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A Study of D.C Motor Speed Control through Pulse Width Modulation Implemented by MATLAB Simulation

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Abstract: Direct current (DC) motor has already become an important drive configuration for many applications across a wide range of powers and speeds. We can easily control the performance of the DC motors and ensure that the number of applications using them will continue to grow for the future. In this paper it has presented the realization of the speed control by using Pulse Width Modulation.PWM is generated using Microcontroller 8051 and to drive the motor, H-bridge is used which is made up of four MOSFETs. Precise control of low torque DC motor is obtained by using simple and inexpensive hardware. This paper shows that accurate and precise control of small DC motors can be done effectively and efficiently without using complicated circuitry and costly components.

Keywords: DC motor, H-bridge, Pulse Width Modulation.

1. INTRODUCTION

DC motor plays an important role in modern industries. They are widely used in industries because of its low cost, less complex control structure and wide range of speed and torque. DC motors provide high starting torque which is required for traction applications. There are several types of applications where the load on the DC motor varies over a wide range. These applications may demand high-speed control accuracy and good dynamic responses. Higher torques can be obtained by using geared motors. The term geared motor is used to define a motor that has a gear reduction system (or gearbox) integrally built into the motor. The gearbox increases the torque generating ability of the motor while simultaneously reducing its output speed. DC motors are used in portable machine tools supplied from batteries, in automotive vehicles as starter motors, blower motors, and in many control applications as actuators and as speed and position sensing devices. Such as hand drills and kitchen appliances, use a dc servomotor known as a universal motor.

Those motors can work well on both AC and DC power. One of the drawbacks (precautions) about series wound DC motors is that if they are unloaded, the only thing limiting their speed is the wind age and friction losses. When compared to AC or wound field DC motors, PM motors are usually physically smaller in overall size and lighter for a given power rating. There are only three methods of the speed control of DC drives namely field control, armature voltage control and armature resistance control. In general, armature voltage control method is widely used to control the DC drives. In thyristor method, a controlled rectifier, or chopper is used to vary the supplied voltage by changing the firing angle but due to involvement of power electronics elements, nonlinear torque speed characteristics are observed which are undesirable for control performance. DC motor drives are used for many speed and position control systems where due to excellent performance, easily control and high efficiency are desirable characteristics. Pulse-width modulation (PWM) is the technique of using switching devices to produce the effect of a continuously varying analogue signal; this PWM conversion generally has very high electrical efficiency. In this paper, method of analog pulse width modulation has discussed that drives DC motor by switching the MOSFETs connected in H-bridge.

2. D.C MOTOR

DC motor is the devices that convert electrical power into mechanical power. It can be traced to disc-type machines conceived and tested by Michael Faraday, who has formulated fundamental concepts of electromagnetism.

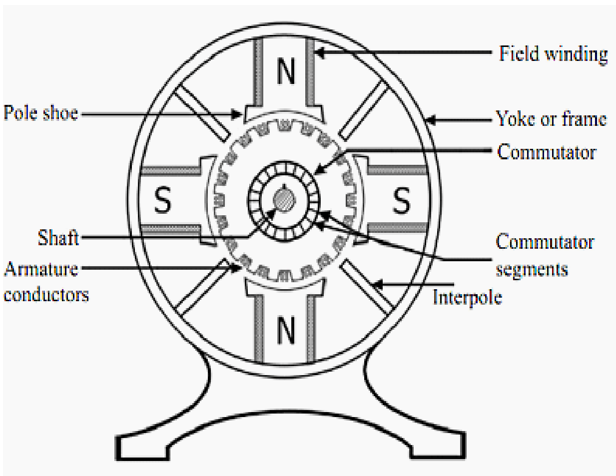

Figure (A). Construction of DC Motor

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DC motor uses electricity and a magnetic field to produce torque, which causes it to turn. It requires two magnets of opposite polarity and an electric coil, which acts as an electromagnet. The repellent and attractive
Electromagnetic forces of the magnets provide the torque that causes the motor to turn. It also consists of one set of coils, called armature winding, inside a set of permanent magnets, called the stator. Applying a voltage to the coils produces a torque in the armature, resulting in its motion.

