

# **Real-Time Speech Recognition System for Prosthetic Arm Control**

A dissertation submitted in partial fulfilment of the requirements for the  
award of degree of

**Master of Engineering**  
In  
**Electronic Instrumentation and Control**



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## DECLARATION


I hereby certify that the work is being presented in this thesis work entitled “**Real-Time Speech Recognition System for Prosthetic Arm Control**” in partial fulfillment of award of degree of **Master of Engineering in Electronics Instrumentation & Control Engineering** submitted in Electrical & Instrumentation Engineering Department, Thapar University, Patiala is an authentic record of my own work carried under the supervision of **Dr. Ravinder Agarwal**, Professor, Department of Electrical & Instrumentation Engineering, Thapar University, Patiala.

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*"Achievement is finding out what you would be doing, what you have to do. The higher the summit, higher will be the climb."* It has been rightly said that we are build on the shoulders of others but the satisfaction that accompanies the successful completion of any task would be incomplete without the mention of the people who made it possible.

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## ABSTRACT

Prosthesis is an artificial approach, which is used to replace a disabled body part. Prostheses are typically used to replace and provide supplement to disabled/defective body parts. Disabled body parts can be of any reason like lost accidentally, birth physical disability *etc.* In addition to the standard artificial limb for every-day use, many disable have special limbs and devices to aid in the participation of sports and recreational activities. The main requirement is that its function should be as natural as real arm. There are various designs of artificial arm that are available in the market, categorized as electrical, mechanical and Myo-electric arm. Mechanical prostheses use some motion of the body to provide the power necessary to control the prosthetic component. Electrical arms activate the hand by a motor which is driven by micro switches and relays.

Voice is the most popular and easy tool for communication and simple tool for man machine interface, as it is user friendly and wireless. In this study the hardware of voice controlled prosthetic arm was designed and implemented. For man machine interface through speech a voice recognition module was used, which was initially trained for five voice commands to control the movements of hand. This prosthetic hand having two degrees of freedom was designed with the help of geared DC motor, which has the ability of simply picking up and placing the objects. Further, the prosthetic arm was tested using a glass that contains different quantity of water in it and their respective response time was calculated in placing the glass from one fix position to another fixed position. As soon as the condition of failure exists, the motor was changed with higher specifications and the same procedure was repeated using higher weights.

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## **List of Abbreviations**

ASR	:	Automatic Voice Recognition
PCB	:	Printed Circuit Board
ADC	:	Analog to Digital Converter
CPU	:	Central Processing Unit
ALU	:	Arithmetic Logic Unit
RAM	:	Random Access Memory
ROM	:	Read Only Memory
IES	:	Instruction Execution Section
LCD	:	Liquid Crystal Diode
IC	:	Integrated Circuit
DC	:	Direct Current

# 1. INTRODUCTION

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## 1.1 Prosthetic: A Brief History

A prosthetic limb is an artificial device or a replacement of missing body part. A prosthetic arm is a fake arm for those who amputated their arm. Earlier armories used prostheses mainly in battle to hold sword and shield. Modern prosthetic principles evolved after II world war. In 1949 first myoelectric switch was developed. Earlier body powered prosthesis components have not much changed because most of the research has focused on externally powered prosthesis and high cost of manufacturing also a prime issue.

The first microprocessor-controlled prosthetic knees became available in the early 1990s. The Intelligent Prosthesis was first commercially available microprocessor controlled prosthetic knee. Blatchford & Sons, Ltd., of Great Britain, in 1993 made walking with the prosthesis feel and looks more natural. An improved version was released in 1995 by the name Intelligent Prosthesis Plus. Blatchford released prosthesis, the Adaptive Prosthesis, in 1998 [1]. The Adaptive Prosthesis utilized hydraulic controls, pneumatic controls and a microprocessor to provide control action.

The first experiment with a healthy individual was done by the British scientist Kevin Warwick in 2002. In this case an implant was interfaced directly into nervous system. The electrode array, containing hundred electrodes, was placed in the median nerve. The signals produced were detailed enough that a robot arm was able to mimic the actions of prosthetic arm. [1].

### 1.1.1 Hand Prosthetic

“The hand is an extension of the human brain.”Immanuel Kant- German Philosopher

To a person who has assisted an upper-limb amputation, the control interface between himself and the prosthesis is critical for the success of the device. The capability of the interface to speak intended movements to the prosthesis sets the upper limit for its performance. A wide range of control systems for powered upper-limb prostheses is used today. Typically, user generates the command signal by myoelectric control, the

application of force, or a measurement of expedition of body. However, the relative extent to which these interfaces limit the prosthetic use is unknown. The aim of this study was to quantify the usefulness of two control interfaces that could be used to provide input to a motorized prosthetic arm.

### **1.1.2 Myoelectric Arm**

Myo-electric prosthesis uses electromyography signals or potentials from freely contracted muscles surrounded by a person's residual limb on the surface of the skin to control the activities of the prosthesis, such as elbow flexion/extension, wrist supination/pronation (rotation) or hand opening/closing of the fingers. Prosthesis of this type utilizes the lasting neuro-muscular system of the human body to control the functions of an electric powered prosthetic hand, wrist or elbow. To resist electric switch prosthesis requires straps and/or cables actuated by body activities to operate switches that control the activities of prosthesis or one that is totally automatic. It is not obvious whether those few prostheses provide feedback signals to those muscles are also myoelectric in nature. It has a self-suspending socket with pick up electrodes placed over flexors and extensors for the movement of flexion and extension respectively [2].

Electromyogram (EMG) or myoelectric is control by far the most common user interface for powered prostheses and generally used each time possible. Its advantages are relative ease of use, comfort and promotion of muscle tone. The physical attempt for operation is low because the muscle activity needed is relatively.

Today's highly developed commercial prosthetic hands are largely guarded by electromyography (EMG). EMG signals are read by using surface or needle electrodes that perceive electrical activity associated with the subject's arm muscles. Controller in the prosthetic hand interprets several channels of EMG acquired from the intact part of the arm and subsequently it drives the appropriate actuators to perform the intended activity. In 2013, Max Ortiz Catalan and Rickard Brånemark[3] of the Chalmers University of Technology and Sahlgrenska University Hospital in Sweden, succeeded in

making the first automatic arm which is mind-controlled and can be temporarily attached to the body (using osseointegration).

In the present study, it is seen that although a number of subjects could control these prosthetic hands after several training and experimentation, the main shortcoming of this EMG-driven approach is that the majority of the subjects suffer from early fatigue, as they need to continuously send suitable signals to their arm muscles. Due to the high concentration essential to control a wide range of concurrent inputs, until now only “single channel hands” have been demonstrated for as an acceptable result.

## **1.2 Voice Command over EMG Signal**

In order to advance automatic manipulator grasp functionality, several studies have been done to quantify and better recognize of the human grasping operation. The most complicated commercially obtainable hand prostheses use half a dozen feedback signals to control the hand operation. None of these signals are indicative of the derivative of the forces acting on the prosthesis. Degree of applied grip force and rate of adjust of force are most important parameters of the feedback control.

Various groups have shown that EMG control of prosthesis with greater movement dexterity can be achieved using different combinations of extracted characteristics and classification methods. As far as the decoding of intramuscular myoelectric signals is concerned, Hargrove *et al.*[4] have recently shown that there was no considerable difference when the decoding accuracy of the particular EMG was compared to that of surface-based EMG signals in wrist and hold activities.

Due to the limitations and complexity of EMG-based hand prostheses, in the present study it was decided to explore the option of a much simpler approach based on voice operated. Assuming that the subject does not have any speech destruction, voice commands are greatly easier to interpret than the EMG signals to control the prosthetic arm.[4] Therefore, the first and foremost advantage of this technique is that the associated prosthesis is extremely relaxing and easy to use, and there is no hurt or fatigue involved

in using this. Further, the advantages of voice-controlled prosthetic arm design approach include:

- a) Simpler and more energy efficient design of controller electronics.
- b) Simpler fitting of the hand, as there is no requiring placing surface or needling EMG electrodes.
- c) No need to train the user, and simple to understand.

### **1.3 Speech Recognition**

Speech recognition is the method by which a device or controller (or any type of arrangement) identifies the verbal words. It simply means ordering to device and it exactly recognizes the voice instruction given. Speech Recognition is an ability of computer software program or hardware mechanism to decode the human command into digitized speech that can be interpreted by the computer or hardware device. Voice recognition is commonly used to operate a device, perform commands, or to command robot to pick items or to do a certain work.

### **1.4 Dissertation Organization**

**Chapter I** introduces the main objective of research related to previous studies conducted in this area. It briefly describes the main phases followed during the development of real-time ASR system.

**Chapter II** introduces important research which is already done in this area. It gives a short idea about important references and it emits the basic problem, methodology used and results of that particular research.

**Chapter III** contains basic theory about this dissertation. It introduces about soft computing analysis and hardware design basics. It deals with research problem statement, previous methods, limitation of those methods and how these limitations are overcome.

**Chapter IV** gives a brief idea about material and methods used to develop the complete system description; system operation and component description are basic points which are explained.

**Chapter V** contains the Result and Discussion part of the thesis.

**Chapter VI** gives the idea of conclusion and Future Scope of the thesis

## 2. Literature Review

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**L. McLean, *et al***[1] discovered the designing of myo-electric control of prosthetic arms from its conception in post-war Germany through its popular acclaim in "bionic arms" toward its undertaking as a procedure and correct option for many arm amputees. Discrete and evidently unrelated conceptions of myoelectric control in Germany, the United Kingdom, the USSR, the USA and Canada are followed with particular attention to the gradual achievement of collaborative research and the even slower evolution of commercial products for natural applications.

