ARM EXOSKELETON

USING EMG

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ABSTRACT

An exoskeleton is a supporting structure on the outside of the body. The name stems from the words exterior and skeleton. The design of this exoskeleton takes its controlling signal from electrical signals from the arm muscles. The processed electromyography (EMG) signals can be classified in order to understand the motion intended by the person. Control signals can then be sent to the exoskeleton actuator. In this manner, the exoskeleton will assist in bearing a load on the human arm. The core objective of this project is the development of an exoskeleton controller for a prototype robotic arm, which is stand alone, portable, programmable, and easy to use and maintain. The design and implementation utilises microcontroller and flex sensors to meet this objective. At present, exoskeleton controllers of robotic manipulators are usually bulky, stationary and usually dependent on a pc or mainframe. The product of this project can become a basis for future exoskeleton controller designs, where it can make a significant impact on almost everyone especially in industry and research.

ACKNOWLEDGEMENT

We express our sincere gratitude to **Dr. V. P. Devassia**, Principal, Govt. Model Engineering College for providing us with the opportunity and the necessary support which we required for completing this project design. We are greatly obliged to **Mr. Vinu Thomas**, HOD, Department of Electronics Engineering, Govt. Model Engineering College for the encouragement and support that he provided. We are immensely indebted to our project coordinator, **Mrs. Sheeba P.S**, Assistant Professor, Department of Electronics Engineering, Govt. Model Engineering College, for her guidance and advice. We are also thankful to our project guide,

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CHAPTER 1

INTRODUCTION

Integrating human and robot into a single system offers remarkable opportunities for creating a new generation of assistive technologies for both healthy and disabled people. Humans possess naturally developed algorithms for control of movement, but they are limited by their muscle strength. In addition, muscle weakness is the primary cause of disability for most people with neuromuscular diseases and injuries to the central nervous system. In contrast, robotic manipulators can perform tasks requiring large forces; however, their artificial control algorithms provide the flexibility and quality of performance that is naturally achievable by human beings. It seems, therefore, that combining these two entities, the human and the robot, into one integrated system under the control of the human, may lead to a solution that may benefit from the advantages offered by each subsystem. In this scenario, the exoskeleton robot serving as an assistive device, is worn by the human and function as a human-amplifier. Its joints and links correspond to those of the human body, and its actuators share a portion of the external load with the operator. Several generations of exoskeleton can be defined based on the level of the human machine interface (HMI) between the exoskeleton robot and the human operator: (I) kinematic; (II) dynamic; (III) neuromuscular, eg: surface electromyography (sEMG); (IV) brain, eg: non-invasive electroencephalogram (EEG)or invasive action potential signal measured directly from the motor cortex. The third generation utilises the body's own neural command signals as one of the primary command signals of the exoskeleton. The main advantage of establishing the interface at the neuromuscular level is the ability to estimate the effects of muscle contraction even before these effects can be directly measured using other means. In fact, an electro-(chemical)-mechanical delay (EMD) inherently exists in the musculoskeletal system. This inherent time delay refers to the interval between the time when the neural system activates the muscular system and the time when the muscles and associated soft tissues contract mechanically and generate movements around the joints. EMD values vary considerably depending on the muscle, the person and the experimental technique used for the measurements and can be assumed in the range of 26-131 ms with values for some upper limb muscles in the middle-lower part of this interval. If the EMD can be exploited in the control algorithm of the exoskeleton a non-invasive and seamless integration between the human operator and the exoskeleton can be achieved in such a way that the device becomes a natural extension of the operator's own body. The primary component of the third generation exoskeleton that takes advantage of the EMD and sets the HMI at the neuromuscular level is the myoprocessor. A myoprocessor is a set of computational representations (models) of a human muscle predicting joint torques in real time. During the EMD the system gathers information regarding the physiological muscle's neural activation level based on processed EMG signals, the joint position, and the angular velocity. This information is fed into the myoprocessor which in turn predicts the movement that will be developed by the physiological muscle relative to the joint. The predicted movement is fed into the exoskeleton such that, by the time the physiological muscle contracts, the exoskeleton amplifies the joint movement by a preselected gain factor. Part of the time gained by using these predicted muscle movements is employed by the electro-mechanical subsystems of the powered exoskeleton to compensate for their own inherent reaction time.

CHAPTER 2

LITERARY REVIEW

EMG signal based research is on-going for the development of simple, robust, user-friendly, efficient interfacing devices or systems. The paper "**Data Acquisition And Monitoring Of EMG (Electromyogram) Signals**", presents a simple, low cost and effective circuit which is designed for the acquisition and processing of EMG signals to finally interface with a working unit. The EMG signals are acquired by a data acquisition system, those signals are further conditioned to drive and monitor the functioning of a movable unit. The signal conditioning unit comprises of instrumentation amplifier, low pass and high pass filter, rectifier, amplifier and comparator was developed for conditioning the acquired EMG signals. Finally at the end the design circuit was interfaced with a motor by using arduino microcontroller.

The paper "**Real Time Control of Robotic Arm Using Electromyogram (EMG) Signals**" , talks about how nowadays, the rate of disabled and the people who find difficulties in using their limbs due to age are increasing. A human-assisting robot is a better option for them to overcome this problem. An Electromygraphy (EMG) is a physiological signal that is produced due to the electrical activity when muscle contracts. These signals can be used as control signals for serving the robot. In this project, a robotic arm is controlled using the EMG signals acquired from the forearm of the user. The proposed interface can be used to control a pick and place robotic arm in real time. EMG signals are acquired from the forearm of the user with the help of surface electrodes attached to the user's skin, which avoids bulky interface sensors. Moreover, it is found as the proposed system is robust to muscle fatigue or adjustments of contraction level.

