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Sudan University of Science and Technology

College of Engineering

Electrical Engineering

A STEPPER MOTOR APPLICATION IN SMART DISH

تطبيق المحرك الخطوي في الطبق الذكي

A project Submitted in Partial Fulfillment for the Requirement of the Degree of B.Sc.(Honor) in Electrical Engineering

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الاية

قال تعالى :

(وَقُلِ اعْمَلُوا فَسَيَرَى اللَّهُ عَمَلَكُمْ وَرَسُولُهُ وَالْمُؤْمِنُونَ وَسَتُرَدُّونَ إِلَى عَالِمِ الْغَيْبِ وَالشَّهَادَةِ فَيُنَبِّئُكُم بِمَا كُنتُمْ تَعْمَلُونَ)

صدق الله العظيم

سورة التوبة الآيه (105)

DEDICATION

This project is lovingly dedicated to our respective parents who have been our constant source of inspiration. They have given us the drive and discipline to tackle any task with enthusiasm and determination. And as expected in every step in our career building, Without their love and support this project would not have been made possible.

ACKNOWLEDGEMENT

Project is like bridge between theoretical and practical working.in the accomplishment of this project successfully, many people have best owned upon me their blessings and support.

Primary we thank Allah for being able to complete this project with success. Then we would like to thank every engineer how gives us help or how giving us the information’s that's we were need and all the staff working in the mechanic workshop.

Abstract

A stepper motor can be looked upon as a digital electromagnetic device where each pulse input results in a discrete output (i.e. a definite angle of shaft rotation). There are different modes to drive stepper motor such as wave drive mode, full step drive mode, half step drive mode and micro stepping. In wave drive mode, one phase of stator windings is energized at a time. In full step drive mode, two phases are energized simultaneously. Half stepping can be achieved by alternating between the wave drive and full drive and the step angle is reduced by half. Finally micro stepping is obtained by deliberately making two phases currents unequal in the full drive mode.

In this project, we aim to study the application of stepper motor in Smart Dish using Adriano.

المستخلص

المحرك الخطوي هو عبارة عن جهاز كهرومغناطيسي رقمي يقوم بتحويل الاشارة المدخلة اليه في صورة نبضات الي حركة ميكانيكية متقطعة ينتج عنها حركة لمحرك بما يعرف بزاوية الخطوة. هنالك عدة طرق مختلفة يتم من خلالها التحكم في شكل و زاوية حركة العضو الدوار، سيتم في هذا المشروع دراسة اربع طرق منها وهي : طريقة التشغيل الموجي، وطريقة التشغيل الكامل، وطريقة التشغيل النصفي وطريقة التشغيل الدقيق، وسيتم دراسة تطبيق المحرك الخطوي في الطبق الذكي.

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LIST OF ABBREVIATIONS

D.C.	Direct Current
A.C.	Alternating Current
VR	Variable Reluctance
PM	Permanent Magnet
LNB	low-noise block downconverter
MCU	Microcontroller
emf	Electromotive force
MOSFET	Metal Oxide Semiconductor Field Effect Transistor
PWM	Pulse Width Modulation
RISC	Reduced Instruction Set Computer
ARM	Advanced RISC Machine
AVR	Alf and Vegards RISC Processor
ROM	Read Only Memory
EPROM	Erasable Programmable Read Only Memory
EEPROM	Electrically Erasable Programmable Read Only Memory
POWER PC	Performance Optimization with Enhanced RISC Performance Computing
IDE	Integrated Development Enviroment

Chapter One
Introduction

1.1 Overview

The stepper motors are used to through a fixed angular step in response to each input current pulse received by its controller. In recent years, there has been wide-spread demand of stepper motors because of the explosive growth of the computer industry. Their popularity is due to the fact that they can be controlled directly by computers, microprocessors and programmable controllers .

Stepper motor can be a good choice whenever controlled movement is required. They can be used in applications where we need to control rotation angle, speed, position and synchronism such as printers, plotters, robotics, hard disk drives, fax machines, automotive and many more.

1.2 Research Problems

Stepper motor is a brushless D.C. electric motor that divides a full rotation into a number of equal steps. In other words, a stepper motor is a special kind of motor that moves in individual steps. And stepper motors include low efficiency where motors draws power regardless of load, Torque drops rapidly with speed, low accuracy, no feedback to indicate missed steps, low torque of inertia ratio, motor gets very hot in high performance, motor won’t ‘pick up’ after momentary overload, motors low output power for size and weight.

Motor is audibly very noisy at moderate to high speeds and requires microstepping to move smoothly .

The shaft spindle of a stepper motor rotates in discrete step increments when electrical command pulses are applied to it in the proper sequence. The motors rotation has several direct relationships to these applied input pulses. The sequence of the applied pulses is directly related to the direction of motor shafts rotation.

The speed of the motor shafts rotation is directly related to the frequency of the input pulses and the length of rotation is directly related to the number of input pulses applied .

There are different modes to use a sequence of input pulses to energize motor coils according to the number of energized phases. These modes are wave drive mode, full step drive mode, half step drive mode and microstepping.

1.3 Objectives

The objectives of this project are: Study the stepper motor basics and theory. Study and simulate the application of stepper motor in smart dish.

1.4 the Project Layout

This report is organized as follows:

Chapter 2: This chapter reviews stepper motor working theory, its applications and the waveforms used to drive it.

Chapter 3: This chapter describes the principles of speed control of the stepper motor, the drive circuit and microstepping drive.

Chapter 4: This chapter represents the application of the stepper motor in smart dish.

Chapter 5: This chapter contains conclusions of the overall study of the project.

Chapter Two

The Stepper Motors

2.1 Introduction

An electric motor is an electric machine that converts electrical energy into mechanical energy.

The principle behind production of mechanical force by the interactions of an electric current and a magnetic field, Ampère's force law, was discovered by André-Marie Ampère in 1820. The conversion of electrical energy into mechanical energy by electromagnetic means was demonstrated by the British scientist Michael Faraday in 1821. A free-hanging wire was dipped into a pool of mercury, on which a permanent magnet (PM) was placed. When a current was passed through the wire, the wire rotated around the magnet, showing that the current gave rise to a close circular magnetic field around the wire. Though Barlow's wheel was an early refinement to this Faraday demonstration, these and similar homopolar motors were to remain unsuited to practical application until late in the century.

A stepper motor is an electromechanical device which converts electrical pulses into discrete mechanical movements. In other words, it’s a special kind of motor that moves in individual steps which are usually 0.9 degrees each. Each step is controlled by energizing one or more of the coils inside the motor which then interacts with the permanent magnets attached to the shaft. Turning these coils on and off in sequence will cause the motor to rotate forward or reverse.

2.2 Step Angle

The angle through which the motor shaft rotates for each command pulse is called the step angle (β). Smaller the step angle, greater the number of steps per revolution and higher the resolution or accuracy of positioning obtained. The step angle can be as small as 0.72 or as large as 90 . But the most common step sizes are 1.8 , 2.5 , 7.5 , and 15 The value of step angle can be expressed either in terms of the rotor and stator poles (teeth) N_r and N_s respectively, or in terms of stator phases (*m*) and the number of rotor teeth.

$$\beta = \frac{N_s - N_r}{N_s \times N_r} \times 360^{\circ} \tag{2.1}$$

$$\beta = \frac{360^{\circ}}{\text{No. of stator phases} \times \text{No. of rotor teeth}} = \frac{360^{\circ}}{m \times N_r} \tag{2.2}$$

For example, if $N_s = 8$ and $N_r = 6$ then

$$\beta = \frac{8-6}{8 \times 6} \times 360^{\circ} = 15^{\circ}$$

Resolution is giver by the number of steps needed to complete one revolution of the rotor shaft. Higher the resolution, greater the accuracy of positioning of objects by the motor.

$$\text{Resoltuion} = \text{No. of steps per revolution} = \frac{360^{\circ}}{\beta} \tag{2.3}$$

The stepper motor has the extraordinary ability to operate at very high stepping rates (up to 20,000 steps per seconds in some motors) and yet to remain falling in synchronism with the command pulses. When the pulse rate is high, the shaft rotation seems continuous.

Operation at high speeds is called (slewing). When in the slewing range, the motor generally emits an audible whine having of fundamental frequency equal to stepping rate. If *f* is the stepping frequency (or pulse rate) in pulses per second (pps) and β is the step angle, then motor shaft speed is given by

$$n = \beta \times \frac{f}{360^{\circ}} = \text{pulse frequency resolution} \quad (2.4)$$

Stepper motor are designed to operate for long periods with the rotor held in a fixed position and with rated current following in stator windings.

2.3 The types of the stepper motors

The types of the stepper motor are:

2.3.1 Variable Reluctance Stepper Motor

This type of stepper motor has been around for a long time. It is probably the easiest to understand from a structural point of view. Figure 2.1 shows a cross section of a typical V.R. stepper motor. This type of motor consists of a soft iron multi-toothed rotor and a wound stator. When the stator windings are energized with D.C. current the pole

become magnetized. Rotation occurs when the rotor teeth are attracted to the energized stator poles.