**Z. Escudero, *et al***[2] demonstrated handicapped people that amputees are one of the most necessary groups in the nature. The aspiration of developing prostheses is mainly to improve their circumstances of life and to help them recover freedom and dignity. Replacing an amputated limb is a complex assignment, as it is desired to replace the osseous structure, to collocate a locomotive system and to give to the prosthesis a command operation. The real challenge for the engineers is to make the system occupy the same space that the arm occupied basically, to make it weight less than it weighted previously, to make it produce a similar force to that produced by a sound arm and in addition to operate the whole system by a reduced control arrangement.

**M. H. Asyali, *et al***[3] says that electromyography (EMG) signal and existing assessment have validated that multichannel EMG signal controls are not appropriate due to early fatigue problems and high effort essential to perform even simple movements. Therefore, a new voice-controlled active hand prosthesis to execute several basic functions was presented. The prosthetic hand engaged 3 DC motors and gears to transmit motion to the fingers. The second part of the study incorporated the use of speech recognition to control the prosthetic hand. The control circuit that developed consisted of an HM2007 speech recognition IC and a PIC microcontroller to drive the DC motors moving the fingers. The control hardware to recognize simple pick up and release operations and have successfully tested.

**A. Vijayaraj *et al***[4] demonstrated mobile robot is controlled by using speech signal. The input speech signal is given through micro phone. Speech extractor is used to convert the given speech signal to word signal. The word signal produces the command. According to the given commands the various operations were demonstrated in the mobile robot like move forward, backward, left and right, clockwise rotate, anticlockwise rotate, open, close, up, down, and stop. The methods used in this research are Linear Predictive Coding (LPC) and Hidden Markow Model(HMM). Sampling rate of the speech signal was taken 8 kHz and the speech signal sampled for 0.5 seconds.

**D. S. Koliouisis *et al***[6] presented the hardware designing of a theoretical Isolated Word Recognition (IWR) system introduced in an earlier study. The recognizer uses a short-term energy and zero-crossing based detection arrangement, and a discrete Hidden Markov model recognizer implemented to recognize seven different words. The hardware system implemented uses economic off-the-shelf (COTS) electronic components, in-ear microphone, importable and economic. The microprocessor processes the identified speech input signal in real-time. The microprocessor's I/O devices work adequately with the audio codec and computer for sampling, testing and training, without intercommunication complications or data loss.

**Kailash Pati Dutta *et al***[8] proposed the proposal of design and implementation of a microcontroller based voice operated wireless system. As speech is the preferred mode of communication for human, this assignment aspires to build the voice oriented command words for controlling home appliances. In this study, voice recognition module has been added to the system. The voice command is user independent. The system consists of transmitting section and receiving section. Initially, the voice command is stockpile in the data base with the help of the function keys. Then the input voice signals are transferred through wireless. The signal received is processed in the voice recognition system where the quality of the voice command is extracted and matched with the existing sample in the stored database. The module recognizes the voice and sends control signal to the microcontroller. The programmed microcontroller then processes the received data and switches the respective device via coupled driving circuits.

**Rachna Jain et al**[9]explained the research and development of voice automated mobile robot. The robot is controlled through connected speech input signals. The language input allows a user to interface with the robot which is familiar to most of the people. The benefits of speech activated robots are wireless and fast data input performance. In future, it is expected that speech recognition systems will be used as man-machine interface. The speech recognition system is trained in such a way that it perceives particular voice commands and the construct robot drives based on the direction through the Speech input Commands. The results shown that developed robot is able of understanding and act according to the meaning of speech commands.

**Tanmay Pal, et al**[10]determined that an on-line characterization of system has been refined for DC motors working in Micro-manufacturing utilization. These precise applications require high precision and high speed of response. The system was programmed on ARM microcontroller, it controls DC motor and automatically collects data while it is being accelerated and acquire a steady speed ; the embedded routines process it instantly and returns the present values of inertia, friction coefficient, back-emf constant and torque constant. A model of system for DC motor control has been designed and developed in laboratory, it has been characterized and control analysis has been operated.

**Biswarup Neogi, et al**[11]find out that any part of the human body replication procedure commences the prosthetic control. Hardware design procedure of a prosthetic arm with employment of gear motor control aspect was came to know. The prosthetic control arm movement has been established in this paper applying processor programming and with the successful testing of the fabricated prosthetic model. The architectural idea of the prosthetic arm here has been replaced by lighter material instead of heavy metal, as well as the traditional EMG (electro myographic) signal has been changed by the muscle strain.

**Shruti Shrivastava et al**[12]demonstrated the different types of motors AC, DC, SERVO or stepper are utilized depends upon the application and hardware developed; of these DC motors are extensively used because of easier controlling. Among the various

control methods for DC motor armature voltage control method using pulse width modulation (PWM) is very famous. PWM using H-bridge built with IGBT switches or transistors was realizing for controlling the speed of motor. To generate PWM signals PIC16F72 microcontroller was used.

### 3.1 Introduction

Automatic Speech Recognizers (ASR) can be used to facilitate communication between humans and machines. Speech-based, human-machine interaction is demonstrated in several everyday applications, such as voice-mail systems in telephony, hands-free machine operations, communication interfaces for people with special abilities, dictation systems, and translation devices. ASR systems have been designed for different applications, in many areas, under a combination of restrictions, such as specific language and vocabulary, speaker dependency, noise-free environments and low talking rates, with excellent results.

Software analysis, designing and implementation are the basic steps required to develop the ASR theoretical processing model into a microprocessor-based system. Analysis is the step where the theoretical and technical information of the ASR system are combined to produce proper processing algorithms. Based upon this analysis a hardware model developed which first recognize the voice or command and then with the help of microcontroller based embedded system moment of motor driven prosthetic hand is controlled.

Complete analysis is divided into two components, software and hardware for their implementation. In the first step, the design components are transformed into microcontroller programs for system evaluation. Second step is to hardware designing of the prototype of the motor driven prosthetic hand. After complete software and hardware interfacing the system was tested on the different loads. Durability of the system was checked for respective loads. Geared motor were specially designed for constant rotation speed. But during testing it was observed that response time of the arm is also increasing with increase in load while placing the object from one position to another position [Table 5.1 – 5.4].

## **3.2 Methods of Prosthetic Control**

Current principal control methods include passive, cable, experimental neural control and myoelectric control. In passive control, a prosthetic hand is essentially locked into one of a limited number of chosen positions. Passive models are generally used as strictly cosmetic devices, with limited manipulative abilities.

Cable or body powered control allows for the simple control of a prosthetic device. They make the use of cables connected to existing residual limbs in order to control the hand. The Otto Bock mechanical hand, *e.g.*, uses deliberate pulls on a cable to control movement [2]. Neural control is a potential future control method. It works by using electrodes on the brain's surface to intercept limb control signal in the form of electrical signals input to any control system. These are then translated into movement using a microcontroller. Neural control is not yet fully practical and does not work efficiently for a single limb below-elbow amputation.

Presently, the most effective and accurate type of prosthetic control is myoelectric control. First envisioned in 1945 by Reinhold Reiter of Munich University [3] says that all muscles generate natural electrochemical potential when they contract and expand. These myoelectric signals (EMG) can be read by Myo-electrodes and amplified to measure a muscle's naturally generated electricity. After processing *via* a microprocessor, these signals can be designated to control a particular degree of freedom in the motor driven prosthesis.

## **3.3 Limitations of Current Prosthetic Control Methods**

Though the most sophisticated current control method is advanced pattern-recognition myoelectric control, it still has a number of disadvantages. It remains relatively inaccurate, with advanced models correctly determining muscle activation approximately 95% of the time when using four input channels. Therefore, one out of 20 times, the hand will operate in an undesirable manner. Pattern recognition, a control method under development, requires the surgical implantation of electrodes, which runs the risk of becoming infected or falling out of position. Finally, extensive signal processing must be

performed to interpret the signal and remove excess noise before it can control a myoelectric device. Various processing techniques, including time frequency analysis, wavelet analysis, neural network and fuzzy classifications have been developed, but none works without failing. The need for customized signal processing makes it difficult to customize one design for different users with different needs and disabilities.

Creating an improved control method that can overcome these obstacles is essential to patient. This work focuses on using voice signals in place of Myo-electrodes as a new intelligent prosthetic control method. It has been seen that the signal strength from amputee stump decreases as the years of amputation increase. Muscle slowly loses its elasticity, if it remains unused for a number of years. Above 20 years of amputation, the muscles permanently lose their elasticity and come under a permanent fatigue state. EMG signal is lost forever when the signal strength from amputee stump decreases. Myoelectric arm will be of no use at that time. Prosthetic arm with two movements- Palm movement and Elbow movement with three levels of grip / movement forces is proposed in the current dissertation work with voice signals.

### **3.4 Objectives**

- a. Design and Implementation of a microcontroller based system which can understand human voice commands
- b. Design a simple prototype prosthetic hand with the help of geared D.C. motor which can perform simple pickup and drop operation
- c. Interface of microcontroller based embedded system with prototype prosthetic hand to the voice commands
- d. Testing of system on different loads with D.C. motors to check its durability

### **3.5 Fundamental of Speech**

#### **3.5.1 Speech Definitions**

Speech is a basic way of communication between humans. As a human action, speech communication can be characterized as a sequence of the following events:

- a. Speaker's brain produces a "thought".
- b. Brain expresses the thought in a series of words according to specific linguistic rules.
- c. Brain produces a series of commands to activate the speech production mechanism in a specific way to produce sounds that represent these words.
- d. Speech production mechanism organs move according to the brain commands and produce the desired sound pressure waves.
- e. Sound waves travel in air.
- f. Sound waves are captured by the listener's auditory system and translated into neurological signals.
- g. Listener's brain translates the neurological signals into words according to the same linguistic rules used by the speaker to form the speech.

From an engineer's perspective, a "speech waveform is an acoustic sound pressure wave that originates from voluntary movements of anatomical structures" [Deller, 1993]. Speech is a time-varying, and consequently, non-stationary signal [1]. To mitigate these problems, speech signal processing can be extended to include the study of the human speech production mechanism. A general description of the speech production mechanism and the main characteristics of speech follow.