In "**Design and Control of Low- Cost Portable EMG Driven Exoskeleton Device for Human Wrist Rehabilitation**", they propose a method of initiating motion in disabled or physically weak human wrist using his/her diminutive muscular force. The present work introduces a process of sensing Electromyography signals for wrist motion. A lowcost device is presented which involves active bidirectional (hyperextension/flexion) movement of the wrist joint, controlled by specific EMG signals triggered by forearm muscles. The design undertakes all procedures and techniques for extraction of EMG signal, sensatory circuit, signal acquisition, amplification and filtering, ADC, and interfacing of simple model hand controlled by a controller (Arduino) via DC motor for bidirectional wrist movement. The instrument assists its user in moving and strengthening respective muscles. The concept is well-suited for rehabilitation robotics and prosthetic devices for handicap individuals.

The paper, " **Signal Analysis and Application for Arm Exoskeleton Control**", throws light on the concept of electromyography (EMG) signals and how they can be applied to real world applications through the employment of motion support exoskeleton. The scope of the present research is to design a low power, low cost EMG based exoskeleton system and its experimental implementation in an elbow joint, naturally controlled by the human. Preamplifier section is designed with operational amplifier OPA4227 through which raw EMG signal is extracted by passive electrodes. Amplified EMG signal is passed through filter section for restriction of frequency range. This restricted signal is rectified to acquire constant polarity for higher average output voltage. Acquisition and processing of EMG signal is done by ATMEGA 32U4 microcontroller. Data is transmitted to computer for visualization through Zigbee module. Surface EMG amplitude and the torque about elbow joint construct the system design.

In the article, " **2-d Robotic Arm Control using EMG Signal**", a robotic arm is controlled using the EMG signal acquired from the electrodes attached to the human arm. The EMG signals are acquired from three different muscle groups of the upper forearm. The EMG signal is very noisy and of the order of micro volts. Faithful extraction of the EMG signal is the prime objective in the presented work. The acquired signal is then fed to signal conditioning unit consisting of signal acquisition, amplification, rectification and final filtration. The output of the signal conditioning unit is then converted to digital signal using a 16-bit serial ADC. The digitized signal is used as feedback and control signal for final control of the robotic arm. The robotic arm is attached to the shaft of the stepper motor for motion. Stepper motor is interfaced using microcontroller. There may be more than one stepper motor to give multi-dimensional motion to robotic arm. It can be assumed that with one single stepper motor, ideally we can have 360/θ no. of positions (θ being the step angle). Presently we have used only two stepper motors for up-down motion at two joints thereby enabling to give (360/θ)2 no. of positions.

According to "**Design of an Arm Exoskeleton Controlled by the EMG Signal**", An exoskeleton is a supporting structure on the outside of a body. The name stems from the words exterior and skeleton. In the context of this project, it is an exterior support structure of the human arm amplifying the force delivered by the biceps brachii. The actuator of the exoskeleton taking the place of the biceps is a DC motor acting on the elbow joint of the exoskeleton. The design of this exoskeleton takes its controlling signal from electrical signals in the biceps muscle. This electrical signal, called the Electromyogram (EMG), is a measure of the electrical activity in the biceps. The amplitude of this EMG signal is directly related to the amount of force delivered by the biceps. From this amplitude we can make a close determination of the force delivered by the biceps and translate this force into the torque which can then be sent to the exoskeleton actuator – the DC motor. In this manner, the exoskeleton will assist in bearing a load on the human arm.

In the article "**Electromyographic control of a robotic arm for educational purposes**", they describe an experimental and educational tool based on the design and development of a robotic arm controlled by EMG surface signals, captured at the biceps brachii muscle and digitally processed. We present the hardware design for the biosignal pre-processing and describe the post-processing and the microcontroller for three servomotors. The design has been used in classroom to promote and integrate different BME curriculum knowledge.

CHAPTER 3

RELATED THEORY

An exoskeleton is the supporting structure on the outside of the body. The name stems from the words exterior and skeleton. In this project, it is an exterior support structure of the human arm amplifying the force delivered by the biceps and triceps. The design of this exoskeleton takes its controlling signals from electrical signals in the biceps and triceps muscle. The electrical signal is called Electromyogram (EMG). Electromyography is a technique for evaluating and recording the electrical activity produced by the skeletal muscles. EMG is performed using an instrument called the electromyograph, to produce a record called an electromyogram. An electromyography detects the electrical potential by muscle cells when these cells are electrically or neurologically activated.

Generation of EMG signal:

- In terms of how a muscle EMG signal is produced a muscle fibre can be thought of as the most basic contributing part.
- A muscle fibre is innervated by a nerve fibre to produce an action potential (AP).
- This single nerve fibre can innervate several muscle fibres, all part of a single motor unit.
- Therefore when the motor neuron is ‘fired’ all the muscle fibres under its control produce a signal referred to as the motor unit action potential (MUAP).
- If the motor neuron is fired repeatedly then several MUAPs will be produced, forming what id referred to as a motor unit action potential train (MUAPT).

When a muscle is relaxed, a more or less noise-free EMG Baseline can be seen. The raw EMG Baseline noise depends on many factors, especially the quality of MG amplifier, the environment noise and the quality of the given detection condition. Raw EMGs can range between +/- 5000 microvolt and typically the wave contents ranges between 6 and 500 Hz, showing most frequency power between -20 and 150Hz.

3.1. FACTORS INFLUENCING EMG SIGNAL.

On its way from the muscle membrane up to the electrodes, the EMG signal can be influenced by several factors altering its shape and characteristics. They can be grouped in:

1) Tissue characteristics.

   The human body is a good electrical conductor, but unfortunately the electrical conductivity varies with the tissue type, thickness, physiological changes and temperature. These conditions can greatly vary from subject to subject and prohibit a direct quantitative comparison of EMG amplitude parameters calculated on the unprocessed EMG signal.

