" I hereby declare that I have read through this report entitle "Fabrication and Testing of BLDC Driver Circuit" and found that it has comply the partial fulfilment for awarding the degree of Bachelor of Electrical Engineering (Power Electronics and Drives)"

Signature : ……..

Supervisor's Name : ……..

Date : ……..

FABRICATION AND TESTING OF BLDC DRIVER CIRCUIT

AHMAD SAUFI BIN ABU

A report submitted in partial fulfilment of the requirement for the degree of

Bachelor of Electrical Engineering (Power Electronics & Drives)

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2015

I declare that this report entitle "*Fabrication and Testing of BLDC Driver Circuit*" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ……..

Name : ……..

Date : ……..

To my beloved family

ACKNOWLEDGEMENT

I am Ahmad Saufi Bin Abu would like to express the gratitude to Allah for His guidance throughout the process of finishing this report while undergoing this project. Alhamdulillah, this progress report has been completed with success and full of inspiration. I would like to offer thanks to my parents who gave their full moral support and encouragement that I managed to complete this report. Besides that, a lot of thanks to my supervisor Dr. Raja Nor Firdaus Kashfi Bin Raja Othman who is willingly to guide me and teach me a lot in order to give better understanding and to accomplish my project. Lots of thanks to all friends for the guidance, cooperative and compromise that they had given to me for the success of this project.

ABSTRACT

Brushless Direct Current Motor (BLDC) is widely used, especially in automation application, food processing and others. It use permanent magnet to be replace the coil winding in stator. The advantages of BLDC motor compared to brushed DC motor are, speed versus torque characteristics, high dynamic response, high efficiency, noiseless operation and high speed ranges. To operate BLDC motor, it requires specific driver to run. This project is covered about redesigning the circuit to suit with Scrubber Machine project. The circuit is at first simulated by using MATLAB, Simulink to verify the operation of the circuit before fabrication process. Suitable material for PCB fabrication and component placement is important to ensure losses could be reduced by appropriate thermal ventilation. BLDC motor driver is using logic gate combination AND gate and NOT gate represented in IC's HD 4804 and HD 4808 and 3 Phase Bridge Inverter where MOSFET (IRF640) is used to drive the BLDC motor. After circuit is fabricated, test had been held to test the functionality and the efficiency in term of power switching losses in switching components. In addition, the speed of BLDC motor is observed by the different injected voltage at input voltage. Outcome of this project is the circuit size and compatibility achieved without avoiding losses probability and design structure is part of prioritized.

ABSTRAK

Motor arus terus (A.T.) tanpa berus digunakan secara meluas terutamanaya dalam bidang automasi, penghasilan makanan dan sebagainya. Ia menggunakan magnet kekal bagi menggantikan penggunan gegelung dalam stator. Kelebihan yang ada pada motor arus terus tanpa berus ini berbanding motor arus terus menggunakan berus adalah ia mempunayai ciri-ciri kelajuan melawan daya kilas, dinamik respon yang baik, mempunyai kecekapan yang tinggi, berkeupayaan beroperasi dalam hingar yang kurang dan mempunyai had kelajuan yang boleh dilaras. Untuk menggerakkan motor tersebut, ia memerlukan litar pemacu yang khusus bagi memacu perkerakan motor. Projek ini berkisarkan proses merekabentuk semula litar bagi disesuaikan dengan projek Mesin Pemberus. Litar pada mulanya melalui proses simulasi menggunakan perisian MATLAB Simulink bagi memastikan litar itu beroperasi sepenuhnya sebelum menjalani proses penghasilan (fabrikasi). Pemilihan bahan bagi penghasilan Papan Litar Bercetak (PCB) adalah penting bagi memastikan kehilangan dapat dikurangkan denngan pengaliran pemanasan yang sesuai. Litar ini meggunakan kombinasi get AND dan get NOT yang terdapat dalam litar bersepadu (IC) HD 4804 dan HD 4804. Penukar Jejambat 3 Fasa menggunakan MOSFET (IRF 640) bagi memacu motor arus terus tanpa berus. Setelah litar berjaya dihasilkan, pengujian telah dijalankan bagi memastikan litar berfungsi sepenuhnya dan kecekapan seperti kehilangan pensuisan dalam komponen penyusian dapat ditingkatkan. Tambahan pula, kelajuan motor dapat diuji dengan menyambungnya dengan perbagai julat kelajuan pada voltan masukan. Hasil daripada projek ini litar yang dihasilkan adalah bersaiz kecil dan kompak tanpa mengabaikan ciri-ciri bagi mengurangkan kebarangkalian berlakunya hingar.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AC	Alternating Current
BLDC	Brushless Direct Current
DC	Direct Current
EMF	Electromotive Force
IR	International Rectifier
PWM	Pulse Width Modulation
V*in*	Input Voltage

