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Review Article

Closed Loop Angular Position Control of Stepper Motor Using Parallel Port on PC

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Abstract: Stepper motors find wide applications in sophisticated manufacturing machines for positioning of work-piece into a predefined location upon which some operations may be performed. They are commonly used in open loop position control systems and various automation system applications. But open loop control of stepper motor may cause loss of steps or slip of steps. Acceleration and deceleration are also limited. To overcome these problems, computer controlled flexible positioning system as well as an error checker circuit has been developed to show, if any wrong position (i.e. due to loss of steps or slip of steps) of stepper motors have been achieved. So in the present paper, a programming method in Visual Basic has been described to control the angular position of a stepper motor using Parallel port on PC where the Stepper Motor has been connected to the Line Printer Terminal (LPT) of the Computer to achieve accurate position of stepper motor, within a considerable step angle limit. Experimental results indicate that the proposed system has high performance and efficiency with percentage error within tolerable limits.

Keywords: Computer controlled, Error Checker Circuit, Parallel Port on PC, Position control, Stepper Motor.

1. INTRODUCTION

Stepper Motor based positioning system is very much useful and popular requirement in the industry. The principal aim of this motion control is to design control systems which are able to make automatic movement of a machine. In recent times thus PC based digital control is also becoming convenient and popular for research and development in quite a lot of fields. The combination of motion and position control technology with PC gives developers and end users a very useful tool with much greater flexibility because PC has a lot of programming languages with powerful debugging tools and useful drawing applications with which users are much familiar. Many schemes on the present problem have been proposed in past couple of years. Bianculli and J.Anthony[1] has explained a computer controlled positioning system where stepper motor has been used to create sophisticated manufacturing equipments via closed-or open-loop motor-driven system each offering distinct advantages. Economical stepper motor for speed control applications has been presented by J.T.Boys[2]. The application of Microcomputer for speed control of stepper motor with a digital driving circuit has been described by C.Chen[3]. C.T.Chin[4] has provided us with a microstepping technique for the rotation of the rotor of the Stepper Motor which provides high accuracy than open loop control of stepper motor, which suffers from disadvantages of unstable oscillation in certain speed ranges. A precision stepper motor controller capable of both independent and and synchronized control of multiple number of stepper motors has been discussed by D.P.Mital[5] where a 16-Bit Microprocessor has been used as a controller to provide fast and reliable control operations. M.Bodson, J.N.Chiasson,R.T.Novotnak and R.B Rekowski[6] has studied a high performance non-linear feedback control of permanent magnet stepper motor where line encoders, PWM amplifiers and Motorala as digital signal processor has been implemented. A new methodology using a single microprocessor to control the speed, direction and rotation angle of DC Stepper Motor has been implemented by Z.L.Kang[7]. The main elements of Stepper Motor Control System have been presented by Rhine[8] and a comparison of open loop and closed loop control has been also briefly discussed. E.T.Ososanya[9] has described the full implementation of a low cost real time digital control system of a stepper motor where a PC or a single board computer has been used to monitor and control mechanical equipments. A digital control of a multi-axis-system has been developed by A.S.Zein El Din[10] using Programmable Logic Controllers (PLC) for controlling the rotor position, direction and speed of stepper motors. K.G.Adams and M.Van Reenen[11] has developed a work based on a low cost stepper motor positioning system with closed loop control where two different closed loop positional controllers have been designed. Motion Control of Stepper Motors with the Parallel Port on PC and its applications has been described by T.H.Woo,G.S.Zhang, M.Wang, B.Z.Xu, B.Gang, C.Li[12]. Digital position control scheme of a motorized valve using microcontroller for controlling the stepper motor as an actuator has been designed by Subrata Chattopadhyay and Sagarika Pal[13]. A Stepper Motor Drive Control based on MCU has been proposed by Shi Rongrong[14]. B.Aranjo[15] has presented an efficient and versatile drive system for stepper motors using MATLAB Simulink Software to provide precise control with smallest possible step angle. Controlling of Stepper Motor by Parallel Port Controller using MATLAB has been described by Darshana K.Sayre, Dipaknanada B.Mane[16]. Stepper Motor Position Control using 8051 Microcontroller has been developed by Kausik Chakraborty, Nisarga Chand, Bappaditya Roy, Pabitra Kumar Nandi[17]. Indira Mazumdar, Reetam Mondal and Sagarika Pal[18] have explored an approach and application of constructing a simple low cost color sensor in angular position Control System of a Stepper Motor. An Embedded System of DC Motor Closed Loop speed control of DC Motor based on 8051 Microcontroller has been discussed by Reetam Mondal, Arumay Mukhopadhyay and Debdoot Basak[19] to study the reaction of controlled variable to set-point changes.

