BRUSHLESS DC MOTOR SPEED CONTROL USING MICROCONTROLLER

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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: Hall position sensors, Brushless DC motor, Microcontroller.

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 8051 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.

II. TYPES OF CONTROL TECHHIQUE OF BLDC MOTOR

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 communtator 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].Modeling 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 achieve by using the microcontroller programming .

III. CONSTRUCTION AND OPERATING PRINCIPLE

Brushless DC motors were developed from conventional brushed DC motors with the availability of solid state power semiconductors. Brushless DC motors are similar to AC synchronous motors. The major difference is that synchronous motors develop a sinusoidal back EMF, as compared to a rectangular, or trapezoidal, back EMF for brushless DC motors. Both have stator created rotating magnetic fields producing torque in a magnetic rotor.

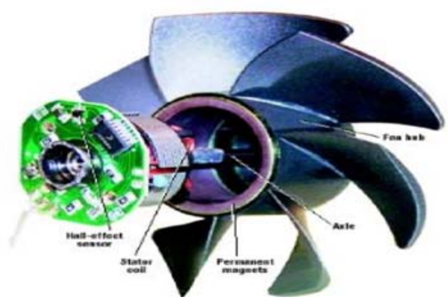


Fig.1 : Construction of BLDC motor

The basic construction of a brushless-dc consists of a fan blade attached to a permanent magnet rotor that surrounds the electromagnetic coils of the stator and associated control electronics.

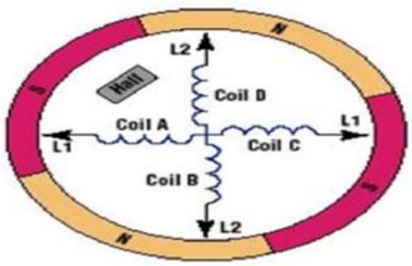


Fig.2 : DC Motor schematic diagram

A typical biphase brushless fan motor is made from a permanent magnet rotor assembly that surrounds four electromagnetic coils. The coils work in pairs, with coils A and C forming one phase and coils B and D the other phase. A Halleffect sensor monitors rotor position, providing feedback to the embedded MCU for commutation, speed regulation, and fault detection.

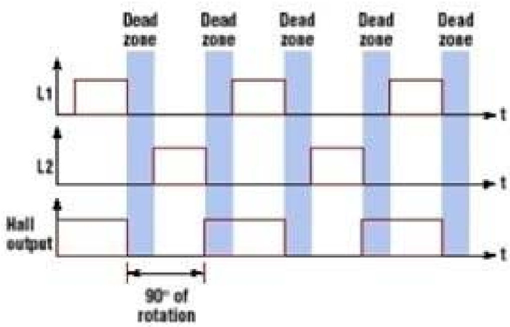


Fig . 3: Commutation Timeline Diagram

Commutation between the two phase windings in the dc fan takes place electronically by alternately applying power to L1 and L2. Dead zones between the power pulses limit current for speed control and helps minimize a cogging effect when the rotor magnets align with the stator coils. The on-and-off power of the commutation period resembles the output from a pulse-width modulator, or PWM.

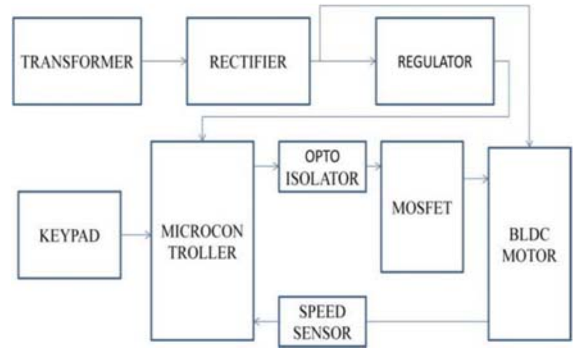


Fig .4 : Block Diagram

The Fig 4 describes the overall system design for the Closed loop control of BLDC motor. The MCU uses a PWM to control the period of the motor drivers and, thus set fan speed.

