BLDC Motor Controller

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CERTIFICATE

We accept the work contained in the report titled (BLDC motor controller) as a confirmation to the required standard for the partial fulfillment the degree of BEE.

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Dedication

We would dedicate this project to our parents, siblings and supervisor sir Jehanzeb Ahmad. It was only because of their consistent support and faith on us that we did this project. They provided us with moral and emotional support which played a very vital part during our project. We are very thankful to them to bear with us and for encouraging us in this time and it was just because of them that our morale remained high and we completed this project.

Acknowledgements

In the first place, we would like to thank Allah almighty who is the creator of this universe and without his will and help we would not had been able to complete our final year project.

Furthermore, we are really grateful to our project supervisor Sir Jehanzeb Ahmad and we thank him from the core of our heart. This project was possible only due to his bestowed knowledge, motivation, teachings, instructions and guidance. Without his support and faith on us this project would not had been completed. He not only assisted us on every step but also made us believe that nothing is impossible if you provide hard work and devotion.

Other than this we would also like to show gratitude to our class fellows from BEE-8B who kept us motivated throughout the project and helped us wherever we required their support.

Abstract

With the advances in the technology, new inventions are taking place on daily basis and following this trend the electronics industry is flourishing a lot. In the electronics industry the home appliance's industry is in a lot of limelight these days. Almost all of the home appliances may it be an air conditioner, a cooler, a microwave, a refrigerator or washing machine all are making use of motors and that's from where the BLDC motors are getting across the board consideration. The reason for getting such a great deal of attention are the remarkable characteristics that the Brush Less Direct Current (BLDC) motor possess which include no noise, higher efficiency, compact size, and more speed. These are the characteristics that make the BLDC motor superior than the normal DC motor and this is main reason for the widespread attention the BLDC motors are getting. Despite such useful attributes the BLDC motors are still not so common in the market. The reason why the BLDC motors aren't employed as commonly as the DC motors is because of the complex control they possess and that's where our project lies. In our project we are making a BLDC motor controller and controlling the speed of the motor by varying the knob of potentiometer. In order to control the speed of the motor we are making the use of the back EMF sensing methodology and thus controlling the speed using the feedback information. We are controlling the speed of motor by providing a DC supply to the switching circuit which after switching goes to the BLDC motor and rotates it, then the back EMF values are collected and given to the controller circuit which gives the value accordingly to the switching pattern and the same procedure is repeated thereby running the BLDC motor by back EMD approach. We are controlling the speed of the motor manually by changing the value on potentiometer and then adjusting the speed of the motor accordingly. We are also making use of an 8051 microcontroller which is providing the commutation pattern. Following this approach a microcontroller based back EMF sensing BLDC motor controller is built which can be used in variety of electronics.

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Chapter # 1

Introduction

1.1 Project Background

With the increasing technological trends engineers are coming up with latest innovations solving almost any type of faced dilemma. Nowadays home appliances are of a lot of interest at the consumer's end. In the electronics industry the most common appliances used nowadays are air conditioners, microwave ovens, vacuum cleaners, washing machines, dryers, refrigerators, heaters, toasters, window fans and etc. In all these appliances one part that is used commonly is the electric motor. Up till now normal dc motors have had been used in such electronics but following the latest trends in technological revolution, now Brush Less Direct Current (BLDC) motors are considered over the normal motors due their superior performance and distinctive characteristics. The technological boom in this era demand much more which the normal dc motors are now unable to provide. To meet such demands BLDC motors have had been used lately following the superior features it provides such as no noise due to absence of carbon brushes, more efficiency, more speed, more speed range, small size, low maintenance and other convenient properties.

Figure 1.1 BLDC motor used in latest electronics [19]

1.2 Comparison of BLDC motor and Normal Brushed DC Motor

Until now normal dc motors have had been employed for usage in different electronics but with technological advancements the requirements have increased and so BLDC (Brush Less Direct Current) motors are now preferred over the DC motors. A normal DC motor simply uses a DC power supply and the parts it constitutes are commutator, rotor, brushes and an axle with a field magnet attached.

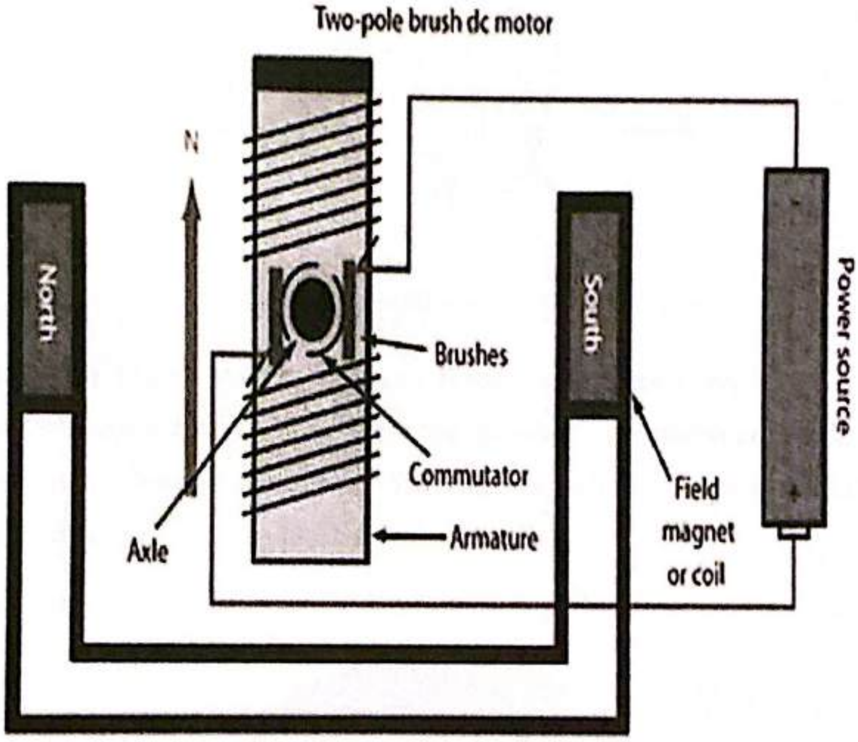


Figure 1-2 Structure of a DC motor

The performance of such motor depends on the material by which it is made and the no of turns wound around it. There are two magnets used, one is the permanent magnet that's the field magnet and the other one is the electromagnet which forms on the rotor. When the DC power is supplied the electromagnet magnetizes and getting repulsion from the permanent magnet the motor rotates in either clockwise or anticlockwise direction which can be controlled by changing the polarities.

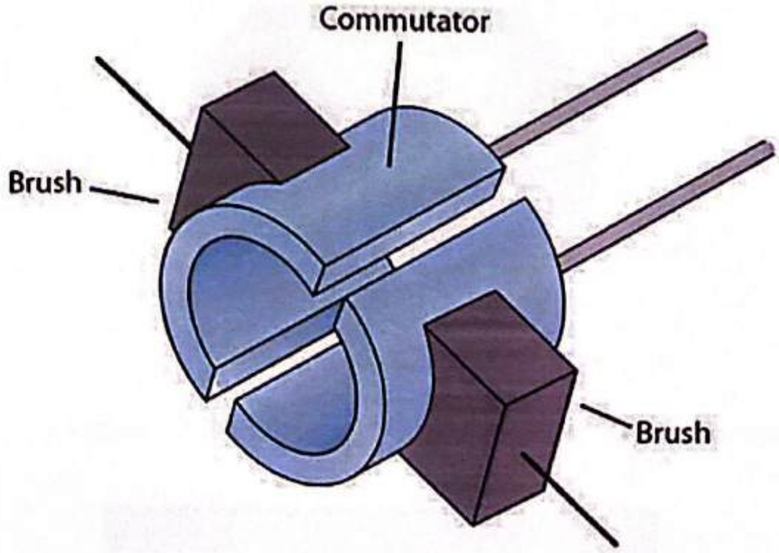


Figure 1-3 brushes attached with commutator are shown

When talking about the BLDC motors, the name Brush Less Direct Current Motor simply distinguishes it as the name straight away indicates that the motor is brushless and so the carbon brushes are not attached. There are some other differences as well like the permanent magnets are mounted around the rotor.

Figure 1-4 top view of a BLDC motor showing magnets mounted at the rotor

Rotor is the main part of the BLDC motors and magnets are attaches onto it. It uses a circuit to control it instead of other components like brushes, commutator etc. To detect where the rotor is at a certain time, BLDC motors employ different techniques such as the Back EMF sensing or using Hall Effect sensors. The BLDC motors are of synchronous motor type as their stator and rotor rotate at same frequency.

Figure 1-5 Brush motor: windings on rotor, magnets on stator

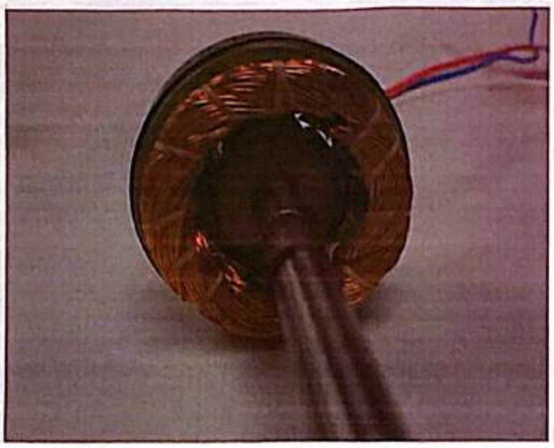


Figure 1-6 Brushless Motor: Windings on stator, magnets on rotor

Although the BLDC motors are much better than the DC motors in terms of performance but still both have their own advantages and disadvantages. The advantage of simple DC motor is that it is very reasonable in cost and its control is very easy compared to the BLDC motor.

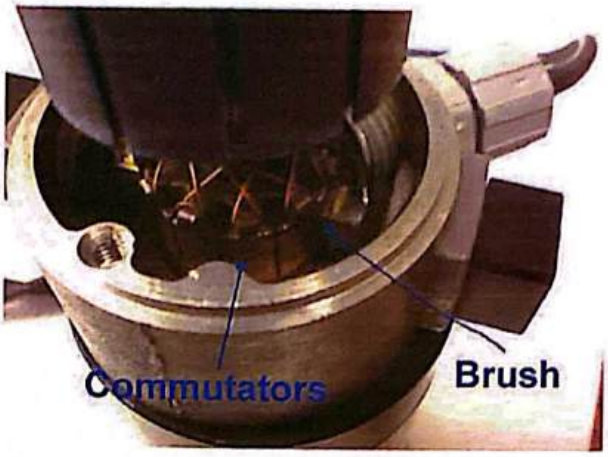


Figure 1-7 DC motor showing Brushes and Commutators

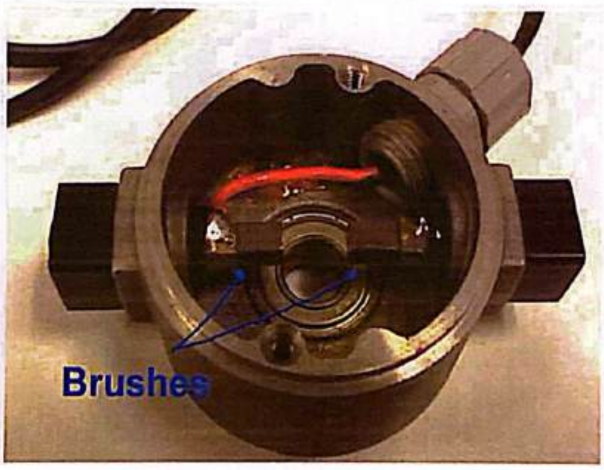


Figure 1-8 Showing Motor Brushes with Rotor removed

On the other hand although the BLDC motor is a bit expensive and difficult to control but it provides much better efficiency, its size is smaller, it is more durable, it is noise free, it can run on larger speed, its maintenance is very easy as the brushes do not need to be replaced due to absence of the carbon bushes.

