DEVELOPMENT OF A DC MOTOR CONTROL

NASRUL HADI BIN HAZAL

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BY

NASRUL HADI BIN HAZAL

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LIST OF ABBREVIATIONS

ABBREVIATION	DESCRIPTION
DC	Direct Current
IDE	Integrated development environment
IGBT	Insulated-Gate Bipolar Transistor
LCD	Liquid Crystal Display
MOSFET	Metal–Oxide–Semiconductor Field-Effect Transistor
P	Proportional
PD	Proportional-Derivative
PI	Proportional–Integral
PID	Proportional–Integral–Derivative
PMDC	Permanent Magnet Direct Current
PWM	Pulse Width Modulation
rpm	Round-per-Minute
SR	Speed Regulation

LIST OF SYMBOLS

SYMBOLS	DESCRIPTION
$\omega_{m,nl}$	Angular velocity at no load
$\omega_{m,fl}$	Angular velocity at full load
$n_{m,nl}$	Speed in rpm at no load
$n_{m,fl}$	Speed in rpm at full load
V_o	Output Voltage
k	Duty Cycle in percent
V_i	Input voltage
$G_c(s)$	Controller transfer function
K_o	Gain Factor
K_i	Integral Factor
K_d	Derivative Factor
rpm_{ss}	Steady-State Speed
rpm_o	Speed Overshoot

ABSTRAK

Sebuah motor DC boleh beroperasi tanpa menggunakan apa-apa pemandu tetapi dengan berbuat demikian, motor akan dirompak daripada potensi yang sepenuhnya contoh seperti punyai kawalan kelajuan yang lebih baik. Dengan itu, projek ini telah dilaksanakan dengan mempunyai 3 objektif untuk menyelesaikan isu tersebut. Salah satu daripadanya adalah untuk membangunkan pemacu motor dan kawalan sistem DC berdasarkan mikropengawal Genuino Uno dengan paparan LCD dan papan kekunci. Satu lagi objektif ialah untuk mengintegrasikan kawalan PID gelung tertutup ke dalam sistem untuk meningkatkan prestasi kawalan motor di bawah beban atau tanpa beban. Akhir sekali ialah untuk mengimplementasikan sistem kawalan modul ke dalam satu prototaip kawalan pemacu motor DC dan menguji prestasinya. Berdasarkan objektif-objectif ini, metodologi yang telah dirancang ialah lukisan litar, penulisan kod, pembinaan prototaip, dan pengujian prestasi pemacu. Ujian ini dibahagikan kepada 2 bahagian: tiada analisis beban, dan analisis di bawah beban dengan setiap bahagian diuji dengan mengunakan cara kawalan yang berbeza. Parameter prestasi yang dipertimbangkan dalam penilaian adalah masa penetapan, peratusan terlajak, dan masa tindak balas ralat. Parameter dibandingkan untuk motor tanpa pengawal pemacu, pengawal P, pengawal PI , dan pemacu pengawal PID. Daripada keputusan parameter itu, pengawal PID dan pengawal PI didapati mempunyai prestasi yang lebih baik berbanding dengan semua kaedah kawalan yang lain. Pengawal PI mempunyai masa penetapan dan masa tindak balas ralat tetapi ianya juga mempunyai peratusan terlajak yang besar, manakala pengawal PID mempunyai masa penetapan dan masa ralat tindak balas yang perlahan tetapi ianya mempunyai peratusan terlajak yang lebih kecil berbanding pengawal PI.

ABSTRACT

A DC motor can operates without any driver but by doing so, the motor will be robbed of is full potential such as having a better speed control. With that in mind, this project was done by having 3 objectives to solve the issue. One of it is to develop a DC motor drive and control system based on Genuino Uno microcontroller with LCD display and keypad interface. Another one is to integrate a close-loop PID control to the system to improve the performance of motor control under load or without load. Last but not least is to implement the modules and control system into a single, simple DC motor control prototype and test its performance. Based on those objectives, a methodology was planned including circuit drawing, code writing, and constructing the prototype, and testing the controller performance. The testing was divided into 2 parts: no load analysis and under load analysis with each part tested on different controller scheme. The performance parameters that were considered in the evaluation are the settling time, percentage of overshoot, and error response time. The parameters were compared for motor with open-loop driver, P controller, PI controller, and PID controller driver. From the result, PID controller and PI controller were found to have better performance compared to all the other control methods. PI controller has better settling time and error response time but has a huge percentage of overshoot while PID controller has slower settling time and error response time but smaller percentage of overshoot compared to PI controller.

CHAPTER 1

INTRODUCTION

1.1 Project Overview

DC motor has been the primary choice for most motor application due to its simple construction and easy speed control. A typical DC motor takes electricity in the form of direct current (DC) and convert it into mechanical energy, hence the name DC motor.

There are many ways to control the speed of the DC motor, but the most popular one is to control the DC motor armature voltage. The speed of the DC motor depends on the armature voltage supplied to it. The higher the voltage, the faster the speed of the rotation until the voltage reach nominal and vice versa. The voltage can be varied in many ways, but in this project, the voltage will be varied through square wave PWM modulation where the duty cycle determines the armature voltage.

