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# Brushless DC Motor Speed Control Using Microcontroller

**E. Kannan**
*P.G. Research Scholar*
*Department of Electrical engineering*
*Sri Chandrasekharendra Saraswathi Viswa Mahavidyalaya University*
*Kanchipuram, (T.N.) [INDIA]*
*Email: vlk347ae@tnebnet.org*

**S. Lavanya**
*Assistant Professor*
*Department of Electrical engineering*
*Sri Chandrasekharendra Saraswathi Viswa Mahavidyalaya University*
*Kanchipuram, (T.N.) [INDIA]*
*Email: lavan_sivaa@yahoo.co.in*

## Abstract

*The hardware project is designed to control the speed of a BLDC motor using closed loop control technique. BLDC motor has various application used in industries like in drilling, lathes, spinning, electric bikes etc. The speed control of the DC motors is very essential. This proposed system provides a very precise and effective speed control system. The user can enter the desired speed and the motor will run at that exact speed.*

***Keywords:—*** *BLDC motor, Speed Control, electric bikes.*

## I. Introduction

Permanent-magnet excited brushless DC motors are becoming increasingly attractive in a large number of applications due to performance advantages such as reduced size and cost, reduced torque ripples, increased torque-current ratio, low noises, high efficiency, reduced maintenance and good control characteristics over a wide range in torque–speed plan. In general, Brushless DC motors such as fans are smaller in size and weight than AC fans using shaded pole or Universal motors. Since these motors have the ability to work with the available low voltage sources such as 24-V or 12-V DC supply, it makes the brushless DC motor fans convenient for use in electronic equipment, computers, mobile equipment, vehicles, and spindle drives for disk memory, because of its high reliability, efficiency, and ability to reverse rapidly. Brushless dc motors in the fractional horsepower range have been used in various types of actuators in advanced aircraft and satellite systems [1-4]. Most popular brushless DC motors are mainly three phases [5-7] which are controlled and driven by full bridge transistor circuits. Together with applying permanent magnet excitation, it is necessary to obtain additional torque components. These

Components can be obtained due to a difference in magnetic permeance in both quadrature and direct axis; therefore, reluctance torque is developed and torque null regions are reduced significantly [8, 11]. In this paper, a brushless DC motor with distributed winding and a special form of PM-rotor with special stator periphery are described. Which develop a speed control system for a BLDC motor by closed loop control technique.

The proposed system uses a microcontroller of the PIC 30F4011 family and a rectified-power supply. A set of IR transmitter and photodiode are connected to the microcontroller for counting the number of rotations per minute of the DC motor as a speed sensor. Optocoupler is connected to trigger the MOSFET for driving the BLDC

Motor which is duly interfaced to the microcontroller. A matrix keypad is interfaced to the microcontroller for controlling the speed of the motor. The speed control of the BLDC motor is archived by varying the duty cycles (PWM Pulses) from the microcontroller according to the program. The microcontroller receives the percentage of duty cycles from the keypad and delivers the desired output to switch the motor driver so as to control the speed of the BLDC motor. The speed sensed by the IR sensor is given to the microcontroller to display it on the LCD display.

The common DC motor has a permanent magnet, 3 coil windings and rotating mechanical switches called commentator for each coil (Figure 1a). Current flows through two of the coils whenever a voltage is applied at the brushes. This current interacts with the magnetic field of the permanent magnet and produces a torque and this torque moves the rotor. When the motor rotates, the brushes will automatically come in contact with the commentator of a different coil causing the motor to continue its rotation. It will turn faster if the voltage is increased and it will produce more torque if the magnetic field is also increased.

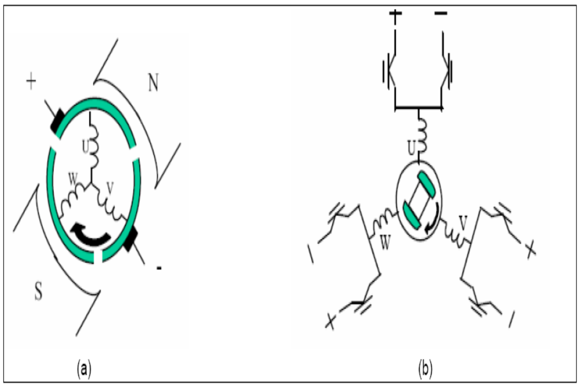


*Figure 1 a) Bushed DC Motor b) Bushless DC Motor*

## II. TYPES OF CONTROL TECHNIQUE OF BLDC MOTORS

Though various control techniques are discussed in [8] basically two methods are available for controlling BLDC motor. They are sensor control and sensor less control. To control the machine using sensors, the present position of the rotor is required to determine the next commutation interval. Motor can also be controlled by controlling the DC bus rail voltage or by PWM method. Some designs utilize both to provide high torque at high load and high efficiency at low load. Such hybrid design also allows the control of harmonic current [9]. In case of common DC motors, the brushes automatically come into contact with the commutator of a different coil causing the motor to continue its rotation. But in case of BLDC motors the commutation is done by electronic switches which need the rotor position. The appropriate stator windings have to be energized when rotor poles align with the stator winding.

