MOTOR SPEED CONTROLLER USING FUZZY LOGIC METHOD FOR PCB DRILLING OPERATION

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A report submitted in partial fulfilment of the requirements

for the award of the degree of

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We hereby declare that we have checked this project and in our opinion this project is satisfactory in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering

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I hereby declare that this thesis entitled "*Motor Speed Controller using Fuzzy Logic Method for PCB Drilling Operation*" is the result of my own research and observation except quotations and summaries which have been duly acknowledged. The thesis has not been accepted for any degree and is not concurrently submitted for award of other degree.

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For my love Puteri Emme Marina, Family, Lecturers and Friends

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ABSTRACT

This thesis is generally about how the mechanical system reacts when a load is given or friction is happen to touch the mechanical system. Every mechanical system will always be affected when there is a disturbance. Drilling operation is one of the common operations in the industry. When the drilling operation works, there must be a friction occurs when the work is done. Thus, there will be lack of performance for the drilling machine. The lack of the performance of the drilling machine will lead to the speed of the machine that will decrease slightly. That is the main part of this project. To make the performance of the drilling machine maintain, the speed must be increase as soon the friction is given to the drilling machine. To solve the problem, the Fuzzy Logic Method is use in this project. Using Fuzzy Logic Method, new equation will be finding and use it for this project. From the method, the speed of the motor will increase when the drilling operation is given a friction. There will be feedback for the error that the sensors detect from the drilling machine. The feedback will calculate the error and from the calculation the new increasing voltage will be determined. For the conclusion, the method is trying to find the new voltage for the drilling machine to maintain the speed of the machine. From the fact, we know that when the voltage in increase, the speed will also increase. Thus, the performance of the drilling machine will become more efficient.

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ABSTRAK

Tesis ini secara menyeluruh menceritakan mengenai bagaimana system mekanikal bertindak apabila beban atau daya geseran dikenakan pada sistem mekanikal. Setiap mekanikal sistem sentiasa akan terdedah dengan ganguan. Operasi mengerudi adalah salah satu operasi yang banyak di dalam industri kita. Apabila operasi mengerudi dijalankan, geseran pasti akan berlaku apabila kerja sedang dilakukan. Oleh itu, kebolehan mesin gerudi akan berkurang. Kebolehan mesin gerudi akan menyebabkan kelajuan mesin tersebut berkurang. Ini adalah bahagian paling penting dalam projek ini. Untuk meningkatkan kebolehan mesin gerudi. Kelajuan mesin gerudi mesti ditingkatkan apabila geseran dikenakan pada mesin gerudi. Untuk menyelesaikan masalah ini, Fuzzy Logic akan digunakan dalam projek ini. Menggunakan Fuzzy Logic, persamaan baru akan diwujudkan dan akan digunakan dalam projek ini. Daripada Fuzzy Logic, kelajuan motor akan meningkat apabila operasi mengerudi dikenakan geseran. Tindak balas akan berlaku apabila bacaan yang dikesan oleh pengesan mengenal pasti sedikit perbezaan dalam bacaan. Tindak balas tersebut akan mengira perbezaan tersebut dan daripada pengiraan tersebut, voltan baru akan dikenal pasti. Untuk kesimpulan, Fuzzy Logic akan cuba mengira voltan baru untuk mesin gerudi mengekalkan kelajuan asalnya. Daripada fakta, kita mengetahui bahawa apabila voltan dinaikkan, kelajuan turut akan ditingkatkan. Ini boleh menyebabkan kebolehan mesin gerudi turut meningkat.

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LIST OF SYMBOLS

π	-	pi
ω	-	Rotational Speed in rad/s
ω_m	-	Shaft Velocity of the Motor
φ	-	Magnetic Flux
AC motor	-	Alternate Current motor
D	-	Diameter
D	-	Duty Cycle
DAC	-	Digital to Analog
DC motor	-	Direct Current motor
e_b	-	Back EMF
F	-	Feed
I_a	-	Armature Current
i_a	-	Armature Current
K_e	-	Voltage Constant
K_m	-	Proportional Constant
MRR	-	Material Removal Rate
N	-	Rotational Speed in RPM
PCB	-	Printed Circuit Board
PD	-	Proportional Derivatives
PI	-	Proportional Integral
PV	-	Process Variable
PIC	-	Programmable Integrated Circuit

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PID	-	Proportional Integral Derivatives
PWM	-	Pulse Width Modulation
R	-	Armature Resistance
RPM	-	Revolution Per Minute
RTCC	-	Real Time Clock Counter
SP	-	Set Point
T	-	Torque
T	-	Overall Pulse Length
T_m	-	Motor Torque
T_{pulse}	-	On – Pulse length
V	-	Applied Voltage

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CHAPTER 1

INTRODUCTION

1.1 PROJECT MOTIVATION

Drilling Machines is used to make a hole and it is widely used in industry. Other processes for producing holes are punching and various advanced machining processes. The cost of holes making is one of the highest machining costs. There are several types of drilling which are gun drilling, twist drill, and trepanning. The most common drill is the conventional twist drill.

Many products used drilling as their major processes. Without drilling operation, the work cannot be done successfully. Drilling operation has been used in many sectors of industries such as automotive, piping, major industries also minor industries. The importance of drilling is increase by time because of the modern world and the used of high speed product in our life.

Drilling operation also used in electronic industries. One of the examples is to produce a hole on a circuit board. Even as tiny as a ants, it also need to use drilling operation. That show us how important is drilling operation.

Motor is a device that converts electrical energy to mechanical energy. Most of our activities will use motor to reduce the usage of human energy. This will reduce human responsible in daily life, not like the old days that many used human energy to produce works. There are two types of motor that are DC motor and AC motor.

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Motor speed controller is used to maintain the speed, increase or decrease the speed. It can give use our demanded speed. It used sensors to detect the right speed. This device is important to the society. The sensor detects the problem and recover it automatically without human command at that time but it is already calculated it the programming. The scope of motor speed controller is very wide, such as in domestic applications, office equipments, medical equipments, commercial applications, industrial applications, vehicle applications and many more.

1.2 PROJECT BACKGROUND

In drilling operation, there is many error can occur if the step to use drilling machine is not followed. The friction that occurs between the drill and workpiece will reduce the speed of the motor. When the speed is reduce, the performance of the drilling machine will also decrease and it will operate less efficient. This will affect to the workpiece. To avoid it, the rpm of the motor must be increase. To increase the speed, the voltage also must be increase. Increase in voltage will increase the speed.

To control the speed to the demanded speed or maintain the speed, Proportional integral derivatives (PID) controller can be use in the drilling machines. PID controller is the combination of PD controller and PI controller. PD controller can add damping to a system, but the steady state response is not affected while PI controller can improve the relative stability and improve the steady state error also but the rise time is increased.

To increase the voltage, the driver amplifier can be use in the drilling machine. Amplifier will make the input resistance is higher than output resistance. When the ratio of input over output resistance is high, the voltage will also increase (Ryan Sherry, 1995; Hulick T.P., 1989).

There are 2 types of motor which are DC motor and AC motor. There are several type of DC motor such as permanent magnet DC motor, separately excited DC motor and series DC motor. Permanent magnet DC motor will be used in this project. The magnetic field of a permanent magnet DC motor will collide with electromagnetic field

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and produce a rotation of the motor. This motor will make the drilling rotates and the higher voltage means the increasing in speed of the rotation (Germanton et al, 1999).

To detect whether the speed is reduce or not, the sensor can be use in this project. The sensors that will be use are encoder. Incremental encoders are used for converting linear or rotary displacement into digital coded or pulse signals (Benjamin C. Kuo, 1995). When the signal is receive, it will go back to the speed controller, amplifier and permanent magnet DC motor. This is to increase the voltage and to achieve to the demanded speed.

Fuzzy logic will be use as the method to solve the problem. Fuzzy logic will be applied in the speed controller. A programming code will be created in the system.

In this project, an efficient and reliable DC motor will be build based on Fuzzy logic method to control the speed of the DC motor in the drilling machine.

1.3 PROJECT PROBLEM STATEMENT

The problem in this project is the decreasing speed of the drilling machine. Reducing in speed will affect the performance of the drilling machines. The performance of the machines also will affect the efficiency of the machine. This phenomenon occurs when there is friction between the drill and the workpiece.

When the speed is reduces, means the RPM of the drills is reduces. When the RPM is reduces, the material removal rate also will reduce. Means, this also will affect to the power of the drill. Thus, the torque of the drill also will be decrease (Serope Kalpakjian, 2001).

The excellent drilling operations happen when the speed of the drill is maintain. Means, the rpm of the drill must be increase to the demanded speed. To increase the speed, the voltage of the motor also must be increase. The problem will be detected by the sensors and when the sensors sense the decreasing of the speed, amplifier will increase the voltage of the motor (Germanton et al, 1999). Thus, it will also increase the

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speed of the drill. This process required programming code to go through with the process.

The problem for this project is to correct the speed of the motor and it will be solve by using fuzzy logic method.

1.4 PROJECT OBJECTIVES

The project research objectives are:-

i. To build the circuit of motor speed controller.

ii. To make a programming code for fuzzy logic method.

iii. To make sure the PCB drilling works accurately.

iv. To maintain the speed of drilling machine.

1.5 Project Scope

The project research scopes are listed as below:-

i. The motor speed controller is only an experimental and not readily use for commercial product.

ii. The motor speed controller can be use only for PCB drilling

iii. Permanent magnet DC motor is the only type of motor will be used in this model

iv. The parameter that will be considered is only the frequency of the motor

v. Sensors that will be use is encoder

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1.6 PROJECT REPORT ORGANIZATION

The rest of the reports are organized as follows:

Chapter 2: literature review and background knowledge of motor speed controller and fuzzy logic method. Explain briefly about the methods on how to use fuzzy logic. Find the easiest way to find the solution using fuzzy logic method. The project will be discussed about the advantage and disadvantage of using fuzzy logic method at motor speed controller.

Chapter 3: Design and Methodology of the motor speed controller will be built in the simplest design and using the simplest equation to make the product is working perfectly. Finally all the components will be assemble and ready to use for the presentation.

Chapter 4: Results will be taken twice and are presented

Chapter 5: Project Conclusion and the recommendation will be added and the device will be improved from time to time for the future project works. All the recommendation will be presented.

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CHAPTER 2

LITERATURE REVIEW

2.1 DRILLING OPERATION

Hole making is one of the most important process in manufacturing (Serope Kalpakjian, 2001). One of the methods to make a hole is by drilling operation (Osawa et al, 2005). Drills basically have high length to diameter ratios, thus they are capable to produce a deep holes (Serope Kalpakjian, 2001). However, the friction will occur when the drills touches the surface of the work piece (Serope Kalpakjian, 2001). This situation will make the rpm of the motor decreasing and this will make the hole making less accurate as it should be from theoretically. There are several type of drilling which are gun drilling, twist drill, and trepanning.

Material removal rate (MRR) in drilling is the volume of material removed per unit time. Below is the equation for MRR;

$$MRR = (\pi * D^2/4)FN$$

Where, D = diameter of the drill

F= feed (the distance the drill penetrates per unit revolution)

N = rotational speed in rpm

From MRR equation, reduce in speed will reduce the value of MRR. This will make the performance of the drill less efficient and power. To make the drilling operation increase, the rpm of the drill must be increase. We can see the lack of power

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using power equation. Below is the equation to calculate power required for drilling machines;

Power = MRR * specific energy

Furthermore, speed also affect on the torque of the drill. Below is the equation to calculate the torque of the drill;

T = power/ω

Where, ω = rotational speed in rad/s (speed of one rotational per unit time)

Figure 2.1: Drilling operation (http://www.electricstuff.co.uk/drill.jpg)

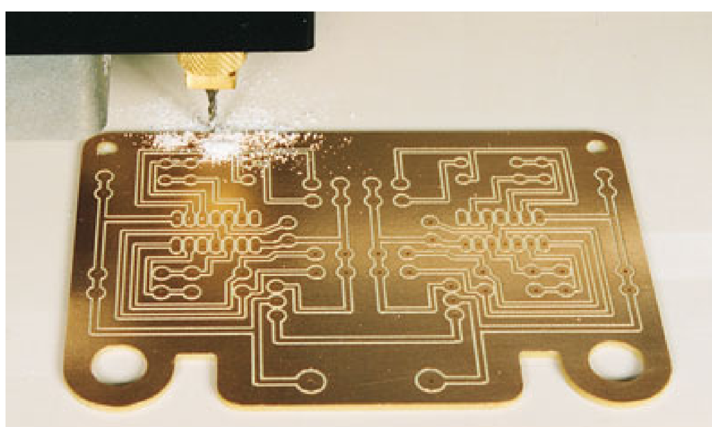

Figure 2.2: PCB drilling (http://www.techsoftuk.co.uk/pcb_drilling.jpg)

2.2 FEEDBACK CONTROL SYSTEM

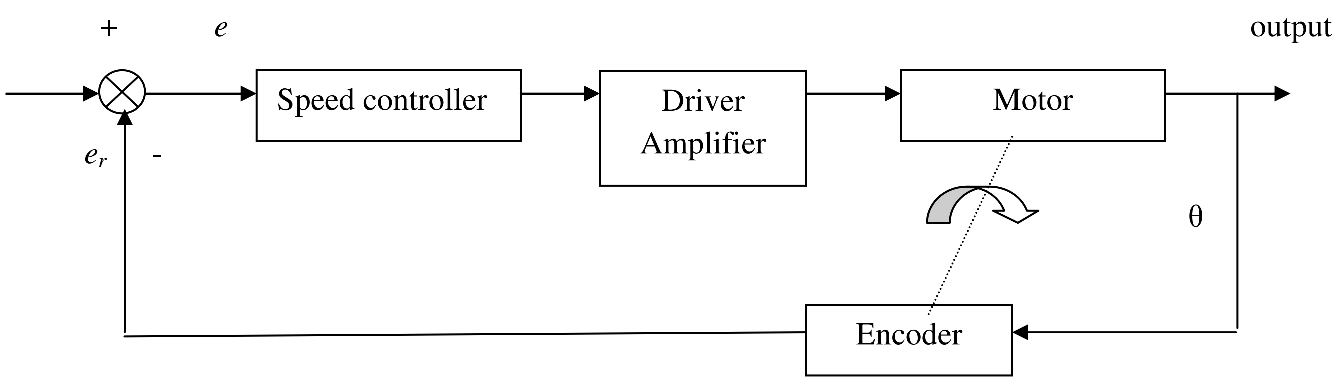

Figure 2.3: Velocity-control system with feedback (Benjamin C. Kuo, 1995)

The objective of feedback is to reduce the error between the reference input and the system output (Benjamin C. Kuo, 1995). Feedback also has effects on such system performance characteristics as stability, bandwidth, overall gain, disturbance and sensitivity (Benjamin C. Kuo, 1995). Feedback happens in many situations, whenever there are a closed sequence of cause and effect relationship, feedback is exist on the system (Benjamin C. Kuo, 1995). Feedback may be classified in many ways, depending on the purpose of the classification (Benjamin C. Kuo, 1995). There are Sample Data system and Phase-Locked system in the feedback types. The use of this feedback type is depends on the system requirement.

2.2.1 Sampled Data System

A sampled-data system is a control system where a continuous-time plant is controlled with a digital device. Under periodic sampling, the sampled-data system is time-varying but also periodic, and thus it may be modeled by a simplified discrete-time system obtained by discretizing the plant. However, this discrete model does not capture the intersample behavior of the real system, which may be critical in a number of applications.

