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Speed Control of Brushless DC Motor using Microcontroller

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***Abstract*— In this paper we are designing a low cost microcontroller based speed control of Brushless DC motor. Brushless DC motor has various industrial applications like Linear motors, Servo motors, Drilling etc. Brushless DC motor uses a permanent magnet external rotor, three phase of driving coils, one or more Hall Effect devices are used to sense the position of the rotor. This system provides a very precise and effective speed control. [5].**

***Index Terms*— Microcontroller, Brushless DC motor, Hall Effect devices, Permanent magnet external rotor.**

I. INTRODUCTION

Brushless DC electric motor (BLDC motors, BL motors) also known as electronically commutated motors (ECMs, EC motors), or synchronous DC motors, are synchronous motors powered by DC electricity via an inverter or switching power supply which produces an AC electric current to drive each phase of the motor via a closed loop controller. The controller provides pulses of current to the motor windings that control the speed and torque of the motor.
Brushed DC motors develop a maximum torque when stationary, linearly decreasing as velocity increases. Some limitations of brushed motors can be overcome by brushless motors; they include higher efficiency and a lower susceptibility to mechanical wear. These benefits come at the cost of potentially less rugged, more complex, and more expensive control electronics.

II. BRUSHLESS DC MOTOR

A. Construction

The construction of a brushless motor system is typically similar to a permanent magnet synchronous motor (PMSM), but can also be a switched reluctance motor, or an induction (asynchronous) motor. The development of semiconductor electronics in the 1970s allowed the commutator and brushes to be eliminated in DC motors. In brushless DC motors, an electronic servo system replaces the mechanical commutator contacts. An electronic sensor detects the angle of the rotor, and controls semiconductor switches such as transistors which switch current through the windings, either reversing the direction of the current, or in some motors turning it off, at the correct time each 180° shaft rotation so the electromagnets create a torque in one direction. The elimination of the sliding contact allows brushless motors to have less friction and longer life; their working life is only limited by the lifetime of their bearings.

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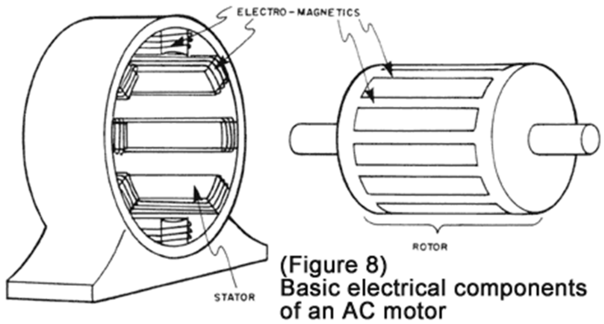
B. Rotor and Stator



(Figure 8)
Basic electrical components of an AC motor

ROTOR

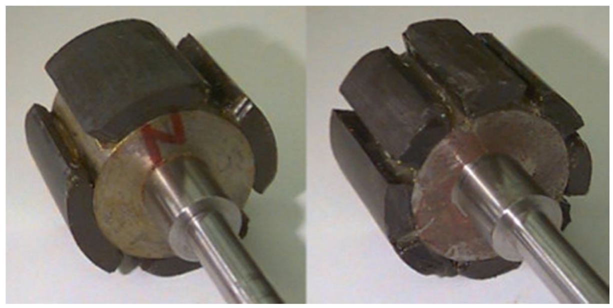


Fig1.

The rotor of a typical BLDC motor is made out of permanent magnets. Depending upon the application requirements, the number of poles in the rotor may vary. Increasing the number of poles does give better torque but at the cost of reducing the maximum possible speed.

