POWER SUPPLY CONTROL

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MAY 2006

"I hereby declare that I have read through this report and found that is sufficient in terms of scope and quality to be awarded of the Degree of Bachelor in Electrical Engineering (Industrial Power)"

Signature: ....

Name of Supervisor: Mr. Auzani Bin Jidin

Date: MEI 2006.

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Fakulti Kejuruteraan Elektrik
Kolej Universiti Teknikal Kebangsaan Malaysia

May 2006

"I declare that this report is the result of my own research expect as cited in the references"

Signature : ....

Name : Khairul Hisyam Bin Muhamad

Date : 4.5.2006

“This dedicated to my beloved father and mother”

Acknowledgement

Assalamulalaikum w.b.t. after a few month dedicated and hard work, I have finally be able to conclude the projects of power supply control under supervisory Mr. Auzani Bin Jidin. PSM is a very good practice to the undergraduate to make sure that it will be the better preparation before getting involved in the work environment.

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Thank you.

Abstract

The purpose of this project is to study a power supply control which focus on dc-dc buck converter. To design the dc-dc buck converter, it is important to get transfer function of the overall system which consists of compensated error amplifier, PWM and buck converter. Then the overall system transfer function has been analyzed through small signal analysis to obtain the proper value s of controller which is the elements of compensated error amplifier. In this report's project, it will be presented that the closed loop system of dc-dc buck converter results good performance response which are fast transient, insensitive to the input and load disturbance. The dc-dc buck converter has been design using type 2 compensated error amplifier. In this report, the detail about the design process will be discussed. It will be shown that the system of the power supply control is designed using Simulink-Matlab and OrCAD P-Spice. Due to the hardware limitation to implement the buck converter system, the scope of the project is limited to test the system design using OrCAD which can be represented as practical experimental set-up. Finally the dc-dc buck converter has been simulated using Simulink and PrCAD and the simulation result using both simulation packages result in close agreement to each other.

Abstrak

Projek ini bertujuan untuk mempelajari kawalan bekalan kuasa yang memfokuskan pada litar penurun voltan arus terus. Untuk mereka litar penurun voltan ini, adalah penting untuk mendapatkan keseluruhan formula atau persamaan untuk sistem ini iaitu litar penguat terpampas, PWM dan litar penunrun voltan. Kemudian keseluruhan persamaan yang telah didapati akan di analisis melalui analisa isyarat kecil untuk mendapatkan nilai yang bagus kepada pengawal yang mana pengawalan itu terdiri daripada litar penguat terpampas. Laporan projek ini mengandungi keputusan sistem penurun voltan arus terus yang menggunakan sistem gelung tertutup yang mana sistem ini mempunyai tindakbalas prestasi yang baik iaitu transien yang pantas, sensitif kepada perubahan masukan dan beban. Litar punurun voltan ini direka dengan menggunakan litar penguat terpampas jenis dua. Di dalam laporan ini juga menyatakan secara terperinci tentang keseluruhan perjalanan proses mereka. Proses mereka ini sistem kawalan bekalan kuasa ini adalah dengan menggunakan Simulik-Matlab dan OrCAD P-Spice. Oleh kerana masalah rekaan untuk litar penurun voltan yang sebenar, skop untuk projek ini adalah terhad dalam kepada pengujian dalam OrCAD dimana dalam simulasi ini, ia telah menjurus kepada pengujian praktikal yang sebenar. Akhir sekali litar penurun voltan arus terus ini telah diuji dengan menggunakan Simulink dan OrCAD serta keputusan diantara kedua – dua pengujian ini menunjukkan ada persaman di antaranya.