2) Physiological cross talk.

   Neighbouring muscles may produce a significant amount of EMG that is detected by the local electrode site. Typically this ‘cross talk’ does not exceed 10%- 15% of the overall signal contents or isn’t available at all. However care us be taken for narrow arrangements within muscle groups. ECG spikes can interfere with the EMG recording especially when performed on the upper trunk/ shoulder muscle.

3) External noise.

   Special care must be taken in very noisy environments. The most demanding is the direct interference of power hum, directly produced by incorrect grounding of other external devices.

4) Electrodes and amplifiers.

   The selection/quality of electrodes and internal amplifier noise may add signal contents to the EMG Baseline. Internal amplifier noise should not exceed 5 Vrms.

3.2. EMG-AMPLIFIERS

They act as differential amplifiers and tier main function is the ability to reject or eliminate artifacts. The differential amplifier detects the potential difference between the electrodes and cancels the external interference out. Typically external noise signals reach both electrodes with no phase shift. These common mode signals are signals equal in phase and magnitude. Here, the CMRR should be as high as possible because the elimination of interfering signals plays a major role in quality. The main use of the small EMG pre-amplifiers are located near the detection site. They are the early pick up of the signal, amplifying it and transmitting it on a low Ohm level that is less sensitive to movement.

3.3 A/D RESOLUTION.

Before a signal can be displayed and analyzed in the computer, it has to be converted from an analog voltage to a digital signal.

3.4 A/D SAMPLING RATE.

In order to accurately translate the complete frequency spectrum of signal, the sampling rate which determines the voltage of the input signal must be at least twice as high as the maximum frequency expected of the signal.

CHAPTER 4

DESIGN OF WORK

4.1. BLOCK DIAGRAM

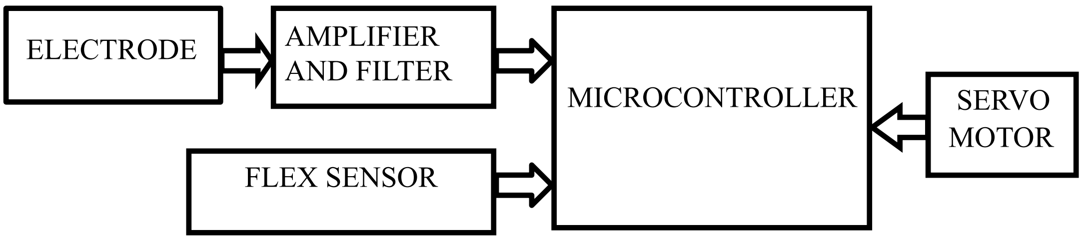

Fig 4.1: Block diagram representation.

4.2. BLOCK LEVEL EXPLANATION

4.2.1 ELECTRODES

System works by acquiring the EMG signal from the hand. It is done by using three electrodes. Two are placed on the biceps and two are placed on the triceps and the reference ground for the circuit is connected to the bony part which will be placed below the joint of the elbow. Electrodes used are Ag/AgCL disposable electrodes. Silver-silver chloride (Ag-AgCl) electrodes provide accurate and clear transmission of surface bio potentials. EL250 series reusable lead electrodes are suitable for most applications (ECG, EEG, EGG, EMG, EOG, and ERS recordings.

Fig 4.2: Electrode Placement Positions.

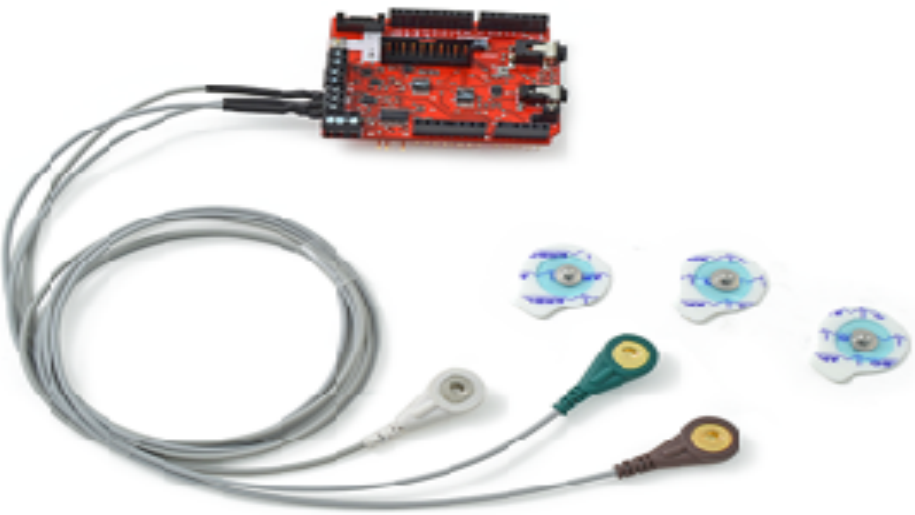

Fig 4.2: EMG Module.

