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Microcontroller Based Closed Loop Speed and Position Control of DC Motor

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Abstract— Direct current (DC) motor has become an important drive configuration for many applications across a wide range of powers and speeds, due to its easy control and excellent performance. This project is mainly concerned on design and implementation of bidirectional dc motor speed and position control system by using microcontroller ATMEGA32 and Lab VIEW software. It is a closed-loop real time control system, where optical encoder is coupled to the motor shaft to provide the feedback speed signal and angular position of shaft to the microcontroller. Pulse Width Modulation (PWM) technique is used which is generated using microcontroller Atmega32 the PWM signal generated will drive the motor driver circuit. By varying the duty cycle the voltage across the motor is varied. Lab VIEW software is used to provide a graphic user interface (GUI) for the user to enter desired speed or desired angle. From the hardware results it is observed that the speed of dc motor remains constant irrespective of the load across it. The angular position control was on par with the desired values.

Index Terms— Mmicrocontroller ATMEGA32, Graphical User Interface, Pulse width modulation

I. INTRODUCTION

Developments of high performance motor drives are very essential for industrial applications. A high performance motor drive system must have good dynamic speed command tracking and load regulating response. DC motors provide excellent control of speed for acceleration and deceleration. The power supply of a DC motor connects directly to the field of the motor which allows for precise voltage control, which is necessary for speed, position and torque control applications. DC drives, because of their simplicity, ease of application, reliability and favorable cost have long been a backbone of industrial applications. DC drives are less complex as compared to AC drives system [1], [2]. Speed and position control of dc motor could be achieved using mechanical or electrical techniques. In the past, speed and position controls of dc drives are mostly mechanical, requiring large size hardware to implement. Advances in the area of power electronics have brought a total revolution in the speed and position control of dc drives [1]. The use of power electronics for the control of electric machines offers not only better performance caused by precise control and fast response, but also maintenance, and ease of implementation.

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In parallel with the advance in power electronic there have been great advances in microcontroller-based control systems due to the microcontroller flexibility and versatility. This is because all the control algorithms are implemented in the software [2] - [3]. Now days, Induction motors, Brushless D.C motors and Synchronous motors have gained widespread use in electric traction system. Even then, there is a persistent effort towards making them behave like dc motors through innovative design and control techniques. Hence dc motors are always a good option for advanced control algorithm because the theory of dc motor speed control is extendable to other types of motors as well [4]. The motor speed can be controlled by controlling armature voltage and armature current. It is obvious that speed control is possible by varying.

- Flux per pole, Φ (Flux control).
- Resistance Ra of armature circuit (Rheostat Control).
- Applied voltage V (Voltage Control) [5].

The above methods have some demerits like a large amount of power is wasted in the controller resistance. Hence, efficiency is decreased. It needs expensive arrangement for dissipation of heat produced in the controller resistance. By these data that are acquainted we can draw a conclusion that these electric and electromechanical methods are less adaptive so electronic techniques are used for speed control. These methods provide higher efficiency, greater reliability, quick response, higher efficiency [6]. One such technique is Pulse Width Modulation. We apply this technique in our project so as to control the speed and position of the DC motor.

II. EXISTING METHODS

The electric drive systems used in many industrial applications require higher performance, reliability, variable speed and ease of controllability. The speed control of DC motor is very crucial in applications where precision and protection are of essence. Purpose of a motor speed controller is to take a signal representing the required speed and to drive a motor at that speed. Different methods are used to control the speed of dc motor. For precise speed control of servo system, closed-loop control is normally used. The block diagram of closed-loop control is shown in Figure 1. The speed, which is sensed by analog sensing devices (e.g., tachometer), is compared with the reference speed to generate the error signal and to vary the armature voltage of the motor [1]-[7].

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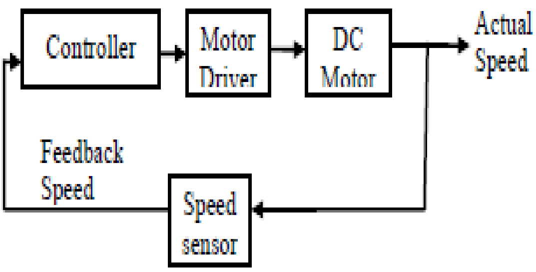

Fig 1: Basic Block Diagram for DC Motor Speed Control

There are several controllers that can used to control the speed of the motor such as:

- Armature voltage using Rheostat method for low power dc motors.
- Use of conventional PID controllers.
- Neural Network Controllers.
- Phase-locked-loop control
- Ac-dc buck-boost converter with only one switching device used for armature voltage control.
- Fuzzy Logic Controller and etc.

