“DC-DC POWER SUPPLY”

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MARCH 2005

"I/We acknowledge that I already gone through this report and I/We are in the opinion that this report covers the scope and quality for the purpose of graduation in Bachelor of Engineering in Electric (Power Industry)."

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DESIGN OF DC-DC POWER SUPPLY

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I hereby verify that this paper work is done on my own except for the references I made which I have stated the sources clearly on the specified section.

Sign : ____________________

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Date : 9 MARCH 2005

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ABSTRACT

The purpose of this project is to design a "DC-Dc Power Supply" which has an input of 24Vdc and the output of 9Vdc. Simulation analysis using Proteus 6 Lite is required to determine the component values and waveforms associated for this converter. For switching purpose, a control circuit is needed to produce the output of 9V. The implementation of pic controller is used for the switching process through the control circuit.

The complete construction of converter is done after the control circuit works properly.

In this report, a detailed description of this power supply design has been explained. The results that are obtained from the simulation are included.

ABSTRAK

Tujuan projek ini adalah untuk menghasilkan sebuah "Dc-Dc Power Supply" yang akan menghasilkan 9vdc daripada voltan masukan 24vdc. Bagi tujuan simulasi, Proteus 6 Lite telah diaplikasikan untuk menentukkan nilai-nilai komponen dan juga untuk menghasilkan gelombang keluaran untuk "Power Supply" ini. Untuk tujuan pensuisan, sebuah litar pengawalan harus digunakan untuk memberikan voltan keluaran yang dijangkakan iaitu 9vdc. "PIC Controller" harus digunakan untuk mengimplementasikan proses pensuisan melalui litar kawalan.

Satu binaan "converter" boleh dipertikaikan setelah litar kawalan berfungsi dengan berkesan. Dalam laporan ini, satu diskripsi penuh tentang binaan "power supply" telah diterangkan. Keputusan simulasi juga telah disertakan di dalam laporan ini.

CONTENTS

LIST OF FIGURES

LIST OF APPENDIX

CHAPTER 1

INTRODUCTION

1.1 Introduction to the Project

The dc-dc converters are widely used in regulated switch mode dc power supplies. Switch-mode dc to dc converters are used to convert the unregulated dc input into a dc output at a desired voltage level.

In many applications, a DC/DC Converter is used to produce a regulated voltage or current, derived from an unregulated power supply, or from a battery. Examples of these applications include battery chargers, electronic air purifiers, emergency exit signs, and distributed power systems. In some of those applications, a dedicated Switched Mode Power Supply (SMPS) Controller IC is used in conjunction with a microcontroller.

In other applications, however, a dedicated SMPS Controller IC may be overkill. An alternative approach is to generate a low cost SMPS function in a smart microcontroller. [1]

1.2 Dc-Dc Converters

There are several popular DC/DC Converters such as the step down (buck) converters, boost (or step up) Converter, step-down/step up (buck-boost converter, cuk converter and also the full bridge converter.

In any type of DC/DC Converter circuit, the power device selections are very important. The key parameters to look for the transistor are the switching time and current rating. These two parameters greatly affect the maximum switching frequency of the converter, and also how much current the converter can be designed for.

A DC/DC Converter is normally chosen because of its high efficiency in converting the input power to output power. Unlike a linear regulator, the efficiency measure of a DC/DC Converter generally increases as its load increases. A properly designed DC/DC Converter can yield an efficiency measure of greater than 90% at full load. The efficiency of a DC/DC Converter is expressed as the ratio of output power and input power. [2]

1.3 Control of Dc-Dc Converters

In dc-dc converters, the average dc output voltage must be controlled to equal a desired level, though the input voltage and the output load may fluctuate. Switch-mode dc-dc converters utilize one or more switches to transform dc from one level to another. In a dc-dc converter with a given input voltage, the average output voltage is controlled by controlling the switch on and off durations (t_{on} and t_{off}).

One of the methods for controlling the output voltage employs switching at a constant frequency (hence, a constant switching time period $Ts = t_{on} + t_{off}$) and adjusting the on duration of the switch to control the average output voltage. In this method, called pulse-width modulation (PWM) switching, the switch ratio D, which defined as the ratio of the on duration to the switching time period, is varied. [3]

1.4 Objective

The objective of the project

- To design the power supply model using PIC Controller
- To model the converter system by using software simulation
- To design the drive circuit
- To drive any small dc system

CHAPTER 2

LITERATURE REVIEW

Literature review is the documentation of a comprehensive review of the published and unpublished work from secondary sources of the data in the areas specific interest to the researcher. The purpose of the literature review is to ensure that no important variables are ignored that has in the past been found to have an impact on the problem.