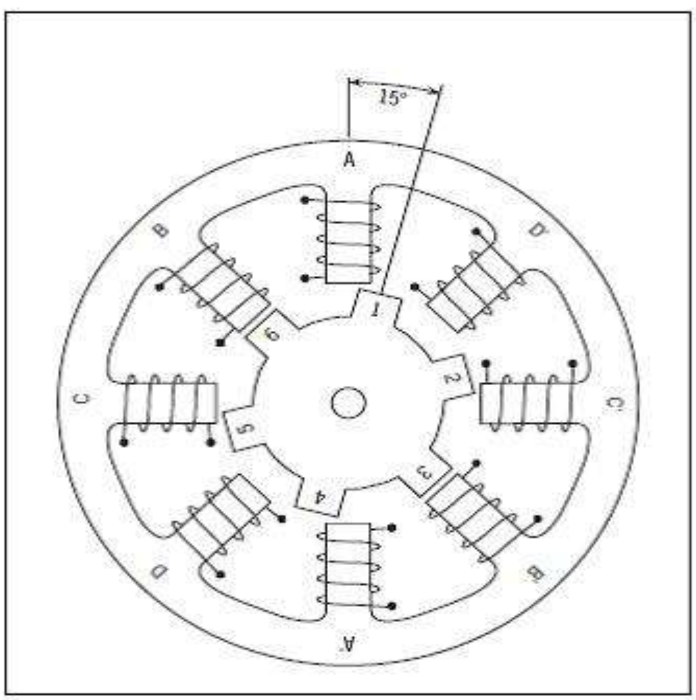

Figure (2.1) represent Cross-section of a variable reluctance (VR) motor

2.3.2. Permanent Magnet Stepper Motor (PM)

Figure (2.2) shows permanent magnet stepper motor. Often referred to as a “tin can” or “can stock” motor. The permanent magnet step motor is a low cost and low resolution type motor with typical step angles of 7.5 to 15 (48 to 24 steps/revolution). PM motors as the name implies have permanent magnets added to the motor structure. The rotor no longer has teeth as with the VR motor. Instead the rotor is magnetized with alternating north and south poles situated in a straight line parallel to the rotor shaft. These magnetized rotor poles provide an increased magnetic flux intensity and because of this the PM motor exhibits improved torque characteristics when compared with the VR type. Permanent magnet stepper motor has two types, which are unipolar and bipolar motors.

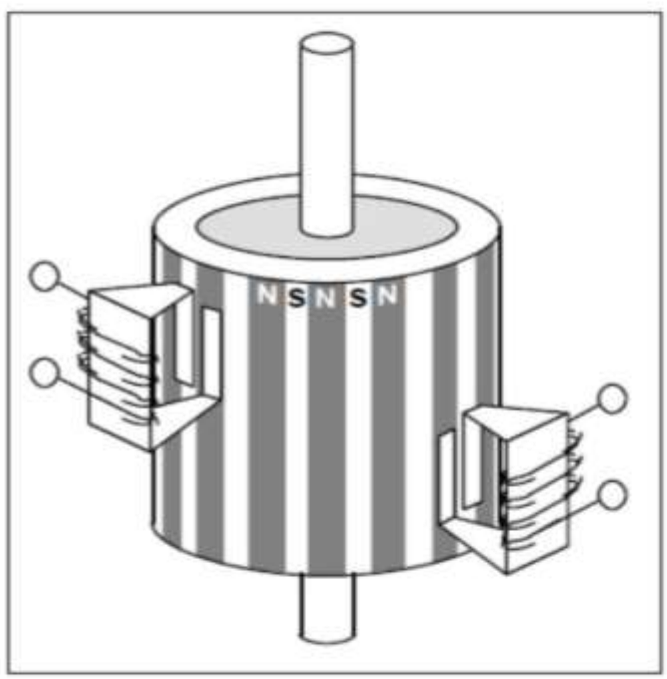

Figure (2.2) PM or tin-can stepper motor

- Unipolar Motors

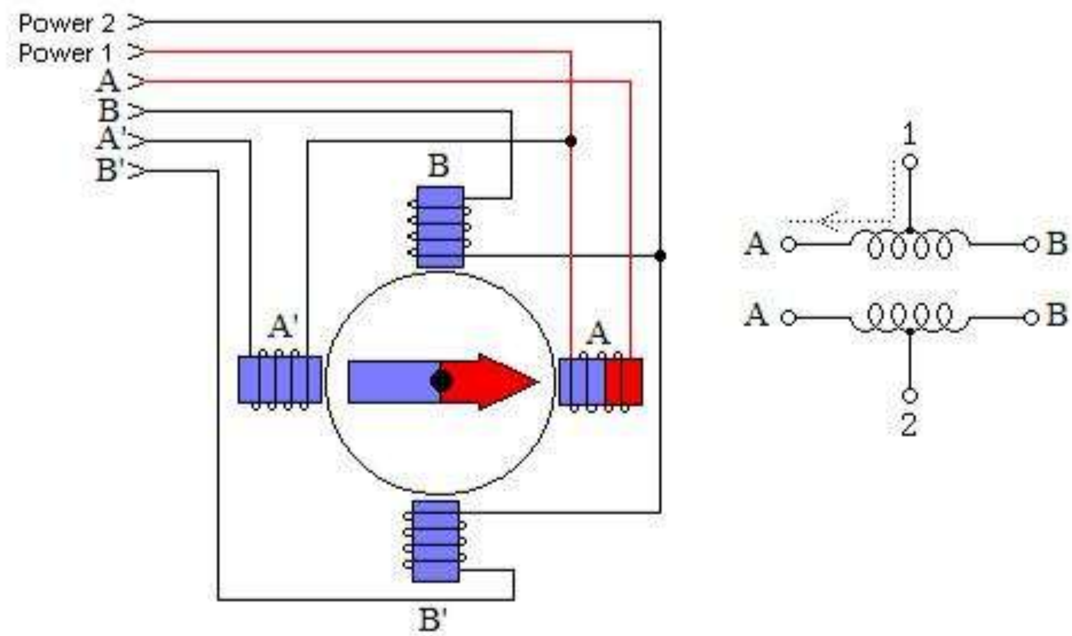

Figure (2.3) represents unipolar motors

A unipolar stepper motor (shown in figure 2.3) has one winding with center tap per phase. Each section of windings is switched on for each direction of magnetic field. 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, the center tap 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. A microcontroller or stepper motor controller can be used to activate the driver in the right order, and this ease of operation makes unipolar motors popular with hobbyists; they are probably the cheapest way to get precise angular movements.

- **Bipolar Motors**

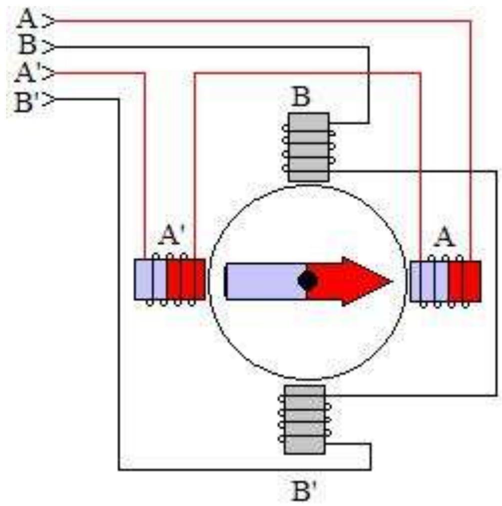

Figure (2.4) represents bipolar stepper motor

Bipolar motors (shown in figure 2.4) 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. There are two leads per phase, none are common.

Because windings are better utilized, they are more powerful than a unipolar motor of the same weight. This is due to the physical space occupied by the windings. A unipolar motor has twice the amount of wire in the same space, but only half used at any point in time, hence is 50% efficient. Though a bipolar stepper motor is more complicated to drive, the abundance of driver chips means this is much less difficult to achieve.

2.3.3 Hybrid Synchronous Stepper Motor

Figure (2.5) shows this type of stepper motors. It is more expensive than the PM stepper motor but provides better performance with respect to step resolution, torque and speed. Typical step angles for the HB stepper motor range from 3.6 to 0.9 (100 to 400 steps per revolution). The hybrid stepper motor combines the best features of both the PM and VR type stepper motors. The rotor is multi-toothed like the VR motor and contains an axially magnetized concentric magnet around its shaft. The teeth on the rotor provide an even better path which helps guide the magnetic flux to preferred locations in the air-gap. This further increases the detent, holding and dynamic torque characteristics of the motor when compared with both the VR and PM types.

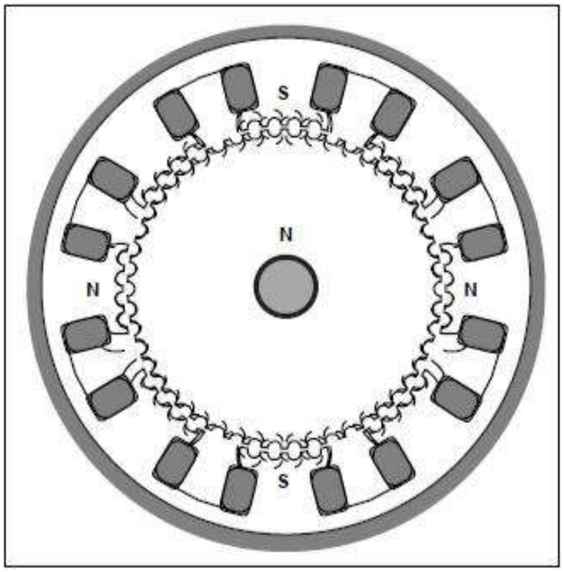

Figure (2.5) represent Cross-section of a hybrid stepper motor

2.4 Differences Between Stepper Motor and D.C. Servo Motor

The main difference between stepper motors and D.C. servo motors that steppers can be used "open-loop" without the need for expensive encoders to check their position. Other differences can be summarized as:

Steppers are susceptible to missing steps. The controller won't know if external torque stalls the motor. A higher torque margin is therefore required. Steppers should be avoided where external conditions may cause large torques to be applied. Steppers are easy to drive, the software can be written easily allowing the microcontroller to control a stepper motor directly with just a driver chip.

Servos are more complex to drive and most applications rely on third-party servo controller boards

2.5 Applications of Stepper Motor

Stepper motors are used in a wide variety of applications in industry, including computer peripherals, business machines, motion control, and robotics, which are included in process control and machine tool applications.

