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Design and Implementation of a Low-cost MOSFET Based Chopper Drive DC Motor Speed Control

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Abstract: Electric drives have numerous applications in diverse areas such as rolling mills, electric trains and robotic manipulators. Inefficient control of motor speed can destroy the equipment itself; even can cause a severe accident. In this project, a low-cost MOSFET based chopper drive DC motor speed control system was designed and implemented. In this system, the feedback voltage from the load controls the speed of the DC motor through speed controller. From the measurement, it is clear that for a maximum rpm of 210, the percentage of error varied from 1.10 to 14.28 for 12 V supply voltage. The total cost of the speed control scheme is only 18 USD. Such a drive will be appropriate for the speed control of DC motor in household to industrial appliances.

Keyword: DC motor, Speed control, MOSFET, DC chopper, separately excited DC motor.

1. Introduction

Development of high performance motor drives are very essential for industrial application which must have good dynamic speed command tracking and load regulating response. DC drives have been a backbone of industrial applications for the long time because of their simplicity, ease of application, reliability and favorable cost. DC motors are conveniently portable, and have compatible torque/speed characteristics with most mechanical loads which makes it controllable over a wide range of speeds by proper adjustment of the terminal voltage [1]. Speed control techniques in separately excited DC motor can be achieved either by varying the armature voltage below rated speed or by varying the field flux to achieve speed above the rated speed.

There are different kinds of speed controlling devices such as IGBT, Thyristor, BJT and MOSFET that are used in practical circuits. An IGBT or insulated gate bipolar transistor is a solid state device with no moving parts. IGBT employed chopper gives fast switching, high efficiency and less switching losses [2]. Thyristors, on the other hand, have been the traditional workhorses for bulk power conversion and control in industry. The modern era of solid state power electronics started due to the introduction of this device in late 1950s. Basically, it is a trigger into conduction device that can be turned on by positive gate current pulse but once the device is on, a negative gate pulse cannot turn it off [3]. The device turn on process is very fast and turn off process is slow because the minority carriers are to be cleared from the inner junctions by “recovery and recombination” processes.

The bipolar junction transistor (BJT) is a well-known semiconductor device described in detail in the majority of the electronic or semiconductor treaties. These transistors are current-controlled devices. The metal–oxide–semiconductor field-effect transistor (MOSFET) is a type of field-effect transistor (FET). It has an insulated gate, whose voltage determines the conductivity of the device. This ability to change conductivity with the amount of applied voltage can be used for amplifying or switching electronic signals [4]. Table 1 shows a performance comparison of different types of motor speed control systems.

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Table 1 Comparison of different types of motor speed control system.

Ref	Title	Switching Device	Supply Voltage (V)	RPM range (rpm)
[5]	Speed control of DC motor using IGBT	IGBT	AC (220-440)	Induction motor (4 Pole) (2500)
[6]	Speed control of DC motor using Thyristor	Thyristor	AC 240	Induction motor (4 Pole) (2050)
[7]	Speed control of DC motor using BJT	BJT	AC 220	5000
[8]	MOSFET based chopper drive DC motor speed control	MOSFET	AC 220	(40-2500)

From this comparison it is clear that these kind of switching device like IGBT, Thyristor, BJT and MOSFET their supply voltage are AC (220-440 V), Thyristor AC 240 V, BJT AC 220 V and MOSFET AC 220. It is noticed that the rpm range of these controlling device are IGBT (induction motor 4 pole 2500 rpm), Thyristor (induction motor 4 pole 2500 rpm), BJT 5000 rpm and MOSFET 40-2500 rpm. From these performance analysis, it is clear that MOSFET based speed control system is more efficient than other controlling devices because in this system motor rpm can be varied from 40-2500 rpm and it can be perfectly control the speed of motor by using the system.

2. Research Method

Fig. 1 shows the block diagram of DC motor speed controller. It consists of three main parts containing of speed controller, power converter and feedback which can give reference value to control the speed of DC motor. Fig. 2 shows the complete circuit diagram of the proposed speed control scheme of the DC motor.