4.2.2 AMPLIFIER AND FILTER

Consists of an instrumentation amplifier followed by second higher order high pass filter and low pass filter

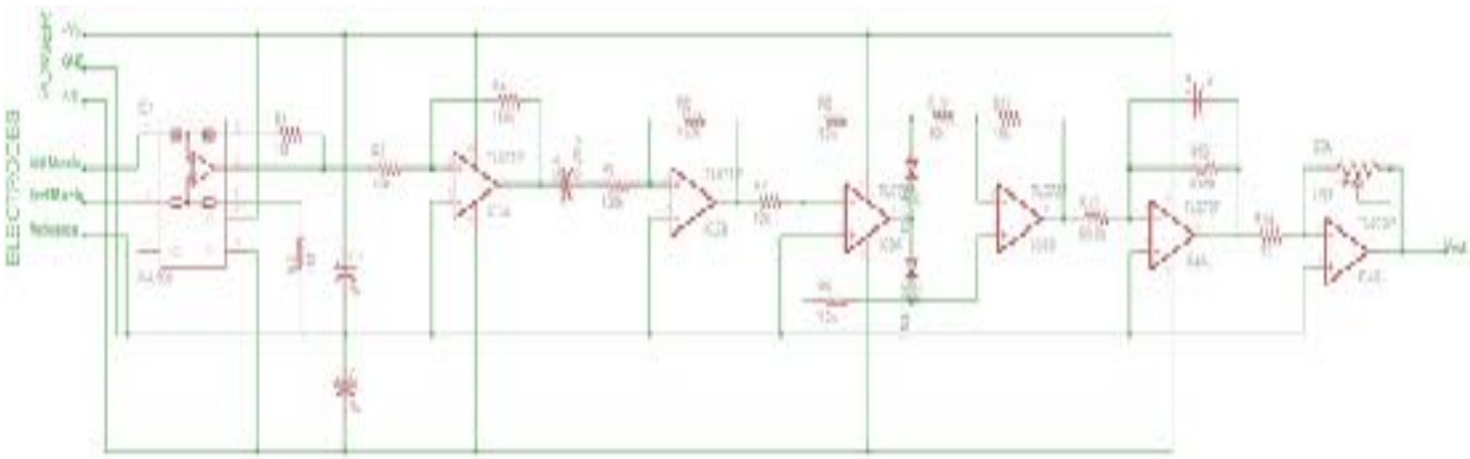

Fig 4.3: Amplifier and Filter.

4.2.2.1 INSTRUMENTATION AMPLIFIER

Instrumentation amplifier used is INA126. Signals acquired by electrodes are fed to instrumentation amplifier. It is used to subtract all common signals receiving from the electrodes. Thus the noise received by the electrodes get attenuated. It is necessary to amplify the collected signals from 0-30V. In this IC amplification of 100 is used.

FEATURES OF INA106:

The INA106 and INA2126 are precision instrumentation amplifiers for accurate, low noise differential-signal acquisition. Their two-op-amp design provides excellent performance with low quiescent current (175 µA/channel). Combined with a wide operating voltage range of ±1.35 V to ±18 V, makes the INAx126 ideal for portable instrumentation and data acquisition systems.

4.2.2.2 HIGH PASS FILTER

Butterworth second order high pass filter is used. This filter is best suited for applications requiring preservation of amplitude linearly in the pass band region. Almost all EMG signals are located between 10 and 250Hz and these signals are amplified to 10 to 500Hz range by using high pass filters. And it is necessary to remove all the frequencies less than 10Hz.

4.2.2.3 LOW PASS FILTER

Low pass filters are used to filter out frequencies above 500Hz. Butterworth low pass filters are used.

TL072 is used in the design of high pass and low pass circuits.

- Low Power Consumption
- Wide Common-Mode and Differential Voltage Ranges

- Low Input Bias and Offset Currents
- Output Short-Circuit Protection
- Low Total Harmonic Distortion: 0.003% Typical
- Low Noise
- Internal Frequency Compensation
- Latch-Up-Free Operation
- High Slew Rate: 13 V/µs Typical

After the signal is filtered using high pass and low pass filters, it is amplified again using amplifier INA126. This is to make sure that a strong clean signal is provided.

4.2.3 FLEX SENSOR

It's a variable resistor. The resistance of the flex sensor increases as the body of the component bends.

Fig 4.5: Flex Sensor.

4.2.4 MICROCONTROLLER ATMEGA32

Microcontroller is a programmable device. A microcontroller has a CPU in addition to a fixed amount of RAM, ROM, I/O ports and a timer embedded all on a single chip. It is used to control the various functions of the system. Here the microcontroller is used to process the EMG signal, control the flex sensor, conversion from analog to digital signal and to control the servo motor. Atmega32 has got 40 pins. Two for power, two for oscillator, one for reset, three for providing necessary power and reference voltage to its internal ADC and 32 (4*8) I/O pins. It has two 8 bit timers (timer 0 and timer 1) and one 16 bit (timer 1). It has one 16 bit successive approximation type ADC in which total 8 single channels are selectable.

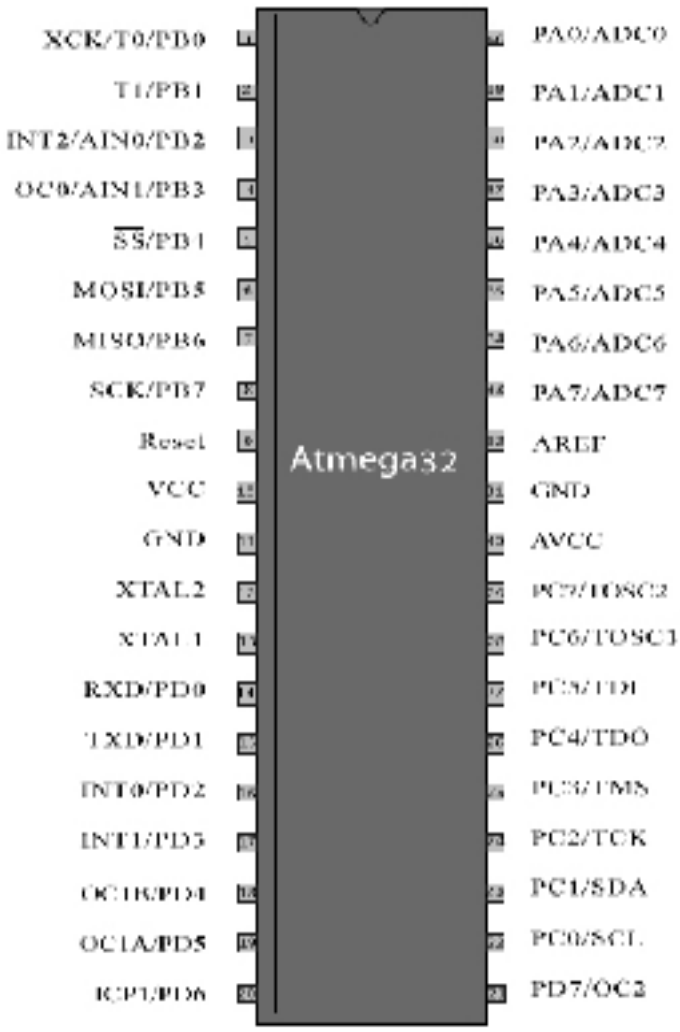

Fig 4.5: Microcontroller ATMEGA32.

