UNIVERSITI MALAYSIA PAHANG

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JUDUL: **ADJUSTABLE CLOSED-LOOP DC MOTOR SPEED CONTROLLER**

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ADJUSTABLE CLOSED-LOOP DC MOTOR SPEED CONTROLLER

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Submitted to the Faculty of Electrical Engineering
in partial fulfillment of the requirement for the degree of
Bachelor in Electrical Engineering (Power System)

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I declare that this thesis entitled "Adjustable Closed-loop DC Motor Speed Controller" is the result of my own research

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ABSTRACT

The speed control of DC motors is very crucial in applications where the importance of precision and protection. Purpose of a motor speed controller is to take a signal representing the required speed and to drive a motor at that speed. Micro controller can provide easy control of DC motor. This project is about speed control system of DC motor by using micro controller and it is a closed-loop control system. Pulse Width Modulation (PWM) technique is used where its signal is generated in microcontroller which is the signal will send to motor driver to vary the voltage supply to control motor speed.

ABSTRAK

Kawalan kelajuan motor DC adalah sangat penting dalam aplikasi di mana kepentingan ketepatan dan perlindungan. Tujuan pengawal kelajuan motor adalah untuk mengambil isyarat yang mewakili kelajuan yang diperlukan dan untuk memacu motor pada kelajuan itu. Mikro pengawal boleh menyediakan kawalan mudah motor DC. Projek ini adalah mengenai sistem kawalan kelajuan motor DC dengan menggunakan pengawal mikro dan ia adalah satu sistem kawalan gelung tertutup. Pulse Width Modulation (PWM) teknik digunakan di mana isyarat yang dijana dalam mikropengawal yang merupakan isyarat akan menghantar pemacu motor untuk mengubah voltan bekalan untuk mengawal kelajuan motor.

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LIST OF SYMBOLS

K_E	-	A constant based on motor construction
Ø	-	Magnetic flux
f_{out}	-	Frequency of output waveform
rpm	-	Rotation per unit
V_{ave}	-	Average voltage supply to DC motor
t_{on}	-	Time ON of switch
T	-	Period

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

A direct current (DC) motor is an electromechanical device that converts DC electrical energy into mechanical energy. When direct current is applied to the motor, it produces a mechanical rotary action of the motor's shaft which connected to a machine or other mechanical device to perform some sort of work. In other words, the DC motor converts electric power into mechanical works.

Direct current motors have variable characteristics and are used in variable-speed drives. DC motor is possible to obtain speed control over wide range and it is also can provide a high starting torque. DC motors are used for many applications in industry. Some of the application where the load on the DC motor varies over a speed range and may demand high speed control accuracy and good dynamic responses. It is very important to make a controller to control the speed of DC motor in desired speed

. Nowadays in this modern technology the control of DC motor is a common practice so that it makes the implementation of DC motor of controller speed is important. DC motor is widely used in speed control system in many applications which needs high control requirement such as rolling mill, fuel pump control and double-hulled tanker. Thus, it is very important to control the speed to achieve good production and also it is more precise and reliable.

1.2 OBJECTIVE

The objectives of this project are:

i. To control the adjustable closed-loop of DC motor speed by using micro controller.

ii. To vary the speed of DC motor by using Pulse Width Modulation technique.

1.3 SCOPE OF PROJECT

The scopes of this project are:

i. Design an adjustable speed control system of DC motor by using micro controller.

ii. Build hardware for the system.

iii. Programming of micro controller for the system.

1.4 PROBLEM STATEMENT

DC motor plays an important role in modern industrial. There are some types of applications need the load on the DC motor varies a speed range. These applications may demand high-speed control accuracy and good dynamic response. Besides, manual controller is also not practical in modern era which can waste time and cost. Regarding to this situation it is important to make a controller to control the speed of DC motor which user can monitor their system at certain place rather than going to the plant. Furthermore this system is more precise and reliable.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter includes the study of DC motor, closed-loop system and Pulse Width Modulation (PWM). Besides, it also a brief discuss about microcontroller.

2.2 DC motor

Direct current (DC) motor is widely used in many industrial applications. The torque/speed characteristics of DC motor is compatible with most mechanical loads. DC motor speed control methods are simpler and less expensive than other types of motors and speed control over a large range rated is easy to achieve [1]

There are many types of DC motor. Table 2.1 listed the information of DC motor with their advantages and disadvantages [2].

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

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

2.3 Closed-loop control system

Closed-loop control system is the system that self-regulating and eliminate many of the disadvantages, such as sensitivity to disturbances and disable to correct these disturbances that occur in open-loop control system [3]. In the other words, this control system is one in which an input forcing function. Measurement response of a physical system is compared with a desired response. The difference or error between this two responses initiates actions that will result in the actual response to achieve the desired response. The difference signal usually is processed by another physical system such as compensator, a controller or a filter for real-time control system applications [4]. A closed-loop block diagram is shown in Figure 2.1.

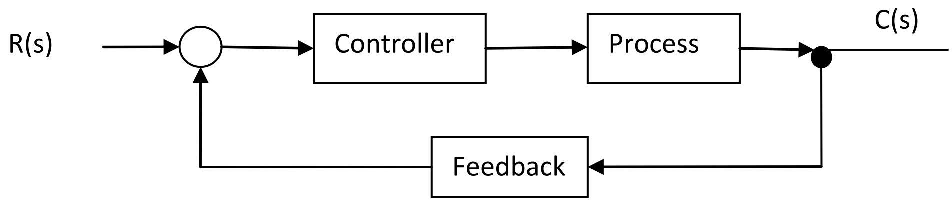

Figure 2.1: Closed-loop control system [4].

Based on the Figure 2.1 a feedback component is applied together with the input R. The difference between the input and feedback signal is applied to the controller. Then, the controller acts on the process forcing C to change in the direction that will reduce the difference between the input signal and the feedback component according to this difference. Thus, it will reduce the input to the process and result in a smaller change in C. This event will be continuing until a time is reached when C approximately equal to R [3].

2.4 Speed Measurement by Using Tachometer

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

The magnitude of the EMF is given by [5],

$$EMF = K_E \varphi N \qquad (2.1)$$

Where K_E = a constant based on motor construction

φ = magnetic flux

N = speed of motor (in rpm)

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

$$N = \frac{EMF}{K_E Ø} \qquad (2.2)$$

Thus, the relationship between motor speed and EMF is the motor speed is directly proportional to the EMF voltage and inversely proportional to the field flux. When the EMF measured is increase, the speed of the motor is also increases with the gain for DC motor. So, the speed can be measured by using tachometer by measuring the back EMF.

2.5 Speed Measurement by Using Optical Encoder

By using an optical encoder is the best way to measure speed. It shines a beam of light from a small space around the transmitter and receiver to detect the other end. If the disc is placed in the space, which has slots cut into it, then the signal will be detected only when the slot is between the transmitter and receiver [6]. Figure 2.2 is the example of a disc.

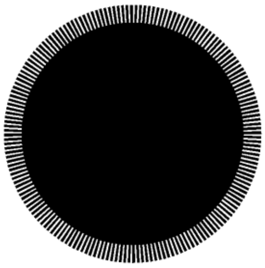

Figure 2.2: Sample disc of encoder

The encoder transmitter must be supplied with a suitable current and the receiver biased. This will have a +5 V output when the light is blocked and about 0.5 V when the light is allowed to pass through the slot in the disc [7]. The frequency of the output waveform is given by,

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

Where f_{out}= frequency of output waveform

rpm = speed in revolutions per minutes

N = number of slots at disc

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

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

2.6 Pulse Width Modulation (PWM)

Pulse Width Modulation (PWM) is a powerful technique for controlling analog circuits with a processor's digital outputs. PWM is employed in a wide variety of applications, ranging from measurement and communications to power control and conversion. By varying the average voltage sent to the motor it can make speed controller works but is quite inefficient. A better way is to switch the motor's supply on and off very quickly. The motor does not notice as if the switching is fast enough and it only notices the average effect. The PWM signals can be generated in a number of ways. Current digital technologies provide several clear advantages over the analog ones for the functions of generating the PWM switching signals and of processing the protection signals of the DC motor speed control [8].

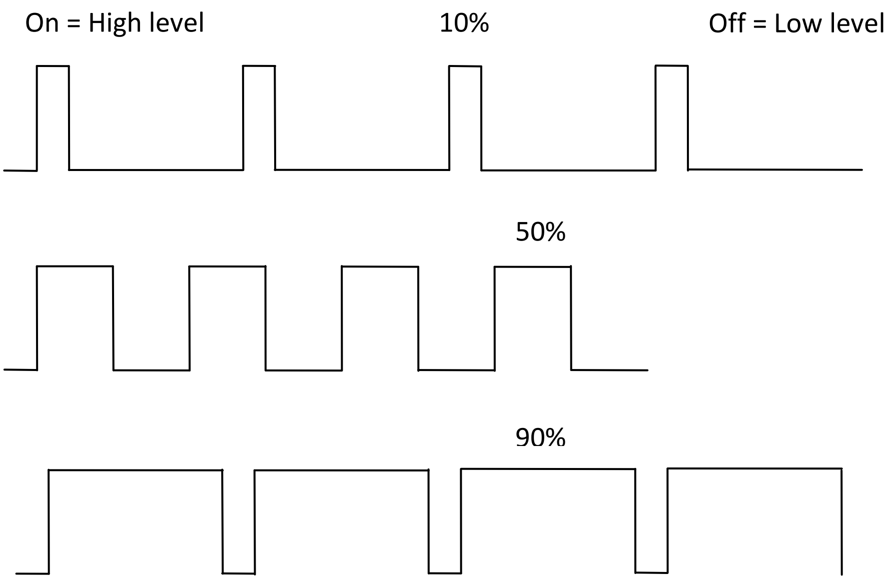

Figure 2.3: PWM signal by varying duty cycle [6].

Figure 2.3 shows three different PWM signal which is the first signal shows 10% duty cycle PWM output means that the signal is on for 10% of the period and off for 90%. Besides, the second signal show PWM output 50% and the third signal is show for 90% output signal.PWM is a way of digitally encoding analog signal levels. The duty cycle of a square wave is modulated to encode a specific analog signal level. The on-time is the time during which the DC supply is applied to the load and the off-time is the periods during which that supply is switched off.

2.6.1 Advantages and Disadvantages of PWM

The advantage of PWM is its duty cycle control technique enables greater efficiency of the DC motor. PWM switching control methods can reduce the power losses in the system and improve speed control. Besides, it will produce more torque in a motor when the pulses reach the full supply.

The disadvantages of PWM circuit are the added complexity and the possibility of generating radio frequency interference. It can give speed below the full speed and not above. Besides, it cannot be used for fast controlling speed [9].

2.6.2 Speed Control by Using PWM

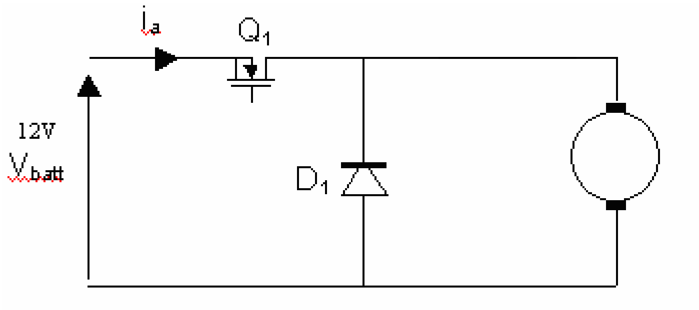

Figure 2.4: Simple motor circuit

A simple circuit that connects a battery as power supply through a switch MOSFET (Metal-Oxide-Semiconductor Field Effect Transistor) as shown in Figure 2.4. When the switch is closed, the motor sees 12 Volts, and when it is open it sees 0 Volts. If the switch is open for the same amount of time as it is closed, the motor will see an average of 6 Volts, and will run more slowly accordingly.

A MOSFET (Metal-Oxide-Semiconductor Field Effect Transistor) is a device that can turn very large currents on and off under the control of a low signal level voltage. This *on-off* switching is performed by power MOSFETs. As the amount of time that the voltage is *on* increases compared with the amount of time that it is *off*, the average speed of the motor increases and vice versa.