DC motor provides excellent control of speed for acceleration and deceleration. DC drives are normally less expensive for most horsepower ratings. DC motors have a long tradition of use as adjustable speed machines and a wide range of options have evolved for this purpose.

3. BIDIRECTIONAL FULL BRIDGE CIRCUIT

Driving a brushed DC motor in both directions, by reversing the current through it, can be accomplished by using a full-bridge circuit which consists of four N channel MOSFETs. A full bridge circuit is shown in the figure (B). Each side of the motor can be connected either to battery positive, or to battery negative. Note that only one MOSFET on each side of the motor must be turned on at any one time otherwise it will be short and battery burn out.

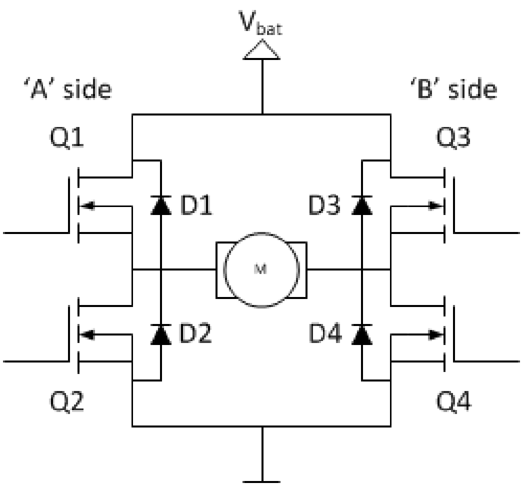

Figure (B). Full H-bridge driver circuit diagram

To make the motor go forwards, Q4 is turned on, and Q1 has the PWM signal applied to it. The current path is from Q1 to Q4. Note that there is also a diode connected in reverse across the field winding. This is to take the current in the field winding when all four MOSFETs in the bridge are turned off. Q4 is kept on so when the PWM signal is off, current can continue to flow around the bottom loop through Q2's intrinsic diode. To make the motor go backwards, Q2 is turned on, and Q3 has the PWM signal applied to it. Q2 is kept on so when the PWM signal is off, current can continue to flow around the bottom loop through Q4's intrinsic diode. For regeneration, when the motor is going backwards for example, the motor (which is now acting as a generator) is forcing current right through its armature, through Q3's diode, through the battery (thereby charging it up) and back through Q2's diode .The speed of a DC motor is directly proportional to the supply voltage, so if we reduce the supply voltage from 12 Volts to 6 Volts, the motor will run at half the speed. A better way is to switch the motor's supply on and off very quickly. If the switching is fast enough, the motor doesn't notice it, it only notices the average effect. This type of on-off switching is performed by power MOSFETs. This is the principle of switch mode speed control. Thus the speed is control by Pulse Width Modulation (PWM).

4. PULSE WIDTH MODULATION

There are many forms of modulation are used for communication information. When a high frequency signal has amplitude varied in response to a lower frequency signal. When the signal frequency is varied in response to the modulation signal we have FM. These signal are used for radio modulation because the high frequency carrier signal is needs for efficient radiation of the signal. A simplest method to control the rotation speed of a DC motor is to control its driving voltage. Higher the voltage, higher the speed of the motor tries to reach. In many applications simple voltage regulation would cause a lot of power loss on control circuit, so a pulse width modulation methods (PWM) are used in many DC motor controlling applications. The ratio of “on” time to “off” time is what determines the speed of the motor. When doing PWM controlling, keep in mind that a motor is a low pass device. Basically the reason is that a motor is mainly a large inductor. It is not capable of passing high frequency energy, and hence will not perform well using high frequencies. Reasonably low frequencies are required, and then PWM techniques will work. Lower frequencies are generally better than higher frequencies, but PWM stops being effective at too low a frequency.

