arm with various additional features such as rotational and linear movement of the for arms, arms muscles, and fingers with the help of series of inputs from the muscles .The expected system is assumed to produce valid outputs in both static and dynamic cases [7].

# CHAPTER 3: SYSTEM REQUIREMENTS

## 3.1 Software Requirement

### i. MATLAB

MATLAB (matrix laboratory) is a multi-paradigm numerical computing environment and fourth-generation programming language. The MATLAB platform is optimized for solving engineering and scientific problems. The matrix-based MATLAB language is the world's most natural way to express computational mathematics. Built-in graphics make it easy to visualize and gain insights from data. A vast library of prebuilt toolboxes lets you get started right away with algorithms essential to your domain. The desktop environment invites experimentation, exploration, and discovery. These MATLAB tools and capabilities are all rigorously tested and designed to work together.

### ii. Proteus

The Proteus Design Suite is an Electronic Design Automation (EDA) tool including schematic capture, simulation and PCB Layout modules. It is a CAD Design software used for Schematic Capture, Microcontroller Simulation and PCB Design. Before hardware implementation, the whole circuit is simulated in this Cad designing software and based on the result the product is made.

### iii. Arduino Software (IDE)

The Arduino Integrated Development Environment - or Arduino Software (IDE) - contains a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions and a series of menus. It connects to the Arduino and Genuino hardware to upload programs and communicate with them. Programs written using Arduino Software (IDE) are called sketches. These sketches are written in the text editor and are saved with the file extension .ino. The message area gives feedback while saving and exporting and also displays errors. The console displays text output by the Arduino Software (IDE), including complete error messages and other information.

### iv. IDLE

IDLE (Integrated Development Environment or Integrated Development and Learning Environment) is an integrated development environment for Python, which has been bundled with the default implementation of the language since 1.5.2b1. It is packaged as an optional part of the Python packaging with many Linux distributions. It is completely written in Python and the Tkinter GUI toolkit (wrapper functions for Tcl/Tk). IDLE is intended to be a simple IDE and suitable for beginners, especially in an educational environment. To that end, it is cross-platform, and avoids feature clutter.

### v. Pyplot

It provides a MATLAB-like plotting framework. Pylab combines pyplot with numpy into a single namespace. This is convenient for interactive work, but for programming it is recommended that the namespaces be kept separate. This script falls onto math library which constantly checks and processes the signal within the microprocessor.

### vi. Matplotlib

Matplotlib is a Python 2D plotting library which produces publication quality figures in a variety of hardcopy formats and interactive environments across platforms. Matplotlib tries to make easy things easy and hard things possible. You can generate plots, histograms, power spectra, bar charts, error charts, scatterplots, etc., with just a few lines of code. For a sampling, see the screenshots, thumbnail gallery, and examples directory.

## 3.2 Hardware Requirement

### i. Arduino

Arduino is an open-source project that created microcontroller-based kits for building digital devices and interactive objects that can sense and control physical devices. The project is based on microcontroller board designs, which use inputs and outputs in the same way an ordinary computer does. Inputs capture information from the user or the environment while outputs do something with the information that has been captured. An input could be digital or analog, and could come from the environment or a user. Outputs can control and turn on and off devices such as motors or other computers. These systems provide sets of digital and analog input/output (I/O) pins that can interface to various expansion boards (termed shields) and other circuits. The boards feature serial communication interfaces, including Universal Serial Bus (USB) on some models, for loading programs from personal computers. For programming the microcontrollers, the Arduino project provides an integrated development environment (IDE) based on a programming language named Processing, which also supports the languages C and C++. The Arduino language is very similar to C, but provides several libraries for ease of use.

Figure 3.1: Arduino Uno

### ii. Electrodes

Electromyography (EMG) is a diagnostic procedure to assess the health of muscles and the nerve cells that control them (motor neurons). Motor neurons transmit electrical signals that cause muscles to contract. To record the EMG signal, electrodes must be used as transducers. These are usually made of metal. The most widely used electrodes for biomedical applications are silver electrodes which have been coated with sliver chloride by electrolyzing them for a short time in a Sodium Chloride solution. All electrode suffer from variations in contact resistance due to movement, and drying out of any coupling medium. This is improved by setting the electrode back slightly from the surface of the skin (floating electrode) on a quantity of coupling jelly (electrolyte paste).

Figure 3.2: Surface Bio Electrode

### iii. ICs

- **Instrumentation Amplifier - AD620AN**

The AD620 is a low cost, high accuracy instrumentation amplifier that requires only one external resistor to set gains of 1 to 10,000. Furthermore, the AD620 features 8-lead SOIC and DIP packaging that is smaller than discrete designs and offers lower power (only 1.3 mA max supply current), making it a good fit for battery powered, portable (or remote) applications. Furthermore, the low noise, low input bias current, and low power of the AD620 make it well suited for medical applications.

- **Quadruple Op-Amp - LM324AN**

The LM124-N series consists of four independent, high-gain, internally frequency compensated operational amplifiers designed to operate from a single power supply over a wide range of voltages. Operation from split-power supplies is also possible and the low-power supply current drain is independent of the magnitude of the power supply voltage.

### iv. Servo Motors

A servo motor is a rotary actuator or linear actuator that allows for precise control of angular or linear position, velocity and acceleration. It consists of a suitable motor coupled to a sensor for position feedback. It also requires a relatively sophisticated controller, often a dedicated module designed specifically for use with servomotors. Servomotors are not a specific class of motor although the term servomotor is often used to refer to a motor suitable for use in a closed-loop control system. The very simplest servomotors use position-only sensing via a potentiometer and bang-bang control of their motor; the motor always rotates at full speed (or is stopped). This type of servomotor is not widely used in industrial motion control, but it forms the basis of the simple and cheap servos used for radio-controlled models.