### **3.5.2 Human Speech Production System**

Figure 3.1 shows the anatomy of the human speech production mechanism. Here, two main regions can be distinguished namely, sub glottal system and the supra-laryngeal vocal tract. The sub-glottal system consists of diaphragm, lungs, trachea, oesophagus and larynx. The supra-laryngeal vocal tract consists of three different cavities, pharyngeal cavity, oral cavity and nasal cavity.

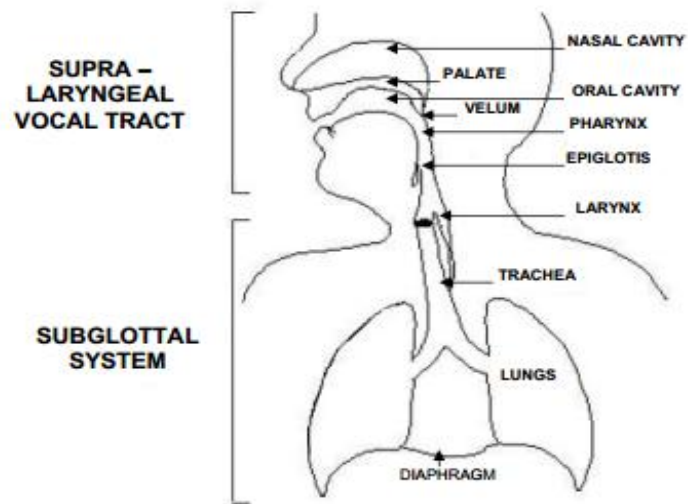


Figure 3.1 Anatomy of human speech production mechanism [Tummala, 2007]

In addition, speech characteristics are also affected by other factors like speaker's anatomy, age and current physical situation. The sub glottal system can be thought of as the speech excitation source which can be viewed as the input to a filter. The filter's characteristic transfer function is affected by the three cavities and their components such as tongue, teeth, lips and velum. These components are called articulators. Their movements are responsible for the resulting shape of sound waves radiating from the speaker.

## 4. Materials and Method

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Hand amputees at present have the option of several kinds of prosthetic devices. They are mostly automatically activated body powered signals, which activate with the use of cables. Electrically driven arm with relays, switch come next while EMG operated arms (myoelectric) are also used. In myoelectric arm the input signal to actuate the arm is given by the EMG which is order of few micro volts to mini volts. A highly precise and accurate signal conditioning system is required to process this EMG signal.

In prosthetic hand small motor provide functions of hand and control is being done through proper sensing of movements of muscles. In the present work, another design of prosthetic system was attempted, which operates by remote signals. It is particularly useful for the amputees whose stump muscle is of no use. The control strategy of our design involves voice controlled system along with a suitable circuitry for controlling the gripping feature. This particular system is simple in nature and not much training is required for amputees to understand the operating procedure

### 4.1 Voice Controlled Prosthetic Arm

Automatic Speech Recognition (ASR) systems consist of two major parts: the speech processing and the recognition. This section describes the main issues associated with these two ASR's components. Speech is a non-stationary signal and processing and is usually conducted over short-time frames where stationary can be assumed. This section introduces the basic idea behind Automatic Speech Recognition (ASR) in the context of isolated word and continuous speech recognition applications.

### 4.2 System Description

Complete system contains three main sub systems, these sub systems work together in a pipe line process. All sub systems are interfaces together such a way that ultimate objective can be accomplished. These sub systems are voice Recognition Module V2, microcontroller based PCB Designing and a prototype of a prosthetic hand designed with the help of DC geared motor.

Voice Recognition Module V2 was used for automatic speech recognition. This module can store up to 15 voice instruction. Voice Recognition module V2 generates a specific hex code for each specific voice command and this hex code send serially to microcontroller and then a code is written to the microcontroller to control hand moments according to given voice commands.

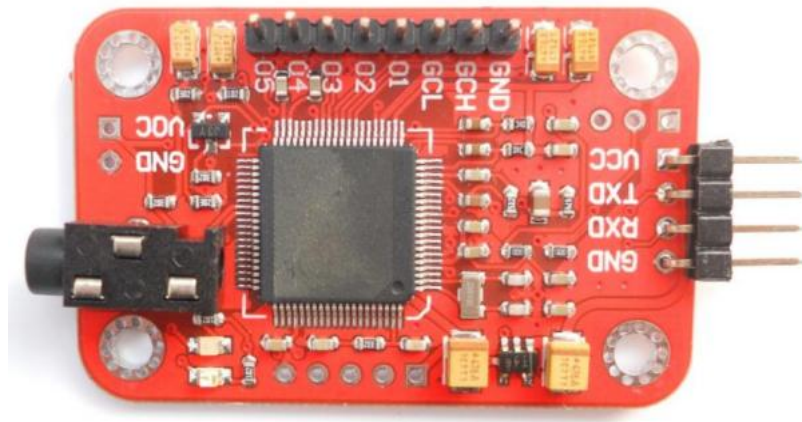


Figure 4.1 Voice Recognition Module V2

Printed Circuit Board (PCB) designing part includes implements and test for required operation. Main steps to complete this sub system are circuit designing on PCB, drilling and soldering the components on PCB, implementation and testing.

#### 4.2.1 Circuit Designing and PCB Fabrication

A printed circuit board (PCB), is used to automatically support and electrically connect electronic components using conductive pathways, tracks or signal traces etched from copper sheets laminated onto a non-conductive substrate. There are several basic steps involved in producing a printed circuit board (PCB). A general steps used in the fabrication of PCB designing is shown in Figure 4.2

In the present study single layer PCB was fabricated.

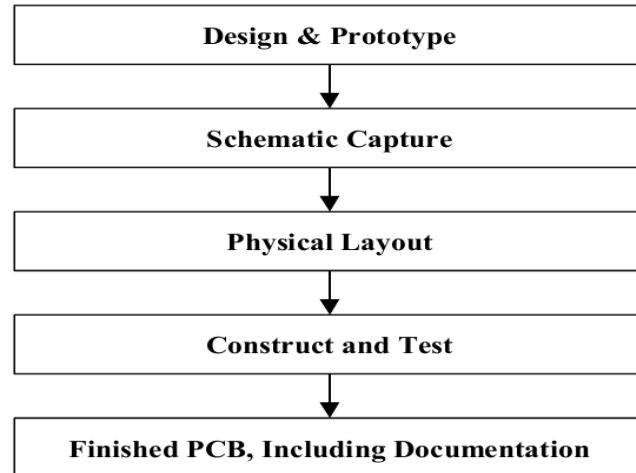


Figure 4.2 Steps involve in PCB Design

Following steps are involved in fabrication of PCB;

- a. Prepare Board design
- b. Print the layout of the design
- c. Clean the PCB board and Press the paper on PCB Board
- d. Removal of the paper from PCB board
- e. Etching Process
- f. Testing of tracks
- g. Drilling and Holing
- h. Mounting Components and Soldering

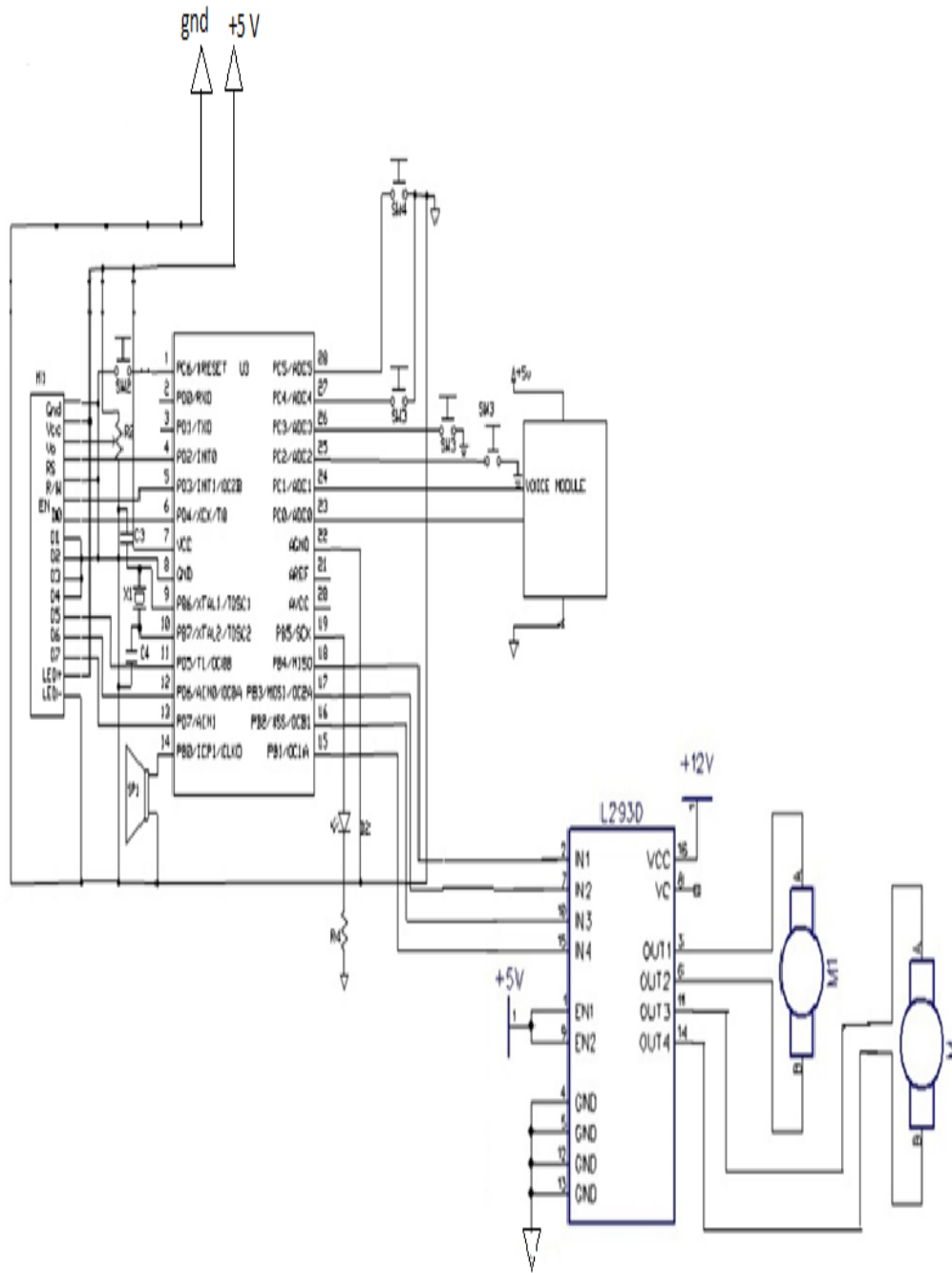


Figure 4.3 Circuit Diagram

### A) Prepare the Board Design

First step in PCB fabrication is to design the circuit in CAD software Eagle 6.6 was used; its steps for design consideration are as follows:

## Step I: Select the Components

First step to Begin layout is adding the components. Select the parts from the *ADD toolbox*. Eagle 6.6 has already very rich library of components but if we don't find and specific component in its library that component can be added in library if ADD toolbox.