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INTRODUCTION

1. Switching Converter

Switching converter are widely used as the major building block in high efficiency and light power supplies such as in computer applications. A major weaknesses of switching converters, is its transient output response to a fast load change. Because most switching power converters include an output inductor, a switching power converter's transient response is limited. For example, a typical buck converter have a switches, filter and load, and a feedback circuit. The feedback circuit monitor the converter output voltage and use pulse width modulation control over the switches. When there is a fast dynamic load change, the converter's ability to respond is limited by the feedback circuit and the power stage. The feedback circuits can be designed to respond quicker through traditional linear or non-linear approaches. The response of the converter however, is limited by the power stage and, in particular, the output inductor. Some people have tried to improve the power converter's dynamic response by using an inductor with a small inductance value. This technique improve the power converter's dynamic response because current flow can change much more quickly when a small indicator is used. This technique, however, is disadvantaged in that the use of a small inductor results in a ripple current during normal operation. High ripple current introduces high root mean square current in the converter switches and passive components and, as a result, increases the power loss. Others have tried to reduce power losses by using parallel switches to share the current, but this increases the cost and complexity of the converters. Still others have tried to improve the converter's transient response by increasing the converter's switching frequency. This technique is disadvantaged in that it induces excessive switching losses in the switches and excessive magnetic losses in the inductor core. Moreover, high frequency operation requires the use of high performance drive circuit which can further escalate the converter's cost. Therefore, there remains a need for a method of providing a switching power converter with a fast transient response while minimizing the converter's power loss.

1.1 Project background

In switching dc-dc converters, the output voltage is a function of the input voltage and duty ratio. In real circuit with non-ideal component, the output is also a function of the load current. A power supply output is regulated by modulating the duty ratio to compensated for variations in the input or load. A feedback control system for power supply control compares output voltage to a reference and converts the error to a duty ratio. The buck converter produces a lower average output voltage than the dc input voltage and operating in the continuous – current mode is used to illustrate the basics of power supply control. Figure 1.1 shows the converter and feedback loop consisting of:

- The switch, including the diode and drive circuit
- The output filter
- A compensated error amplifier
- A pulse – width modulating circuit, which convert the output of the compensated error amplifier to a duty ratio to drive the switch.

The regulated converter is represented by the closed – loop system of figure 1.2.

Other application to stabilize a buck converter is using Fuzzy logic. Fuzzy control is the one of the most active control areas because it can control highly nonlinear, time variant and ill-defined system. Proportional integral (PI) is another procedure to get a better result because it can obtain zero steady state error, good dynamic response (fast transient response with minimum overshoot) and make the system less sensitive to disturbance.