In order to achieve speed control through PWM modulation, a driver is needed to vary the duty cycle and a microcontroller is also needed to make the driver work. In this project, a Genuino Uno microcontroller will drive the 10 A DC motor driver to control the speed and direction of rotation of a 12 V DC motor based on the user input through switches connected to the microcontroller and at the same time, an LCD will display the status of the motor such as the actual speed of the motor.

1.2 Project Motivations

The importance of this project is to create a DC motor controller that can control the speed and rotation with a push of a button for easy access of the motor speed control. Apart from that, achieving close-loop feedback controller is also one of the project motivations to make the motor having a constant speed even when a load torque was applied to the motor. This is extremely important especially in applications where the motor needs to keep rotating even when faced with a load torque like drilling and ventilation fan. Apart from that, DC motor control is also important for many other applications from carpentry to robotic field. For example, DC motor control is used in lathe machine to cut and drill on a work piece. By having a speed control, precise operation can be done using the DC motor and with a close-loop feedback, it will help the motor to achieve better performance.

1.3 Problem Statement

The problem with the current DC motor driver is that there is no method to control the motor without directly changing the voltage straight from the voltage source. Most DC motor was controlled by varying the armature voltage of the motor. Higher armature voltage translates to higher speed and vice versa.

There are several methods to control the DC motor as mentioned in [1] such as using the model reference adaptive control , adaptive robust control, observer-based robust control and optimal state space control to achieve good performance to control electric drives. However, these methods are complex and require deep understanding of control system.

Another method to drive the DC motor was to use the Ward-Leonard driver. However, it requires 2 more additional machines, one being a 3-phase motor (induction or synchronous), another being a DC generator. This not only makes the whole system bulkier than necessary, [2] has also pointed out that there are many issues with the driver at low brush current density such as the occurrence of excessive general and random brush wear, brush-track grooving, gramophoning and development of copper picking, and significant quantities of copper were worn off from the commutator which results in high maintenance cost. From the article, Ward-Leonard driver cannot be used as a simple driver for the DC motor.

Furthermore, generic motors do not have a close-loop feedback in the system. Most motor was built in an open-loop system rather than a close-loop system, meaning the motor cannot react accordingly to stabilize itself to steady-state when an increasing load was applied.

Another problem with the typical DC motor was that there was no way to know the speed of the motor instantly. Most speed measurement was done externally by measuring the shaft of the motor using a tachometer or similar instrument.

Therefore it was vital to solve these problems by having a good driver to run the DC motor driver, a way to change the speed and direction of the motor easily, a close-loop feedback controller to make the motor maintain its speed as close to its steady-state as possible regardless of load torque, and a way to display the speed and status of the motor, while minding its simplicity and low production cost.

1.4 Objectives

The main purpose of this project is to develop a DC motor drive using H-Bridge driver with LCD display and keypad control with close-loop feedback controller. From that purpose, a few objectives that are derived from it are:

1. To develop a DC motor drive and control system based on Genuino Uno microcontroller with LCD display and keypad interface.
2. To integrate a close-loop PID control to the system to improve the performance of motor control under load or without load.
3. To implement the modules and control system into a single, simple DC motor control prototype and test its performance.

1.5 Project Scope

The scope of this project is to create a simple driver that is able to control a 12 V DC motor through button presses; a button to increase the speed, decrease the speed, change the rotation, and to stop the motor. At the same time, a 16x2 LCD screen will display the status such as current speed and rotation of the motor.

Another scope of this project is to create a close-loop system by using the close-loop PID controller to improve the performance of the motor. Other methods such as observer-based robust control, adaptive robust control, and more will not be focused on.

Most of the project works are more towards programming and modules integration into a single system. The programming was mostly done using the Arduino IDE instead of other IDE available like Eclipse.

After the integration, the prototype was tested by measuring and comparing its speed for different duty cycle and when it was under load with PID feedback and without PID feedback.

This project is targeted to control the PMDC motor rather than other types of DC motor such as the shunt, series, or compound DC motor for simplicity purposes.

1.6 Thesis Organization

This thesis is divided into five chapters with different focus. The descriptions for the chapters are given below:

Chapter 1 introduces the reader about the project that has being done in general. It also discussed about the problem statement, about what obstacles that has occurred or may occur while doing the project as well as problems that this project should solve at the end of it. The objectives helps to guide the reader in what should they aim for if it is to be replicated for improvement. The project scopes states what this project covers and what it does not covers.

Chapter 2 is about literature review. Literature materials such as journals, articles, text books, and even websites were cited and referred as information sources. Each materials cited and referred are written at the Citations and References page.

Chapter 3 talks about the project methodology, the ins and outs of the project and how it was done step by step. This chapter also tries to justify the method used in the project by explaining the logic behind the design as well as the design of experiment.

Chapter 4 is the result and discussion chapter. This chapter will have the results from testing the prototype design and its performance. Furthermore, the result will be discussed based on the driver behavior.

Chapter 5 is the conclusion chapter. The conclusion chapter will provide a conclusion on this project and explain if the objectives of the project have been achieved. It also includes recommendation for future works in case anyone wants to further improve the prototype into a better one.

CHAPTER 2

LITERATURE REVIEW

2.1 The Direct Current Motor

Based on definition by S.J. Chapman in [3], DC motor is a DC machine that converts DC electric energy to mechanical energy. There are five types of DC motors in general. They are the separately excited DC motor, the shunt DC motor, the permanent-magnet DC motor, the series DC motor, and the compounded DC motor.