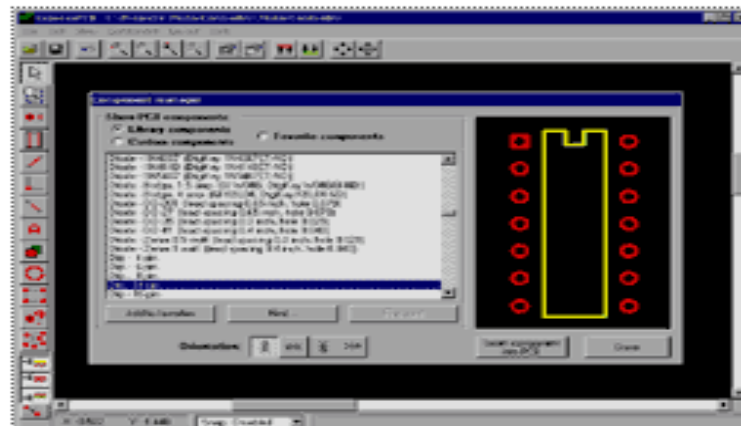


Figure 4.4 Selection of Components

## Step II: Position the Components

Each component to the desired location on board was dragged. This step includes all the components that need to be placed in specific locations. Placing the components decides the length of tracks so it is very important to place the components in a way to minimize the track length. After placing all the components, print out a copy of the layout.

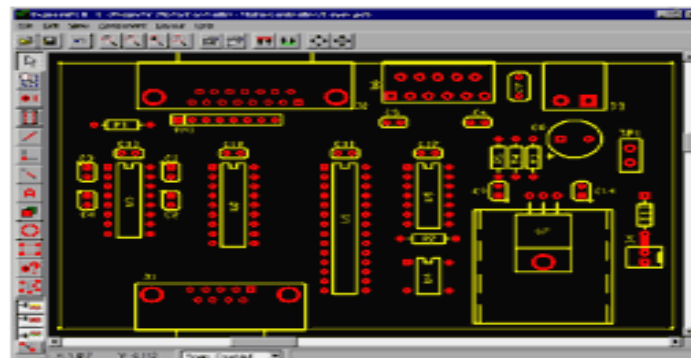


Figure 4.5 Placing the components in specific place

### Step III: Add the Traces

Once the components are placed, next step is to lay the power and ground traces. It is essential when working with ICs to have solid power and ground lines, using wide traces that connect to common rails for each supply. It is very important to avoid snaking or daisy chaining the power lines from part-to-part. By clicking on an optimal tool it automatically connects all the pins in optimal way so that minimum track length and maximum expose of the components can be achieved. After connecting all the pins while saving it already generates all the necessary files like drill file, PCB layout files, *etc.*

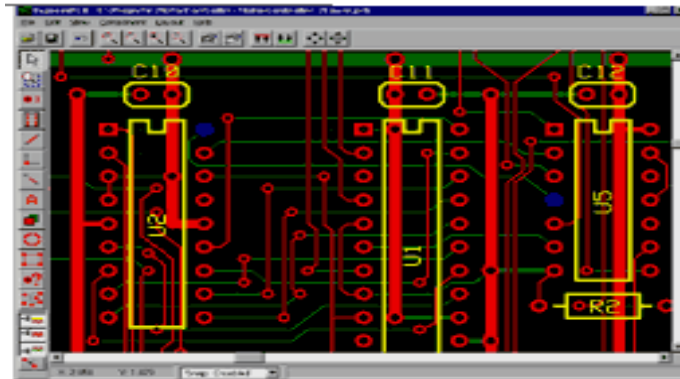


Figure 4.6 Added tracks on placed components

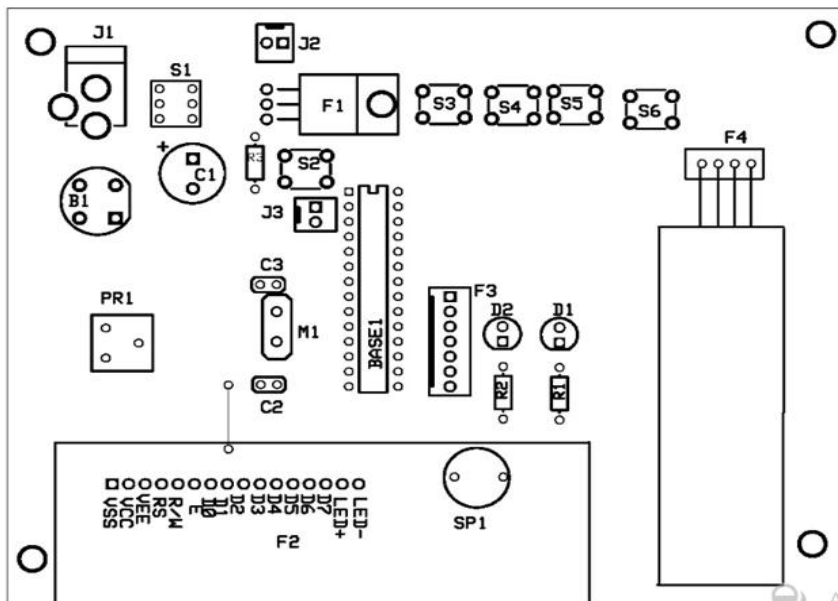


Figure 4.7 Schematic of circuit diagram

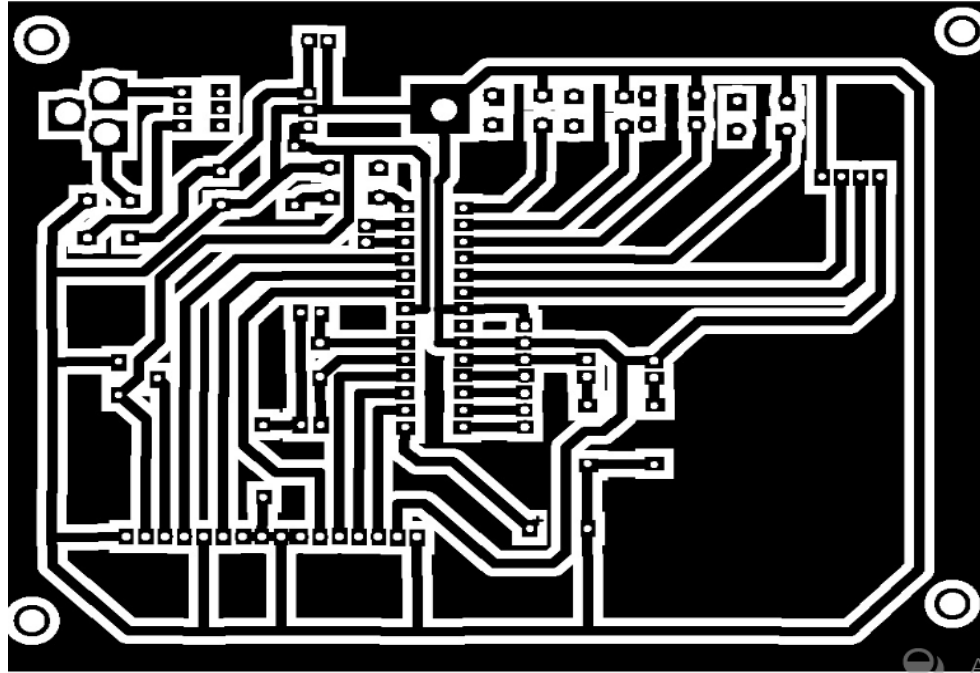


Figure 4.8 Actual PCB layout of the system

### **B) Print, Cleaning and Press the Paper on PCB Board**

After preparing PCB layout of the system next step is to take print out of the design in white glossy paper. Photographic paper is best suitable for this purpose. After that printing the design on glossy paper a PCB board of same size is taken. Clean the PCB board with hard side of kitchen sponge and dishwashing liquid. Try to avoid sent paper for this purpose. Transfer toner from the paper to the board using iron preheated to the maximum possible temperature. It is very important to have iron at its maximum temperature so that complete circuit can be transferred from paper to PCB board.

Next step is the general removal of the paper from the board. For this purpose the PCB boards is kept in hot water and remove the paper generally using figures. Paper should be removed layer by layer by soft hands.

### **C) Etching Process**

Next step is to expose the board in Ferric Chloride and water solution. Ferric Chloride is recommended for this process because it is the best suitable for gentle etching and use of

other chemical can damage the PCB. Ferric Chloride solution is very toxic in nature so be very careful while this process. After this remove the toner acetone and cotton pad

#### **D) Testing of tracks**

Testing of PCB tracks can be done with the help of multi-meter by simply checking the continuity of tracks. This is very important task after developing the PCB board if any discontinuity is there in tracks that can be connected through a jumper wire or by connecting that discontinuity by a conducting wire.

