A

MINI PROJECT REPORT

ON

"GESTURES IN BIONIC ARM"

FOR PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR
MINI PROJECT SUBJECT
OF T.E. E&TC – 2019 COURSE, SPPU, PUNE

By

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ACADEMIC YEAR: 2021 - 2022

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Pune Institute of Computer Technology, Pune – 43

CERTIFICATE

This is to certify that the Mini Project Report entitled

“Gestures in Bionic Arm”

has been successfully completed by

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Is a bonafide work carried out by them under the supervision of Prof. Hemantkumar Mali and it is approved for the partial fulfillment of the requirements for the Employability skills and Mini Project of T.E. E&TC – 2019 Course of the Savitribai Phule Pune University, Pune.

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Place: Pune
Date: 19/05/2022

ACKNOWLEDGEMENT

It is our great pleasure to present the honor and sincere gratitude to our guide Prof. H.B. Mali, who had helped us in joining the hands in developing each and every step of this project and for valuable guidance and constant encouragement during completion of project work.

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Raghav Bhutada

Malhaar Karandikar

ABSTRACT

Physical impairment can limit the physical function. Such individual then can be called as a handicap. In cases of individuals with loss of limbs and next to nothing residual capacity, it is very difficult for them to associate with daily activities as well as employment, education, independent living, etc. This project will depict the information relating the substitution of the upper limb of an amputee by Myoelectric Prosthetic Arm. The objective of this project was to redesign a prosthetic arm that would be affordable for common people and be best fit for ages from eighteen to fifty. The advances in science and technology have led to development of externally powered prosthesis that interface directly with the neuromuscular system and recreate some of a normal hand's sophisticated proprioceptive control.

This hand is based on biological electronic sensors, is battery operated, controlled by microprocessor, and driven by motors. It then translates this muscle activity as triggered by the user into information via microcontroller, which control the artificial limbs movements via electric motors. The result is that the artificial limb moves much like a natural limb, according to the mental stimulus of the user. The Myoelectric artificial limb does not require any unwieldy straps or harnesses to function. Instead, it is custom made to fit and attach to the remaining limb. Myoelectric hand/arm component perform better than conventional prosthesis in terms of function, weight, comfort, and cosmetics. The final design includes a robust and strong design, which can easily be manipulated by the user. It contains cheap, light, but also strong materials.

Raghav Bhutada

Malhaar Karandikar

List of Figures:

Abbreviations

If report includes formulae and special words or symbols mention their meaning here for reference. If it is not included in report; this page may be removed from final report.

Symbol/word	meaning
EMG	Electromyography
DOF	Degree Of Freedom

CONTENTS

Feasibility report

Title: Gestures in Bionic Arm

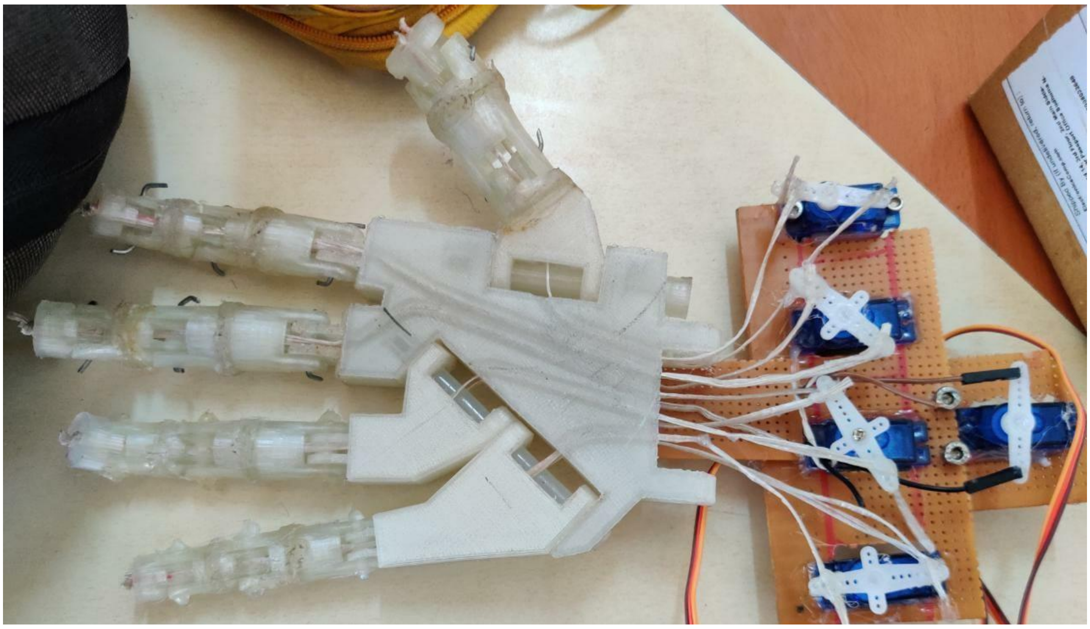
Group members:

1) Raghav Bhutada (32304)
2) Malhaar Karandikar (32328)

Tools required	Testing possibility	Controller	Cost
Hardware/components	**Hardware** **Yes** **No**	**STM32F103C8T6**	**640/-**
Software	**Software** **Yes** **No**	**Solidworks(3D modeling)** **Creality Slicer** **(3d printing)** **Arduino Uno**	**-**
Tools available within campus or outside	**Sensors required**	**Signal conditioning if any**	
3D printers	**EMG sensor**	**NA**	**1200/-** **Sensor** **500/-** **3d print**
Applications if any	**PCB design and fabrication**	**Datasheets/ application notes available**	
Functioning prosthetic Limbs.	**Power supply**	**Datasheet of EMG sensor**	**400/-**
Mechanical design	**Enclosure design**	**Demonstration**	
3D printed Hand	**-**	**-**	**-**

Gestures in Bionic Arm

Front panel of system HW/ home Screen shot for SW-



Electric specification	Mechanical specification
Input specifications- 5V and 9V Output specifications- Analog Signal Features if any	Enclosure design, any special mechanical arrangement- 1. Pulley system 2. Two bar linkage

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CHAPTER 1

Introduction

1.1 Background

People with loss of limbs and next to nothing residual capacity, it is very difficult for them to associate with daily activities as well as employment, education, independent living, etc.

1.2 Relevance

This project is combination of electronics and mechanical background.
This project needs mechanical knowledge for designing and building Robotic Arm and electronics for controlling and providing gestures to hand

1.3 Literature Survey

Several arms such as the Be-bionic 3 and iLimb are myoelectric controlled robotic arms commercially available to the public. Numerous more prosthetic arms exist in research around the world which are usually developed as prototypes to test advanced designs and concepts. Research prosthetics are generally more complex in terms of mechanical design and control and monitoring systems but are inferior to commercial devices in terms of practicality, cost, and robustness.

1.3.1 The Human hand:

The human hand comprises of at least 27 bones (depending on the individual) , more than 30 individual muscles and over 100 named ligaments, nerves and arteries. As shown in fig: 2.1. Prostheses aim to replicate the functions of the human body and return functionality to persons with missing extremities. No current prosthetics can match the dexterity, flexibility and fluidity of the human hand. Before any further discussion, let us briefly explain the meaning of a “degree of freedom” (DOF) for a reader with a non-engineering background.