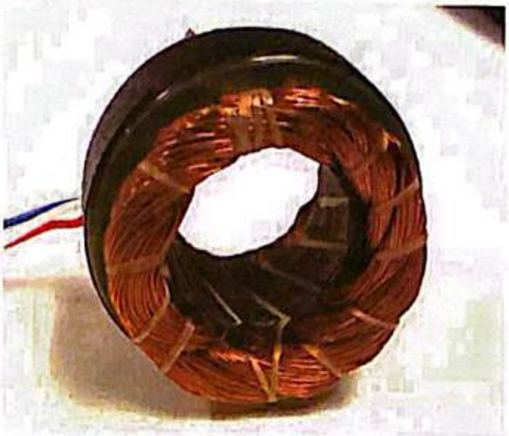


Figure 1-9 Brushless motor stator

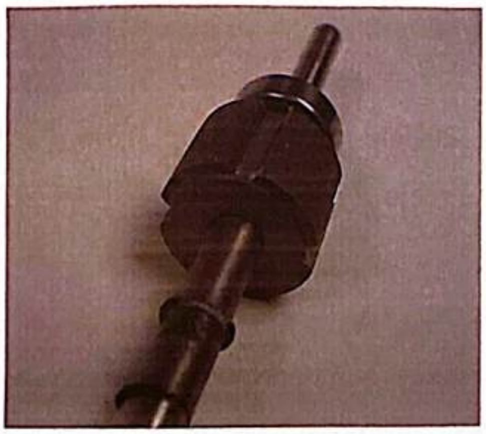


Figure 1-10 Brushless Motor Rotor

Now having looked at both the motors it could be said that despite numerous advantages of BLDC motors, DC motors are also used in some places and both motors are used in different things according the requirement. Like for example a motor has to be installed in an ordinary toy for kids than instead of using an expensive difficult to control BLDC motor we would prefer a simple inexpensive DC motor.

Similarly when we would be making an efficient solar powered Air conditioner, then instead of using a typical DC motor we would make use of an efficient and durable BLDC motor. So it's basically a tradeoff, according to the requirements or we can it's the price versus the quality.

1.3 Problem Description

As the name indicates the BLDC motors do not make use of carbon brushes and so possess no carbon brushes for the process of commutation. This quality makes the BLDC motor more beneficial in a lot ways. As electronic commutation is based on back emf method or Hall position sensors so very less no maintenance is required due to absence of the carbon brushes. The Speed/Rotating force is much greater and flexible and all speeds can be achieved. The efficiency is a lot better as no voltage drops across the brushes. The size of the motor is compact. The heat degeneracy is a lot better because BLDC has the windings on the stator, which is connected to the case. The speed range is also advanced as no mechanical restriction is imposed by brushes or the commutator. In addition to these the noise is also very low due to nonexistence of carbon brushes.

Even with all these benefits there are a limited glitches also associated with the brush less DC motor, the main problem is controlling the BLDC motor and that too controlling the speed of the BLDC motor and that is where our focus of FYP lies. A lot of different methodologies are used to control the Brushless motors which include Hall Effect sensor method, Back EMF method and etc. In this project we intend to follow the sensor less approach and that is using the Back EMF approach as it is more flexible and also cost efficient compared to the other methods.

1.4 Project Objectives

The objective of this project is to design, run and create an inexpensive, efficient and flexible Brush less direct current motor controller that is designed specifically to control the speed of the brushless motor, upon changing the value of load. There are several objectives that are needed to be done in order to successfully achieve our goal. These are stated below:

1. Designing of a DC to 3 phase AC inverter.

2. Designing a commutation pattern using the 8051 microcontroller.

3. Using the commutation method to generate gate pulses to be further provided into the voltage comparators

4. Simulation on Livewire and Proteus software

5. Hardware implementation on Bread board

6. Hardware implementation on Vero Board

7. Coding on 8051 microcontroller

8. Synchronizing the hardware and software.

9. Manually controlling the speed of the motor by varying the value of load.

By the end of this project, a full fledge Brushless Direct Current Motor Controller is built which can effectively control the speed of the Brushless Direct Current motor by varying the value of load.

1.5 Project Scope

With the technological development and highly required efficiency in the present times the properties of Brushless Direct Current Motor make it very worthwhile to be used in almost all the latest Household appliances, electronics and even the automotive industry. Other than this Brushless Direct Current Motors are specifically used in places where sparking may occur as lack of carbon brushed in brushless motors make them spark immune.

In past few years a lot of work has been done on Brushless Direct Current Motors and a lot of emphasis has been put upon them which has vastly increased its usage and applications making them used almost in every industry which requires use of motors. A few common applications are as follows:

1. Latest Air Conditioners.
2. Washing machines.
3. Quad copters.
4. Refrigerators and freezers.
5. Electric Coolers.
6. Vacuum cleaners.
7. Computers.
8. Electric Heaters.
9. Garage door openers.
10. Drones.
11. Actuation systems in industry.
12. Latest cars.

Chapter # 2

Literature Review

2.1 Literature review

The advancement in the technology has increased many folds. New technologies are emerging every day. Scientist are discovering new methods to enhance the efficiency of the current product and introducing new product to reduce the power consumption and increase the overall efficiency of the product. The brushless direct current motor (BLDC) is one the innovation that is used in everything e.g. DC invertor air conditioner, robots, cod copter, car air conditioner etc. our project is basically is to design the controller for BLDC motor. The BLDC motor has no brushes so they are commutated through electronic control circuit. A lot of research has been done on speed control and torque control of BLDC motor. There are two types of controller for BLDC motor

1) BLDC motor control through Hall Effect sensor.
2) BLDC motor control through back EMF.

The Hall Effect sensor control is basically a sensor which senses the position of the rotor and sends the values to controller for commutation. On the other hand, the back EMF method or sensor less control use back EMF of the coil to help us predict the rotor position of BLDC motor and to start the commutation.

In [1] the author did a research on BLDC motor, the proposed model was based on phase shifting. The control circuit was designed which included three-phase invertor with phase shift of 120 degree. The analysis of the motor efficiency was done on MATLAB. The simulation was done for the speed and torque characteristics. The simulation was done with two conditions i.e. for no load and when there was load on output rotor. The conclusion based on analysis was that, the motor was running smooth with no load condition while on the other hand, when load was applied, the motor draw extra current. The difference was 4 ampere in total.

In [2] the author proposed the model in which they considered two things for control i.e. the inner and the outer close loop system. The control was based on PI controller. The loops controlled the current flowing through rotors. This design is based on the requirements and user application.

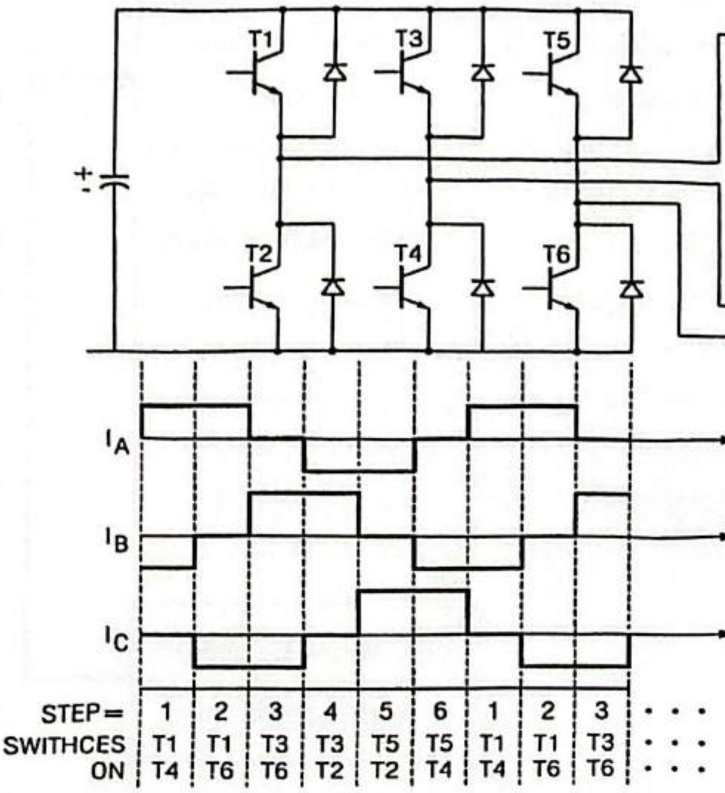


Figure 2-1: three phase invertor circuit for BLDC motor [1]

In article [3] the author proposed a model in which they proposed a simulation based on actual back EMF wave rather than taking ideal wave form. In this proposal, the characteristics of torque on wave form are also taken in consideration.

The back EMF trapezoidal wave has been used in this process [3]. Through this process, the author concluded that simulation of BLDC motor can be done using the dynamic feature of brushless DC motor with real trapezoidal wave of back EMF.

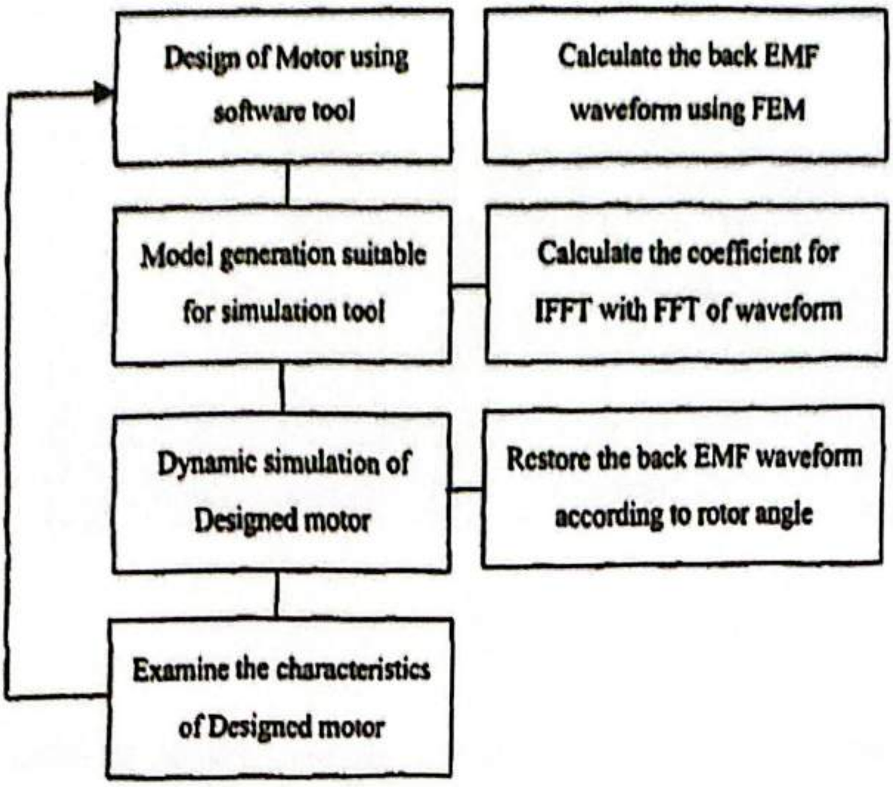


Figure 2-2 : flow diagram of process for simulation of BLDC motor using real back EMF wave form [3]

In research article [4] the author did a comparative study on different driver circuit for brushless DC motor. They did a mathematical analysis on the controller. They produced mathematical model for efficiency of brushless DC motor and compared the efficiency and performance of different BLDC motor diver circuit. The study was based on two model i.e. PI model and PID model.