The idea that a lower frequency PWM works better simply reflects that the “on” cycle needs to be pretty wide before the motor will draw any current (because of motor inductance). A higher PWM frequency will work fine if you hang a large capacitor across the motor or short the motor out on the “off” cycle. The reason for this is that short pulses will not allow much current to flow before being cut off. Then the current that did flow is dissipated as an inductive kick - probably as heat through the fly back diodes. The capacitor integrates the pulse and provides a longer, but lower, current flow through the motor after the driver is cut off. There is not inductive kick either, since the current flow isn’t being cut off. Knowing the low pass roll-off frequency of the motor helps to determine an optimum frequency for operating PWM. Here the motor is tested with a square duty cycle using a variable frequency, and then the drop in torque is observed as the frequency is increased. This technique can help determine the roll off point as far as power efficiency is concerned. However, when we work out the power dissipation in the stray resistances in our motor and speed controller, for the DC case:

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$P=I^2R$
and for the switching case, the average power is
$P=\frac{(2I)^2R}{2} + 0^2R/2$
$P = 2I^2R$

So in the switching waveform, twice as much power is lost in the stray resistances. In practice the current waveform will not be square wave like this, but it always remains true that there will be more power loss in a non-DC waveform.

5. BLOCK REPRESENTATION

First of all the PWM signals are generated and then the signal is fed to the driver networks which drive the motor. Driver circuit contains energy bank. The feedback loop is created between the microcontroller and the energy bank by the application of ADC. When the voltage level of the motor varies from the fixed point for different load conditions and speed of the motor also varies. ADC gets this error signal and corresponding PWM signal is generated to retain the fixed voltage level. Thus maintain a fixed motor speed at different load conditions.

