DESIGN AND IMPLEMENTATION OF A BIONIC LIMB

EMPLOYABILITY SKILLS AND MINI PROJECT REPORT

SUBMITTED BY

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CERTIFICATE

DEPARTMENT OF ELECTRONICS AND TELECOMMUNICATION

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This is to certify that

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Class: TE (E&TC) have successfully completed project titled, **"DESIGN AND IMPLEMENTATION OF A BIONIC LIMB"** as a part of Semester II of Third Year of Bachelor of Engineering in Electronics and Telecommunication (A.Y. 2020-2021) of Savitribai Phule Pune University.

Prof. Harshali Mane — Project Guide

Prof. Risil Chhatrala — HOD(E&TC)

Principal

Place : Pune

External Examiner

Date :14/05/2021

ABSTRACT

This project deals with the design and development of Bionic Limb for amputated person. The design of the system is based on a simple, flexible and optimal control strategy that enables the person to use the device as normal arm. The hand system has independent commands to move the limb up and down precisely. Implementation of the mechanical hardware design of the human hand is based on connected double re volute joint mechanism. The tendon system of the double re-volute joint mechanism and feedback network provides the hand with the ability to confirm to object topology and therefore providing the advantage of using a simple control algorithm. The model should be fabricated with Servo motors and force sensors for fingers actuation. The entire setup is mounted on to the shoulder of the amputated person. Inputs for the motors can be generated through EEG signals generated from touch sensor, which enables the user to grasp the objects. This thesis explores the boundaries of one of the most advanced multi material 3D printers today. By doing so, inspiring others to create more natural looking and less power consuming prosthetic.

Contents

Chapter 1

Introduction

1.1 Background

Prosthetic is an artificial device that replaces a missing body part, which may be lost through trauma, disease, (or) congenital conditions. When a person becomes a limb amputee, he or she is faced with staggering emotional and financial lifestyle changes. The amputee requires a prosthetic devices and services which become a life-long event. Prosthesis is an artificial extension that replaces a missing body part such as an upper or lower body extremity. It is part of the field of biomechatronics, the science of fusing mechanical devices with human muscle, Brain, skeleton, and nervous systems to assist or enhance motor control lost by trauma, disease, or defect. An artificial limb is a type of prosthesis that replaces a missing extremity, such as arms or legs. The type of artificial limb used is determined largely by the extent of an amputation or loss and location of the missing extremity. Artificial limbs may be needed for a variety of many types of Prosthesis Reasons, including disease, accidents, and congenital defects. There are four main types of artificial limbs. These include the transtibial, transfemoral, transradial, and transhumeral prostheses. From many papers on biomedical and mechatronics it is studied and analyzed the grip force distribution for different prosthetic hands designs and the human hand fulfilling a functional task is taken and the design approach of the prosthetic hand and it's mainly focused on increasing the functionality, cosmetic and controllability of the prosthetic hand. Many times even experienced electromyographers fail to provide enough information and detail on the protocols, recording equipment and procedures used to allow other researchers to consistently replicate their studies. The values from the above papers are taken into consideration. .

Chapter 2

Literature Survey

[1]Srijan Rajput, Himanshu Burde, Udit Suraj Singh, addressed the problem of Ex pensive and Time consuming production of much more heavier prosthetic limb. Their study addresses this problem and proposed an alternative design for prosthetic foot and calf.

[2]R. Richardson, D. Moser and D. Bradley wrote a paper for development of a semi active prosthetic knee, which can work in both active and passive modes based on the energy required during the gait cycle of various activities of daily livings (ADLs). R.G.E. Clement and K.E. Bugler discussed some of the key areas of research that could lead to vast improvements in bionic limb functionality that may one day be able to fully replicate the biological hand or perhaps even surpass its innate capabilities. H. Xie, K. Chen, and F. Li,

[3]Johnny L. G. Nielsen et al. proposed a novel approach done with surface electromyogram to record information from one upper limb to force generated using the collateral limb. They measured from the right wrist in multiple degrees of freedom along with different movements.

[4]J. Carpaneto et al. proposed a prosthetic limb using the EMG signal. EMG-based stimulation is done by machine learning in the nervous system and the use of implantation of electrodes in the muscles. The vector machine algorithm had been used to predict different types of grip including grasp gestures using both distal and

proximal upper limb tissues.

[5]. Siliveru Ramesh, M.Gopi Krishna, MadhuNakirekanti, "Brain Computer Interface System for Mind Controlled Robot using Bluetooth", International Journal of Computer Applications, vol. 104,pp 20-23, October 2014.

[6]. Sridhar Raja .D, "Application of BCI in Mind Controlled Robotic Movements in Intelligent Rehabilitation", International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, vol. 2, pp 1231-1238, April 2013.

[7]. Brendan Allison. Brain computer interface systems. http://bci.ucsd.edu/,1999.

[8].Charles W. Anderson and Zlatko -5 8Sijerˇci´c. Classification of EEG signals from four subjects during five mental tasks. In Solving Engineering Problems with Neural Networks: Proceedings of the Conference on Engineering Applications in Neural Networks (EANN'96), pages 407–414, 1996.

[9]. W. W. Armstrong and M. Thomas. Handbook of Neuronal Computation, chapter Adaptive logic networks. Oxford University Press, 1996. [10]. Fabio Babiloni. Solving the Puzzle of Neuroimaging: from High Resolution EEG to Multimodal Integration with MEG and MRI Techniques. PhD thesis, Helsinki University of Technology, 2000.

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Chapter 3

Proposed Methodology

3.1 Problem Summery

The project mainly focuses on a person who has been a victim of any fatal accident or any paralytic disorder which has cause loss of human hand or has been handicapped and not having hand by birth, the prosthetic hand offered by medical field has a very high cost. So to serve as an alternative for this, additive manufacturing method and particularly 3D printing method can give a highly cost effective and flexible method of making a prosthetic hand.

3.2 Problem Statement

The aim of this project is to create a prototype of a hand which can be placed on the forearm of the body. This hand would achieve the basic movements of grabbing an object in two different ways: [1]Impingement, with the index, middle finger and thumb. For smaller objects and more precision. [2] Enclosure, with the whole fingers. For standard objects. To developed a prosthetic arm which is low in cost, and restricted in the movement. The proposed system can be controlled by signals from a set of muscles in the body (i.e., EMG signals) and will have a functional elbow and hand with independent functionality. More over the arm will be lightweight and strong enough for daily activities.

Objective:

- The main objective is to design and develop a reliable low - cost prosthetic arm control circuit.
- A control system circuit using Arduino will be proposed.
- A Simulation of the proposed system will be run.
- Performance evaluation of the proposed system will be carried out.

3.3 Problem Motivation

According to a study conducted by National Informative Centre in Kolkata, 26.8 percentage of the amputation population consisted of upper limb amputees, the most common age group affected by amputation being those in their 20s and 50s.There are currently 0.11 million amputees in India that have suffered below elbow limb loss and almost 16500 people added about every year. The total number of persons with an amputation, and those using a below elbow upper limb prosthesis, is expected to increase by at least 47 percentage by the year 2020.

The hand injuries have an important relevance, because they are an exceptional anatomic region with high value, due to be used in almost all professions or occupations. Any level of amputation leads to a degree of disability that may limit the human to perform basic activities like feeding and grooming permanently.

3.4 Problem Specification

In this new era of technology, there are many other alternatives to make a prosthetic hand. But as we dig deep in this prosthetic hand and its manufacturing system. We found this currently various technologies that are used to make prosthetic hand are very expensive. So that it is hard to afford a prosthetic hand for a person who has low economic background. The prosthetic hand which are available in market are cost up to 1.5 to 2 lacks. Considering that excessive money factor, we thought of made cost effective prosthetic hand. In addition of that, as prosthetic hand is being an external part of the human body so synchronization of prosthetic hand and human body is essential. For that at certain particular time user should have to visit to consultant doctor. The prosthetic hand which are available now have very complex structure. To manufacture this complex geometry is hard. So that its manufacturing time varies from some weeks to some months depend up the designing and geometric measures of the prosthetic hand.

