DC TO DC CONVERTER USING CMOS

MUHAMMAD ISMINHAZWAN BIN ISMAIL

This report is submitted in partial fulfillment of the requirement for the award of Bachelor of Electronic Engineering (Industrial Electronics) With Honours

Faculty of Electronic and Computer Engineering
University Technical Malaysia, Melaka

MAY 2008

UNIVERSITI TEKNIKAL MALAYSIA MELAKA
FAKULTI KEJURUTERAAN ELEKTRONIK DAN KEJURUTERAAN KOMPUTER

BORANG PENGESAHAN STATUS LAPORAN
PROJEK SARJANA MUDA II

Tajuk Projek : DC to DC Converter Using CMOS

Sesi Pengajian : 2007/2008

Saya Muhammad Isminhazwan Bin Ismail

mengaku membenarkan Laporan Projek Sarjana Muda ini disimpan di Perpustakaan dengan syarat-syarat kegunaan seperti berikut:

1. Laporan adalah hak milik Universiti Teknikal Malaysia Melaka.
2. Perpustakaan dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Perpustakaan dibenarkan membuat salinan laporan ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. Sila tandakan (√) :

☐	**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) (COP DAN TANDATANGAN PENYELIA)

Alamat Tetap: No. 10 Kg Tanah Merah,
Lubok Kawah,
28000 Temerloh,
Pahang Darul Makmur

Tarikh: 16 MAY 2008 Tarikh: 16-5-2008

"I hereby declare that this report is the result of my own work except for quotes as cited in the references."

ZULKARNAIN B ZAINUDIN
Pensyarah
Fakulti Kej Elektronik dan Kej Komputer (FKEKK),
Universiti Teknikal Malaysia Melaka (UTeM),
Karung Berkunci 1200,
Ayer Keroh, 75450 Melaka

Signature : ....

Author : MUHAMMAD ISMINHAZWAN BIN ISMAIL

Date : 11 MAY 2008 ....

"I hereby declare that I have read this report and in my own opinion this report is sufficient in terms of the scope and quality for the award of Bachelor of Electronic Engineering (Industrial Electronics) With Honours."

ZULKARNAIN B ZAINUDIN
Pensyarah
Fakulti Kej Elektronik dan Kej Komputer (FKEKK),
Universiti Teknikal Malaysia Melaka (UTeM),
Karung Berkunci 1200,
Ayer Keroh, 75450 Melaka

Signature : ....

Supervisor's Name : ENCIK ZULKARNAIN BIN ZAINUDIN

Date : 16-5-2008

Special dedicated to my beloved parents, family, lecturers, friends, who had strongly encouraged and supported me in my entire journey of learning.

ACKNOWLEDGEMENT

I have completed my thesis which is a partial fulfilment of requirements for the degree of Bachelor in Electronic Engineering (Industrial Electronic).

On this opportunity, I would like to express my gratitude to the Faculty of Electronic Engineering, Universiti Teknikal Malaysia Melaka generally and especially to my supervisor En Zulkarnain Bin Zainudin for her help, advices and guidance throughout the process of searching, collecting information, analyzing and completing the report.

To my parents, I would like to express million of thanks to them for their support and love to me. Last but not least, I would like to thank to all my friends in 4 BENE and also to everyone who involve in this project either direct or indirectly.

ABSTRACT

In this DC to DC Converter using CMOS, the theory of this method is to build a DC to DC converter that can step-up the input voltage to the desired output voltage. Designing the circuit based on the basic of boost converter circuit that consist of inductor, diode, dc supply, capacitor and a switching component. From these components with their characteristic will act to produce the desired output voltage. This method also has its disadvantage as stated in chapter before. The problem statement is Conventional dc power supplies are designed to operate at a given output voltage into a constant or near-constant load. Pulse lasers, flash lamps, rail guns, and other pulse power systems, however, require short but intense bursts of energy that may be derived from rapidly charging an energy storage capacitor. Some objectives are to understand and design a DC to DC converter using CMOS, to generate the desired output voltage, and to learn well about programming software that will be used. The methodology for this project is firstly preparing Gantt chart, doing literature review and software simulation and demonstration of the project. The result hopefully can fulfill the theory DC to DC converter using CMOS which the main point is to generate the desired DC output voltage from a DC input voltage.

