Remote Controlled Operated Prosthetic Arm

A Thesis

Submitted in partial fulfilment of the
Requirements for the Award of Degree

of

Master of Engineering
in

Electronic Instrumentation and control Engineering

By

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DECLARATION

I hereby certify that the work which is being presented in the thesis entitled, **"Remote controlled operated prosthetic arm"**, in partial fulfillment of the requirements for the award of degree of Master of Engineering in Electronics Instrumentation and Control Engineering submitted in Department of Electronics Instrumentation and Control Engineering, Thapar University, Patiala, is an authentic record of my own work carried out under the supervision of Dr. Amod Kumar Scientist 'G', H.O.D of Biomedical Instrumentation Unit, CSIO, Chandigarh and **Dr. Ravinder Agarwal** EIED, Thapar University, Patiala.and refers other researcher's works which are duly listed in the reference section.

The matter presented in this thesis has not been submitted for the award of any other degree of this or any other university.

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This is to certify that the above statement made by the candidate is correct and true to the best of my knowledge.

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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. First, with deep sense of gratitude and hearty thanks to my project guide **Dr. Ravinder Agarwal,** EIED, Thapar University, Patiala, for their invaluable guidance to undertake the project work and being supportive at each and every step, and giving me an opportunity to understand the concept.

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ABSTRACT

Prosthesis is an artificial extension that replaces a missing body part. Prostheses are typically used to replace parts lost by injury or missing from birth or to supplement defective body parts. In addition to the standard artificial limb for every-day use, many amputees have special limbs and devices to aid in the participation of sports and recreational activities.

Prosthetic arm is a boon for those persons who have lost their arm (below elbow) due to some mishap. One of the main requirements of artificial arm is that functionally, it should be as near to the natural hand as possible. Various designs of artificial arm are available in the market, categorised as mechanical, electrical and Myo-electric arm. Mechanical devices are functional prostheses that use some motion of the body to provide the force necessary to control the prosthetic component. Electrical arms operate the hand by a motor driven by micro switches and relays. Myo-Electric arm is stimulated by muscle signal available from the stump of amputee.

It has been observed that as the time of amputation increased, the signal strength from amputee stump decreases and muscles lost their activity and acquire a permanent fatigue state. Amputation period of more than about 10 years causes the permanent loss of the muscular action and no EMG output is available from such patients, EMG operated arm is useless for them. So a new prosthetic arm has been proposed, which operates wirelessly by the remote control system consists of four switches for four different operations besides opening & closing of hand with two different levels of grip forces.

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INTRODUCTION

1.1 PROSTHETIC ARM

Prosthetic arm was first implemented by Reinhold Reiter, a physics student at Munich University in May 1945. The report of Reiter's work, in German medical newspaper, described a myoelectric prosthetic arm designed for the amputee factory worker. A prototype was demonstrated at the Honnover export fair in 1945. The research leading to this device was supported by the Bavarian Red Cross and private source. Pudlusky was Reiter's business manager for the project. Development of the system was terminated due to the lack of funds after the German currency reform in 1948 [1].

The idea behind the control system was to amplify the myoelectric signal from a contracting muscle in order to control a wooden hand, which was modified to be actuated by an electric solenoid. Reiter used single muscle site in the residual limb. Control of opening and closing motion was derived from using 'two different rhythms of contraction'. This scheme of using the signal from a single muscle to control two motions was later to be known as 'three state control'. Reiter's work was not alone in being overlooked in the early development of myoelectric control. The myoelectric signal has been used to monitor lookout alertness as early as 1947 and by 1957 to control respirators for polio victims. Indeed, it has been investigated as a possible control source for prosthesis as early as 1949, with encouraging results.

In the late 1950s and early 1960s, research again started in myoelectric control system. This work occurred independently and almost simultaneously in the USSR, the United Kingdom, the USA, Europe and Canada. It was aided greatly by the availability of transistors, without which a truly portable myoelectric prosthesis was not practical.

1.2 ARTIFICIAL ARM

Artificial arm is a boon for those persons who have lost their hand due to some mishap. One of the main requirements of artificial arm is that it should be as near as possible to the natural arm. There are various designs of artificial arm. These designs fall under the categories of mechanical, electrical and myoelectric arm. Mechanical devices are functional prostheses that use some motion of the body to provide the force necessary to control the prosthetic component. Electrical arms operate the hand by a motor driven by micro-switches and relays. Myoelectric arm is stimulated by muscle signal available from the stump of amputee.

Powered hand prostheses are used to replace the function of a lost natural hand. Most of the commercial prosthetic hands in clinical use are controlled by myoelectric signal and are referred to as myoelectric hands. One of the important organs of the body is the hand. We perform 90% of our daily work by hand like eating, lifting, gripping an object, writing, typing, driving etc. Many persons, especially industrial workers carrying out different type of machining tasks in the factory, lose their arm due to accidents. Their lost arm is to be replaced by an artificial arm which fulfils all the criteria of a normal arm so that the amputee may lead the life of a normal person and feels rehabilitated. Efforts to develop mechanical artificial arms have been initiated since long and prosthesis of many such arms has been implemented successfully on many amputees. In the last decade, many electronic arms have been introduced in the market. With the advent of new signal processing techniques, advanced features like operation with muscle signal and proportional grip force have been added to the capabilities of these arms offering the user a wide choice to select a model according to user requirements.

Prosthesis is a field of biomechatronics, the science of fusing mechanical devices with human muscle, skeleton and nervous systems to assist or enhance motor control lost by trauma, disease, or defect. Prostheses are typically used to replace parts lost by injury (traumatic) or missing from birth (congenital) or to supplement defective body parts. In addition to the standard artificial limb for every-day use, many amputees have special limbs and devices to aid in the participation in sports and recreational activities.

1.3 TYPE OF ARTIFICIAL ARMS

Various types of artificial arms have been reported in the literature. They may be categorized as:

- Mechanical Arm
- Electrical Arm
- Hybrid Arm
- Myo-Electric Arm

1.3.1 MECHANICAL ARM

These devices are functional prostheses that use some motion of the body to exert the force needed to control the prosthetic component. Particularly noteworthy is the Bowden cable for use in the prosthetics field. A Bowden cable consists of an inner core cable that is free to move within a sleeve cable which is fixed in place at either end. These devices require a harness, to be worn about the shoulders, to which one or more Bowden cables are attached. The conventional below-elbow, body-powered prosthesis has a single control cable that runs from the harness to a terminal device. Terminal-device opening and closing is then controlled by shoulder shrug and/or flexion of the residual upper arm. An above-elbow amputee has additional control cable, which is used to switch control of the harness from terminal device opening to elbow flexion by unlocking the elbow. Body-powered prostheses are the most common kind of prosthesis used all over the world, due to the intimate connection of the control cable, which is provided between input and output. It helps the user of a body-powered limb to feel closely connected to the operation of the prosthesis. These prostheses are also lightweight, durable and of relatively low cost. However, body-powered prostheses have a number of shortcomings. The major issues are the uncomfortable harness mechanism, the somewhat ungainly control motions, particularly in the case of above-elbow prostheses, restricted range of motion and limited load-lifting capacity.

1.3.2 ELECTRICAL ARM

These are externally powered devices and receive their power from an external electric source to the body. These are relatively new (last 15 to 20 years) addition to the armamentarium of prosthetic devices.

a) **Touch Switches:** A pair of touch switches remains in contact with antagonistic wrist muscles flexors and extensors. The wrist flexors activate the 'CLOSE' switch while extensors operate the 'OPEN' touch switch.

b) **Control Circuit:** Each microswitch is connected to a Flip-flop which is configured to operate in set-reset mode. It is 'SET' by the micro switch and 'RESET' by the limit switches provided at the extremities of hand positions.

c) Control Relay: A semiconductor relay working at 6V/9V operates the motor. When the flip-flop has one polarity, DC voltage is applied by the relay to the motor such that motor rotates in one direction. When flip-flop output changes its polarity due to operation of second touch switch, the relay also changes the polarity of DC voltage being applied to the motor. Consequently, motor rotates in opposite direction. Thus, the hand closes and opens.

1.3.3 HYBRID ARM

When body-powered and externally powered systems are linked together they are called hybrid systems. Hybrid systems are used most frequently with persons who have amputations above the elbow or who have bilateral arm amputations. Such systems can provide the user with high gripping and/or high lifting capacities of powered systems and fine control of body power. Providing the amputee with a body-powered limb on one side and an electric-powered limb on the other side, they enable the wearer to use the limb that is most appropriate for a specific task. This method also enables the limbs to be operated independently of each other i.e. the body motions required to operate the body-powered side do not influence the state of the powered side of limb and vice versa, as they are decoupled.

1.3.4 MYO-ELECTRIC ARM

The electrically powered prosthesis under the control of myoelectric signals from residual muscles did not become commercially available until late 1960s and did not gain widespread clinical acceptance until the early 1980s. Myoelectrically controlled upper limb prosthesis offers the highest level of rehabilitation available today. Myoelectric control derives its name from the electromyogram (EMG) signal, which is produced by a muscle when it contracts.

1) Raw EMG signal acquired by the needle electrodes is of the order of 0.5 mV.

2) The surface electrodes signals lies in the range of tens of microvolts. Three surface electrodes are generally used in this type of arm, one acting as reference electrode, another as active electrode and the third as ground electrode. The difference signal between reference and active electrode is processed to reduce noise in the system.

3) A normally innervated muscle shows no electrical activity at rest. These signals provide important information on the physiological status of the skeletal muscle and its nerve supply. The intensity of EMG signal increases as the muscle tension increases.

4) The frequency range of EMG signal which shows change with opening and closing of hand is 15 to 500 Hz.

5) There are two sets of muscles in forearm which get activated whenever an object is grasped or left by our fingers. These 180° apart muscle groups are called flexors and extensors. In myoelectric prosthesis, it is achieved by making the use of these two muscles to open or close the terminal device. The electrodes accommodated in the prosthetic socket pick up the signals from these muscles which after conditioning are used to control the prosthesis. This type of system results in high grip force and grip speed**.**

Prosthetic arm is one of the main requirements for those persons who have lost their arm due to some mishap. The main requirement of prosthetic arm is to provide the functionality of the natural hand. In the current thesis work prosthetic arm movements are controlled by using remote signals. It contains all the necessary features.

2

LITERATURE REVIEW

STATUS OF PROSTHETIC ARM RESEARCH WORK

Microprocessor is used to control the motion of a prosthetic arm by external power. The developed controller incorporates several new features, including force loops closed in software (these loops had previously been closed by analog electronics to achieve sufficient bandwidth), auto-adjustment of control parameters, increased communication speed to the user interface running on a PC, lower power consumption, smaller package size and finally, more sophisticated control algorithms [2].

Loss of a natural hand means that the neural connections between the brain and the palm, fingers and thumb are also lost, including any feedback paths e.g. sensing temperature. In this research, the author is having an artificial hand with sensors allowing for the inclusion of automatic control loops, freeing the user from the cognitive burden of object holding which is similar to the natural low level spinal loops that automatically compensate for object movement. Force, object slip and finger positions are variables that need to be measured in a hand designed for the physically impaired person. A high specification is required for any sensor design [3].