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2.2.2 Phased-Locked Control

Phased-locked loop is a control system that generates a signal that has a fixed relation to the phase signal. A phase-locked loop circuit responds to both the frequency and the phase of the input signals, automatically raising or lowering the frequency of a controlled oscillator until it is matched to the reference in both frequency and phase. Phase-locked loop techniques are well suited to provide this control by phase locking the motor to a stable and accurate reference frequency (Merrimack, 1987). With phase-locked loop, a motor speed is controlled by forcing it to track a reference frequency (Merrimack, 1987).

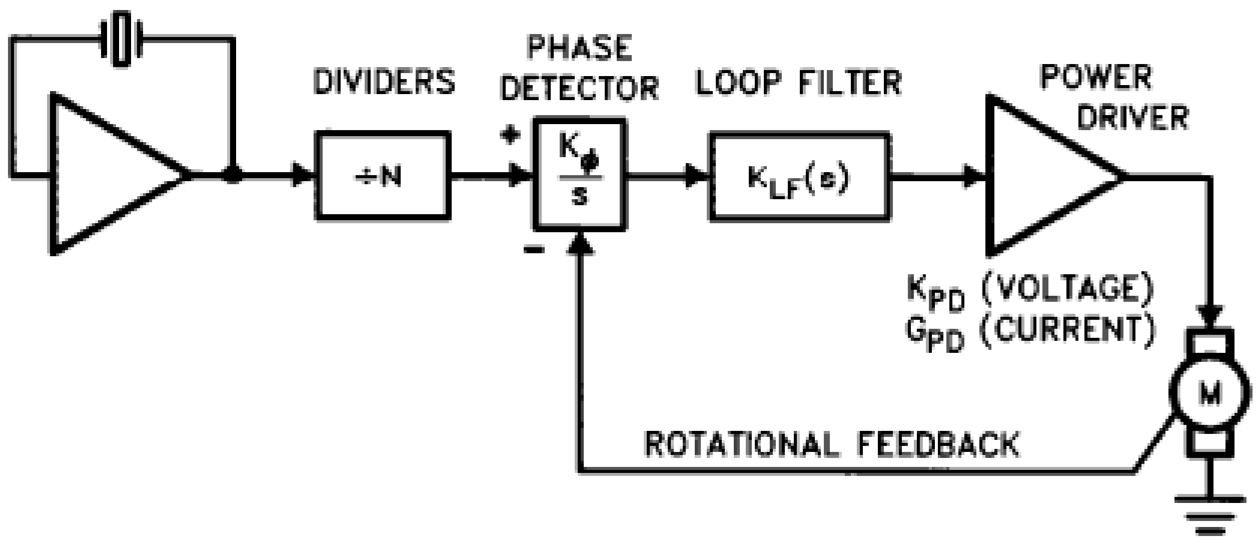

Figure 2.4: Motor speed control is obtained by phased-locked loop

(Merrimack, 1987)

2.3 SPEED CONTROLLER

The objective of a motor speed controller is to take a signal representing the demanded speed, and to drive a motor at the order speed. The controller may not actually measure the speed of the motor unless there is a Feedback Speed Controller or Closed Loop Speed Controller, if it does not have feedback speed controller, then it is called an Open Loop Speed Controller. Feedback speed control is better, but more

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complicated. The speed controller motor drive output will be different depending on the type of motors. To make the motor speed controller run faster or slower, it all depending on the voltage that the motor speed controller accept. Increase in voltage will increase the speed while decrease in voltage will decrease the speed (Germanton et al, 1999; Ogino et al, 2007).

2.4 TYPE OF CONTROLLER

The function of controllers is to increase the gain without decreasing the damping ratio (Ashok Kumar, 2006). Increase in gain will reduce the steady state error (Ashok Kumar, 2006). Controllers can be introduced in feedback or forward path to control the steady state error and transient performance (Ashok Kumar, 2006). Many types of controllers are available such as PD controller, PI controller, PID controller, Phase-Lead controller, Phase-Lag controller, Lead-Lag controller (Benjamin C. Kuo, 1995).

2.4.1 Digital PID controller

PD controller can add damping to a system, but the steady state response is not affected while PI controller can improve the relative stability and improve the steady state error also but the rise time is increased. PID controller is a Proportional-Integral-Derivative controller. PID controller controls a continuous feedback loop that keeps the process output flowing normally by taking corrective action whenever there is a deviation from the desired value of the process variable. PID controller will receives the signal from the sensors and computes the correct value to get the exact value. PID is a well-known type of adaptive control algorithm that has long been used for controlling motors (Stockberger et al, 2008). PID controller will receives the signal from the sensors and computes the correct value to get the exact value.

Proportional – Referred to Proportional Gain. The proportional term is the corrective action which is proportional to the error. In mathematical terms:

Proportional action = proportional gain X error

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Error = Set point (SP) – Process Variable (PV)

Integral – Referred to as reset action. The reset term is the integral sum of the error values over period of time

Derivative – Referred as a rate. Its job is to generate a contribution to the output in advance.

2.4.2 Design of PID- like Fuzzy Controllers

Fuzzy controller can be designed using the same experiment as PID controller in a model free basis or simple models. The overall idea is that any PID with bounded input and output can be reproduced exactly by Fuzzy systems.

2.5 DRIVER AMPLIFIER

Amplifier is any devices that usually increases the amplitude of a signal usually voltage or current. Amplifier is used to get the output resistance value is lower than input resistance, when the ratio input over output is higher, means more voltage is produce (Ryan sherry, 1995).

2.5.1 Linear amplifier

A linear amplifier is an electronic circuit whose output is proportional to its input, but capable of delivering more power into a load. The advantage of linear amplifier is it can amplify the signal.

2.5.2 Pulse width modulation

Conventionally, a PWM circuit that controls electric power supplied to a load by varying a duty ratio of a pulse signal has been in use for controlling speed of a motor (Matsui, 2008). PWM power amplifiers is a device moving current up and down, it also has only an on or an off states at its output. The on/off control of the switching devices drives highly efficiently the load (Shinohara, 2007). When a high level period is

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lengthened, the electric power supplied will increases and this also will increases the rotational speed of the motor (Matsui, 2008).

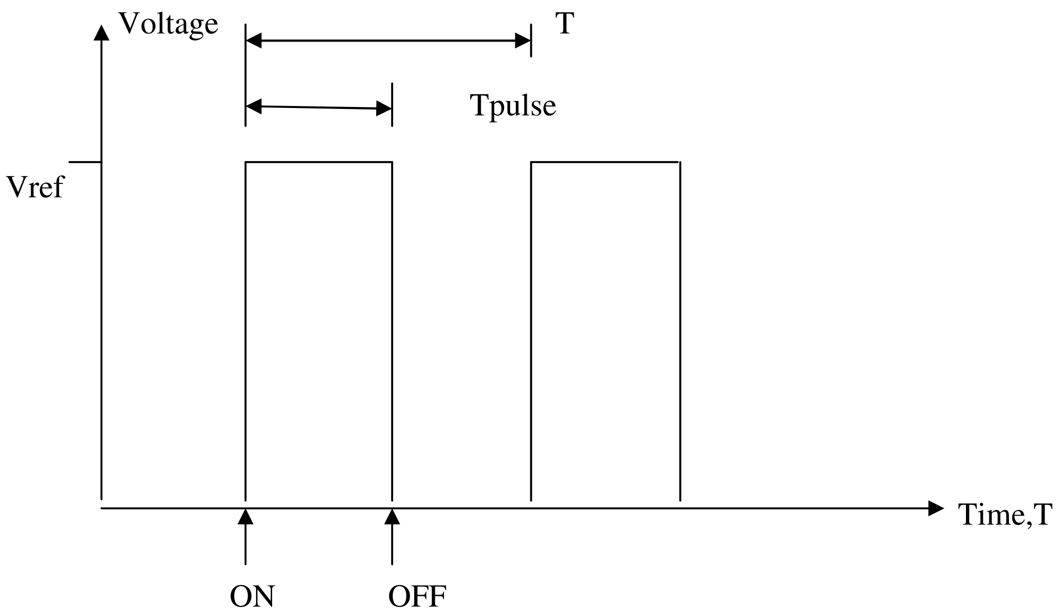

Figure 2.5: Typical PWM signal

(http://www.dominant-semi.com/atweb/site/download/Dimming%20InGaN%20LED_verA.pdf)

Duty cycle, D = Tpulse/T * 100%

The longer Tpulse produced, the high voltage will be produced while the Vref and T kept fixed. We can use low pass filter to convert pulses to analog voltage.

2.6 MOTORS

Motor is a device that converts electrical energy to mechanical energy or imparts motion (http://www.businessdictionary.com/definition/motor.html). Most rotary motion application today depends on motor (http://www.emerson-ept.com/eptroot/public/schools/motors.pdf). Motor is a common device in any component. Most of our activities will use motor to produce works because by doing that we can use less human energy and the work will be easier.

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2.6.1 DC Motor

DC motor operated product has risen rapidly in recent years (Bhagwat et al, 1990). DC motors were extensively used because their flux and torque can be easily controlled. DC motor offer great deals since it can be used practically anywhere without extension cords (Bhagwat et al, 1990). DC motor are more expensive than AC motor because of the brushes and commutators (Benjamin C. Kuo, 1995). Today, with all the technology and the development of the rare-earth magnet, it is possible to get very high torque-to-volume PM dc motor at reasonable cost (Benjamin C. Kuo, 1995). Furthermore, the upgrade made in brush and commutator technology have made these wearable parts practically maintenance free (Benjamin C. Kuo, 1995).

Figure 2.6: DC motor
(http://www.supplierlist.com/photo_images/15960/DC_MOTOR.jpg)

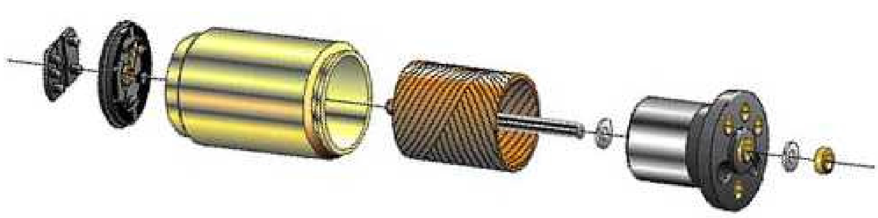

Figure 2.7: Assemble part of DC motor
(http://www.solarbotics.net/starting/200111_dcmotor/200111_dcmotor2.html)

DC motor control can be employed to drilling tools (Germanton et al, 1999). Furthermore, DC motor controller can be utilized a zero displacement switch and associated electronic control circuitry (Germanton et al, 1999). Majority of drilling machines accomplish what is commonly called torque limiting (Germanton et al, 1999).

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These devices decouple power but not torque (Germanton et al, 1999). Ideally, certain of the devices convert power into torque (Germanton et al, 1999). Torque is a moment of rotational and when torque times RPM is equal to the horse power (Germanton et al, 1999). Motor speed controller circuit is improved when DC motor powered products is providing variable speed with feedback system (Bhagwat et al, 1990). To make the motor speed controller run faster or slower, it all depending on the voltage that the motor speed controller accept. The increasing voltage will make the motor speed controller run faster while decreasing voltage will make motor speed controller slower (Germanton et al, 1999).

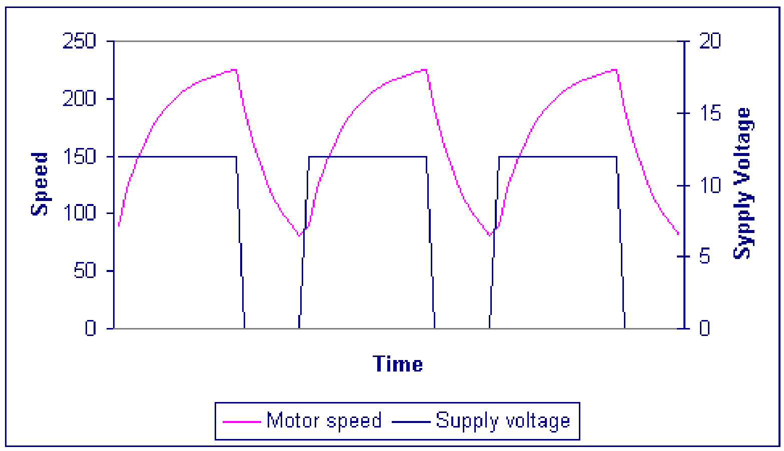

Figure 2.8: relationship between speed of a motor and the supply voltage (http://homepages.which.net/~paul.hills/SpeedControl/SpeedControllersBody.html)

DC motor is basically is a device that converts electrical energy to mechanical energy (Phillips C. L, 1995). The magnetic field of a dc motor can be produced by permanent magnets (Benjamin C. Kuo, 1995). The torque developed on the motor shaft is directly proportional to the field flux and the armature current (Benjamin C. Kuo, 1995). A current carrying conductor is established in a magnetic field with flux φ, and the conductor is located at a distance are from the center of rotation. The relationship among the developed torque, flux and current is,

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$T_m = K_m \varphi i_a$

where T_m = motor torque

φ = magnetic flux

i_a = armature current

K_m = proportional constant

When the current moves in the magnetic field, a voltage is generated across its terminals (Benjamin C. Kuo, 1995). This voltage known as the back emf which is proportional to the shaft velocity, tends to oppose current flow (Benjamin C. Kuo, 1995). The relationship between the back emf and the shaft velocity is,

$e_b = K_m \varphi \omega_m$

where e_b = back emf

ω_m = shaft velocity of the motor

The velocity of the motor can be calculated using this equation;

$\omega_m = [V - (I_a * R)]/(K_E)$

$= (V/K_E) - (R/K_E)I_a$

Where, V = applied voltage K_E = Voltage constant for given motor

I_a = armature current

R = armature resistance

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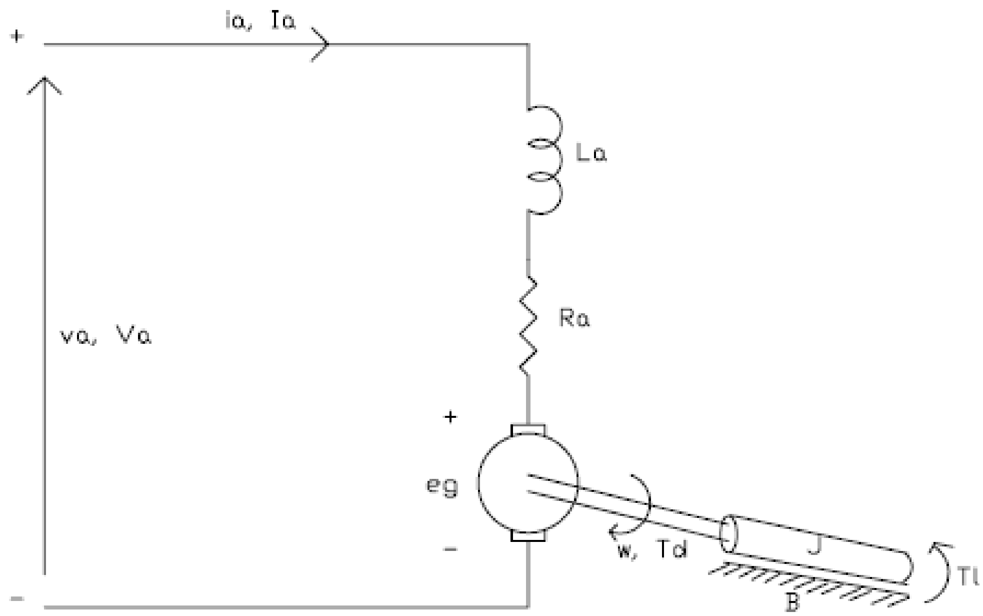

Figure 2.9: Equivalent circuit of a permanent magnet DC motor
(http://www.ece.osu.edu/ems/ee647/Lab_Manuals/Lab6.pdf)

2.6.2 AC motor

AC motor also known as AC induction motors (ACIM). AC motors can be divided into two categories that are asynchronous and synchronous. It is simple, reliable and easy to manufacture. They can develop power levels from fractional to thousands of horsepower. In reality, AC motors are more difficult to control especially for position control and their characteristics are quite nonlinear, which makes the analytical task more difficult (Benjamin C. Kuo, 1995).

