DC MOTOR SPEED CONTROL USING

MICROCONTROLLER PIC 16F877A

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"I hereby declared that I have read through this report and found that it has comply the partial

fulfillment for awarding the degree of Bachelor of Electrical Engineering

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Date   : APRIL 2009

"I hereby declared that this report is a result of my own work except for the excerpts that have been cited clearly in the references."

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Date   : APRIL 2009

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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 for the foreseeable future. This project is mainly concerned on DC motor speed control system by using microcontroller PIC 16F877A. It is a closed-loop real time 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. Microcontroller acts as proportional (P) controller with $K_p =1$ in this study. The PWM signal will send to motor driver to vary the voltage supply to motor to maintain at constant speed. Besides, it also shows a graph of motor speed versus time to let the user monitor the performance of the system easily. Based on the result, the reading of tachnometer built is quite reliable. Through the project, it can be concluded that microcontroller PIC 16F877A can control motor speed at desired speed although there is a variation of load.

ABSTRAK

Motor arus terus telah menjadi satu komponen yang penting untuk aplikasi dalam julat kuasa dan kelajuan yang tinggi. Kawalan motor arus terus yang mudah dan prestasi yang baik akan menjamin motor arus terus untuk digunakan secara meluas pada masa depan. Projek ini tertumpu kepada rekaaan satu sistem kawalan kelajuan motor arus terus dengan menggunakan mikropengawal PIC 16F877A. Ia merupakan satu kawalan gelung tutup dan masa nyata sistem, di mana pengekod optic(yang dibina dalam projek ini) yang dipasang pada rotor akan menghantar isyarat kelajuan suapbalik kepada pengawal. Teknik *Pulse Width Modulation (PWM)* digunakan di mana isyarat ini dibekal oleh mikro pengawal. Mikropengawal berperanan sebagai pengawal gandaan, *P* di dalam projek ini. Isyarat *PWM* akan dihantar kepada pemacu motor untuk mengubah voltan yang dibekalkan kepada motor supaya ia dapat dikawal pada kelajuan yang ditetapkan. Selain itu, ia juga memaparkan satu graf kelajuan motor melawan masa untuk membolehkan pengguna mengkaji prestasi sistem tersebut. Keputusan menunjukkan bahawa bacaan daripada tachnometer yang dibina adalah boleh dipercayai. Melalui projek ini, boleh disimpulkan bahawa mikropengawal PIC 16F877A dapat mengawal kelajuan motor pada kelajuan tetap walaupun terdapat perubahan beban.

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K_E - A constant based on motor construction

φ - Magnetic flux

I_f - Field current

I_a - Armature current

R_f - Field resistor

L_f - Field inductor

R_a - Armature resistor

L_a - Armature inductor

K_v - Motor constant

K_t - Torque constant

T_d - Developed torque

T_L - Load torque

B - Viscous friction constant

J - Inertia of the motor

w - Motor speed

α - Firing angle of thyristor

t_{on} - Time ON of switches

T - Period

s - Standard deviation

rpm - Rotation per minute

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CHAPTER 1

INTRODUCTION

1.1   Background

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. Why do we need a speed motor controller? For example, if we have a DC motor in a robot, if we just apply a constant power to each motor on a robot, then the poor robot will never be able to maintain a steady speed. It will go slower over carpet, faster over smooth flooring, slower up hill, faster down hill, etc. So, 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.

In home appliances, washers, dryers and compressors are good examples. In automotive, 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.

1.2   Objective of Project

The main core of this project is to design a speed control system of DC Motor by using microcontroller. This system will be able to control the DC motor speed at desired speed regardless the changes of load.

1.3   Scope of Project

In order to achieve the objective of the project, there are several scope had been outlined. The scope of this project is simulated project using Protues includes using MicroC to program microcontroller PIC 16F877A, build hardware for the system. Last but not least, a graph of speed versus time is obtained.