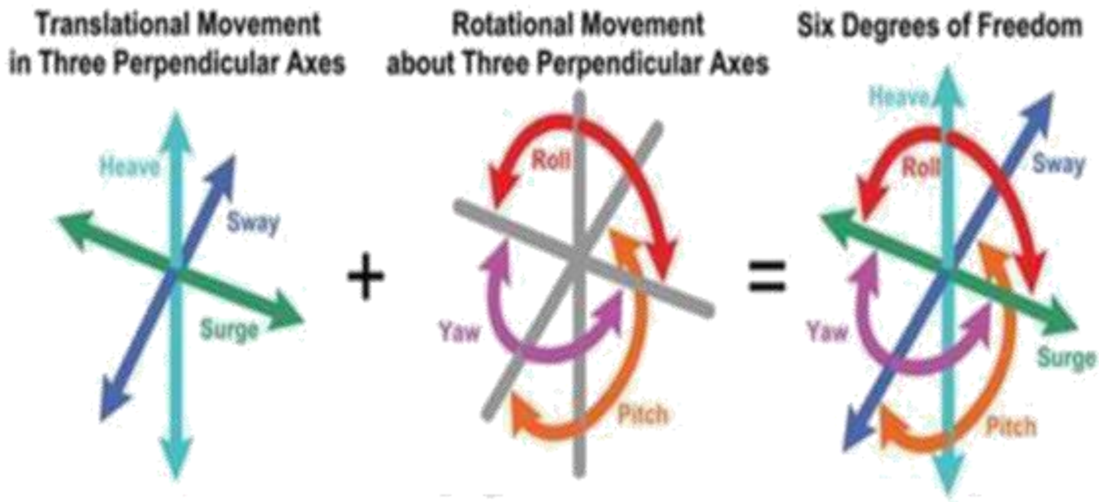


Figure 1.1 – Degrees of freedom at a single point

Looking at the above fig, imagine a point in space. From this point translation can be achieved (move) along 3 different axes i.e., this can move forward/backward, up/down and left and right. At the same point this can also rotate around 3 different axes. The human neck for example has 3 degrees of rotational freedom –this can look left/right, up/down and tilt our head sideways. So, in total a single point can have a maximum of 6 degrees of freedom (3 translational, 3 rotational).

The human finger in total has 4 degrees of freedom as shown in fig below. Three of these are the rotations of each joint (DIP, PIP, MCP) which combine to control flexion and extension of the finger. The knuckle (MCP joint) also allows for abduction/adduction (wiggling the finger from side to side).

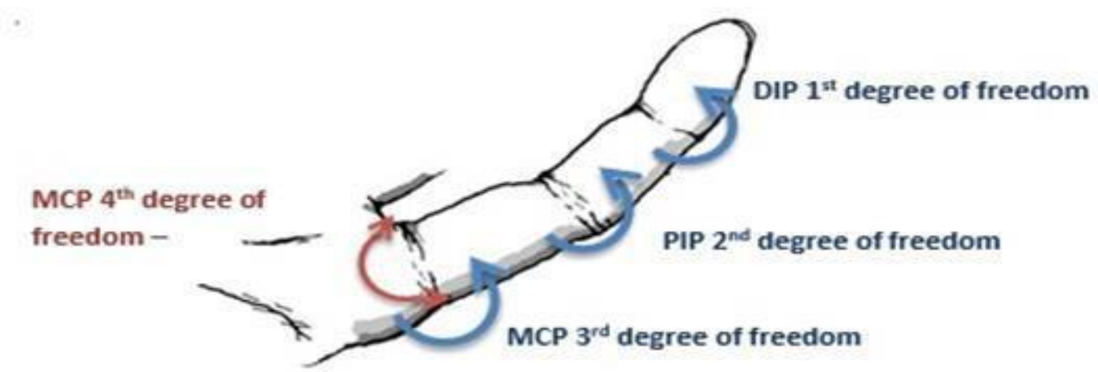


Figure 1.2 – Depiction of the degrees of freedom in a human finger

In the thumb the lower CMC joint also allows for abduction/adduction – which gives 5 DOFs in the thumb. Finger and all joints in the human body are actuated (moved) via contraction of muscles and tendons.

1.3.2 The Bebionic 3

The Bebionic 3 is a world leading commercial myoelectric arm. Like others of its kind, the Bebionic 3 uses a predefined grip system. A user can select from 14 different grip patterns using muscle activity around their upper forearm. The user does not essentially have control of individual finger movements, rather they can select a grip pattern and then use muscle activity to activate the movements of that specific grip. Four of the fourteen grips of the Bebionic 3 are shown in below figure.

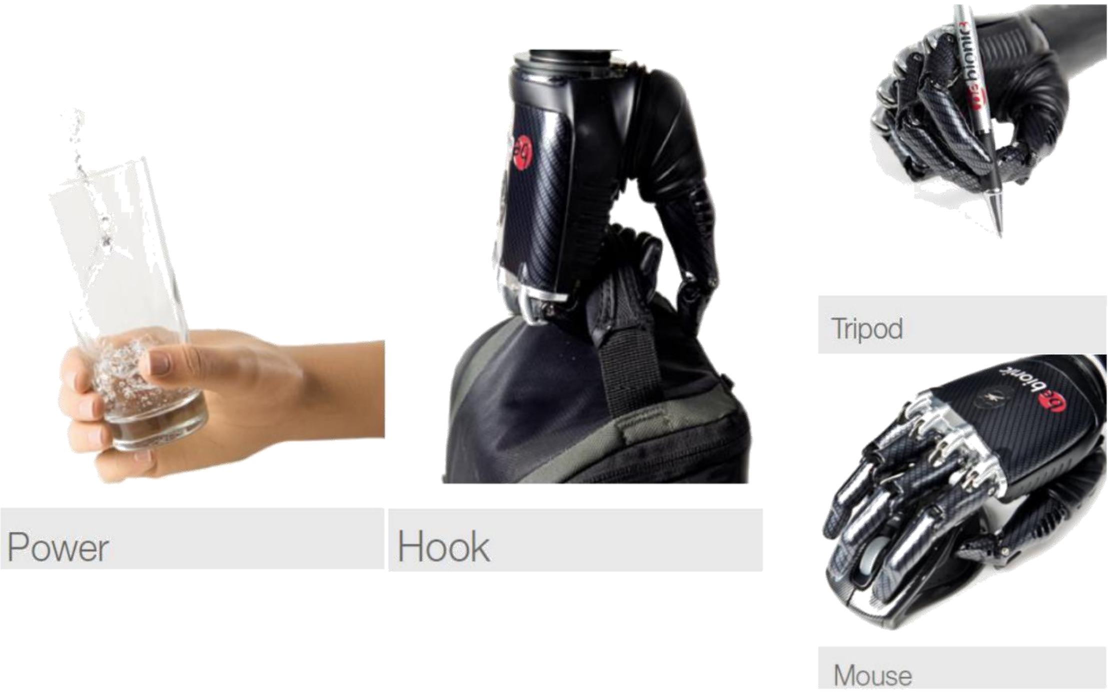


Figure 1.3 - Various grip patterns of the Bebionic 3

The problem with a predefined grip system is that the user cannot finely control finger positions in order to grip a specific object or complete a task. Rather, a user must choose a grip pattern that best suits the job at hand and then actuator that grip pattern.

Furthermore, the user must cycle through a number of grip patterns before they get to their desired choice. For example, unzipping a bag, picking up a heavy object, placing it in that bag and then zipping the bag up could require a number of grip changes. As a result certain simple tasks like this could actually take quite some time to complete and can become tedious and frustrating.

