UNIVERSITI MALAYSIA PAHANG

BORANG PENGESAHAN STATUS TESIS♦

JUDUL: **DIRECTION AND SPEED CONTROL OF DC MOTOR**

SESI PENGAJIAN:**2011/2012**

Saya **NORFADILAH BINTI ZULKEFLI**
(HURUF BESAR)

mengaku membenarkan tesis (Sarjana Muda/~~Sarjana~~ /~~Doktor Falsafah~~)* ini disimpan di Perpustakaan dengan syarat-syarat kegunaan seperti berikut:

1. Tesis adalah hakmilik Universiti Malaysia Pahang (UMP).
2. Perpustakaan dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Perpustakaan dibenarkan membuat salinan tesis ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. **Sila tandakan (√)

	SULIT	(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di dalam AKTA RAHSIA RASMI 1972)
	TERHAD	(Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)
√	**TIDAK TERHAD**	

Disahkan oleh:

(TANDATANGAN PENULIS) (TANDATANGAN PENYELIA)

Alamat Tetap:

NO.148 BLOK 7 FELDA LAKUM,
28500 LANCHANG,
PAHANG DARUL MAKMUR.

NOR LAILI BINTI ISMAIL
(Nama Penyelia)

Tarikh: **21 JUNE 2012** Tarikh: : **21 JUNE 2012**

CATATAN:
* Potong yang tidak berkenaan.
** Jika tesis ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali tempoh tesis ini perlu dikelaskan sebagai atau TERHAD.
♦ Tesis dimaksudkan sebagai tesis bagi Ijazah doktor Falsafah dan Sarjana secara Penyelidikan, atau disertasi bagi pengajian secara kerja kursus dan penyelidikan, atau Laporan Projek Sarjana Muda (PSM).

"I hereby acknowledge that the scope and quality of this thesis is qualified for the award of the Bachelor Degree of Electrical Engineering (Power System)"'

Signature : ___________________________

Name : MISS NOR LAILI BINTI ISMAIL

Date : 19 June 2012

DIRECTION AND SPEED CONTROL OF DC MOTOR

NORFADILAH BINTI ZULKEFLI

This thesis is submitted as a partial fulfilment of the requirements for the award of the Bachelor Degree of Electrical Engineering (Power System)

Faculty of Electrical and Electronics Engineering
Universiti Malaysia Pahang

MAY 2012

"All the trademark and copyrights use herein are property of their respective owner. References of information from other sources are quoted accordingly; otherwise the information presented in this report is solely work of the author."

Signature :______________________________

Author :NORFADILAH BINTI ZULKEFLI

Date : 19 June 2012

Special dedicated,

To my beloved family

Thanks for your morale support and understanding

To my supervisor

Thanks for your guidance

To my lovely friends

Thank you for all your help

May Allah bless all of you.

ACKNOWLEDGEMENT

In the name of Allah, the Most Gracious and the Most Merciful

Alhamdulillah and praise to Allah for the strengths and blessing given to me in completing my final year project entitled “Directionand speed control of DC Motor”. Special appreciation goes to my supervisor, Miss NorlailiBinti Ismail, for her advice, supervision and constant support. She had been guiding me from the start of the project until the final touch of the thesis write up. With her helps, I had learned many things regarding the project as well as extra knowledge that I believe I would not have this sort of opportunity elsewhere.

In particular, I would like to express my appreciation to my family for their support, encouragement, love that they give to me while I was struggling with this project. Very special thanks to all of my lecturers and staffsespecially who had given their full co-operation and sharing their ideas for completing my project.Without their ideas, I am pretty sure that I will not be able to accomplish and complete my final year project on time.

Last but not least, I would like to thank to all my friends and others for their suggestions and support either directly or indirectly. I am very grateful and lucky to have all those who involved. Thank you so much.

ABSTRACT

Direct current motor is an important drive configuration for many applications across a wide range of powers and speeds. It have variable characteristics and used extensively in variable-speed drives. The goals of this project are to control the direction and speed of Direct Current (DC) motor. The Radio Frequency (RF) modules also used to make this project as a user friendliness to control the interface yet make it more useful. This project divided into two part of circuit. First circuit is for transmitter and another circuit is for the receiver. Pulse Width Modulation (PWM) technique is used where its signal is generated by PIC 18F4550. The PWM signal will send to the motor driver to vary the voltage supply to the motor in a desired speed. The DC Motor driver L293D is used in this project as it is a component that has dual full bridge driver where it also can control the direction of the DC motor. A rotary encoder plate is coupled to the end of motor shaft to provide the feedback speed signal to the controller. The RF modules used here are NT-T10A for transmitter module and CWC-12 for the receiver module. Four push buttons are built at the transmitter side as switches to control the speed and direction of DC motor. The four switches are interfaced to the RF transmitter module through PIC 18F4550. 16 x 2 Liquid Crystal Display (LCD) Modules is added at receiving side. It functions to display the outputs or corresponding action that obtain from the PIC 18F4550. In conclusion, the direction and speed of DC motor can be controlled. Plus, this motor controller can be applied as a basis in roboting system, kid's toys and also industrial field.

.

ABSTRAK

Motor arus terus adalah konfigurasi pemacu yang penting untuk banyak aplikasi dalam pelbagai bidang kuasa dan kelajuan. Ia mempunyai pelbagai ciri-ciri dan digunakan secara meluas dalam pemacu kelajuan boleh ubah. Matlamat projek ini adalah untuk mengawal arah dan kelajuan motor arus terus. Modul Frekuensi Radio juga digunakan untuk menjadikan projek ini mesra pengguna disamping menjadikan ia lebih berguna dengan menggunakan komunikasi dua hala. Projek ini terbahagi kepada dua bahagian litar. Litar pertama adalah untuk litar pemancar dan litar kedua adalah litar penerima. Teknik *Pulse Width Modulation* digunakan di mana isyarat dibekalkan oleh PIC 18F4550. Isyarat PWM akan dihantar kepada pemacu motor untuk mengubah bekalan voltan kepada motor dalam kelajuan yang dikehendaki. L 293D adalah pemacu motor yang digunakan dalam projek ini kerana ia merupakan komponen yang boleh mengawal arah serta kelajuan motor arus terus. Pengekod optik disambungkan pada rotor motor arus terus untuk memberi maklum balas isyarat kelajuan kepada mikropengawal. Modul Frekuensi Radio yang digunakan dalam projek ini adalah NT-T10A untuk pemancar dan CWC-12 bagi modul penerima. Empat butang penekan saling berkait dengan modul Frekuensi Radio pemancar melalui PIC 18F4550.Modul *16 x 2 Liquid Crystal Display (LCD)* disambungkan pada bahagian penerima. LCD ini berperanan untuk memaparkan keluaran yang dihantar oleh PIC 18 F4550. Melalui projek ini, dapat disimpulkan bahawa arah dan juga kelajuan motor arus terus boleh dikawal. Selain itu, pengawal motor ini boleh digunakan sebagai asas dalam sistem robot, permainan kanak-kanak dan juga di dalam bidang industri.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

DC	-	Direct Current
RF	-	Radio Frequency
PIC	-	Programmable Interface Controller
V	-	Voltage
Rpm	-	Rotation per minute
N	-	Number of slots at disc
PWM		Pulse Width Modulation
ROM	-	Read only memory
RAM	-	Random Access Memory
Km	-	kilometre
AM	-	Amplitude Modulation
FM	-	Frequency Modulation
I/O	-	Input/Output
ADC	-	Analog to Digital Converter
MHz	-	Megahertz
GHz	-	Gigahertz
T	-	Time period
f_{out}	-	Output Frequency
t_{on}	-	Time ON of switches
V_{ave}	-	Average voltage supply to DC motor
m	-	metre
cm	-	centimetre

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background of projects

In a modern industrial situation, DC motor is widely used which is due to the low initial cost, excellent drive performance, low maintenance and the noise limit. As the electronic technology develops rapidly, its provide a wide scope of applications of high performance DC motor drives in areas such as rolling mills, electric vehicle tractions, electric trains, electric bicycles, guided vehicles, robotic manipulators, and home electrical appliances.

DC motors have some control capabilities, which means that speed, torque and even direction of rotation can be changed at anytime to meet new condition. DC motors also can provide a high starting torque at low speed and itis possible to obtain speed control over a wide range. So, the study of controlling DC motor is more practical significance.

Control theory is an interdisciplinary branch of engineering and mathematics that deals with the behaviour of dynamical systems. For controlling a motor in any system, a controller is needed which is to give input to gate driver. For motor actuation, the microcontroller does not directly actuate the DC motor. It will have a device that known as gate driver which is function to drive the motor. For this system, it use motor driver as PWM amplifier to provide variable output voltage for controlling the speed of the motor and positive or negative voltage to control the direction of motor rotations.

1.2 Problems statement

In real world, motor applications not only use the maximum speed of motor. It maybe uses only 50% of its speed. So, the speed of the motor must be control. For some applications, motor is using not only one direction but with alternate direction to control a machine. In industrial field, some machine or robots cannot get in touch according to safety and the location of those things.

1.3 Objectives

The main objectives of this project are:

1) To control direction and vary the speed of DC motor by using microcontroller.
2) To develop a software using assembly language of the microcontroller.

1.4 Scope of project

1) Design a circuit for controlling speed and direction of DC motor.
2) Develop programming for the microcontroller.

CHAPTER 2

LITERATURE REVIEW

2.1 Microcontroller

A microcontroller is known as a computer-on-a-chip, or prefer as a single chip computer[15]. Another term to describe a microcontroller is embedded controller, because the microcontroller and its support circuits are often built into, or embedded in, the devices they control. This single IC contains microprocessor, memory, I/O capability and other chip resources.

Microcontrollers are used in automatically controlled products and devices, such as automobile engine control systems, implantable medical devices, remote controls, office machines, appliances, power tools, toys and other embedded systems. Figure 2.1 shows the block diagram for a typical full-featured microcontroller. The CPU (Central Processor Unit) is responsible for executing the software stored in ROM and controls all other component. The RAM is volatile data storage component[4]. It is use to store current settings and values when a program is running. When power is turn off, all the data in RAM will disappear as well. While RAM is temporary storage component, ROM is used to store data permanently (non-volatile). For choosing a microcontroller that suitable for this project, some of the condition and features are considered: [3]

1. Built in feature

2. Device cost
3. Familiarity and availability

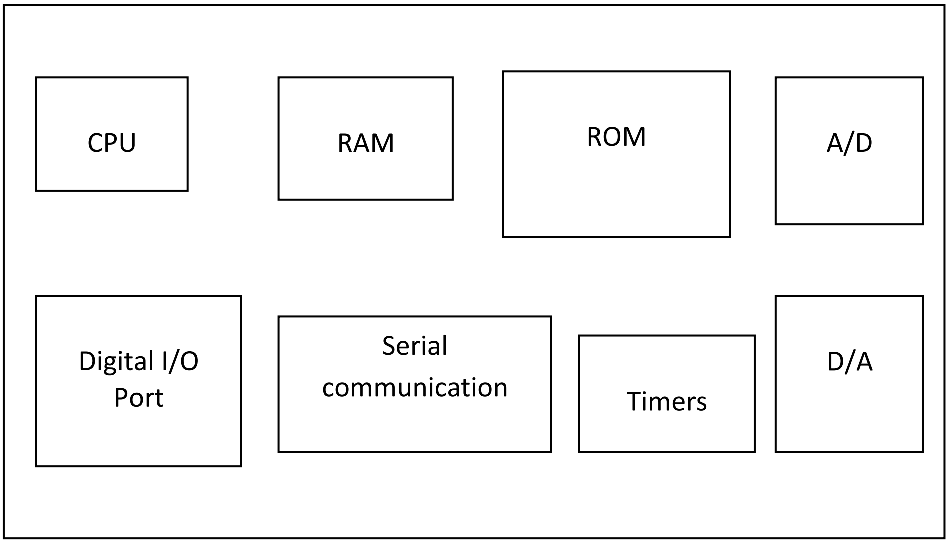


Figure 2.1 Typical Diagram of Microcontroller [4][7]

The digital I/O ports, analog to digital converter (A/D) and digital to analog converter (D/A) are used for input/output signal conditioning and interfacing. For coordinate various function from other or to other microcontroller, the I/O ports can also be used to transmit the signal. From transmit data from or to external devices, microcontroller will used a serial port, provided these devices support the same serial communication protocol. As precaution in creating delay or ensure event occur at precise time interval, onboard timers are usually provided[3][4] [7].

Most microcontrollers contain circuitry to generate the system clock[13]. This square wave is the heartbeat of the microcontroller and all operations are synchronized to it[9][14]. It controls the speed at which the microcontroller functions.

Advantages of using PIC over other controlling devices for controlling the DC motor are given below:

- Speed: The execution of an instruction in PIC IC is very fast (in micro seconds) and can be changed by changing the oscillator frequency. One instruction generally takes 0.2 microseconds.
- Compact: The PIC IC will make the hardware circuitry compact.
- RISC processor: The instruction set consist only 35 instructions.
- EPROM program memory: Program can be modified and rewritten very easily.
- Inbuilt hardware support: Since PIC IC has inbuilt programmable timers, ports an interrupts, no extra hardware is needed.
- Powerful output pin control: Output pins can be driven to high state, using a single instruction. The output pin can drive a load up to 25mA.
- Inbuilt I/O ports expansions: This reduces the extra IC's which are needed for port expansion and port can be expanded very easily.
- Integration of operational features: Power on reset and brown/out protection ensures that the chip operates only when the supply voltage is within specification. A watchdog timer resets PIC if the chip ever malfunctions and deviates from its normal operation.

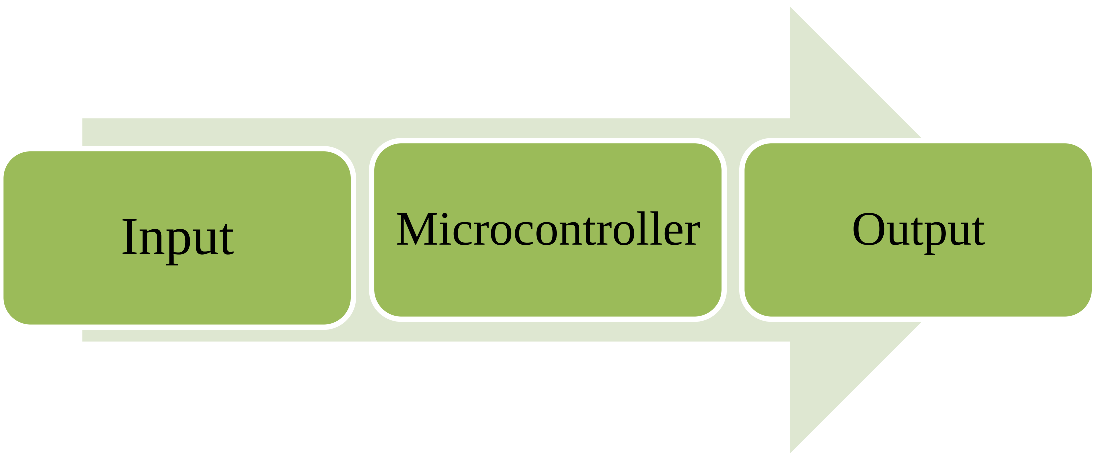


Figure 2.2 DC motor controlling system

Figure 2.2 shows the block diagram of the DC motor controlling system. This circuit controls the speed and direction of the motor[7]. The PWM (Pulse Width modulation) output from the port pins in microcontroller is given to the H-Bridge circuit which drives the motor. By changing the duty cycle (ON time), the speed changed. By interchanging output ports, it changes direction of the motor. The PIC microcontroller is the brain of the circuit controlling all actions to be done. Inputs are given to control the speed and direction of the motor through a gate driver which is function to rotate the DC motor[7][6].

2.2 Wireless Communication

Wireless communication is the transmission of information without using of electrical conductors. Distances involved is probably several meters such as in the television remote control or thousands kilometres for radio communications[15]. In general, wireless communication regarded as a branch of telecommunications. It covers wide range of fixed radio, portable two-ways radio and wireless networking. Wireless operation allows services such as long distance communication which is impossible to implement with the use of wires[20][18]. It usually used in telecommunication industries which is refer to telecommunication system that used some form of energy such as radio frequency (RF), laser light and visible light to convey information without need of wires[17].

The information is transferred in short and long distance. Wireless communication depends on limited resources which is radio spectrum[16]. Those that allowed higher frequencies to be used more efficient, the use of spectrum for wireless communication required the key complementary technologies that been developed and also more sophisticated. A systematic development standard is also required to get the most efficient of wireless communication[15][14]. Wireless communication starts with a message that swapped into electronic signals by a device called transmitter. This system are involving either one-way of transmission or two-way transmission. The principles technologies involved in wireless communications are infrared (IR), Bluetooth and Radio Frequency (RF).

2.3 Radio Frequency Technology (RF Technology)

Radio Frequency is a mode of communication for wireless technologies such as cordless phone, radar and television broadcast. Nowadays, the use of RF technology as one part of the daily routine is rampant. RF waves invisible to the human eyes due to slower frequencies than those of visible light[14]. Radio Frequency is referring to oscillations in electromagnetic radiation or electrical circuit that normally used in wireless communication[17]. The frequency of a wave is determined by its oscillations or cycles per second where one cycle is equal to one hertz (Hz)[17][16].

2.3.1 Radio Frequency Module (RF Module)

RF module is a small electronic circuit that used to transmit, receive or transceiver radio wave on one of a number of carrier frequencies. The main components of a RF communication are the transmitter and receiver[16][18]. Transmitter used to transmit signal while receiver function to receive RF signal from transmitter that have same range of frequencies. Figure 2.3 shows the components of RF module. Table 2.1 shows the RF range, specification and also its applications[16].

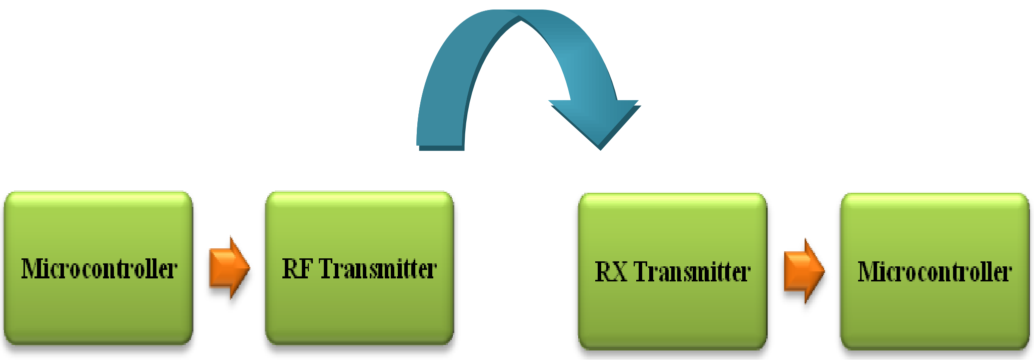


Figure 2.3 Simple flow of RF module

Table 2.1 RF specifications and applications[16]

Type of Frequencies	Frequency Range	Distance of operation	Applications
Low frequency	30-300KHz	1km-10km	AM Broadcasting navigational beacons.
Medium frequency	300-3MHz	100m-1km	Navigational beacons, AM broadcasting maritime and aviation communication.
High frequency	3-30MHz	10m-100m	Shortwave, amateur radio, citizens' band ratio
Very high frequency	30-0.3GHz	1m-10m	FM broadcasting television., aviation, GPR
Ultra high frequency	300-3GHz	10cm- 100cm	Broadcasting television, mobile telephones, cordless telephones, wireless networking, remote keyless entry for automobiles, microwave ovens, GPR.
Super high frequency	3-30GHz	1cm-10cm	Wireless networking, satellite links, microwave links, satellite television, door openers.
Extreme high frequency	30-300GHz	1 mm-10mm	Microwave data links, radio astronomy, remote sensing advanced weapons systems.

2.4 H-Bridge

The H-bridge circuit derives its name from the full-bridge circuit shown in Figure 2.4. An H-bridge is an electronic circuit which enables a voltage to be applied across a load in either direction. The motor forms the cross-piece in the "H" [4]. Speed and direction are controlled as current flows through the motor in the direction which is determined by the position (On or Off) of the switches in the bridge.

These circuits are often used in robotics and other applications to allow DC motors to run forwards and backwards[7]. H-bridge driver are constructed by combining a four switches. In figure 2.4, with switches "S1" and "S4" closed, the motor will operate in a clockwise (CW) direction. When "S2" and "S3" closed, the motor will operate in the counter clockwise (CCW) direction.

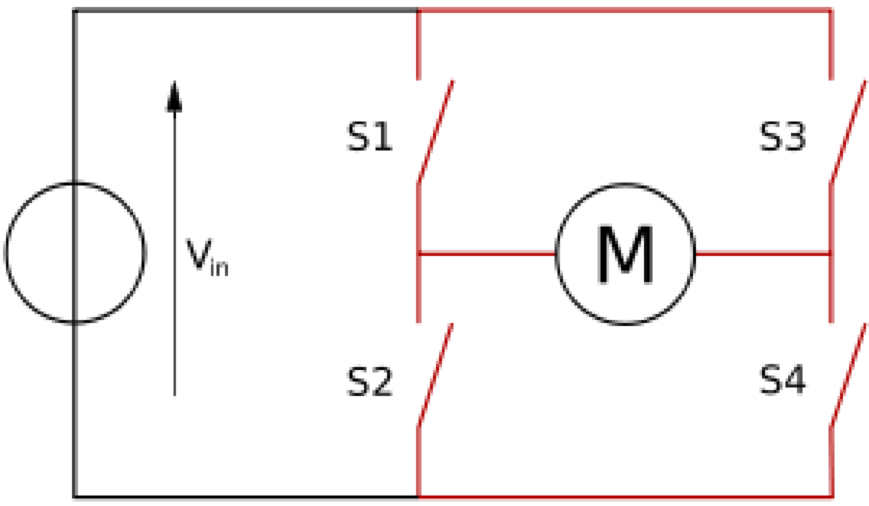


Figure 2.4 H-Bridge configuration

Based on the configuration, the switches S1 and S2 should never be at the same time. The same applies to the switches S3 and S4 because this would cause a short circuit on the input voltage source which known as shoot-through. Table 2.1 summarizes all the operation of the H-Bridge configuration [7].