1.4   Outline of Thesis

This thesis consists four chapters. In first chapter, it discuss about the objective and scope of this project as long as summary of works. While Chapter 2 will discuss more on theory and literature reviews that have been done. It well discuss about types of motor, various kind of speed measurement and controllers (thyristor, phase-lock loop and PWM technique) that can be used to control the speed of the motor.

In Chapter 3, the discussion will be on the methodology hardware and software implementation of this project. The result and discussion will be presented in Chapter 4. Last but not least, Chapter 5 discusses the conclusion of this project and future work that can be done

1.5   Summary of Works

Implementation and works of the project are summarized into the flow chart as shown in Figure 1.1. Gantt charts as shown in Appendix D show the detail of the works of the project that had been implemented in the first and second semester.

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                                          ┌─────────────────────────┐
                                          │ DC Motor controller     │
                                          │ Design                  │
                                          └───────────┬─────────────┘
                                                      │
      ┌─────────────────────────┐                     ▼
      │ VB programming writing  │         ┌─────────────────────────┐
      │ for input desired speed │────────▶│ Interfacing with computer│
      │ and display graph speed │         │ and controller          │
      │ versus time             │         └───────────┬─────────────┘
      └───────────┬─────────────┘                     │
                  │                                    ▼
                  │                        ┌─────────────────────────┐
                  │                        │ Control DC motor speed  │
                  │                        └───────────┬─────────────┘
                  │                                    │
                  │                                    ▼
                  │                        ┌─────────────────────────┐
                  │                        │ Real Speed detection    │
                  │                        └───────────┬─────────────┘
                  │                                    │
                  │                                    ▼
                  │                        ┌─────────────────────────┐
                  └───────────────────────▶│ Feedback and display real│
                                           │ speed on screen computer │
                                           └───────────┬─────────────┘
                                                       │
                                                       ▼
                                           ┌─────────────────────────┐
                                           │ Speed error correction  │
                                           └─────────────────────────┘
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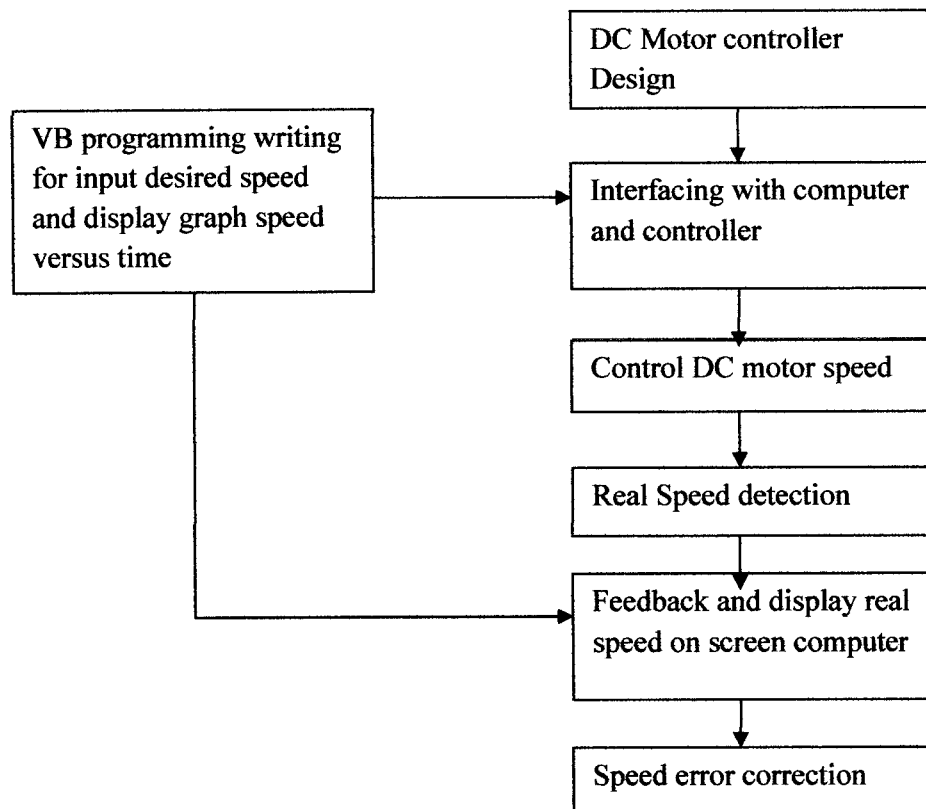
Figure 1.1 Project overview of DC Motor Speed Control