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Project Background/Motivation

In recent years, DC motor is widely used in the growth of technology in human activity, industrial application and others. There are various kinds of motor in markets such as Permanent Magnet Synchronous Motor, Induction Motor, Brushed DC Motor and Brushless DC Motor. In small applications used, BLDC looks more suitable for Scrubber Machine project. Therefore, BLDC required a suitable driver to control BLDC motor operation. New generations of equipment must have higher performance parameters such as better efficiency and reduced electromagnetic interference. System flexibility must be high to facilitate market modifications and to reduce development time. All these improvements must be achieved, while at the same time, decreasing system cost [1].

Currently, BLDC drives technique has become an interesting topic for researchers due to the motors combine high reliability with high efficiency, and for a lower cost in comparison with brush motors, although the brushless characteristic can be applied to several kinds of motors (the AC synchronous motors, stepper motors, switched reluctance motors, AC induction motors). BLDC motor produce trapezoidal back-electromotive force and 120º stator currents and widely used as offer the following advantages such as assuming the motor has pure trapezoidal back EMF and stator phase commutation process is accurate, the mechanical torque developed by the motor is constant. Secondly, the BLDC drives show a very high mechanical density. In order to maximize the performances of BLDC motor, the key of effective torque and speed control of a BLDC motor is based on relatively simple torque and back EMF.

The principle of BLDC motor is, at all-time the phase pair is energized which can produce high torque. To optimize this effect the back EMF shape is trapezoidal. The combination of a DC current with a trapezoidal back EMF makes it theoretically possible to

produce a constant torque. In practice, the current cannot be established instantaneously in a motor phase as a consequence the torque ripple is present at each 60° phase commutation. There are various kinds of control technique purpose to drive a BLDC motor such as PIC microcontroller, Pulse Width Modulations (PWM) and etc.

Fabrication of BLDC Motor Driver is a hardware based project where a driver will be develop based on previous design to drive BLDC motor for Scrubber Machine. BLDC driver is capable to control BLDC motor based on voltage control. Through the control method used which is digital control by logic and switching control technique by using 3-Phase inverter. BLDC driver is connected to the Hall Effect sensor to sense the position of the rotor in BLDC motor. Commutation is where the voltage is supplied to the motor phase in such a way to keep the motor rotating (magnetic flux vector rotating). The commutation for BLDC motors are a six-step process. All six sides of the 3-phase H-bridge are turned on and off to create the six flow vectors. These vectors make the BLDC motor point 60° to the next position. Referred to Figure 1.1 shows the six steps cause a full revolution (6 steps x 60° = 360°). For each step, positive position (+U) means high side transistor on and low side off, negative position (-U) means high side transistor off and low side on, and neutral position means both transistors are on.

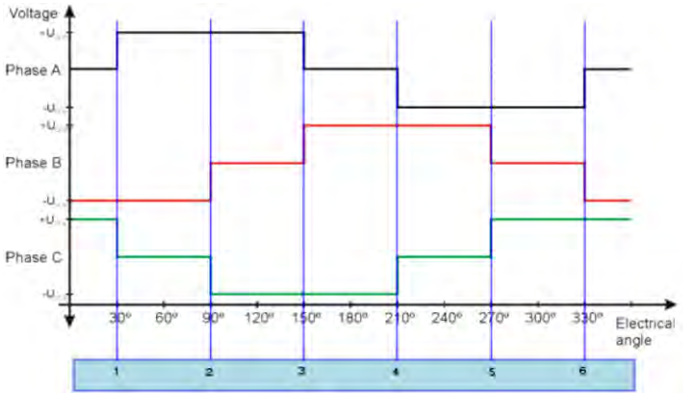


Figure 1.1: Six-Step [7]