The average of voltage that supply to DC motor is given by,

$$V_{ave} = t_{on}/T \times V_{in}$$

where V_{ave} = average voltage supply to DC motor

t_{on} = time ON of switches

T = period of PWM

T_{on}/T = duty cycle

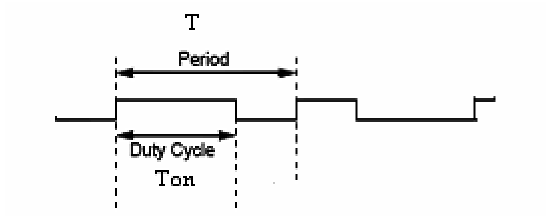

Figure 2.5: PWM signal

The time that it takes a motor to speed up and slow down under switching conditions is depends on the inertia of the rotor (basically how heavy it is), and how much friction and load torque there is. Based on the Figure 2.5 it shows that the average speed is around 150 rpm, although it varies quite a bit. If the supply voltage is switched fast enough, it won't have time to change speed much, and the speed will be quite steady. This is the principle of switch mode speed control. Thus the speed is set by PWM – Pulse Width Modulation.

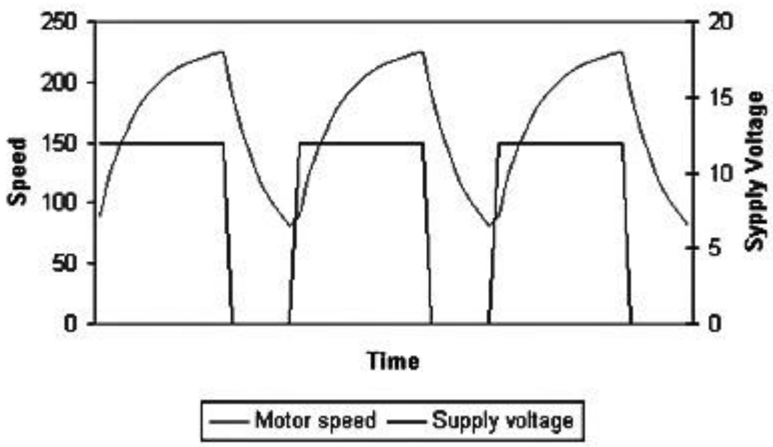

Figure 2.6: Relation of supply voltage with motor speed [2]

2.7 Microcontroller

Microcontroller must contain at least two major components of random access memory (RAM), and a set of instructions. RAM is a kind of internal logic unit that temporarily stores information. RAM contents are disappear when power is off. While RAM is used to hold any data type, RAM some specialized, referred to as the register. Instruction set is a list of all commands and their corresponding functions. In operation, the microcontroller will go through the program (firmware). Each set of valid commands and internal matching tools that differentiate one from another microcontroller [10].

A microcontroller is an entire computer on a chip which is it has a processor, memory, IO peripherals and more all on a single silicon die. They are used to control consumer products and industrial systems. The earliest version had programs permanently written into memory. It is impossible to change those devices once it is programmed. Modern versions use flash memory that allows their programs to be changed. The newest and most powerful versions for future operating system enabling them to do highly complex task. Microcontroller interacts with the world through a number of peripherals. These can be simple switch, analog to digital converters, pulse width modulators, communication channels etc.

Microcontrollers contain circuitry to generate the system clock. The generated square wave signal is the heartbeat of the microcontroller and all operations are synchronized to it. It controls the speed at which the microcontroller functions. All that needed to complete the clock circuit would be the crystal or RC components. Therefore, the operating speed critical can be precisely select to many applications.

To summarize, a microcontroller contains (in one chip) two or more of the following elements in order of importance [11].

i. Instruction set

ii. RAM

iii. ROM, PROM or EPROM

iv. I/O ports

v. Clock generator

vi. Reset function

vii. Watchdog timer

viii. Serial port

ix. Interrupts

x. Timers

xi. Analog-to-digital converters

xii. Digital-to-analog converters

2.7.1 Speed Control DC Motor Using Microcontroller

The electric drive system used in industrial applications is increasingly required to meet higher performance and reliability requirements. The DC motor is an attractive place of equipment in many industrial applications requiring variable speed and load characteristics due to its ease of controllability. Microcontrollers provide a suitable means of meeting these needs [12].

A simple form of speed control is achieved through a variable potentiometer for a manually controlled system. The operator compares the actual speed to a desired speed and sets the potentiometer accordingly. A simple form of speed control is achieved through a variable potentiometer for manually controlled system. By comparing the speed in revolution per seconds (rps) updated on the screen each second to a desired speed. The current speed is corrected by rotating the potentiometer clockwise to increase or counterclockwise to reduce the speed [12].

2.7.2 Advantages Using PIC

The advantages of using PIC over other controlling devices for controlling the DC motor are [12]:

i. Speed – The execution of an instruction in PIC is very fast (in micro seconds) and can be changing the oscillator frequency. One instruction generally takes 0.2 microseconds.
ii. EPROM Program Memory – Program can be modified and rewritten very easily.
iii. Inbuilt Hardware Support – Since PIC IC has inbuilt programmable timers, ports and interrupts, no extra hardware is needed.
iv. 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.
v. In built I/O Ports Expansions – This reduces the extra IC's which are needed for port expansion and port can be expanded very easily.

CHAPTER 3

METHODOLOGY

3.1 Introduction

Microcontroller will be used as the controller to control DC motor speed at desired speed for this project. Encoder will measure the actual speed of DC motor and give feedback to microcontroller. The duty cycle will send to DC motor driver either to accelerate or decelerate DC motor at desired speed. It is a closed-loop control system. The block diagram of the system is shown in Figure 3.1.

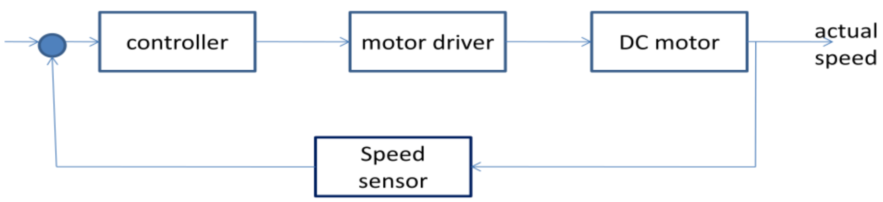

Figure 3.1: Block diagram of DC motor speed control system

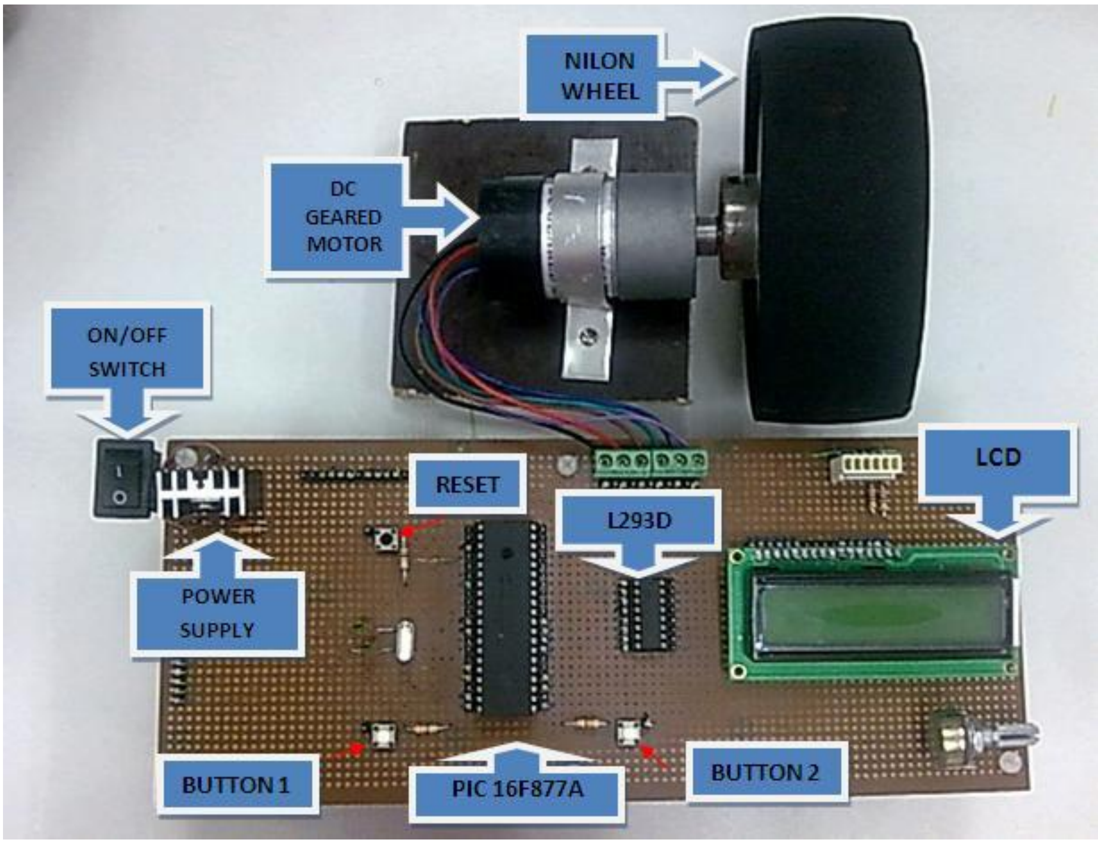

Figure 3.2: Picture of the project

Figure 3.2 shows the picture of the project. The project is divides into two parts that are software and hardware implementation. Each part of the project will discuss in the following section.

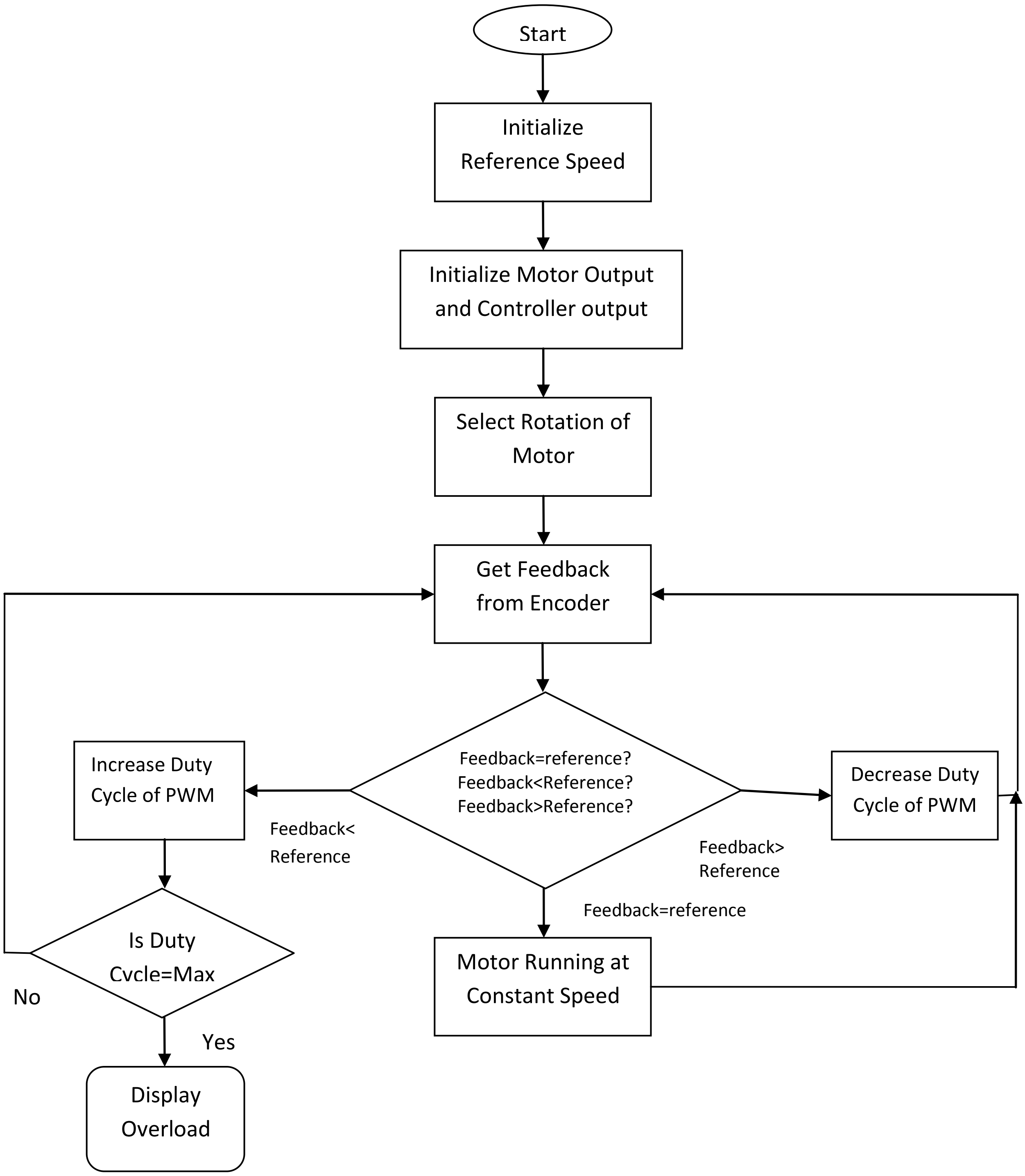

Figure 3.3: Operational flow chart of DC motor speed controller

3.2 Hardware Implementation

This section will discuss about component that will be used for this project which are DC motor, microcontroller PIC 16F877A, DC motor drive power supply +5V and Liquid Crystal Display (LCD).