STATOR

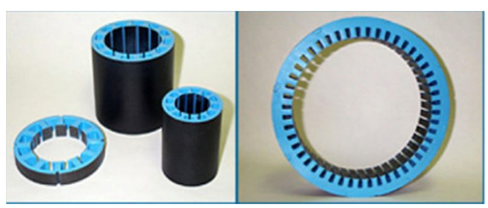
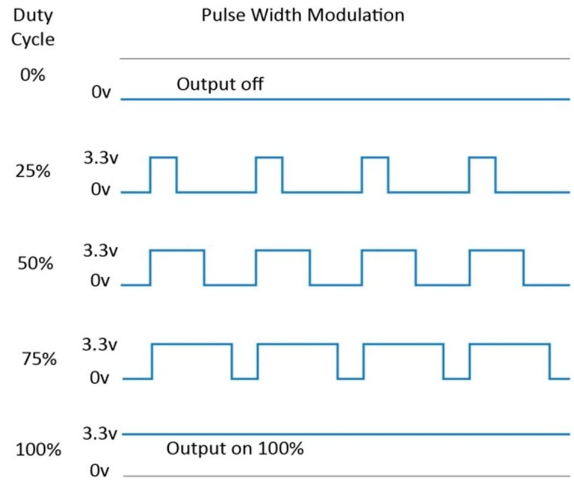


Fig 2.

Similar to an induction AC motor the BLDC motor stator is made out of laminated steel stacked up to carry the windings. Windings in a stator can be arranged in two patterns. Star pattern and Delta pattern.[2]
The underlying principles for the working of a BLDC motor are the same as for brushed DC motor i.e. internal shaft position feedback. In case of a brushed DC motor, feedback is implemented using a mechanical commutator and brushes. The most commonly used sensors are Hall sensors and optical encoders.

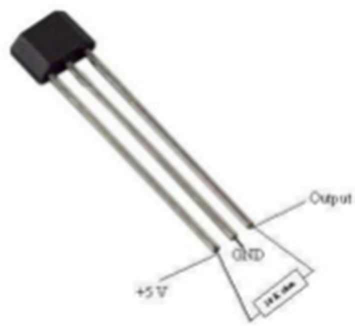
III. Speed Control of BLDC Motor

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 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. PWM has also been used in certain communication systems where its duty cycle has been used to convey information over a communications channel. The desired speed can be obtained by changing the duty cycle. [4].



IV. HALL SENSORS

A Hall Effect sensor is a transducer that varies its output voltage in response to a magnetic field. Hall Effect sensors are used for proximity switching, positioning, speed detection, and current sensing applications. [5].



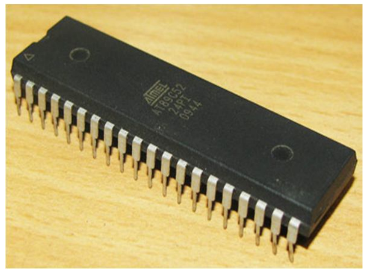
V. HALL EFFECT

The Hall Effect is the production of a voltage difference (the Hall voltage) across an electrical conductor, transverse to an electric current in the conductor and a magnetic field perpendicular to the current. It was discovered by Edwin Hall. The Hall coefficient is defined as the ratio of the induced electric field to the product of the current density and the applied magnetic field. It is a characteristic of the material from which the conductor is made, since its value depends on the type, number, and properties of the charge carriers that constitute the current.[5].

VI. MICROCONTROLER

The AT89C52 is a low-power, high-performance CMOS 8-bit microcomputer with 8Kbytes of Flash programmable and erasable read only memory (PEROM). The on-chip Flash allows the program memory to be reprogrammed in-system.

The AT89C52 provides the following standard features: 8Kbytes of Flash, 256 bytes of RAM, 32 I/O lines, three 16-bit timer/counters, six-vector two-level interrupt architecture, a full duplex serial port, on-chip oscillator, and clock circuitry. In addition, the AT89C52 is designed with static logic for operation down to zero frequency and supports two software selectable power saving modes.