In the present investigation attempts has been made to design and develop closed loop angular position control of stepper motor using software technique through computer's parallel port. So, a set point angular position value is given through the computer parallel port to the stepper motor via the stepper motor driver ULN 2003 to form an open loop system. Now to achieve a desired angular position, the mechanical movement of the Stepper Motor is converted into digital pulse by use of optical sensor like incremental encoder attached with the Motor Shaft. Then this signal from the sensor is fed back to the computer through the input terminal of the parallel port. By using suitable software the instantaneous angular position of the stepper motor is compared with the set-point value. The error obtained due to loss of steps would be nullified by the software programming using Visual Basic, thus achieving the exact angular position of the stepper motor either in clockwise or anticlockwise direction.

2. METHODOLOGY AND BLOCK DIAGRAM

The overall block diagram of the proposed system shown in **Fig.1.** consists of a Stepper Motor Driver ULN2003 which has been interfaced with the parallel port of the PC or the LPT Terminal. By using software programming in Visual Basic four bit patterns are generated and provided to energize the four coils of the Stepper Motor simultaneously so that the motor rotates according to the wave stepping sequence, thus converting these electrical pulses into mechanical movements. Many electrically driven mechanical systems such as machining devices and paper feeds are dependent upon such a conversion. Between the computer and the stepper motor the driver ULN 2003 is required so that the output signal from it can supply sufficient driving current to energize the coils of the stepper motor for proper rotation.

As the motor shaft rotates the incremental encoder attached with the shaft coverts the mechanical movement of the Stepper Motor into electrical pulses by means of an optical sensor. In the optical sensor circuit the transmitter is an LED with a particular color which transmits a beam of light through the white transparent slots on the incremental encoder which falls on the receiver i.e. a phototransistor at the other end. Thus it generates a pulse train corresponding to the number of steps rotated by the Stepper Motor, which is fed back to the input terminal of the parallel port of the PC. With a suitable software the controller compares these feedback signal pulses with the given input set-point data and regenerates bit pattern to nullify the error if any due to slip of steps, to achieve an accurate angular position of the Stepper Motor. In this present development Stepper Motor with Step Angle of 1.8º has been used. Two sets of display units are designed, one to display the set-point value and the other to display the feedback value. So, the error can be seen at a glance from the hardware system itself. Thus, Closed Loop Motion and Position Control of Stepper Motor Using Parallel Port on PC have been achieved.

