Development of Wireless emg & voice control system for rehabilitation devices

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Certificate

This is to certify that the thesis entitled "**Development of Wireless emg & voice control system for rehabilitation devices**" by **PRASHANT DUBEY (212BM1352),** in partial fulfillment of the requirements for the award of the degree of Master of Technology in Biotechnology Engineering during session 2012-2014 in the Department of Biotechnology and Medical Engineering, National Institute of Technology Rourkela is an authentic work carried out by him under our supervision and guidance. To the best of our knowledge, the matter embodied in the thesis has not been submitted to any other University/Institute for the award of any Degree or Diploma.

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Acknowledgement

He offers quality to the exhausted and expands the force of the feeble: Isaiah 40:29

The LORD is my strength and my shield; my heart trusts in him, and I am helped. My heart leaps for joy and I will give thanks to him in song. Psalm 28:7

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Abbreviations

Abbreviations	Definition
IA	Instrumentation Amplifier
CMRR	Common Mode Rejection Ratio
DAQ	Data Acquisition
LED	Light Emitting Diode
EMG	Electromyography
EOG	Electrooculography
EEG	Electroencephalography
DRL	Driven Right Leg
BCI	Brain Computer Interface
VI	Virtual Instrument
CNS	Central Nervous System
Opam	Operational Amplifier
V	Volt
RF	Radio Frequency

Abstract

Restoration gadgets are progressively being utilized to enhance the nature of the life of differentially capable individuals. Human Machine Interface (HMI) have been mulled over broadly to control electromechanical recovery supports utilizing biosignals, for example, EMG, EEG and EOG and so on around the different biosignals, EMG indicators have been examined in profundity because of the event of a positive indicator design. Persons experiencing amazingly constrained fringe portability like paraplegia or jumbling generally can facilitate hand developments. The current venture concentrates on the advancement of a model engine wheelchair controlled by EMG indicators. EMG signs were utilized to produce control indicators for the development of the wheelchair. As a piece of this work an EMG sign procurement framework was produced. The obtained EMG indicator was then prepared to create different control signs relying on the sufficiency and length of time of sign segments. These control signs were then used to control the developments of the model mechanized wheelchair model.

Keywords: Electromyography (EMG), Wrist movements, Rehabilitation aids, HMI.

Chapter I

Introduction and Objectives

1.1 Requirement of rehabilitation techniques

A substantial area of our general public experiences one or the other sort of incapacities because of mischances, neurological issue, mind harms and so forth. These handicaps compel these patients to rely on upon their relatives or guardians for everyday-exercises including versatility, correspondence with nature's turf, controlling the house hold supplies and so on. Recovery gadgets empower persons with incapacities to live, work, play or study freely. At the end of the day they build the personal satisfaction headed by the differentially abled individuals and increment their respect toward oneself.

A Rehabilitation gadget is one that helps a differentially abled individual to control his or her surroundings and convey all the more adequately. These assistive gadgets push more terrific autonomy by empowering individuals to perform errands with the assistance of innovation[1].

A perfect recovery help helps in gathering data from the surroundings, examine the data, pass on it to the client lastly get summons from the client. With developments in picture and sign preparing, we can gadget frameworks that can decipher the data naturally. The utilization of these recovery helps aids the differentially abled individual to do his/her everyday exercises autonomously.

1.2 Overview of current rehabilitation techniques

With change in engineering, there is a tremendous improvement in the field of recovery strategies. Investigates are happening to create dependable, minimal effort and simple to utilize gadgets. Out of all the recovery procedures, HCI (Human Computer Interface) and HMI (Human Machine Interface) are the most recent and best systems. Explores in these fields are constantly

Completed widely. The principle goal of the HMI framework is transformation of indicators created by people through different motions to control some electromechanical gadgets. While in HCI framework some key strokes or cursor developments on the screen are controlled by utilizing these indicators. In HCI and HMI both biosignals and non biosignals are utilized as a medium of control. The boss biosignals utilized within the Interface are Electromyography (EMG), Electroencephalography (EEG) and Electrooculography (EOG) [2]. HMI is normally utilized by engine hindered patients to control wheelchair.

Restoration gadgets are comprehensively grouped into two classifications; the first class incorporates each one of those gadgets which are biosignal and the second classification incorporates non biosignal based gadgets. Non biosignal recovery supports give 100% exactness and oblige less preparing for patients however the utilization of these gadgets is restricted to patients with halfway or complete adaptability in their body parts. Biosignal based recovery gadgets mostly utilize biosignals like EEG, EOG or EMG as control signs [2]. The point of interest of utilizing biosignal methodology is that when patients get to be totally deadened, the main asset accessible to them then is biosignals. Be that as it may it generally needs client preparing and has lesser exactness than non biosignal methodologies. The biosignal approach generally obliges client adjustments in light of the fact that biosignals generated by every individual are special because of contrast in singular physiological properties and skin conductance.

1.2.1 Non biosignal approach

By and large non biosignal based restoration gadgets incorporate strategies which make utilization of taste-n-puff reaction, tongue control, eye following, head development following and jaw control [3].

The sip-n-puff innovation is an old method which is utilized to control mechanized wheel seat by quadriplegic patients. In this technique, control signs are given to a gadget utilizing gaseous tension by "tasting" (breathing in) or "puffing" (breathing out) on a pneumatic tube. SNP innovation for the most part makes utilization of four control indicators which are prepared by hard taste, hard puff, delicate taste and delicate puff. Average provision of Sip-and-Puff gadgets is the control of mechanized wheelchair. Control normally comprises of four separate inputs from the client. A starting hard puff will empower the wheelchair to advance, while a hard taste will stop the wheelchair. Then again, an introductory hard taste will empower the wheelchair to move regressive, while a hard puff will stop the wheelchair. A constant delicate taste or delicate puff will empower the wheelchair to move left or right separately relying upon the span of tasting or puffing. The mouth-controlled info gives clients a basic and successful approach to control mouse development. Nonetheless, the essential detriment of the taste and puff method is that muscles of numerous paraplegics and other incapacitated patients are not equipped for taste and puff activity. An alternate normal system is the Head Movement Tracking method. In this, head developments are converted into cursor developments on the screen. Cursor developments are relative to head developments. Head developments are ascertained by distinctive techniques like accelerometer set in a patient's top or by catching feature of head developments. Be that as it may the issue with this procedure is that differentially abled individuals of specific classifications, for example, cerebral paralysis patients can't even move their head agreeably. An alternate issue of this procedure is that temple dependably needs to face the Polaroid.

In the chin control strategy, the button sits in a glass formed joystick handle and is typically controlled by chin developments. This framework is material just for patients with great head control. It gives more adaptability than head control.

Tongue controlled recovery is attained by numerous routines. In one system, a perpetual magnet is joined to the tongue and development of tongue to an air-center incitement loop changes the inductance of curl complying with Faraday's laws. In an alternate strategy, a weight delicate isometric joystick is worked by the patient's tongue. This joystick and the two switches give cursor control and left/right catch.

1.2.2 Biosignal approach

As specified prior, these biosignal based recovery gadgets mostly utilize biosignals like EEG, EOG or EMG as control signs. The point of interest of utilizing this methodology is that when patients get to be totally incapacitated, the main assets accessible to them are biosignals.

1.2.2.1 EEG based methods

The Electroencephalography (EEG) records electrical cerebrum signs from the scalp, where the mind sign begins from post-synaptic possibilities, totals at the cortex, and exchanges through the skull to the scalp. BCI is a gadget that concentrates EEG information from cerebrum and proselytes it into gadget control charges utilizing indicator preparing procedures. The cerebral electrical exercises of the cerebrum are recorded by means of the EEG, through cathodes that are appended to the surface of the skull. The indicators measured by the cathodes are enhanced, separated and digitized for handling in a workstation where characteristic extraction is performed. This is trailed by grouping and a suitable control charge is produced.

This is a standout amongst the most essential advances for patients with loss of motion who experience the ill effects of extreme neuromuscular issue, since BCI conceivably gives them the method for correspondence, control, and recovery devices to help adjust for or restore their lost capacities. EEG systems are non-intrusive and ease. Anyway it brings incredible tests to sign transforming and design distinguishment, since it has generally poor indicator-to-clamor proportion and constrained land determination and recurrence range.

1.2.2.2 EOG based methods

The Electrooculogram (EOG) is the electrical indicator that compares to the potential distinction between the retina and the cornea of the eye. This distinction is a result of the way that event of metabolic exercises in the cornea area is higher than that in the retinal district. Generally the cornea keeps up a voltage of +0.40 to +1.0 millivolts which is higher than the retina. At the point when the eyes are moved upward or descending, positive or negative beats are produced. As the moving plot expands, the sufficiency of the beat likewise builds and the width of the beat is in immediate extent to the length of time of the eyeball moving methodology.

The EOG is the electrical recording relating to the bearing of the eye and makes the utilization of EOG for provisions, for example, HCI exceptionally appealing. EOG-based systems are extremely helpful for patients with extreme cerebral paralysis or those conceived with an inherent mind issue or the individuals who have endured serious cerebrum trauma.

1.2.2.3 EMG based methods

EMG measures electrical ebbs and flows that are produced in a muscle throughout its compression. A muscle fiber contracts when it gets a movement potential. The EMG watched is the total of all the activity possibilities that happen around the cathode site. In very nearly all cases, muscle compression causes an increment in the general plentifulness of the EMG [4].

EMG indicators might be utilized for a mixed bag of requisitions including clinical provisions, HCI and intuitive workstation gaming [4]. They are not difficult to procure and of moderately high extent than different biosignals. Then again, EMG signs are effortlessly powerless to clamor. EMG indicators hold muddled sorts of commotion that are brought about by inalienable gear clamor, electromagnetic radiation, movement ancient rarities, and the communication of distinctive tissues. Subsequently preprocessing is important to channel unwanted commotion in EMG. The EMG indicates additionally have distinctive marks relying upon age, muscle improvement, engine unit ways, skin fat layer, and motion styles. The outside appearances of two people's motions may appear to be indistinguishable, however the normal for EMG signs are distinctive.

1.3 Objectives

The fundamental point of the work introduced in this theory is to create a solid and simple to utilize biosignal obtaining framework and recovery method: a RF controlled mechanized model wheelchair model created as a restoration help. This work incorporates:

1. Creating an information procurement framework for securing EMG signals.

2. Creating another calculation for recognizing essential hand developments.

3. Executing restoration gadgets which might be controlled utilizing EMG.

1.4 Thesis organization

Chapter II – Literature Review examines the essentials of the human muscle compression methodology and basics of Electromyography. It additionally surveys some related works done here.

The complete procedure of innovative work is clarified in **Chapter III – Development of a wireless voice control system for rehabilitative devices**. It controls the quadbot movement with the help of voice signal.

Chapter IV- Development of Wireless EMG control system for rehabilitation devices holds sorted out assessment and dialog of electronic circuit, DAQ, microcontroller, programming gadgets created and got charts and outcomes

The fate of the gadget as far as upgrades and plausibility of open discharge is examined in Chapter **V - Conclusions and Prospects**.

All related works which have given some understanding into the advancement of the proposed gadget are recorded in **Reference** section.

Chapter II

Literature Review

2.1 Principle of electromyography

Electromyography (EMG) is the investigation of muscle capacity through dissection of the electrical indicators exuded throughout husky compressions. Electromyography is measuring the electrical indicator connected with the enactment of the muscle. This may be voluntary or automatic muscle compression. This muscle fiber contracts when the movement possibilities (drive) of the engine nerve which supplies it achieves a depolarization limit. The depolarization produces an electromagnetic field and the potential is measured as a voltage. The depolarization, which spreads along the film of the muscle, is a muscle activity potential. The engine unit activity potential is the spatio and transient summation of the singular muscle movement possibilities for all the filaments of a solitary engine unit. Subsequently, the EMG indicator is the arithmetical summation of the engine unit movement possibilities inside the pick-up zone of the anode being utilized [5].

2.2 **Anatomy and physiology of the muscle contraction**

Muscle is a delicate tissue found in generally creatures. Muscle cells hold protein fibers of actin and myosin that slide past each one in turn, handling a constriction that changes both the length and the state of the cell. Muscles capacity to generate drive and movement. They are fundamentally answerable for keeping up and evolving carriage, velocity, and also development of inward organs, for example, the constriction of the heart and the development of sustenance through the digestive framework by means of peristalsis. Muscle tissues are inferred from the mesodermal layer of embryonic germ cells in a methodology known as myogenesis. There are three sorts of muscle, skeletal or striated, cardiovascular, and smooth. Muscle movement might be considered being either voluntary or automatic. Heart and smooth muscles contract without cognizant thought and are termed automatic, while the skeletal muscles contract upon summon. Muscles are transcendently fueled by the oxidation of fats and carbs, however anaerobic concoction responses are additionally utilized, especially by quick twitch strands [6]. These compound responses produce adenosine triphosphate (ATP) atoms which are utilized to power the development of the myosin heads.

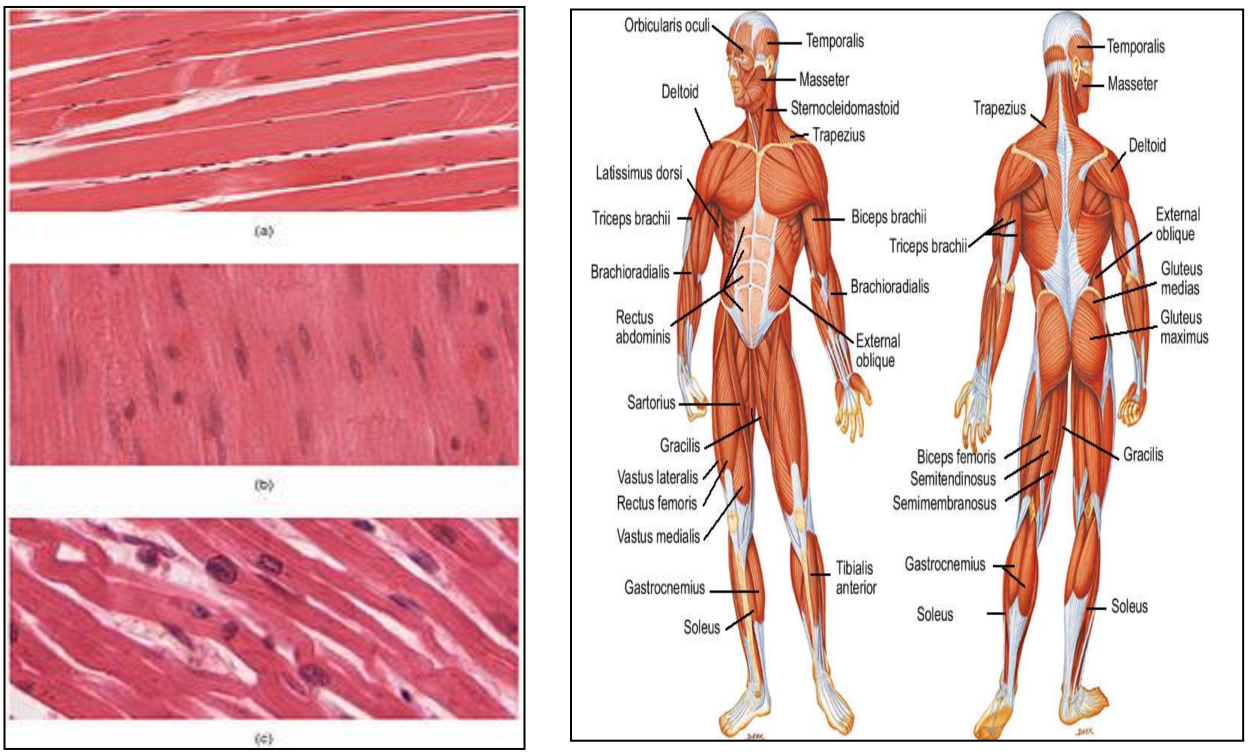


Figure 2.1 Different body muscles and structure [6].