The proportional integral model was used in first test [4]. The responsibility of this PI controller was to keep the check on error that was produced in current in driver circuit or controller circuit. Based on these signal, the driver circuit for BLDC motor would produce pulses of PWM which will go to invertor and finally to the rotor. The overall system was less sensitive. And the efficiency was also reduced. In second test the author used PID controller which is proportional integral derivative. This controller increased the sensitivity of the circuit. The efficiency of the BLDC motor controller was observed to be increased.

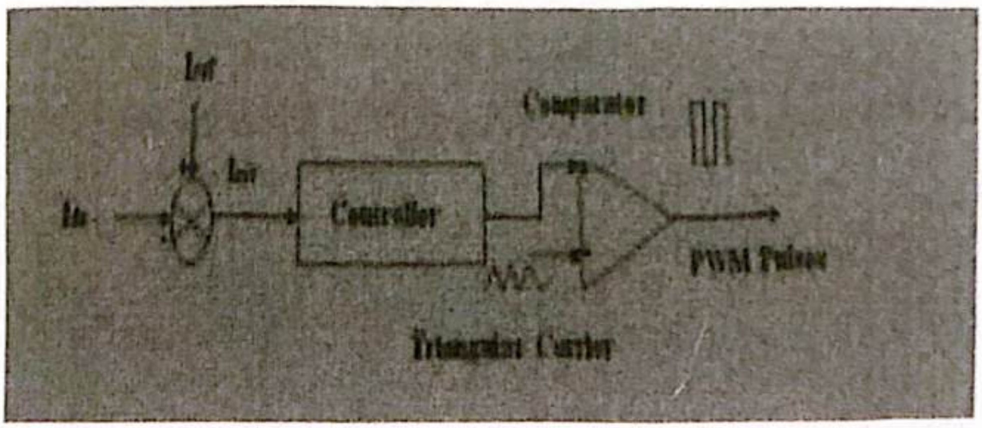


Figure 2-3: Comparator circuit controller

In article [5] the author proposed a model in which the control was based on sensor less approach. The author presented two methods in this regard.

- Using back EMF as feedback.
- Detecting rotor coil position using current (I) and voltage (v) factor.

The back EMF in this model provides the instance of commutation. The overall cost of system implementation is also reduced because there are no sensors. It requires less space. The back EMF signal will go to controller and on the basis of the signal provided by the EMF, the controller will control the switching circuit. The model of the proposed solution is given in Fig 2.4 below.

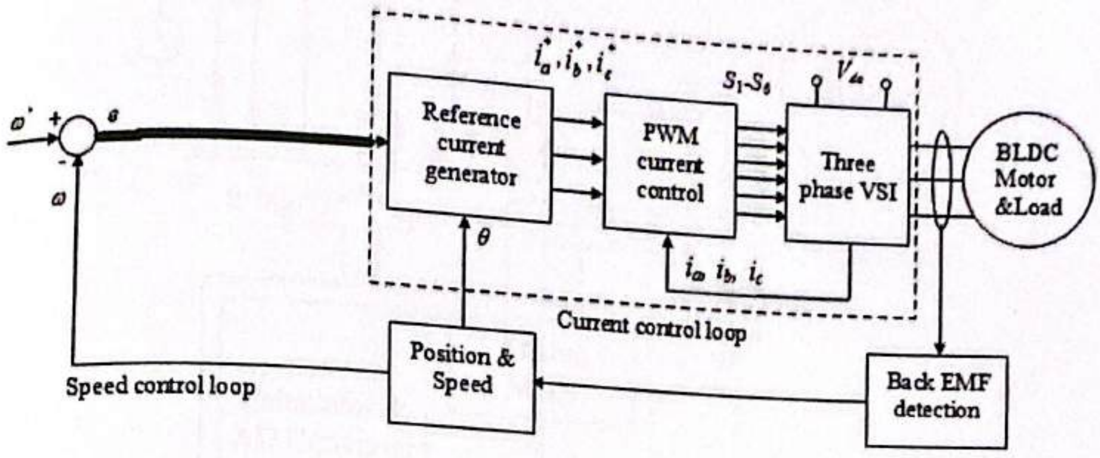


Figure 2-4: brushless DC motor controller using back EMF as feedback [5]

The proposed model was based on low RPM application. BLDC parameter such as torque was also controlled using different parameter like current. The speed was controlled using voltage parameters.

In [6] the author presented a solution which was cost effective and cheap. The model was based on back EMF and zero crossing detection. The controller used in this model was microcontroller which is very cheap. The author used analog to digital convertor which is embedded in controller. This AD convertor will be used to find voltage at terminal side.

This method is very effective because there will be no delays because of microcontroller [6]. The zero crossing was determined through mathematical equation which eliminated the low pass filters and comparator.

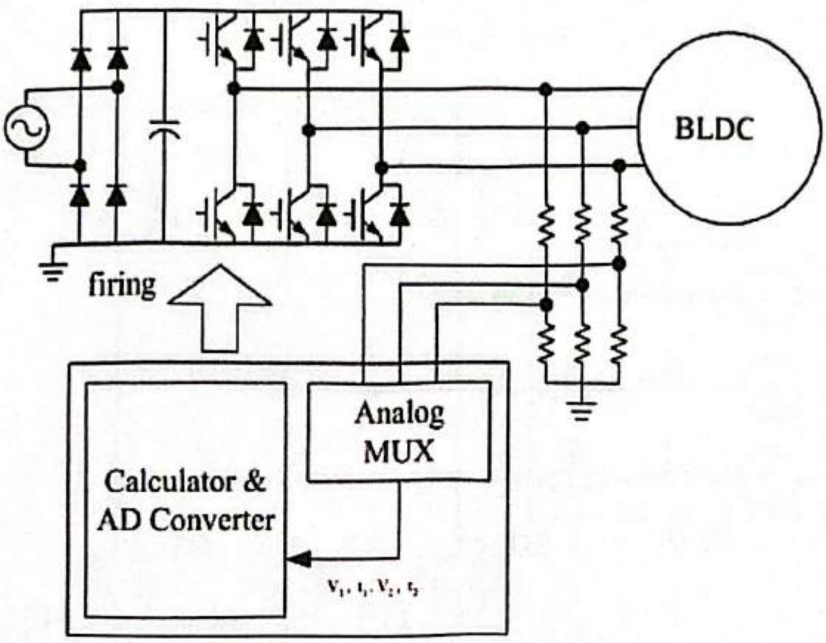


Figure 2-5: BLDC controller block diagram [6]

In this proposed model, the zero detection for commutation is free of PWM pulse state. The whole model requires less space and hardware equipment.

In [7] the author proposed a solution in which they used zero detection of BLDC motor to start the commutation process. Advantage of this method was that it does not need any phase delay. Speed can also be changed as per need. The variation of speed is done by changing the frequency. Invertor is used for switching purpose. The fig 2.6 shows the block diagram of the proposed model.

The BLDC motor has pairs of coil. We can represent each coil with the inductor capacitor and back EMF voltage as shown in fig 2.6 below.

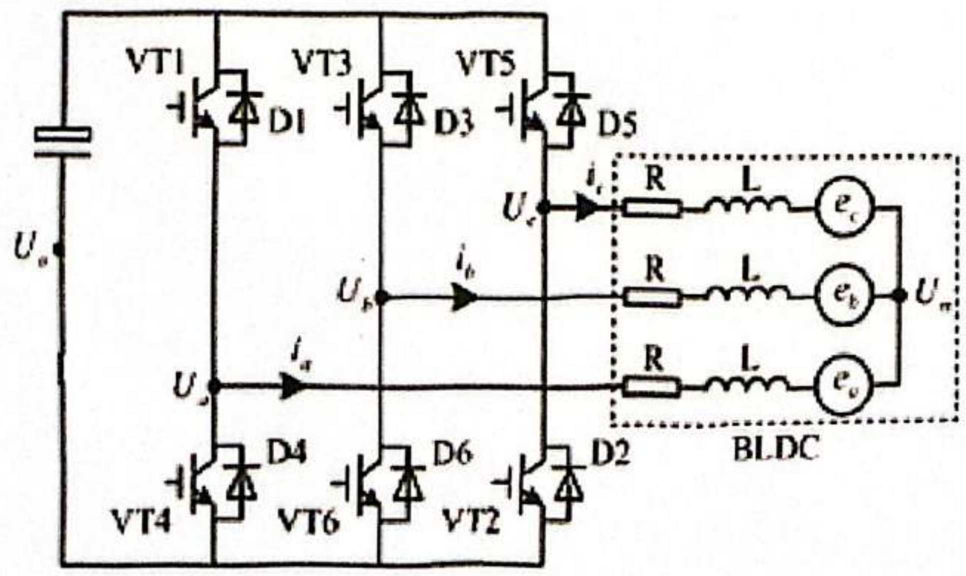


Figure 2-6: BLDC switching circuit model [7]

Chapter # 3

Requirement Specifications

3.1 Existing System

The most commonly used system to control BLDC motor is by using Hall Effect sensors. Hall Effect is the generation of potential difference in an electrical conductor when a magnetic field is applied perpendicular to the current flowing. The Hall Effect sensors are embedded in the stator of BLDC motor.

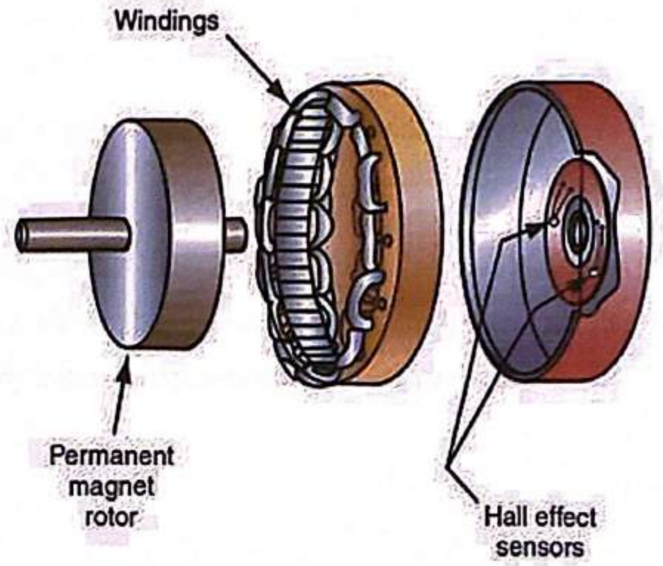


Figure 3-1 Hall Effect Sensor Embedded on Stator

In three phase motor normally there are three hall sensors present inside the motor that are 120 electrical degrees apart. The sensor helps to detect the state of stator coils thus providing a data to the controller. Motor having Hall Effect has mostly six wires present in them. The first three wires are for phase supply and the remaining three are the wires for Hall Effect [19].

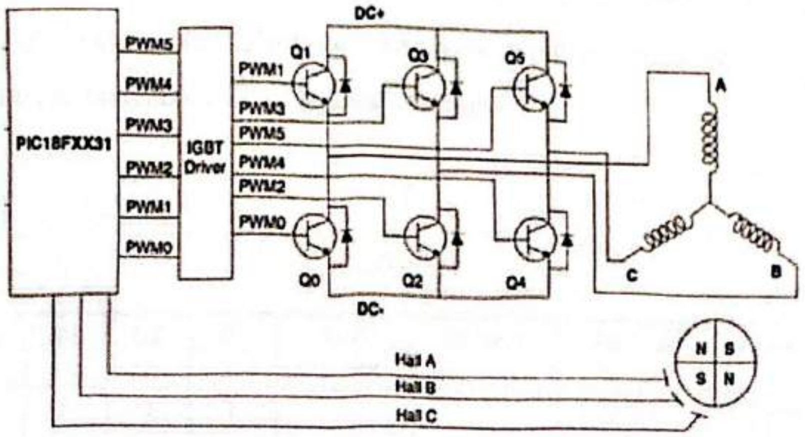


Figure 3-2 BLDC Power Supply Control Systems Using an 8 Bit Microcontroller [19]

The figure 3.2 tells us the arrangement of driving a BLDC motor. It is suggested to use PIC18FXX31 along with the hall sensors to control the motor [19]. This method is outdated and involves lot of complication compare to our proposed method.

