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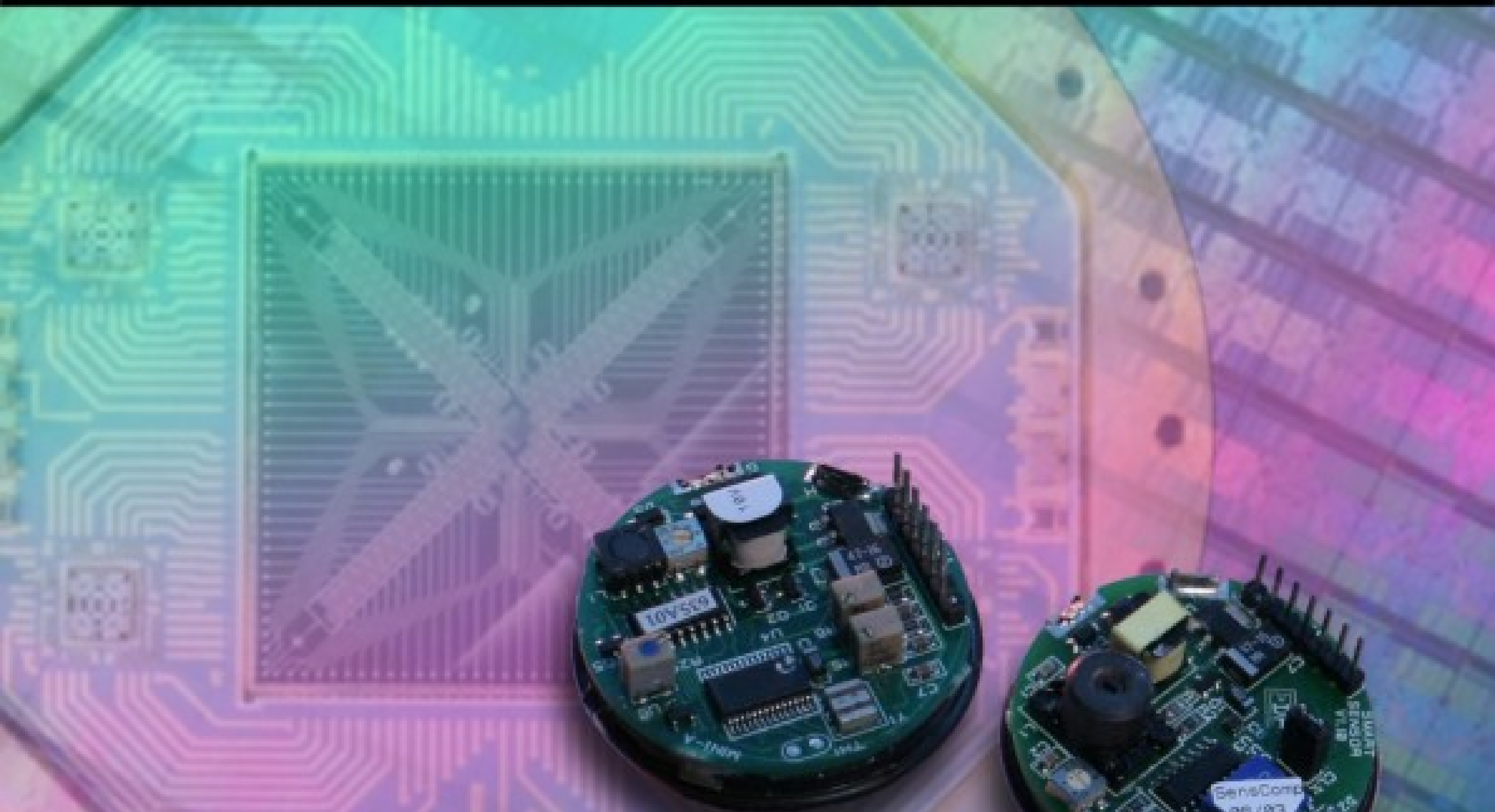

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Contents

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Microcontroller Based Closed Loop PMDC Motor Position Control System

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Abstract: The position control systems used in different applications need to meet the high performance, accuracy and reliability to achieve the desired output. Microcontrollers can be used as suitable means for meeting these needs. The PMDC motor is a low cost electrical device, which can be used for precise position control system. In the present paper, a DC chopper, driven by a PWM signal has been utilized for position control of a PMDC motor. Controlling the duty cycle of the PWM signals has been implemented by microcontroller as equivalent to controlling the motor terminal voltage, which in turn adjusts directly the motor rotational movement. Experimental characteristics have been reported which revels the satisfactory performance of PMDC motor in position control system. The system has good repeatability and the percentage deviation of position of motor is within tolerable limit. *Copyright © 2009 IFSA.*