2.5.1 Dot Matrix printers

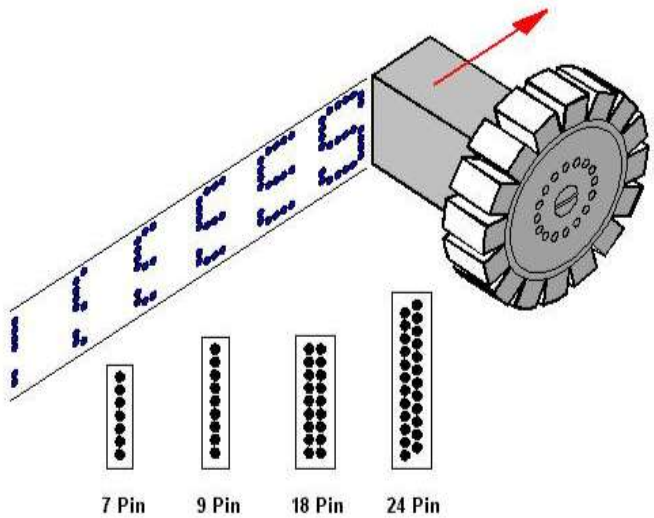

Figure (2.6) represents dot matrix printers

Figure (2.6) shows dot matrix printing or impact matrix printing which is a type of computer printing which uses a print head that runs back and forth, or in an up and down motion, on the page and prints by impact, striking an ink-soaked cloth ribbon against the paper. The printer head is attached to a metal bar that ensures correct alignment, but horizontal positioning is controlled by a rubber band that attaches to sprockets on two wheels at each side which is then driven with an electric motor. Actual position can be found out either by dead count using a stepper motor, rotary encoder attached to one wheel or a transparent plastic band with markings that is read by an optical sensor on the printer head.

2.5.2 Robotics

In robotics stepper motors are primarily used in stationary robots as they tend to consume quite a lot of power. They are ideal for movements that have to be accurate and are larger than 180°.By using control devices (e.g. microcontrollers) and push buttons or Joy sticks the movement of the robot can be controlled by transferring the motion from the stepper motor.

Figure (2.7) shows robotic arm.

2.5.3 Precise Industrial Controls

Stepper motor can be used in industrial operations and its uses can be summarized in table 2.1

Table 2. 1 Uses of stepper motor application

Application	**Use**
Card Reader	position cards
Copy Machine	paper feed
Banking Systems	credit card positioning
Banking Systems	paper feed
Typewriters (automatic)	head positioning
Typewriters (automatic)	paper feed
Copy Machine	lens positioning
Card Sorter	route card flow

2.6 Stepper Motor command waveform

Stepper motors have input pins or contacts that allow current from a supply source into the coil windings of the motor. Pulsed waveforms in the correct pattern can be used to create the electromagnetic fields needed to drive the motor. Depending on the design and characteristics of the stepper motor and the motor performance desired, some waveforms work better than others. Although there are a few options to choose from when selecting a waveform to drive a two phase PM stepper motor, such as full-stepping or half-stepping**.** Figure 2.8 shows detailed unipolar and bipolar stepper motor with indicators for each movement of the different driving modes.

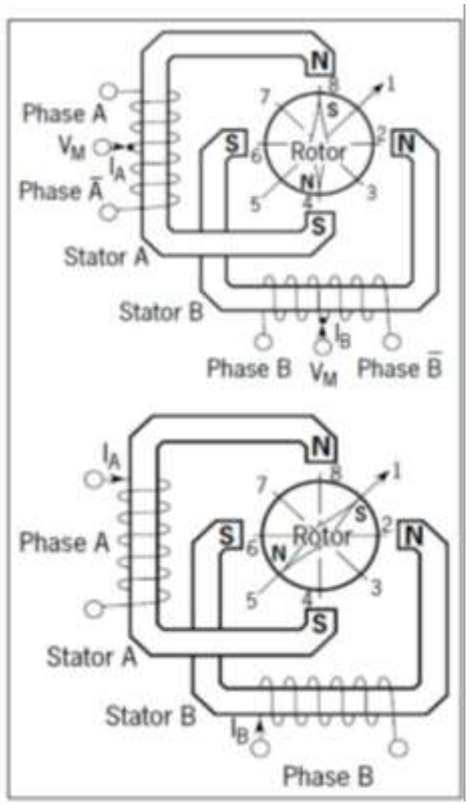

Figure (2.8) Unipolar and bipolar wound stepper motor

2.6.1 Wave Drive (one phase on)

In Wave Drive only one winding is energized at any given time. The stator is energized according to the sequence which shown in figure (2.9) and the rotor steps from position (8 → 2→ 4 → 6). For unipolar and bipolar wound motors with the same winding parameters this excitation mode would result in the same mechanical position. The disadvantage of this drive mode is that in the unipolar wound motor you are only using 25% and in the bipolar motor only 50% of the total motor winding at any given time. This means that you are not getting the maximum torque output from the motor.

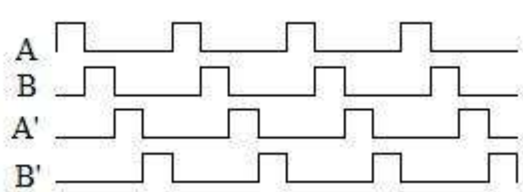

Figure (2.9) represent Wave Drive Waveform

2.6.2 Full Step Drive (two phases on)

In Full Step Drive you are energizing two phases at any given time. The stator is energized according to the sequence which shown in figure (2.10) and the rotor steps from position $(1 \rightarrow 3 \rightarrow 5 \rightarrow 7)$. Full step mode results in the same angular movement as one phase on drive but the mechanical position is offset by one half of a full step. The torque output of the unipolar wound motor is lower than the bipolar motor (for motors with the same winding parameters) since the unipolar motor uses only 50% of the available winding while the bipolar motor uses the entire winding.

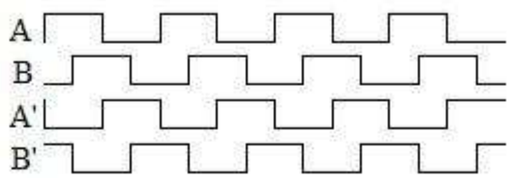

Figure (2.10) represent Full Step Drive Waveform

2.6.3 Half Step Drive (one and two phases on)

Half Step Drive combines both wave and full step (one and two phases on) drive modes. Every second step only one phase is energized and during the other steps one phase on each stator. The stator is energized according to the sequence which shown in figure (2.11) and the rotor steps from position $(1 \rightarrow 2 \rightarrow 3 \rightarrow 4 \rightarrow 5 \rightarrow 6 \rightarrow 7 \rightarrow 8)$. This results in angular movements that are half of those in 1- or 2-phases-on drive modes. Half stepping can reduce a phenomena referred to as resonance which can be experienced in 1- or 2- phases-on drive modes.

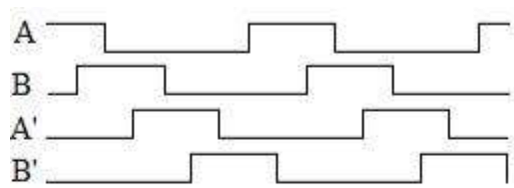

Figure (2.11) represent Half Step Drive Waveform

The excitation sequences for the drive modes are summarized in Table 2.2.

Table 2. 2 Excitation sequences for different drive modes

Wave Drive					Full Step Drive				Half Step Drive							
phase	1	2	3	4	1	2	3	4	1	2	3	4	5	6	7	8
A	1	0	0	0	1	0	0	1	1	0	0	0	0	0	1	1
B	0	1	0	0	1	1	0	0	1	1	1	0	0	0	0	0
$A^{/}$	0	0	1	0	0	1	1	0	0	0	1	1	1	0	0	0
$B^{/}$	0	0	0	1	0	0	1	1	0	0	0	0	0	1	1	1

2.7 Stepper motor construction and theory

The principle of working of stepper motor is electro-magnetism. It constructs of a rotor that is of permanent magnet and a stator that is of electromagnets. Figure (2.12) shows the construction of a practical stepper motor.

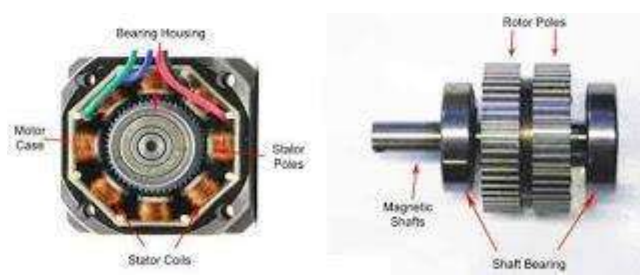

Figure (2.12) represent Practical Stepper Motor

Now when we gives supply to stator's winding. There will be a magnetic field developed in the stator. Now rotor of motor that is made up of permanent magnet, will try to move with the revolving magnetic field of stator. This is the basic principle of working of stepper motor. Now we are going to discuss its types. In this section you will find the real method of working of specific type of stepper motor.

2.7.1 Permanent Magnet Type Stepper Motor

The permanent magnet type stepper motor shown in figure (2.13) has a stator, that is of electromagnets and a rotor that is of Permanent Magnet, therefore this motor is called permanent magnet type stepper motor. When we gives supply to the stator, the winding of stator is energized and hence produces magnetic field. As described above, the rotor is made up of permanent magnet, that is why it tends to follow the revolving field. Thus an stepper motor works. The speed or torque of a permanent magnet type motor is changed by the number of poles used in stator, If we use a large number of poles in stator then the speed of motor will increase and if we use a less number of poles then the speed will decrease.

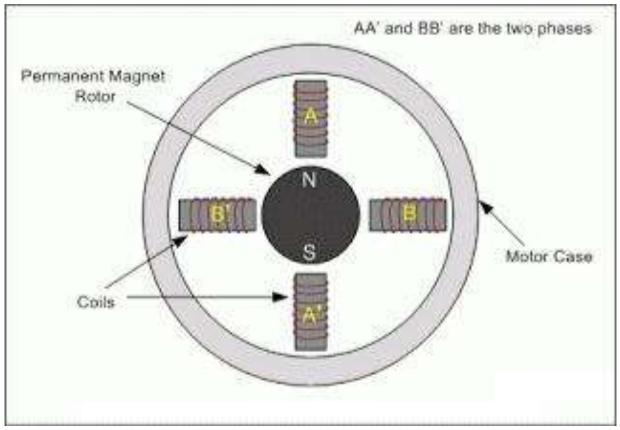

Figure (2.13) represent Two-Phase Permanent Magnet Type Stepper Motor

2.7.2 Variable Reluctance Motor

In Variable reluctance stepper motor shown in figure (2.14), we uses a non-magnetic iron core rotor, which has winding turned on its surface. The stator is same as used in the Permanent Type Stepper Motor. When we apply supply to the stator, a magnetic field is induced in the stator winding which causes an emf. induction in the rotor's winding, thus a magnetic field is also set up in the rotor which tends to follow the magnetic field of stator. The speed control method is almost same as in the permanent magnet type motor. In this motor we can increase the speed by increasing the number of poles of stator as well as by increasing the number of teeth of rotor and vice versa.