An electrically driven locking mechanism has been built, which is controlled by the electromyogram (EMG) of the surviving muscles in the upper arm. Hybrid technology is used for the construction of the associated electronic circuitry. Many similar applications are now being considered in an attempt to improve the performance of upper-limb prostheses [4].

Development, testing and experimentation work of a device for the hand rehabilitation was done by Mulas *et al*. The system designed is intended for people who have partially lost the ability to control correctly the hand musculature, for example after a stroke or a spinal cord injury. Based on EMG signals the system can "understand" the subject volition to move the hand and actuators can help the fingers movement in order to perform the task. This paper describes the device and discusses the first results conducted on a healthy volunteer [5].

An “ideal” upper limb prosthesis should be perceived as part of the natural body by the amputee and should replicate sensory-motor capabilities of the amputated limb. However, such an ideal “cybernetic” prosthesis is still far from reality: current prosthetic hands are simple grippers with one or two degrees of freedom (DOF), which barely restore the capability of the thumb index pinch. This paper describes the development of a novel prosthetic hand based on a “biomechatronics” design. The proposed hand is designed to augment the dexterity of traditional prosthetic hands while maintaining approximately the same dimension and weight. Our approach is aimed at providing enhanced grasping capabilities and “natural” sensory-motor coordination to the amputee, by integrating miniature mechanisms, sensors, actuators, and embedded control. A biomechatronics hand prototype with three fingers and a total of six independent DOFs has been designed and fabricated. The paper is focused on the actuators system, which is based on miniature electromagnetic motors [6].

Embedded control architecture for the action and perception of an anthropomorphic 16 degree of freedom, 4 degree of actuation prosthetic hand for use by transradial amputees has also been reported. The prosthetic hand is provided with 40 structurally integrated sensors useful both for automatic grasp control and for biofeedback delivery to the user through an appropriate interface (either neural or non-invasive). The paper briefly describes the mechatronic design of the prosthesis, the set of sensors embedded in the hand and finally focuses on the design of the control architecture that allows action and perception for such a sophisticated device [7].

The objective of this research work was to design and construct a prosthesis that will be strong and reliable, while still offering control on the force exerted. The design had to account for mechanical and electrical design reliability and size. These goals were targeted by using EMG in the electrical control system and a linear motion approach in the mechanical system. The prosthetic gripper uses EMG to detect the amputee's intended movement. Two control systems were implemented for the gripper: (i) electrical control to convert the amputee impulses into the gripper actions. (ii) mechanical control to regulate the force exerted by the prosthetic fingers. The control system requires an adaptation mechanism for each amputee's characteristics [8].

In this research the author used proportional myoelectric control of a one-dimensional virtual object to investigate differences in efferent control between the proximal and distal muscles of the upper limbs. Restricted movement was allowed while recording EMG signals from elbow or wrist flexors/extensors during isometric contractions. Subjects used this proportional EMG control to move the virtual object through two tracking tasks, one with a static target and one with a moving target (i.e., a sine wave) [9].

Researchers have also studied the neural network feasibility for categorizing patterns of EMG signals. The signals recorded by the surface electrodes are sufficient to control the movements of a virtual prosthesis. The presented method offers great potential for the development of future hand prostheses [10].

A signal processing system based on RAM as a look-up table (LUT) has been presented in this paper. This provides a fast response besides being compact in size. Several algorithms for programming it have been proposed. Experiments have been undertaken for prosthetic hand control [11].

Myoelectric prosthetic hand enables the user to enact a simple grasp with strength proportional to the contraction of certain muscle group. This paper describes the development of a system that will allow complex grasp shapes to be identified based on natural muscle movement. The application of this system can be extended to a general device controller where input is obtained from forearm muscle, measured using surface electrodes. This system provides the advantage of being less fatiguing than traditional input devices [12].

Evolvable Hardware (EHW) has been proposed as a new method for designing systems for real-world applications. In this paper, it is applied for evolving a prosthetic hand controller. It is shown that better generalization performance than neural networks can be obtained. The proposed architecture is based on digital logic gates and its configuration is determined by two separate steps of evolution [13].

Applying a mouse’s roller with a gripper to increase the efficiency of a gripper can lead to material handling without slipping. To apply a gripper, the optimization principle is used to develop material handling by use of a signal for checking a roller mouse that rotates. In case the roller rotates, it means that the material slips. A gripper will slide to material handling until the roller does not rotate [14].

In an attempt to improve the functionality of a prosthetic hand device, a new fingertip has been developed that incorporates sensors to measure temperature and grip force and to detect the onset of object slip from the hand. The sensors have been implemented using thick-film printing technology and exploit the piezoresistive characteristics of commercially available screen printing resistor pastes and the piezoelectric properties of proprietary lead-zirconate-titanate (PZT) formulated pastes. The force sensor exhibits a highly linear response to forces. The force sensor response is also extremely stable with temperature. The ability of the piezoelectric PZT vibration sensor to detect small vibrations of the cantilever, indicative of object slip, has also been demonstrated [15].

This paper describes the design features of artificial limbs that are lightweight, compact and dexterous, that mimics human anatomy and maintain a high lifting capability. The key to satisfying these objectives is the use of Shape Memory Alloy (SMA) artificial muscles as actuators [16].

An electrically-operated hand, controlled by myopotentials, has been fitted with strain gauges in the index finger which measure the gripping force between thumb and index finger. These strain gauges cause an electrical stimulus to be applied to the skin directly above the median nerve. This stimulus consists of a series of pulses with the pulse repetition rate increasing as the pinch force increases. Patients fitted with prostheses incorporating this feedback report an improved level of confidence when using the prosthesis. [17].

Jacobsen et al have developed a robotic end effectors intended to function as a general purpose research tool for the study of machine dexterity. The high performance, multi-fingered hand provides two important capabilities. It permits the experimental investigation of basic concepts in manipulation theory, control system design and tactile sensing. Also, it serves as a "test bed" for the development of tactile sensing systems [18].

Externally powered upper extremity prosthesis has been considered as a system in which the necessary components to design a better prosthetic arm are viewed and divided into four subsystems: input, effecter, feedback and support. Current research is reviewed in terms of these subsystems. Each subsystem performs its own task, but they are related to each other and together they function to make up a prosthetic upper extremity, which provides the movement to the amputee [19].

To carry out day-to-day activities, human hand plays a very important role. Objects of different weight require different grip of hand for grasping. For example, thermocol glass requires a very little force to grip it, whereas heavy objects demand correspondingly higher force so that they do not slip down. Grip force control ensures superior performance, greater productivity and cost saving through less stress and fatigue. This paper presents a new and cost effective technique to control the normal grip force of artificial human hand. EMG signal from the residual stump muscle is recorded and analyzed based on its strength. The torque of a DC motor is controlled proportionally to control the grip force exerted by the artificial hand. This is called controlled torque topology [20].

3

PROBLEM STATEMENT

3.1 INTRODUCTION

The human body is an ingenious result of evolution. Intelligent prosthetic devices, those utilizing computerized system and minimal user input, cannot yet mimic the human range of motion; however, new technologies are making it increasingly possible to restore partial function.

State-of-the-art prosthetic devices are often prohibitively expensive and may require the surgical implantation of electrodes and sensors, something that many people with limb deficiencies will not tolerate. Those in need of prosthetics usually prefer a device that is easy to maintain, equip and learn.

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 use of cables connected to existing residual limbs in order to control the hand. The OttoBock mechanical hand, for example, uses deliberate pulls on a cable to control movement.

Neural control is a potential future control method that is in its infancy. It works by using electrodes on the brain's surface to intercept limb control signal in the form of goal and trajectory signals. 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. All muscles generate natural electrochemical potential when they contract. These myoelectric signals (MES) can be read by Myoelectrodes 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 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. Primarily, 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 flaws. 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 remote signals in place of Myoelectrodes as a new intelligent prosthetic control method.

3.4 OBJECTIVES

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 too movements- Palm movement and Elbow movement with three levels if grip / movement forces is proposed the current thesis work with remote signals.

4

METHODOLOGY OF PROSTHETIC ARM

4.1 INTRODUCTION

Hand amputees at present have the option of several kinds of prosthetic devices. They are mostly mechanically activated body powered grippers, which activate with the use of Bowden cables. Electrically driven arm with relays, switch come next while EMG operated arms (myoelectric) are also used. In myoelectric arms, speed and strength of the grip is proportional to the EMG signal that is read from amputees stump muscle. 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 remote controlled switches along with a transmitter, receiver and 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.

4.2 REMOTE CONTROL PROSTHETIC ARM

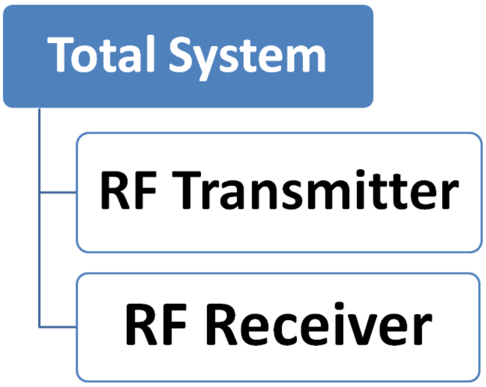
Remote control is a component of an electronics device, used for operating the device wirelessly from a short line-of-sight distance. In this prosthetic arm, RF (radio frequency) based remote is used because

- 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.

Remote control prosthetic arm has all the features of a myoelectric arm but the input feed is not an EMG signal, and it operates using remote signals.

4.3 SYSTEM DISCRIPTION

The whole system is divided on two parts - RF Transmitter with switches and RF Receiver with grip controlled circuitry.



4.4 RF TRANSMITTER WITH SWITCHES

A generator of radio-frequency (RF) signals is used for wireless communication over some distance, which can vary from the short ranges within a building to intercontinental distances. RF transmitter is used to amplifying a radio-frequency carrier signal, modulating the carrier signal with intelligence, and feeding the modulated carrier to an antenna for radiation into space as electromagnetic waves.

In our design, in RF transmission circuitry, four switches were used. These switches were followed by an encoder and RF transmitter module which is AM modulated with 434 MHz carrier frequency and a small antenna to transmit RF modulated wave as shown in Figure (2) & (3). The various components used in the circuitry are as follows:

a) Switches

In electronics, a switch is an electrical component that can break an electrical circuit, interrupting the current or diverting it from one conductor to another. The most familiar form of switch is a manually operated electromechanical device with one or more sets of electrical contacts. Each set of contacts can be in one of two states: either 'closed' meaning the contacts are touching and electricity can flow between them, or 'open', meaning the contacts are separated and not conducting as shown in Figure 1.

A switch may be directly manipulated by a human as a control signal to a system, such as a computer keyboard button, or to control power flow in a circuit, such as a light switch. Automatically-operated switches can be used to control the motions of machines.

