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Design and implementation of dc motor speed control based on pic microcontroller

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Abstract: The electric drive systems used In Industrial applications are increasingly required to meet higher performance and reliability requirements. The DC Motor is an attractive piece of equipment in many Industrial applications requiring variable speed and load characteristics due to its ease of controllability. Microcontrollers provide a suitable means of meeting these needs. In this paper, Implementation of the AT89C51 Microcontrollers for speed control of DC motor fed by a DC chopper has been investigated. 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 paper is designed to develop a speed control system for a DC motor using microcontroller PIC AT89C51. The motor is operated in four quadrants i.e. clockwise; counter clock-wise, forward brake and reverse brake. It also has a feature of speed control.

Keywords: DC Motor, Microcontroller, Speed Control, PWM, L293D.

1. Introduction

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. In this project we are controlling speed of DC motor. As we increase the speed of DC motor as a result an increase in the productivity of material. The application of this is used in domestic's purpose examples are hair dryer, mixer, zero machine, elevator and industrial purpose examples are traction and elevator. In this project we have control the actual speed of dc motor as per our requirement. This can be achieved through PIC microcontroller. The microcontroller computes the actual speed of the motor by sensing the terminal voltage and displayed on LCD.

In this paper firstly we are giving the supply to PIC AT89C51 microcontroller. Then controller generates the pulse generally 5VDC.The generated pulse is nothing but PWM signal, which is given to the driver circuit. The function of this driver circuit is to generate 12V DC pulse. This is necessary to switch/trigger the MOSFET. Thus the speed of DC motor is controlled through duty/PWM cycle. This PWM pulse is given to MOSFET for triggering purpose.

The Design & Implementation of this paper is done through the software. It then compares the actual speed of the motor with the reference speed and generates a suitable control signal which is fed into the triggering unit. This unit drives a Power MOSFET amplifier, which in turn supplies a PWM voltage to the dc motor. DC Motors can be used in various applications.

2. Model of Separately Excited DC motor & PWM Techniques

Figure 1 shows a model of separately excited DC motor. When a separately excited motor is excited by a field current of I_f and an armature current of I_a flows in the circuit, the motor develops a back EMF and a torque to balance the load torque at a particular speed. The I_f is independent of the I_a. Each winding are supplied separately. Any change in the armature current has no effect on the field current. The I_f is normally much less than the I_a. The relationship of the field and armature are shown in below Equation.

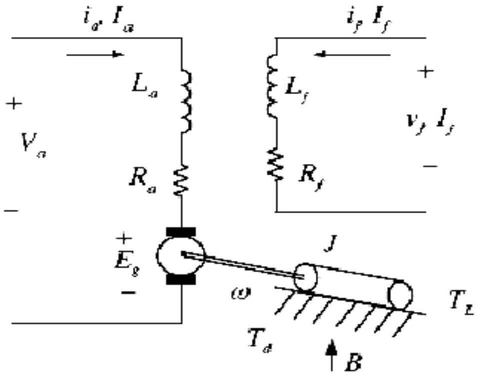

Figure 1. Separately Excited DC Motor

Instantaneous field current:

$$V_f = R_f\, i_f + L_f\, di_f/dt$$

Where R_f and L_f are the field resistor and inductor resp.

Instantaneous armature current:

$$V_a = R_a\, i_a + L_a\, di_a / dt + e_g$$

Where R_a and L_a are the armature resistor and inductor resp.

The motor back EMF which is also known as speed voltage is expressed as

$$e_g = K_v\, w\, i_f$$

Where K_V is the motor constant (in V/A-rad/s) and w is the motor speed (rad/s).

The torque developed by the motor is

$$Td = K\, \phi\, i_f$$

Where ($K_t = K_v$) is the torque constant (in V/A-rad/s).

Sometimes it is written as:

$$Td = Kt\, \phi\, i_a$$

For normal operation, the developed torque must be equal to the load torque plus the friction and inertia, i.e.:

$$Td = J\, dw / dt + Bw + T_L$$

where

B = viscous friction constant (N.m/rad/s)

T_L = load torque (N.m)

J = inertia of the motor (kg.m^2)

Under steady-state operations, a time derivative is zero. Assuming the motor is not saturated.

