© 2015 IJSRST | Volume 1 | Issue 2 | Print ISSN: 2395-6011 | Online ISSN: 2395-602X
Themed Section: Science

Speed Control of DC Motor Using Microcontroller

Katke S.P*1, Rangdal S.M2

*1 Electrical Department, BMIT, Solapur , Maharashtra, India

2 Electronics Engineering Department, VVPIT, Solapur , Maharashtra, India

ABSTRACT

Direct current (DC) motor has already become an important drive configuration for many applications across a wide range of powers and speeds. The ease of control and excellent performance of the DC motors will ensure that the number of applications using them will continue grow in future. This paper is mainly concerned on DC motor speed control system by using microcontroller PIC 16F877A. It is a closed-loop control system, where optical encoder (built in this project) is coupled to the motor shaft to provide the feedback speed signal to controller. Pulse Width Modulation (PWM) technique is used where its signal is generated in microcontroller. The PWM signal will send to motor driver to vary the voltage supply to motor to maintain at constant speed. Through this paper, it can be concluded that microcontroller PIC 16F877A can control motor speed at desired speed although there is a variation of load.

Keywords: DC Shunt Motor, Optical Encoder, Pulse Width Modulation (PWM), H-Bridge Using MOSFET, Peripheral Interface Controller (PIC).

I. INTRODUCTION

Direct current (DC) motors have variable characteristics and are used extensively in variable-speed drives. DC motor can provide a high starting torque and it is also possible to obtain speed control over wide range. It is important to make a controller to control the speed of DC motor in desired speed. DC motor plays a significant role in modern industrial. These are several types of applications where the load on the DC motor varies over a speed range. These applications may demand high-speed control accuracy and good dynamic responses.

DC motors are suitable for belt-driven applications and the applications where great amount of torque is required. In Train and automotive traction, fuel pump control, electronic steering control, engine control and electric vehicle control are good examples of these. In aerospace, there are a number of applications, like centrifuges, pumps, robotic arm controls, gyroscope controls and so on. For precise speed control of servo system, closed-loop control is normally used. Basically, the block diagram and the flow chart of the speed control are shown in Figure 1 & Figure 10. The speed, which is sensed by optical sensing devices (e.g., LED & Photo diode), is compared with the reference speed to generate the error signal and to vary the armature voltage of the motor.

II. SPEED CONTROL USING MOSFET

Figure 1 shows the block diagram of DC motor speed control by using MOSFET. The MOSFET is used to supply a variable DC voltage to motor, thus it can control the speed of motor. The average output of voltage is given by

$$V_{ave} = \frac{V_m}{2\pi}(1 + \cos\alpha)$$

where Vm = peak voltage of voltage supply and α = firing angle

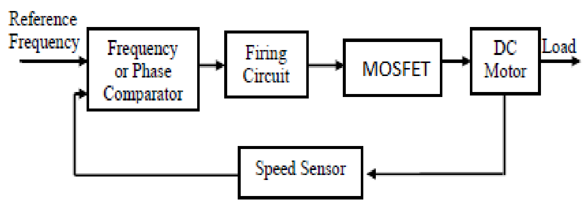


Figure 1: Block diagram of DC Motor speed control by using MOSFET

By controlling the firing angle, α, the average of output DC voltage can be varied. If the motor speed is low, the speed sensor frequency will be below the reference frequency. The frequency difference produces a change in the firing circuit that causes the MOSFET to fire sooner (firing angle, α is reduced). There is a resulting increase in motor speed which brings the output speed back up to the value which is equal to the reference signal.

Conversely, if the speed sensor output frequency is above the reference, then the firing circuit will be modified to allow the MOSFET to conduct for a shorter period of time, the decrease in conduction reduces the DC motor speed. The average of voltage that supply to DC motor is given by,

$$V_{ave} = \frac{t_{on}}{T} \times V_{in}$$

Where Vave = average voltage supply to DC motor

ton = time ON of switches (ie. Duty Cycle)

T = period of PWM

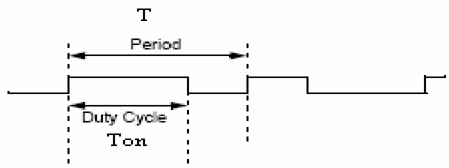


Figure 2: PWM Signal

As the amount of time that the voltage is on increases compared with the amount of time that it is off, the average speed of the motor increases and vice versa. The time that it takes a motor to speed up and slow down under switching conditions is depends on the inertia of the rotor (basically how heavy it is), and how much friction and load torque there is.

