PI ALGORITHM FOR A SPEED CONTROL OF DC MOTOR WITH TACHOMETER FEEDBACK

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May 2009

"I hereby declared that I have read through this report entitled PI Algorithm for a Speed Control of DC Motor with Tachometer Feedback and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Power Electronic and Drive)"

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DEVELOPMENT OF A PI ALGORITHM FOR A SPEED CONTROL OF DC MOTOR WITH TACHOMETER FEEDBACK.

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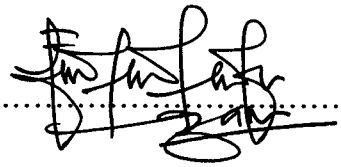
This Report Is Submitted In Partial Fulfillment of Requirements for the Degree of Bachelor in Electrical Engineering (Power Electronic and Drive)

Faculty of Electrical Engineering
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

MAY 2009

I declare that this report entitle "*PI Algorithm for a Speed Control of DC Motor with Tachometer Feedback*" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : 

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Date : 07 MAY 2009

To my beloved parents and sisters

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ABSTRACT

The used of DC motor these recent years has been increased due to the human needs that been applied to the Robotic, Machine and other. 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 PIC16F684. It is a closed-loop real time control system, where tachometer 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. Overall, the development of this project is uncompleted according to plan because the problems occur at the Gate Drive part cannot be solved and need some more period experiment.

ABSTRAK

Kepenggunaan Motor Arus Terus sejak kebelakangan ini telah meningkat menurut kehendak pengguna dalam aplikasi Rabot, Mesin dan sebaginya. Kawalan yang mudah dan prestasi yang cemerlang pada Motor Arus Terus menyebabkan peningkatan kepenggunaannya yang berterusan pada masa yang mendatang. Projek ini menfokuskan sistem Motor Arus Terus dengan menggunakan mikropengawal PIC16F684. Sistem ini mengaplikasikan sistem gelung tertutup dimana Penjana Takometer digandingkan dengan aci motor untuk menyediakan isyarat maklum balas laju untuk mikropengawal. Teknik Pemodulatan Lebar Denyut digunakan di mana isyaratnya adalah dihasilkan dalam mikropengawal. Isyarat PWM akan dihantar kepada pemandu motor untuk mengubah bekalan voltan supaya kelajuannya dapat dikekalkan sepenuhnya. Keseluruhannya projek ini gagal dibangunakan mengikut perancangan kerana berlaku masalah pada bahagian Get Pemacu yang memerlukan tempoh lanjutan ujikajinya.

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LIST OF ABBREVIATION

DC	-	Direct Current
ADC	-	Analog to Digital Converter
DAC	-	Digital to Analog Converter
PI	-	Proportional Integral
CMOS	-	Complementary Metal–Oxide–Semiconductor
RAM	-	Random Access Memory
CPU	-	Central Processing Unit
VCC	-	Supply Voltage
GND	-	Ground
LED	-	Light Emitting Diode
HEX	-	Hexadecimal
USB	-	Universal Serial Bus
PWM	-	Pulse Width Modulation
PLL	-	Phase Locked Loop

LIST OF APPENDIX

CHAPTER 1

INTRODUCTION / LITERETURE RIWIEW

1.0 Introduction DC Motor Speed Control

Direct current (DC) motor has variable speed drives used. It also has variable characteristics using in industry. DC motor has specialized where it can provide a high starting torque and also it possible obtains control speed over wide range. Speed motor controller is an important part in industry and robotic. For the 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. Example this case are, the motor will go slow over carpet, faster over smooth flooring, slower up hill, and faster down hill. In industrial application, conveyer will go slowly when a lot material and go faster moving when have a bit material. So, it proved that the speed motor controller is an important application in industry to make to control the speed of DC motor in desired speed.

In modern industrial, DC motor plays a significant role. These are several type of application where the load on the DC motor varies over a speed range. These applications may demand high-speed control accuracy and good dynamic responses.