3.2.1 DC motor

Figure 3.3 shows the DC motor that will be used for this project and also the specification of the motor is shown in Table 3.1.

Figure 3.4: SPG30E-20K

Table 3.1: Specification of DC motor

Rated voltage	12VDC
Output Power	1.1 Watt
Rated speed	185 rpm
Rated current	410 mA
Rated torque	78.4 mNm

Table 3.2: Pin connection of SPG30E-20K

Pin	Name	Description
1	Motor -	Output of motor driver
2	Motor +	Output of motor driver
3	Hall effect sensor Vcc	Supply voltage for sensor circuit (4.5V-5.5V)
4	Hall effect sensor GND	Ground
5	Channel A	Output of the encoder
6	Channel B	Output of the encoder

This DC geared motor with encoder is formed by a quadrature Hall Effect encoder board. Two Hall Effect sensors are placed 90 degree apart to sense and produce two outputs A and B which is 90 degree out of phase and allowing the direction of rotation of rotation to be determined. This encoder provides 3 counts per evolution of the rear shaft.

This DC Geared Motor already has its own encoder in it. This encoder will be used to measure the DC motor speed. The used of encoder is capable of much better performance than the generator type of tachometer (by using back EMF).

3.2.2 Microcontroller PIC 16F877A

PIC 16F877A is selected to control the speed of DC motor. This chip is selected because its size is small and equipped with sufficient output ports without having to use a decoder or multiplexer and its portability and low current consumption. Besides, it has PWM inside the chip itself which allow varying the duty cycle of DC motor drive. This chip is also can be programmed and reprogrammed easily.

Refer to Table 3.3 for the pin connection of PIC16F877A in DC Motor speed control system. Pins not stated in the table are not used and left hanging. Figure 3.4 shows the schematic circuit of microcontroller PIC16F877A. At the beginning, microcontroller will receive desired speed from the selected button. The detected motor speeds from encoder will feedback to microcontroller. The microcontroller will operate as it programmed to produce a new duty cycle (from CCP2) that proportional to the error speed. Thus, average of voltage supply from DC motor drive can be varied in order to maintain the speed at desired value.

Table 3.3: Pin connection of PIC16F877A for DC motor speed control system

Pin Name	Pin No	Description	Application
V_{DD}	11,32	Positive Supply (5V)	Power Supply to Chip
V_{SS}	12,31	Ground Reference	Ground Reference
OSC1	13	For oscillator or resonator	Connected to resonator 20MHz with 22Pf
OSC2	14	For oscillator or resonator	Connected to resonator 20MHz with 22pF
MCLR	1	Reset Input	Connected to +5V
RA0	2	Input/ Output pin	Input of motor speed
RA1	3	Input/ Output pin	Input of motor speed
RA2	4	Input/ Output pin	Input of motor speed
RB1	34	Input/ Output pin	Output to control CW/ CCW
RB2	35	Input/ Output pin	Output to control CW/ CCW
CCP2	16	Capture/ Compare/ PWM	Output of duty cycle (PWM) to control motor speed

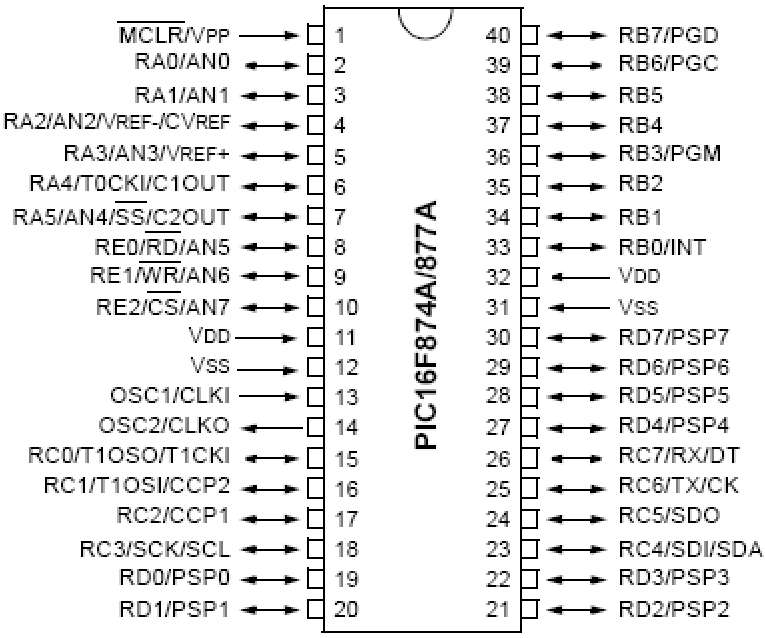

Figure 3.5 Pin diagram of PIC 16F877A

3.2.3 DC motor drive

DC motor drive is needed to control the magnitude of supply voltage in order to control the speed of DC motor. Chip L293D, quadruple high-current half- H driver will be used for this project. The operating supply voltage of chip L293D is up to 36V and total DC current up to 4A. The time to enable the chip L293D will be determined by the duty cycle pulse sent from PWM in microcontroller.

Table 3.4: Pin function of chip L293D

Pin	Name	Function
3;6	Out 1; Out 2	Outputs of the Bridge 1; the current that flows through the load connected between these two pins is monitored at pin 1.
8	Vs	Supply Voltage for the Power Output Stages. A non-inductive 100nF capacitor must be connected between this pin and ground.
2;7	Input 1; Input 2	TTL Compatible Inputs of the Bridge A.
1;9	Enable 1; Enable 2	TTL Compatible Enable Input: the L state disables the bridge 1(enable 1) and/or the bridge 2 (enable 2).
4;5;12;13	GND	Ground.
16	Vss	Supply Voltage for the Logic Blocks. A100nF capacitor must be connected between this pin and ground.
10;15	Input 3; Input 4	TTL Compatible Inputs of the Bridge 2.
11;14	Out 3; Out 4	Outputs of the Bridge 2. The current that flows through the load connected between these two pins.

3.2.4 Power Supply +5V

LM 7805 voltage regulator IC is used to make a +5V power supply. This is because most digital logic circuits and processors need a +5V power supply and to use these part a regulated +5V source need to be build. Usually it starts with an unregulated power supply ranging from 9 to 24 V DC. The IC is shown in Figure 3.5.

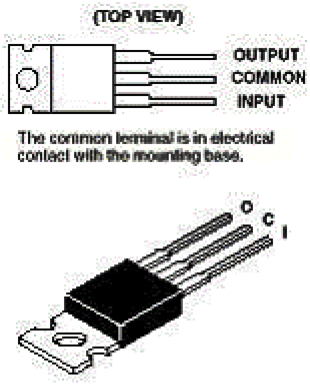

Figure 3.6: IC LM7805

3.2.5 Liquid Crystal Display (LCD)

LCD (Liquid Crystal Display) screen is an electronic display module and found various applications. 16x2 LCD display module is very basic and commonly used in a variety of devices and circuits. This module is preferable to seven segment and other multi segments of the LED. The reasons being LCDs are economical, easily programmable, does not limit the special features and even custom characters (unlike in seven segments), animation and so on.

16 x 2 LCD means it can display 16 characters per line and there are two such lines. The command register stores the command instructions given to the LCD. A command is an instruction given to LCD to do predefined task like initializing it, clearing its screen, setting the cursor position and controlling display. The data register stores the data to be displayed on the LCD.

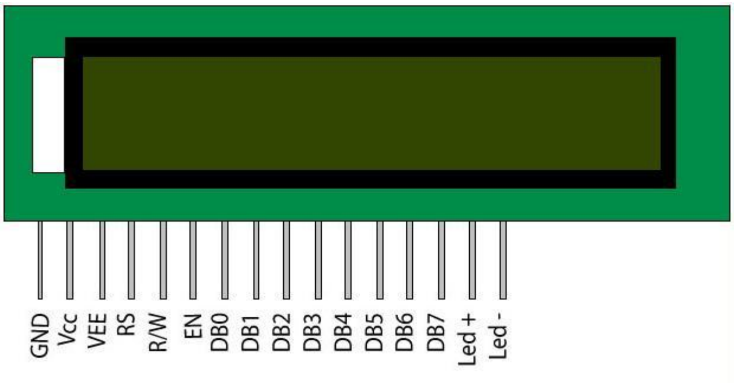

Figure 3.7: 16x2 LCD

Table 3.5: Pin description of LCD

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

3.3 SOFTWARE IMPLEMENTATION

For software implementation, Proteus 7 is used to design circuit and simulation. Besides, CCS C compiler is used to program microcontroller and PICKit 2 v2.40 is used to download the program into PIC microcontroller.

3.3.1 PROTEUS 7

PROTEUS 7 is a Virtual System Modeling (VSM) that combines circuit simulation, animated components and microprocessor models to simulate the complete microcontroller based design. This software is used to test the microcontroller designs before constructing a physical prototype in real time. This is also allow the users to interact with the design using on screen indicator or LCD and LED displays.

One of the main components of circuit simulation PROTEUS 7 is a product that uses the kernel combined with the analog simulator SPICE3f5 simulator driven by digital events that allow users to use any of the SPICE model by any manufacturer.

PROTEUS VSM comes with extensive debugging features, including breakpoints, single stepping and variable display for a neat design prior to hardware prototyping. PROTEUS 7 is a program to use when you want to simulate the interaction between software running on a microcontroller and any analog or digital electronic devices associated with it.

3.3.2 CCS C Compiler

The CCS C Compiler is develop exclusively for the PIC MCU which is making it the most optimized compiler for Microchip parts. The compiler has a generous libry of built-in functions, preprocessor commands and ready to run example programs to quickly jump-start any project. Drivers for real-time clocks, LCDs, A/D converters and many more are innate features to the CCS C Compiler. There are several versions of compilers that represent the compatible families of Microchip ranging from 12-bit to 24-bit [13].

3.3.3 PICKit 2 v2.40

This software is use to download the program into PIC microcontroller. Since programmer board is compatible with PICKit 2, thus PICKit 2 programming software should be installed. In order to downloading to PIC microcontroller, this software only can be read in format hex.file. Steps taken to download program into PIC microcontroller:

i. Write program at CCS C Compiler

ii. Change program file to file.hex by using CCS C Compiler

iii. Import file.hex by using PICKit 2 v2.40

iv. Download the program by click icon 'Write' at PICKit 2 v2.40

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

Some testing and simulations had been conducted for this project. The first simulation had been done to check the power circuit whether the circuit is function properly or not. The simulation had been done by using PROTEUS and also CCS as the PIC compiler. The result should show the desired output.

