Asian Journal of Applied Science and Technology (AJAST)
Volume 1, Issue 7, Pages 10-14, August 2017

A Novel Speed Control of Brushless DC Motor Using Arduino UNO R3 and BOT

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Article Received: 14 July 2017 *Article Accepted: 29 July 2017* *Article Published: 01 August 2017*

ABSTRACT

Wireless monitoring and control is the new technology that most of the nations are interested in since majority of the people are now using the cellular phone. This paper proposes a system which would replace the wired connection between an electrical drive and the control terminal by a sophisticated Bluetooth connection, while providing an Android-based user interface that would enable control and supervision of the drive with minimal efforts on the user's part. The duty cycle determines the speed of the motor. The desired speed can be obtained by changing the duty cycle. The PWM in Arduino microcontroller is used to control the duty cycle .Speed control is achieved in three stages, input, processing and output stage. The input stage consists of entering the required speed through mobile phone. The processing stage provides RPM reference of the motor, by a shaft mounted IR sensor interfaced to the microcontroller in the circuit. The Arduino microcontroller develops PWM pulses which are varied with switches to regulate power to the BLDC motor such that the desired speed is achieved. The output stage uses an IGBT being driven by the microcontroller output. The driving technique is trapezoidal pulse-width-modulation (PWM) wave which called trapezoidal control.

Keywords: Wireless, Arduino, BLDC, ESC, PWM and IGBT.

1. INTRODUCTION

Brushless DC motors are becoming more common in a variety of motor applications such as fans, pumps, appliances, robotic automation, and automotive drives. The reasons for their increased popularity are better speed versus torque characteristics, high efficiency, long operating life, and noiseless operation. In addition to these advantages, the ratio of torque delivered to the size of the motor is higher, making it useful in applications where space and weight are critical factors.

The stator of a BLDC motor is similar to that of an induction machine but the windings are distributed quite differently. The two different common distributions of the windings are distributed and sinusoidal. A distributed winding will have a trapezoidal back EMF while a sinusoidal winding will have a sinusoidal back EMF. This application note will focus on BLDC motors with distributed stator windings. The rotor of a brushless DC motor is different in the fact that the rotor contains permanent magnets instead of additional windings.

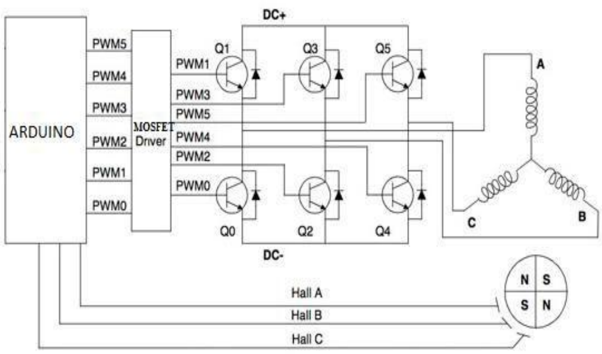

Fig 1: Basic block diagram

Unlike a brushed DC motor, the commutation of a BLDC motor in controlled electronically. To rotate the BLDC motor, the stator windings should be energized in a sequence. In order to make sure the motor controller is energizing coils in the correct sequence; Hall Effect sensors must be used to detect the position of the rotor in the motor. When the rotor is spinning inside the motor either a North or South Pole will pass by the Hall Effect sensors which will cause the sensor to output which section of the rotor is passed.

The main differences between brushless DC motor controllers are the types of control algorithms that are implemented on their microcontrollers. The two main types of control algorithms are sensored and sensorless control. Sinusoidal and trapezoidal are the two different output types that must be picked from after a control method is selected. In this paper a sensored control algorithm uses IR sensor senses the speed of rotor at all times. The Arduino microcontroller uses the output of the IR sensors to know the present speed and varying the duty cycle to get the required speed of the rotor. Universal Serial Bus (USB) on some models, which are also used for loading programs from personal computers. The micro controllers are typically programmed using a dialect of features from the programming languages C and C++.

