MICROCONTROLLER BASED VARIABLE GATE VOLTAGE FOR MOSFETs

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“I hereby acknowledge that the scope and quality of this thesis is qualified for the award of the Bachelor Degree of Electrical Engineering (Electronics)”

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Specially dedicated to
My beloved mother, brothers
Supervisor, lecturers, staffs and
Friends

Thousands of thanks for helping, attentions,
Supports and encouragement.

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ABSTRACT

Metal Oxide Semiconductor Field Effect Transistor, MOSFETs are important and expansive switching devices in many power electronic circuit applications. MOSFETs require adequate pulses at its gate terminal in order to work properly. The amount of current going through the source and drain terminals is controlled by the magnitude pulses supplied. Normally, the magnitude of gate pulses is fixed and set to a nearly maximum allowable current of MOSFET. The problem with fixed type gate pulses is whenever overload occurs; the MOSFETs may experience very high current and thus working beyond their safe operating area (SOA). This situation might destroy the MOSFET. This project is implement base on PIC16F84A to generate PWM. The IR2109 use provide variable magnitude of PWM pulses and then to drive the based gate of the MOSFET. IR2109 is selected because of its ability to withstand high voltage input.

ABSTRAK

Metal Oxide Semiconductor Field Effect Transistor, MOSFET merupakan suis elektronik yang amat penting dan mahal. Ianya banyak digunakan dalam aplikasi litar elektronik kuasa. MOSFET memerlukan dedenyut yang mencukupi pada terminal *gate* untuk membolehkannya berfungsi dengan sempurna. Jumlah arus yang melepasi terminal *source* dan *drain* dikawal oleh magnitud dedenyut yang dibekalkan kepadanya. Normalnya, magnitud dedenyut yang dibekalkan di terminal *gate* adalah malar dan ditetapkan kepada arus maksimum yang boleh diterima oleh MOSFET. Masalah dengan magnitud dedenyut ini adalah, apabila berlaku lebihan beban, MOSFET akan berhadapan dengan jumlah arus yang besar melebihi kemampuannya dan menyebabkan ia beroperasi di luar zon selamat. Situasi ini akan menyebabkan MOSFET musnah. Projek ini akan menggunakan aplikasi PIC 16F84A untuk menghasilkan dedenyut manakala IR2109 digunakan untuk menghasilkan dedenyut yang berubah-ubah magnitudnya. Dedenyut ini akan digunakan untuk mengawal MOSFET. IR 2109 dipilih kerana kebolehannya untuk beroperasi dengan nilai voltan yang tinggi.

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MOSFET	-	Metal oxide semiconductor field effect transistor
PWM	-	Pulse width modulation
PIC	-	Peripheral interface controller
IC	-	Integrated circuit
V_{GS}	-	Gate-to-source voltage
V_{TH}	-	Threshold voltage
IR	-	International Rectifier

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Overview

MOSFET is a power electronics device that operated with high frequency and high efficiency switching application in electronics industry. MOSFET is categorized as Field Effect Transistor, FET family. FET technology was invented in 1930, some 20 years before the bipolar transistor. The first signal level FET transistors were built in the late 1950's while power MOSFETs have been available from the mid70's. Today, millions of MOSFET transistors are integrated in modern electronic components, from microprocessors, through "discrete" power transistors [1].

MOSFET are widely used in analog and digital circuits. The MOSFET is composed of a channel of n-type or p-type semiconductor material and is accordingly called an NMOSFET or PMOSFET (also commonly nMOSFET, pMOSFET) [2]. MOSFET is three terminal devices. The terminals are gate, drain and source.

As stated earlier, MOSFET is one of FET family. FET is different with Bipolar Junction Transistor, BJT. The major different between them are BJT is a current-controlled device, whereas FET is a voltage-controlled device. In other words, for BJT collector current, I_C is a direct function of the level of base current, I_b. For the FET the drain current, I_D will be a function of the gate-source voltage, V_{GS}. In each case the current of the output circuit is controlled by a parameter of the input circuit-in one case a current level and in the other an applied voltage [3]. From this statement, in order to make the MOSFET function the adequate voltage has to be supplied to its gate. The focus of this project is to variable the gate voltage that being supplied to the gate of the MOSFET.