3.5 Process description

A bionic arm works by picking up signals from a user's muscles. When a user puts on their bionic arm and flexes muscles in their residual limb just below their elbow; special sensors detect tiny naturally generated electric signals, and convert these into intuitive and proportional bionic hand movement. The bionic hand is controlled by tensing the same muscles which are used to open and close a biological hand.

Most Bionic Arm users are able to control their bionic hand within just ten minutes, whereas some require a little more rehabilitation to strengthen their muscle sites. The technology fitted inside the bionic arm is known scientifically as electromyography, and the special sensors are electromyographical, or EMG, electrodes. Myoelectric bionic arms are plug and play, meaning users can take their bionic arm on and off with ease. The bionic Arm has an adjustable dynamic socket for maximum comfort. No surgery is required

The implementation of 3D printing and computer numerical control (CNC) machining in biology is a relatively new and exciting field of study. Organs are being printed and robotics are becoming more and more lifelike. Robotic limbs and prosthesis are mainly constructed with bolt joints, motors and actuators, components you will not normally find in the human body. Every new product is lighter and better, and effort is made to make robotics more realistic looking.

Most bionic limbs have built-in computers that detect the muscle signals. Some bionic limbs require sensors to be implanted into the remaining muscles of the limb stump. This type of bionic limb is much more advanced and can allow users to control the limb with their minds.

This type of prosthetic limb gives users maximum control and adapts to how quickly or slowly the muscles tense. When the muscles are tensed more gently, the bionic limb will respond slower. When muscles are tensed quickly, the limb will react faster.

3.5.1 Mechanisms

The implementation of the movements of the articulations in the hand is based on some mechanisms to extend and fold the fingers. Basically the used ones are; transmission bars, drive pulleys, motors added in each articulation and just pulling strings.

- bar mechanism
- Mechanism with Drive Pulleys
- Mechanism with motors in each joint

Bar mechanism:

The bars are configured in a way that they fold at the same time just moving one bar towards or forwards, with this system you don't need motors and the manufacturing is easy and cheap. The movements are quite limited just because as it's said the flexion is produced at the same time in the three articulations.

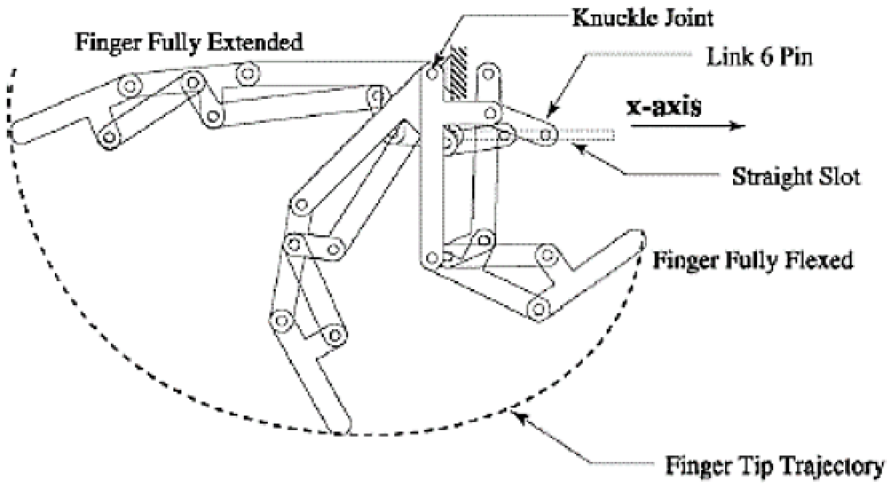


Figure 10: Toronto mechanism

Mechanism with drive pulleys:

The idea of this mechanism is really similar with the bars one, just because to achieve the movement you have to perform one action in this case make one pulley turn around, with a motor for example, and the configuration of the pulleys will make the others do the desired movement. This system makes the weight of the hand goes down and it's easy to implement.

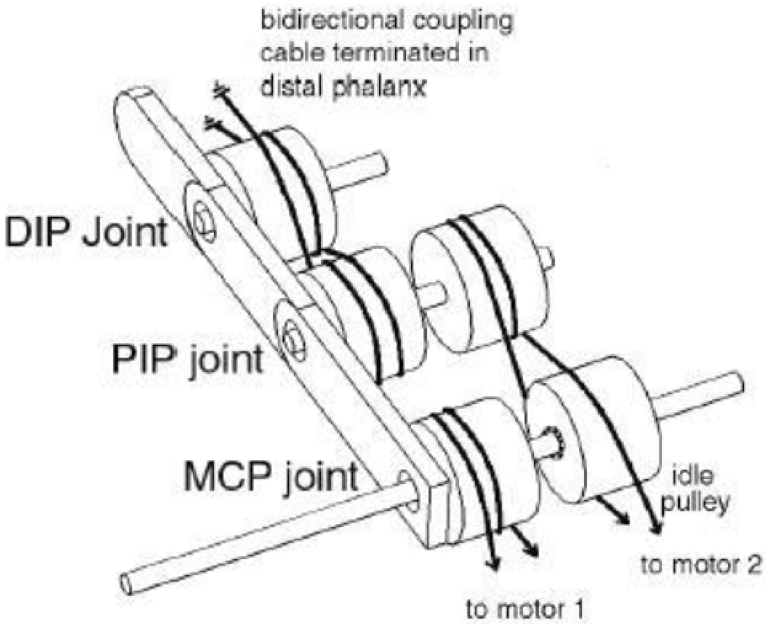
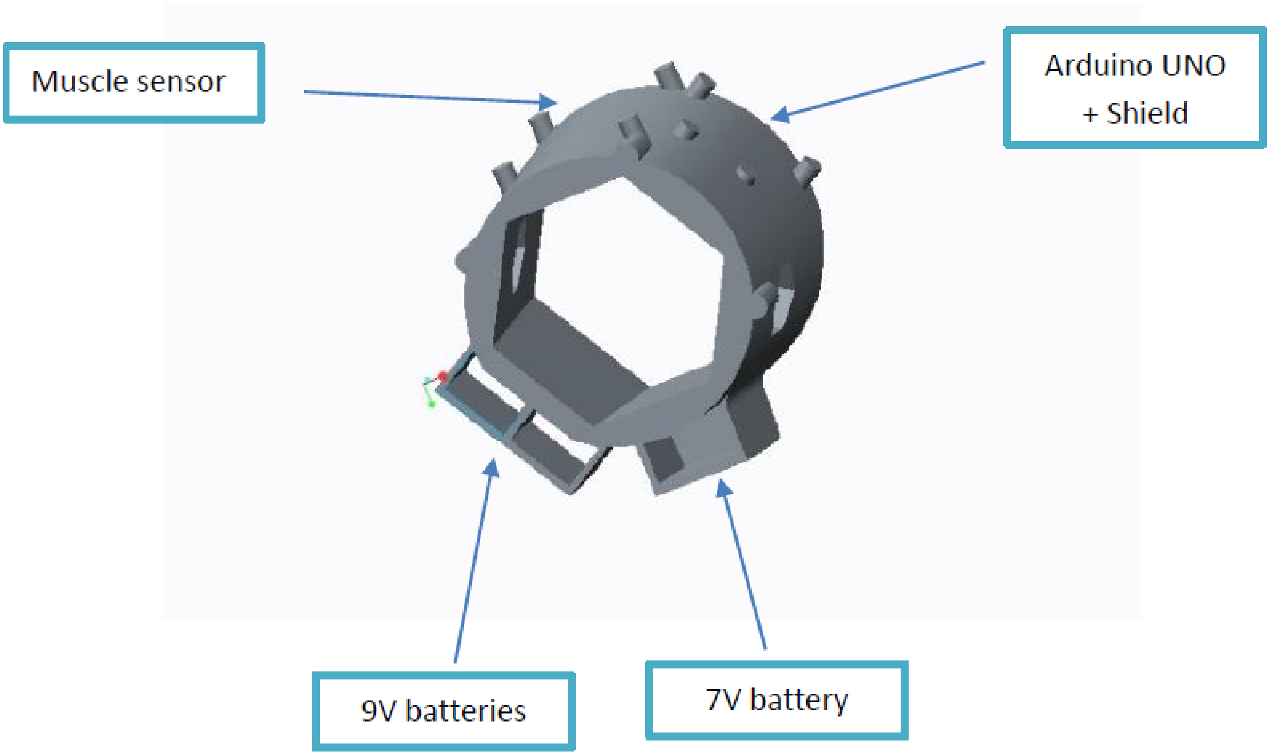