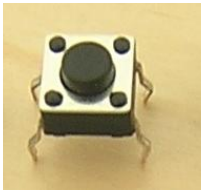


Figure 4.1: Pushbutton switches (Tactile switches)

In our transmitting circuitry

- All the switches are of Microswitch type
- They are connected with four input data pins of Encoder
- The switches are marked as "OPEN"; "CLOSE WITH LOW GRIP"; "CLOSE WITH MEDIUM GRIP"; "CLOSE WITH HIGH GRIP" (Right to left)

a) Encoder

An encoder is a device that converts information from one format or code to another, for the purposes of standardization. The HT 12E Encoder ICs are series of CMOS LSIs for Remote Control system applications. They are capable of Encoding 12 bit of information which consists of N address bits and 12-N data bits. Each address/data input is externally trinary programmable if bonded out.

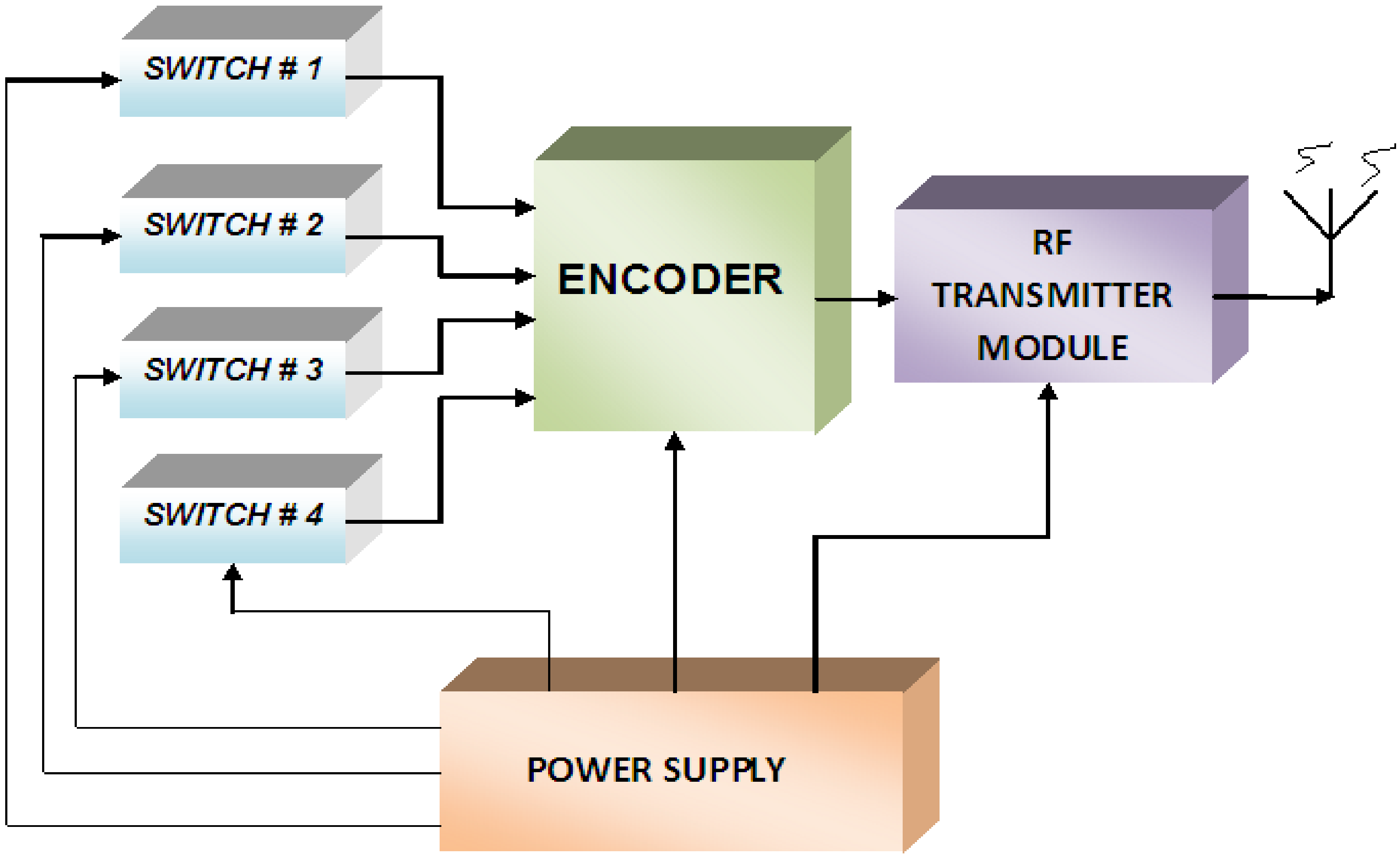


Figure 4.2: Block diagram of RF transmitter

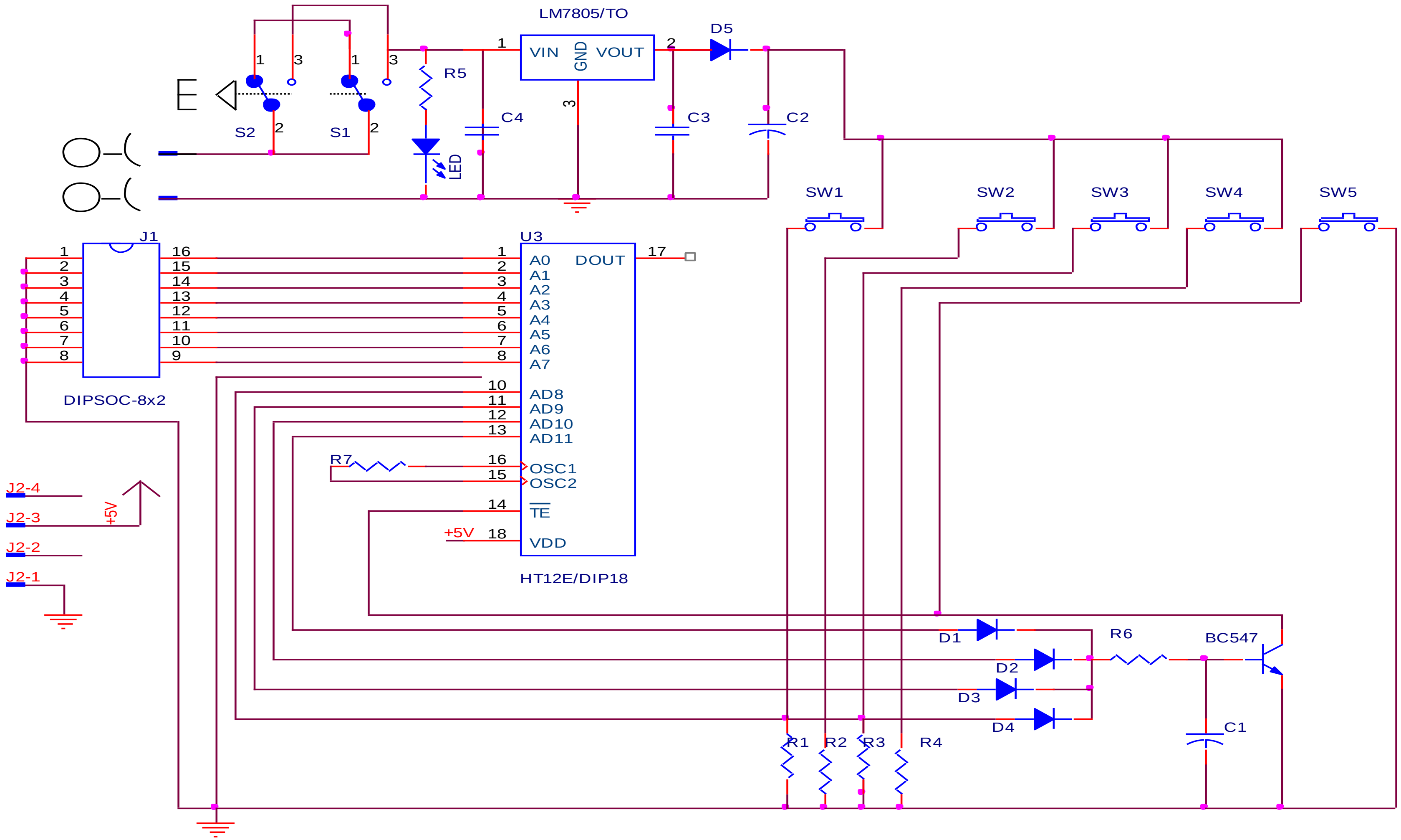


Figure 4.3: Circuit diagram of RF transmitter

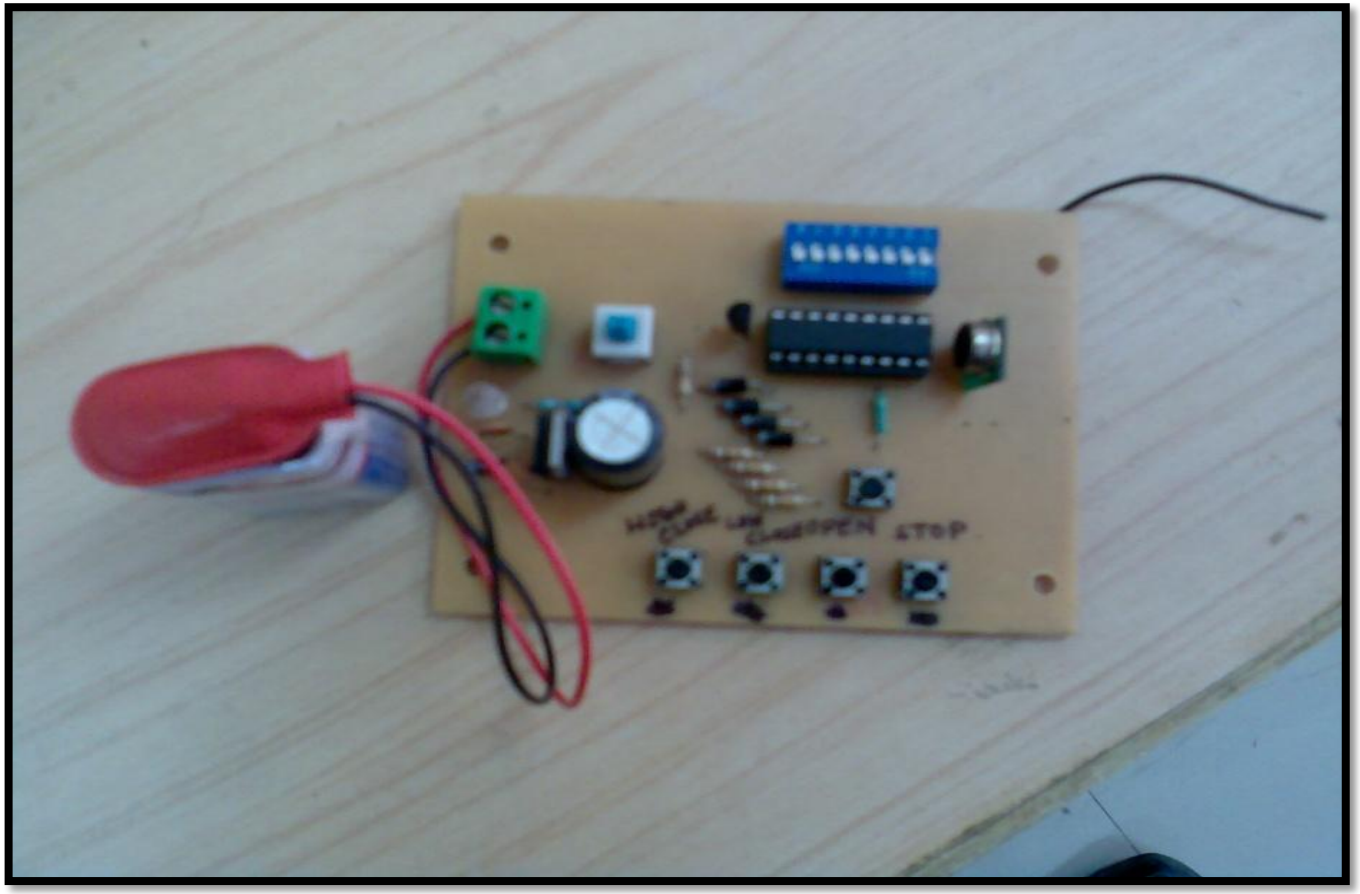


Figure 4.4: Circuit board of RF transmitter

Figure 4.5: HT12E Encoder ICs

- 18 PIN DIP
- Operating Voltage : 2.4V ~ 12V
- Low Power and High Noise Immunity CMOS Technology
- Easy Interface with and RF or an Infrared transmission medium
- The encoder has 8 bit address bus, four bit data bus
- One Transmission enable port pin, denotes whether the transmission is successful or not
- The address bus is grounded as no another device except switches are connected
- One internal crystal which provides the clock for data transmission

b) RF Transmission module

The Transmission module TWS-434 is extremely small, and is excellent for applications requiring short-range RF remote controls. It is only 1/3 the size of a standard postage stamp, and can easily be placed inside a small plastic enclosure. The transmitter output is up to 8 mW at 433 MHz with a range of approximately 400 feet (open area) outdoors. Indoors, the range is approximately 200 feet, and will go through most walls.

