UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Electrical Engineering

DESIGN OF COMPACT HIGH POWER DC MOTOR DRIVER

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Bachelor of Electrical Engineering in Power Electronic and Drives

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in fulfillment of the requirement for the degree of Bachelor of Electrical Engineering
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2015

DECLARATION

I declare that this thesis entitled "Design of compact high power DC motor driver" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidate of any other degree.

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APPROVAL

I hereby declare that I have read this dissertation/report and in my opinion this dissertation/report is sufficient in terms of scope and quality as a partial fulfillment of Bachelor of Electrical Engineering in Power Electronic and Drives.

Signature	:	…………………………………
Supervisor Name	:	En. Mohd Zulkifli Bin Ramli
Date	:	………………………………....

ABSTRACT

The DC motor driver based on electronic drives is a driver that consists of sophisticated electronic devices which are high speed, inexpensive and reliable. The development of this electronic drive produced a change in the control of the DC motor. The purpose of this project is to design the DC motor driver that can control the speed and direction of the DC motor and to reduce the complexity of the circuit in the DC motor driver itself. Unlike the conventional DC motor driver that only provide the constant speed at one time, the proposed design will be equipped by the four powers MOSFET that constituting the H-bridge and the gate drive that using the IR21844 IC. This driver also introduces the bootstrap method as bootstrap power supply that consists of diode and capacitor. By using bootstrap method, sophisticated electronic device part can be reduced. Furthermore, it will make the design much smaller and the complexity of the circuit can be simplified. Another advantage of using a bootstrap method is the driver will consume less power. Note that the speed of the DC motor is directly proportional of the output voltage of the DC motor driver. So, to adjust the speed of the DC motor the H-bridge of the power MOSFET will play the role as a switch. To increase the speed, the duty cycle of the power MOSFET needs to be increased and vice versa. The overall project outcome is to fabricate and design a compact driver which can be used especially for high current motor drive application.

ABSTRAK

Pemacu motor Arus Terus berdasarkan pemacu elektronik adalah pemacu yang merangkumi peralatan elektronik yang berkelajuan tinggi, murah dan boleh dipercayai. Kemajuan pemacu elektronik telah merubah kawalan motor Arus Terus. Tujuan projek ini adalah untuk mereka pemacu motor Arus Terus yang boleh mengawal kelajuan dan arah pusingan motor Arus Terus untuk mengurangkan kadar kompleks untuk pemacu motor Arus Terus. Tidak seperti pemacu motor Arus Terus yang konvensional yang hanya mampu mengawal satu kelajuan pada satu masa, cadangan reka bentuk ini merangkumi empat MOSFET yang berpandukan jambatan H dan pemacu gate IR21884. Pemacu ini juga menggunakan teori bootstrap yang merangkumi diod dan kapasitor. Dengan menggunakan teknik bootstrap,penggunaan komponen elektronik dapat dikurangkan lalu mengurangkan kompleksiti litar tersebut. Kelebihan lain ialah litar kaedah bootstrap menggunakan tenaga elektrik yang lebih rendah. Umum mengetahui yang kelajuan motor Arus Terus adalah berkadaran dengan voltan keluaran pemacu. Jadi untuk mengawal kelajuan, motor arus terus jambatan H bagi MOSFET akan menggunakan prinsip pensuisan. Untuk meningkatkan kelajuan, kitaran untuk MOSFET perlu ditingkatkan atau sebaliknya. Keseluruhan dapatan projek ini adalah untuk mereka bentuk pemacu motor yang kompak di samping boleh digunakan untuk aplikasi pemacu motor dengan penggunaan arus yang tinggi.

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LIST OF ABBREVIATIONS

DC	Direct Current
AC	Alternating Current
MOSFET	Metal-Oxide Semiconductor Field-Effect Transistor
IGBT	Insulated Gate Bipolar Transistor
FET	Field-Effect Transistor
JFET	Junction Field Effect Transistor
BJT	Bipolar Junction Transistor
TTL	Transistor-Transistor Logic
CMOS	Complementary Metal-Oxide Semiconductor
HVIC	High Voltage Integrated Circuit
SCR	Silicon-Controlled Rectifier
PCB	Printed Circuit Board
PWM	Pulse Width Modulation
CCU6	Capture Compare Unit 6
ADC	Analog-to-Digital Conversion
DAC	Digital-to-Analog Conversion
LED	Light Emitting Diode
HI	High Output
LO	Low Output

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CHAPTER 1

INTRODUCTION

1.1. Research background

Nowadays, the DC motor is still the choice for many applications in the industry. The DC motor is an electrical machine that transforms electrical energy into mechanical energy. The DC motor drives the application that has a definite torque-speed characteristic or highly variable one. DC motor have chosen by the industry because they give several advantages such as capability of operating in all the four quadrants of the speed-torque plane, smooth speed control over a wide range without sophisticated electronics and overload capacity [2, 3]. DC motor also has the record of unexcelled in speed control applications. But by the introduction of power electronic drives, AC motor start to challenge the DC motor [4]. However, the DC motor also gets the advantages from this introduction.