For the other example appliances; washers, dryers and compressors are good examples in home appliances; fuel pump control, electronic steering control, engine control and electric vehicle control are good examples in automotive appliances, and like centrifuges, pumps, robotic arm controls, gyroscope controls are good example in an aerospace appliances.

1.1 Problem statement.

Basically, Industrial application used DC Motors because the speed-torque relationship can be varied to almost any useful both motor and regeneration application in either direction of rotation. DC Motor is some of the motor use in Robotic Machine, Lift Motor, Crane Motor and etc. So the motor must be operate in perfect condition to avoid the machine can not smoothly movement. DC Motor also needs to use any addition controller to control the performance rotation the motor on starting condition.

Mostly of industry uses the DC Motor without controller in order to save the cost. The effect of this case, the part mostly damage (DC motor burn) at certain times especially when the motor always start and stop condition and also the performance or motion of motor is not smoothly and precisely. So, when use the controller, we can overcome the problem them (damage).

For this case, using the PI controller it's not only to reduce that problem but can easily control or adjust to any situation especially for time, speed, rotation, position in long time for starting and running a DC Motor condition. By using PI mode, we can monitor the condition of the motor and then control it. So, the motor can run/operate in stable condition and the performance or motion of the motor is very smoothly and also precisely.

1.2 Objectives.

There are several objective want to achieve during this project. The objectives are;

1) To develop PI algorithm foe speed of DC motor.
2) To reduce steady state error
3) To get good dynamic response.
4) To make the system insensitive to disturbance.

1.3 Scope.

In order to achieve the objectives of the project, there are several scope had been outlined. The scopes of this project includes using MPLAB IDE to program microcontroller PIC 16F684, build hardware for the system, and interface the hardware and programming microcontroller by using PICkit™ 1 FLASH Stater Kit. Last but not least, a graph of output voltage at tachometer is obtained by using Digital Oscilloscope 1G to observe the performance of the system. This project will not cover graphic user interface (GUI) for the user to enter desired speed at computer.

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. It also discusses the theory and literature review 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. While Chapter 2 will be discuss the material and method implementation of this project. In Chapter 3, the result will be present along of this project. The discussion of result will present in Chapter 4. Last but not least, Chapter 5 discusses the summary and 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 were shown in Appendix for the detail of the works of the project that had been implemented in the first and second semester.

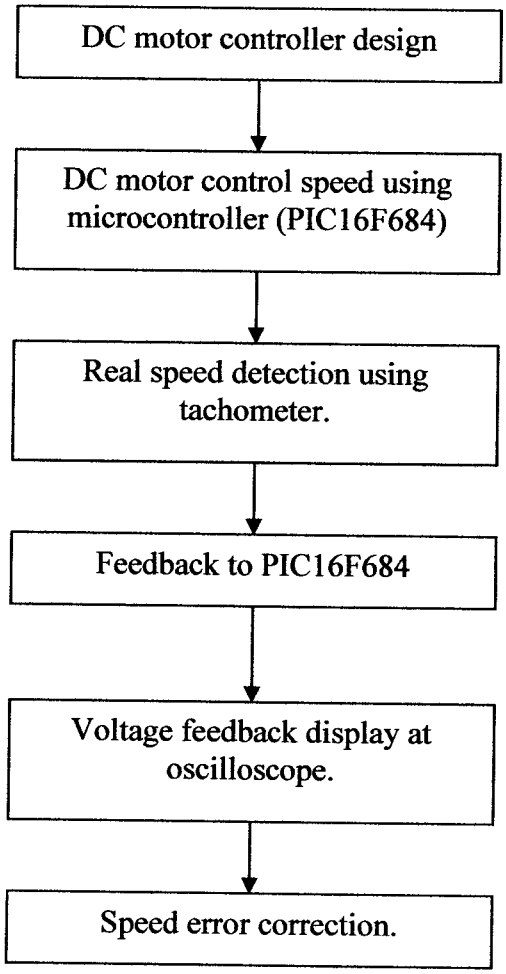

Figure 1.1 Project Overview

1.6 Speed measurement of DC Motor.

To control speed DC motor, we need some device that will measure the speed of the motor shaft. According to previous studies, there are several methods which can use to measure the speed of motor shaft. Here, tachometer and optical encoder only will be discussed about speed measurement.