The BLDC motor can also be driven with predefined commutation interval. But to achieve precise speed control and maximum generated torque, brushless commutation should be done with the knowledge of rotor position. In control methods using sensors, mechanical position sensors, such as a hall sensor, shaft encoder or resolver have been utilized in order to provide rotor position information. Hall Position sensors or simply Hall sensors are widely used and are popular. Whenever the magnetic poles pass near the sensors, they either give a high or low signal, indicating North or South Pole is passing the pole. The accurate rotor position information is used to Generate precise firing commands for power converter. This ensures drive stability and fast dynamic response. The speed feedback is derived from the position sensor output signals. Between the two commutations signals the angle variation is constant as the

Hall Effect Sensors are fixed relative to the motor, thus reducing speed sensing to a simple division. Usually speed and position of a permanent magnet brushless direct current motor rotor is controlled in a conventional cascade structure. The inner current control loops runs at a larger width than the outer speed loop to achieve an effective cascade control [10]. Various senseless methods for BLDC motors are analyzed in [11].Modelling of BLDC is given in [12]. [11] Proposes a speed control of brushless drive employing PWM technique. The above literature does not deal with reduction of speed oscillations and also the motor can't runs at exact speed in BLDC drive. This paper deals with control method to reduce speed oscillations and to runs the motor at exact entered speed. This is achieving by using the microcontroller programming.

## III. BLDC Motor Details

Brushless Direct Current (BLDC) motors are one of the motor types rapidly gaining popularity. BLDC motors are used in industries such as Appliances, Automotive, Aerospace, Consumer, Medical, Industrial Automation Equipment and Instrumentation. As the name implies, BLDC motors do not use brushes for commutation; instead, they are electronically commutated. BLDC motors have many advantages over brushed DC motors and induction motors. A few of these are:

- Better speed versus torque characteristics
- High dynamic response
- High efficiency
- Long operating life
- Noiseless operation

## IV. Construction

BLDC motors are a type of synchronous motor. This means the magnetic field generated by the stator and the magnetic field generated by the rotor rotates at the same frequency. BLDC motors do not experience the "slip" that is normally seen in induction motors. BLDC motors come in single-phase, 2-phase and 3-phase configurations. Corresponding to its type, the stator has the same number of windings.

### *4.1 Stator*

The stator of a BLDC motor consists of stacked steel laminations with windings placed in the slots that are axially cut along the inner periphery (as shown in Figure 3). Traditionally, the stator resembles that of an induction motor; however, the windings are distributed in a different manner. Most BLDC motors have three stator windings connected in star fashion. Each of these windings is constructed with numerous coils interconnected to form a winding. One or more Coils are placed in the slots and they are interconnected to make a winding. Each of these windings is distributed over the stator periphery to form an even numbers of poles. There are two types of stator windings variants: trapezoidal and sinusoidal motors. This differentiation is made on the basis of the interconnection of coils in the stator windings to give the different types of back Electromotive Force (EMF).

As their names indicate, the trapezoidal motor gives a back EMF in trapezoidal fashion and the sinusoidal motor's back EMF is sinusoidal, as shown in Figure 1 and Figure 2. In addition to the back EMF, the phase current also has trapezoidal and sinusoidal variations in the respective types of motor. This makes the torque output by a sinusoidal motor smoother than that of a Trapezoidal motor. However, this comes with an extra cost, as the sinusoidal motors take extra winding interconnections because of the coils distribution on the stator periphery, thereby increasing the copper intake by the stator windings. Depending upon the control power supply capability, the motor with the correct voltage rating of the stator can be chosen. Forty-eight volts, or less voltage rated motors are used in automotive, robotics, small arm movements and so on. Motors with 100 volts, or higher ratings, are used in appliances, automation and in industrial applications

### 4.2 Rotor

The rotor is made of permanent magnet and can vary from two to eight pole pairs with alternate North (N) and South (S) poles. Based on the required magnetic field density in the rotor, the proper magnetic material is chosen to make the rotor. Ferrite magnets are traditionally used to make permanent magnets. As the technology advances, rare earth alloy magnets are gaining popularity.

The ferrite magnets are less expensive but they have the disadvantage of low flux density for a given volume. In contrast, the alloy material has high magnetic density per volume and enables the rotor to compress further for the same torque. Also, these alloy magnets improve the size-to-weight ratio and give higher torque for the same size motor using ferrite magnets. Neodymium (Nd), Samarium Cobalt (SmCo) and the alloy of Neodymium, Ferrite and Boron (NdFeB) are some examples of rare earth alloy magnets. Continuous research is going on to improve the flux density to compress the rotor further. Figure 4 shows cross sections of different arrangements of magnets in a rotor.

