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Variable Speed BLDC Motor Drive Using PIC Microcontroller

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***Abstract*—This paper aims to design and implementation of BLDC motor speed control based on the POT variation. This project is mainly concerned on BLDC motor speed control system by using microcontroller PIC 16F877A. Motor speed can be controlled with variable POT, based on which the PWM pulse is generated. So, this programming device can be used to control any motor and their speed. The POT is used to give the speed range to the controller. The heart of the circuit is the POT and microcontroller which controls all its function. The PIC microcontroller has 10bit resolution ADC, which is used to convert the POT's analog signal into digital. The speed variation can be in large range (i.e, 1024 different speeds). A hall sensor is used for the feedback from the BLDC motor to measure the rotor position. Based on the rotor position the MOSFET switches in the VSI will be switched with the PWM pulse from the controller. The VSI has 6 MOSFET switches. The speed of the motor is displayed on an LCD. In this project, PIC 16F877A microcontroller can control motor speed at desired range with variable POT and rotor position.**
***Keywords*— Brushless Direct Current motor, Pulse Width Modulation, Voltage Source Inverter, Liquid Crystal Display, Analog to Digital Conversion**

I. INTRODUCTION

Now-a-Days, Brushless DC (BLDC) motors are one of the electrical drives that are rapidly gaining popularity, due to their high efficiency, good dynamic response and low maintenance and are widely used in many motor applications developing high torque with good speed response. A BLDC motor finds its applications in numerous fields like aerospace, home appliances, defense systems, electronic gadgets etc. Efficiency and cost are the major concerns in the development of low-power motor drives targeting household applications such as fans, water pumps, blowers, mixers, etc. The use of the brushless direct current (BLDC) motor in these applications is becoming very common due to features of high efficiency, high flux density per unit volume, low maintenance requirements and low electromagnetic-interference problems. These BLDC motors are not limited to household applications, but these are suitable for other applications such as medical equipment, transportation, HVAC, motion control, and many industrial tools. Brushless DC motors can in many cases replace conventional DC motors. BLDC motors are available in many different power ratings, from very small motors as used in hard disk drives to large motors in electric vehicles. Three phase motors are most common but two phase motors also have many applications. The BLDC motors have many advantages over brushed DC motors. BLDC motors have trapezoidal back emf and uses Hall Effect position sensors to determine the position of the rotor field. 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 computation can be determined. Every 60 electrical degrees of rotation, one of the hall sensors changes the state. Given this, it takes six steps to complete an electrical cycle. Corresponding to this, with every 60 electrical degrees, the phase current switching should be updated. POT variation is used to change the PWM pulse width, which is used to control the operation of VSI switches. The required speed will be given by the POT variation. The speed of the motor is displayed on LCD.

In the proposed system the speed control of BLDC motor can be done automatically based on the potential meter variation. PWM pulse width is varied based on the input it is given to Voltage Source Inverter. The proposed system controls the speed the motor in an efficient manner.

II. BLOCK DIAGRAM

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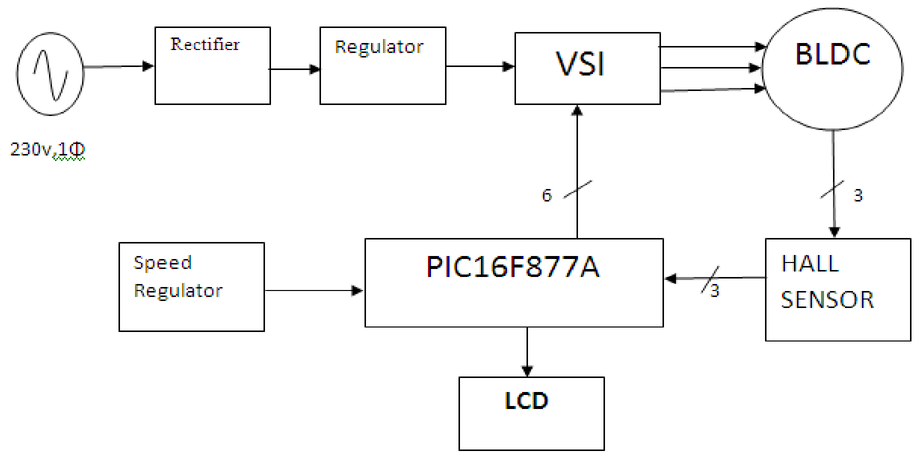

Fig. 1 Overall block diagram Unit

The speed of BLDC motor is directly proportional to the POT voltage. Pulse duration is directly proportional to the value of the input voltage. When the value of voltage is low, pulse will be narrow and when the value of voltage is high, pulse width will be wide. PWM control adjusts the duty ratio of the BLDC motor. The average DC value of the signal can be varied by varying the duty cycle. The PWM pulse is used to trigger the MOSFET switches of the voltage source inverter (VSI).

