Modeling MOSFETs by Using C++

ROY STEPHEN ANAK JOEL JIMBAI

This project is submitted in partial fulfilment of
The requirements for the degree of Bachelor of Engineering with Honours
(Electronic and Telecommunication Engineering)

Faculty of Engineering
UNIVERSITI MALAYSIA SARAWAK
2008/2009

UNIVERSITI MALAYSIA SARAWAK

R13a

BORANG PENGESAHAN STATUS TESIS

Judul: **MODELING MOSFETs BY USING C++**

SESI PENGAJIAN: 2008/2009

Saya **ROY STEPHEN ANAK JOEL JIMBAI**
(HURUF BESAR)

mengaku membenarkan tesis * ini disimpan di Pusat Khidmat Maklumat Akademik, Universiti Malaysia Sarawak dengan syarat-syarat kegunaan seperti berikut:

1. Tesis adalah hakmilik Universiti Malaysia Sarawak.
2. Pusat Khidmat Maklumat Akademik, Universiti Malaysia Sarawak dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Membuat pendigitan untuk membangunkan Pangkalan Data Kandungan Tempatan.
4. Pusat Khidmat Maklumat Akademik, Universiti Malaysia Sarawak dibenarkan membuat salinan tesis ini sebagai bahan pertukaran antara institusi pengajian tinggi.
5. ** Sila tandakan (✔) di kotak yang berkenaan

☐ SULIT (Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di dalam AKTA RAHSIA RASMI 1972).

☐ TERHAD (Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/ badan di mana penyelidikan dijalankan).

☑ TIDAK TERHAD

Disahkan oleh

(TANDATANGAN PENULIS)	(TANDATANGAN PENYELIA)
Alamat tetap: 52 A, KPG QUOP BATU 10, JLN KCH/SERIAN, 93250 KUCHING.	MR. NORHUZAIMIN JULAI Nama Penyelia
Tarikh:	Tarikh:

CATATAN

* Tesis dimaksudkan sebagai tesis bagi Ijazah Doktor Falsafah, Sarjana dan Sarjana Muda.

** Jika tesis ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh tesis ini perlu dikelaskan sebagai SULIT dan TERHAD.

This Final Year Project attached here:

Title	: Modeling MOSFETs by Using C++
Student Name	: Roy Stephen anak Joel Jimbai
Matric No	: 10916

has been read and approved by:

________________________ ____________________

Mr. Norhuzaimin Julai Date

(Supervisor)

Dedicated to my beloved family and friends

ACKNOWLEDGEMENT

Upon completion of this project, I would like to express the highest appreciation to my supervisor, Mr Norhuzaimin Julai for his endless hours of help, suggestions, ideas and guidance during the development of this final year project.

I also would like to take the opportunity to express my gratitude to all lectures and staffs, who helped by giving their time and guide, advice and support in the process of making this project.

I also would like to thank my parent, Joel Jimbai and Menggusi Raeg, my family and friends for all their love, care support and companion that helped me in sailing through the many hard days in lives and studies all these while.

Last but not least, I would like to thank his beloved Jeascye, for her love, constant support and understanding.

ABSTRAK

Dewasa ini, penggunaan secara meluas transistor ‘*Metal Oxide Semiconductor Field-Effect Transistor’* (MOSFET) meliputi penggunaan di dalam peranti –peranti elektronik , terutama dalam bidang rekacipta litar paduan (ICs), merupakan litar-litar mikro yang dipasang di atas sekeping cip silikon. Oleh kerana itu, dalam laporan ini, serba sedikit kriteria “MOSFET” dihuraikan, yang merupakan salah satu objektif untuk projek ini iaitu untuk memodelkan kriteria-kriteria ini menggunakan sebuah perisian yang dikenali sebagai “Microsoft Visual C++”. Fungsi-fungsi “C++” yang dihasilkan oleh penulis sendiri, yang mana akan digunakan sebagai aplikasi untuk membuat fungsi penyongsang (inverter), dan kemudiannya digunakan pula untuk membuktikan penyongsangan pasangan logik-logik seperti DAN/TAKDAN, ATAU/TAKATAU dan EKSKLUSIF ATAU/ EKSKLUSIF TAKATAU dan juga “Half-Adder”. Masalah-masalah yang dihadapi penulis disertakan dengan pandangan dan cadangan yang mungkin berguna untuk perintis masa depan bagi projek ini.