Figure 12: Driving Pulleys System scheme

3.5.2 Development of the Prototype

3D Design of the Prosthetic Arm:



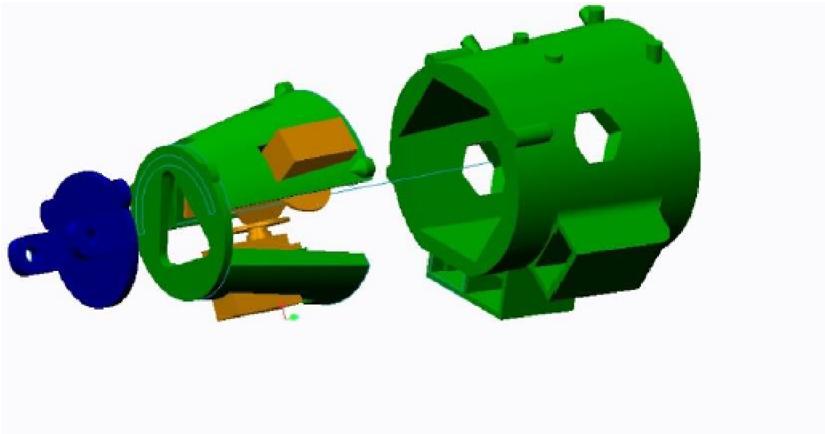


Figure 36: Assembly of the forearm pieces

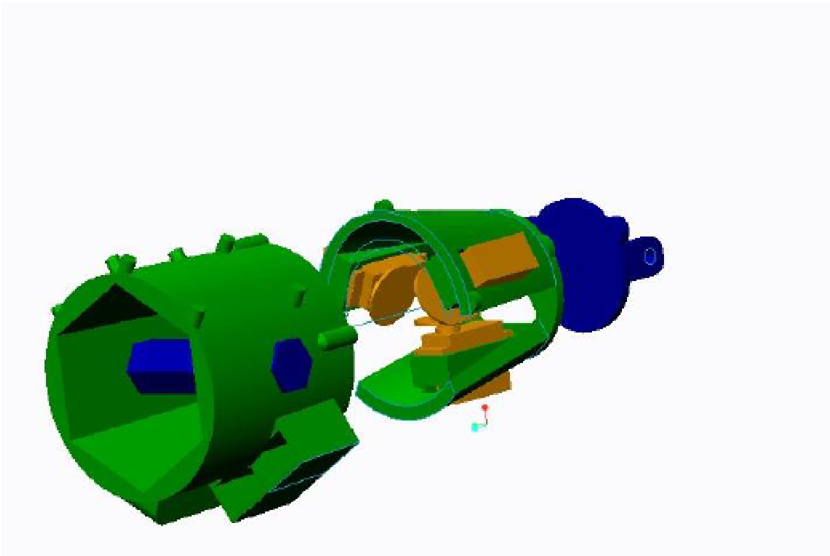


Figure 37: Assembly of the forearm pieces with hexagonal bar

Figure 68: Assembly of all pieces

3.6 Requirement Analysis

Additive manufacturing required some basic concepts and platforms for manufacturing the product. Basic requirement of 3D manufacturing process is to develop a software based digital model of product. To develop a digital model of we can utilize a different CAD software i.e. Pro-E, Creo, SolidWorks, CATIA, Blender etc. To manufacture the prosthetic hand with use of the additive manufacturing/3D printer we have to set some parameter for printing. To set that parameter i.e. bed temperature, nozzle temperature, alignment of object, coordinates of the object, layer thickness etc. different software are used. One of the software used for this application is ‘CURA’. After setting all parameter in software, we just input that software generated file to 3D printer. 3D printer will read the file and manufacture the object according to given dimension and parameter

3.7 List of Hardware Components

The major mechanical components used are:

- Fishing line
- Allen bolts and Screw
- Acrylonitrile butadiene styrene (ABS) for 3D printer

Fishing Line is used as string for drive pulley mechanism. Fishing lines have high Tensile strength, hence, more reliable and cost effective.

Allen Bolts and Screws are the only parts in this project which are not 3D printed.These are used in different sizes according to design specifications.

ABS is used as 3D printing material.

Mechanical Components

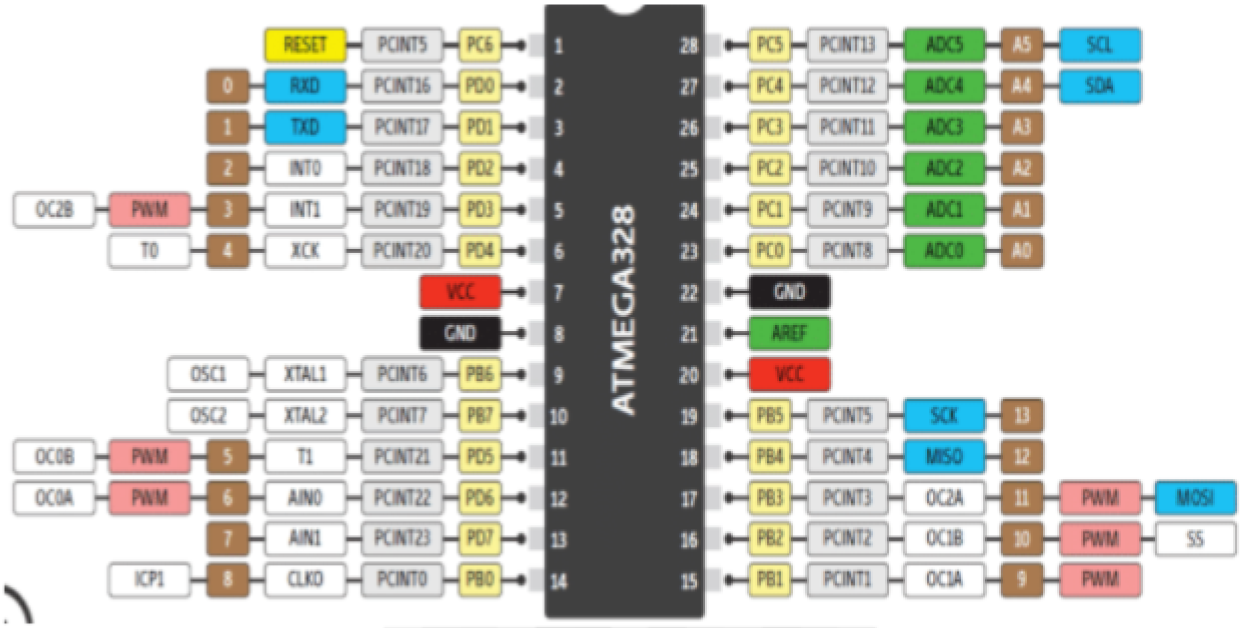
Servo Motor Mechanism HS422	Motors
Pack 16 electrodes (4x4cm)	Electrodes
PCB boards	components
Muscle Board and M-controller	
TFT ILI9225 LCD	LCD
TL084 and INA125P Amplifier	Muscle Board
7.4V LIPO Battery 1200 mAh	Power Supply for Boards
9V battery	Power Supply for Motors
Atmega328P and components	Microcontroller INA125P

INA125P is a differential amplifier that amplifies the difference between two input voltages but suppresses any voltage common to the two inputs. There so, it amplifies the difference between the two electrodes but not its own voltage. INA106 is more preferred than INA125P due to better differential gain. TL084 is operational amplifier which amplifies it with a relation of gain between resistances. It is not only used in amplify section of Muscle Board but also in rectification part to flip any negative values in signal to positive values. Along with that capacitors are used to smoothen the signal in each phase and eliminate alternate current distortions. TFT ILI9225 is a 2inch LCD screen with 176RGBx220 Resolution and 262K color which can be easily connected to microcontroller board by SPI Interface. We designed two PCBs: Microcontroller board and Muscle Board.