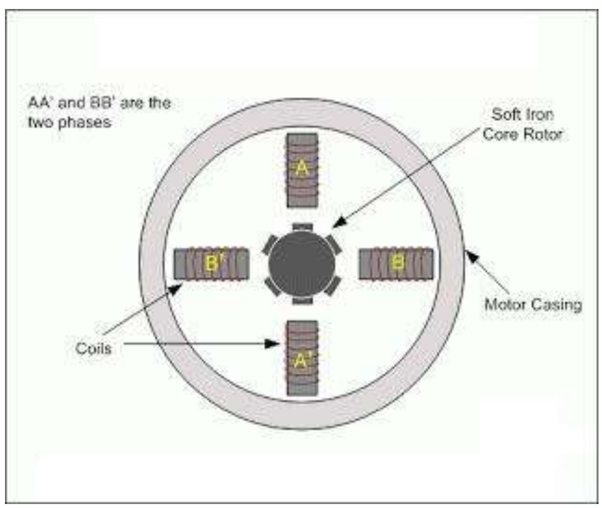

Figure (2.14) represent Two-Phase Variable Reluctance Stepper Motor

2.7.3 Hybrid Type Stepper Motor

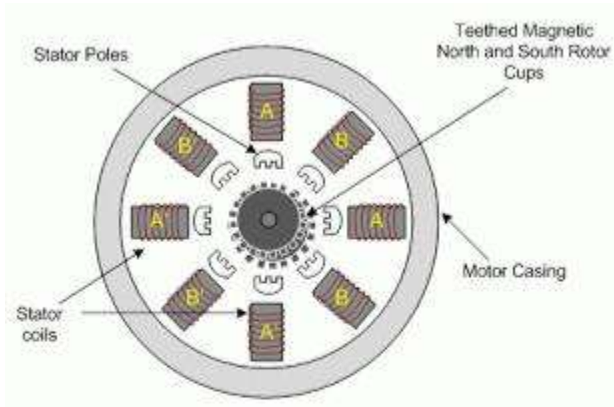

Figure (2.15) represent Two-Phase Hybrid Motor

The Hybrid type motor shown in figure (2.15), as the name suggests is a mixture of both above types. This consists a rotor which is magnetic and as well as teethed. The rotor of this type of motor is made up of two rotors joining like a shaft of motor. One of them is for north and other is for south pole. These poles arrange in alternative manner as they designed in such a manner.

Chapter Three

Stepper Motor Drives

3.1 Introduction

A stepper motor drive is a circuit which is used to drive or run a stepper is often called a stepper motor driver. A stepper motor drive usually consists of a controller, a driver and the connections to the motor.

A lot of drive circuits are available in the market today. Many circuits are so easy to interface to a motor that you can almost instantly connect the stepper motor to it and you are ready to run the motor. These circuits come in a variety of ratings for current and voltage and one should select them according to the needs of the motor which will be used It.

3.2 Linear Speed Control

Stepper motors take in electrical signals and output mechanical movement. Their high accuracy and low cost make them popular in applications ranging from printers to cameras. Current in the stator coil creates magnetic fields that move a rotor, as the current into the stator is modified the rotor spins at different speeds.

As we mentioned before, with the help of a stepper motor controller, stepper motors convert electrical energy into precise mechanical motion. The stepper motor rotates a specific incremental distance per each step. The number of steps that are executed controls the degree of rotation of the motor's shaft. This characteristic makes step motors excellent for positioning applications. The stepper motor controller can very accurately control how far and how fast the stepper motor will rotate. The number of steps the motor executes is equal to the number of pulse commands it is given by the controller. A stepper will rotate a distance and at a rate that is proportional to the number and frequency of its pulse commands.

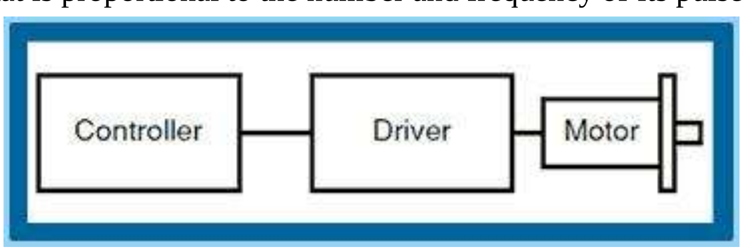

Figure (3.1) represent the basic stepper motor system

Figure (3.1) shows a typical step motor based system. Each component's performance will have an effect on the others.

The stepper driver's function is to control the magnitude and direction of current flow into the motor windings. The driver takes the pulses from the controller and determines how and when the windings should be energized. The windings must be energized in a specific sequence to generate motion.

So, to increase the speed of the rotation (motor steps), the frequency of the input pulses should be increased and vice versa for decreasing. And to increase the speed of a single step (the speed of the rotor to complete the desired angle), the width of the pulse of this step should be decreased (the time that the rotor takes to complete one step), and to decrease the speed of a single step, the width should be increased. All of these operations are called linear speed control of stepper motor.

Beside this method, there are many other ways to control the speed of the stepper motor we can mention and explain briefly two of them

3.3 Series Resistance for Speed Control

Stepper motors operate based on input current. As seen in Figure (3.2), speed and current are directly proportional to each other.

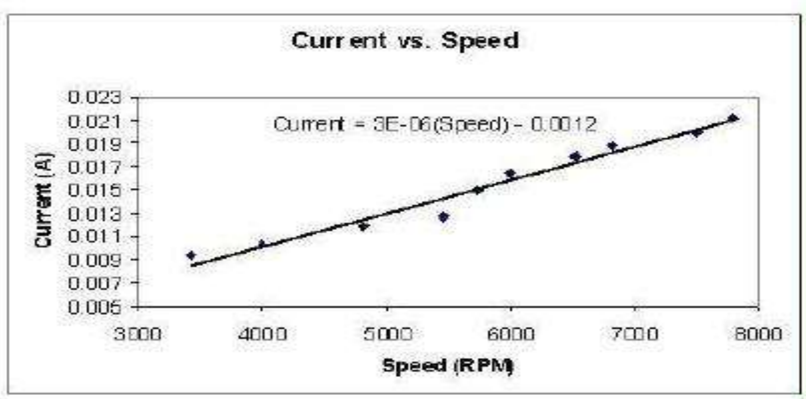

Figure (3.2) represent Sample Current vs Speed Plot

By placing a resistor in series with the motor as in Figure (3.3), the supplied current is limited.

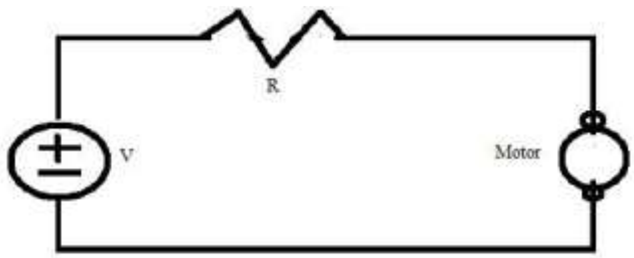

Figure (3.3) represent Series Resistance Layout

Potentiometers allow for the most flexibility in this setup. In cases where the load will require different torques, the demanded current varies thus the resistance must be flexible. Because stepper motors vary a great deal in capabilities, a single circuit will not sufficient.

The resistor or potentiometer must be able to limit the current. Often times the current levels are larger than most normal components are meant to handle. The selected part must have high current tolerances as a result.

3.4 Gearboxes Control

Mechanical gears provide another solution for speed regulation. This method requires a stepper motor to connect through an intermediate gearbox. The properties of gear ratios allow for this method.

$$\text{Gear Raio} = \frac{\text{Output gear} \times \text{teeth}}{\text{Input gear} \times \text{teeth}} \tag{3.1}$$

The output speed is given by the equation

$$\text{Output Speed} = \frac{\text{Input Speed}}{\text{Gear Ratio}} \tag{3.2}$$

It is important to understand gear ratios because it affects torque, as well.

3.5 Driver Circuit

In electronics, a driver is an electrical circuit or other electronic component used to control another circuit or other component, such as a stepper motor. They are usually used to regulate current flowing through a circuit or is used to control the other factors such as other components, some devices in the circuit. The term is often used, for example, for a specialized integrated circuit that controls high-power switches in switched-mode power converters. An amplifier can also be considered a driver for loudspeakers, or a constant voltage circuit that keeps an attached component operating within a broad range of input voltages.

The stepper motor cannot be directly driven using the MCU I/O pins as the MCU cannot supply the required current to drive the stepper motor. Also, the stepper motor will cause a back e.m.f. in the circuit while it is accelerating or decelerating. This can cause to MCU to be damaged. Hence we use a driver circuit which isolates the stepper motor circuit from the MCU circuit. The driver circuit must be able to withstand the current required by the stepper motor. Figure (3.4) shows an example for a hybrid stepper motor drive.

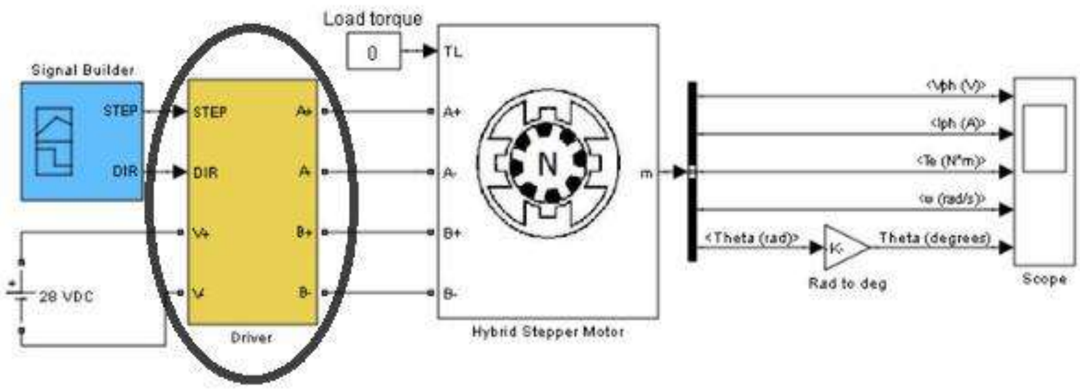

Figure (3.4) represent Hybrid Stepper Motor Drive

3.6 Hybrid Two-Phase Model

The motor phases are fed by two H-bridge MOSFET PWM converters connected to a 28 V DC voltage source. The motor phase currents are independently controlled by two hysteresis-based controllers which generate the MOSFET drive signals by comparing the measured currents with their references. Square-wave current references are generated using the current amplitude and the step frequency parameters specified in the dialog window. The movement of the stepper drive is controlled by the STEP and DIR signals received from external sources.