4.2 Simulation on Testing of Power Circuit.

The purpose of this simulation is to ensure the power circuit is functioning properly. Besides, this simulation is to check whether the PIC is in good condition or not. The testing is conducted by creating a simple program to on the LED. The LED will activate when button 1 is pressed. Below is the simple program for this simulation.

```
#include <16F877A.h>
#fuses HS, NOWDT, NOPROTECT, NOLVP, PUT
#use delay (clock=20M)
#define LED1 PIN_B1
#define BUTTON1 PIN_A0
void main ()
{
set_tris_a(0xFF);
set_tris_b(0x00);
output_a(0xFF);
output_b(0x00);
while (TRUE)
(!input (BUTTON1))
{
output_high(LED1);
}
}
```

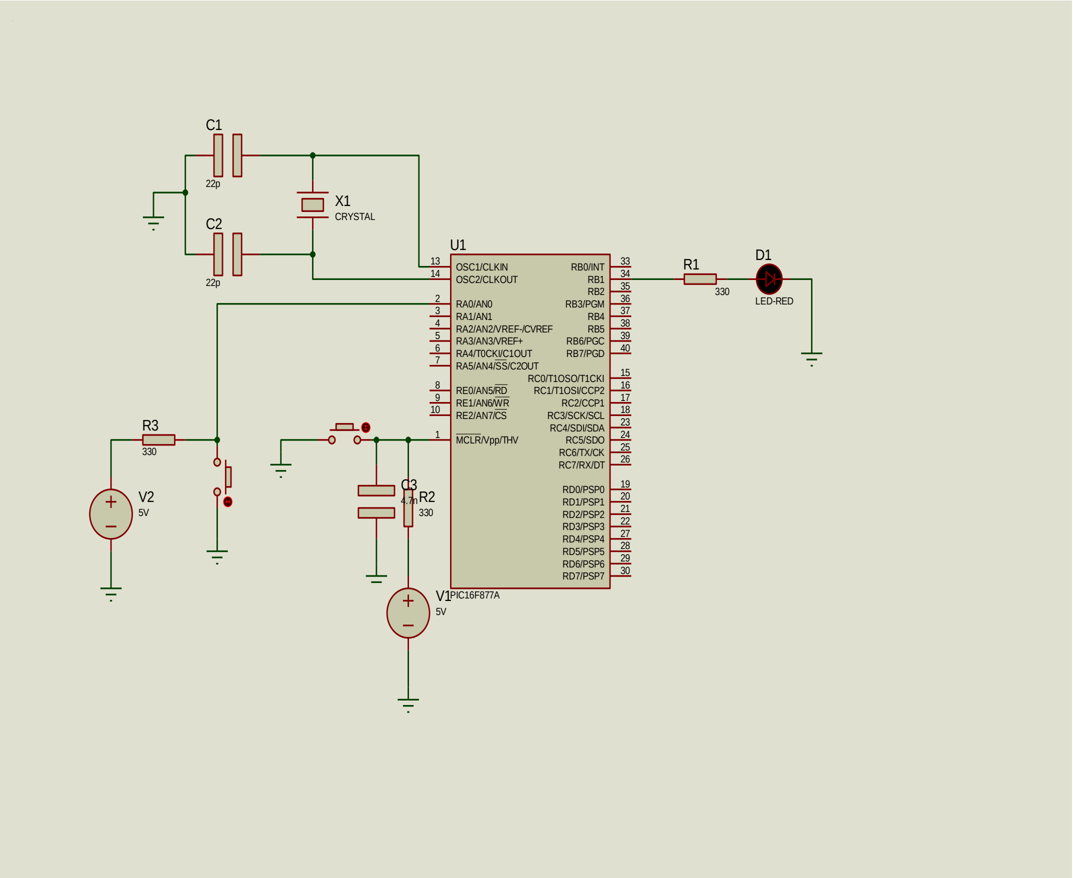

Figure 4.1: Simulation schematic circuit for testing power circuit

The 7805 is a linear regulator that takes in DC electricity of at least 7 V and outputs a constant 5 V. This circuit is fed by 9 V battery and the output obtain is 5 V that measured by multimeter. This result shows that the power circuit is in good condition and function properly. After that, for the next simulation is on testing PIC condition. Regarding to the programming above the simulation is successful which the LED is turn on when button 1 that connected to the input PIC port is pressed. Based on this result it shows that the PIC is functioning very well.

4.3 Simulation on Testing of LCD

The purpose of this simulation is to ensure the LCD is functioning properly. Besides, this simulation is to check whether the PIC is in good condition or not. The testing is conducted by creating a simple program to on the LED and LCD. The LED and LCD will turn on when button 1 is pressed. Below is the simple program for this simulation.

```
#include <16F877A.h>
#fuses HS, NOWDT, NOPROTECT, NOLVP, PUT
#use delay(clock=20M)
#include <lcd.c>
#define BUTTON1     PIN_A0
#define LED1   PIN_B1

#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
void main()
{

 set_tris_a (0xFF);
 set_tris_b (0x01);
 set_tris_c (0x00);
 output_a (0xFF);
 output_b (0x01);
 output_c (0x00);
 lcd_init () ;
 while (true)
```

```
if (!input (BUTTON 1))
{
output_high (LED1);
lcd_putc("\f DC MOTOR");
}
}
```

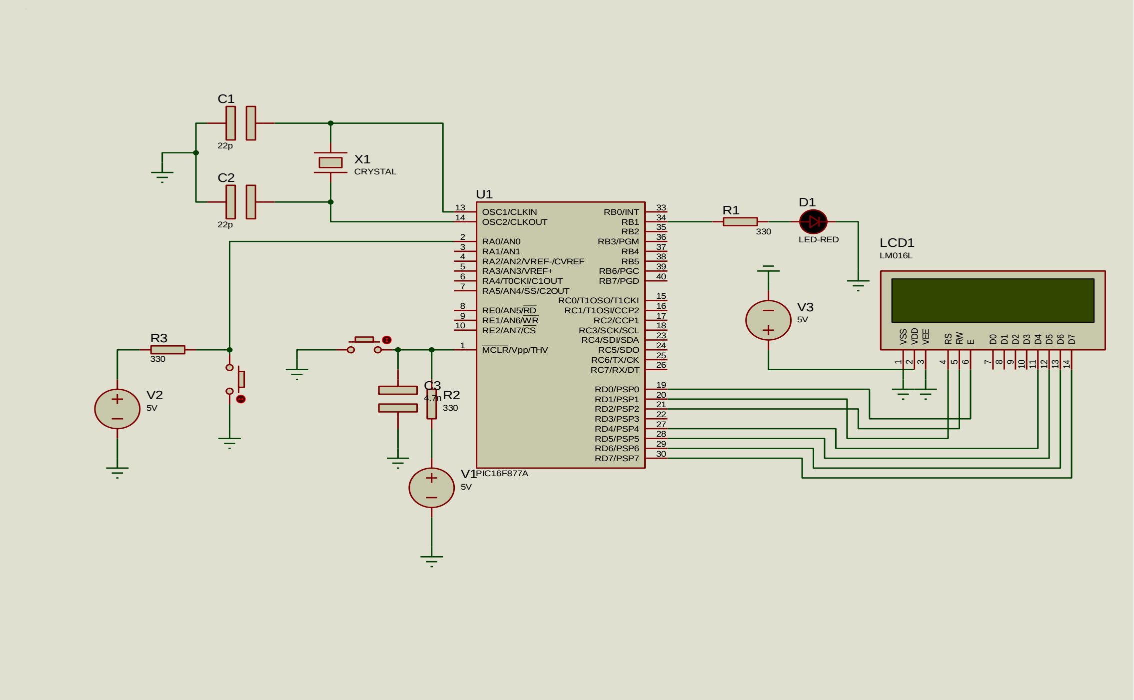

Figure 4.2: Simulation schematic circuit for LCD

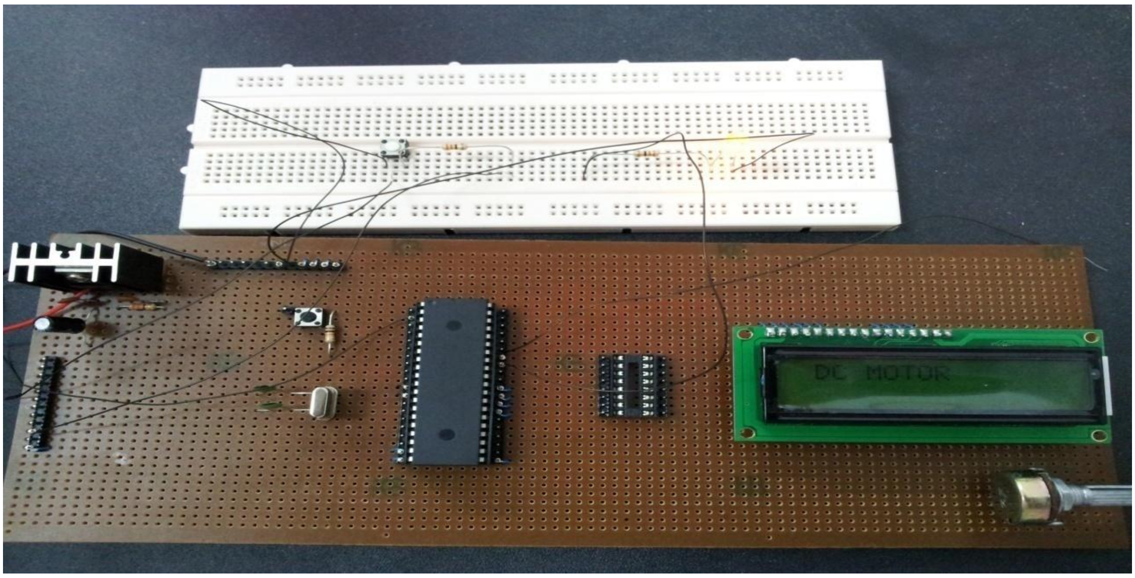

Figure 4.3: Hardware Circuit

The simulation for testing LCD is successful by creating the simple programming above. Button 1 is connected at PORT A in PIC as the input while the LCD is connected at PORT D in PIC as the output. The circuit is function when button 1 is pressed and the LCD display 'DC MOTOR' as the expected result. It can be conclude that the LCD can be used for this project as it functioning properly.

4.4 Simulation on Testing DC Motor

The simulation is to test the DC motor move in forward direction with the maximum speed. The speed of the motor is determined by the PWM that setting in the programming. The PWM is set 255 which is the maximum duty cycle and it can give the maximum speed of the motor. The motor will move in forward direction continuously. The output of the simulation gives the same result with hardware implementation.

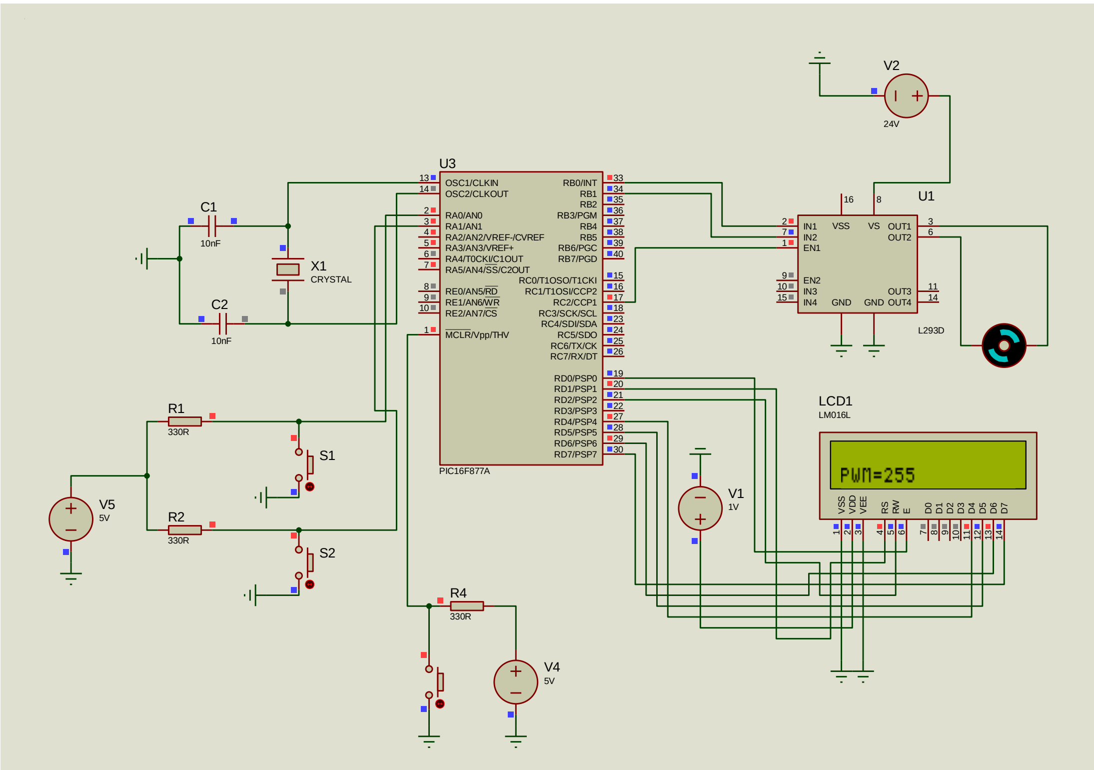

Figure 4.4: Simulation schematic circuit for forward DC motor

```
#include <16F877A.h>
#fuses HS,NOWDT,NOLVP,NOPROTECT,PUT
#use delay (clock=20M)
#include <lcd.c>

/// switch
#define S1  PIN_A0
#define S2  PIN_A1

//pwm
#define PWM_MOTOR PIN_C2

//control direction
#define MOTOR_FOR PIN_B0

#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

void main()
{

/// port initialize

set_tris_a(0xFF);
set_tris_b(0x00);
set_tris_c(0x00);
set_tris_d(0x00);

output_a(0xFF);
output_b(0x00);
output_c(0x00);
output_d(0x00);
lcd_init();

setup_timer_2 (T2_DIV_BY_4,254,1);
setup_ccp1 (ccp_pwm);


      while(TRUE)
      {
     if (!input(S1)
     {
          //motor forward
          output_high(MOTOR_FOR);
```

```
            output_low (MOTOR_REV) ;
            lcd_putc("\nPWM=255");
            set_pwm1_duty (255);
        }
        }
}
```