#### **E) Drilling and Holing**

Holes are drilled through the board using an automated drilling machine. The holes are used to mount electronic components on the board and to provide a conductive circuit from one layer of the board to another. To make holes on PCB a simple hand drill is used. Precautions which taken into mind while drilling are listed below:

- a. Always drill vertically or use a proper vertical drill stand
- b. When drilling with carbide bits, it's important to hold the PCB down firmly, as the drill bit can snatch the board upwards as it breaks through, and this will usually break the bit if the board isn't held down.
- c. A good strong light on the board when drilling is required to ensure accuracy. It can be useful to raise the working surface about 15 cm above normal desk height for more comfortable viewing.

#### **F) Mounting Components and Soldering**

Soldering is the process of fastening a part lead to a PCB. It uses heat to melt a metallic compound around the lead and onto the copper pad of the board. The most fundamental skill needed to assemble any electronic project is that of soldering. It takes some practice to make the perfect joint. Turning to the actual techniques of soldering, firstly it's best to secure the work somehow so that it doesn't move during soldering and affect accuracy.

Another step to successful soldering is to ensure that the temperature of all the parts is raised to roughly the same level before applying solder. Heating one part but not the other is far less satisfactory joint, so strive to ensure that the iron is in contact with all the components first, before touching the solder to it. The melting point of most solder is in the region of 188°C (370°F) and the iron tip temperature is typically 330°C to 350°C (626°F to 662°F) [28].

#### **4.2.2 Implementation and Testing**

After complete the hardware designing in all aspects the complete system is tested on the different loads and the durability of the system is checked for respective loads. Geared motor are specially designed for the constant rotation speed but during testing one thing is been observed that response time of time of the arm is also increases with increase the load in order to place that load from one fix point to another fix destination. A table has been made according to increasing response time as per increasing load.

### **4.3 Component Description**

The main components used were Voice Recognition Module V2, microcontroller, motors, motor driver, resisters, voltage regulator IC's, switches, LCD display *etc.* Detailed description of these components is given below:

#### **4.3.1 Voice Recognition Module V2**

The module can recognize voice. It receives configuration commands or responds through serial port interface. This module can store up to 15 voice commands. Those 15 commands are divided into 3 groups, with 5 in each group. Initially train the module with voice instructions group by group and then import one group before it could recognize the 5 voice instructions within that group. If instruction of other group need to be implemented it's necessary to import that group first. This module is speaker dependent it means if a person train the module for some voice commands the other person may or may not operate it so it's good to train the module in own voice before using it for further.

## A) Specification

- a. Voltage: 4.5-5.5V
- b. Current: <40mA
- c. Digital Interface: 5V TTL level UART interface and GPIO
- d. Analog Interface: 3.5mm mono-channel microphone connector and microphone pin interface
- e. Size: 30mm x 47.5mm
- f. Recognition accuracy: 99% (under ideal environment)

## B) Serial Commands

This module can be configured by sending commands via serial port. Configuration will be not erased after powered off. For the first-time use, some configuration is done:

- a. Select the serial baud rate (default 9600)
- b. Select the communication mode: Common Mode or Compact Mode
- c. Recording five instructions of the first group( or 2<sup>nd</sup> or 3<sup>rd</sup> as required)
- d. Import the group you need to use (only recognize 5 instructions within one group at the same time)

After all the setting, speak or send voice instruction to it. If identified successfully, returned the results via serial port in the format: group number + command number.

Serial port setting:

- |                   |   |       |
|-------------------|---|-------|
| a. Baud rate      | : | 9600, |
| b. Parity bit     | : | None  |
| c. Data bit       | : | 8     |
| d. Stop bit       | : | 1     |
| e. Send format    | : | Hex   |
| f. Receive format | : | Char  |

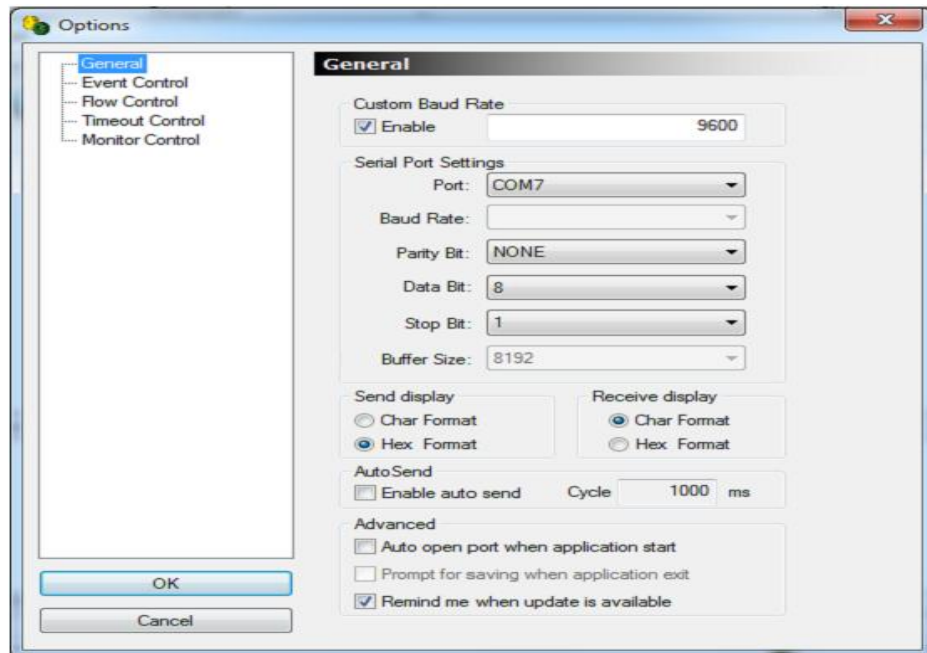


Figure 4.9 Send command

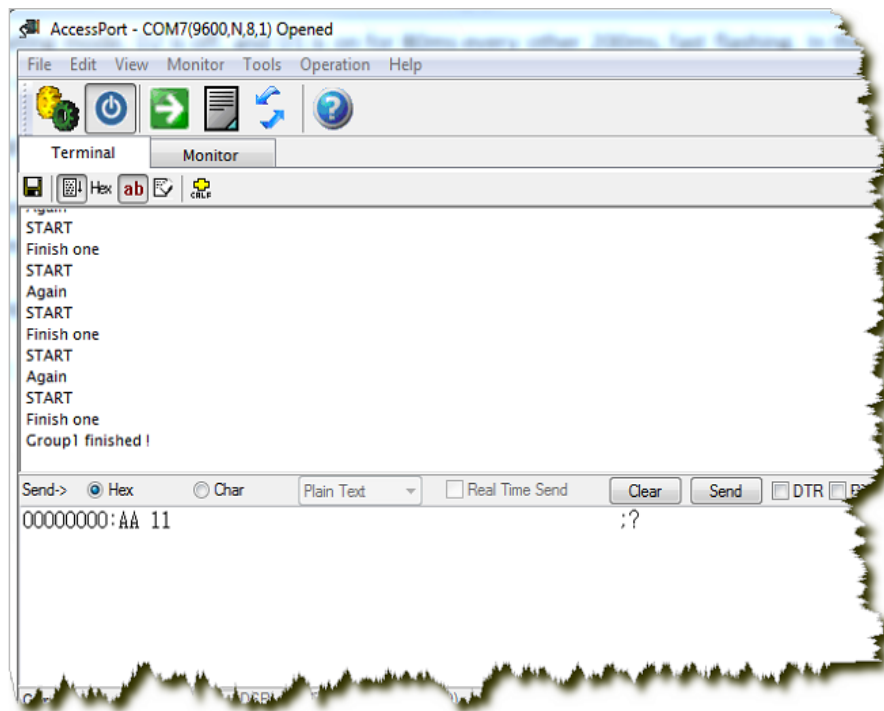


Figure 4.10 Running Mode

Send: 0xaa11

Receive (in Common Mode):

START

No voice // No voice command is given

START

Speak now

Again

START

Speak again now

Different // Voice commands are not matched

START

Speak now

Again

START

Speak again now

Finish one // recording one instruction successfully

START

Again

START

Finish one

START

Again

START

Finish one

START

Again

START

Finish one

START

Again

START

Finish one

Group1 finished! // recording group 1 successfully

### C) Recognition

Another way to import the voice instruction group in V2.is:

- a. Send command 0xAA21 to import group 1.
- b. Send command 0xAA22 to import group 2.
- c. Send command 0xAA23 to import group 3.

Looking at the following picture, could control GCH and GCL pins. Those two pins are all 5V TTL.

<i>GCH</i>	<i>GCL</i>	<i>Working State</i>
<i>LOW</i>	<i>LOW</i>	<i>No Change</i>
<i>LOW</i>	<i>HIGH</i>	<i>Import Group 2</i>
<i>HIGH</i>	<i>LOW</i>	<i>Import Group 1</i>
<i>HIGH</i>	<i>HIGH</i>	<i>Import Group 3</i>

Figure 4.11 Selections of Groups

Once the group is important, it will output message through serial port. It could have 15 voice instructions in 3 groups. Each time need to import the group before it could recognize instructions in that group. It means this module could recognize 5 voice instructions at the same time. In recognition stage, this module could receive other serial commands. It will not exit the recognition stage until you send 0xAA00, or delete that group, or begin recording instructions.