For field circuit,

$$Vf = R_f\, i_f$$

The back EMF is given by:

$$eg = Kv\, w\, i_f$$

The armature circuit,

$$Va = I_a R_a + Eg = I_a R_a + Kv\, w\, i_f$$

The motor speed can be easily derived:

$$W = Va - I_a R_a / Kv\ if$$

If R_a is a small value (which is usual), or when the motor is lightly loaded, i.e. Ia is small,

$$W = Va / K_v I_f$$

That is if the field current is kept constant, the speed motor speed depends on the supply voltage. These observation leads to the application of variable DC voltage to control the speed and torque of DC motor.

2.1 PWM TECHNIQUE

PWM is a method for binary signals generation, which has 2 signal periods (high and low). The width (W) of each pulse varies between 0 and the period (T). The main principle is control of power by varying the duty cycle. Here the conduction time to the load is controlled. Let for a time t1, the input voltage appears across the load i.e. ON state and for t2 time the voltage across the load is zero.

- The average voltage at output is given by
  $Va = 1/T \int v_o dt = t_1/T\ Vs = f\ t_1\ Vs = kVs$
- The average load current $I_a = V_a/R = kV_s/R$ where,
  T is the total time period $= t_1 + t_2$,
  $k = t_1/T$ is the duty cycle.
- The rms value of output voltage is $V_0 = (i/T \int V_0^2\, dt)^{½} = k\ Vs$
- The output power and is given by
  $P_i = 1/T \int v_0 i dt = 1/T \int v_0^2/R\ dt = kV_s^2/R$

2.2 Speed Control by Using PWM and Full H Bridge Motor Drive

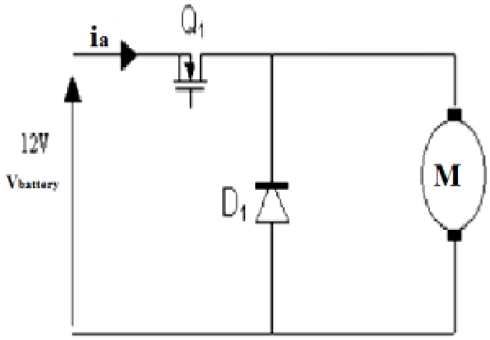

Figure.2. Simple Motor Circuits

Let us consider a simple circuit that connects a battery as power supply through a switch MOSFET (Metal-Oxide-Semiconductor Field Effect Transistor) as shown in Figure 2. When the switch is closed, the motor sees 12 Volts, and when it is open it sees 0 Volts. If the switch is open for the same amount of time as it is closed, the motor will see an average of 6 Volts, and will run more slowly accordingly.

This on-off switching is performed by power MOSFETs. A MOSFET (Metal-Oxide-Semiconductor Field Effect Transistor) is a device that can turn very large currents on and off under the control of a low signal level voltage.

The average of voltage that supply to DC motor is given by,

$$Vavg = (t_{on} / T) * Vin$$

Where

V_{avg} = average voltage supply to DC motor

t_{on} = time ON of switches
T = period of PWM
(t_{on} / T) =DC duty cycle

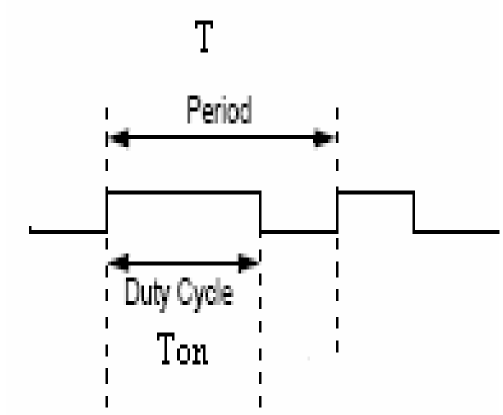

Figure.3. PWM signal

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 4 shows the speed of a motor that is being turned on and off fairly slowly:

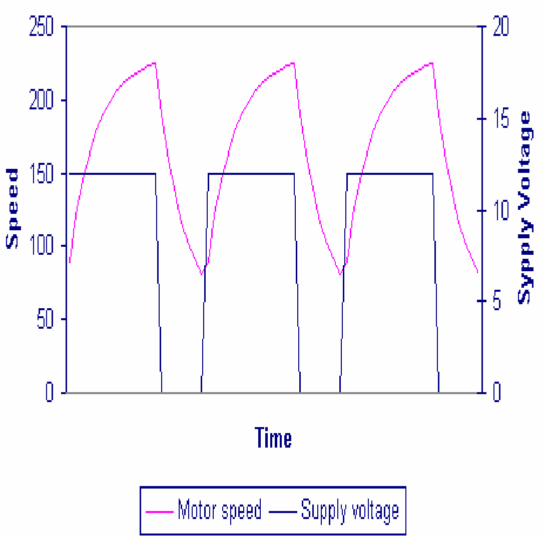

Figure.4.Relation of supply voltage with motor speed

We can see that the average speed is around 150 rpm, although it varies quite a bit. If the supply voltage is switched fast enough, it won't have time to change speed much, and the speed will be quite steady. This is the principle of switch mode speed control. Thus the speed is set by PWM – Pulse Width Modulation.

3. Hardware Design and Implementation

Motion control plays a vital role in industrial automation. Manufacturing plants in industries like chemical, pharmaceutical, plastic and textile all require motion control. And it may be a flat belt application, flow-control application or mixing of substances. Different types of motors—AC, DC, servo or stepper—are used depending upon the application. Of these, DC motors are widely used because controlling a DC motor is somewhat easier than other kinds of motors.

3.1 Hardware Design

Figure 5 shows the schematic diagram of the complete automatic speed control system of the DC motor.

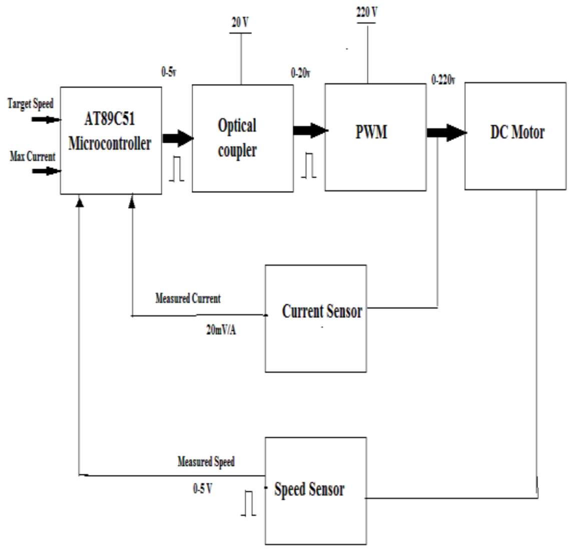

Figure.5. Block diagram of automatic speed control system.

The AT89C51 microcontroller implements the control algoritlm1 by conditioning the speed and current signals and performance the speed regulation according to speed reference fed through the switch. The software includes a routine to read the motor current and sends emergency shutdown signal to protect the dc motor from over current, also this signal can be activated manually by inserting a designated character by the switch, which causes a software interrupt and executes the emergency shutdown routine. The hardware control system includes the dc shunt motor, power circuit, AT89C51 microcontroller, speed sensor (shaft, encoder), and current sensor. The system hardware block diagram is shown in Fig. 6. The conventional digital proportion MCU technique and the pulse width modulation (PWM) technique are adopted in dc motor control system. An optical encoder was used to measure the speed of the motor. The output of the encoder is a stream of pulses with variable' frequency according to the speed of the motor. The resolution of the encoder in this work was 500PPR.The current sensing was accomplished by using Hall Effect current sensor. It senses the current and feeds the current signal to microcontroller. Port PE4 of the microcontroller is dedicated for the current signal and a continuous conversion mode where used to read from the AID port. The opto-isolator was used to isolate the high voltage circuits from the low voltage controlling signals. The de motor is the plant that will be controlled. The rating of the motor should be chosen according to the rating of the power circuit switch. For this study a dc shunt motor with ratings 2400RPM, 220V, 2.2A, O.37kW is used.