Figure (3.5) waveforms are obtained from a simulation of 0.25 sec operation of the stepper motor drive during which the stepper rotates during 0.1 sec in the positive direction, stops for 0.05 sec, rotates in the reverse direction for 0.05 sec and stops.

This example presents a stepper motor drive using the Hybrid Two-Phase model. The D.C. bus is represent by a 28 V D.C. voltage source. The movement of the stepper drive is controlled by the STEP and DIR signals received from signal builder block. The current amplitude and the stepping rate of the driver are selected to be 2A and 500 step/s, respectively. The STEP signal from the signal builder block controls the movement of the stepper drive. A positive value (1.0) will make the motor rotating and a zero value will stop the rotation. The DIR signal controls the rotation direction. A positive value (1.0) will impose the positive direction while a zero value will impose the reverse direction. The stepper motor drive operation is illustrated by the main waveforms (voltages, currents, torque, speed and position) displayed on the Scope block. Further look of the driver circuit shown in figure (3.6).

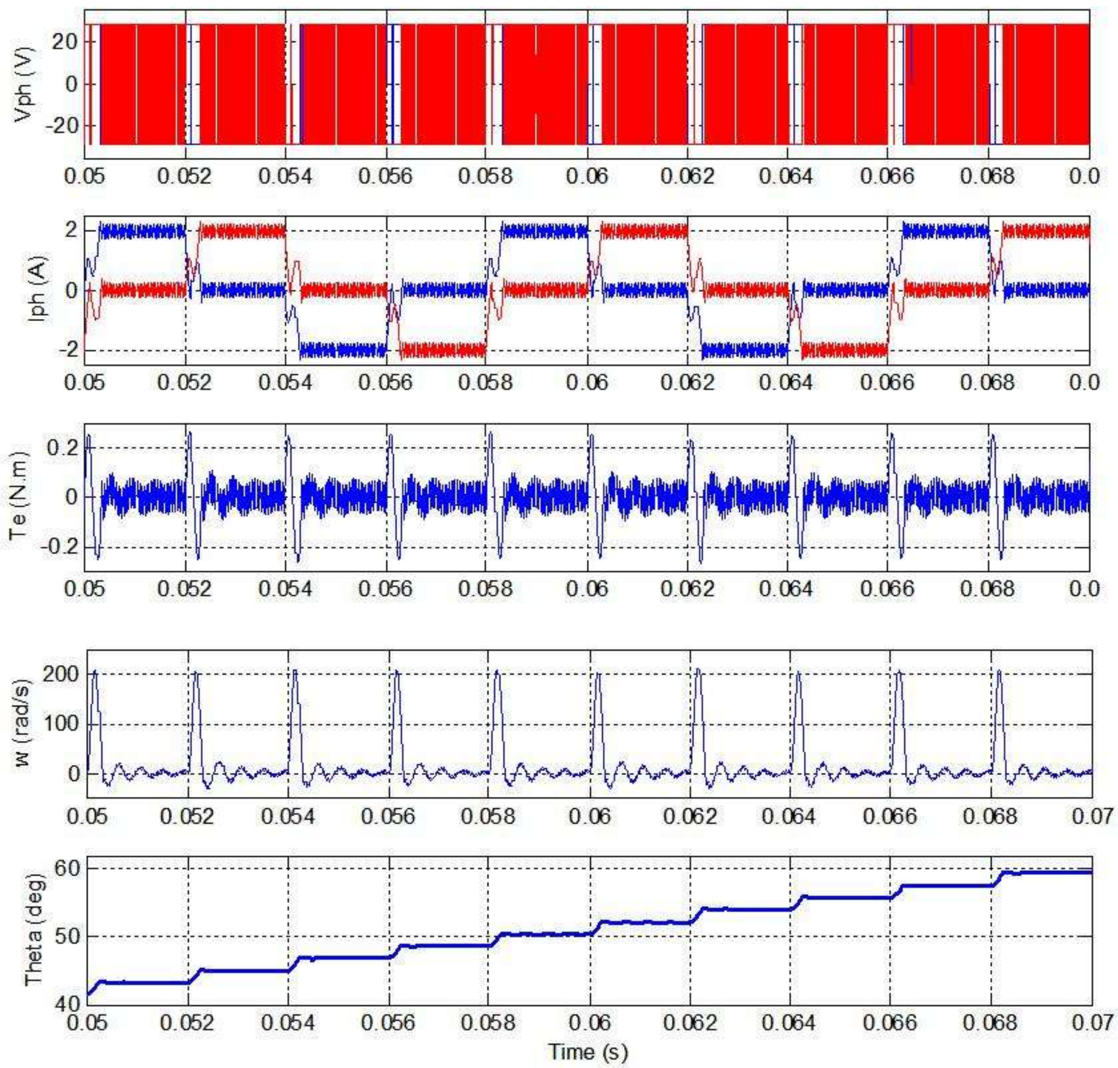

Figure (3.5) represent Parameters of Stepper Motor Drive

Given the inputs DIR and STEP from the signal builder, which should be the direction and the movement command, either +1 or -1 clock wise or anti-clockwise or 0 stop signal passes through the switches. This signal is then passed through a rate transition which is used to normalize time differences between system components, and then integrated. The signal is then divided by 4 and the modulo (i.e. MOD) of the result is passed through another rate transition, at which point the same signal goes through two branches. In both, the mod result is compared against the look-up table and multiplied by (reference value). The comparison result (after the summer) is then fed to a delay element and multiplexed so that it controls the Convertor mask. Given the signals from V+ and V- (The activation of the driver circuit potentials), the convertor generates the current value. Thus, there are A+, A-, B+, B- that drive the stepper motor. The arrangement of components in this way depends on the model that needed to be represented along with the control strategy desired, in terms of selecting measurement and control variables.

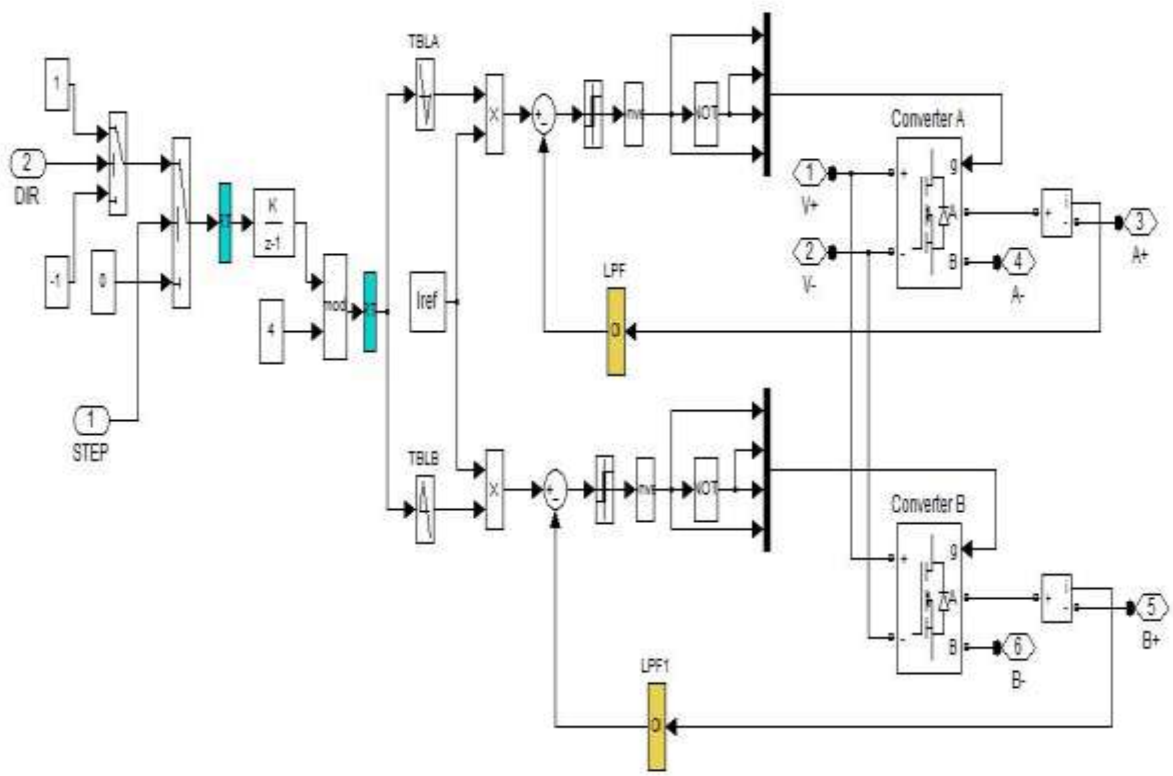

Figure (3.6) represent Driver Circuit

3.7 Microstepping Control

Microstepping is a way of moving the stator flux of a stepper more smoothly than in full- or half-step drive modes. This results in less vibration, and makes noiseless stepping possible down to 0 Hz. It also makes smaller step angles and better positioning possible.

In many applications microstepping can increase system performance, and lower system complexity and cost, compared to full- and half-step driving techniques. Microstepping can be used to solve noise and resonance problems, and to increase step accuracy and resolution. Microstepping can also be used to increase stepper motor position accuracy beyond the manufacturer's specification.

There are a lot of different microstepping modes, with step lengths from full step down to –full step or even less. Theoretically it is possible to use non-integer fractions of a full-step, but this is often impractical.

