

MOBILE ROBOTIC ARM MANIPULATION

A Thesis

**Submitted to the Department of Electrical and Electronic Engineering
Of
BRAC University**

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Of

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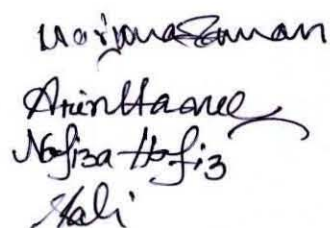
BRAC University, Dhaka, Bangladesh

DECLARATION

We hereby declare that this thesis is based on the results established by us. Materials of work found by other researchers are mentioned in the reference. This thesis, neither in whole nor in part, has been previously submitted for any degree.

A handwritten signature in blue ink, appearing to be 'R. S.', with the date '15/4/10' written below it.

Signature of
Supervisor

Three handwritten signatures in blue ink, stacked vertically. The top signature is 'U. S. Man', the middle is 'Aminul Haque', and the bottom is 'Nafiz Hossain'.

Signature of
Authors

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BRAC University, 2010.

ABSTRACT

In this modern era, robotics has brought a revolutionary success in technology. In our thesis, we are going to implement a mobile robotic arm manipulator. The arm manipulator will perform embedded actions using microcontroller. We are going to generalize the definition of manipulability to the case of mobile robotic arm manipulation in our entire project. Through the entire project analysis, this mobile robotic arm will be manipulated with the help of three degrees of freedom. The targeted arm will consist of base, upper arm, forearm and gripper. In this arm manipulator, various joints are going to be constructed using stepper motors, we will be using metal arm structure, and for base movement we are going to use DC motors. Finally the robotic arm manipulator will be able to perform picking, placing and embedded movement.

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CHAPTER I

Introduction

Background:

In this era of technology since lots of research associated with robotics are on process, we have decided to develop and improve an embedded mobile robotic arm manipulator which will be efficient as well as cost efficient. The overall goal of this research is to develop a unified interface and control architecture to support both the manipulation so that the system can function effectively as a human surrogate in critical and hazardous environments such as power plants, industrial settings, etc. The system is designed in order to help the operators to reduce their burden so that they can focus on critical tasks (such as grasping, holding, placing, reaching etc.).

In many industries, hospitals, super shops there are much similar type of tasks which are generally done by workers. These tasks are not only time consuming but also these can cause harm to the workers. Our main objective to implement an independent arm that acts as a substitute of human workers, can perform multiple tasks like moving from place to place, picking and placing objects according to given instructions.



Figure 1: Robotic Arm

In chapter II, robotics, its classifications and various components of robotics are described to show how our project is related to robotics and which methodologies are being used to complete the entire project. Chapter III leads to the project overview where the general working concept is described. Chapter IV features to the various parts of the arm manipulator. Elaborate description of base, upper arm, forearm and gripper is given in this chapter. Detailed portrayal of various motors, which are used to build the arm, is given in chapter V. Chapter VI explains the elaborated working principle along with the program which is being used to manipulate the arm according to our application. A variety of applications is featured in this chapter too.

CHAPTER II

Robotics

At this present age, robotics has added a new dimension to the world of science and technology. This project is utterly related to robotics that is why before starting the elaborate description session, some important technical terms associated to robotics are introduced here.

2.1) Robot:

A robot is an automatically guided machine that is able to do tasks on its own. Another common characteristic is that by its appearance or movements, a robot often conveys a sense that it has intent of its own. The word "ROBOT" can refer to both physical robots and virtual software agents. There is no consensus on which machines qualify as robots, but there is general agreement among experts and the public that robots tend to do some or all of the following: move around, operate a mechanical limb, sense and manipulate their environment, and exhibit intelligent behavior, especially behavior which mimics humans or other animals.

2.2) Robotics:

Robotics is the engineering science and technology of robots, and their design, manufacture, application, and structural disposition. Robotics is the art, knowledge base and designing, applying and using robots in human endeavors. Robotic system consists of not only robots but also some other devices and systems are used together with the robots to perform necessary tasks. Robotics is an inter-disciplinary subject that benefits from mechanical, electronic and electrical engineering.

2.3) Arm Manipulator:

The most common types of robot technology that have evolved for industrial purposes are arms and are known as "Arm Manipulator". These are reprogrammable and multifunctional mechanisms those are designed to move materials, tools and many other devices. The emphasis in these manipulators is being able to program them to be able to perform tasks with higher degrees of accuracy.

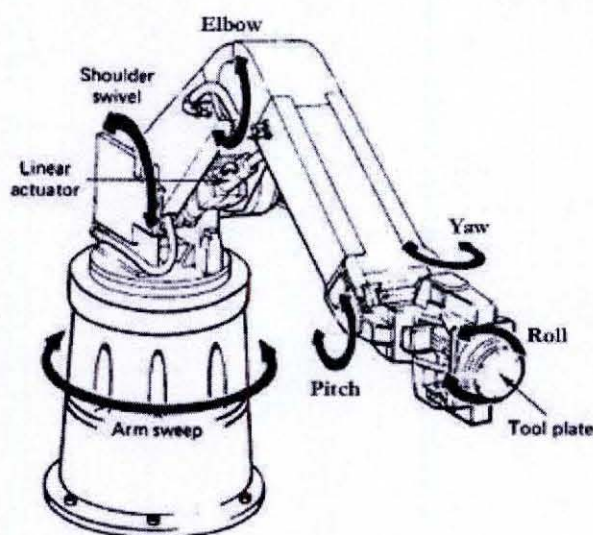


Figure 2:2.3: Articulated Arm Manipulator

The following is the classifications of robots according to the Japanese Industrial Robot Association (JIRA) and Robotics Institute of America (RIA).

- 1) Manual-handling Device
- 2) Fixed-Sequence Robot
- 3) Variable-Sequence Robot**
- 4) Playback Robot
- 5) Numerical Control Robot and
- 6) Intelligent Robot

In our research, we have implemented the arm manipulator according to the VARIABLE-SEQUENCE ROBOT where the device performs the

successive stages of a task according to a predetermined, unchanging method and this is easy to modify.

2.4) Components of Arm Manipulator:

An arm manipulator consists of the following elements, which are integrated together to form a whole:

2.4.1) Manipulator:

This is the main body of the arm and consists of links, joints, and other structural elements of the arm.

2.4.2) End Effectors:

This is the last part that is connected to the last joint (hand) of a manipulator, which generally handles objects, makes connections with other devices and performs required tasks. In most cases, it is simply a gripper.

2.4.3) Actuators:

Actuators are the “muscles” of the manipulator. Common types of actuators are stepper motors, servo motors, hydraulic cylinders etc.

2.4.4.) Controllers:

The controller is rather similar to brain but does not have the power of brain. But still it controls the motions of the arm manipulator. It receives data from processor, controls and coordinates the motions of actuators.

2.4.5) Processors:

This is the brain of the manipulator. It calculates the motions of the joints, determines the desired speed and distances and oversees the coordinated actions of the controllers. Controllers and Processors are placed at the same unit but to be done with two different functions.