A DC motor position control finds wide applications in servo systems, especially in aerospace, automotive and mechatronics applications. The position of a DC motor can be controlled by controlling the Armature Voltage or Field Voltage. The following are few of the simple methods of controlling a DC motor shaft position [9].

- Open loop - without feedback of current position, method is ineffective and inaccurate in the presence of load disturbance.
- On-off controller - motor is turned on with maximum torque till it reaches set point and switches off, this may result in overshoots and oscillations [8]-[12].

Single directional control - reaches set point in a single direction only, the angular position of a DC motor can also be controlled by varying the torque generated by varying the armature voltage or field voltage. In most digital applications, PWM (Pulse Width Modulation) is generally used to control the speed of the DC motor. It is relatively easier to generate pulses of varying duty cycles with a microcontroller or microprocessor. The pulses with varying duty cycle when applied to the armature will result in variable torque proportional to the duty cycle. The control methodology used in this project is to apply an average voltage proportional to the error between actual position and the set point and reduce the average voltage as the current position approaches the set point. This kind of control is very effective in systems with high inertia as an inherent property, so that no control effort is essential when the set point is reached [10].

III. BLOCK DIAGRAM OF THE PROPOSED SYSTEM

Block diagram used for the project work is shown in figure 2. Block diagram has following important parts.

- Permanent magnet dc motor (pmdc motor)
- Microcontroller atmega-32
- Motor driver circuit
- Personal computer
- ZigBee module
- Battery

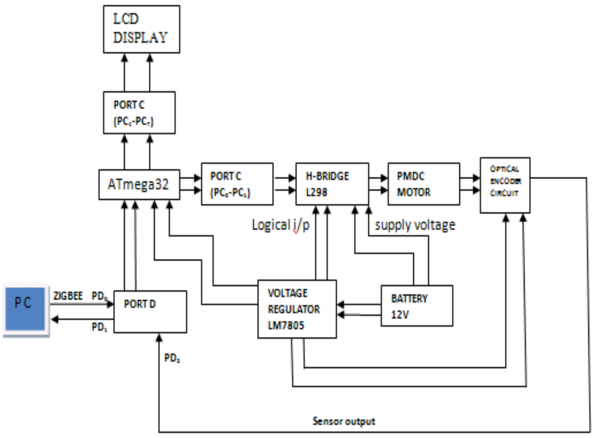

Fig. 2: Block Diagram of the Proposed System

Programming is done using this microcontroller to control the speed and position of dc motor. Following ports of Atmega 32 microcontroller are used for the project work.

- PORT A: Higher order pins (PA7…PA4) are interfaced to a 2 X 16 LCD. The lower order pins (PA3…PA0) has no connection.
- PORT C: Pins PC7 & PC6 are used for enable and reset LCD respectively. PC0 and PC1 are used to provide gate drive signals to H-bridge circuit & all other pins are left free.
- PORTD: Pins PD0 & PD1 are used for ZigBee communication & PD2 is used measure sensor output & all other pins are left free.

Personal computer is used to accept the commands from the user. The LabVIEW software installed in the PC is used to provide graphical user interface (GUI). Through GUI user has to give commands like whether to use the drive system as speed control drive or position control drive and should enter desired speed or angular position respectively. The communication between the PC and the microcontroller is achieved by ZigBee module. The speed of the dc motor is measured by using optical encoder placed on the dc motor shaft. A beam of light is passed from a transmitter across a small space and this light is detected with a receiver at the other end. If a disc is placed in the space, which has slots cut into it, then the signal will only be picked up when a slot is between the transmitter and receiver. In this project LCD is interfaced with microcontroller Atmega 32 through port C. Pin numbers PC4 to PC7 of port C are used as output pins which are fed to LCD to display. LCD displays information such as name of the drive system, mode of the drive system i.e. position control drive or speed control drive, time period for which drive system is operated etc. ZigBee is used in this project work to transfer the data between the microcontroller and the computer.

IV. SOFTWARE TOOLS AND FLOW CHART FOR THE PROPOSED SYSTEM

In this project all of three timers are used:

- **Timer 0** in Normal Mode was used to count pulses from motor speed encoder.

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- **Timer 1**, which has two independent PWM channels, was used to generate PWM waveform to control of the motor speed, one channel for one motor. Timer1 is set on Phase Correct PWM mode.
- **Timer 2** in CTC Mode was used to generate constant time periods.