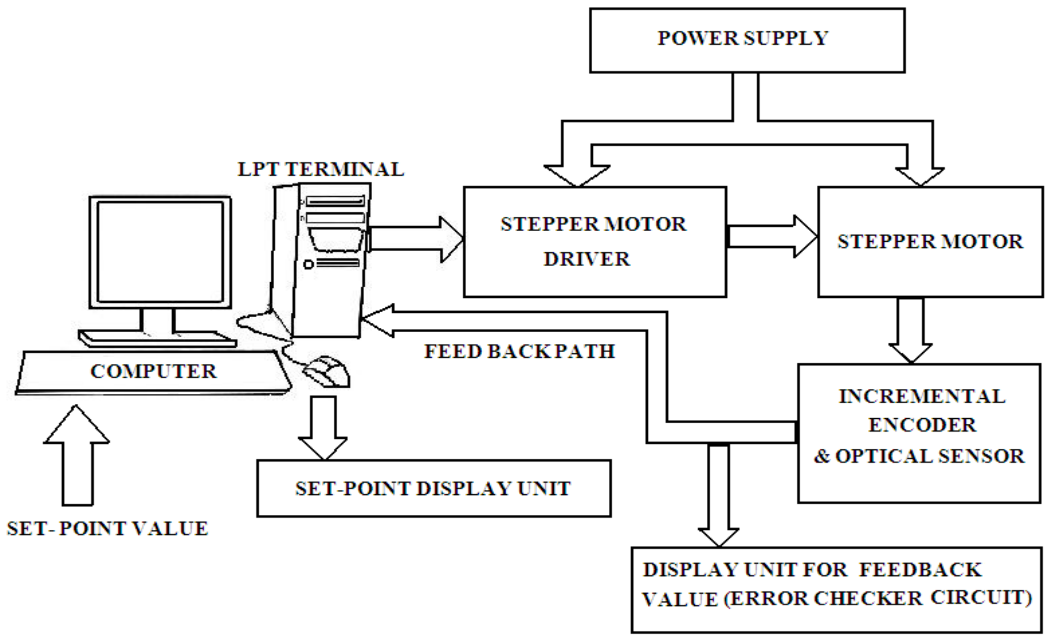

Fig.1. Basic Block Diagram of the Proposed System

2. INTERFACING OF THE STEPPER MOTOR DRIVER WITH PC PARALLEL PORT

The parallel port is an excellent interfacing mechanism, allowing all sorts of devices to be connected to and controlled by the PC. The primary use of these parallel ports is to connect printers to the computer and therefore it is often called as printer port. It is a 25 pin female (DB 25) connector to which the printer is connected. The parallel port has several I/O lines which can be partitioned into three groups which are data lines (8-bit Data Bus), control lines and status signals. As the name refers the data are transferred over the data lines, control lines are used to control the peripherals and of course these peripherals returns some status signals back to the computer through status lines. These lines are connected to the Data, Control and Status registers internally. So by manipulating these registers in the software program one can easily read or write data to the parallel port through the parallel port with programming languages like C or Visual Basic. Whatever is written to these registers will appear in corresponding lines as voltages which can be measured using a multi-meter. For example if 1 is written to the data register the line Data0 of the parallel port will be driven to +5 Volts. Thus one can programmatically turn on and off any of the data lines and the control lines.