The block representation of the proposed control circuit are given below

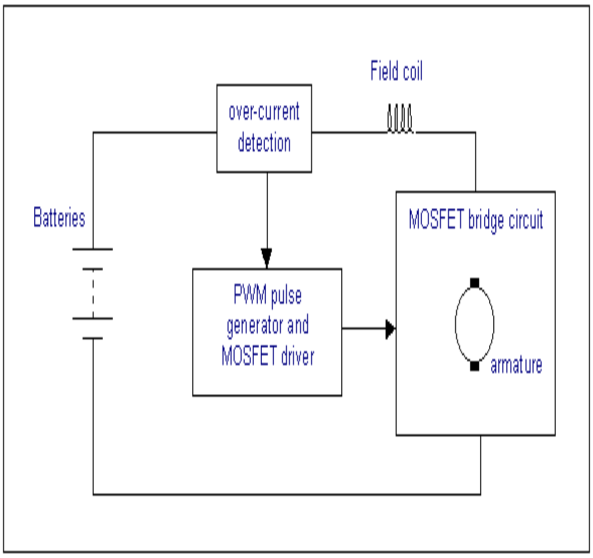

Figure (C). Block diagram of motor control circuit

6. SIMULATION RESULTS

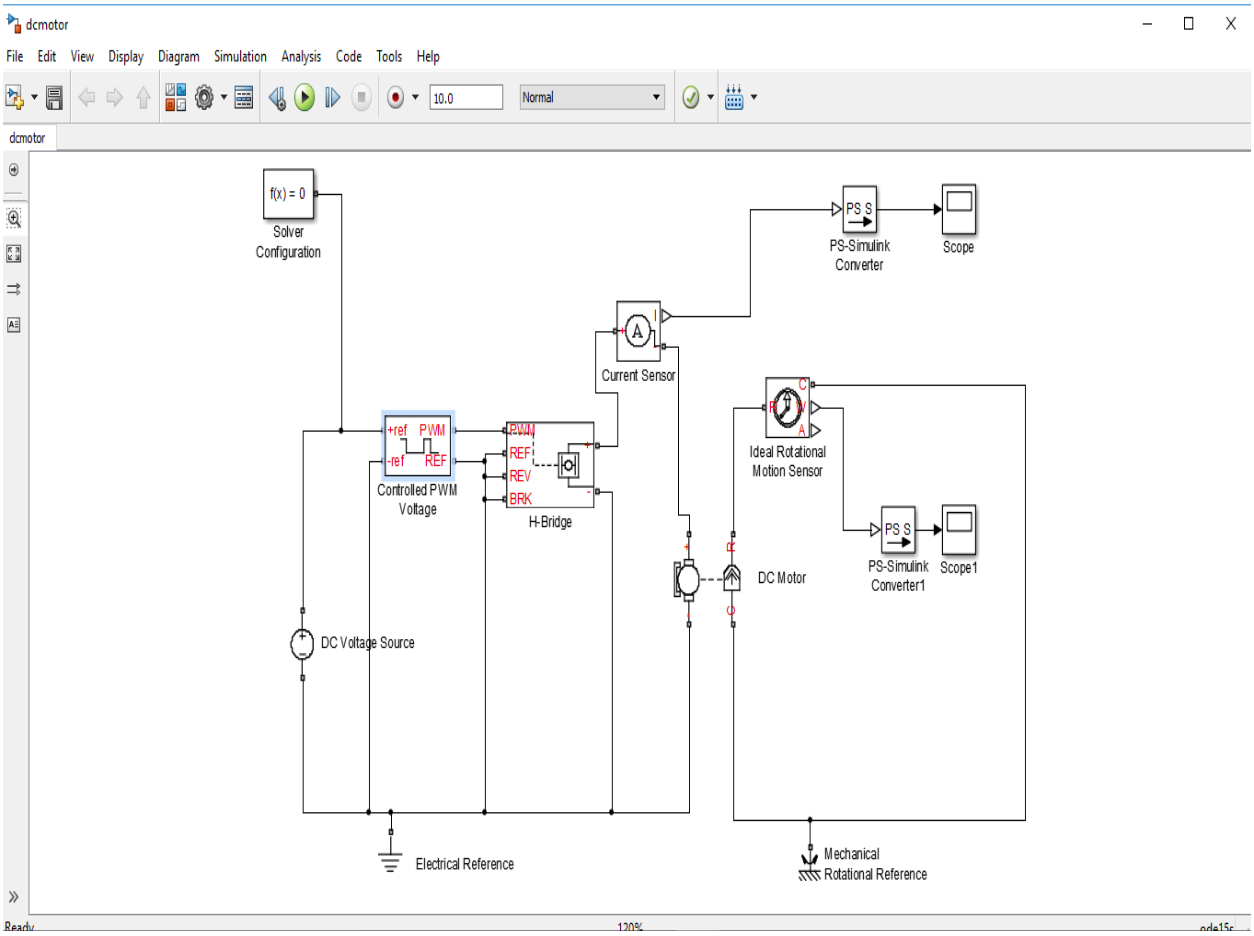

Figure (D). Block Diagram of Simulation of Speed control of DC Motor Using PWM

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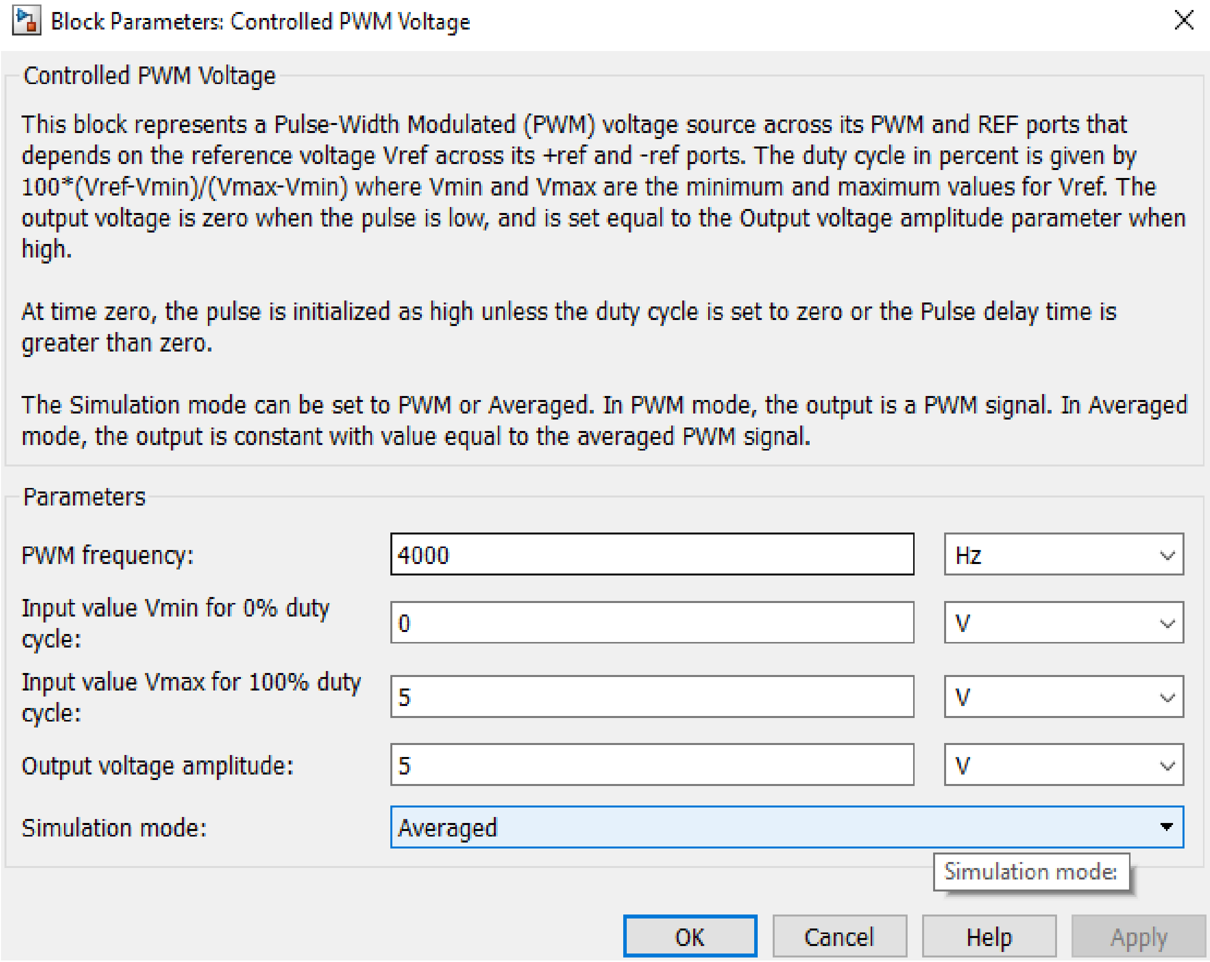

