MICROCONTROLLER BASED OPEN-LOOP SPEED CONTROL SYSTEM FOR DC MOTOR

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ABSTRACT

This paper presents open loop speed control scheme for the speed control of a permanent magnet DC motor using an AVR Microcontroller. The microcontroller has been programmed to automatically vary the duty cycle of the H-bridge chopper depending upon the set/required speed of the motor. The chopper is driven by a high frequency PWM signal. Controlling the PWM duty cycle is equivalent to controlling the motor terminal voltage, which in turn adjust directly the motor speed. The PC interfacing has been done using serial port (DB9 Connector). Experimental results show that proposed system is suitable for different industrial applications such as trolley buses, subway cars, or battery-operated vehicles.

Keywords: *Microcontroller, PWM, Speed control.*

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I. INTRODUCTION

Variable speed dc drives have become widespread in home appliance area. The DC motor is usually employed in many applications as it gives variable speed and load characteristics due to its ease of controllability. Microcontrollers provide a suitable means of control and interface functions. The dc motor with chopper has higher efficiency as there are no copper and iron losses. The main advantage of PWM circuit over a resistive power controller is that in a resistive controller system most of the power is wasted in series resistor in the form of heat. A reasonable number of works have been found in the literature regarding the control of dc drives [1-4]. Ula and Steadman in [5] utilized the microcomputer to control the speed of the dc motor. The control algorithms are stored and implemented by the microprocessor of the microcomputer. The system employs the use of a thyristor, which is controlled by using the software stored in the microcomputer. Nicolai and Castagnet in [6] used a microcontroller for speed control of DC motor by a PWM signal generated from a microcontroller unit (MCU). The motor voltage control is achieved by measuring the rectified mains voltage with the analog to digital converter present on the MCU and adjusting the PWM signal duty cycle accordingly. Haas and McPherson [7] described motor controller using PWM and tachometer feedback. The controller uses a quadrature encoder to allow the user to enter the desired speed and generates PWM signal. This signal will be the output to dc motor which has a inbuilt tachometer and its output voltage is fed back to the controller to adjust the speed to the desired value. Carmadi Machbub and Yoseph Dwi Cahaya in [8] presented design and implementation of adaptive neural networks for dc motor speed control system. DC Motor is actuated by Pulse Width Modulation (PWM)-based H-Bridge actuator. Neural networks were developed using the dc motor modeling with PWM actuator as a single order linear system. plant's parameter changes can be estimated and used to produce appropriate control action. However, to use a microcontroller as a closed loop controller is relatively complex and may not be required for simple application. In this paper designing of Microcontroller based open loop controller for dc motor has been proposed. The microcontroller system is equipped with a LCD display and a keyboard and software is written to monitor the registers on the LCD and read command from the keyboard. The hardware structure of the system consists of a Microcontroller (ATmega16), Chopper circuit (IC L293D), Display and keyboard circuits. The software program has been developed in C language. The software includes programming for PWM signal generation, initialization, LCD display, and Keyboard interfacing. A 12V, 300W, 2400 rpm permanent magnet dc motor and 5v, 500mA regulated power supply has been used

II. THE PERMANENT MAGNET DC MOTOR AND ITS CONVERTER

The speed of the motor can be varied by varying the armature voltage in the constant torque region or by varying the field flux in the constant power region to achieve below rated and above rated speeds respectively. The ability to produce high torque at low speeds and compact size makes PMDC motor suitable for many applications.

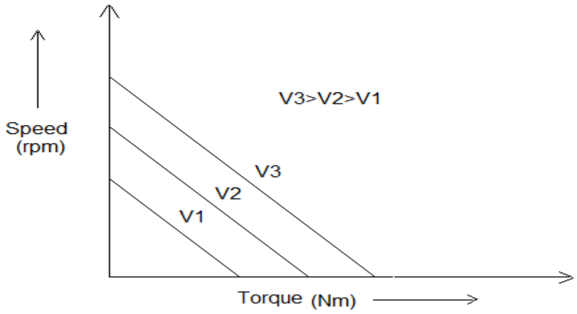

Fig.1. Speed-Torque Characteristics of PMDC Motor

Speed of the PMDC motor is proportional to voltage and torque is proportional to current and it can generate high torques, typically 10 to 12 times the rated torque. Speed torque characteristics of PMDC motor are as shown in the fig.1. Speed can be controlled by varying the voltage applied to the armature. In this paper voltage control is used which is obtained with the help of H-bridge chopper as shown in the fig. 2 & 3.