VII. SIMULATION RESULTS FOR VARIOUS PWM PULSES

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.[4]
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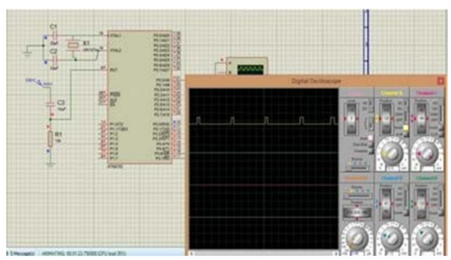
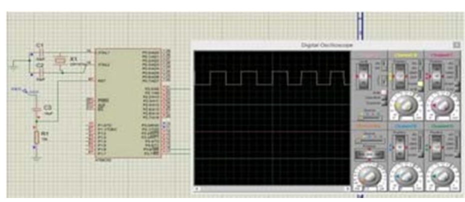
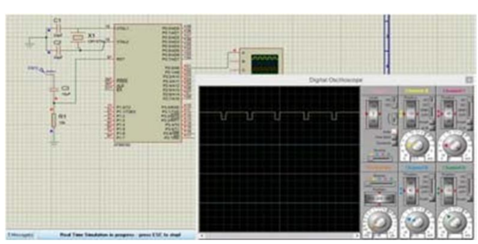


PWM Output for 20%



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

VIII. HARDWARE IMPLEMENTATION

The aim of the project is to control the speed of a BLDC motor using a microcontroller with the help of SVPWM-technique. As far as the hardware implementation is concerned, it is implemented for open loop of operation.

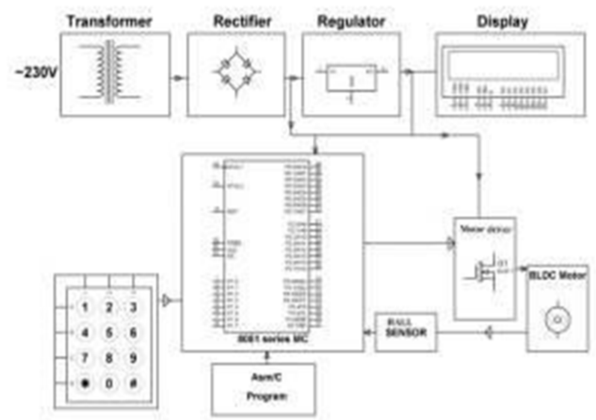


Fig 6.1 Block diagram

The entire power required is drawn from a single phase AC Source. This source is used to derive gate driving voltages for the motor driver, control circuit operating voltage and finally to drive the motor through motor driver bridge.

A. Circuit Specifications

This section covers a BLDC motor drive controlled by microcontroller with the following specifications.

- Input : 12 volts to Motor Driver
- BLDC Motor AT2212 Motor
- Microcontroller: AT89C52
- Hall Sensors : 17X131
- Motor Driver : HW30A
-

B. Operation

The operation of the circuit can be explained in three parts.

Control circuit

This gives out the switching signals to the converter bridge. A microcontroller is dedicated to generate the switching pulses. The microcontroller is programmed to give out pulse according to SVPWMM technique. Program is compiled in Keil software. The HEX code generated is loaded into the Microcontroller. The controller used is AT89C52. The controller is operated at 11.059 MHz frequency.

Motor driver and Gate driving circuit

Instead of using an inverter and a regulator we have used a motor driver HW30A which acts as inverter to supply the voltage for the Motor. HW30A is an inbuilt Inverter which is having Inverter circuit as well as MOSFET Driver circuit. We are using this type of technique because of on using general inverter we are facing the difficulties like large Heat dissipation, so that this heat would cause a heat sinking problem which in turn results in the failure of the Inverter. SO, by using this motor driver the circuit complexity is reduced and the heat dissipation problem, is also reduced.

Converter circuit

The converter circuit is provided by the Motor driver. The D.C supply is fed through a bridge rectifier. The switches in the Motor driver are turned ON and OFF as per the program. The Motor Drive is capable carrying a continuous current of 30A at 25 degree centigrade.

The rectifier circuit is made of diodes.

The component used is IN4007 which is capable of blocking a reverse voltage of 1000 V DC and can carry a current of 10A continuous. All these components are placed on General PCB. Control circuit and gate driving circuit components are soldered directly on the pcb, whereas, the power components as connected with suitable connectors as they carry larger currents.

IX. Future Work

The design of fuzzy logic controller for online remote control of DC motor has been taken up in this work along with real-time implementation in robotics. Few modification can be carried out in the presented work and can be applied for different applications.

The fuzzy logic algorithm can be extended for:

- Image processing to recognize objects and to analyse the scenes.
- Path planning and path tracking to achieve autonomous control.
- Implementation in real time for real robots.
- Brushless DC motors.

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