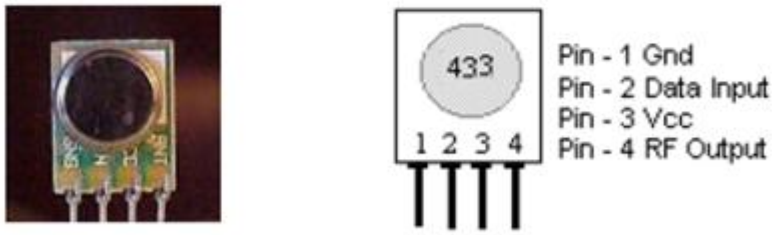


Figure 4.6: Pin Diagram of TWS-434 transmitters

The TWS-434 transmitter accepts both linear and digital inputs can operate from 1.5 to 12 Volts-DC, and makes building a miniature hand-held RF transmitter very easy.

c) <u>Antenna for RF communication</u>

An antenna is a specialized transducer that converts radio-frequency (RF) fields into alternating current (AC) or vice-versa. In the transmitting antenna, this is fed with AC from electronic equipment and generates an RF field.

- It is a simple wire
- It is stripped at another end, which acts as a simple wire radiator antenna

4.5 RF RECEIVER WITH PALM/ ELBOW MOVEMEN CONTROLLED CIRCUITRY

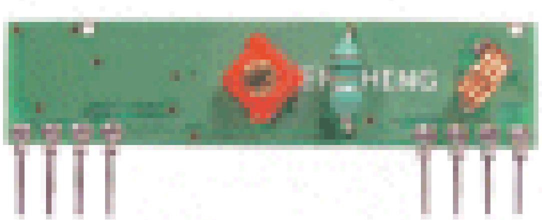
In RF receiver circuitry, the receiving antenna is followed by a RF receiver module, which is AM demodulated and synchronized properly with 434 MHz. Demodulated signal is decoded by a decoder with four channel output. These four channels are interfaced with a microcontroller followed by a motor driving IC and an external pulse shaping circuitry, which controls the duty cycle of motor driving pulses as shown in Figure 8.

a) ***Antenna for RF Receiver***

An antenna is a specialized transducer that converts radio-frequency (RF) fields into alternating current (AC) or vice-versa. In the receiving antenna, this intercepts RF energy and delivers AC to electronic equipment.

b) ***RF Receiving module***

RWS-434: The receiver also operates at 434 MHz, and has a sensitivity of 3μV. The RWS-434 receiver operates from 4.5 to 5.5 volts-DC, and has both linear and digital outputs.



RWS-434 Receiver

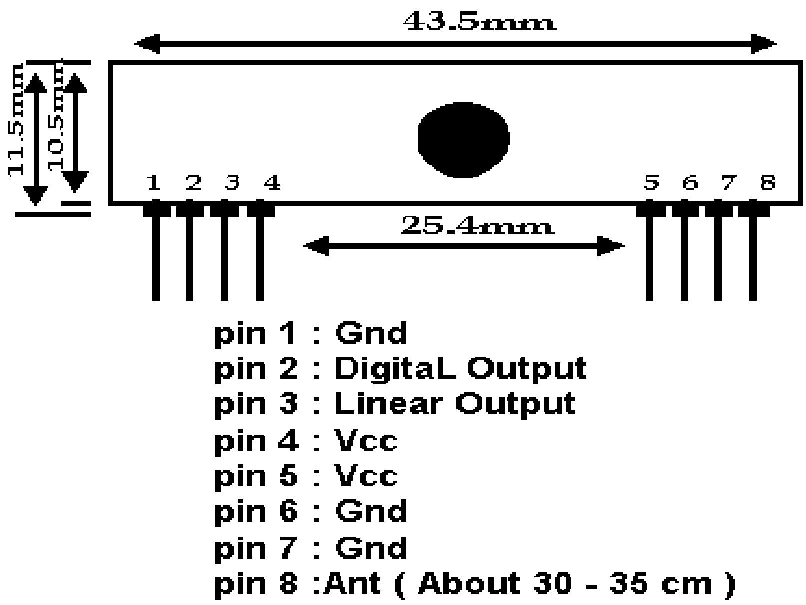


Figure 4.7: Pin Diagram of RWS-434 receivers

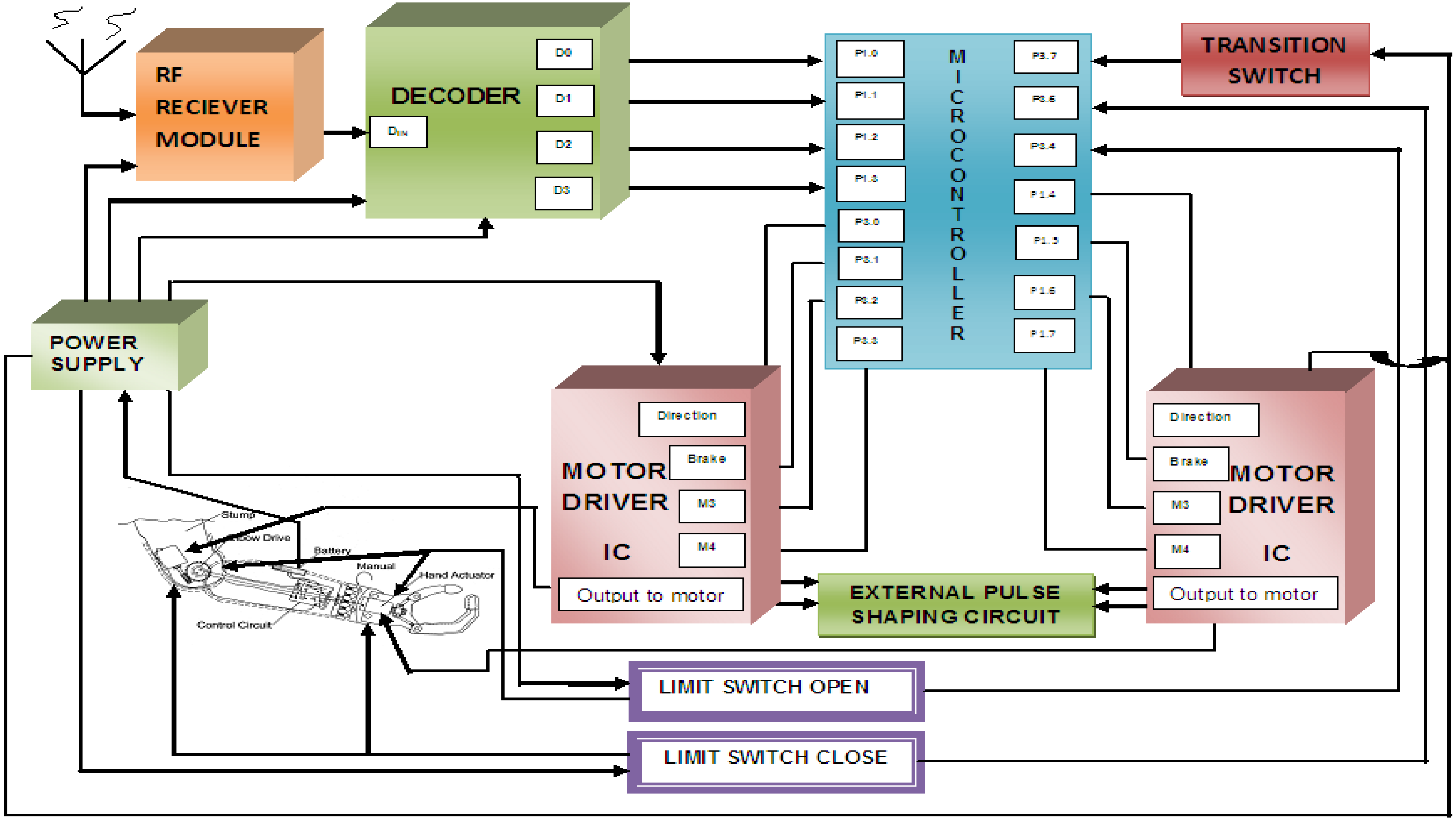


Figure 4.8: Block diagram of RF receiver with palm/ elbow movement controlled circuitry