The three sorts of muscle (skeletal, heart and smooth) have noteworthy contrasts. Be that as it may, every one of the three utilizes the development of actin against myosin to make constriction. In skeletal muscle, compression is invigorated by electrical driving forces transmitted by the nerves, the motoneurons (engine nerves) specifically. Cardiovascular and smooth muscle constrictions are empowered by inner pacemaker cells which customarily contract, and proliferate withdrawals to other muscle cells they the neurotransmitter acetylcholine.

Function:

The activity a muscle creates is dictated by the root and insertion areas. The cross-sectional zone of a muscle (instead of volume or length) decides the measure of energy it can produce by characterizing the amount of sarcomeres which can work in parallel.[citation needed] The measure of power connected to the outside environment is controlled by lever mechanics, particularly the proportion of in-lever to out-lever. Case in point, moving the insertion purpose of the biceps all the more distally on the span (more distant from the joint of pivot) might build the power created throughout flexion (and, accordingly, the most extreme weight lifted in this development), yet diminish the greatest pace of flexion. Moving the insertion indicate proximally (closer the joint of turn) might bring about diminished compel yet expanded speed. This could be most effortlessly seen by contrasting the appendage of a mole with a stallion - in the previous, the insertion point is situated to augment energy (for burrowing), while in the recent, the insertion point is situated to amplify speed (for running).

The Sliding Filament Theory-

For a withdrawal to happen there must first be an incitement of the muscle as a drive (movement potential) from an engine neuron (nerve that interfaces with muscle)[7].

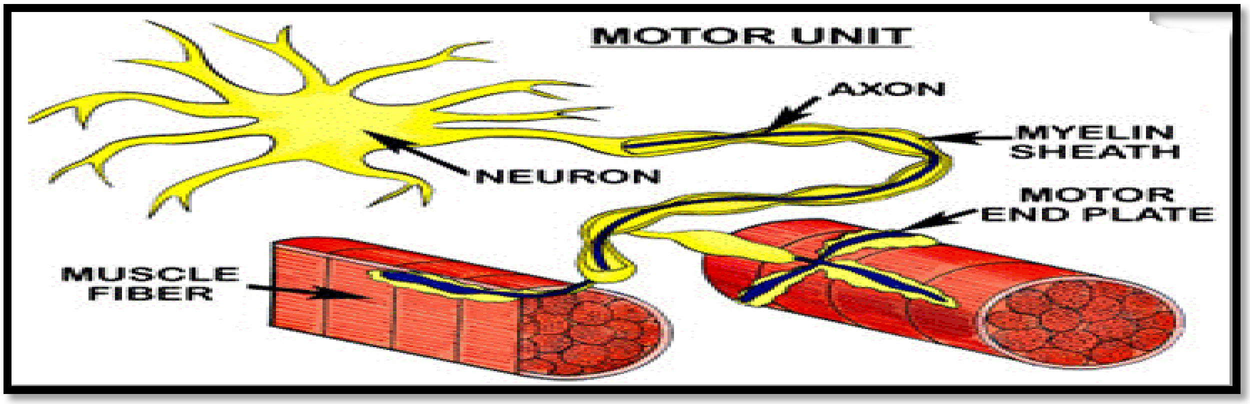


Figure 2.2 Motor unit

The singular engine neuron in addition to the muscle strands it animates, is known as an engine unit. The engine end plate (otherwise called the neuromuscular intersection) is the intersection of the engine neurons axon and the muscle strands it fortifies. At the point when a drive achieves the muscle filaments of an engine unit, it invigorates a response in every sarcomere between the actin and myosin fibers. This response brings about the begin of a constriction and the sliding fiber hypothesis. The response, made from the landing of a drive fortifies the "heads" on the myosin fiber to arrive at forward, join to the actin fiber and draw actin towards the middle of the sarcomere. This methodology happens at the same time in all sarcomeres, the end procedure of which is the shortening of all sarcomeres. Troponin is an unpredictable of three proteins that are vital to muscle withdrawal. Troponin is appended to the protein tropomyosin inside the actin fibers, as seen in the picture underneath. When the muscle is loose tropomyosin obstructs the connection locales for the myosin cross extensions (heads), in this way forestalling compression [8]. At the point when the muscle is fortified to decrease by the nerve motivation, calcium diverts open in the sarcoplasmic reticulum (which is adequately a stockpiling house for calcium inside the muscle) and discharge calcium into the sarcoplasm (liquid inside the muscle cell). Some of this calcium connects to troponin which causes a change in the muscle cell that moves tropomyosin off the beaten path so the cross scaffolds can connect and produce muscle withdrawal.

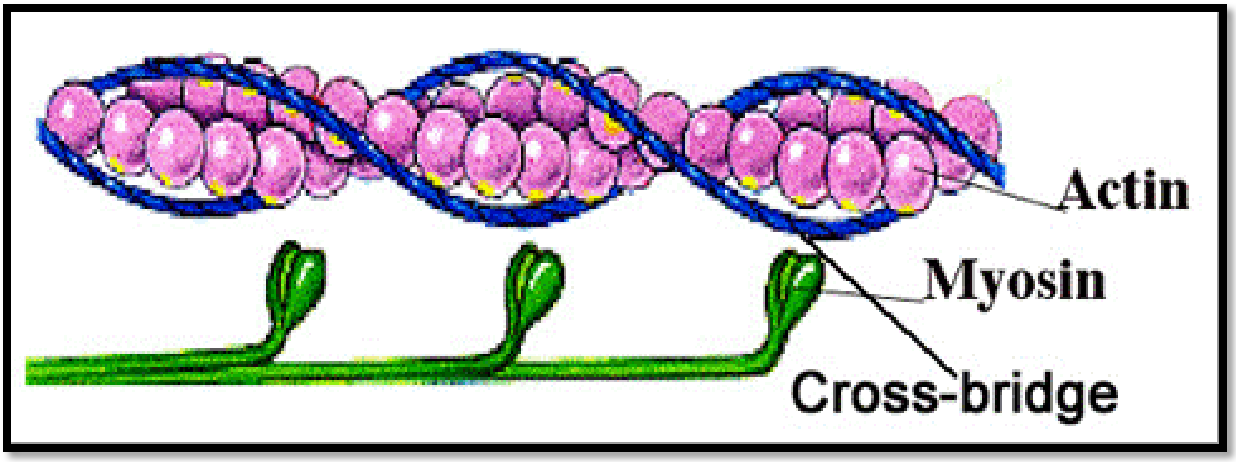


Figure 2.3 Actin, myosin and cross bridge [8].

2.3 Types of muscles in the body

There are more or less 642 skeletal muscles inside the run of the mill human, and practically every muscle constitutes one a piece of a couple of indistinguishable reciprocal muscles, found on both sides, bringing about pretty nearly 320 sets of muscles, as introduced in this article. All things considered, the careful number is troublesome to characterize on the grounds that distinctive sources gathering muscles in an unexpected way, e.g. concerning is characterized as diverse parts of a solitary muscle or as a few muscles. The muscles of the human body could be classified into various gatherings which incorporate muscles identifying with the head and neck, muscles of the middle or trunk, muscles of the upper appendages, and muscles of the easier appendages.

2.4 Types of muscles in the hand

The hand is a complicatedly unpredictable structure that is adjusted to allow an unequaled show of development. There are in excess of sixty separate muscles which produces combined effort to finish the work. Flexion and broadening of the hand and phalanges or fingers are proficient by extraneous muscles of the hand (or those of lower arm). Exact finger developments that require the coordination of snatching and adduction with flexion and expansion are practically the assignment of the little inalienable muscles (those inside) of the hand. The natural muscles of the hand are further separated into thenar (concerning palm on the thumb side) and hypothenar (concerning palm beside the little finger), and the halfway gatherings.

The extension between the hand and the lower arm is the wrist (or carpus), a gathering of eight little bones fitted together in a cobblestone system and bound set up by solid ligaments. The fingers are basically controlled by solid muscles in the lower arm. These muscles may join with tendons at the wrist, which help both the wrist and the hand to expressive. Alternately they join to tendons that stretch out along each one finger and are installed in long sheaths on the palm side of the hand. At the point when the lower arm contracts it pulls on the tendon and the sheath to twist the finger. A circle inside the wrist permits the 180 switch of the top for the bottom of the hand that is called pronation and supination. Each of the four fingers on each one hand carries on correspondingly to the others and has comparative musculature, yet the thumb is to some degree remarkable. The thumb is greatly vital to the hand's adaptability on the grounds that it restricts alternate fingers, which implies we can squeeze a little question between the thumb and finger to lift it up. It is the idea of most anthropologists that the human thumb is answerable for man's prevalence over the easier primates. Our thumb provides for us aptitude to assemble instruments and to record history.

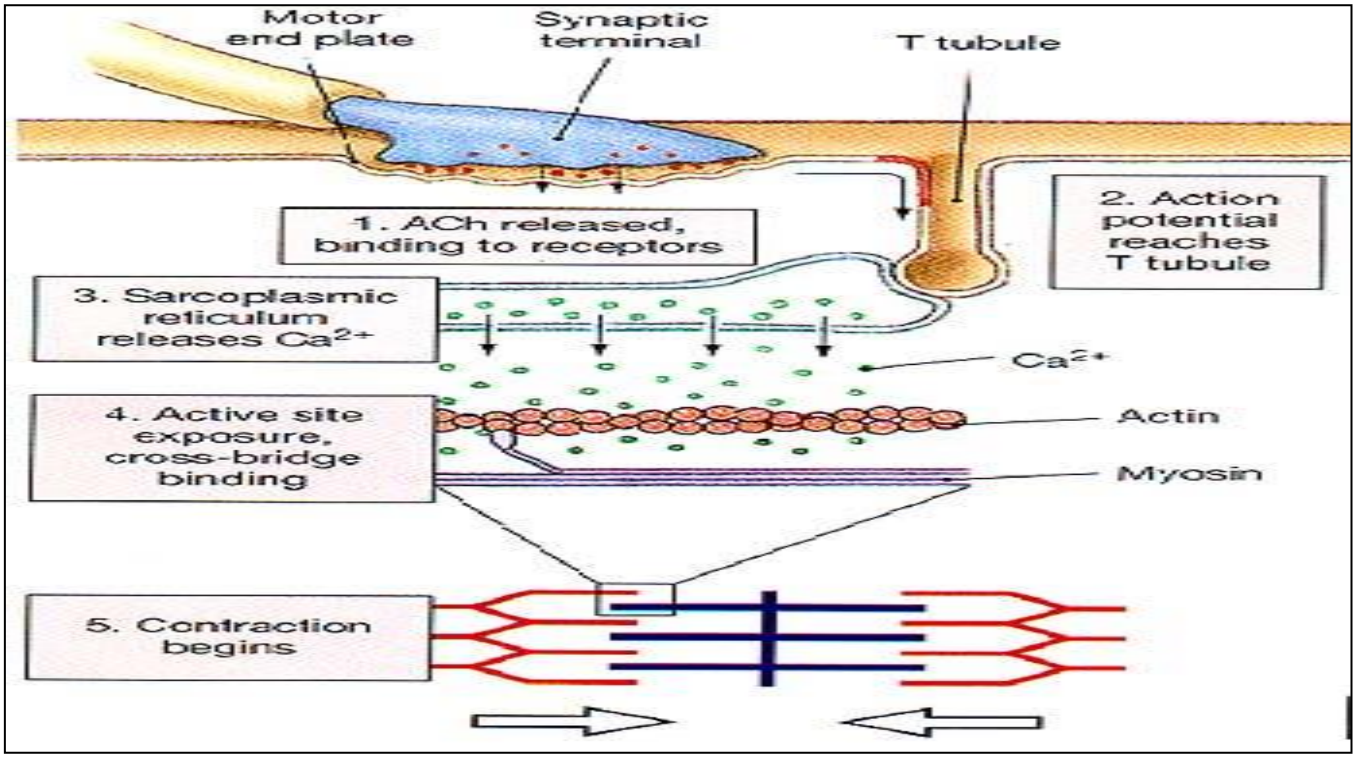


Figure 2.4 Generation of EMG [9]

2.5 Generation of EMG

The EMG is produced when an engine neuron movement potential from the spinal line lands at an engine end plate. Its landing causes an arrival of Ach (Acetylcholine) at the synaptic separated (1) which causes a depolarization (Action Potential). This activity potential electrically voyages descending from the surface in a transverse tubule (2). This thusly causes an arrival of Ca++ (3), bringing about cross-extension tying (4) and the sarcomere of the muscle to get (5). An electromyography (EMG) is an estimation of the electrical movement in muscles as a side effect of constriction. An EMG is the summation of movement possibilities from the muscle filaments under the anodes set on the skin[9]. The more muscles that fire, the more amazing the measure of movement possibilities recorded and the more stupendous the EMG perusing.

2.6 Advantages and disadvantages of EMG signal

EMG has both advantage and disadvantage-

Advantages of EMG signal-:

1. It is inexpensive in comparison to other technique.
2. It gives a lot of data which is both scalar and continuous.
3. It can detect more subtle muscular activity than visual measurement

Disadvantages of EMG signal-:

1. It is very intrusive.
2. It may alter natural expression.
3. Surface EMG has channel crosstalk.

2.7 Related works done in EMG based rehabilitation systems

Bibhu K. Biswal, Kunal Pal, Sirsendu S. Ray, Subhranshu Samantray and Devki N. Tibarewala developed a low-cost electromyogram (EMG) signal data acquisition system (DAQ). They used Instrumentation Amplifier AD620 which has a high CMRR and can handle signals in microvolt range. Total gain of 750 was achieved by using AD620. The output terminal (PIN 6) signal of the instrumentation amplifier was fed into the reference terminal (PIN 5) of AD620 through an integrator so as to eliminate the electrode DC offset. An active ground was used to further reduce the common mode 50 Hz signal from the output. The input impedance of the EMG bio-signal amplifier was 10 GΩ. Disposable pre-gelled electrodes were used as non-polarizable electrodes for bio-potential acquisition. The EMG signal was tapped from PIN 6 with respect to the PIN 5 and was fed into USB-6008 data acquisition system (DAQ) for interfacing with a laptop, which was being operated in battery mode, for digital acquisition of the signal. The acquired signals were subjected to on-line low-pass filtering (fc= 1 KHz) and high-pass filtering (fc=20 Hz). The pre-processed signals were stored as Lab VIEW measurement (LVM) files. The EMG data acquiring system was regarded as EMG-DAQ[10].