4.5 DC Motor Speed Control Result

Table 4.1: DC motor performance

BUTTON	**MOTOR PERFORMANCE**
BUTTON 1	Motor forward with high speed - the speed will maintain at desired speed with any load condition - the LCD will display ‘overload’ if there is overload condition
BUTTON 2	Motor forward with low speed - the speed will maintain at desired speed with any load condition - The LCD will display ‘overload’ if there is overload condition

Figure 4.5: LCD Display for reference speed of high speed

Figure 4.6: LCD Display for actual speed of high speed with normal load

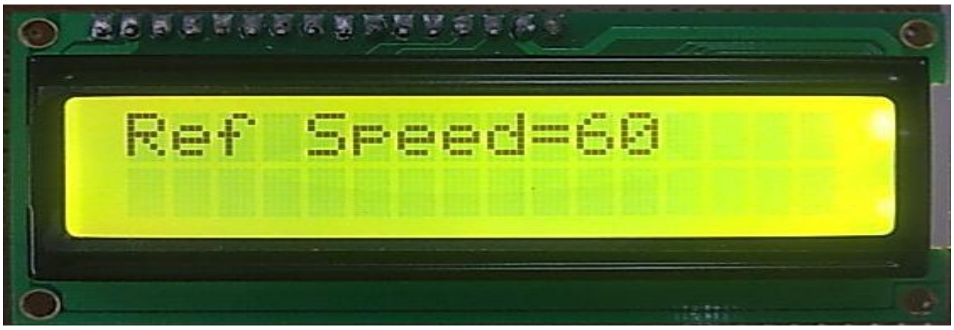

Figure 4.7: LCD Display for reference speed of low speed

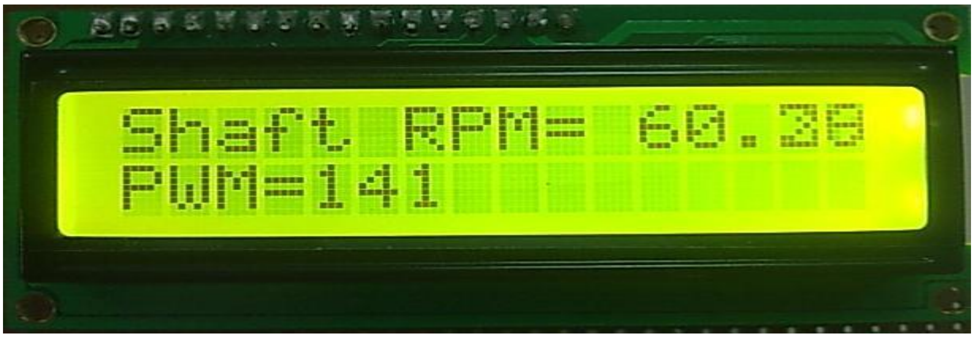

Figure 4.8: LCD Display for actual speed of low speed with normal load

4.5.1 DC Motor Pulse

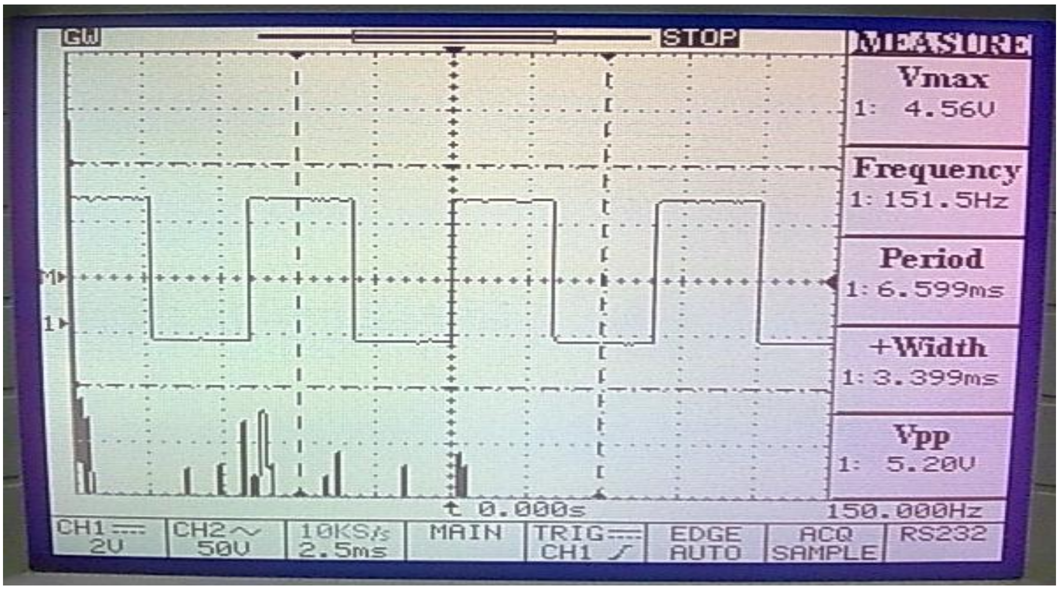

Figure 4.9: DC Motor pulse for high speed

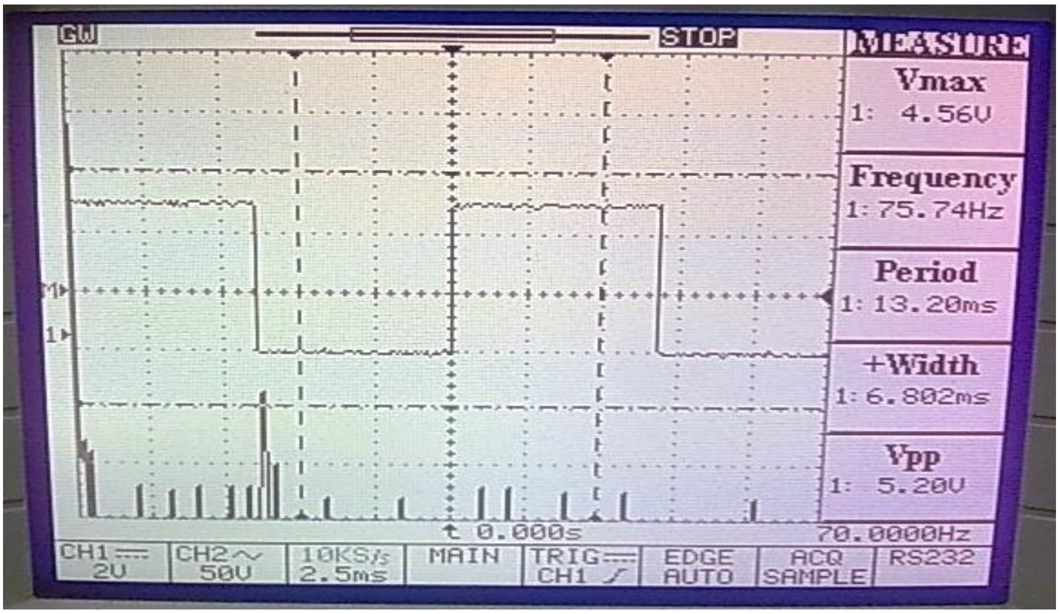

Figure 4.10: DC Motor pulse for low speed

4.5.2 PWM Waveform

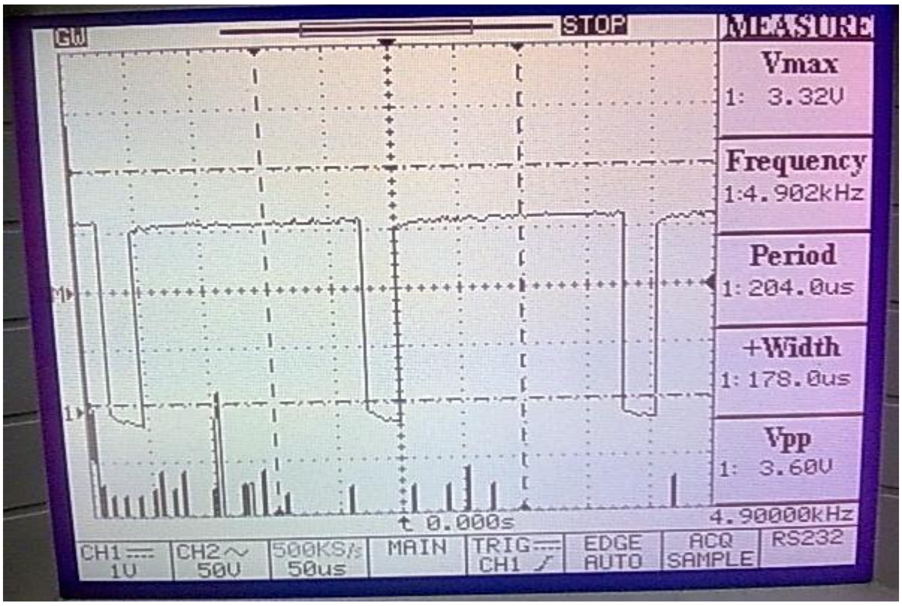

Figure 4.11: PWM waveform for high speed of DC motor

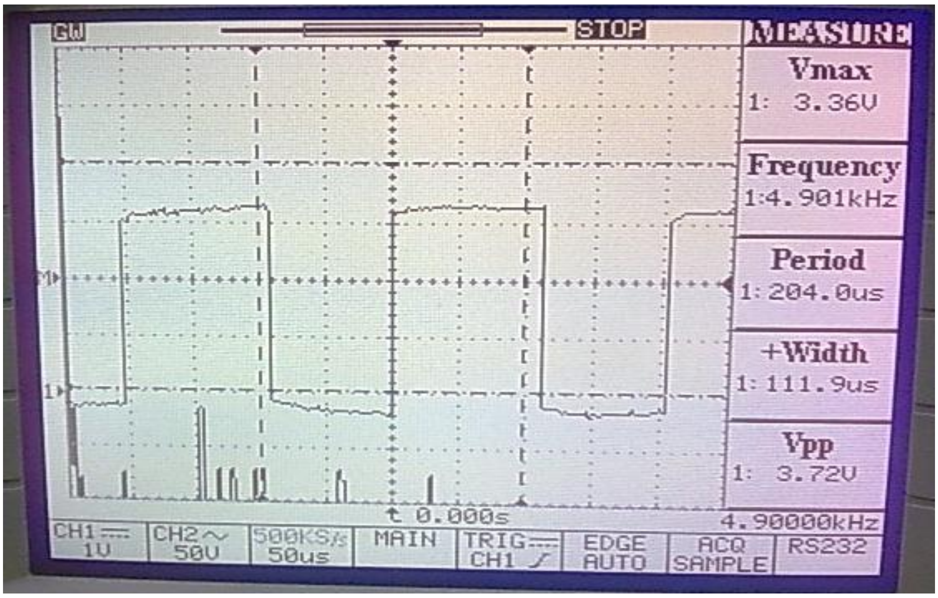

Figure 4.12: PWM waveform for low speed of DC motor

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This project is to design a DC motor speed control system by using a microcontroller. The microcontroller that choose to be used is PIC 16F877A. It is a closed-loop real time control system. The system is able to maintain the speed at any load condition in forward direction. The encoder will count the speed of the motor to provide the feedback speed signal to controller. The speed of DC motor is varying by using PWM technique where its signal is generated in microcontroller. The PWM signal will send to motor driver to vary the voltage supply to maintain at constant speed.