2.1 Smart Dc-Dc Switching Mode Power Converter

In 1997, Lau Kwok Kit and Sung Wai Tee Electrical and Electronic student from the Hong Kong University of Science and Technology has design the "Smart Dc-Dc Switching Mode Power Converter" under their supervisor Dr. Philip Mok. In this project, a controller which can perform both PWM (PULSE-WIDTH MODULATION) and PFM (PULSE FREQUENCY MODULATION) was designed the condition for mode switching depends on the load current level. When the load current is high, PWM will be performed and vice versa and this mode switching mechanism is automatic. The main advantage of using PWM as control method is that the frequency of the pulse train is fixed.

PWM is the standard scheme used in dc-dc converters where the frequency is kept constant and the width of the pulse is modulated to control the duty ratio of the synchronous switches. PFM is defined as the output voltage is sensed and compared with Vref + and Vref- (upper reference voltage and lower reference voltage). If it is below Vref-, then a burst of fixed width pulses are supplied to the synchronous switches and Vout starts rising. As soon as Vout crosses Vref + synchronous switches are switched off. Vout starts decreasing because of the current drainage from the load and eventually comes below Vref – which against starts the burst of pulses. The cycles keep on going.

In this design, the mode of operation will automatically switch when the load current of power converter reaches a certain limit, in the case of 200mA. The students also implemented the controller for the smart Dc-Dc switching mode power converter. The result controlled by the switch between PWM and PFM automatically as the load current changes. In this design, the power transistor is on the chip and allows us to design a simple current detection method.

But in simulation, they found out that the on chip power transistor have much larger on-resistance as compare to the components. This makes extra power loss and reduces the efficiency of the power converter. The circuit diagram is as below.

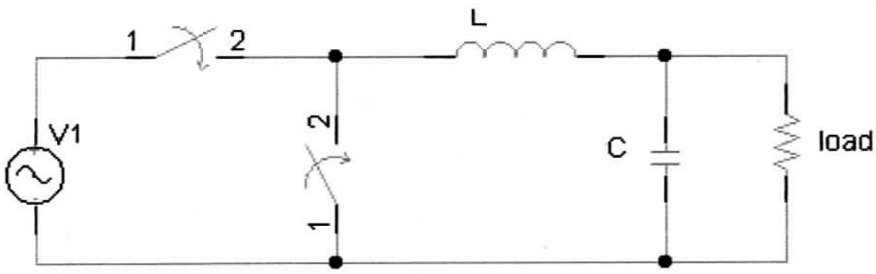

Figure 1: The Circuit Diagram

They also mention about the advantage and also the disadvantage of this project. The advantage is this converter suitable for high frequency operation and the accuracy is good. The disadvantage is the circuit diagram design is complex. The circuit design as below;

The both diagram shows two typical full bridge topologies those achieve ZVS. Diagram 2 shows ZVS is achieved by placing an inductor in series with the power transformer, while the diagram 3 shows it is achieved by placing an inductor in parallel with the power transformer. In both topologies, a snubber capacitor is placed across each switch.