Feedback from the Hall sensor monitors actual fan rpm and indicate when communication should take place.

The MCU continuously monitors motor speed by measuring the output period of the Hall effect sensor.

A period that run shorter than the target length indicates motor speed is too fast. The schematic diagram of closed loop control 1 of BLDC motor is shown in fig. 5.

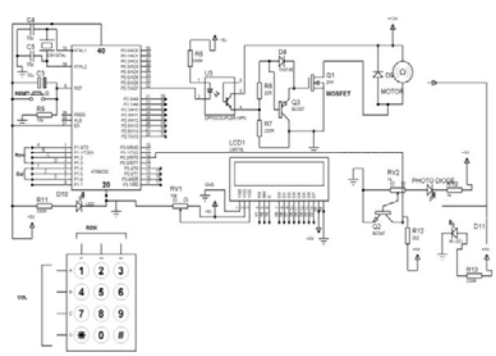


Fig 5. Schematic Diagram

IV. BLDC MOTOR SPEED CONTROL

Pulse-width modulation (PWM) is a commonly used technique for controlling power to an electrical device, made practical by modern electronic power switches. The average value of voltage (and current) fed to the load is controlled by turning the switch between supply and load on and off at a fast pace. The longer the switch is on compared to the off periods, the higher the power supplied to the load is. The PWM switching frequency has to be much faster than what would affect the load, which is to say the device that uses the power. Typically switching's have to be done several times a minute in an electric stove, 120 Hz in a lamp dimmer, from few kilohertz (kHz) to tens of kHz for a motor drive and well into the tens or hundreds of kHz in audio amplifiers and computer power supplies

The term duty cycle describes the proportion of on time to the regular interval or period of time; a low duty cycle corresponds to low power, because the power is off for most of the time. Duty cycle is expressed in percent, 100% being fully on.

The main advantage of PWM is that power loss in the switching devices is very low. When a switch is off there is practically no current, and when it is on, there is almost no voltage drop across the switch. Power loss, being the product of voltage and current, is thus in both cases close to zero. PWM works also well with digital controls, which, because of their on/off nature, can easily set the needed duty cycle.

PWM has also been used in certain communication systems where its duty cycle has been used to convey information over a communications channel.

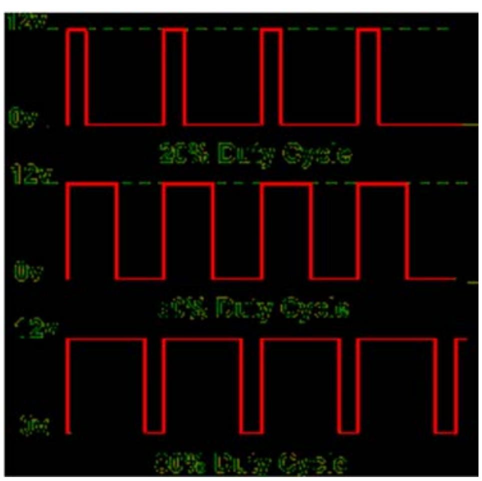


Fig.6 : PWM Pulses

The duly cycle determines the speed of the motor .

The desired speed can be obtained by changing the duty cycle. The PWM in microcontroller is used to control the duty cycle of DC motor.