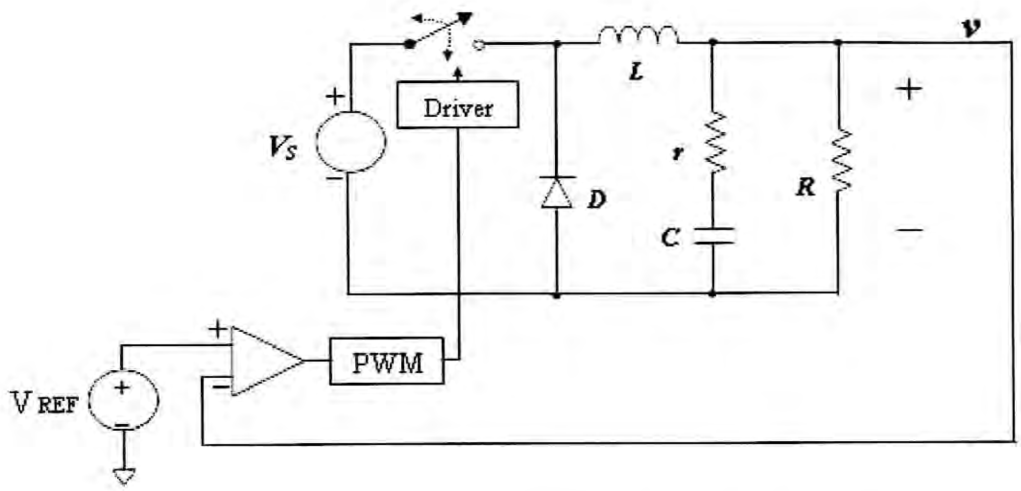

Figure 1.1: buck converter with feedback

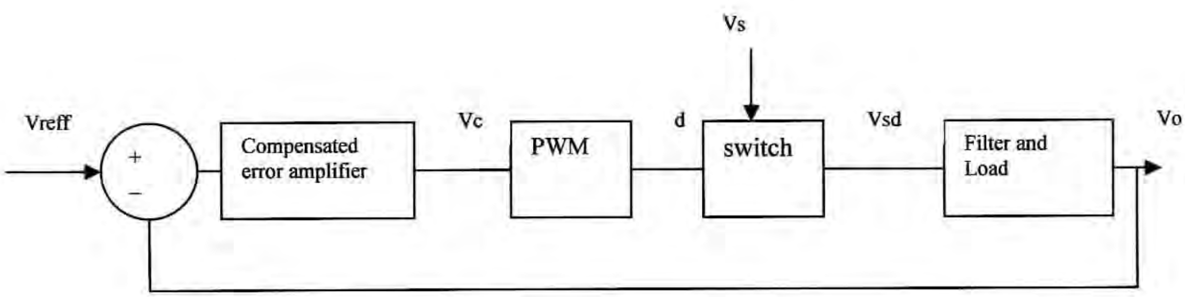

Figure 1.2: control representation

1.2 Project objective

The objective of this project are as follows:

I. to design a power supply control using a buck converter(include design a filter, design error amplifier, and design a compensated error amplifier) that represented by the closed loop system.

II. to increase the performance and stability of the control loop for regulating the output voltage for a converter by using feedback loop.

III. to convert the output from the compensated error amplifier into duty ratio to drive the switch using power width modulation.

IV. to study the operation of dc – dc converter.

V. to learn the technique for the analysis and design of dc converter.

1.3 Scope of project

The first thing to do this project is the analysis and research. The information for this project is collected from the internet, books and many more. Knowledge about Matlab Simulink and OrCAD P-Spise is important too. This is because, to design the compensated error amplifier, the result is getting from the Simulink and then attached it to the OrCAD P-Spise. Here is the step to design the part of this project:

I. Find the transfer function of the compensated error amplifier

II. Determine the values of capacitors and resistors through the small signal analysis using Simulink Matlab. To evaluate the controller, the system has been tested under large signal analysis.

III. Based on designed system of the Simulink Matlab, the converter is reconstructed using OrCAD P-Spise

1.4 Project organization

The rest of the project chapter are organized are as follows.

Chapter 2: overview about the circuit of buck converter. This chapter also explain the analysis open loop of buck converter and the type of compensation that have been chosen.

Chapter 3: describe about the analysis of the closed loop buck converter with compensated error amplifier. This chapter also explain the theory about this project, the transfer function and the design of the compensated error amplifier.

Chapter 4: explain and describe about the simulation result. Analysis, effect of the load and the performance.

Chapter 5: give the conclusion and suggestions for this project

CHAPTER 2

OVERVIEW CIRCUIT OF BUCK CONVERTER

2.1 Introduction

The purpose of this chapter is to explain about the analysis of the open loop buck converter and the type of compensation network that have been chosen in this project.

2.2 Analysis for open loop of buck converter

The Buck Converter is used in DC-to-DC step-down voltage control applications where the input voltage is greater than the output voltage. The basic Buck Converter circuit is shown in figure 2.1.

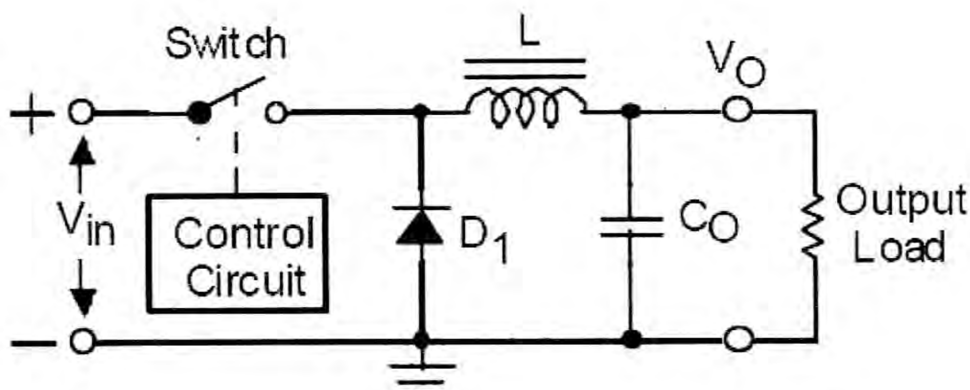

Figure 2.1: buck converter circuit

2.2.1 Analysis when the switch is closed

When the switch is closed in figure 2.2, the diode is reversed bias, current flows through the switch, inductor, and to the output load. As the inductor (L) current flow increases, the energy in the inductors magnetic field increase too. In addition, the capacitor charges with the indicated polarity