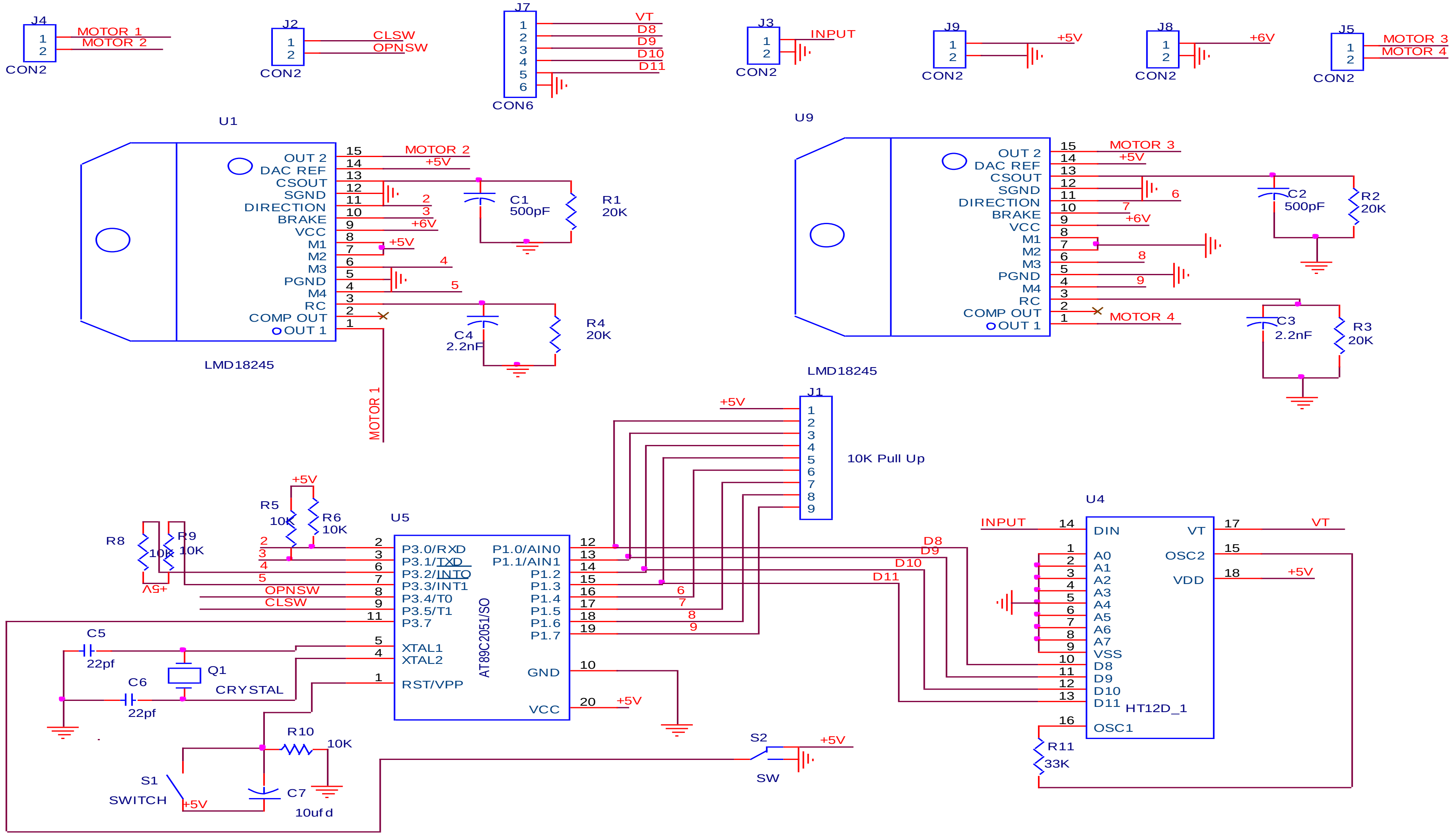


Figure 4.9: Circuitry diagram of RF receiver with palm/ elbow movement controlled circuitry

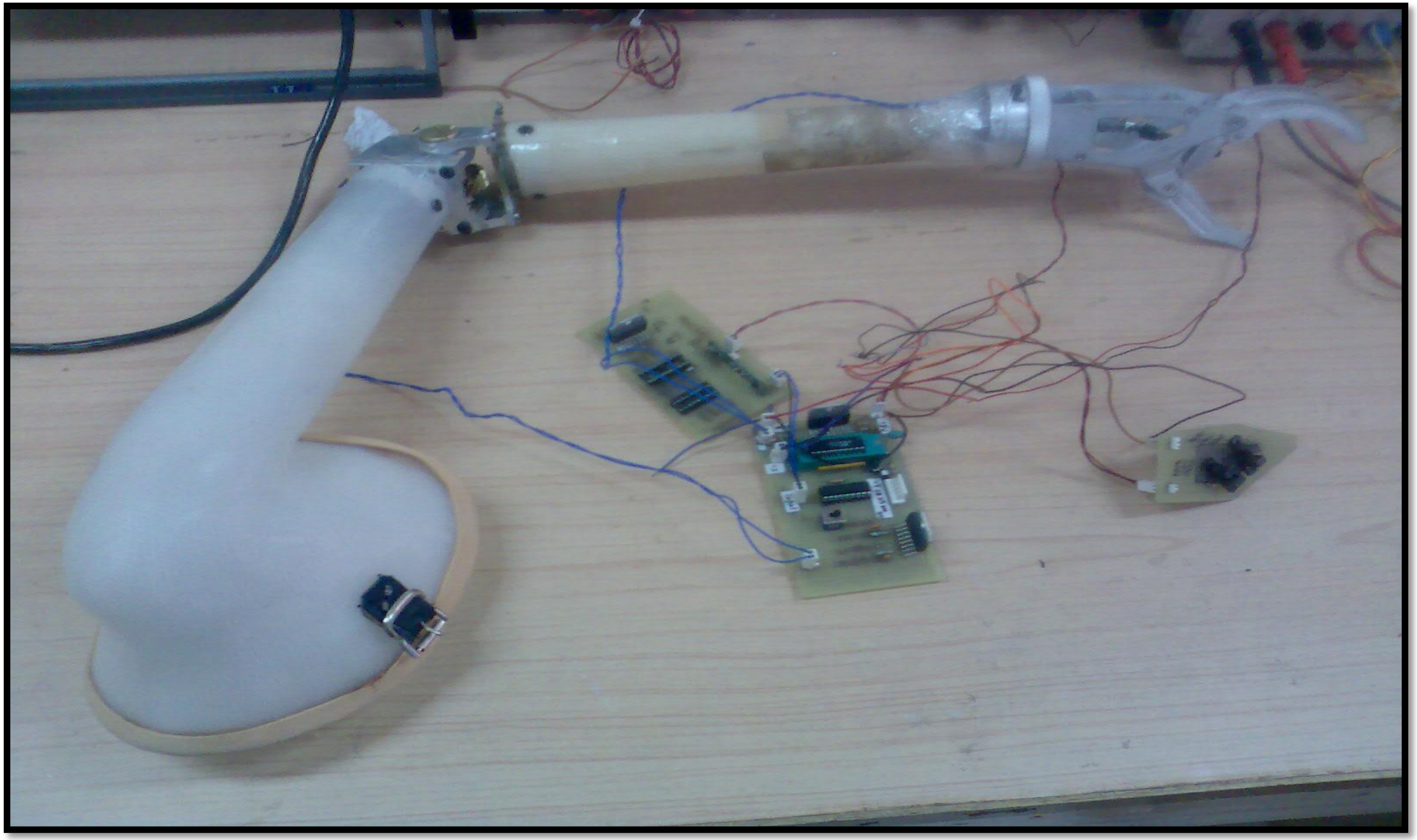


Figure 4.10: Circuitry board of RF receiver with palm/ elbow movement controlled circuitry

c) ***Decoder***

The HT 12D ICs are series of CMOS LSIs for remote control system applications. These ICs are paired with each other. For proper operation a pair of encoder/decoder with the same number of address and data format should be selected. The Decoder receive the serial address and data from its corresponding decoder, transmitted by a carrier using an RF transmission medium and gives output to the output pins after processing the data.

Figure 4.11: HT12D Decoder ICs

- 18 PIN DIP, Operating Voltage : 2.4V ~ 12.0V
- Low Power and High Noise Immunity, CMOS Technology
- Capable of Decoding 12 bits of Information
- Easy Interface with an RF of IR transmission medium
- The decoder is synchronized with encoders in all prospect
- The decoder has same 8 bit address bus, four bit data output. All the data output pins are connected to the microcontroller pins
- One valid transmission port pin denotes whether the transmission is valid or not
- The address bus is grounded
- One internal crystal which provides the clock for data receiving

d) ***Microcontroller With Motor Driver***

Microcontroller is used to control the speed of motor, direction of rotation and can also do encoding of the rotation made by DC motor.

- It is the heart of the whole system.

- All four output pins from decoder and the motor driver pins are connected with microcontroller as shown in the block diagram of receiver.
- The two limit switches measure the maximum extent of opening & closing of hand.
- The opto-switches are used as limit switches.
- Microcontroller drives the DC motor through driver circuitry as the signal (Low to High) is received from the decoder output pins.
- External Pulse shaping circuit is used to control the duty cycle of the pulses generated to control the speed of DC motor.

4.6 SYSTEM OPERATION

Initially, all the switches are in zero state. The decoder is perfectly synchronized with the encoder system, i.e., each of the four switches has particular code which decoder can identify and activate the corresponding channel. Four particular tasks like *"OPEN","CLOSE WITH LOW GRIP","CLOSE WITH MEDIUM GRIP" and "CLOSE WITH HIGH GRIP"* were assigned to four particular switches and if all four switches are pressed together the operation is stopped . When both transmitter and receiver were switched on, five particular events could happen. The palm movement and elbow movement has same operation system of three level of movements through the transition switch.

4.6.1 OPENING THE PALM/ ELBOW

Table 1 shows that if the amputee presses "Switch # 1" then hand will start opening as per the requirement and by pressing the "Switch # 1", "Switch #2", "Switch #3", "Switch #4" all together the action is stopped. If the "Open Limit Switch" is pressed, then maximum extent of opening limit will reach, "Switch #1" will become inactive and only closing switches will be working at that time. Similarly, if the hand is closed totally by pressing the "Closed Limit Switch", then only "Switch # 1" will be active and "Switch #2", "Switch # 3" and "Switch # 4" will be of no use.