Average Voltage=D * Vin

V. LOGICAL OPERATION OF BLDC MOTOR

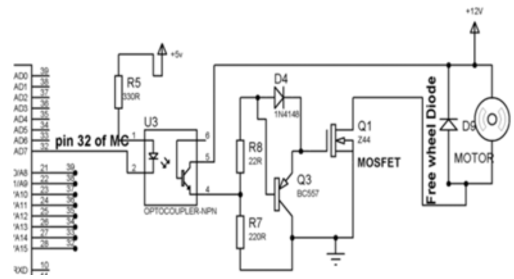


Fig.7 : PWM Generating Circuit

While logic high during the on time duty cycle is delivered by the microcontroller to the input of the OPTO U3 , The opto led glows to bring the opto transistor pin no 5 and 6 to conduct . Now 12V supply is given at the junction point of R7 and R8 and reaches the gate of the MOSFET Q1 via D4 for Q1 to conduct thus enabling the motor to get supply to run. A freewheel diode is used across the motor to conduct the charge stored in the motor during off period. During off time of the duty cycle the opto transistor does not conduct and the charge which is stored in the gate of Q1 forces Q3 to conduct while the motor stops. This ON and OFF the motor reduces the speed . The DC power is available to the motor via the MOSFET as per the PWM generated by micro controller depending upon the input given to micro controller from a keypad. As well as the speed is displayed on a liquid crystal display. To sense the speed of BLDC motor an IR LED in photo diode arrangement is used. The value of speed is changed in percentage by using fuzzy logic. Fuzzy logic is something i.e. approximate but not accurate. So a program is written in to micro controller that uses fuzzy logic due to which we get the values almost equal to accurate values. A 230v -12v step down transformer is used to decrease AC supply voltage to 12v, now this ac voltage is rectified by using a full wave bridge rectifier, a blocking diode is used before the filter capacitor to get the pulsating D.C. to get the fixed output D.C a 7805 voltage regulator is employed because micro controller fixed +5v pure DC. To filter pulsating D.C an electrolytic capacitor of value 470 micro farad's or 1000micro farad's is connected at the input of 7850. One more electrolytic capacitor is connected at the output of 7850 to remove complete ripple's if there any +5v D.C. A LED with a series resistor's is connected to indicate the power. 40 Micro controller has to generate PWM pulses as per error signal received from the speed sensing input to match the keyboard input in order to run the motor at the input RPM.

A push button is connected at the 9th pin of micro controller which is known as reset a 10 micro farad's electrolytic capacitor is connected across the button and a 10k resistor is used to pull down 9th pin of micro controller. When this reset pin is pressed during the operation , the program written in micro controller starts from beginning.

A crystal across oscillator of value 11.0592 MHz is connected across 18th & 19th pins of micro controller with the 33pico farad's ceramic capacitors are connected for stabilising it.

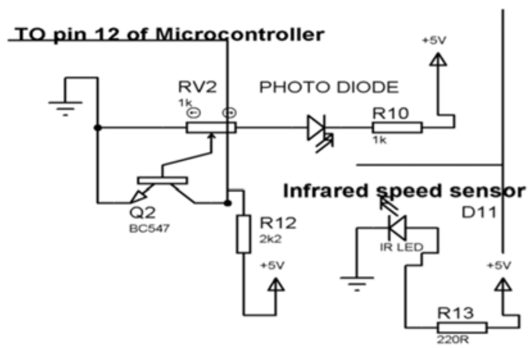


Fig.8 : Speed Sensing Circuit

To sense the speed of BLDC motor an infrared(IR) diode and photo diode are used. When light falls on photo diode the resistance across it decreases and vice versa. Hence photo diode is employed in a potential divider with a variable resistor. This potential divider supplies voltage to an N-P-N transistor whose collector is connected to micro controller input.

So, the IR LED and photo diode are placed near the shaft of BLDC motor and a white spot is made on the shaft infrared light gets reflected by white colour and the reflected light keeps falling on photo diode, due to which the voltage across it keeps changing thereafter the voltage at base of transistor also changes therefore at the collector of transistor a pulse is generated which is given to micro controller for counting the number of rotations per minute of D.C motor.

This sensed speed is displayed on LCD in rpm. To change the speed a keypad is used as an input to the micro controller. By using this we can enter how much percentage of speed would be required for the motor to run. Pressing '#' twice the maximum running speed is stored. After which pressing '*' the desired percentage of speed is entered. There after pressing # the desired speed is saved which are displayed on the LCD.There after the on time of the pulse width progressively goes on reducing to result the speed reduction. Speed sensors continuously send the error signal to pin 12 of the MC to lock the running speed of the motor at the desired speed.