The thumb accounts for arguably 40 percent of human hand use [1]. Thumb design is critical in all prosthetic hands and is more complex than the other fingers.

The Bebionic 3 has an adjustable thumb which can be placed in an opposed or non-opposed position, the difference between these positions can be seen in the images below. This prosthesis cannot directly change the thumbs position. In order to switch between opposed and non-opposed positions the user must apply an external force to "click" the thumb into position, e.g., use the other hand to change the prosthetic thumb position.

1.3.4 iLimb digits

One major difficulty with developing prosthetic arms is that amputation can occur at any point along the arm and is unique in every case. The Bebionic 3 arm previously discussed incorporates electric motors into the palm to actuate the fingers. As a result, the Bebionic would be of no use to an amputee who has lost several fingers but still has their palm intact.

The iLimb digits developed by touch bionics incorporate electric motors directly into the prosthetic fingers. This allows for the palm area to fit into a socket connection attaching the prosthetic fingers to the hand. The image below shows possible amputations which would be suitable for use of the iLimb digits.

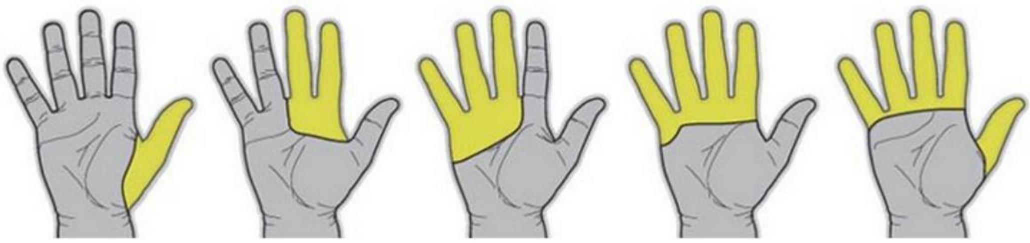


Figure 1.4 – Examples of amputations suitable for the iLimb Digits

A custom socket is designed to fit around the remaining area of the users palm and as many digits as necessary can be added to the system. Like the Bebionic 3, the iLimb digits are controlled through EMG electrodes, which are placed over muscle regions in the palm. A small package must be worn around the user's wrist which contains the battery and controller for the system. A disadvantage of this system is that relatively small motors have to be used to be able to fit inside the fingers. This leads to digits which move slower and are weaker than those in other commercial prostheses.

Figure 1.5 – iLimb Digits attached to an amputee four fingers and the thumb but palm still intact

1.3.5 3D Printed Bionic Arms

Over the past couple of years developing 3D printed bionic limbs has become quite popular. InMoov is an independently run project developing a life like humanoid robot from 3D printing technology. The entire project is open source and provides great mechanical design insight into producing 3D printed robotic body parts.

The open-source nature of this project allows the public to access computer aided designs and follow step by step guides on how to 3D print and assemble this system. The InMoov fingers are controlled by tendons actuated through servo motors placed in the forearm.

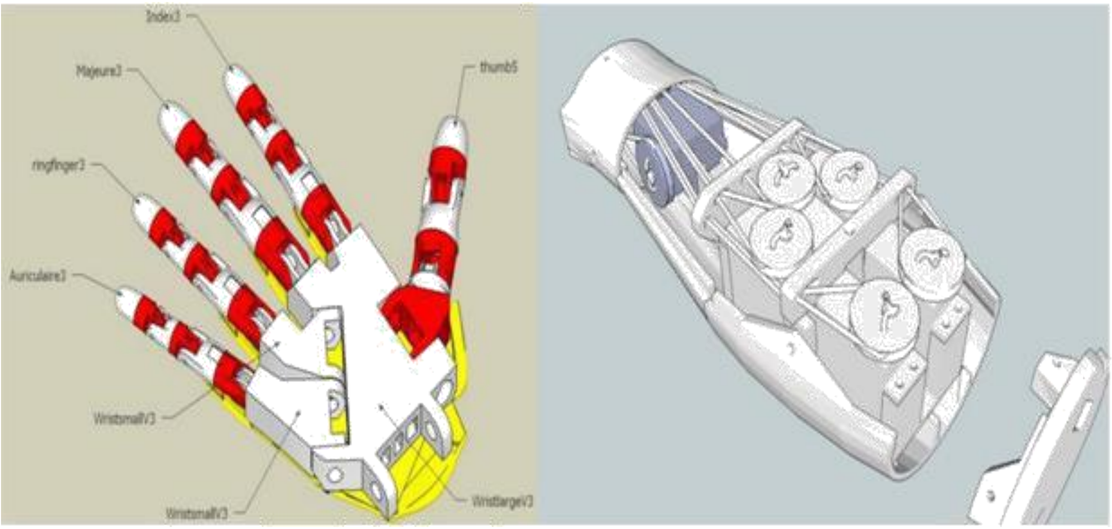


Figure1.6 – Design of 3D printed hand and forearm

The InMoov fingers (including the thumb) only have a single degree of freedom which limits the dexterity of the hand. However, this is a simple solution which has a great advantage over other anthropomorphic hands which is that this design is low cost and easily manufactured through 3D printing.

The problem with the InMoov hand is that the Servos take up the entire forearm leaving no room for it to be attached to a stump between the elbow and wrist.

1.4 Aim of the Project

Aim is to provide a Bionic Arm to Handicap peoples , and add functionality to arm. Also to provide extraordinary functionalities of professionals like Doctors , Miners , etc. Where precision and more power is required.

1.5 Technical Approach

3D modelling the arm first and then by using EMG sensor can be used to control the 3d Printed Arm.

CHAPTER 2

Block Diagram

2.1 Introduction

It could be argued that the most valuable possession to any human being is their body. Replacing a missing human limb, especially a hand, is a challenging task which makes one truly appreciate the complexity of the human body. For centuries innovators have been trying to replace lost limbs with manmade devices. Several prosthetic devices have been discovered from ancient civilizations around the world demonstrating the ongoing progress of prosthetic technology.

Until recent times the design of prosthetic limbs has progressed relatively slowly. Early innovations such as the wooden leg can be thought of as simple prosthetic devices. History shows that for a long-time prosthesis have remained passive devices that offer little in terms of control and movement.