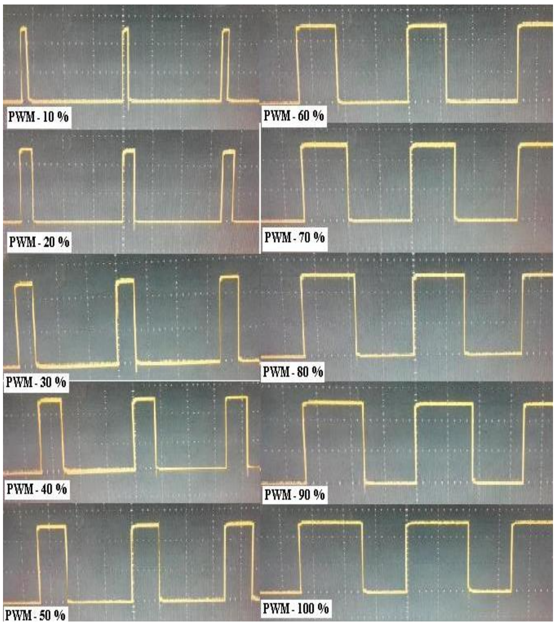


Figure 3: PWM waveform at 10 to 100 % on DSO

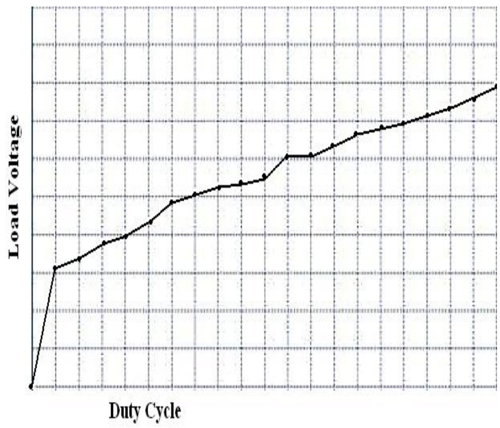


Figure 4: Relation of armature voltage with motor speed

III. SPEED MEASUREMENT BY USING OPTICAL ENCODER

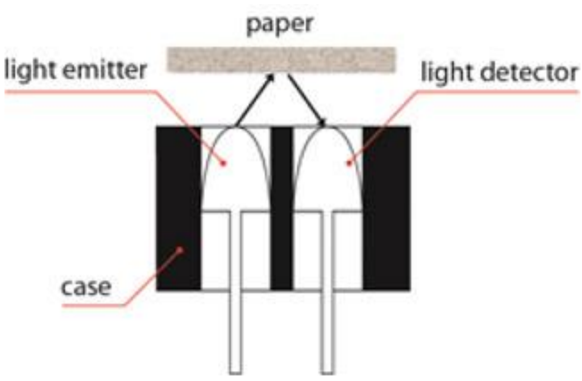
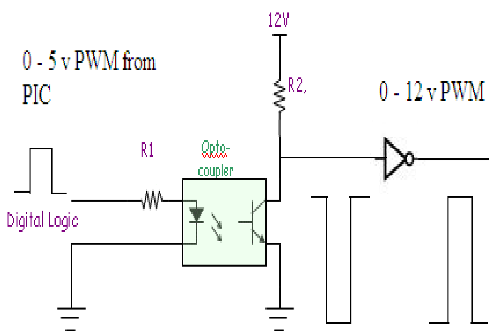


Figure 5: Optical Encoder

An optical encoder is a elector mechanical system which consist of a disc which is mounted on motor shaft & half surface of disc is covered with reflective material. An IR Emitter is a light emitting diode (LED) IR Receivers is also called sensors since they detect the wavelength and spectral radiation of the light from the IR emitter. Photo reflectors or reflective type sensors are side-by-side emitter-sensor (photo interrupter) devices that detect reflected beams from a surface. Reflected beam is converted into electrical pulses of 0-5V. Counting of pulses is converted into speed of motor in rpm.