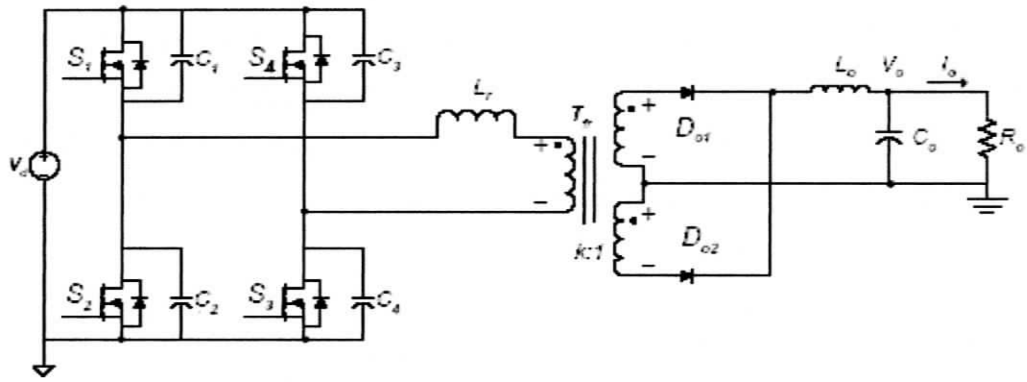

Figure 3: ZVS Topology with Series Inductor

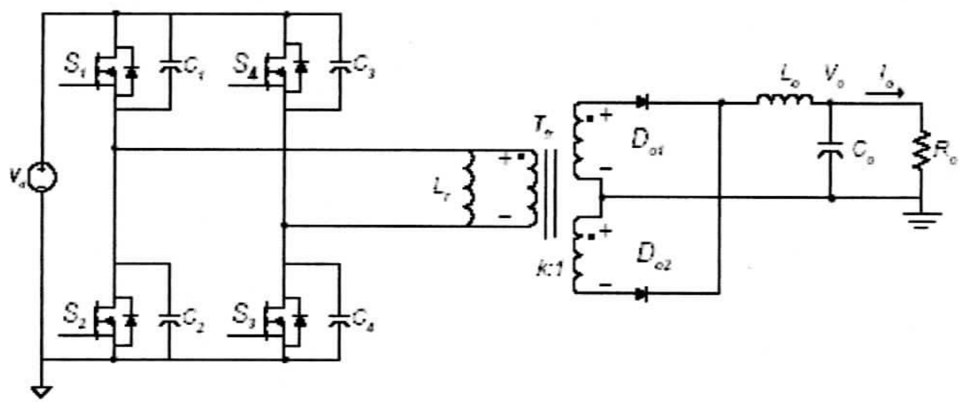

Figure 4: ZVS Topology with Parallel Inductor

2.3 PWM-PFM Controller

In different project, Ershad Ahmed and Syed Asif Eqmal did their 2003 Final project in Colorado. The project is "PWM-PFM Controller" for Dc-Dc Converters. The objective of the project is to design of a PWM-PFM Controller of the dc-dc converter intended for use in the portable battery operated mobile devices.

The target of this project is for portable battery operated mobile devices. In such devices the battery voltage in converted to the desired level using a buck converter and then fed to the base-band processor or other loads. The buck converter working in PWM mode shows high efficiency at higher values of the load current. As the load current falls to low values, the efficiency of the buck converter goes down to very low values. A battery operated mobile device spends most of its time in sleep mode and hence such a converter-based device will show very poor overall efficiency.

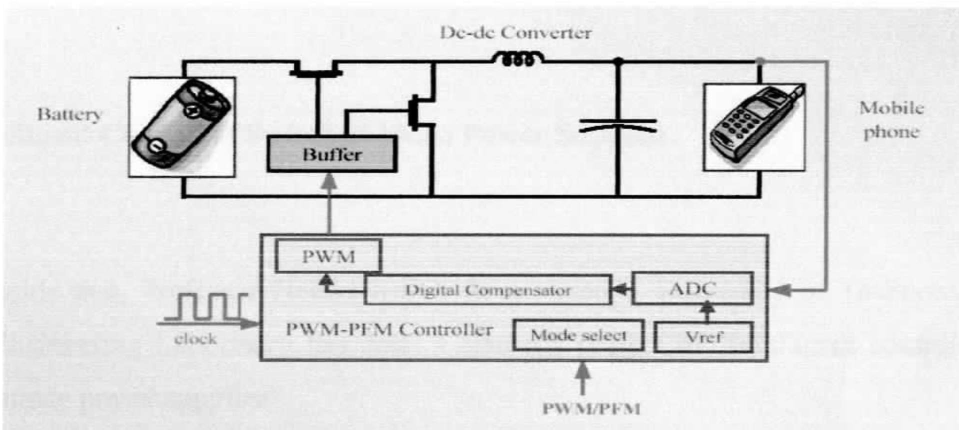

Figure 5: The Converter Circuit Design

A PFM mode buck converter shows high efficiency at low values of load but has other problems associated with it such as high output ripple and relatively low efficiency at high values of load current. So, to maximize the efficiency of a buck converter it is necessary to have a PWM / PFM controller which can operate in either mode as demanded by the load value.

The advantage of this project is, it's a power saving method. The overall design is much faster and cheaper as compared to a pure analog design.