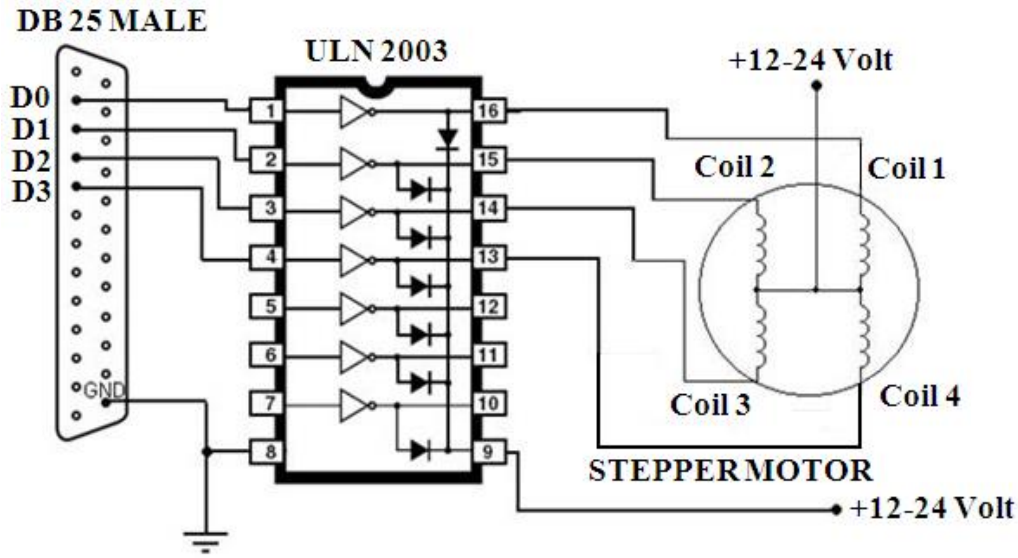

Fig.2. Interfacing of Stepper Motor Driver with PC Parallel Port

Driving the stepper motors requires the switching of current from one stator winding to another. This switching function has been provided by the driver circuit which arranges, distributes and amplifies pulse trains from the signal control circuit. The stator windings of the stepper motor are excited at specified sequence. Therefore, in this present scheme ULN 2003 Stepper Motor Driver IC has been interfaced with the Printer Parallel Port of the PC (DB 25) as shown in **Fig.2.** through which the control software generates a sequence of bit pattern which goes to the Stepper Motor to achieve the desired angular position and direction of rotation. The IC ULN2003 are high voltage, high current Darlington arrays each containing seven open collector Darlington pairs with common emitters. Each channel rated at 500mA and can withstand peak currents of 600mA. These versatile devices are useful for driving a wide range of loads including solenoids, relays DC Motors, LED displays, filament lamps, thermal print heads and high power buffers. Therefore they are used to amplify weak signals so that they can be clearly detected by another circuit. Thus they help to obtain a very high level of current gain, so that the signal is clear. Instead of ULN 2003 transistors can also be used. If transistors are used as drivers, diodes must be used to take care of inductive current generated when the coil is turned off. As ULN 2003 has inbuilt driver circuit so it has been preferred.

3. ROLE OF ROTARY OPTICAL SHAFT ENCODERS AND OPTICAL SENSORS

In many motion systems rotary optical shaft encoders[20] provide the most versatile and economical means to obtain feedback signals for angular position and speed control. The operation of these devices is similar to optical tachometer. Shaft encoders comprise of a transparent or opaque glass disk, a pattern of opaque and transparent sections is created around the periphery of the disc. A light beam provided a LED is passed through the disc. The rotation of the disc and the pattern around the periphery causes the light beam to make and break for the transparent and the opaque sections respectively. The pulsed signal is then amplified and fed back to the digital controller.