4.2.5. SERVO MOTOR

A servo motor is an electrical device which can push or rotate an object with great precision. If you want to rotate and object at some specific angles or distance, then you use servo motor. It is just made up of simple motor which run through servo mechanism. If motor is used is DC powered then it is called DC servo motor, and if it is AC powered motor then it is called AC servo motor. We can get a very high torque servo motor in a small and light weight packages.

Servo motor is controlled by PWM (Pulse with Modulation) which is provided by the control wires. There is a minimum pulse, a maximum pulse and a repetition rate. Servo motor can turn 90 degree from either direction form its neutral position. The servo motor expects to see a pulse every 20 milliseconds (ms) and the length of the pulse will determine how far the motor turns. For example, a 1.5ms pulse will make the motor turn to the 90° position, such as if pulse is shorter than 1.5ms shaft moves to 0° and if it is longer than 1.5ms than it will turn the servo to 180°.

Servo motor works on PWM (Pulse width modulation) principle, means its angle of rotation is controlled by the duration of applied pulse to its Control PIN. Basically servo motor is made up of DC motor which is controlled by a variable resistor (potentiometer) and some gears. High speed force of DC motor is converted into torque by Gears. We know that WORK= FORCE X DISTANCE, in DC motor Force is less and distance (speed) is high and in Servo, force is High and distance is less. Potentiometer is connected to the output shaft of the Servo, to calculate the angle and stop the DC motor on required angle.

Servo motor can be rotated from 0 to 180 degree, but it can go up to 210 degree, depending on the manufacturing. This degree of rotation can be controlled by applying the Electrical Pulse of proper width, to its Control pin. Servo checks the pulse in every 20 milliseconds. Pulse of 1 ms (1 millisecond) width can rotate servo to 0 degree, 1.5ms can rotate to 90 degree (neutral position) and 2 ms pulse can rotate it to 180 degree.

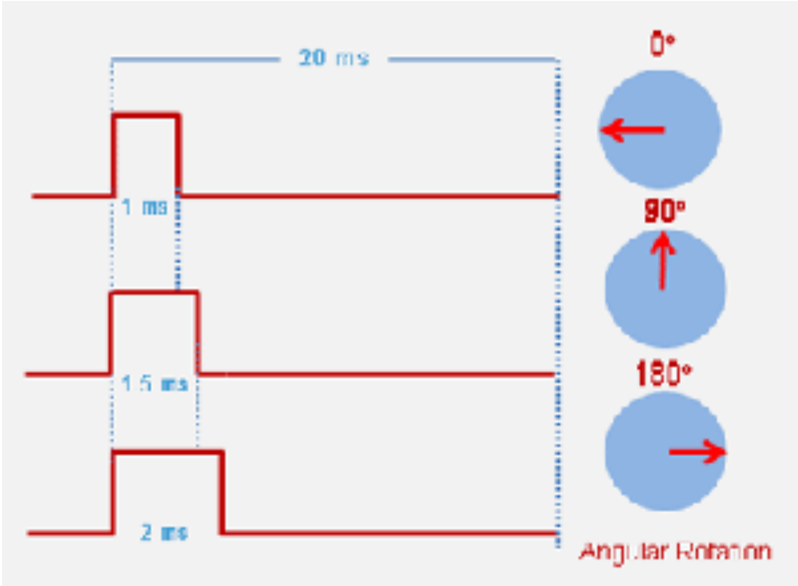

Fig 4.6: Servo motor working.