Chun Sing Louis Tsui, Pei Jia, John Q. Gan, Huosheng Hu and Kui Yuan (2010) design and developed a system in which EMG signal are used to control the direction of the wheelchair and EOG signal are used to control the speed of the device. Both EMG and EOG are acquired simultaneously in order to produce the control signal which further used to control the speed and direction of the wheelchair. A trigger system is used to avoid the accidental activation of the device. When device is under non operating state user is free to perform his activities without concerning about the activation of the device

EOG controls the speed of the wheelchair during its movement in all direction. When EOG signal is detected during the motion of the wheelchair, the system will slowdown the wheelchair as a safety concern[11].

Fukuda, O. ; Dept. of Ind. & Syst. Eng., Hiroshima Univ., Japan ; Tsuji, T. ; Ohtsuka, A.(1988) this paper proposes the theory of a human-robot interface as rehabilitation aid and advances the prototype system. The prototype structure means to be used as a manager for the robotic manipulator and as rehabilitation system for the disabled person. In order to get used to the system to the distinctiveness of the operator's electromyogram (EMG) signal, the EMG sample discrimination process using the neural network is develop as an necessary technique of our arrangement. In the experiments, it can be seen that the robotic manipulator can be controlled with high precision using the operator's EMG signal, and that the adaptive knowledge of the neural network advance the discrimination capability of the EMG signal [12].

X Zhang, X Chen, W Wang, J Yang, V Lantz(2009) This paper introduces a new hand motion detection system that utilizes concurrently both multi-channel surface electromyogram (EMG) sensors and 3D accelerometer (ACC) to understand user-friendly relations between individual and computers. Signal segments with important effects are resolute from the continuous EMG signal inputs. Multi-stream Hidden Markov Models consisting of EMG and ACC streams are used as assessment combination technique to identify hand movements. This paper also presents a practical Rubik's Cube game that is controlled by the hand motion and is used for showing the performance of our hand gesture recognition system. For a set of 18 kinds of gestures, each trained with 10 repetitions, the average recognition accuracy was about 91.7% in real application. The proposed method presents an intelligent and accepted control based on gesture interaction [13]

Xiang Chen ; Univ. of Sci. & Technol. of China, Hefei ; Xu Zhang ; Zhang-Yan Zhao ; Ji-Hai Yang(2007) In this paper HCI, accelerometers and surface EMG electrodes are combinedly used to observe arm motion in order for multiple hand motion recognition. Experiments were intended to gather motion data with both sensing techniques to weigh against their presentation in the acknowledgment of different wrist and finger gestures. Acknowledgment tests were done using different subsets of information: accelerometer and EMG data independently and combined sensor information. Resolts shows that mixture of electrodes and accelerometers enhance the accuracy by 5-10%. The accuracy of the system is quite large in comparison to normal surface electrodes which shows the advantage of device over normal device [14].

Inhyuk Moon ; Korea Orthopedics & Rehabilitation Eng. Center, Incheon, South Korea ; Myungjoon Lee ; Jeicheong Ryu ; Museong Mun(2003) Design and developed a system in which EMG signal, voice signal and gestures are used to control the movement of the wheelchair. The control signals are transferred to wheelchair through HCI. In order to avoid any accident an ultrasonic sensor is placed on the wheelchair so that wheelchair is able to keep itself away from the obstacles. Control signal mapping between computer and wheelchair is take place through HCI. The developed device is very helpful for disabled and aged people[15].

Chapter III

Development of a wireless voice control system for rehabilitative devices

Materials & Methods

3.1 Materials and methods used for voice control based assistive technique

3.1.1 Materials

IC LM-324 (Texas instruments), electret microphone, Arduino UNO & Arduino wireless proto shield (Arduino, Italy), LabVIEW 2010 (National Instruments, USA), USB-4704 DAQ (Advantech Inc., Taiwan), Xbee-S1 wireless transreceiver module (Digi International, USA), and Quadbot (Simplelabs, India) were used in the study.

3.1.2 Method used for voice control based assistive technique

Basic Block Diagram of EMG based control system is given in Figure 3.1

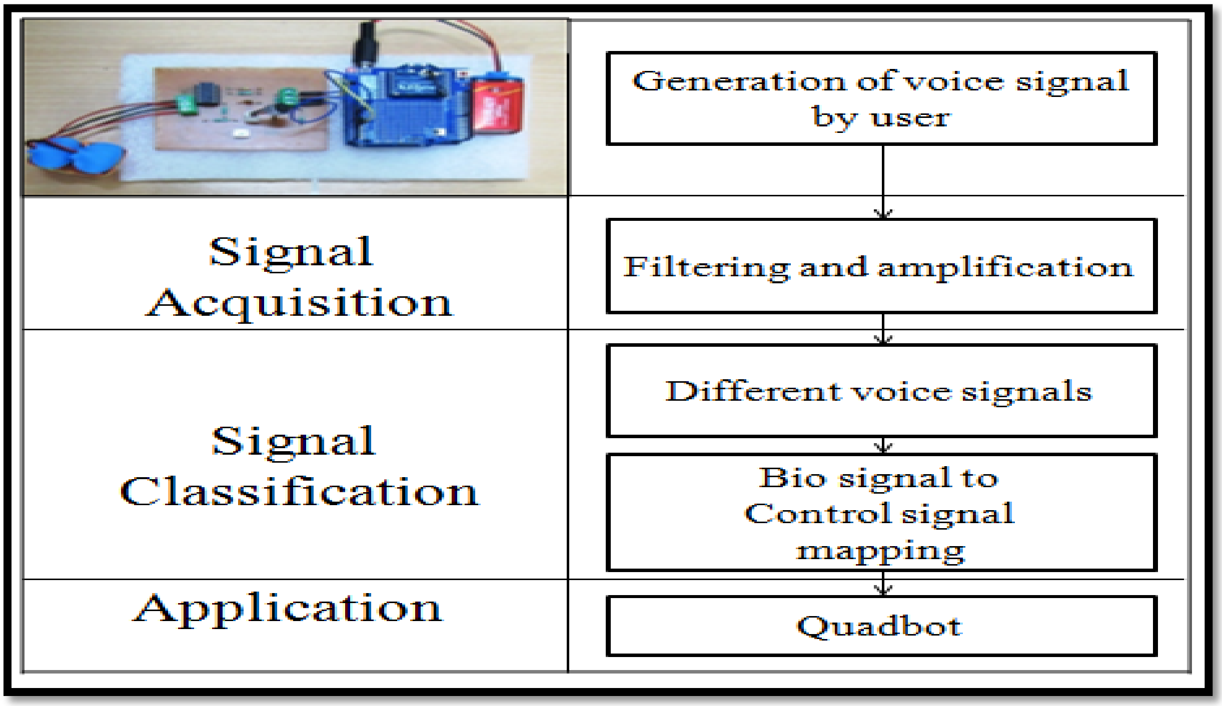


Figure 3.1 Basic Block Diagram of EMG based control system

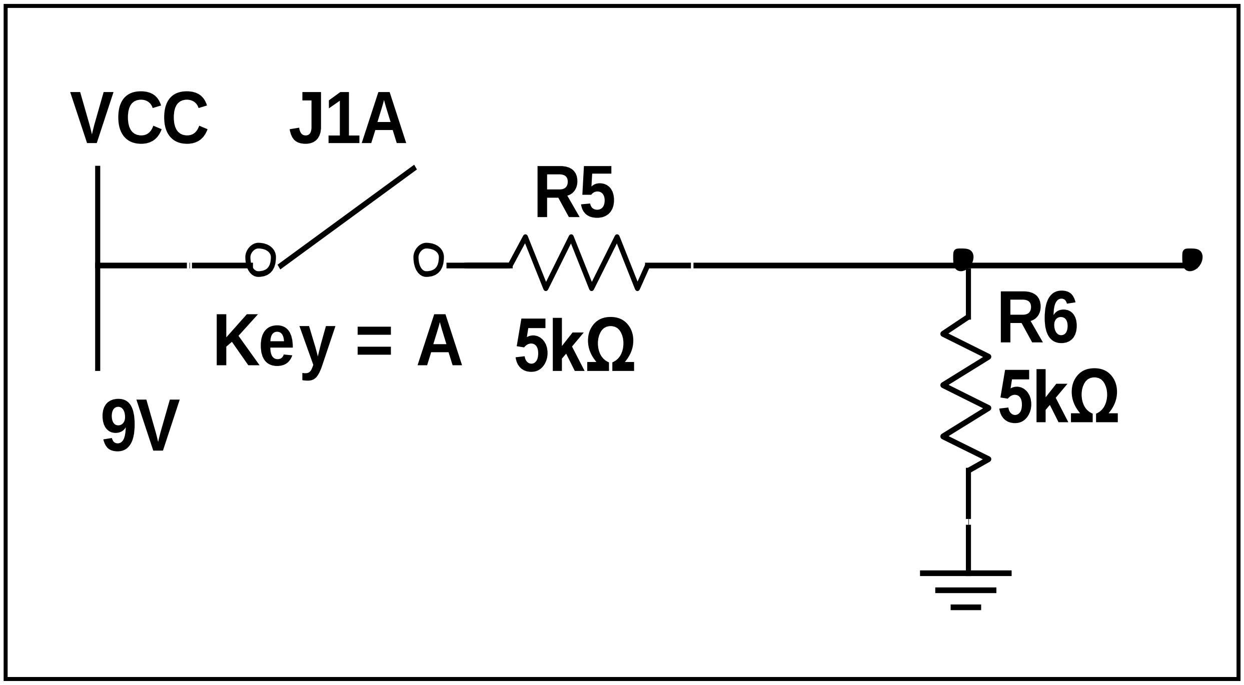
The designing of the voice-controlled device was accomplished in two steps-

1- Development of a voice acquisition and classification module

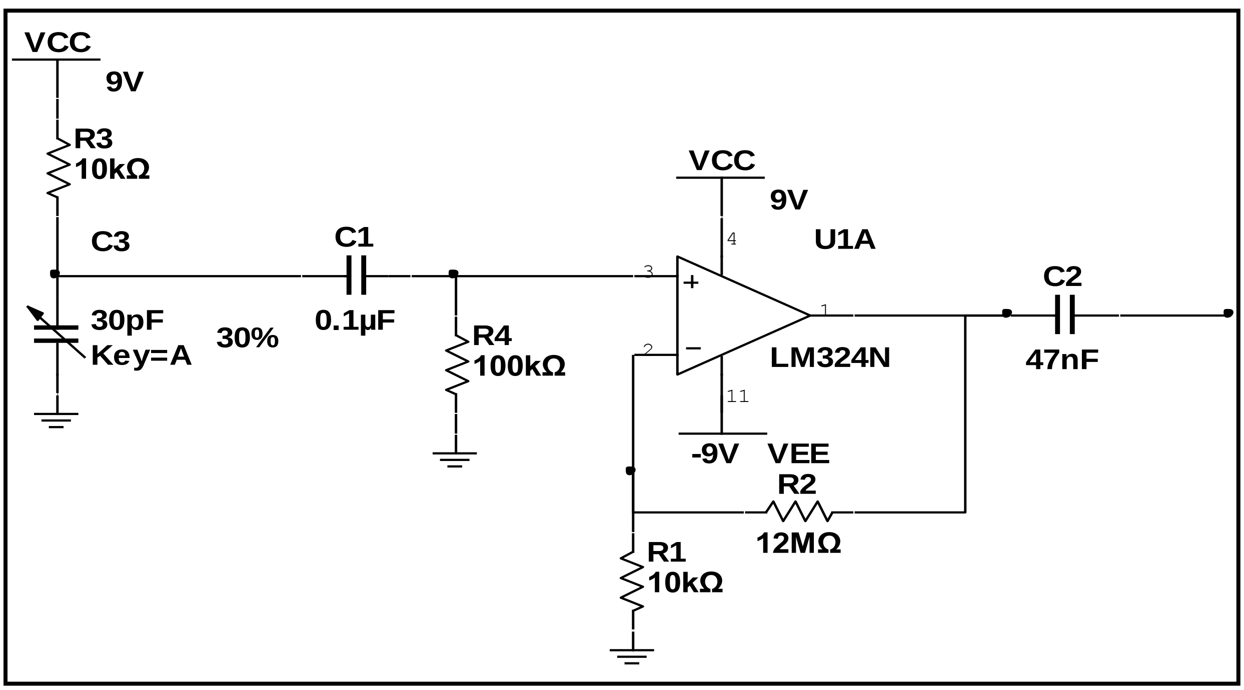
2- Servo motor control module for automation

3.1.2.1 Development of a voice acquisition and classification module

An electrect microphone coupled with a non-inverting amplifier (A_f =100) was used to amplify the voice signal. A switching device was also introduced into the circuit (Fig. 1). The amplified voice signal and the output of the switching device were acquired in PC by USB-4704 using a LabVIEW program. The program was designed to classify the voice signals into 3 categories as per the maximum amplitude of the processed voice signal. The schematic representation of the process has been shown in Fig. 3.2. The binary output of the classification logic was used to put-on virtual LEDs (implemented in the LabVIEW program) corresponding to the specific classification category (Fig. 3.3). In a separate experiment, the classified voice signals were used to activate the digital output (DO) terminals of USB-4704 for glowing 3 LEDs corresponding to each command (Fig. 3.3). The LEDs were pre-initialized by activating the switching module before providing the commands. The schematic representation of the voice acquisition system has been shown in Fig.3.3. After the preliminary study using the LabVIEW based program, attempts were made to devise a standalone control system using Arduino UNO microcontroller using the same analogy. Further, the control signals were transmitted using Xbee transreceiver. The receipt of the control signals at the receiver end was tested by glowing 3 LEDs.