3.8 Software Configurations for Electronics:

We used Proteus software for Electrical simulation and and PCB Designing.

3.8.1 Microcontroller Board:



3.9 Impact Analysis

India is a country where people who are disabled seldom get proper treatment.Due to the high price of prosthesis ,only the higher income families can afford them. For the rest,amputation in India is looked down upon as a mark of social out cast and amputees are looked upon as a liability.Under lack of psychological consultancy, the amputees start losing their self-confidence.In this project we tried to remove this bar and develop a cheap yet effective product which would bring smile to many such deprived people in India as well as in other countries and make them feel and lead a normal life. the product will have a crucial impact in bringing back the amputees in to mainstream life where disabled people will no longer have to seek help for simple day to day activities. The unsupervised data from the cloud would be able to give a relative measure of this positive change in their self-esteem after a span of continuous use.And this is intended to monitor the cloud data for the same over a span of every 6 months for a particular user.This data could be further used to analyze the natural behavior pattern of an individual and help in predictive analysis to assist the amputees in their advancing years. This project can envision the product as a blessing of technology to the amputees which is modular and that can be fitted to people who've suffered from limb loss specially below elbow. The product is not only portable but also accurate in several ways like pressure sensing,force sensing,fall sensing.Moreover its accuracy is achieved by the combination of both data sent by the muscle sensor as well as the brain waves which in turn gives us a lot more accuracy than using either one of them. Not only this project limits the product to arm amputees but also extended it to suit the case of paralyzed people who have no sensation of their hands at all. By using this product the amputees could also use a hand which would act according to their thoughts. Nowadays,life has become very busy and we are unable to look after these people every time. Keeping this in mind the product have introduced the notification system which would send sms,twitter alerts to the guardian/local hospital in case of any emergency.Last but not the least, It monitors all the data sent by the sensors thus if any problem arises in the device or to the person using it , hence can be fixed instantly thus preventing any major damage to the device or the patient.

Social:

Positive Impacts:

- Limb Movement
- Perform Various Activities
- Physical Manipulation of things
- Active Participation In social Activities

Negative Impacts:

- May Experience Severe pain
- Extra weight of limb
- Uneasiness

3.10 Professional Ethics Practices to be followed

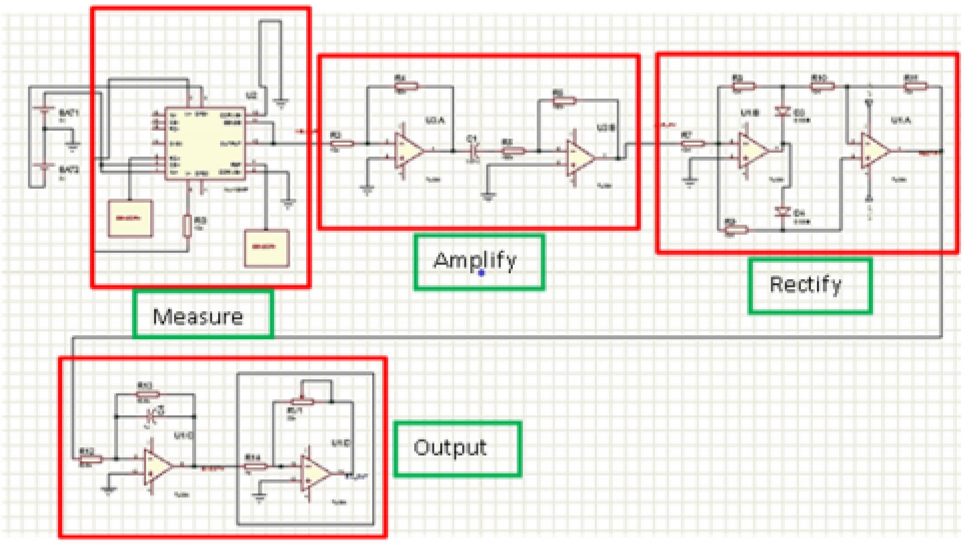
Social Acceptance Factors In the following, we will review acceptance factors for prosthesis use from a social science perspective, i.e., beyond pure technical performance measurements. We will then draw recommendations from this research for improvement of prosthetic care. 2.1. Social Environment The acceptability of assistive technology is dependent not only on its efficiency, but also on the reactions it elicits in people surrounding the user, as people with limb loss themselves have rated social outcomes as more important for assessing quality of life outcomes than their physical impairment. Good social support has been identified as a predictor for not only the perceived quality of life, but also the functional outcome after amputation . The very definition of disability is highly dependent on the environment defining this term, which further solidifies the need to pay more attention to a patient's surroundings and their place therein. People with limb loss reported that they experienced a "disabled" identity mostly through the reactions of others. Perception of functional outcomes in relation to prostheses use have repeatedly been linked to the social environment of a patient, with higher satisfaction and lower anxiety levels if prosthesis users felt accepted by their social surroundings. Therefore, the understanding of the social realities of prosthesis users does not only allow for more empathy, but it can maximise the potential for positive outcomes of prosthesis fitting. 2.2. Psychosocial Adjustment, Expectations and Personal Significance When trying to assess factors related to prosthesis usage, the overarching theme of potentially traumatic limb loss needs to be addressed. The experience of losing a limb, through either trauma or disease, can have a significant impact on a person's psychological reality. In addition to, potentially significant, pain, people with limb loss commonly experience reduced self-worth, heightened anxiety in social situations, depression, and even post-traumatic stress disorder. Thus, how well people adjust to the experience of limb loss itself has a significant impact on their ability to later accept and integrate a prosthesis into their lives. Psychosocial adjustment is defined as an individual's response to events having a significant impact on their lives, which require adaptation. Influential factors on positive psychosocial adaptation have not been explored widely, despite the fact that it seems like this adaptation is one of the most powerful facilitators of later prosthesis use and a high quality of life. There is, however, some evidence that factors such as an active coping style, as well as general (dispositional) optimism, a tendency for "downwards social comparison", as well as the feeling that one has some control over one's own situation, are all favourable indicators for good psychosocial adjustment. Widehammar et al. hypothesised that the care patients receive in early rehabilitation stages can be a significant contributory factor to the development of effective coping. Thus, this specific goal might need to receive more attention in mainstream rehabilitation protocols.

Chapter 4

Project Implementation

4.1 Circuit Designing

4.1.1 Schematic of Muscle Board:



Proteus Schematic of Muscle Sensor It has been schematized in Proteus 8 and made the design of the final board with the same program. The Circuit Schematic of the muscle sensor has four steps:

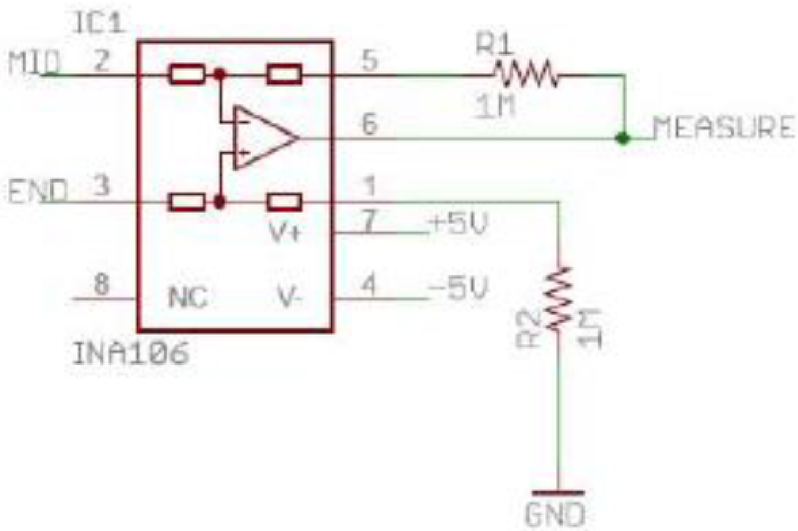


Figure 73: INA106 (Measurement)

Measure:

Measure of the signal coming of the sensors, recommended an INA106, actually used in this project with an INA125P. INA125P is a differential amplifier that amplifies the difference between two input voltages but suppresses any voltage common to the two inputs. There so, it amplifies the difference between the two electrodes but not its own voltage.

