DESIGN AND BUILD THE DC-DC BUCK CONVERTER FOR INDUSTRIAL AND DOMESTIC APPLICATION

MUHAMMAD BIN ZAKARIA

18 NOVEMBER 2005

"I hereby declared that I have read through this report and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Industrial Power)".

Signature : ....

Supervisor Name : MOHD. ARIFF BIN MAT. HANAFIAH

Date : 22/11/2005

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This Report Is Submitted In Partial Fulfillment Of Requirements For The Degree Of Bachelor In Electrical Engineering (Industry Power)

Fakulti Kejuruteraan Elektrik
Kolej Universiti Teknikal Kebangsaan Malaysia

November 2005

"I admit this report is produced by me except the summary and extraction for each I have been clearly presented."

Signature : ....

Name : Muhammad Bin Zakaria

Date : 18 November 2005

Dedicated to my beloved family…..

ACKNOWLEDGEMENT

First of all I would like to express my gratitude to my supervisor, Mr Mohd Ariff Bin Mat Hanafiah for him guidance and advised throughout the development of this project.

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ABSTRACT

A buck converter or step-down switch mode power supply can also be called a switch mode regulator. Popularity of a switch mode regulator is due to its fairly high efficiency and compact size and a switch mode regulator is used in place of a linear voltage regulator at relatively high output. The project is regarding the switch mode power supply (SMPS) with 24 volt input voltage and 9 volt output voltage. The main specifications of buck converter design among others are to look for the values inductor and capacitor relative to the switching frequency and duty cycle. MOSFET device have been used in buck converter circuit because of its higher switching speed. Multisim simulation software is used in the analysis and design process. Once obtaining the results then the hardware or the real Buck Converter circuit with known specifications are built.

ABSTRAK

Buck converter atau pensuisan bekalan kuasa langlah turun juga dikenali sebagai pengatur suis mode. Ia amat digemari dan banyak digunakan kerana mempunyai kecekapan tinggi dan bersaiz padat. Mode pensuisan pengatur digunakan di kawasan yang mempunyai keluaran yang tinggi pada penetap voltan sekata. Projek ini merupakan bekalan kuasa pensuisan mode dengan voltan masukan 24 volt dan menghasilkan keluaran 9 volt. Setelah menetapkan spesifikasi yang diperlukan dalam mereka buck converter iaitu inductor, kapasitor, frekuensi pensuisan dan kitar kerja. Peranti MOSFET digunakan dalam litar buck converter disebabkan ia pensuisan kelajuan tinggi. Perisian simulasi Mutlisim digunakan untuk menganalisa dan proses merekabentuk. Setelah keputusan diperolehi maka perkakas atau litar sebenar buck converter dengan spesifikasi yang diketahui akan dibina.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Projek Sarjana Muda (PSM) is one of knowledge research that related to student's discipline. This task should be completed by the student before they can finish their bachelor study in the university. The project has been divided into three categories, design project, software development and case study.

1. Design project should be base on certain design and finally could end with product or design.
2. Software development project should concentrate on the computer software that relates to student's discipline their selves.
3. The case study project is more on study research on certain case or topic. By the end of this project, student should come with solution of the problem.

I have been chosen the design project and my project title is "Design and Build the DC-DC Buck Converter for Industrial and Domestic Application". So, by the end of this project, I should design the buck converter to be build used for the industrial and domestic application.

1.2 Objective

The objectives of my project to build dc-dc buck converters are:

1. To understand the performance parameters of dc-dc buck converters.
2. To be able to build the circuit of dc-dc buck converter for a real application.
3. To understand and be able to build the switching controller for the converter
4. To learn to manage the cost, schedule and resources when handling a project.

CHAPTER 2

PROJECT BACKGROUND

2.1 Introduction

In many industrial applications, it is required to converter a fixed-voltage dc source into a variable-voltage dc source. A dc-dc converter converts directly from dc to dc and is simply known as a dc converter. A dc converter can be as equivalent to an ac transformer with a continuously variable turns ratio. Like a transformer, it can be used to step down or step up a dc voltage source.

Dc converters are widely used for traction motor control in electric automobiles, trolley cars, marine hoist, forklift trucks and mine haulers. They provide smooth acceleration control, high efficiency and fast dynamic response. Dc converters can be used in regenerative braking of dc motor to return energy back into the supply and this feature result in energy savings for transportation system with frequents tops. Dc converters are used in dc voltage regulators and also used in junction with an inductor, to generate a dc current source.

2.2 Switching Mode Regulators

Dc converters can be used as switching-mode regulators to convert a dc voltage, normally unregulated, to a regulated dc output voltage. The regulation is normally achieved by PWM at fixed frequency and the switching device is normally BJT, MOSFET or IGBT. The output of dc converters with resistive load is discontinuous and contains harmonics. The ripple content is normally reduced by an LC filter.

