DIRECTION AND SPEED CONTROL OF DC MOTOR

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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.

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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.

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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

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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

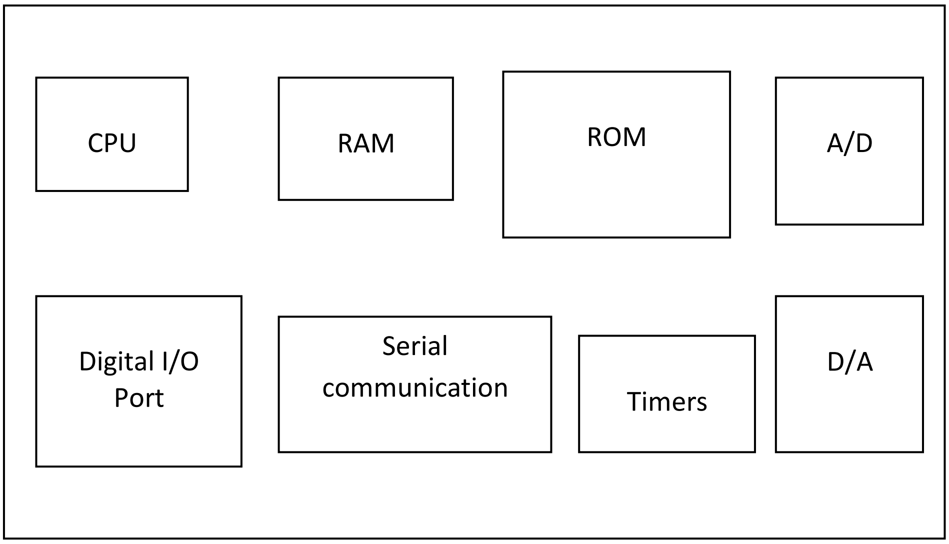

Figure 2.1 Typical Diagram of Microcontroller [4][7]

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.

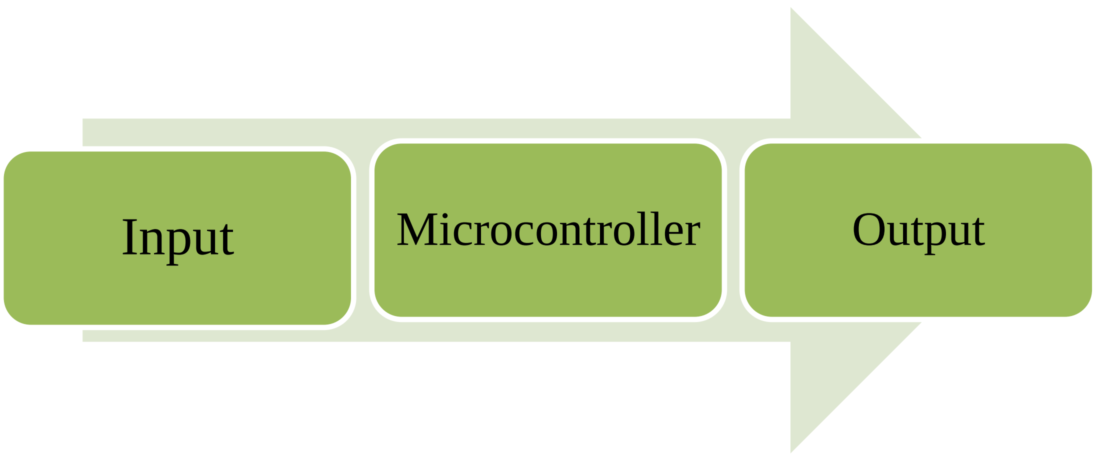

Figure 2.2 DC motor controlling system

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].

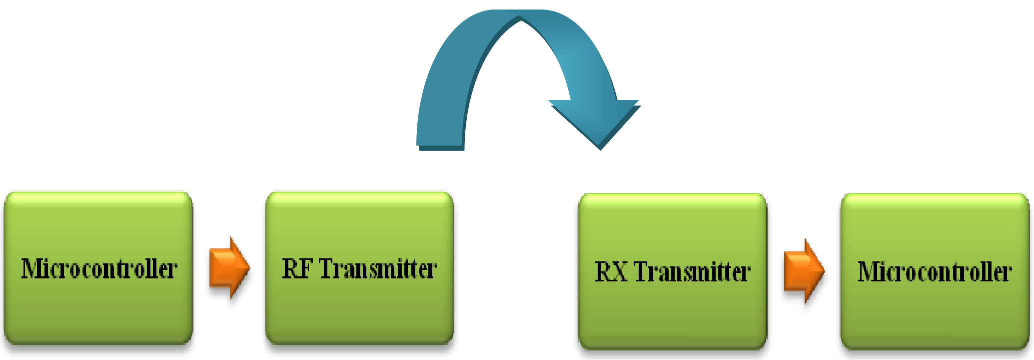

Figure 2.3 Simple flow of RF module

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.