Keywords: PMDC motor, microcontroller, position control, DC chopper, PWM signal

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1. Introduction

The pneumatic or hydraulic controllers [1], [2] giving command signals to the final control elements may be found to have a number of running and maintenance problems. So these controllers are now being replaced by electronic, microprocessor or PC based controllers [1], [2], [18]. The control signals from these controllers are electric voltage or current signals, which are required to be converted into pneumatic or hydraulic signals to operate a pneumatic [16] or hydraulic control valve or actuator. In order to overcome the cost of these converters, along with higher maintenance and manufacturing costs, the electric motor actuated or motorized final control elements [4], [6], [7], [8], [12], [19] are now being used instead of pneumatic or hydraulic actuator. There are different types of position control techniques of a motorized final control element such as firing angle control of a thyristor drive unit, armature control of dc motor [1], [2], stepping motor [3], [5], [11], linear motor control [15], PC based control [18] etc. Fractional horsepower dc drives are widely employed as servo means for positioning [10]. S. C. Bera, et. al [20] have shown in their paper how integrated circuits can be utilized to design a low cost servo type analog position control system of a motorized valve along with the opto-isolation facility, so that the valve may be operated by the analogue dc voltage signal obtained from the analogue module of a PLCor a microprocessor based controller or an analogue electronic controller.

To overcome the draw backs like signal drifts, parameter variation present in analog controller and non-flexibility etc owing to the involvement of large number of components (MTBF is decreased) in analog position control system, the microcontroller along with the power electronic devices for the control of electric machines are used for precise control, fast response, reliability, long service life, ease of implementation and maintenance. This is because all control algorithms are implemented in the software, which can very easily be altered to suit changes in the operating conditions without changing the hardware [14].

Ula, et. al [9] have shown a speed control scheme of a dc motor using thyristor, which is controlled using the software incorporated on the microcomputer. Nicolai and Castagnet [13] utilized control algorithms stored in the microcontroller. The drive gets power from rectified voltage, consisting of chopper driven by a PWM signal generated from a microcontroller and motor voltage control is achieved by adjusting the PWM duty cycle. Here, PC has not been used as interfacing device. Kheol and Hadidi [17] reported a microprocessor based control system for dc motor using power MOSFET. The Microprocessor computes the speed error and generates a suitable control signal that is fed to the triggering unit, which drives a H-bridge power MOSFET, which in tern supplies a PWM voltage to the DC motor.

The objective of the present paper is to explore the approach of designing a Microcontroller based closed loop controller with on line calculation in order to keep better flexibility and versatility. The interface circuit and the software are all designed with the consideration of short sampling time to achieve a better performance.

In the present investigation, a Microcontroller based position control system has been designed and developed, so that actuator may be operated by the signal obtained from the PC (through key board). Microcontroller based PI controller controls the position of the motor with interactive display control facilities. Here Personal Computer is used in order to make the entire system user friendly. 12V, $10/30/150\ rpm$, PMDC gear motor has been used. The actuator position has been calibrated and the calibration results are reported. From the experimental results, the high degree of repeatability and linearity of the proposed control system are found. This digital system consisting of random logic circuits and an AT89C52-24PC Microcontroller offers overall advantages in performance, price, flexibility, reliability and power requirements.

2. Method of Approach

Servo position feedback analog signal is converted to digital signal by means of an ADC and then it is fed to the Microcontroller. PC feeds input set point signal to the Microcontroller. It compares the feedback value with the set point value and generates PWM and control action signals in order to rotate the motor in desired direction and stops at the desired position when the error is zero. Fig. 1 shows the schematic diagram of the complete automatic position control system using PMDC motor.