4.3. CIRCUIT DIAGRAM

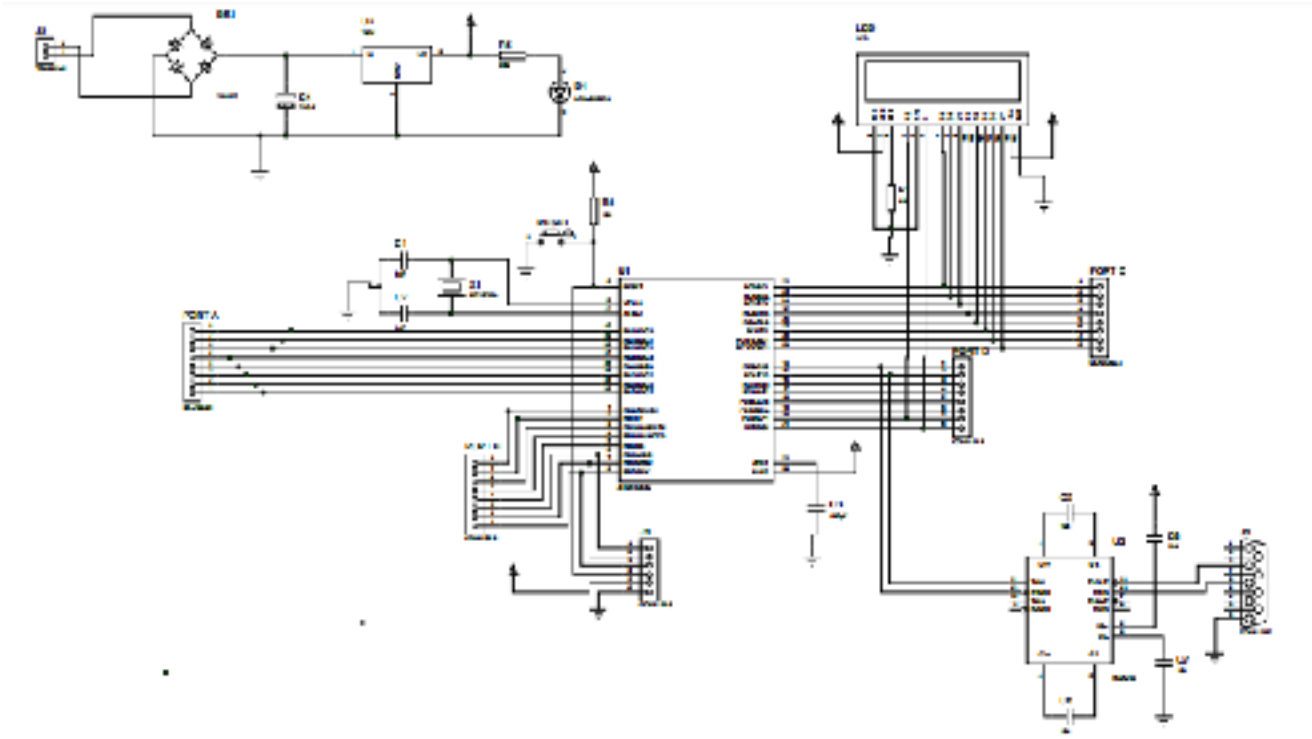

Fig 4.5: Circuit Diagram.

CHAPTER 5

PCB FABRICATION

The materials required for PCB fabrication are copper clad sheet, little paint drilling machine and ferric chloride solution.

The PCB fabrication involves the following steps:

5.1. PREPARATION OF THE PCB LAYOUT

The layout is commonly prepared in the scale of *2:1*. It offers a reasonable compromised below accuracy gain and handling convenience as *2:1* part of art work has the actual PCB area. Grid systems are commonly used for preparation of the layout. The use of the grid sheet gives more convenience in placement of components and conductors. The grid system based on 0.1 is found to be too coursing, a grid equidistant of *0.1mm* is recommended.

Procedure:

• Each and every PCB is viewed from component side.

• The designing of the layout is started with an absolutely clear component list and circuit diagram.

• The large components are placed first and the space in between is filled with smaller area.

• In the designing of PCB layout, it is very important to divide circuit into sub units. Each of these sub units are realized in the defined portion of the board.

• The components are placed in the print sheet tanning and standard length and width.

• The punched component layout is circled to taking the standard size of the land pads.

5.2. PATTERN TRANSFER

After the film is processed the film master are obtained. The transfer of the conductor which is on the film master on to the copper clad base material is done by two methods mainly photo printing and screen printing. Photo printing is extremely accurate which is also applied to the fabrication of semiconductors. Screen printing is comparatively cheap and simple method for pattern transfer although less precise than photo printing. But this is less costly, so this method is commonly used.

5.3. SCREEN PRINTING

In screen printing, the processing is very simple. A screen fabric with uniform meshe sand opening stretched and fixed on a solid frame of metal or wood. The circuit pattern is photographically transferred on to queue through the opening master onto the surface of the material to be printed. The light sensitive material is coated on to the screen and using film master the pattern is transferred to the screen. Then using ink the pattern is transferred to the copper cladsheet. Two methods are used for screened printing pattern into screen.

1. Direct method
2. Indirect method

In direct method the photographically sensitive film is transferred to screen. The film is exposed and then pasted to the screen. The pattern is then transferred to screen using the links and squeegee.

5.4. ETCHING

The removal of unwanted copper from copper clad sheet is known as etching.

For these 4 types of tanks are used.

1. Ferric Chloride
2. Cupric Chloride
3. Chromic acid
4 .Alkaline ammonia

Among these Ferric Chloride is cheap and also suited for home and industrial applications. The high corrosive power of FeCl leads to short etching time and little under etching. Ferric chloride matches well photo and screen printed resists.

5.5. DRILLING

Drilling of components, mounting holes into the PCBs is by the most important mechanical machining operation in PCB production process. The importance of the hole drilling on PCB has further group with electronic component miniaturization and its need for smaller hole diameters and higher packing density where hole punching is practically routed out.

Four types of drilling are commonly used.

1. Drilling by direct sight
2. Drilling by optical sight
3. Jig drilling
4. NC drilling

5.6. COMPONENT MOUNTING

Component is basically mounted on one side of the board. On polarized two lead components are mounted to give the marking or the orientation throughout the board. The component orientation can be both horizontal as well as vertical but uniformly, direction is placed. The uniformity in orientation of polarized component is determined during design of PCB.