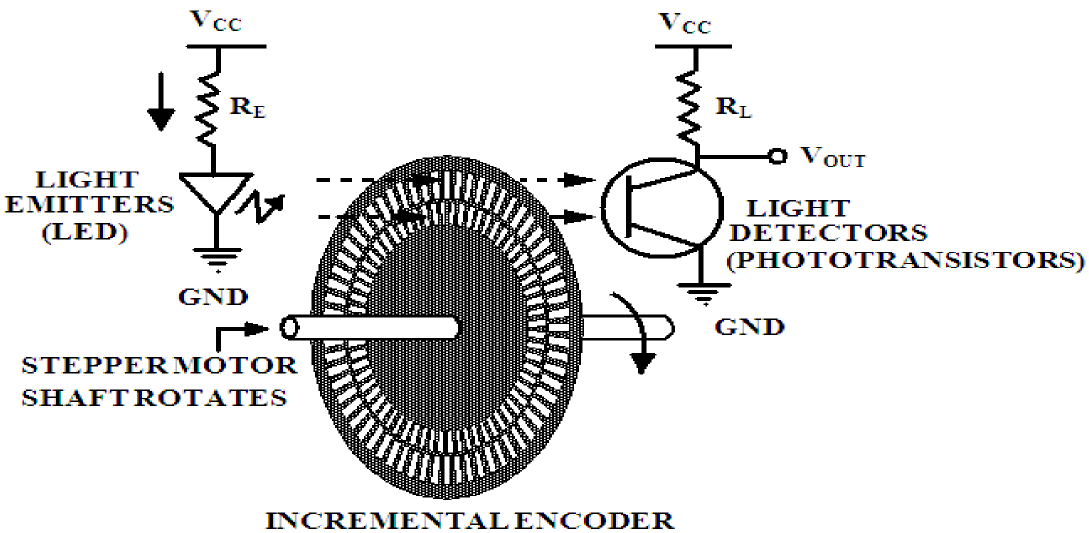

Fig.3. Rotary Optical Shaft Encoder and Optical Sensor arrangement

The Rotary optical encoders are classified into incremental and absolute[20]. Incremental encoders are more widely used than absolute encoders, mainly because they are cheaper. In this present work of closed loop angular position control of stepper motor incremental encoders have been used. The mechanical movement of the stepper motor has been converted into electrical pulses by means of these incremental encoders. The Optical sensor circuits comprises of a transmitter i.e. LED and a phototransistor as a receiver at the other end. In between the LED and the phototransistor an incremental encoder is placed. When the stepper motor rotates the incremental encoder attached with the motor shaft interrupts the light source or the LED in the optical sensor circuit. When the light from the LED passes through the transparent sections of the incremental encoder the output from the collector terminal of the phototransistor will be 0 Volts and when it does not fall on the base of the phototransistor the output at the collector terminal is 5 volts. The emitter of the phototransistor is grounded as shown in **Fig.3**. Accordingly the encoder provides information to the controller about the instantaneous angular position of the rotating shaft by producing one square wave cycle per increment of the shaft movement which is referred to as the resolution of the encoder. For example an encoder with 1000 graduation marks will emit a signal sequence of 1000 pulses while completing a single revolution.

4. SOFTWARE IMPLEMENTATION OF THE CONTROL UNIT

According to the general design requirement and hardware circuit principle of the system, the character of the hardware connection and each module chip, and the function requirement, as well as the improvement of program readability, transferability and convenient debugging the software design has been modularized as shown in **Fig.4**. Software design of the system also includes developing algorithm for the system, allocating memory blocks as per functionality, writing separate routines for different interfacing devices and testing them on the designed hardware.