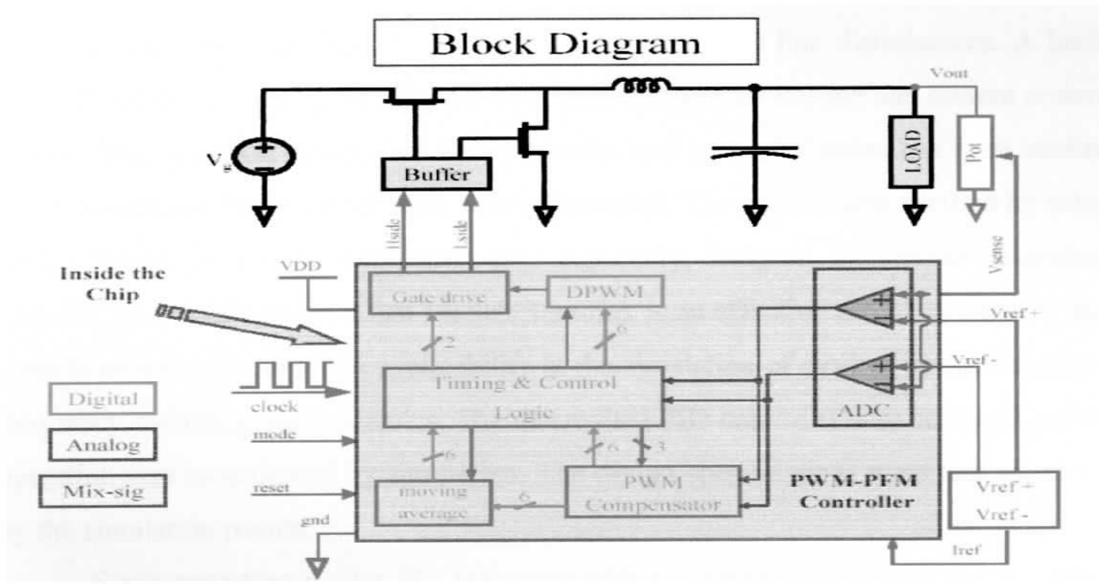

Figure 6: The Block Diagram

2.4 Intelligent Control of Switched-Mode Power Supplies

Beside that, Professor Heikki Koivo from Helsinki University of Technology, Control Engineering Laboratory has done a research project of "Intelligent control of switched-mode power supplies".

The project belonged in an essential way to the field of control theory, in which new control methods are developed and applied in different applications.

The topic of the project provided a good example of how to replace analog solutions with microprocessor algorithms, which contain intelligent control strategies. The research extended new control ideas into the field of electronics and narrowed the gap between theory and practice. It also demonstrated a fast way of developing the prototype of a new product by using efficient simulation tools such as Matlab/Simulink. All this improved the cooperation between control engineers and electrical engineers.

A 500 W switching power supply was chosen as a target to study the control of the output voltage. The desired control accuracy was ±0.3 V in normal operation, ±2V for maximum load disturbances, and ±0.5 V for maximum line disturbances. A basic DC-DC converter topology (Buck) has been modeled in both voltage and current control modes. The operation of standard PID controller and its modification has been studied and simulated by using the software *Matlab/Simulink*. The results were verified by using *Saber*, which is a large simulation tool especially designed to simulate electrical systems. The results showed that Matlab/Simulink is an effective and accurate tool, and there is no question about its applicability in the simulation of devices containing high-frequency switching and dynamics. The discredited PID controller was designed and its operation was investigated by simulation. The design specifications were met as shown by the simulation results.

Some operation modes like the cases with a constant power load and modified constant power load were studied both theoretically and from the control viewpoint. The theoretical problems related to these issues (e.g. regarding stability) were solved and suitable control solutions were provided. Because in the constant power load case the control problem becomes nonlinear, a fuzzy control algorithm was designed and tested by using the software *FuzzyTech*.

The non-ideal characteristics of a real switching power supply were modeled by including equivalent series resistors (ESRs) in the model. Also the effect of line and load disturbances were studied and taken into account in the controller design to meet the design objectives. For comparison, an internal model control (IMC) algorithm was designed and tested to achieve the desired output voltage especially in the case of load disturbances.

A test bench for testing the control algorithms was constructed by removing the analog control part from a real power supply and connecting a DSP board to control the output voltage.

The scientific and engineering results of the project consist of Modeling, analysis, controller design, and simulation of a DC-DC converter. In the same hand, to build a test bench to verify the operation.

2.5 Digitally Controlled Dc-Dc Converter

In the other hand, The NASA Glenn Research Center and the Cleveland State University have developed a digitally controlled dc-dc converter to research the benefits of flexible, digital control on power electronics and systems. Initial research and testing has shown that conventional dc-dc converters can benefit from improved performance by using digital-signal processors and nonlinear control algorithms.