The system has been developed to control DC motor speed. The system had been done part by part and various tests have been conducted to prove the capability of the system. Through this project the microcontroller PIC 16F877A can control motor speed and the motor always run in forward direction. The rotation of the encoder is determined to get the speed of the motor as a feedback to the microcontroller. So, the speed will be able to maintain at any load condition.

5.2 Recommendation

For the future, some recommendations have been listed in order to improve and get better performance for the system.

i) Developed a program by using Visual Basic 6.0. This program is able for user to key in the data for the desired speed. Then the data will send to the microcontroller to give the output of desired speed of DC motor. Besides, the performance of the system can be monitor by the user by plotting a graph of detect speed versus time.

ii) Use fuzzy logic microcontroller for the control system which combine the idea of fuzzy logic in microcontroller in order to get a DC motor speed control system with high performance.

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APPENDIX A

Program in Microcontroller PIC 16F877A for DC Motor Speed Control

```
#include <16f877a.h>
#fuses HS, NOWDT, NOPROTECT, NOLVP, PUT
#fuses NOBROWNOUT, CPD, NODEBUG, NOWRT
#use delay (clock=20M)
#include <lcd.c>

#define S1  PIN_A0
#define S2  PIN_A1
#define PWM_MOTOR PIN_C1

//control direction
#define MOTOR_FOR PIN_C4
#define MOTOR_REV PIN_C5

//count rpm
int overflow_countRPM;
unsigned int32 start_timeRPM, end_timeRPM;
float period=0;
float RPM=0;
double sRPM=0;

void main(void);
void Initialize(void);
void TIMER1_isr (void);
void CCP1_isr(void);
void rpmcount(void);

#INT_TIMER1
void TIMER1_isr(void)
{
++overflow_countRPM;
//TMR1IF=0;
}

#INT_CCP1
void CCP1_isr(void)
{
end_timeRPM = (int32)CCP_1;
period = ((int32)0x10000 * (int32)overflow_countRPM) - (int32)start_timeRPM +
(int32)end_timeRPM; //rpm timer

RPM = (int32)150E6/period;
sRPM=RPM*185/7000;

start_timeRPM = end_timeRPM;
overflow_countRPM = 0;
```

```
//CCP1IF = 0;
}
int s=0;
void main(void)
{
RPM=0;
Initialize();
lcd_init();
setup_timer_1 (T1_INTERNAL|T1_DIV_BY_1);
setup_ccp1 (CCP_CAPTURE_RE);


disable_interrupts(GLOBAL);
enable_interrupts(INT_TIMER1);
enable_interrupts(INT_CCP1);
enable_interrupts(GLOBAL);


setup_timer_2 (T2_DIV_BY_4,254,1);
setup_ccp2 (ccp_pwm);
  printf(lcd_putc,"\fAutomatic speed");
  delay_ms(700);
do
  {
  while (!input(S1))                                  //high speed
  {
   printf(lcd_putc,"\fRef Speed=120");
   delay_ms(2500);
    while(1)
    {
   rpmcount();
    if (sRPM<=119)
    {
        if (s==255)
    {
    output_low(MOTOR_FOR);
    output_low (MOTOR_REV);
    output_low (PWM_MOTOR);
    printf(lcd_putc,"\fOVERLOAD");
    break;
    }
    else{
    output_high(MOTOR_FOR);
    output_low (MOTOR_REV);
    s+=1;set_pwm2_duty (s);
    delay_ms(20);
    }
    }
    if (sRPM>=121)
    {
```

```
    output_high(MOTOR_FOR);
    output_low (MOTOR_REV);
    s-=1;set_pwm2_duty (s);
    delay_ms(20);
    }
  }
  }
  while (!input(S2))                                    //low speed
  {
   printf(lcd_putc,"\fRef Speed=60");
   delay_ms(2500);
   while(1)
   {
   rpmcount();
    if (sRPM<=59)
    {
     if (s==255)
    {
    output_low(MOTOR_FOR);
    output_low (MOTOR_REV);
    output_low (PWM_MOTOR);
    printf(lcd_putc,"\fOVERLOAD");
    break;
    }
    else{
    output_high(MOTOR_FOR);
    output_low (MOTOR_REV);
    s+=1;set_pwm2_duty (s);
    delay_ms(20);
    }
    }
    if (sRPM>=61)
    {
    output_high(MOTOR_FOR);
    output_low (MOTOR_REV);
    s-=1;set_pwm2_duty (s);
    delay_ms(20);
    }
  }
   }
  }while(1);
 }
void rpmcount (void)
{
   if (RPM>=700)
   {
    lcd_gotoxy(1,1);
    printf(lcd_putc,"\fShaft RPM= %f\nPWM=%u",sRPM,s);
    delay_ms(40);
   }
```

```
   else
   {
   RPM=0;sRPM=0;
    lcd_gotoxy(1,1);
    printf(lcd_putc,"\fShaft RPM= %f\nPWM=%u",sRPM,s);
    delay_ms(40);
   }
}
void Initialize(void)
{
PORT_B_PULLUPS(TRUE);
SET_TRIS_A(0Xff);
SET_TRIS_B(0x1F);
SET_TRIS_C(0xf7);
SET_TRIS_D(0x00);
SET_TRIS_E(0x00);
}
```

APPENDIX B

PIC16F877A

MICROCHIP

PIC16F87XA

28/40/44-Pin Enhanced Flash Microcontrollers

Devices Included in this Data Sheet:

- PIC16F873A
- PIC16F874A
- PIC16F876A
- PIC16F877A

High-Performance RISC CPU:

- Only 35 single-word instructions to learn
- All single-cycle instructions except for program branches, which are two-cycle
- Operating speed: DC – 20 MHz clock input
  DC – 200 ns instruction cycle
- Up to 8K x 14 words of Flash Program Memory, Up to 368 x 8 bytes of Data Memory (RAM), Up to 256 x 8 bytes of EEPROM Data Memory
- Pinout compatible to other 28-pin or 40/44-pin PIC16CXXX and PIC16FXXX microcontrollers

Peripheral Features:

- Timer0: 8-bit timer/counter with 8-bit prescaler
- Timer1: 16-bit timer/counter with prescaler, can be incremented during Sleep via external crystal/clock
- Timer2: 8-bit timer/counter with 8-bit period register, prescaler and postscaler
- Two Capture, Compare, PWM modules
  - Capture is 16-bit, max. resolution is 12.5 ns
  - Compare is 16-bit, max. resolution is 200 ns
  - PWM max. resolution is 10-bit
- Synchronous Serial Port (SSP) with SPI™ (Master mode) and I^2C™ (Master/Slave)
- Universal Synchronous Asynchronous Receiver Transmitter (USART/SCI) with 9-bit address detection
- Parallel Slave Port (PSP) – 8 bits wide with external $\overline{RD}$, $\overline{WR}$ and $\overline{CS}$ controls (40/44-pin only)
- Brown-out detection circuitry for Brown-out Reset (BOR)

Analog Features:

- 10-bit, up to 8-channel Analog-to-Digital Converter (A/D)
- Brown-out Reset (BOR)
- Analog Comparator module with:
  - Two analog comparators
  - Programmable on-chip voltage reference (V_{REF}) module
  - Programmable input multiplexing from device inputs and internal voltage reference
  - Comparator outputs are externally accessible

Special Microcontroller Features:

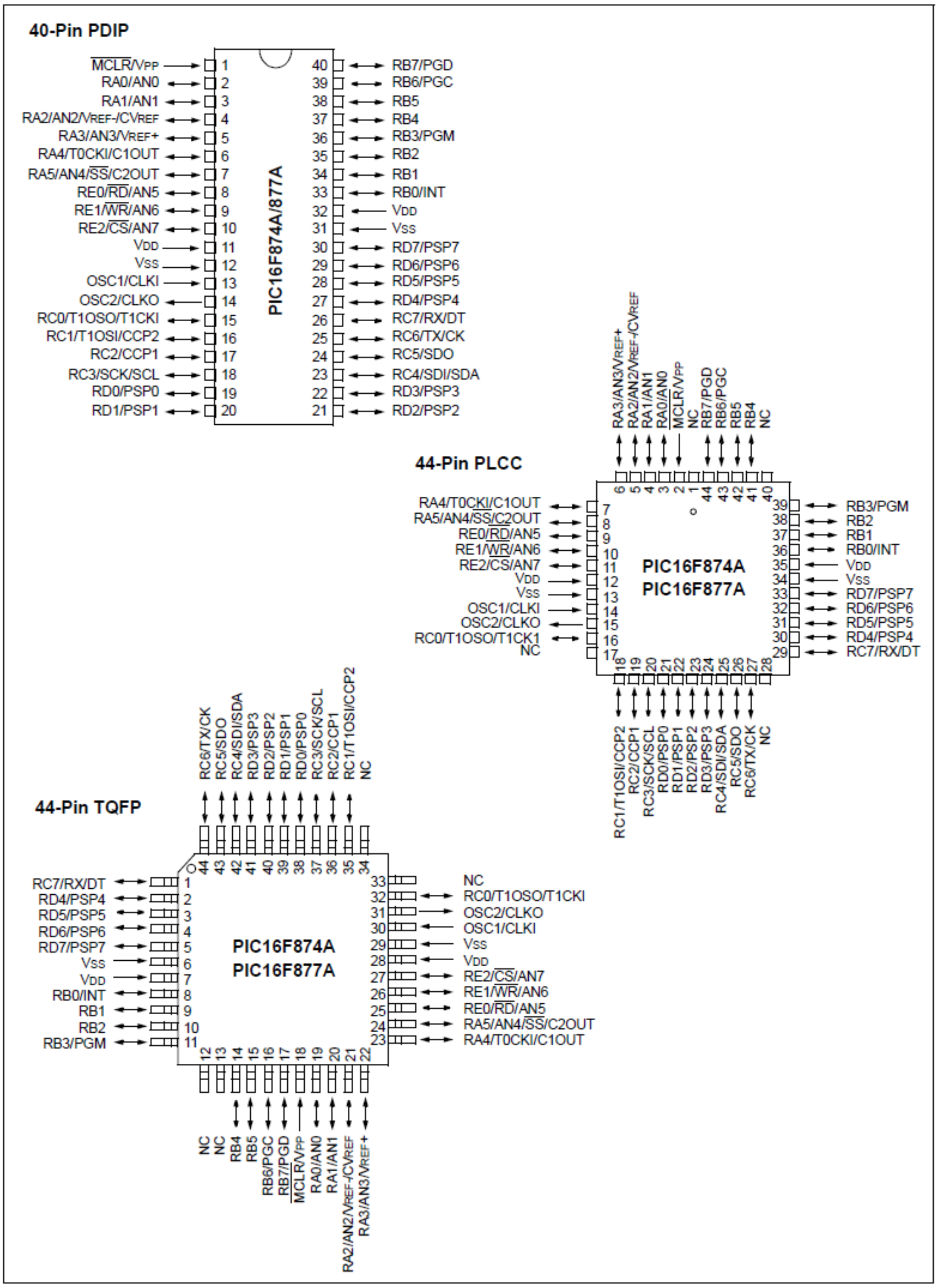
- 100,000 erase/write cycle Enhanced Flash program memory typical
- 1,000,000 erase/write cycle Data EEPROM memory typical
- Data EEPROM Retention > 40 years
- Self-reprogrammable under software control
- In-Circuit Serial Programming™ (ICSP™) via two pins
- Single-supply 5V In-Circuit Serial Programming
- Watchdog Timer (WDT) with its own on-chip RC oscillator for reliable operation
- Programmable code protection
- Power saving Sleep mode
- Selectable oscillator options
- 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)
- Commercial and Industrial temperature ranges
- Low-power consumption

Device	Program Memory		Data SRAM (Bytes)	EEPROM (Bytes)	I/O	10-bit A/D (ch)	CCP (PWM)	MSSP		USART	Timers 8/16-bit	Comparators
	Bytes	# Single Word Instructions						SPI	Master I^2C			
PIC16F873A	7.2K	4096	192	128	22	5	2	Yes	Yes	Yes	2/1	2
PIC16F874A	7.2K	4096	192	128	33	8	2	Yes	Yes	Yes	2/1	2
PIC16F876A	14.3K	8192	368	256	22	5	2	Yes	Yes	Yes	2/1	2
PIC16F877A	14.3K	8192	368	256	33	8	2	Yes	Yes	Yes	2/1	2

Pin Diagrams (Continued)



1.0 DEVICE OVERVIEW

This document contains device specific information about the following devices:

- PIC16F873A
- PIC16F874A
- PIC16F876A
- PIC16F877A

PIC16F873A/876A devices are available only in 28-pin packages, while PIC16F874A/877A devices are available in 40-pin and 44-pin packages. All devices in the PIC16F87XA family share common architecture with the following differences:

- The PIC16F873A and PIC16F874A have one-half of the total on-chip memory of the PIC16F876A and PIC16F877A
- The 28-pin devices have three I/O ports, while the 40/44-pin devices have five
- The 28-pin devices have fourteen interrupts, while the 40/44-pin devices have fifteen
- The 28-pin devices have five A/D input channels, while the 40/44-pin devices have eight
- The Parallel Slave Port is implemented only on the 40/44-pin devices

The available features are summarized in Table 1-1. Block diagrams of the PIC16F873A/876A and PIC16F874A/877A devices are provided in Figure 1-1 and Figure 1-2, respectively. The pinouts for these device families are listed in Table 1-2 and Table 1-3.