2.7 SENSORS

Sensors are important components for feedback in control system. It also used to monitor the performance. Nowadays, most of machine use sensors to detect the output value.

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2.7.1 Tachometer

Tachometers are electromechanical devices that convert mechanical energy into electrical energy (Benjamin C. Kuo, 1995). Most of the tachometers used are using dc signal. Dc tachometers can be used as velocity indicators to provide velocity feedback or speed control or stabilization (Benjamin C. Kuo, 1995). Tachometers used are generally connected directly to a voltmeter calibrated in revolutions per minute (Benjamin C. Kuo, 1995).

2.7.2 Encoder

Incremental encoders are used for converting linear or rotary displacement into digital coded or pulse signals (Benjamin C. Kuo, 1995). The encoders that output a digital signal are known as absolute encoders. Incremental encoders provide a pulse for each increment of resolution but do not make distinctions between the increments. The type of encoder to use depends on economics and control objectives. Absolute encoders has much to do with the concern for data loss during power failure or the applications involving periods of mechanical motion without the readout under power while the incremental encoder's simplicity in construction, low cost, ease of application, and versatility. Incremental encoders are available in rotary and linear forms. A basic rotary incremental encoder has four basic parts that is a light source, a rotary disk, a stationary mask, and a sensor.

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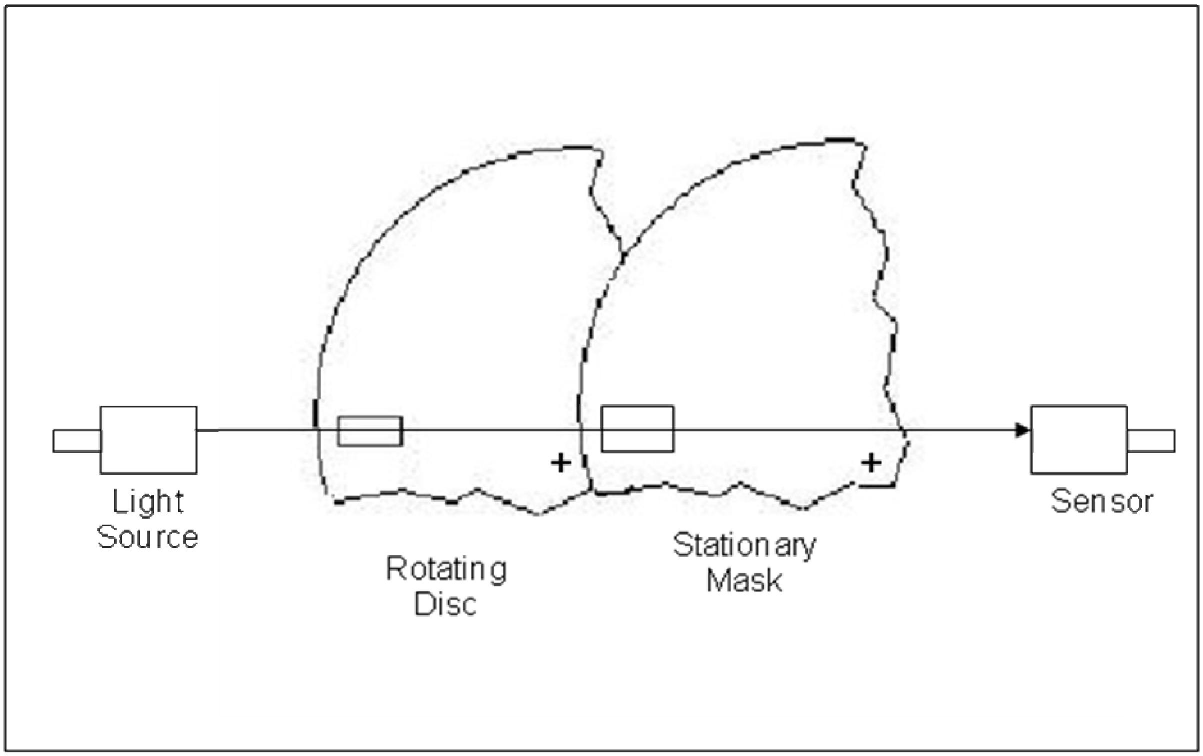

Figure 2.10: Encoder (Ashok Kumar, 2006)

2.8 FUZZY CONTROLLER DESIGN

2.8.1 Fuzzy Logic Control

Fuzzy logic is very suitable to use for the system that are too complex to analyze by conventional techniques (Huaguang Zhang et al, 2006). The whole idea of FLC is that an experienced human operator can competently control a process without the knowledge of its original dynamics. The effective control strategies that human operator learn through their experience can be expressed as a set of condition-action rules, which describe condition about the process using linguistic terms such as increase slightly or decrease moderately (Huaguang Zhang et al, 2006). Fuzzy logic controllers are customizable, it is easier to understand and modify the rules, because it is not only humanlike decisions but also are expressed in linguistic term used in natural language (Huaguang Zhang et al, 2006).

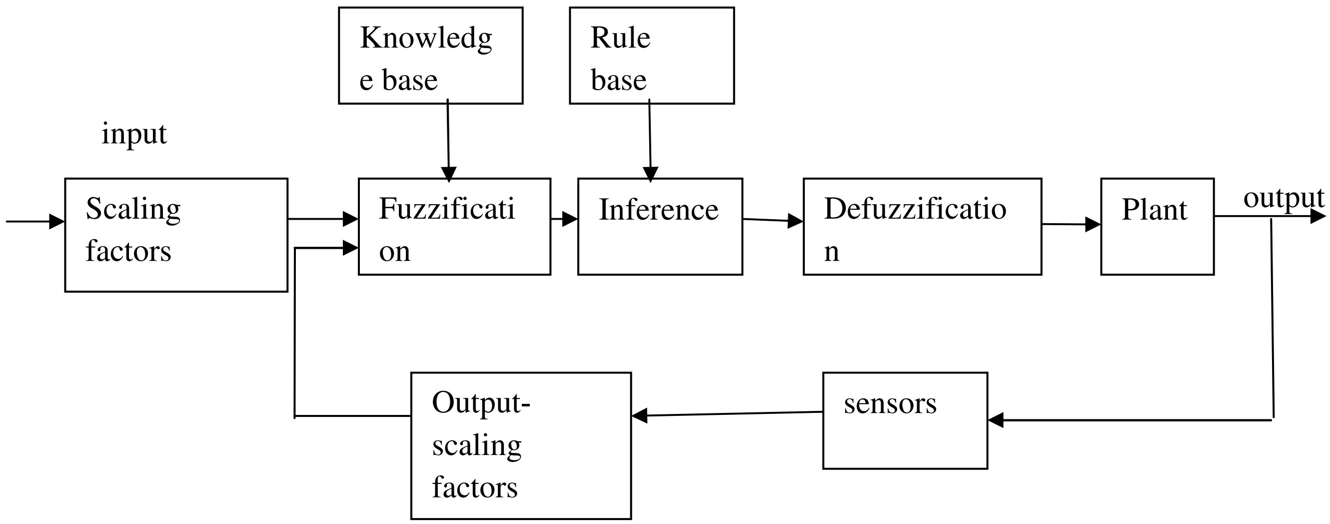

Figure 2.11: Block diagram of a typical fuzzy logic controller (M. N. Cirstea et al, 2002)

2.8.2 Fuzzy rules

The objective of fuzzy controllers is to get exactly like human thought and action or to make humanlike decisions by using the knowledge about controlling a target system (Zdenko kovačić et al, 2006). This can be achieved by knowing fuzzy rules that constitute a fuzzy rule base (Zdenko kovačić et al, 2006). The fuzzy rule base is a central component of the fuzzy controller and it represents the intelligence in any fuzzy control algorithm (Zdenko kovačić et al, 2006). This is the component where designer's knowledge and experience must be interpreted correctly and organized into an appropriate set of rules (Zdenko kovačić et al, 2006).

Fuzzy rule can be divided into two parts, that is IF and THEN (Zdenko kovačić et al, 2006). IF and THEN represent on how to make the decision. IF means what is the condition while THEN is to know what decision should be make or done.

2.8.3 Fuzzification

Fuzzification is define as the quantization and membership function for input variable, error and rate and output variable (M. N. Cirstea et al, 2002). The fuzzification

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module converts the crisp value of the control input into fuzzy values, so the crisp value is compatible with the fuzzy set representation in fuzzy rule base (M. N. Cirstea et al, 2002).

2.8.4 Defuzzification

Defuzzifiation is an optional step in the Fuzzy expert system. It depends mostly on whether the user wants to have real numbers or keep the fuzzy ones (M. N. Cirstea et al, 2002 ; Zdenko kovačić et al, 2006). The choice of deffuzification methods usually depends on the application and the available processing power (M. N. Cirstea et al, 2002 ; Zdenko kovačić et al, 2006).

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CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter will be about what are the steps that need to work on in order to complete this project and to achieve all the objectives. Several steps had been listed to make sure that the flow of the project is done perfectly. The first thing that had to be done in this project is starting building the digital circuit since the digital circuit is the parts that important in reading the data and results. After that, the program must be complete using programming software in C language or C code. The next step is to find the mathematical method for this project. The mathematical part is the most important part to find the exact value of the error and the exact value of the right frequency. In this part, it has to make sure that the PCB drilling can maintain the speed even there is a load or friction. The method to find the mathematical method is using the Fuzzy Logic method. After the mathematical is done, the tuning part takes place to ensure that the permanent magnet DC motor rotates more accurate and the performance is better. When everything is complete, the last part is to test the system with the PCB drilling and give a friction to the PCB drilling. After that, the result of the testing will be collect and the conclusion will be made according to the result.

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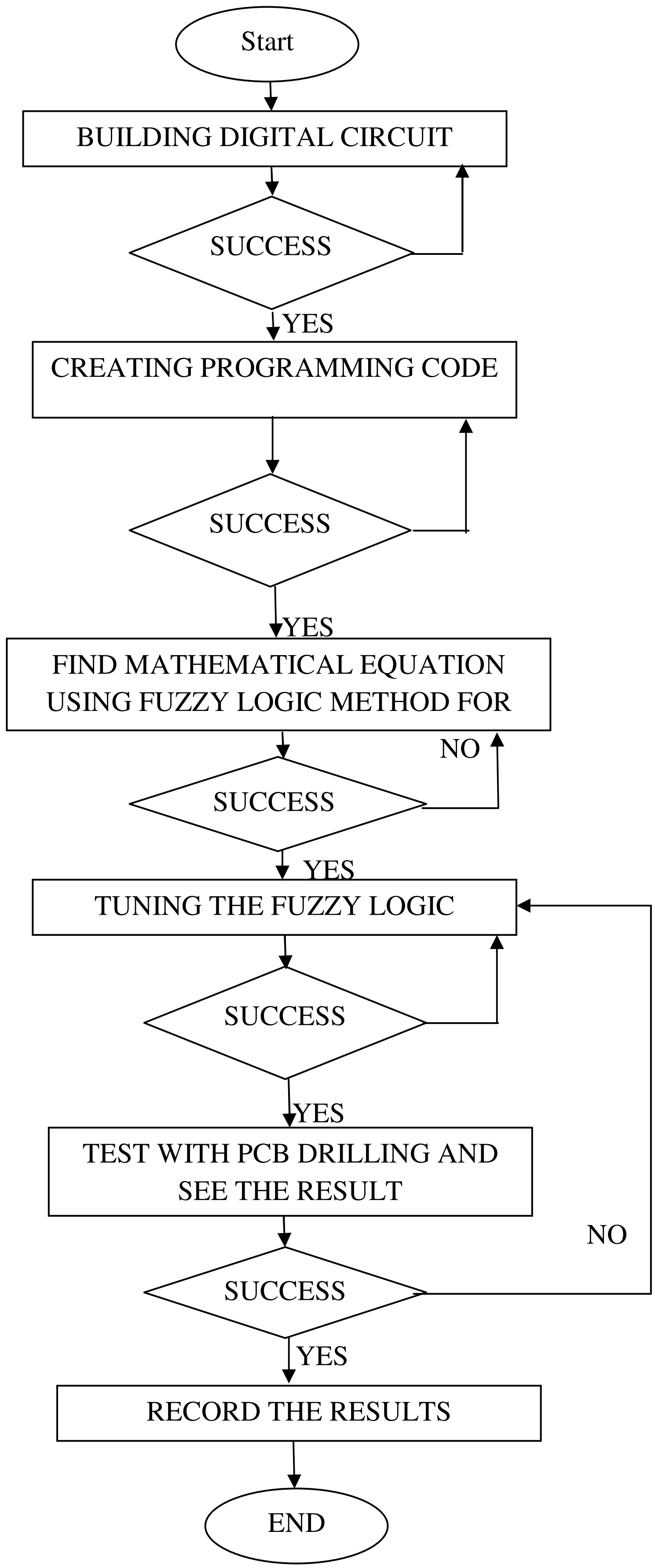
3.1.1 Methodology Flowchart



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3.2 BUILDING THE DIGITAL CIRCUIT

To build the digital circuit, firstly we need to determine the electronic parts that suitable for the motor speed controller. We have to consider how the signal accepted and the output. This is to make sure that the signal can be read and feedback. There are several functions that we need to discover and the parts is divided to 7 parts. The functions are:

- The electronic parts that can store memory and process the signal and data
- The signal converter, to convert the input data
- Type of driver to amplify the signal to the DC motor when friction occurs
- Type of sensors that use to get the signal from the DC motor
- The converter that use to transfer signal and data to the computer

After knowing all the function that needed, the process to build the circuit can be proceed. Before build the circuit, all the functions and the limitation of the electronic parts must be study to avoid the electronic parts from broken.

3.3 CREATING THE PROGRAM FOR MOTOR SPEED CONTROLLER

The program is very important to process the data. This is where the data will be process and feedback. Before creating the program, we have to make sure that the electronic parts understand all the command that will be created. In this program, all the data will be collect and the process of the calculation will be done. Then it will display on the computer. The common language used is the C language and the programming used is the C programming.

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3.4 FIND THE MATHEMATICAL MODEL FOR THE FUZZY LOGIC

After the circuit and the main program code is finished, the mathematical model for fuzzy logic must be create. The mathematical model is specifically will calculate the signal that accepted from the sensors and calculates it to exact and needed output. The method to find the mathematical model is fuzzy logic method. Fuzzy logic method is basically based on the creator equation or thought. Furthermore, the language use for fuzzy logic is very easy to understand as it is using linguistic terms in our natural language. To get the mathematical model, there are few steps need to be done. The steps are:

- Get the frequency responses of the motor while running without any friction at voltage that has been decide.
- Use the frequency that we get as a constant and assumption for our mathematical model.
- Set the original frequency, this is the frequency that use to run the motor
- The original frequency is the exact frequency for the motor speed. The frequency can be controlled by controlling the voltage.
- Make a model of fuzzy logic method that can create an equation.
- From the graph, we can determine the equation.
- Then, declare the equation in the programming using the C language.