A stepper motor is a synchronous electrical motor. This means that the rotor's stable stop position is in synchronization with the stator flux. The rotor is made to rotate by rotating the stator flux, thus making the rotor move towards the new stable stop position. The torque (T) developed by the motor is a function of the holding torque (T_H) and the distance between the stator flux (f_s) and the rotor position (f_r).

$$T = T_H \times \sin(f_s - f_r) \qquad (3.4)$$

Where and are given in electrical degrees.

The relationship between electrical and mechanical angles is given by the formula:

$$f_{el} = \frac{n}{4} \times f_{mech} \qquad (3.5)$$

where n is the number of full-steps per revolution. When a stepper is driven in full-step and half-step modes the stator flux is rotated 90 and 45 electrical degrees, respectively every step of the motor. From the formula above we see that a pulsing torque is developed by the motor, see figure (3.9), which also shows the speed ripple caused by the torque ripple. The reason for this is that $f_s - f_r$ is not constant in time due to the discontinuous motion of f_s.

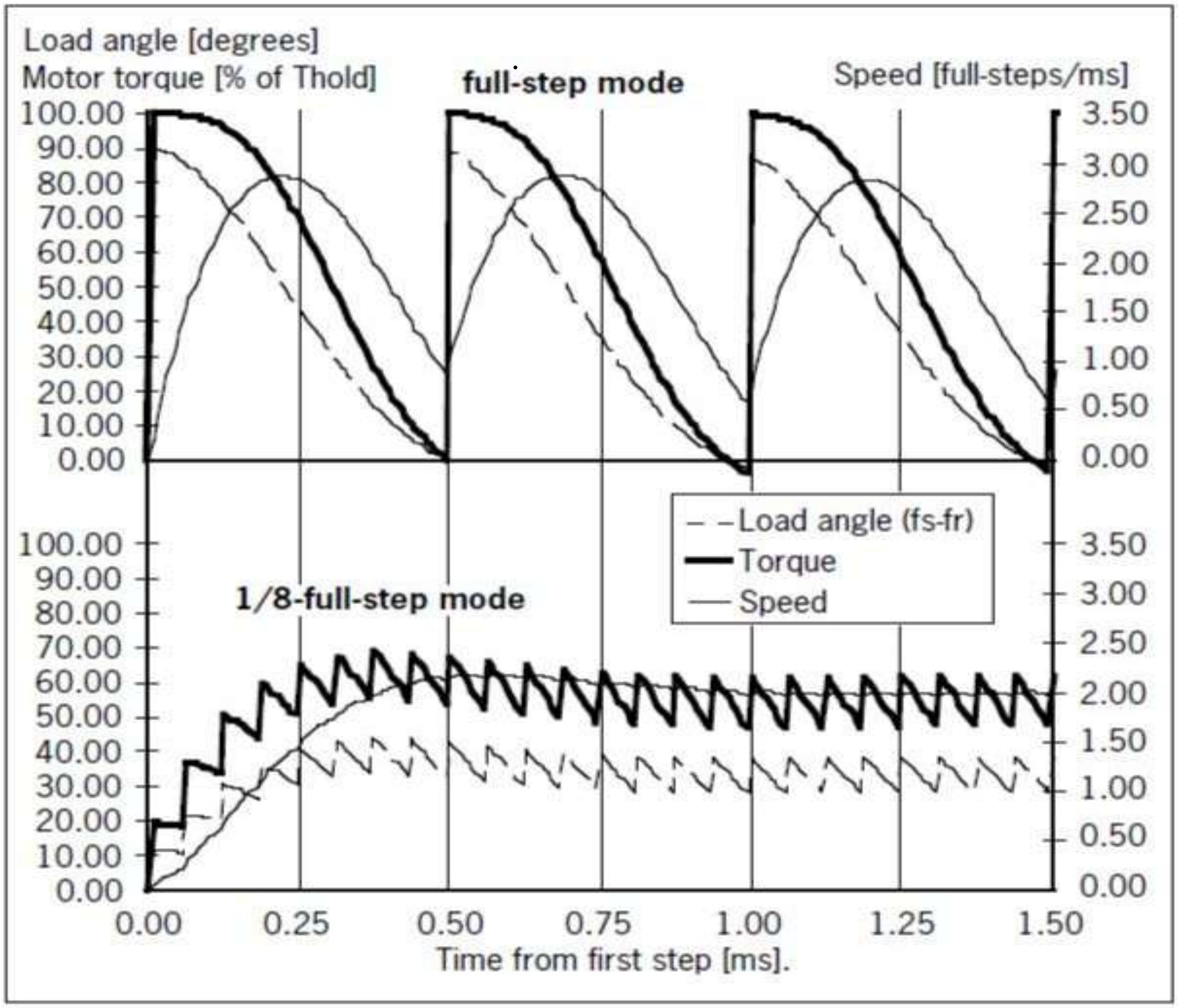

Figure (3.7) Torque and Speed Ripple as Function of Load Angle

Generating a stator flux that rotates 90 or 45 degrees at a time is simple, just two current levels are required I_{on} and 0. This can be done easily with all type of drivers. For a given direction of the stator flux, the current levels corresponding to that direction are calculated from the formulas:

$$I_A = I_{peak} \times \sin f_s \tag{3.6}$$

$$I_B = I_{peak} \times \cos f_s \tag{3.7}$$

By combining the and 0 values in the two windings we can achieve 8 different combinations of winding currents. This gives us the 8 normal 1-

and 2-phase-on stop positions corresponding to the flux directions 0, 45 , …, 315 electrical degrees.

If we have a driver which can generate any current level from 0 to 141% of the nominal 2-phase-on current for the motor, it is possible to create a rotating flux which can stop at any desired electrical position, see figure (3.8).

It is therefore also possible to select any electrical stepping angle 1⁄4-full-step (15 electrical degrees), 1⁄8 full-step or 1⁄32-full-step (2.8 electrical degrees) for instance. Not only can the direction of flux be varied, but also the amplitude.

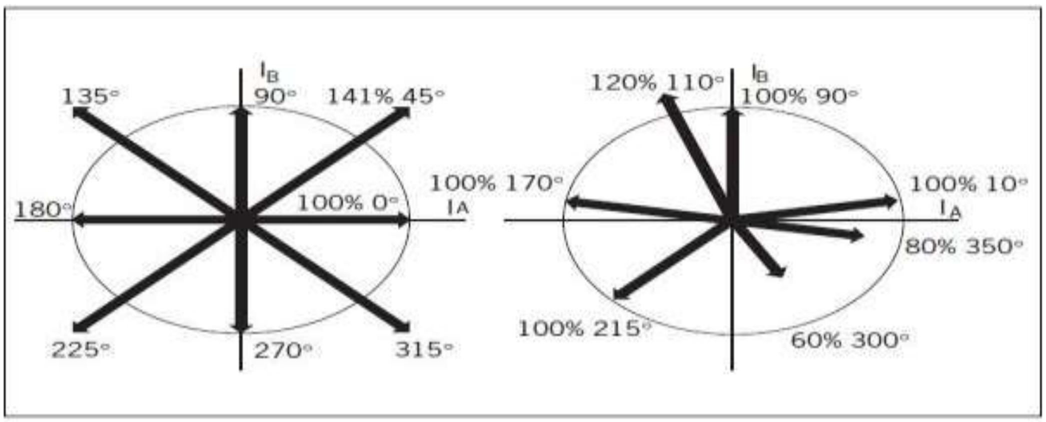

Figure (3.8) Flux Directions for Normal Half and Full-Step Stop Positions. Length is Proportional to Ding Torque.

From the torque development formula, we can now see that the effect of Microstepping is that the rotor will have a much smoother movement on low frequencies because the stator flux, which controls the stable rotor stop position, is moved in a more continuous way, compared to full and half-step modes. With frequencies above 2 to 3 times the system's natural frequency, Microstepping has only a small effect on the rotor movement compared to full-stepping. The reason for this is the filtering effect of the rotor and load inertia. A stepper motor system acts as a low pass filter.

Chapter Four

Application (Smart Dish)

4.1 Introduction

Smart Dish is a Dish which connected with two stepper motors, Arduino and stepper motor drivers. It adjust its position according to the satellite's position to receive the signal, the Arduino takes the data from the software then processes it and applies it on the hardware (steppers) ; which makes the steppers moves to reach the desired point. The Smart Dish plays the role of the human in adjusting the Dish's position or angle, which gives the best signal from the satellite without making an effort.

The steppers are in two axis (x , y) so the Dish moves Vertically and Horizontally - the steppers are connected with drivers that's form a link between the steppers and the controller.

4.2 The System Main Block Diagram

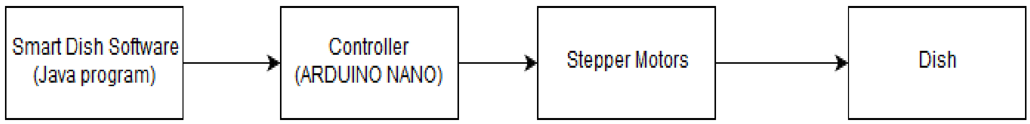

Figure (4.1) represent the system block diagram

In this block data comes from the software as input to the controller, the controllers receives the data and processes it then applies it on the steppers (hardware), according to this the steppers operates and moves the Dish to the desired location that user had defined it and this preform the output of this block diagram.

4.2.1 Smart Dish Software

It's a software written by java program language. It consist of two main parts:

- Graphical User Interface (GUI)
- Back End
- Graphical User Interface (GUI)

Figure (4.2) represent graphical user interface

It’s the part of the software that appears on the screen to the user, it form the shape of the software. It is also consist of three parts :

- Work space
- Buttons
- Signal columns

- **workspace**

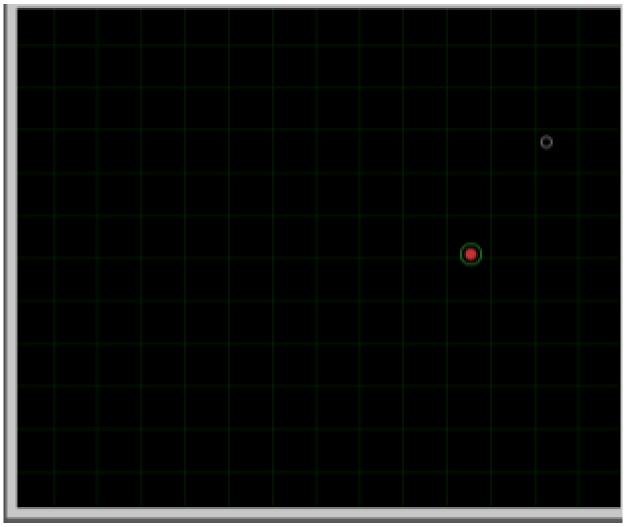

Figure (4.3) represent the work space

It’s the display screen for the software that shows the actual position of the Dish and the desired position. For example our actual position in the point (10, 20) in figure (4.2) where 10 is the position of the first stepper an x-axis and 20 is the position of the second stepper in y-axis and our desired position on the point (20,20) , so we need to move our first stepper in x-axis to the point 20 , to make our Dish reach the desired position in the point (20,20) in figure (4.3). And the below figures display it.