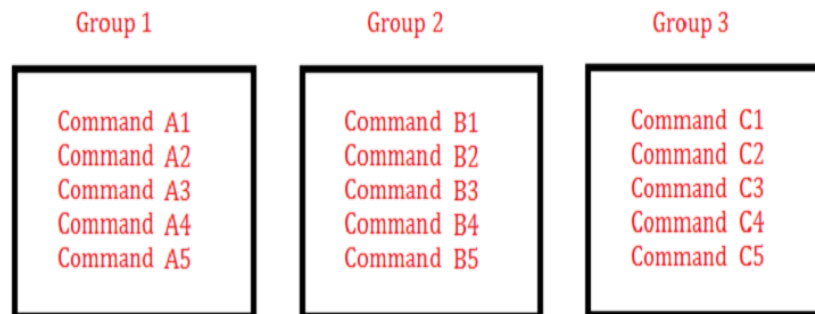


Figure 4.12 Distribution of voice commands in different groups

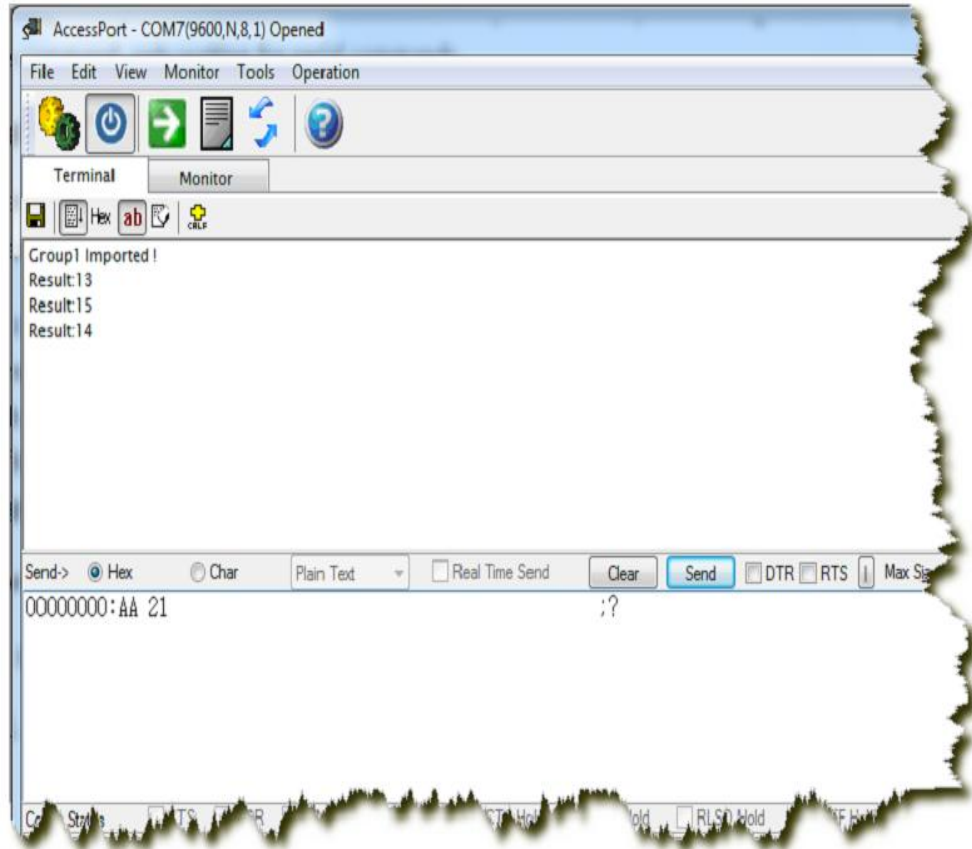


Figure 4.13 Selection of group in software

#### D) Reset the Serial Port

On V2, a way to reset the serial port is added since many customers would forget the serial parameter some time later after they changed it. Before powering on the module, bridge the TX and RX pins. [7]

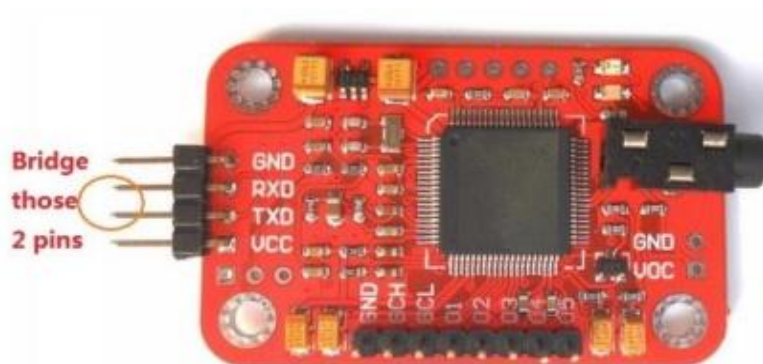


Figure 4.14 Connections of Pins

### 4.3.2 ATmega 168 Microcontroller

Atmel ATmega48/88/168 is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. By executing powerful instructions in a single clock cycle, the ATmega48/88/168 achieves throughputs approaching 1 MIPS per MHz allowing the system designed to optimize power consumption versus processing speed.

AVR follows Harvard Architecture format. in which the processor is equipped with separate memories and buses for Program and the Data information. Here while an instruction is being executed, the next instruction is pre-fetched from the program memory.

#### A) Processor Architecture

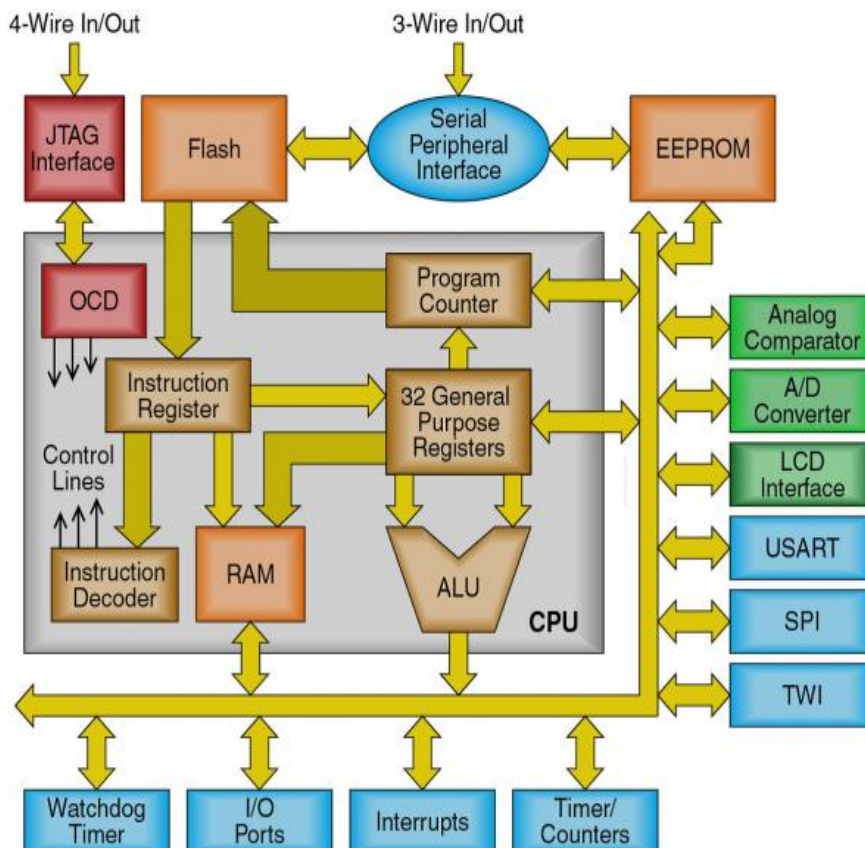


Figure 4.15 Block Diagram of ATmega 168

## **B) Arithmetic Logic Unit (ALU)**

The high-performance AVR ALU operates in direct connection with all the 32 general purpose working registers. Within a single clock cycle, arithmetic operations between general purpose registers or between a register and an immediate are executed. The ALU operations are divided into three main categories – arithmetic, logical, and bit-functions. Some implementations of the architecture also provide a powerful multiplier supporting both signed/unsigned multiplication and fractional format.

## **C) In-System Reprogrammable Flash Program Memory**

The ATmega168 contains 16K bytes On-chip In-System Re-programmable Flash memory for program storage. Since all AVR instructions are 16 or 32 bits wide, the Flash is organized as  $8K \times 16$ . For software security, the Flash Program memory space is divided into two sections, Boot Loader Section and Application Program Section in ATmega168.

## **D) Program Counter**

A program counter is a register in a computer processor that contains the address (location) of the instruction being executed at the current time. As each instruction gets fetched, the program counter increases its stored value by 1. After each instruction is fetched, the program counter points to the next instruction in the sequence. When the computer restarts or is reset, the program counter normally reverts to 0. In computing, a program is a specific set of ordered operations for a computer to perform. Program counter is very important feature of the microcontrollers.

## **E) Random Access Memory (RAM)**

RAM stands for random access memory. This type of memory storage is temporary and volatile. If system is working slowly we say that increase the RAM processing will increase. Let us understand in detail. Let us consider two cases to execute a task first the complete task is execute at one place(A), second the task is distributed in parts and the

small tasks are executed at different places(A,B C)and finally assembled. It is clear the work will be finished in second case earlier.

#### **F) Instruction Execution Section (IES)**

It has the most important unit—instruction register and instruction decoder to control the flow of the instruction during the processing's.

#### **G) Input / Output Ports**

To interact with the physical environment there are different input and output ports in every system like in PC VGA port to connect the monitor are there, USB port for flash memory connections and many more ports. Similarly ATMEGA 168 has its input and output ports with different configurations depending on the architecture like only input, only output and bi-directional input output ports. The accessing of this port is referred as input output interface design for microcontrollers. IT has analog input port, analog output port, digital input port ,digital output port, serial communication pins, timer execution pins etc.