ABSTRACT

The Metal Oxide Semiconductor Field-Effect Transistors (MOSFET) has become by far the most widely used electronic devices, especially in the design of integrated circuits (ICs), which are circuits fabricated on a single silicon chip. The reason for the label metal-oxide-semiconductor FET is: *metal* for the drains source and gate connection to the proper surface- in particular, the gate terminal and the control to be offered by the surface are of the contact, structure on which the n- and p-type regions are diffused. Thus, in this paper, the characteristics of the MOSFETs are briefly discussed at which one of the objectives is to model these characteristics by using software, Microsoft Visual C++ and in this project, the drain characteristics of both NMOS and PMOS is modelled. As goes further this paper, the created C++ programming for the inverter which are then further implement to verify the operation of pairs of gate logics ; AND/NAND, OR/NOR and XOR/XNOR and also Half -Adder. Nevertheless, the constraints faced by the author are concluded and few recommendations are suggested for future apprentices.

LIST OF CONTENTS

CHAPTER 3 METHODOLOGY

CHAPTER 4 RESULT, ANALYSIS AND DISCUSSION

LIST OF TABLES

LIST OF FIGURES

FIGURE **PAGES**

CHAPTER 1

INTRODUCTION

1.1 Background

Digital circuits are comprised of millions of transistors. Transistors are made of MOSFETs (Metal Oxide Semiconductor Field-Effect Transistors). This is a particular kind of FETs (Field-Effect Transistors) that controls the current between two points. The FET operates by the effects of an electric field on the flow of electrons through a single type of semiconductor material. This is why the FET is sometimes called a unipolar transistor. MOSFET is extremely popular in the industry. It uses the integrated-circuit technology called microelectronic that capable of producing circuits that contain millions of components in a small piece of silicon (known as a silicon chip) whose area is on the order of $100mm^2$ [11].

MOSFETs are either NMOS (n-channel) or PMOS (p-channel) transistors, which are fabricated as individually packaged discrete components for high power applications as well as by the hundreds of millions inside a single chip. Compared to BJTs (Bipolar Junction Transistor) or other devices, MOSFETs are small can be well packed together on the high density chip thus the MOSFET manufacturing process is relatively simple.

1.2 History of MOSFETs

A conceptually similar structure was first proposed and patented by Lilienfeld [4] and Heil [2] in 1930, but was successfully demonstrated until 1960 where the first MOSFET was fabricated by Kahng at Bell Laboratory [3]. The main technological problem was the control and reduction of the surface states at the interface between the oxide and the semiconductor.

For the last four decades, the MOSFET circuit technology has dramatically changed. The MOSFETs has evolved from the PMOS in the 1960's to the NMOS in the 1070's. Another important development in the evolution of the MOSFETs is the replacement of metal gate with poly-silicon gate. Early MOSFETs used aluminum as a gate electrode, hence the name MOSFET. However the use of heavily doped poly-silicon as a gate material opened a whole new vista and allowed tremendous improvement in scalability of MOSFETs and technology.

Starting with ten-micron PMOS process with an aluminum gate and a single metallization layer around 1970, the technology has evolved into tenth-micron selfaligned-gate complementary-MOS (CMOS) process with up to five metallization levels. The transistor from dopant diffusion to ion implantation, from thermal oxidation to oxide deposition, from metal gate to a poly-silicon gate, from wet chemical etching to dry etching and more recently from aluminum (with 2% copper) wiring to copper has provided vastly superior analog and digital CMOS circuits. CMOS forms the basis of the vast majority of all high density ICs manufactured today [12].

1.3 Objectives

The main objectives of this project are:

i) To model the MOSFETs characteristics by using C++

ii) To model the operating functions of MOSFETs with C++ and implement for inverter application.

1.4 Organization of The Report

This document is organized in such a way to represent the development stages of the whole project. The report can be categorized into two stages; theory and implementation. The first stage consists of Chapter 1, 2 and 3 whereas the second stage covers Chapter 4 and 5.

In Chapter 1, a brief background of MOSFETs is introduced by giving a general overview of MOSFETs evolution via the microelectronic technology. Next, Chapter 2 discusses the theory of MOSFET in term of its characteristics and applications. This chapter gives a better view understanding the operation of MOSFET and how these characteristics give privileges to MOSFET to be implemented as switches, amplifiers and logic inverter.

For the implementation part, Chapter 3 focuses more on the methodology of modeling the MOSFETs using Microsoft Visual C++ software. This chapter also represents a step-by-step approach applied to use the user-defined functions for MOSFETs analysis. The functions created afterward will be tested by putting in values and the outputs are then analyzed in the Chapter 4. Discussions on problems, modifications and improvement on the source codes are generally explained. Finally, last but not least, Chapter 5 concludes the execution of the project. It also gives some recommendations on improvements and future works that can be made to the project in the future.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction to MOSFETs

The Metal-Oxide-Semiconductor Field-Effect Transistor (MOSFET), the most popular and widely used type of field effect transistor is far commonly used in both digital and analog circuits. Figure 2.1 shows the structure of MOSFET.