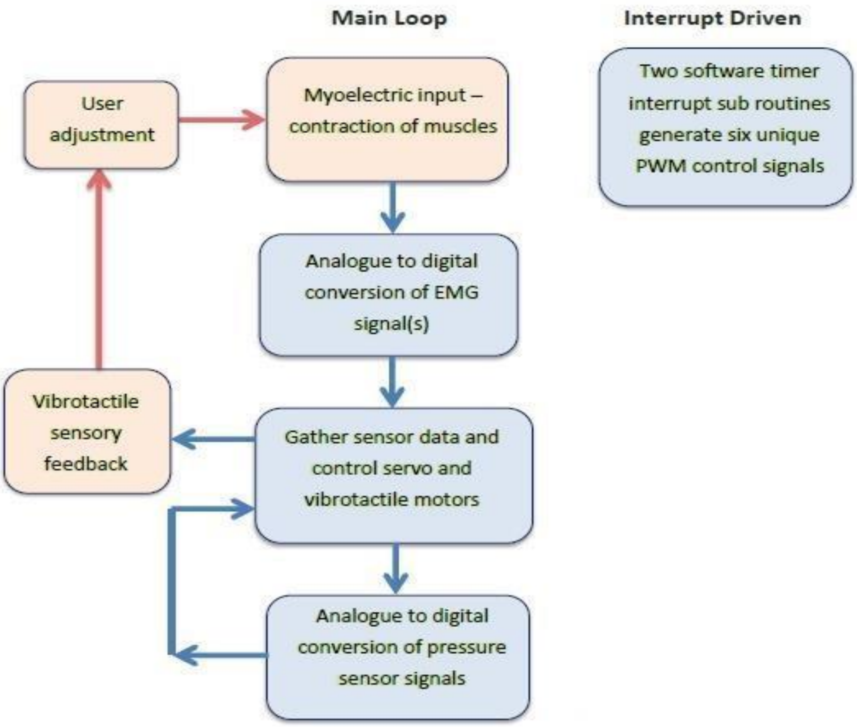
Over time materials improved and designs started incorporating hinges and pulley systems. This led to simple mechanical body powered devices such as metal hooks which can open and close as a user bends their elbow for example.

Recent times however have given way to enormous advancements in prosthetic devices. Focus is not only on the physical aspects of a device but also the control and biofeedback systems. Slowly scientist is approaching an advanced trans-human integration between machine and body. Perhaps sometime in the future prosthetic devices will be faster, stronger, and maybe even healthier than our biological limbs.

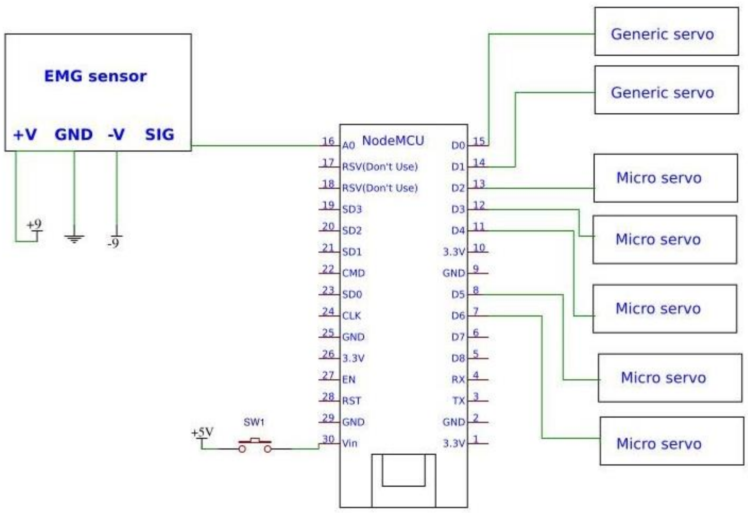
This project is aimed to design a device which mimics the function of the human arm as best as possible and can be controlled to some extent by muscular contractions.

2.2 Block diagram

2.2.1 Block1-



2.2.2 Block2 –



CHAPTER 3

COMPONENT DESIGN & MANUFACTURING

3.1 Mechanical Design

To create a useful myoelectric prosthesis, it is necessary to have a well-designed mechanical system which mimics the functionality of the human arm as best as possible. Among many other things mechanical design involves how joints are actuated and the types of forces present in the system. The bionic arm design presented in this section can be entirely manufactured with a 3D printer and basic tools.

3.1.1 Early Ideas

After researching several actuation methods for prosthetic arms an artificial tendon design was chosen. As seen in the literature reviews of the Shadow Hand, UB Hand and InMoov artificial tendons are a viable way of actuating bionic hands. The tendons can be any high strength line which does not stretch when tensioned. These lines connect to the fingers and are tensioned by motors in the forearm. Pulling on the tendons cause the fingers to open and close to make it portable and attachable to an amputee.

3.1.2 Ergonomics

Ergonomics is the interaction between humans and machines. The field of prosthetics is interesting as it deals with ergonomics between prosthetics and amputees such – physical attachment to the body and sensory feedback. Ergonomics must also be considered for the interaction between a person's prosthesis and other people. An ideal prosthesis is physically comfortable for the amputee to wear, easy and natural to control, provides useful sensory feedback and interacts well with its environment.

The dimensions of a large male hand have been used for design proportions. A universal goal in prosthetic design is to achieve shapes and sizes that match an average female physique. It is much easier to scale a design up in size rather than shrink it down to fit a smaller person.

Scalability has been kept in mind throughout the design process. Components can be easily rescaled in computer modeling software and printed relatively fast. This allows for various size prototypes to be developed with ease.

3.1.3 Computer Assisted Design-

Solid works is a computer design software package made for modeling solid mechanical components and assemblies. Solid works is a popular tool in the engineering industry and has been used extensively in designing and analyzing mechanical components.

Fingers-

Each finger consists of three individual printed components linked together with polypropylene pins. The artificial tendon loops around the inside tip of the finger to create a tendon locking point. This tendon runs through channels inside the finger to form an enclosed loop. When the tendon is pulled, rotational forces are applied to all the joints and the finger curls up as shown in fig 3.1.

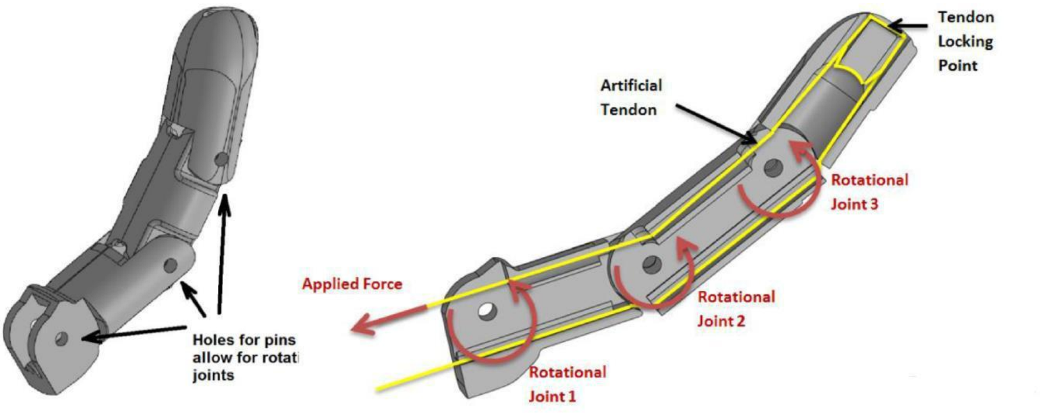


Figure 3.1- Index Finger Design

The tendon locking point is essential so that when the tendon is tensioned it pulls the tip of the finger and causes all joints to rotate. If the tendon did not lock it would just slip when tensioned and the finger would not move. To open the finger from a closed position tension is applied to the other end of the tendon.

High quality braided fishing line has been used as it offers minimal stretch when tensioned. Nylon fishing line would stretch over time leading to a loss of tension which would negatively affect finger movements. Tendons in the biological human hand work in a similar way, however there are far more biological tendons attached to different bones – allowing for more precise control of the fingers.

Thumb-

The thumb has also been designed in a similar fashion as shown in fig 3.2. Most commercial and research prosthetic hands aim to provide at least two degrees of freedom in the thumb. This thumb however only provides a single degree of freedom – it can only open/close in a single way. Guide holes have been incorporated into the design of the fingers and thumb to optimize tendon orientation and prevent the tendon lines from getting caught on a sharp edge.