2.4.6) Software:

There are three groups of software that are used in robotics. One is the Operating System, the second one is the Robotic Software which calculates the motions and the third one is the Collection of Routines and Application Programs.

2.5) Degrees Of Freedom:

In mechanics, degrees of freedom (DOF) are the set of independent displacements and rotations that specify completely the displaced or deformed position and orientation of the body or system. This is a fundamental concept related to the systems of moving bodies in mechanical engineering, aeronautical engineering, robotics, structural engineering, etc. A particle that moves in three dimensional spaces has three translational displacement components as, while a rigid body would have at most six including three rotations. Translation is the ability to move without rotating, while rotation is angular motion about some axis.

The term "Degrees of freedom" or DOF is very important to understand. Each degree of freedom is a joint on the arm, a place where it can bend or rotate or translate. It can be typically identified the number of degrees of freedom by the number of actuators on the robot arm. Now this is very important, while building a robot arm, to be sure about the number of degrees of freedom because each degree of freedom requires a motor, often encoder, and exponentially complicated algorithms and cost.

2.6) Joints:

Most robots or manipulators have either "Linear or Prismatic" joint or "Revolute" joint. In our project, we have used revolute joints which are rotary, electrically driven and driven by either stepper motors or most commonly, by servo motors.

2.7) Coordinates:

Robotic manipulators generally follow various coordinates such as Cartesian / Rectangular / Gantry, Cylindrical, Spherical, Anthropomorphic / Articulated etc. Our robotic arm manipulator is following Articulated coordinate where the joints revolute, similar to human arm. This is perhaps the most common configuration which is followed by industrial manipulators.

CHAPTER III

Project Synopsis

Our goal is to develop a mobile robotic arm manipulator. A brief description of the components which are needed to develop the mobile robotic arm, along with their functions and working principles are also described in this chapter. Automation is playing a key role in the Industrial development of Bangladesh. A portable mobile Robotic Arm will be a handy tool in this automation process. In this project, a low cost, robust mobile robotic arm which can perform multiple functions will be implemented. The innovation of this robotic arm is in its ability to move in any direction programmed.

3.1) Overview:

The arm manipulator will be embedded and controlled by microcontroller which is the processor. The arm will be able to pick and place objects while revolving and moving to any desired direction. The manipulator will have three degrees of freedom. This device will consist of a robotic arm with multiple points of rotation and these points of rotation are known as "Revolute Joints". The first point of rotation will be at the base which will be accompanied by mounting and a stability device. The base will have two wheels; the wheels will control left and right movement along with forward and reverse movements. The wheels will be connected with two DC motors. A supporter is being used to balance the overall movement of the base car. A stepper motor will be used on the top of the base to rotate the arm along 360 degrees so that it can pick objects from anywhere and place accordingly. This stepper motor makes the shoulder joint where the upper arm is jointed with the base. The upper arm and forearm will be connected at the elbow joint using another stepper motor. The forearm will be connected with the gripper at the wrist joint using another DC motor. Various motors used here are known as "Actuators" or "Muscles". The

gripper will be capable of grasping and releasing motion. Microcontroller will direct all the movements.

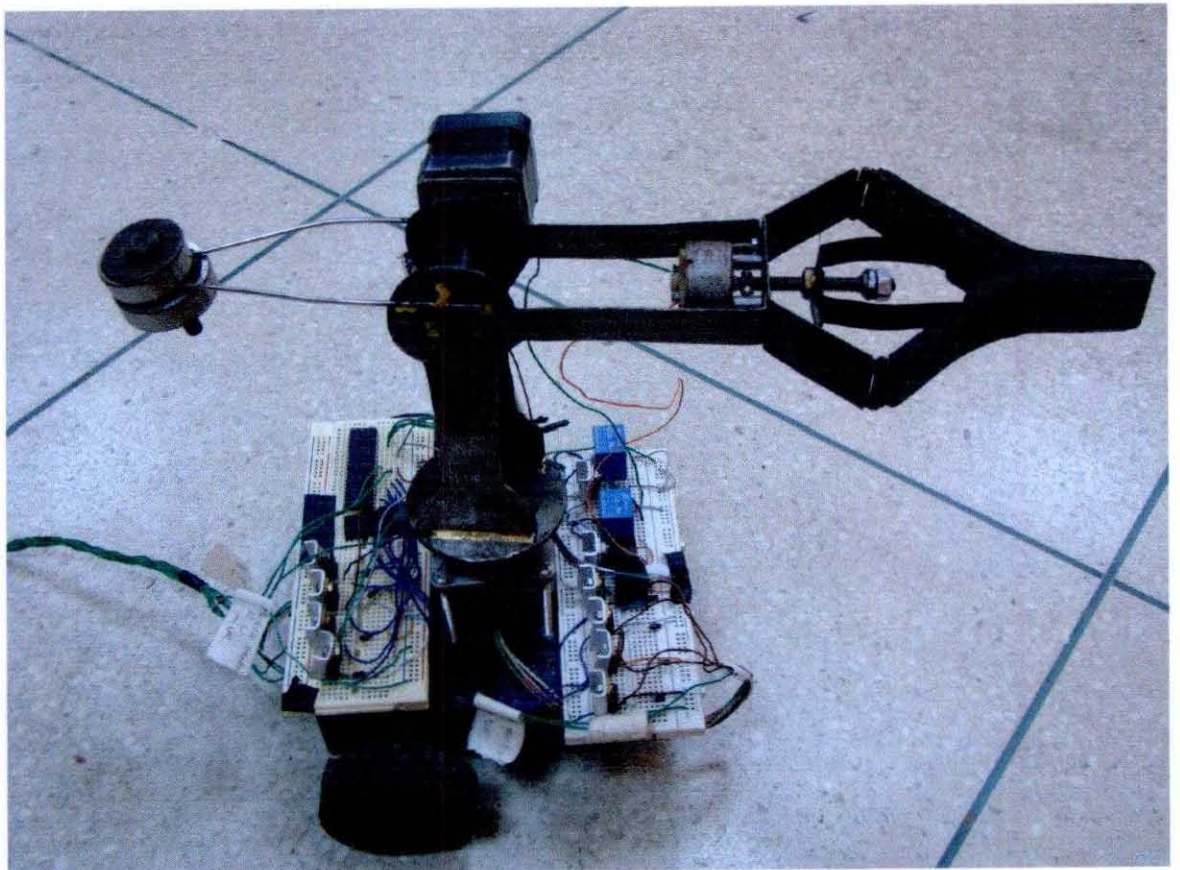


Figure 3:3.1: Arm Manipulator

CHAPTER IV

Various Parts of Arm Manipulator

A brief description of the components, needed to develop the mobile robotic arm, along with their functions and working principles, are described in this chapter. While constructing the whole structure, the arm manipulator has been divided into three important parts. These are Base, Arm and Gripper. After being completed, all the three parts have been mounted on the whole. In this chapter, all these three parts will be described ornately.