Before getting the right equation, the model of the fuzzy logic must be determined. There are various type of model can be determined by our own creativity and decision. The model is just a simple model. The shape of the model is a triangle and the more triangles determined in one model, it will be more accurate and more complex as the calculation also will be long. After developed the model and decide it. Then, this

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is the part where we can find the mathematical model. Below are types of simple model of fuzzy logic:

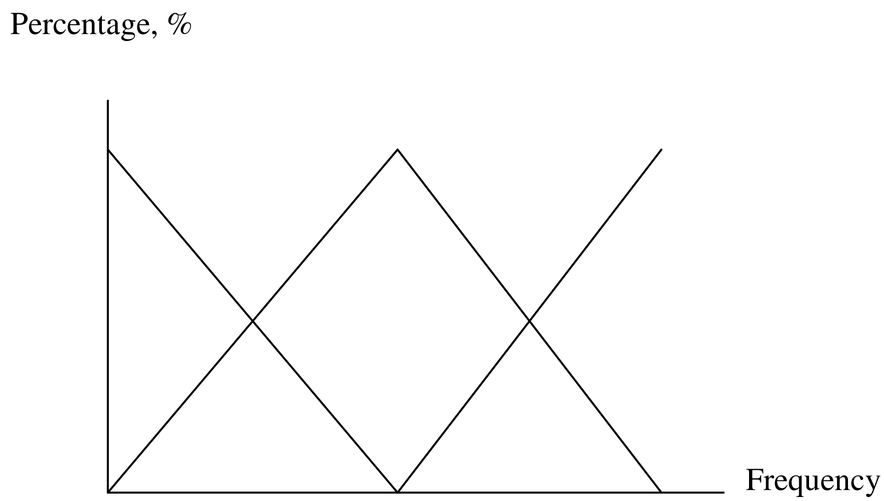

Figure 3.1: First model

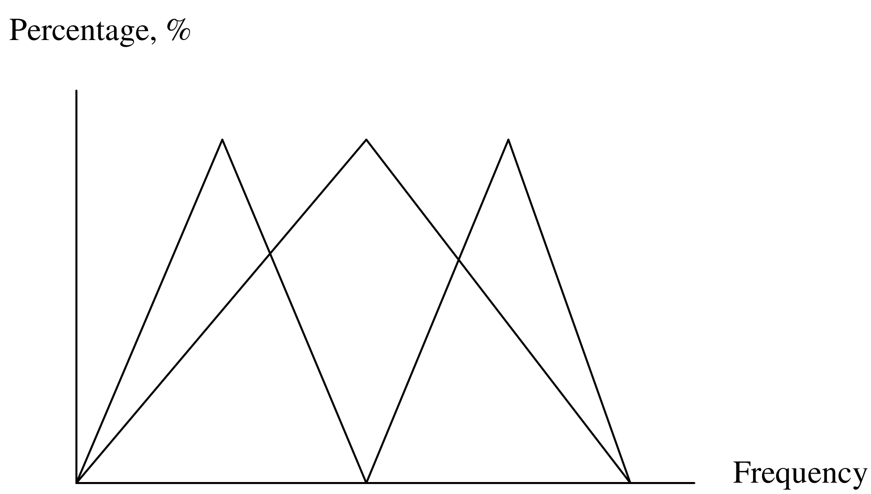

Figure 3.2: Second model

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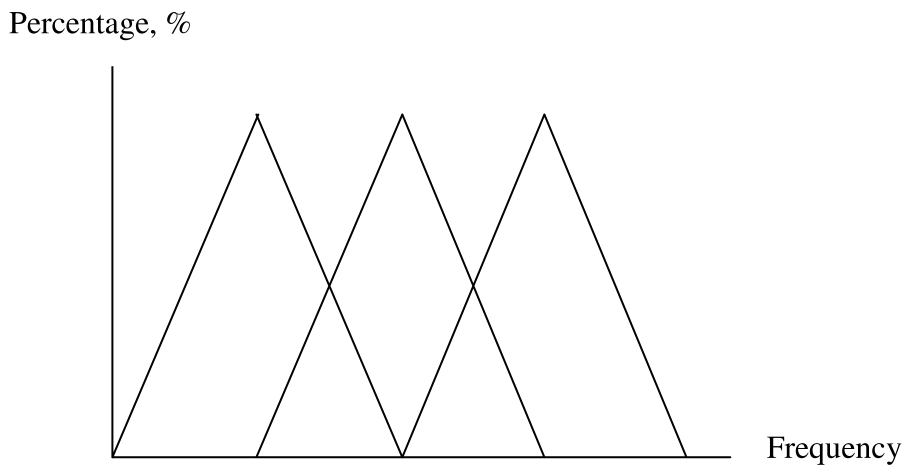

Figure 3.3: Third model

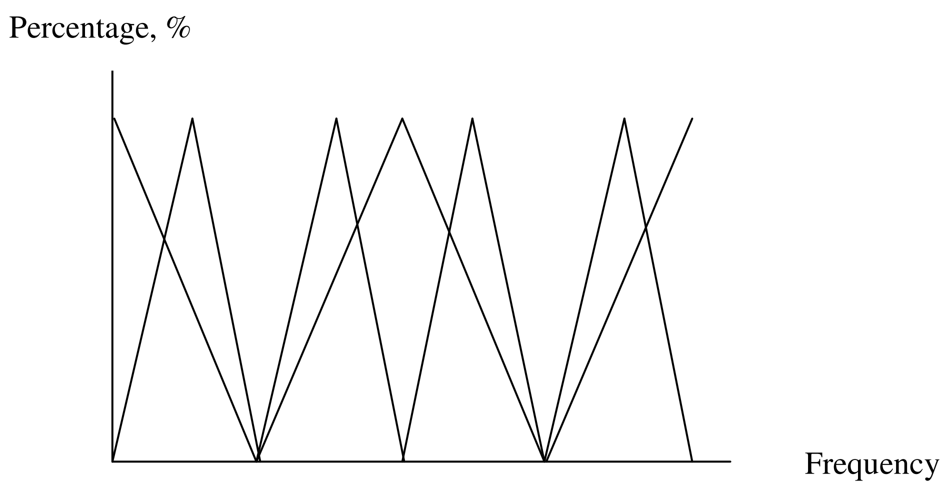

Figure 3.4: Fourth model

After the mathematical model is finished, the test can be done. By having the right equation, the feedback response of the fuzzy logic will be accurate. Furthermore, this will lead us to the best actual performance from the DC motor that will be use. The tuning process can be done to improve more the performance by defining more constant and assumption.

3.5 FUZZY LOGIC TUNING

For the tuning part, the part that needs to be adjusted is the C program for the fuzzy logic. This is to ensure that the data collected are accurate. To make sure it runs smoothly, the program must be tested and checked again. The steps to do the tuning are as below:

- Make a model for a fuzzy logic method to determined the rough equation
- From the model, get the natural frequency value for assumption in the model at reference voltage that has been set.
- Make assumption on the model in order to find the equation.
- Create an equation that can find the height of the model when there is an interaction of the frequency when the friction is given to the PCB drilling operation

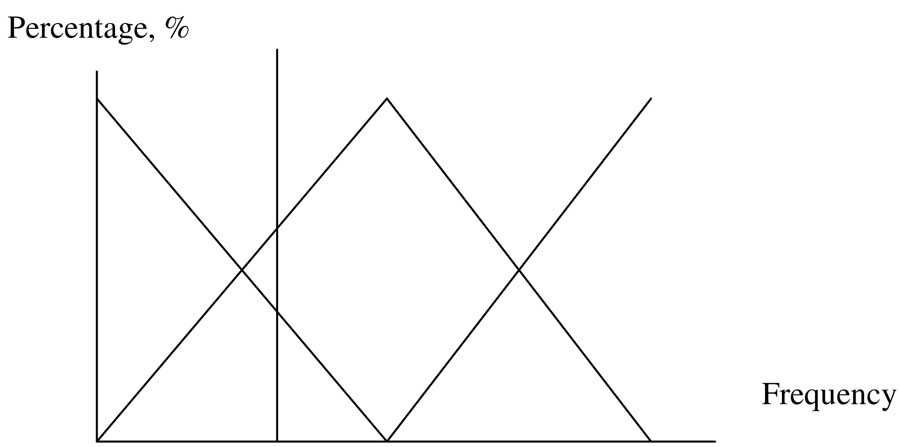

Figure 3.5: Example model when there is friction on DC motor

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- Find the height of the interference triangle.
- Calculate the area of the new triangle with new height.
- Find the percentage of the frequency that lies between the triangles.
- Multiply the percentage with 255 in order to find the output in bit.

3.6 TEST THE SYSTEM PERFORMANCE OF THE FUZZY LOGIC WITH THE PCB DRILLING OPERATION

When all the digital circuit and the C program that using Fuzzy Logic method is finished. The system is tested in order to find out the performance of the PCB drilling operation is better than before or not. If it is not, the system must be tuning until the performance is better.

- Run the motor without any adjustment and load, to make sure all the digital circuit is working.
- Set the desired speed to run the DC motor.
- Drill the PCB drilling with given load and friction.
- Observe the drilling process.
- Adjust the C program for an improvement.
- Set the desired speed again.
- Repeat step 3 and 4.
- Observe the frequency or the speed of the motor by plotting a graph.

After completing testing, observe the plotting graph and from the graph it is clearly stated that Fuzzy Logic method can control the speed of the DC motor even there is a load on the PCB drilling.

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CHAPTER 4

RESULTS AND DISCUSSION

4.1 INTRODUCTION

In this chapter, the explanation on how to do the project will be explained in more details. The method of the project will be shown step by step and how the digital circuit and the programming run also will be shown in this chapter. This chapter also will be showing all the results and findings that have been recorded after the data have been collect. The results also will be observed from the start until the end. The permanent magnet DC motor performance also will be improved by tuning the coding for the Fuzzy Logic method. The tuning part takes place after the first test already done. If the test is satisfy, then the data will be collect and it will be observe by plotting a graph and the conclusion of the results will be done.

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4.2 BUILDING THE DIGITAL CIRCUIT

After completing designing the digital circuit, it shows that it has 8 main parts that need to be built. By combining all the parts can make the circuit works for the fuzzy logic. The parts are:

I. Programmable Integrated Circuit (PIC)
II. Digital to analog converter
III. Operational Amplifier
IV. Transistor
V. DC motor
VI. Encoder
VII. Multichannel RS232 driver
VIII. RS232 cable for computer port

The PIC is used to store the programming and process all the data received. The data that has been calculated will be sent to the output that will lead to the digital to analog converter. Digital to analog converter is used to convert the data output from the PIC since the PIC output is in digital signal. The signal will go through to the amplifier and this is where the voltage will be amplified according to the signal received. The increasing in voltage will make the frequency of the motor will maintain even it had been given extra friction. Furthermore, the encoder is used to measure the error that occurs from the DC motor and it feedback the signal to the PIC. The complete schematic diagram will be shown in the appendix.

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4.2.1 The Programmable Integrated Circuit (PIC)

The PIC is a device that react as a memory and it is use to program and process the data from the sensors output. The data received will be calculated as the program had been set in the C programming. The PIC that will be use is PIC16F877A. PIC16F877A has five bidirectional input-output ports, named port A to E. PIC also have some advantages that can be use is the Real Time Clock Counter (RTCC) and the PIC itself can use the RS232 to receive and send data direct to the computer. From this, we can see the signal output from the encoder and also the changes in frequency signal.

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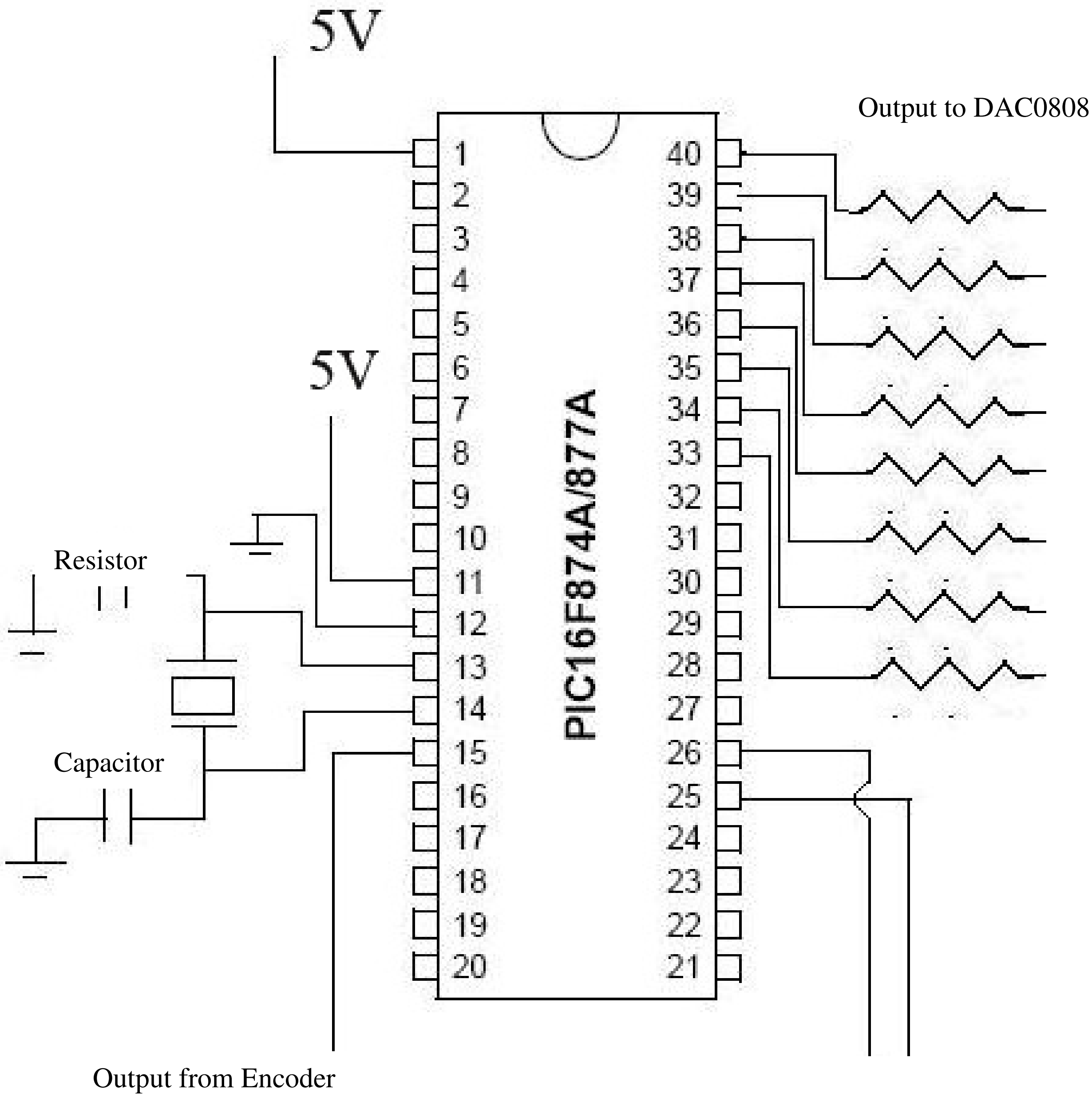

Figure 4.1: PIC circuit

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From the figure, it shows that all port B is defined as the output of the PIC. Port B will send the data that had been process direct to the digital to analog converter. All the output at port B will use to send the signal because the digital signal needs 8 port to create a complete digital signal which is 8 bit. Port B was chosen because the place is easy to connect direct to the digital to analog converter.

The first pin that also named MCLR port is used to supply 5 volts from the power supply to the PIC and it also react as an on off switch. For pin 11 and 12 both will be set for 5 volts and the ground as to make sure the PIC operate perfectly.