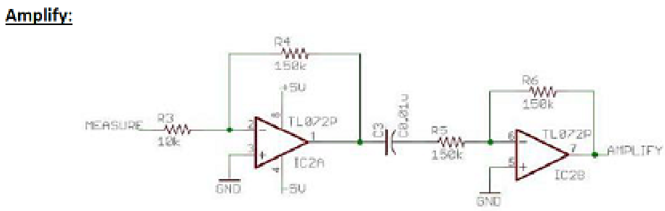


Figure 75: TL072P (Amplify)

Amplify:

Amplify the signal from the measurement with operational amplifiers, there recommended TL072P but actually used TL084. Basically the operational amplifiers take an input signal and amplifies it with a relation of gain between resistances. In addition are placed some capacitors at the entrance of the signal in order to suppress any alternate current.

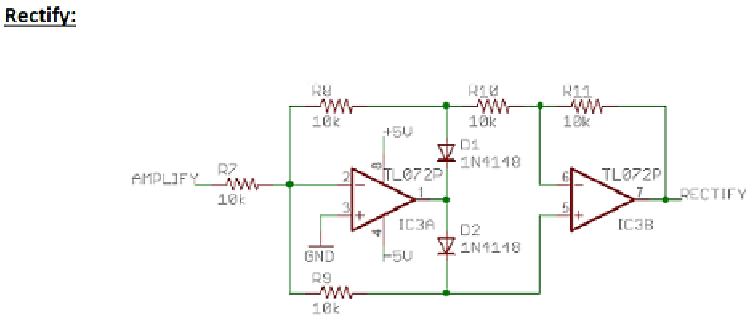


Figure 77: Rectification stage

Rectify:

On this phase the amplified signal is rectified in order to not allow the signal take negative values. It flips all the negative values to positive with the diodes.

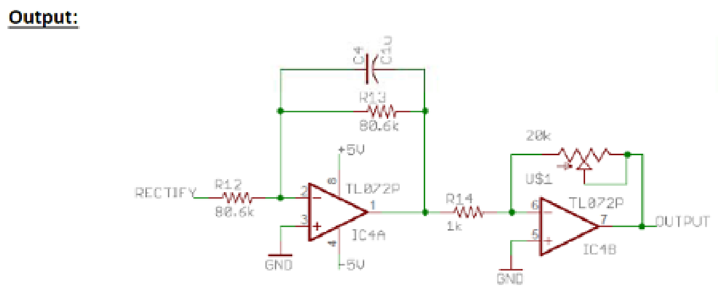
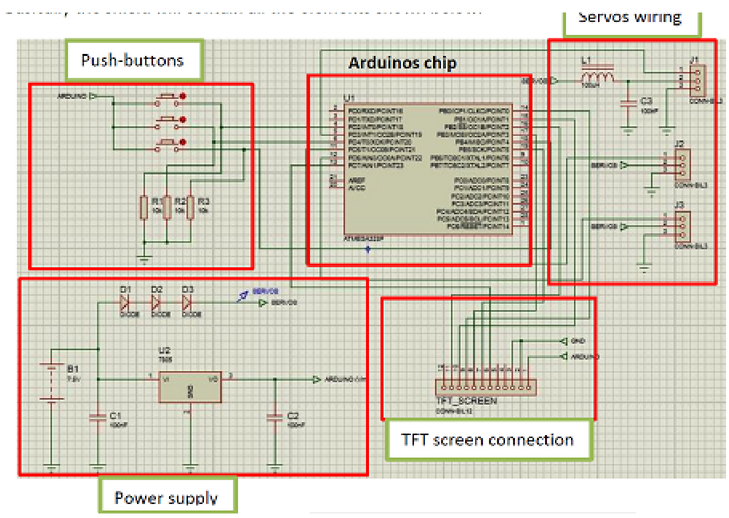


Figure 78: Output

Output:

The final stage is composed by an integer of the signal and another operation amplifier with an adjustable output gain in order to control the peaks of the outgoing voltage. The integer softens the signal.

4.1.2 Schematic of Shield scheme and configuration:



Arduino Shield

It's been decided to put an information screen above, for this kind of gadgets added to an Arduino, exists an invention called Shield. It consists on an electronic board which fits perfectly in Arduino's pins and it's possible to manage for connecting a lot of different devices. In this case it has been decided to put a TFT screen The screen chosen its TFT ILI9225 with 2.2" of screen and a resolution of 176x220., also will be the board where servos will be connected and provided with energy and the signal. Due to the Shield will cover all the pins from Arduino's board, all the connections (in / out) have to be on it. In fact, the Analogical Input from Muscle sensor board will also be on. Moreover, the power supply from the 7V battery will also feed Arduino and the servomotors as it is going to be explained below.

Figure 81: TFT screen front

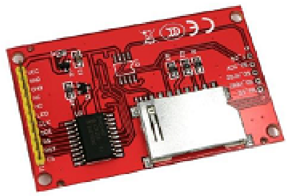
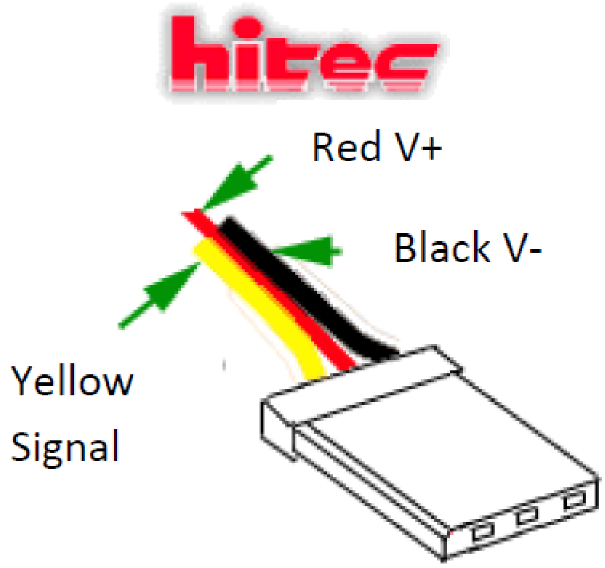


Figure 80: TFT screen back

Push-Buttons:

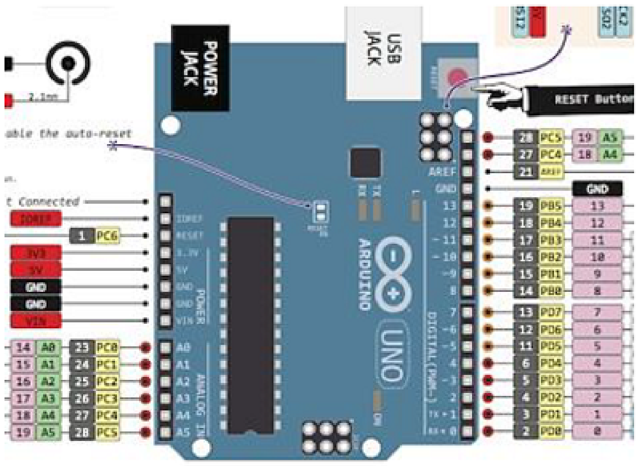
It's been added three surface push-buttons in order to facilitate the configuration of different aspects such as force calibration and Mode changing.

Servos wiring: The Servos connection is composed by three wires, two of alimentation (V+/ V-) and the third to send the signal which commands the position of the servo between (0-180º). Servos wiring shows, the type of connector is like that. It's been added a filter based on a capacitor and a coil to avoid interferences from the servos.