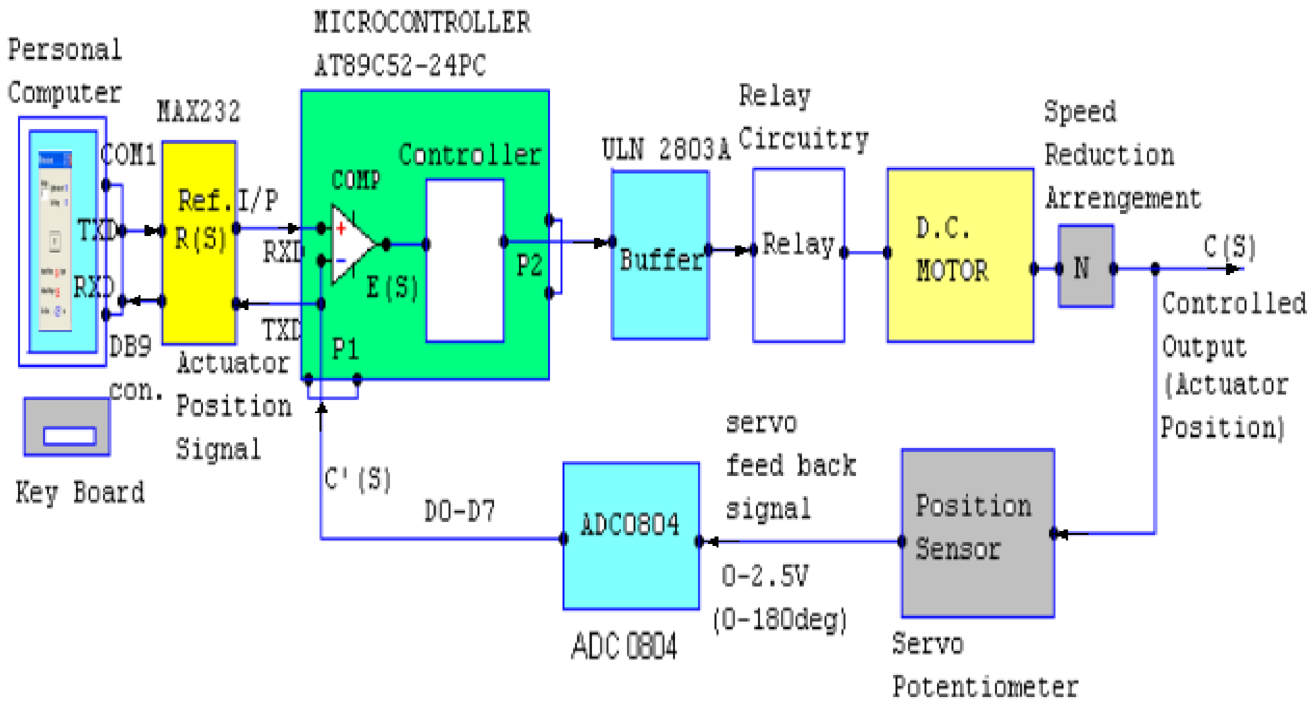

Fig. 1. Block diagram of a Microcontroller based position control system using PMDC motor.

3. Design

The AT89C52-24PC Microcontroller implements the control algorithm by conditioning the position signal and performs the position adjustment according to position reference fed through the keyboard. The system hardware diagram is shown in Fig. 2.

The conventional digital proportion MCU technique and the PWM technique are adopted in PMDC motor position control system.

Servo potentiometer feedback analogue position signal is fed to the $ADC0804$ to convert analog signal to 8-bit digital signal. The $ADC0804$ has an internal clock generator; the $CLKIN$ and $CLKR$ pins are connected to a capacitor $150\,pF$ and a resistance $10k$ in order to get the conversion time $1.10\mu s(f = 1/1.1RC)$. Reference voltage is given to the $V_{ref}/2$ pin via a potentiometer for proper adjustment/calibration. The value of the reference voltage should be adjustable until the digital output code is just changing from 11111110 to 11111111 and this value is maintained throughout the experiment.

Now the microcontroller receives 8-bit digital output data through the port $P1$ and compares the feed back value with the set point value received from the PC through its COM1 port (DB-9 connector). The microcontroller sends the controlled value of position signal to PC to monitor the position of actuator. Communication between PC and microcomputer is made through serial ports via a voltage converter MAX 232 since RS232 is not compatible with the microcontroller. Baud rate is chosen as 9600 (with 8 bit data, no parity bit and 1 stop bit), which is supported by PC BIOS. A buffer / driver is placed between the microcontroller and the motor /relay. All chips / components are fabricated on a SONA 2050 Vero board.