### v. Basic Components

Basic hardware components are

- PCB board
- Power sources
- Serial cable
- Connecting wires

# CHAPTER 4: SYSTEM OVERVIEW

## 4.1 System Overview

The system is divided into three parts namely Signal Acquisition, Controller and Mechanical. The Signal Acquisition part consists of five blocks as mentioned below:

### 4.1.1 Signal Acquisition System:

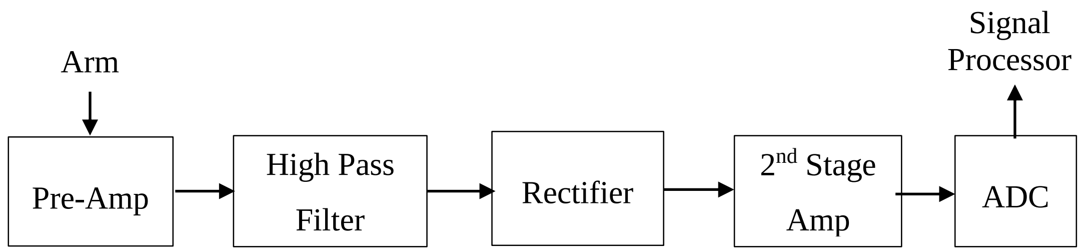


Figure 4.1: Block Diagram for Signal Acquisition

- **Pre-Amplification**

The amplitude of the EMG ranges from 0.5 mv to 5mv. Similarly the frequency of EMG varies between 10Hz to 2000Hz with practical usable frequency from 20Hz to 500Hz. The EMG signal amplifications consists of two stages. The pre-amplification is done by using a differential amplifier, AD620N, with a gain of 200. The differential amplifier reject the common mode signal and amplifies only the potential difference between the two electrodes.

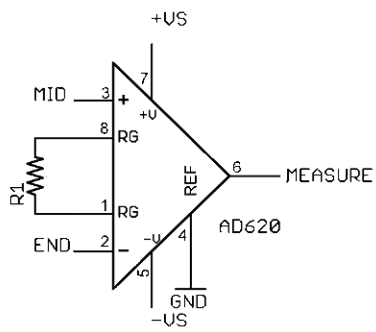


Figure 4.2: Pre-Amp Circuit

- **Filtration and Rectification**

Generally, the frequency of EMG varies between 10Hz to 2000Hz. The Filtration of signal is generally done by using a fourth order Sallen key band pass circuit constructed by using a 2nd order Sallen Key High pass filter cascade with other 2nd order Sallen Key Low pass filter both with unity gain that filters out the frequency range between 20Hz to 1 KHz which also filters out low dimensional noise at 10Hz.

The filtered signal is passed through a Rectifier circuit consisting of two zener diodes and an operational amplifier. Each diode conduct the signal to the inverting and non-inverting terminal of the op-amp respectively and the op-amp inverts the negative signal rectifying the filtered signal.

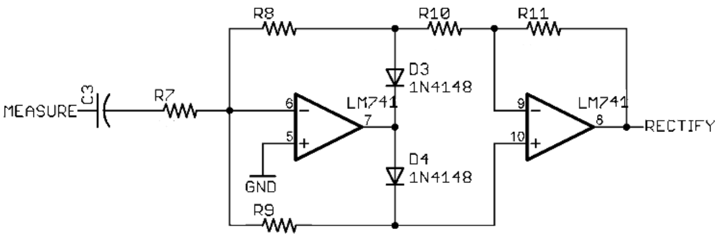


Figure 4.3: Filter and Rectifier Circuit

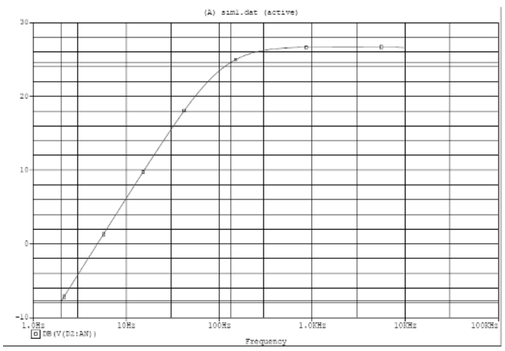


Figure 4.4: Frequency curve of LPF

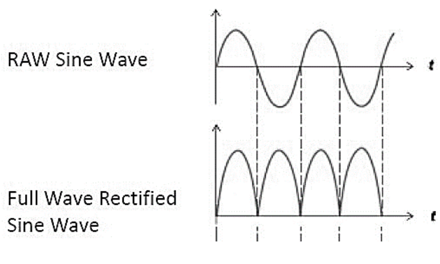


Figure 4.5: Signal Rectification

- **Smoothing and 2nd Stage Amplification**

The rectified signal is passed through a simple Low pass RC filter to smoothen the signal and then amplified using an inverting amplifier with adjustable gain ranging from 1 to 10 times to compensate for the amplitude loss in previous stages.

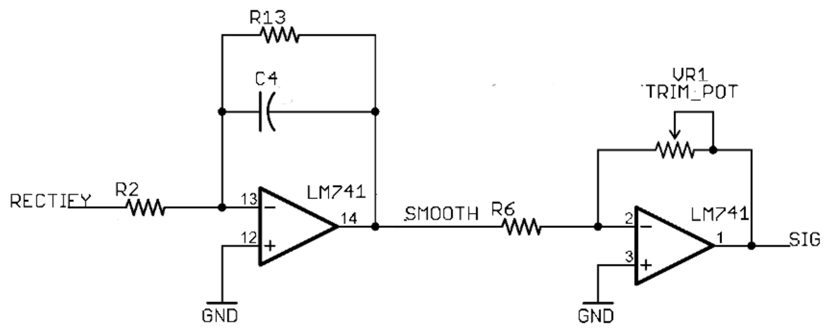


Figure 4.6: Smoothing and Amplifier Circuit

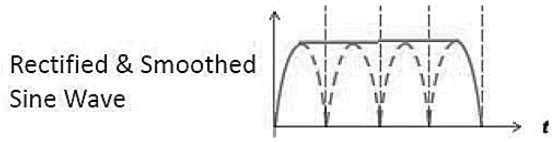


Figure 4.7: Signal after Smoothing

### 4.1.2 Controller and Mechanical System

The Signal is then passed to the microcontroller which is an Arduino Uno. The Arduino is used to read the EMG signal using its ADC, and then use the EMG signal received to control the servomotors that defines the movement of the robotic arm.