CHAPTER 2

THEORY AND LITERATURE REVIEW

2.1   Introduction

This chapter includes the study of different types of DC motors, speed measurement of DC motor, model of separately excited DC motor, several types of DC motor speed controller. It also brief discuss about microcontroller.

2.2   DC Motor

A DC motor works by converting electric power into mechanical work. This is accomplished by forcing current through a coil and producing a magnetic field that spins the motor. The simplest DC motor is a single coil apparatus. DC motors have many thousands of practical applications in the modern environment. Whether it's starting a car, operating a computer printer, or spinning your washing machine, electric motors have as much demand as they ever did. There are several types of DC motors that are available. Their advantages, disadvantages, and other basic information are listed below in the Table 2.1.

Table 2.1 Advantages and disadvantages of various types of DC motor.

Type	Advantages	Disadvantages
Stepper Motor	Very precise speed and position control. High Torque at low speed.	Expensive and hard to find. Require a switching control circuit
DC Motor w/field coil	Wide range of speeds and torques. More powerful than permanent magnet motors	Require more current than permanent magnet motors, since field coil must be energized. Generally heavier than permanent magnet motors. More difficult to obtain.
DC permanent magnet motor	Small, compact, and easy to find. Very inexpensive	Generally small. Cannot vary magnetic field strength.
Gasoline (small two stroke)	Very high power/weight ratio. Provide Extremely high torque. No batteries required.	Expensive, loud, difficult to mount, very high vibration.

2.3 Speed Measurement of DC Motor

To start with this project, the process need a device that will measure the speed of the motor shaft. There are several methods which can use to measure the speed of motor. Here, only discuss about speed measurement by using tachometer and optical encoder.

2.3.1 Speed Measurement by Using Tachometer

Tachometer is an instrument that measure speed motor based on concept of back EMF induced in motor when it is running. The EMF is voltages appear on the commutator segments caused by rotated in the magnetic field by some external force.

The magnitude of the EMF is given by [1],

$$EMF = K_E \varphi N \tag{2.1}$$

where K_E = a constant based on motor construction

φ = magnetic flux

N = speed of motor (in rpm)

The actual relationship between motor speed and EMF follows and is derived from Equation 2.1,

$$N = \frac{EMF}{K_E \varphi} \tag{2.2}$$

Thus, the motor speed is directly proportional to the EMF voltage ad inversely proportional to the field flux. For permanent magnet DC motor, when the EMF measured is increases, the speed of the motor is also increases with the gain. So, the speed of motor can be measured by measuring the back EMF using tachometer.

2.3.2 Speed Measurement by Using Optical Encoder

The best way to measure speed is to fit an optical encoder. This shines a beam of light from a transmitter across a small space and detects it with a receiver 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. An example of a disc is shown as Figure 2.1.
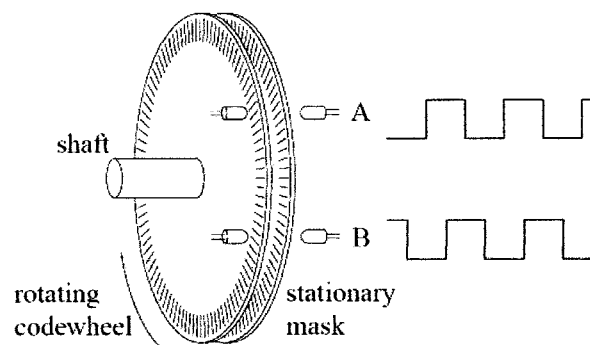

Figure 2.1 Sample disc of encoder [1]

The optical encoder's disc is made of glass with transparent and opaque areas. A light source and photo detector array reads the optical pattern those results from the disc's position at any one time. This code can be read by a controlling device, such as a microprocessor, to determine the angle of the shaft. The absolute analog type produces a unique dual analog code that can be translated into an absolute angle of the shaft (by using a special algorithm).