Programming tools used for the proposed work are embedded C – to generate PWM for the H-bridge switches using microcontroller and LABVIEW software package where graphical programming is done to provide Graphical User Interface. The flow chart used to control position of DC motor is shown in fig 3. Flow chart for the speed control of DC motor is given in fig 4.

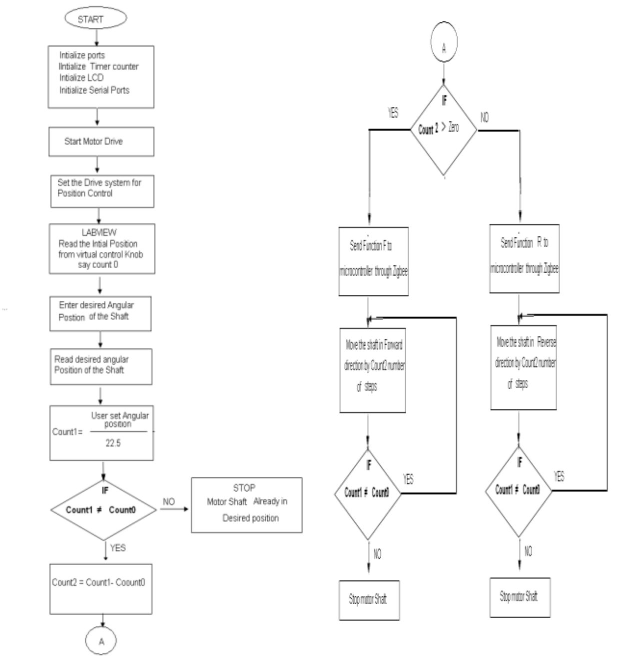
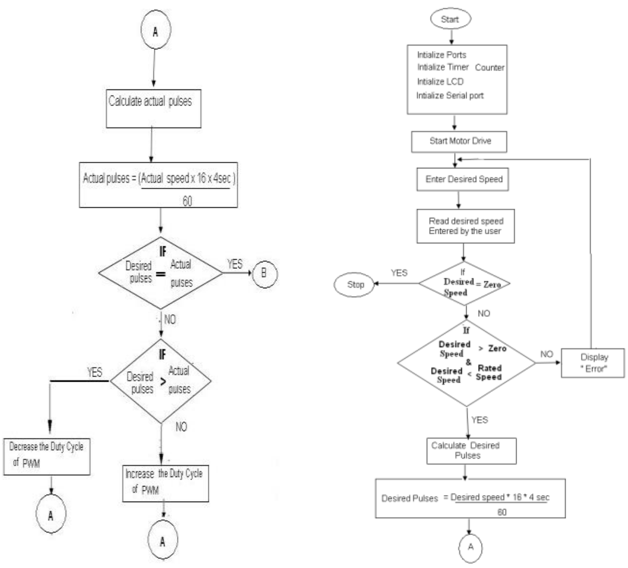