- **ADC**

It is recommend that the raw EMG after appropriate amplification and filtration should be stored in the buffer memory for signal processing. According the Nyquist Criteria of Sampling, the minimal acceptable sampling frequency should be at least twice the highest frequency cut-off of the extraction EMG signal. Similarly all the 10 bits of ADC are used to transmit the rectified analog signals through the microcontroller. With the execution time of 110 us and sampling rate of around 9 kHz, the minimum sampling frequency should be greater or equal to two times the maximum obtained frequency (2000 x 2), which improve accuracy and resolution.

Sampling rates below twice the highest frequency cut-off produces aliasing effect [13]. ATmega32 has an ADC on chip. An ADC converts an input voltage into a number. An ADC has a resolution of 10bits. A 10 Bit ADC has a range of 0-1023. (2^10=1024) The ADC also has a Reference voltage (ARef). When input voltage is GND the output is 0 and when input voltage is equal to ARef the output is 1023. So the input range is 0-ARef and digital output is 0-1023.

- **Signal Processing**

For Signal Processing, each rectified signal pulse are analyzed. The amplitude of the measured EMG signal defines the position and movement of the robotic arm.

The Bluetooth module connects with an android phone which enables the user to setup the system for an individual as the amplitude of the emg signal is seen to be different from person to person.