Port 13 and 14 is use to ensure the signal receive from the encoder to the Real Time Clock Counter (RTCC). Port 13 and 14 has been given 20Mhz to clocking the Real Time Clock Counter (RTCC). RTCC is use to count the time for one full cycle of the signal pulse to get the frequency of the motor at certain voltage.

Port 23, 24, 25 and 26 also named as C4, C5, C6 and C7 was use to connect the MAXIM232 and RS232. It can directly send the signal to the computer as an output. For pin 23 and 24 it needs to connect to the 5 volt and the ground.

The encoder also will be connected directly to the PIC. Port C0 or port 15 will be used to receive the signal pulse from the encoder. This port will receive the data and the PIC will calculate the data as it has been program from the C programming.

4.2.2 The Digital to Analog Converter (DAC)

Digital to Analog converter is use to convert the digital signal to analog signal. The output from the PIC is in digital signal while the DC motor only can read the analog signal to rotate the motor. The Digital to Analog Converter use is DAC0808LCN model. This model of converter has 16 ports and converts the binary numbers to the analog signal.

For this project, port 5 to 12 is use to receive the digital signal from the PIC. Port 5 will be set as the most significant bit and port 12 is set as less significant bit which that is refer to the first bit to refer is at the most significant bit.

Other than that, port 3 and port 16 is connect to -15V as a Vee while port 13 is connected to 5V as a Vcc. These three port is use to power the converter. Port 14 is connected with 10V as a Vref. Vref is needed to avoid overload or damages to the DAC. Port 2 and 15 are connected to the ground while port 4 will be the analog signal output from the DAC.

After converting the digital signal to the analog signal, an amplifier is needed in order to change the signal from current to voltage. Port 4 from the DAC will be connected with the operational amplifier. Operational amplifier that had been chosen is UA741CN. UA741CN is a high performance monolithic operational amplifier.

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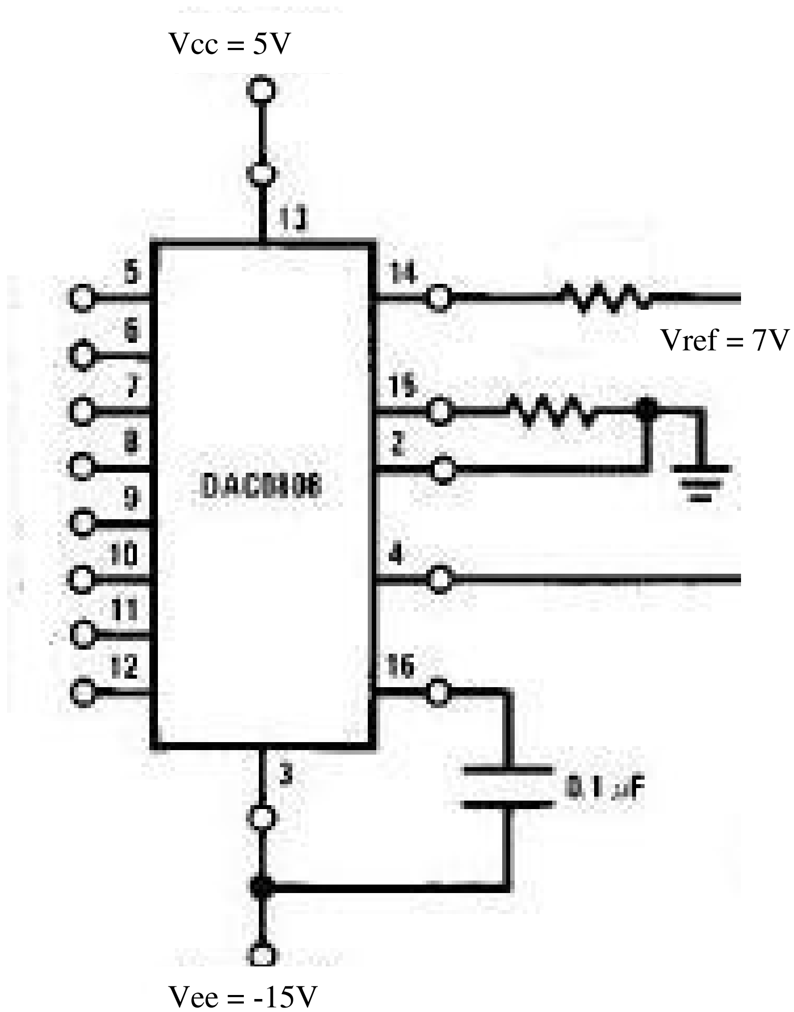

Figure 4.2: Digital to Analog Converter (DAC0808)

4.2.3 Operational Amplifier

Type of operational amplifier that will be use is UA741CN. UA741CN is a high performance monolithic operational amplifier constructed on single silicon chip. It is invented for a wide range application.

- Summing amplifier
- Voltage follower
- Integrator
- Active Filter
- Function Generator

UA741CN has total 8 ports. The output from the DAC will connect directly to the Port 2 of the operational amplifier. The operational amplifier will change the signal from the frequency to the voltage. Then it feedback to amplify the voltage needed in order to maintain the speed of the motor.

Port 4 is going to connected to the -15V as a Vee while port 3 will directly connected to the ground to completed the circuit. Port 7 is use to power the operational amplifier, it will connected to 15V as a Vcc.

For the feedback, Port 6 which is the output for this operational amplifier will also connected back to the port 2. This is where the voltage will be amplify and the amplify voltage will be the output of the operational amplifier which is at port 6.

The amplify voltage from port 6 is connected with the transistor to control a large amount of voltage.

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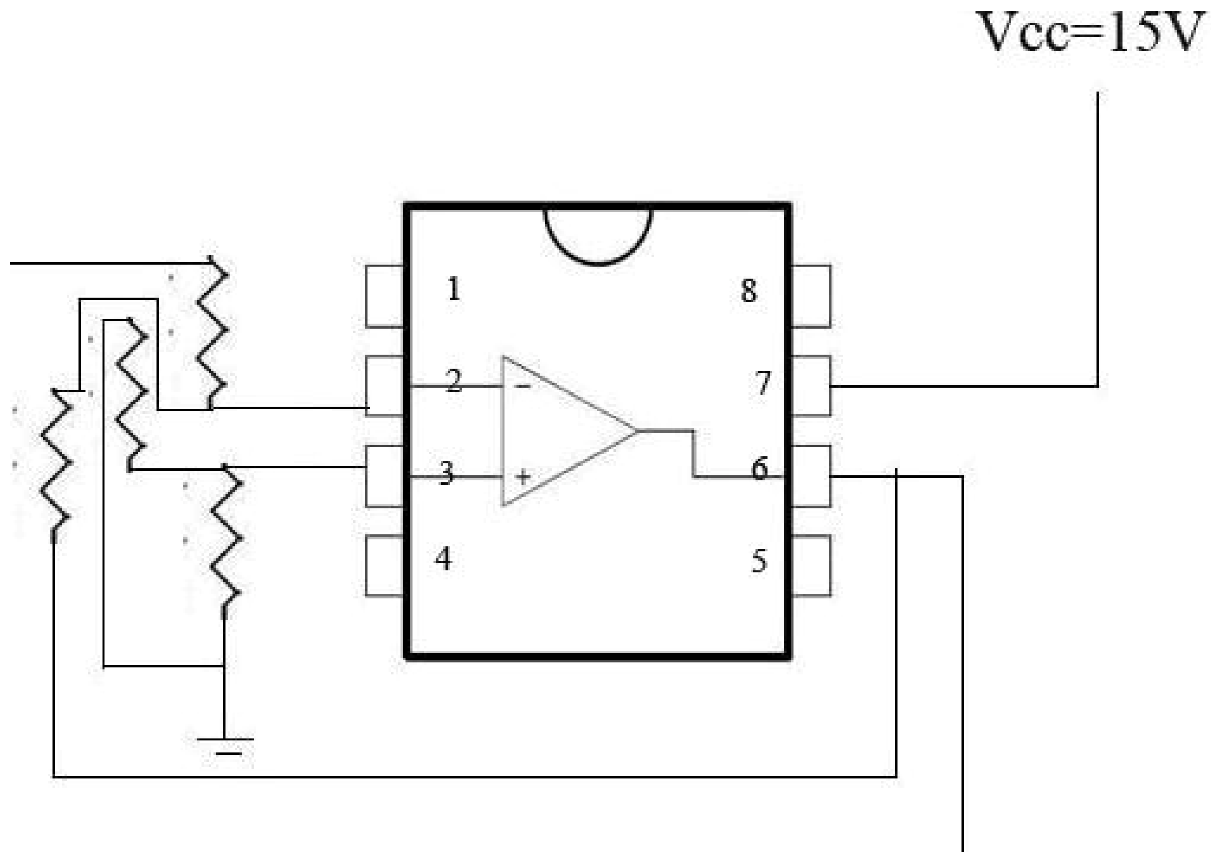

Figure 4.3: Operational Amplifier (UA7741CN)

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4.2.4 Transistor

The transistor type that will be use is TIP31. TIP31 is a pnp-type transistor. The transistor is an active device, it requires power supply to operate and can increase the power between input and output. Input circuit acts as a control circuit which controls a much larger power level in the output circuit using a much smaller power level at the input circuit. TIP31 has three terminals that is Base (B), Collector (C), and Emitter (E).

The output from the operational amplifier is connected to the Base (B) while the Collector (C) will be connected to the Vref. The emitter will be connected to the DC motor and rotate the motor with it desired speed and voltage.

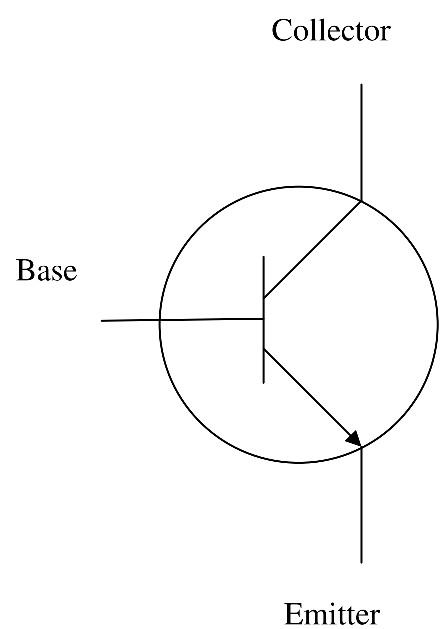

Figure 4.4: Transistor (TIP31)

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4.2.5 The Encoder and light sensors

In this project, the encoder is use to create a pulse signal from a movement of the DC motor. The encoder used in this project is made with 1.5mm sheet metal with a round shape. The encoder was installed at the DC motor and it is placed between the light sensors. The light sensor was used is EE-SX672. In order to power the light sensor, it must be connected to 5V and ground. The function of the encoder is when the DC motor is rotate, the encoder will create an on-off situation which is recognize by the light sensors. The light sensors will create the pulse signal and directly connect the output to the PIC. When the PIC get the pulse signal, it will calculate the output to give the feedback reaction. Other than that, a RS232 was connected to the computer port through the PIC and the MAXIM232. The signal that calculated was collected in the computer. The signal output can be read in the serial port monitor.

Figure 4.5: Encoder light sensors (EE-SX672)

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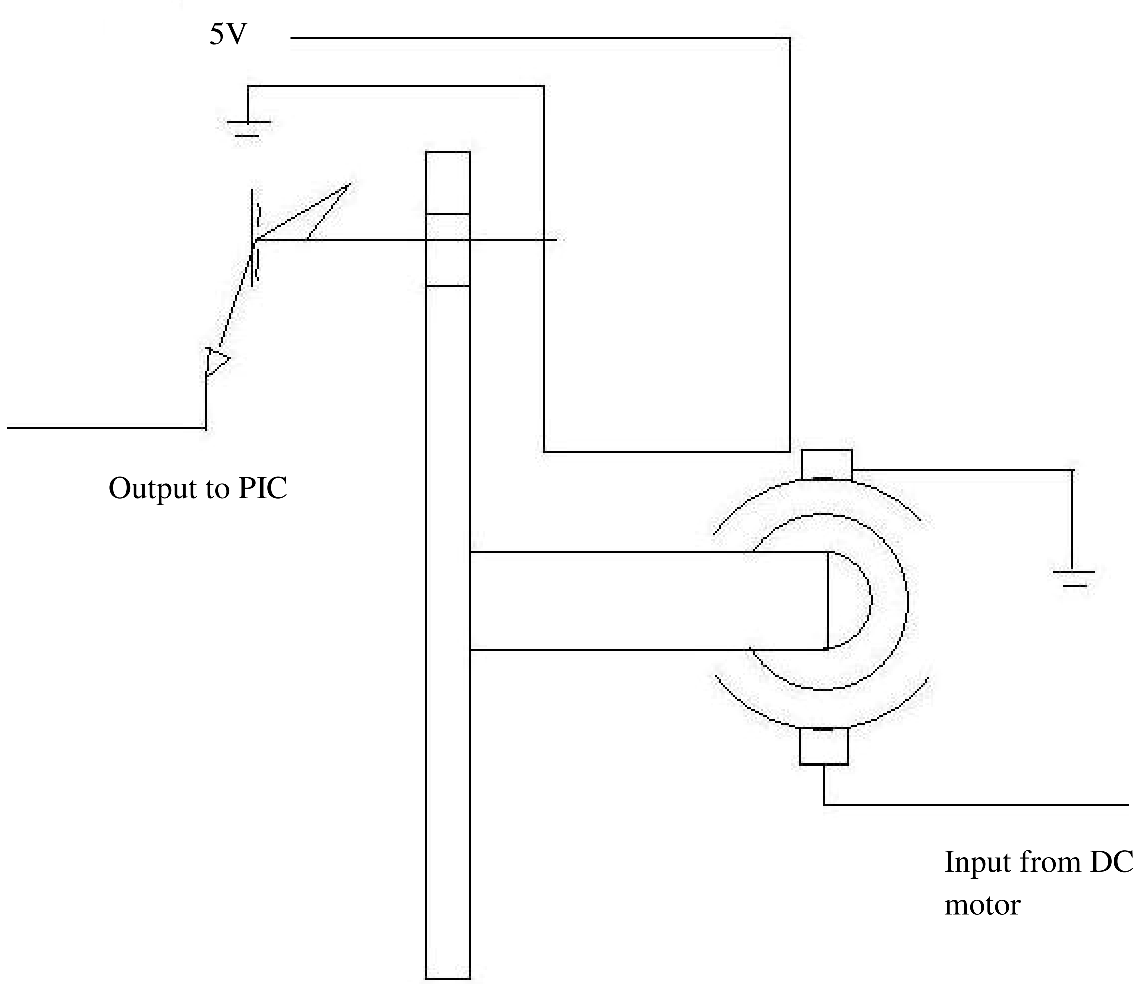

Figure 4.6: Encoder and light sensors

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4.2.6 The multichannel RS232 driver

Multichannel RS232 driver (MAXIM232) is used to transfer data from the PIC to the computer by connected MAXIM232 with PIC and RS232cable. MAXIM232 has 16 ports. To operate MAXIM232, port 16 and 2 were connected to 5V and port 15 was connected to the ground. Furthermore, port 6 was connected to the ground.