4.1) Base:

To construct the base, two steel frames are used together. Frames are connected together by screws and a piece of paper has been used between the frames so that they do not become shorted. In between the frames two DC gear motors have been placed with two wheels. A supporter has been placed at the bottom and base circuit has been placed in between the two frames which is consists of Microcontroller, L293d. Input is coming from microcontroller's port D3, D4, D5, D6. The wheels control the forward and backward movements of the base along with left and right movements. The base is made very carefully so that it can manage the entire load of arm, gripper, and the objects as well which the arm is going to pick.

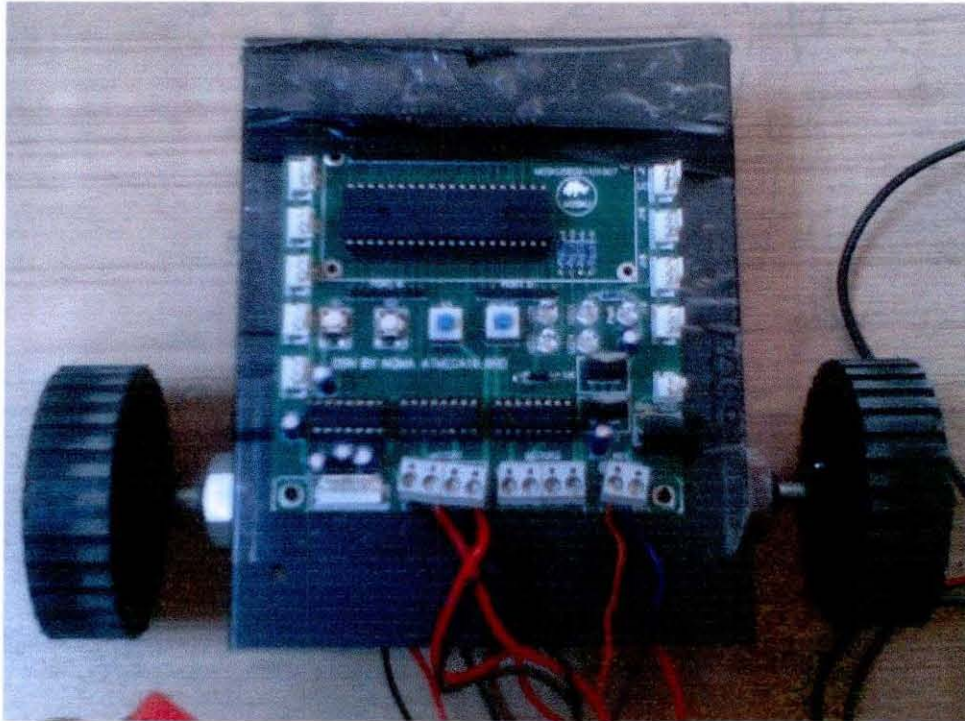


Figure 4:4.1(a): Base

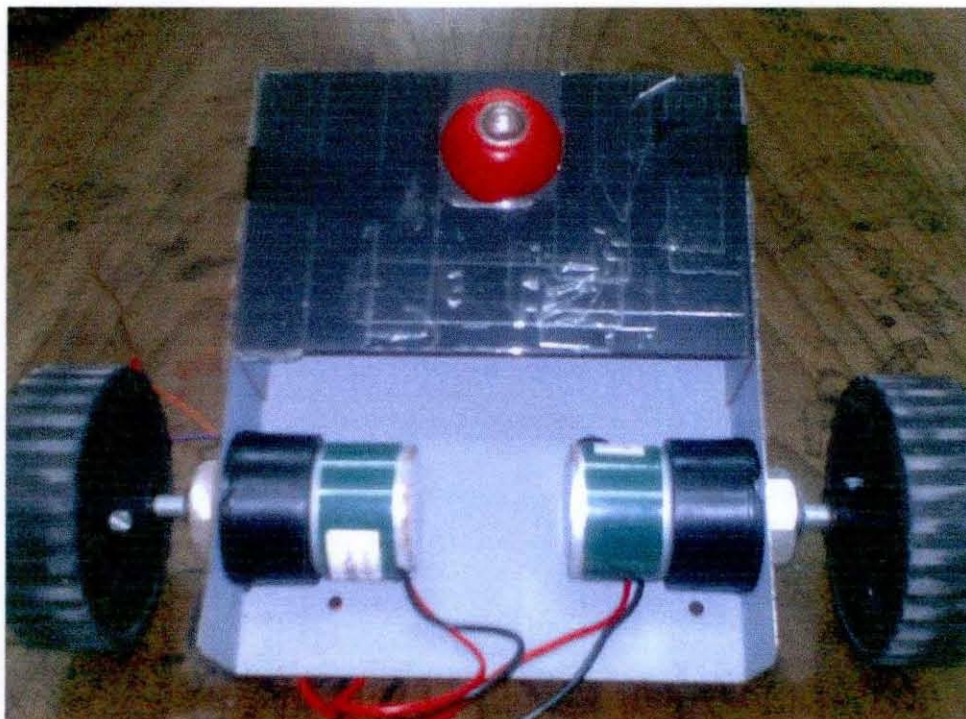


Figure 5:4.1(b): Internal Position of DC Motor and Supporter

4.2) Arm:

One of the most important parts of this project is the arm. Special care must be taken to construct the arm and it works according to the given instructions. Shape of the arm, weight, and load management, all these are very important factors to be considered so that the arm can work properly. Both the upper arm and fore arm have been made by thin iron plate. Upper arm is jointed with base through shoulder joint and forearm is jointed with upper arm at the elbow joint and at the wrist joint gripper is jointed with forearm. Some loads have been added at the back to manage the load.

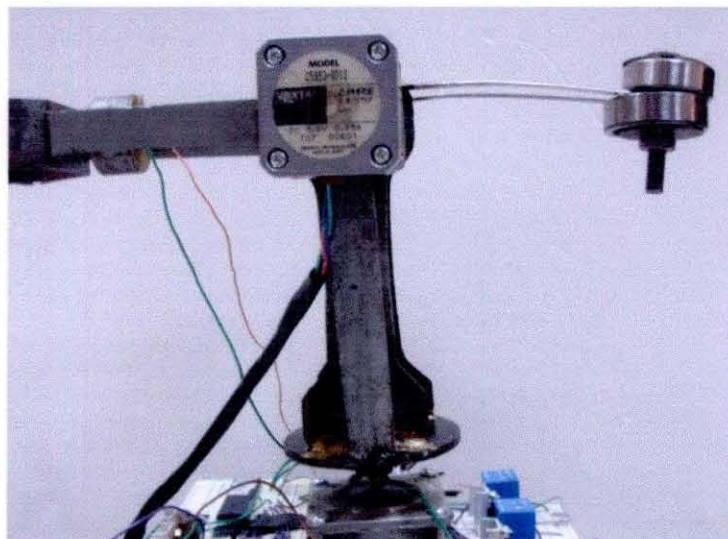


Figure 6:4.2: Upper Arm and Forearm Jointed with Base Stepper Motor

4.3) Gripper:

Gripper is made of thin steel sheet, jointed with the wrist joint. DC motor is used at the wrist joint to control the picking, holding and releasing actions.