In this research, with the advent of the power electronic drive as the driver of a DC motor, it will make the DC motor have more advantage over the AC motor. The purpose of this project is to design the DC motor driver that can rotate motor with power electronics concept but in high ampere state eventhough it is in compact state.

The main concern in this project is to focus on the design a compact, high power DC motor driver using H-bridge power MOSFET with the half bridge gate driver that combine with the bootstrap operation. The MOSFET is a voltage-controlled device and these devices are widely used in the modern electronic devices. The generally, there are two types of MOSFET which consists of enhancement mode and depletion mode. These MOSFET also has another type channel which is N-channel and P-channel. In this driver, the MOSFET used is set to depletion mode, N-channel type. The advantages of using this power electronic component are, it has a higher switching frequency and it can withstand the frequency switching up to 100kHz [11]. While for the half bridge gate drive, bootstrap operation is applied. This bootstrap operation gives some advantages to the driver such as low cost and reduce the complexity of the circuit. The role of the bootstrap in the gate driver is bootstrap power supply that consists of the capacitor and diode.

1.2. Problem statement

In DC motor driver, it is important for the driver to have the ability to control the speed and to control the torque of DC motor. But nowadays the size of the circuit driver also play the big role in order to reduce space and cost. However the conventional DC motor driver has a complex circuit and this will affect the size. Therefore, the design of this DC motor driver is proposed to reduce the complexity in the circuit driver. The speed and the torque also can be controlled by using this proposed driver.

1.3. Objective

i. To build up the DC motor driver
ii. To reduce the complexity of the circuit driver
iii. To control the speed and direction of a DC motor using high frequency of switching technique

1.4. Scopes of project

The scope of the project is to design the driver only can drive separately excited DC motor and its rated voltage and rated current 24V and 12A respectively. The driver will be consist of gate drive and H-bridge MOSFET. The IC used for the half bridge gate driver is IR21844. The analysis of the hardware only in term of voltage control, duty cycle and frequency switching. This driver is an open loop system where no feedback control.

1.5. Report outline

This report contains a combination of five chapters which are divided into several progress elements.

Chapter 1 is the introduction that will explain about the project background, general information about the DC motor and electronic driver. Problem statement, objective and scope of the project, expected outcomes and report outline also described in this chapter.

Chapter 2 will contain about the literature review regarding the project. This element is the critical element of the research because it needed to demonstrate knowledge and ideas that have been established on a specific topic in order to justify the reason of the research. It is about the study of the primary sources such as, journal article, collective work, research report and conference papers. All the keyword of the research will be discussed in this chapter.

Chapter 3 covers the research methodology. This chapter will discuss about the detailed scope of the project. All the development of the hardware and the steps to obtain the solution are discussed in details. The progress of the project will be done through designing the driver using OrCAD and PCB layout.The build of the hardware and analyse the behaviour of the driver based on the specifications that have been made. The control circuit also need to be programmed in order to receive input from the power supply and to generate PWM signal appropriately according to input signal.

Chapter 4 show the result obtained. All the result will analysed and it will be discussed in this chapter. The figures and tables are included to make the result more understandable.

Lastly, in chapter 5, the conclusion is made based on the result and some suggestions for further work are recommended.

CHAPTER 2

LITERATURE REVIEW

Chapter Overview

In this chapter, all the theory and basic principles that related to the project is discussed in order to have a better understanding. The previous related work also will be discussed in this chapter. This phase is important in order to give an idea for preparation of the project and it will help to establish a theoretical framework for the subject area.

2.1. DC motor theory

DC motor plays a key role in the industry. It is an efficient device in converting energy from various sources of motive power. DC motor developed for use as a prime mover [1]. The characteristic of the DC motor can be defined from the basic equation (1) the DC motor:

$$V_T = E_A + I_A R_A \qquad (1)$$

Where V_T is total applied voltage, E_A is generated voltage, I_A is armature current and R_A is armature resistance.