DC motors are a popular choice especially in application where speed variation is required. DC motors are compared mostly by their speed regulation (SR). SR is defined as:

$$SR = \frac{\omega_{m,nl} - \omega_{m,fl}}{\omega_{m,fl}} \; x \; 100\% \qquad (2.1)$$

Or ;

$$SR = \frac{n_{m,nl} - n_{m,fl}}{n_{m,fl}} \; x \; 100\% \qquad (2.2)$$

Where $\omega_{m,nl}$ is the angular velocity at no load, $\omega_{m,fl}$ is the angular velocity at full load, $n_{m,nl}$ is the speed in rpm at no load, and $n_{m,fl}$ is the speed in rpm at full load.

SR basically is a crude indicator of the form of the motor torque-speed characteristic, with positive speed regulation indicates the motor speed drops with increasing load and vice versa. The magnitude of the SR shows tells how steep the slope of the torque-speed curve is.

2.1.1 The Permanent Magnet Direct Current Motor

The PMDC motor is a DC motor whose poles, instead of turns of copper wire, is made out of permanent magnets. Because of this, it does not require an external field circuit thus reducing the field current copper losses as well as reducing its size significantly. Generally, PMDC motor holds better advantages over traditional DC motor with external field circuit such as having higher efficiency, less expensive, smaller in size, and just plain simpler, making it an excellent choice for DC applications.

However, PMDC motor also comes with a few disadvantages. Such disadvantages include reduced flux density compared to motor with externally supplied shunt field. This in turn reduces the induced torque τ_{ind} per ampere of armature current I_A [4].

2.1.2 Four Quadrant Operation

A motor can have many combinations of speed and torque under operation. These combinations of speed and torque can be described using the four quadrants of the torque-speed plane as shown in Figure 2.1:

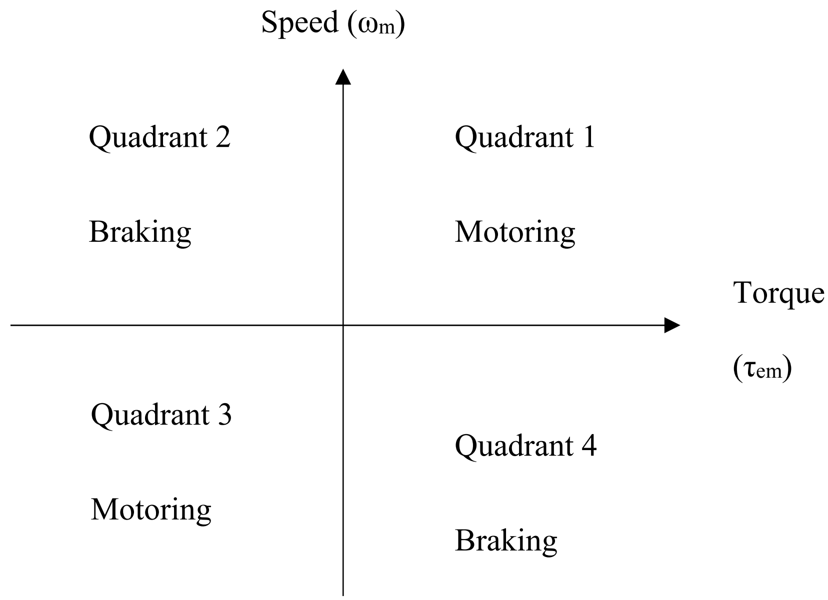


Figure 2.1: Speed-Torque Four Quadrant

In quadrant 1, the motor drives the load in the same direction as the torque. The same goes for quadrant 3 albeit in opposite direction compare to quadrant 1. When a motor operates in this quadrant, the average power is positive and the power flows from the motor to the load.

In quadrant 2 and 4, the motor drives the load in the opposite direction of the torque. The power flows from the load to the motor because in order to control the load speed, it needs to operate in regenerative braking mode [5].

2.2 The DC Motor Driver

2.2.1 The Ward-Leonard Driver

Before solid-state electronics were developed, the armature voltage of DC motor was varied using another DC generator. This system as shown in Figure 2.2 is called the Ward-Leonard System where the DC generator output is supplied to the DC motor. The generator output can be varied by changing the speed of prime mover or varying the field excitation current.