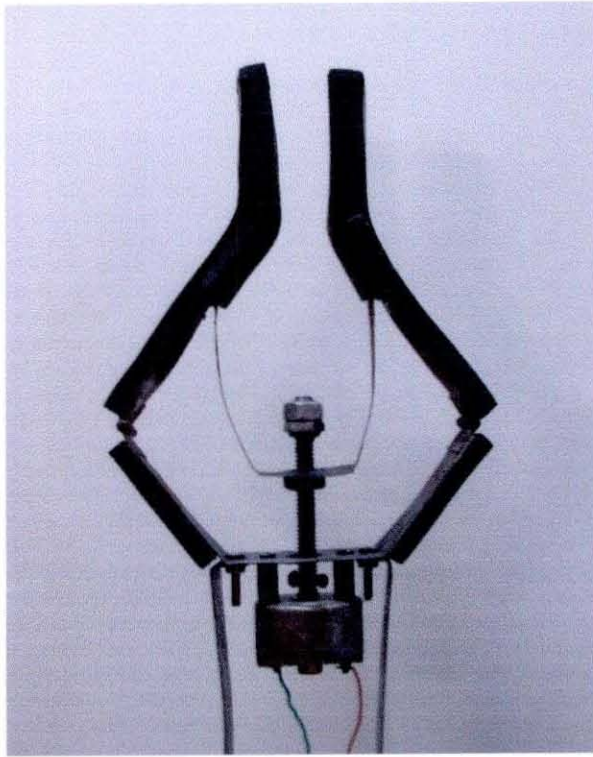


Figure 7:4.3: Gripper

CHAPTER V

Descriptions of Motors

While considering the preliminary design of the arm, its configurations: keeping in mind the possible actuators of the arm manipulator is actually a good idea. Types of links, joints are also considered while the arm manipulator is constructed. As mentioned earlier, actuators are the “muscles” of the manipulator, are made up of stepper motors, servo motors, hydraulic cylinders etc.

5.1) Stepper Motor:

Stepper motors are versatile, long lasting and very simple to use. Stepper motors come in different forms and principles of applications. Unlike regular DC/ AC motors, these motors do not rotate when connected to the power supply. These rotate only when the magnetic field is rotated through different windings.

A stepper motor is a brushless, synchronous electric motor that can divide a full rotation into a large number of steps. The motor's position can be controlled precisely without any feedback mechanism, as long as the motor is carefully sized to the application.

A stepper motor's shaft has permanent magnets attached to it. Around the body of the motor is a series of coils that create a magnetic field that interacts with the permanent magnets. When these coils are turned on and off the magnetic field cause the rotor to move. As the coils are turned on and off in sequence the motor will rotate forward or reverse. This sequence is called the “Phase Pattern” and there are several types of patterns that will cause the motor to turn. Common types are full-double phase, full-single phase, and half step. To make stepper motor rotate, coils must be turned on and off constantly. If simply one coil is energized, the motor will just jump to that position and stay there resisting change. This energized coil pulls full current even though the motor is not turning. The

stepper motor will generate lots of heat at standstill. The ability to stay put at one position rigidly is often an advantage of stepper motors. The torque at standstill is called the "Holding Torque". Because steppers can be controlled by turning coils on and off, these are easy to control using digital circuitry and microcontroller chips. The controller simply energizes the coils in a certain pattern and the motor will move accordingly. At any given time the computer will know the position of the motor since the number of steps given can be tracked. This is true only if some outside force of greater strength than the motor has not interfered with the motion. Most stepper motor control systems will have a home switch associated with each motor that will allow the software to determine the starting or reference "home" position.

There are two basic winding arrangements for the electromagnetic coils in a two phase stepper motors: 1) Bipolar and 2) Unipolar.

5.1.1) Bipolar Stepper Motor:

Bipolar motors have a single winding per phase. The current in a winding needs to be reversed in order to reverse a magnetic pole, so the driving circuit must be more complicated, typically with an H-bridge arrangement. There are two leads per phase, none are common. Static friction effects have been observed with certain drive topologies. Unlike unipolar motors, these motors have no center taps. The advantage of not having center taps is that current flows through the entire winding instead of just half of the windings at a time. As a result, more torque is produced rather than unipolar motors and for this reason; more complex control circuitry is required.

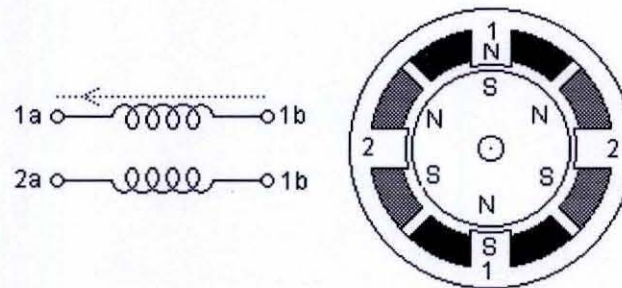


Figure 8:5.1.1: Internal Winding of Bipolar Stepper Motor

5.1.2) Unipolar Stepper Motor:

A unipolar stepper motor has two windings per phase, one for each direction of magnetic field and each with a center tap. Since in this arrangement a magnetic pole can be reversed without switching the direction of current, the commutation circuit can be made very simple for each winding. Typically, given a phase, one end of each winding is made common: giving three leads per phase and six leads for a typical two phase motor. Often, these two phase commons are internally joined, so the motor has only five leads. Regardless the number of wires, the center tap is connected to the power supply and the ends of the wires are alternately connected to ground.