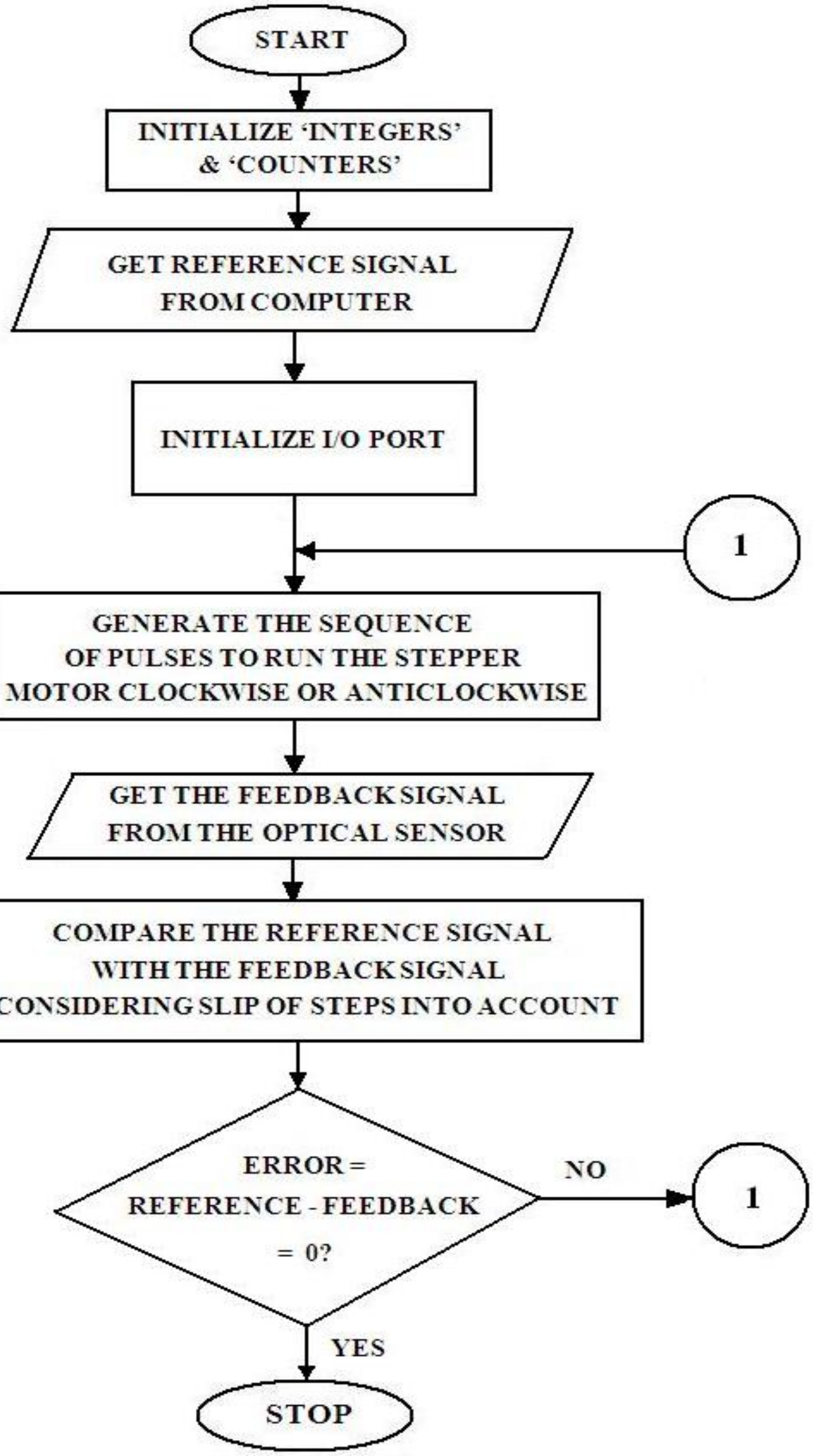

Fig.4. Software Flow diagram for the Control Unit

For implementation of the control unit the reference value or set value signal has been given from the computer keyboard. The sequence of pulses has been generated to run the motor either in clockwise or anticlockwise direction. Actual angular position information from the stepper motor has been received by the computer through the optical encoder as feedback signal. The reference signal has been compared with the feed back signal coming from the encoder considering actual slip of steps into account. If and error has been generated, that has been corrected through generation sequence of pulses and sending the same to the stepper motor.

5. EXPERIMENTAL RESULTS AND DISCUSSIONS

In the proposed system as the controller is designed by using computer software technique, there is a flexibility to insert change any time very easily according to our requirement, without hampering experimental hardware condition.The system is more stable and accuracy is high because the controller is processor based .The system has been tested repeatedly. The results have been found excellent. From the experimental data the best-fit straight-line curve has been plotted, as shown in **Fig.5**. The percentage error of the experimental data from this linear trend line equation has been calculated. The percentage deviation curve from linearity is found to lie within ± 0.8 % as shown in **Fig. 6**. It shows that the deviation of the curve from the trend line equation is very small which means that the variation of the measured or observed value from the true value is almost linear. Thus the experimental results indicate that the system has good linearity and repeatability.

Table-1: Angular Position Control of Stepper Motor with Step Angle of 1.8º in closed loop mode

Sl. No.	Positional Angle Set in Degree	Position Angle obtained in Degree	Error (%)
1.	18	18	-0.03887
2.	27	27	-0.02592
3.	36	36	-0.01944
4.	50	50.4	0.78589
5.	72	72	-0.00972
6.	85	84.6	-0.47878
7.	108	108	-0.00648
8.	120	120.6	0.494138
9.	180	180	-0.00389
10.	200	199.8	-0.1035
11.	240	239.4	-0.25291
12.	270	270	-0.00259
13.	300	300.6	0.197662
14.	320	320.4	0.12281
15.	360	360	-0.00194