Arduinos chip (ATMega328P):

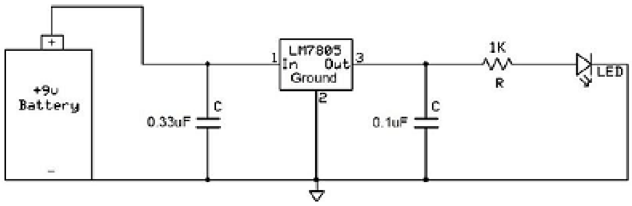
Although it is not going to be used Arduino's chip apart of its board, only the scheme has been designed as if the chip has been ejected and connected with a socket, respecting the inner configuration of the corresponding pins of the board, as it is shown



in the above figure.

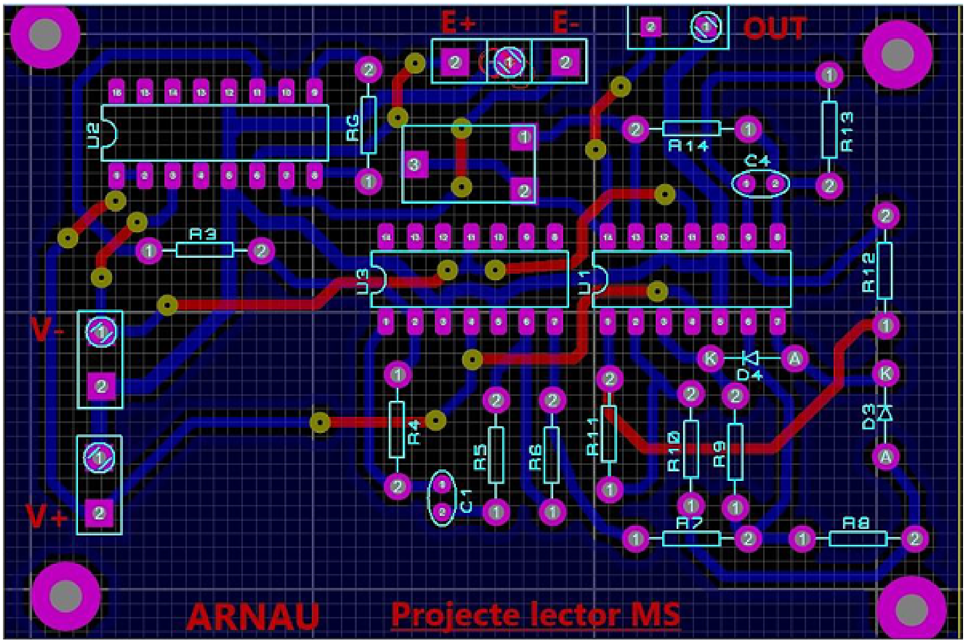
On the one hand, it is needed an external device to provide energy to each servo-motor, it's been thought to put a battery about 7 Volts and to supply the servos just add three diodes to make the voltage decrease from 7V to 5V (7 – (0.7x3) 5V), which is the best voltage to work for this type of servos.

On the other hand, the same battery will provide the energy to Arduino in order to make it work. Arduino's board, needs a 5V voltage to turn on, at the Vin pin. To make sure that this voltage will be constant and exact, it's been decided to put a device which takes an input voltage between 7 to 25 V and supplies a constant 5V output voltage. This device is called LM7805

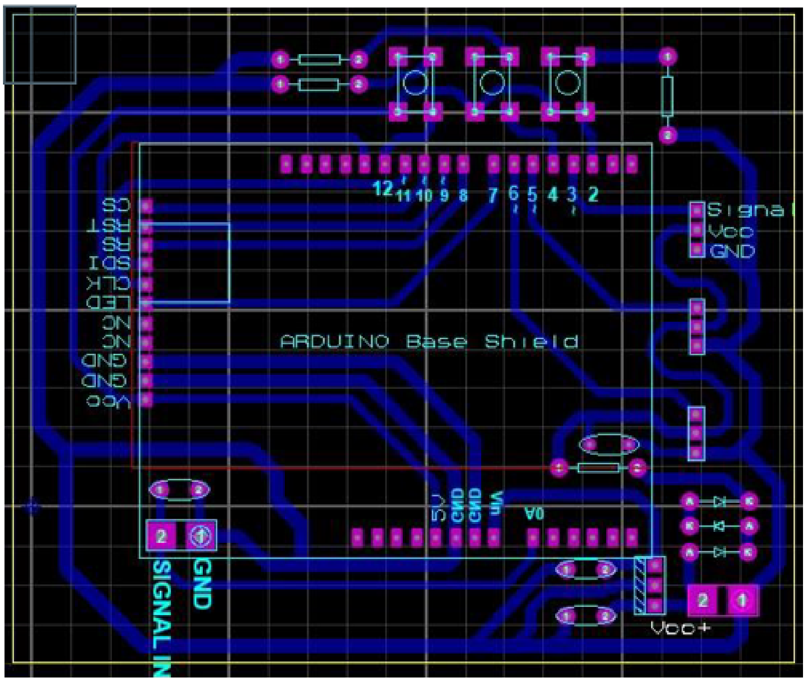


4.2 PCB designing

4.2.1 PCB Design of a muscle sensor

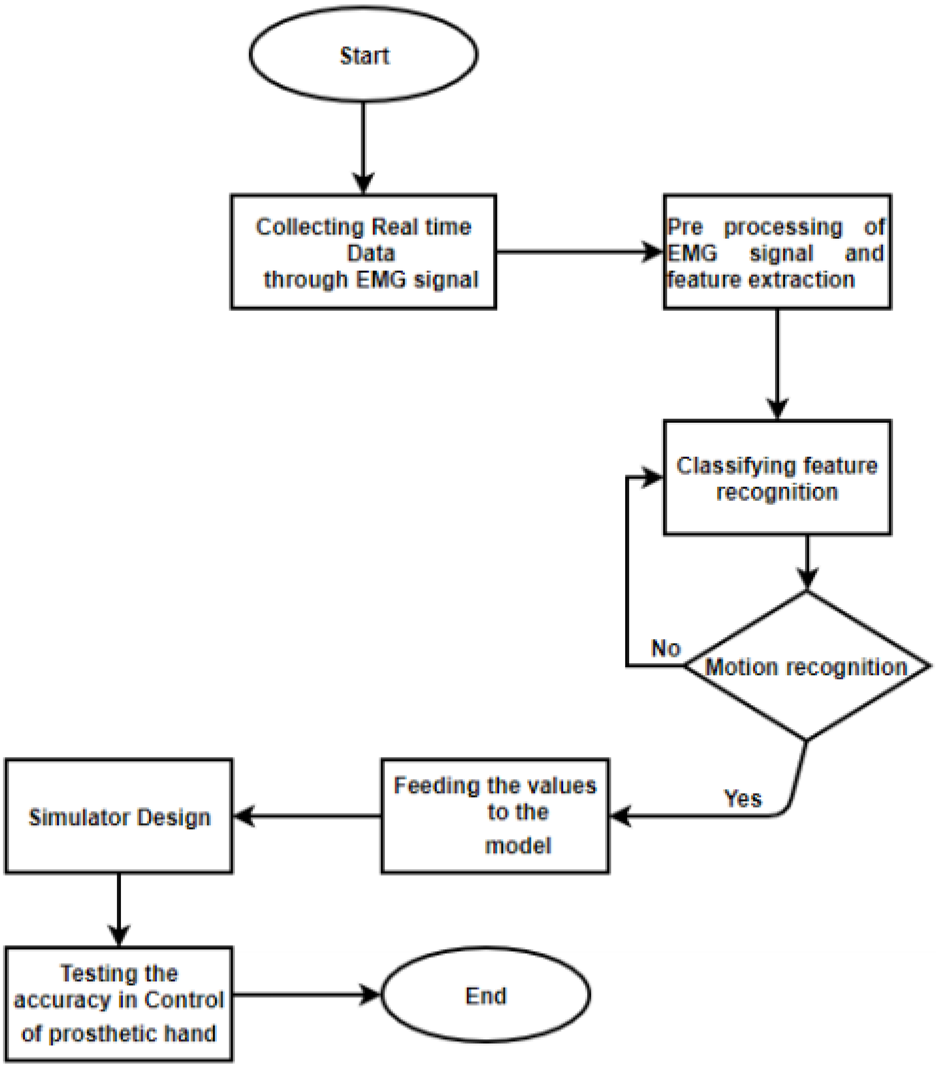


4.2.2 PCB Design of the Arduino Shield Scheme



4.3 Flowchart

In this proposed model, real data has been collected, pre-processed and feature extraction of that data has been done using different methods. After that, data set has been classified for getting the most accurate value for motion recognition. Finally, those values has been implemented on the system's simulated model in order to asses the accuracy of the system. The whole method has been represented in flowchart