Figure (4.4) represent smart dish display

Figure (4.5) represent smart dish display

- **Buttons**

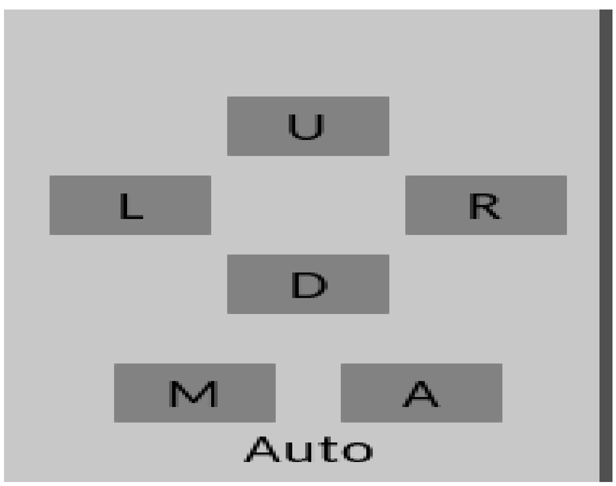

Figure (4.6) represent buttons in smart dish software

In (GUI) we have 6 buttons (U→Up-D→Down-L→Left-RRright-A→Auto-M→Manual) theses are control buttons which control in the position of the hardware (steppers).

- **A→Auto**

When enabling this button the rest of the buttons are disabled and our steppers moves automatically to our desired position when locating the point in the work space.

- **M→Manual**

When enabling this button all the buttons are enabled exept the (A) button, and moving to our desired position becomes manually.

- **Signal columns**

Figure (4.7) represent signal columns

There is two columns for the signal of the Dish – one represents the strength of the signal and the other represents the quality of the signal.

- **Back End**

Second part of the software is back end – the code that operates all the function in (GUI) – and without it the program won't function.

In most of the software of the programs the (GUI) and the back end are written in different language , here both of them are written in java language.

4.2.2 Arduino Nano

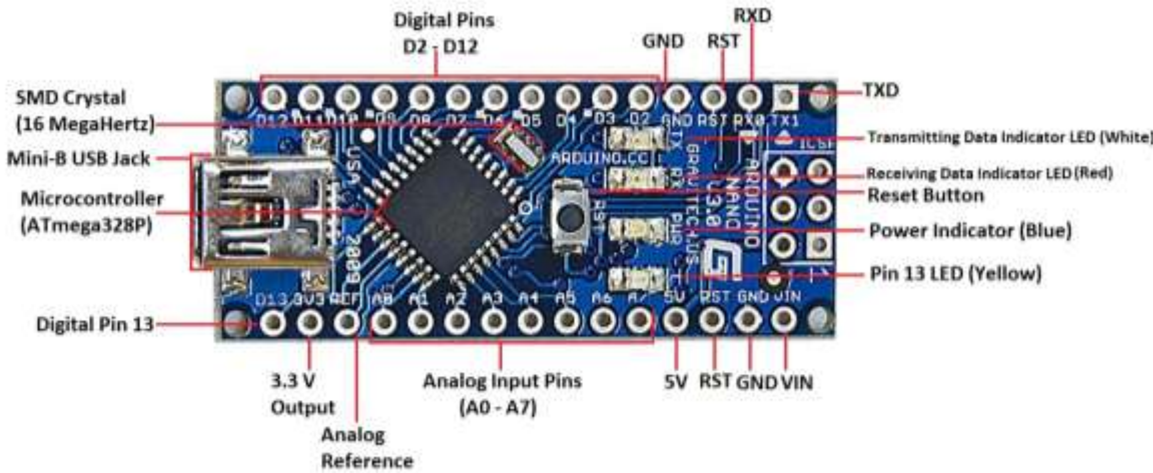

Figure (4.8) represent Arduino nano

Is a microcontroller board, developed by Arduino.cc and based on ATmega328p/AtMega168.It comes with an operating voltage of 5V, however, the input voltage can vary from 7 to 12V.There are 14 digital pins which can be configured as input or output and 8 analog pins incorporated on the board. More or less all these analog pins can be used and configured exactly the same way as digital pins.

Digital pins are used as input pins when they are interfaced with sensors while driving of load is carried out when digitals are used as output. Functions like pin Mode () and digital Write () are used to control the operations of digital pins while analog Read () is used to control analog pins, The analog pins come with a total resolution of 10bits which measure the value from zero to 5V. Arduino Nano comes with a crystal oscillator of frequency 16MHz. It is used to produce a clock of precise frequency using constant voltage. There is one limitation using Arduino Nano i.e. it doesn't come with DC power jack, means you cannot supply external power source through a battery, This board doesn't use standard USB for connection with a computer, instead, it comes with Mini USB support. Tiny size and breadboard friendly nature make this device an ideal choice for most of the applications where a size of the electronic components are of great concern. Memory is 16KB or 32KB that all depends on the Atmega board i.e Atmega168 comes with 16KB of flash memory while Atmega328 comes with a flash memory of 32KB. Flash memory is used for storing code. The 2KB of memory out of total flash memory is used for a bootloader.

4.2.3 Stepper Motor & Drivers

Stepper motor is an electric motor used in small machines that need precision control. Control of this type of motors need special cards to be as a link between it and the controller. Stepper motor drivers are specifically designed to drive stepper motor, which are capable of continuous rotation with precise position control, even without a feedback system. Our stepper motor drivers offer adjustable current control and multiple step resolutions, and they feature built-in translators that allow a stepper motor to be controlled with simple step and direction inputs. These modules are generally basic carrier boards for a variety of stepper motor driver ICs that offer low-level interfaces like inputs for directly initiating each step. An external microcontroller is typically required for generating these low-level signal.

In this project we used drivers for the stepper called L293D.

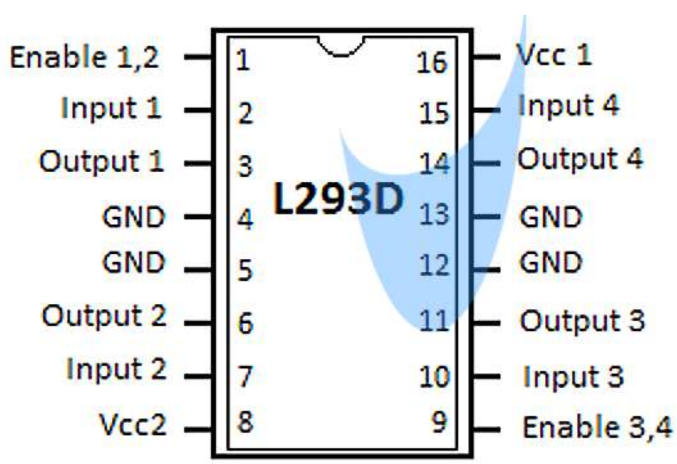

Figure (4.9) represent L293D driver

The L293D is an integrated explanation used to drive inductive loads (reels, motors...) which cannot be controlled by microcontrollers or other control circuit directly.

This chip is used to make a connection or isolation between these loads and control circuit. This chip is used extensively in driving motors in robotics project and in most projects that use motors within its system.

4.3 System simulation

Simulation system by using proteus :

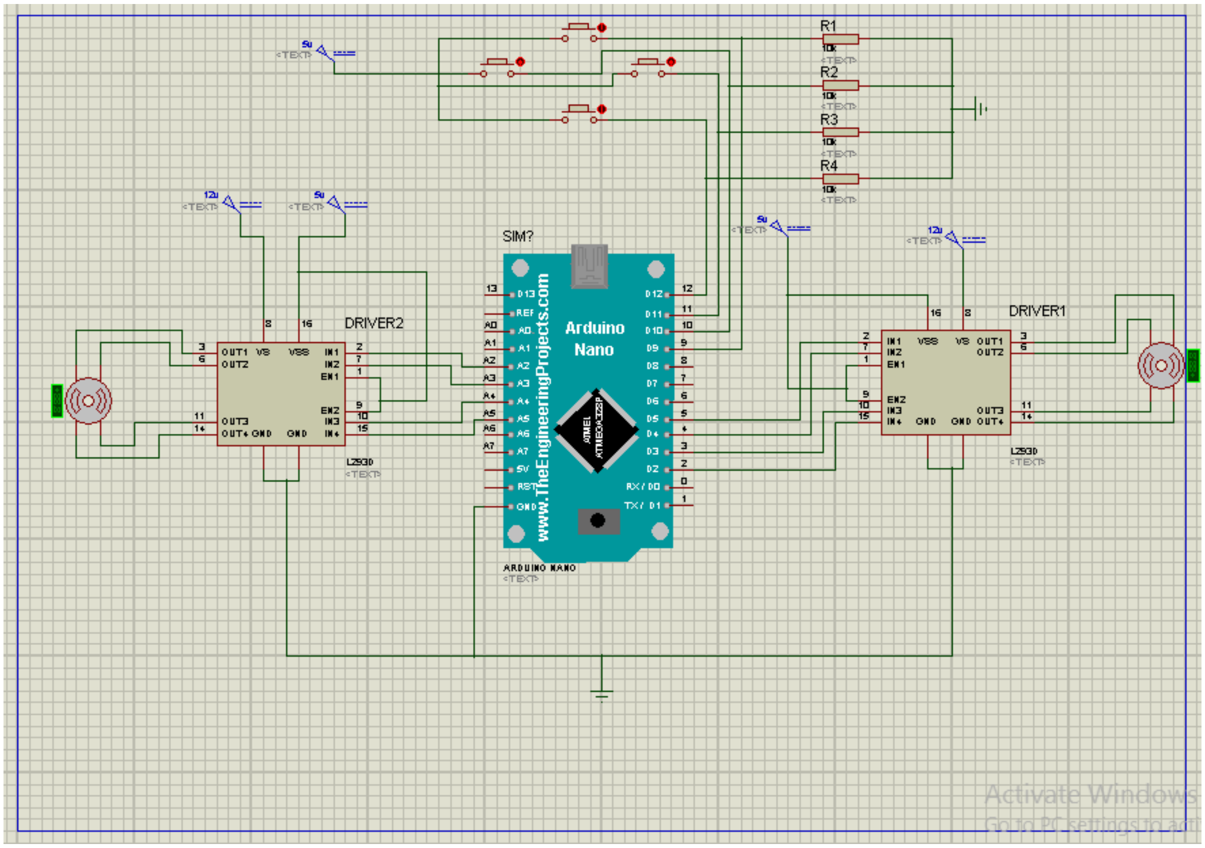

Figure (4.10) represent the system simulation

4.3.1 Introduction

After the study of the stepper motor theory and how to drive it, we need to apply these concepts. As known, any application must pass through certain steps. The first step is to select the suitable algorithm to perform the application effectively. This can be done by simulating the real system or design through a specified software. That called software implementation. It is used as a previous knowledge about the expectable results to make hardware implementation more easy and useful.