### 4.3 Hall Sensors

Unlike a brushed DC motor, the commutation of a BLDC motor is controlled electronically. To rotate the BLDC motor, the stator windings should be energized in a sequence. It is important to know the rotor position in order to understand which winding will be energized following the energizing sequence. Rotor position is sensed using Hall Effect sensors embedded into the stator. Most BLDC motors have three Hall sensors embedded into the stator on the non-driving end of the motor. Whenever the rotor magnetic poles pass near the Hall sensors, they give a high or low signal, indicating the N or S pole is passing near the sensors. Based on the combination of these three Hall sensor signals, the exact sequence of commutation can be determined.

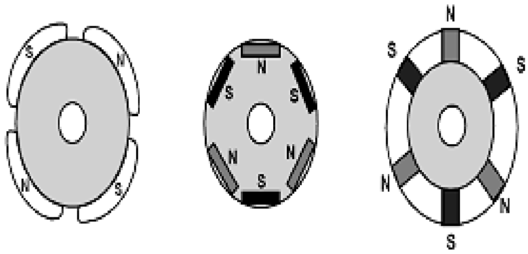

*Figure 2. Rotor Cross Sections*

### 4.4 Hall Effect Theory

If an electric current carrying conductor is kept in a magnetic field, the magnetic field exerts a transverse force on the moving charge carriers which tends to push them to one side of the conductor. This is most evident in a thin flat conductor. A buildup of charge at the sides of the conductors will balance this magnetic influence, producing a measurable voltage between the two sides of the conductor. The presence of this measurable transverse voltage is called the Hall Effect after E. H. Hall who discovered it in 1879. The Hall sensors require a power supply. The voltage may range from 4 volts to 24 volts. Required current can range from 5 to 15 m Amp. Hall sensors are embedded into the stationary part of the motor. Embedding the Hall sensors into the stator is a complex process because any misalignment in these Hall sensors, with respect to the rotor magnets, will generate an error in determination of the rotor position. To simplify the process of mounting the Hall sensors onto the stator, some motors may have the Hall sensor magnets on the rotor, in addition to the main rotor magnets. These are a scaled down replica version of the rotor.

Therefore, whenever the rotor rotates, the Hall sensor magnets give the same effect as the main magnets. The Hall sensors are normally mounted on a PC board and fixed to the enclosure cap on the non-driving end. This enables users to adjust the complete assembly of Hall sensors, to align with the rotor magnets, in order to achieve the best performance. Based on the physical position of the Hall sensors, there are two versions of output.

The Hall sensors maybe at 60° or 120° phase shift to each other. Based on this, the motor manufacturer defines the commutation sequence, which should be followed when controlling the motor.

## V. Comparing BLDC Motors to Other Motor Types

Compared to brushed DC motors and induction motors, BLDC motors have many advantages and few disadvantages. Brushless motors require less maintenance, so they have a longer life compared with brushed DC motors. BLDC motors produce more output power per frame size than brushed DC motors and induction motors. Because the rotor is made of permanent magnets, the rotor inertia is less, compared with other types of motors.

This improves acceleration and deceleration characteristics, shortening operating cycles. Their linear speed/torque characteristics produce predictable speed regulation. With brushless motors, brush inspection is eliminated, making them ideal for limited access areas and applications where servicing is difficult. BLDC motors operate much more quietly than brushed DC motors, reducing Electromagnetic Interference (EMI).

Low-voltage models are ideal for battery operation, portable equipment or medical applications. Table 1 summarizes the comparison between a BLDC motor and a brushed DC motor. Table 2 compares a BLDC motor to an induction motor.

**Type :** 3Ø BLDC Motor
**Power :** 100W
**Speed :** 3000 RPM
**Voltage :** 24V
**Current :** 5A
**No. Pole :** 4 Pole
**Feed Back :**
Three Number of Hall sensor (120 degree)

*Figure 3: BLDC Motor*

**Hardware Details:**


*Figure 4: 3Ø Voltage Source Inverter Power Module*

This voltage source inverter power module is designed for DC to Single phase (or) 3 phase AC Conversion applications. This module can be used for speed control application of Single phase, 3 phase AC induction motor, brushed DC motor, brushless motor (BLDC & PMSM) along with suitable PWM controller.