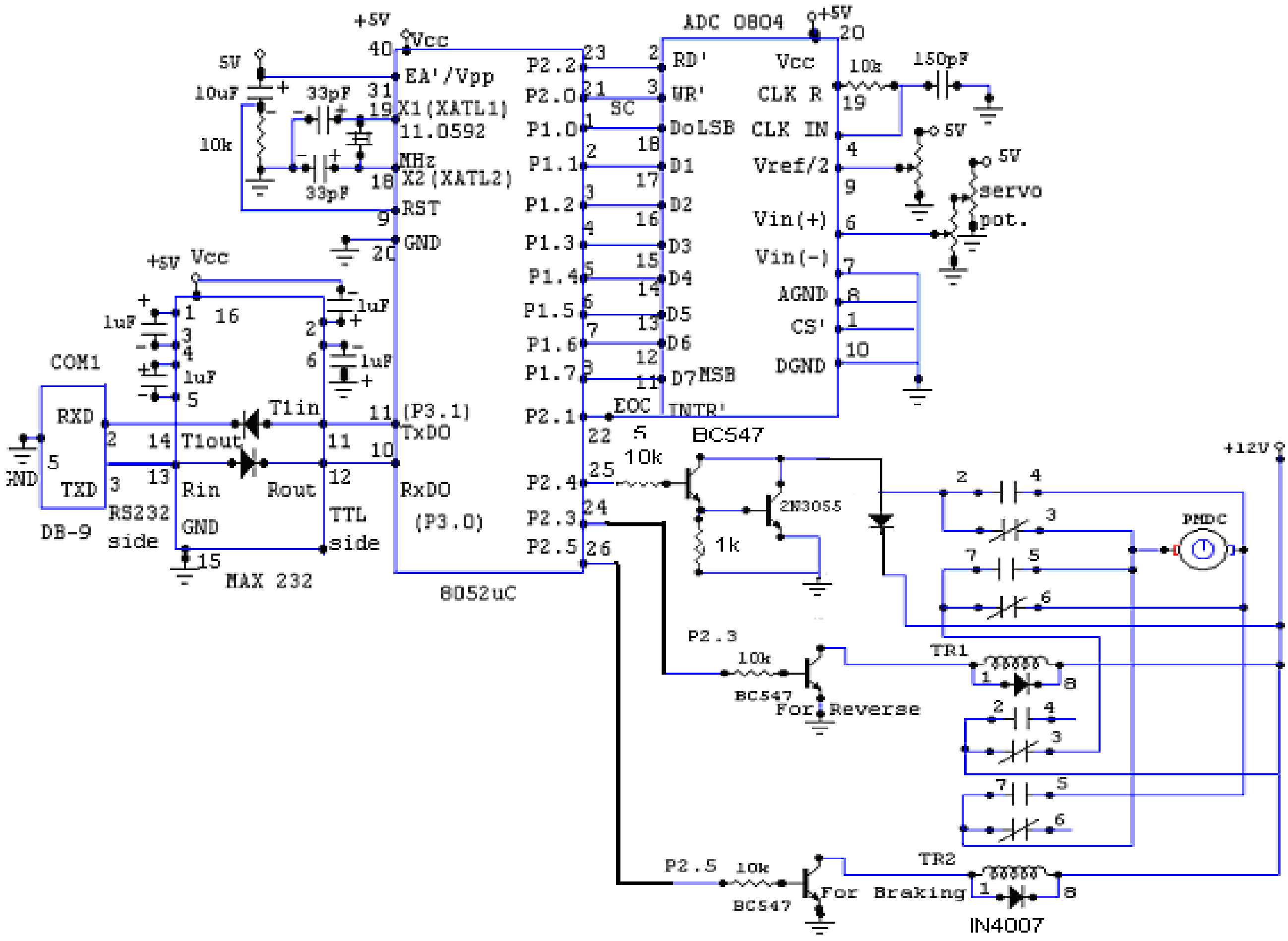

Fig. 2. Circuit diagram of a micro controller based closed loop position control system for a PMDC motor.

4. Principle of Operation

Microcontroller controls the operation as per software programs fed into the Flash Memory. The AT89C52 - 24PC Microcontroller (MPU) can control the position of dc motor accurately with minimum hardware and at low cost.