5.7. PCB DIAGRAMS

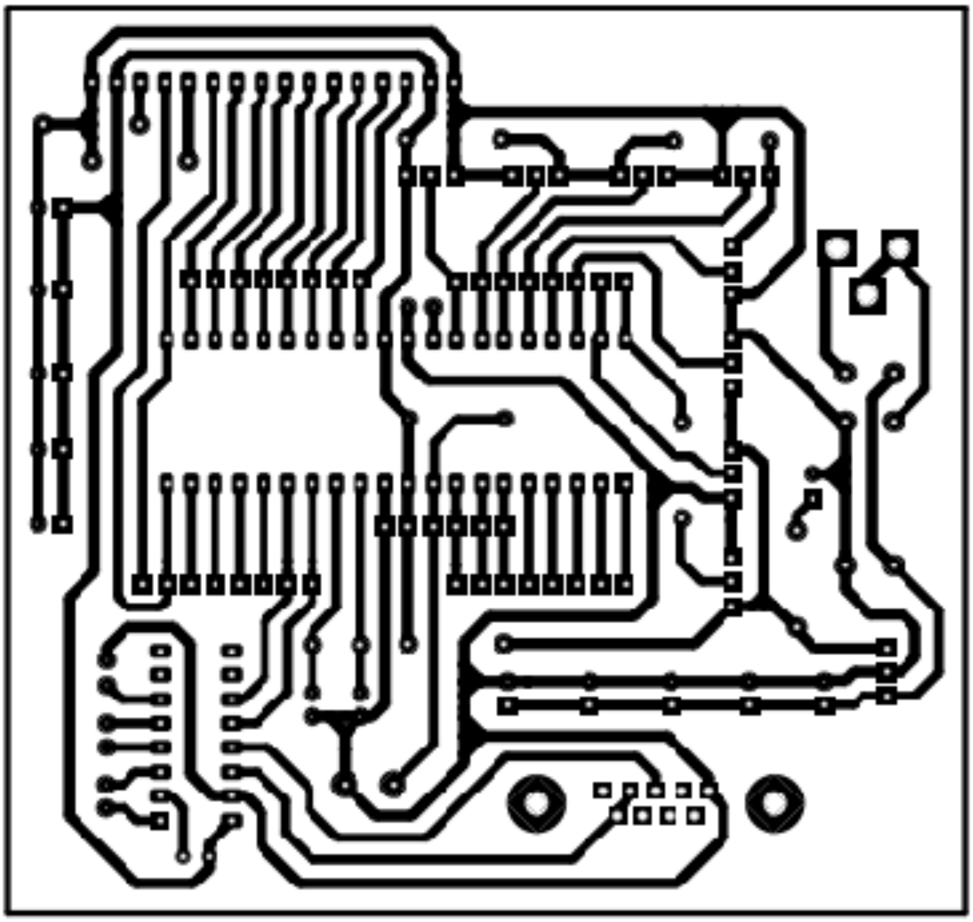

Fig 5.1: PCB Layout Bottom.

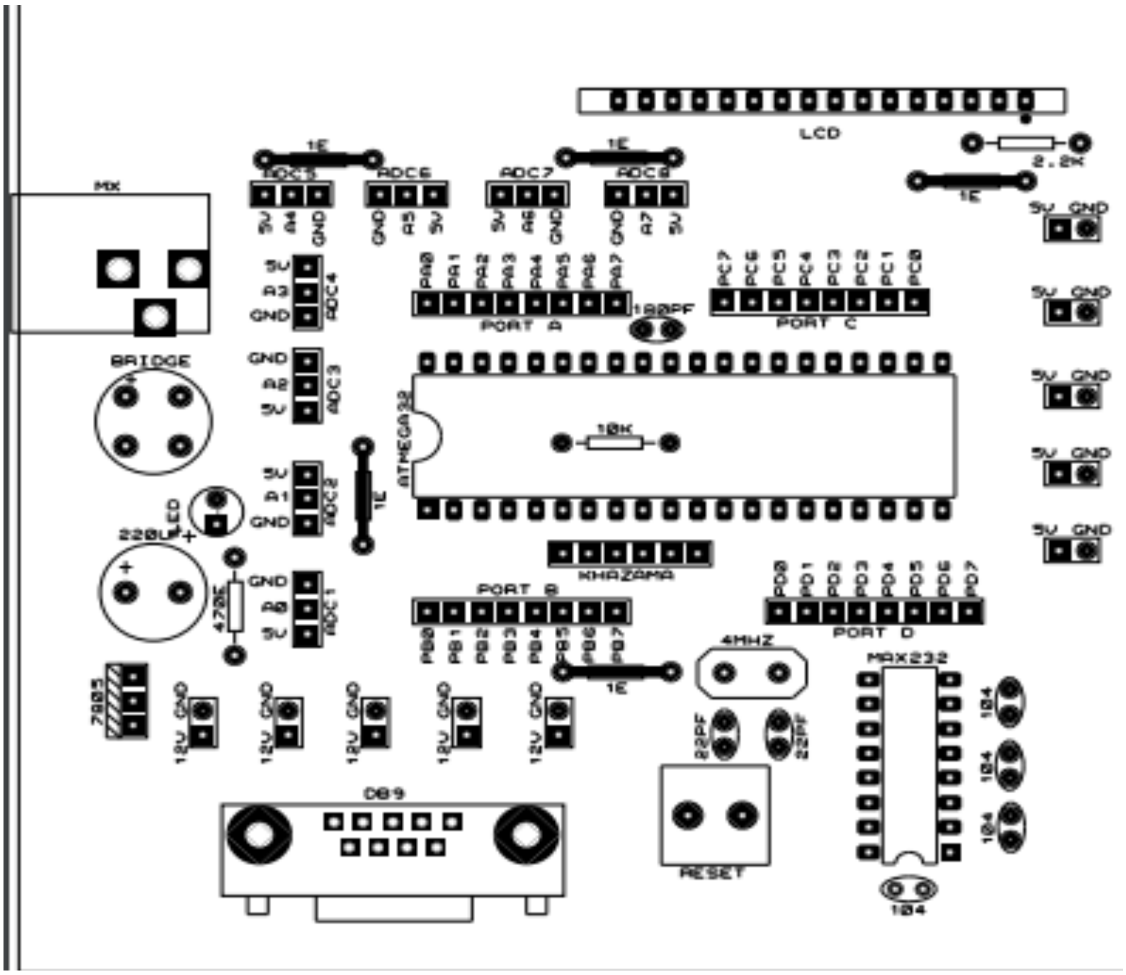

Fig 5.2: PCB Layout Top.