1.6.1 Speed Measurement by using Tachometer.

The back EMF will induce in motor when it is running. So, tachometer is an instrument that measure speed motor based on that concept. The EMF is voltages appear on the commutator segment caused by rotated in the magnetic field by some external force. The magnitude of the EMF is given by [1];

$$EMF = K_E \phi N \tag{1.1}$$

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 follow and is derived from Equation 2.1;

$$N = \frac{EMF}{K_E \phi} \tag{1.2}$$

According from equation 2.2, the motor speed is directly proportional to the EMF voltage and inversely proportional to the field flux. So, when the EMF measured is increases, the speed of the motor is also increases with the gain. It proved that, the speed of motor can be measured by measuring the back EMF using tachometer.

1.6.2 Speed Measurement by using Optical Encoder.

Optical encoder measure speed concept when shine 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 signal will only be picked up when a slot is between the transmitter and receiver. An example disc is shown in figure 1.2

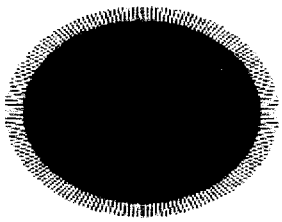

Figure 1.2: Sample disc of encoder.

Suitable current and receiver biased is needed to supply for encoder transmitter as figure 1.3.

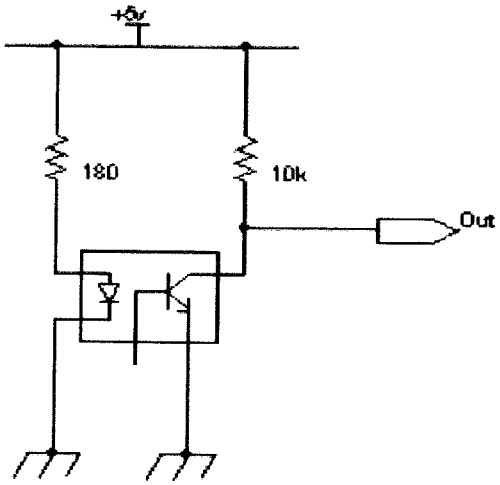

Figure 1.3: Basic schematic circuit of optical encoder.

When the light is blocked, output will receive +5V and about 0.5V when light is allowed to pass through the slots in the disc. The frequency of the output waveform is giver by,

$$f_{out} = \frac{N \times rpm}{60} \qquad (1.3)$$

Where f_{out} = frequency of output waveform

Rpm = speed in revolution per minutes

N = number of slots at disc.

According from Equation 1.3, the speed of DC motor in rpm is given by,

$$rpm = \frac{f_{out} \times 60}{N} \qquad (1.4)$$

1.7 Control Method

The controller must be programmed with certain algorithm so that the controlling can be done effectively. Studies in [6] – [10] have introduced several control methods which are as follows:

i. Phase-Locked-Loop (PLL) Control.
ii. Speed Control by using Thyristor.
iii. Speed Control by using PWM and Full H Bridge Motor Drive.