Table 2.2 Disc of encoder position

Sector	Contact 1	Contact 2	Contact 3	Angle
1	off	off	off	0° to 45°
2	off	off	on	45° to 90°
3	off	on	off	90° to 135°
4	off	on	on	135° to 180°
5	on	off	off	180° to 225°
6	on	off	on	225° to 270°
7	on	on	off	270° to 315°
8	on	on	on	315° to 360°

In general, where there are n contacts, the number of distinct positions of the shaft is 2^n. In this example, n is 3, so there are 2^3 or 8 positions.

In the above example, the contacts produce a standard binary count as the disc rotates. However, this has the drawback that if the disc stops between two adjacent sectors, or the contacts are not perfectly aligned, it can be impossible to determine the angle of the shaft. To illustrate this problem, consider what happens when the shaft angle changes from 179.9° to 180.1° (from sector 4 to sector 5). At some instant, according to the above table, the contact pattern will change from off-on-on to on-off-off. However, this is not what happens in reality. In a practical device, the contacts are never perfectly aligned, and so each one will switch at a different moment. If contact 1 switches first, followed by contact 3 and then contact 2, for example, the actual sequence of codes will be;

off-on-on (starting position)

on-on-on (first, contact 1 switches on)

on-on-off (next, contact 3 switches off)

on-off-off (finally, contact 2 switches off)

Now look at the sectors corresponding to these codes in the table. In order, they are 4, 8, 7 and then 5. So, from the sequence of codes produced, the shaft appears to have jumped from sector 4 to sector 8, then gone backwards to sector 7, then backwards again to sector 5, which is where we expected to find it. In many situations, this behavior is undesirable and could cause the system to fail. For example, if the encoder were used in a robot arm, the controller would think that the arm was in the wrong position, and try to correct the error by turning it through 180°, perhaps causing damage to the arm.

The encoder transmitter must be supplied with a suitable current, and the receiver biased as Figure 2.2.
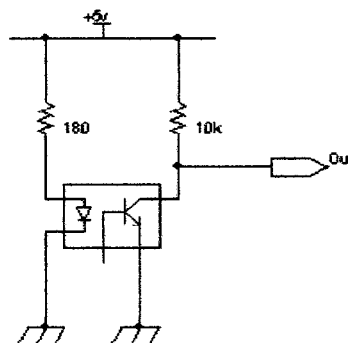

Figure 2.2 Basic schematic circuit of optical encoder

This will have an output which swings to +5v when the light is blocked, and about 0.5 volts when light is allowed to pass through the slots in the disc. The frequency of the output waveform is given by,

$$f_{out} = \frac{rpm \times N}{60} \tag{2.3}$$

where f_{out} = frequency of output waveform

rpm= speed in revolutions per minutes

N= number of slots at disc

So, from Equation 2.3, the speed of DC motor in rpm is given by,

$$rpm = \frac{f_{out} \times 60}{N} \tag{2.4}$$

2.4 Model of Separately Excited DC motor

A model of separately excited DC motor is shown in Figure 2.3. 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 Equation 2.5.
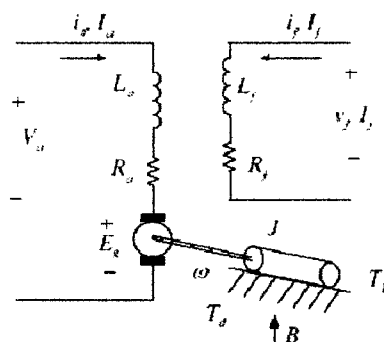

Figure 2.3 Model of separately excited DC motor[1]