4.1. Program Algorithm/Flowchart

The main program flow chart corresponding to the system operation is shown in Figure3. The program can be divided into three main parts. The initialization is the beginning of the software to initialize timers, I/O ports. The second part (I/O scan) is reading the position from ADC. The Microcontroller reads the command from PC through keyboard. From the position sensor and the position reference (from keyboard) the Microcontroller calculates the error and the controls the output and then it calculates the PWM signal width. This is the last part of the program, which is called program scan. This part ends by updating the timers to generate the PWM. Then the Microcontroller repeats the I/O scan and then again the program scan.

When the set point value is more than the feed back value, microcontroller will drive the motor in forward direction. When the set point value is less than the feed back value, it will drive the motor in reverse direction by altering the armature connection through energizing a relay.

When the error signal comes to zero, regenerative braking will be imposed by energizing another relay, which helps the motor to stop immediately. Free wheeling diodes are used to prevent the control circuit from being damaged due to back EMI spike created by the electromagnetic relays when they are energized and de- energized.

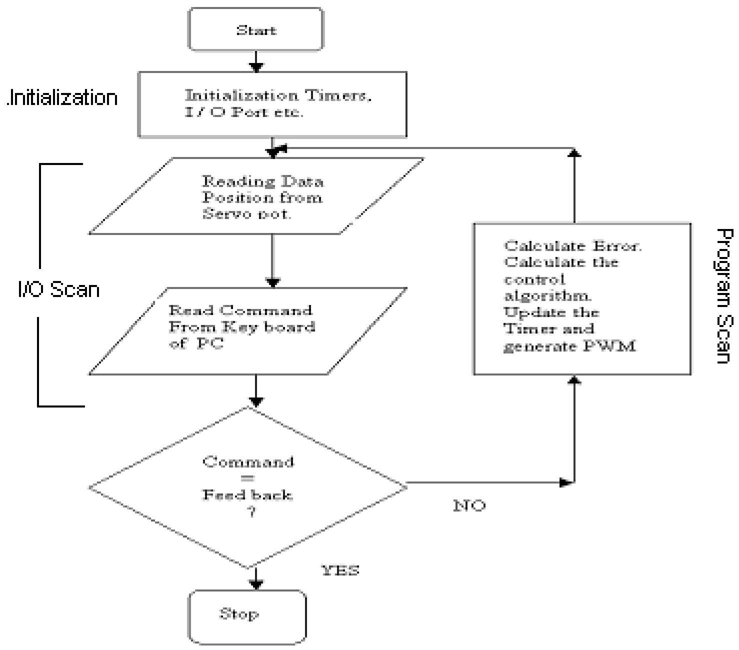

Fig. 3. Main program flow chart.

4.2. Control Algorithm

The interface circuit and the software for control operation are designed with consideration of a short sampling time to achieve a better performance. In order to make the control algorithm executable in real time, a simple PI control algorithm has been developed. Timer overflow interrupt has been used instead of polling to help to shorten the calculation time.

The implementation of the PI controller has been done by writing the assembly-language program.

The digital controller parameters were selected purely from the standpoint of the performance and physical realizability in the analytical and theoretical sense.

There is an interlocking arrangement, which prevents the motor from being damaged due to short circuit owing to simultaneous closing of both relays, (shown in Fig. 2).

The output of the PI -controller is V_0

$$V_0 = \mathbf{Kp * e\,(kT) + Ki * u\,(kT)} \tag{1}$$

$$V_0 = Kp * e\,(kT) + Ki * \{u\,[(k-1)\,T] + Te\,(kT)\} \tag{2}$$

Transfer Function of the controller,

$$G_c(Z) = \frac{\lfloor (K_p + TK_i)Z - K_p \rfloor}{(Z-1)} \tag{3}$$

The control is applied to the dc motor system at $t = kT$, $k = 0,1,2$, ----. The control is updated every T s and is held constant between the sampling instant. The sampling time T is very small.

Here the motor position $\theta(kT)$) is sampled and then converted to an 8-bit binary number by the ADC circuitry. A finite conversion time is associated with the conversion process.