### 4.1.3 System Block Diagram

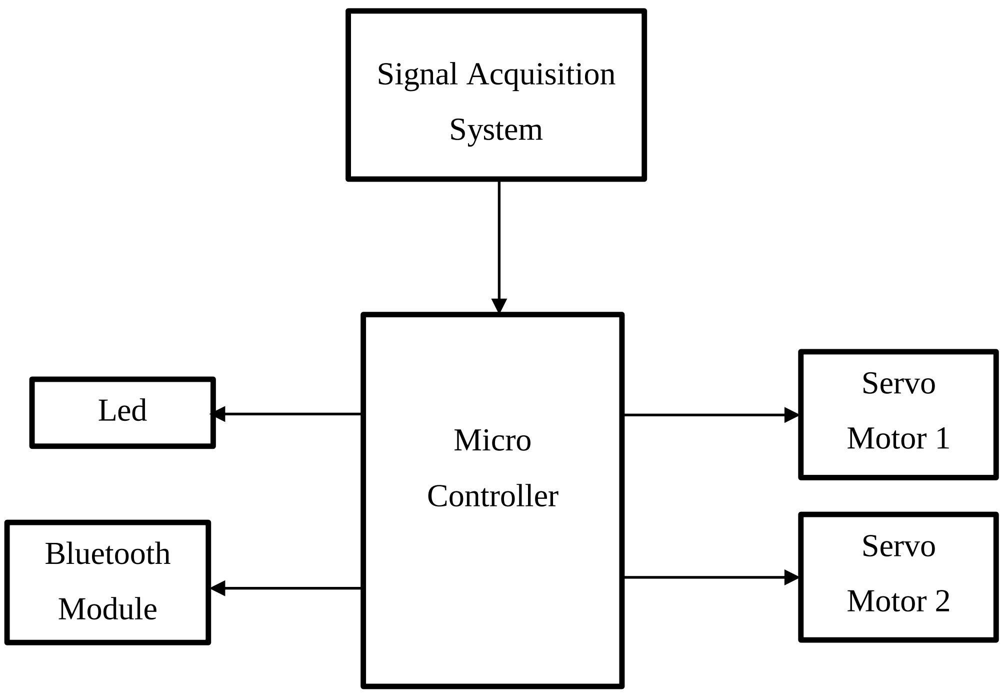


Figure 4.8: System Block Diagram

### 4.1.4 Flowchart of the System

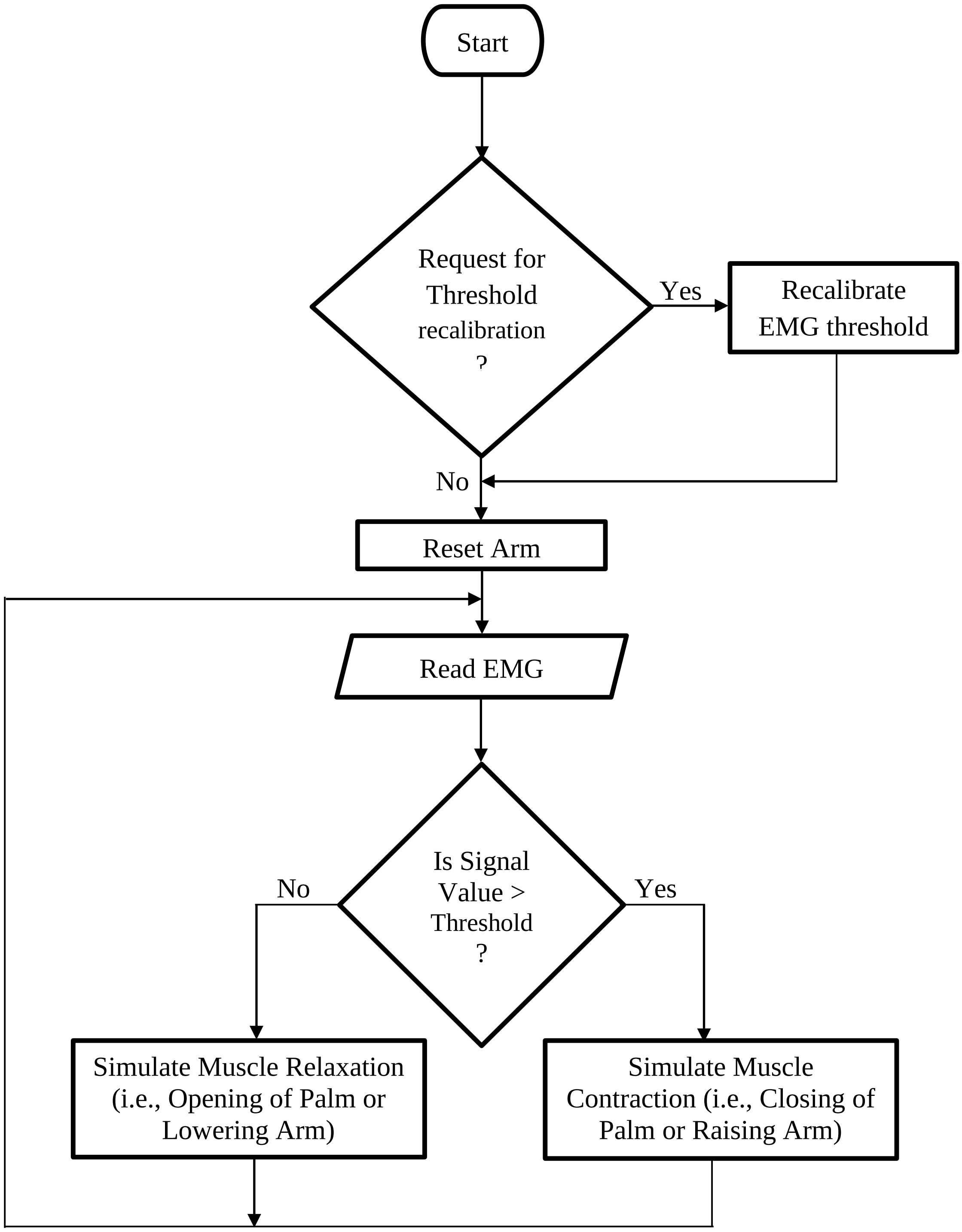


Figure 4.9: Flowchart of the System

## 4.2 Methodology

The basic concept is to use a low dimensional input derived from electromyography data to control a robotic arm. First we verify the system that is used to record the human body signals is adaptable to other forms of bio signal input; in particular, direct connection to a human brain via Muscle movement via Electromyography (EMG). Since the signals are very low appropriate filtering and amplification is used to map the signals. An Electromyography detects the electric potential generated by muscle cells, when these cells are electrically or neurologically activated. Importantly, EMG activity (as measured in microvolt) is linearly related to the amount of muscle contraction as well as the number of contracted muscles – or in other words, the stronger the muscle contraction and the higher the number of activated muscles, the higher the recorded voltage amplitude will be. Since EMG activity is even measurable when we do not move our body i.e. during stationary positions, a system is to be design to remove such behaviors.

Similarly, a robotic arm is designed in accordance to work with bio-medical signals with placement of various motors and so-on. The idea is to use the Bio-Robotic arm as similar to a human arm as a form of a prosthetics arm. With the movement in the host muscles determines the output of the Bio-Robotic arm with rotational and translation motions [3]. The analyze signals of muscle movement inputs are mapped to a specific outputs. The signals are transferred to the Bio-Robotic arm via a wireless module i.e. Bluetooth signals. A microcontroller specific the output of the arm be comparing the input signals with the mapped signals. The muscles movements and its stability can be monitored. With the combinations of all the signals, the proposed arm is expected to work as a prosthetics arm in both static and dynamic cases [7].

The generation of movements involves the activation and control of muscles forces. The body can be represented as a system of articulated segments in static or dynamic balance [8]. With the cause of force in the muscles, there is the generations of an electrical signal waveform. The associated electrical activity is called as electromyography and the waveform is the electromyogram which can be closely observed by placing the electrode on the associated muscles.  However it's not possible to directly measure such signal since the signal power is very low generally in millivolts.  But studies by Lippold in 1952 suggest that there is a linear relationship between force and EMG.  However the relationship is not simple mechanism. The signals needs to be further refined, made error free and amplified to measure the responses.

The contraction of muscles fibers occur when the potentials are generated in motor neurons. When the neuron and axon exceeds the threshold in Postsynaptic Membrane of Neuromuscular junction, it becomes a muscle action potential. Difference in the potentials, the muscles potential is propagated in both directions of muscles fiber triggering the process of the sliding of action filaments on myosin [9]. On contractions of Muscles Unit (MU) with the combinations of activations and synchronizations, various numbers of fibers are activated. The frequency of MU refers to contractions, relaxing after each activations that produces temporal pules of two or more MU firing in combinations. Generally small muscles such as hand and big muscles such as legs can be controlled by activations and synchronizations.

- **Electrode Positions:**

As EMG signal is low in amplitude in comparison to other ambient skin surface signal, it is continently necessary to detect the EMG signal with a differential combinations. Here the two differential electrode are subtracted to further amplifications. During this the shape and area of the surface electrodes and distances between them plays an important role. In actuality, if the inter-detection surface spacing is set so as not to alias the EMG signal, the spectrum of the EMG signal should fit in the low end of the band-pass filter, thus for practical purposes, the differential electrode behaves as a high pass filter [10]. Muscles fibers are classified either as type I or type II, according to the metabolic and functional capabilities. As the number of MUs per muscle is variable, the ratio of fiber type varies among individuals. Type IA fibers are the first recruited muscles contraction and are always active during exercise intensity whereas type IIB are typically recruited after type IA during higher level of exercise involving rapid effort, high power and intensity [9].