Table 2.2 Switching technique for H-bridge[4]

S1	S2	S3	S4	RESULT
1	0	0	1	Forward
0	1	1	0	Reverse
0	0	0	0	Motor Free
0	1	0	1	Motor Brake
1	0	1	0	Motor Brake

2.5 Pulse Width Modulation (PWM)

The new method, which extensively used in motor controller, is pulse width modulation (PWM). PWM switching technique is a best method to control the speed of DC motor compare to another method. The duty cycle can be varied to get the variable output voltage[11]. The concept of this system is same like DC-DC converter which is the output voltage depends on their duty cycle.

Digital-to-analog conversion is not necessary because PWM itself is a signal that remains digital all the way from processor to control the overall system. By keeping the signal digital, noise effects are minimized unless there is a change from logic 1 to logic 0, which will make noise affect the digital signal[3].

The Pulse-Width-Modulation (PWM) in microcontroller is used to control duty cycle of DC motor drive. PWM is an entirely different approach to controlling the speed of a DC motor. Power is supplied to the motor in square wave of constant voltage but varying pulse-width or duty cycle. Duty cycle refers to the percentage of one cycle during which duty cycle of a continuous train of pulses[6]. Since the frequency is held constant while the on-off time is varied, the duty cycle of PWM is determined by the pulse width. Thus the power increases duty cycle in PWM.

The expression of duty cycle is determined by:

$$\%Duty\ cycle = \frac{ton}{T} x100\% \qquad (2.1)$$

2.6 Direct Motor (DC) Motor

A direct current (DC) motor converts DC electrical energy into mechanical energy. It produces a mechanical rotary action at the motor shaft where the shaft is physically coupled to a machine or other mechanical device to perform some type of work[2]. DC motors are well suited for many industrial applications. For example, DC motors are used where accurate control of speed or position of the load is required and can be accelerate or decelerate quickly and smoothly. Plus, the direction easily reversed.

Generally, a simple two pole DC motor has six basic parts which are rotor or armature, axle, stator, field magnets and brushes. Figure 2.5 is the illustration of DC motor and table 2.3 shows the parts of DC motor with its explanation.

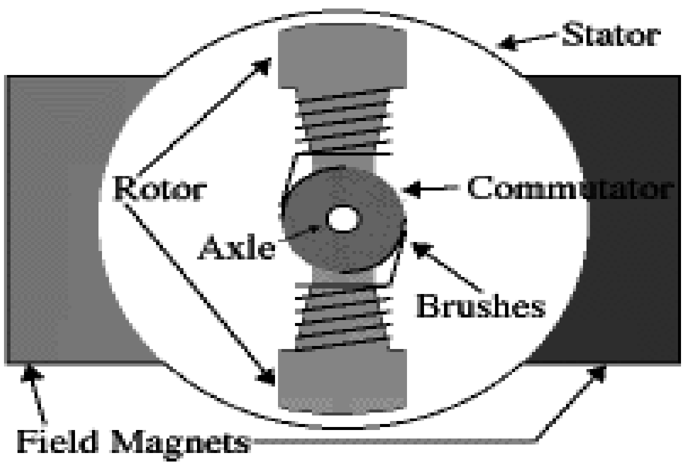


Figure 2.5 Parts of DC Motor

Table 2.3 Description of DC motor

Parts	Descriptions
Rotor	• Consist of windings that being electrically connected to commutator. • It is rotating together with axle and attached commutator with respect to the stator.
Axle	• Attached with commutator and rotor.
Commutator	• Composed of conductive segments which represent the termination of individual coils of wire distributed around the armature.
Stator	• Stationary part of the motor which includes the motor casing.
Brushes	• Remain stationary with the motor's housing but ride (or brush) on the rotating commutator.
Fields Magnet	• Winding that represent North and South polarization.

There are many types of DC motor that are available such as permanent magnet DC motor, stepper motor and others. Table 2.4 illustrates the types of DC motor [1][12]. The variety types of DC motor gives variety of control method and also the variety of application that can be performed. Theoretically, as the voltage increase, the speed of DC motor also increases[5]. Thus, speed control of DC motor can be control by varying the average voltage supply[8]. Based on figure 2.6, the direction of DC motor which is its rotation can be change by reversing the polarity of current that flow through the gate drive[12].

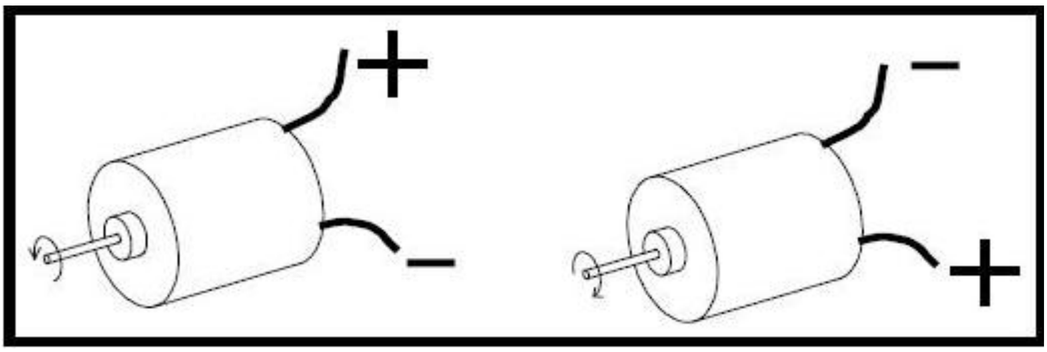


Figure 2.6 DC Motor rotations

Table 2.4 Types of DC motor with advantages and disadvantages [4][3]

Types	Advantages	Disadvantages
Series Coils	• High starting torque	• Speed varies
Permanent Magnets	• Variable speed • Small and compact • Cheap	• Heavy magnets • Cannot vary magnetic field strength.
Shunt Coils	• Constant speed	• Low starting torque
Stepper motor	• Very precise speed and position control	• Expensive • Require a switching control circuit

There are three ways to vary the speed of DC motor :[16][5]

1. With the use of mechanical gears to achieve the desired speed
2. Reduce the motor voltage with a series resistor. Higher the current, larger the voltages drop across the series resistor and less voltage to the motor.
3. Apply full voltage supply to the motor in pulse and eliminate the series dropping effect that called pulse width modulation (PWM). As the pulse increase, the motor run faster.

2.6.1 Speed Control by using PWM and Full H-Bridge Motor Drive

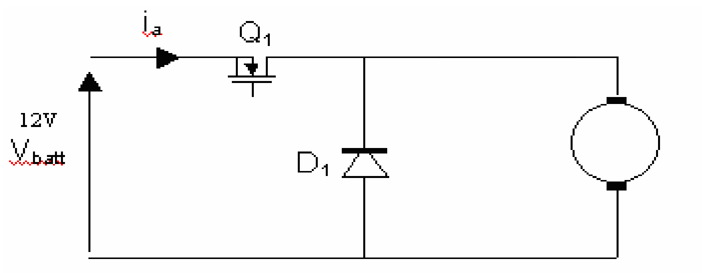


Figure 2.7 Simple motor circuit

Switching converter is an efficient alternative for the pulse width modulation technique. The MOSFET, Q_1 in the figure 2.4 act as an electronic switch that can turn very large currents on and off under the control of a low signal level voltage. Based on figure 2.7, when switch is open, there is no current in it and when switch is closed, there is no voltage across it[6]. Assuming the switch is ideal, thus the average voltage supply to the motor is in equation 2.2.

$$Vo = \frac{1}{T}\int_0^{DT} Vsdt = VsD \tag{2.2}$$

The average of voltage that supply to DC motor is given in equation 2.3.

$$Vave = \frac{ton}{T}\ x\ Vin \tag{2.3}$$

Where

$Vave$ = average voltage supply to DC motor

Vin = voltage input

ton = time ON of switch

T = period of PWM

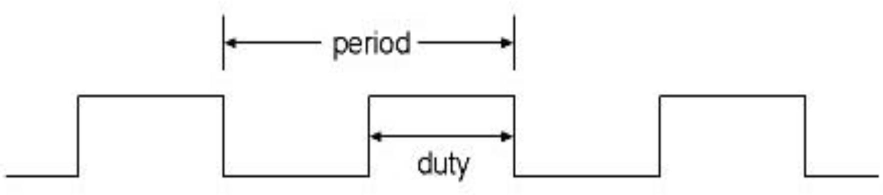


Figure 2.8 Pulse Width Modulation signal

As the amount of time that the voltage is t_{on} increases compared with the amount of time that it is off, the average speed of the motor increases and average speed of motor decrease as the voltage at t_{on} decrease[4][7]. The inertia of the rotor and quantity of friction and load torque effect the time that motor takes to speed up or slow down.

Figure 2.9 shows the H-Bridge or also known as full bridge circuit. For each side, only one MOSFET that can be on or otherwise it will short out the battery and burn out the component in the circuit. To make the motor go forward, Q1 and Q4 must on while Q2 and Q3 are off. For reversing the motor,Q2 and Q3 are on while Q1 and Q4 are off. This is the basic configuration of H-bridge motor drive.

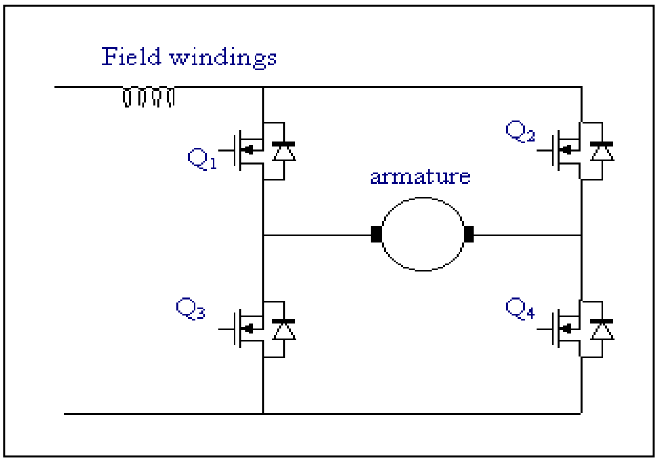


Figure 2.9 H-Bridge motor drive[3]

2.6.2 Speed Measurement by using Rotary Encoder

Closed-loop control normally used to obtain a precise speed control of DC motor. To measure the speed, a rotary encoder is used. The transmitter shines a beam of light across a small space and the receiver will detect it at the other end. When a disc placed in the space of slots between the transmitter and receiver, then the signal will be picked up[4]. Example of a disc is shown in figure 2.10. This rotary encoder will convert the data of rotary motion into a series of electrical pulses which is readable by controller. It has 8 slots that provide 16 transitions. The frequency of the output waveform is given by the equation 2.4.

Figure 2.10 Sample plate of encoder

$$f_{out} = \frac{N \times rpm}{60} \quad (2.4)$$

Where

f_{out} = frequency of output waveform

rpm = speed in revolutions per minutes

N = number of slots at disc

From the equation of 2.4, the speed of a DC motor in rpm is obtained. Equation 2.5 shows the equation.

$$rpm = \frac{f\text{ out} \times 60}{N} \quad (2.5)$$

Where

f_{out} = frequency of output waveform

rpm = speed in revolutions per minutes

N = number of slots at disc

CHAPTER 3

METHODOLOGY

3.1 System Description

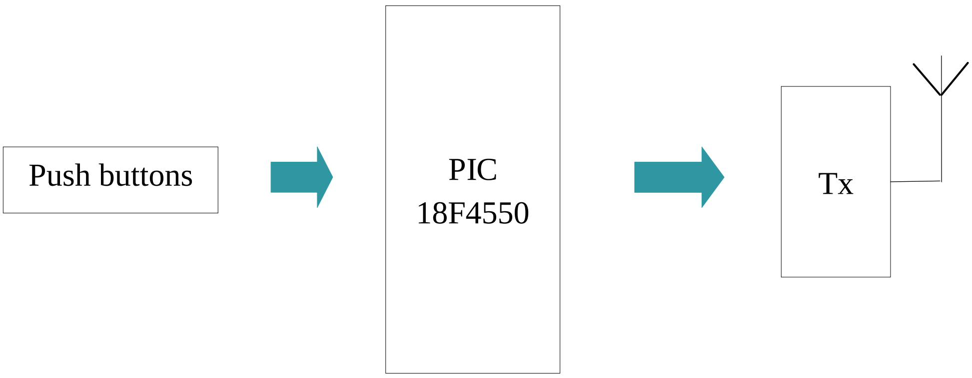


Figure 3.1 Block diagram for transmitter circuit (Tx)

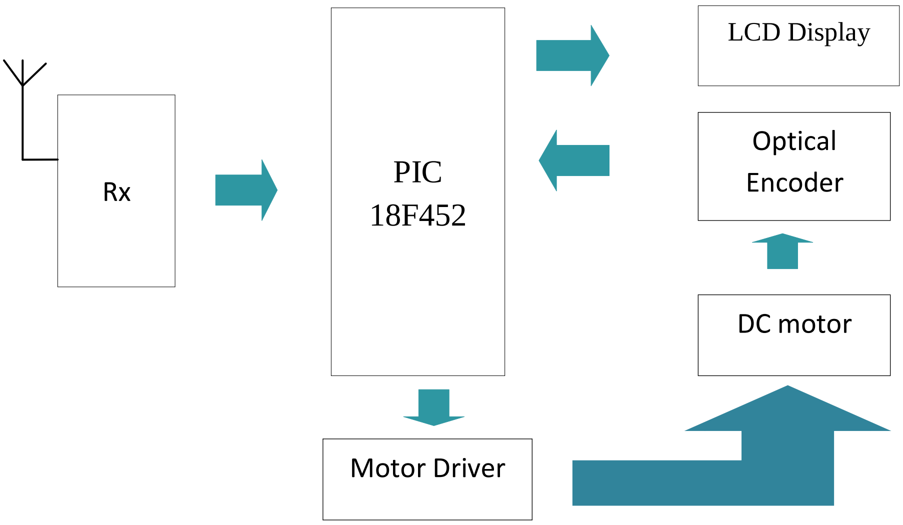


Figure 3.2 Block diagram for receiver circuit (Rx)

This chapter explains on the methodology in order to complete the project and the flow of the system from the beginning until the end. In general, this project is about control the direction and speed of DC motor using RF module. All the entire parts need to be done in order to build a complete system. This project involves two parts which are hardware and software implementation. Before create and test the hardware part, the circuit must be designed first using software. After the designed is complete, simulations need to be done in order to run the system or project.

Figure 3.1 shows the overall flow for transmitter side. It contains push buttons, PIC 18F4550 and transmitter module. PIC 18F4550 converts the digital to analog signal that receive from the push buttons and send the data to the transmitter and LCD display. The PIC 18F4550 will reads the ongoing status of the switches, transfer the data to the RF transmitter. The transmitter transmits the analog information through electromagnetic waves to the receiver section. The LCD is displayed the data that PIC 18F4550 send. The push buttons that used are manually operated.

For figure 3.2, it shows the flow at the receiver side. It consists of receiver module, PIC 18F452, motor driver, optical sensor and LCD display. For receiver section, it receives data through the receiver module then transfers the signal to the PIC 18F452. Then the PIC 18F452 will read the data and perform the corresponding action by sending the data to the motor driver and LCD module. For the feedback, the rotary encoder will count the rotation of the DC motor and send the value to the PIC 18F452.

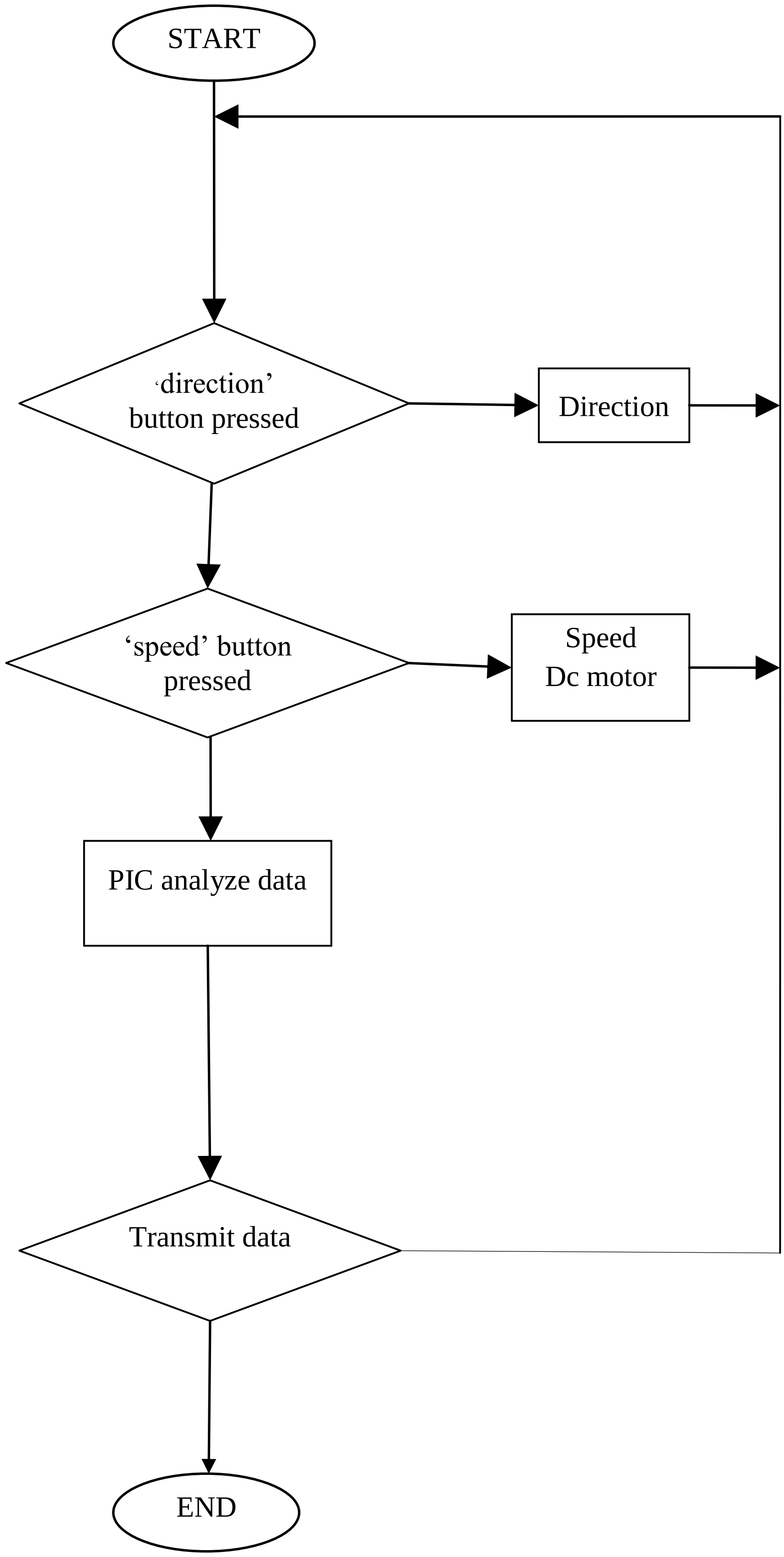


Figure 3.3 Flow chart of transmitting section

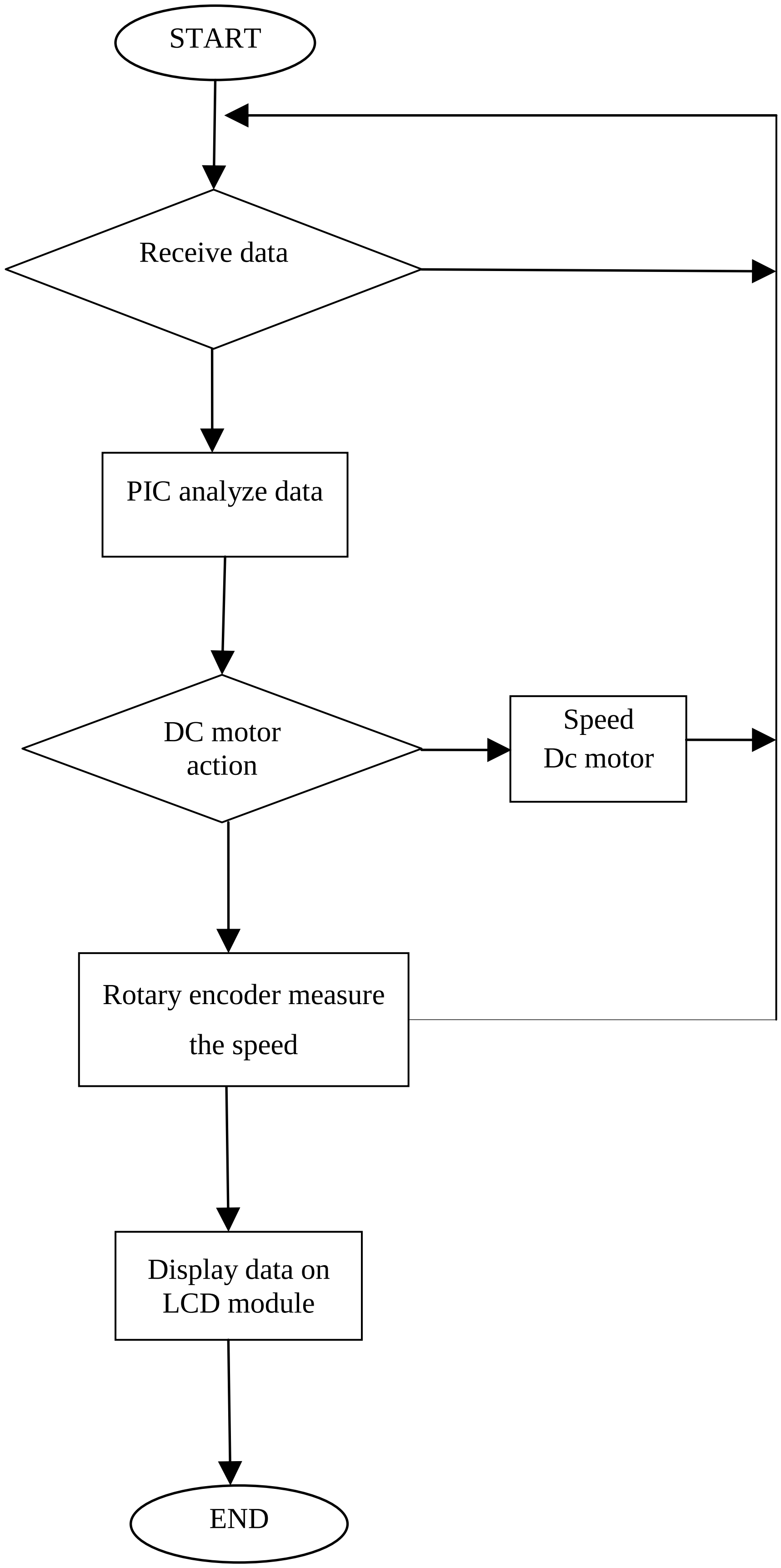


Figure 3.4 Flow chart of receiving section

3.2 Hardware Implementation

This part will discussed about main components that used for this project such as PIC18F452, PIC 18F4550, Motor Driver, Power supply +5 V, DC motor, Radio Frequency(RF) Module , and rotary encoder.