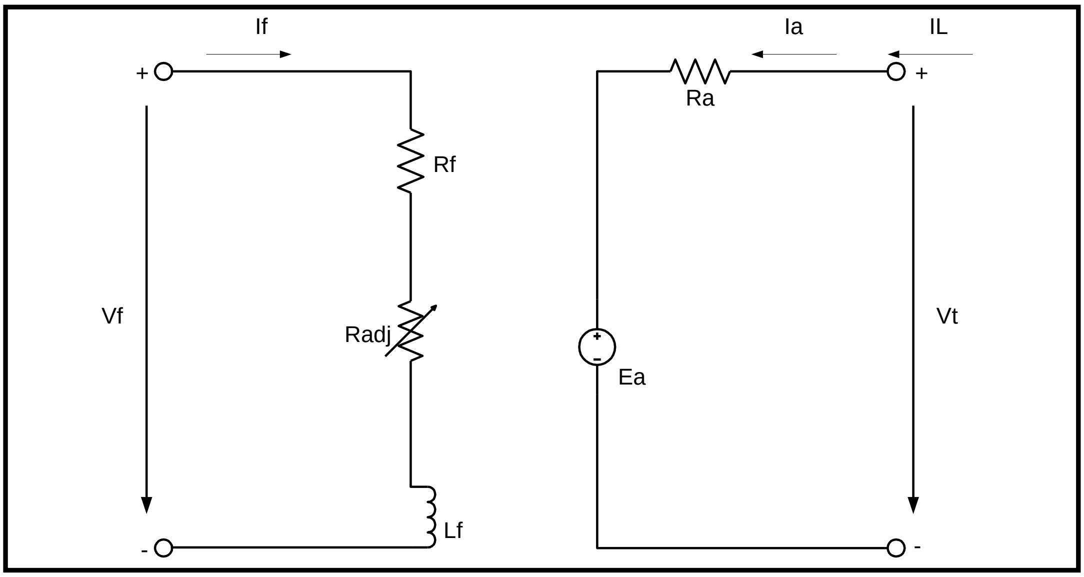

Figure 2.1: The equivalent circuit of a separately excited DC motor [5]

This basic equation gain from the **Figure 2.1** by using Kirchhoff voltage law (KVL). From the equation (1), when generated voltage is constant, it can be said that the armature current can be increased by increase in the applied voltage. While generated voltage, E_A is directly proportional to the flux in the machine and speed of rotation of the machine as shown in equation (2):

$$E_A = K\text{Ø}\omega_m \quad (2)$$

Where K is the constant. For induced torque, it can be defined by the equation (3)

$$T_{ind} = K\text{Ø}I_A \quad (3)$$

From those three equations above, let relate to the speed control of the DC motor. In DC motor, there are several methods to control the speed of the DC motor. One of the methods involved is changing the voltage applied to the armature of the motor without changing the voltage applied to the field. It should be noted that the motor must be separately excited.

Assume that only V_T is the manipulated variable. So from the equation (1) when V_T is increased, it will affect the increasing of I_A. As I_A increase, T_{ind} also increase and make the T_{ind} higher than T_{load}. This will affect the increasing in speed of rotation of the motor, ω_m. Based on equation (2), when ω_m increase automatically E_A also increase and cause the I_A to decrease. This affects the decrement of T_{ind} and causing T_{ind} to equal to T_{load} at a higher rotational speed [4].

2.2. Power Electronic Driver

Power electronic drives have proven to be high competence switching mode power amplifier where the efficiency may go as high as 98% to 99%. Another importance of power electronic drives is it is free from noise, low cost, high reliability and static of equipment. It also gives a positive impact in energy conversion and environmental pollution control trend.

Power electronic drive circuit is an electrical circuit that is constructed to control another circuit or component. This power electronic drive circuit will provide an interface between the control signal (small signal electronics) and power circuit. **Figure 2.2** below shows the block diagram of the main part in the power electronic driver [22].