The bandwidth of signal depends upon the distance between detection surfaces. Similarly the shape and areas of surface detection determines the number of muscle fibers seen by the electrode which thereby affects the amplitude, i.e. the greater the area coverage, the greater the amplification of EMG signals because the MU are somewhat randomly scattered throughout the cross-sections of the Muscles which generates a force throughout the muscle. But practically, the distance the between surface and electrode cannot be small as the detection surface may be shunted electrically if the surface of the skin becomes moist, sweat which is conductive. As a result the signal decreases the electrical amplitude that affects (deteriorates) the signal to noise ratio, and may filter out the higher frequency components.

In time domain analysis, two parameter Root Mean Square (RMS) and Average Rectified Value are commonly used. For EMG signals detected during contractions, the RMS value may be appropriated since it represents the signal power. Whereas the average rectified value is used to measure the area under the signal [11].

The timing of the muscles activation does not mattered if the contractions is isometric. The timing is only considered if any segment of muscle on the vicinity of the electrode is active which may affects if the signal obtained with certain range of noise of the signal, detection and recording equipment. Crosstalk is an issue during such case as the amplitude of the signal is near to the noise level. An adjacent active muscle connected to the electrode can be affected by the nearby muscles movements which acts as cross talk thereby misinterpreted as the original muscle signal. An approach of determining the signal originate from the appropriate muscle is to cross-correlate the signal separately. If the cross-correlation value is below calculated threshold value then there is no cross talk present. Such crosstalk may be reduces by placing reference electrode on bone surface which acts as virtual ground. The approach cannot be fully reliable as the muscles are anisotropic which causes multiple diffraction of the electric field vector and may generate multiple paths of frequency domains and becomes uncorrelated [12]. In such case frequency analysis should be done.

Two differential signals are obtained, one from detection surface electrode 1 and 2 and another from the electrode 2 and 3 then a differential signals are obtained from those two. Thus by resulting two levels of differentiations, the signal can be extracted. The second way is by placing the electrode on the adjacent muscles and wire electrodes in the deep muscles to monitor them for the activity. This approach may include large number of surface electrode and wire electrodes. Use of wire electrodes reduces cross talk far more than surface electrode. It is also necessary to consider certain number of delay between the muscle contraction and activations with its respective time course of the force parameter which may depend upon certain factor such as dynamic firing rate of muscles and surface EMG. Similarly the fast twitch muscle fiber will have shorter time delay between signal and its respective force. Similarly, the slower twitch, slower fatiguing of muscle fiber have a relatively slower rise time. In addition, there is physiological limit to the accuracy of the resolution during estimation of on-off times of the EMG signal. Thus, resolution should not be greater than 10ms compared to the on-off times among various muscles and the conduction velocity decreases and arrival time of EMG signal increases [10].

# CHAPTER 5: PROJECT PLAN

## 5.1 Project Plan

Table 5.1: Work Schedule

| Work | Date |
|---|---|
| Documentation | Throughout the project |
| Research | 25 Nov – 27 Dec, 2016 |
| Designing the Schematics | 15 – 30 Jan, 2016 |
| Collection of Hardware | 23 Feb, 2016 – 10 March, 2017 |
| Assembling | 11 March – 10 June , 2017 |
| Programming | 11 June – 20 July, 2017 |
| Testing and modification | 21 – 28 July, 2017 |
| Debugging | 29 July – 3 August, 2017 |

## 5.2 Cost Estimation

Table 5.2: Cost Estimation

| S.N | Components | Quantity | Unit Price(RS) | Net Price(RS) |
|---|---|---|---|---|
| 1. | EMG electrodes | 30 | 15 | 450 |
| 2. | Materials for Arm | 1 | 7000 | 7000 |
| 3. | Bluetooth module | 1 | 1200 | 1200 |
| 4. | Microcontrollers | 2 | 800 | 1600 |
| 5. | Servos & motors | 6 | 300 | 1800 |
| 6. | ICs:<br>i. AD620AN<br>ii. LM741<br>iii. LM324 | <br>2<br>5<br>2 | <br>100<br>35<br>50 | <br>200<br>175<br>100 |
| 7. | Capacitor, resistors, led | - | 1500 | 500 |
| 8. | Total | | | 13025 |

# CHAPTER 6: EPILOGUE

## 6.1 Results and Discussion

### i. Analysis of Pre-recorded EMG signal

As a reference, the Pre-recorded signals obtain from Physiolab was analyzed by using Matlab and Originlab. The frequency of the signal was calculated. The result from two applications were compared and verified.

### ii. Design of EMG sensing circuit

By the taking the myoware EMG circuit as a reference, the EMG extraction is designed and tested with a cut-off frequency between 20Hz to 1 KHz. A differential amplifier with a gain of 200 was used to calculate the potential difference and removed the common noise between them taking a bony surface as a reference point.