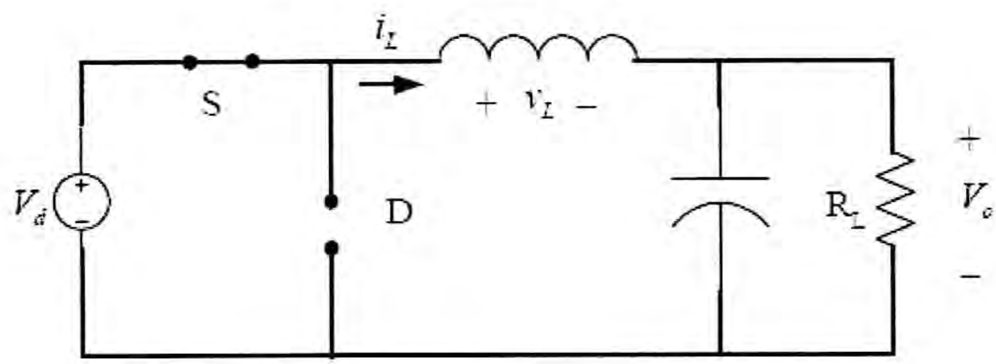

Figure 2.2: switch closed buck converter

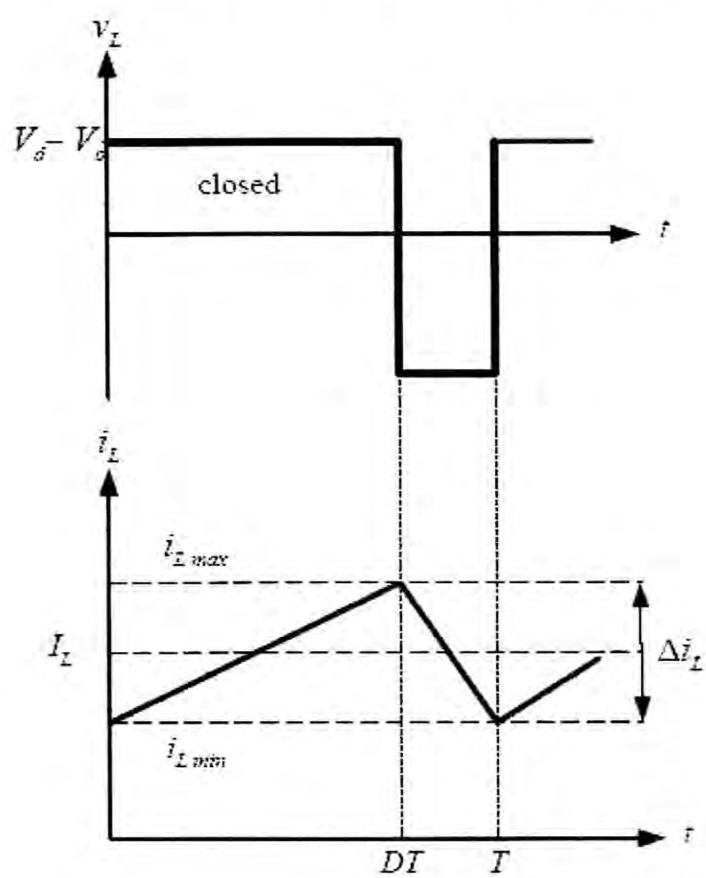

Figure 2.3: switch closed characteristic

Inductor voltage:

$$v_L = V_d - V_o \tag{2-1}$$

$$v_L = L\frac{di_L}{dt} \tag{2-2}$$

$$\frac{di_L}{dt} = \frac{V_d - V_o}{L} \tag{2-3}$$

Since the derivative of inductor current is a positive constant, therefore the current increase linearly