The Hall Sensor is used to find the rotor position of the motor. Based on this the VSI switches will be given with PWM pulses. For each position of the rotor, different MOSFET switches are given with PWM pulse. Speed of the motor is displayed on the LCD, which is varied based on the POT voltage.

A. BLDC Motor Speed Controller

For precise speed control of BLDC motor, closed-loop control is normally used. The basic block diagram of the BLDC motor speed control is shown in Figure 2. The rotor position, which is sensed by the HALL sensor is given to the microcontroller, it is used to sense the each 60degree rotation.

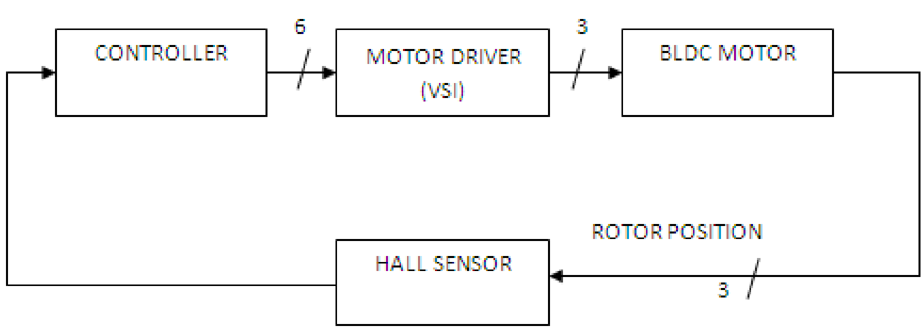

Fig. 2 Basic block diagram for DC Motor speed control

B. Principle used for motor speed control using PWM

The speed of the BLDC motor can be modified by varying the DC voltage across the three stators of the motor. However if we take a DC fan and switch on the DC supply across it, the fan motor takes some time to speed up. This is because the fan motor has an inductive coil so it does not respond immediately to the applied voltage. If we switch the power off before the motor reaches full speed, the motor starts to slow down. If we switch the power on and off quickly enough the fan motor and hence the fan run at some speed between the zero and full speed. This is what is achieved through the PWM signal. The fan speed can be modified with the variation in the duty cycle of the PWM signal.

C. Method of motor speed control using a power MOSFET

To control the speed of the BLDC motor using the PWM signal, we need to use a switch which can be switched on and off at PWM frequency and hence control the supply voltage across the BLDC motor. This switch can be made by using a high switching speed power MOSFET. The action of switch is to connect and disconnect the power across the motor at PWM frequency.

The Voltage Source Inverter is used for the speed control of BLDC motor. It has 6MOSFET switches. It produces 3phase voltage to the 3 stators of the BLDC motor. With respect to the rotor position the MOSFET switches are triggered.

III. HARDWARE DESCRIPTION

A. PIC Microcontroller

PIC is a family of Harvard architecture microcontrollers made by Microchip Technology, derived from the PIC1640 originally developed by General Instrument's Microelectronics Division. The name PIC initially referred to "Peripheral Interface Controller".

PICs are popular with developers and hobbyists alike due to their low cost, wide availability, large user base, extensive collection of application notes, availability of low cost or free development tools, and serial programming (and re-programming with flash memory) capability.

B. Liquid Crystal Display

LCD stands for Liquid Crystal Display. LCD is finding wide spread use replacing LEDs (seven segment LEDs or other multi segment LEDs) because of the following reasons: The ability to display numbers, characters and graphics. This is in contrast to LEDs, which are limited to numbers and a few characters. Incorporation of a refreshing controller into the LCD, thereby relieving the CPU of the task of refreshing the LCD. In contrast, the LED must be refreshed by the CPU to keep displaying the data.

C. BLDC Motor

Brushless DC electric motor (BLDC motors, BL motors) also known as electronically commutated motors (ECMs, EC motors) are motors that are powered by a DC electric source via an integrated inverter/switching power supply, which produces an AC electric signal to drive the motor. In this context, AC, alternating current, does not imply a sinusoidal waveform, but rather a bi-directional current with no restriction on waveform. Additional sensors and electronics control the inverter output amplitude and waveform (and therefore percent of DC bus usage/efficiency) and frequency (i.e. rotor speed).

D. Voltage Source Inverter

The word ‘inverter’ in the context of power-electronics denotes a class of power conversion (or power conditioning) circuits that operates from a dc voltage source or a dc current source and converts it into ac voltage or current. The ‘inverter’ does reverse of what ac-to-dc ‘converter’. Even though input to an inverter circuit is a dc source, it is not uncommon to have this dc derived from an ac source such as utility ac supply.