## VI. Control Circuit and Block Diagram

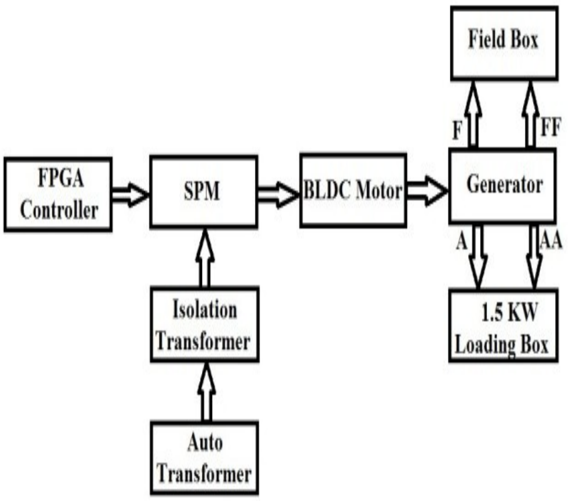


*Figure 5. Block Diagram of Speed Control of BLDC Motor*

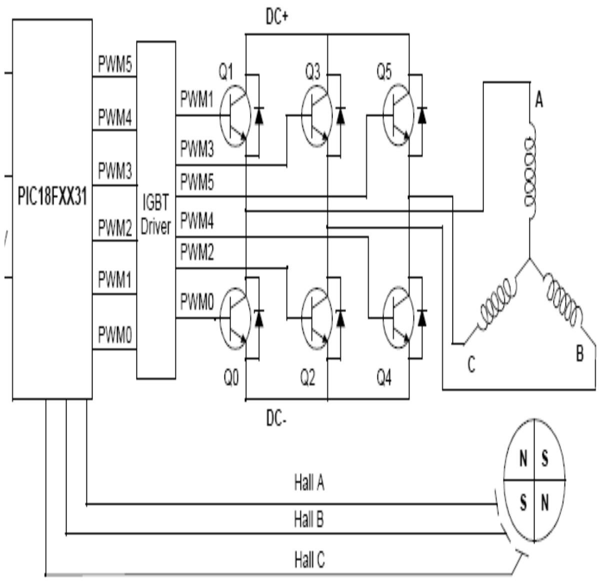


*Figure 6. Circuit Diagram of Speed Control of BLDC Motor*

## VII. Output Waveform

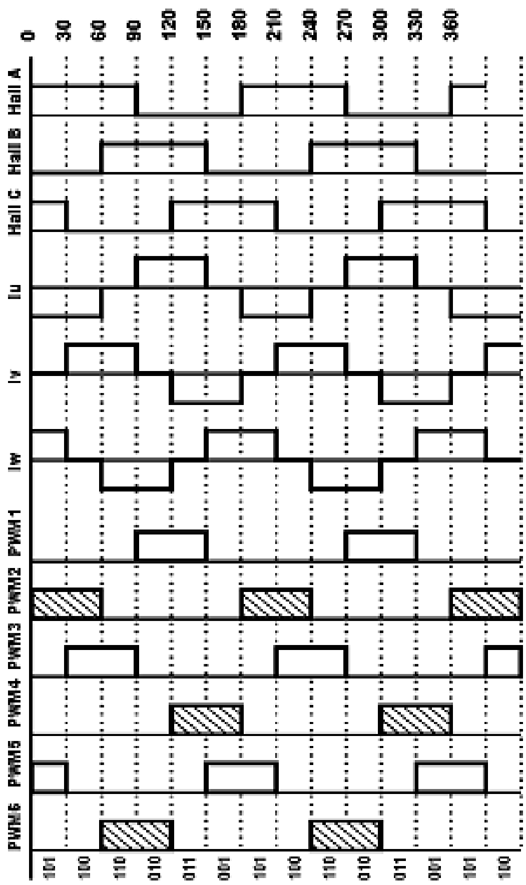


*Figure 7. Output wave form in Forward Direction*

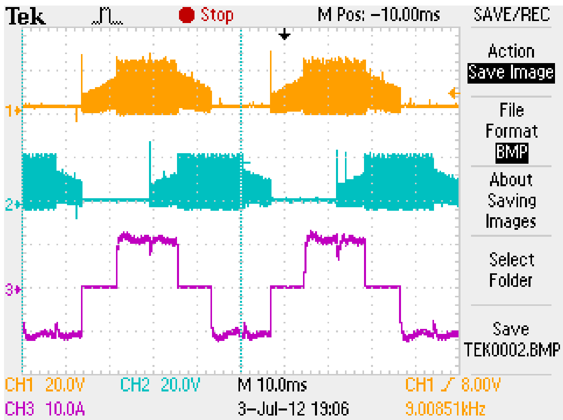


*Figure 8. Final Output wave form in CRO Screenshot*

## VII. Conclusion

The hardware for closed loop control of BLDC motor using microcontroller is designed. By using the PWM technique speed of the BLDC motor was controlled and it was made to run at exactly entered speed. In future this hardware will be implemented in dSPACE and the speed control will be observed.

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