3.2.1 Microcontroller PIC 18F452

Microcontroller is a single IC which functions as a brain of a direction and speed control of DC motor system. It contains 40 pins 8-bit CMOS flash which can be programmed by using appropriate device to transfer the program into the chip[19]. The PIC 18F452 can be driven at maximum clock speed of 40 MHz. This chip selected based on some reason:[19][4]

i. Low current consumption and it has PWM inside the chip itself which allow us to vary the duty cycle of DC motor drive.
ii. Can be programmed and reprogrammed easily using the universal programmer
iii. It was equipped with sufficient output ports without have to use decoder or multiplexer.

Table 3.1 Some application of PIC 18F452 pin

Pin name	Description	Application
MLCR	Reset pin	Reset to the device
RC6	TX pin	For transmitting data
RC7	RX pin	For receiving data
Vdd	Positive supply +5V	Power supply to chip
Vss	Ground reference	Ground
RC1/CCP2	Capture/compare/PWM	Output of duty cycle
RC2/CCP1	Capture/compare/PWM	Output of duty cycle
Ports A,B,C,D,E	I/O Ports	Input or output pin

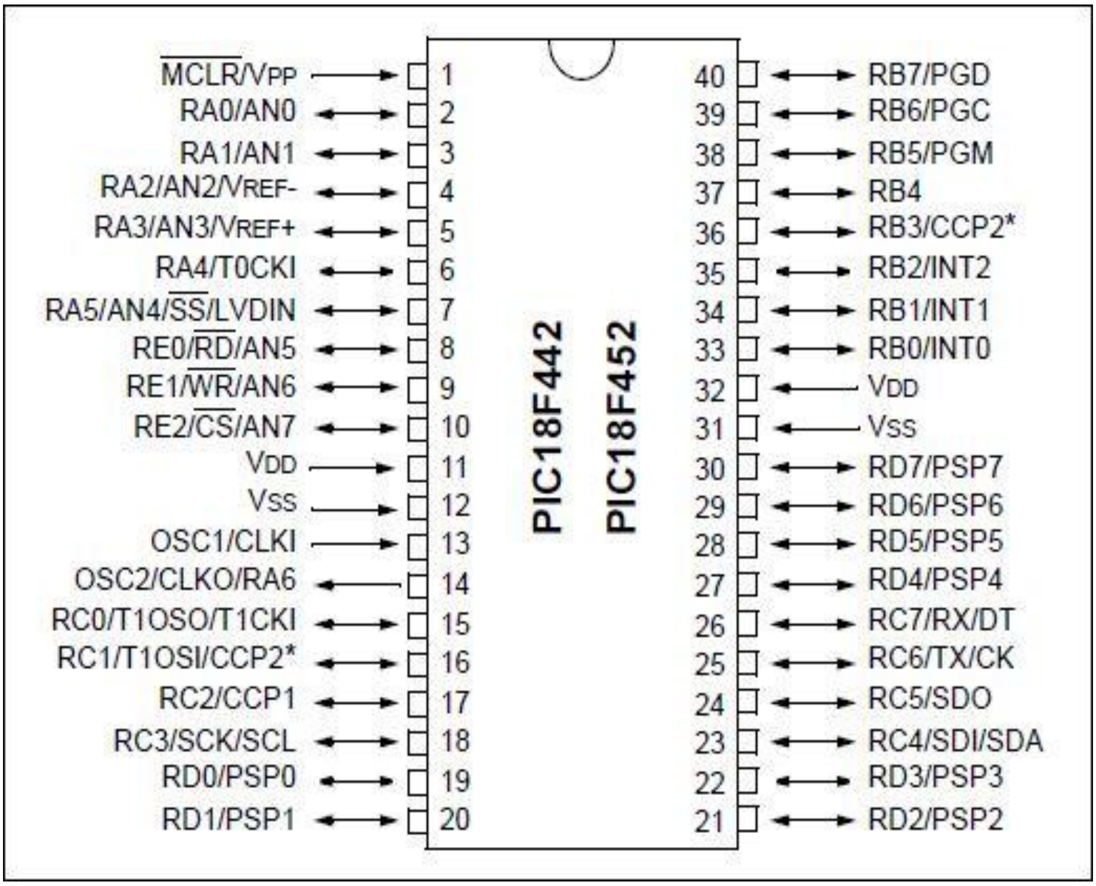


Figure 3.5 PIC 18F452 pin diagram. [19]

3.2.2 Microcontroller PIC 18F4550

Microcontroller PIC 18F4550 is used as the main controlling unit with 40 pin built in. It has 5 ports which are port A, port B, port C, port D and port E. Table 3.2 shows the device features while Figure 3.3 shows the pin diagram of PIC 18F4550.

Table 3.2 PIC 18F4550 pin out descriptions

Pin name	Description	Application
MLCR	Reset pin	Reset to the device
RC6	TX pin	For transmitting data
RC7	RX pin	For receiving data
Vdd	Positive supply +5V	Power supply to chip
Vss	Ground reference	Ground
RC1/CCP2	Capture/compare/PWM	Output of duty cycle
Ports A,B,C,D,E	I/O Ports	Input or output pin

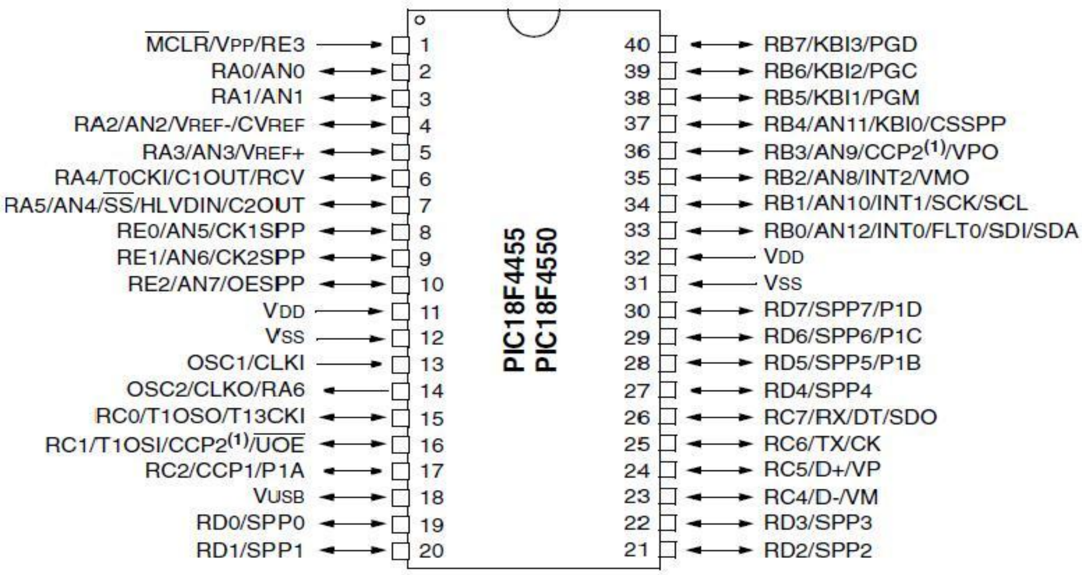


Figure 3.6 PIC 18F4550 Pin Diagram

3.2.3 DC Motor Driver

Continuous power will be supplied to the DC motor as the DC motor connected to the supply voltage[4]. Due to continuous power to the motor, the speed of the motor will reduce when heavier loads and will accelerate when the load is lighter. In order to control the speed of DC motor, the DC motor driver is needed to control the magnitude of supply voltage. In this project, L293D will be used as a DC motor Driver. This motor driver also used to protect microcontroller and the DC motor[3]. L293D is a chip that designed to provide bidirectional drive currents up to 600 mA at voltage range 4.5 V to 36 V. Figure 3.7 and figure 3.8 show the L293D chip while table 3.3 shows the pin function of chip L293D.

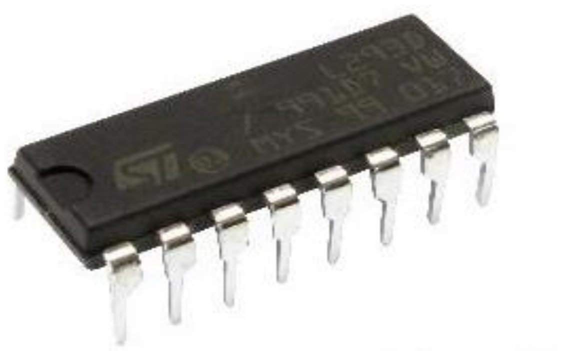


Figure 3.7 L293D chip

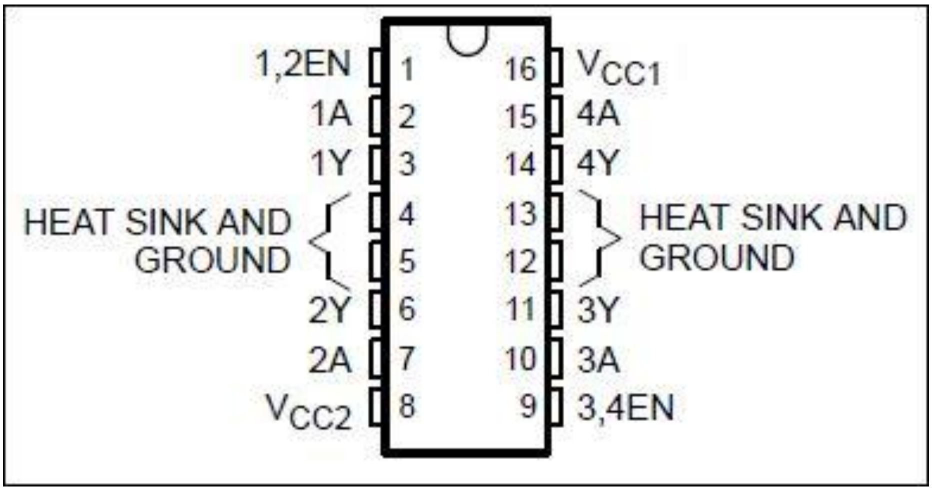


Figure 3.8 L293D chip diagram

Table 3.3 Pin function of chip L293D [4]

Pin no.	Pin name	Descriptions
1	Enable 1	Input PWM from PIC CCP1 pin 17
2	Input 1	Input data from PIC RC5 pin 24
3	Output 1	Connected to motor 1
4,5,13 & 12	Ground	Ground Reference
6	Output 2	Connected to motor 1
7	Input 2	Input data from PIC RC4 pin 23
8	Voltage motor	Power supply to motor 1 & 2
9	Enable 2	Input PWM from PIC CCP2 pin 16
10	Input 3	Input data from PIC RC7 pin 26
11	Output 3	Connected to motor 2
14	Output 4	Connected to motor 2
15	Input 4	Input data from PIC RC6 pin 25
16	Vcc	Power supply for motor driver

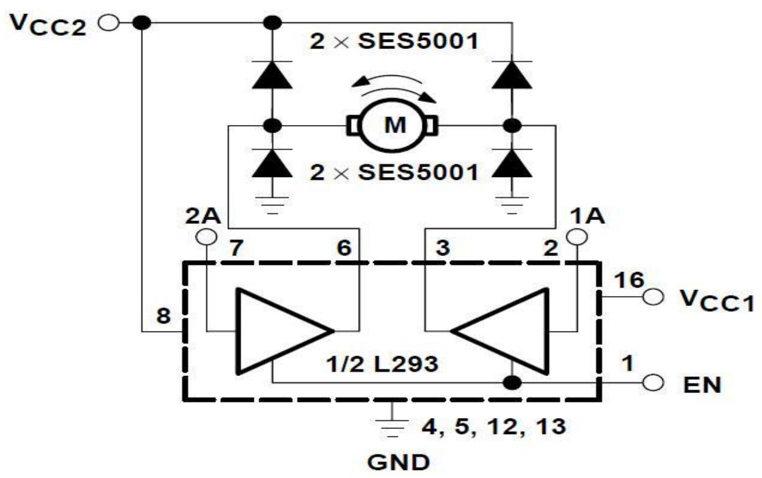


Figure 3.9 Bidirectional DC motor controls

Based on figure 3.9, when pin 2 (1A) is high (1), pin 7 (2A) is low (0) the motor will run in left direction which is reverse. When pin 2 (1A) is low (0), pin 7 (2A) is high (1) the motor will run in right direction which is forward direction. When both pin 2 (1A) and pin 7 (2A) have same input which either both are high (1) or both are low (0), the motor will stop running. For the speed control of DC motor in this project, it will depend on the PWM signal input to pin 1 (EN)[4].

3.2.4 DC Motor

In this project, 12 V Mabuchi motor has been chosen. This motor is a brushed DC motor type. Figure 3.10 shows the 12 V Brushed DC motor.A Brush DC Motor provides simple speed control without the need of complicated electronics. The voltage applied to a Brush DC Motor is proportional to rotational speed, while torque is proportional to the current. By applying variable supplyvoltage, speed control can be achieved.

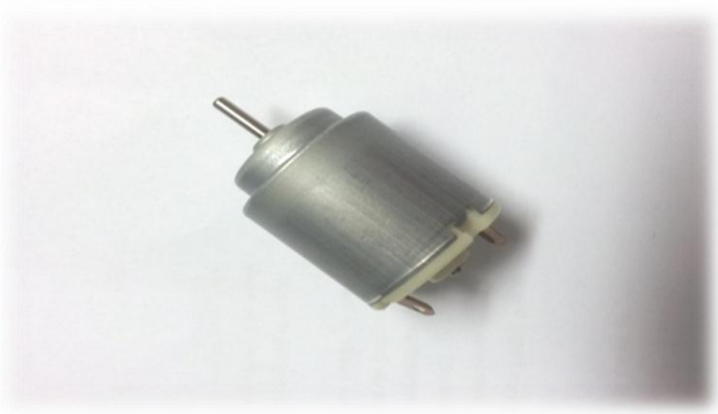


Figure 3.10 Mabuchi 12 V DC motor

Table 3.4 Specification of Mabuchi 12 V DC motor

Rated voltage,V	12 Vdc
Rated current,I	0.18 A
Rotation per minute,RPM	16400 RPM

3.2.5 Rotary Encoder

Optical encoder functions as speed sensor to measure the speed of DC motor. This sensor has much better performance than the tachometer. An analog tachometer will face problems due to changes in gap, temperature and magnet strength but for optical encoder, the entire list is not such a problem and it will not give any effect. When the optical disc is properly mounted on the motor shaft, it generates a frequency directly proportional to motor speed. Figure 3.11 show slotted disc and optical sensor (H21A). The H21A1 is selected for this project because it consists of a gallium arsenide infrared emitting diode coupled with a silicon photodiode in a plastic housing. An Infrared Emitting Diode (IED) as transmitter is put at one side of the disc and a photodiode, as receiver is fixed on the other side of the disc.

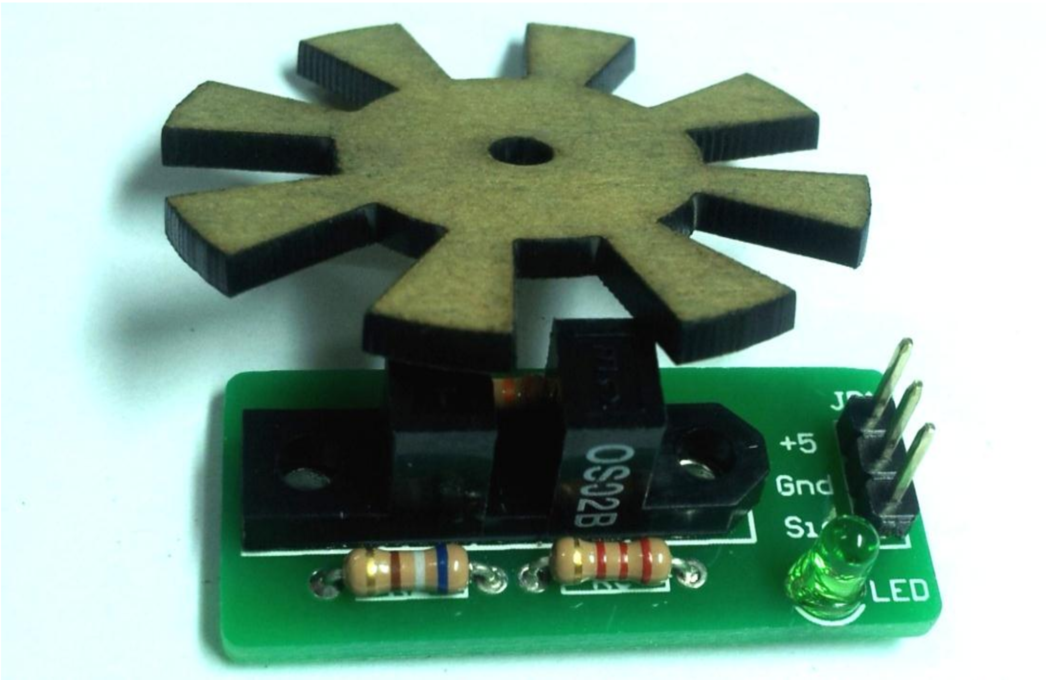


Figure 3.11 Optical encoder with Plate

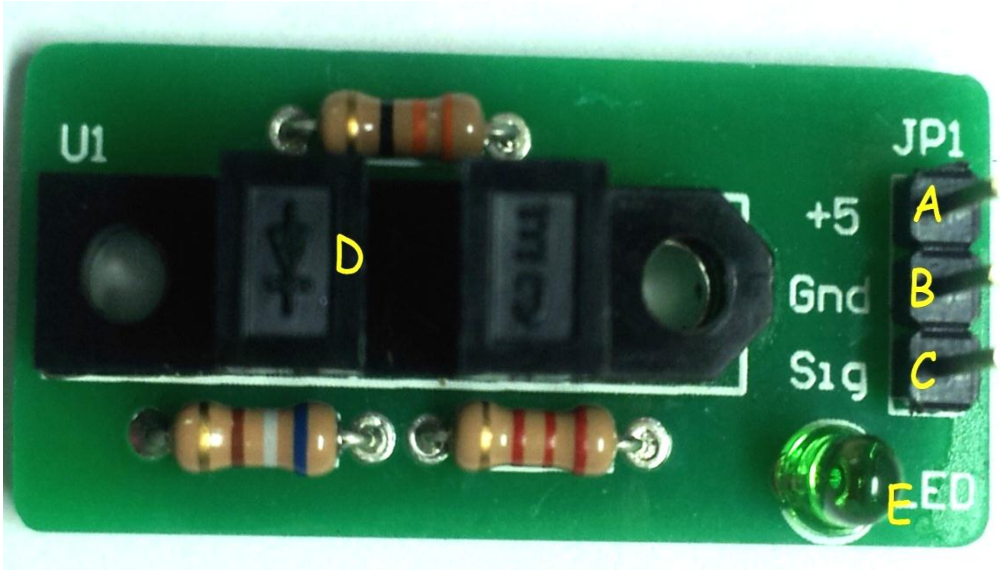


Figure 3.12 Optical Sensor Configurations

Figure 3.12and table 3.5 show optical sensor configuration. Header pin at "A" connected to input supply which is +5V from voltage regulator at power supply circuit. Header pin "B" is connected to ground of 5V supply. Header pin "C" is signal output of sensor board where this pin is internally pull-up to 5V. The part "D" will detect the missing slot of disc when the disc rotate, further generate pulses at signal pin. The part "E" is functioned as indicator. This LED will light ON if the disc does not block the optical sensor.

Table 3.5 Optical sensor configuration

Label	Function
A	+5V input Supply
B	Ground
C	Signal output/Pulse output
D	Optical Sensor
E	Indicator LED

The onboard infrared beam detects missing slots in a slotted encoder disc, and generates a pulse train with 0 or 5 V output. When optical beam is blocked, +5 V will produce while 0 V obtained when the beam is unblocked. Table 3.6 shows the summary of operation Optical Encoder.