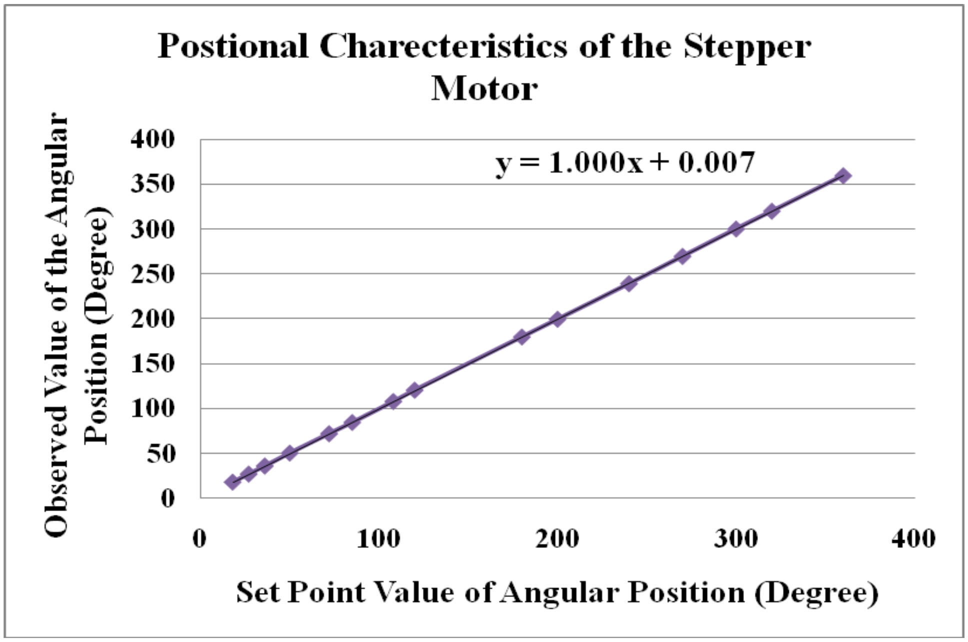

Fig.5. Setpoint Value Vs Observed Value of angular position of Stepper Motor

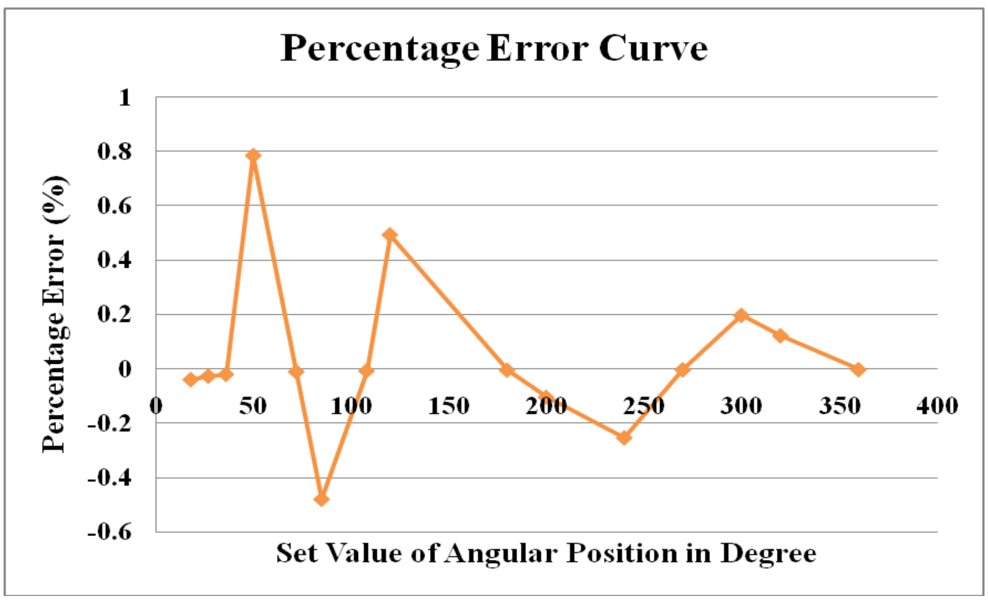

Fig.6. Percentage Error Curve

6. CONCLUSIONS AND FUTURE SCOPE OF WORK

A PC based, low-cost position control system of Stepper Motor has been successfully developed. An efficient and versatile stepper motor drive system using IC ULN 2003 has also been investigated in the present paper. This drive system can provide precise control of a stepper motor by selecting options of half or full step, forward or reverse movement and the speed in RPM or the fixed number of steps that the motor should move, up to 1 degree micro-step and hence it is apt for any robotic and mechatronic applications. The above problem has been implemented in hardware by fusing the software program into a hardware module. The key features of this controller lie in its flexibility to provide for high positional resolution operation of a given stepping motor control system. The controller has been extensively tested for its accuracy. There had been absolutely no missing step problem during the testing. The controller is capable of controlling multiple numbers of stepper motors simultaneously with very precise resolution. The error in the measurement of angular position of the Stepper Motor used is within ±0.8% which is tolerable and thus verified that the system is running smoothly with stability, with high precision and high rapid responding capability. The system developed is very much simple, rugged, and cost effective. Application of such control system of stepper motor in remote surveillance system is the future scope of this work.