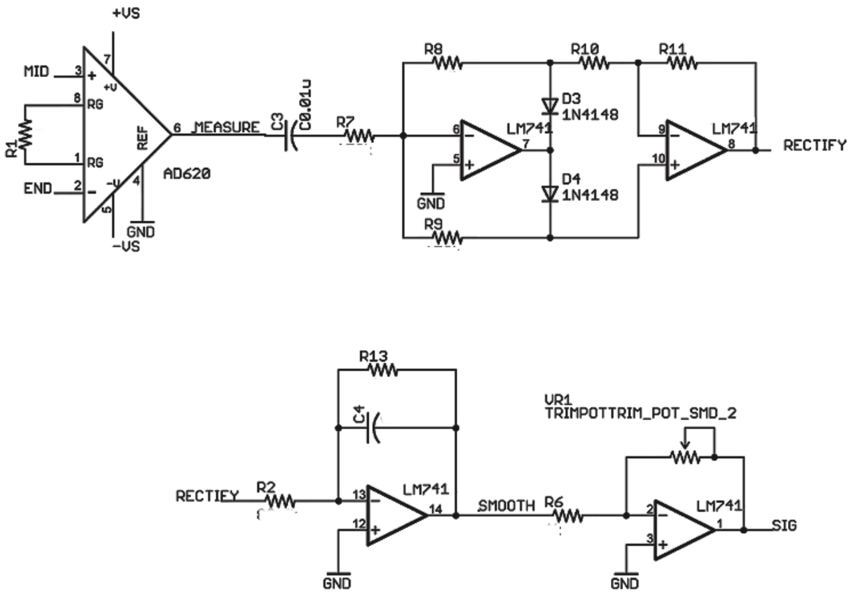


Figure 6.1: EMG sensor Circuit

### iii. Specifying the Frequency range

A Sallen key filter is used to filter out the low dimension noise and high frequency component as it is very responsive for low dimensional signal. As EMG signal ranges for 10 Hz to 2 KHz, the filtered is designed to work under 20Hz to 1Khz eliminating low dimensional noise at 10Hz and high frequency components.

### iv. Time domain Analysis

The filtered signal was rectified and further smoothen for better analysis using a basic non inverting terminal low pass filter. The circuit was stimulated using Proteus and Pspice and was tested using a Sine Function as a reference. After various testing and modification, rectified EMG Signal was extracted.

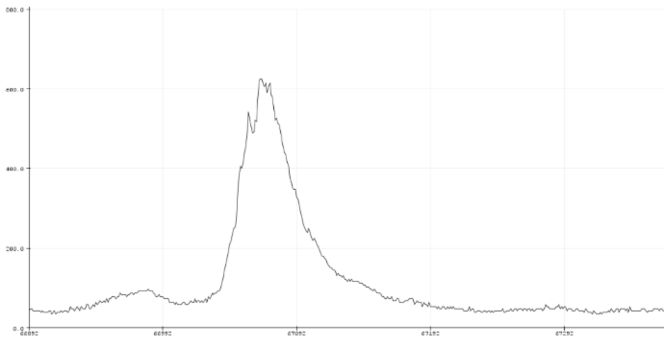

Figure 6.2: Amplitude of signal during muscle contraction

### v. Movement of arm

The motor is rotated according to the measured EMG signal's value.

- **Movement of Palm**

By using a signal Servo motors, the design arm is capable of tight grasp of the objects. A signal servo motor is rotated from 0 to 180 degrees, opening the palm and closing the palm respectively. EMG signal input from two electrodes with a common reference point placed at lower forearm is used to control this

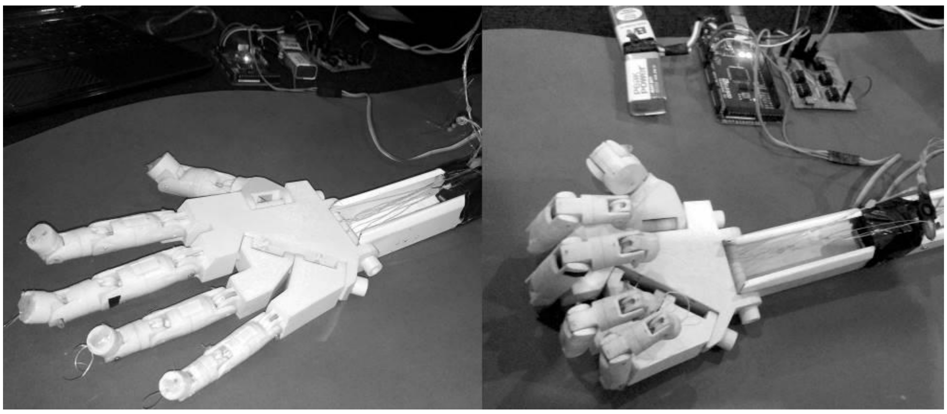

Figure 6.3: Opening and closing of Palm

- **Movement of Forearm**

Using a servo motor and a hinge support, the upper part is capable of lifting and moving the lower part of the arm. EMG signal input from two electrodes with a common reference point placed at biceps is used to control this motion.

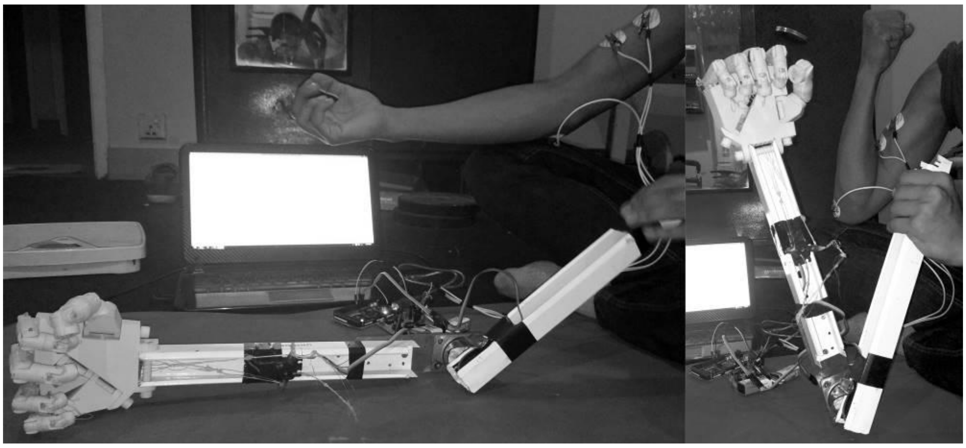

Figure 6.4: Movement of the arm

## 6.2 Application

- For Archeiropody patients and amputation patients as a prosthetic arm.
- In industries and robotics as a pick and place device.
- As a bomb disposal device to reduce casualties.