1.7.1 Phase-Locked-Loop (PLL) Control

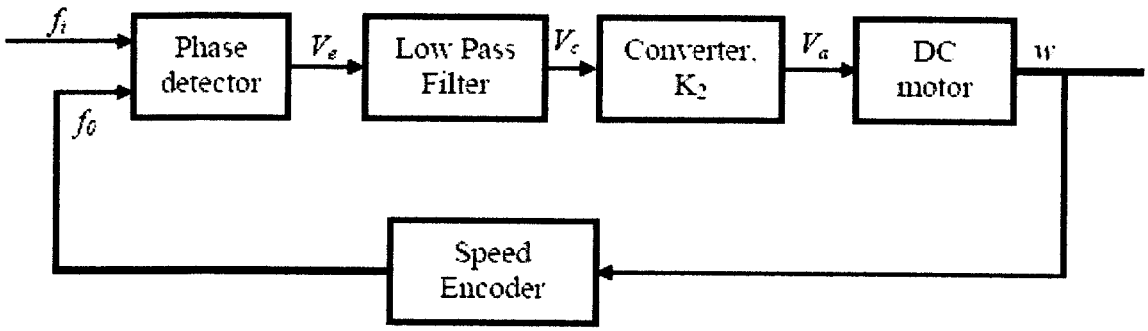

Figure 1.4 Phase-locked loop control system.

Figure 1.4 above show the block diagram of a converter-fed dc motor drive with phase-locked-loop control. The concept of this system is the motor speed is converted to a digital pulse train by using a speed encoder. This output of the encoder acts as the speed feedback signal of frequency f_o.

After that, the phase detector will compare the reference pulse train f_r with the feedback frequency f_o and directly provide a pulse-width-modulated (PWM) output voltage V_e. That output voltage is proportional to the difference in phase and frequencies of the reference and feedback pulse trains. The phase detector (or comparator) is available in integrated circuit. A low-pass loop filter converts the pulse train V_e to continuous dc level V_c, which varies the output of the power converter and in turn the motor speed.

When the same speed achieved as the reference pulse train, the two frequencies would be synchronized (or locked) together with a phase difference. The output of the phase detector would be a constant voltage proportional to the phase difference and the steady-state motor speed would be maintained at fix value irrespective of the load on the motor.

Any disturbance contributing to the speed change would result in a phase difference and the output pf the phase detector would respond immediately to vary the speed of the motor in such direction and magnitude as to retain the locking of the reference and feedback frequencies. That response of the phase detectors is very fast. As long as the two frequencies are blocked, the speed regulation should ideally be zero.
According to studies [6]-[7], PLL controlled motor drives have shortcomings following below:

i. PLL-controlled motor systems tend to be unstable for low-speed operation.
ii. PLL-controlled motor systems have large response time.
iii. PLL-controlled motor systems may get out of synchronization for an abrupt load variation.

1.7.2 Speed Control by using Thyristor

The Thyristor is used to supply a variable DC voltage to motor, thus it can control the speed of motor. Figure 1.5 shows the block diagram of this system:

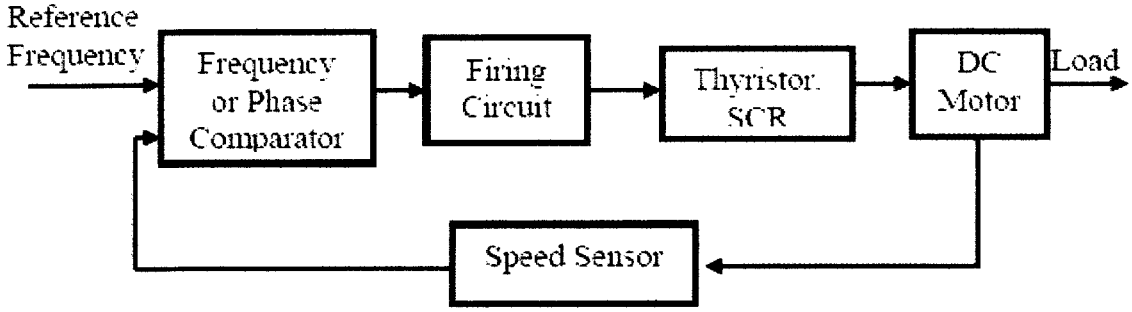

Figure 1.5 Block diagram of DC Motor speed control by using Thyristor.