ABSTRAK

DC kepada DC Converter menggunakan CMOS, teori kaedah ini adalah membina satu penukar DC kepada DC yang boleh menaik voltan keluaran yang diingini daripada voltan masukan. Litar ini adalah berdasarkan tentang litar peningkatan penukar asas yang mengandungi induktor, diod, dc supply, kapasitor dan sebuah komponen pensuisan. Daripada komponen-komponen ini dengan ciri mereka, akan bertindak menghasilkan voltan keluaran yang diinginkan. Kaedah ini juga mempunyai kekurangan seperti yang akan dinyatakan dalam bab di hadapan. Kenyataan masalah adalah bekalan tenaga biasa dc adalah direka untuk beroperasi di bagi satu voltan keluaran ke dalam satu pemalar. Beberapa objektif adalah akan memahami dan reka bentuk satu DC untuk penukar DC menggunakan CMOS, untuk menjana voltan keluaran terhasrat, dan mempelajari mengenai perisian pengaturcaraan yang akan digunakan. Kaedah untuk projek ini adalah mula-mula menyediakan carta Gantt, melakukan ulasan karya dan perisian simulasi dan demonstrasi projek ini. Semoga hasil projek ini boleh memenuhi teori penukar DC kepada DC menggunakan CMOS yang mana asasnya adalah untuk menjana voltan keluaran DC daripada satu voltan masukan DC.

CONTENTS

FIGURE LIST

SYMBOL, SHORT FORM & TERM LIST

DC	Direct Current
CMOS	Completmentary Metal-Oxide-Semiconductor
CCPS	Capacitor charging power supply
LED	Light-emitting diode
IGBT	Insulated gate bipolar transistor
MOSFET	Metal oxide field effect transistors
FBSOA	Forward-biased safe operating area
SOA	Safe operating area
BV_{CES}	Collector-Emitter Blocking Voltage
BV_{ECS}	Emitter-Collector Blocking Voltage
V_{GES}	Gate-Emitter Voltage
I_C	Continuous Collector Current
I_{CM}	Peak Collector Repetitive Current I_{CM}
P_D	Maximum Power Dissipation
T_j	Junction Temperature
I_{LM}	Clamped Inductive Load Current
I_{CES}	Collector-Emitter Leakage Current
$V_{GE(th)}$	Gate-Emitter Threshold Voltage
$V_{CE(SAT)}$	Collector-Emitter Saturation Voltage
g_{FE}	Forward Transconductance
Q_G	Total Gate Charge
t_d	Turn-on Delay Time
t_r	Rise Time

$t_{d(off)}$	Turn-off Delay Time
t_f	Fall Time
C_{ies}	Input Capacitance
C_{oes}	Output Capacitance
C_{res}	Reverse Transfer Capacitance

CHAPTER 1

INTRODUCTION

1.1 Introduction to project

This paper concerns the design and implementation of a DC-DC Converter using CMOS. This design is based on a basic boost converter with a little adjustment. It can be used for many applications but is best for charging capacitor banks. The input voltage will be 12V DC, 12V is used for many applications and it is easy to get battery or dc input voltage that supply 12V. The output voltage will be around 280V to 600V. The operation of this DC to DC converter is applied from a basic boost converter. Boost converter is a dc-to-dc converter that steps up the dc voltage from its fixed low level to a desired high level. It is also called the fly-back converter because the energy transfer, from the source to the load, takes place only during the off period of the switch. The high output voltage is suitable for many applications that require high-quality, small, lightweight, reliable, and efficient power supplies.

1.2 Project Objectives

The objectives for this project are:

1. To understand and design a DC-DC converter using CMOS
2. To generate the desired high DC output voltage
3. To learn and understand very well how to use programming software.

For the first objective, for this project I have to understand very well the whole thing about my final my project that is a DC-DC converter using CMOS. After understanding the project very well, I will be able to design this converter.

After finishing designing and completing the prototype of the circuit, I must be able to generate the desired high DC output voltage that vary from 280V to 600V. In order to achieve that, I must understand very well the basic design of boost converter and the operation of the entire component that I have chosen for this DC-DC converter.