1.1 BLDC

Brushless DC electric motor (BLDC motors also known as electronically commutated motors are synchronous motors powered by DC electricity via an inverter/ switching power supply which produces an AC/ bi-directional electric current to drive each phase of the motor via a closed loop controller. The motor structural elements of a brush less motor system is typically permanent magnet synchronous motor, but can also be a switched reluctance motor, or induction motor. The design equations for the armature winding are as $Va = Ria + Ldia/dt$ (1)

$$Vb = Rib + Ldib/dt \qquad (2)$$

$$Vc = Ric + Ldic/dt \qquad (3)$$

Where L-armature self-induction in [H]
R-armature resistance in [Ω]
Va, Vb, Vc –terminal phase voltage in [V]
ia, ib, ic-motor input current in [A]
ea, eb, ec-motor back-Emf in [V]
Back-Emf of each phase has a phase difference of 120 electrical degrees and back- Emf and rotor condition are related Via some performance. Equation of each phase for back-Emf is as attend:-

$$ea= (\theta e)\ \omega \qquad (4)$$

$$eb= (\theta e - 2\pi/3) \qquad (5)$$

$$ec= (\theta e+2\pi/3) \qquad (6)$$

Where Kw=back-Emf constant of one phase [V/rads-1] θe -rotor angle in electrical degree
ω- Rotor speed [rads-1]

Rotor angel electrical [θe] and Rotor angle mechanical [θm] are related as:-

$$\theta e = P/2\theta m \qquad (7)$$

Where P is the no of poles on rotor. Thus the total electromagnetic torque Te in N-M can be expressed as follows:-

$$Te = (eaia+ebib+ecic)/\ \omega \ (8)$$

The mechanical torque transferred to the motor shaft:-

$$Te - Tl= Jdw/dt+ B\omega \qquad (9)$$

Where Tl = load torque [N-M]
J= inertia of the rotor shaft [Kgm2]
B = friction constant [Nms.rads-1]

1.2 ESC

Regard less of the type used, an ESC interprets control information not as mechanical motion as would be the case of a servo, but rather in a way that varies the switching rate of a network of field effect transistors. ESC systems for brushed motors are very different by design; as a result brushed ESC's are not compatible with brushless motors. Brushless ESC systems basically create a tri-phase AC power output of limited voltage from an onboard DC power input, to run brushless motors by sending a sequence of AC signals generated from the ESC's circuitry, employing very low impedance for rotation.

2. CONTROL STRATEGY

PWM technique is one of the most popular speed control techniques for BLDC motor. In this technique a high frequency chopper signal with specific duty cycle is multiplied by switching signals of VSI.

Therefore it is possible to adjust output voltage of inverter by controlling duty cycle of switching pulses of inverter. The disadvantages of analog methods are that they are prone to noise and they change with voltage and temperature change.

Also they suffer changes due to component variation .They are less flexible as compared to digital methods. The principle of generating PWM Counter is used to generate triangular wave. If the value of compare register is less than the value of triangular wave, then PWM is '1', else PWM is '0'.

An IGBT-based inverter has been designed for the experiment to test the relationship of the inverter switch on-off states and the Hall sensor position. The Hall sensor state and the corresponding drive state require for commutation.

Switching interval in deg	**Step sequence**	**Hall A**	**Hall B**	**Hall C**	**Phase A**	**Phase B**	**Phase C**
0-60	1	1	0	0	-V	+V	NC
60-120	2	1	0	1	NC	+V	-V
120-180	3	0	0	1	+V	NC	-V
180-240	4	0	1	1	+V	-V	NC
240-300	5	0	1	0	NC	-V	+V
300-360	6	1	1	0	-V	NC	+V

Table1: Switching sequence

2.1 ARDUINO UNO BOARD

Arduino board designs use a variety of microprocessors and controllers. The boards are equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards (shields) and other circuits.

The boards feature serial communications interfaces, including Universal Serial Bus (USB) on some models, which are also used for loading programs from personal computers.

The microcontrollers are typically programmed using a dialect of features from the programming languages C and C++.