REFERENCES

1. Bianculli and J.Anthony, "*Stepper Motor Apllication and Selection*", IEEE Spectrum 1970, 7, 12, 25-29.
2. J.T.Boys, "*Economical Stepper Motors for Speed control Applications*", IEEE Journal on Electric Power Applications, 1979, 2, 1, 27-28.
3. C.Chen, **"**Microcomputer Speed Control of Stepper Motor**"**,IEEE Control System Magazine, 1982, 2, 1, 17 – 20.
4. C.T.Chin, "*A Stepper Motor Controller*", IEEE International Conference on Control 1988,500-505.
5. D.P. Mittal, "*A precision stepper motor controller for robotic applications*", IEEE Industrial Application Society Annual Meeting (Conference) 1989, 1, 686-691.
6. M.Bodson, J.N.Chiasson,R.T.Novotnak and R.B Rekowski, **"***High performance nonlinear feedback control of a permanent magnet Stepper motor***",** IEEE. Trans. Control Syst. Technol.1993,1,1,5-14.
7. Z.L.Kang, "*A new methodology for using single microprocessor to control DC stepper motors*", Proceedings of IEEE International Conference on Industrial Technology 1994, 543-545.
8. R.Innes, "*Industrial Applications of Stepper Motor Control Systems*", IEEE Colloquium on Stepper Motors and Their Control,1994, 1-3.
9. E.T.Ososanya, "*Microprocessor control of mechanical systems*", Proceedings of IEEE Southeastcon 1995, 417-421.
10. A.S.Zein El Din, "*High performance PLC controlled stepper motor in robot manipulator*",Proceedings of the IEEE International Symposium on Industrial Electronics 1996, 2, 974-978.
11. K.G.Adams and M.VanReenen, "A low-cost stepper motor positioning system with minor closed-loop control" Springer Journal,2005, 10,3.

12. T.H.Woo,G.S.Zhang, M.Wang, B.Z.Xu, B.Gang, C.Li, "*Motion Control with the Parallel Port on PC and its applications*", International conference EUROCON 2007, 809-811.
13. Subrata Chattopadhyay, Utpal Chakraborty, Arindam Bhakta and Sagarika Pal, "*Digital Position Control System of a Motorized Valve in a Process Plant Using Hybrid Stepper Motor as Actuator*",Sensors and Tranducers Journal (IFSA),2009,105,73-80.
14. Shi Rongrong, "*Stepper Motor Drive Control based on MCU*", IEEE International Conference on Control, Automation and Systems Engineering, CASE, 2011, 1-3.
15. B.Aranjo, "*Stepper Motor Drives for Robotic Applications*", IEEE International Conference on Power Engineering and Optimization, PEDCO, 2012, 361-366.
16. Darshana K.Sayre, Dipaknanada B.Mane, "*Controlling for Stepper Motor by Parallel Port Controller using MATLAB*", Proceedings of International Conference on Electronics and Communication Engineering ECE, 2013, 91-95.
17. Kausik Chakraborty, Nisarga Chand, Bappaditya Roy, Pabitra Kumar Nandi, "*Design and Development of Stepper Motor Position Control System Using Atmel 89c51 Microcontroller*", International Journal of Emerging Research in Management & Technology, 2013, 2,12,44-48.
18. Indira Mazumdar, Reetam Mondal, Sagarika Pal, "*Design and Development of a Low Cost Colour Sensor and its application in Angular Position Control System of a Stepper Motor*", International Journal of Electronics and Computer Science Engineering (IJECSE), 2013,2,4, 1241-1251.
19. Reetam Mondal, Arumay Mukhopadhyay, Debdoot Basak, "*Embedded System of DC Motor Closed Loop Speed Control based on 8051 Microcontroller*", Elesevier,2013,10,840 -848.
20. D.Patranabis, "*Principles of Indutrial Instrumentation*", Tata McGrawhill publications 2010, Third Edition.

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