Fig. 3: Flow Chart for Position Control of DC Motor



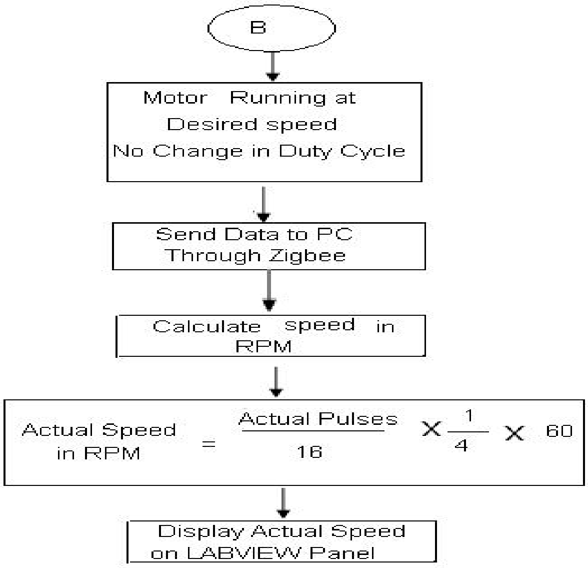


Fig. 4: Flow Chart for Speed Control of DC Motor

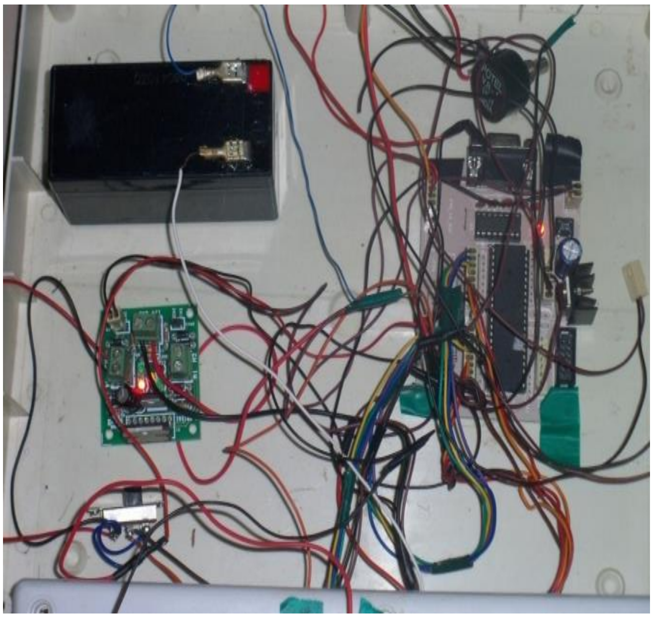


Fig. 5: Snapshot of the Hardware Setup

Hardware module which was fabricated on printed circuit board needed a graphical user interface which is developed using Lab VIEW software module. Graphical user interface enables the user to communicate with microcontroller through ZigBee module. In Lab VIEW software front panel was developed. Front panel has provisions for user where the user can set drive system as speed control system or position control system. If user intends to use the drive system as speed control drive system then the user has to set desired speed at which motor shaft has to be rotated. Front panel also displays actual speed of the motor shaft. If user intends to set the drive system as position control drive system then user has to set angular position at which motor shaft has to be rotated using virtual control knob on front panel. The motor shaft can moved in either direction thus making drive system as bidirectional drive system. Fig 6 shows the snap shot of front panel developed in Lab VIEW software.

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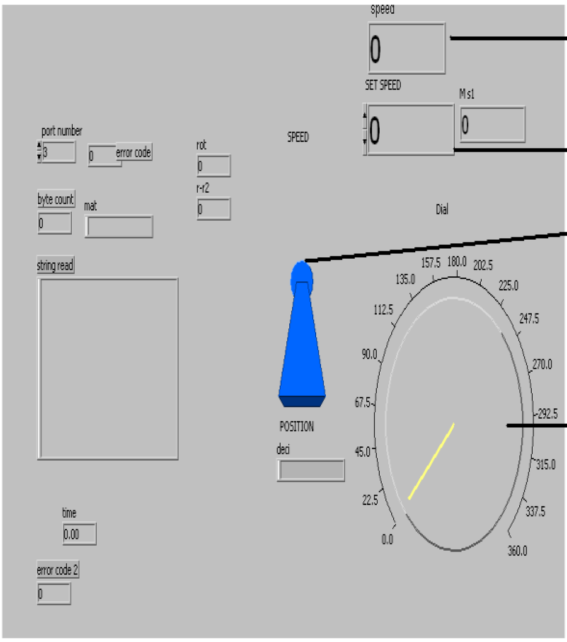

Fig. 6: Snap Shot of Front Panel Developed in Lab VIEW Software

V. EXPERIMENTAL RESULTS AND ANALYSIS

The experimental set up of project model equipped with software module was tested for various conditions. The observation for different mode of operation of drive system is given below.

Case 1:

Mode of drive system: Speed control
Desired speed: 30rpm
Obtained speed: 30rpm

At the start when dc supply is given to dc motor it runs at its rated speed i.e. 100rpm. When user sets the desired speed as 30rpm then microcontroller in conjunction with LabVIEW software decreases the duty cycle of pwm which is given to motor driver circuit. After motor reaches the desired speed the same is displayed on the front panel. Fig 5.6 shows the front panel with desired speed set as 30rpm and corresponding obtained speed. Fig 5.7 shows the corresponding pwm across the h-bridge. The pulses below the reference line give the turn on time where as above gives the turn off time.