1.2 Problem Statement

Normal MOSFET that used nowadays has a fix value of gate voltage. Other than that, it was also set nearly maximum allowable current of MOSFETs. The problem with fix variable gate voltage are, whenever overload occurs, the MOSFETs may experience very high current and thus working beyond their Safety Operating Area (SOA). This situation of overloading might destroy the MOSFET.

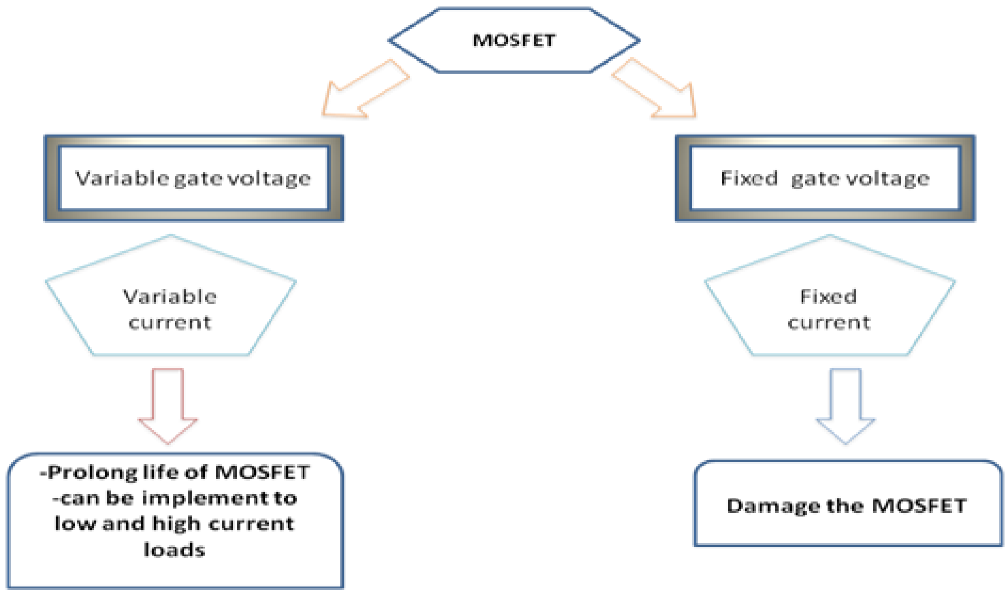

Figure 1.1: Problem statement

In this project the variable gate voltage of MOSFET was implemented. The advantages with variable gate voltage are the current flowing through the MOSFET can be variable, prolong life of MOSFET and the MOSFET can be implement to drive low and high current loads.

1.3 Objective

The objectives of this project are:

I. To find a method on how the variable magnitude pulse gate could be implemented.

II. To understand the switching behaviour of MOSFETs.

1.4 scope of Project

The scopes of work of this project are:

I. Set up the power supply:

   The power supply that being used are 5V and 15V. 5V power supply is used to supply the voltage to Programmable Integrated Controller, PIC whereas 15V power supply is used to ON the MOSFET.

II. Write the program of PIC:

   PIC is used to produce Pulse Width Modulation, PWM by coding the PIC.

III. Set up the driver circuit for MOSFET:

   Driver circuit is used to drive the MOSFET. In other to function, MOSFET require adequate pulse that fed by driver circuit.

CHAPTER 2

LITERATURE REVIEW

2.1 The Construction of MOSFET

The *n*-type Metal-Oxide-Semiconductor Field-Effect-Transistor (nMOSFET) consists of a source and a drain, two highly conducting *n*-type semiconductor regions, which are isolated from the *p*-type substrate by reversed-biased p-n diodes. A metal or poly-crystalline gate covers the region between source and drain. The gate is separated from the semiconductor by the gate oxide [4]. The basic structure of an *n*-type MOSFET and the corresponding circuit symbol are shown in Figure 2.