1.2 Problem Statement

The condition of previous circuit it seems not suitable for Scrubber Machine application. The previous circuit is not strong, bulky, prone to noise and losses. The previous circuit board is made of doughnut board where the copper is exposed to oxidation and cause it to rust. Furthermore, improper soldering method cause fragment or component parts are not

soldered properly. It indirectly causes the amount of current flowing not at the maximum level, hence losses occurred. New BLDC circuit in Figure 1.2 (a) is designed according to the specifications set for the size of metal containers (120 mm x 140 mm) which in a compact size. Figure 1.2 (b) shows the metal container will then be placed in a bag that is part of the scrubber machine. The current circuit fabricated using FR- 4 material. FR - 4 is a composite material composed of woven fiberglass cloth with an epoxy resin binder that is flame resistant.

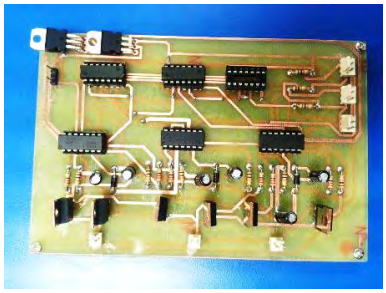


Figure 1.2 (a) Current BLDC circuit Figure 1.2 (b) 120 mm x 140 mm Metal Case

The advantages of the present circuit are more compact sized BLDC circuit which is designed using dual layer FR - 4 PCB. The use of FR - 4 glass epoxy is a versatile high - pressure laminate grade thermoset plastic with good strength to weight ratios. With near zero water absorption, FR - 4 is most commonly used as an electrical insulator possessing considerable mechanical strength. The material is known to retain its high mechanical values and electrical insulating qualities in both dry and humid conditions. These attributes, along with good fabrication characteristics, utility lend to this grade for a wide variety of electrical and mechanical applications. [2]

1.3 Objective

This project embarks on the following objectives:

1. To simulate and verify previous BLDC motor driver circuit using MATLAB
2. To fabricate and test BLDC circuit based on specification required
3. To reduce potential losses of driver circuit

1.4 Research Scope

The BLDC schematic circuit is redesigned from the previous circuit into a compact size and less losses. The experimental parameter to be measured is switching signals of 3-Phase inverter, digital logic signal of Hall Effect sensor, switching current and voltage drop (losses). Simulation is based on switching signal from 3-Phase inverter and digital logic signal conducted by MATLAB Simulink. The circuit schematic is redesigned by using Proteus ISIS and fabricated using Protel99 SE.

Within the scope does not cover in this project is about the BLDC motor fabrication. It is quite related to the performance of the BLDC driver by the unforced error in the BLDC number of turns and size of the coil. Moreover, back-EMF is part of an element that does not cover. In BLDC motor, the rotor position must be at perfect angles in order to align the applied voltage with the Back-EMF. The alignment between Back-EMF and commutation is important because in this condition the motor act as DC motor and run smoothly.

1.5 Report Outline

This report consist of 5 chapters begun with the introduction of each chapter consist of brief explanation of BLDC driver operation. In this chapter, it have been stated that this project is about fabrication and testing of BLDC motor driver. The objective, scope and significant is also clarified in this chapter.

Chapter 2 discuss about literature review of this project. This includes the explanation BLDC operating situation. The major thing that need to know is the principle of BLDC, 3-Phase Bridge Inverter, fabrication of BLDC and testing parameter of BLDC. .BLDC operation is also illustrate in block diagram and flow diagram.

Chapter 3 discuss about process flow of project involving Gantt chart and milestone. Experimental procedure setup is stated briefly to analyse the result obtained from experiment.

Chapter 4 describe the fabrication hardware and simulation result obtain from experiments held. The result is discuss clearly to analyse and ensure objective achieved.

Chapter 5 stated conclusion of project implementation. Recommendation is also purposed for the next study.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In order to gain enough information to recommend the appropriate method that can be implemented to complete this project, comparison between certain techniques include in PCB board fabrication and BLDC circuit include in this chapter are taken from the thesis, books, journals, and any academic articles that are related to the research topic and will be clearly cited. The outlines in this chapter related to the theory, basic principles, review of previous related work, and summary of this project. In the first section in this project covers the basic operation of each particular section of BLDC circuit itself. There will be explained regarding to the operation of BLDC driver. Besides, this section reviews on the system performance degradation, factor of losses that could be considered to reduce losses during the fabrication of this circuit.