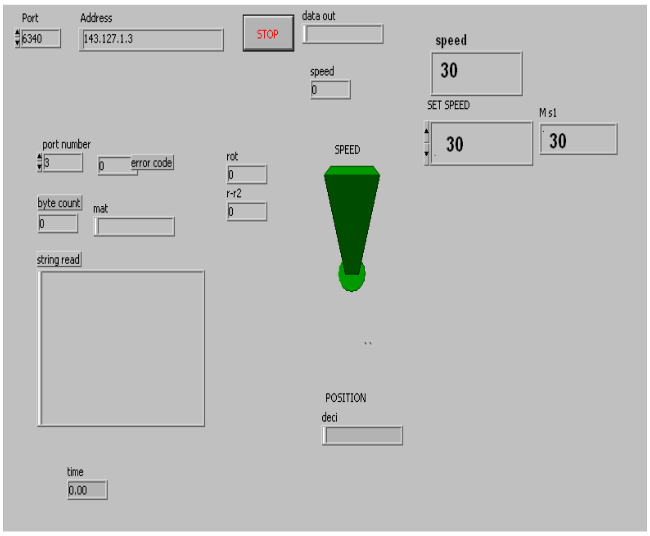

Fig. 7: Front Panel with Desired Speed Set as 30 rpm

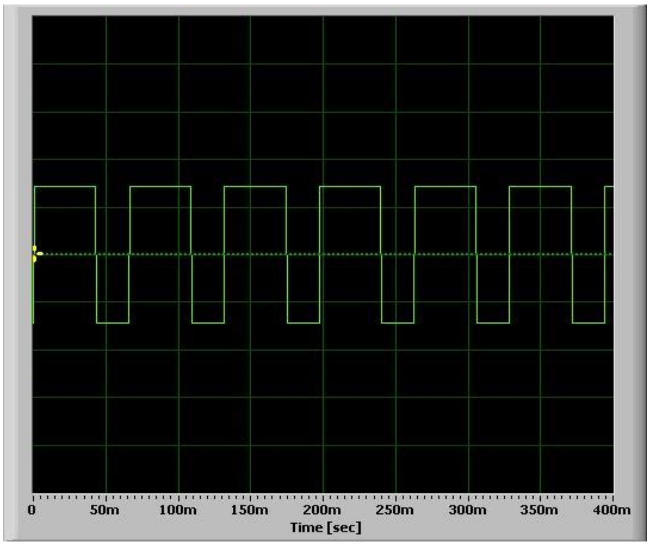

Fig. 8: PWM Across H-Bridge for 30rpm Desired Speed

Case 2:

Mode of drive system: Speed control
Desired speed: 90rpm
Obtained speed: 90rpm

Fig 5.10 gives the snap shot of front panel with desired speed set as 90rpm. Fig 5.11 gives the corresponding pwm across the h-bridge for the desired speed 90rpm.

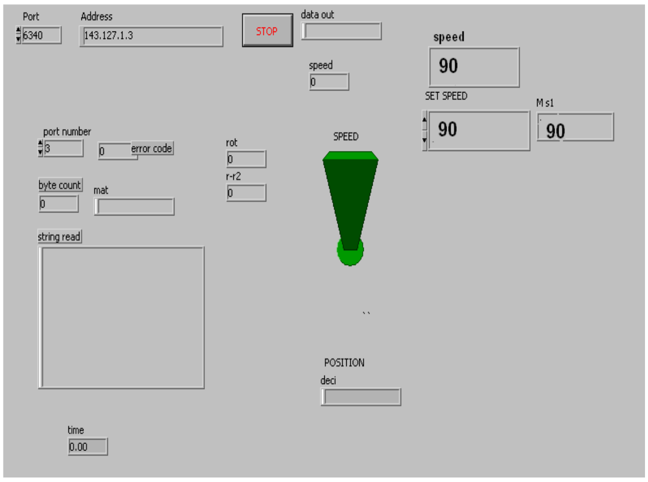

Fig. 9: Front Panel with Desired Speed Set as 90 rpm

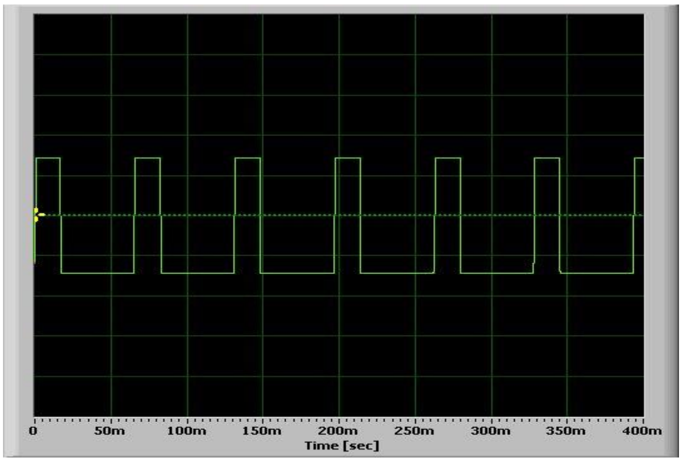

Fig. 10: PWM Across H-Bridge for 90rpm Desired Speed

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Case 3:

Mode of drive system: Position control mode

Desired angular position: 180º

Initially needle on virtual control knob was on zero degrees when user sets the desired angular position as 180º, microcontroller generates required pulses to move the motor shaft from zero degree position to 180º position. Methodology is discussed in chapter 4.