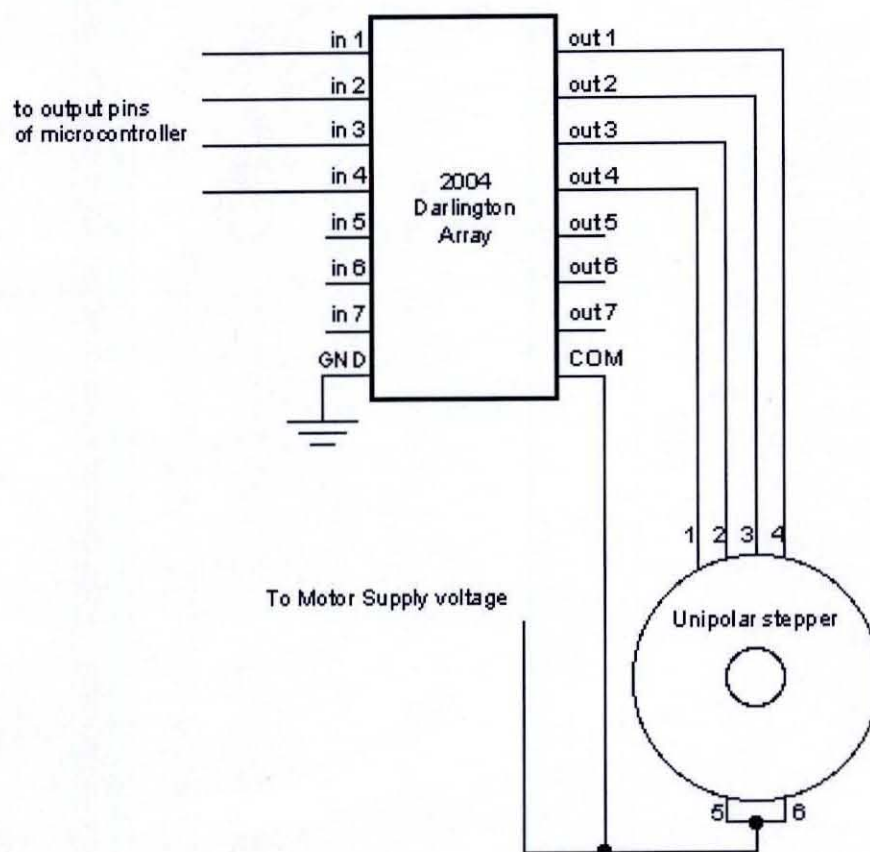


Figure 9: 5.1.2(a): Unipolar Stepper Motor

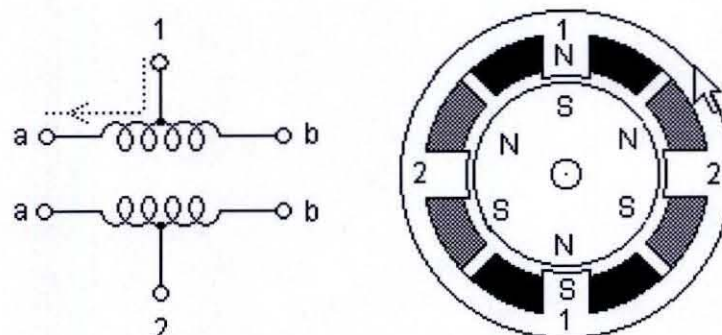


Figure 10:5.1.2(b): Internal Winding of Unipolar Stepper Motor

In our project, we are using unipolar stepper motors. The reasons behind using this type of motors are described in the following:

5.1.3) Why Unipolar Stepper Motors:

As a bipolar stepper motor uses the entire windings while energized, it produces approximately 30% more torque than unipolar stepper motor of same volume. The higher torque generated by bipolar stepper motors requires more complex control circuitry than unipolar stepper motors which is complicated to uphold properly and has an effect on the cost of applications. Another important reason to avoid bipolar stepper motors for our project is if we wish to rotate the direction of rotation of the motor we can do that easily for unipolar motor just by changing the code 1 to 0, but for Bipolar motor an external H bridge or relay coil will be required which can again complicates our project. For these reasons, we are using unipolar stepper motors.

Specifications of Base stepper motor:

- 1) 23LM-K307-PL
- 2) 1.8 Degree per Step.
- 3) 1.7 A.
- 4) 5 V.

Combinations of Pins and Colors:
Of Base stepper Motor

- 1) Red
- 2) Green/White
- 3) Red/White
- 4) Green
- 5) VCC: White and Black

Specifications of Elbow Joint Stepper Motor:

- 1) PK244-03A
- 2) 1.8 Degree per Step
- 3) 0.4 A.
- 4) 12 V.

Combinations of Pins and Colors:
Of Elbow Joint stepper Motor

- 1) Black
- 2) Red
- 3) Green
- 4) Blue
- 5) VCC: Yellow and White.

5.2) Stepper Motor Driver Circuit:

Stepper motors do not rotate when connected to the power supply. They rotate only when the magnetic field is rotated through different windings. The maximum torque develops when the motor do not turn. Even when not powered, motors have a residual torque called "Holding Torque" which requires an external torque to turn the motor. As a result, all stepper motors need a driver circuit to be turned.

In our project, stepper motor driver has been used to drive the stepper motors more precisely. As we all know that ULN 2003 has been used as the motor driver which consists of a high voltage and high current Darlington transistor arrays of seven NPN Darlington pairs that features high-voltage and high-current outputs . Using ULN 2003, at best 500-700 mA current is possible to achieve but much more current is needed to drive the motors of our project. That is why we have made our own Darlington Pairs to provide more current.

Two arrays of Darlington pair are made for two stepper motors. One stepper motor is being used at the base and another one is being used at the elbow joint. To drive the Base stepper motor, four transistors (TIP 122) have been used to make the Darlington Pair. Base of each transistor is connected with the input, coming from microcontroller's port B0 to port B3. Output is achieved from the collectors of the transistors and each emitter is grounded. To drive the middle stepper motor which is jointed at the elbow joint, another four transistors (TIP 122) have been used to make the Darlington Pair. Base of each transistor is connected with the input, coming from microcontroller's port B4 to port B7. Output is achieved from the collectors of the transistors and each emitter

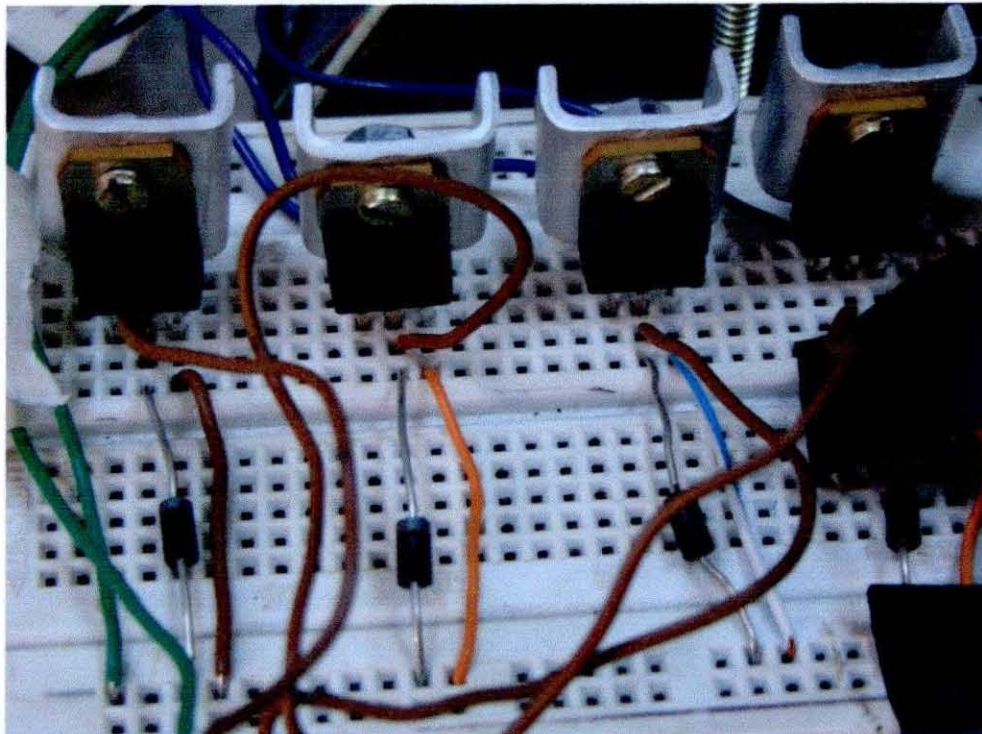


Figure 11:5.2: Stepper Motor Driver Circuit

5.3) DC Motor:

DC motors are very common in industry and have been used for a long time. As a result, they are reliable, sturdy, and relatively powerful.