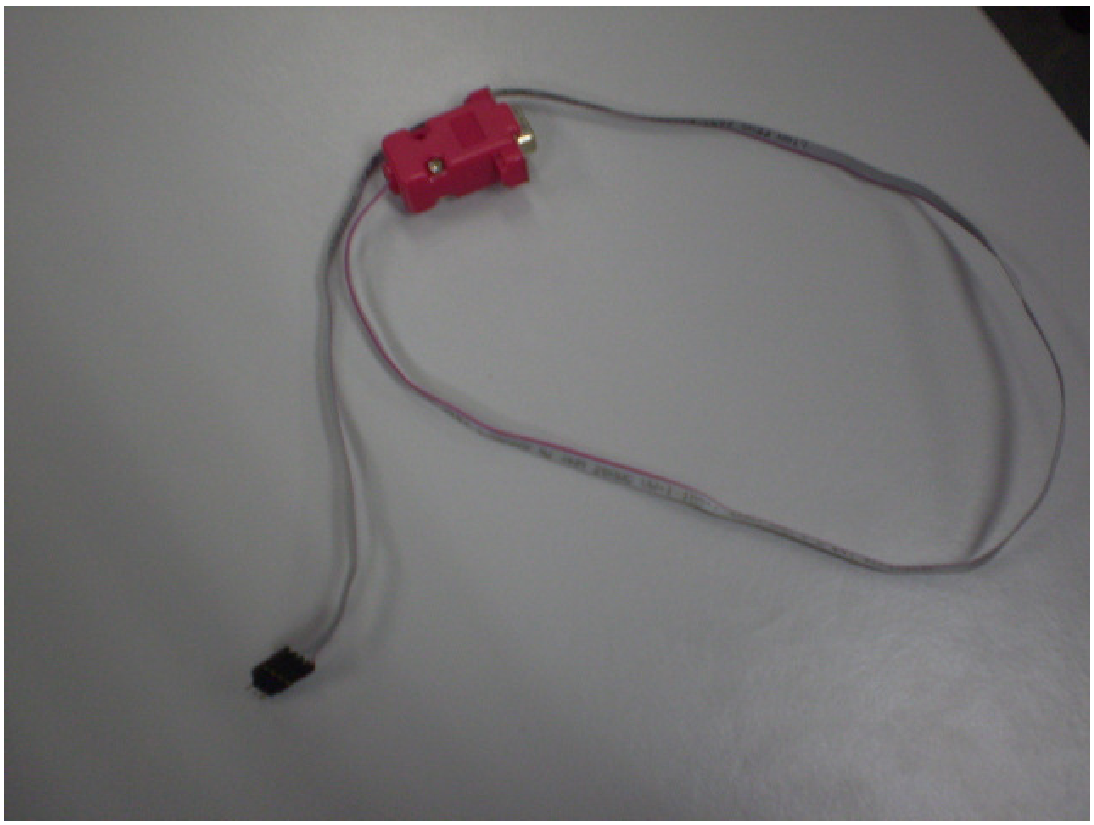

Figure 4.7: RS232 computer cable

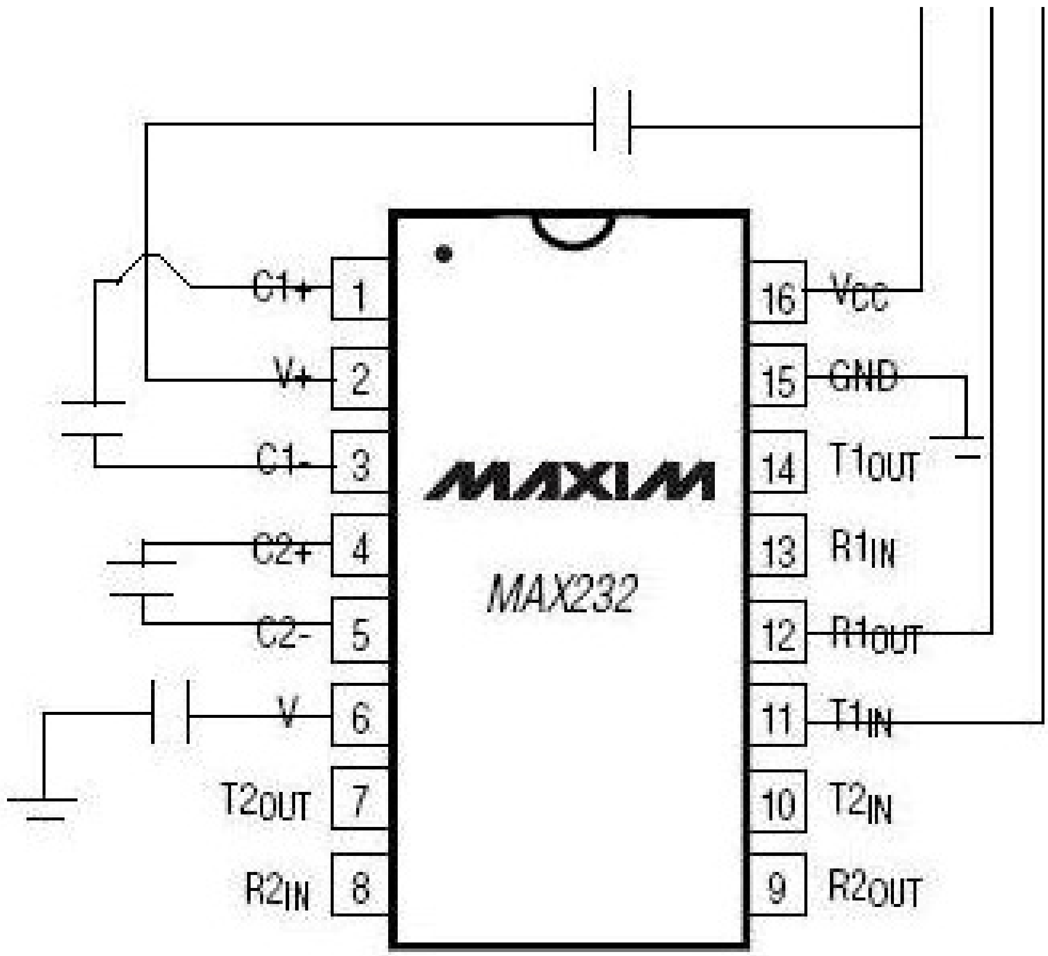

Figure 4.8: Multichannel RS232 driver (MAXIM232)

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4.3 THE DIGITAL C PROGRAM

When the circuit is completed, the programming will be installed in the PIC16F877A by using the PCW compiler software. The device that can upload the program is the downloader.

The most important part in the C program is the Real Time Clock Counter (RTCC). The RTCC is use to count the time for one complete single pulse. The time recorded will be use to calculate the frequency of the motor. To calculate the frequency, math.h must be added to the program. The calculation is done when the frequency is received and it will compare the value of the earlier frequency reference. In order to get exact value, the RTCC will counts the single pulse for 3 times and get the average value for the last two counts recorded. It is approved that the last two counts have slightly same value and can be assume stable to get the exact value of time. Other than that, others function also need to be state on the C program such as the RS232, PIC and the delay.

The first step to use the program is to install the programming into the PIC. The program will be installed in the PIC by open the PIC kit. Then browse the hex file of the programming. The PIC will be put at the downloader that is connected to the computer. Then the PIC is ready for the test run. If the output and the result are not too accurate, then the program must be tuning and check until the project is finished.

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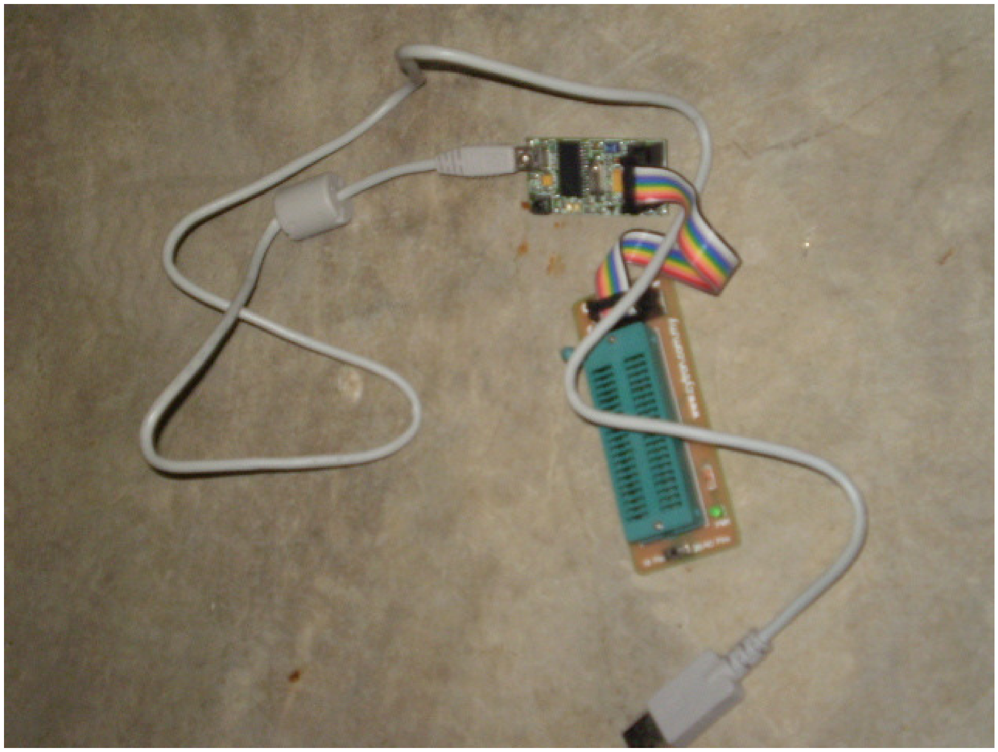

Figure 4.9: The Downloader

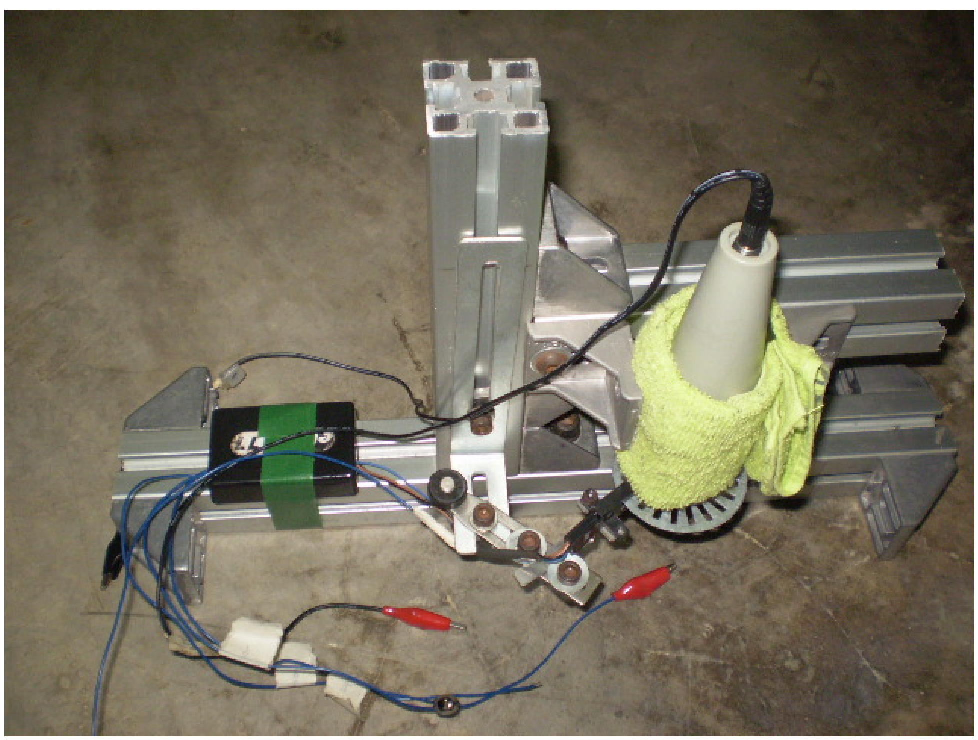

Figure 4.10: Mechanical part

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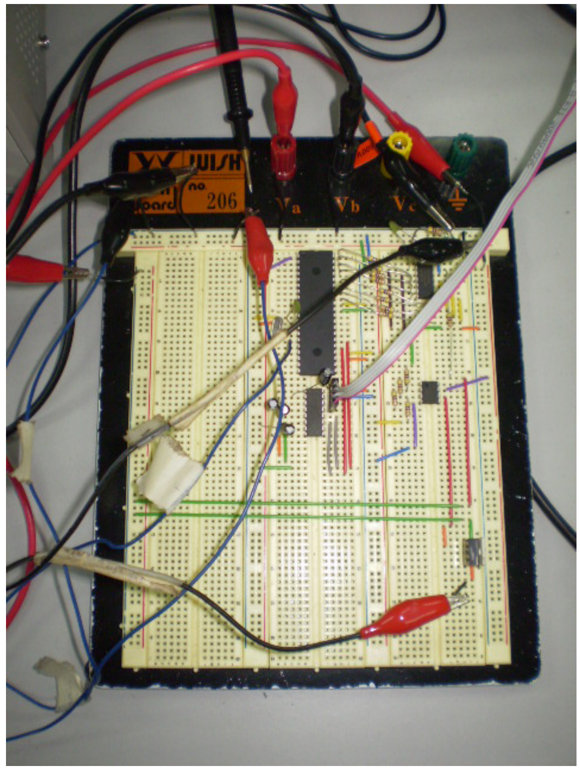

Figure 4.11: Fully digital circuit

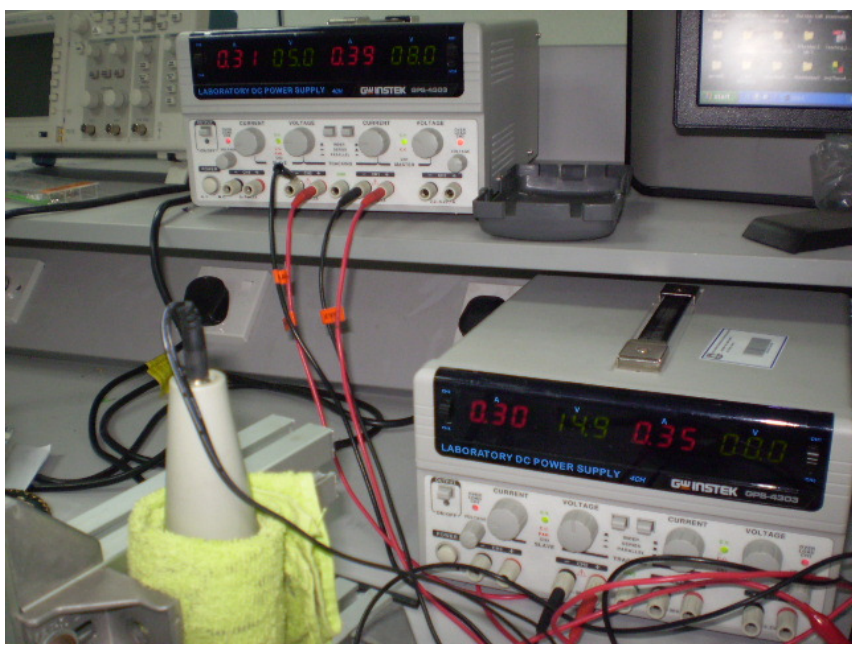

Figure 4.12: Power supply

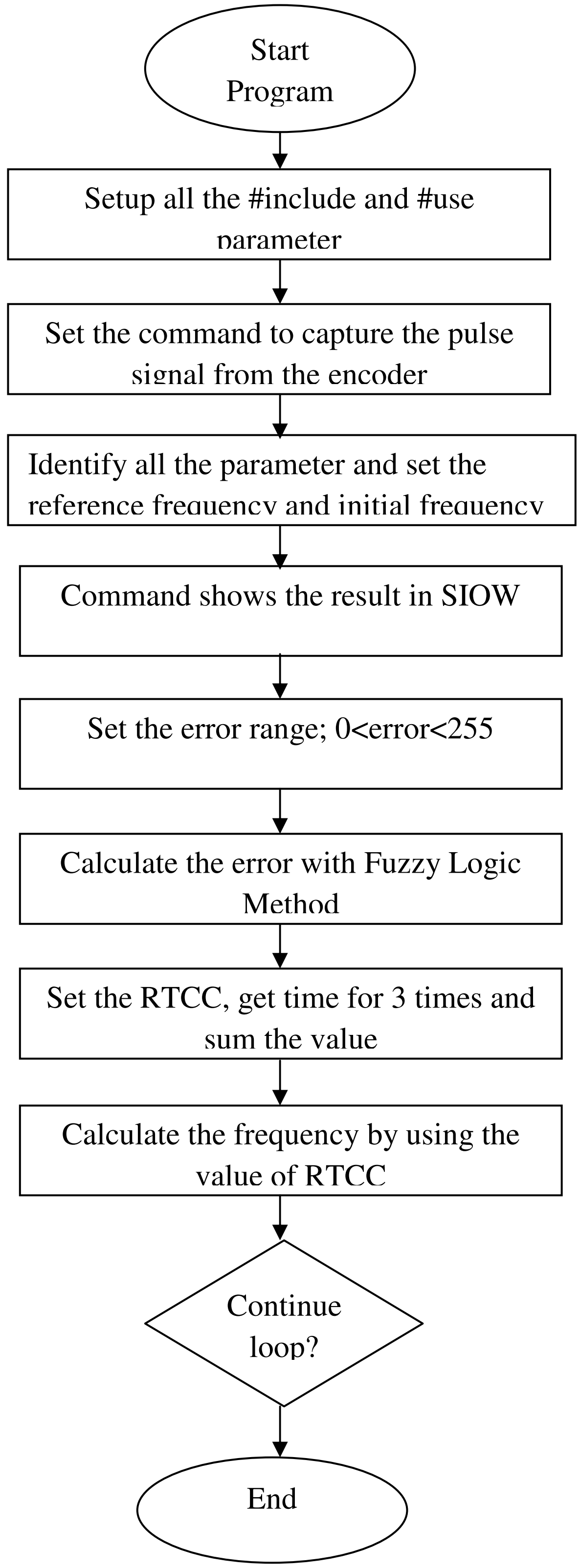

Figure 4.13: Flow Chart for the digital C program

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4.4 THE MATHEMATICAL MODEL FOR FUZZY LOGIC