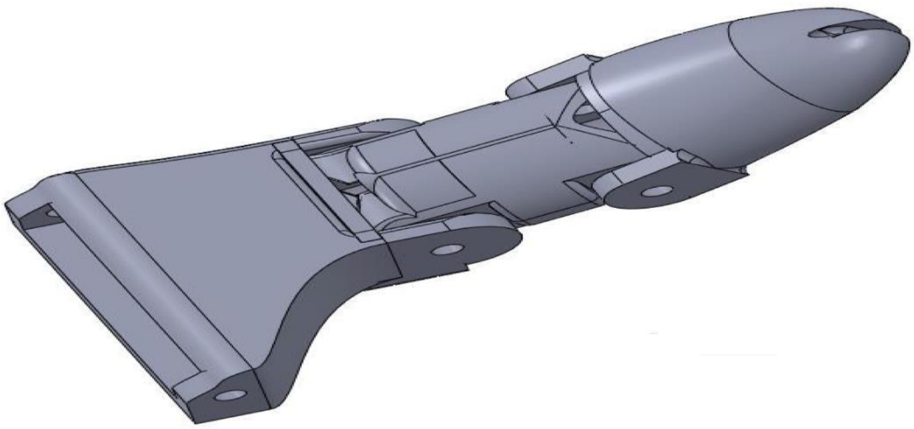


Figure 3.2 – Thumb Section

Palm

Each finger connects to the palm by polypropylene pins. The bottom of the palm incorporates part of the wrist rotation mechanism discussed on the following page.

Figure 3.3 – Palm Section

Wrist

The continuous rotation servos have no angular position feedback. In order to rotate the hand to a specific position a mechanical block would have to be designed or less accurate open loop control methods would have needed to be used.

To avoid these problems it was decided to drop the gear system and instead press fit the palm section directly onto the shaft of the servo in the forearm as shown below. A passage through the pivot point of this joint allows the tendons to pass from the fingers through to the forearm. This allows for ± 90 degrees of rotation about the wrist and eliminates the problem of angular position control. The challenge with this design is providing enough strength. A large opening around the base cylinder had to be left for the tendons to pass through as the wrist rotates through 180O. This big opening concentrates stress around the small cross-sectional area near the base of the palm. The images on the previous page show a wrist model which snapped during testing as it was too weak. The latest model operates on the exact same principle but includes far more material around the base to increase the component strength and prevent fractures occurring at this point.

Drive system-

The tendons wrap around custom 3D printed servo horns creating a closed loop As the servo motor rotates one way it pulls on the tendon and closes the finger. To open the finger the motor is rotated in the opposite direction.

The fig 3.5 shows the artificial tendon drive for the index finger. All other tendons have been omitted for clarity. The thumb, index and middle fingers are connected to individual servo motors. Because the interior space of the arm is limited the ring and pinky fingers have both been tied to the same servo, meaning they open and close in tandem.

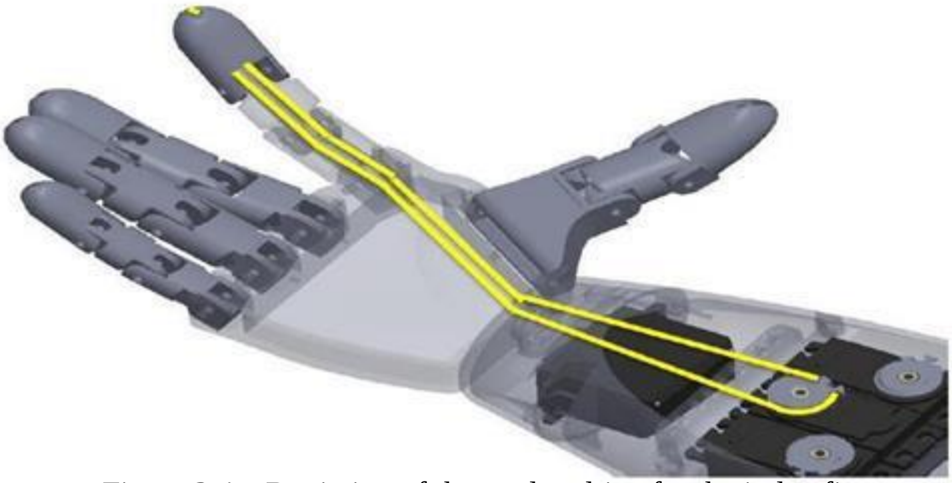


Figure 3.4 – Depiction of the tendon drive for the index finger

3.1.4 Manufacturing & Assembly-

All mechanical components have been produced using an Creality 10S and Ender3 modeling 3D printer. This type of 3D printer produces what is known as support material which provides support to horizontal planes during printing. Care must be taken when removing this support material as to not damage the component.

All the pins used within the device, such as at the finger joints, have been 3mm diameter polylactic acid filament. After printing these pin holes were drilled with a 3mm bit to improve dimensional accuracy.

3.2 Electrical Design-

Signal Flow Overview-

A user flexing generates an analogue signal which is amplified, rectified and smoothed by the EMG sensor board. The microcontroller uses this analogue signal to generate a pulse width modulated signal. This drives servo motors which tension the tendons causing the fingers to curl up.

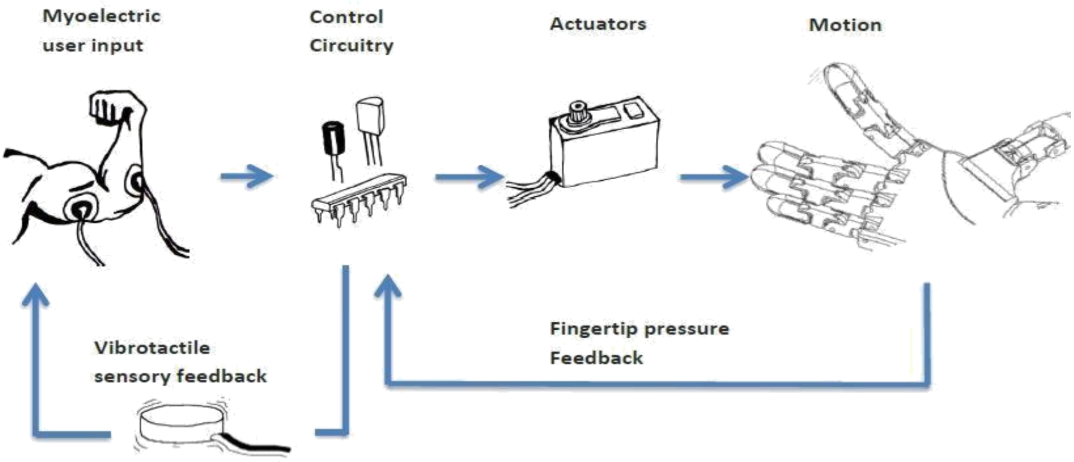


Figure 3.5 – Signal flow diagram

3.2.0 Actuation

As previously discussed, the actuators used in this system are standard servo motors. These motors can be controlled to rotate to angular positions up to ± 90 degrees from rest.

Since the artificial tendons move little in order to open and close each finger, the angular precision of each servo somewhat affects how precisely the fingers can be controlled. Relatively inexpensive servo motors have been used in this system to maintain a low cost. The use of higher quality servos would of course increase finger strength and precision but would cost significantly more.