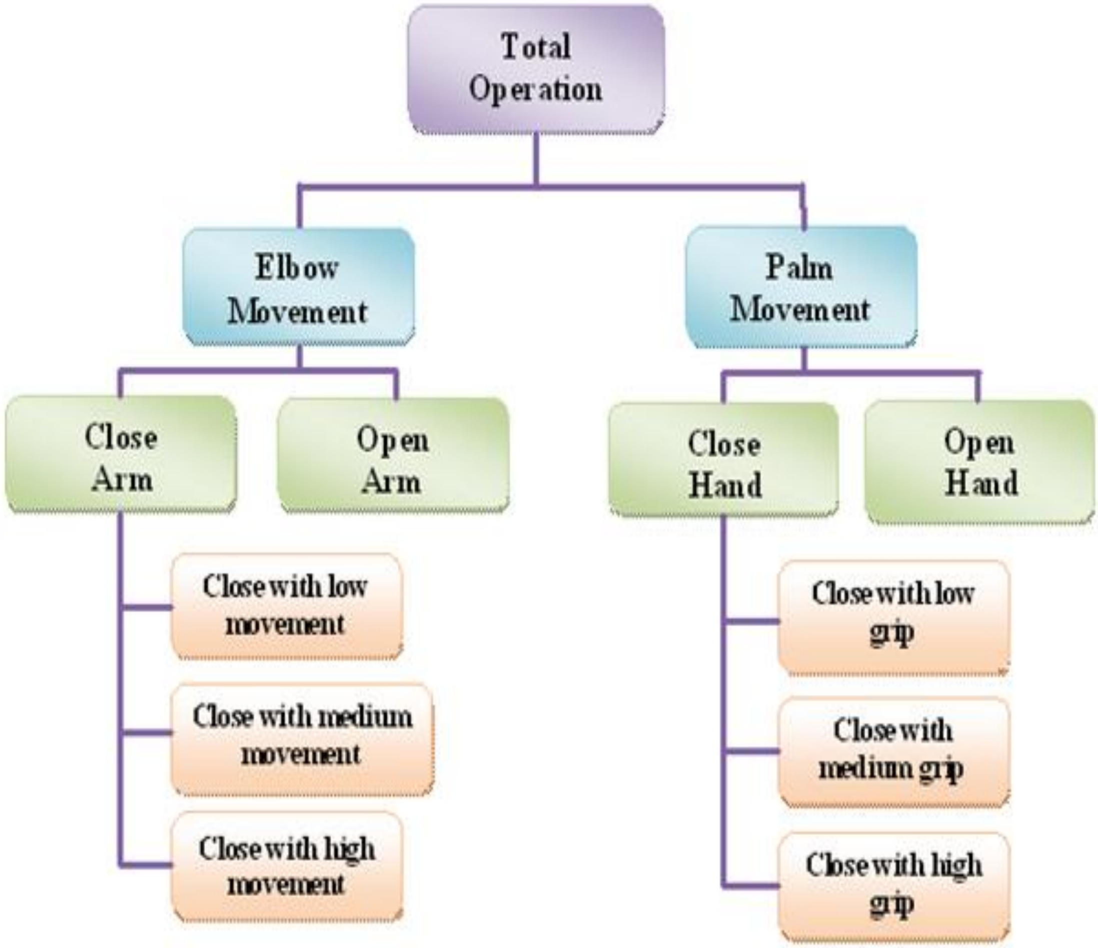


Figure 4.12: System operation

4.6.2 CLOSING THE PALM/ ELBOW WITH LOW MOVEMENT

Table 1 show that if the requirement is to grip a thermocol glass, then after opening the hand up to a certain extent, “Switch # 2” has to be pressed, so that the hand starts closing with low grip and when the object is grasped, press “Switch # 1”, “Switch # 2”, “Switch #3”, “Switch #4” together to stop the motor.

4.6.3 CLOSING THE PALM/ ELBOW WITH MEDIUM MOVEMENT

Table 1 show that if the requirement is to grasp a medium weight object, then after opening the hand up to the required extent, press “Switch # 3” to close the hand with medium grip and after the object is grasped, press “Switch # 1”, “Switch # 2”, “Switch #3”, “Switch #4” together to stop the motor.

4.6.4 CLOSING THE PALM/ ELBOW WITH HIGH MOVEMENT

Table 1 show that if the requirement is to grasp a heavy weight object like a big bottle filled up with water, then after opening the hand up to the required extent, press “Switch # 4” to close the hand with high grip and after the object is grasped, press “Switch # 1”, “Switch # 2”, “Switch #3”, “Switch #4” together to stop the motor.

Table 1: Port Pin logic

Port Pins & Status	Pin Name	Port Pins & Status	Pin Name
			Limit Switches
P3.7 = Logic 1 ⇨ = Logic 0 ⇨	Palm Movement Elbow Movement	P3.4 = Logic 1 ⇨ P3.5 = Logic 1 ⇨	Maximum Open limit is reached Maximum Close limit is reached
	Direction		
P3.0 = Logic 1 ⇨ = Logic 0 ⇨	Anticlockwise ⇨ Open Clockwise ⇨ Close	P1.0 = Low to High ⇨	Microcontroller instruct the driver to close the Palm/ Elbow with high movement
	Brake	P1.1 = Low to High ⇨	Microcontroller instruct the driver to close the Palm/ Elbow with medium movement
P3.1 = Logic 1 ⇨ = Logic 0 ⇨	Apply Brake Release Brake	P1.2 = Low to High ⇨	Microcontroller instruct the driver to close the Palm/ Elbow with low movement
Switch#4 ⇨D0 ⇨ P1.0 Switch#3 ⇨D1 ⇨ P1.1 Switch#2 ⇨D2 ⇨ P1.2 Switch#1 ⇨D3 ⇨ P1.3	Synchronization of encoder switches with decoder channels & hence with microcontroller	P1.3 = Low to High ⇨	Microcontroller instruct the driver to open the Palm/ Elbow
	Speed Control Lines	P1.0 = P1.1 = P1.2 = Low to High ⇨	Microcontroller instruct the driver to stop the Palm/ Elbow instantly

P3.3 ⇨ M3 P3.2 ⇨ M4 M2 & M1 both are in logic 1	M4	M3	M2	M1	
	0	0	1	1	⇨ Closing Palm/ Elbow with low movement
	0	1	1	1	⇨ Closing Palm/ Elbow with medium movement
	1	0	1	1	⇨ Closing Palm/ Elbow with high movement
	1	1	1	1	⇨ Opening the Palm/ Elbow

Table 2: Flow chart of the complete system

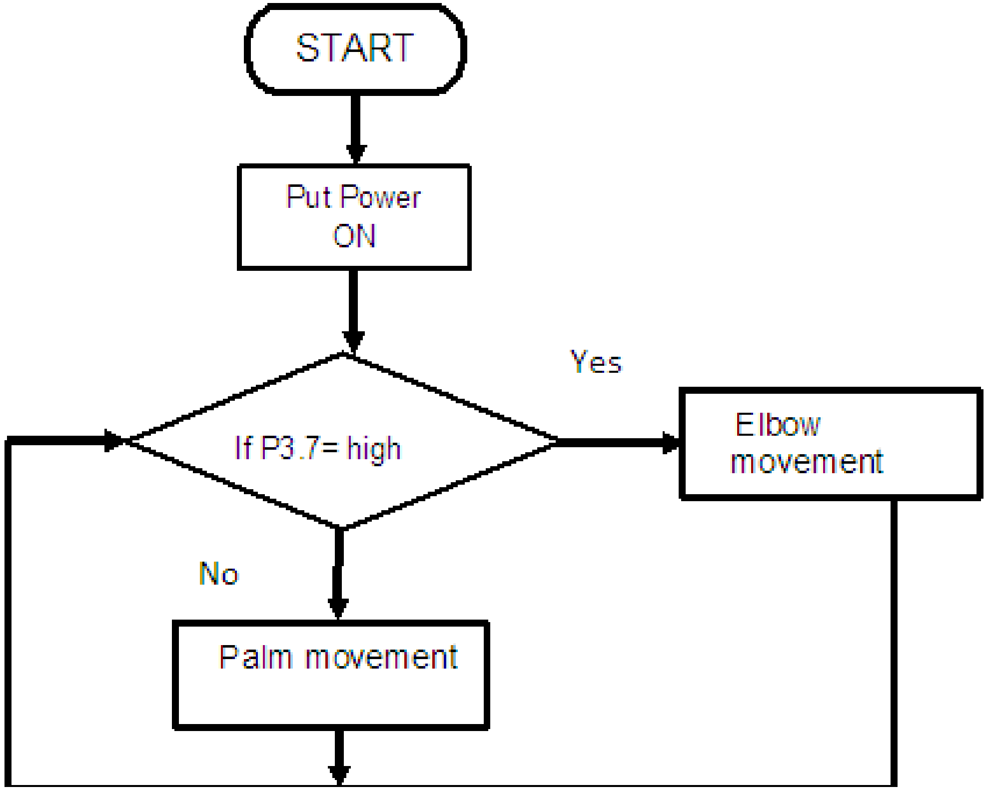
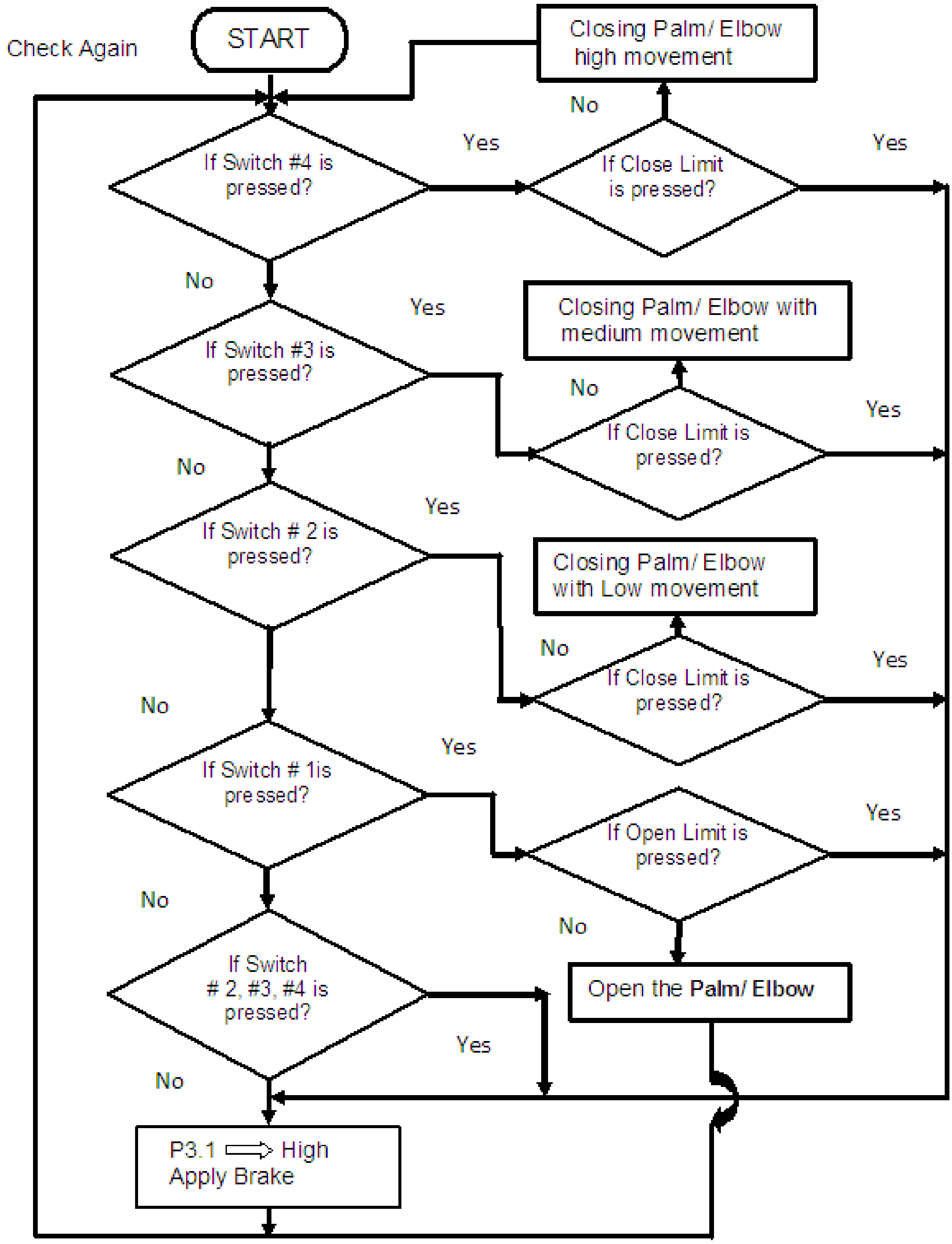


Table 3: Flow chart of palm/ elbow movement



4.7 COMPONENTS DESCRIPTION

a) ***DC Motor***

DC motors function using direct current power supply. To allow the rotor to rotate without twisting the wires, the ends of the coil are connected to a set of contacts called the commutator, which rub against a set of conductors called the brushes. The brushes make electrical contact with the commutator as it spins, and are connected to the positive and negative leads of the power source, allowing electricity to flow through the loop. The electricity flowing through the loop creates a magnetic field that interacts with the magnetic field of the permanent magnet to make the loop rotate.