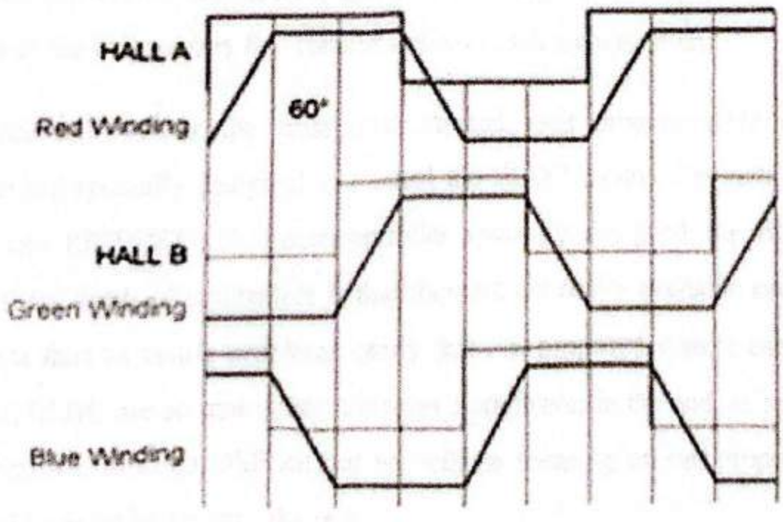


Figure 3-3 Hall Sensors Wave

The figure 3.3 shows how the wave form of Hall Effect sensors varies with respect to the wave form of the voltage in coils. Hall Effect provides us its output in form of binary data that can be easily manipulated or understood by us and the controller.

Table 3-1

Step	H1	H2	H3	Hall Binary	Phase A	Phase B	Phase C
1	1	0	1	5		Lower	Upper
2	1	0	0	1	Upper	Lower	
3	1	1	0	3	Upper		Lower
4	0	1	0	2		Upper	Lower
5	0	1	1	6	Low	Upper	
6	0	0	1	4	Low		Upper

The table 3-1 shows how each step has a unique combination of outputs from hall sensors. The upper and lower represents the mosfets that are on during the each step of BLDC motor. The table also tells us the hall sensors that remain active in each commutation.

Along with the hall sensor the traditional method uses programmable or preprogramed controllers that are specially designed to control the BLDC motor. The author Saranya.B [12] suggested to use PIC16f877. A microcontroller specially designed for BLDC motor. The problem with these kinds of controllers is that they are not easily available and are of high cost thus this system fails to tackle problems easily that our proposed system can. The number of ways to control BLDC are so many that it creates a confusion in the end, as another author [13] suggests to control it through DSP kit but we will be focusing on our proposed methodology which we consider to be better than the rest.

3.1.1 Drawbacks:

Despite being most commonly used method to control BLDC Motor, it has some draw backs that makes it undesirable over back EMF due to number of reasons which are given below:

- Overall cost is high due to presence of hall sensors that increase the cost of the entire system.
- Sensors lose their effectiveness working with the passage of time due to the factors present in environment such as dust and temperature variations.
- Hall sensors are generally used in motor that are of high power thus we will have to use back EMF method to operate a small BLDC motor.
- Hall sensor introduces extra wiring in the system which causes less reliability.
- Hall sensors tend to perform better at high and constant speed but when we are going to vary it at lower speed they begin to offer us some jerk.

3.2 Proposed System

The answer to the problem faced by us in hall sensor can be easily solved by using back EMF methodology. Back EMF is also sometimes called electromotive force. It is the force that is caused in opposite direction of the current that induces it. Our proposed methods intents to find the back EMF induced in the coils of BLDC motor from back EMF detection circuit. The author has suggested a way to provide sensor less control to BLDC by zero crossing which we will be utilizing [14]. By detecting back EMF circuit we can easily provide a switching sequence to the coils of motor.

Coils have to be energized in opposite pairs one by one in order to run the motor efficiently. Each set of coil is connected to a certain phase of the motor and that phase will go to the switching circuit and it will be responsible to turn on and off the phase.

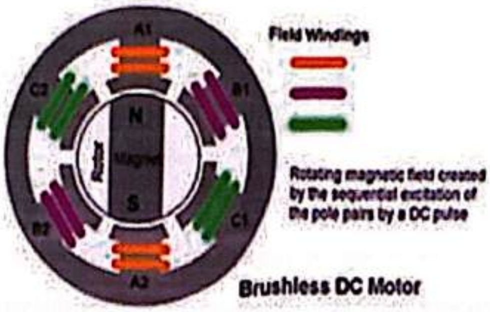


Figure 3-4 Coils Energized To Create Back EMF [7]

A comparator circuit is responsible to detect the back EMF generated by the motor coils. The coil that has current inside it can easily be detected by comparator as that coil will generate back EMF signals and the comparator will sense it. The figure 3.5 shows how a comparator is connected to a single phase of BLDC motor [18]. We will be requiring three separate comparators for each phase to know the status of coil.

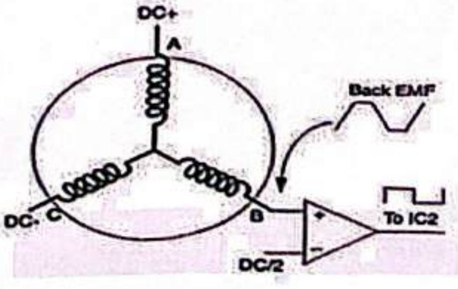


Figure 3-5 Comparator Connected To Phase of BLDC [7]

Six step commutations can be done with the help from microcontroller. The controller will provide voltage to the gate of Mosfets which cause Mosfets to turn on by creating n channel.

The 8051 microcontroller used in our project overall makes the system cheap compare to the conventional system. The cost of using a microcontroller reduces the cost of the controlling part to almost one tenth of the value of the system previously proposed system by the authors.

3.3 Requirement Specification

Our BLDC motor has maximum continuous output power of 480 watts for 30 seconds but we will not be utilizing its maximum power because our job is to run the motor at a variable speed only. The motor Model no is KDE 2315XF-2050 and can run on 5-26 volt supply. The BLDC can tolerate maximum continuous current of 44 amperes. The figure3.6 shows motor used in our project.

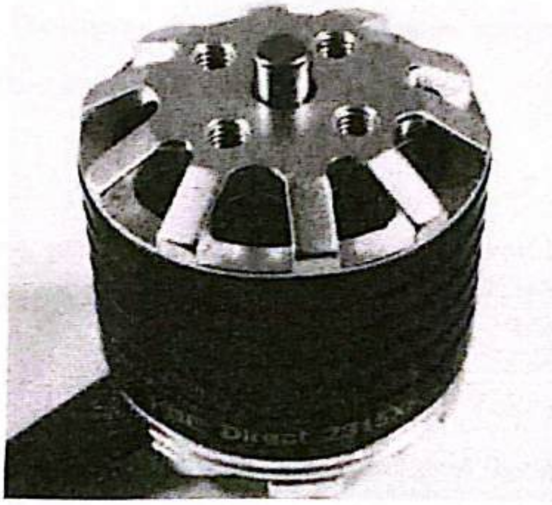


Figure 3-6 KDE BLDC Motor

We will be using 80nF70 Mosfets that can withstand maximum current of 98 amperes and maximum voltage 68 volts thus making it perfect to meet the specification of the motor.

There are two Voltage regulators are attached with the system. The first one is with 555 timer and the second one is with micro controller module. Regulator will help to run these modules smoothly as they require 5v to remain active.

Environmental condition will not create any difficulty in back EMF detection as it does not contain any sensors therefore our project can easily run on those areas that have harsh environmental conditions. Our project is a less error prone design thus it almost meet every demand to launch it commercially.

3.4 Use Cases

BLDC motors are used widely in almost every industry due to its high output efficiency and increased reliability compare to conventional dc motors. The examples of BLDC motor applications are given below:

Transport:

They are found in electric and hybrid vehicles mostly .Cars such as Toyota Prius coming after 2012 have BLDC motor installed in them. Other well-known companies such as Segway and Vectrix also use them in their scooters.

Toys:

Most of the RC helicopters, jets and cars have BLDC motor to provide high efficiency, making them a perfect kid toy that can run on high speed.

Industry:

Huge companies such as nestle prefer to use BLDC motor even though they are expensive then dc motor because the want to generate high output power with less electric consumption. Such companies value environment over money.

Aero Dynamics:

BLDC motors are rated popular among air craft industry. Even the prototypes models are fitted with BLDC motor.

Chapter # 4

System Design

4.1 System Architecture

The architecture of BLDC motor controller is designed in such a way that the motor runs efficiently at high and low speed. The block diagram below shows the architecture of the system. Supply is provided to power up the modules. Voltage regulator will help to maintain the supply at constant value which will provide optimum working of the modules. Timer will help us to generate duty cycle which will go to the decade counter that will help us to generate outputs with delay and that output will go to the microcontroller which will act as brain of the entire system. The controller will be responsible to control the output of the switching circuit which will drive the BLDC motor. Back EMF data can be collected from the three phases of BLDC motor which will provide switching sequence to the coil of BLDC motor. By adopting this architecture the motor will offer us jerk free smooth movement. Figure 4.1 shows the diagram of the explained architecture.

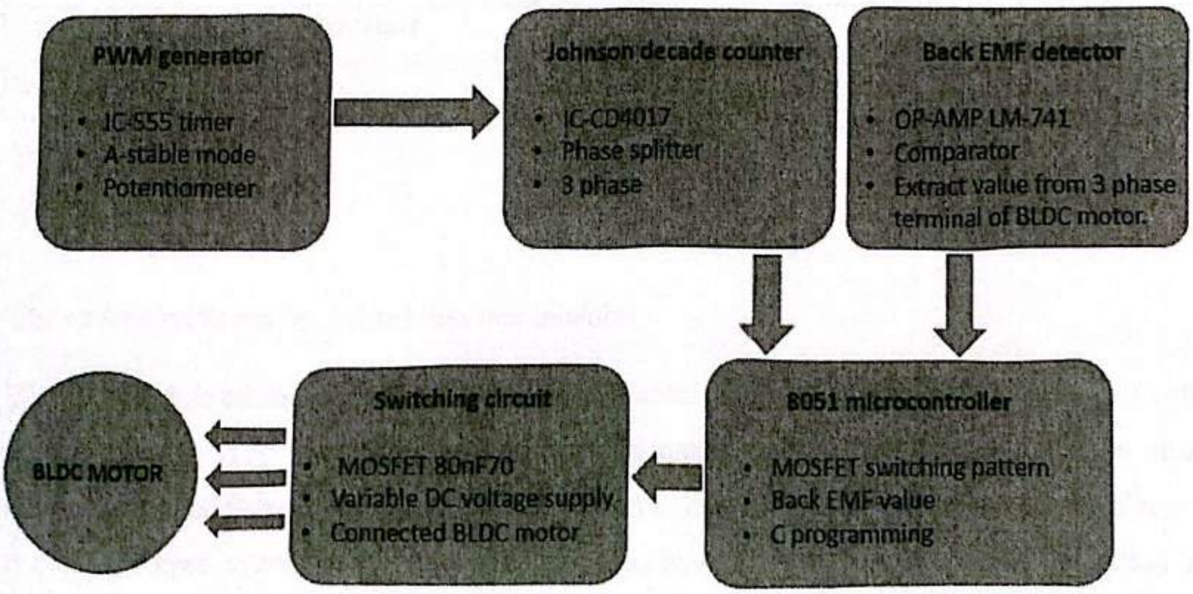


Figure 4-1 block diagram of controller

4.1.1 Components Used:

The major components used in our project are given in the table below:

Table 4-1-1

Serial Number	Name	Model
1	Voltage regulator	7805
2	Timer IC	555
3	Decade counter	4017
4	Mosfets	80F70
5	Transistors	C905
6	Microcontroller	8051
7	BLDC motor	KDE
8	Operational Amplifier	Lm741
9	Variable resistor	250K
10	Different Resistors	
11	LEDs	

4.1.2 Modules

The entire system can be divided into four modules.