Table 3.6 Summary of operation Optical Encoder [ ]

Optical Sensor	Signal	LED Status	Comment
Unblocked	0V	ON	Low state at “Sig” output pin
Blocked	5V	OFF	High state at “Sig” output pin

3.2.6 Power Supply +5V

Microcontroller cannot connect directly through the power supply which is more than 5 V. Thus it must have voltage regulator that convert the higher voltage become 5 V. LM7805 is a voltage regulator that used to make +5 V power supply. This component is an electrical regulator that designed to automatically maintain a constant voltage level and it also regulates the input to it. Capacitors are added in this circuit to remove the ripples that come from the power supply and make the output of the power supply smooth. Those capacitors also used to stabilize the voltage input and output of LM7805. Figure 3.13 shows the component of LM7805 with their pins labelled while figure 3.14 shows the schematic drawing of the power supply circuit

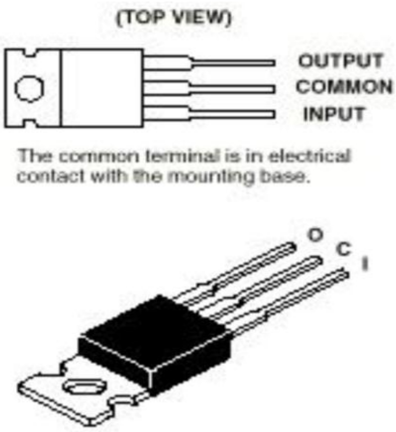


Figure 3.13 IC LM7805

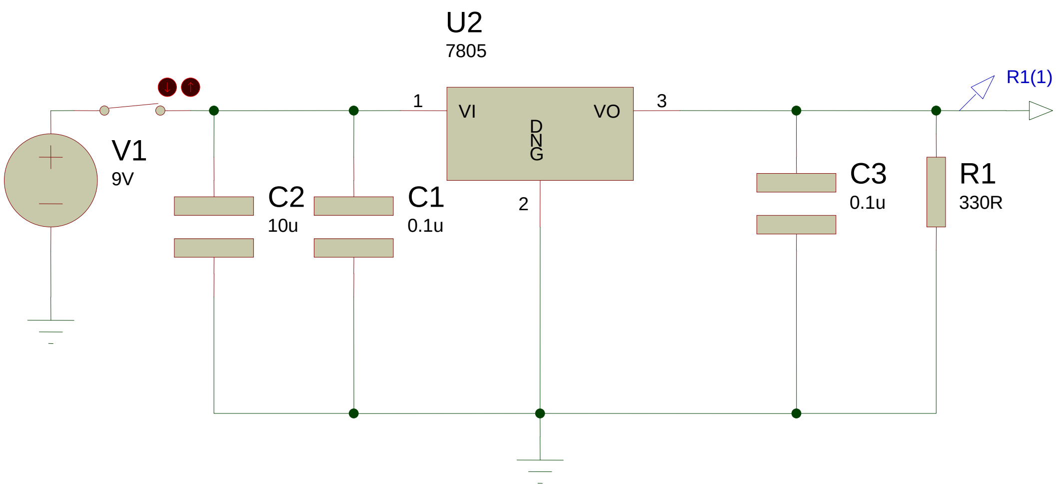


Figure 3.14 Schematic circuit of +5 V Power Supply

3.2.7 USB PIC Programmer V2009

This programmer used to download and burn the coding which in hex file into the microcontroller. It is a user friendly PIC USB programmer solution for developer, hobbyist and students. This programmer is able to burn a program into any chip as long as the microcontroller belongs to Microchip family such as PIC 12F, PIC 16F and PIC 18F family. Figure 3.15 below shows the picture of PIC Programmer.

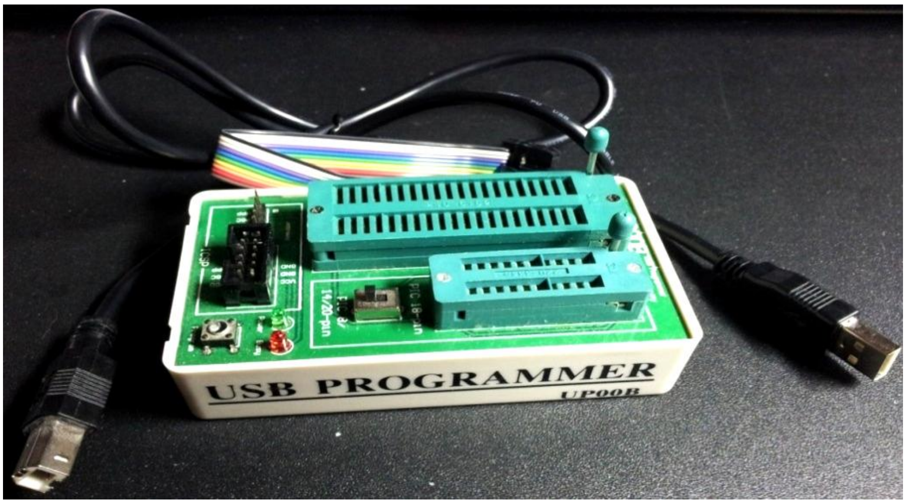


Figure 3.15 USB PIC Programmer V2009

3.2.8 16 x 2 Liquid Crystal Display (LCD)Module

LCD is an electronic module that display any output that has download into the PIC. This device is commonly used in various devices and circuits. It can display 16 characters per line and there are two lines in it. Each character in this LCD is display in 5x7 pixel matrix.

LCD has two register which are Command and Data. Command is an instruction given to LCD to do an initializing, clearing screen, setting the position and displaying data. Command register stores the command instruction that given to the LCD. The data register stores the data to be displayed on the LCD. The data is the ASCII value of the character to be display on the LCD.

This LCD are easily programmed and do not have limitation of displaying animation. Figure 3.16(a) and figure 3.16(b) shows the 16 x 2 Liquid Crystal Display Module with connection to the PIC18F452. This LCD module has 16 pins that every pin has their own specification. Table 3.7 shows the pin description for each pin at the 16 x 2 Liquid Crystal Display Module.

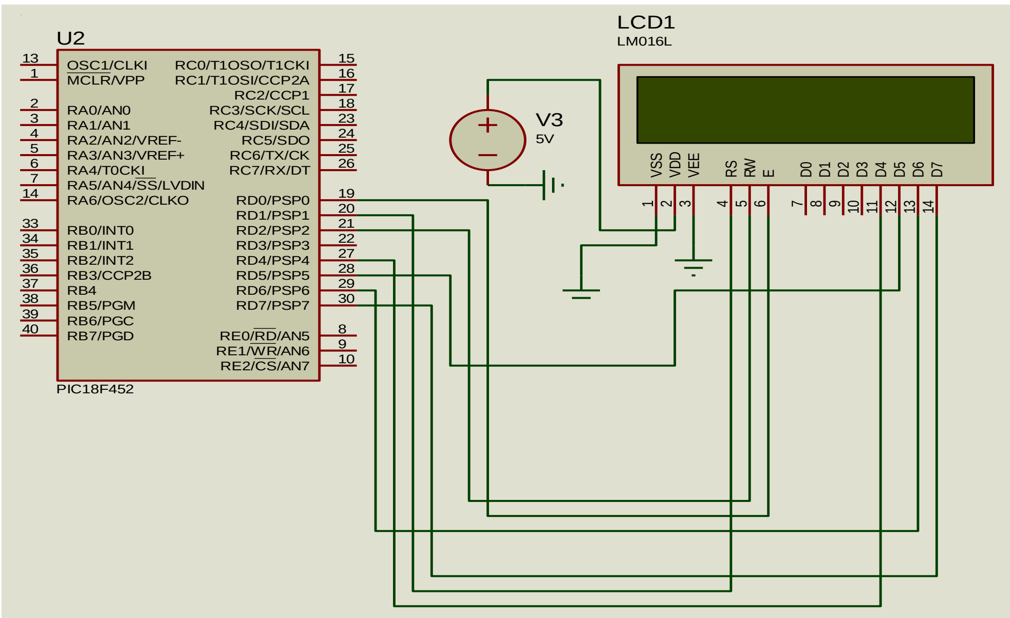


Figure 3.16(a) Connection of LCD with PIC 18F452

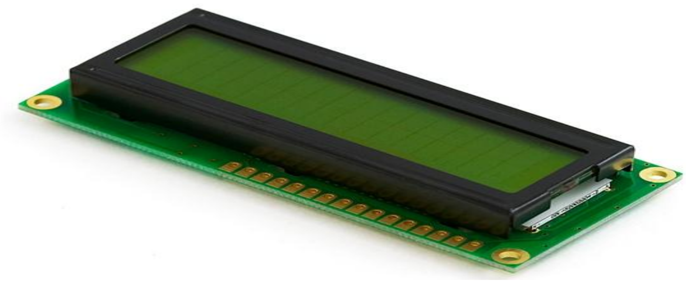


Figure 3.16(b) 16 x 2 Liquid Crystal Display Module

Table 3.7 Pin description of 16 x 2 Liquid Crystal Display Module

Pin No.	Name	Function
1	Ground	Ground (0V)
2	Vcc	Supply voltage; 5V (4.7V – 5.3V)
3	V_{EE}	Contrast adjustment; through a variable resistor
4	Register Select	Selects command register when low; and data register when high
5	Read/write	Low to write to the register; High to read from the register
6	Enable	Sends data to data pins when a high to low pulse is given
7	DB0	8-bit data pins
8	DB1	8-bit data pins
9	DB2	8-bit data pins
10	DB3	8-bit data pins
11	DB4	8-bit data pins
12	DB5	8-bit data pins
13	DB6	8-bit data pins
14	DB7	8-bit data pins
15	Led +	Backlight V_{CC} (5V)
16	Led -	Backlight Ground (0V)

3.2.9 Radio Frequency (RF) Transmitter Module

NT-T10A is a transmitting module that used to transmit signal in range of 100 meters. This transmitter can be applied for industrial remote control, remote measurement and remote sensing. There are 4 pins to connect in RF transmitting module. Vcc pin connect to the supply voltage and GND connect to the ground. DATA pin is connected to the TX pin in PIC 18F4550. This RF transmitter is a low cost device but it has some benefits which are wide input supply, easy to integrate and very small dimension. Table 3.8 shows the technical specification of RF transmitter module while figure 3.17 is the RF transmitter module.

Table 3.8 Technical specifications

Operating Voltage	3 V – 12 V
Operating Current	2 mA (3 V) , 95 mA (12V)
Modulation	ASK
Working Frequency	315 MHz

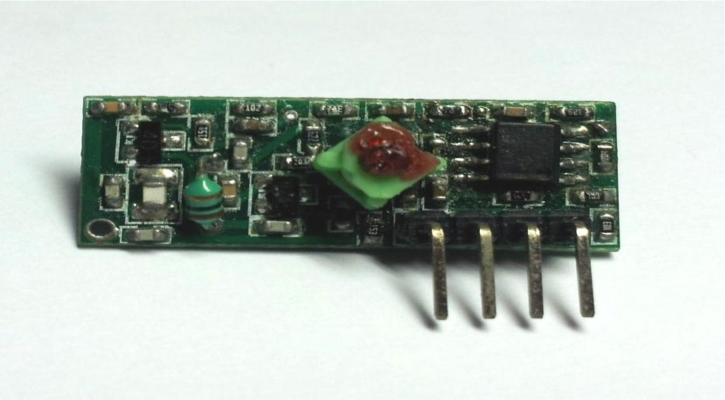


Figure 3.17 RF Transmitter Module

3.2.10 Radio Frequency (RF) Receiver Module

CWC-12 is a low cost receiving module that used to receive signal from any transmitter that have same range of frequencies. This module has their own benefits which are low power consumption, easy to integrate and very small dimension. For this receiver module, it has four pins. The two data pins internally connected each other. So, if one pin only that connecting to the pin RX at PIC 18F4550 is sufficient. Vcc pin is connected to the 5 V and the GND pin connected to the ground of the circuit board.Table 3.9 shows the specification of the RF receiving module and figure 3.18 shows the RF receiver module.

Table 3.8 Technical specifications

Operating Voltage	4.5 V – 5.5 V
Operating Current	4 mA (5 V)
Operating Temperature	-10 ºC to -60 ºC
Working Frequency	315 MHz

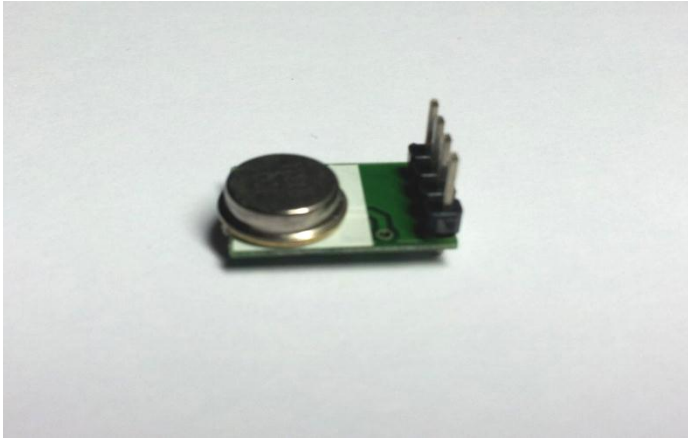


Figure 3.18 RF Receiving Module

3.3 Software Implementation

This project involved three types of software development. First parts are the development of software for designing the circuit using Proteus 7 Professional. Proteus 7 Professional is one of the software that uses to design the schematic diagram. This layout then will be reference to solder it on the independent board. The second software that involved in this project is PIC C Compiler. This software is really easy to understand compared to others software. Any programming that had been built will be compiled then will be import to the PIC in Proteus 7 Professional. Then, PICkit 2 v2.55 is used for programming the program into the PIC 18F452 and PIC 18F4550.

3.3.1 Proteus 7.0 Professional

Proteus 7 is a Virtual System Modelling (VSM) that combines animated components, microprocessor models and circuit simulation to simulate into the complete microcontroller based designs. This software is a tool for testing any microcontroller designs before constructing a physical prototype in real time. One of main component in Proteus 7 Professional is the circuit simulation. Figure 3.19 shows the proteus software and figure 3.20show the sample of circuit design using Proteus 7 Professional.

Figure 3.19 Proteus Software

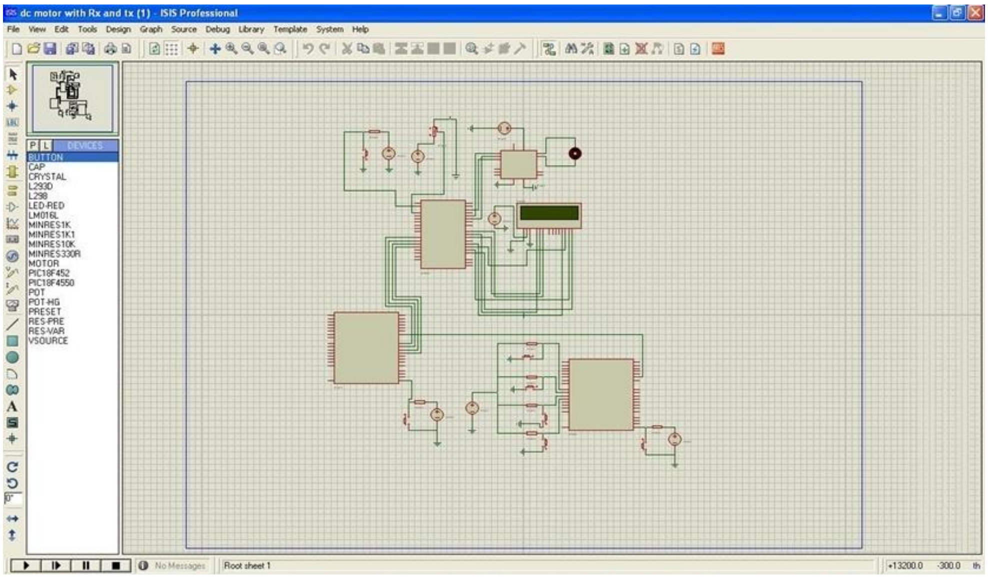


Figure 3.20 Sample circuit design in Proteus 7.0 Professional

3.3.2 PICkit 2 v2.55

This PICkit 2 v2.55 software used to download the hex file project and burn the coding into the PIC microcontroller. This software also can erase the earlier coding that has in the PIC microcontroller. Figure 3.21 shows the PICkit 2 v2.55 programmer window before downloading the hex file.

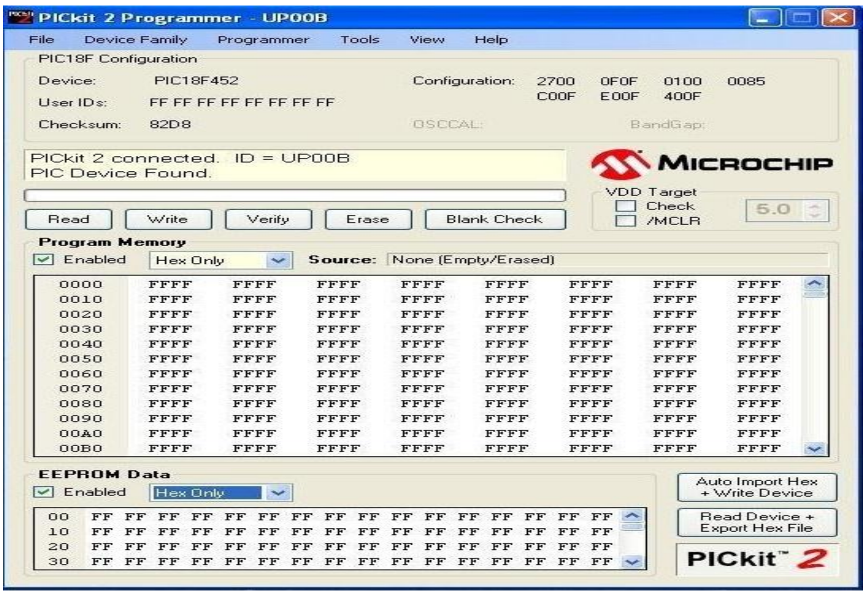


Figure 3.21 PICkit 2 v2.55 programmer window

3.3.3 PIC Basic Pro Compiler

This software is the easiest way to program the fast and powerful Microchip Technology PICmicro microcontrollers (MCUs). It converts the basic program into files that can be programmed directly into the MCUs. The Pic Basic Pro Compiler can create programs for any of Microchip's PICmicro microcontrollers. Figure 3.22 shows the illustration of the PIC Basic Pro Compiler.

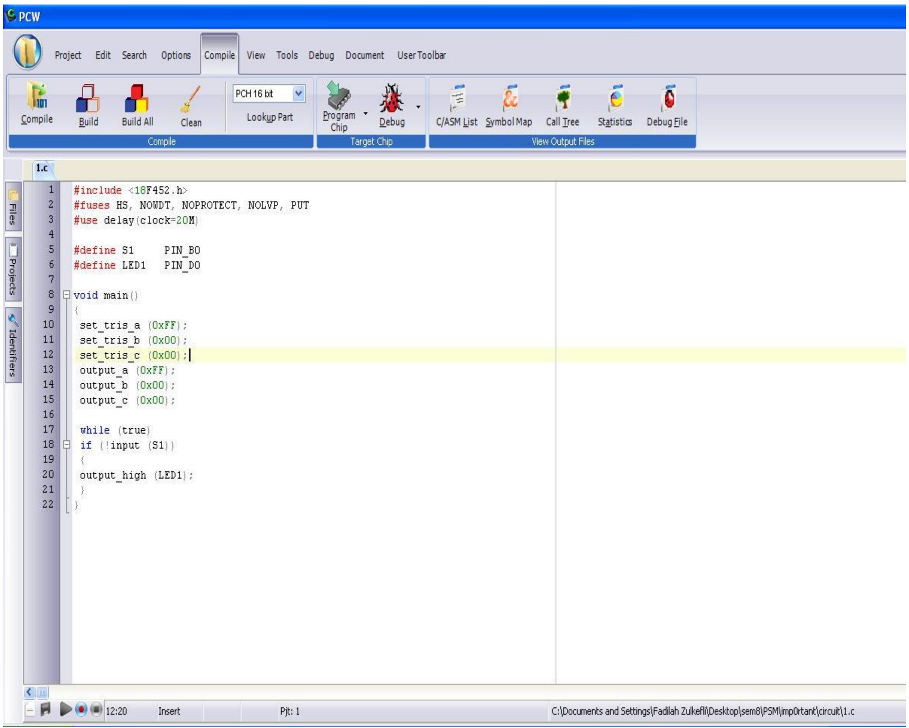


Figure 3.22 PIC Basic Pro Compiler

CHAPTER 4

RESULTS ANALYSIS

4.1 Introduction

For this project, some experiments are conducted to test the component and circuits design. In this chapter, the experiments that carried out are +5 V power supply circuit, push button circuit, directions of DC motor and speed control of DC motor. This experiment used to test the circuit and also the programming that had been programmed. If the output that obtained from the experiment are exactly as what the user want, that means it was achieved.

4.2 Power Supply +5 V

Power supply is one of the critical parts in designing the direction and speed control of DC motor. The PIC required specific amount of power supply to drive it. Power supply should be able to supply power for the DC motor without having any difficulties. Battery is used as main supply for this circuit but since the PIC 18F452 needs +5 V at pin V_{DD}, a circuit was built using voltage regulator to yields 5 V as an input supply to PIC 18F452. The 5 V that obtained from the output was regulated by the voltage regulator LM7805 that used in this circuit. Figure 4.1 shows the circuit using Proteus 7 Professional while figure 4.2 shows the hardware of the power supply +5 V. A switch is added to the circuit as a device to connect or disconnect supply from the battery or other power supply.