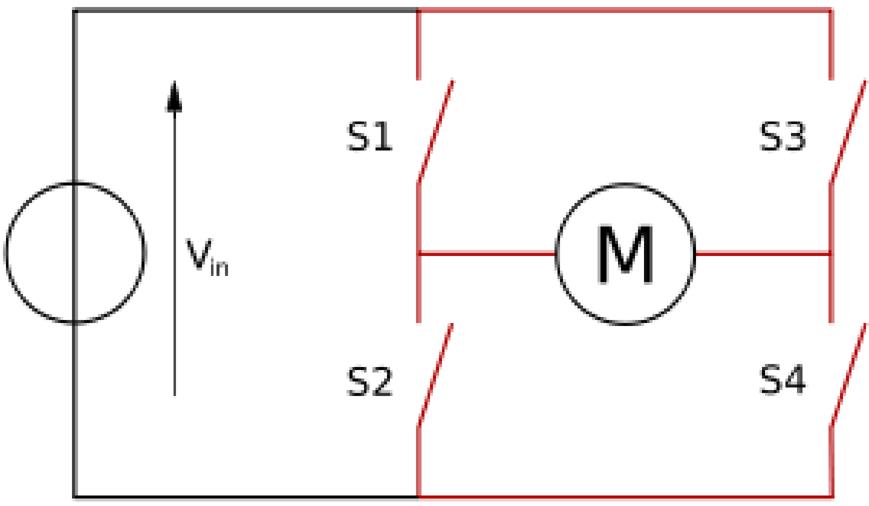

Figure 2.4 H-Bridge configuration

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.

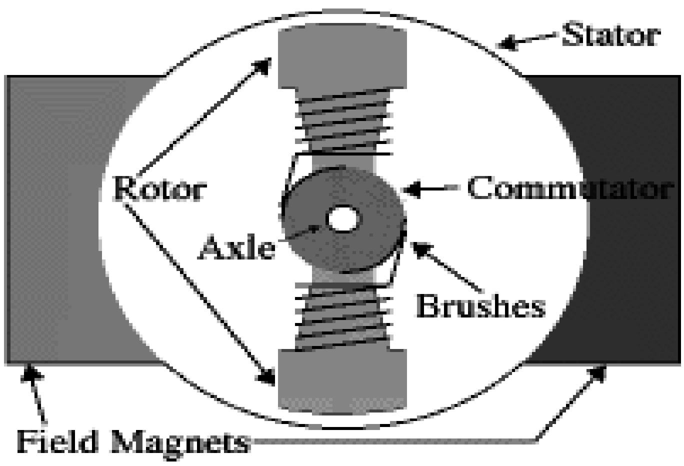

Figure 2.5 Parts of DC Motor

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].

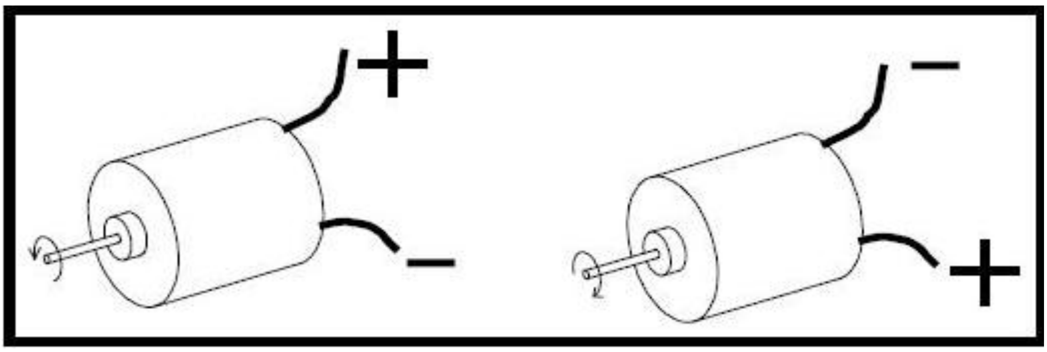

Figure 2.6 DC Motor rotations

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

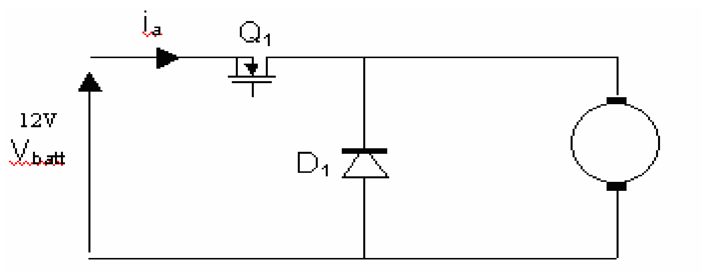

Figure 2.7 Simple motor circuit