(a)



(b)

Fig. 3.2 Circuit diagrams (a) Switching Circuit, and (b) Voice Amplifier

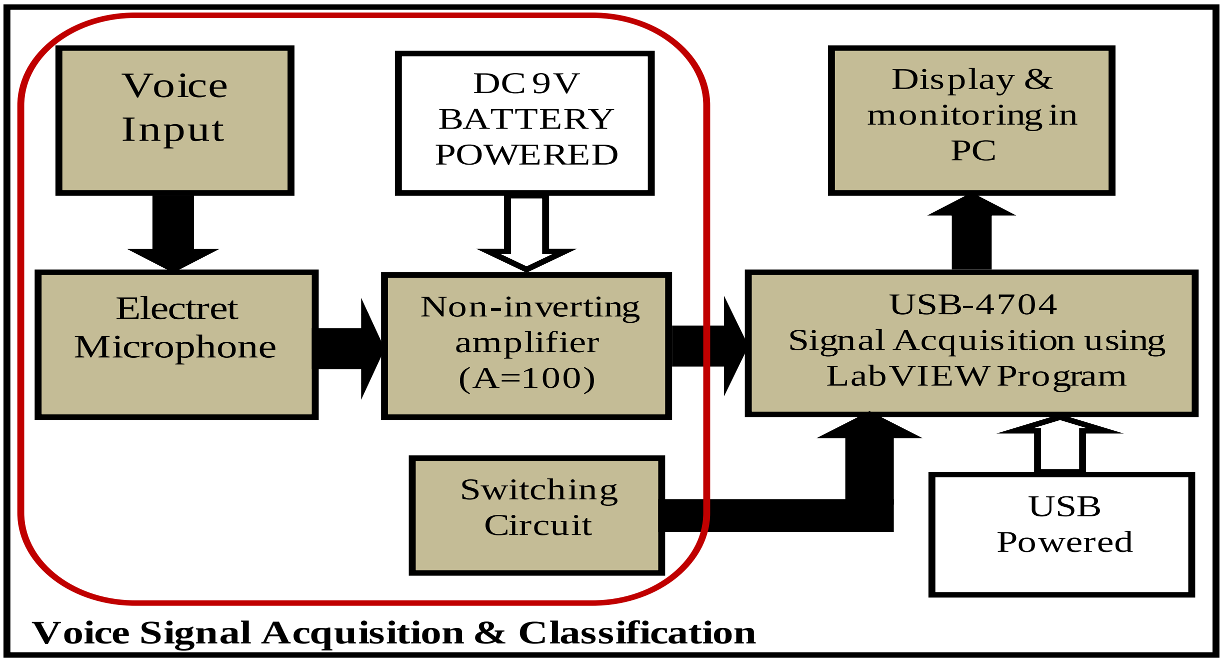


Fig. 3.3 Schematic representation of the voice signal acquisition and classification (in LabVIEW) module

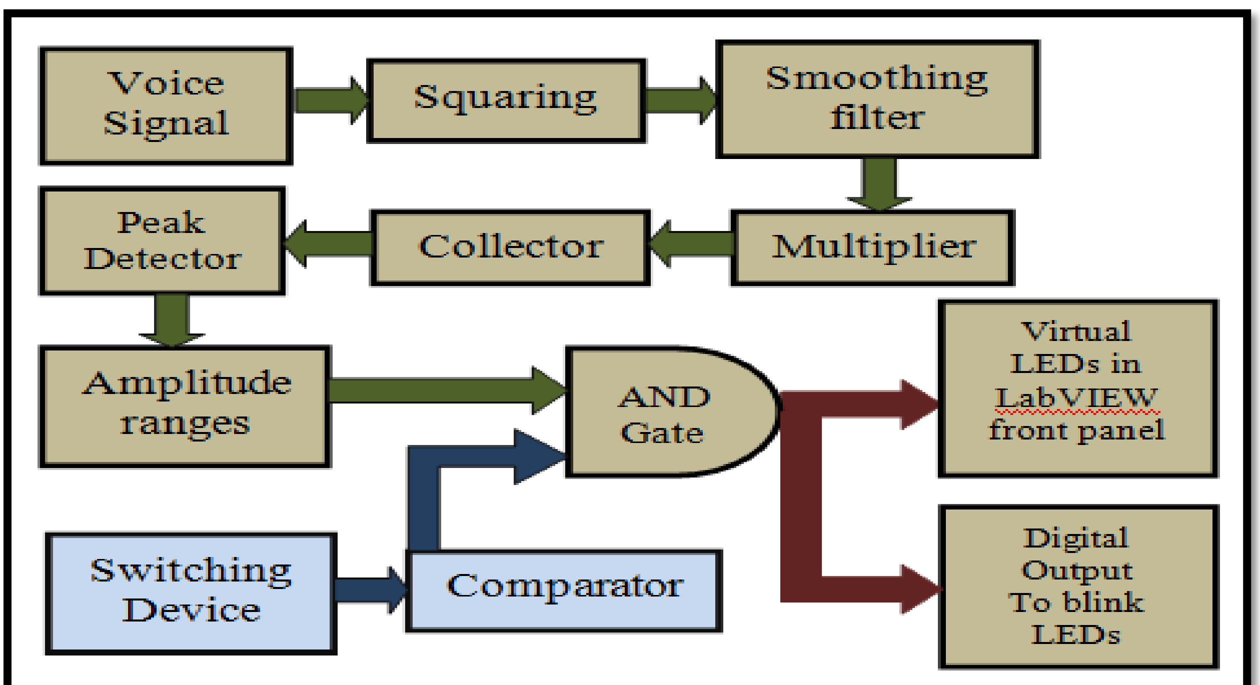


Fig. 3.4 Logic of the LabVIEW program used for voice signal acquisition and classification for glowing LEDs (Virtual and actual).

3.1.2.2 Servo motor control module for automation

The control signals at the receiver end of the Xbee transreceiver was used to control the servo motors of the quadbot. The program was made to move the quadbot in three directions, namely: right, left and forward. The schematic representation of control module is shown in figure 3.5.

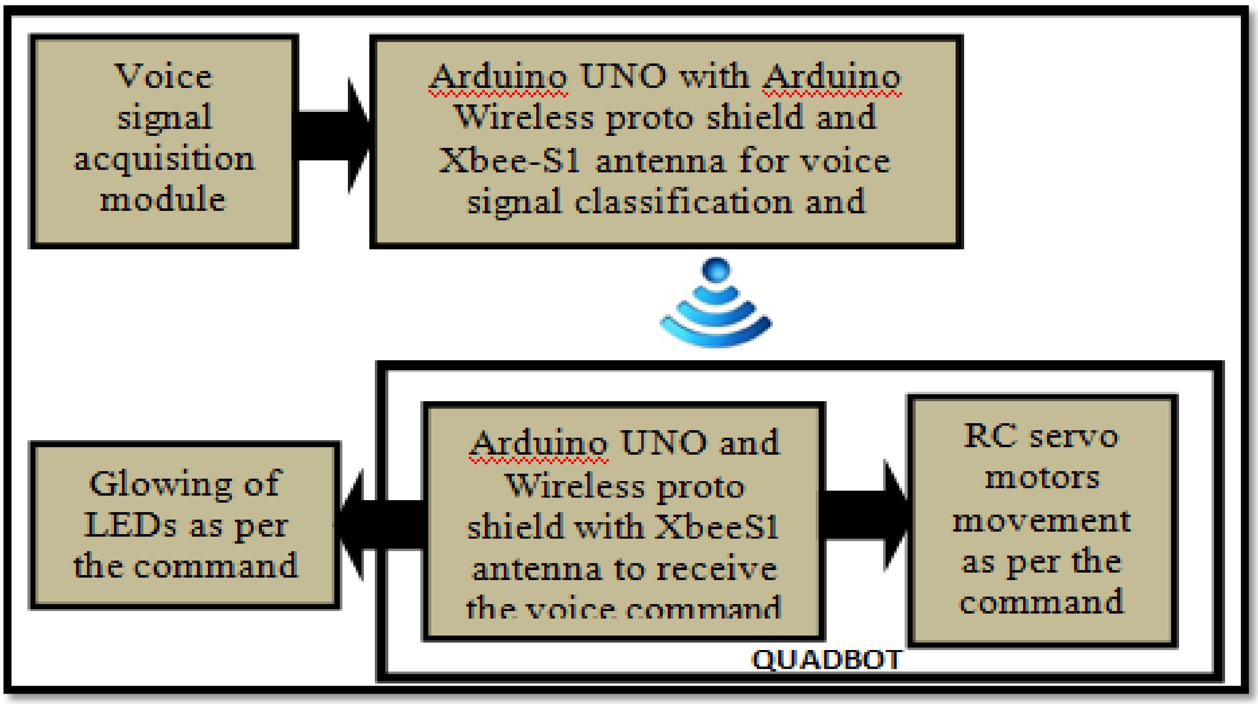


Fig. 3.5 Schematic representation of the developed control system either for glowing LEDs or quadbot (interfaced with Arduino) movement

Results and Discussion

3.2.1 Development of a voice acquisition and classification module

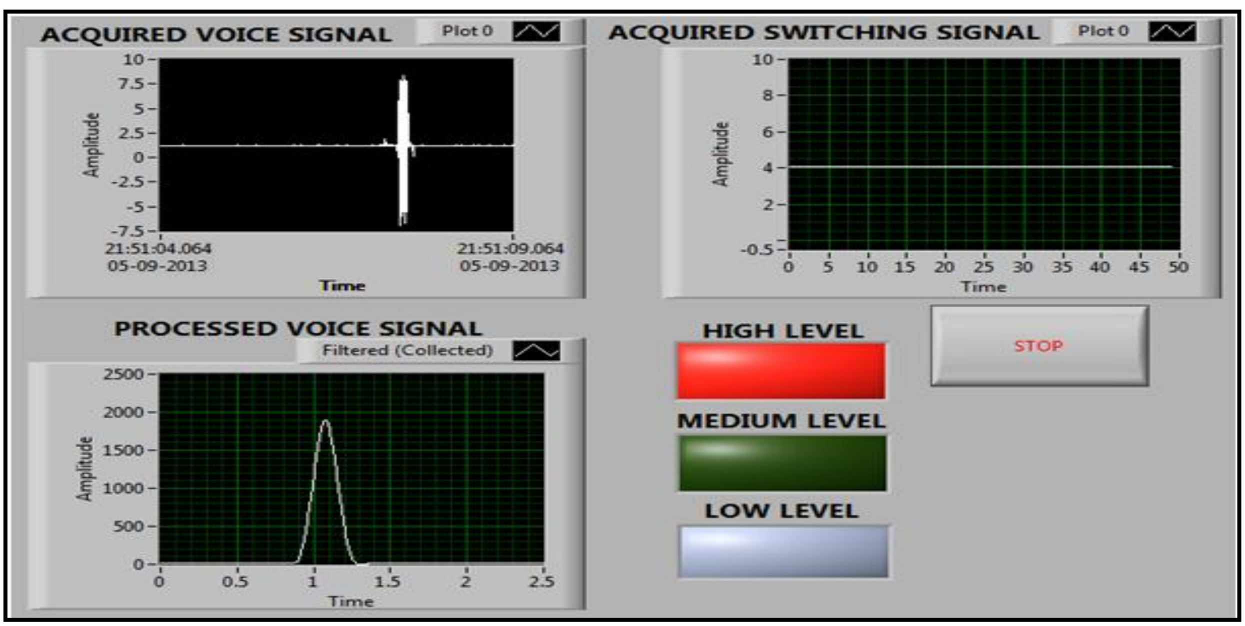
An electret microphone was used as a sensor for voice signal acquisition. The voice signal was amplified using a non-inverting amplifier (designed with LM324). The gain of the amplifier was 100. The amplification of the voice signal was done so as to improve the signal strength before it could be acquired in the PC. A switch was intentionally introduced in the circuit to avoid accidental activation of the device. The amplified voice signal and the output of the switching device were acquired in the PC using USB-4704. A LabVIEW program was developed for the acquisition of the signals. The acquired voice signal was squared and subsequently smoothened to obtain an envelope of the squared signal. The maximum amplitude of the signal envelope was obtained using a peak detector. The classification of the signal was done as per the maximum amplitude of the detected peak and comparing them with the standard values provided. The standard amplitude ranges used for the comparison has been provided in table 1. The output from the comparators served as one of the inputs for the AND Boolean operator. The other input of the AND operator was the signal from the switch. This resulted in the generation of the control signals for the LEDs only when both the inputs (Boolean signal after comparison of the peak amplitude of the smoothened voice signal and high signal from the switch) of the AND operator were in a high state. This ensured that there was no unintentional activation of the device. The front panel of the voice analysis program and the corresponding activation of the LEDs (shown as insert) have been shown in fig 3.6.

A standalone device was made using Arduino microcontroller. The device was made using the same analogy as per the LabVIEW program. The microcontroller acquired the signal from the developed voice acquisition system. Subsequently, the acquired signals were classified and the control signals were generated. The control signals were used to glow LEDs (Fig. 3.7).

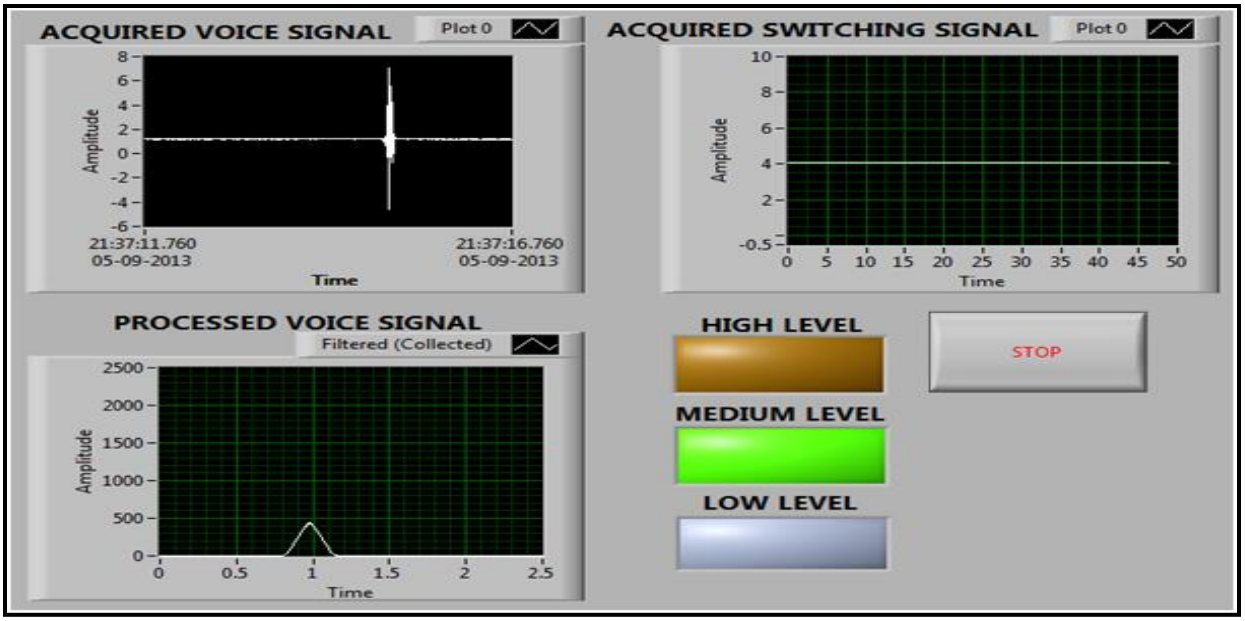
Thereafter, the control signals were transmitted using Xbee transreceiver to a remote microcontroller for the analysis of the control signals by glowing LEDs (Fig.3. 8).