3.2.3 Electromyography Sensor

Easy to use single channel EMG sensor boards have been used to sense and measure muscle activity. This kit contains a small PCB and three surface electrodes. Two of these electrodes measure the voltage potential across a muscle and the third is a ground reference point placed on a boney feature.

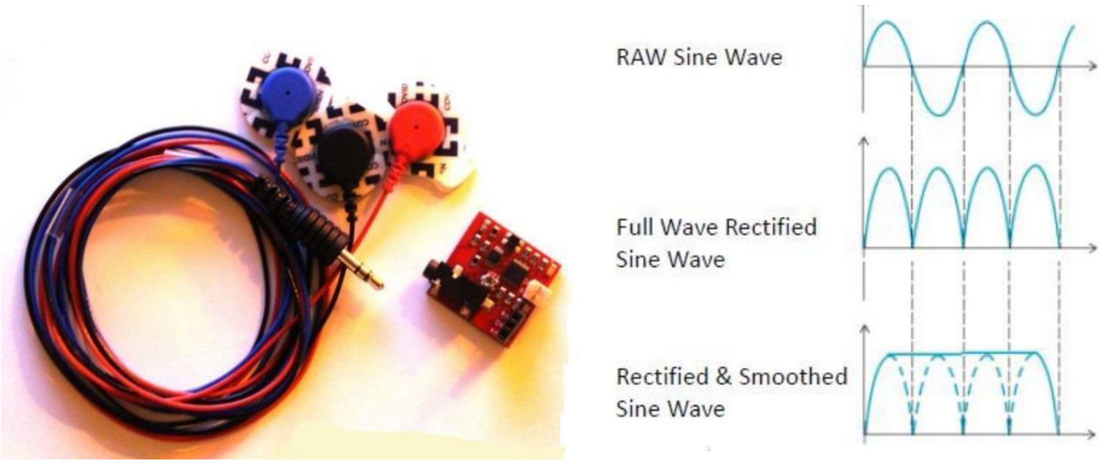


Figure 3.6 – EMG sensor kit & signal output

The muscle sensor kit is designed to be used directly with a microcontroller. As a user flexes, an internal amplification system converts minute electrical pulses into a rectified and smoothed signal that can be used as an input to a microcontroller's analogue to digital converter.

CHAPTER 4

TESTING AND RESULTS

Testing-

Our testing began by plotting the output of the Myoware sensor. The initial testing showed a result that seemed to match our readings. But after studying the signals, a lot of noise that didn't correspond to movement was observed.
Our second test was to check the mechanical movement of each finger. While the test was successful, and this mechanical hand achieved 4 Degree of Freedom, though the movement did not seem to mimic real human fingers.
Our third test was checking the operation of our servos which was successful, and the results were as expected.
Our fourth test was of the final assembly. This included connecting the servos to our bionichand and actuating each finger with the same. Initially, mechanical linkages were not good enough and the movement left much to be desired. So, simple solution to fix this issue which was adding circular mounting points to give the servos a consistent leverage.
Our last test was trying to actuate the hand with the input from the MyoWare sensor. This test was a failure because the output signal of EMG sensor was varying from 5Khz to 450 Khz, and the isolation of this signal from the noise was unsuccessful.
Now, mechanical arm runs successfully.

Results:

Received signals from the EMG sensor successfully:

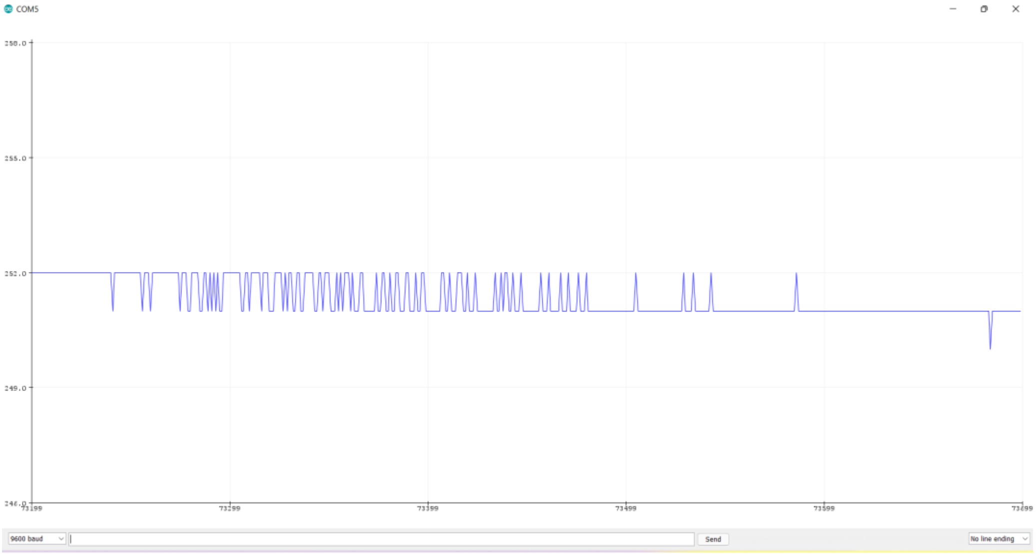


Figure 4.1 – Serial Plotter Graph

Successfully created a mechanically functioning bionic arm with 3D printed parts, plastic cables, 9g servos and perf boards:

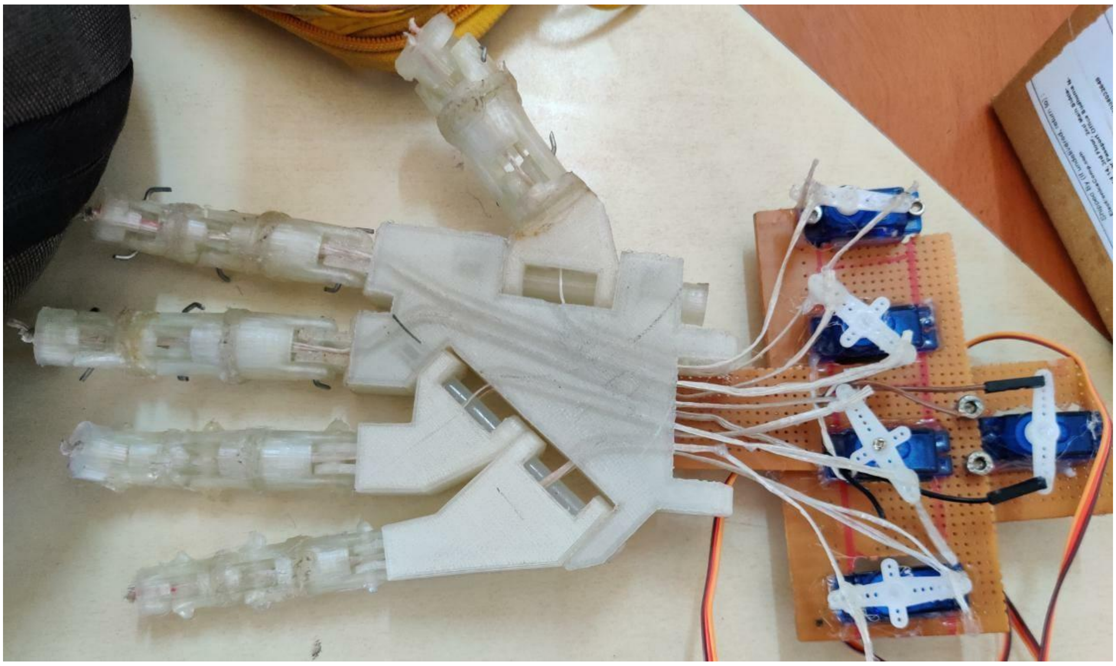


Figure 4.2 – 3D printed bionic hand

Conclusions :

The academic goals of this thesis were initially uncertain and certainly change throughout the course of the year. The initial aim was to develop a low-cost 3D printed myoelectric prosthetic arm. The goals and expectations for this thesis have been achieved and it is hoped that the presented body of work allows for several new thesis topics to be researched in the future.