The first module contains 555 timer and decade counter. There are three modes in which we can use 555 timers [17]. These modes are bi-stable, mono-stable and astable. Bistable is also sometimes called Schmitt trigger in this if the input is low, the output becomes high and if reset is pressed output is turns low. Mono stable is a mode in which pulse is produce only if a button is pressed. Our area of interest is concentrated at astable mode of 555 timer as we want to provide variable duty cycle to the circuit. The variable resistor attached with the timer helps to generate our desired duty cycle for the motor [17]. The higher the resistance the less is the frequency of the PWM. The generated wave at the output will comprise of square wave as shown in figure 4.2.The formula for frequency of duty cycle is give below:

$$f = \frac{1.44}{(R1 + 2VR1) \times C1}$$

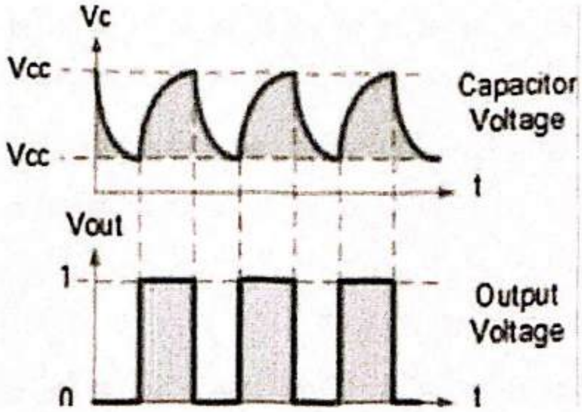


Figure 4-1 Generated Wave (PWM) [15]

We will be using VR1 as a variable resistor here to vary the duty cycle of the circuit. This variable resistor will increase or decrease charge and discharge time of the capacitor thus varying the duty cycle. In short the duty cycle is responsible to control the speed of motor [15].

The decade counter used in this circuit has a very simple function. It is responsible to count the pulses and provide them to their outputs.

The second module consists of switching circuit having N channel Mosfets 80F70.When the potential is provided to its gate it creates an n channel which runs the motor. This circuit has a similar function as H Bridge .The figure below shows how Mosfets operate the coils of motor.

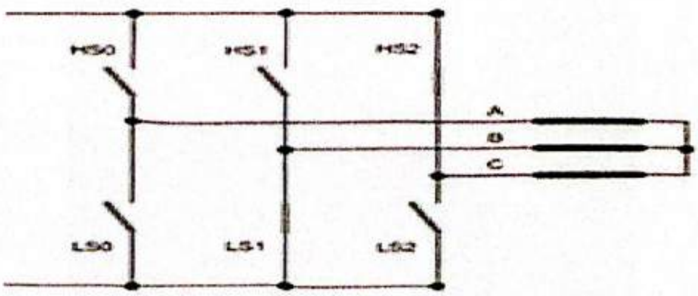


Figure 4-2 Switching Circuit [19]

The third module is the central unit of the entire circuit which is 8051 microcontroller. The controller is programmed in such a way that it provides smooth and continuous movement of the motor. The controller will decide the switching circuit on and off timings depending on the PWM duty cycle and back EMF data collected at its input port

The last module is responsible to detect the back EMF of the circuit. The module will sense zero crossing across the circuit by using lm741 in comparator mode.

4.2 Design Constraints

Like many systems our project also have constraints in its design that can be easily overcome if more time and money are spend on it. The difficulty that we faced during our project was the implementation of a suitable switching circuit that required Mosfets which were able to resist heat and work for a long time. The Mosfets mostly available in the market are of cheap quality thus they are not able to meet the efficiency mentioned in their specification sheet. We were first using 75n75 Mosfets which used to get short even when the motor was started at low voltage and for short duration. In order to tackle this problem we replaced these Mosfets with 80F70 that are of better quality but still they heat up. This situation can be easily overcome if purchase our Mosfets from reputed company that manufactures high quality products.

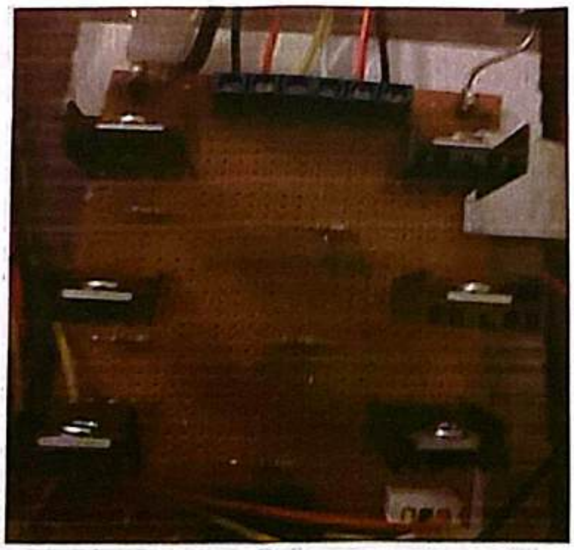


Figure 4-3 MOSFET Switching Circuit

Another difficulty that we faced was the availability of BLDC motor. A high quality and sensor less BLDC motor was not available in twin cities therefore we had to order it from America.

4.3 Design Methodology

BLDC in back EMF works on the principle of coil switching. Two sets of coil need to be active simultaneously in order to run the motor while other coil remains off. For example u can see in the figure 4.5 that if a switching circuit turn coil A and B active only then rotor having North and south will be forced to move towards the charged coils. When the rotor gets close to the coils A and B one of the coil will turn off and the coil C will charge up. This pattern is going to repeat itself that will cause the motor rotation. The phenomena charging and discharging of coils in BLDC causes motor to rotate [20].

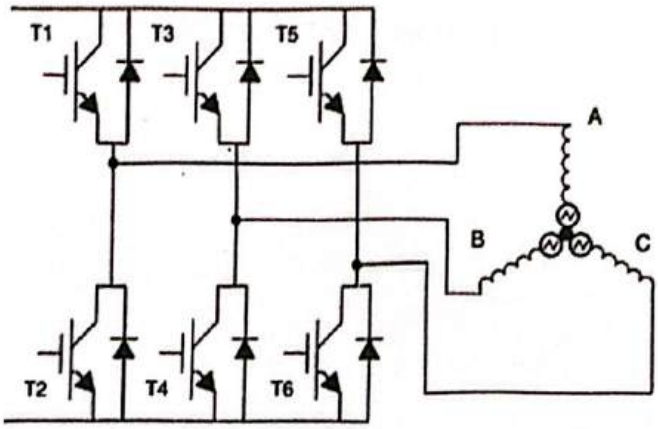


Figure 4-4 BLDC Coils [20]

The use of 555 timer in a-stable mode will generate wave by changing value of resistor and in this way we can controlled its duty cycle [17].The generated duty cycle will be in form of rectangular waves as shown in figure 4.5.We can also see in the figure the duty cycle increase the brightness of bulb thus it will also have ha same effect on the motor. Phase shifter IC is a decade counter it will count the pulses and deliver them to its outputs. The micro controller in the end will cause rotation of the motor based on the data collected from PWM and Back EMF. The back data can be acquired from comparators circuit very easily. We have designed a three phase comparator circuit that will provide input to the controller if there is current in coil. The 8051 Micro controller will then take decision according to the code implemented inside it and provide switching to the Mosfets.

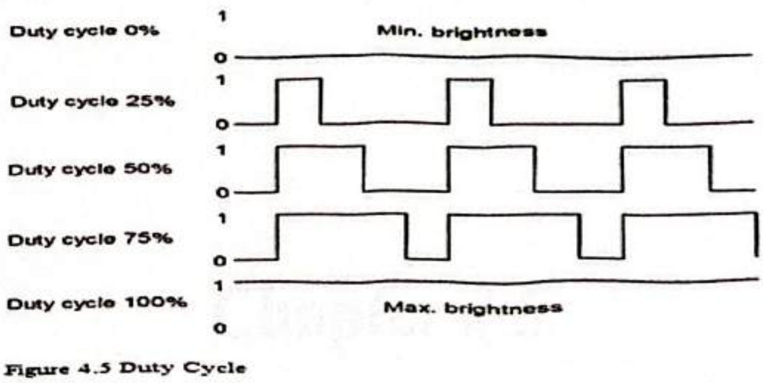


Figure 4-5 Duty Cycle [17]

Chapter # 5

System Implementation

5.1 System Implementation

BLDC motor is the device which is now used in many efficient devices. The specs of these motors are many folds higher than the normal DC motor. The life time of BLDC motor is also greater than normal DC motor. The efficiency of BLDC is due to the reason that it has no carbon brushes. So no carbon brushes means that no sparking will occurs at the terminal points which are connected to the rotor of BLDC motor. The power losses are also low in this motor. The tricky part of this motor is the designing of the controller circuit. There are two types of controller in this motor.

- Hall Effect sensor controller. implementation
- Back EMF detection controller.

The Hall Effect sensor controller is accurate but it is expensive and it increases the wiring in the circuit. Also it occupies more space which causes issues in some devices. Fig 5.1 shows the Hall Effect sensor in BLDC motor.

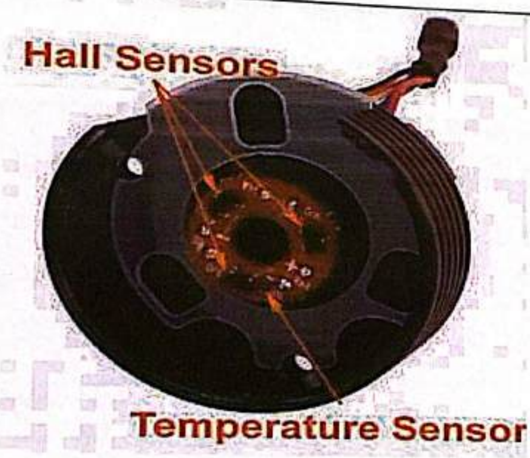


Figure 0-1: BLDC motor with hall effect sensor [21]

In our project, we are controlling our BLDC motor through the back EMF method. This method is efficient because it requires less space, less wiring, and the overall cost is also reduced in this process.

5.2 Modules

Our project is comprised of following modules. Each module is constructed on Vero board. Following is the list of modules in our hardware part for BLDC motor controller.

I. Voltage regulator.
II. Oscillator part.
III. 10 Johnson counter IC-CD4017
IV. Switching circuit.
V. BLDC motor.
VI. Comparator part.
VII. Microcontroller.
VIII. Software part.

Our main project which was assigned by our supervisor was to control the BLDC motor in such a way that we can vary its speed through potentiometer and it should also change its speed depending on the power supply. In market, the controller chips that are available are for the Cod copter. These controller chips are called electronic speed controller (ESC). We can't use these chips in our project because these chips maintain constant speed. And we must supply them a constant power. So we have constructed the whole controller form the scratch so that our requirement can be achieved. Now coming to the modules, the first module is the oscillator module which is discussed below and so on.