Fuzz Logic is a based human operator decision. The steps in building the fuzzy logic system are:

I. Determine the control system input that is Frequency or the RPM of the DC motor

II. Determine the control system output. For a DC motor, the output adjustment of the voltage that causes the speed of the DC motor return to its desired speed.

III. Determine the frequency reference of this model.

IV. Choose word description for the status of input and output. The input status is too slow, about right and too fast. For output status is speed up, not much change needed and slow down.

V. Translate the input and output status into statements:

- Rule 1: if the motor is running too slow, then speed it up.
- Rule 2: if motor speed is about right, then not much change is needed
- Rule 3: If motor speed is fast, then slow it down.

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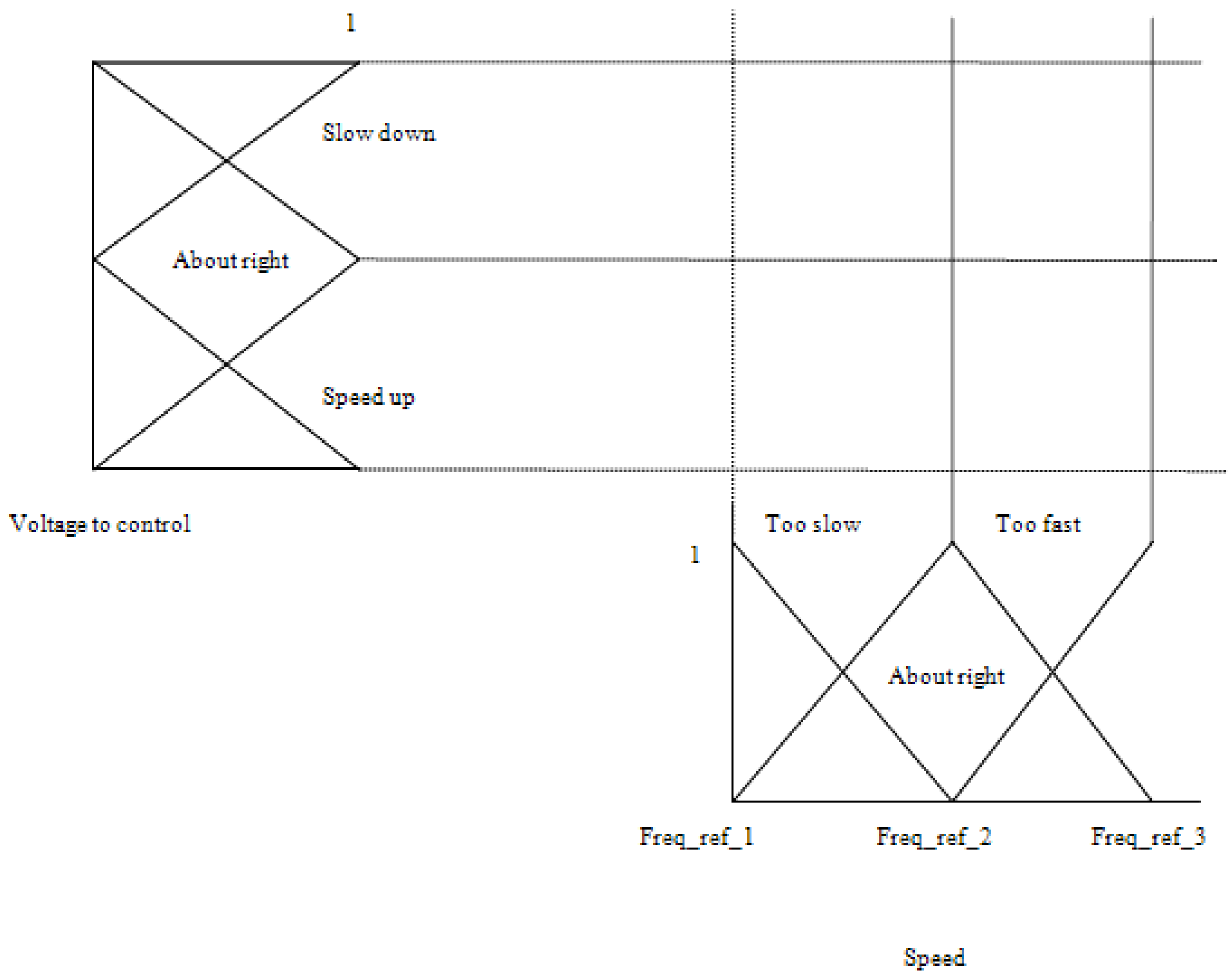

Figure 4.14: Fuzzy logic model

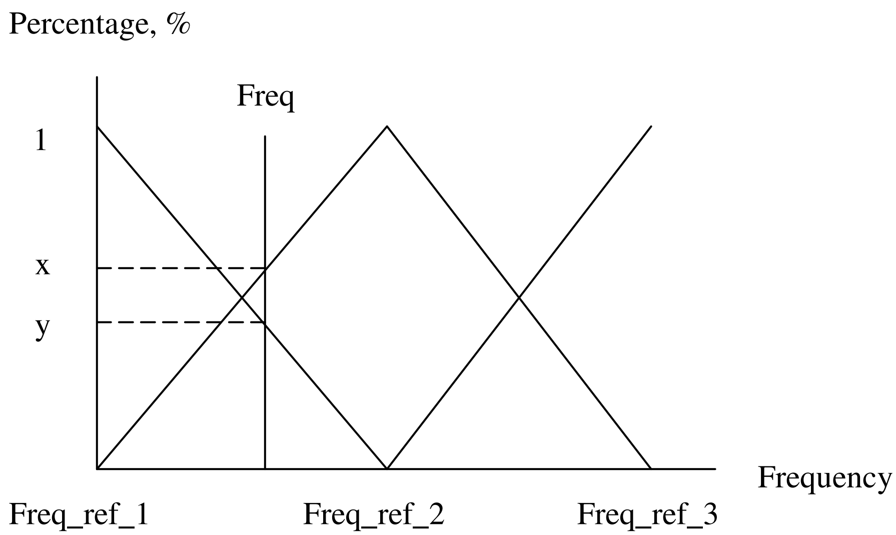

Figure 4.15: The basic model for Fuzzy Logic

VI. Measure the height of the triangle

y = (Freq_ref_2 – Freq) / (Freq_ref_2 – Freq_ref_1)

x = (Freq – Freq_ref_1) / (Freq_ref_2 – Freq_ref_1)

VII. Draw the new triangle with new height for the voltage

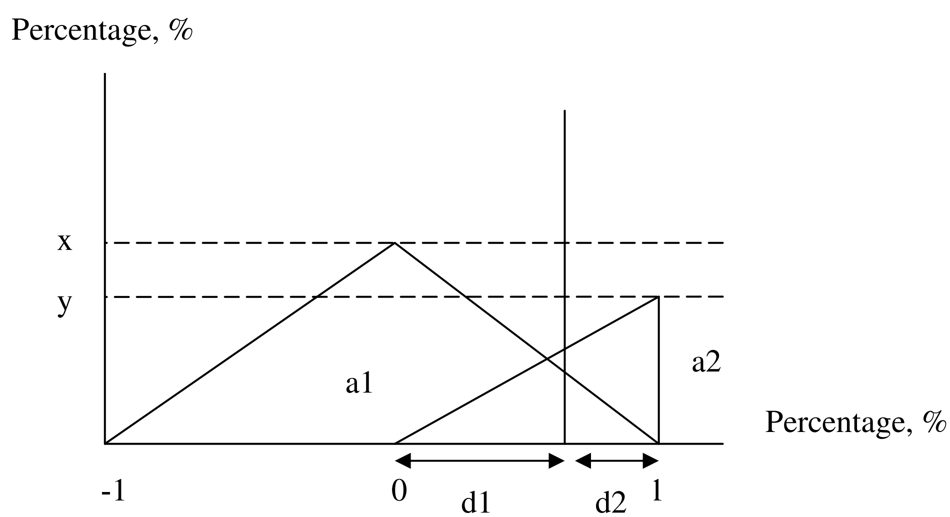

Figure 4.16: The basic model of Fuzzy Logic for voltage

VIII. Calculate the area of the triangle

Area_1 = (y*(Freq_ref_3 – Freq_ref_2)) / 2

Area_2 = (x*(Freq_ref_3 – Freq_ref_1)) / 2

IX. Find the d1 and d2

d1 + d2 = 1 (equation 1)

d1*Area_1 = d2*Area_2 (equation 2)

X. Find the output by multiply the value d1 with 255

a = d1

value = a* 255

In this project, 7V was stated as a reference voltage while 6V and 8V was assume as other reference voltage if the voltage upper and lower than 7V. The output of the PIC from C program is the value. The value will converts it value to bit and amplify the voltage to increase the speed of DC motor and maintain the DC motor.

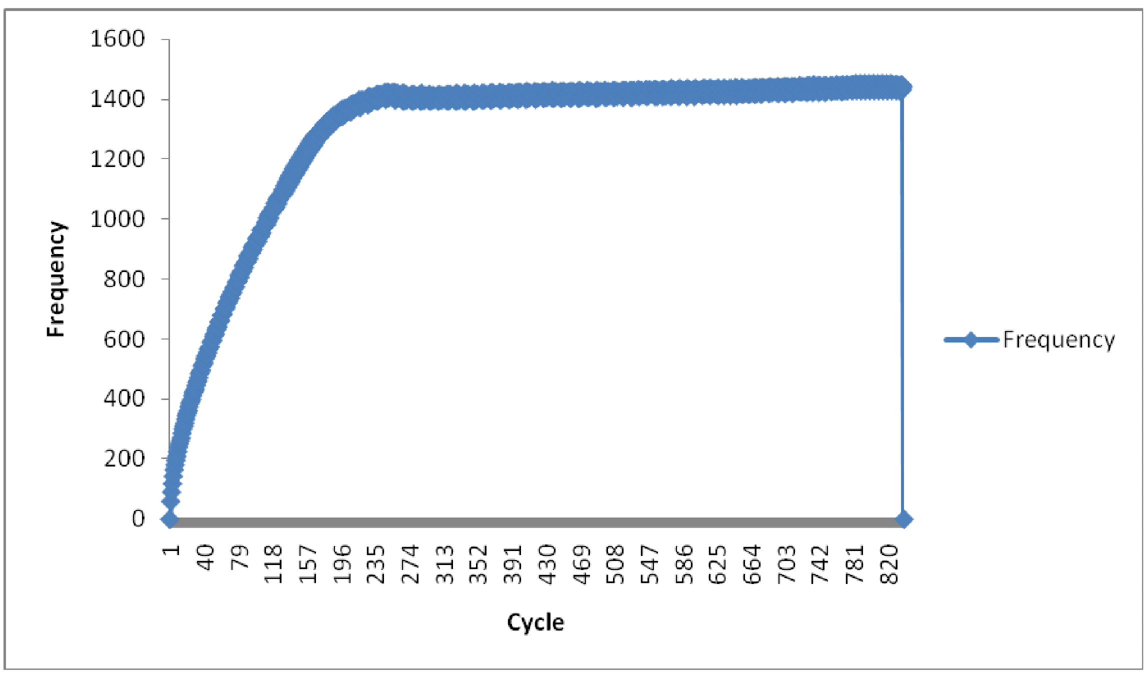

Figure 4.17: Graph for frequency vs cycle when at 6V

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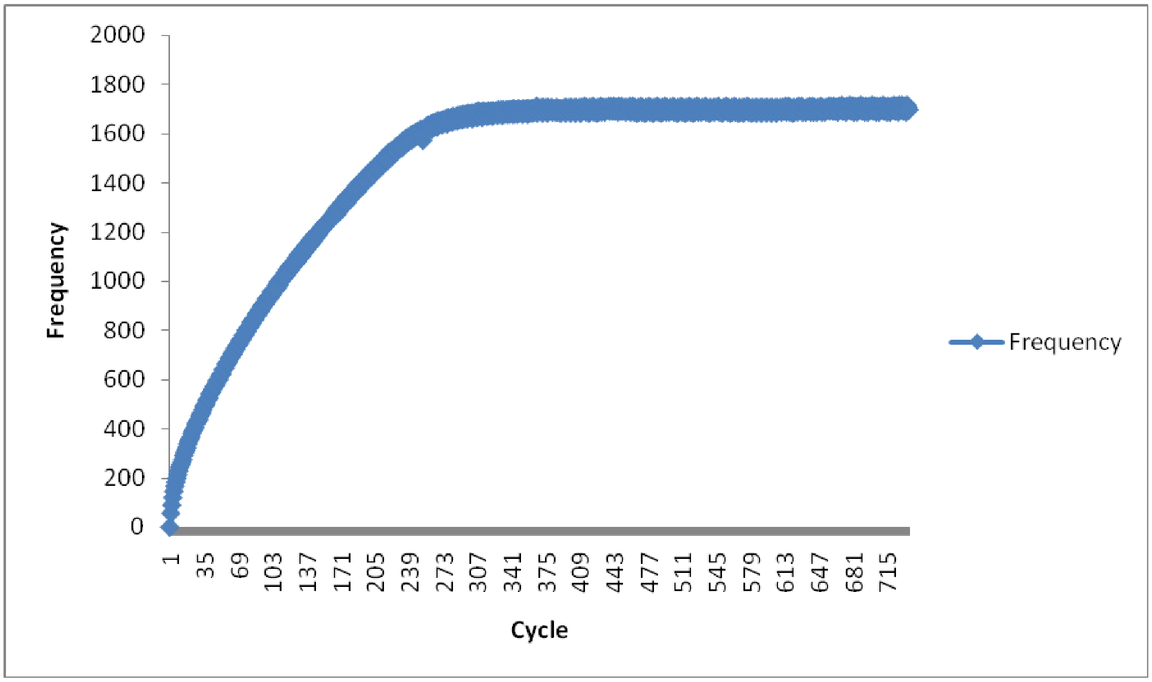