In DC motors, the stator is a set of fixed permanent magnets, creating a fixed magnetic field, while the rotor carries the current. The direction of current is changed continuously through brushes and commutators, causing the rotor to rotate. Conversely, if the rotor is rotated within the magnetic field, a DC current will develop and the motor will act as a generator though the output is DC, but not constant.

DC motors are used in the base with the wheels to control forward and backward movements. Another DC motor is used to control the gripper in our project. Using a relay circuit, four combinations have been made to manipulate the direction of rotation of the DC motor and the gripper works accordingly.

5.4) Relay and Relay circuit:

5.4.1) Relay:

A relay is an electrically operated switch. Current flowing through the coil of the relay creates a magnetic field which attracts a lever and changes the switch contacts. The coil current can be on or off, so relays have two switch positions. Relays find applications where it is necessary to control a circuit by a low-power signal, or where several circuits or combinations must be controlled by one signal. A type of relay that can handle the high power required to directly drive an electric motor is called a Contactor (A contactor is an electrically controlled switch used to switch power or control circuit. A contactor is controlled by a circuit which has a much lower power level than the switched circuit). Solid-state relays control power circuits with no moving parts, instead using a semiconductor device to perform switching.

5.4.2) Relay Circuit:

A relay circuit is typically a smaller switch or device which drives (opens/closes) an electric switch that is capable of carrying much larger amount of current and which operates the coil from one source and uses a separate power source to drive another device. A relay circuit does not imply massive current switching. It is a means to isolate one source to another.

A relay circuit is a circuit that uses a small mechanical switch or a semiconductor device to energize a relay, which will then close a contact set to complete another circuit. In this project, relay circuit is used to change the direction of rotation of the DC motor which is placed at the gripper. To make our own relay circuit, we have used two 6 volt relays (SRU-06VDC-SL-C), two transistors (TIP 41). Input is coming from microcontroller's port D0 and D1 and connected to the base of each transistor. Each emitter is grounded and each collector is connected to the VCC through an electromagnet coil. Output is being collected from the 5th

pin of each relay and these outputs are connected with the DC motor which is maneuvering the gripper. Four combinations are used to maneuver the gripper action. The combinations are-

- 1) 00 = gripper closes
- 2) 11 = gripper opens
- 3) 01 = no actions
- 4) 10 = no actions

When polarity changes, at different combinations, relay gives desired outputs and DC motor rotates clockwise and anti-clockwise and gripper performs desired actions accordingly as well.