TABLE I
LOUDNESS CORRESPONDING TO AMPLITUDE VARIATION

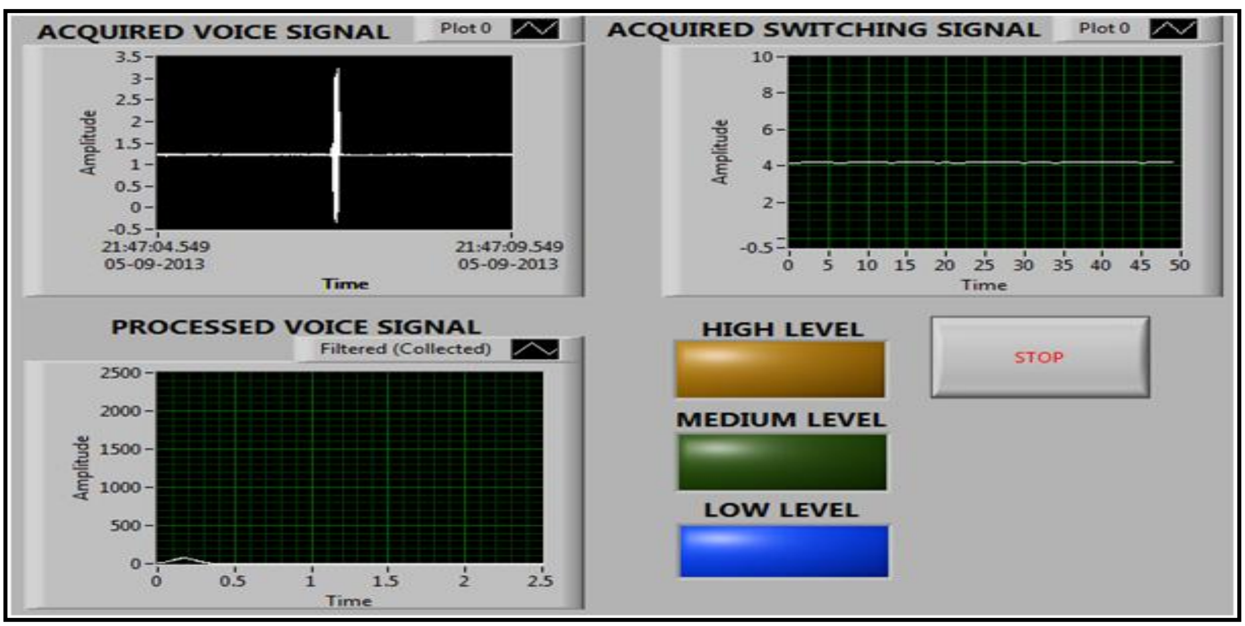
Sound Level	**Amplitude Ranges (Units)**
High	>1800
Medium	351-1799
Low	100-350



(a)



(b)



(c)

Fig.3.6 Front panel of Lab VIEW program and the glowing of LEDs as per the classification. (a) High level (red LED) (b) Normal level (green LED) and (c) Low level (yellow LED).

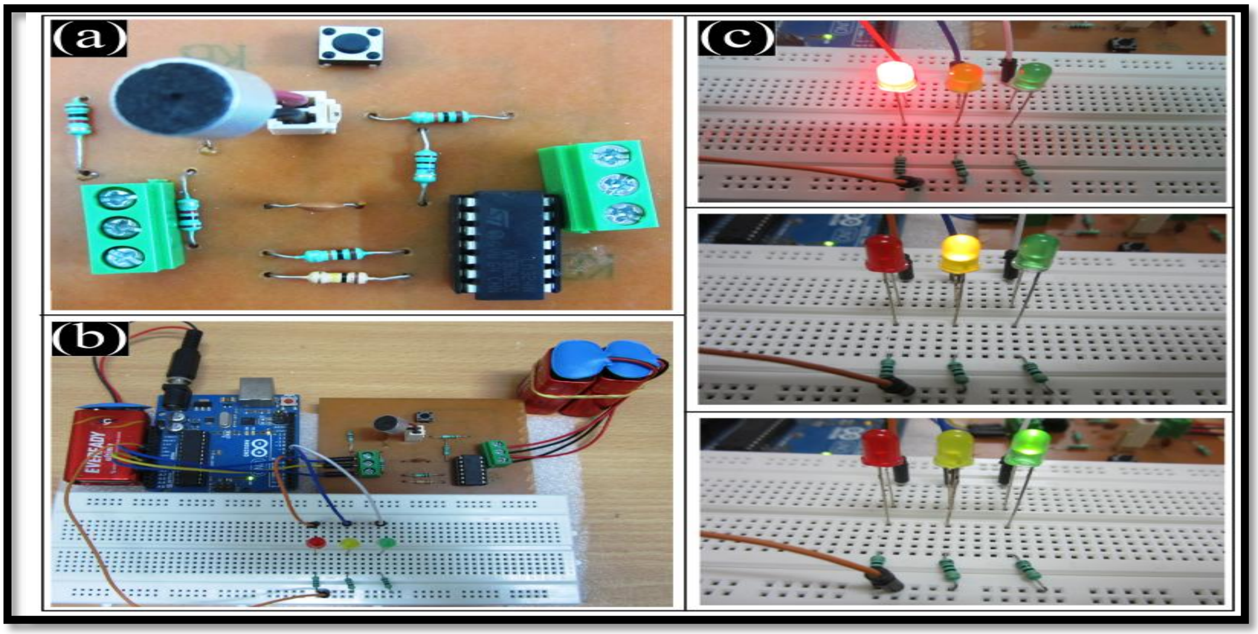


Fig.3.7 Voice signal acquisition, classification and generation of control signals using Arduino UNO. (a) PCB layout of the signal acquisition system, (b) Signal classification and generation of control signals, and (c) Using the control signals to glow LEDs.

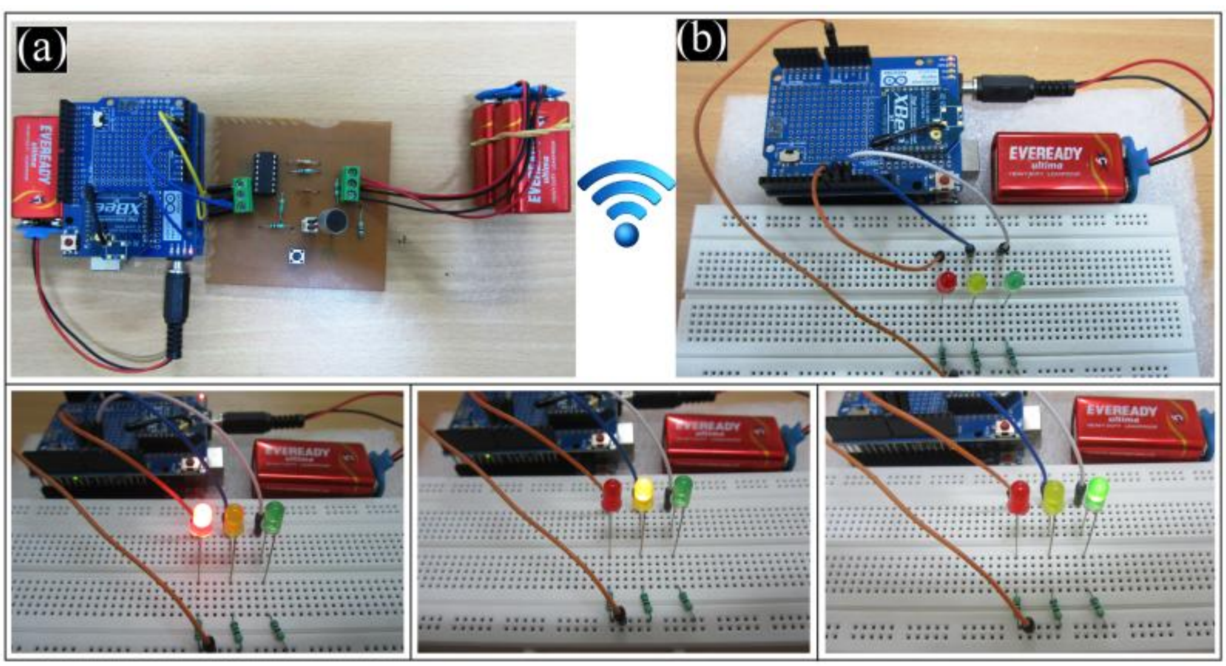


Fig. 3.8 Wireless transmission of the control signals. (a) Wireless control signal transmission module, and (b) Using the wirelessly transmitted control signals to glow LEDs.

3.2.2 Servo motor control module for automation

After the successful implementation and analysis of the voice acquisition and classification unit, the unit was used for controlling the servo motors of the quadbot to control its movement. The developed wireless standalone control device has been shown in fig. 3.8. The three control signals were used to initiate the three movements (“Forward”, “Left” and “Right”) (Fig.3. 9). The use of the microcontroller and the Xbee transreceiver helped in making the total system a standalone device with much less complexity in the hardware. The relationship of the type of the movement of the quadbot and the corresponding type of the voice command has been tabulated in table 2.

10 volunteers were trained to operate the control system and were requested to control the movement of the quadbot. The volunteers were able to control the movement with ease after the training period, which lasted for 10-15 min.

TABLE II

RELATIONSHIP OF THE QUADBOT MOVEMENT AND TYPE OF THE VOICE SIGNAL

Movements	**Loudness**
Left	High
Right	Low
Forward	Normal

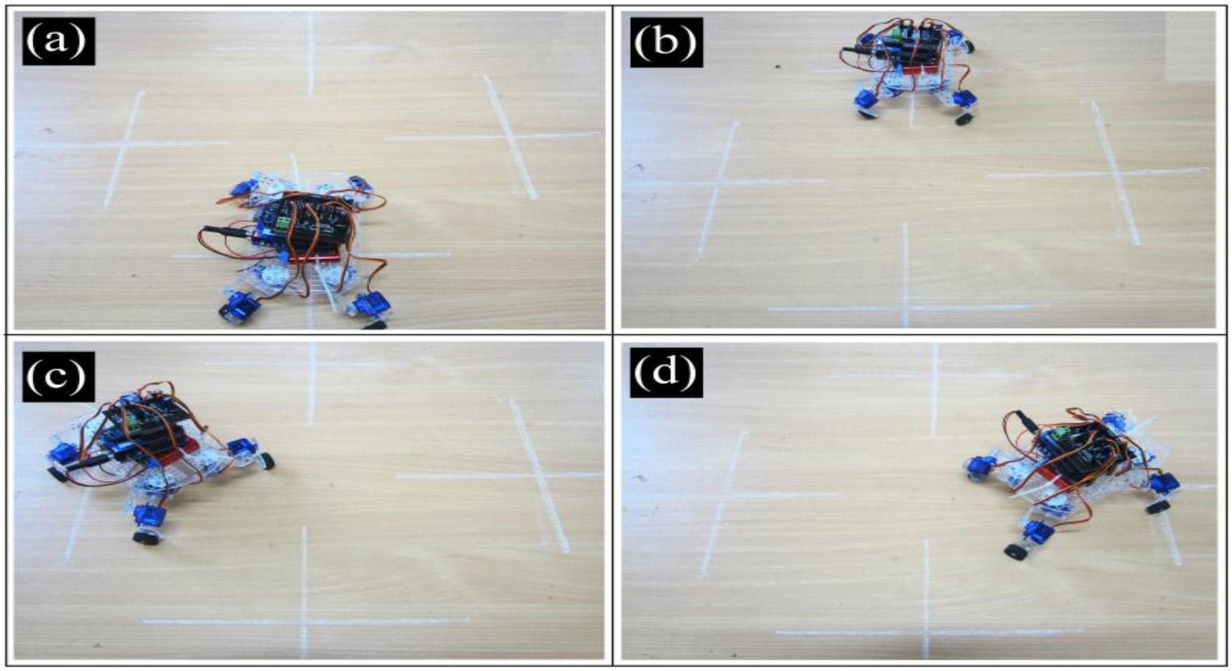


Fig.3.9 Intended quadbot movement (a) initial position (b) Forward (c) left and (d) right

Chapter IV

Development of Wireless EMG control system for rehabilitation devices

4.1 Materials and methods used for EMG based assistive technique

4.1.1 Materials

AD620 (Texas instruments), Ag/AgCl throwaway electrodes (BPL, India) with linking probes, Arduino UNO (Arduino, Italy), Arduino wireless proto shield (Arduino, Italy), Xbee-S1 wireless transreceiver module (Digi International, USA), and custom in-house made miniaturized wheelchair model were used in the study. The capacitors, resistors, motors and other parts were procured from local market.

4.1.2 Method used for EMG based assistive technique

Basic Block Diagram of EMG based control system is given in Figure 4.1

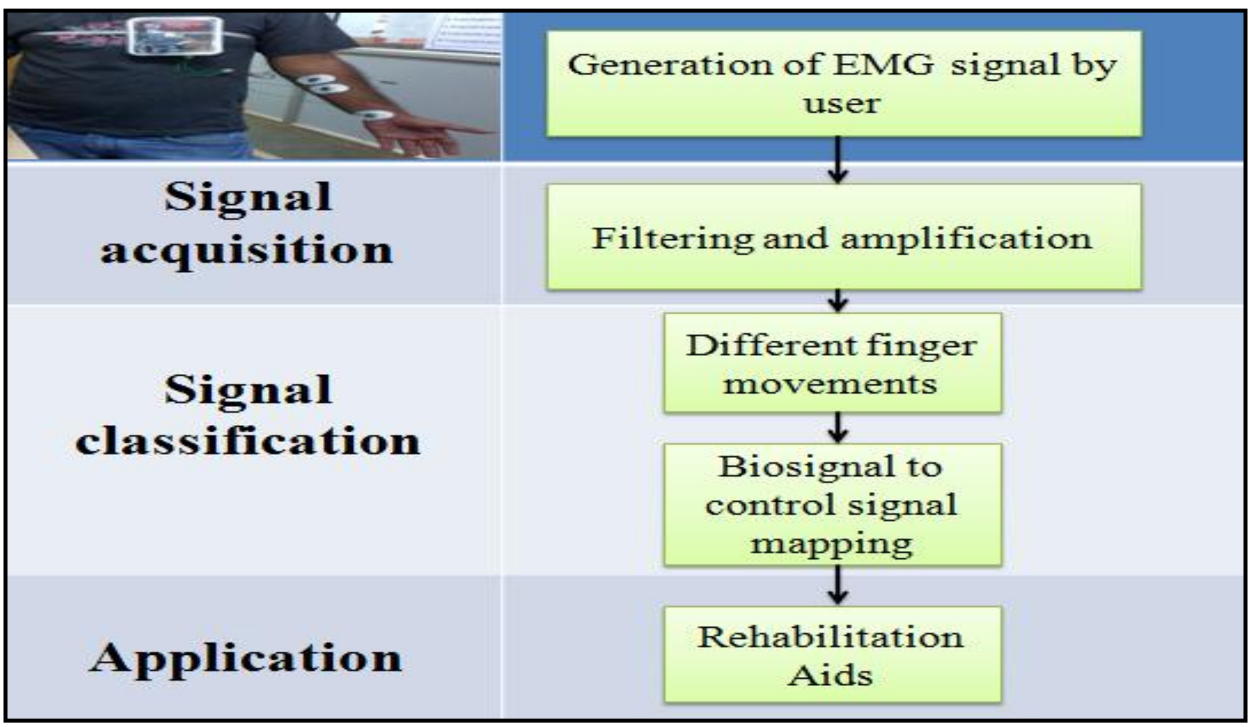


Figure 4.1 Basic Block Diagram of EMG based control system

The development work involved three parts:

1. **Signal acquisition part** included development of EMG acquisition system.
2. **Signal classification part** included classification of different finger movement types.
3. **Application part** involved implementation of rehabilitation devices which can be controlled using EMG.