With future growth of the 3D printing industry advanced printers and materials will allow students to develop more ‘commercial-like’ prosthetic devices – robust and durable systems that could benefit a wide range of peoples with a missing limb.

With ongoing research improvements will hopefully lead to a system that is more durable and offers improved dexterity and control. Perhaps a future design will someday benefit amputees and improve the quality of people’s lives.

CHAPTER 5

Future Scope

1.Using better mechanical elements that mimic human limbs more accurately.

2.Using EEG instead of EMG for better more usable input.

3.Adding extra functions and algorithms.

Functionality to Bionic ARM-

1. Drill Bit to any finger.

2. Automatic hand sanitizer.

3.Various medical tools for doctors like surgery assisting devices.

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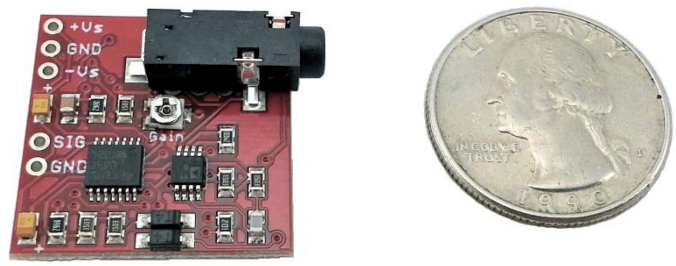
Advancer Technologies
Advancing the Future



Three-lead Differential Muscle/Electromyography Sensor for Microcontroller Applications

FEATURES

- Small Form Factor (1inch X 1inch)
- Specially Designed For Microcontrollers
- Adjustable Gain – Improved Ruggedness
- New On-board 3.5mm Cable Port
- Pins Fit Easily on Standard Breadboards

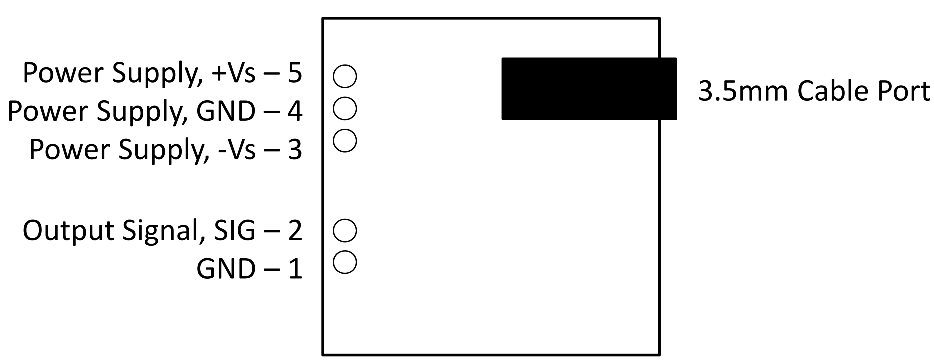
APPLICATIONS

- Video games
- Robots
- Medical Devices
- Wearable/Mobile Electronics
- Powered Exoskeleton suits

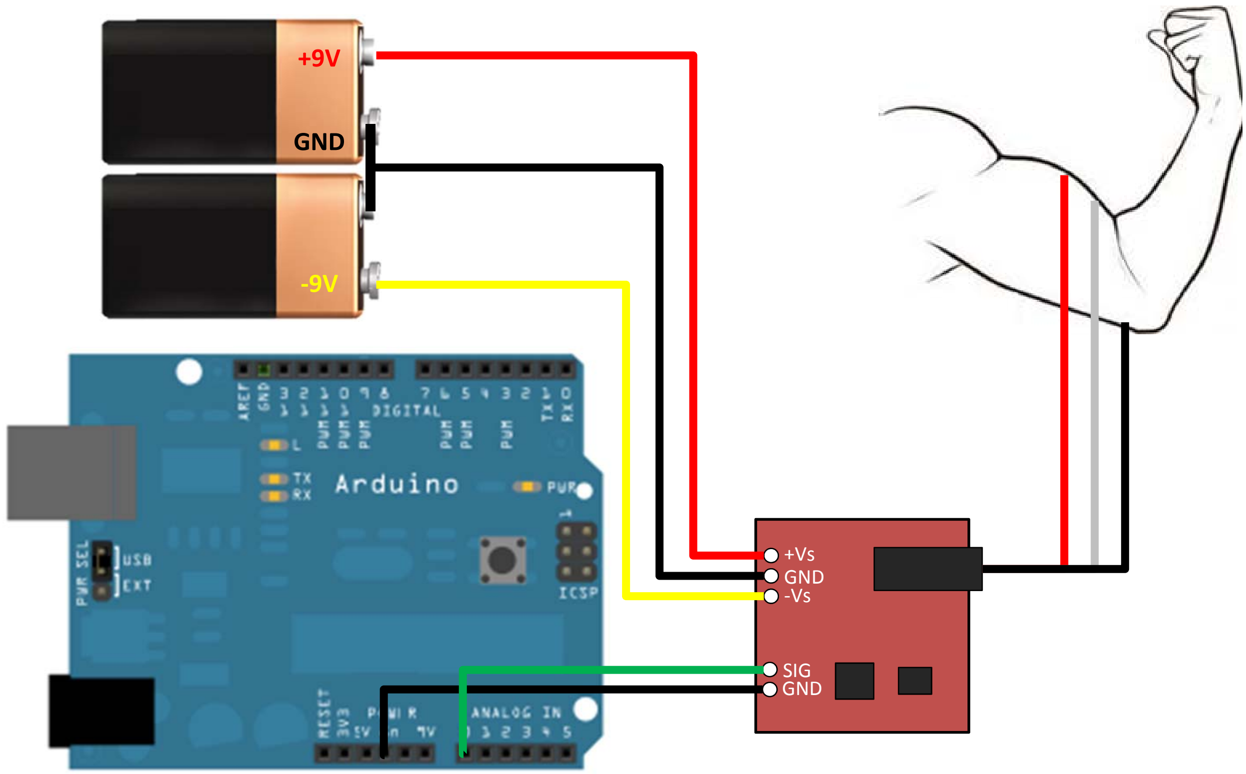
What is electromyography?

Measuring muscle activation via electric potential, referred to as electromyography (EMG), has traditionally been used for medical research and diagnosis of neuromuscular disorders. However, with the advent of ever shrinking yet more powerful microcontrollers and integrated circuits, EMG circuits and sensors have found their way into prosthetics, robotics and other control systems.