The ‘inverter’ is referred as a circuit that operates from a stiff dc source and generates ac output. If the input dc is a voltage source, the inverter is called a voltage source inverter (VSI). The VSI circuit has direct control over ‘output (ac) voltage’ whereas the CSI directly controls ‘output (ac) current’. Shape of voltage waveforms output by an ideal VSI should be independent of load connected at the output.

E. Hall-effect sensors

These kinds of devices are based on Hall-effect theory, which states that an electric current carrying conductor is kept in magnetic field exerts a transverse force on the moving charge carrier that tends to push them to one side of the conductor. A build-up of charge at the sides of the conductor will balance this magnetic influence producing a measurable voltage between the two sides of the conductor.

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The presence of this measurable transverse voltage is called the Hall-effect. Most BLDC motors have three Hall sensors inside the stator on 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.

F. Power Supply

The ac voltage, typically 220V rms, is connected to a transformer, which steps that ac voltage down to the level of the desired dc output. A diode rectifier then provides a full-wave rectified voltage that is initially filtered by a simple capacitor filter to produce a dc voltage. This resulting dc voltage usually has some ripple or ac voltage variation.

A regulator circuit removes the ripples and also remains the same dc value even if the input dc voltage varies, or the load connected to the output dc voltage changes. This voltage regulation is usually obtained using one of the popular the popular voltage regulator IC units.

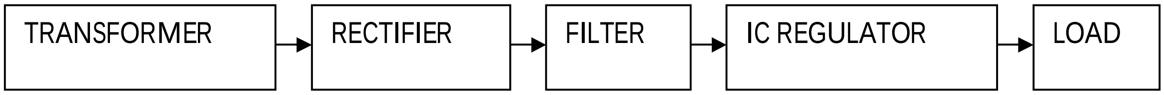


Fig. 3 Block Diagram (Power Supply)

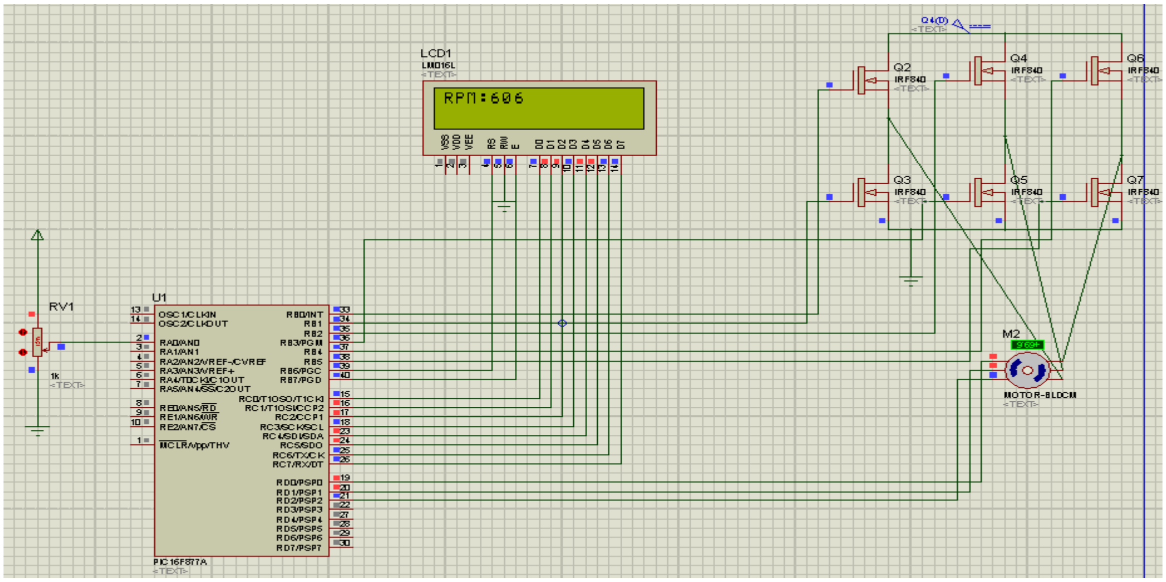
G .Potential Meter

Variable resistors are often called potentiometers, or pots, for short, because one very common use for them is as an adjustable voltage divider. For many years they were often called volume controls, because another very common use was in adjusting the audio volume produced by amplifiers, radio and TV receivers.

Pots are made in a variety of physical forms, and with the actual resistance element made from different materials. Some pots are made for frequent manual adjustment via a control knob, while others are designed to be adjusted only occasionally with a screwdriver or similar tool, for fine tuning of circuit performance. The latter type is usually called preset pots or trim pots.

Potentiometers are rarely used to directly control significant amounts of power (more than a watt or so). Instead they are used to adjust the level of analog signals (for example volume controls on audio equipment), and as control inputs for electronic circuits.