4.1.3 EMG signal acquisition system

4.1.3.1 Electrodes and input cables

Disposable pre-gelled Ag/AgCl electrodes were used to acquire EMG signals from the body. Since the EMG signal amplitude range was in mill volts, they were very much susceptible to various noise sources. To overcome the effects of RF noise and electromagnetic interference, shielded wires were used to connect Ag/AgCl electrodes and signal acquisition circuits.

4.1.3.2 Safety regards

Since electrical protection of the patients was a key concern for the development of biomedical tools, the circuit shown above run only using two 9 volt batteries. Apart from that, Advantech DAQ was powered by means of the USB terminal of a laptop, which was run in the battery powered mode to make sure electrical safety of the patients. Being operated in battery mode also abridged the power line interfaces to a limit.

4.1.3.3 Amplifier circuit

In general EMG signal amplitude varies from 1-10 mill volts. Hence additional care should be taken during the digitization of the signal in order to minimize the error. Amplifier circuit consists of an instrumentation amplifier (AD620) whose gain is adjusted to 1000. The instrumentation amplifier has taken because of its high input impedance and CMRR. The output of the instrumentation amplifier from PIN 6 is fed in to the reference PIN 5 through an integrator in order to remove the dc offset. An active ground was formed in order to reduce the common mode signal from the output. The output of the amplifier circuit is fed in to the low pass filter of frequency 500 Hz. The output of the filter is fed in to the lab view where classification of signal is done. A same program was made in arduino in order to control the servo motor of the wheelchair. Schematic diagram of the circuit is given in figure 4.2

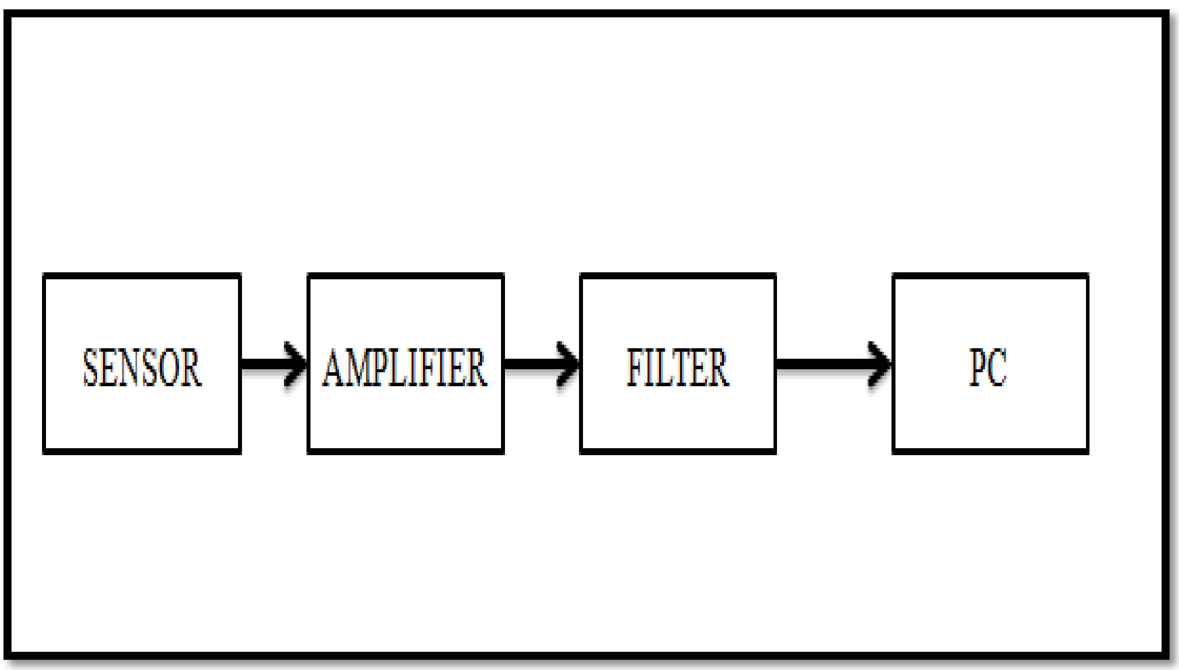


Figure 4.2 Schematic diagram of EMG signal acquisition system

4.1.4 EMG signal classification

Output of the EMG acquisition system is fed in to the lab view using DAQ 4704 and a program was framed in such a way that four different ranges are defined for different amplitude and if particular amplitude satisfies any ranges then corresponding LED will glows. Same classification is done in arduino in order to control the wheelchair movement. Amplitude for corresponding finger movement is shown in table I. Schematic diagram of signal classification and corresponding glowing of LED as per classification are shown in figure 4.3[12].

TABLE II

Amplitude Corresponding to different hand movement

Different hand movement	Amplitude (units)
Index flexion	1-10
Middle flexion	11-24
Thumb flexion	25-50
All finger abduction	>50

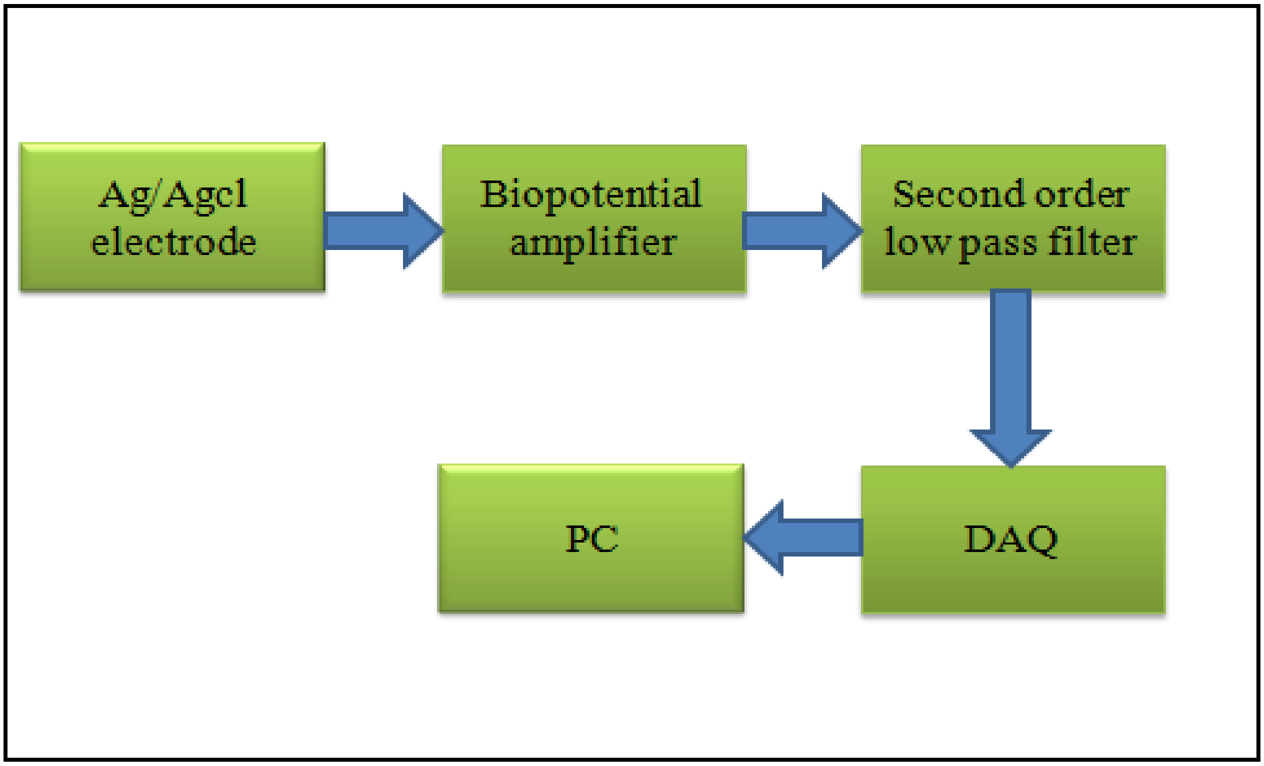


Figure 4.3 Schematic diagram of EMG signal classification system

4.1.5 Application

In application part a wheelchair model is developed which is controlled by the EMG signal. After acquisition and classification of EMG signal wireless transmission of signal takes place trough xbee transreceiver. Generated control signal are transmitted by xbee from the transmitter end and received by the xbee at the receiver end. The schematic representation of the process has been shown in Fig. 4.4 [16].

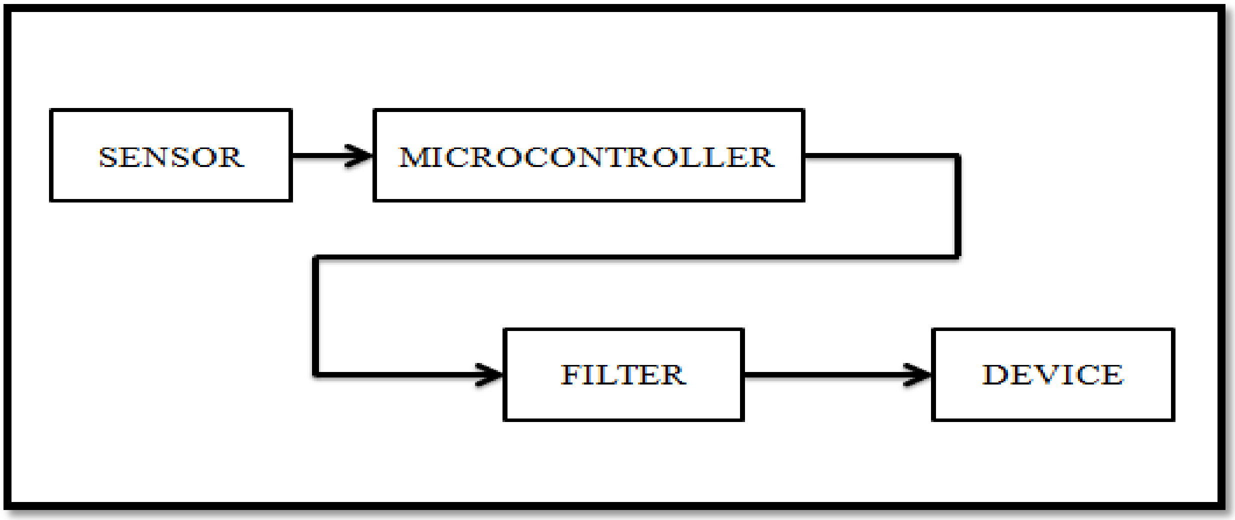


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Fig. 4.4 Schematic representation of the developed wireless control system.

Received control signals were used to control the servo motor of the wheelchair [17]. Control signal test was done by glowing the LED as per command. The program was made to move the wheelchair model in four directions, namely: forward, backward, rotate, stop.

Results and Discussion

4.2 EMG based motorized wheelchair

4.2.1 EMG signal acquisition system

4.2.2 Biopotential amplifier circuit

In general EMG signal amplitude varies from 1-10 mill volts. Hence additional care should be taken during the digitization of the signal in order to minimize the error. Amplifier circuit consists of an instrumentation amplifier (AD620) whose gain is adjusted to 1000. PCB design of biopotential amplifier is shown in figure 4.5 and hardware design of signal acquisition system is given in figure 4.6 [18].

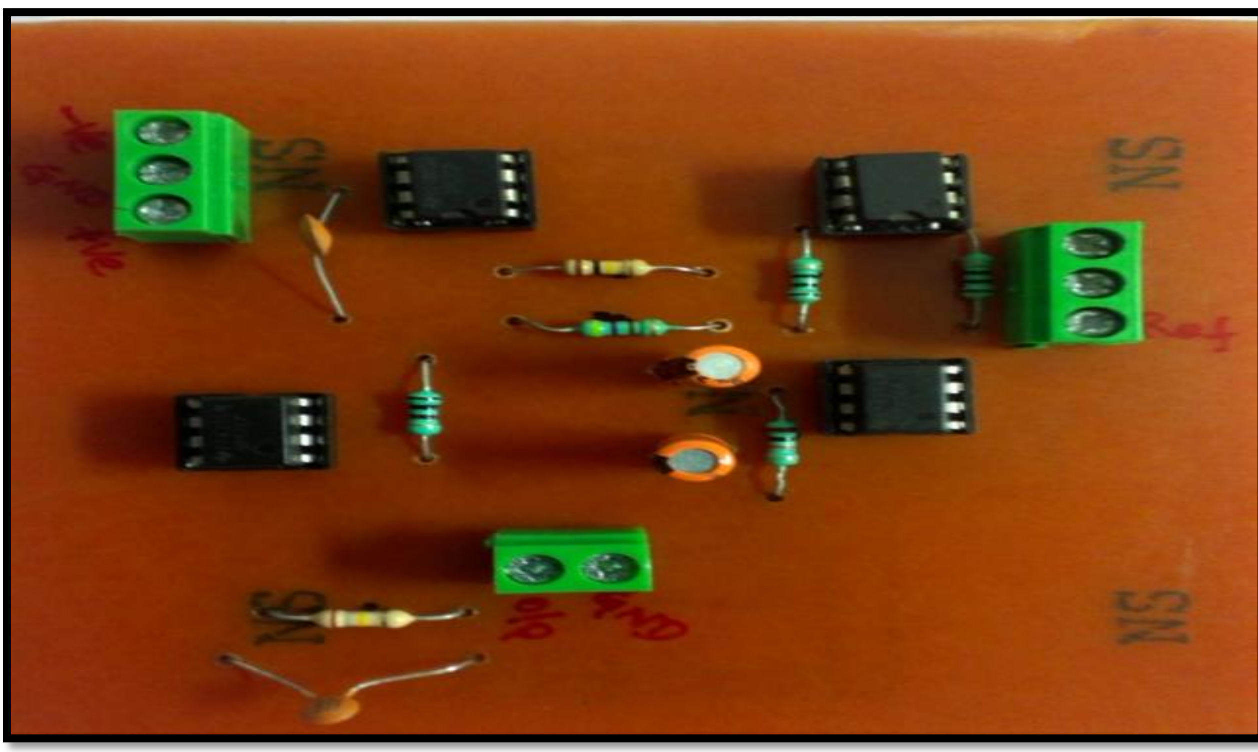


Figure 4.5 PCB design of biopotential amplifier.