CHAPTER 6

SOFTWARE DETAILS

6.1. PROTEUS

Proteus is a Virtual System Modelling and circuit simulation application. The suite combines mixed mode SPICE circuit simulation, animated components and microprocessor models to facilitate co-simulation of complete microcontroller based designs. Proteus also has the ability to simulate the interaction between software running on a microcontroller and any analog or digital electronics connected to it. It simulates Input / Output ports, interrupts, timers, USARTs and all other peripherals present on each supported processor.

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The Proteus Design Suite is an Electronic Design Automation (EDA) tool including schematic capture, simulation and PCB Layout modules. It is developed in Yorkshire, England by Labcenter Electronics Ltd with offices in North America and several overseas sales channels. The software runs on the Windows operating system and is available in English, French, Spanish and Chinese languages.

6.2 MikroC

MikroC, a full-featured C compiler available for seven different microcontroller architectures. It has over 600 function libraries. It uses powerful IDE with user-friendly interface and additional software tools. It is a part of a toolchain of compatible MikroElektronika development boards. It is the centre of the MikroElektronika toolchain, allowing you to code, compile, program, run, and debug, all within the same environment by just connecting the right development board. mikroLab contains everything a developer needs to explore the possibilities of any of the microcontroller architectures we offer: a development board (with integrated programmer and debugger), the compiler license, an assortment of accessories, and as a bonus, a free license for one of our GUI design tools (either Visual TFT or Visual GLCD).

CHAPTER 7

FUTURE SCOPE AND CONCLUSION

In this project, user's intention of motion is estimated from the EMG signals taken from the disabled person's limb. These signals are then manipulated and used to control the arm exoskeleton. This exoskeleton coupled with the use of an FPGA serves as the system's main processor that makes the controller of robotic arm easier to move, handle, understand and maintain. The product of this project can become a basis for future exoskeleton controller designs, where it can make significant impact in industry and research. This project if implemented on a large scale can be considered valuable in automated factory processes, construction, toxic waste handling, honey-bee culturing, deep sea exploration etc.

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APPENDIX:

ADC INTERFACING PROGRAM:

```
unsignedintadc;

void main()

{

 ADCON1 = 0x80;

 TRISA = 0xFF;                                  // PORTA is input

 TRISC = 0x3F;                            // Pins RC7, RC6 are outputs

 TRISB = 0x00;                                 // PORTB is output

do

 {

adc = ADC_Read(1);                  // Get 10-bit results of AD conversion

                                                          //of channel 1

 PORTB = adc;                             // Send lower 8 bits to PORTB

 PORTC = adc>> 2;              // Send 2 most significant bits to RC7, RC6

 }

while(1);

}
```

SERVO MOTOR INTERFACING PROGRAM

```
    void servoRotate0() //0 Degree

    {
```

```
unsignedinti;
for(i=0;i<50;i++)
  {
    PORTB.F0 = 1;
Delay_us(800);
    PORTB.F0 = 0;
Delay_us(19200);
  }
}

void servoRotate90() //90 Degree
{
unsignedinti;
for(i=0;i<50;i++)
  {
    PORTB.F0 = 1;
Delay_us(1500);
    PORTB.F0 = 0;
Delay_us(18500);
  }
}
```

```
void servoRotate180() //180 Degree
{
unsignedinti;
for(i=0;i<50;i++)
  {
    PORTB.F0 = 1;
Delay_us(2200);
    PORTB.F0 = 0;
Delay_us(17800);
  }
}

void main()
{
  TRISB = 0; // PORTB as Ouput Port
do
  {
servoRotate0(); //0 Degree
Delay_ms(2000);
servoRotate90(); //90 Degree
Delay_ms(2000);
servoRotate180(); //180 Degree
```

```
}while(1);

}
```

LCD PROGRAM

```
#include <avr/io.h>

#define F_CPU 4000000UL

#include <util/delay.h>

#define LCD_DATA PORTC

#define LCD_RS 6

#define LCD_EN 7

char con[5];

void delay(char x)

{

  int j,i;

  for(i=0;i<x;i++)

  for(j=0;j<1000;j++);

}

void lcd_init()

{

  DDRD=0XFF;

  DDRC=0XFF;

  //-------passing commands to lcd------
```

```
  lcd_command(0X38);
  lcd_command(0X80);//puts the cursor beginning of first line
  lcd_command(0X0C);
  lcd_command(0X06);
  lcd_command(0X01);
  //delay(2);
  _delay_ms(100);
}
//-----------function lcd command---------
void lcd_command(char c)
{
  LCD_DATA=c;
   PORTD&=~(1<<LCD_RS);
  PORTD|=(1<<LCD_EN);
  _delay_ms(1);
   PORTD&=~(1<<LCD_EN);
}
//-----------function lcd data---------
void lcd_data(char d)
{
  LCD_DATA=d;
   PORTD|=(1<<LCD_RS);
```

```
  PORTD|=(1<<LCD_EN);

  _delay_ms(1);

   PORTD&=~(1<<LCD_EN);

}


//-----------function lcd puts---------

void lcd_puts(const char *s)

{

  while(*s)

  {

		lcd_data(*s++);

		//delay(2);

  }

}

void hexascii(int u)

{

  con[4]='\0';

  con[3]=(u%10)+0X30;

  u=u/10;

  con[2]=(u%10)+0X30;

  u=u/10;

  //con[2]='.';
```

```
  con[1]=(u%10)+0X30;
  con[0]=(u/10)+0X30;
}
```

PORT INITIALIZING

```
void port_init()
{
  _delay_ms(100);
  DDRA=0x00;
  DDRB=0xF0;
  DDRC=0xFF;
  DDRD=0xE0;
  PORTD|=(1<<PD2);
  PORTD|=(1<<PD3);
}
```