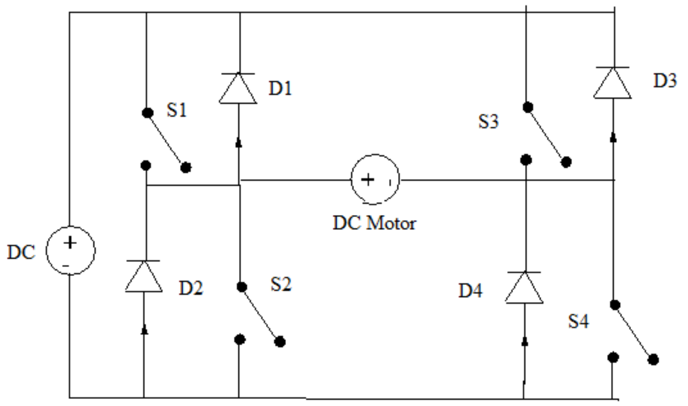

Fig. 2. H-Bridge chopper

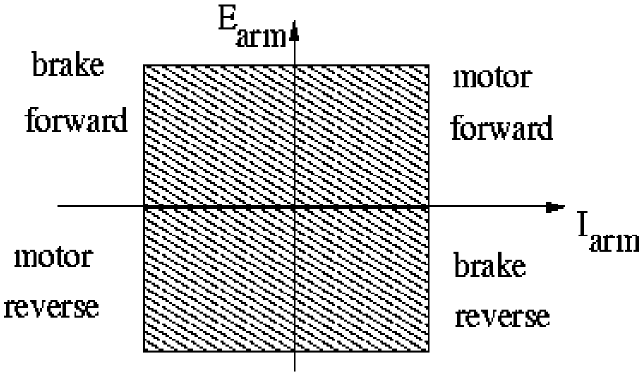

Fig. 3. Four quadrant operation

This paper presents two modes of operation i.e. first and third quadrants by operating switches S1, S2, S3 and S4 in different order. The motor rotates in clock wise direction in first quadrant (S_1-ON, S_4-ON) and anti-clock wise in third quadrant (S_2-ON, S_3-ON).

III. HARDWARE DESIGN

A. Mechanism of DC Motor speed control

The ATMEGA-16 Microcontroller implements the control algorithm according to the speed given through the keypad. Port-B pins PB3 and PB4 are given for driving the L293D Chopper IC. The Opto-coupler MCT2E is used to isolate the high voltage circuit from the low voltage controlling signals. The user can give commands through the keypad for running the motor either clockwise or anticlockwise directions. A digital Tachometer is used to measure the speed of the motor.

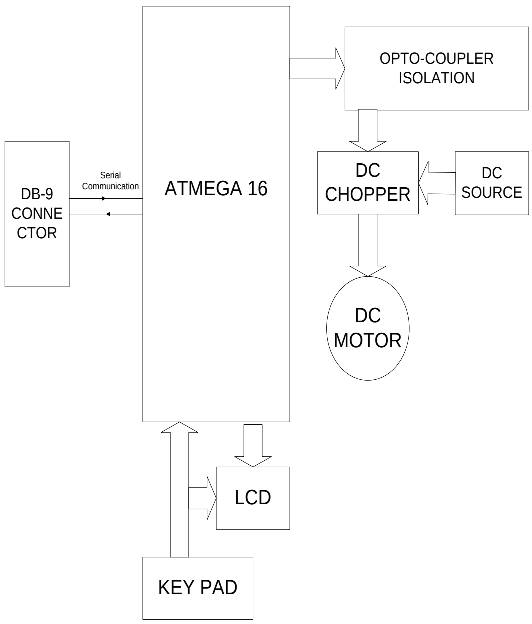

Fig. 4. DC Motor speed control hardware block

B. *H-Bridge Chopper L293D*

This device is a monolithic integrated high voltage, high current 4 channel designed to accept standard DTL or TTL logic levels and drive inductive loads and switching power transistors. To simply use as two bridges each pair of channels is equipped with an enable input. It is suitable for use in switching applications at frequency up to 5 KHz.