I must also learn and understand very well how to use programming software. In this project, I will be using PSPICE, MULTISIM, and PROTEUS. These programming software will be used to generate and simulate the desired circuit that will be used in this project.

1.3 Problem Statement

Modern electronic systems require high-quality, small, lightweight, reliable, and efficient power supplies. Linear power regulators, whose principle of operation is based on a voltage or current divider, are inefficient. This is because they are limited to output voltages smaller than the input voltage, and also their power density is low because they require low frequency (50 or 60 Hz) line transformers and filters. Linear regulators can, however, provide a very high-quality output voltage. Their main area of application is at low power levels. Electronic devices in linear regulators operate in their active (linear) modes, but at higher power levels switching regulators are used. Switching regulators use power electronic semiconductor switches in on and off states. Because there is a small power loss in those states (low voltage across a switch in the on state, zero current through a switch in the off state), switching regulators can achieve high energy conversion efficiencies. Modern power electronic switches can operate at high frequencies. The higher the operating frequency, the smaller and lighter the transformers, filter inductors, and capacitors. In addition, the dynamic characteristics of converters improve with increasing operating frequencies. The bandwidth of a control loop is usually determined by the corner frequency of the output filter. Therefore, high operating frequencies allow for achieving a faster dynamic response to rapid changes in the load current and/or the input voltage. Conventional dc power supplies are designed to operate at a given output voltage into a constant or near-constant load. Pulse lasers, flash lamps, rail guns, and other pulse power systems, however, require short but intense bursts of energy that may be derived from rapidly charging an energy storage capacitor. The rate at which the capacitor discharges is called the repetition rate and may vary from 0.01 Hz for large capacitor banks to a few kilohertz for certain lasers. After the energy storage capacitor is discharged, it must be recharged to a specified voltage using a capacitor charging power supply (CCPS).

1.4 Scope of Work

1) Analyze and research the design of a DC-DC converter using CMOS:
    a. Study and research of design of the DC-DC converter using CMOS.
    b. Study and research of operation of a basic boost converter.
    c. Study and research the components that are going to be used for the design.
    d. Obtaining the result of simulation.

2) Design the circuit of a DC-DC converter using CMOS:
    a. Identify the suitable components for the designed circuit.
    b. Simulate the designed circuit.
    c. Study the result of the simulated circuit.

3) Construct the designed circuit
    a. Construct the designed circuit based on programming software.
    b. Study the appropriate component to be used for constructing the designed circuit.
    c. Test and compare the determined result to expected result.

4) Build the prototype of the circuit
    a. Design the casing for the prototype
    b. Build the circuit on printed circuit board (PCB)

1.5 Methodology

Boost Converter

Boost converter is a dc-to-dc converter that steps up the dc voltage from its fixed low level to a desired high level. It is also called the **fly-back converter** because the energy transfer, from the source to the load, takes place only during the off period of the switch. Its circuit topology is given in Figure 1.

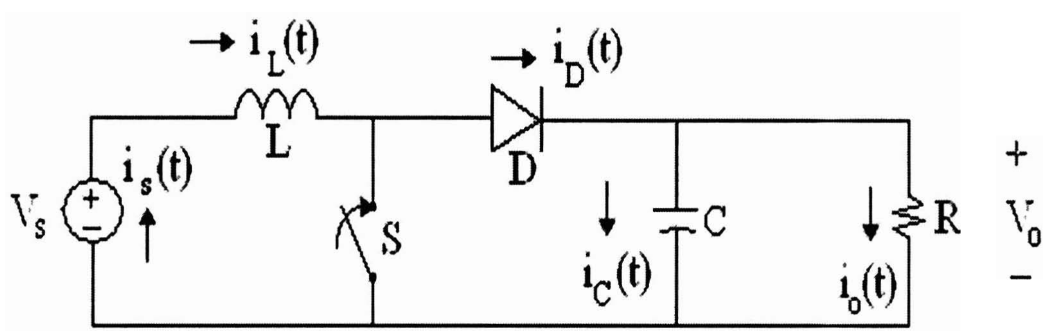

Figure 1.1: Boost Converter

The switch S is usually an electronic device that operates either in the conduction mode (on) or the cut-off mode (off). The on and off time-periods are controlled by the suitably designed gating circuits, which are usually not shown. The on time of the switch is a fraction of its time period T such that T_{ON}=DT, where D is the duty cycle.