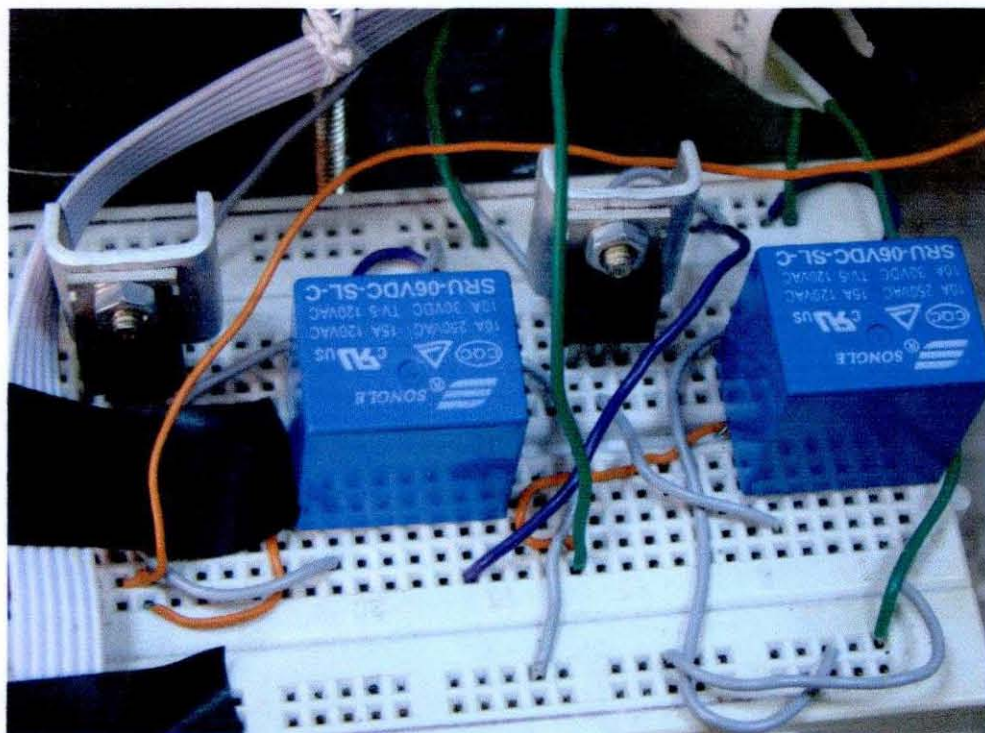


Figure 12:5.4.2(a): Relay Circuit

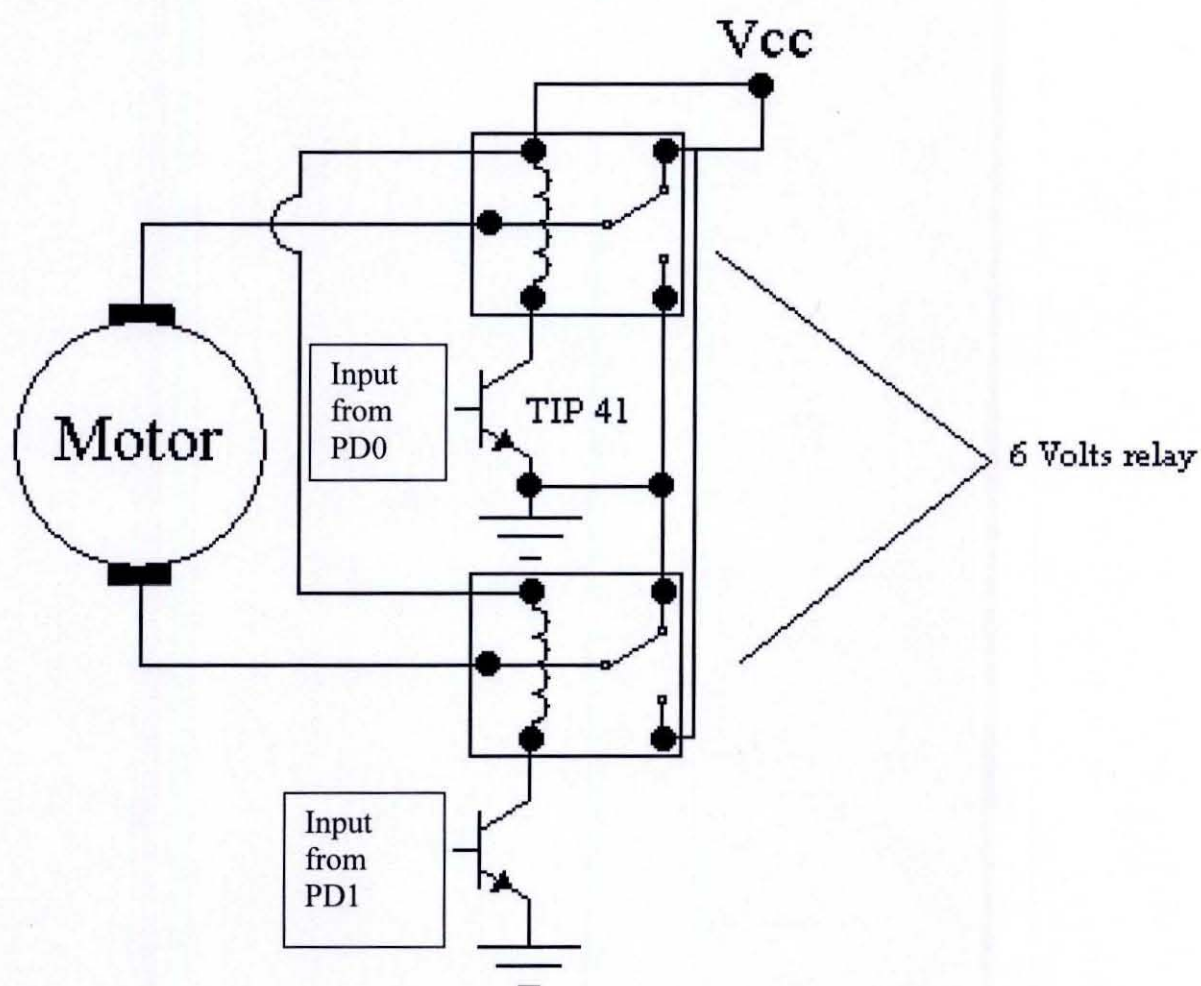


Figure 13:5.4.2(b): Relay Circuit Diagram

5.5) Microcontroller:

A microcontroller can be considered a self-contained system with a processor; memory can be used with an embedded system and only the software needs to be added. Microcontrollers are intelligent controller and these are reprogrammable devices. The majority of microcontrollers in use today are embedded in other machinery, such as automobiles, telephones, appliances, and peripherals for computer systems. These are called embedded systems. While some embedded systems are very sophisticated, many have minimal requirements for memory and program length, with low software complexity and typical input and output devices include switches, relays, solenoids, LEDs etc are required.

In this project, an 8-bit AVR microcontroller with 32K bytes is used as the Processor. Atmel AVR is using "RISC" architecture (Reduced Instruction Set Computer) which is very user friendly with low software complexity and larger memory.. Program simulators and downloader can be made easily and downloader is easy to use also. ATmega32 is a 40 pin package. It has 32KB of programmable memory that a hex file maximum of 32 KB can be loaded into IC. It has four ports for input and output. Namely PORTA, PORTB, PORTC and PORTD. Every port has 8 pins for I/O. All the ports are capable of both input and output.

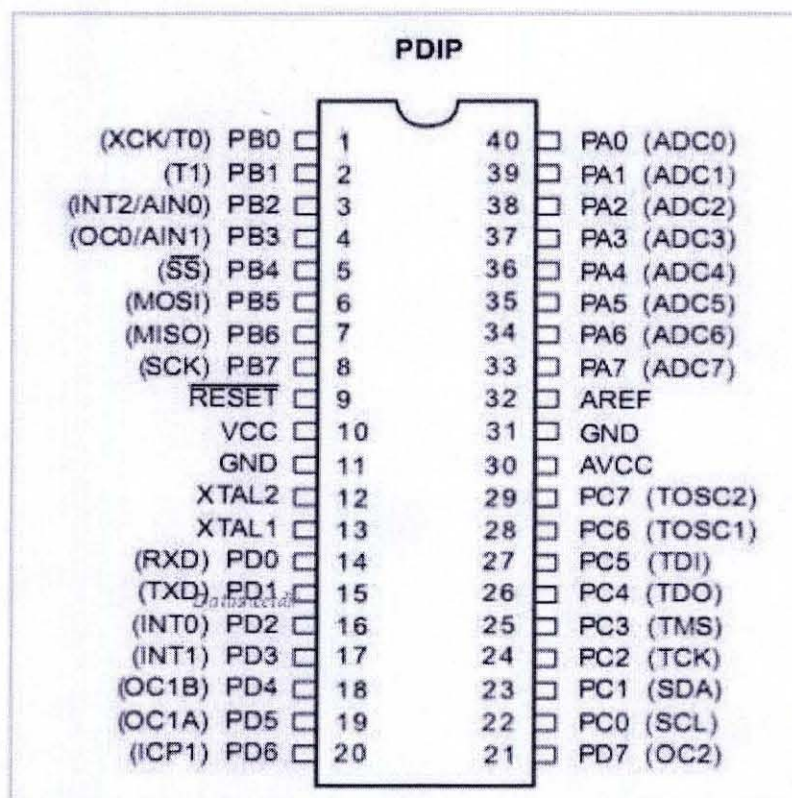


Figure 14: 5.5: Pin Configuration of Atmega 32

CHAPTER VI

Applications

As designed and implemented, the robotic arm manipulator can perform embedded picking, placing and can move around independently. According to its efficiency, two applications have been decided to be done by the arm manipulator. The applications are

- 1) Picking and placing and
- 2) Playing Hockey

6.1) Picking and Placing:

At the beginning, the arm will be placed at its home position (a certain position which will be previously decided). After getting power supply, the base moves forward and the arm rotates 90 degrees at the right side. After that, forearm goes upward 43.2 degrees; then the gripper opens to pick the targeted object and car moves forward. Gripper picks the object and holds it and the forearm goes up 5 degrees. The base rotates 90 degrees at the right side and moves forward to place the object. Forearm goes down 5 degrees and gripper releases the object and again closes. After that, forearm goes down 43.2 degrees and the base rotates right 90 degrees again and moves forward to reach at the initial position.

6.2) Playing Hockey:

At the beginning, the arm will be placed at its home position (a certain position which will be previously decided). After getting power supply, the gripper closes to hold the hockey stick. After that base moves towards the ball and the forearm goes down 30 degrees. Then the arm rotates right 43.2 degrees and left 50.4 degrees to hit the ball. After hitting the ball, the

forearm goes upward 50.4 degrees and finally the ball goes to the goal post.

CHAPTER VII

Conclusion

7.1) Conclusion:

The world is getting revolutionized day by day. The older technologies are getting obsolete, giving way to the new generation of technologies. Hence, in the modern industrial & research world, robotic arms are getting in. The researchers in this field are putting all their efforts in making precise robots.