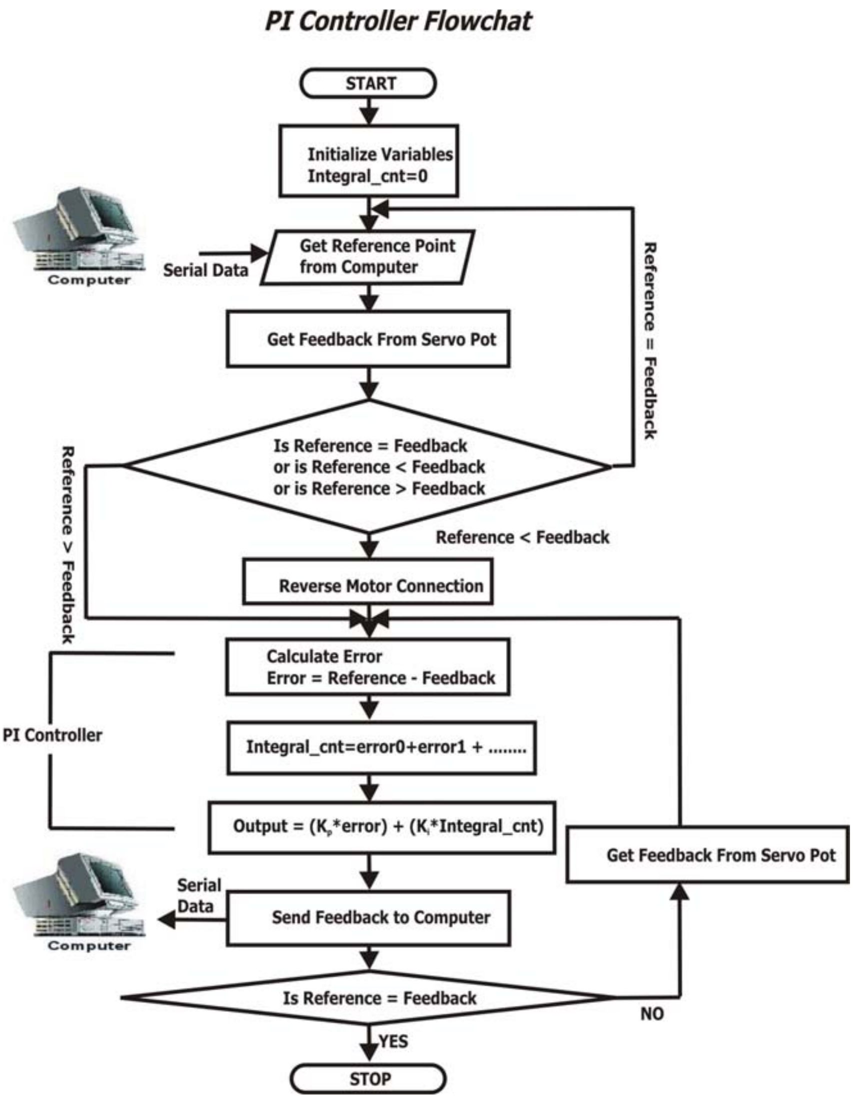

Fig. 4. PI Controller flow chart.

The PI algorithm uses a new tool to generate an analog like output directly from the microcontroller without using any DAC (digital to analog converter). This technique is known as the PWM *(Pulse Width Modulation)*. In PWM a square wave is generated with a constant frequency, the change in the On-Time or Off-Time of the square wave changes the average output i.e. the change in duty cycle changes average output. The following equation shows the relation between duty cycle and average output voltage:

$$V_{av} = V_{in} \frac{T_{on}}{T_{on} + T_{off}} \tag{4}$$

With PI algorithm features, the microcontroller generates PWM with varying duty cycle resulting effective control action signal across the motor which is analogous to the output signal of PI controller which helps the motor to reach steady state condition, steady state error become zero. The values of K_p and K_i were determined by trial and error method in order to get the better transient response with nearly zero overshoot. Fast and accurate positioning of motor has been achieved by using microcontroller-based PI controller.

4.3. Software Approach

There are two parts in software section, one is the Microcontroller program, which has been written in assembly level language and the other one is the Front End program developed using Visual Basic.

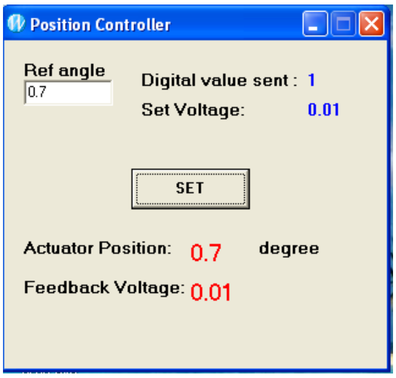

Fig. 5. Minimum step angle 0.7^0.

5. Experimental Results

The design is implemented and tested on the PMDC motors position control system with closed loop control. Tests have been carried out thoroughly to investigate the effectiveness of the approach used both in control algorithms and in electronic circuit design.