5.3 Voltage Regulator

Every IC needs specific voltage. Beyond that, the IC will get damaged. So in order to tackle this problem, we used voltage regulators. The IC that we used in this module is IC-7805 MOSFET. This voltage regulator IC has input voltage and output voltage. Its circuit also contains capacitors for smoothing the output voltage. These capacitors remove the ripples in the voltage. The input is attached at one side of the circuit as shown in the figure 5.2 and the smooth 5 volts is the output that come from the other side of the circuit. We used the LED light in this circuit. The LED acts as an indicator that 5 volts is available. If voltage is less than 5 volts then the LED will remain off. This circuit will ensure that our components get the desired voltage that they require for their system.

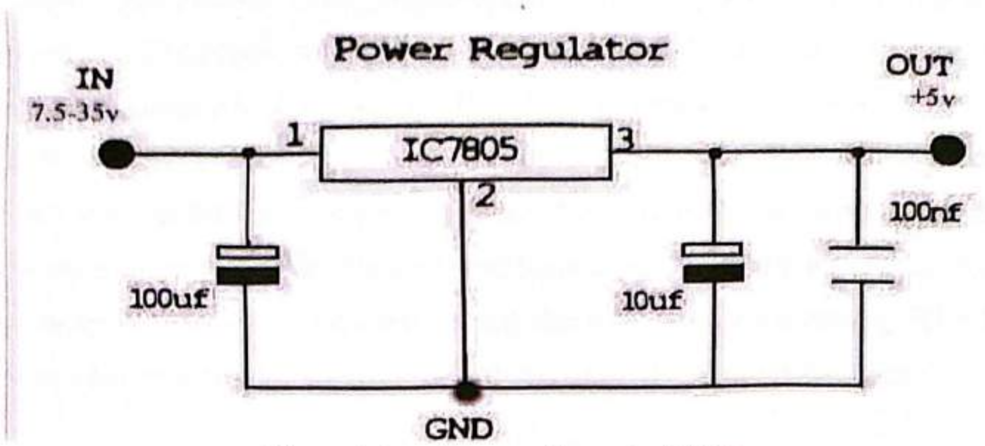


Figure 5-1: voltage regulator circuit [16]

This is the hardware implemented circuit picture of the voltage regulator. The fig 5.3 is shown below.

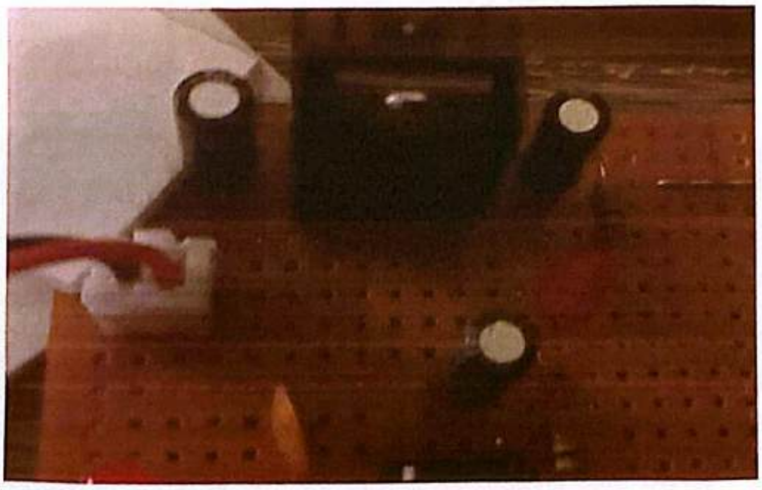
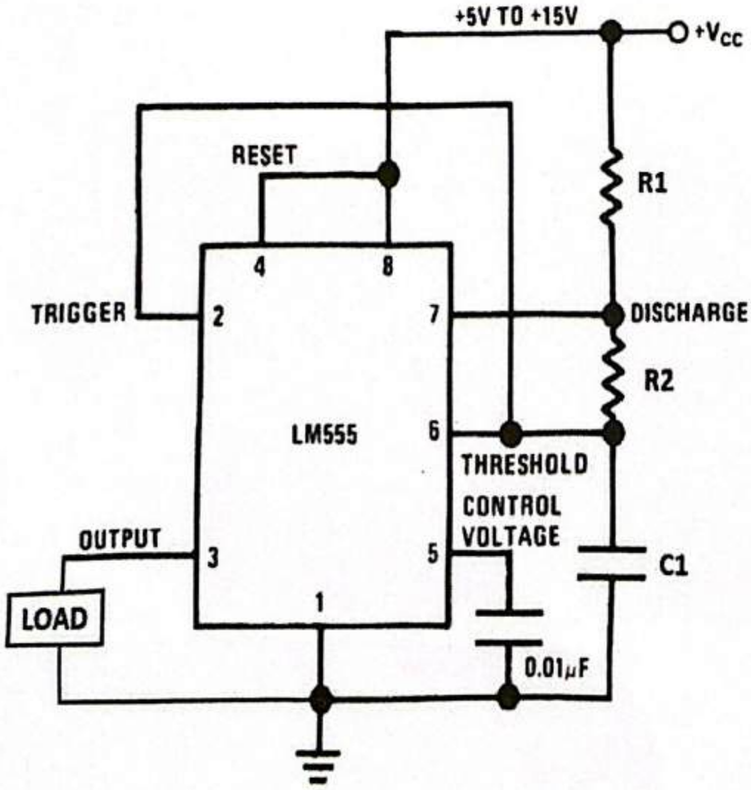


Figure 5-2: hardware implementation of voltage regulator

5.4 Oscillator

The oscillator module is required in our circuit in order to produce square wave oscillation. These oscillations were achieved through IC-555 timer. This IC requires 5 volts to perform its function properly. The 555 timer has three modes. Each mode has its own unique function. We used a stable mode because in this mode, the IC-555 timer produces square wave. It has two resisters i.e. R1 and R2. By changing R1, we can get different wave. Through this, we can change the duty cycle of the wave produced by IC-555 timer. Through this we get the required PWM that we need to run the circuit. We used potentiometer and replaced it with R2. By doing this, we can change the duty cycle of the wave in real time when the motor is running. With this, we can vary speed of brushless DC motor. The figure 5.4 shows the IC in a stable mode.



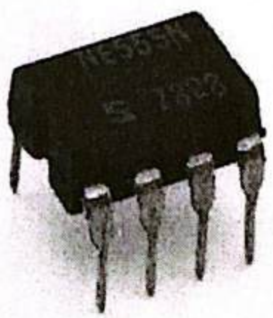


Figure 0-4: IC-555 timer in A-stable mode [17]

The output is achieved through pin 3. R2 resister in the circuit is variable. We used potentiometer in that place the mathematical formula is given below

$$\text{Duty Cycle} = \frac{T_{ON}}{T_{OFF} + T_{ON}} = \frac{R_1 + R_2}{(R_1 + 2R_2)} \%$$

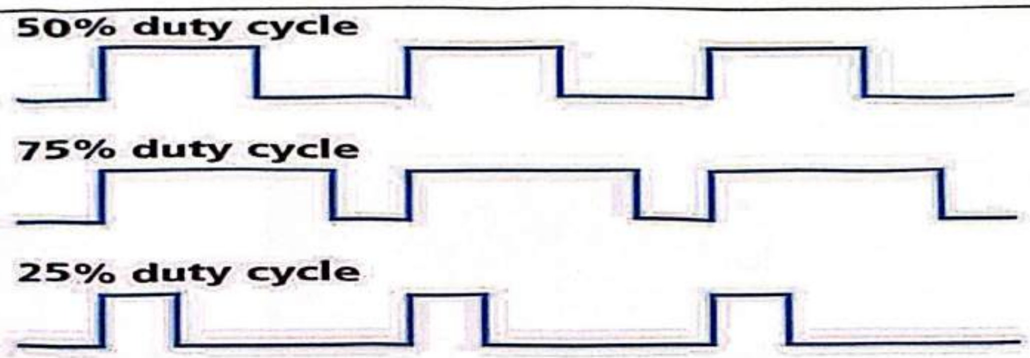


Figure 0-5: square wave generated through IC-555 with different duty cycle. [17]

The fig 5.6 shows the hardware implemented picture of the oscillator circuit that we made in our project.

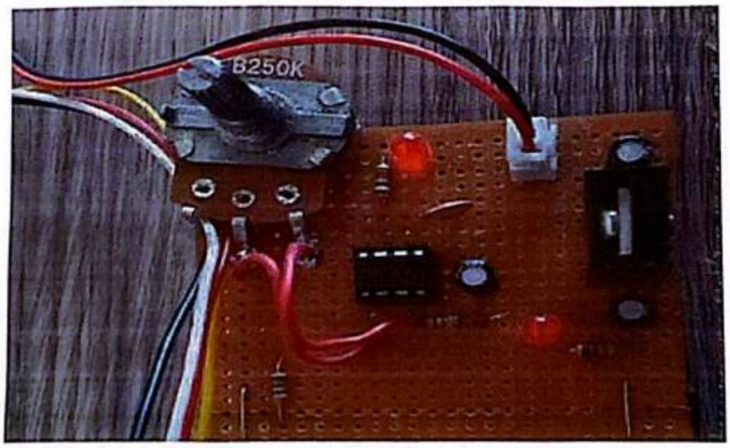


Figure 0-6: IC-555 timer module in a stable mode.

5.5 Johnson Counter Ic-Cd4017

The output from the oscillator circuit will be coming out from pin 3 of IC-555 timer will go to the pin 14 of the IC-CD4017. Pin 14 is the pulse pin of the IC. We will take output from 3 pins and connect it to the port p1 of the microcontroller. Given below is the circuit diagram of implemented hardware of Johnson counter IC-CD4017 figure 5.7.

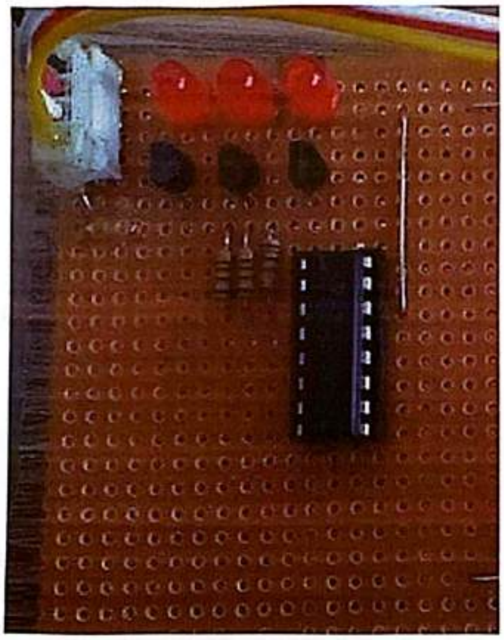


Figure 0-7: Johnson counter IC-CD4017

5.6 Switching Circuit

BLDC motor has pair of coils. The motor has three wires that are connected to the pair of coils. The BLDC motor does not starts through normal means like DC motors. To start BLDC motor, we need controller and switching circuit for that purpose, the switching circuit that we constructed is made of MOSEFT IC-80NF70. This IC can pass 68 Volts and 98 Ampere. Total 6 MOSFETS are used. MOSEFT has 3 pins i.e. source gate and drain. The source and drain is attached to the positive and negative terminal of the battery while gate is attached to the microcontroller. The MOSEFT starts supplying power when it gets the signal at the gate. Given below is the figure 5.8 of switching circuit.