Fig-2: ARDUNIO UNO R3

3. SYSTEMARCHITECTURE

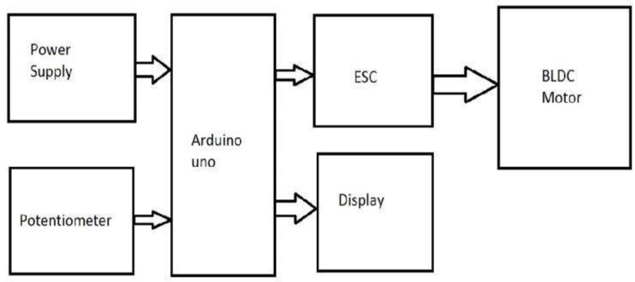

Fig-3: System architecture

The Arduino Uno controller is used to control the ESC. The Arduino varies the speed as compared to the value of potentiometer, which is directly connected to the Arduino uno. The speed of the motor in percentage is shown on display. The language used to program Arduino uno is c and c++. The basic block diagram of speed control of BLDC motor is shown in figure 2.1. It consists of basically five blocks: potentiometer controller (ATMEGA328), Inverter, BLDC motor and RPM measuring circuit. To drive BLDC motor, three phase six inverter bridge is used. Switches of Inverter Bridge are turned on-off as per the sequence generated by the controller. Output of Inverter Bridge is applied to three stator windings of BLDC motor. Depending on switching sequence of inverter, current in the stator windings keeps on changing and accordingly magnetic field is generated and rotor which is made up of permanent magnet starts rotating in synchronism with the stator. The position of rotor is sensed by the hall sensor the output of which is digital and further it is applied to the controller for generating switching sequence for the inverter. As per the programming done the controller generates 6 PWM sequence which is given as inputs to the switches of the inverters which converts dc supply to ac required for running the motor. For RPM measuring circuit ATMEGA328 controller**s** are used which is work as contactless tachometer. In this RPM measuring circuit interface with LCD who shows the RPM of Brushless Direct Current Motor. In this circuit hall sensor are used for catch pulse of rotor magnet**.**

4. SPEED CONTROL OF BLDC MOTOR

An electronic Brushless DC Controller (also known as a Driver, or Electronic Speed Controller), replaces the mechanical commutation system utilized by a Brush DC Motor, and is required by most Brushless DC Motors to operate. In a Brushless DC Motor controller, either a Hall Effect Sensor or Back EMF (Electromotive Force) is used to identify the position of the rotor. Understanding the orientation of the rotor is crucial to operating the Brushless DC Motor. The Hall Effect uses three hall sensors within the Brushless DC Motor to help detect the position of the rotor. This method is primarily used in speed detection, positioning, current sensing, and proximity switching.

A Hall sensor can act as an on/off switch in a digital mode when combined with circuitry. As a inverter circuit six IGBT'S bridge is used. Controller generates PWM sequences which drive the BLDC motor. For control a speed of motor variable register is used which is work as variable frequency drive. To increase or decrease the duty cycle user can get the speed of motor exactly they want. Opto-couplers are used for isolating between controller side voltage and motor side voltage. Hall sensors sense the position of rotor and gives digital output to controller at that time controller generate PWM for next stator winding and operate inverter circuit to drive motor.

5. THE PULSE WIDTH MODULATION (PWM)

The supply voltage is chopped at a fixed frequency with a duty cycle depending on the current error. Therefore, both the current and the rate of change of current can be controlled. The two phase supply duration is limited by the two phase commutation angles. The main advantage of the PWM strategy is that the chopping frequency is a fixed parameter; hence, acoustic and electromagnetic noises are relatively easy to filter. There are also two ways of handling the drive current switching: hard chopping and soft chopping. In the hard chopping technique, both phase transistors are driven by the same pulsed signal: the two transistors are switched-on and switched-off at the same time. The soft chopping approach allows not only a control of the current and of the rate of change of the current but a minimization of the current ripple as well. In this soft chopping mode, the low side transistor is left ON during the phase supply and the high side transistor switches according to the pulsed signal. In this case, the power electronics board has to handle six PWM signals. 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 BLDC motor

$$\text{Average voltage} = D * \text{Vin}$$

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

$$\text{Duty Cycle} = 100\% \text{ x Pulse Width/Period}$$

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

6. BLUETOOTH MODULE

Bluetooth is a wireless standard for data exchange over short distances. It creates personal area networks (PANs) with high security level, which is an essential factor in this system. Bluetooth operates in the range of 2400-2483.5 MHz (including guard bands) and frequency-hopped spread spectrum technology. Bluetooth is a packet-based protocol