The input signal was increased in steps at 5% and at each step the actual actuator position was obtained in both increasing and decreasing modes (for different speed of motors). The position characteristics thus obtained by plotting the observed actuator position against the input set point signal is shown in Fig. 6 The % error from linearity is found to lie within $+/-0.35\%$ as shown in Fig. 7. Minimum position resolution comes to 0.7^0.

5. Discussion

Microcontroller provides very less requirement of hardware.

The performance and flexibility within tolerable limit and on line calculation can be obtained by using a low cost microcontroller.

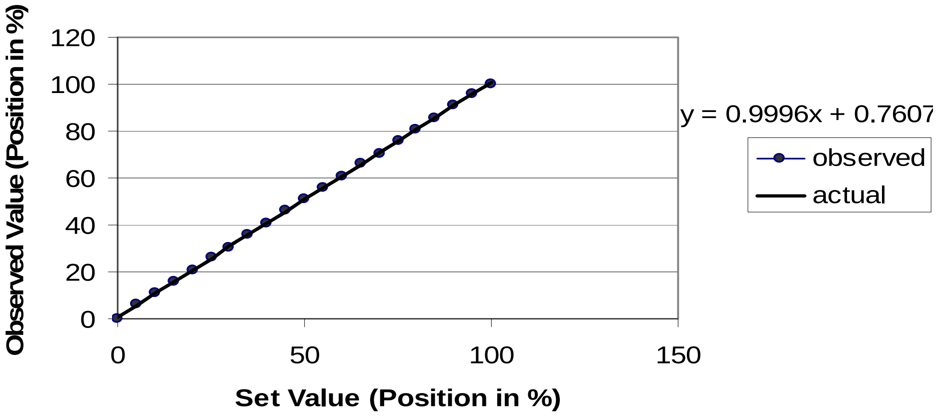

Fig. 6. Position Characteristics of a PMDC Motor (with PI Controller).

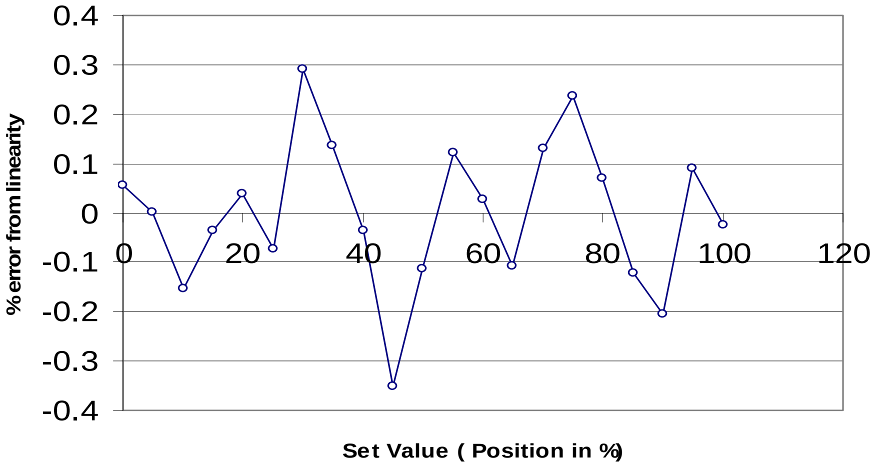

Fig. 7. The % error from linearity (PMDC Motor with PI Controller).

Position characteristics of actuator as shown in Fig. 6 is quite linear. The % error from the linearity is within tolerable limit.

The positional resolution obtained from a dc motor is basically limited by the size / word length of the microcontroller and ADC used in the hardware circuit. Resolution comes to 0.7^0. Performance has been found to be highly reliable and the cost of the control circuit is quite less.

This system (with PI controller algorithm) is applicable to different sizes of motor and capable of controlling the position of the motors with very high precision.

Microcomputer based position control system offers distinct advantages because of the flexibility and versatility. This is because all the control algorithms are implemented in Software, which can very easily be altered to suit changes in the operating conditions without changing the hardware.

Reliability of this system is much higher with good inherent noise immunity. Thus it can be concluded that the system, which is presented here, is reliable with good service life and maintenance of the motor can be improved.

Input and output signals and the digital controller parameters of the system is restricted by the number of bits (here it is 8 bits) of the processor used. Better resolution can be obtained by using higher bits processors.

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Guide for Contributors

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