VI. SIMULATION RESULTS FOR VARIOUS PWM PULSES.

The speed control technique employed here is pulse width modulation (PWM) technique The duty cycle determines the speed of the motor. The desired speed can be obtained by changing the duty cycle. The PWM in microcontroller is used to control the duty cycle of DC motor.

Average voltage = D * Vin

The average voltage obtained for various duty cycles is also mentioned and as the duty cycle percentage decreases average voltage also decreases from the supply voltage.

Duty cycle is defined as the percentage of time the motor is ON. Therefore, the duty cycle is given as

Duty Cycle = 100% x Pulse Width/Period

Where,

Duty Cycle in (%)

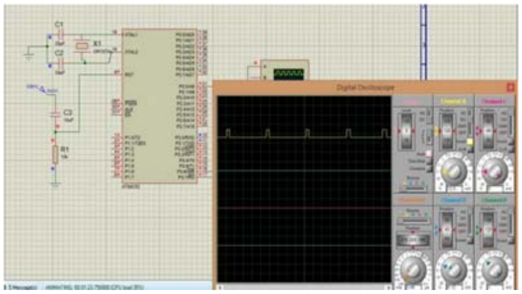
Pulse Width = Time the signal is in the ON or high state (sec)

Period = Time of one cycle (sec).

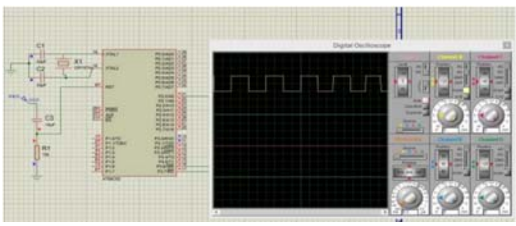
The program for the closed loop control of BLDC motor operation is written in embedded C and executed in keil software.

The PWM pulses generated from the microcontroller are viewed for various duty cycles,

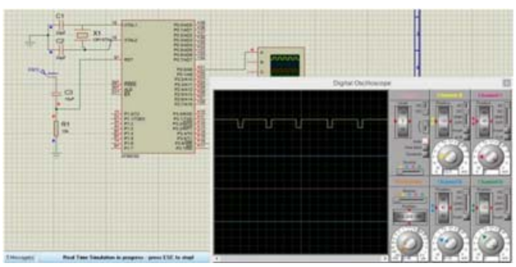
PWM Output for 20%



PWM Output for 50%



PWM Output for 80%

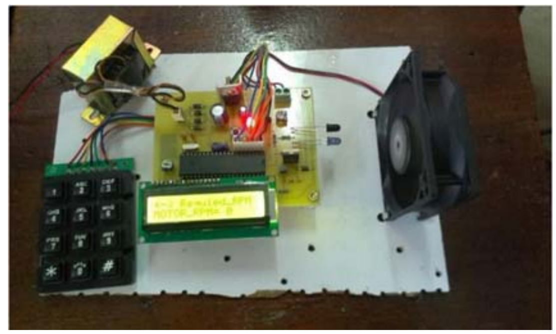


OUTPUT RESPONSE

INPUT DUTY CYCLE IN %	OUTPUT VOLTAGE	OUTPUT SPEED IN RPM
25%	3V	650
50%	6V	1300
75%	9V	1950
100%	12V	2600

HARDWARE SETUP

The hardware is designed and the operation has been done based upon the program written in the microcontroller for the Closed loop control of the BLDC motor and the speed is also controlled by using PWM technique. The hardware set up for the project is given below.



VII. OPERATION PROCEDURE

1. Press ‘#’ once display shows the store Max RPM.
2. Press ‘#’ again to store Max.RPM.
3. Press ‘*’ to get the required RPM. Display shows % of Req_RPM:
4. Enter the required percentage using Keypad. 5. Press ‘#’ to save the required RPM.

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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