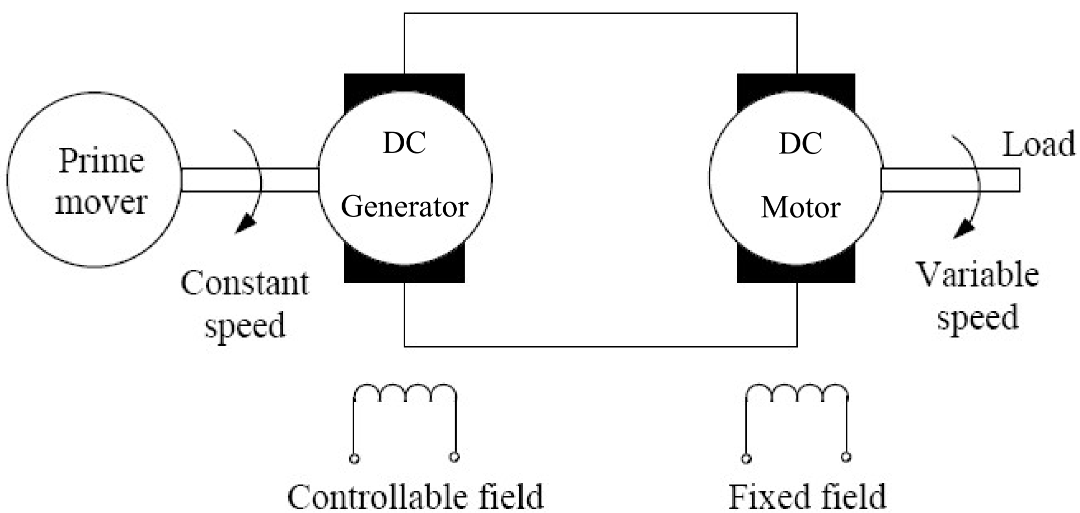


Figure 2.2: The Ward-Leonard Driver [6]

This system provides a good speed-control performance, but the motor-generator set does not convert the energy efficient enough. As a way to overcome this problem, the set is replaced by two sets of three-phase full-wave thyristor to enhance the efficiency of energy conversion [7]. The system with added thyristor is called as the Thyristor-Leonard system.

However, [8] wrote that even by improving the system with a 6-pulse SCR drive, it still suffers from low power factor at low speeds. Furthermore, the system also needs bulky DC noise filters to filter out the 360 Hz and 720 Hz audible noise.

2.2.2 The H-Bridge Driver

The H-Bridge driver is a motor driver that uses the DC-to-DC switching converter to control the magnitude of the armature current as well as to control the direction of rotation.

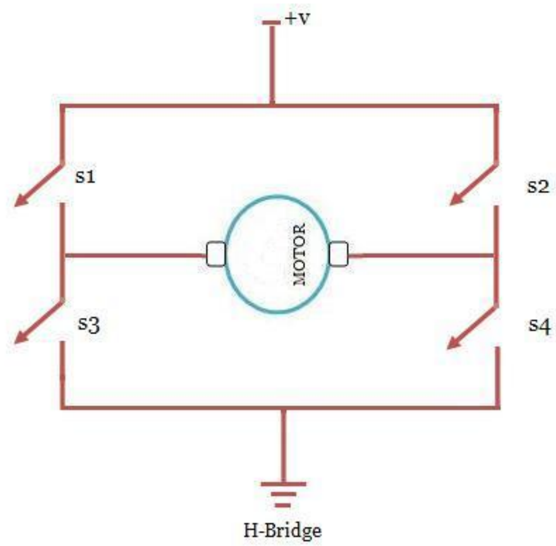


Figure 2.3: Basic H-Bridge Driver Circuit [9].

Based on Figure 2.3, when S1 and S4 switches are closed and S2 and S3 are open, the motor will run in one direction, for example in clockwise direction. When S2 and S3 are closed and S1 and S4 are open, the direction of rotation will change to counter-clockwise.

To control the motor speed, the switches pair are made to open and closed at a certain interval, this converts the DC signal into a PWM signal.

By doing so, the total voltage is affected and depending on the duty cycle, the speed of the motor will change. Because of its high speed switching requirement, IGBT are used as the switches instead of normal analog switches [10].

2.2.3 Comparison between the Ward-Leonard Driver and the H-Bridge Driver

The Ward-Leonard Driver in retrospective is an effective DC motor driver for its speed-control performance. Compared to the H-Bridge, it does not need complex switching or high-speed IGBT or MOSFET to perform the speed control. The speed control is easier than H-Bridge. It can be changed by controlling the DC generator excitation field with a primary mover moving connected to it. Larger excitation field feeds larger current to the DC motor, resulting in faster speed while smaller field produce smaller current to the DC motor, resulting in slower speed. However, as mentioned before, it requires additional machines to operate properly which are a primary mover and a DC generator to operate properly. Not only this causes the system to be very bulky, effecting the setup and maintenance cost, it is also less efficient due to the power loss in transferring the energy from the primary mover to the DC generator and then to the DC motor driver.

From that, this driver is more suited for large operation, high capacity DC motor application such factory application where normal, lower rated transistors are not enough as a motor driver.

Compared to the Ward-Leonard Driver, the H-Bridge driver is a much lighter, lower cost option that can be considered. It only requires four IGBT or MOSFETS to operate with additional four optional diodes for reverse voltage protection.

However, it requires complex switching method to control the on-off of a transistor pair with the purpose of controlling the duty cycle of the armature voltage for speed control. Apart from that, a method to control which one of the two transistors pairs to be turned on and off is also required for direction control. However, this method is more efficient as there are minimal power losses from the source to the motor armature apart from the switching losses. It is also more cost effective due to its cheap, easy to find IGBT for switching purposes. Table 2.1 tabulates the advantage and disadvantages of both drivers.