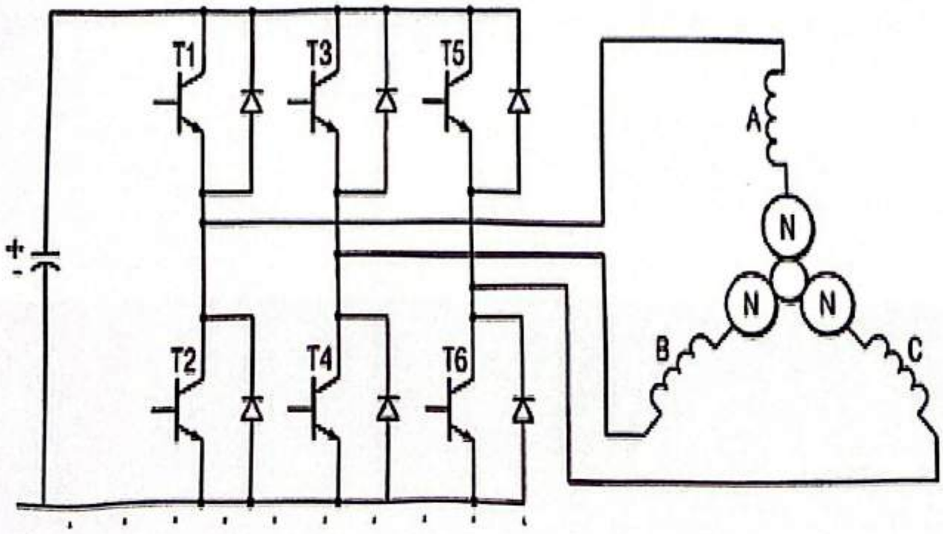


Figure 0-8: switching circuit for BLDC motor [5]

Similarly the hardware implemented circuit for the switching is shown below in figure 5.9.

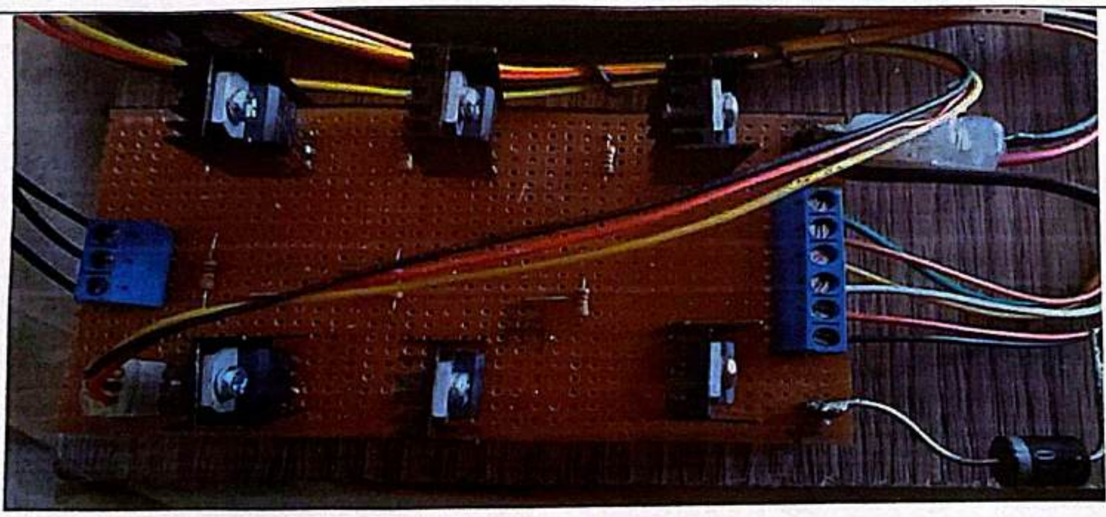


Figure 0-9: MOSFET switching circuit for BLDC motor

5.7 BLDC motor

We imported our BLDC motor from America. We bought it online from KDE DIRECT (www.kdedirect.com). Our motor is very stable and it is of very high quality. It is high power motor. It has RPM value equal to 2050 RPM/V. It can take the voltage from 7 volts to 26 volts. It has efficiency rate of 90%. It has 12 stator poles. Given below is the specs sheet of the BLDC motor.

Kv	2,050 RPM/V
Maximum Continuous Current*	44+ A (180 s)
Maximum Efficiency	> 90%
Voltage Range	7.4 V (2S LiPo) - 26.1 V (6S LiHV)
Io (@10V)	1.3 A
Rm (Wind Resistance)	0.034 Ω
Stator Poles	12 (12S14P)
Magnetic Poles	14 (12S14P)
Bearings	Triple, MR84ZZ, MR104ZZ
Mount Pattern	M3 x ϕ19 mm, M2.5 x ϕ16 mm, M3 x ϕ16/19 mm
Stator Class	2315, 0.2 mm Japanese
Shaft Diameter	ϕ4 mm (ϕ4 mm Internal)
Shaft Length	3.5 mm
Motor Diameter	ϕ28.3 mm
Motor Length	28.5 mm
Motor Weight	64 g (75 g with Wires/Bullets)
Propeller Size	Up to 8" (6" Maximum on 6S)
Motor Timing	22° - 30°
ESC PWM Rate	16 - 32 kHz (+)

Figure 0-10 :BLDC motor [18]

Figure 0-11 : BLDC motor [18]

5.8 Comparator

As we are controlling our BLDC motor through back EMF, we need a comparator circuit which could tell us about the coil status. There will always be one coil out of three coils that will be giving out back EMF. We will use this information for the commutation and switching. The microcontroller will decide on the basis of the information which the comparator circuit will send. This method is also called zero detection method. On the basis of this information, the microcontroller will send the signal to the MOSFET gates so that it can start switching and give power to the BLDC motor coils. The IC that we are using in this process is LM-741. The back EMF wire will be connected to its inverting terminal while the non-inverting terminal will be grounded. Total three comparator circuit will be needed in our project. The outputs of these OP-AMPS are connected to the microcontroller. This will send the data about the coils that would be either on or off at that moment. And the microcontroller will take action accordingly. Given below is the figure 5.11 in which it shows the comparator circuit. LED lights are connected with each comparator so that it could act as an indicator when the circuit is on and the signal is coming.

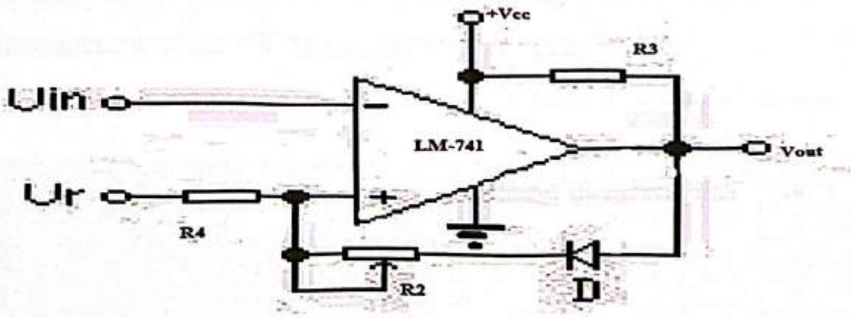


Figure 0-12: comparator circuit using IC LM-741 [17]

Given below is the hardware implementation of the comparator circuit.

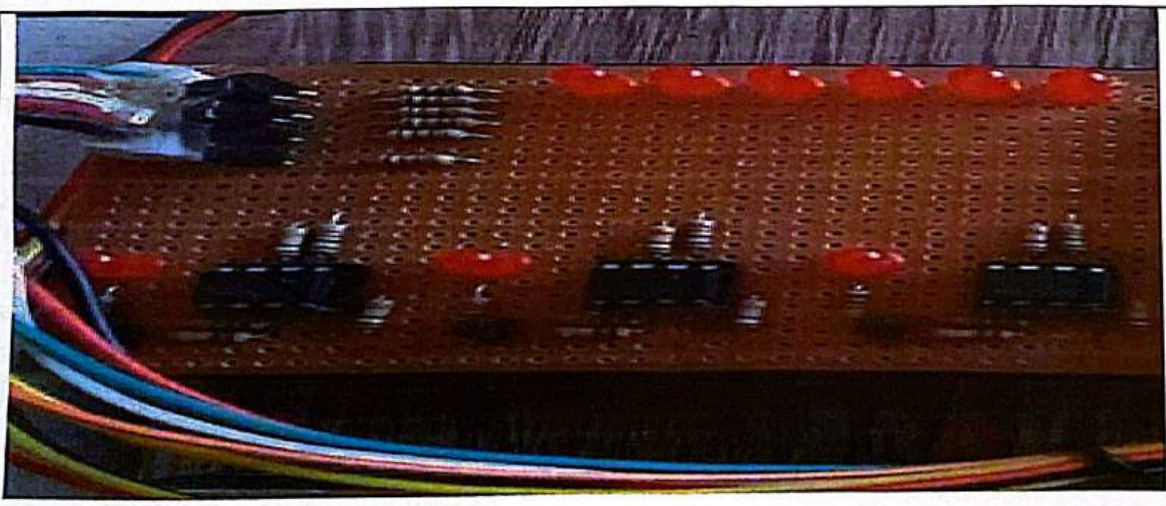


Figure 0-13: comparator circuit using LM-741 for zero crossing detection

5.9 Microcontroller

The brain of this project is microcontroller. On the basis of back EMF process, the controller is controlling the switching and commutation. We are using 8051 microcontroller. We will give ground to the pin 20. Also the Vcc will be given at pin 40. Crystal oscillator of the value 11.0592 KHz will be attached at pin 18 and 19. There are total 4 ports in 8051 microcontroller. At port P1, three wires are connected at the position P1.0, P1.1, P1.2. Oscillator and back EMF value from comparator will be sent here. At port 2, we used 6 pins i.e. P2.0, P2.1, P2.2, P2.3, P2.4, P2.5. These ports are connected to the gates of the MOSFETS for switching purpose. Based on the value from back EMF we will commutate and start switching. Given below is the hardware implementation of the 89C51 microcontroller figure 5.14.