7. USER INTERFACE

The UI is an Android-based application. This application is installed on an Android mobile phone or tablet. The application uses Bluetooth hardware present in the Android device and communicates with the Bluetooth module

(HC-05) present at the drive-end. It provides a user interface for a number of functions:

- Switching the motor ON/OFF.
- Setting priming speed.
- Setting different values of speed and duration of running. This will be set in a number of sequential steps with different settings.
- Displaying feedback to monitor parameters.

8. HARDWARE IMPLEMENTAION

- BLDC motor
- Arduino Uno board
- ESC
- LCD 16x2Display
- Potentiometer
- Power Supply
- Cell phone

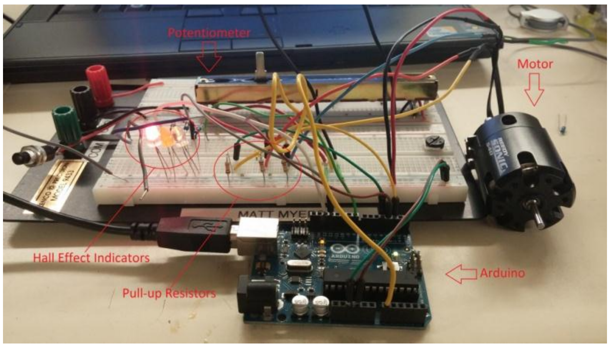

Fig-4: Hardware implementation of brushless dc motor using arduino

Flow Chart

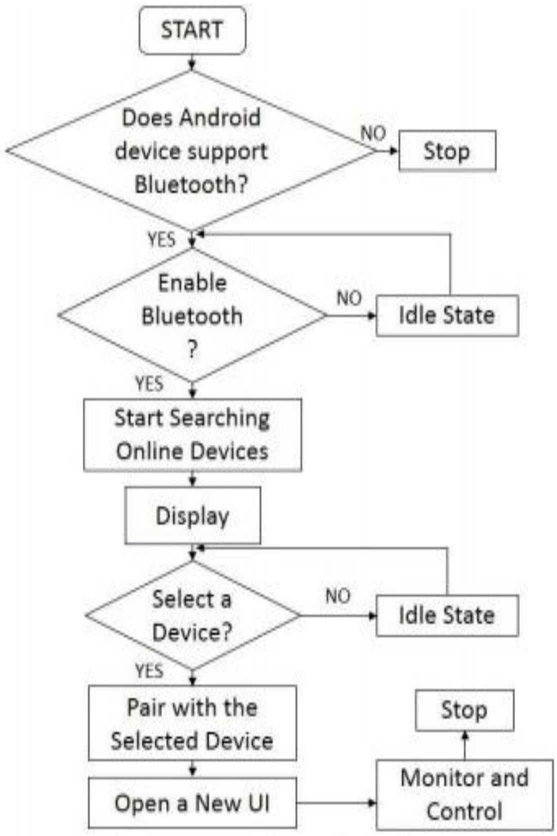

Fig 5: Flowchart of Android Application

9. RESULTS

The duty cycle determines the speed of the BLDC motor. The desired speed can be obtained by changing the duty cycle. The PWM in ArduinounoR3 is used to control the duty cycle of BLDC motor to successfully vary the speed of BLDC motor which is displayed on LCD16x2Display.Setting different values of speed and duration of running via Bluetooth user interface.

Fig 6: LCD display showing speed for set duty cycle

10. CONCLUSION

The system once fully functional will enable wireless control and monitoring of the parameters of an electrical drive. This paper presents the speed control method of BLDC Motor via Bluetooth technology. As the results of experiments, speed response and performance evaluation has been verified with different speed. Future scope of wireless automation includes usage of flexible networks of microcontroller based systems to control and monitor a bank of electrical appliances in industrial and residential arenas. These networks would not be restricted to Bluetooth but would also use Wireless Fidelity (Wi-Fi), Radio Frequency Identification (RFID) and Zigbee etc.

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