Figure 4.18: Graph for frequency vs cycle when at 7V

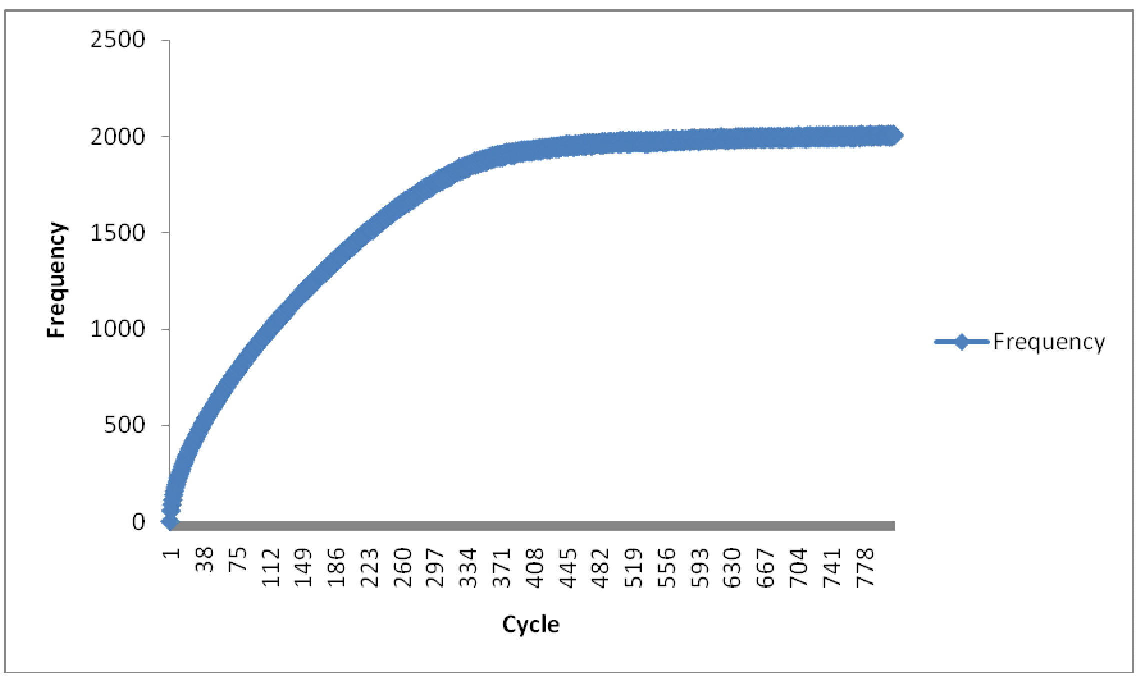

Figure 4.19: Graph for frequency vs cycle when at 8V

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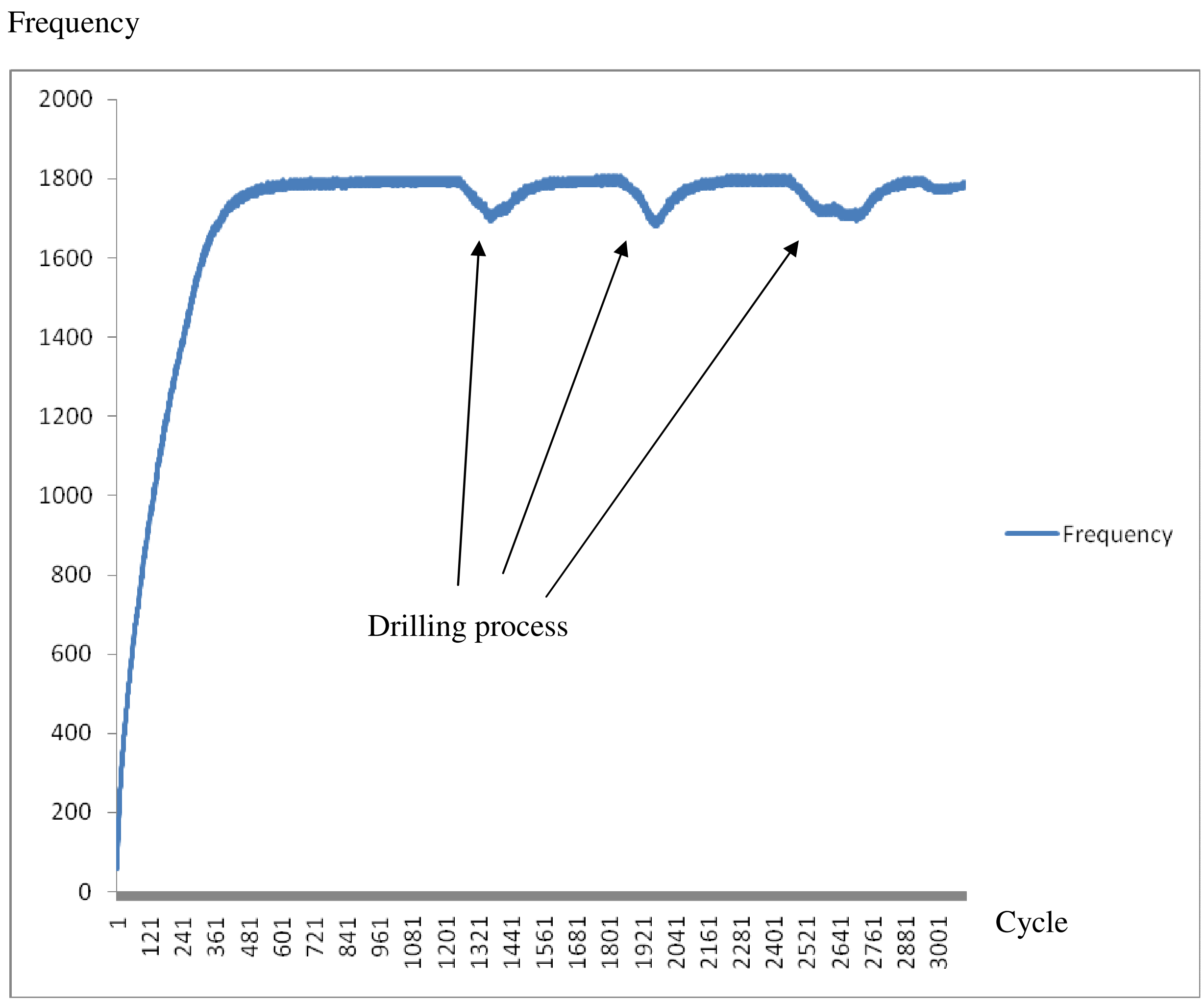

Figure 4.20: Graph frequency vs cycle when drilling operation

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

From this project, it is clear that the fuzzy logic can be use to control the speed of the Permanent magnet DC motor. The critical situation for the DC motor is when there is a friction, the performance of the DC motor will lack. From the theoretical fact, when there is a friction on a motor. The motor will lack performance a bit. Even for just a little lack, it still can affect the production. The purpose of this project is to improve the usage of the permanent magnet DC motor.

After the digital circuit and the programming code for Fuzzy Logic is finished, it can clearly conclude that this project had improve the performance of the permanent magnet DC motor. When the load or friction is applied on the PCB drilling, the sensors will detect the error and give out the output to the PIC. The PIC will calculate the error and fix the error to increase the voltage at the right voltage so the speed of drilling process can be maintain at the desired speed.

Other than that, fuzzy logic also is easy to understand because it is based on human thought. The language of this method is easy to understand because it is use the natural language which we use every day. The Fuzzy Logic is done by making an assumption on the model. The assumption that has been set must be finding and test in order to get the value. The tuning part also not that hard, we can change it directly in the C program. Fuzzy logic can calculate every little error speed of the DC motor. We can

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define which type of error that we want to calculate. In this project, the calculation is only done when the speed a bit decrease and when the speed is a bit increase.

After doing some testing and experiment, the results have been collect and this project can conclude that the experiment achieve all the objective and Fuzzy Logic method can be use for permanent magnet DC motor.

5.2 RECOMMENDATION

After Completing this project, there is some recommendation that can be use to improve the PCB drilling operation. The idea will be improve more to the mechanical parts of the PCB drilling and the movement of the drilling can be done automatically. The movement must be set from the program and can move when the command is given.

Other than that, the new project also can be done using fuzzy logic method but using difference parameter. The other parameter that can be done is the temperature. The project of the developing new method of increasing the temperature in the room can be done. This project can be applied to the air conditioner.

`

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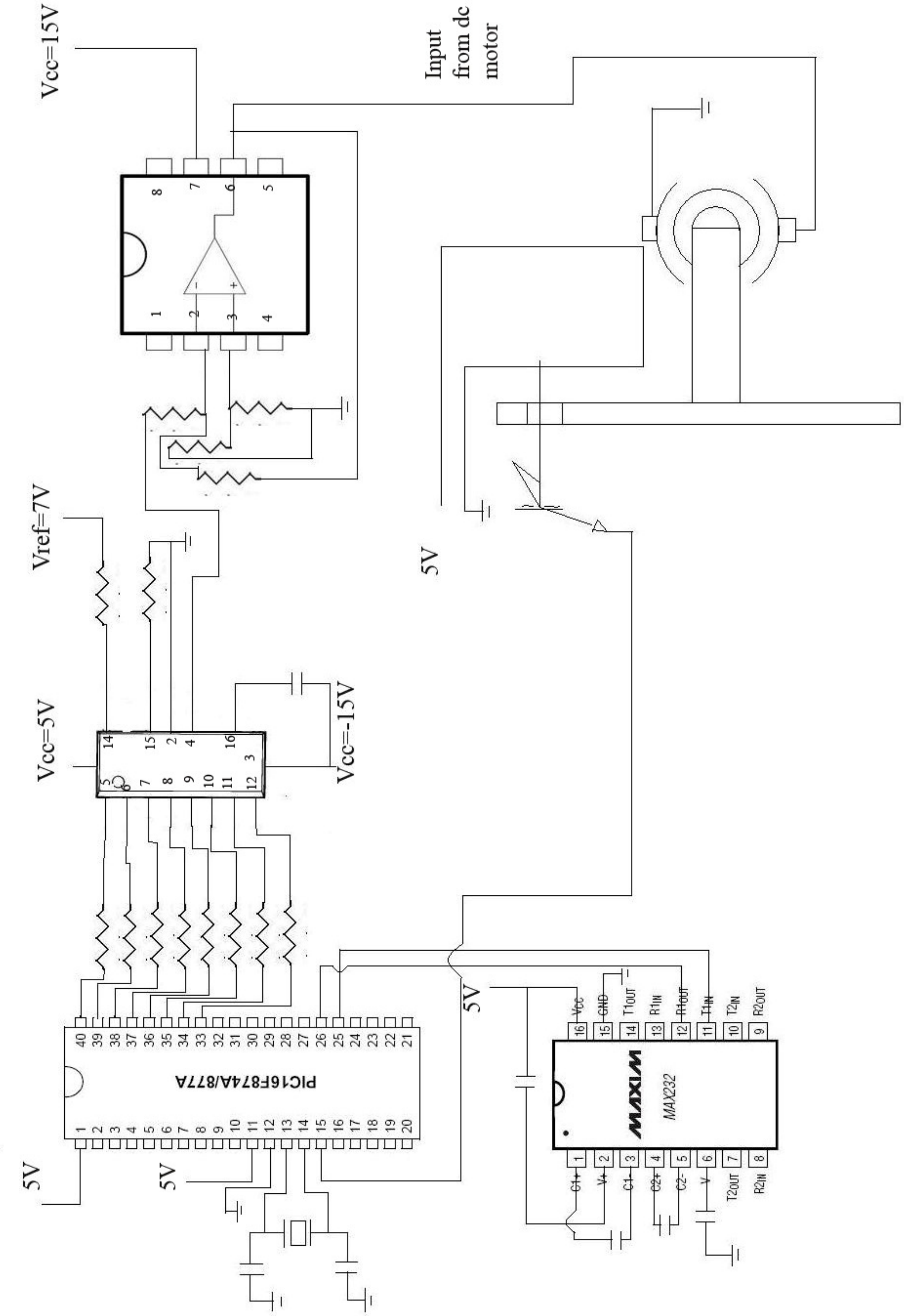
`

APPENDIX A


Vcc=15V
Input from dc motor
Vref=7V
Vcc=5V
Vcc=-15V
5V
PIC16F874A/877A
MAX232

APPENDIX B

```
#include <16F877a.h>

#fuses HS,NOWDT,NOPROTECT,NOLVP

#use delay(clock=20000000)

#use rs232(baud=115200, xmit=PIN_C6, rcv=PIN_C7)

#include <ctype.h>

#include <math.h>



void wait_for_low_to_high()

 {

   while(input(PIN_C0)) ;

   delay_us(1);

   while(!input(PIN_C0));

 }

 void wait_for_low()

 {

   while(!input(PIN_C0))

   delay_us(1);

   while(input(PIN_C0));

 }
```

`

```
void main()

{

float freq,freq_ref_1,freq_ref_2,freq_ref_3,error;

int32
time1,time2,time3,average_total_time,total_time,intersection_1,intersection_2,
area_1,area_2,d1,d2,value,a;



freq=0;

freq_ref_1=1470;

freq_ref_2=1740;

freq_ref_3=2010;



set_tris_b(0x00);



while (TRUE)

{

  printf("%5.1f\r\n",freq);

  if(freq<freq_ref_2&&freq>freq_ref_1);

    intersection_1=((freq_ref_2-freq)/(freq_ref_2-freq_ref_1));

    intersection_2=((freq-freq_ref_1)/(freq_ref_2-freq_ref_1));
```

`

```
   area_1=((intersection_1*(freq_ref_2-freq_ref_1))/2);

   area_2=((intersection_2*(freq_ref_3-freq_ref_1))/2);

   d1=((1*area_2)/(area_1+area_2));

   a=d1;


if(freq>freq_ref_2);

   intersection_1=((freq-freq_ref_2)/(freq_ref_3-freq_ref_2));

   intersection_2=((freq_ref_3-freq)/(freq_ref_3-freq_ref_2));

   area_1=((intersection_1*(freq_ref_3-freq_ref_2))/2);

   area_2=((intersection_2*(freq_ref_3-freq_ref_1))/2);

   d2=((1*area_1)/(area_1+area_2));

   a=-d2;


   value=a*255;


   output_b(value);
```

`

```
setup_timer_1( T1_INTERNAL| T1_DIV_BY_8 );

set_timer1(0);

wait_for_low_to_high();

wait_for_low();

time1=get_timer1();

setup_timer_1(T1_DISABLED);


setup_timer_1( T1_INTERNAL| T1_DIV_BY_8 );

set_timer1(0);

wait_for_low_to_high();

wait_for_low();

time2=get_timer1();

setup_timer_1(T1_DISABLED);


setup_timer_1( T1_INTERNAL| T1_DIV_BY_8 );

set_timer1(0);

wait_for_low_to_high();

wait_for_low();

time3=get_timer1();

setup_timer_1(T1_DISABLED);
```

`

```
      total_time=time2+time3;

      average_total_time=total_time/2;

      freq=1/(10*(average_total_time*0.00000016));
    }
  }
```

`