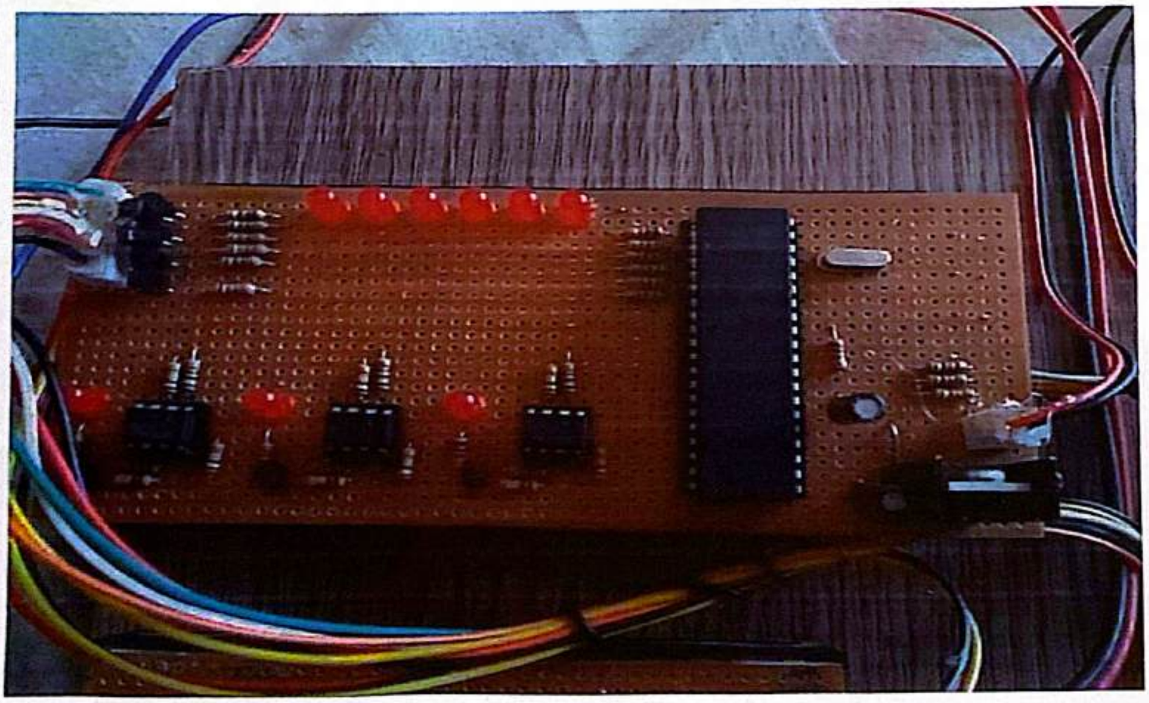


Figure 0-14: 89C51 microcontroller hardware implementation

5.10 Complete Hardware

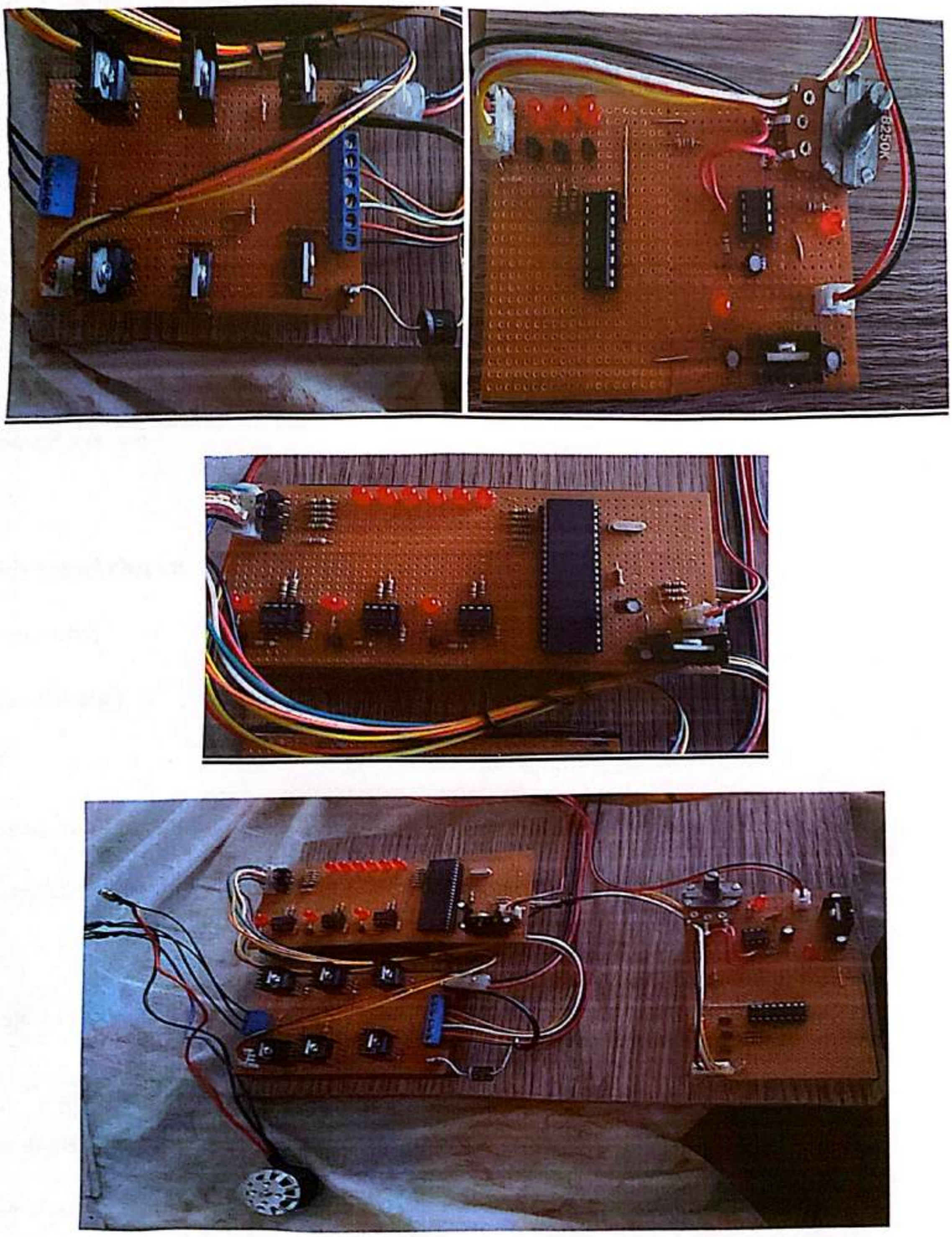


Figure 0-15 : complete hardware implementation

5.11 Software

We did our programming in C language. We programmed it using keil-u-vision software. This software is easy to use with microcontroller. After programming, we burnt the HEX file into 8051 microcontroller. Given below is the c code of 8051 microcontroller.

C-CODE

```
#include<Reg51.h>

#include<stdio.h>

#include<string.h>

struct sys_var

{

unsigned char cnt;

}system;

void wait()

{

unsigned long int kk;

for(kk=0;kk<=10000;kk++);     //////// timer for interrupt of input signal

}

void main()

{

unsigned char k;

while(1)

{

k=P1&0x07;
```

```
switch(k)

{
case 5:{P2=0x06;}break;     ////  port 21 22 23 24 25 26 se output for mosfet
case 4:{P2=0x24;}break;
case 6:{P2=0x21;}break;     ///// break mean delay after on off pin no 1 2 3


case 2:{P2=0x09;}break;
case 3:{P2=0x18;}break;     ////// back emf signal interrupt low when hi output
case 1:{P2=0x12;}break;

}}
```

Chapter # 6

System Testing and Evaluation

6.1 Proteus and Live Wire Simulation

Controlling of BLDC is a complex job which requires lot of hard work and dedication. The circuit along with the coding needs to be very well analyzed in order to obtain a high and fine output from the motor. Our main aim in this project was to analyze the factors that will help us to control the motor. In order to fulfill our aim we went through thorough evaluation of our circuit design. We implemented the entire circuitry on Live-Wire and some part of it was also tested on Proteus. Figure shows how circuit has been tested and evaluated on Live-Wire.

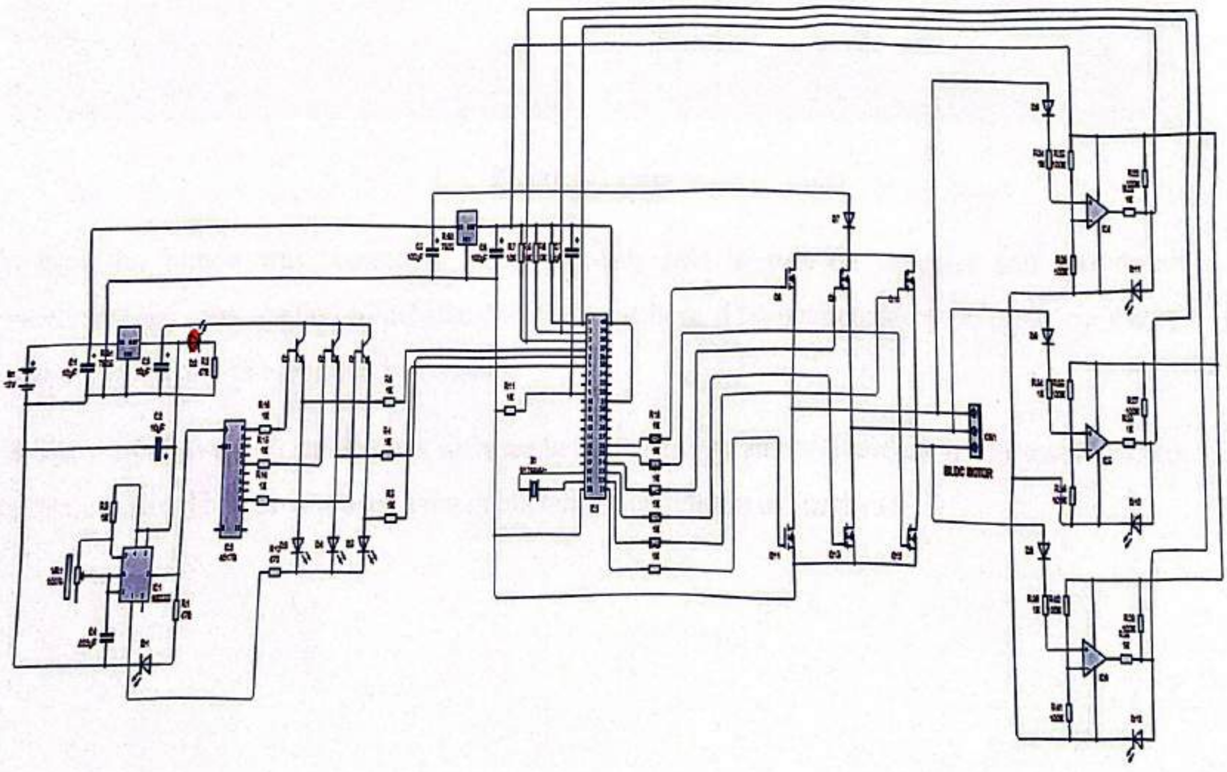


Figure 6-1 Live Wire

The problem that we faced in both proteus and Live-Wire was the absence of Sensor less BLDC motor for that we learned to use two softwares to find the solution but in the end failed. The controller circuit was designed on proteus as well to double check the results. Later on the hardware designed through both softwares worked properly.

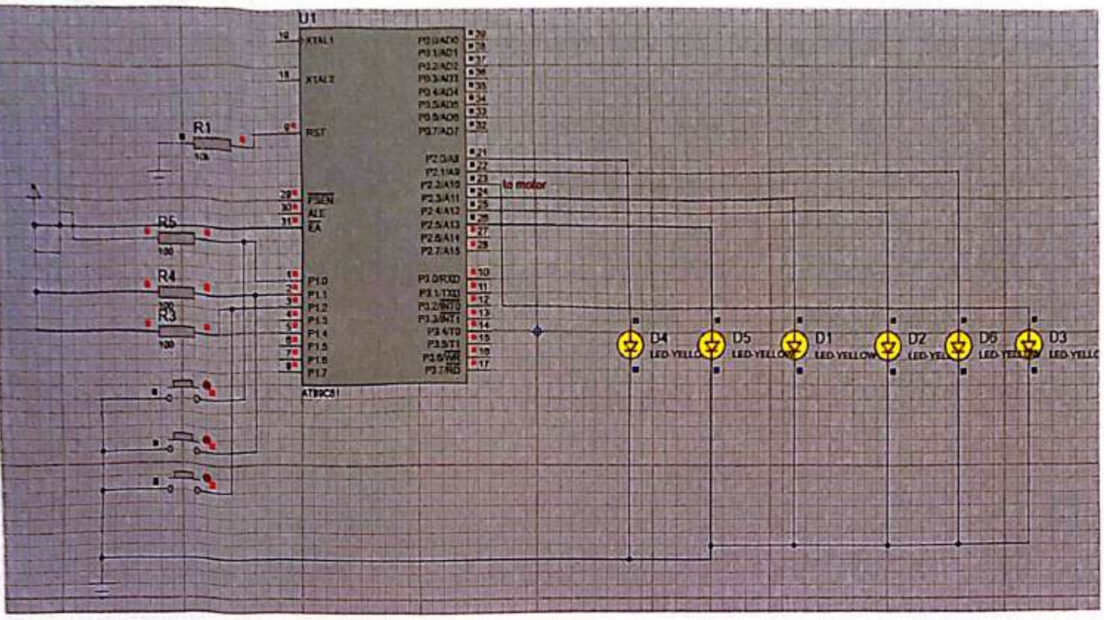


Figure 6-2 Proteus

When the button was pressed in figure the leds start to turn on in pairs and this same methodology was applied to achieve Mosfets switching. The buttons were replaced by PWM waves and leds were replaced by Mosfets.

In short of above both simulations software helped us to test and evaluate the performance of our entire circuit. They even proved vital in implanting our circuit on hardware.