PIN LAYOUT

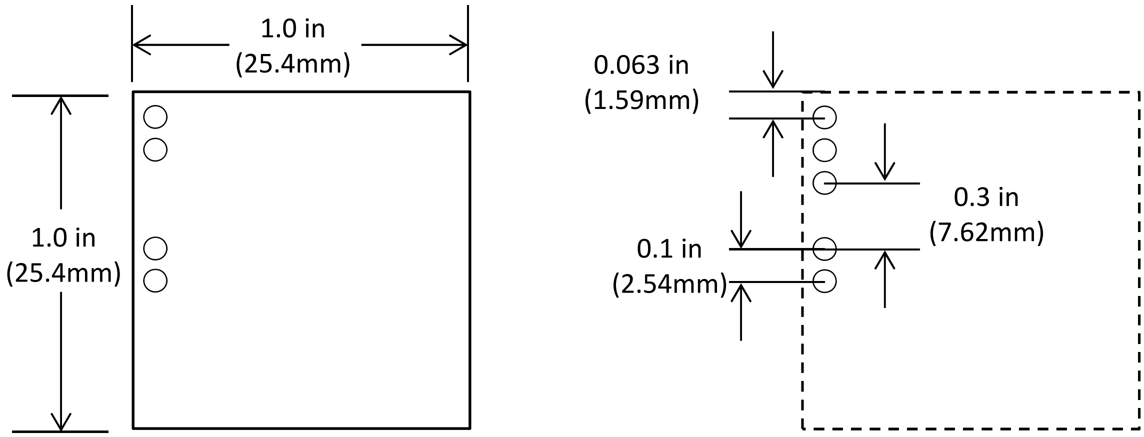


Getting Started Using Two 9V Batteries

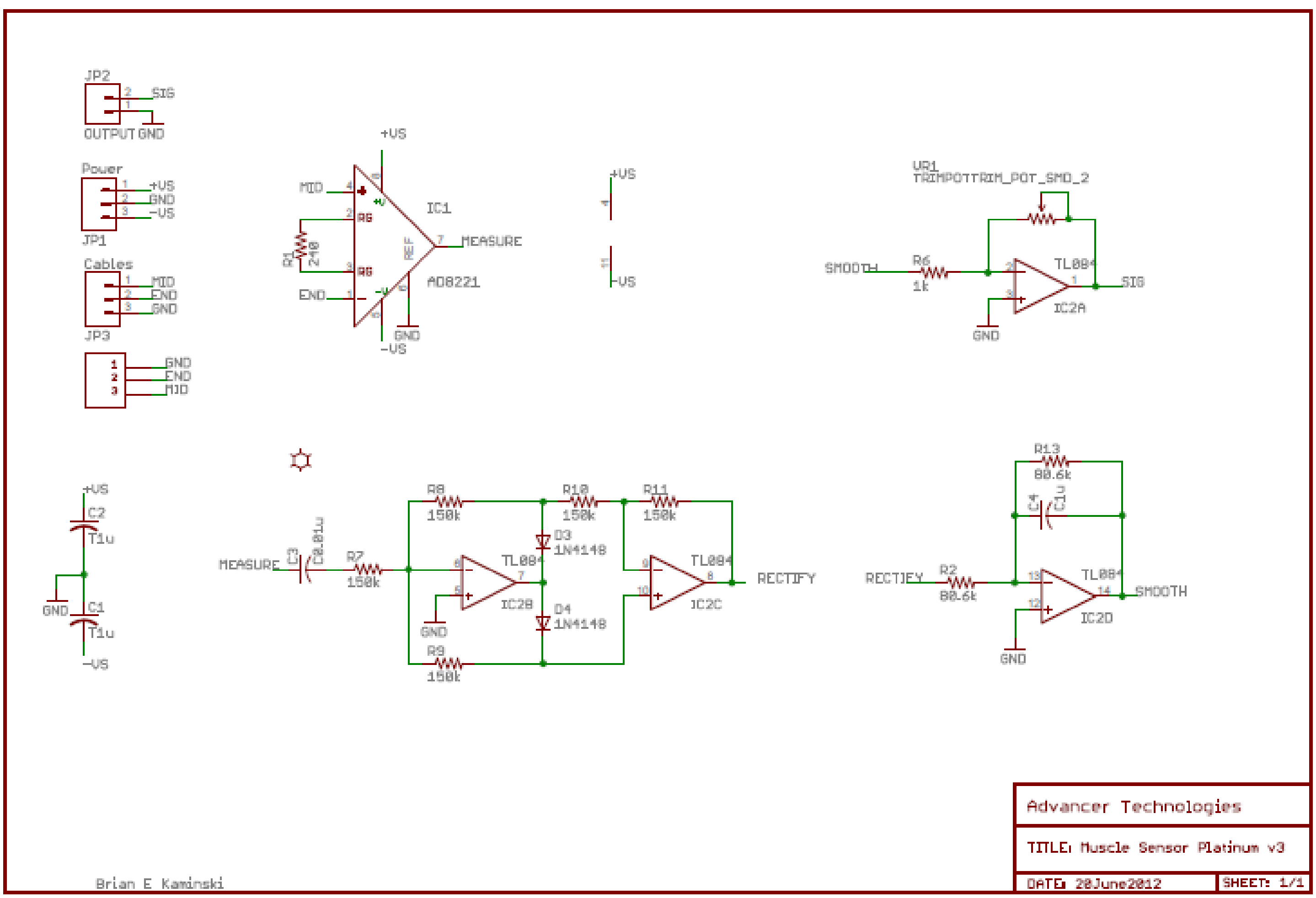


1) Connect the power supply (two 9V batteries)
   a. Connect the positive terminal of the first 9V battery to the +Vs pin on your sensor.
   b. Connect the negative terminal of the first 9V battery to the positive terminal of the second 9V battery. Then connect to the GND pin on your sensor.
   c. Connect the negative terminal of the second 9V battery to the –Vs pin of your sensor.
2) Connect the electrodes
   a. After determining which muscle group you want to target (e.g. bicep, forearm, calf), clean the skin thoroughly.
   b. Place one electrode in the middle of the muscle body, connect this electrode to the RED Cable's snap connector.
   c. Place a second electrode at one end of the muscle body, connect this electrode to the Blue Cable's snap connector.
   d. Place a third electrode on a bony or non-muscular part of your body near the targeted muscle, connect this electrode to the Black Cable's snap connector.
3) Connect to a Microcontroller (e.g. Arduino)
   a. Connect the SIG pin of your sensor to an analog pin on the Arduino (e.g. A0)
   b. Connect the GND pin of your sensor to a GND pin on the Arduino.

Dimensions



Circuit Schematic



Electrical Specifications

Parameter	Min	TYP	Max
Power Supply Voltage (Vs)	±3V	±5V	±30V
Gain Setting, Gain = 207*(X /1 kΩ)	0.01 Ω (0.002x)	50 kΩ (10,350x)	100 kΩ (20,700x)
Output Signal Voltage (Rectified & Smoothed)	0V	--	+Vs
Differential Input Voltage	0 mV	2-5mV	+Vs/Gain

ELECTROSTATIC DISCHARGE SENSITIVITY

This sensor can be damaged by ESD. Advancer Technologies recommends that all sensors be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure.

RAW EMG vs Rectified & Smoothed EMG

Our Muscle Sensors are designed to be used directly with a microcontroller. Therefore, our sensors do not output a RAW EMG signal but rather an amplified, rectified, and smoothed signal that will work well with a microcontroller's analog-to-digital converter (ADC). This difference can be illustrated by using a simple sine wave as an example.

RAW Sine Wave

Full Wave Rectified Sine Wave

Rectified & Smoothed Sine Wave