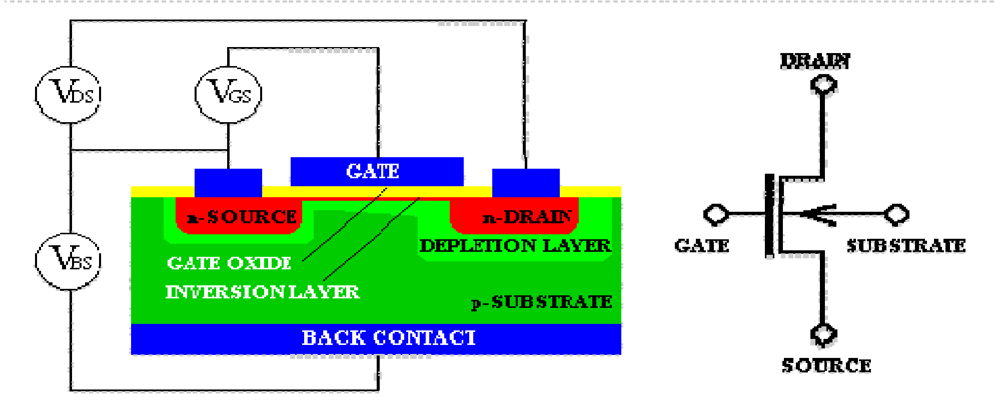

Figure 2.1 : Cross-section and circuit symbol of an *n*-type Metal-Oxide-Semiconductor-Field-Effect-Transistor (MOSFET)

As can be seen on the figure the source and drain regions are identical. It is the applied voltages, which determine which *n*-type region provides the electrons and becomes the source, while the other *n*-type region receives the electrons and becomes the drain. The voltages applied to the drain and gate electrode as well as to the substrate, by means of a back contact, are referred to the source potential, as also indicated Figure 2 [4].

A conceptually similar structure was proposed and patented independently by Lilienfeld and Heil in 1930, but the MOSFET was not successfully demonstrated until 1960. The main technological problem was the control and reduction of the surface states at the oxide-semiconductor interface.

Initially, it was only possible to deplete an existing *n*-type channel by applying a negative voltage to the gate. Such devices have a conducting channel between sources and drain even when no gate voltage is applied. They are called "depletion-mode" devices [4].

A reduction of the surface states enabled the fabrication of devices, which do not have a conducting channel unless a positive voltage is applied. Such devices are referred to as "enhancement-mode" devices. The electrons at the oxide-semiconductor interface are concentrated in a thin (~10 nm thick) "inversion" layer. By now, most MOSFETs are "enhancement-mode" devices [4].

While a minimum requirement for amplification of electrical signals is power gain, one finds that a device with both voltage and current gain is a highly desirable circuit element. The MOSFET provides current and voltage gain yielding an output current into an external load, which exceeds the input current, and an output voltage across that external load which exceeds the input voltage [4].

The current gain capability of a Field-Effect-Transistor (FET) is easily explained by the fact that no gate current is required to maintain the inversion layer and the resulting current between drain and source. The device has therefore an infinite current gain in dc. The current gain is inversely proportional to the signal frequency, reaching unity current gain at the transit frequency [4].

The voltage gain of the MOSFET is caused by the current saturation at higher drain-source voltages, so that a small drain-current variation can cause a large drain voltage variation [4].

2.2 Modes of Operation of MOSFETs

2.2.1 Cut-off or Sub-threshold or Weak Inversion Mode

This phenomenon is occurring when gate-source voltage, V_{GS} is less than threshold voltage, V_{th}. According to the basic threshold model, the transistor is turned off, and there is no conduction between drain and source. In reality, the Boltzmann distribution of electron energies allows some of the more energetic electrons at the source to enter the channel and flow to the drain, resulting in a subthreshold current that is an exponential function of gate–source voltage. While the current between drain and source should ideally be zero when the transistor is being used as a turned-off switch, there is a weak-inversion current, sometimes called subthreshold leakage [2].