#### **H) Inbuilt ADC of AVR**

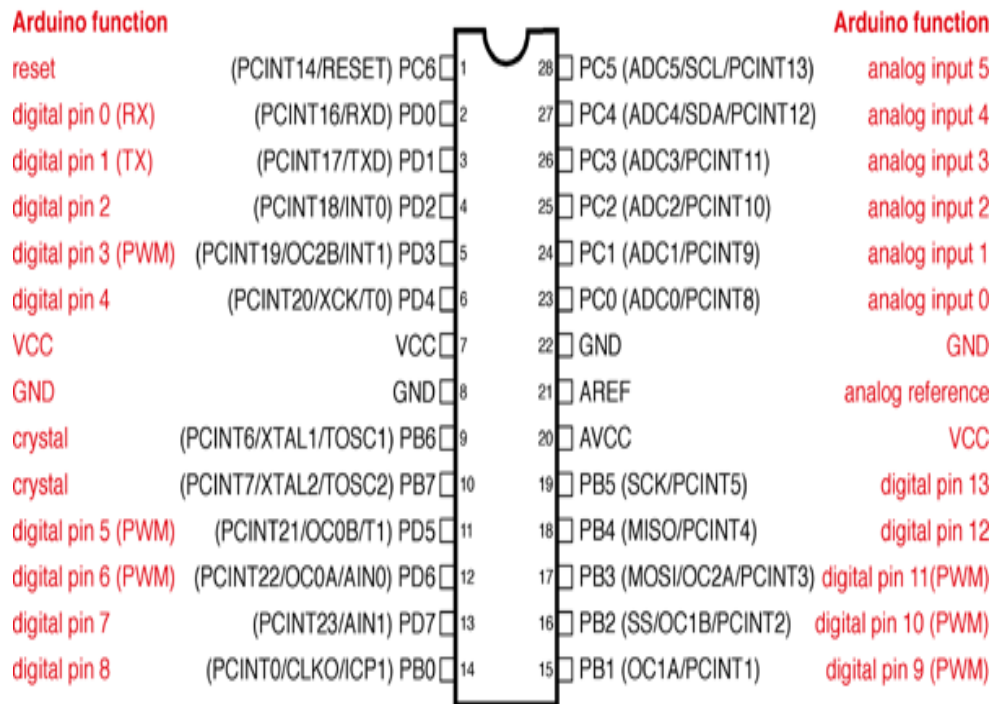
The ADC is multiplexed with PORTA that means the ADC channels are shared with PORTA. The ADC can be operated in single conversion and free running mode. In single conversion mode the ADC does the conversion and then stop. While in free it is continuously converting. It does a conversion and then start next conversion immediately after that.

The ADC in ATmega168 has 6 channels that mean that means 6 different analog sensors can be connected to the microcontroller.

#### **I) Pin Description**

ATmega 168 is a 28 pin I.C. which has 23 input- output pins. Complete pin description can be understand by the Figure 4.16.

## Atmega168 Pin Mapping



Digital Pins 11, 12 & 13 are used by the ICSP header for MISO, MOSI, SCK connections (Atmega168 pins 17, 18 & 19). Avoid low-impedance loads on these pins when using the ICSP header.

Figure 4.16 Pin Configuration of ATmega 168

### 4.3.3 DC Motor

DC motors are inexpensive, small, and powerful motors that are widely used. DC geared motor is shown in Figure 3.5. Gear-train reductions are typically needed to reduce the speed and increase the torque output of the motor. A DC motor is an electric motor that runs on direct current (DC) electricity. DC motors are normally very easy to reverse simply by changing the polarity of the DC input. This changeover process can be achieved via a simple changeover switch or for remote or electronic control, via a suitable relay. A big advantage of DC motors is that variable speed control is easy and can be achieved with just a suitable variable resistor / rheostat or variable DC power supply.



Figure 4.17 Geared DC Motor

DC motor has a gradual acceleration and deceleration curved which causes slow stabilization. The addition of gearing to motor reduces this problem up-to some extent, but overshoot is still present and will exceed the anticipated stop position. A potentiometer which acts as feedback mechanism is also attained to determine the exact positioning of the motor. In addition control circuit, which compares the position of motor with the desired position, moves the motor accordingly. DC motor generally does not produce high torque levels at low speed without the aid of gearing mechanism. However, the DC motor is capable of producing quite high levels of torque at higher speeds. With the need for variable speed, it was established the gear box required for speed reduction.

#### 4.3.4 Motor Driver IC

L293D are quadruple high-current motor driver. The L293 is built to afford two directional drive currents of up to 1 A at voltages from 3 V to 12 V. It is a 16 pin IC. The pin diagram of this IC is shown in Figure 4.18. L293D is a dual H-bridge motor driver integrated circuit (IC). Motor drivers work as current amplifiers because they intake a low-current control signal and provide a higher-current signal output. This high current signal is used to drive the motors in two directions.

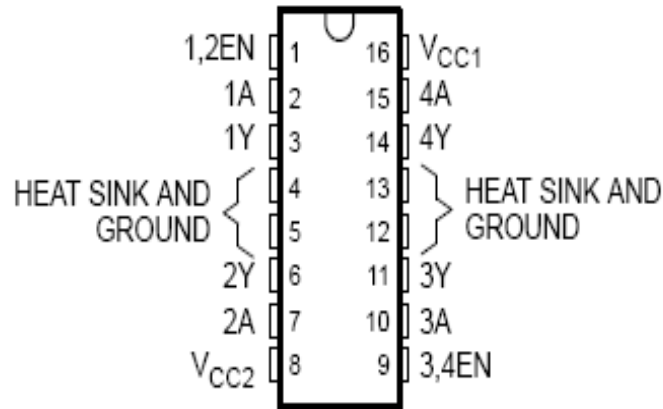


Figure 4.18 Pin Diagram of L293D

Table 4.1 Motor action based on status of input pins

Input(1A,4A)	Input(2A,3A)	Motor action
Logic 0	Logic 1	Moves clockwise
Logic 1	Logic 0	Moves anticlockwise
Logic 1	Logic 1	Stop
Logic 0	Logic 0	Stop

Motor connected to H- Bridge IC can generate output signal to control the rotation of the motor in both the direction

#### 4.3.5 L.C.D. Display

LCD (Liquid Crystal Display) screen is an electronic demonstrates module and find a wide range of applications. A 16x2 LCD display is very basic module and is very usually used in various devices and circuits. A 16x2 LCD means it can display 16 characters per line and there are 2 lines. In this LCD each character is displayed in 5x7 pixel matrix. This LCD has two registers, namely, Command and Data. The command register stores the command instructions given to the LCD. A command is an instruction given to LCD to do a predefined task like initializing it, clearing its screen, setting the cursor position, controlling display etc.

The data register stores the data to be displayed on the LCD. The data is the ASCII value of the character to be displayed on the LCD.

#### **A) Features**

- a. 5 x 8 dots with cursor
- b. Built-in controller (KS 066 or Equivalent)
- c. + 5V power supply (Also available for + 3V)
- d. 1/16 duty cycle
- e. B/L to be driven by pin 1, pin 2 or pin 15, pin 16 or A.K (LED)
- f. N.V. optional for + 3V power supply

These are the sequences to write in the LCD:

- a. To begin, E is low
- b. Select the register to write to by setting RS high (data) or low (control)
- c. Write the eight bits of data to the LCD
- d. Set the Enable signal high then low again.

After power up and initialization address 00h is the first character of the top line and address 40h is the first character of the bottom line. The address counter is set to address 00h and is automatically incremented after each byte is written. Only the first 16 bytes of each line are visible. Now start writing data to the LCD it will be stored from address 00h on but only the first 16 characters is displayed. To display the rest of the characters display need to be scrolled.

## B) Pin Description

Table 4.2 Pin Description of LCD display

PIN NUMBER	SYMBOL	FUNCTION
1	V <sub>SS</sub>	GND
2	V <sub>DD</sub>	+3V or +5V
3	V <sub>0</sub>	Contrast Adjustment
4	RS	H/L Register Select Signal
5	R/W	H/L Read/Write Signal
6	E	H?L Enable Signal
7	DB0	H/L Data Bus Line
8	DB1	H/L Data Bus Line
9	DB2	H/L Data Bus Line
10	DB3	H/L Data Bus Line
11	DB4	H/L Data Bus Line
12	DB5	H/L Data Bus Line
13	DB6	H/L Data Bus Line
14	DB7	H/L Data Bus Line
15	A/V <sub>EE</sub>	+ 4.2V for LED/Negative Voltage Output
16	K	Power Supply for B/L (0V)

## C) LCD Interfacing Diagram

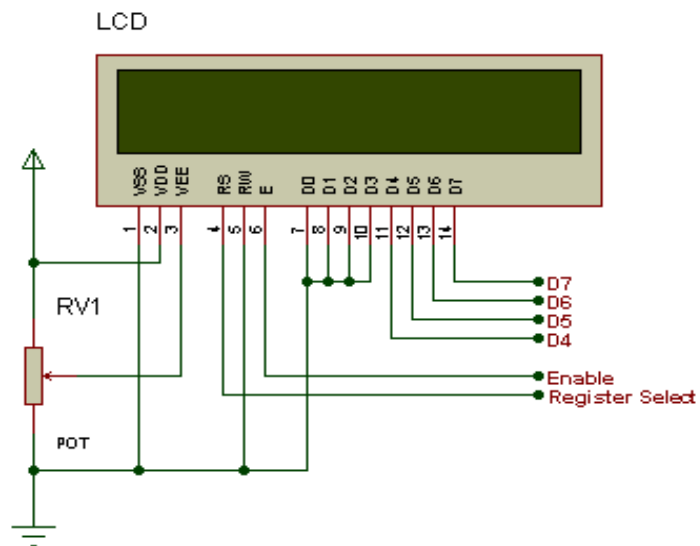


Figure 4.19 Connection Diagram of LCD

## 4.4 System Operation

A simplified flow-chart of the system operation is shown in Figure 4.19. Recording mode is already explained and as we know that Voice Recognizing Module V2 generates a hexadecimal code according to each recorded command when any voice command is matched a hexadecimal value according to that voice command is sent serially to microcontroller and action of hand as done according to that serially received hexadecimal value.