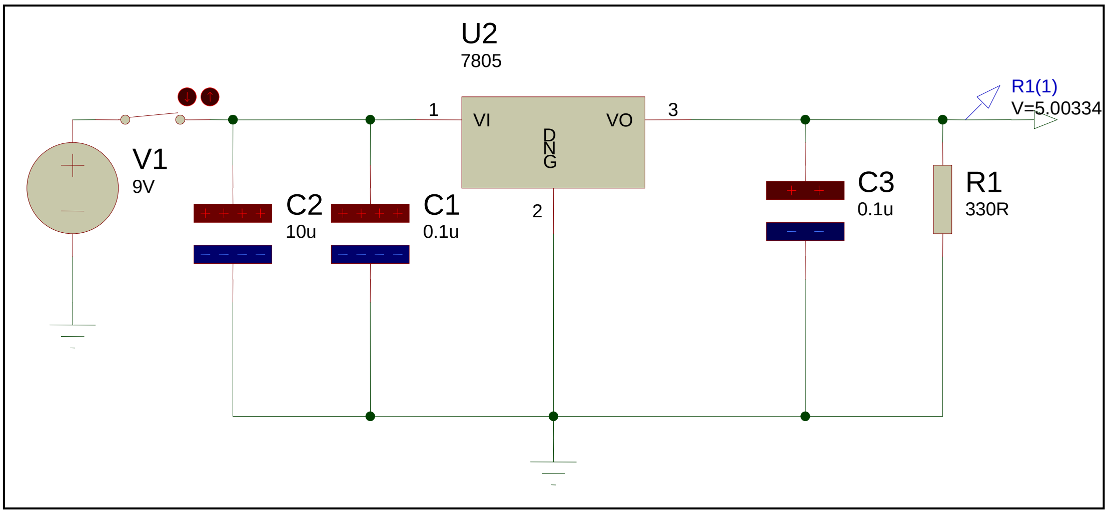


Figure 4.1 Power Supply +5 V

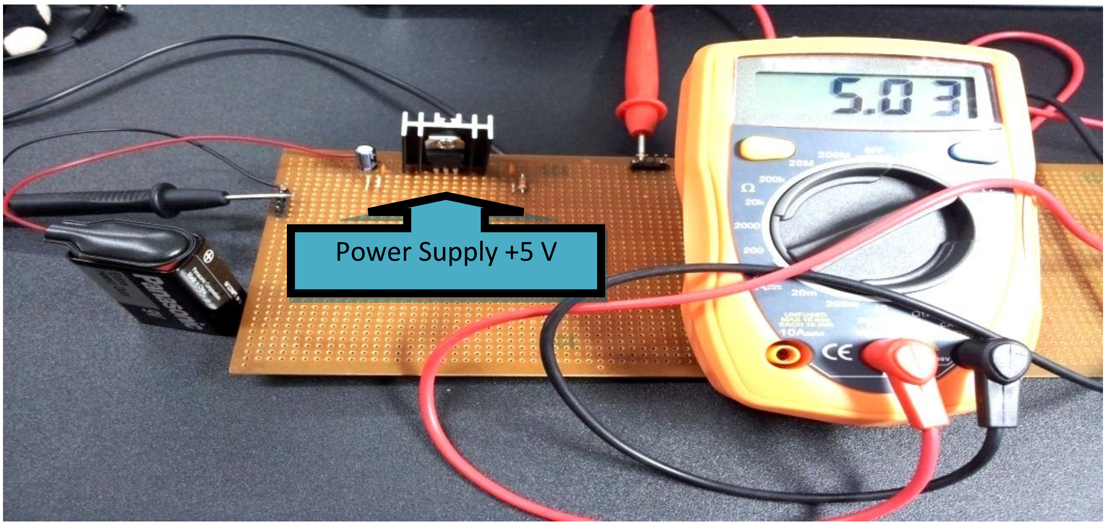


Figure 4.2 Hardware of power supply +5 V

4.3 PIC 18F452 and PIC 18F4550 Testing

PIC 18F452 and PIC 18F4550 are component that may damage due to some situation. For testing the both of the microcontroller, a simple circuit is designed in the Proteus 7.0 Professional. A coding also created for programming the PIC microcontroller as a simulation. Based on figure 4.3, one push button functions as an input to the PIC. Then, the microcontroller will analyze and transfer the data to the output. When the push button is pressed, the LED turning on and this means that the

PIC 18F452 is in a good condition. The experiment is repeated to the PIC 18F4550 too. Figure 4.3 shows the schematic diagram of simple circuit to turn on the LED using push button while figure 4.4 shows the hardware of the simple PIC testing circuit.

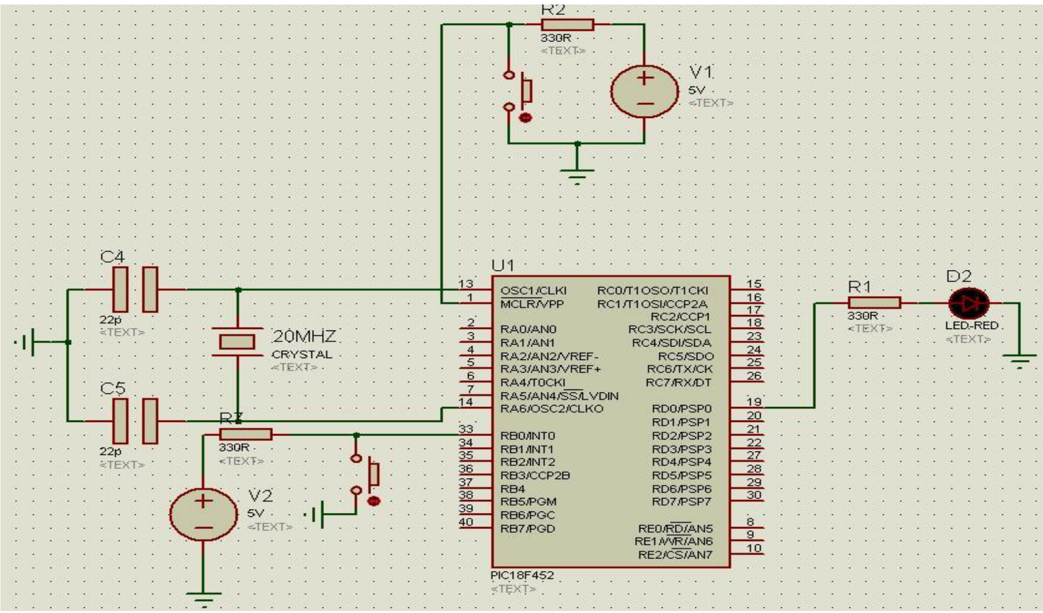


Figure 4.3 Schematic diagram of simple circuit

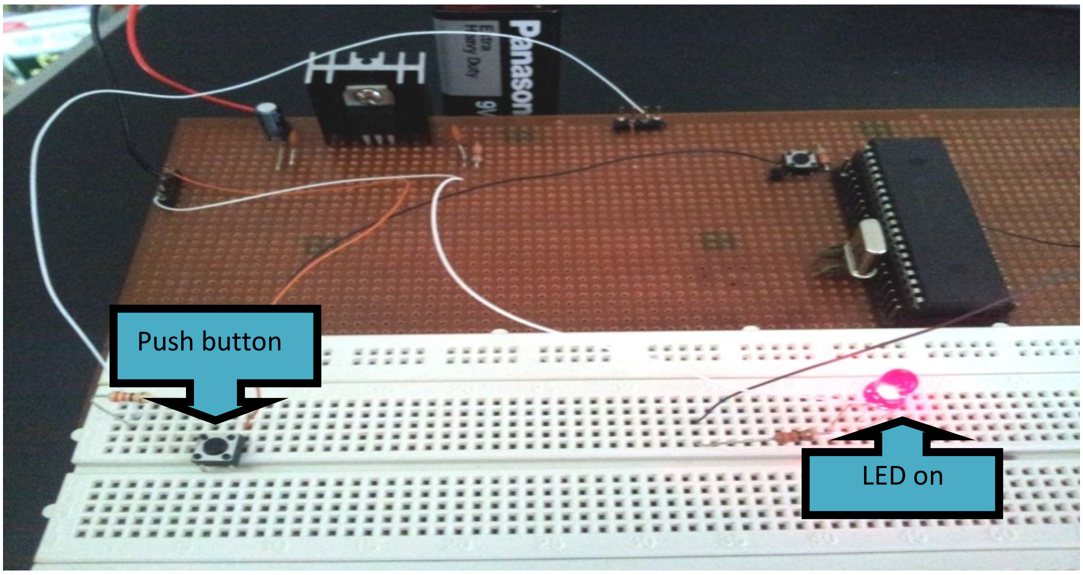


Figure 4.4 Hardware of simple circuit

This simple circuit coding is dividing into header part, I/O declaration, initialization part and main program.

Header part

```
#include <18f452.h>            //if PIC 18F4550, change the value in '<>'
#device *= 16
#device adc=8
#fuses HS, NOWDT, NOPROTECT, NOLVP, PUT
#fuses NOBROWNOUT, CPD, NODEBUG, NOWRT
#use delay (clock=20M)         //20MHz crystal used
```

I/O declaration

```
#define S1    PIN_A0           //push button
#define LED1  PIN_B0           //LED
```

Initialization part

```
set_tris_a (0xFF);             //set all port A as input port
set_tris_b (0x00);             //set all port B as output port
set_tris_c (0x00);             //set all port C as input port
output_a (0xFF);               //reset port A
output_b (0x00);               //reset port B
output_c (0x00);               //reset port C
```

Main program

```
while (true)
if (!input (S1))          //push button is pressed
output_high (LED1);            //LED turn on
```

4.4 16 x 2 Liquid Crystal Display (LCD) Display Testing

LCDs are used in a wide range of applications. For this project, two LCD are tested to ensure that the LCD is functional well. Figure 4.5 show the schematic diagram of LCD testing while figure 4.6 shows the output at the LCD from hardware testing. For this test circuit, one push button is used to give input to the PIC and the LCD will display the data that it receives from the PIC. Once the push button is pressed, the LCD displayed "LCD display" on the screen. For header part, the coding is repeated from previous experiment. Since this experiment used LCD module, the header for LCD is wrote. The input and port used is same with the PIC testing, so the coding is still the same. Below is the coding and explanation for LCD test display.

Header Part

```
#include <lcd.c>                //LCD display header file is adding to previous coding
```

I/0 declaration

```
#define LCD_E    PIN_D0        //PIN E
#define LCD_RS   PIN_D1        //PIN RS
#define LCD_RW   PIN_D2        //PIN RW
#define LCD_D4   PIN_D4        //PIN D4
#define LCD_D5   PIN_D5        //PIN D5
#define LCD_D6   PIN_D6        //PIN D6
#define LCD_D7   PIN_D7        //PIN D7
```

Port Initialize

```
lcd_init () ;                  //Initialize LCD is add
```

Main Program

```
while (true)                   //program below is always repeat
if (!input (S1))          //when pressed button 1
output_high (LED1);            //LED turn on
lcd_putc("\f LCD display");    //message display at LCD display
```

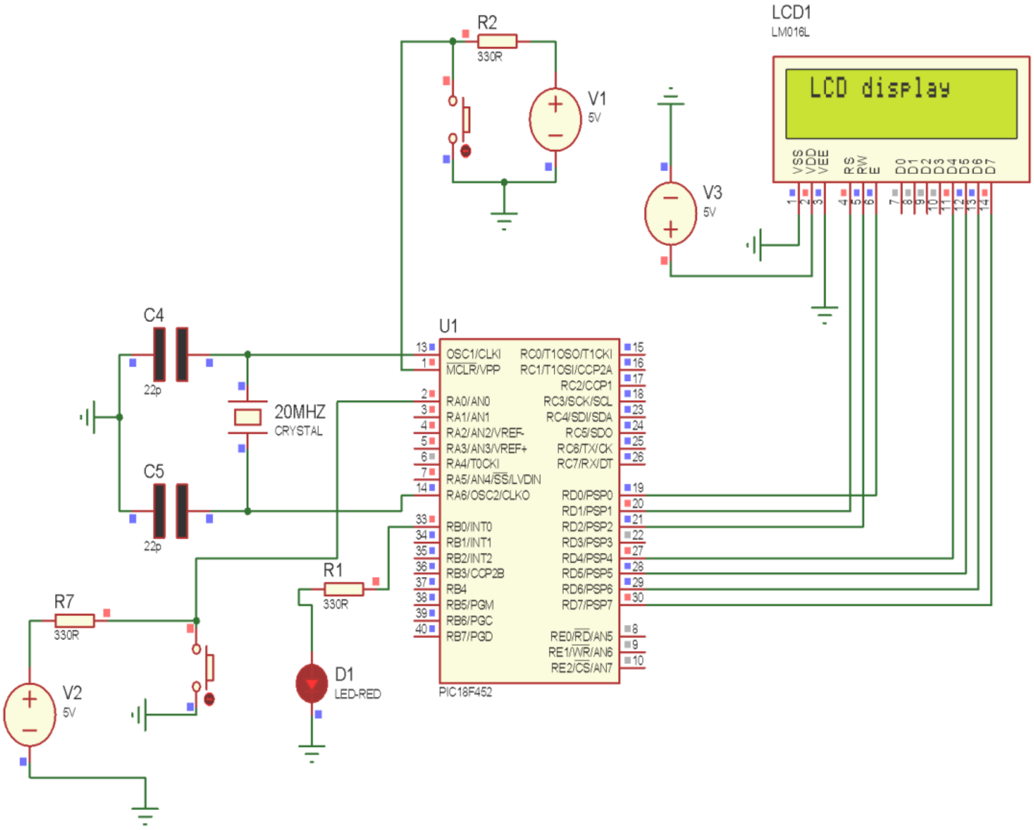


Figure 4.5 LCD display for button S1

Figure 4.6 LCD Display Testing

4.5 DC Motor Testing

For DC motor testing, the direction and speed control of dc motor is tested. At this stage, the speed of dc motor is varied using potentiometer which is analog input while the direction of dc motor is controlled by using two push buttons. Figure 4.7 shows the schematic circuit and also the output that carried out after the simulation. Since it has two push buttons, analog control and pwm control, the I/O declaration is added. Based on figure 4.8, the LCD is displayed the direction and also the speed of the DC motor in PWM when push button 1 is pressed. To vary the speed, adjust the variable resistor. Below is the coding for this test circuit.

I/O Declaration

```
#define S2  PIN_B1                      //Push button
#define PWM_MOTOR PIN_C2                //PWM for DC motor
#define MOTOR_FOR PIN_C4                //DC motor forward
#define MOTOR_REV PIN_C5                //DC motor reverse
byte s=0;                               //initial condition
lcd_init();
lcd_putc("\f");                         //clear all the previous data in LCD
setup_adc_ports(adc_clock_internal);
setup_adc(AN0);                         //only RA0 is analog input
set_adc_channel(0);                     //initial condition
```

Port Initialize

```
set_tris_a(0xFF);                       //set all port A as input port
set_tris_b(0xFF);                       //set all port A as input port
set_tris_c(0x00);                       //set all port A as output port
output_a(0xFF);                         //reset port A
output_b(0xFF);                         //reset port B
output_c(0x00);                         //reset port C
setup_timer_2 (T2_DIV_BY_4,254,1);
setup_ccp1 (ccp_pwm);                           //PWM 1 output configuration
printf(lcd_putc, "\fPWM& Motor\nDirection");    //PWM 1 duty cycle
```

Main program

```
if (!input(S1))                                  //for push button 1
read_adc(adc_start_only);
while(!adc_done());
s = read_adc(adc_read_only);                     //read the analog input
lcd_gotoxy(1,1);                                 //starting target point
printf(lcd_putc, "\fPwmFoward=%u" ,s);           //feed message at LCD
output_high(MOTOR_FOR);                          //motor forward
output_low (MOTOR_REV) ;                         //motor forward
set_pwm1_duty (s);                               //set the PWM value
delay_ms(60);

else if (!input(S2))                             //for push button 2
read_adc(adc_start_only);
while(!adc_done());
s = read_adc(adc_read_only);
lcd_gotoxy(1,1);
printf(lcd_putc, "\fPwm Reverse=%u" ,s);
output_low(MOTOR_FOR);                           //motor reverse
output_high (MOTOR_REV) ;                   //motor reverse
set_pwm1_duty (s);
delay_ms(60);
```

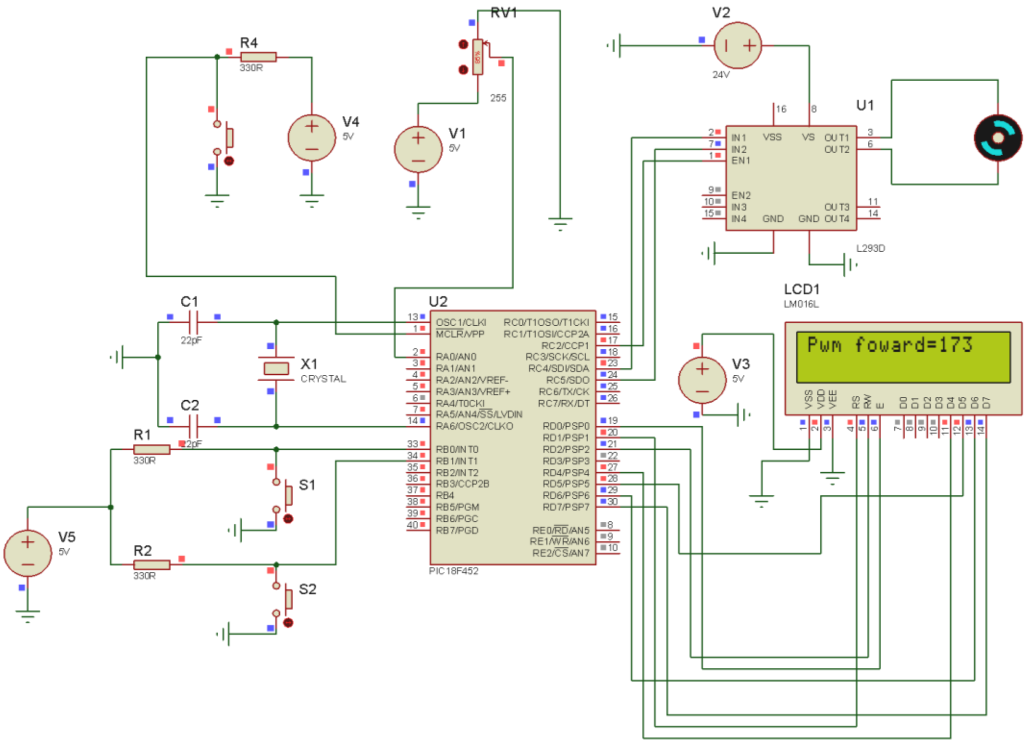


Figure 4.7 Results of DC motor test circuit

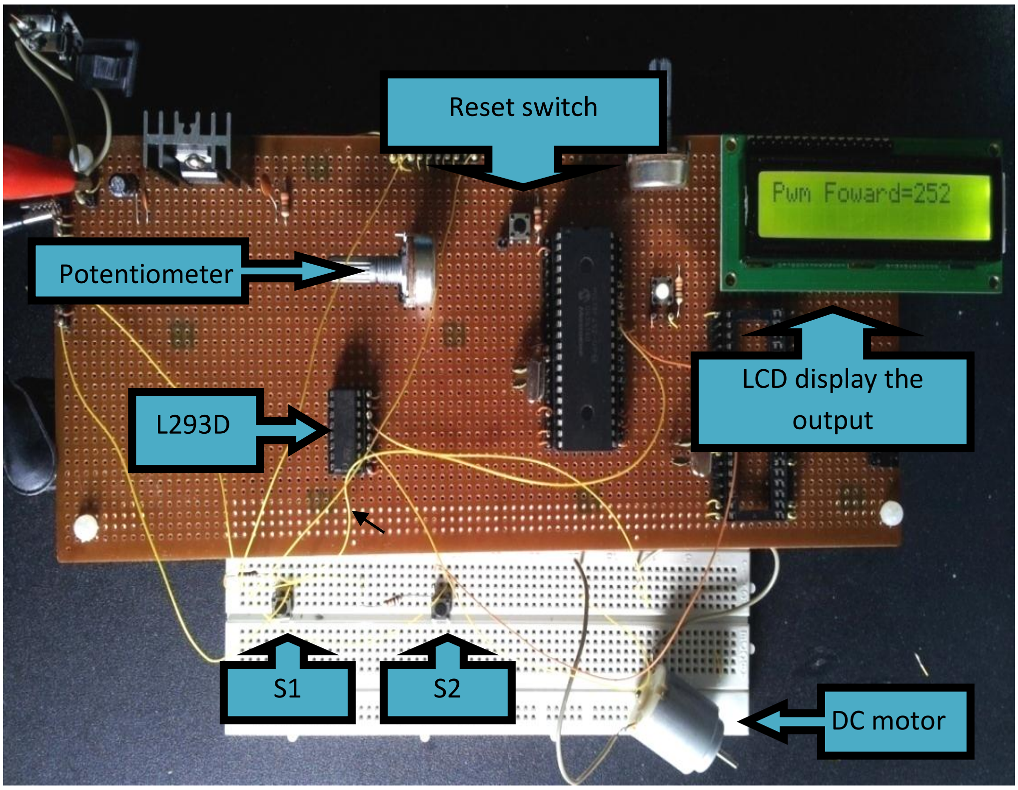


Figure 4.8 Hardware testing for DC motor

4.6 Speed Motor Testing

This testing is conducted for testing the speed of DC motor using push button. It used the same connection and circuit but with different input. For this experiment, it only tests one direction only which is forward as the direction is not the main thing in this experiment. When push button is pressed, the pwm value will increase or decrease according to the data in PIC. Figure 4.9(a), figure 4.9(b) and figure 4.9(c) shows some of the results. Coding below is only for the increasing and decreasing value of pwm.