Review of previous related work on fabrication of 2- layer of BLDC driver for automotive and simulation of BLDC driver designed by previous researcher will be discussed. Besides, each method is explained clearly on how it works. The performance is verified for improvising the existence losses of system for the convenience of motor to perform. The comparison is determined whereby the suitable method is taken as reference for the fabrication of the BLDC driver circuit.

2.2 Theory and Basic Principles

Brushless DC Motor fed by two-phase conduction mode has several benefits that is, higher torque or current ratio and higher power. In comparison with three-phase feeding permanent magnet synchronous motor (PMSM), this two-phase conduction scheme is less expensive due to concentrated windings which shorten the end windings [10].

Figure 2.1 shows BLDC motor construction made up of permanent magnet rotor and wire wound stator poles. Rotor construction consists of a magnet (pole north and south). Electrical energy is converted into mechanical energy by the magnetic force between the permanent magnet rotor and rotating magnetic field induced in the wound stator poles.

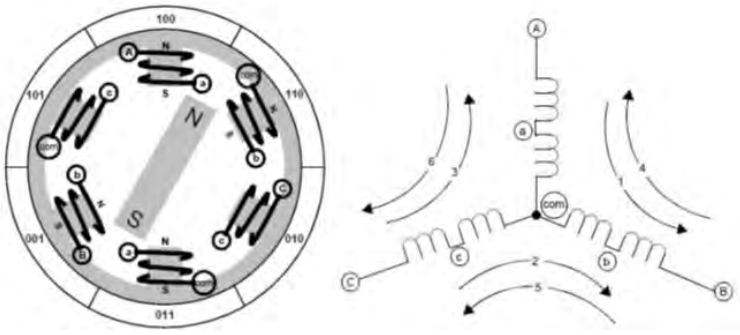
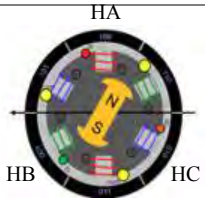
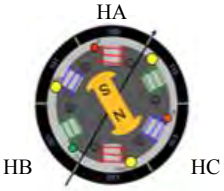
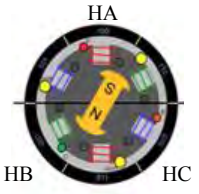


Figure 2.1: BLDC Motor Construction [10]

The key to BLDC commutation is to sense the rotor position, then energize the phases that will produce the most amount of torque. The rotor travels 60 electrical degrees per commutation step. The appropriate stator current path is activated when the rotor is 120 degrees from alignment with the corresponding stator magnetic field, and then deactivated when the rotor is 60 degrees of alignment, at which time the next circuit is activated and the process repeats [10].

The numbers at the top correspond to the current phases shown in Figure 2.1. It is apparent from Figure 2.2 that the three sensor outputs overlap in such a way as to create six step three-bit codes corresponding to each of the drive phases. The numbers shown around the peripheral of the motor diagram in Table 2.1 represent the sensor position code. The north pole of the rotor points to the code that is output at that rotor position. The numbers are the sensor logic levels where the MSB is sensor C and the LSB is sensor A. Each drive phase consists of one motor terminal driven high, one motor terminal driven low, and one motor terminal left floating [11].

Table 2.1: Commutation Step

`	Step Description	HA	HB	HC	Rotor Position
1	Red (A) winding is driven positive Green (B) winding is driven negative Blue (C) winding is not driven	1	0	0	
2	Red (A) winding remains positive Blue (C) winding is driven negative Green (B) winding is not driven	1	1	0	
3	Green (B) winding is driven positive Blue (C) winding is driven negative Red (A) winding is not driven	0	1	0	
4	Green (B) winding is driven positive Red (A) winding is driven negative Blue (C) winding is not driven	0	1	1	
5	Blue (C) winding is driven positive Red (A) winding is driven negative Green (B) winding is not driven	0	0	1	
6	Blue (C) winding is driven positive Green (B) winding is driven negative Red (A) winding is not drive	1	0	1	

2.2.1 BLDC Driver Operation

BLDC motor using concept of positioning of rotor by referring to sensor located in BLDC motor, thus to operate this motor require appropriate gate driver and switching elements. Figure 2.2 shows the operation of BLDC driver operation where bench power supply will supply DC voltage to BLDC circuit. Before that, voltage is regulated by using LM7505 and LM7815 in order to get 5VDC and 15VDC. 5VDC is used to supply logic IC's, MOSFET driver IC's and sensor. However, 15VDC is used to power MOSFET IRF640 and operate BLDC motor. Hall sensor is placed in BLDC motor connected to driver logic circuit (HD7404 and HD7408).