Table 2.1: Comparison between Ward-Leonard and H-Bridge Driver

Type of Driver	Advantages	Disadvantages
Ward-Leonard	• Easy speed control, requires less complex method to control motor speed	• Bulky, requires additional prime mover and DC generator to work • Expensive, need to spend more for the addition of prime mover and DC generator • Not power efficient, major power losses from transferring energy from prime mover to DC generator.
H-Bridge	• Cost-efficient, uses cheap and easy to find components (MOSFETS) • High power efficiency, no major power losses apart from switching losses	• Complex operation, requires complex switching method to control the transistors pairs

2.3 Pulse Width Modulation Signal

Pulse Width Modulation is a common technique to change a DC voltage from a higher value to a lower value. The voltage value is highly dependent on the duty cycle; lower duty cycles will convert the DC voltage to lower value while higher duty cycle will make the average output voltage closer to the input voltage. The formula for the average output voltage is:

$$V_o = \frac{kV_i}{100\%} \tag{2.2}$$

Where V_o is the output voltage, k is the duty cycle in percent, and V_i is the input voltage.By varying the duty cycle, different voltage output can be obtained from a single DC input.

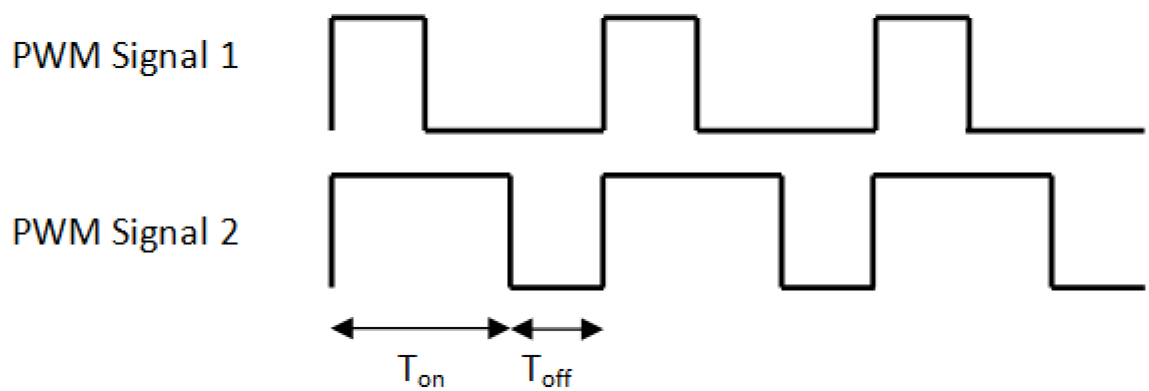


Figure 2.4: PWM Signal with Different Duty Cycle

Figure 2.4 compares two PWM signal with different duty cycle. PWM signal 1 has lower duty cycle causing it to have lower average voltage compares to PWM signal 2 that has higher duty cycle which have higher average voltage across it.

2.4 Incremental Rotary Encoder

A rotary encoder for motor application is a sensor that converts the angular position of the motor shaft into analog or digital signal.

An incremental rotary encoder gives an output only when the sensor is being rotated. It can be mechanical, optical, or even magnetic. Incremental encoder is used to track motion and in turn to track positioning and also velocity.

Typically, incremental rotary encoder has 2 output signals called ‘A’ and ‘B’. Both signals are offset by 90° off each other in order to detect the encoder rotation. A ‘Z’ signal may also exist in some encoder as reference point but it is totally optional [11]. Figure 2.5 shows a typical signal generated by a rotary encoder.

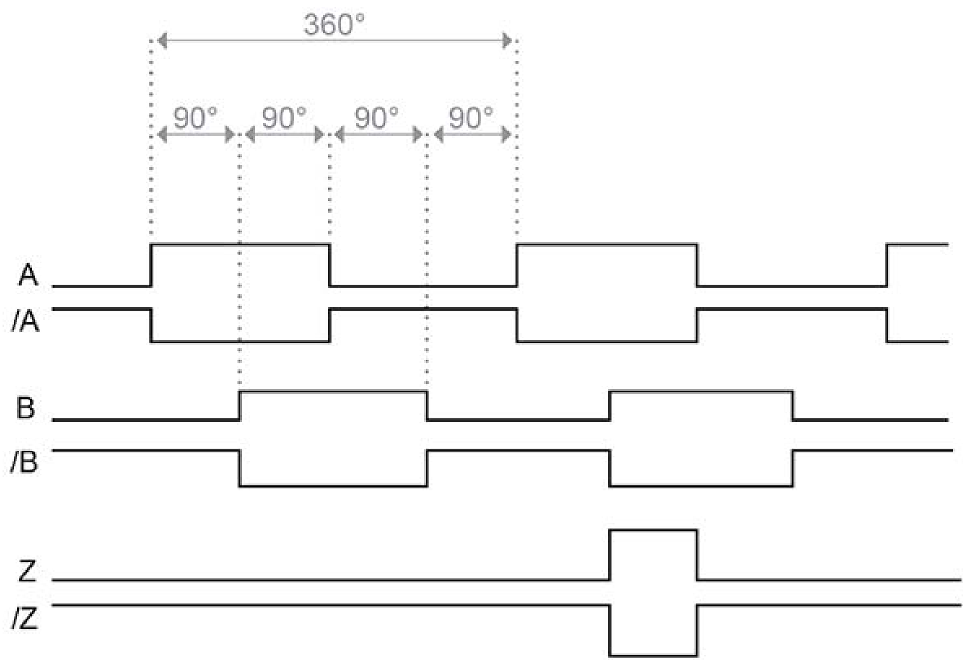


Figure 2.5: Incremental Rotary Encoder Signals

An encoder that utilized two signal output is called as quadrature encoder as they are out of phase by 90□. Using the signals output, the direction of rotation can be determined by looking at the truth table as shown in Figure 2.6 and Table 2.2.