IV. SIMULATION RESULT



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Proteus is the best simulation software for various designs with microcontroller. It is mainly popular because of availability of almost all microcontrollers in it. So it is a handy tool to test programs and embedded designs for electronics hobbyist. You can simulate your programming of microcontroller in Proteus Simulation Software. After simulating your circuit in Proteus Software you can directly make PCB design with it so it could be all in one package for students and hobbyists. So I think now you have a little bit idea about what is proteus software.

V. CONCLUSION

Recent developments in science and technology provide a wide range scope of applications of high performance BLDC motor drives in area such as medical equipment, transportation, HVAC, motion control, many industrial tools and the home electric appliances require speed controllers to perform different tasks. BLDC motors have speed control capabilities, which means that speed, torque and even direction of rotation can be changed at anytime to meet new condition.The goal of this project is to design a BLDC motor speed control system by using microcontroller PIC16F877A. It is a closed-loop real time control system. The controller will maintain the speed at desired speed when there is a variation of POT. By varying the PWM signal from microcontroller to the motor driver, motor speed can be controlled back to desired value easily. The actual set speed is getting displayed on the LCD screen.

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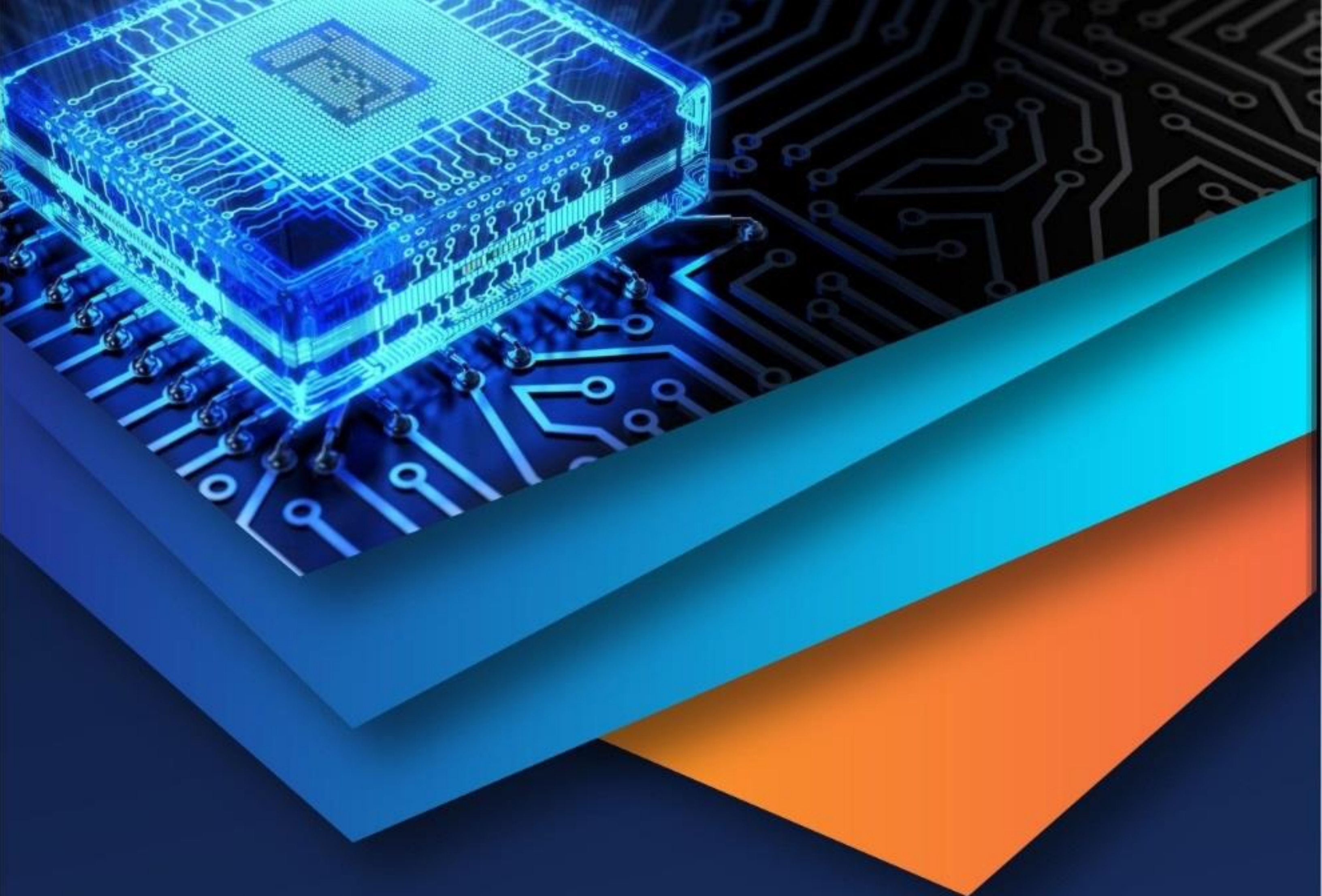

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