Logic circuit will detect rotor position in BLDC by receiving feedback signal from the sensor and determines the excitation sequence of motor windings. The circuit signal then connected to MOSFET driver (IR2110) and MOSFET IRF640.

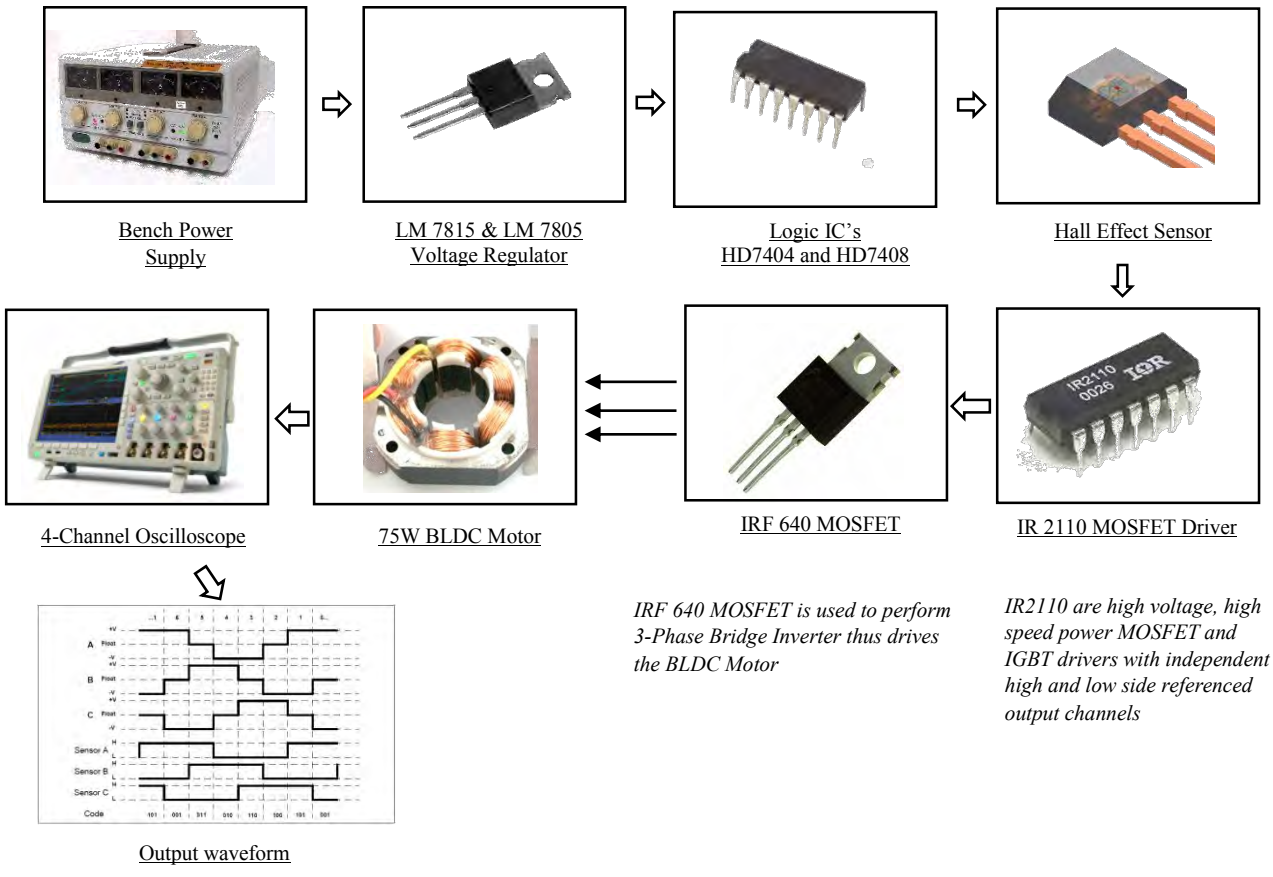


Figure 2.2: BLDC Operation Block Diagram