IV. ISOLATION AND DRIVER CIRCUIT



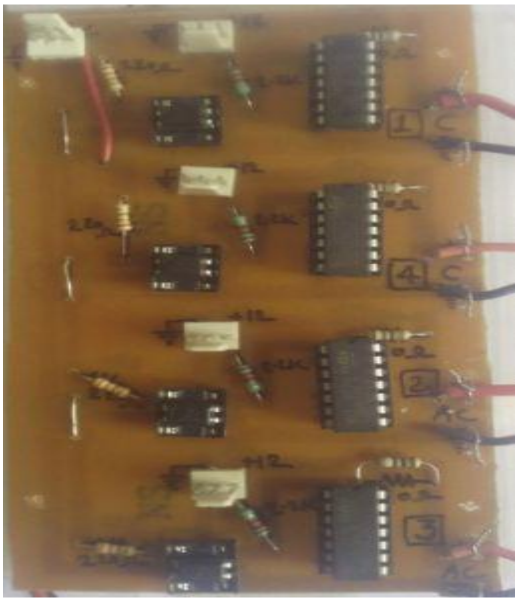


Figure 6: Opto coupler as Isolator & Driver

An Optocoupler, also known as an Opto-isolator or Photo-coupler, is an electronic component that interconnects two separate electrical circuits by means of a light sensitive optical interface.

The basic design of an optocoupler consists of an LED that produces infra-red light and a semiconductor photo-sensitive device that is used to detect the emitted infra-red beam. Both the LED and photo-sensitive device are enclosed in a light-tight body or package with metal legs for the electrical connections as shown. An optocoupler or opto-isolator consists of a light emitter, the LED and a light sensitive receiver which can be a single photo-diode, or photo-transistor.

When pulse of PWM from PIC, current passes through the input LED which emits an infra-red light whose intensity is proportional to the electrical signal. This emitted light falls upon the base of the photo-transistor, causing it to switch-ON and conduct in a similar way to a normal bipolar transistor. The base connection of the photo-transistor can be left open for maximum sensitivity or connected to ground via a suitable external resistor to control the switching sensitivity making it more stable.

When the current flowing through the LED is interrupted, the infra-red emitted light is cut-off, causing the photo-transistor to cease conducting. The photo-transistor can be used to switch current in the output circuit. R1 is 220 ohm & R2 is 2.2 K ohm. R1 is used to limit the current through optocoupler at input side which is 50 mA. At output side R2 - 2.2K is used to limit the current. Due to R2 the small curve like shape appears in the leading & trailing edge of PWM, Inverter CD 4069 is used invert the signal & makes the PWM edges sharp. By using this circuit we keep isolate the PIC circuit & driver circuit. Driver circuit is used to drive the power MOSFET, to turn on the MOSFET (IRFP 460) we require ±20 V between gate to source (rated value). But ±12 V is also sufficient to conduct MOSFET. So output of inverter is connected to the gate of MOSFET, H-Bridge is consist of four MOSFET therefore four separate sections of Isolator & drivers are formed as shown in fig.6 actual photo of circuit

V. H- BRIDGE

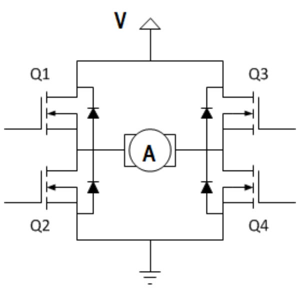


Figure 7: H-Bridge

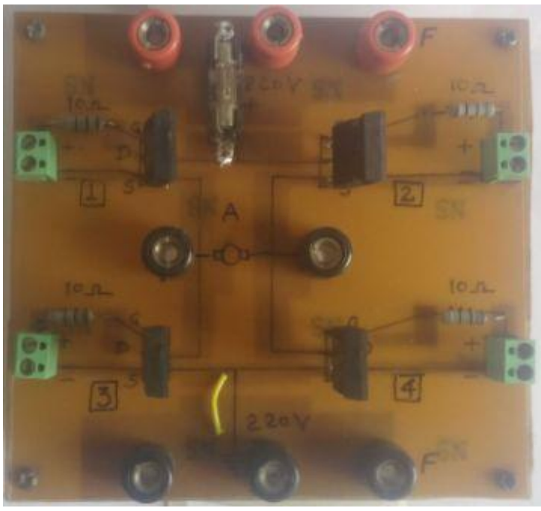


Figure 8: Actual H-Bridge Circuit

In general an H-bridge is a rather simple circuit, containing four switching element, with the load at the center, in an H-like configuration. The switching elements (Q1, Q2, Q3, Q4) are usually MOSFET. The basic operating mode of an H-bridge is fairly simple: if Q1 and Q4 are turned on, the left lead of the armature will be connected to the power supply, while the right lead is connected to ground. Current starts flowing through the armature which energizes the motor in (let's say) the forward direction and the motor shaft starts spinning. If Q2 and Q3 are turned on, the reverse will happen, the motor gets energized in the reverse direction, and the shaft will start spinning backwards.