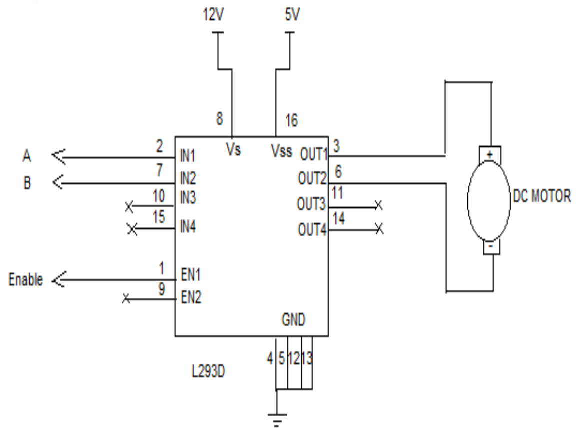

Fig.5. Connection diagram for L293D

A	B	Description
0	0	Motor stops or Breaks
0	1	Motor runs Anti-clockwise
1	0	Motor runs Clockwise
1	1	Motor stops or Breaks

Table. 1. Truth Table for Chopper L293D

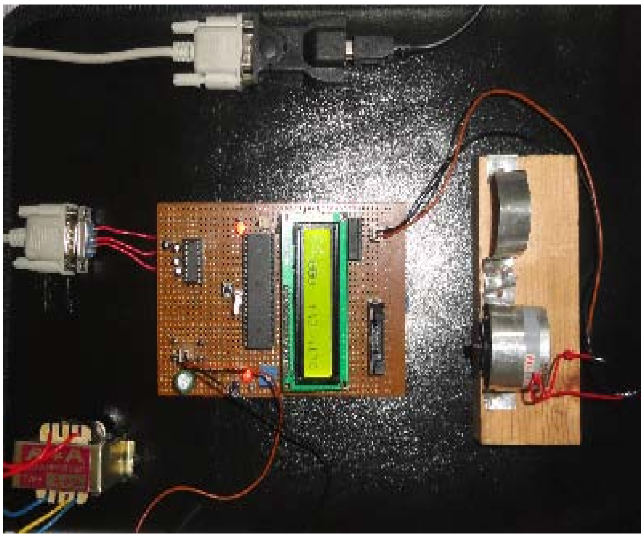

Fig.6. Photograph of Hardware

IV. SOFTWARE DESIGN

A. Algorithm for Speed control

The AVR Microcontroller can control speed of the DC motor accurately with minimum hardware at low cost. The MCU has inbuilt timer and counter register.

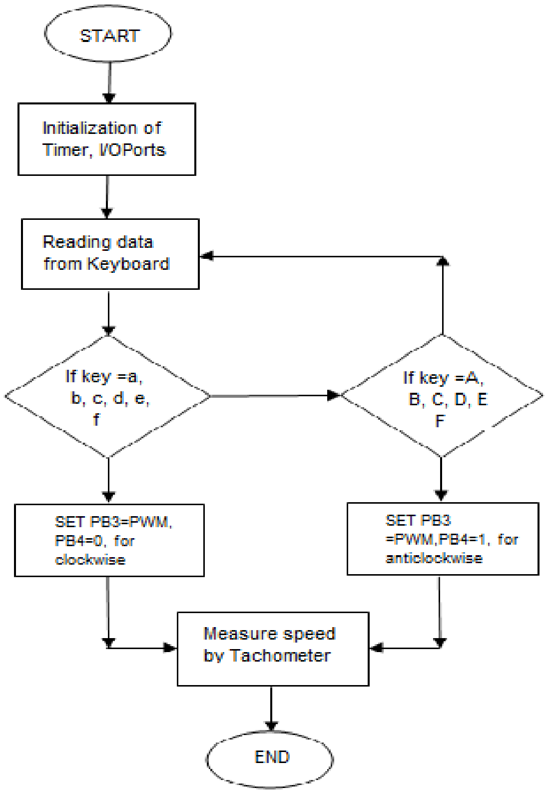

Fig. 7. Algorithm for Speed control

The algorithm shown in the fig.7 describes the speed control program which first initializes the timers and I/O ports then reads the commands from the keyboard. Each key is designated with a specific count which is equivalent to different duty cycles. On the basis of the count Microcontroller generates a PWM signal and the motor can be stopped by keying a specific character anytime.