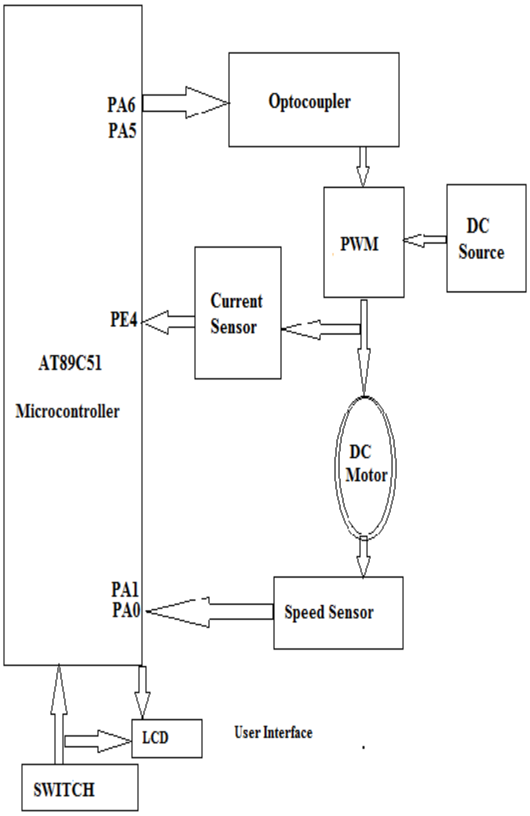

Figure.6. DC motor control hardware block Diagram.

The hardware of the microcontroller includes mainly the AT86C51 system with LCD and keypad for user interface. Changing the terminal voltage by means of DC to DC chopper (the power circuit) that is controlled by the microcontroller generated PWM signal controls the speed of the motor.

The motion of a DC motor is controlled using a DC drive. DC drive changes the speed and direction of motion of the motor. Some of the DC drives are just a rectifier with a series resistor that converts standard AC supply into DC and gives it to the motor through a switch and a series resistor to change the speed and direction of rotation of the motor. But many of the DC drives have an inbuilt microcontroller that provides programmable facilities, message display on LCD, precise control and also protection for motors. Using the DC drive you can program the motion of the motor, i.e., how it should rotate.

Here are some of the features of this DC motor controller:

1. Controlled through microcontroller AT89C51.
2. Message displayed on the LCD module.
3. Start, stop and change of direction of the motor controlled by pushbutton switches and indicated by LED.
4. Changes the running mode of the motor to continuous, reversible or jogging.
5. Changes the speed of the motor.
6. Time settings are possible for forward and reverse running of the motor.

4. Result & Discussion

The eight pushbutton switches are connected for eight different functions as –

When S1 is pressed, the microcontroller sends low logic to port pin P2.5. The high output of inverter N2 drives transistor T1 into saturation and relay RL1 energises. So the output of NE555 is fed to inputs IN1 and IN2 of L293D through both the contacts of relay RL2. Now at the same time, after RL1 energises, the microcontroller starts generating PWM signal on port pin P2.4, which is fed to trigger pin2 of NE555 through inverter N3. The base frequency of the generated PWM signal is 500 Hz, which means the time period is 2 ms (2000µs). The output pulse width varies from 500 µs to 1500 µs. The R-C time constant of the monostable multivibrator is kept slightly less than 500 µs to generate exactly the same inverted PWM as is generated by the microcontroller.

When switch S2 is pressed, port-pin P2.5 goes high and RL1 de-energises to stop the motor.

When switch S3 is pressed, relay RL2 energises. Pin IN1 of motor driver L293D receives the PWM signal and pin IN2 connects to ground. As a result, the motor rotates in one direction (say, clockwise).

When switch S4 is pressed again, relay RL2 de-energises. Pin IN2 of motor driver L293D receives the PWM signal and pin IN1 connects to ground. The motor now rotates in opposite direction (anti-clockwise).

When switch S3 is pressed, different modes are selected in cyclic manner as given below:

1. *Continuous mode.* The motor rotates continuously with the set speed in either direction

2. *Reversible mode.* The motor reverses automatically after the set time

3. *Jogging mode.* The motor rotates for the set time in either direction and then stops for a few seconds and again rotates for the set time. It is also called 'pulse rotation'
Switches S5 and S6 are used to set the speed of the motor, either in increasing order or decreasing order, in continuous mode only. Switches S7 and S8 are used to set the time either in increasing order or decreasing order.

Table.1. Result of Dc motor speed control by AT89C51

Switch	Function
S1	TO START MOTOR
S2	TO STOP THE MOTOR
S3	CHANGE THE DIRECTION
S4	CHANGE THE MODE
S5	INCREASE SPEED
S6	DECREASE SPEED
S7	INCRESE TIME
S8	DECRESE TIME

5. Conclusion

The goal of this paper is to design a DC motor speed control system by using microcontroller PIC AT89C51. It is a closed-loop real time control system. The controller will maintain the speed at desired speed when there is a variation of switch. By varying the PWM signal from microcontroller to the motor driver, motor speed can be controlled back to desired value easily.

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