Gain of instrumentation amplifier AD620 is given by

$$G = \frac{49.4k\Omega}{Rg} + 1$$

Where, Rg was the resistor connected between the 1st and 8th pin of the AD620.

$$Rg = 54\Omega$$

When Rg 54Ω Gain is approximately equal to 1000. Output of the biopotential amplifier is fed in to the second order low pass filter of frequency 500Hz. The frequency of low pass filter is given by

$$f_C = \frac{1}{2\pi\sqrt{R_1C_1R_2C_2}} \text{ Hz}$$

Here R1=470Ω, R2=100Ω, C1=.1uf and C2=.1uf gives f=500Hz.

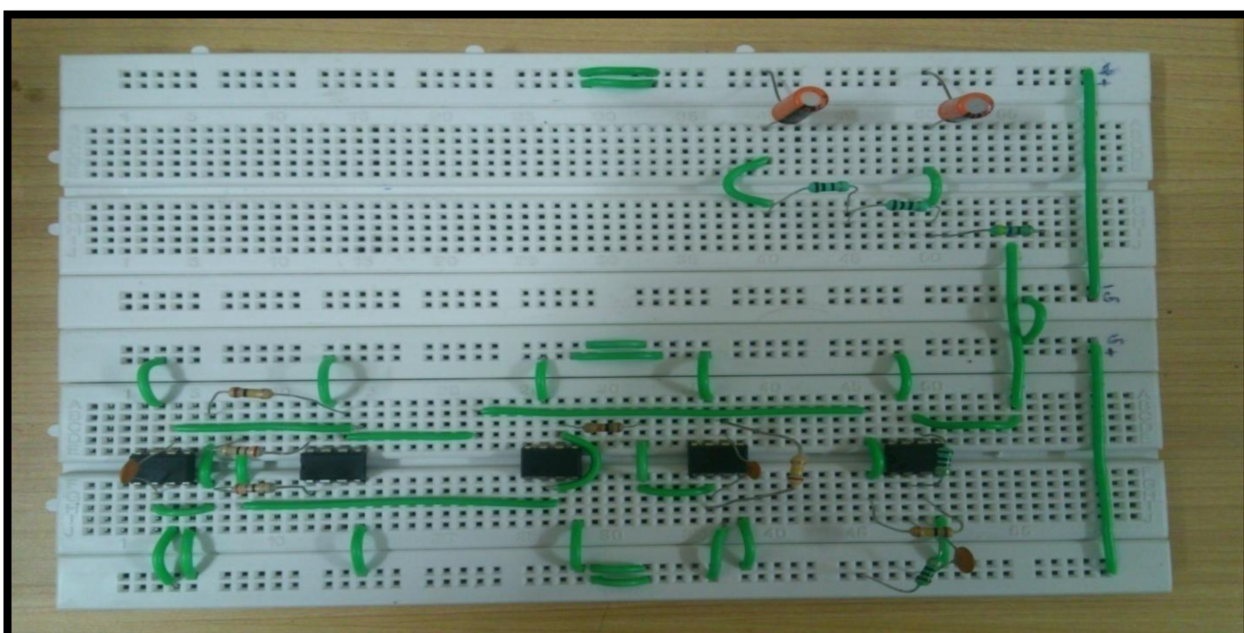
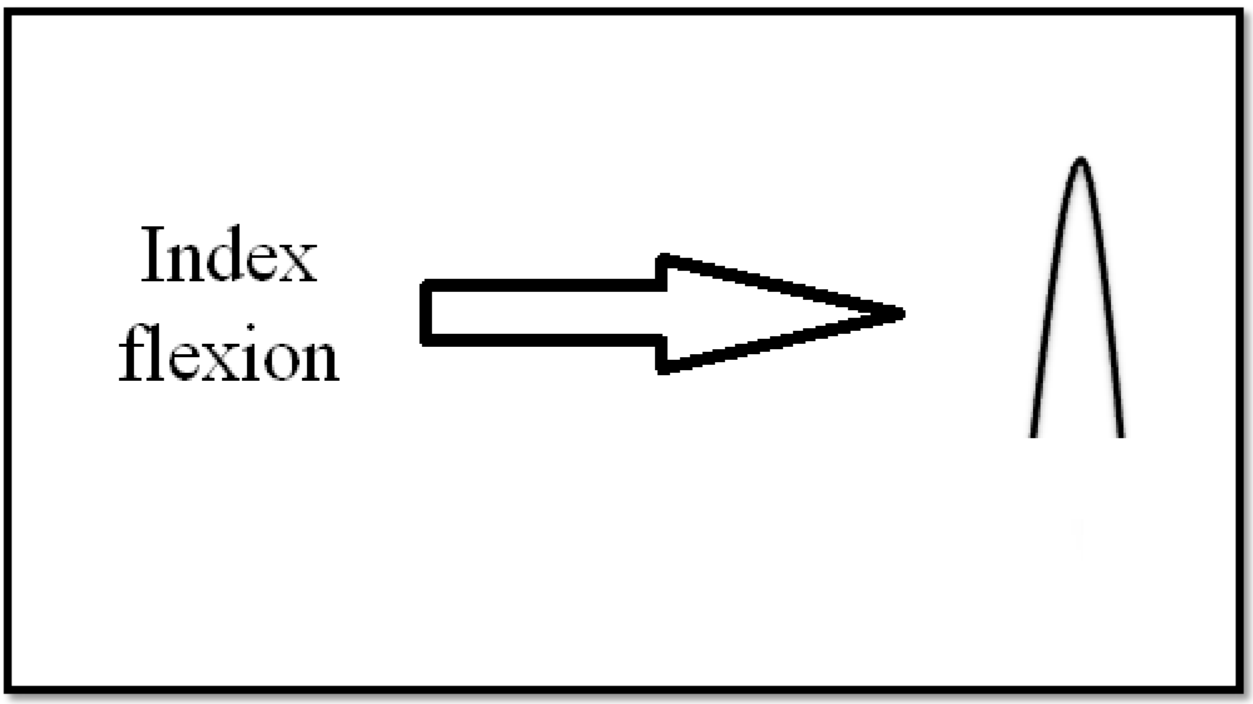


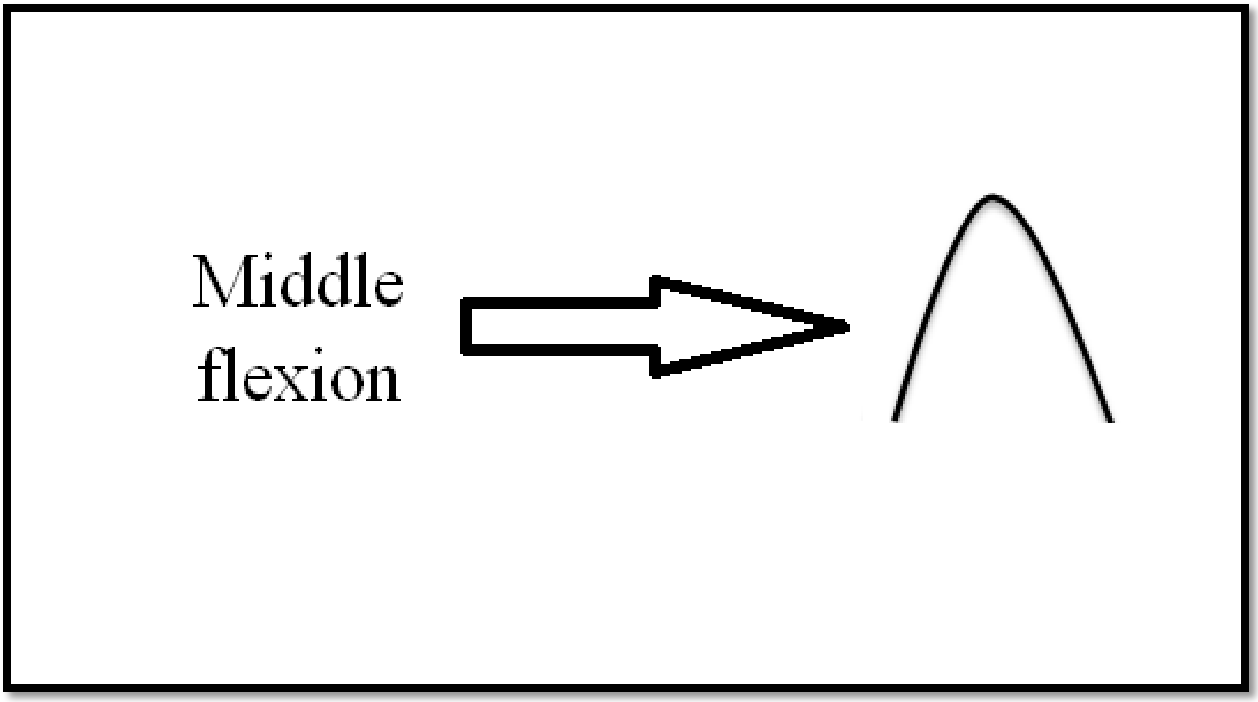
Figure 4.6 Hardware design of signal acquisition system.

4.2.3 EMG signal classification

Output of the signal acquisition system was fed in to the lab view where classification of signal was done. Analog output from the circuit was fed in to the lab view using DAQ 4704 and a program was framed in such a way that four different ranges are defined for different amplitude and if particular amplitude satisfies any ranges then corresponding LED will glows. Amplitude of signal as per the classification are shown in figure 4.7 and block diagram of the program is shown in figure 4.8 [19].



(a)



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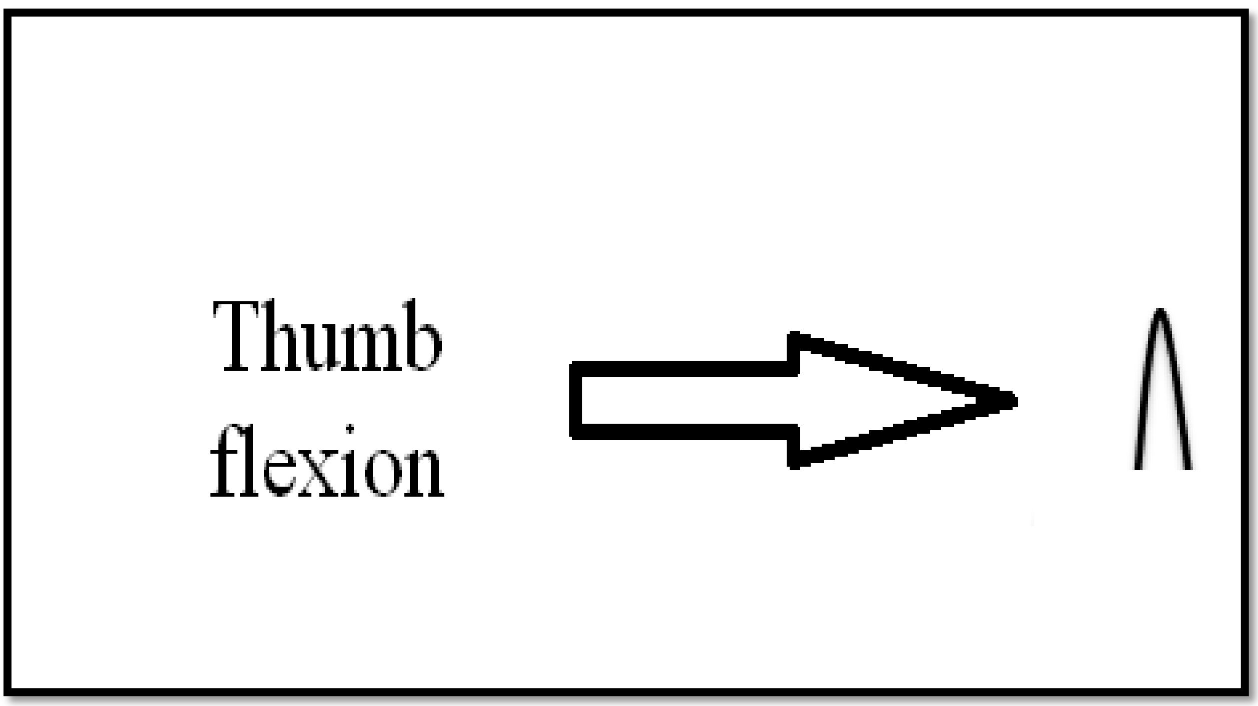

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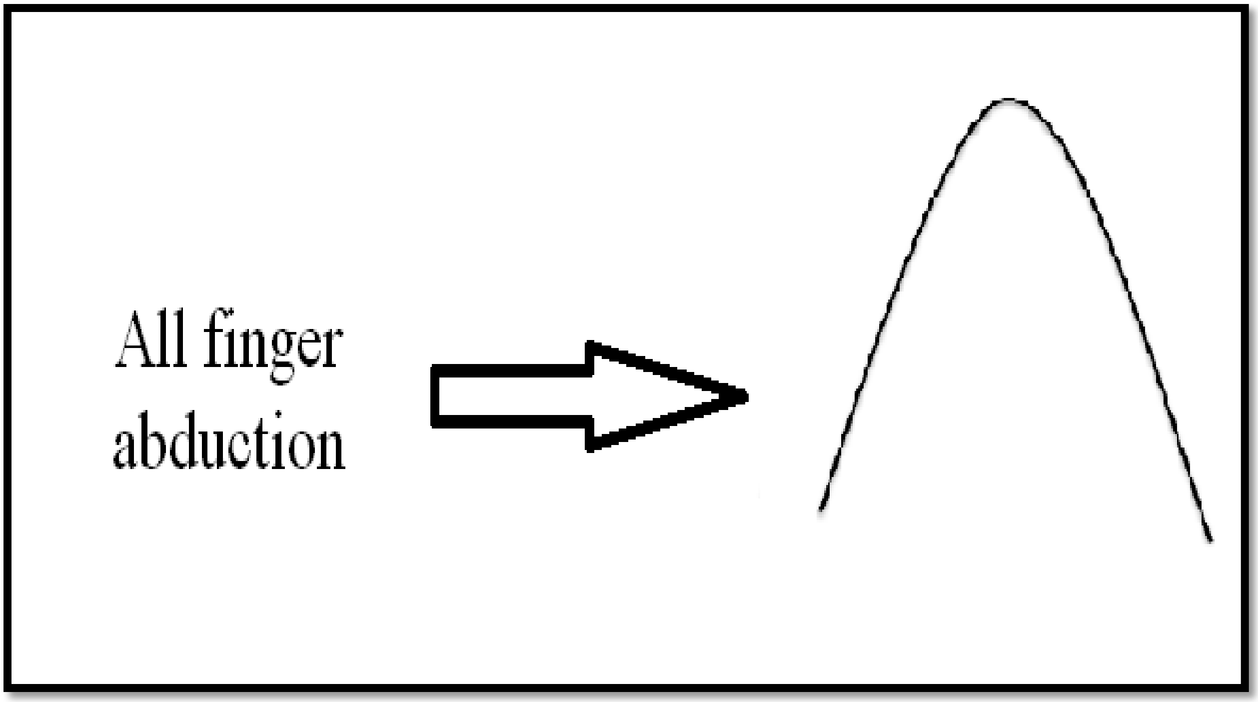

(d)

Fig.4.7 Amplitude of signal for different finger movement (a) Index flexion (b).Middle flexion (c) Thumb flexion and (d) all finger abduction.