Additional information may be found in the PICmicro® Mid-Range Reference Manual (DS33023), which may be obtained from your local Microchip Sales Representative or downloaded from the Microchip web site. The Reference Manual should be considered a complementary document to this data sheet and is highly recommended reading for a better understanding of the device architecture and operation of the peripheral modules.

TABLE 1-1: PIC16F87XA DEVICE FEATURES

Key Features	PIC16F873A	PIC16F874A	PIC16F876A	PIC16F877A
Operating Frequency	DC – 20 MHz	DC – 20 MHz	DC – 20 MHz	DC – 20 MHz
Resets (and Delays)	POR, BOR (PWRT, OST)	POR, BOR (PWRT, OST)	POR, BOR (PWRT, OST)	POR, BOR (PWRT, OST)
Flash Program Memory (14-bit words)	4K	4K	8K	8K
Data Memory (bytes)	192	192	368	368
EEPROM Data Memory (bytes)	128	128	256	256
Interrupts	14	15	14	15
I/O Ports	Ports A, B, C	Ports A, B, C, D, E	Ports A, B, C	Ports A, B, C, D, E
Timers	3	3	3	3
Capture/Compare/PWM modules	2	2	2	2
Serial Communications	MSSP, USART	MSSP, USART	MSSP, USART	MSSP, USART
Parallel Communications	—	PSP	—	PSP
10-bit Analog-to-Digital Module	5 input channels	8 input channels	5 input channels	8 input channels
Analog Comparators	2	2	2	2
Instruction Set	35 Instructions	35 Instructions	35 Instructions	35 Instructions
Packages	28-pin PDIP 28-pin SOIC 28-pin SSOP 28-pin QFN	40-pin PDIP 44-pin PLCC 44-pin TQFP 44-pin QFN	28-pin PDIP 28-pin SOIC 28-pin SSOP 28-pin QFN	40-pin PDIP 44-pin PLCC 44-pin TQFP 44-pin QFN

TABLE 1-3: PIC16F874A/877A PINOUT DESCRIPTION

Pin Name	PDIP Pin#	PLCC Pin#	TQFP Pin#	QFN Pin#	I/O/P Type	Buffer Type	Description
OSC1/CLKI	13	14	30	32		ST/CMOS(4)	Oscillator crystal or external clock input.
OSC1					I		Oscillator crystal input or external clock source input. ST buffer when configured in RC mode; otherwise CMOS.
CLKI					I		External clock source input. Always associated with pin function OSC1 (see OSC1/CLKI, OSC2/CLKO pins).
OSC2/CLKO	14	15	31	33		—	Oscillator crystal or clock output.
OSC2					O		Oscillator crystal output. Connects to crystal or resonator in Crystal Oscillator mode.
CLKO					O		In RC mode, OSC2 pin outputs CLKO, which has 1/4 the frequency of OSC1 and denotes the instruction cycle rate.
$\overline{\text{MCLR}}$/VPP	1	2	18	18		ST	Master Clear (input) or programming voltage (output).
$\overline{\text{MCLR}}$					I		Master Clear (Reset) input. This pin is an active low Reset to the device.
VPP					P		Programming voltage input.
							PORTA is a bidirectional I/O port.
RA0/AN0	2	3	19	19		TTL	
RA0					I/O		Digital I/O.
AN0					I		Analog input 0.
RA1/AN1	3	4	20	20		TTL	
RA1					I/O		Digital I/O.
AN1					I		Analog input 1.
RA2/AN2/VREF-/CVREF	4	5	21	21		TTL	
RA2					I/O		Digital I/O.
AN2					I		Analog input 2.
VREF-					I		A/D reference voltage (Low) input.
CVREF					O		Comparator VREF output.
RA3/AN3/VREF+	5	6	22	22		TTL	
RA3					I/O		Digital I/O.
AN3					I		Analog input 3.
VREF+					I		A/D reference voltage (High) input.
RA4/T0CKI/C1OUT	6	7	23	23		ST	
RA4					I/O		Digital I/O – Open-drain when configured as output.
T0CKI					I		Timer0 external clock input.
C1OUT					O		Comparator 1 output.
RA5/AN4/$\overline{\text{SS}}$/C2OUT	7	8	24	24		TTL	
RA5					I/O		Digital I/O.
AN4					I		Analog input 4.
$\overline{\text{SS}}$					I		SPI slave select input.
C2OUT					O		Comparator 2 output.

Legend: I = input O = output I/O = input/output P = power
— = Not used TTL = TTL input ST = Schmitt Trigger input

Note 1: This buffer is a Schmitt Trigger input when configured as the external interrupt.
2: This buffer is a Schmitt Trigger input when used in Serial Programming mode.
3: This buffer is a Schmitt Trigger input when configured in RC Oscillator mode and a CMOS input otherwise.

TABLE 1-3: PIC16F874A/877A PINOUT DESCRIPTION (CONTINUED)

Pin Name	PDIP Pin#	PLCC Pin#	TQFP Pin#	QFN Pin#	I/O/P Type	Buffer Type	Description
							PORTB is a bidirectional I/O port. PORTB can be software programmed for internal weak pull-up on all inputs.
RB0/INT	33	36	8	9		TTL/ST(1)	
RB0					I/O		Digital I/O.
INT					I		External interrupt.
RB1	34	37	9	10	I/O	TTL	Digital I/O.
RB2	35	38	10	11	I/O	TTL	Digital I/O.
RB3/PGM	36	39	11	12		TTL	
RB3					I/O		Digital I/O.
PGM					I		Low-voltage ICSP programming enable pin.
RB4	37	41	14	14	I/O	TTL	Digital I/O.
RB5	38	42	15	15	I/O	TTL	Digital I/O.
RB6/PGC	39	43	16	16		TTL/ST(2)	
RB6					I/O		Digital I/O.
PGC					I		In-circuit debugger and ICSP programming clock.
RB7/PGD	40	44	17	17		TTL/ST(2)	
RB7					I/O		Digital I/O.
PGD					I/O		In-circuit debugger and ICSP programming data.

Legend: I = input O = output I/O = input/output P = power
— = Not used TTL = TTL input ST = Schmitt Trigger input

Note 1: This buffer is a Schmitt Trigger input when configured as the external interrupt.
2: This buffer is a Schmitt Trigger input when used in Serial Programming mode.
3: This buffer is a Schmitt Trigger input when configured in RC Oscillator mode and a CMOS input otherwise.

TABLE 1-3: PIC16F874A/877A PINOUT DESCRIPTION (CONTINUED)

Pin Name	PDIP Pin#	PLCC Pin#	TQFP Pin#	QFN Pin#	I/O/P Type	Buffer Type	Description
							PORTC is a bidirectional I/O port.
RC0/T1OSO/T1CKI	15	16	32	34		ST	
RC0					I/O		Digital I/O.
T1OSO					O		Timer1 oscillator output.
T1CKI					I		Timer1 external clock input.
RC1/T1OSI/CCP2	16	18	35	35		ST	
RC1					I/O		Digital I/O.
T1OSI					I		Timer1 oscillator input.
CCP2					I/O		Capture2 input, Compare2 output, PWM2 output.
RC2/CCP1	17	19	36	36		ST	
RC2					I/O		Digital I/O.
CCP1					I/O		Capture1 input, Compare1 output, PWM1 output.
RC3/SCK/SCL	18	20	37	37		ST	
RC3					I/O		Digital I/O.
SCK					I/O		Synchronous serial clock input/output for SPI mode.
SCL					I/O		Synchronous serial clock input/output for I^2C mode.
RC4/SDI/SDA	23	25	42	42		ST	
RC4					I/O		Digital I/O.
SDI					I		SPI data in.
SDA					I/O		I^2C data I/O.
RC5/SDO	24	26	43	43		ST	
RC5					I/O		Digital I/O.
SDO					O		SPI data out.
RC6/TX/CK	25	27	44	44		ST	
RC6					I/O		Digital I/O.
TX					O		USART asynchronous transmit.
CK					I/O		USART1 synchronous clock.
RC7/RX/DT	26	29	1	1		ST	
RC7					I/O		Digital I/O.
RX					I		USART asynchronous receive.
DT					I/O		USART synchronous data.

Legend: I = input O = output I/O = input/output P = power
— = Not used TTL = TTL input ST = Schmitt Trigger input

Note 1: This buffer is a Schmitt Trigger input when configured as the external interrupt.
2: This buffer is a Schmitt Trigger input when used in Serial Programming mode.
3: This buffer is a Schmitt Trigger input when configured in RC Oscillator mode and a CMOS input otherwise.

TABLE 1-3: PIC16F874A/877A PINOUT DESCRIPTION (CONTINUED)

Pin Name	PDIP Pin#	PLCC Pin#	TQFP Pin#	QFN Pin#	I/O/P Type	Buffer Type	Description
							PORTD is a bidirectional I/O port or Parallel Slave Port when interfacing to a microprocessor bus.
RD0/PSP0	19	21	38	38		ST/TTL(3)	
RD0					I/O		Digital I/O.
PSP0					I/O		Parallel Slave Port data.
RD1/PSP1	20	22	39	39		ST/TTL(3)	
RD1					I/O		Digital I/O.
PSP1					I/O		Parallel Slave Port data.
RD2/PSP2	21	23	40	40		ST/TTL(3)	
RD2					I/O		Digital I/O.
PSP2					I/O		Parallel Slave Port data.
RD3/PSP3	22	24	41	41		ST/TTL(3)	
RD3					I/O		Digital I/O.
PSP3					I/O		Parallel Slave Port data.
RD4/PSP4	27	30	2	2		ST/TTL(3)	
RD4					I/O		Digital I/O.
PSP4					I/O		Parallel Slave Port data.
RD5/PSP5	28	31	3	3		ST/TTL(3)	
RD5					I/O		Digital I/O.
PSP5					I/O		Parallel Slave Port data.
RD6/PSP6	29	32	4	4		ST/TTL(3)	
RD6					I/O		Digital I/O.
PSP6					I/O		Parallel Slave Port data.
RD7/PSP7	30	33	5	5		ST/TTL(3)	
RD7					I/O		Digital I/O.
PSP7					I/O		Parallel Slave Port data.
							PORTE is a bidirectional I/O port.
RE0/$\overline{RD}$/AN5	8	9	25	25		ST/TTL(3)	
RE0					I/O		Digital I/O.
$\overline{RD}$					I		Read control for Parallel Slave Port.
AN5					I		Analog input 5.
RE1/$\overline{WR}$/AN6	9	10	26	26		ST/TTL(3)	
RE1					I/O		Digital I/O.
$\overline{WR}$					I		Write control for Parallel Slave Port.
AN6					I		Analog input 6.
RE2/$\overline{CS}$/AN7	10	11	27	27		ST/TTL(3)	
RE2					I/O		Digital I/O.
$\overline{CS}$					I		Chip select control for Parallel Slave Port.
AN7					I		Analog input 7.
VSS	12, 31	13, 34	6, 29	6, 30, 31	P	—	Ground reference for logic and I/O pins.
VDD	11, 32	12, 35	7, 28	7, 8, 28, 29	P	—	Positive supply for logic and I/O pins.
NC	—	1, 17, 28, 40	12,13, 33, 34	13	—	—	These pins are not internally connected. These pins should be left unconnected.