Figure 4.13: DC motor

DC motors have a gradual acceleration and deceleration curve which causes slow stabilization. The addition of gearing to the motor reduces this problem, but overshoot is still present and will exceed the anticipated stop position. A potentiometer, which acts as a feedback mechanism, is also attached to determine the exact positioning of the motor. In addition, a control circuit, which compares the position of the motor with the desired position, moves the motor accordingly. DC motors generally do not produce high torque levels at low speeds without the aid of a 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 that a gear box was required for speed reduction.

b) <u>Microcontroller</u>

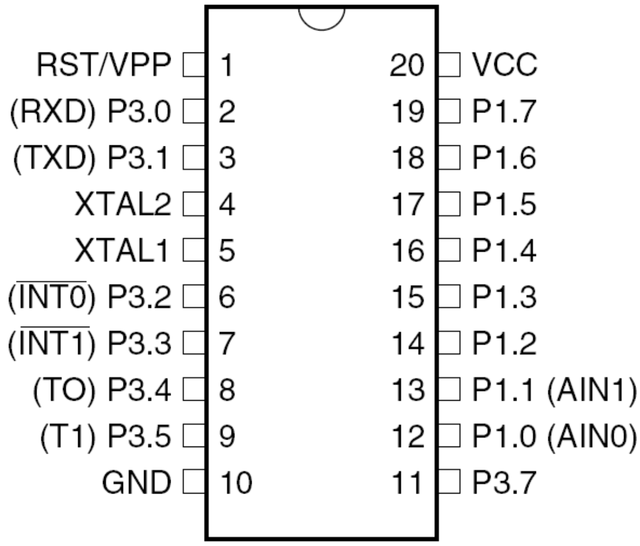


Figure 4.14: Pin diagram of AT89C2051

The AT89C2051 is a low-voltage, high-performance CMOS 8-bit microcomputer with 2K bytes of Flash erasable and programmable read-only memory (EPROM). The device is manufactured using Atmel's high-density non-volatile memory technology and is compatible with the industry-standard MCS-51 instruction set. By combining a versatile 8-bit CPU with Flash on a monolithic chip, the Atmel AT89C2051 is a powerful microcomputer which provides a highly-flexible and cost-effective solution to many embedded control applications. The AT89C2051 provides the following standard features: 2K bytes of Flash, 128 bytes of RAM, 15 I/O lines, two 16-bit timer/counters, a five vector two-level interrupt architecture, a full duplex serial port, a precision analog comparator, on-chip oscillator and clock circuitry. In addition, the AT89C2051 is designed with static logic for operation down to zero frequency and supports two software selectable power saving modes. The Idle Mode stops the CPU while allowing the RAM, timer/counters, serial port and interrupt system to continue functioning. The power-down mode saves the RAM contents but freezes the oscillator disabling all other chip functions until the next hardware reset [21].

c) *Motor Driver*

Figure 4.15: LMD18245

The LMD18245 full-bridge power amplifier incorporates all the circuit blocks required to drive and control current in a brush type DC motor or one phase of a bipolar stepper motor. The multi-technology process used to build the device combines bipolar and CMOS control and protection circuitry with DMOS power switches on the same monolithic structure. The LMD18245 controls the motor current via a fixed off-time chopper technique.

An all DMOS H-bridge power stage delivers continuous output currents up to 3A (6A peak) at supply voltages up to 55V. The DMOS power switches feature low r_{ds}(ON) for high efficiency, and a diode intrinsic to the DMOS body structure eliminates the discrete diodes typically required to clamp bipolar power stages. An innovative current sensing method eliminates the power loss associated with a sense resistor in series with the motor. A four-bit digital-to-analog converter (DAC) provides a digital path for controlling the motor current and by extension, simplifies implementation of full, half and microstep stepper motor drives. For higher resolution applications, an external DAC can be used [22].

d) ***Optoswitches***

The slotted opto switches consist of two separate sections as shown in figure 16. The first section is an infrared light emitting diode (LED) acting as a transmitter. The receiver, in the second section, is a phototransistor. Between the two sections, there is a small gap so that an object may cut the infrared beam of light that passes between the two sections.

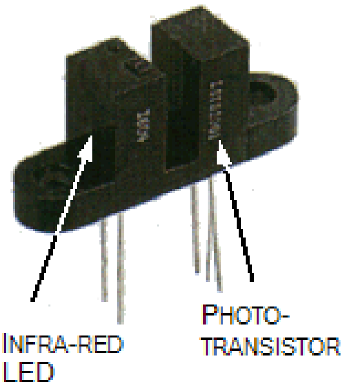


Figure 4.16: Slotted opto switches

The circuit that makes the switch useful is shown in Figure 17. The phototransistor is wired as shown so that when an object cuts the infrared beam of light, the output of the switch becomes 5 V instead of the usual 0 V when there is no object obstructing the beam.

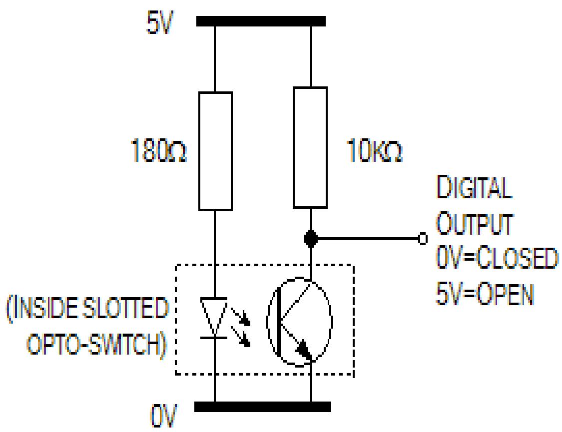


Figure 4.17: Using slotted opto-switches

5

RESULTS AND DISCUSSION

4.1 PALM MOVEMENT

a) Opening hand

If the amputee presses “Switch # 1”, then hand will start opening as per the requirement and by pressing the “Switch # 1”, “Switch #2”, “Switch #3”, “Switch #4” all together the action is stopped.

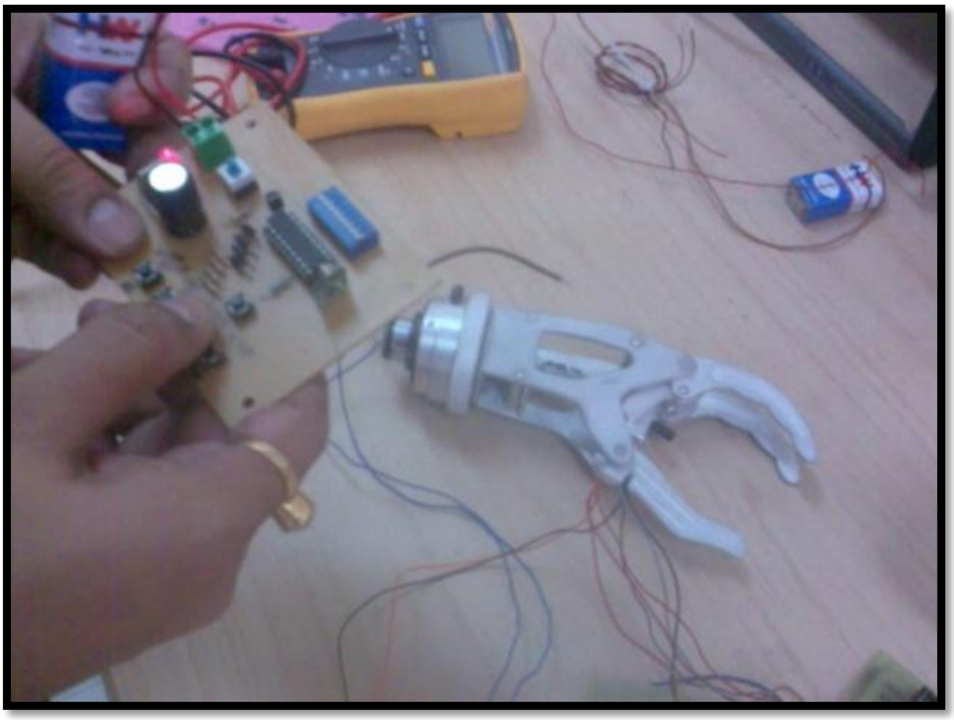


Figure 5.1: Circuit diagram of opening hand

b) Close with low grip

If the requirement is to grip a thermocol glass, then after opening the hand up to a certain extent, “Switch # 2” has to be pressed, so that the hand starts closing with low grip and when the object is grasped, press “Switch # 1”, “Switch # 2”, “Switch #3”, “Switch #4” together to stop the motor.

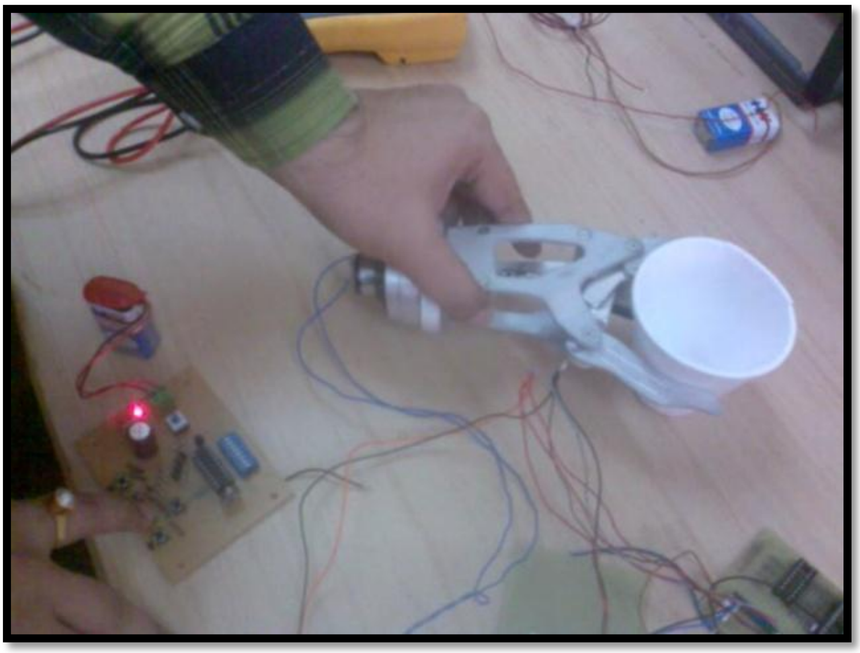


Figure 5.2: Circuit diagram of close with low grip

c) Close with high grip

If the requirement is to grasp a heavyweight object like a big bottle filled up with water, then after opening the hand up to the required extent, press “Switch # 4” to close the hand with high grip and after the object is grasped, press “Switch # 1”, “Switch # 2”, “Switch #3”, “Switch #4” together to stop the motor.