## 6.3 Advantages and Limitations

### Advantages

- Use of EMG signals, motors and 3D printing provide an easier and more natural way to control a prosthetic limb than that provided by strap based fully mechanical designs.
- Use of EMG signal to control humanoid robots allows better replication of human movements.

### Limitations

- The degree of movement is limited by the mechanical design of the robotic arm.

- Rectification and smoothing of signal, which is essential for signal extraction, limits the signal information to amplitude of only one muscle group from a pair of electrode and eliminates most the frequency information.

## 6.4 Problems Encountered

### i. Low SNR due to 50Hz interference signal (External Artifact)

Due to the external electrical ambient signals on the system, there appears a ripple noise in 50 Hz signal. A common example of External Artifact is Ac current produce due to power supply. The problem also due to antenna waves. This problem can be removed by using Driving Red Leg Circuit (DRL). External Artifacts due to AC power signals can be removed by using 50Hz notch filter.

### ii. Lead Artifacts

Movement during the recording of an EMG may produce artifact through both the electrical fields generated by muscle and through a movement effect on the electrode contacts and their leads. The poor contact produces instability in impedance, which leads to slow or sharp varying in amplitude of the signals

### iii. Sweat Artifacts

The surface may be shunted electrically if the surface of the skin becomes moist, sweat which is conductive. This produces decrease in amplitude of the signals which could be unmeasurable.

### iv. Muscles Artifacts

Movement during the recording of an EMG may produce artifact through both the movement of neighboring or associative muscle group. It is one of most common problem in extraction of EMG signals. Muscles Artifacts begins and end abruptly. The duration of Muscle artifacts varies according to the duration of muscle activity thus it can range from less than a second to entire EMG record. The artifacts occurs most commonly in regions with underlying muscle group.

## 6.5 Future Enhancements

- We can use Conductive fabric as electrode implemented in designs like an arm band which allows the user to comfortably wear the electrodes in practical conditions.
- Processing of EMG signal in frequency domain for the detection of muscle activation of different muscles using single set of electrodes and extraction circuit instead of having to use different electrode sets for different muscle groups can enable addition of more motor functions to the arm.
- The robotic arm can be upgraded by adding more motors and better mechanics to allow more movements close to natural hand movement.
- Addition of different sensors (touch sensor, pressure sensor, heat sensor, etc.) can be added to the robotic arm to provide feedback to the system.

## 6.6 Conclusion

This project "Bio-Robotic arm" is project based on a biofeedback mechanical arm that uses a low dimensional input derived from EMG (electromyography) data. Generally, prosthetic arm is not capable of functioning like a human arm. The system relies on the input from the user to control the robotic arm.

We designed the 3D-CAD model of the palm of the robotic arm. Two servos were used to control the motions. One servo for achieving the grab motion and other to control the lower arm. For a reference, we studied the prerecorded bio medical signals using Matlab so that we can observe the behavior of those signals and corresponding characteristics of those signals under various scenarios.

As our research progressed on this project, we found out about various bio-medical signals, its capabilities and designing of hardware. Based on our research, EMG signals was found to be feasible for the movements of the motors with availability of reference voltage. The EMG signals were acquired from two different muscle groups.

Considering the raw EMG to be very low, a differential amplifier with removal of common mode voltage is used to amplify the bio signals and is filtered out using a band-pass filter. The signals are full wave rectified and smoothen for the measurement of the amplitude of respective muscle movements. A reference point is used which acts as a ground point between the two muscles. Generally, a bony surface is taken as a ground point to reduce the effect of muscles artifacts. On comparing the threshold values with the obtained rectified EMG signals, the motion of arm with respective to the muscle unit is achieved.

Hence, we completed the design phase, assembly phase, coding, testing and debugging of our project, encountered various issues during designing and hardware selection and solved most of the issues.