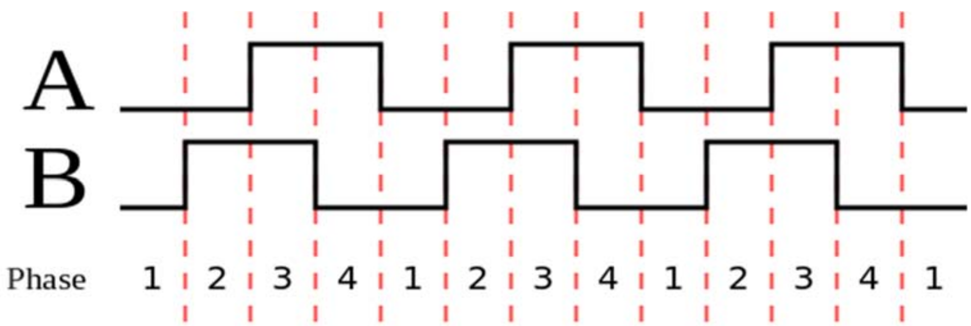


Figure 2.6: Output Signal A and B in Quadrature [12]

Table 2.2: Example of Quadrature Encoder Rotation Truth Table

Clockwise Rotation

Phase	A	B
1	0	0
2	0	1
3	1	1
4	1	0

Counter Clockwise Rotation

Phase	A	B
1	1	0
2	1	1
3	0	1
4	0	0

Figure 2.7 shows the inside of a rotary encoder in a motor.

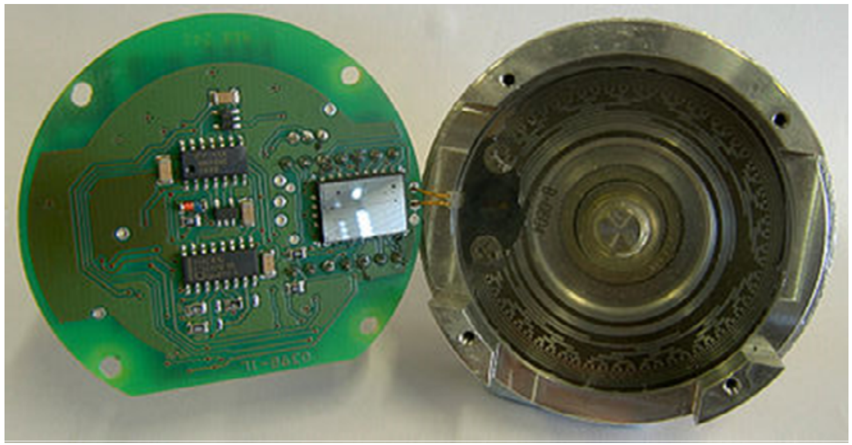


Figure 2.7: Optical Rotary Encoder in a Motor

2.5 Close-Loop Cascaded Controller

In most applications, such as robotics and manufacturing automation require high accuracy when controlling the speed and position. For those applications, a feedback controller such as the PID controller is required. The PID controller is a combination of the proportional, differentiator and integrator operating in parallel, combining the desired performance characteristics of PI and PD control. The block diagram for the P, PI, PD, and PID controller are shown in Figure 2.8, Figure 2.9, Figure 2.10, and Figure 2.11 respectively.

2.5.1 The Proportional Controller

The proportional controller is designed by adding a controller function $G_c(s)$, which is an adjustable gain factor, K_o.

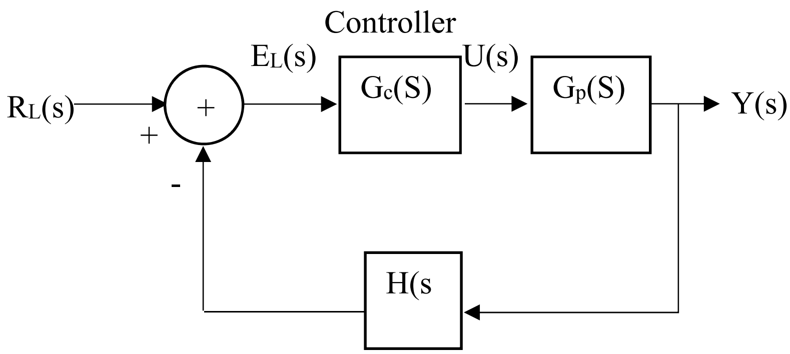


Figure 2.8: The Proportional Controller Block Diagram

For a stable system and a high enough K_o value, the characteristic of $Y(s)/R_L$ are dependent on $1/H(s)$. For $G_c(s)$ equal to K_o:

$$\frac{Y(s)}{R_L(s)} = \frac{K_o G_p(s)}{1+K_o G_p(s) H(s)} \tag{2.3a}$$

If $|K_o G_p(s) H(s)| >> 1$, then

$$\frac{Y(s)}{R_L(s)} = \frac{1}{H(s)} \tag{2.3b}$$

Where K_0 is the gain factor, $R_L(s)$ is the input function, and $Y(s)$ is the output function.