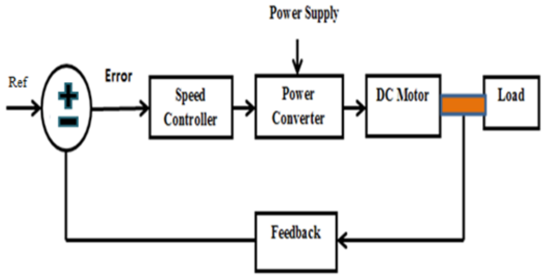

Fig. 1 Block diagram of DC motor speed controller.

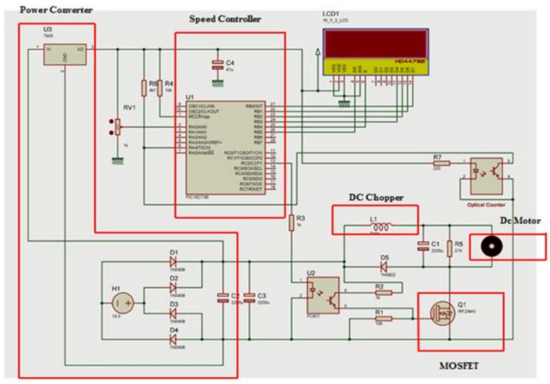

Fig. 2 Circuit Diagram of DC motor speed controller.

In the proposed circuit, 5 V and 12 V DC supplies have been used to power up the microcontroller unit (MCU) and DC motor, respectively. For voltage conversion a step down transformer from 220 V – 12 V DC completed with bridge rectifier diode and a filter capacitor was used. In order to obtain a regulated 5 V DC, a LM7805 fixed voltage regulator is utilized, which supplied 5 V to MCU and other control circuits. The MCU (PIC16F73) is an 8-bit microcontroller to control the whole circuit with pulse width modulation (PWM) produced by a Mikro C Pro coding (frequency increment algorithm). The general purpose input-output (GPIO–RA0) is used along with a potentiometer in order to set the PWM frequency and the output is GPIO-RC2 (test point of oscilloscope). The GPIO-RC2 trigger an opto-coupler (PC817) to drive the MOSFET that joint the chopper transformer. Chopper transformer sets the wave shape with a feedback algorithm for the DC motor. The GPIO-RA4 receives data from IR-Tx and IR-Rx obstacle avoidance algorithm, which shows rotation per minute (RPM) with set values of asking speed. The GPIO RB0-RB5 displayed all data by a (16×2) LCD display.

Fig. 3 demonstrates the design and operation flow of the proposed speed controller. The scheme starts with designing a DC chopper circuit which is later needed to be synchronized with DC motor. These steps are needed to be repeated until an optimum result is obtained.

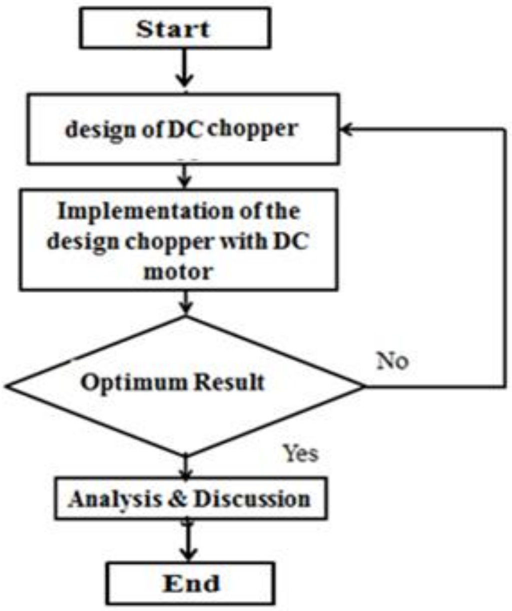

Fig. 3 Flow chart of the DC motor speed control scheme.