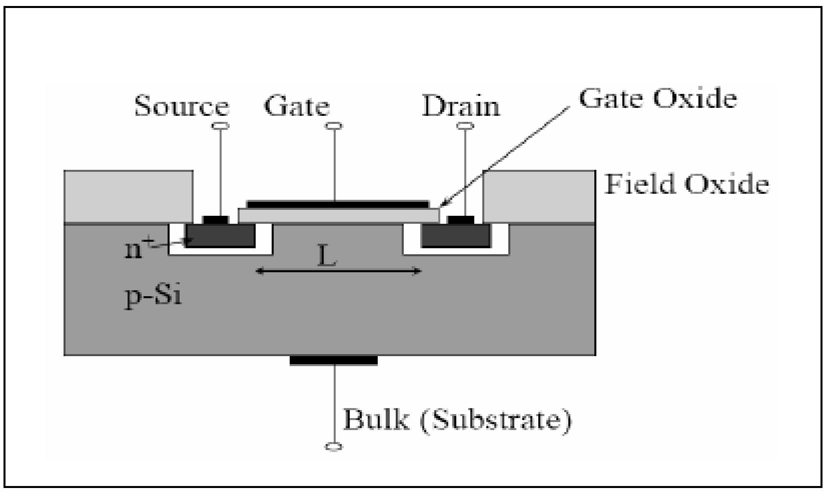

Figure 2.1: MOSFET structure

The MOSFET is composed of a channel of n-type or p-type semiconductor material, fabricated as individually packaged discrete components for high power applications as well as by the hundreds of millions inside a single chip (IC), and is accordingly called an NMOS or a PMOS. Usually the semiconductor of choice is silicon, but some chip manufactures, most notably IBM, have begun to use a mixture of silicon and germanium (SiGe) in MOSFET channels. Unfortunately, many semiconductors with better electrical properties than silicon, such as gallium arsenide, do not form good gate oxides and thus are not suitable for MOSFETs.

2.2 Type of MOSFET

Basically, there are two main types of MOSFETs that are commonly used, named the depletion-type and enhancement-type MOSFETs. The term depletion and enhancement define the MOSFETs' basic mode of operation [1]. Figure 2.2 shows the circuit symbol of these four types of MOSFETs along with their drain current vs gate-source voltage characteristics (transfer characteristics).

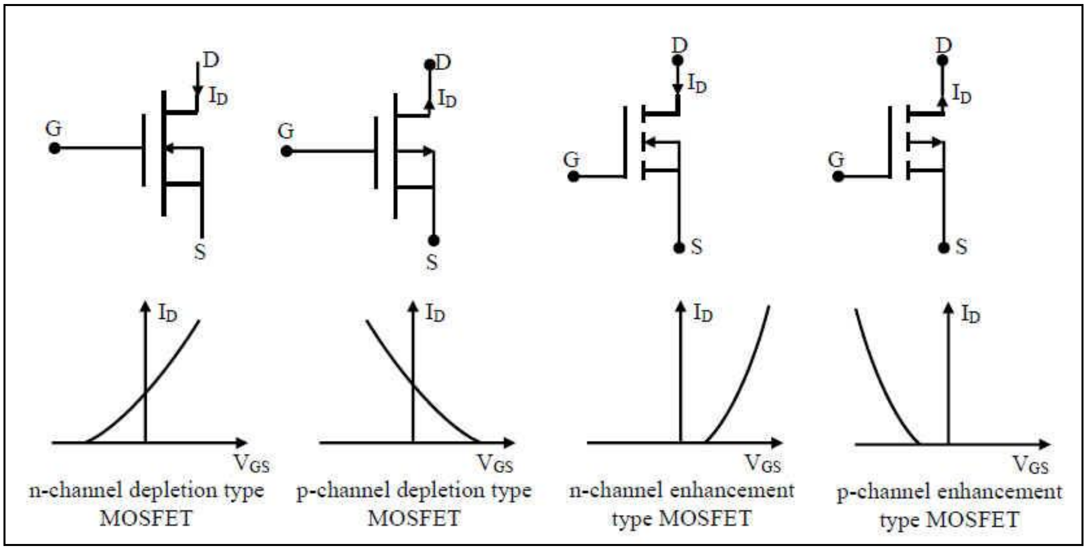

Figure 2.2: Comparison of enhancement-mode and depletion-mode MOSFET symbol

2.2.1 Depletion-type MOSFETs

These are MOSFET devices which are doped so that a channel exists even without any voltage applied to the gate. This type of MOSFETs can be constructed on both n-type and p-type. Depletion-type MOSFETs have similar characteristics as in JFET (Junction Field Effect Transistor) with only few added feature of characteristics. Depletion-type basically forms either n-channel or p-channel, depends upon what substrate it is composed of. When one then applies a voltage to the gate, the channel is depleted, which reduces the current flow through the device. In essence the depletion mode device is equivalent to a normally closed switch.