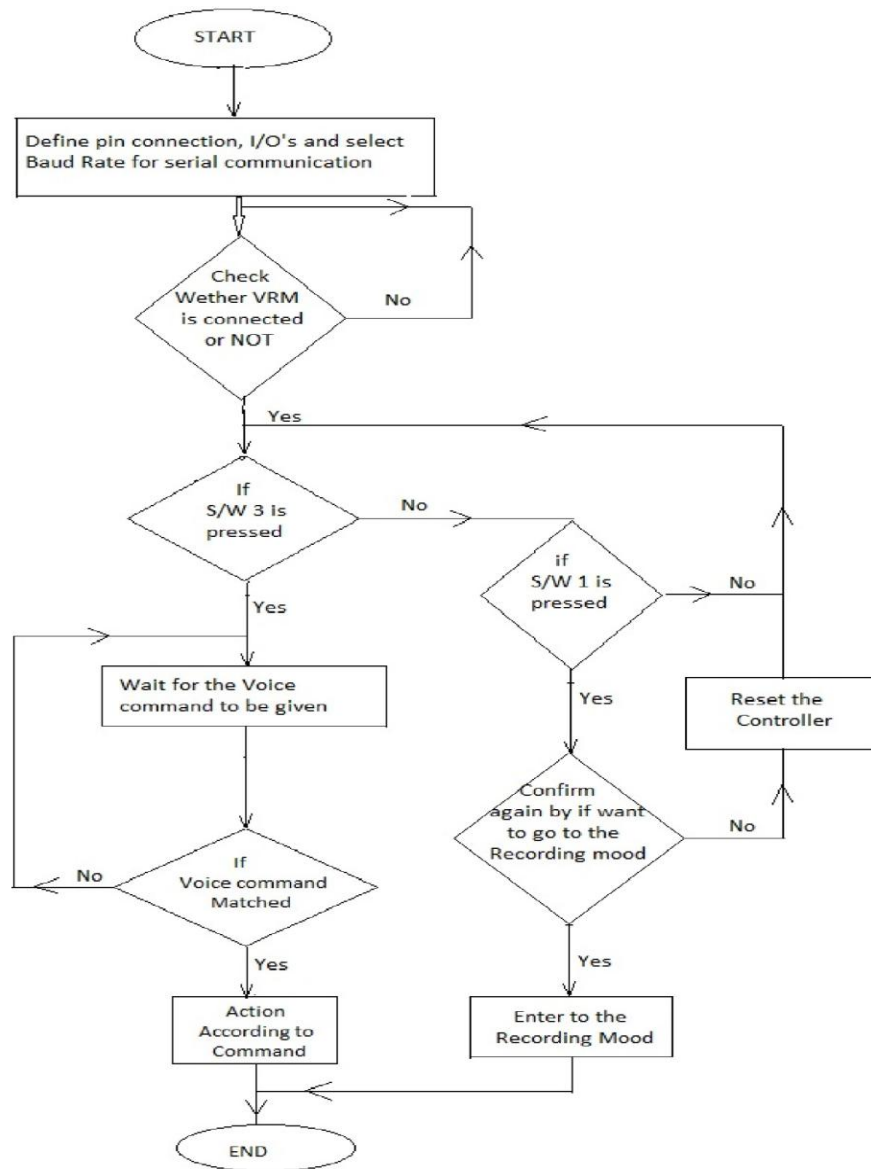


Figure 4.20 Flow chart of the complete operation

## 5. Result and Discussion

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The controller was trained for 5 voice commands. According to these voice commands the movement of arm takes place. The commands were differentiable so that any kind of overlapping between the commands would not create the confusion to microcontroller. Different kind of arm movements such as Palm opening, Palm closing, Elbow up and Elbow down were demonstrated. The testing was done using the different motors and the respective response time was calculated. This response time associated with the specific motor and specific weight will help to build a prosthetic hand with specific application.

### 5.1 Palm Movement

A type of mechanism was applied in motor using one helical gear and two round gears by which simply results as palm opening and palm closing. The rotation of motor is controlled with the help of voice commands. The opening and closing of palm is shown in Figure 5.1.

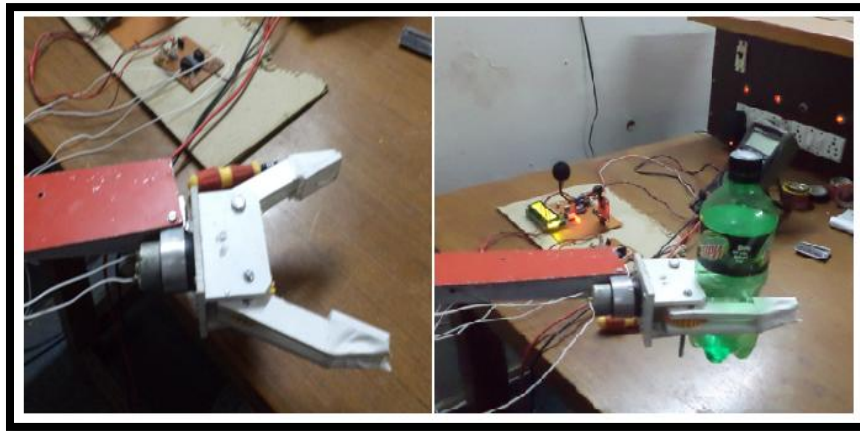


Figure 5.1: Palm Opening and Palm closing

### 5.2 Elbow Movement

Similarly a mechanism has been made to demonstrate so that elbow movement of arm can be controlled by simply controlling the motor and the rotation of motor is controlled with the help of voice commands. The up and down movement of elbow is shown in Figure 5.2.

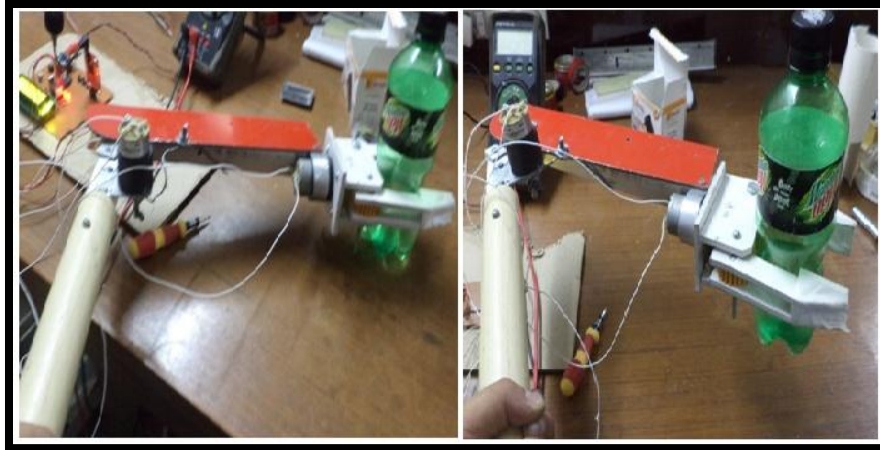


Figure 5.2: Up and Down movement of elbow

Complete system was tested on different loads with motors of different specification. The time taken to place object to place one place to another was calculated. The results presented in Tables 5.1-5.4 indicates durability of motors of different specification. It also helps to find out their response time for respective weight.

Table 5.1 DC geared Motor: 30 RPM, 15 Kg-Cm Torque

<b>WEIGHT</b>	<b>RESPONSE TIME</b>
Empty Bottle	2.3 sec
Bottle with 100 ml water	3.0 sec
Bottle with 200 ml water	3.9 sec
Bottle with 250 ml mater	Failure Condition

Table 5.2 DC geared Motor: 30 RPM, 28 Kg-Cm Torque

<b>WEIGHT</b>	<b>RESPONSE TIME</b>
EmptyBottle	2.2 sec
Bottle with 100 ml water	2.9 sec
Bottle with 200 ml water	3.6 sec
Bottle with 300 ml mater	4.2 sec
Bottle with 350 ml water	Failure Condition

Table 5.3 DC geared Motor: 10 RPM, 15 Kg-Cm Torque

<b>WEIGHT</b>	<b>RESPONSE TIME</b>
Empty Bottle	3.5 sec
Bottle with 100 ml water	4.3 sec
Bottle with 200 ml water	4.8 sec
Bottle with 300 ml mater	5.6 sec
Bottle with 400 ml water	Failure Condition

Table 5.4 DC geared Motor: 10 RPM, 30Kg-Cm Torque

<b>WEIGHT</b>	<b>RESPONSE TIME</b>
Empty Bottle	3.5 sec
Bottle with 100 ml water	4.3 sec
Bottle with 200 ml water	4.6 sec
Bottle with 300 ml mater	5.3 sec
Bottle with 400 ml water	5.9 sec
Bottle with 500 ml water	6.3 sec
Bottle with 600 ml water	Failure Condition

From the above tables it is concluded that if the same RPM motor is taken, the motor with the maximum torque holds higher load as compared to the motor with the minimum torque but the time of response remains almost same. It is also said that when the RPM becomes higher the load carrying capacity of motor decreases and if RPM becomes lower the load carrying capacity of mototr increases.

The specifications of below elbow prosthesis are as follows:

Operating Voltage	:	5V and 12 V
Current Consumption	:	200 mA (Approx)
Opening Width	:	75-100 nm
Average Speed	:	1-2 cm/sec (Approx)
Weight of Arm	:	1.5 kg (Max)

## 6. Conclusion and Future Aspects

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The present research work demonstrate the movement of elbow and simple pickup and drop movement with the help of voice commands. Software analysis, design, implementation and testing are described.

### 6.1 Future Aspects

In the proposed hardware five voice commands namely -pick, drop and elbow moments were implimented and same design can be extented upto 15 voice commands namely- sholder moments and fingure movent (can be added to increase more accuracy).Also, some presion work can be done in the design of arm. Some time controller does not undrstsnd voice signal due to enternal voice interface a new algorithdam can be developed to train voice signal to make it completely free from extarnal noices.

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