Field winding of DC motor already connected to the fixed 200V DC supply. For controlling the speed of motor the controlled voltage is applied to the armature through switching elements such as MOSFET. For smooth operation it is necessary to connect capacitor across the load. The capacity of H-Bridge circuit depends upon the capacity of switching elements (MOSFET), in this project the IRFP 460 MOSFET's are used, which can support 500 V DC, 20 A. Current & voltage rating of MOSFET should twice than the motor rating of safe operation, otherwise MOSFET can burnout due to high current.

In this bridge, never close both Q1 and Q2 (or Q3 and Q4) at the same time. If we did that, just have created a low-resistance path between power and GND, effectively short-circuiting the power supply. This condition is called 'shoot-through' and it is quickly destroy bridge.

VI. METHODOLOGY

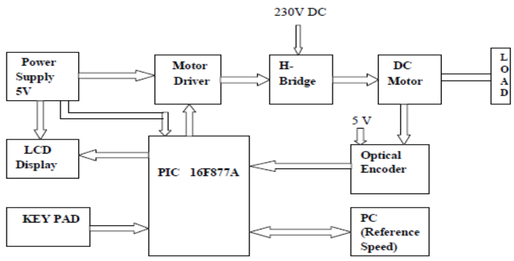


Figure 9: Functional Block Diagram

PIC 16F877A is the heart of the project, which compare actual speed of DC motor with reference speed. Optical encoder circuit converts actual speed in square wave form. As the motor speed changes frequency of the square wave also changes. Reference speed given to the system through PC. PIC 16F877A generate control signal which is proportional to the difference between actual and reference speed. The control signals are in the form of PWM wave having constant frequency.

PWM wave is used to turn ON/OFF the power MOSFET, connected in H- bridge configuration. This arrangement provides facility for speed reversal of DC motor. So the armature winding get average DC voltage which determine the speed of DC motor.

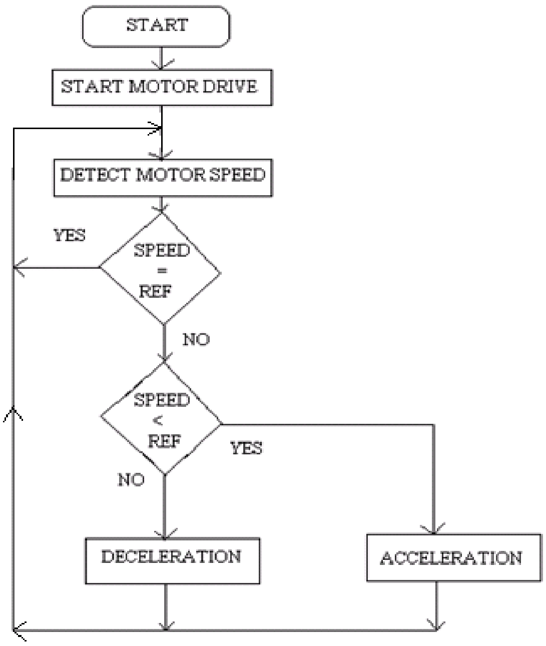


Figure 10: Basic flow chart of DC motor speed control

It is possible to obtain control the speed of motor over very wide range from few rpm to thousand rpm (depends up on the motor specification). Field voltage of DC shunt motor is kept maximum & armature voltage is varying i.e.160V, 180V, 200V etc. according to the PWM % speed of motor is directly proportional as shown in fig. 11.

VII. OBSERVATIONS AND RESULT

The results obtained are discussed as follows.

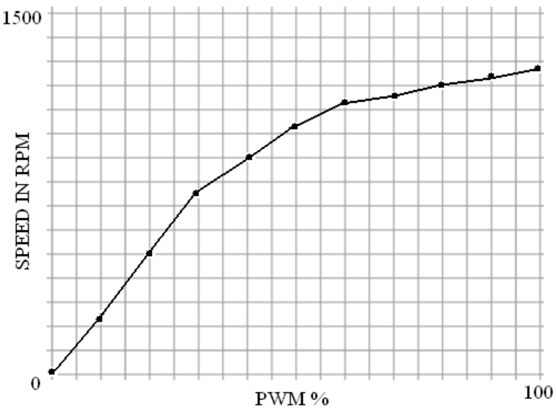
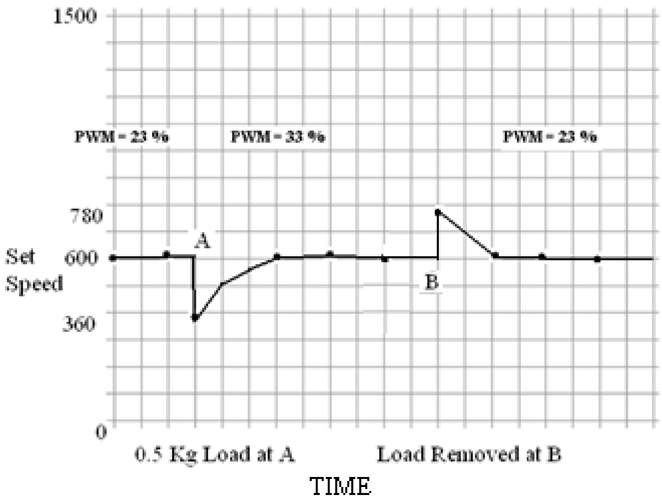