So, firstly we need to know what software implementation is.

4.3.2 Software Simulation

Software simulation is the imitation of the operation of a real-world process or system over time using computer. A computer simulation is an attempt to model a real-life or hypothetical situation on a computer so that it can be studied to see how the system works. By changing variables in the simulation, predictions may be made about the behavior of the system. It is a tool to virtually investigate the behavior of the system under study. Also Simulation software is based on the process of modeling a real phenomenon with a set of mathematical formulas. It is, essentially, a program that allows the user to observe an operation through simulation without actually performing that operation. This can be done among a suitable programing language. The suitable compiler to be used is the PROTEUS.

Here, to control the stepper motor, Arduino was chosen which is directly related with java programing language.

CHAPTER FIVE
CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

All project purposes have been issued. Stepper motor drive modes have been studied and we found that stepper motor is stable, that can drive a wide range of frictional and inertial load, needs no feedback. The motor is also position transducer, Inexpensive relative to other motion control system, standardized frame size and performance, plug and play. Easy to setup and use, safe. If anything breaks, the motor stops, long life. Bearings are the only wear-out mechanism, excellent low speed torque. Can drive many loads without gearing, excellent repeatability. Returns to the same location accurately.

Overload safe. Motor cannot be damaged by mechanical overload.

5.2 Future recommendations

there are many points that this study didn't provide detailed information about them. and they must be studied as soon as possible. These points are:

- How to eliminate step position error.
- Mechanical parameters, load, friction, inertia and their effects on the motion of the stepper motor.
- The relationship between the torque produced by stepper motor and the different drive modes in terms of the step rate and the drive current in the windings. After all these detailed studies, it will be so easy to apply them in fact by choosing any of stepper motor applications and start to design and implement them so that to be sure that stepper motor provides more precise motion than any other types of motors.
- need a sensor that its inside LNB in the dish to make a dish find the satellite automatically.

REFERENCES

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2. T. Kenjo**,** A. Sugawara**,** Stepping Motors and Their Microprocessor Controls, 2nd Edition, Oxford University Press, Oxford, 2003.
3. P. Acarnley, Stepping Motors - A guide to theory and practice, 4th Edition, The Institution of Electrical Engineers, London, 2002.

APPENDIX A

Controller data sheet

ARDUINO NANO is a microcontroller board based on the ATmega328P.AVR architecture. Operation voltage 5 volts, SRAM 2KB, EPROM 1KB, Clock speed 16MHz

It has 8 analog input/output pins, input voltage (7-12) Volts.

Stepper motor data sheet

A Stepper motor is 28Bj-48 model. operation voltage is 5Volts DC

It have 4 phases. Frequency is 100Hz .speed variation ratio is 1/64.

Stride angle is 5.625/64.

APPENDIX B
THE RUNNING CODE OF THE SMART DISH

```
#include<EEPROM.h>


int y0=A5,y1=A4,y2=A3,y3=A2;
int x0=6,x1=5,x2=4,x3=3;
int _stepX=0,_stepY=0,dirX=0,dirY=0,pX,pY,acX=0,acY=0;


byte data[2];
void setup() {
  Serial.begin(115200);


  Serial.print(EEPROM.read(0));
  Serial.print(',');
  Serial.println(EEPROM.read(1));


  pinMode(x0, OUTPUT);
  pinMode(x1, OUTPUT);
  pinMode(x2, OUTPUT);
  pinMode(x3, OUTPUT);


  pinMode(y0, OUTPUT);
  pinMode(y1, OUTPUT);
  pinMode(y2, OUTPUT);
  pinMode(y3, OUTPUT);


}
```

```
void loop() {
  if(Serial.available()>0){
  Serial.readBytes(data,2);
  int axis = int(data[0]);
  if(axis == 0){
   pX= int(data[1]);
   if(pX-acX > 0){
    for(int i=0;i<12;i++)
    stepX(x0,x1,x2,x3,0);
   }
   else if(pX-acX < 0){
    for(int i=0;i<12;i++)
    stepX(x0,x1,x2,x3,1);
   }
   acX = pX;
   EEPROM.write(0,acX);
  }
     else if(axis == 1){
   pY= int(data[1]);
   if(pY-acY > 0){
    for(int i=0;i<12;i++)
    stepY(y0,y1,y2,y3,0);
   }
   else if(pY-acY < 0){
    for(int i=0;i<12;i++)
    stepY(y0,y1,y2,y3,1);
   }
   acY = pY;
```

```
     EEPROM.write(1,acY);
    }


}
}

void stepX(int Pin0,int Pin1 ,int Pin2,int Pin3,int dirX){
 switch(_stepX){
 case 0:
 digitalWrite(Pin0, LOW);
 digitalWrite(Pin1, LOW);
 digitalWrite(Pin2, LOW);
 digitalWrite(Pin3, HIGH);
 break;
 case 1:
 digitalWrite(Pin0, LOW);
 digitalWrite(Pin1, LOW);
 digitalWrite(Pin2, HIGH);
 digitalWrite(Pin3, HIGH);
 break;
 case 2:
 digitalWrite(Pin0, LOW);
 digitalWrite(Pin1, LOW);
 digitalWrite(Pin2, HIGH);
 digitalWrite(Pin3, LOW);
 break;
 case 3:
 digitalWrite(Pin0, LOW);
```

```
digitalWrite(Pin1, HIGH);
digitalWrite(Pin2, HIGH);
digitalWrite(Pin3, LOW);
break;
case 4:
digitalWrite(Pin0, LOW);
digitalWrite(Pin1, HIGH);
digitalWrite(Pin2, LOW);
digitalWrite(Pin3, LOW);
break;
case 5:
digitalWrite(Pin0, HIGH);
digitalWrite(Pin1, HIGH);
digitalWrite(Pin2, LOW);
digitalWrite(Pin3, LOW);
break;
case 6:
digitalWrite(Pin0, HIGH);
digitalWrite(Pin1, LOW);
digitalWrite(Pin2, LOW);
digitalWrite(Pin3, LOW);
break;
case 7:
digitalWrite(Pin0, HIGH);
digitalWrite(Pin1, LOW);
digitalWrite(Pin2, LOW);
digitalWrite(Pin3, HIGH);
break;
```

```
 default:
 digitalWrite(Pin0, LOW);
 digitalWrite(Pin1, LOW);
 digitalWrite(Pin2, LOW);
 digitalWrite(Pin3, LOW);
 break;
 }
 if(dirX > 0){
 _stepX++;
 }else{
 _stepX--;
 }
 if(_stepX>7){
 _stepX=0;
 }
 if(_stepX<0){
 _stepX=7;
 }
 delay(1);
}

void stepY(int Pin0,int Pin1 ,int Pin2,int Pin3,int dirY){
  switch(_stepY){
 case 0:
 digitalWrite(Pin0, LOW);
 digitalWrite(Pin1, LOW);
 digitalWrite(Pin2, LOW);
 digitalWrite(Pin3, HIGH);
```

```
break;
case 1:
digitalWrite(Pin0, LOW);
digitalWrite(Pin1, LOW);
digitalWrite(Pin2, HIGH);
digitalWrite(Pin3, HIGH);
break;
case 2:
digitalWrite(Pin0, LOW);
digitalWrite(Pin1, LOW);
digitalWrite(Pin2, HIGH);
digitalWrite(Pin3, LOW);
break;
case 3:
digitalWrite(Pin0, LOW);
digitalWrite(Pin1, HIGH);
digitalWrite(Pin2, HIGH);
digitalWrite(Pin3, LOW);
break;
case 4:
digitalWrite(Pin0, LOW);
digitalWrite(Pin1, HIGH);
digitalWrite(Pin2, LOW);
digitalWrite(Pin3, LOW);
break;
case 5:
digitalWrite(Pin0, HIGH);
digitalWrite(Pin1, HIGH);
```

```
digitalWrite(Pin2, LOW);
digitalWrite(Pin3, LOW);
break;
case 6:
digitalWrite(Pin0, HIGH);
digitalWrite(Pin1, LOW);
digitalWrite(Pin2, LOW);
digitalWrite(Pin3, LOW);
break;
case 7:
digitalWrite(Pin0, HIGH);
digitalWrite(Pin1, LOW);
digitalWrite(Pin2, LOW);
digitalWrite(Pin3, HIGH);
break;
default:
digitalWrite(Pin0, LOW);
digitalWrite(Pin1, LOW);
digitalWrite(Pin2, LOW);
digitalWrite(Pin3, LOW);
break;
}
if(dirY > 0){
_stepY++;
}else{
_stepY--;
}
if(_stepY>7){
```

```
 _stepY=0;
 }
 if(_stepY<0){
 _stepY=7;
 }
 delay(1);
}
```