From the equation, the ideal transfer function can be achieved by increasing K_o. However, an increase in K_o in a proportional controller will lead to deterioration of stability. Dependence on $1/H(s)$ also comes with reduction in sensitivity to variation of other parameters and reduction in observed effects of nonlinear activity.

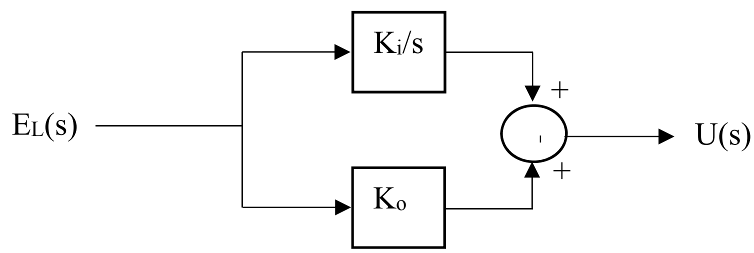
A proportional controller can be improved by adding an integral (PI controller) or derivative (PD controller).

2.5.2 The PI Controller

A PI controller introduces a pole and z zero into the function. The controller is best suited for application where it is required to improve the steady-state performance with an increase in the type number. The PI controller transfer function is:

$$G_c(s) = K_O + \frac{K_i}{s} = \frac{K_O(s+\alpha)}{s} \tag{2.4}$$

Where $\alpha = K_i/K_o$. The expression in terms of K_o and α is useful when there is a gain variation with a fixed zero position



2.9: The PI Controller Block Diagram

2.5.3 The PD Controller

For an ideal PD controller, it introduces an LHP zero into the forward-path function to improve the stability of a system. The transfer function is:

$$G_c(s) = K_d s + K_o = K_o(\frac{s}{\alpha} + 1) \tag{2.5}$$

Where $\alpha = K_o/K_d$. The purpose of expressing the transfer function in terms of α is for its convenience to vary K_o while maintaining α.

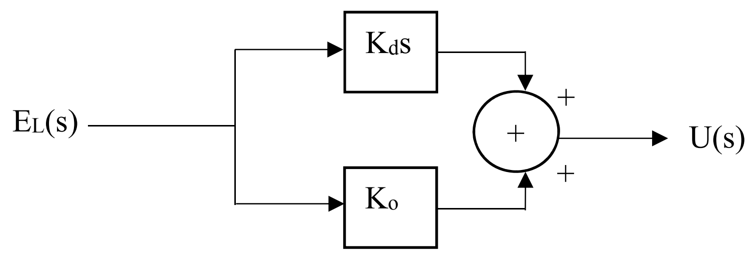


Figure 2.10: The PD Controller Block Diagram

The PD controller can be viewed in such a way that when a system introduces several dominant poles, the poles produce a phase lag that may be excessive in a certain frequency range. The presence of a zero partially counters this effect by introducing a phase lead.

If viewed in time domain, the differentiator provides a signal proportional to the rate of change of error, the output of the differentiator at a particular time can be interpreted as a 'prediction' of future error.

2.5.4 The PID Controller

For the PID controller, the transfer function is:

$$G_c(s) = K_o + \frac{K_i}{s} + \frac{K_d s}{\left(1+\frac{s}{\beta}\right)}, \quad (2.6a)$$

With general form of:

$$G_c(s) = \frac{K(s^2+\alpha_1 s+\alpha_2)}{s\left(\frac{s}{\beta}+1\right)} \quad (2.6b)$$

With, $K = K_d + K_o/\beta$, $\alpha_1 = (K_o + K_i/\beta) / (K_d + K_o / \beta)$, and $\alpha_2 = K_i / (K_d + K_o / \beta)$

Where K_0 is the gain factor, K_i is the integral factor, and K_d is the derivative factor

With the integral control, the type number has increased while the presence of derivative control allows improvement on aspects that are dependent on improved natural response.

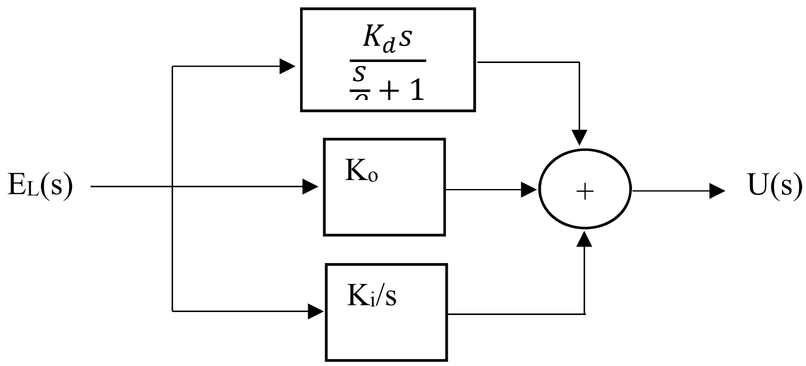


Figure 2.11: The PID Controller Block Diagram

If viewed in the frequency-response characteristics, the integration reshapes the loop gain function in the range of the low-frequency limit while the differentiation extends the high end of the bandpass range. [13].

2.6 Summary

In a nutshell, this chapter provides the background information that related to the project. It starts with the introduction of different types of DC motor in general and the type of DC motor this project focuses on, which is the PMDC motor, and the motor 4 quadrant operation based on direction of torque and speed. Next, this chapter discusses on the DC motor drivers and compares the drivers side by side for a better understanding on at their advantages and disadvantages. The basic of PWM and rotary encoder is also discussed in this chapter. The chapter ends with some explanation on the PID close-loop feedback control system.