Main program

```
if (!input(S1))
if (s<256)
s += 15;
lcd_gotoxy(1,1);
printf(lcd_putc, "\fPwmFoward=%u" ,s);
output_high(MOTOR_FOR);
output_low (MOTOR_REV) ;
            set_pwm1_duty (s);
delay_ms(300);
        if (s>255) {s=s;}
        if (!input(S2))
if(s!=0)
          s -= 15;
lcd_gotoxy(1,1);
printf(lcd_putc, "\fPwmFoward=%u" ,s);
output_high(MOTOR_FOR);
output_low (MOTOR_REV) ;
          set_pwm1_duty (s);
delay_ms(300);
```

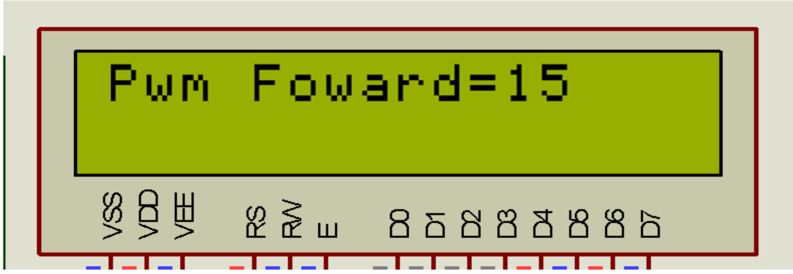


Figure 4.9(a) When pushed button is pressed for first time

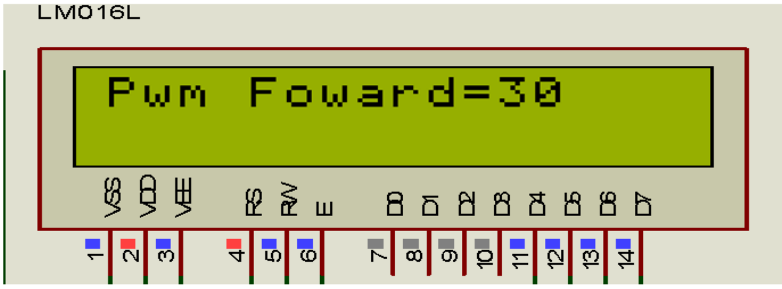


Figure 4.9(b) When pushed button is pressed for second time

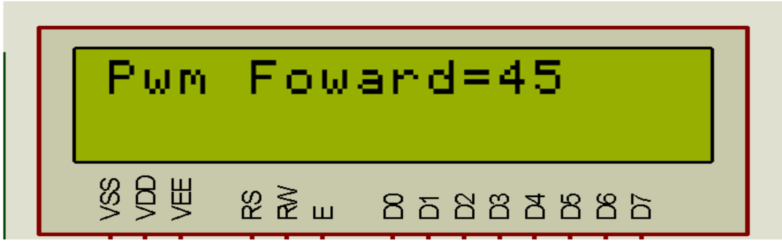


Figure 4.9(c) When pushed button is pressed for third time

Figure 4.9(a).Figure 4.9(b), Figure 4.9(c)

4.7 Transmitting and Receiving Testing

This experiment divide into two circuit which are transmitting side and receiving side. By using RF module, some changes and modification is done to both circuit and program. In this experiment, three push button is used as switched. Since this experiment is for testing the circuit and program, pin 25 (TX) at PIC 18F550 is connected directly to the pin 26 (RX) of PIC 18F452. Figure below shows the result when each of push button is pressed.

Tramsmitting side

```
#include <18f4550.h>
#use delay(clock = 20000000)  //clock=20mhz
#fuses hs, noprotect, nowdt  //default setting
#use rs232(baud=4800,xmit=PIN_C6,rcv=PIN_C7,PARITY=N) //set rf data speed
#byte PORTA=5 //define PORT A address
#byte PORTB=6 //define PORT B address
#byte PORTC=7 //define PORT C address
#byte PORTD=8 //define PORT D address
#byte PORTE=9 //define PORT E address
void main()
{
inttxdata=0;
int count;
intmysend=0;
int bt1=0;
int bt2=0;
int bt3=0;
int bt4=0;
  //set i/o for each pin
set_tris_a(0b00000000);
set_tris_b(0b11110000);
set_tris_c(0b10000000);
set_tris_d(0b00000000);
set_tris_e(0b00000000);

 /* output_high(pin_a0); //on red led
output_high(pin_a1); //on green led
delay_ms(1000);
output_low(pin_a0);  //off red led
output_low(pin_a1);  //off green led
delay_ms(1000);*/
do
  {
```

```
if(input(pin_b0)==0) //if forward button pressed
    {
txdata='a';
mysend=1;
      bt1=1;
    }
else if(input(pin_b0)==1)  //if forward button released
    {
      bt1=0;
    }
if(input(pin_b1)==0) //if minus button pressed
    {
txdata='b';
mysend=1;
      bt2=1;
    }
else if(input(pin_b1)==1)  //if minus button released
    {
      bt2=0;
    }
if(input(pin_b2)==0) //if stop button pressed
    {
txdata='c';
mysend=1;
      bt3=1;
    }
else if(input(pin_b2)==1)  //if stop button released
    {
      bt3=0;
    }
if(mysend==1)  //if ready to send data
    {
output_high(pin_a1);
```

```
        //send data out
for(count=0;count<20;count++)
        {
putc('(');
putc(txdata);
putc(')');
delay_ms(10);
        }
mysend=0;
output_low(pin_a1); //off red led
      }

delay_ms(500);

}while(1);
}
```

Receiving side

```
#include <18f452.h>
#use delay(clock = 20000000)  //clock=20mhz
#fuses hs, noprotect, nowdt  //default setting
#use rs232(baud=4800,xmit=PIN_C6,rcv=PIN_C7,PARITY=N) //set rf data speed
#include <lcd.c>

//LCD
#define LCD_E   PIN_D0
#define LCD_RS  PIN_D1
#define LCD_RW  PIN_D2
#define LCD_D4  PIN_D4
#define LCD_D5  PIN_D5
#define LCD_D6  PIN_D6
#define LCD_D7  PIN_D7

//Port
```

```
#byte PORTA=5  //port a address
#byte PORTB=6  //port b address
#byte PORTC=7  //port c address
#byte PORTD=8  //port d address
#byte PORTE=9  //port e address

int receive=0;
intrx_detect=0;
int a=0;
int b=0;
//int s;


//receive data
#int_rda
voidserial_isr()
{
  a=getch();
if(a=='(')
  {
receive=getch();
    b=getch();
  }
if(b==')')
  {
rx_detect=1;
  }

  a=0;
  b=0;
}
//modules to drive motor1
void motor1_fwd();
void motor1_rev();
```

```
void motor1_stop();
void main()
{
lcd_init();
lcd_putc("\f");
printf(lcd_putc, "\fPWM& Motor\nDirection");
set_tris_a(0b00000000);
set_tris_b(0b00000000);
set_tris_c(0b10000000);
set_tris_d(0b00000000);
set_tris_e(0b00000000);
enable_interrupts(int_rda);
enable_interrupts(GLOBAL);
setup_port_a(NO_ANALOGS);
do
  {
if(rx_detect==1)
    {
rx_detect=0;
if(receive=='a')  //robot forward
      {
        motor1_fwd();
      }
if(receive=='b')   //robot backward
      {
        motor1_rev();
      }
if(receive=='c')   //robot backward
      {
        motor1_stop ();
      }
    }
}while(1);
}
```

```
void motor1_fwd() //module to forward motor1
{
  setup_timer_2 (T2_DIV_BY_4,254,1);
  setup_ccp1 (ccp_pwm);
  set_pwm1_duty (255);
output_high(PIN_C2);
output_high(PIN_C4);
output_low(PIN_C5);
lcd_gotoxy(1,1);
printf(lcd_putc, "\fPwmFoward \n ");
}
void motor1_rev() //module to reverse motor1
{
  setup_timer_2 (T2_DIV_BY_4,254,1);
  setup_ccp1 (ccp_pwm);
output_high(PIN_C2);
output_low(PIN_C4);
output_high(PIN_C5);
  set_pwm1_duty (255);
lcd_gotoxy(1,1);
printf(lcd_putc, "\fPwm reverse");
}
void motor1_stop()   //module to stop motor1
{
output_low(PIN_C2);
output_low(PIN_C4);
output_low(PIN_C5);
lcd_gotoxy(1,1);
printf(lcd_putc, "\fMotor stop");
}
```

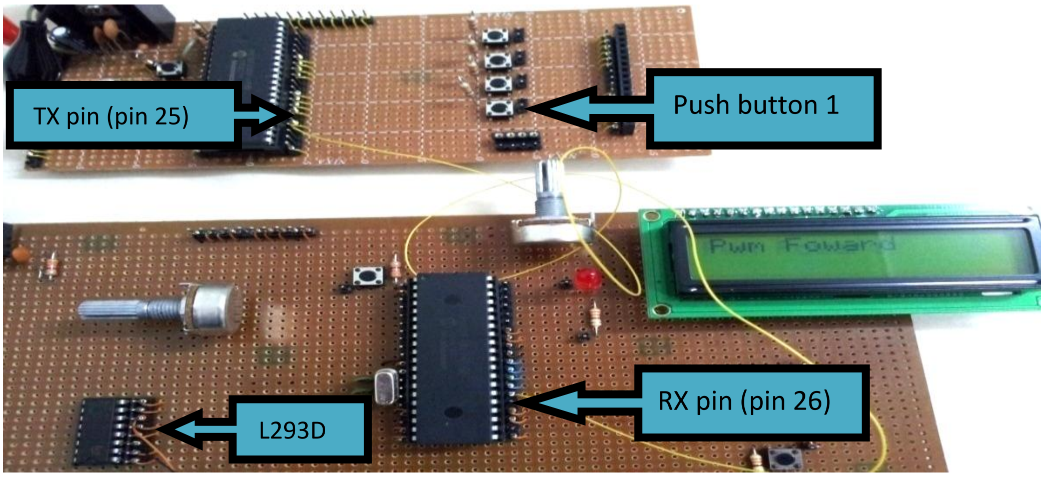


Figure 4.10(a) When press push button 1

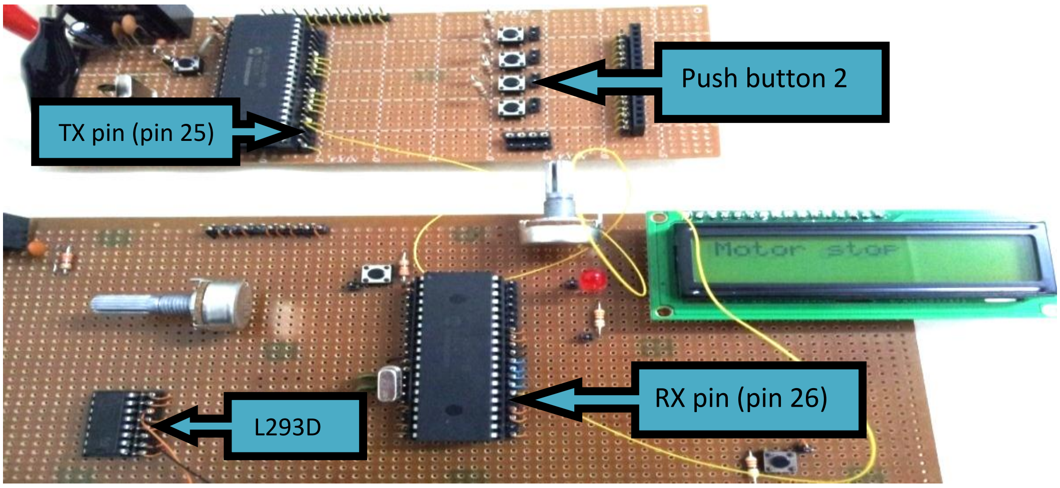


Figure 4.10(b) When press pushbutton 2

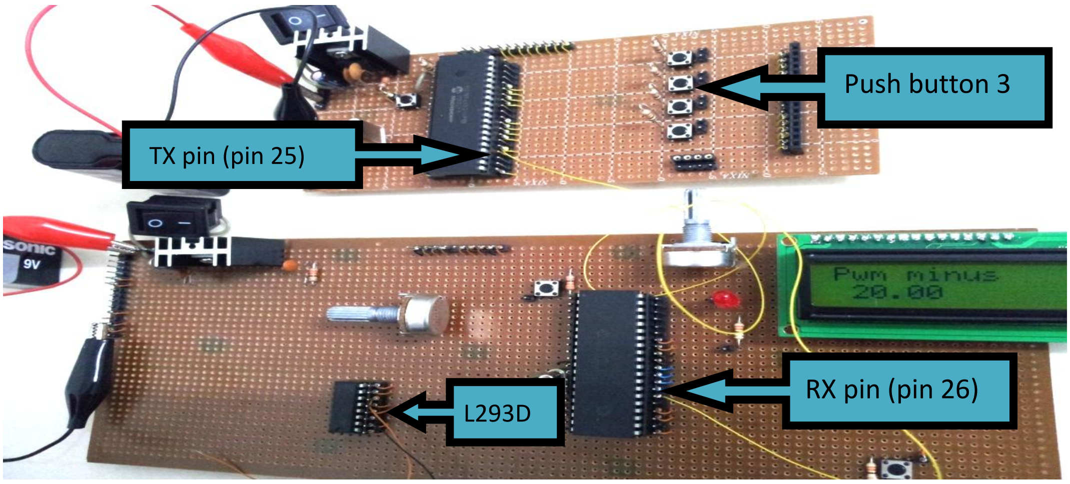


Figure 4.10(c) When press pushbutton 3

4.8 Direction, Speed (RPM) and PWM Signal Testing

Figure 4.11 shows the complete hardware of this experiment which consist of direction, PWM and shaft RPM. This system is applying the wireless method. When push buttons is pressed, the motor will run according to the data that sending by the transmitter circuit. The push buttons functions as start to run the motor without control the speed or direction, stop button to stop the motor, forward up and forward down buttons to run the motor in forward direction with variable speed and reverse up and reverse down button to run the motor in reverse direction with variable speed. This system is manually control by the user. Pulse Width Modulation method used for driving dc motor in varying the speed of the dc motor. The PWM signals are shown in figure 4.12(a), figure 4.12(b), figure 4.12(c), and figure 4.12(d) below.

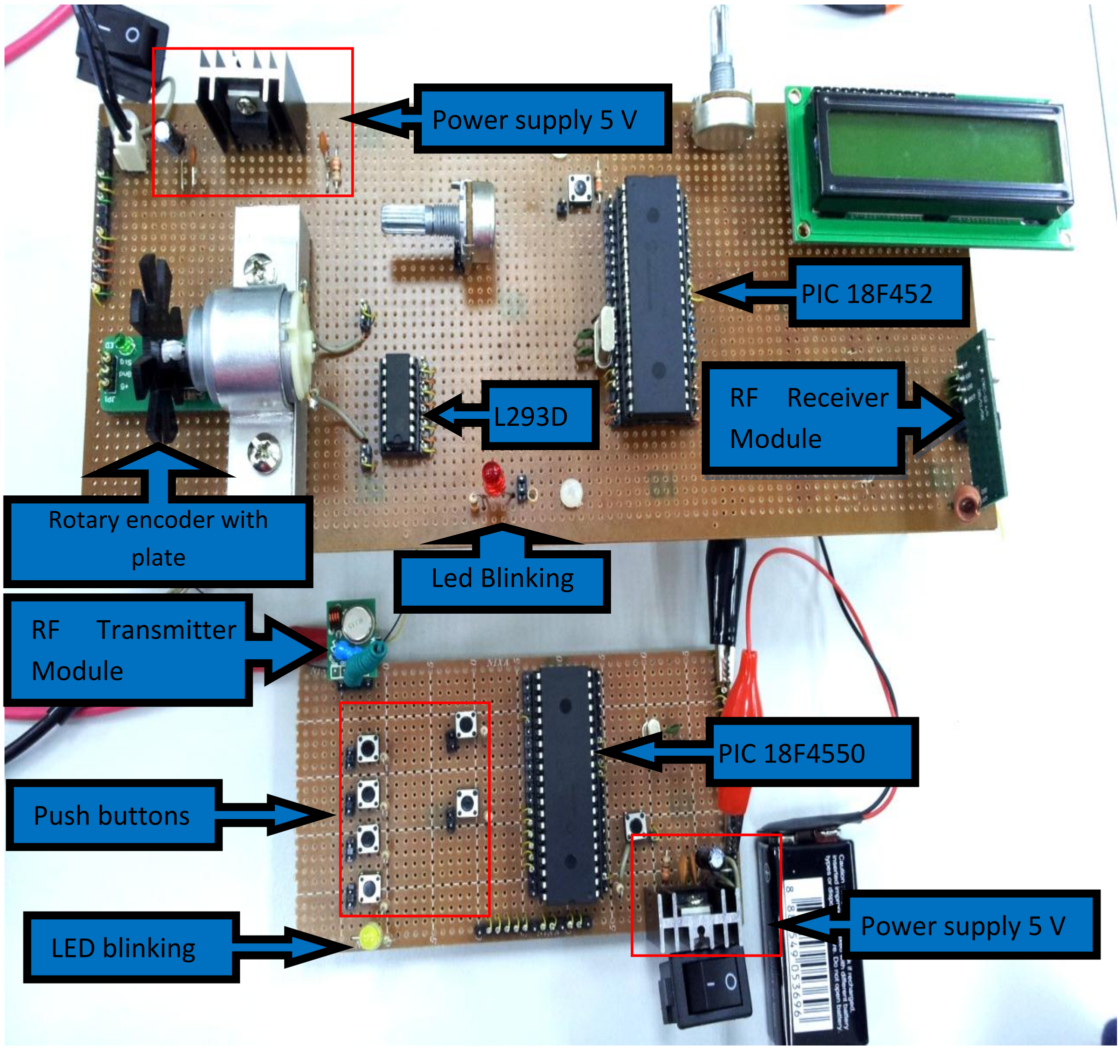


Figure 4.11 Hardware of direction and speed control of dc motor system

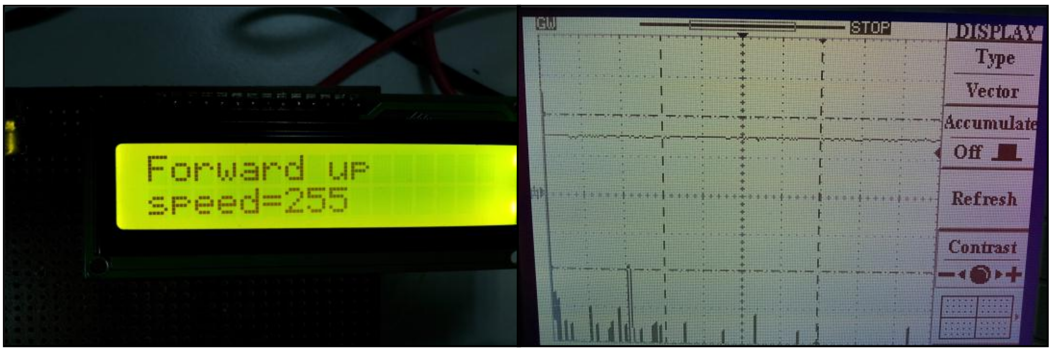


Figure 4.12(a) PWM signal for PWM=255

Figure 4.12(b) PWM signal for PWM=207

Figure 4.12(c) PWM signal for PWM=175

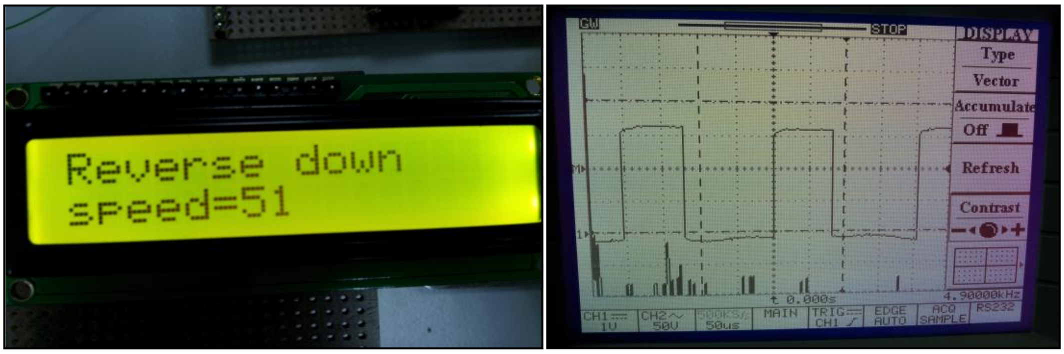


Figure 4.12(d) PWM signal for PWM=51

4.9 Relationship of Voltage Supply and Motor Speed

Voltage supply will affect the motor speed. As the voltage increased, the motor speed also increased. An optical encoder is used in this experiment to measure the rotation per minute (RPM). Figure 4.13 shows the circuit with the connection while table 4.1 shows the results obtained from this experiment.

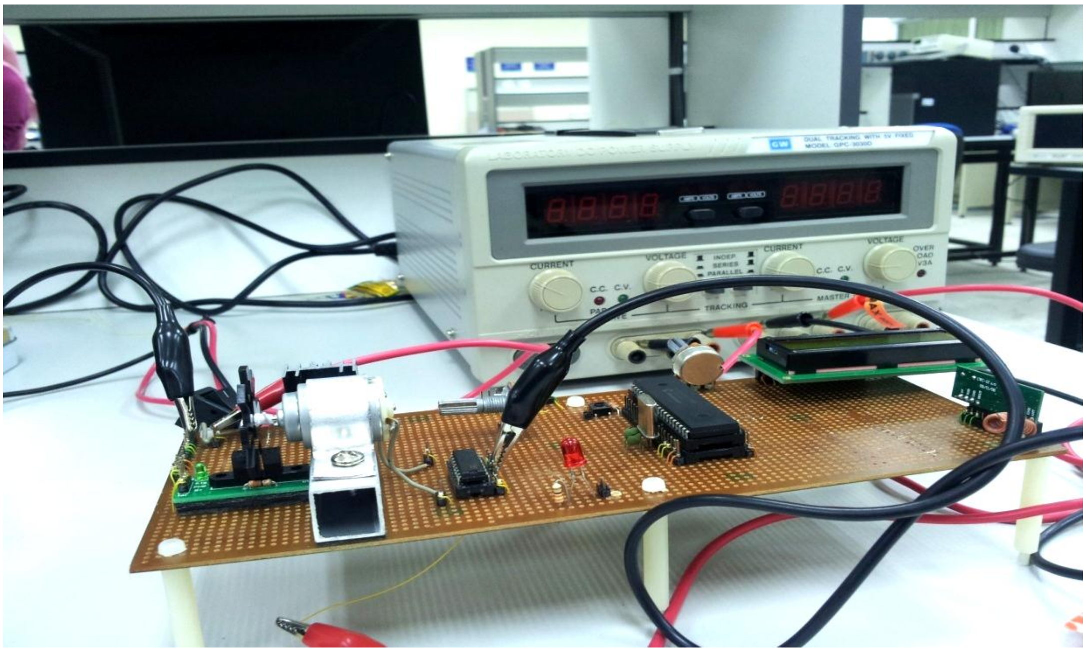


Figure 4.13 Circuit for voltage testing with motor speed

Table 4.1 Results speed versus voltage supply

Input Voltage (V)	Speed (RPM) Motor
0	0
1	0
2	0
3	0
4	0
5	0
6	2709
7	3648
8	4318
9	5132
10	6023
11	7112
12	7828

4.10 Signal Output from optical encoder and RF Modules

The 'sig' pin from optical encoder is connected to the pin 16 of PIC 18F452. This pin produces pulse for providing the counting of speed dc motor. For RF modules, 'Data' pin of the transmitting module is connected to the pin 25(TX Pin) PIC 18F4550 while 'Data' pin of receiving module is connected to the pin 26(RX pin). This data pin also produce the waveform while its transmitting and receiving. Figure 4.14 shows the output pulse from optical encoder while figure 4.15 shows the output signal of RF modules.