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# APPENDICES

# APPENDIX A: PCB Layout of Circuit Used

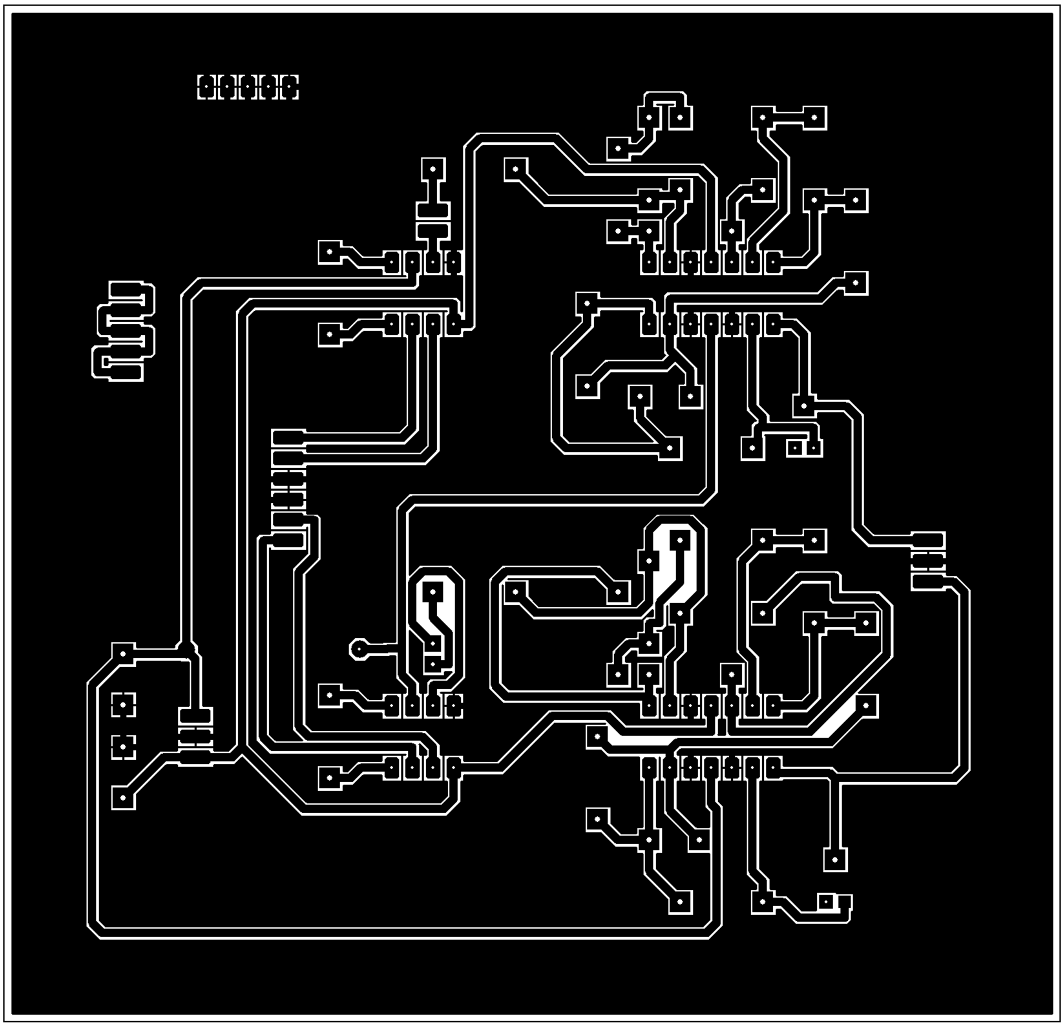

Figure A: PCB layout

# APPENDIX B: 3D CAD Model of Robotic Hand

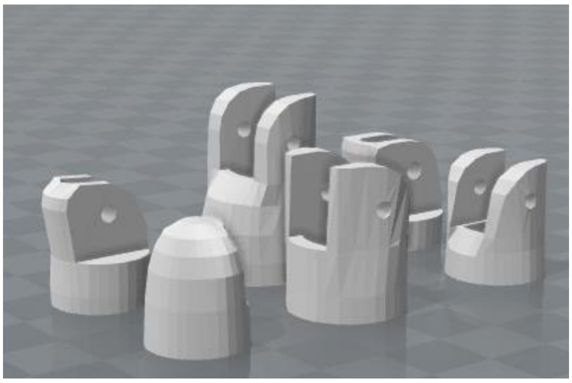

Figure B.1: Index Finger

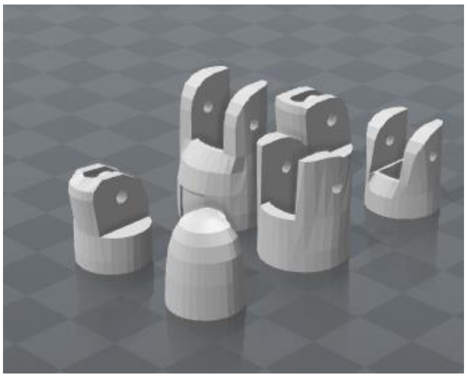

Figure B.2: Auricular finger

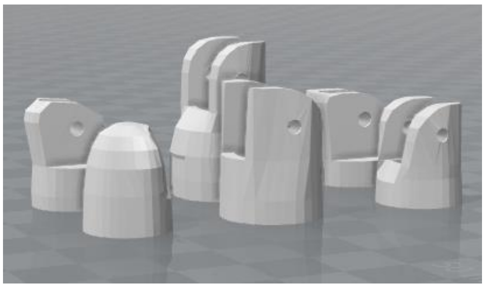

Figure B.3: Majeure finger

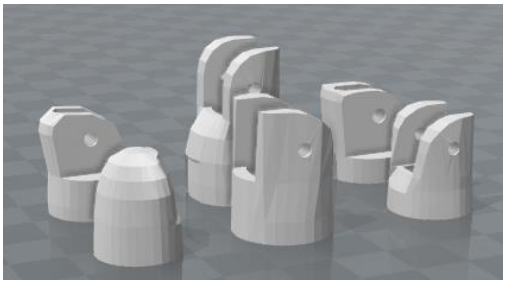

Figure B.4: Ring finger

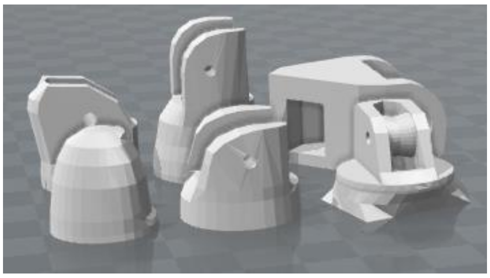

Figure B.5: Thumb

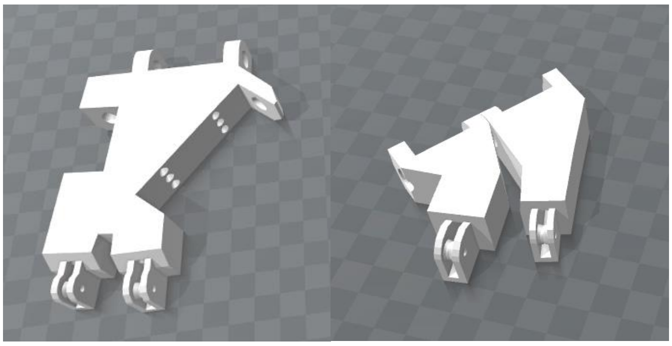

Figure B.6: Palm