3. Results and Discussion

The speed of the motor displayed at the integrated LCD display (rpm 2) with respect to the PWM is shown in Table 2. For the comparison purpose, a tachometer (model-DT2235A) is used to measure the motor speed (rpm 1) and the percentage errors are calculated.

From Table 2 of the calculated average value, it is obvious that the average speed of motor from the display is 117.143 rpm which is almost equal to the average speed of motor from the Tachometer 122.429 rpm. The average error which is calculated from the two rpm values is 5.867% only. The variation of error is from 14.28% to 1.10%, which is due to the deviation of the motor speed from its rating which is 150-180 rpm. Fig. 4 and Fig. 5 shows the variations of the RPM values and the percentage error as a function of PWM, respectively. Table 3 gives the details of the equipment utilized in the project and their costs which is only 1455 BDT = 18.18 USD (considering 1 USD = 80 BDT).

Table 2 Relationship of PWM and motor speed (rpm).

Supply (V)	Power Supply for Motor (V)	Power supply for MCU (V)	PWM (Hz)	Speed of Motor (RPM 2)	Tachometer (RPM 1)	$Error = \frac{rpm1 - rpm2}{rpm1} \times 100$
220	12	5	40	30	35	14.28
220	12	5	60	50	54	7.41
220	12	5	90	80	85	5.88
220	12	5	120	120	125	4.00
220	12	5	150	150	156	3.85
220	12	5	190	180	182	1.10
220	12	5	240	210	220	4.55

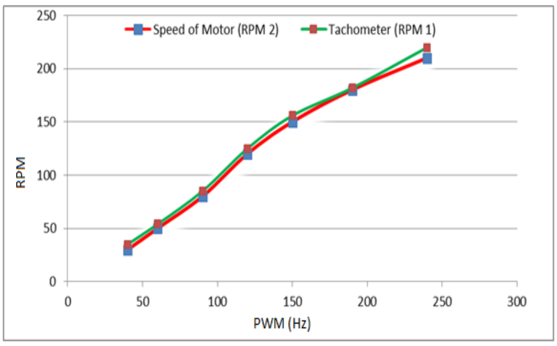

Fig. 4 Comparison between speed motor (RPM 2) and tachometer (RPM 1).

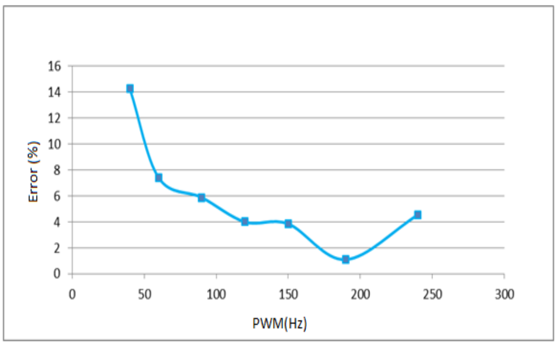

Fig. 5 Graph of Error versus PWM.

Table 3 Cost calculations of the completed project.

Sl. no.	Description	Manufacture	Price (BDT)
01	PIC16F73-8bit MCU	Microchip Inc. USA	95.00
02	LCD 16X 2 Display	Mitsubishi	280.00
03	Optical Counter	STI	200.00
04	Opt Coupler	STI	55.00
05	IRFZ44N-MOSFET	NOVO Crop	45.00
06	Inductor Coil-5uh	Nano Power BD	120.00
07	LM7805 Reg.-IC	STI	20.00
08	1N5408 Diode	STI	40.00
09	DC Motor	Thomson	200.00
10	Resistor’s	STI	50.00
11	Capacitor’s	STI	100.00
12	12V-2A SMPS P/S	Horb Con	250.00
		Total	1455.00

Conclusion

Electric drives are the part of our daily life. In this research, a MOSFET based chopper drive DC motor speed control system was designed and implemented. This controller that for a maximum rpm of 210 and the percentage of error varied from 1.10 to 14.28 for 12 V supply voltage. The total cost of the speed control scheme is only 18 USD. Such a drive will be very suitable for household to industrial appliances.

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