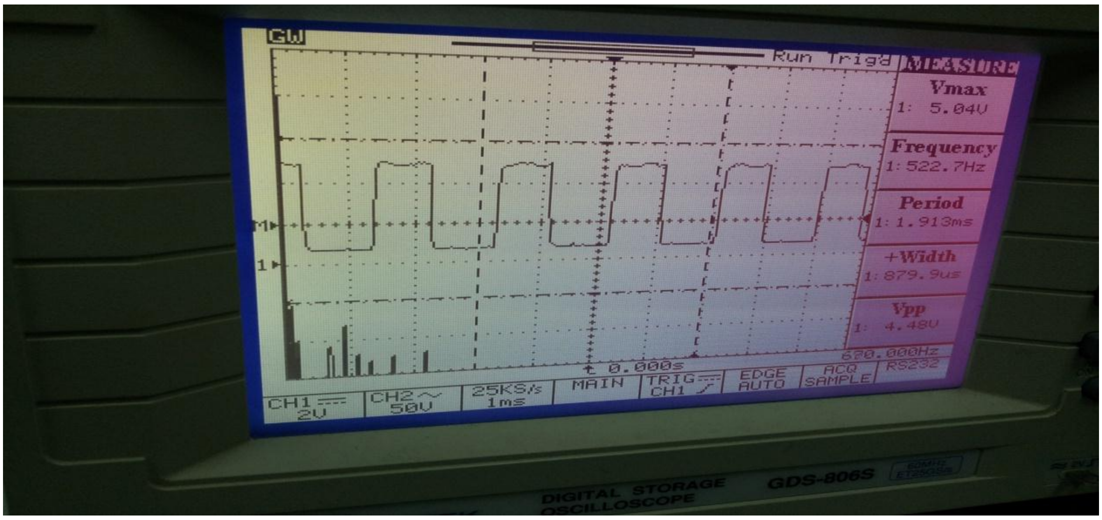


Figure 4.14 Output signal from optical encoder

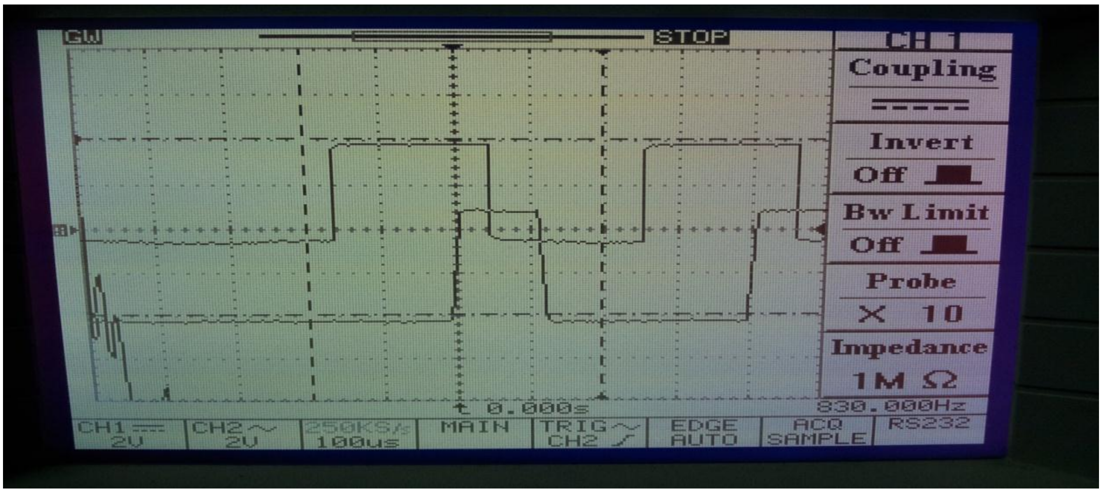


Figure 4.15 Output signal from RF Modules

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

Some of this project has been carried out successfully in design and build the direction and control of DC. First stage is using the potentiometer to control the speed and two push buttons with L293D motor driver to control the direction of DC motor. All components for the first stage are functioning well. The second stage is in increasing the speed of DC motor using push button by varying the pwm in PIC. At this stage, the testing process has been done in a very satisfactory manner. The third stage is testing the program that been created for two-way communication which are inserting the transmitting and receiving circuits. This stage is an upgrade of this dc motor control system as it can be more useful to the society. For transmitting the data from the transmitter side to the receiver side is succeed. The motor is run after give signal from the transmitting circuit.

5.2 Recommendation

In order to improve and upgrade this system into the better performance, some recommendations are listed based on the problems faced in making this project.

i. In obtaining a DC motor speed control system with excellent and brilliant regulation, used the fuzzy logic in microcontroller

ii. For the next project, try this system with different type of DC motor such as stepper motor and servo motor. Plus, also try with the other methods in controlling the speed and direction of DC motor.

iii. For wireless control, use Zigbee module as RF communication because it do not need configuration for out of box RF communications. Plus, it is a simple device.

iv. In order to produce more reliable and effective system, this circuit should be designed using Printed Circuit Board (PCB).

v. Add one more PIC to the receiver module to function as processor.

REFERENCES

[1] Timothy J. Maloney, (2004). *Modern Industrial Electronics*.5th Edition; Prentice Hall.

[2] Terry Barlet, (2002). *Industrial Control Electronics Devices, Systems and Applications.2nd Edition*; Thomson Learning, Inc.

[3] Ea Ai Choon, (2005). *DC Motor Speed Control using Microcontroller PIC 16F877A*. Bachelor's Degree. UniversitiTeknologi Malaysia, Skudai.

[4] Muhammad Nizam Bin Dermawi, (2010). *Development of User Interface for Dual Motor Speed and Direction Control*. Bachelor's Degree. UniversitiTeknologi Malaysia, Skudai.

[5] Amir Faizi and Shailendra Kumar, (2007). *DC motor control using Chopper*.Bachelor's Degree, IEEE.

[6] Muhammad Hafizuddin Bin Abdul Ghafar, (2010). *Smart Car part III: Servomotor and Motor Driver*. Bachelor's Degree. UniversitiTeknologi Malaysia, Skudai.

[7] Nur Fadzilah Binti Othman, (2008). *PIC Based DC motor Controller*. Bachelor's Degree. UniversitiTeknologi Malaysia, Skudai.

[8] Muhammad Bin Hassan, (2011). *Development of PID Controller Using Matlab Software for Controlling Speed of DC Motor*. Bachelor's Degree. Universiti Malaysia Pahang.

[9] Nur Iznie Afrah Binti Mohd Isa, (2008). *DC Motor Controller Using Linear Quadratic Regulator (LQR) Algorithm Implementation on PIC*. Bachelor's Degree. Universiti Malaysia Pahang.

[10] Muhammad H.Rashid, (2001). *Power Electronics Handbook*.Academic Press.

[11] Abu Zaharin Bin Ahmad, (2004). *A New Intelligent In-Series DC Motor Controller*. Master Thesis. UniversitiTeknologi Mara.

[12] Daniel J. Shanefield, (2001). *Industrial Electronics for Engineers, Chemists, and Technicians, with Optional Lab Experiments*: William Andrew Publishing.

[13] Dogan Ibrahim. (2006). *PIC Basic Projects,30 Projects using PIC basic Pro*:Newnes.

[14] Guillem Arimany, (2011). *Radio Frequency communication for Modular Robots.* Master Thesis. University of Southern Denmark.

[15] Joshua S. Gans, Stephen P. King and Julian Wright, (2002). *Handbook of Telecommunications Economics*, "*Wireless Communications', Volume 2.*

[16] Roshni Uppala, (2012). *Wireless Speed and Direction Control of DC Motor using RF Technology.* Bachelor's Degree. Gitam University.

[17] Thian Nyuk How, (2009). *Implementing Wireless Remote Control Using Radio Frequency Module*. Primetech Electronics.

[18] Osman Turkkan, (2008*). Development of A Wireless Transmission Module*. Degree of Master of Science. Atilim University.

[19] Afifah Binti Taat, (2010). *Wireless Water Meter System*. Bachelor's Degree. UniversitiTeknologi Malaysia.

[20] Abdul Aziz Bin Abdul Rahman, (2010). *The Wireless Forklift*. Bachelor's Degree. UniversitiTeknologi Malaysia.

APPENDICES

APENDIX A

Transmitting side

```
#include <18f4550.h>
#fuses hs, noprotect, nowdt
#use rs232(baud=4800,xmit=PIN_C6,rcv=PIN_C7,PARITY=N) //set rf data speed
#include <lcd.c>
#byte PORTA=5 //define PORT A address
#byte PORTC=7 //define PORT C address
#byte PORTE=9 //define PORT E address

void main()
{
  int txdata=0;
  int count;
  int mysend=0;
  int bt;
  int bt1=0;
  int bt2=0;
  int bt3=0;
  int bt4=0;
  int bt5=0;
  int bt6=0;

  //set i/o for each pin
  set_tris_a(0b00000000);
  set_tris_b(0b11110000);
  set_tris_d(0b00000000);
  set_tris_e(0b00000000);
  lcd_init () ;
```

```
lcd_gotoxy (1,1);
lcd_putc("\fPWM & Motor\nDirection");

do
{
  if(input(pin_b0)==0) //if start button pressed
  {
    txdata='a';
  }
  else if(input(pin_b0)==1)  //if start button released
  {
    bt1=0;
  }

  if(input(pin_b1)==0) //if stop button pressed
  {
    txdata='b';
  }
  else if(input(pin_b1)==1)  //if stop button released
  {
    bt2=0;
  }

  if(input(pin_b2)==0) //if forward up button pressed
  {
    txdata='c';
  }
  else if(input(pin_b2)==1)  //if forward up button released
  {
    bt3=0;
  }

  if(input(pin_b3)==0) //if forward down button pressed
  {
```

```
  txdata='d';
}
else if(input(pin_b3)==1)  //if forward down  button released
{
  bt4=0;
}
if(input(pin_b4)==0) //if reverse up button pressed
{
  txdata='e';
}
else if(input(pin_b4)==1)  //if reverse up button released
{
  bt5=0;
}
if(input(pin_b5)==0) //if reverse down button pressed
{
  txdata='f';
}
else if(input(pin_b5)==1)  //if reverse down button released
{
  bt6=0;
}
bt=bt1+bt2+bt3+bt4+bt5+bt6;  //total up all button state
if(bt==0)   //if no button pressed
{
}
else
{

}     {
  for(count=0;count<20;count++)
  {
    putc('(');
    putc(txdata);
```

Receiving side

```
#include <18f452.h>
#fuses hs, noprotect, nowdt , brownout //default setting
#use rs232(baud=4800,xmit=PIN_C6,rcv=PIN_C7,PARITY=N) //set rf data speed
#include <lcd.c>
#byte PORTA=5  //port a address
#byte PORTB=6  //port b address
#byte PORTC=7  //port c address
#byte PORTE=9  //port e address
#define MOTOR_FOR PIN_C4
#define MOTOR_REV PIN_C5
int overflow_countRPM;
float period=0;
float sRPM=0;
void TIMER1_isr (void);
#INT_CCP1
void CCP1_isr(void)
{
end_timeRPM = (int32)CCP_1;
period = ((int32)0x10000 * (int32)overflow_countRPM) - (int32)start_timeRPM + (int32)end_timeRPM; //formula for capture 0.32sec
}
byte s=0;
int a=0;
int b=0;
void motor1_stop();
void main()
{
  set_tris_a(0b00000000);
  set_tris_b(0b00000000);
  set_tris_c(0b10000000);
  set_tris_d(0b00000000);
  set_tris_e(0b00000000);
```

```
setup_timer_1 (T1_INTERNAL|T1_DIV_BY_1);
setup_ccp1 (CCP_CAPTURE_RE);
disable_interrupts(GLOBAL);
lcd_init () ;
lcd_gotoxy (1,1);
lcd_putc("\fPWM & Motor\nDirection");
setup_timer_2 (T2_DIV_BY_4,254,1);
setup_ccp2 (ccp_pwm);
output_low(pin_b0);
delay_ms(1000);
output_high(pin_b0);
do
{
output_low(pin_b0);
delay_ms(250);
output_high(pin_b0);
delay_ms(250);
  if(rx_detect==1)
  {
    rx_detect=0;
    delay_ms(200);
    if(receive=='a')  //start
    {
    lcd_gotoxy(1,1);
    printf(lcd_putc, "\fSTART" );  //start
    s=175;
    output_high (MOTOR_FOR);
    output_low (MOTOR_REV);
    set_pwm2_duty (s);
    delay_ms(100);
    }
    else if(receive=='b')   //stop
    {
    lcd_gotoxy(1,1);
```

```
printf(lcd_putc, "\fSTOP" );
s=0;
output_low (MOTOR_REV);
output_low (MOTOR_FOR);
set_pwm2_duty (s);
delay_ms(100);
}
else if(receive=='c')   //forward up
{
if (s==215)
{
}
else
{
s += 8;
lcd_gotoxy(1,1);
printf(lcd_putc, "\fFoward PWM=%u" ,s);
output_high(MOTOR_FOR);
output_low (MOTOR_REV) ;
set_pwm2_duty (s);
delay_ms(100);
}
}
else if(receive=='d')   //forward down
  {
  if (s==175)
  {
  else
  s -= 8;
  lcd_gotoxy(1,1);
  printf(lcd_putc, "\fFoward PWM=%u" ,s);
  output_high(MOTOR_FOR);
  output_low (MOTOR_REV) ;
  set_pwm2_duty (s);
```

```
        delay_ms(100);
      else if(receive=='e')   //reverse up
        if (s==215)
          else
        s+=8;
        lcd_gotoxy(1,1);
        printf(lcd_putc, "\fReverse PWM=%u" ,s);
        output_low(MOTOR_FOR);
        output_high (MOTOR_REV) ;
        set_pwm2_duty (s);
        delay_ms(100);
      }
      else if (receive=='f')  //reverse down
      else
      {
      s-=8;
      lcd_gotoxy(1,1);
      printf(lcd_putc, "\fReverse PWM=%u" ,s);
      output_low(MOTOR_FOR);
      output_high (MOTOR_REV) ;
      set_pwm2_duty (s);
      delay_ms(100);
     if (sRPM>=350)
 lcd_gotoxy(1,1);
 printf(lcd_putc,"\nShaft RPM= %.1f",sRPM);
 delay_ms(100);
else
sRPM=0;
 lcd_gotoxy(1,1);
 printf(lcd_putc,"\nShaft RPM= %.1f",sRPM);
 delay_ms(100);
```

APPENDIX B

MICROCHIP

PIC18FXX2

28/40-pin High Performance, Enhanced FLASH Microcontrollers with 10-Bit A/D

High Performance RISC CPU:

- C compiler optimized architecture/instruction set
  - Source code compatible with the PIC16 and PIC17 instruction sets
- Linear program memory addressing to 32 Kbytes
- Linear data memory addressing to 1.5 Kbytes

Device	On-Chip Program Memory		On-Chip RAM (bytes)	Data EEPROM (bytes)
	FLASH (bytes)	# Single Word Instructions		
PIC18F242	16K	8192	768	256
PIC18F252	32K	16384	1536	256
PIC18F442	16K	8192	768	256
PIC18F452	32K	16384	1536	256

- Up to 10 MIPs operation:
  - DC - 40 MHz osc./clock input
  - 4 MHz - 10 MHz osc./clock input with PLL active
- 16-bit wide instructions, 8-bit wide data path
- Priority levels for interrupts
- 8 x 8 Single Cycle Hardware Multiplier

Peripheral Features:

- High current sink/source 25 mA/25 mA
- Three external interrupt pins
- Timer0 module: 8-bit/16-bit timer/counter with 8-bit programmable prescaler
- Timer1 module: 16-bit timer/counter
- Timer2 module: 8-bit timer/counter with 8-bit period register (time-base for PWM)
- Timer3 module: 16-bit timer/counter
- Secondary oscillator clock option - Timer1/Timer3
- Two Capture/Compare/PWM (CCP) modules. CCP pins that can be configured as:
  - Capture input: capture is 16-bit, max. resolution 6.25 ns (TCY/16)
  - Compare is 16-bit, max. resolution 100 ns (TCY)
  - PWM output: PWM resolution is 1- to 10-bit, max. PWM freq. @: 8-bit resolution = 156 kHz
    10-bit resolution = 39 kHz
- Master Synchronous Serial Port (MSSP) module, Two modes of operation:
  - 3-wire SPI™ (supports all 4 SPI modes)
  - I^2C™ Master and Slave mode

Peripheral Features (Continued):

- Addressable USART module:
  - Supports RS-485 and RS-232
- Parallel Slave Port (PSP) module

Analog Features:

- Compatible 10-bit Analog-to-Digital Converter module (A/D) with:
  - Fast sampling rate
  - Conversion available during SLEEP
  - Linearity ≤ 1 LSb
- Programmable Low Voltage Detection (PLVD)
  - Supports interrupt on-Low Voltage Detection
- Programmable Brown-out Reset (BOR)

Special Microcontroller Features:

- 100,000 erase/write cycle Enhanced FLASH program memory typical
- 1,000,000 erase/write cycle Data EEPROM memory
- FLASH/Data EEPROM Retention: > 40 years
- Self-reprogrammable under software control
- Power-on Reset (POR), Power-up Timer (PWRT) and Oscillator Start-up Timer (OST)
- Watchdog Timer (WDT) with its own On-Chip RC Oscillator for reliable operation
- Programmable code protection
- Power saving SLEEP mode
- Selectable oscillator options including:
  - 4X Phase Lock Loop (of primary oscillator)
  - Secondary Oscillator (32 kHz) clock input
- Single supply 5V In-Circuit Serial Programming™ (ICSP™) via two pins
- In-Circuit Debug (ICD) via two pins

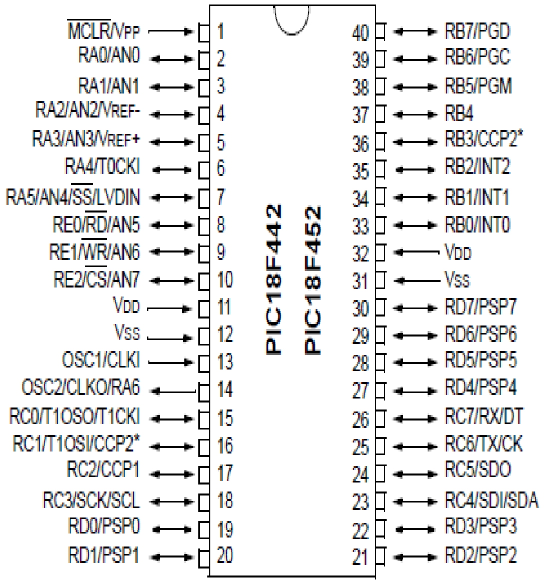
CMOS Technology:

- Low power, high speed FLASH/EEPROM technology
- Fully static design
- Wide operating voltage range (2.0V to 5.5V)
- Industrial and Extended temperature ranges
- Low power consumption:
  - < 1.6 mA typical @ 5V, 4 MHz
  - 25 µA typical @ 3V, 32 kHz
  - < 0.2 µA typical standby current

PIC18FXX2

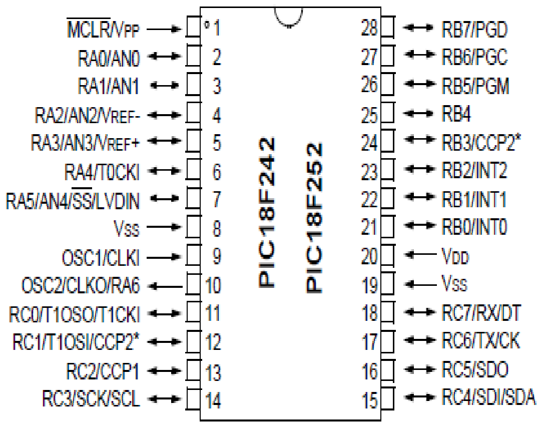
Pin Diagrams (Cont.'d)

DIP



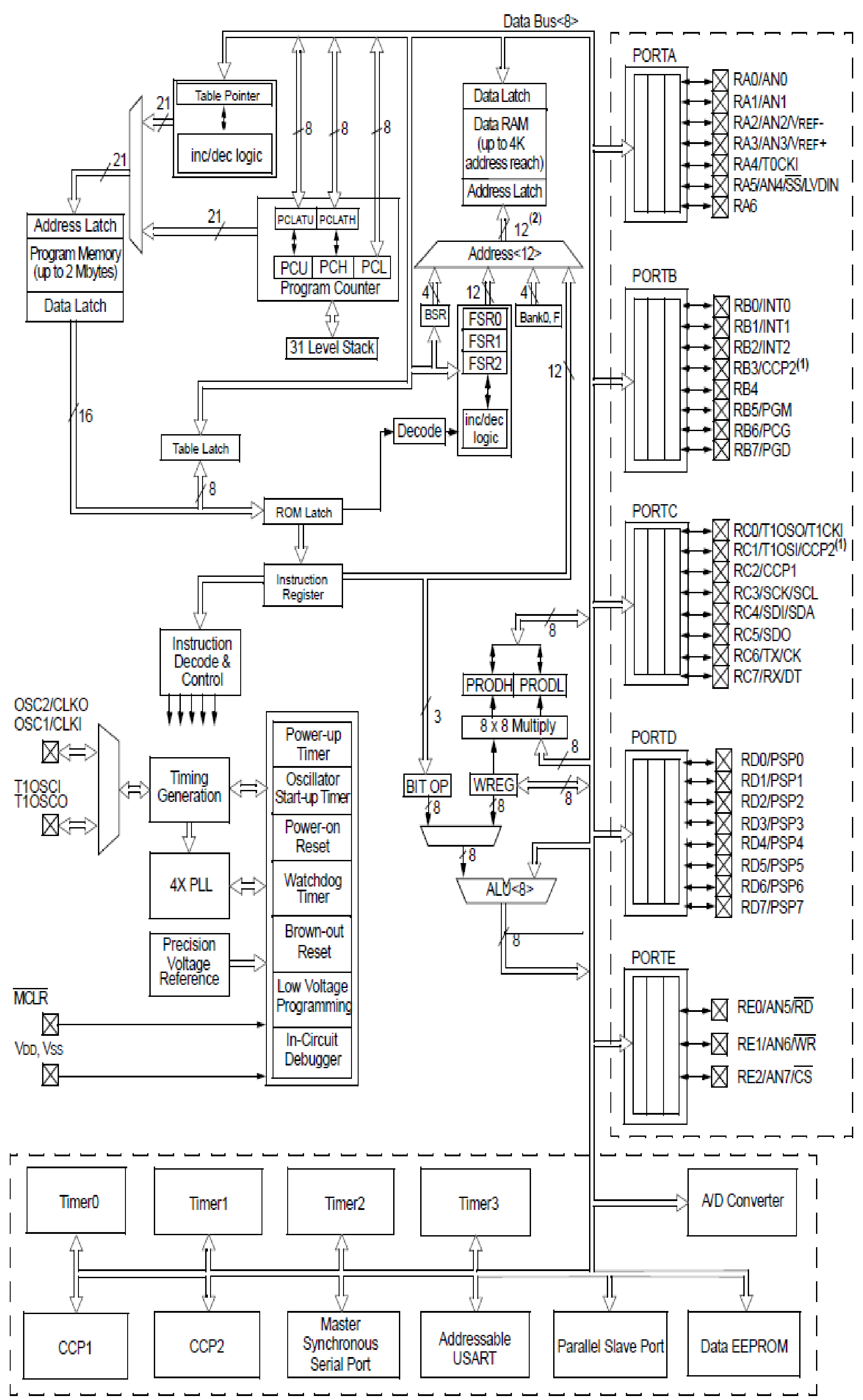
Note: Pin compatible with 40-pin PIC16C7X devices.