Figure 11: Speed Vs PWM Duty cycle



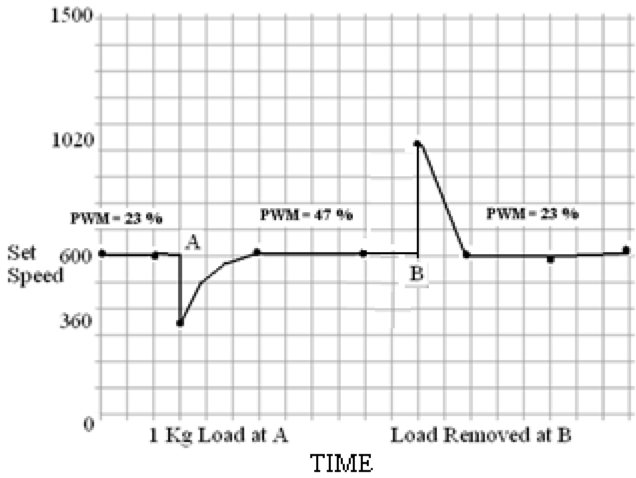


Figure 12: Set Speed at 600 rpm, response of PWM at mechanical load

When mechanical load is applied on motor then speed of motor decreases and PWM % start increasing to maintain constant speed. When mechanical load is removed speed of motor increased due to wider PWM % to maintain speed at set value, PWM % start decreasing. Fig. 12 shows set speed at 600 RPM, PWM 23 %, at 0.5 Kg load, speed decrease up to 360 RPM and PWM start increasing up to 33%. When load is removed speed increase up to 780 RPM, again PWM % start decreasing up to 23%. For 1 Kg load PWM increased from 23 % to 47 % and after remove of 1 Kg load current speed becomes 1020 RPM and PWM % start decreasing to maintain constant speed. This control action taken by controller after comparing set speed with current speed.

VIII. CONCLUSION

Recent developments in science and technology provide a wide range scope of applications of high performance DC motor drives in area such as rolling mills, chemical process, electric trains, robotic manipulators and the home electric appliances require speed controllers to perform tasks. DC motors have speed control capabilities, which means that speed, torque and even direction of rotation can be changed at anytime to meet new condition. The goal of this project is to design a DC motor speed control system by using microcontroller PIC16F877A. It is a closed-loop control system. The controller will maintain the speed at desired speed when there is a variation of load. By varying the

PWM signal from microcontroller (PIC 16F877A) to the motor driver, motor speed can be controlled back to desired value easily.

I. REFERENCES

[1] Muhammad H. Rashid. Power Electronics Circuits, Devices and Applications. 3rd edition. United States of America: Prentice Hall. 2004.

[2] Christopher A. Adkins and Michael A. Marra, Modeling of a Phase-Locked Loop Servo Controller with Encoder Feedback. IEEE Spectrum, August 1999. 51-56.

[3] Moore, A.W. Phase-Locked Loops for Motor-Speed Control. IEEE Spectrum, April 1973. 61-67.

[4] P. C. Sen and M. L. MacDonald. Thyristorized DC Drives with Regenerative Braking and Speed Reversal. IEEE Transactions on Energy Conversion, 1978, Vol. IECI-25, No. 4: 347-354.

[5] http://homepages.which.net/paul.hills/SpeedControl/ Speed ontrollersBody.html.

[6] Abu Zaharin Ahmad and MohdNasirTaib. A study On the DC Motor Speed Control by Using Back-EMF Voltage. Asia SENSE SENSOR, 2003, 359-364.

[7] Iovine John. PIC Microcontroller Project Book. 2nd Edition. Singapore: McGraw-Hill. 121-123; 2000.

[8] Sjhinskey, FG. Process Control Systems. 2ndEdition, Singapore: McGraw-Hill Book Company, 2003.

[9] www.wikipedia.com