Legend: I = input O = output I/O = input/output P = power
— = Not used TTL = TTL input ST = Schmitt Trigger input

Note 1: This buffer is a Schmitt Trigger input when configured as the external interrupt.
2: This buffer is a Schmitt Trigger input when used in Serial Programming mode.
3: This buffer is a Schmitt Trigger input when configured in RC Oscillator mode and a CMOS input otherwise.

APPENDIX C

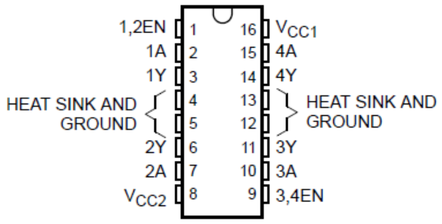
MOTOR DRIVER L293D

L293, L293D
QUADRUPLE HALF-H DRIVERS

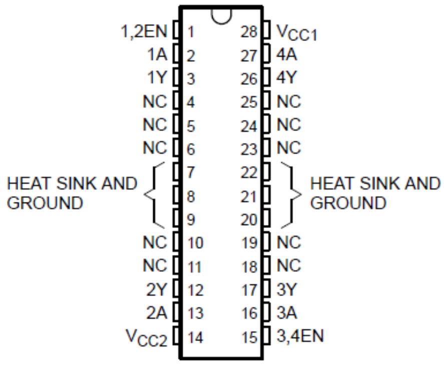
SLRS008B – SEPTEMBER 1986 – REVISED JUNE 2002

- **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.

recommended operating conditions

			MIN	MAX	UNIT
	Supply voltage	V_{CC1}	4.5	7	V
		V_{CC2}	V_{CC1}	36	
V_{IH}	High-level input voltage	$V_{CC1} \le 7$ V	2.3	V_{CC1}	V
		$V_{CC1} \ge 7$ V	2.3	7	V
V_{IL}	Low-level output voltage		–0.3†	1.5	V
T_A	Operating free-air temperature		0	70	°C

† The algebraic convention, in which the least positive (most negative) designated minimum, is used in this data sheet for logic voltage levels.

electrical characteristics, V_{CC1} = 5 V, V_{CC2} = 24 V, T_A = 25°C

PARAMETER			TEST CONDITIONS		MIN	TYP	MAX	UNIT
V_{OH}	High-level output voltage		L293: I_{OH} = –1 A L293D: I_{OH} = –0.6 A		V_{CC2}–1.8	V_{CC2}–1.4		V
V_{OL}	Low-level output voltage		L293: I_{OL} = 1 A L293D: I_{OL} = 0.6 A			1.2	1.8	V
V_{OKH}	High-level output clamp voltage		L293D: I_{OK} = –0.6 A			V_{CC2} + 1.3		V
V_{OKL}	Low-level output clamp voltage		L293D: I_{OK} = 0.6 A			1.3		V
I_{IH}	High-level input current	A	V_I = 7 V			0.2	100	µA
		EN				0.2	10	
I_{IL}	Low-level input current	A	V_I = 0			–3	–10	µA
		EN				–2	–100	
I_{CC1}	Logic supply current		I_O = 0	All outputs at high level		13	22	mA
				All outputs at low level		35	60	
				All outputs at high impedance		8	24	
I_{CC2}	Output supply current		I_O = 0	All outputs at high level		14	24	mA
				All outputs at low level		2	6	
				All outputs at high impedance		2	4	

switching characteristics, V_{CC1} = 5 V, V_{CC2} = 24 V, T_A = 25°C

PARAMETER		TEST CONDITIONS	L293NE, L293DNE			UNIT
			MIN	TYP	MAX	
t_{PLH}	Propagation delay time, low-to-high-level output from A input	C_L = 30 pF, See Figure 1		800		ns
t_{PHL}	Propagation delay time, high-to-low-level output from A input			400		ns
t_{TLH}	Transition time, low-to-high-level output			300		ns
t_{THL}	Transition time, high-to-low-level output			300		ns

switching characteristics, V_{CC1} = 5 V, V_{CC2} = 24 V, T_A = 25°C

PARAMETER		TEST CONDITIONS	L293DWP, L293N L293DDWP, L293DN			UNIT
			MIN	TYP	MAX	
t_{PLH}	Propagation delay time, low-to-high-level output from A input	C_L = 30 pF, See Figure 1		750		ns
t_{PHL}	Propagation delay time, high-to-low-level output from A input			200		ns
t_{TLH}	Transition time, low-to-high-level output			100		ns
t_{THL}	Transition time, high-to-low-level output			350		ns

APPLICATION INFORMATION

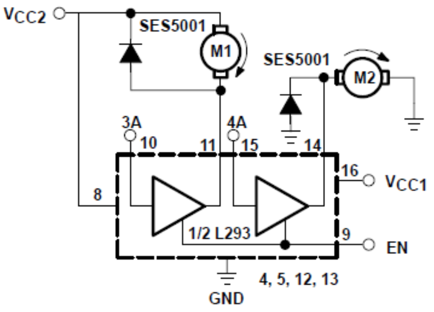


Figure 4. DC Motor Controls (connections to ground and to supply voltage)

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

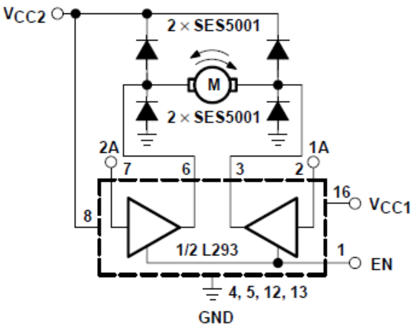


Figure 5. Bidirectional DC Motor Control

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

APPENDIX D

MOTOR SPECIFICATION

SPG30 Series

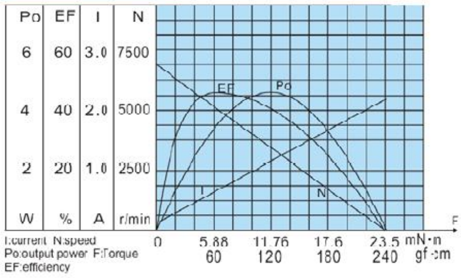
Cytron Technologies

Output Power: 1.1W

Weight: ~160g

Typical applications: Labal printers、auto shutter、welding machines、water meter ICcard、grill、oven、cleaning machine、garbage disposers、househod appliances、slot machines、money detector、automatic actuator、coffee machine、towel dispcsal、lighting、coin refund devices、peristaltic pump.

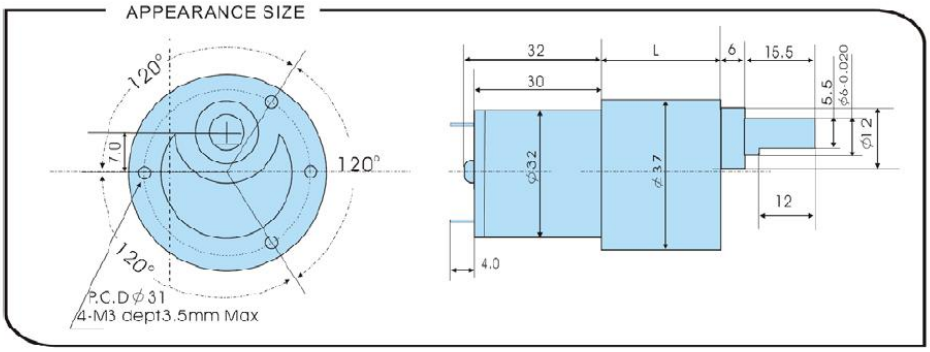
MOTOR CHARACTERISTICS



MOTORTORQUE/SPEED/CURRENT

Rated voltage	12VDC
No load speed	7000r/min
No load current	70mA
Rated torque	60gf・cm 5.88mN・m
Rated current	410mA
Rated speed	5200r/min
Stall torque	240gf・cm 23.5mN・m
Stall current	1.8A

APPEARANCE SIZE



Order Option							
Order Code	Input Voltage	Rated		Weight (g)	Power (w)	Diameter (mm)	L (mm)
		Speed (RPM)	Torque (mN.m)				
SPG10-30K	6	440	29.4	10	-	12	24
SPG10-150K	6	85	107.9	10	-	12	24
SPG10-298K	6	45	176.5	10	-	12	24
SPG20-50K	12	130	58.8	60	0.6	27.2	-
SPG30-20K	12	185	78.4	160	1.1	37	22
SPG30-30K	12	103	127.4	160	1.1	37	22
SPG30-60K	12	58	254.8	160	1.1	37	25
SPG30-150K	12	26	588	160	1.1	37	27
SPG30-200K	12	17	784	160	1.1	37	27
SPG30-300K	12	12	1176	160	1.1	37	27
SPG50-20K	12	170	196	300	3.4	37	23
SPG50-60K	12	56	588	300	3.4	37	26
SPG50-100K	12	34	980	300	3.4	37	26
SPG50-180K	12	17	1960	300	3.4	37	28

1. **Introduction and Overview**

Figure 1.0 DC geared motor with encoder and its removable cover

This document explains the general method to use the encoder for MO-SPG-30E-XXXK. "XXX" is referring to the gear ratio of Cytron's SPG-30 Geared Motor series which is either 20, 30, 60, 150, 200 or 300. This DC Geared Motor with Encoder is formed by a quadrature hall effect encoder board which is designed to fit on the rear shaft of Cytron's SPG-30 Geared Motor series. Two hall effect sensor are placed 90 degree apart to sense and produce two output A and B which is 90 degree out of phase and allowing the direction of rotation to be determined. This encoder provides 3 counts per revolution of the rear shaft. Please note that the encoder is mounted at the rear shaft, the minimum resolution is depends on the motor's gear ratio.

Features of Quadrature Hall Effect Encoder:

- Operating voltage : 4.5 V to 5.5 V
- Two digital outputs (Quadrature waveform)
- Small in size and light in weight
- Resolution: 3 pulses per rear shaft revolution, single channel output.
  - 60 counts per main shaft revolution for 1:20 geared motor

- 90 counts per main shaft revolution for 1:30 geared motor
- 180 counts per main shaft revolution for 1:60 geared motor
- 450 count per main shaft revolution for 1:150 geared motor
- 600 count per main shaft revolution for 1:200 geared motor
- 900 count per main shaft revolution for 1:300 geared motor

1.1. State Diagrams and Waveform

State Diagram

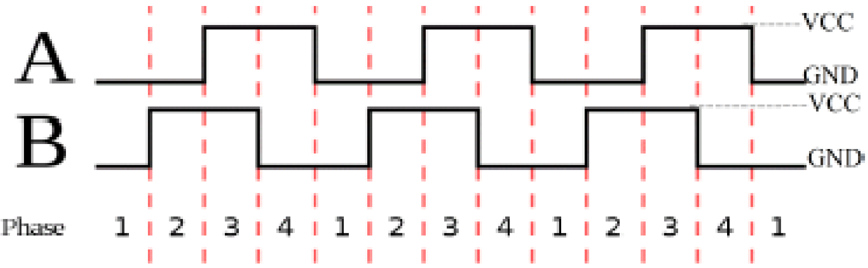
Clockwise Rotation

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

Counter Clockwise Rotation

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

Square quadrature waveform for Channel A and B (Clockwise)



2. Pin Descriptions

Figure 2.0 2020-06 connector pin descriptions

Pin	Name	Description
1	Motor -	Output of motor driver
2	Motor +	Output of motor driver
3	Hall effect sensor VCC	Supply voltage for sensor circuit (4.5V-5.5V)
4	Hall effect sensor GND	Ground
5	Channel A	Output of the encoder
6	Channel B	Output of the encoder