Switching regulators are commercially available as integrated circuits. The switching frequency by choosing the values of R and C of the frequency oscillator. As a rule thumb, to maximize efficiency, the minimum oscillator period should be about 100 times longer than the transistor switching time of 0.5 μs, the oscillator period would be 50 μs, which gives the maximum oscillator frequency of 20 kHz. This limitation is due to a switching loss in the transistor. The transistor switching loss increasing with the switching frequency and as a result the efficiency decreases. Control voltage v_{cr} is obtained by comparing the output voltage with its desired value. There are four topologies of switching regulators/converters:

1. Buck converters
2. Boost converters
3. Buck-boost converters
4. Cúk converters.

2.3 Buck Converter

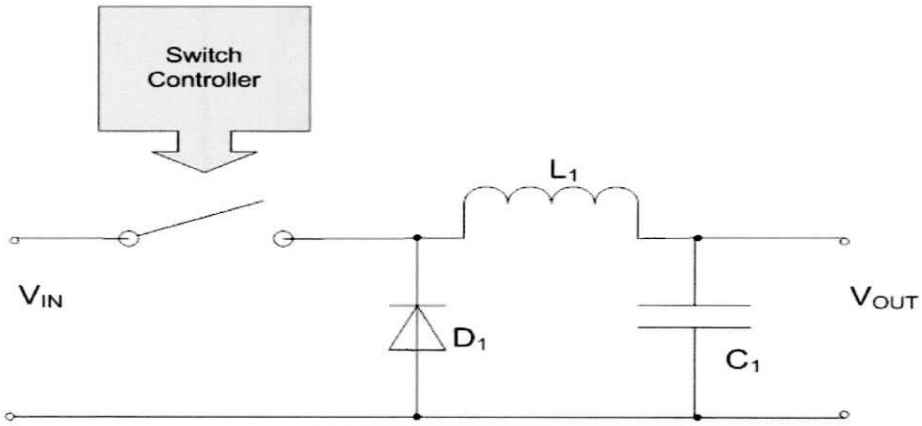

Figure 2.1: Buck Converter

In a buck converter, the average output voltage V_a, is less than the input voltage, V_s hence the name "buck," a very popular converter. In this circuit the transistor turning ON will put voltage Vin on one end of the inductor. This voltage will tend to cause the inductor current to rise. When the transistor is OFF, the current will continue flowing through the inductor but now flowing through the diode. We initially assume that the current through the inductor does not reach zero, thus the voltage at Vx will now be only the voltage across the conducting diode during the full OFF time. The average voltage at Vx will depend on the average ON time of the transistor provided the inductor current is continuous.

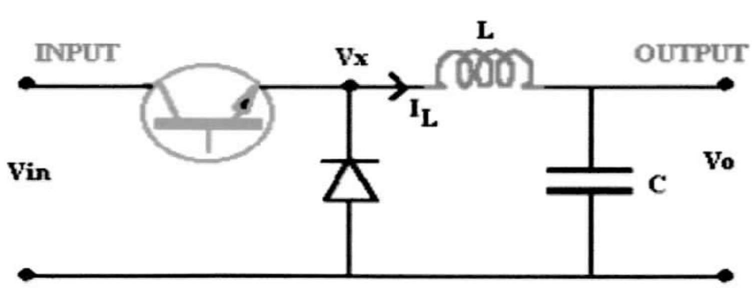

Figure 2.2: Buck Converter

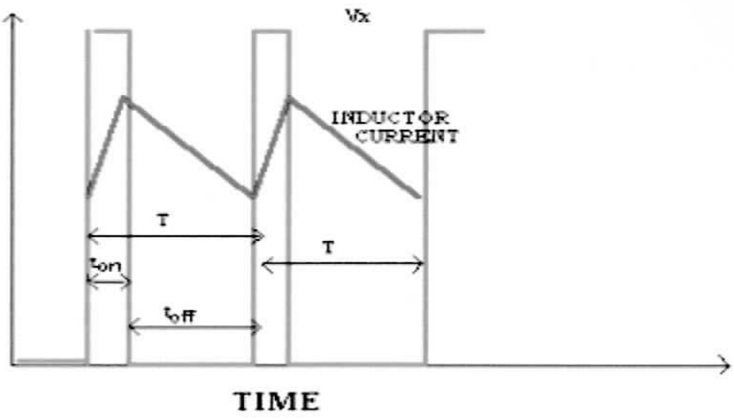

Figure 2.3: Voltage and current changes

To analyse the voltages of this circuit let us consider the changes in the inductor current over one cycle. From the relation

$$V_x - V_o = L\frac{di}{dt} \qquad (2.1)$$

the change of current satisfies

$$di = \int_{ON}(V_x - V_o)dt + \int_{OFF}(V_x - V_o)dt \qquad (2.2)$$

For steady state operation the current at the start and end of a period T will not change. To get a simple relation between voltages we assume no voltage drop across transistor or diode while ON and a perfect switch change. Thus during the ON time V_x=V_{in} and in the OFF V_x=0. Thus

$$0 = di = \int_0^{t_{on}}(Vin - Vo)dt + \int_{t_{on}}^{t_{on}+t_{off}}(-Vo)dt \qquad (2.3)$$

which simplifies to

$$(Vin - Vo)t_{on} - Vo\, t_{off} = 0 \qquad (2.4)$$

or

$$\frac{Vo}{Vin} = \frac{t_{on}}{T} \quad (2.5)$$

and defining "duty ratio" as

$$D = \frac{t_{on}}{T} \quad (2.6)$$

The voltage relationship becomes Vo=D Vin Since the circuit is lossless and the input and output powers must match on the average $V_o * I_o = V_{in} * I_{in}$. Thus the average input and output current must satisfy $I_{in} = D\ I_o$ These relations are based on the assumption that the inductor current does not reach zero.