A standalone digital controller has been integrated with a 1-kW full-bridge dc-dc converter to evaluate digital-control algorithms. The standalone digital controller is made of four circuit boards packaged in one assembly: a digital-signal processor board, a complex programmable logic device board, an analog-to-digital converter board, and an analog signal isolation board. The analog signal isolation board isolates and filters the dc-dc converter output voltage signal, the analog-to-digital converter board converts the analog signal to a digital signal, and the digital-signal processor board runs the data through the nonlinear control algorithms. The complex programmable logic device board manages the pulse-width-modulation switching of the dc-dc converter transistors through four discrete digital signals.

A unique nonlinear control algorithm was developed and has shown superior performance over its linear counterpart. Using the digital controller, 1-kW dc-dc converter, and the nonlinear control algorithm, the controller has demonstrated a load transient response time improvement of 150 percent along with a 50-percent reduction in the load transient magnitüde.

Future work includes the research of digital control algorithms that can tailor the converter's impedance, reduce electromagnetic interference in the system, and guarantee stable operation under all conditions. These advances will result in dc-dc converters with improved performance and electrical power systems with lower design and integration costs.

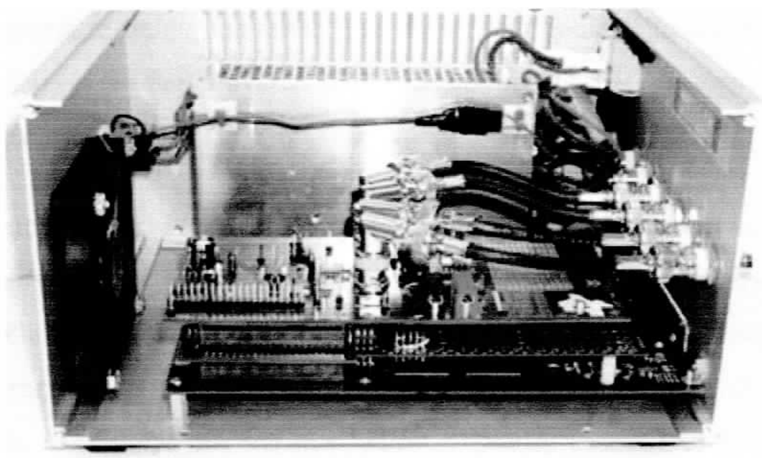

Figure 7: Prototype Digital Controller for the Intelligent Dc-Dc Converter

2.6 Direct-Current To Direct-Current (DC/DC)

In the another projects, the NASA Research Center developed numerous types of direct- current to direct-current (dc/dc) converters with modest outputs (up to 100 watts (W) at 50 volts (V)) for operation over a wide range of temperatures from room temperature to -196 °C (the temperature of liquid nitrogen). For spacecraft that will operate in the cold temperatures of deep space, converters that can operate at low temperatures will require little or no heating (or the associated heating equipment). Consequently, they enable greater design versatility and lower cost. In addition, dc/dc converters can be operated more efficiently at low temperatures than at room temperature.

Recently, developed and demonstrated a high-voltage, 1-kW dc/dc converter that operates from room temperature to -184 °C. A power supply designed for use in a NASA ion beam propulsion system was utilized as a starting point for the design of a low- (wide-) temperature dc/dc converter. For safety, we decided to halve the output voltage and power level, so the converter was designed for an 80-Vdc input and a 550-Vdc output at 1 kW.

The components used in the circuit design were selected from component classes that had been screened and tested for low-temperature operation. Certain N-channel MOSFET's were chosen as switches because they function well at low temperatures and, when they are turned on at -196 °C, have only one-third to one-fourth of their room temperature losses. This graph for the new dc/dc converter shows (for three different operating conditions) that system efficiency increases gradually as temperature decreases from room temperature to -184 °C.

CHAPTER 3

METHODOLOGY

3.1 1ntroduction to the Project

The purpose of this project is to develop a 9-Volt Dc Power Supply from the 24-Volt supply. There are two types of circuit need to be developed which are rectifier and converter. The development of switching circuit that is the heart of generating output signal will be done to drive the converter. PIC Controller will be used to energize and de-energize switch so that required output signal can be obtained. Software simulation is primarily used to analyze the converter circuit virtually so that the circuit parameters such as component specifications in term of voltage and current can be predicted so that the component selection can be done. From this simulation, the waveform of current can be obtained. In the same hand, a clear picture of the design circuit also can be produced.