CHAPTER 3

PROJECT METHODOLOGY

3.1 Introduction

This project focused on creating a DC motor control using Genuino Uno microcontroller board to control the 10A H-Bridge DC motor driver which in turns drives the DC motor. A close-loop PID feedback was then introduced into the software to improve the capability of the DC motor control. The aim of this project is to produce a close-loop feedback DC motor control prototype where the speed can be controlled through button pushes with visible speed measurement on an LCD display. To do so, hardware and software integration of all modules are done and tested to see the performance of the motor. The motor was made to run normally without load and at a certain point of time, a heavy load was introduced to it. After a few seconds, the load was removed. The speed and time signature was taken in intervals and a graph of speed versus time was plotted to see if the speed has any changes when a load was applied to the motor.

3.2 Project Implementation Flow

Before proceeding with the project, several text books and journals were referred to find the basic information regarding DC motor and its drive, how PWM signal works, how a rotary encoder works, as well as details on PID feedback.

The project work flow is shown in Figure 3.1. The work flow began with designing the system circuit.

After that, the coding to make the system work was programmed through Arduino IDE so that the Genuino Uno microcontroller can communicate with every module and command them to do their part. Next was integrating the modules and troubleshooting any problems that arise. The process continued until the prototype worked as intended and there was no more problem. Then the experiment phase, data collection and documentation begin.

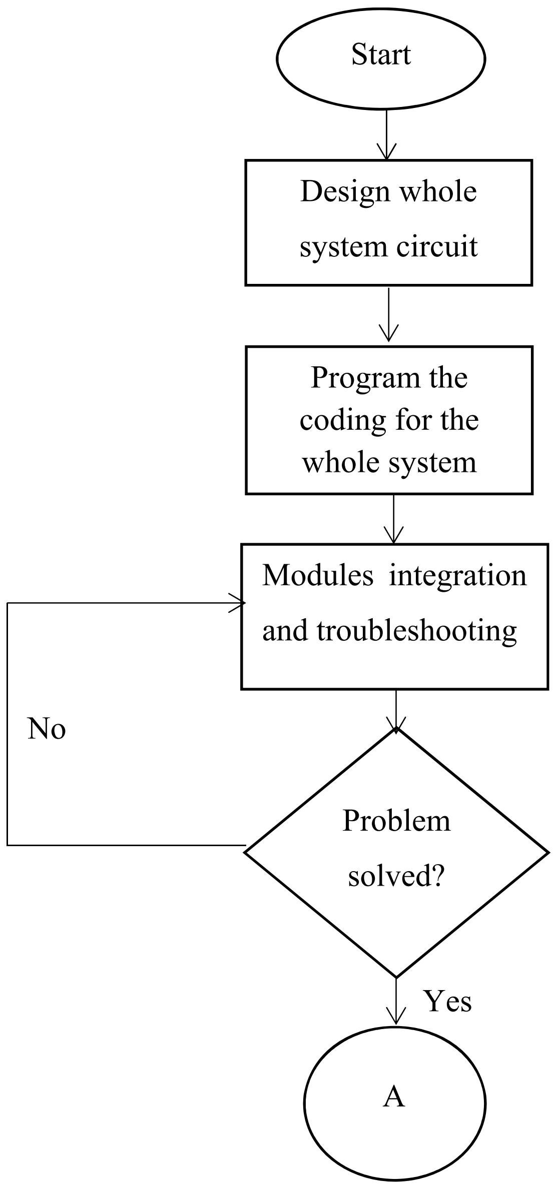


Figure 3.1: Project Flow Chart

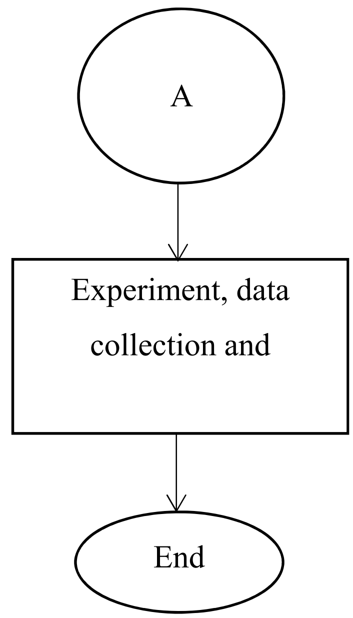


Figure 3.1: Project Flow Chart (cont.)

3.3 Project Requirement

3.3.1 Hardware Requirement

The hardware required for this project are the 12V DC Geared Motor with Encoder SPG30E-20K, 10A DC motor driver, LCD with keypad shield, and the Genuino Uno.

The 12V geared DC motor is the motor that was being controlled by the system. The built-in quadrature encoder enables the ability to measure the average speed of the motor through Genuino Uno. The quadrature encoder gives 60 counts per revolution. From there, the speed can be determined by dividing the counts by the time taken.

The 10A DC motor driver drives the motor to be faster or slower in clockwise direction or counter-clockwise direction. It uses PWM signal to control the voltage fed into the motor. The PWM signal comes from the Genuino Uno.