Figure (E). Functional Block Diagram of Controlled PWM Voltage

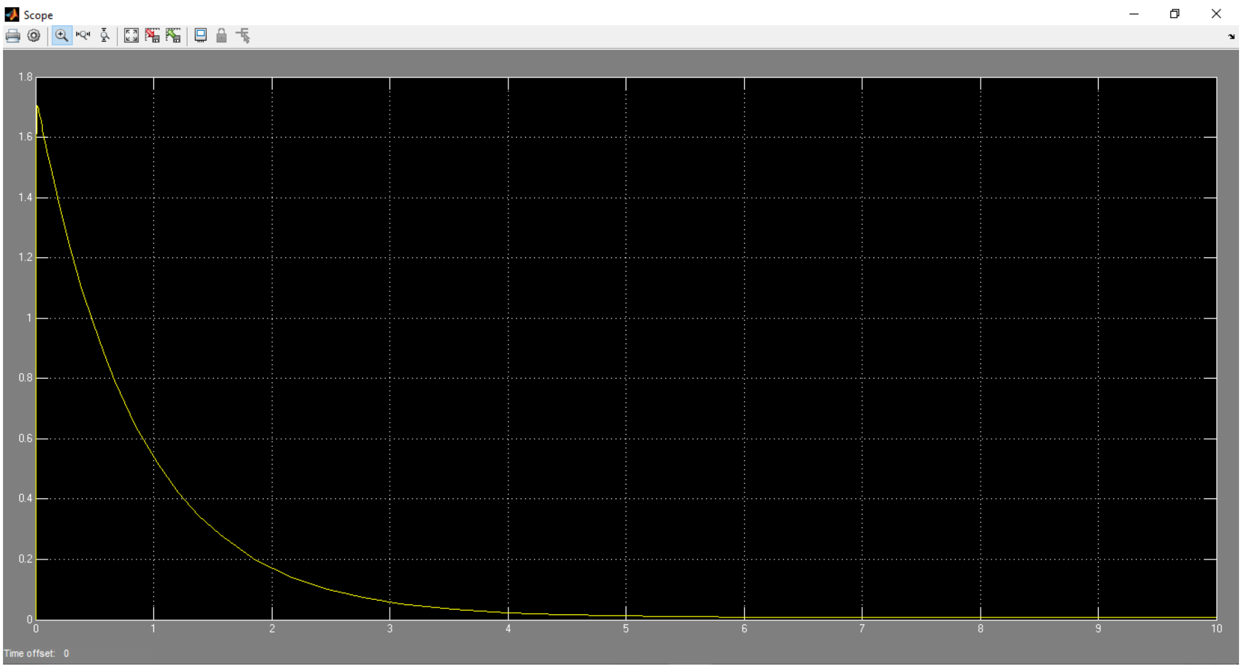

Figure (F). Output Result of Current for DC Motor Using PWM Technique

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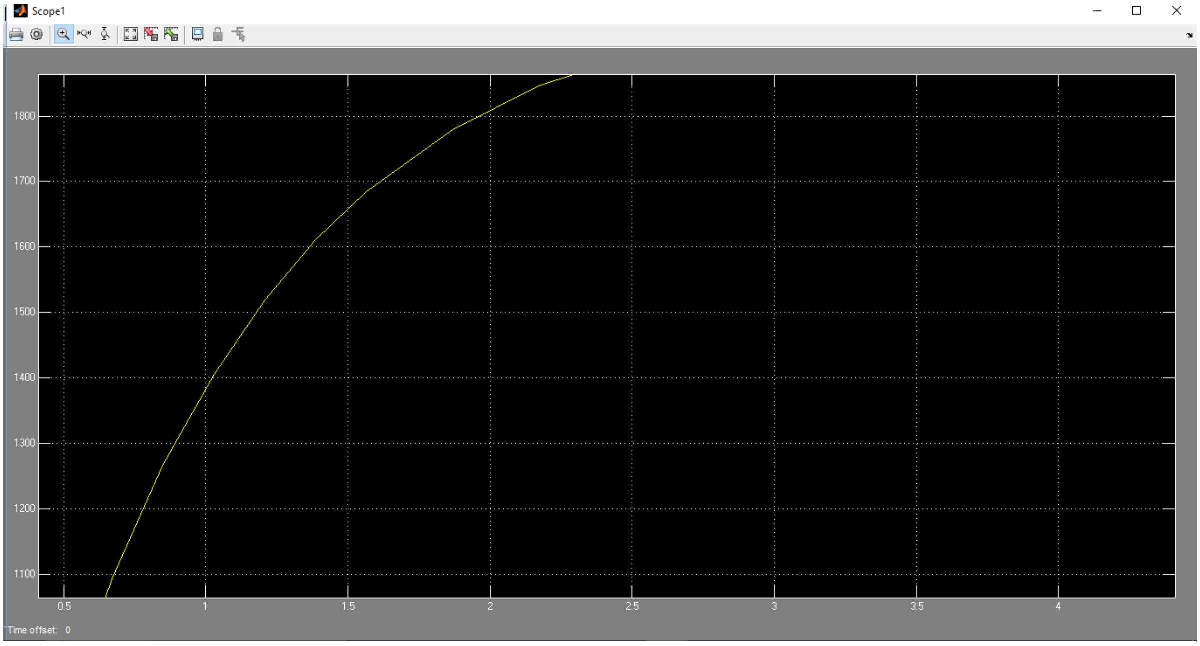

Figure (G). Output Result of Speed Control for DC Motor Using PWM Technique

7. CONCLUSION

We will design a dc motor with fixed speed control system, which has high precision, reliability and adaptability for different motor ratings with better speed response. It means that motor will run at fixed speed at any load condition. It will not vary with the amount of load. This system describes the design and implementation of the Automatic Closed Loop Speed Control of DC Motor that controls the speed of a DC motor by using PWM and MOSFET. In implementing this work frequency, independent PWM output with variable duty cycle that can vary from 0% to 100% is to be generated. Furthermore, an LCD display was fabricated to display the output. This kind of setup provides a complete user interface unit. Hence the system is complete stand-alone and user friendly.

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BIOGRAPHIES

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