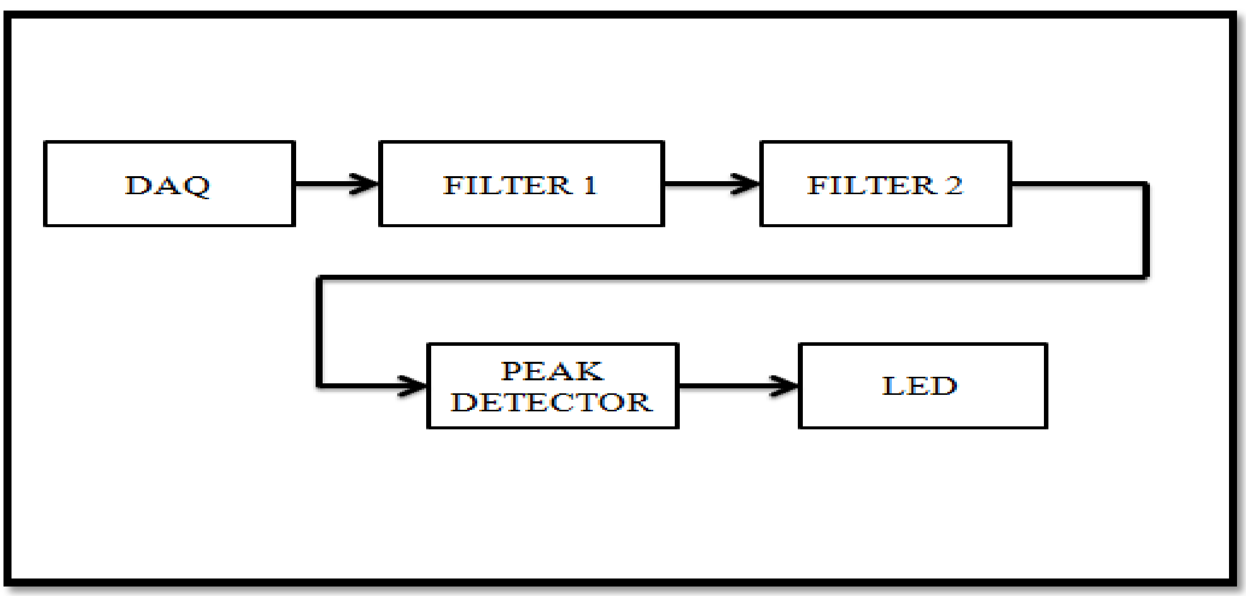

Fig.4.8 Block diagram of the Lab VIEW program.

Obtained signal is fed into the band stop filter of frequency 50-55Hz in order to suppress the noise from the input signal. After suppressing the noise from the input signal squaring and smoothening of the signal is done. Envelope detection is done by smoothening of the signal. After smoothening peak measurement of the signal is done and four different ranges are defined for different amplitude and if peak amplitude satisfies any ranges then corresponding LED will glows.

4.2.4 Application

After the classification of the signal in the lab view same program was implemented in the Arduino UNO microcontroller to generate the control signals. A four LED panel was used to test the generation and transmission efficiency of the control signal. Generation of control signal is shown in figure 4.4.9 and transmission efficiency is shown in figure 4.9.1

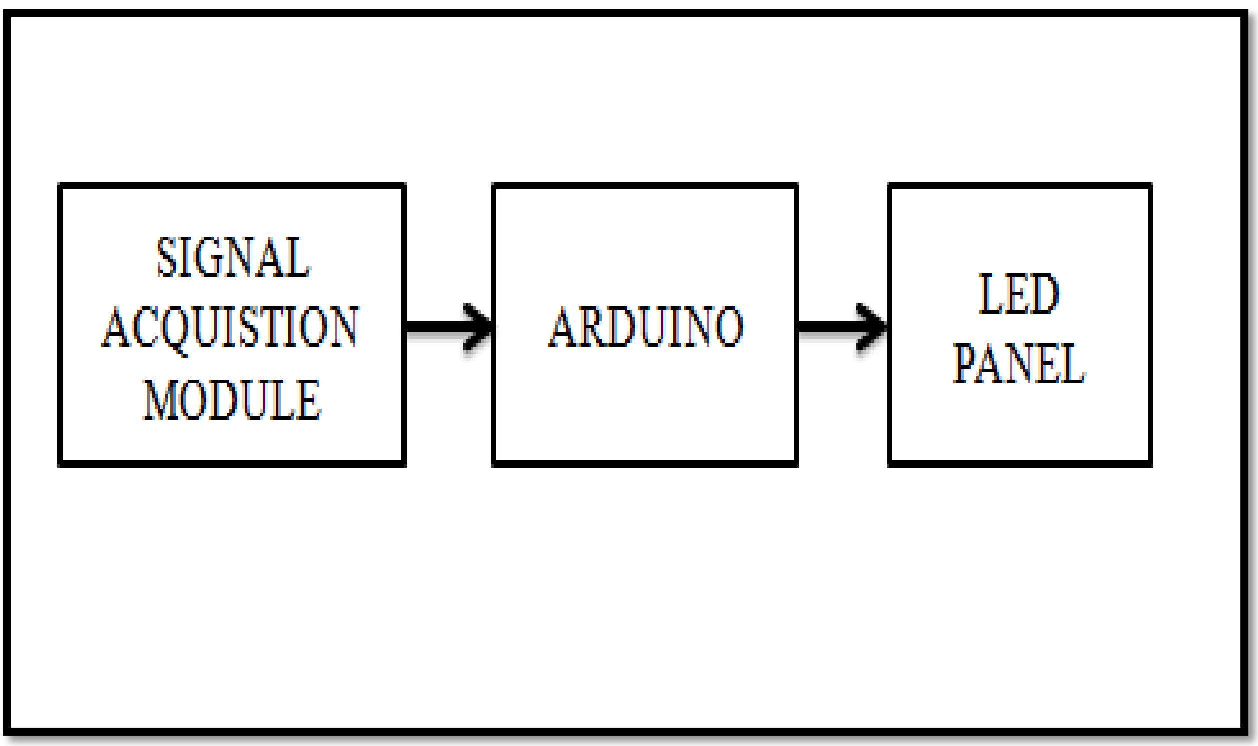

Fig.4.9 Control signal generation using arduino.

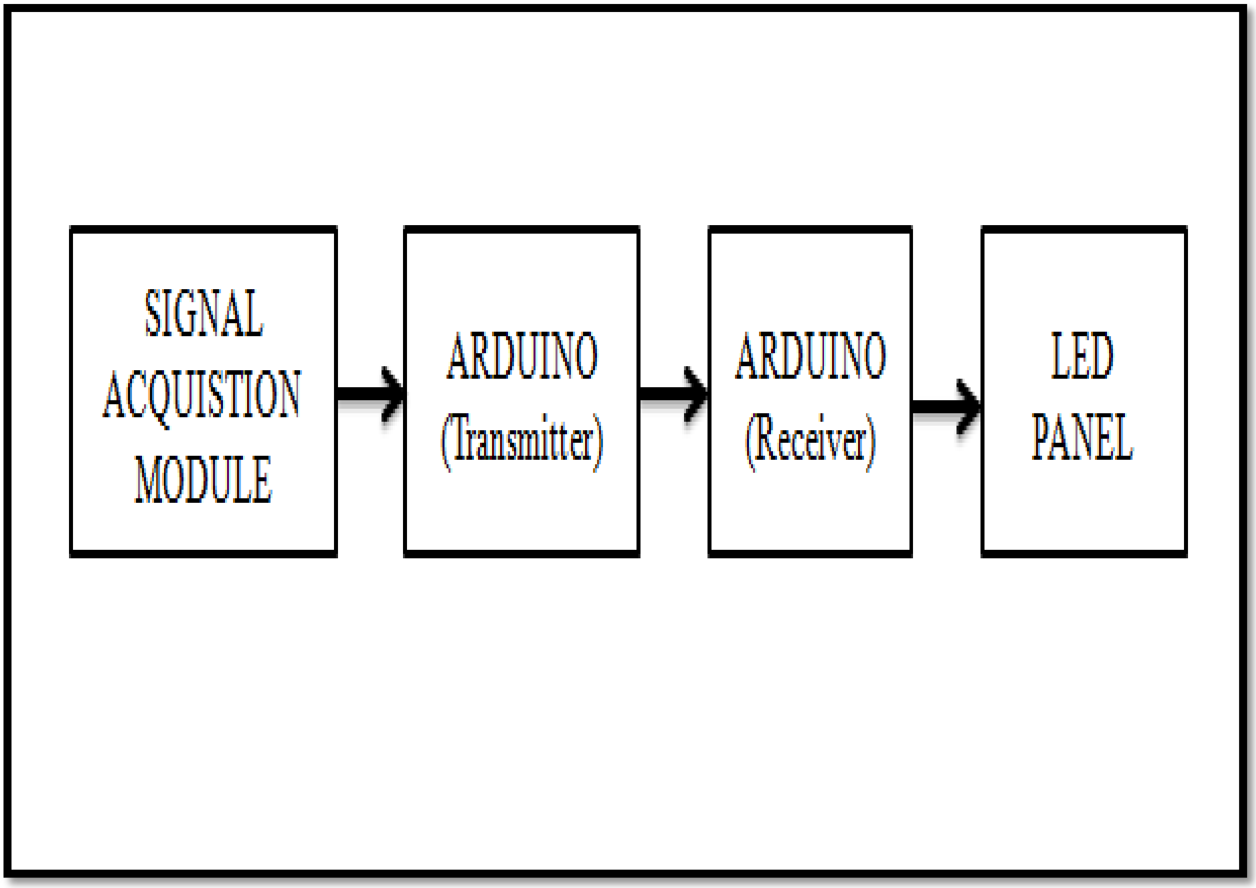

Fig.4.9.1 Control signal transmission using arduino.

Xbee transceiver was used in the transmission and receiving of the signal. In figure 4.6 different LED correspond to different finger movement. The control signals at the receiver end of the Xbee transreceiver was used to control the servo-motors of the wheelchair. The program was made to move the wheelchair model in four directions, namely: forward, backward, rotate, stop. Wheelchair diagram is shown in figure 4.9.2

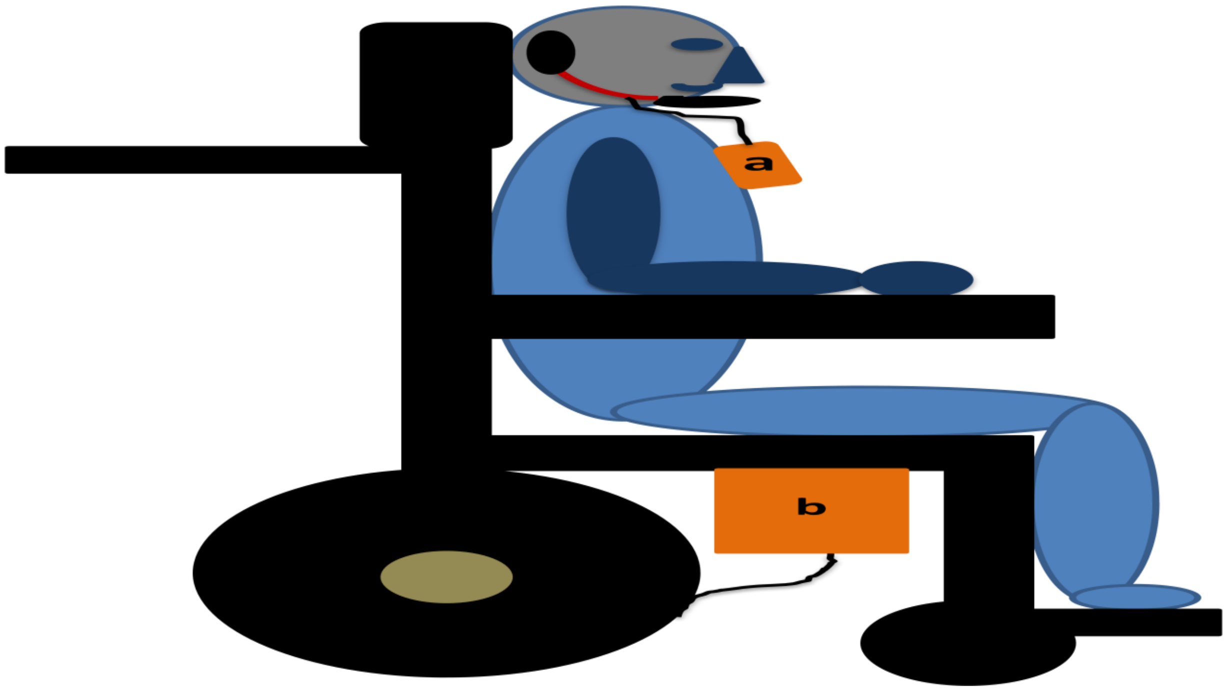

Fig.4.9.2 Wheelchair diagram.

The wheelchair model consists of two servo-motors in the rear position. The different movements of the wheelchair model were achieved by applying various combinations of direction of servo-motor rotation[20].

Chapter V

Conclusion

5.1 Conclusion

In the present work, an EMG and voice signal acquisition system has been designed and implemented. Additionally, a new algorithm for EMG and voice classification for control signal generation was also developed. The proposed systems are not only user friendly but also cost effective in nature. These systems required much less user training in comparison to other classification system. Since the developed control systems use a wireless communication protocol to control the servo-motors of the wheelchair, the freedom of the user is much higher as compared to the wired control systems. Hence it is very much useful for the implementation of rehabilitation aids. In proposed systems voice signal is classified in to three ranges while in case of emg control system four ranges are defined which proofs it's higher accuracy in comparison to voice control system. The developed device will help in eliminating the drawbacks of the traditional electric powered-wheelchair. This system is used to generate the control signal with different hand movement. These generated control signals are used to control the wheelchair model corresponding to hand movement. Development of EMG based control system for assistive device will be a good assistive technique for people suffering from extremely limited peripheral mobility[21]. From the application point of view generated control signal can also used to control the other rehabilitative devices.

5.2 Future work

The future prospects of current project are huge. In future it can be used to control the other rehabilitation device like prosthetic arm etc. Range of the device can also be increased by replacing the RF module by GSM module. Quality of the system can be improved by using high precision components. Range of motion can also be increase by modification in the program.

Same algorithm can also used to control different rehabilitation device by different biopotential signals.

Chapter VI
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