DIP, SOIC



* RB3 is the alternate pin for the CCP2 pin multiplexing.

FIGURE 1-2: PIC18F4X2 BLOCK DIAGRAM



Note
1: Optional multiplexing of CCP2 input/output with RB3 is enabled by selection of configuration bit.
2: The high order bits of the Direct Address for the RAM are from the BSR register (except for the `MOVFF` instruction).
3: Many of the general purpose I/O pins are multiplexed with one or more peripheral module functions. The multiplexing combinations are device dependent.

2.0 OSCILLATOR CONFIGURATIONS

2.1 Oscillator Types

The PIC18FXX2 can be operated in eight different Oscillator modes. The user can program three configuration bits (FOSC2, FOSC1, and FOSC0) to select one of these eight modes:

1. LP Low Power Crystal
2. XT Crystal/Resonator
3. HS High Speed Crystal/Resonator
4. HS + PLL High Speed Crystal/Resonator with PLL enabled
5. RC External Resistor/Capacitor
6. RCIO External Resistor/Capacitor with I/O pin enabled
7. EC External Clock
8. ECIO External Clock with I/O pin enabled

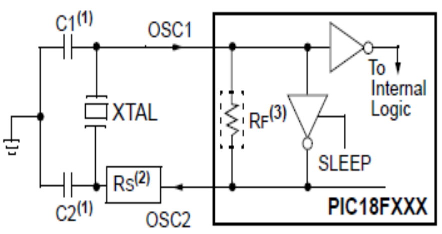
2.2 Crystal Oscillator/Ceramic Resonators

In XT, LP, HS or HS+PLL Oscillator modes, a crystal or ceramic resonator is connected to the OSC1 and OSC2 pins to establish oscillation. Figure 2-1 shows the pin connections.

The PIC18FXX2 oscillator design requires the use of a parallel cut crystal.

Note: Use of a series cut crystal may give a frequency out of the crystal manufacturers specifications.

FIGURE 2-1: CRYSTAL/CERAMIC RESONATOR OPERATION (HS, XT OR LP CONFIGURATION)



Note 1: See Table 2-1 and Table 2-2 for recommended values of C1 and C2.

2: A series resistor (RS) may be required for AT strip cut crystals.

3: RF varies with the Oscillator mode chosen.

TABLE 2-1: CAPACITOR SELECTION FOR CERAMIC RESONATORS

Ranges Tested:			
Mode	**Freq**	**C1**	**C2**
XT	455 kHz 2.0 MHz 4.0 MHz	68 - 100 pF 15 - 68 pF 15 - 68 pF	68 - 100 pF 15 - 68 pF 15 - 68 pF
HS	8.0 MHz 16.0 MHz	10 - 68 pF 10 - 22 pF	10 - 68 pF 10 - 22 pF
These values are for design guidance only. See notes following this table.			
Resonators Used:			
455 kHz	Panasonic EFO-A455K04B	± 0.3%	
2.0 MHz	Murata Erie CSA2.00MG	± 0.5%	
4.0 MHz	Murata Erie CSA4.00MG	± 0.5%	
8.0 MHz	Murata Erie CSA8.00MT	± 0.5%	
16.0 MHz	Murata Erie CSA16.00MX	± 0.5%	
All resonators used did not have built-in capacitors.			

Note 1: Higher capacitance increases the stability of the oscillator, but also increases the start-up time.

2: When operating below 3V VDD, or when using certain ceramic resonators at any voltage, it may be necessary to use high-gain HS mode, try a lower frequency resonator, or switch to a crystal oscillator.

3: Since each resonator/crystal has its own characteristics, the user should consult the resonator/crystal manufacturer for appropriate values of external components, or verify oscillator performance.

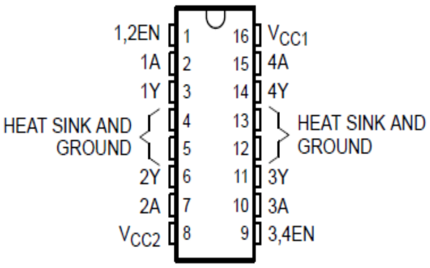
APPENDIX C

L293, L293D
QUADRUPLE HALF-H DRIVERS

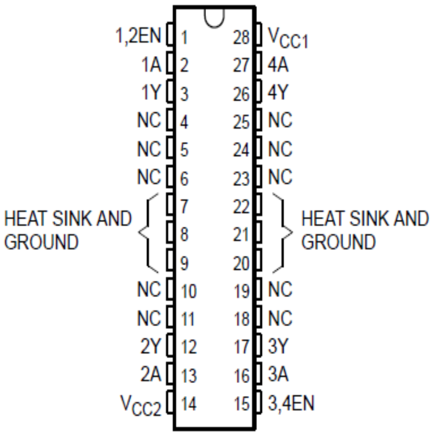
SLRS008B – SEPTEMBER 1986 – REVISED JUNE 2002

- **Featuring Unitrode L293 and L293D Products Now From Texas Instruments**
- **Wide Supply-Voltage Range: 4.5 V to 36 V**
- **Separate Input-Logic Supply**
- **Internal ESD Protection**
- **Thermal Shutdown**
- **High-Noise-Immunity Inputs**
- **Functional Replacements for SGS L293 and SGS L293D**
- **Output Current 1 A Per Channel (600 mA for L293D)**
- **Peak Output Current 2 A Per Channel (1.2 A for L293D)**
- **Output Clamp Diodes for Inductive Transient Suppression (L293D)**

N, NE PACKAGE
(TOP VIEW)



DWP PACKAGE
(TOP VIEW)



description

The L293 and L293D are quadruple high-current half-H drivers. The L293 is designed to provide bidirectional drive currents of up to 1 A at voltages from 4.5 V to 36 V. The L293D is designed to provide bidirectional drive currents of up to 600-mA at voltages from 4.5 V to 36 V. Both devices are designed to drive inductive loads such as relays, solenoids, dc and bipolar stepping motors, as well as other high-current/high-voltage loads in positive-supply applications.

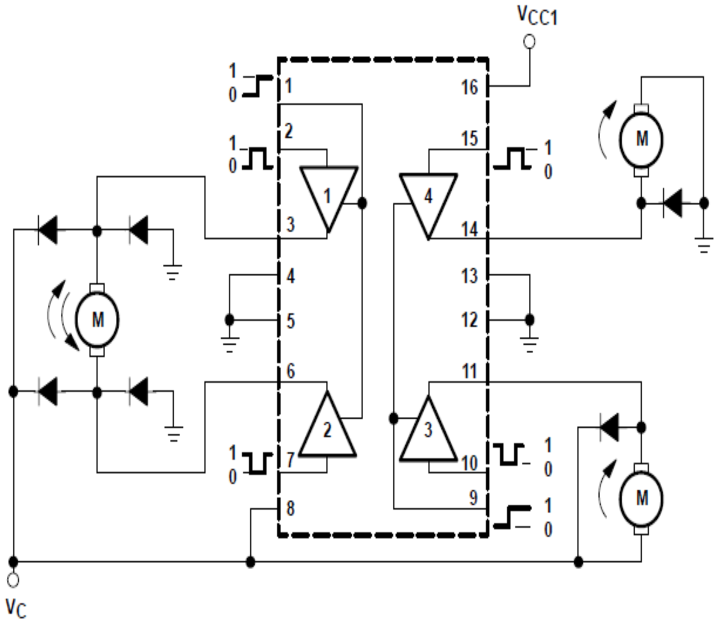
All inputs are TTL compatible. Each output is a complete totem-pole drive circuit, with a Darlington transistor sink and a pseudo-Darlington source. Drivers are enabled in pairs, with drivers 1 and 2 enabled by 1,2EN and drivers 3 and 4 enabled by 3,4EN. When an enable input is high, the associated drivers are enabled and their outputs are active and in phase with their inputs. When the enable input is low, those drivers are disabled and their outputs are off and in the high-impedance state. With the proper data inputs, each pair of drivers forms a full-H (or bridge) reversible drive suitable for solenoid or motor applications.

On the L293, external high-speed output clamp diodes should be used for inductive transient suppression.

A V_{CC1} terminal, separate from V_{CC2}, is provided for the logic inputs to minimize device power dissipation.

The L293and L293D are characterized for operation from 0°C to 70°C.

block diagram



NOTE: Output diodes are internal in L293D.

TEXAS INSTRUMENTS
AVAILABLE OPTIONS

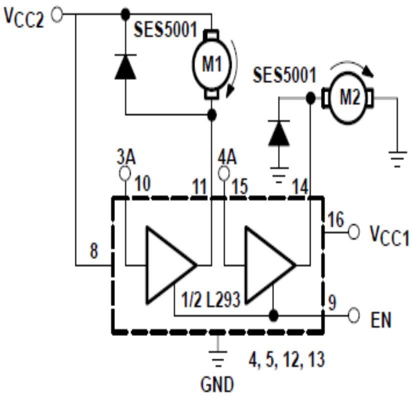
T_A	PACKAGE
	PLASTIC DIP (NE)
0°C to 70°C	L293NE L293DNE

Unitrode Products from Texas Instruments
AVAILABLE OPTIONS

T_A	PACKAGED DEVICES	
	SMALL OUTLINE (DWP)	PLASTIC DIP (N)
0°C to 70°C	L293DWP L293DDWP	L293N L293DN

The DWP package is available taped and reeled. Add the suffix TR to device type (e.g., L293DWPTR).

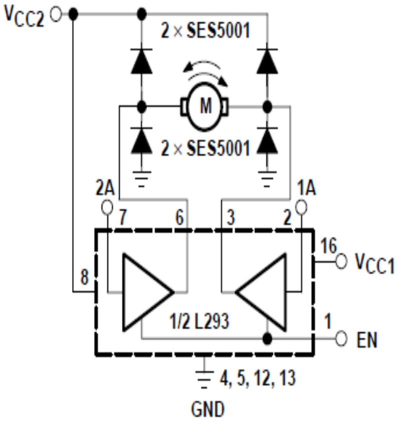
APPLICATION INFORMATION



EN	3A	M1	4A	M2
H	H	Fast motor stop	H	Run
H	L	Run	L	Fast motor stop
L	X	Free-running motor stop	X	Free-running motor stop

L = low, H = high, X = don't care

Figure 4. DC Motor Controls (connections to ground and to supply voltage)



EN	1A	2A	FUNCTION
H	L	H	Turn right
H	H	L	Turn left
H	L	L	Fast motor stop
H	H	H	Fast motor stop
L	X	X	Fast motor stop

L = low, H = high, X = don't care

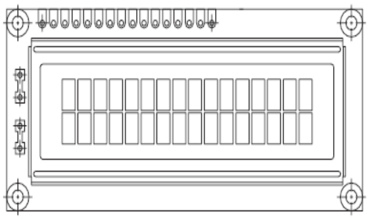
Figure 5. Bidirectional DC Motor Control

APPENDIX D

LCD-016M002B

Vishay

16 x 2 Character LCD



FEATURES

- 5 x 8 dots with cursor
- Built-in controller (KS 0066 or Equivalent)
- + 5V power supply (Also available for + 3V)
- 1/16 duty cycle
- B/L to be driven by pin 1, pin 2 or pin 15, pin 16 or A.K (LED)
- N.V. optional for + 3V power supply

MECHANICAL DATA

ITEM	STANDARD VALUE	UNIT
Module Dimension	80.0 x 36.0	mm
Viewing Area	66.0 x 16.0	mm
Dot Size	0.56 x 0.66	mm
Character Size	2.96 x 5.56	mm

ABSOLUTE MAXIMUM RATING

ITEM	SYMBOL	STANDARD VALUE			UNIT
		MIN.	TYP.	MAX.	
Power Supply	VDD-VSS	- 0.3	–	7.0	V
Input Voltage	VI	- 0.3	–	VDD	V

NOTE: VSS = 0 Volt, VDD = 5.0 Volt

ELECTRICAL SPECIFICATIONS

ITEM	SYMBOL	CONDITION		STANDARD VALUE			UNIT
				MIN.	TYP.	MAX.	
Input Voltage	VDD	VDD = + 5V		4.7	5.0	5.3	V
		VDD = + 3V		2.7	3.0	5.3	V
Supply Current	IDD	VDD = 5V		–	1.2	3.0	mA
Recommended LC Driving Voltage for Normal Temp. Version Module	VDD - V0	- 20 °C		–	–	–	V
		0°C		4.2	4.8	5.1	
		25°C		3.8	4.2	4.6	
		50°C		3.6	4.0	4.4	
		70°C		–	–	–	
LED Forward Voltage	VF	25°C		–	4.2	4.6	V
LED Forward Current	IF	25°C	Array	–	130	260	mA
			Edge	–	20	40	
EL Power Supply Current	IEL	Vel = 110VAC:400Hz		–	–	5.0	mA

DISPLAY CHARACTER ADDRESS CODE:

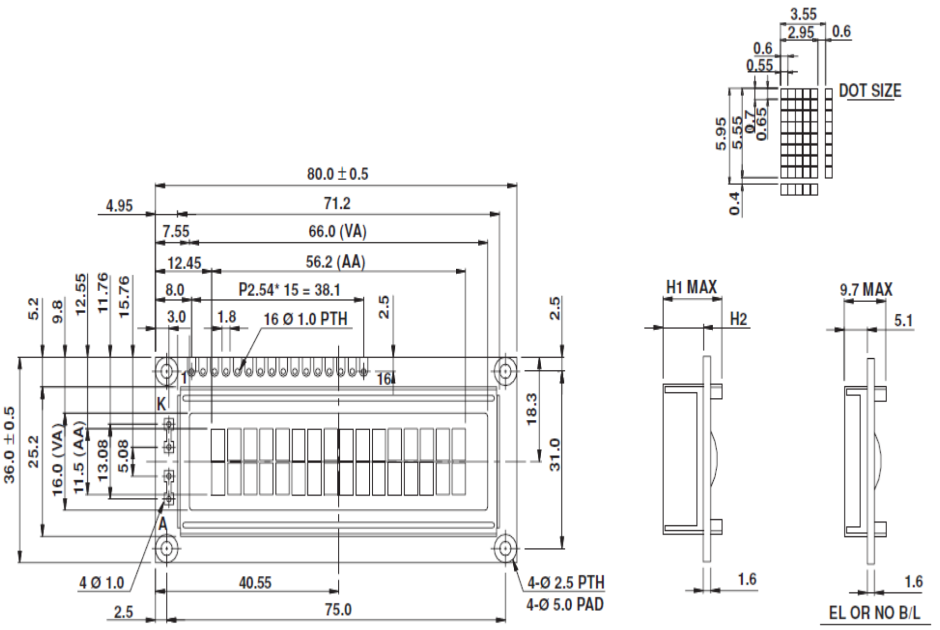
Display Position	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
DD RAM Address	00	01														0F
DD RAM Address	40	41														4F

LCD-016M002B

Vishay 16 x 2 Character LCD

PIN NUMBER	SYMBOL	FUNCTION
1	Vss	GND
2	Vdd	+ 3V or + 5V
3	Vo	Contrast Adjustment
4	RS	H/L Register Select Signal
5	R/$\overline{W}$	H/L Read/Write Signal
6	E	H →L Enable Signal
7	DB0	H/L Data Bus Line
8	DB1	H/L Data Bus Line
9	DB2	H/L Data Bus Line
10	DB3	H/L Data Bus Line
11	DB4	H/L Data Bus Line
12	DB5	H/L Data Bus Line
13	DB6	H/L Data Bus Line
14	DB7	H/L Data Bus Line
15	A/Vee	+ 4.2V for LED/Negative Voltage Output
16	K	Power Supply for B/L (OV)

DIMENSIONS in millimeters



LED - H/L B/L		
	HIGH	LOW
H1	13.2	12.1
H2	8.6	7.5

For Technical Questions, Contact: Displays@Vishay.com

Document Number: 37217
Revision 01-Oct-02

APPENDIX E

MICROCHIP **PIC18F2455/2550/4455/4550**

28/40/44-Pin, High-Performance, Enhanced Flash, USB Microcontrollers with nanoWatt Technology

Universal Serial Bus Features:

- USB V2.0 Compliant
- Low Speed (1.5 Mb/s) and Full Speed (12 Mb/s)
- Supports Control, Interrupt, Isochronous and Bulk Transfers
- Supports up to 32 Endpoints (16 bidirectional)
- 1-Kbyte Dual Access RAM for USB
- On-Chip USB Transceiver with On-Chip Voltage Regulator
- Interface for Off-Chip USB Transceiver
- Streaming Parallel Port (SPP) for USB streaming transfers (40/44-pin devices only)

Power-Managed Modes:

- Run: CPU on, peripherals on
- Idle: CPU off, peripherals on
- Sleep: CPU off, peripherals off
- Idle mode currents down to 5.8 μA typical
- Sleep mode currents down to 0.1 μA typical
- Timer1 Oscillator: 1.1 μA typical, 32 kHz, 2V
- Watchdog Timer: 2.1 μA typical
- Two-Speed Oscillator Start-up

Flexible Oscillator Structure:

- Four Crystal modes, including High Precision PLL for USB
- Two External Clock modes, up to 48 MHz
- Internal Oscillator Block:
  - 8 user-selectable frequencies, from 31 kHz to 8 MHz
  - User-tunable to compensate for frequency drift
- Secondary Oscillator using Timer1 @ 32 kHz
- Dual Oscillator options allow microcontroller and USB module to run at different clock speeds
- Fail-Safe Clock Monitor:
  - Allows for safe shutdown if any clock stops

Peripheral Highlights:

- High-Current Sink/Source: 25 mA/25 mA
- Three External Interrupts
- Four Timer modules (Timer0 to Timer3)
- Up to 2 Capture/Compare/PWM (CCP) modules:
  - Capture is 16-bit, max. resolution 5.2 ns ($T_{CY}/16$)
  - Compare is 16-bit, max. resolution 83.3 ns (T_{CY})
  - PWM output: PWM resolution is 1 to 10-bit
- Enhanced Capture/Compare/PWM (ECCP) module:
  - Multiple output modes
  - Selectable polarity
  - Programmable dead time
  - Auto-shutdown and auto-restart
- Enhanced USART module:
  - LIN bus support
- Master Synchronous Serial Port (MSSP) module supporting 3-wire SPI (all 4 modes) and I^2C™ Master and Slave modes
- 10-bit, up to 13-channel Analog-to-Digital Converter module (A/D) with Programmable Acquisition Time
- Dual Analog Comparators with Input Multiplexing

Special Microcontroller Features:

- C Compiler Optimized Architecture with optional Extended Instruction Set
- 100,000 Erase/Write Cycle Enhanced Flash Program Memory typical
- 1,000,000 Erase/Write Cycle Data EEPROM Memory typical
- Flash/Data EEPROM Retention: > 40 years
- Self-Programmable under Software Control
- Priority Levels for Interrupts
- 8 x 8 Single-Cycle Hardware Multiplier
- Extended Watchdog Timer (WDT):
  - Programmable period from 41 ms to 131s
- Programmable Code Protection
- Single-Supply 5V In-Circuit Serial Programming™ (ICSP™) via two pins
- In-Circuit Debug (ICD) via two pins
- Optional dedicated ICD/ICSP port (44-pin devices only)
- Wide Operating Voltage Range (2.0V to 5.5V)

Device	Program Memory		Data Memory		I/O	10-Bit A/D (ch)	CCP/ECCP (PWM)	SPP	MSSP		EAUSART	Comparators	Timers 8/16-Bit
	Flash (bytes)	# Single-Word Instructions	SRAM (bytes)	EEPROM (bytes)					SPI	Master I^2C™			
PIC18F2455	24K	12288	2048	256	24	10	2/0	No	Y	Y	1	2	1/3
PIC18F2550	32K	16384	2048	256	24	10	2/0	No	Y	Y	1	2	1/3
PIC18F4455	24K	12288	2048	256	35	13	1/1	Yes	Y	Y	1	2	1/3
PIC18F4550	32K	16384	2048	256	35	13	1/1	Yes	Y	Y	1	2	1/3

FIGURE 2-1: PIC18F2455/2550/4455/4550 CLOCK DIAGRAM