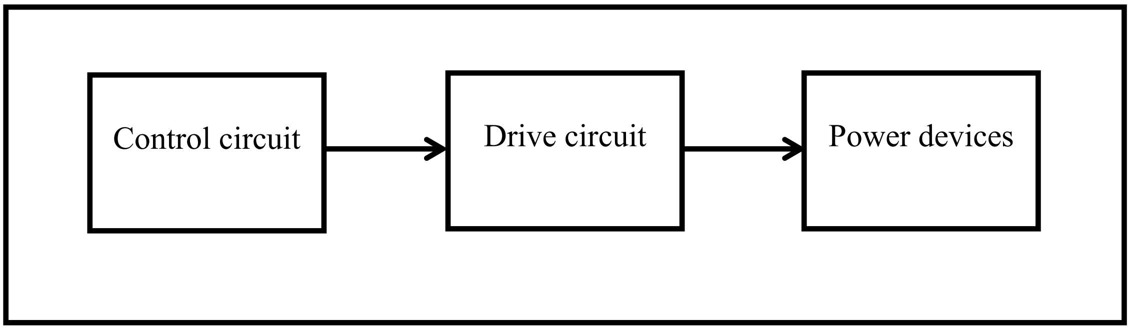

Figure 2.2: Block diagram power electronic driver

2.3. Control circuit

In fact, the circuit driver cannot operate without the presence of control circuit. The control circuit will act as controller whether it is an open loop system or closed loop system. Control circuit with open loop system does not have any feedback attached to the generation of the signal, thus the PWM signal generated only has a constant and precise loop.

Even though open loop system looks simple, but a specific study is needed in order to determine the correct and proper switching technique. Besides, the open loop control circuit does not require much component to compensate the error. For closed loop control circuit, there will be feedback attached to the input signal. Example of feedback control circuit for DC motor are speed, torque and position. To compensate the error for closed loop system there are too many topology needs to be considered of like PI, PD or PID controller. Because of too many feedback topologies discussed before, there will be too many components used to represent the system and thus make it unreasonable for compact design and even though it can recompense for many errors.

Timing of the input signal is in accordance to the desired switching that needed by users such as frequency and duty cycle. But in power electronics there are numerous topology for switching technique even it is an open loop system or closed loop system for example SPWM, square wave technique, wavelet technique, bipolar switching, unipolar switching and many other terms [7].

There are several control circuit that can be propose for this project such as Arduino and XC866 microcontroller. These microcontrollers need to be programmed using C language. The detail about this two microcontroller discussed as below.

2.3.1. XC866-Infineon Technologies

The type of 8051 processors used is XC866 that created and manufactured by Infineon Technologies. XC866 is one of the high performances of 8-bit microcontroller in XC800 family. Core of XC866 is compatible with the industry standard 8051 processor. It has on-chip oscillator with an integrated voltage regulator to allow single voltage supply either 3.0 to 5.5V. This on-chip oscillator actually highly integrated on-chip component. XC866 also equipped by embedded Flash Memory or compatible ROM version. This will give high flexibility in development and ramp-up or to save the cost in high-volume production.

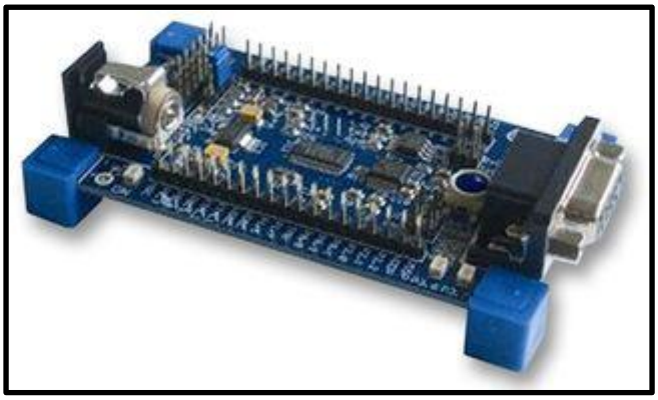

Figure 2.3: XC866 microcontroller [20]

Capture/Compare Unit 6 (CCU6) is included in this XC866. CCU6 is used to generate the pulse width modulated signal with special modes for motor control. 10 bit Analog to Digital converter (ADC) also available for a smoother interface with an analog signal. For low power applications, various power saving modes are readily available for selection by the user. For interrupted handling, Special Function Register (SFR) address range with an intelligent paging has been optimized for usage in this chip.

This XC866 CPU uses a 2-clock machine cycle to allow fast access to ROM or RAM memories without wait state. The instruction sets are divided by 45% one byte, 41% two byte and 14% three byte instructions. It also provides a range of debugging features that include stop/start, breakpoint support, single-step execution read/write access to the data memory, program memory and SFRs[20, 21].

Other features are stated as below;

- Two clocks per machine cycle architecture (for memory access without wait state)
- Wait state support for Flash memory
- Program memory download option
- 15-source, 4-level interrupt controller
- Two data pointers
- Power saving modes
- Dedicated debug mode and debug signals
- Two 16-bit timers (Timer 0 and Timer 1)
- Full-duplex serial port (UART)