B. Timer and its PWM Modes

Timer0 has been used in fast PWM mode as shown in the figure. 8 & 9. As Timer starts, it counts up until it reaches its limit of 0XFF. When it rolls over from 0XFF to 00, it sets the Timer over flow (TOV0) flag. When COM01=1 and COM00=1 then NON-INVERTED mode is used.

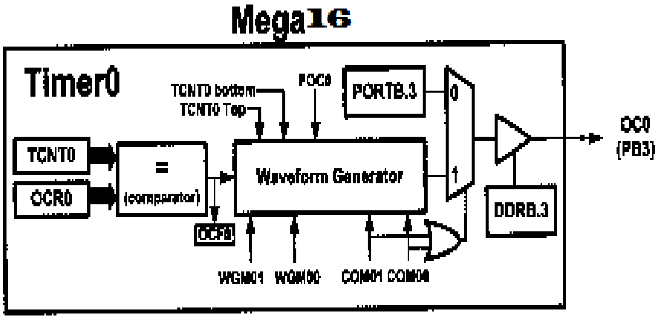

Fig. 8.Waveform Generator

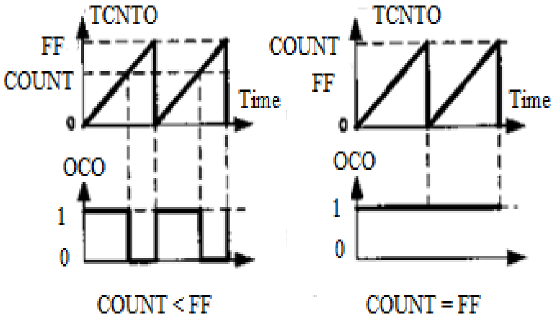

Fig. 9. PWM Signal generation

C. Fast PWM Mode Duty Cycle

Duty cycle can be calculated by using equation 1. The duty cycle can be determined using the OCR0 register, bigger OCR0 value results in a bigger duty cycle. When OCR0 is 255, the OC0 is 256 clocks out of 256 clocks, which means duty cycle is 100percent.

$$\text{DUTY CYCLE} = \frac{\text{OCRO}+1}{256} \times 100 \qquad (1)$$

V. RESULTS

Figure 10 & 11shows speed variation for different duty cycles for clock wise and anti-clock wise rotation respectively. A linear speed Vs voltage curve is obtained.

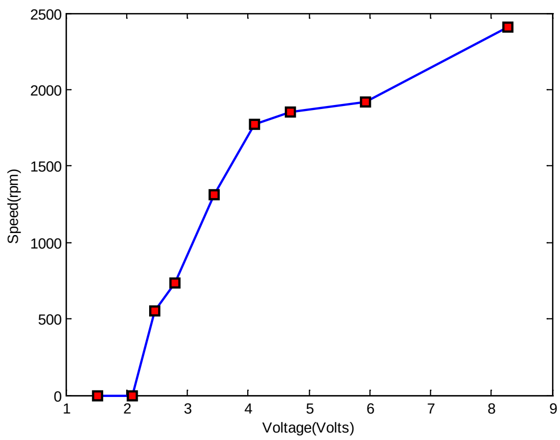

Fig.10. voltage-speed characteristics for clockwise direction

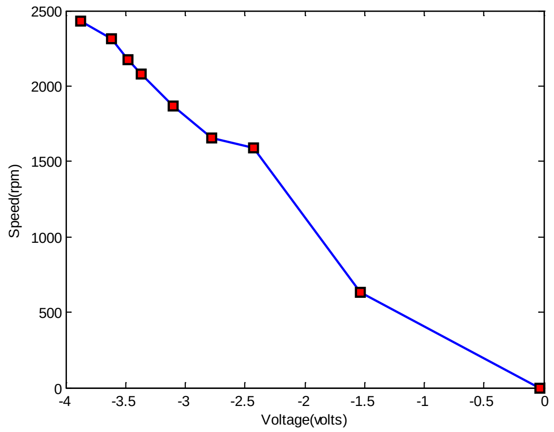

Fig.11. voltage-speed characteristics for Anti-clockwise direction

VI. CONCLUSION

The microcontroller based open loop dc motor speed controller system has been developed. Experimental result shows that microcontroller is a reliable instrument to control the motor with high precision. The proposed method reduces the number of components because the microcontroller can integrate in one package all the functions. The graph obtained from the experimental results is similar that of the permanent magnet dc motor. Thus, the proposed technique suited for industrial applications.

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