2.2.1.1 n-channel Depletion-type MOSFET

The basic construction of the n-channel depletion-type MOSFET is provided in Figure 2.3(a) where the substrate of a slab of p-type material is formed from silicon base. All the source, drain and gate terminals are connected through metallic constants to n-doped regions linked by an n-channel as shown in the figure. However, the gate terminal is remained insulated from the n-channel by a very thin layer of silicon dioxide (SiO_2) layer, an insulator referred to as a dielectric that reveals the fact that there is no direct electrical connection between the gate terminal and the channel of a MOSFET. The symbols are indicated in Figure 2.3(b).

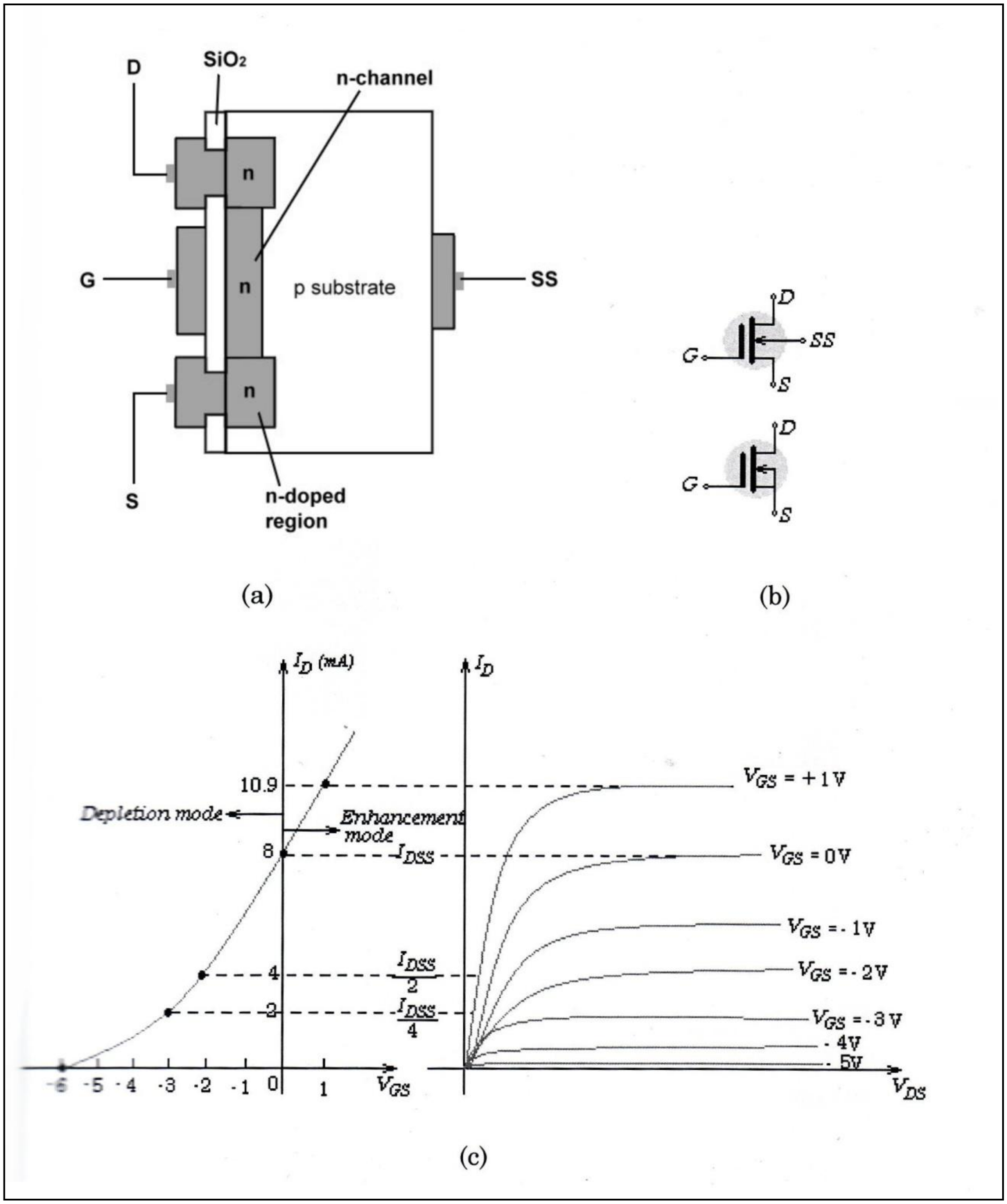

Figure 2.3: n-channel depletion-type MOSFET [1]