During the on time the inductor current increases from its minimum value toward its maximum value. In other words, the stored energy in the inductor increases during the time the switch is in the closed position. During the off time, T_{OFF}= (1-D)T, the switch is open and the inductor current is directed toward the load via diode D. The inductor current therefore charges the capacitor and supplies the load current. The diode D blocks not only the current flow toward the source when the switch is in the closed position but also stops the output voltage from appearing across the closed switch. The inductor also helps control the percent current ripple and determines whether or not the circuit is operating in the continuous conduction mode. The capacitor C provides the filtering action by providing a path for the harmonic currents away from the load. In addition, its value is large enough so that the output voltage ripple is very small.

Using Faraday's law for the boost inductor

$V_S DT = (V_O - V_S)(1-D)T$ (1.1)

From which the dc voltage transfer function turns out to be

$MV \equiv V_O/V_S = 1/1-D$ (1.2)

As the name of the converter suggests, the output voltage is always greater than the input voltage.

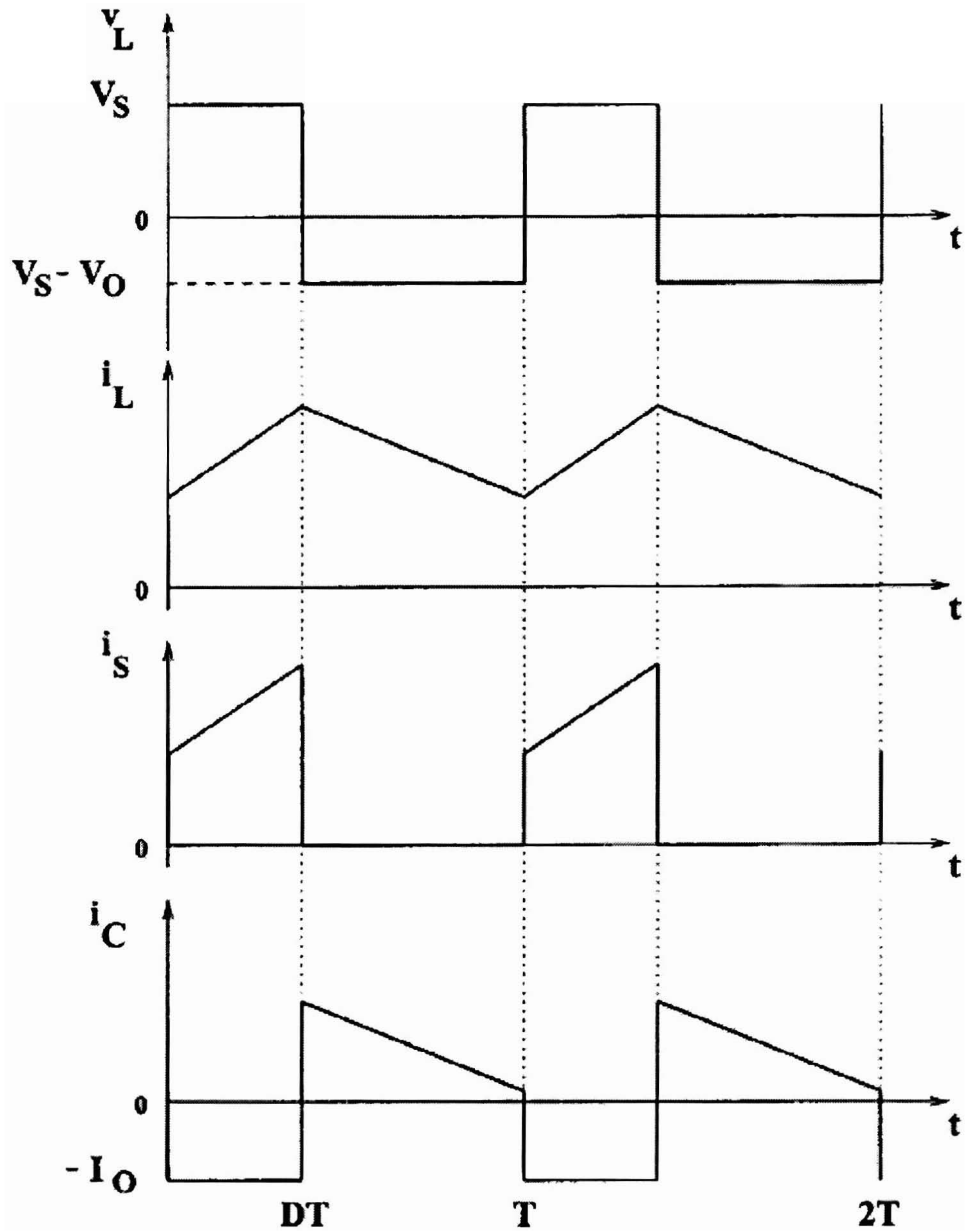

Figure 1.2: Waveforms

As shown in Fig. 2.2, the current supplied to the output RC circuit is discontinuous. Thus, a larger filter capacitor is required in comparison to that in the buck-derived converters to limit the output voltage ripple. The filter capacitor must provide the output dc current to the load when the diode D is off. The minimum value of the filter capacitance that results in the voltage ripple V_r is given by

$$C_{\min} = \frac{DV_O}{V_r Rf} \tag{1.3}$$

CHAPTER 2

LITERATURE REVIEW

2.1 Completmentary Metal-Oxide-Semiconductor (CMOS)

Complementary metal–oxide–semiconductor (**CMOS**) is a major class of integrated circuits. CMOS technology is used in microprocessors, microcontrollers, static RAM, and other digital logic circuits. CMOS technology is also used for a wide variety of analog circuits such as image sensors, data converters, and highly integrated transceivers for many types of communication.

CMOS is also sometimes referred to as **complementary-symmetry metal–oxide–semiconductor**. The words "complementary-symmetry" refer to the fact that the typical digital design style with CMOS uses complementary and symmetrical pairs of p-type and n-type metal oxide semiconductor field effect transistors (MOSFETs) for logic functions.