From figure 2.3;

$$\frac{di_L}{dt} = \frac{\Delta i_L}{\Delta t} = \frac{\Delta i_L}{DT} = \frac{V_d - V_o}{L} \tag{2-4}$$

$$(\Delta i_L)closed = \left(\frac{V_d - V_o}{L}\right) \bullet DT \tag{2-5}$$

2.2.2 Analysis when switch is open

When the switch is opened in figure 2.4, the inductors magnet field collapse and its return the energy back to the inductor. The collapsing magnetic field changed the polarity across the inductor. When the inductor polarity reversed, the diode (D1) becomes forward biased and this make the inductor continued supplying the energy to the load. The capacitor working in conjunction with the inductor provides output voltage filtering by smoothing out or averaging the applied pulses of input voltage

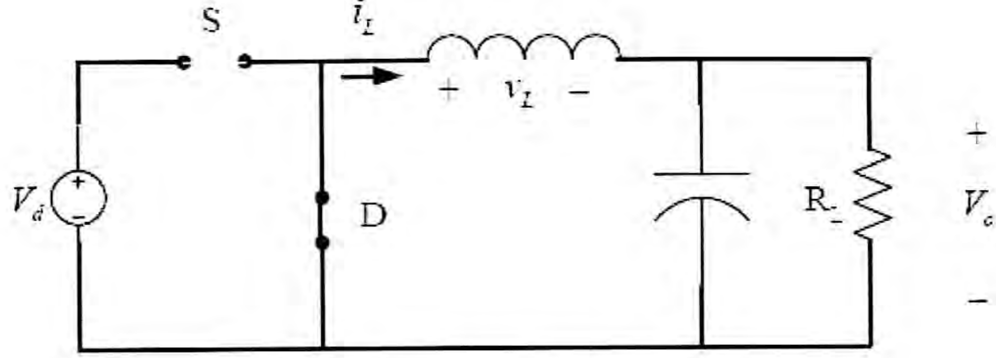

Figure 2.4: switch open buck converter

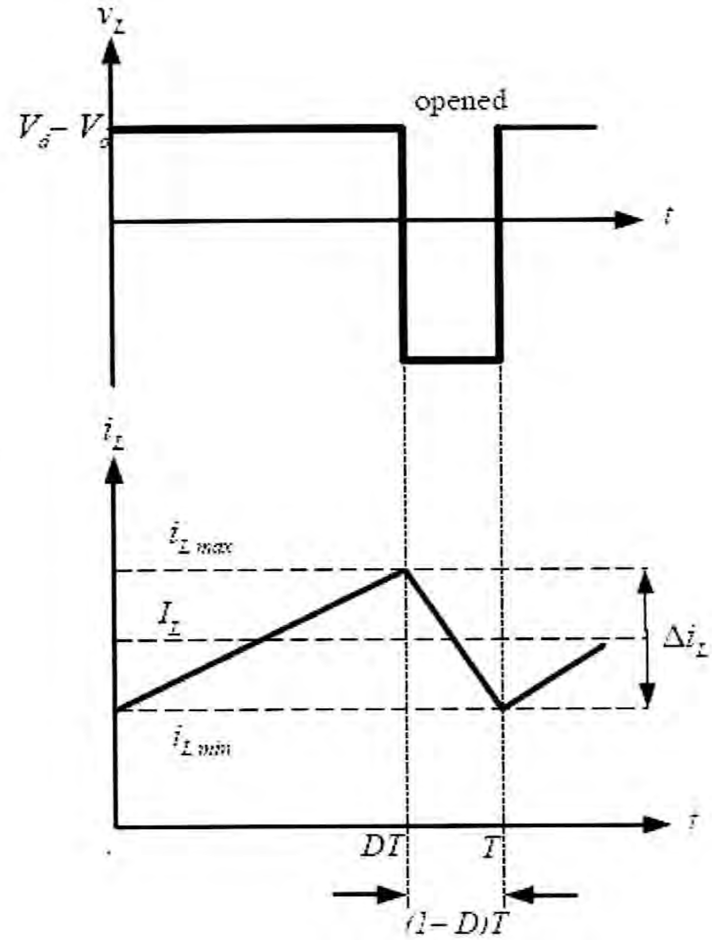

Figure 2.5: switch open characteristic