This project is aimed to serve as a prototype mobile robotic arm manipulator which can be used in industries as well as for other applications. In both applications, we have shown that this robotic arm manipulator can move around autonomously. It can pick and place objects according to given instructions as well. Using these specific properties, we can develop mobile robotic arms and use them in industries, super shops and hospitals to pick and place objects at the right place or distribute medicines and food among patients. By this initiative many industrial accidents can be avoided and human workers can be released from hazardous and monotonous tasks and placed in a more productive and interesting job.

7.2) Future Works:

Although this mobile robotic arm cannot perform tasks intelligently, in future we will improvise the system with the help of sensors to improve performance. To achieve more accuracy and better performance in future, light sensors might be used to detect different objects of different colors. Different features such as Image processing might be included along with the Voice recognition to make this project more efficient.

References

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Appendices

A. Picking and Placing Program:

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

#define F_CPU 8000000

void delay_ms(unsigned int ms){

    while(ms){
        _delay_ms(1.000);
        ms--;
    }
}

int main()
{
    DDRB=0b11111111;
    DDRD=0b11111111;

    unsigned int i;
    while(1){
//DC(grp) motor off
PORTD=0b00000010;

//car move forward
PORTD=0b00110010;
    delay_ms(2000);
//car stop
    PORTD=0b00000010;
    delay_ms(2000);
//base motor rotate 90 on PB0,PB1,PB2,PB3
    for(i=0;i<13;i++){

        PORTB=0b00000001;
        delay_ms(250);
        PORTB=0b00000010;
        delay_ms(250);
        PORTB=0b00000100;
        delay_ms(250);
        PORTB=0b00001000;
        delay_ms(250);
    }
}
```

```

//DEALAY FOR BASE MOTOR
    delay_ms(3000);
//MIDDLE motor rotate 30 on PB4,PB5,PB6,PB7
    for(i=0;i<6;i++){

        PORTB=0b10000000;
        delay_ms(250);
        PORTB=0b01000000;
        delay_ms(250);
        PORTB=0b00100000;
        delay_ms(250);
        PORTB=0b00010000;
        delay_ms(250);

    }

    //MIDDLE MOTOR DELAY 2 S

    delay_ms(2000);

//DC MOTOR OPEN ON PD0,PD1
    PORTD=0b00000011;
    delay_ms(500);
//DC MOTOR STOP
    PORTD=0b00000001;
//DC MOTOR DELAY 5 S
    delay_ms(6000);

//car move forward
PORTD=0b00110010;
    delay_ms(1000);
//car stop
    PORTD=0b00000010;
    delay_ms(1500);
//DC MOTOR CLOSE ON PD0,PD1
    PORTD=0b00000000;
    delay_ms(800);
//DC MOTOR STOP
    PORTD=0b00000010;
    delay_ms(4000);

//MIDDLE MOTOR ROTATE 5 FORWARD
    PORTB=0b10000000;
    delay_ms(250);
    PORTB=0b01000000;
    delay_ms(250);
    PORTB=0b00100000;
    delay_ms(250);
    PORTB=0b00010000;

    delay_ms(5000);

```

```

//car move backward
PORTD=0b01001010;
  delay_ms(1000);

//car stop
  PORTD=0b00000010;
  delay_ms(3000);

//car rotate right
  PORTD=0b00010010;
  delay_ms(1800);
//car stop
  PORTD=0b00000010;
  delay_ms(3000);
//car move forward & stop
  PORTD=0b00110010;
  delay_ms(2000);
  PORTD=0b00000010;
  delay_ms(10000);
//MIDDLE MOTOR ROTATE 5 REVERSE

  PORTB=0b00010000;
  delay_ms(250);
  PORTB=0b00100000;
  delay_ms(250);
  PORTB=0b01000000;
  delay_ms(250);
  PORTB=0b10000000;

  delay_ms(2000);
//DC MOTOR OPEN
  PORTD=0b00000011;
  delay_ms(500);
  PORTD=0b00000001;
  delay_ms(6000);
//car move backward & stop
  PORTD=0b01001010;
  delay_ms(400);
  PORTD=0b00000010;
  delay_ms(10000);

  //DC MOTOR CLOSE ON PD0,PD1
  PORTD=0b00000000;
  delay_ms(800);
  //DC MOTOR STOP
  PORTD=0b00000010;
  delay_ms(4000);
//MIDDLE MOTOR ROTATE [30] REVERSE
  for(i=0;i<6;i++){

```

```

        PORTB=0b00010000;
        delay_ms(250);
        PORTB=0b00100000;
        delay_ms(250);
        PORTB=0b01000000;
        delay_ms(250);
        PORTB=0b10000000;
        delay_ms(250);
    }

    delay_ms(2000);
    //car rotate right & stop
    PORTD=0b00010010;
    delay_ms(2000);
    PORTD=0b00000010;
    delay_ms(1000);
    PORTD=0b00110010;
    delay_ms(3000);
    PORTD=0b00000010;
    delay_ms(1000);
}
return 0;
}

```

B. Playing Hockey:

```

#include<avr/io.h>
#include<util/delay.h>

#define F_CPU 8000000

void delay_ms(unsigned int ms){

    while(ms){
        _delay_ms(1.000);
        ms--;
    }
}

int main()
{
    DDRB=0b11111111;
    DDRD=0b11111111;
}

```

```

    unsigned int i;
    while (1){
//DC(grp) motor off
PORTD=0b00000010;

//DC MOTOR colse ON PD0,PD1
PORTD=0b00000011;
delay_ms(20000);

//car move forward
PORTD=0b00110010;
    delay_ms(2000);
//car stop
PORTD=0b00000010;
    delay_ms(2000);

//MIDDLE motor rotate 30 on PB4,PB5,PB6,PB7
    for(i=0;i<5;i++){

        PORTB=0b00010000;
        delay_ms(250);
        PORTB=0b00100000;
        delay_ms(250);
        PORTB=0b01000000;
        delay_ms(250);
        PORTB=0b10000000;
        delay_ms(250);

    }

    delay_ms(2000);

//base motor rotate right 43+ on PB0,PB1,PB2,PB3
    for(i=0;i<6;i++){

        PORTB=0b00001000;
        delay_ms(250);
        PORTB=0b00000100;
        delay_ms(250);
        PORTB=0b00000010;
        delay_ms(250);
        PORTB=0b00000001;
        delay_ms(250);

    }

    delay_ms(2000);

//base motor rotate left 45+ on PB0,PB1,PB2,PB3
    for(i=0;i<7;i++){

```

```
    PORTB=0b00000001;
        delay_ms(250);
    PORTB=0b00000010;
        delay_ms(250);
    PORTB=0b00000100;
        delay_ms(250);
    PORTB=0b00001000;
        delay_ms(250);
}

delay_ms(2000);

//MIDDLE motor rotate 45+ on PB4,PB5,PB6,PB7
for(i=0;i<7;i++){

    PORTB=0b10000000;
        delay_ms(250);
    PORTB=0b01000000;
        delay_ms(250);
    PORTB=0b00100000;
        delay_ms(250);
    PORTB=0b00010000;
        delay_ms(250);

}

return 0;
}
```