2.3.1 Transition between continuous and discontinuous

When the current in the inductor L remains always positive then either the transistor T1 or the diode D1 must be conducting. For continuous conduction the voltage V_x is either V_{in} or 0. If the inductor current ever goes to zero then the output voltage will not be forced to either of these conditions. At this transition point the current just reaches zero as seen in Figure 3. During the ON time V_{in}-V_{out} is across the inductor thus

$$I_L(peak) = (Vin - Vout) \cdot \frac{t_{ON}}{L} \quad (2.7)$$

The average current which must match the output current satisfies

$$I_L(\text{average at transition}) = \frac{I_L(\text{peak})}{2} = (Vin - Vout)\frac{dT}{2L} = Iout(\text{transition}) \quad (2.8)$$

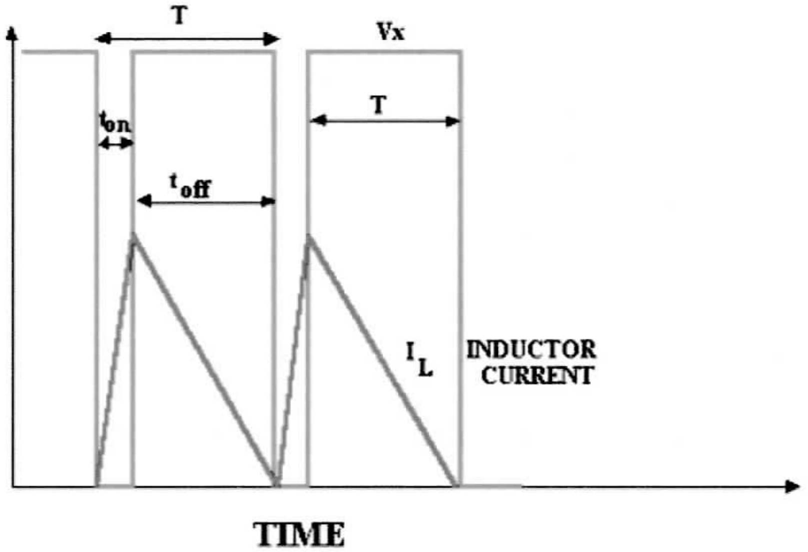

Figure 2.4: Buck Converter at Boundary

If the input voltage is constant the output current at the transition point satisfies

$$Iout(\text{transition}) = Vin\frac{(1-d)d}{2L}T \quad (2.9)$$

2.3.2 Voltage Ratio of Buck Converter (Discontinuous Mode)

As for the continuous conduction analysis we use the fact that the integral of voltage across the inductor is zero over a cycle of switching T. The transistor OFF time is now divided into segments of diode conduction d_dT and zero conduction d_oT. The inductor average voltage thus gives

$$(V_{in} - V_o)\, DT + (-V_o)\, d_d T = 0 \tag{2.10}$$

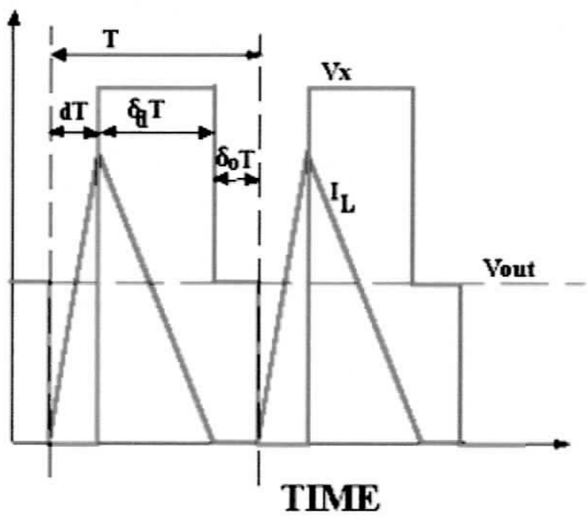

Figure 2.5 : Buck Converter - Discontinuous Conduction

$$\therefore \frac{Vout}{Vin} = \frac{d}{d + \delta_d} \tag{2.11}$$

for the case $d + \delta_d < 1$. To resolve the value of δ_d consider the output current which is half the peak when averaged over the conduction times $d + \delta_d$

$$Iout = \frac{I_L(peak)}{2} d + \delta_d \tag{2.12}$$

Considering the change of current during the diode conduction time

$$I_L(peak) = \frac{V_0(\delta_d T)}{L} \tag{2.13}$$

Thus from (6) and (7) we can get

$$I_{out} = \frac{V_0 \delta_d T \cdot (d + \delta_d)}{2L} \tag{2.14}$$