Two important characteristics of CMOS devices are high noise immunity and low static power consumption. Significant power is only drawn when the transistors in the CMOS device are switching between on and off states. Consequently, CMOS devices do not produce as much waste heat as other forms of logic, for example transistor-transistor logic (TTL). CMOS also allows a high density of logic functions on a chip.

The phrase "metal–oxide–semiconductor" is a reference to the physical structure of certain field-effect transistors, having a metal gate electrode placed on top of an oxide insulator, which in turn is on top of a semiconductor material. Instead of metal, current gate electrodes (including those up to the 65 nanometer technology node) are almost always made from a different material, polysilicon, but the terms MOS and CMOS nevertheless continue to be used for the modern descendants of the original process. Metal gates have made a comeback with the advent of high-k dielectric materials in the CMOS process, as announced by IBM and Intel for the 45 nanometer node and beyond.

CMOS logic uses a combination of p-type and n-type metal–oxide–semiconductor field-effect transistors (MOSFETs) to implement logic gates and other digital circuits found in computers, telecommunications equipment, and signal processing equipment. Although

CMOS logic can be implemented with discrete devices (for instance, in an introductory circuits class), typical commercial CMOS products are integrated circuits composed of millions (or hundreds of millions) of transistors of both types on a rectangular piece of silicon of between 0.1 and 4 square centimeters. These devices are commonly called "chips", although within the industry they are also referred to as "die" (singular) or "dice" (plural).

In CMOS logic, a collection of n-type MOSFETs are arranged in a pull-down network between the output node and the lower-voltage power supply rail, named V_{ss}, which often has ground potential. Instead of the load resistor of NMOS logic gates, CMOS logic gates have a collection of p-type MOSFETs in a pull-up network between the output and the higher-voltage rail, named V_{dd}. Pull-up and pull-down refer to the idea that the output node, which exhibits some internal capacitance, is charged or discharged by the connected pull-up and pull-down networks. By asserting or de-asserting the inputs to the CMOS circuit, individual transistors along the pull-up and pull-down networks become conductive, and a path is connected from the output node to one of the