Figure 5.3: Circuit diagram of close with high grip

4.2 ELBOW MOVEMENT

a) Opening arm

If the amputee presses “Switch # 1” then hand will start opening as per the requirement and by pressing the “Switch # 1”, “Switch #2”, “Switch #3”, “Switch #4” all together the action is stopped.

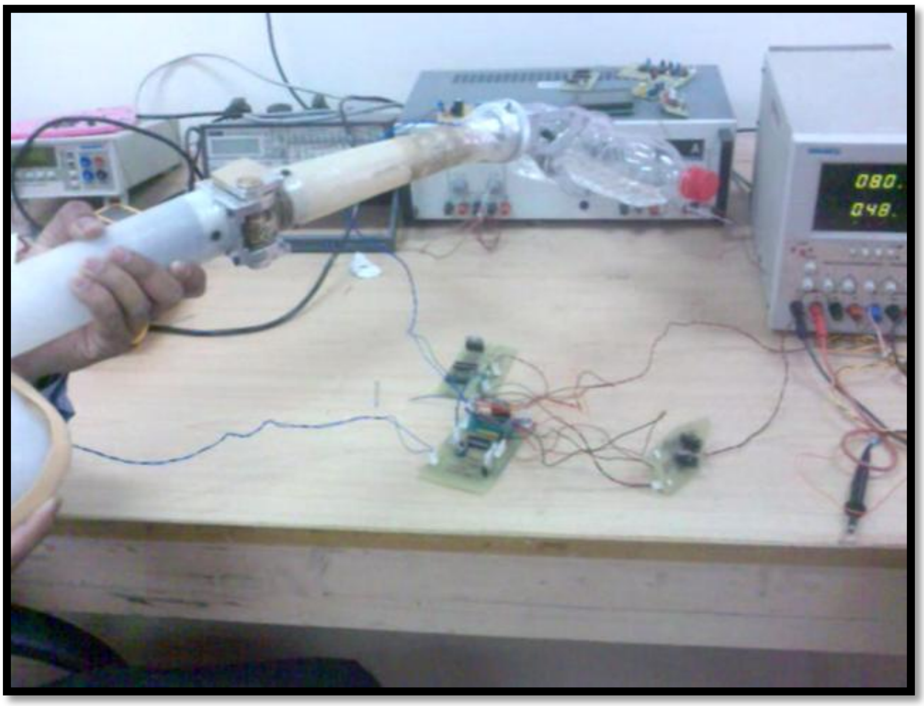


Figure 5.4: Circuit diagram for opening arm

b) Close with low movement

If the requirement is to grip a lightweight object, then after opening the hand up to a certain extent, “Switch # 2” has to be pressed, so that the hand starts closing with low grip and when the object is grasped, press “Switch # 1”, “Switch # 2”, “Switch #3”, “Switch #4” together to stop the motor.

c) Close with high movement

If the requirement is to grasp a heavyweight object like a big bottle filled up with water, then after opening the hand up to the required extent, press “Switch # 4” to close the hand with high grip and after the object is grasped, press “Switch # 1”, “Switch # 2”, “Switch #3”, “Switch #4” together to stop the motor.

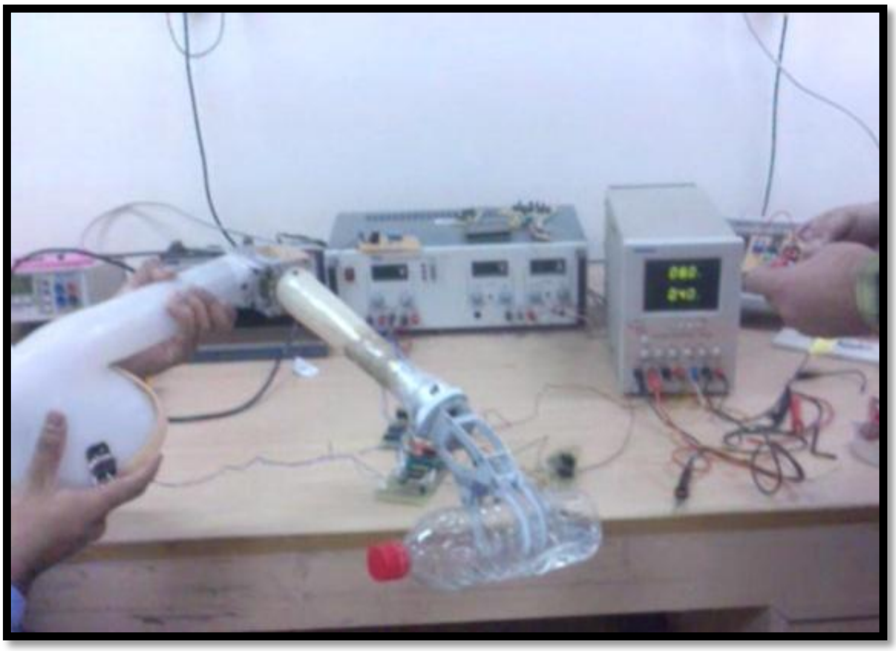


Figure 5.5: Circuit diagram of closed arm

6

CONCLUSION AND FUTURE SCOPE

5.1 CONCLUSION

Prosthetic arm is a boon for those persons who have lost their arm due to some mishap. One of the main requirements of artificial arm is it's functionally. It should be near to the natural hand as possible. Keeping these requirements in mind, remote control prosthetic arm has been developed which contains all the necessary features. This remote control prosthetic arm has two movements - palm movement and elbow movement. This system was designed, fabricated and has been tested successfully with three levels of grip forces and with three levels of elbow movements in the laboratory.

5.2 FUTURE SCOPE

- More precision work can be done; levels of the grip forces can be increased if the numbers of the switches are increased in transmitter section.
- Wrist rotation can be controlled electronically if the mechanical arrangement is modified and attached with motor shaft.

NATIONAL CONFERENCE PAPER

Amardeep Bajwa, Arindam Chatterjee, Amod Kumar, Kanta Garg, Ravinder Aggarwal, "Design of wireless prosthetic hand" National conference on Emerging Medical Instrumentation (CEMI-2010), May 11-12, 2010, Chandigarh

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[21] AT89C2051 Microcontroller datasheet at www.atmel.com/atmel/acrobat/doc0368.pdf

[22] LMD18245 Motor Driver datasheet at www.national.com/mpf/LM/LMD18245.html

Appendix A

The Specifications of Developed Arm

The specifications of below elbow prosthesis are as follows:

Operating Voltage	:	6V / 9 V
Current Consumption	:	200 mA (Approx.)
Opening Width	:	75-100 mm
Grip Force	:	50 N (max.)
Average Speed	:	3-4 cm/sec. (approx.)
Weight of arm	:	2 kg (max.)
On-off switch	:	Integrated

Appendix B

Microcontroller Code

```
                    .ORG 0000H
AGAINCHK:           JB P3.7, PALM_OPERATION
ELBOW_OPERATION:    LCALL ELBOW
                    LJMP HERE
PALM_OPERATION:     LCALL PALM
HERE:               LJMP AGAINCHK

PALM:               JB    P1.0, HIGH_CLOSE
                    JB    P1.1, MID_CLOSE
                    JB    P1.2, LOW_CLOSE
                    JB    P1.3, OPEN_MAX_SPEED
                    LJMP END_PALM
HIGH_CLOSE:         JB    P1.1, MID_CLOSE
                    LCALL HIGH_GRIP
                    LJMP END_PALM
MID_CLOSE:          JB    P1.2, LOW_CLOSE
                    LCALL MID_GRIP
                    LJMP END_PALM
LOW_CLOSE:          JB    P1.3, CHK_FR_STOP
                    LCALL LOW_GRIP
```

```
                        LJMP END_PALM
OPEN_MAX_SPEED:         LCALL OPEN_ARM
                        LJMP END_PALM
CHK_FR_STOP:            LCALL STOP_ARM
END_PALM:               RET

ELBOW:                  JB   P1.0, HIGH_CLOSE1
                        JB   P1.1, MID_CLOSE1
                        JB   P1.2, LOW_CLOSE1
                        JB   P1.3, OPEN_MAX_SPEED1
                        LJMP END_ELBOW
HIGH_CLOSE1:            JB   P1.1, MID_CLOSE1
                        LCALL CLOSE_HIGH
                        LJMP END_ELBOW
MID_CLOSE1:             JB   P1.2, LOW_CLOSE1
                        LCALL CLOSE_MID
                        LJMP END_ELBOW
LOW_CLOSE1:             JB   P1.3, CHK_FR_STOP1
                        LCALL CLOSE_LOW
                        LJMP END_PALM
OPEN_MAX_SPEED1:        LCALL OPEN_ELBOW
                        LJMP END_ELBOW
CHK_FR_STOP1:           LCALL STOP_ELBOW
END_ELBOW:              RET

OPEN_ARM:               JB   P3.4, NEXT1
```

```
                LJMP END1
NEXT1:          SETB P3.0
                CLR P3.1
                SETB P3.3
                SETB P3.2
END1:           RET

HIGH_GRIP:      JB   P3.5, NEXT2
                LJMP END2
NEXT2:          CLR P3.0
                CLR P3.1
                SETB P3.3
                CLR P3.2
END2:           RET

MID_GRIP:       JB   P3.5, NEXT3
                LJMP END3
NEXT3:          CLR P3.0
                CLR P3.1
                CLR P3.3
                SETB P3.2
END3:           RET

LOW_GRIP:       JB   P3.5, NEXT4
                LJMP END4
NEXT4:          CLR P3.0
```

```
                CLR P3.1
                CLR P3.3
                CLR P3.2
END4:           RET

STOP_ARM:       SETB P3.1
                RET

OPEN_ELBOW:     JB   P3.4, NEXT5
                LJMP END5
NEXT5:          SETB P1.4
                CLR P1.5
                SETB P1.7
                SETB P1.6
END5:           RET

CLOSE_HIGH:     JB   P3.5, NEXT6
                LJMP END6
NEXT6:          CLR P1.4
                CLR P1.5
                SETB P1.7
                CLR P1.6
END6:           RET

CLOSE_MID:      JB   P3.5, NEXT7
                LJMP END7
```

```
NEXT7:        CLR P1.4
              CLR P1.5
              CLR P1.7
              SETB P1.6
END7:         RET

CLOSE_LOW:    JB   P3.5, NEXT8
              LJMP END8
NEXT8:        CLR P1.4
              CLR P1.5
              CLR P1.7
              CLR P1.6
END8:         RET

STOP_ELBOW:   SETB P1.5
              RET
```