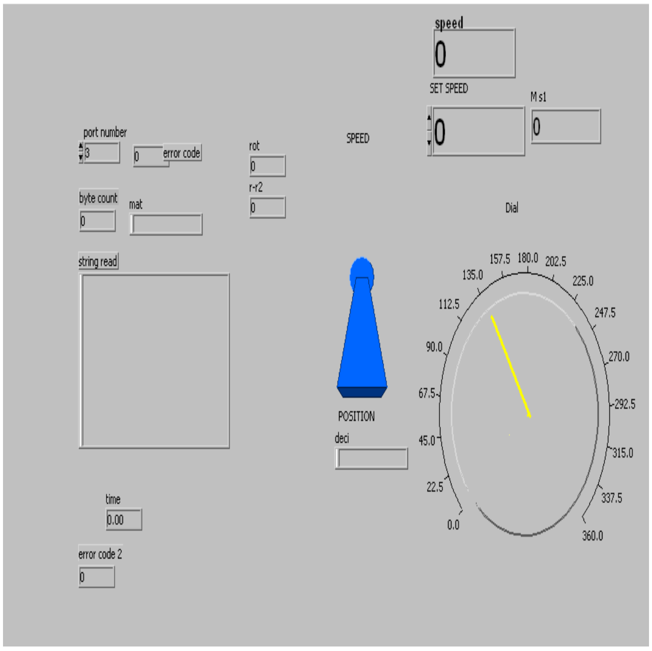

Fig 11: Snap Shot of Front Panel with Angular Position Set as 180º

Case 4:

Mode of drive system: positon control

Desired angular position : 45º

If user sets the desired angular positon as 45º. In previous case the motor shaft was on 180º angular position. Hence microcontroller takes that as initial position and 45º as desired positon. So micrcontroller will generate the pulses such that motor shaft has to be rotated 135º in backward direction. Fig 5.14 gives snap shot of front panel when drive system is moved to 45º i.e 135º backward direction.

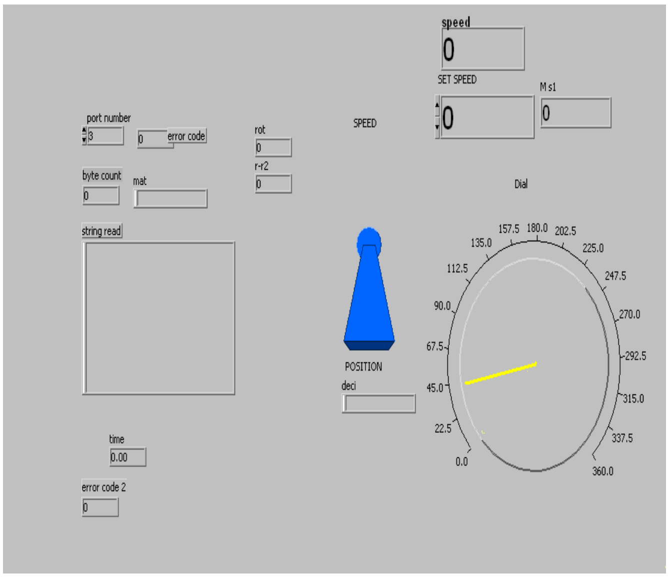

Fig 12: Snap Shot of Drive System at 45º

VI. CONCLUSION

Important conclusions that are drawn out of the investigations in the present work are:

- At any instant the drive system can be either used as speed control drive system or position control drive system.
- Dc motor always runs at a speed set by the user irrespective of the load across it. Position control drive system also works satisfactorily as it rotates the shaft of dc motor to a value set by the user.
- Pulse width modulation (PWM) circuit implemented in a single board Atmega 32 microcontroller, which makes system reliable and compact.
- In addition with high programming flexibility, the design of switching pulse can be further altered easily without any changes in the hardware.

L298 H-bridge which is used in this project work has in built gate drive circuit which reduces the hardware complexity and makes the system compact.

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