Start
Collecting Real time Data through EMG signal
Pre processing of EMG signal and feature extraction
Classifying feature recognition
Motion recognition
No
Yes
Feeding the values to the model
Simulator Design
Testing the accuracy in Control of prosthetic hand
End

4.4 Cost Estimate

Expected Costs and Economic Aspects

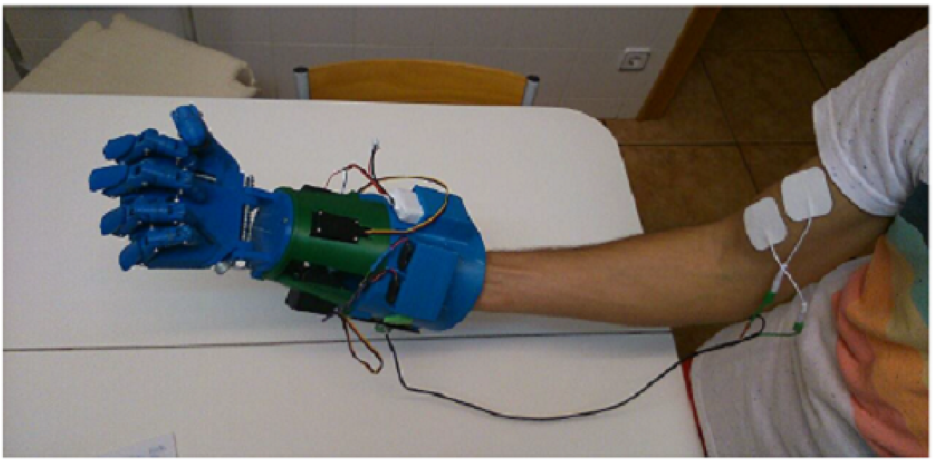
TFT ILI9225	1000rs
Arduino UNO	1500 rs
Pack 16 electrodes (4x4cm)	800rs
Allen bolts	120rs
Pack 100 screws M2x20	400rs
7.4V LIPO Battery 1200mAh	900rs
PCB boards & components	1200rs
9V battery (x2)	800rs
Fishing line	500rs
Total	6750rs

Chapter 5

Result and Discussion

5.1 Experimental Result:

It is needed to evaluate the output signal in order to make sure that the range of the voltages are between 0 - 5V because the analogical input of Arduino works between this values, also it is preferable to obtain a signal really smooth in order to make the servos work properly later. It has been connected the output to an oscilloscope and tested the values of the signal with different forces. To make the signal not exceed 5V, there is a variable resistance to change the final gain of the pulses. Once the final signal has been well limited, it is the time to connect the Arduino and make a simple test with the servomotors.



Analysing the output signals from the different amplifiers.

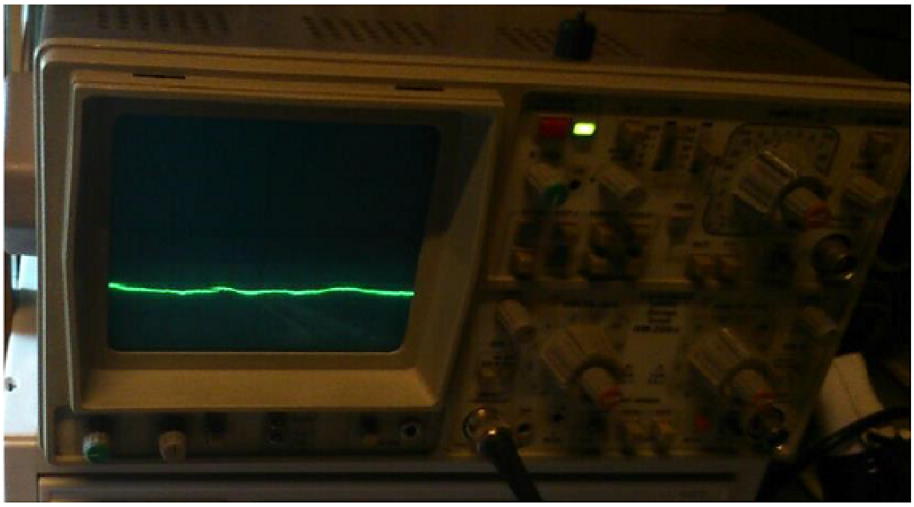


Figure 116: Output signal INA125P

Output signal from INA125P, it's observed that the signal is really small, scale of millivolts. Signal obtained after amplified in TL084.

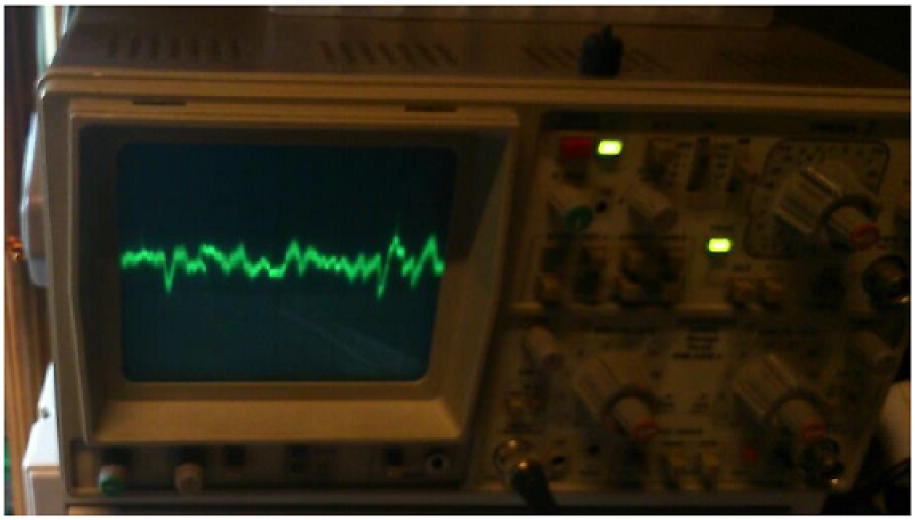


Figure 117: Signal obtained after amplify

It is shown that the signal after Amplify step is too much unstable but quite much bigger than the first one. Finally the signal output from the Muscle Sensor is like that:

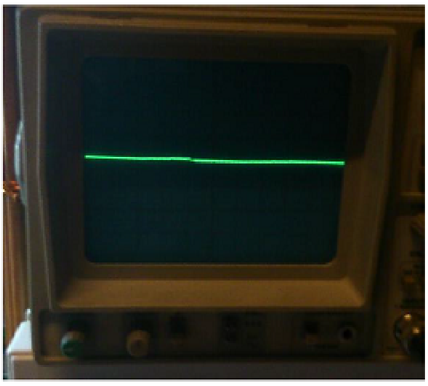


Figure 119: Signal without force

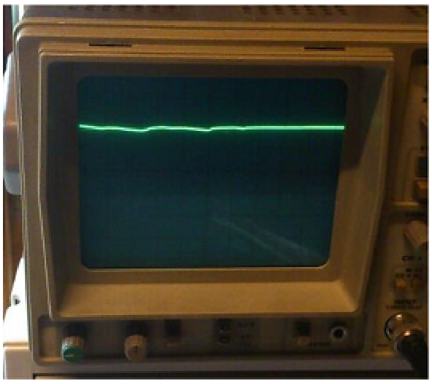


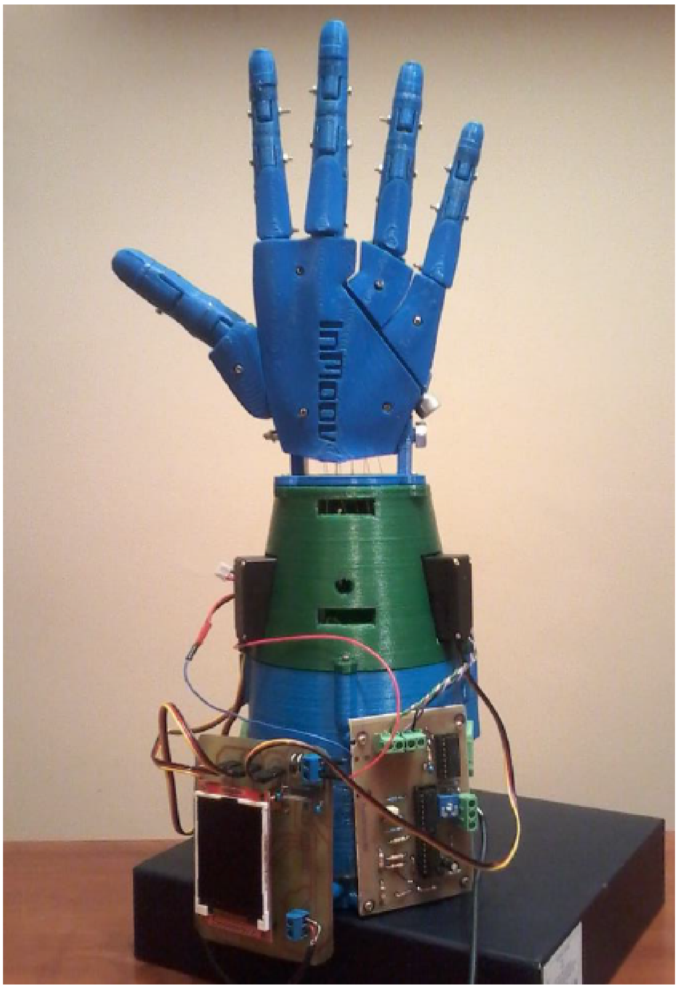
Figure 118:Signal with force

5.2 Conclusions:

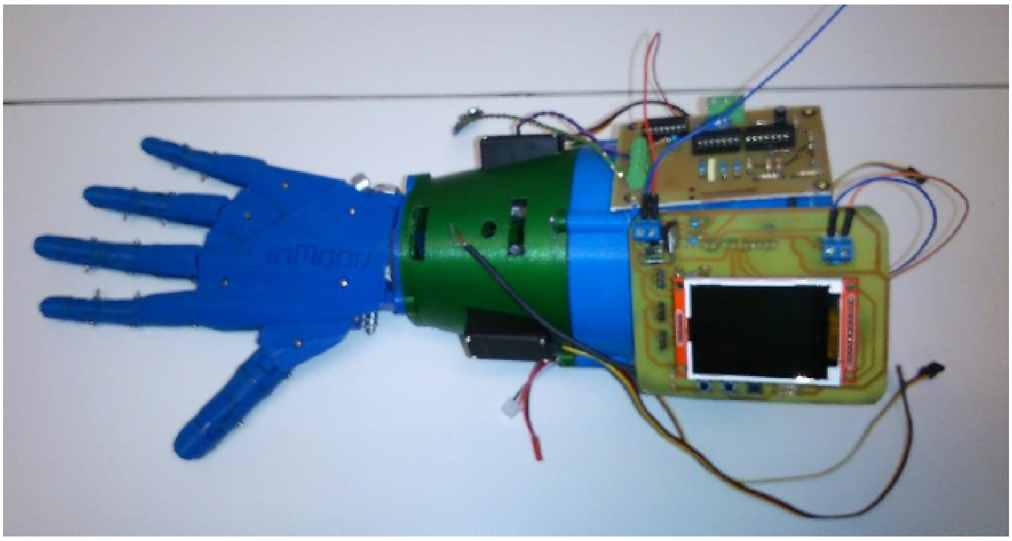
The prosthetic hand through additive manufacturing process is the ultimate solution for a cost effective prosthetic hand. Increase in quality accuracy of the model is achevied. a unique combination of medical science and computer aid designing and manufacturing. To conclude, people are losing their body parts daily in developing countries like Bangladesh. The reason behind this leads to huge road accidents, tracking, diseases like diabetes etc. This kind of amputee people need prosthesis so that they can make their life a little easier. It is very precise as well as affordable system for most of the amputees which can make their life easier. The objectives reflected at the goals description, both types of movement have been achieved with the prototype, enclosure and impingement. As a prototype the final design hasn't been designed in order to be perfectly adapted to an amputated arm, it has been thought to be used by anyone such as a prosthesis tester and it accomplish the expectations. During the project it's been overcome a lot of difficulties, beginning with the 3D printing, because it is not so easy as it seems, It is learnt that the 3D printers are so sensible to any minimal change of the temperatures and if the base or the extruder are not properly configured it is so easy to get an imperfect piece. Also, all the designs invented on this project has been changed several times because of some problems such as, a difficult design which is impossible to be printed with the 3D printer used due to its complex geometry, or because some physical properties weren't well designed before and the shape has had to be changed. Otherwise, the electronics used are quite complex, the signal from the muscles is a really low signal and highly changeable, it has been amplified and smoothed in order to work with it properly, anyway, some troubles have appeared to read the signal, there so, the designs of the PCB has had to be modified also. It's been realized the complexity of the signal processing with the human body. As an important point of this project, is been demonstrated the viability of self-making prosthesis compared with the prices found on the Internet which are impossible to afford for many people. Another point of the conclusions is the improvement or optimization of the final prototype. Surely, it has a lot of aspects to be upgraded, but the most important are:

- Adding a pressure sensor to control the force of the grab when there is something.
- Improve the design of the forearm pieces in order to achieve a more natural and real shape.
- Continuous improvements of the program and the signal reading.
- Try to add more servos to be able to move each finger with independence.

To sum up, it's concluded that the myoelectric prostheses are so difficult to develop but nowadays is growing a new revolutionary idea such as the 3D printing which make easier and cheaper the self-created devices. In the next future these printers would be available and affordable for anyone and the open source designs on the Internet will make the crafting easier.



5.2.1 Prototype of Finally Assembled



5.3 Future Scope:

Automation, Continuous improvements of the program and the signal reading. Improve the design to achieve more natural and real shape.

For centuries prosthetics have been limited to basic attachments replacing missing limbs or extremities, but in the last 20 years, artificial limbs have moved forward at an electric pace.

Today's technologies incorporate more advanced ranges of movement and, with the advent of neuroprosthetics, researchers have brought about the rise of sophisticated brain-controlled prosthetic limbs. These are combined with electrode arrays – placed in the brain, nerves or muscles – to decode the messages between the brain and the limb that control movement, allowing users' brains to power basic movement in, say, a prosthetic arm.

As University of Chicago (UChicago) associate professor and neuroprosthetics researcher Dr Sliman Bensmaia notes, brain-controlled prosthetics have become a vibrant field of research.

"The idea is to put electrodes in [the motor cortex] so when [a tetraplegic patient] tries to move their arm, or imagines moving their arm, there is a characteristic pattern of activation in this motor part of the brain," he says. "We can take the signals from this part of the brain and infer what the patient or the subject wanted to do, and then you make the robotic arm do that. There's a cottage industry of developing different ways of doing that, and they're all slight variants of one another."

Neuroprosthetics have unlocked advances that amputees and paralysed patients previously wouldn't have dreamed of, but as with any rapidly emerging area of research, there's still a long way to go before the field meets its full potential. One of the major limiting factors for the dexterity of neuroprosthetics relates to a sense that most humans take for granted: touch.

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