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

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Name of Supervisor : Encik Zikri Abadi Bin Baharudin

Date : 4/5/06

# SWITCH-MODE POWER SUPPLY IN THE APPLICATION OF UPS

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

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This dedicated to my beloved father and mother

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# ABSTRACT

The Switch Mode Power Supply (SMPS) has been studied and design in the application of Uninterruptible Power Supply (UPS). The converter is powered by a high-voltage main power input and low-voltage backup battery. The converter features a simple's circuit, high efficiency, small size and low cost compared with the conventional cascade of UPS and switching power supply. This converter should find applications in UPS, personal computer and other electronic devices. The methodologies of this project are as follows: (1) Appropriate model of SMPS has been chosen based on the literature review study, (2) Simulation work using the ORCAD in order to investigate the functional, characteristic and performance of the circuit design, (3) Hardware development and analysis (4) comparison between hardware and simulation result. From the analysis conducted, the circuit is unable to be function because of the IC SG2524N was failed to operate. The extensive study should be conducted to enhance the applicability of SMPS and its efficiency.

# ABSTRAK

Dalam projek ini, rekabentuk Switch Mode Power Supply (SMPS) dikaji dan direka bagi aplikasi untuk Uninterruptible Power Supply (UPS). Pengubah dijana oleh kuasa input voltan utama dan bateri sokongan bervoltan rendah. Pengubah mempunyai ciri-ciri litar yag ringkas, berkecekapan tinggi, bersaiz kecil dan kos yang rendah jika dibandingkan dengan UPS dan SMPS yang konvensional. Aplikasi pengubah ini terdapat di UPS, komputer peribadi dan alatan elektronik yang lain. Dalam projek ini, terdapat empat langkah metodologi iaitu ;(1) mengkaji dan memilih model litar SMPS yang bersesuaian berdasarkan kajian terhadap penulisan, (2) membuat simulasi menggunakan ORCAD untuk mengetahui fungsi, ciri dan prestasi litar yang direka, (3) membina litar perkakas dan menguji serta mengenalpasti masalah, (4) membuat perbandingan keputusan antara litar perkakas dan litar simulasi. Namun begitu, litar gagal beroperasi kerana IC SG2524N gagal berfungsi. Projek ini boleh diperbaiki dengan menjalankan kajian yang mendalam lagi dalam penambahbaikan pada kecekapan SMPS.

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# CHAPTER 1

# INTRODUCTION

## 1.1 Background of Switch-Mode Power Supply (SMPS)

A power supply is a buffer circuit that provides power with the characteristics required by the load from a primary power source with characteristics incompatible with the load. It makes the load compatible with its power source. A power supply is sometimes called a power converter and the process is called power conversion. It is also sometimes called a power conditioner and the process is called power conditioning.

The Power Sources Manufacturers Association's (PSMA) Handbook of Standardized Terminology for the Power Sources Industry [1] gives this definition of a power supply:

> *Power Supply is a device for the conversion of available power of one set of characteristics to another set of characteristics to meet specified requirements. Typical application of power supplies include to convert raw input power to a controlled or stabilized voltage and/or current for the operation of electronic equipment*

Power supplies belong to the field of power electronics, the use of electronics for the control and conversion of electrical power. This technology encompasses the effective use of electronic components, the application of circuit theory and design

techniques, and the development of analytical tools toward efficient electronic conversion, control, and conditioning of electric power.

A Switch-Mode Power Supply (SMPS) is a power supply that provides the power supply function through low loss components such as capacitors, inductors, and transformers and the use of switches that are in one of two states, on or off. The advantage is that the switch dissipates very little power in either of these two states and power conversion can be accomplished with minimal power loss, which equates to high efficiency.

The term switch mode was widely used for this type of power supply until Motorola, Inc., who used the trademark SWITCHMODE TM for products aimed at the switching-mode power supply market, started to enforce their trademark. Then more generic terms had to be found. I started using the term switching-mode power supply to avoid infringing on the trademark. Others used the term switching power supply, which seems to be the more popular term. PSMA does not define either switching-mode power supply or switching power supply, but does define switching regulator.

## 1.2 Project Objectives

The objectives of this project are as follows:

i. To design and develop the hardware of Switch-Mode Power Supply (SMPS) using the fly back converter circuit.

ii. To analyze a complete circuit design using ORCAD.

iii. To make comparison between simulation and experimental result.

## 1.3 Scope of Work

This project used the flyback converter circuit and uses the integrated controller IC (SG2524N) in the circuit. The SG2524N is a fixed-frequency pulse-width-modulation (PWM) voltage-regulator control circuit. The SG2524N were designed for switching regulators of polarity, transformer-coupled dc-to-dc converters, transformer less voltage doublers, and polarity-converter applications employing fixed-frequency, pulse-width modulation (PWM) techniques. Comparison between the results of experimental and hardware is used for analysis and verification.

## 1.4 Problem Statement

Lower total solution cost is the result of fewer components, tighter IC tolerances, and built-in features that eliminate or reduce the cost of external components. Tighter temperature and absolute IC tolerances afford a more accurate design. The added tolerances of the numerous parts in a discrete design lead to over sizing the SMPS to meet the power requirements.

## 1.5 Methodology

The methodologies of this project are as follows:

1. Choose appropriate model of SMPS based on the literature review study.
2. Do the simulation work using the ORCAD in order to investigate the functional, characteristic and performance of the circuit design.
3. Develop the hardware and do the testing and the troubleshooting.
4. Comparison between hardware and simulation result.

## 1.6 Literature Review

Literature study is done for the purpose of learning as much as possible, in terms of this project application, about the switch mode power supply in the application of uninterruptible power supply (UPS).

Sabin Lupan (2001) [1] reports on a theoretical and experimental study that the Uninterruptible Power Supply (UPS) contains the battery charger, battery and inverter inside of an enclosure. The battery life is shortened at increased temperature, so it's important to keep the temperature inside the enclosure as low as practically possible. Also the charging voltage has to be adjusted as a function of the battery temperature. The battery charger has to function under a wide range of input voltages and protect itself during over-voltage or voltage-surge conditions. The battery charger keeps the UPS battery fully charged during normal input-voltage range. When the alternate current (AC) power line voltage goes out of normal range (geographical area defined), the power turns off and the battery supplies the power to the load. When the line voltage returns within the normal range, the battery is recharged. In this project will focus on power supply using the Switch-Mode Power Supply (SMPS)

R.Erikson and D.Maksimovic (1995) [2] have discussed that dc-dc converters suitable for use in battery-powered electronic equipment with energy management. To realize the benefits of energy management, these converters must be capable of maintaining regulation of their output voltages at n load, while maintaining high efficiency. Variable frequency operation is shown to give an improvement in efficient operating range of approximately two orders of magnitude. Proportionality of the battery and load current can be maintained over approximate five orders of magnitude, with minimum battery currents of less than 100uA and maximum load currents approaching 10A. Steady-state and small-signal AC characteristics of converters operating with variable-frequency control are tabulated and an AC two-part model is described.

Kwok-wai Ma and Yim-shu Lee (1996) [3] have presented an integrated fly back converter performing the combined functions of uninterruptible power supply (UPS) and Switch-mode power supply (SMPS) is presented. This converter has a high voltage main power input and a low voltage backup battery input. DC output is obtained from the main input via a fly back converter during normal operation and from the backup battery via another fly back converter when input power fails. High conversion efficiency is achieved in normal, backup, and charging modes as there is only a single dc-dc conversion in each mode. The converter circuit is very simple, with two switching transistors, a relay for mode switching, and a single magnetic structure only. This new design offers substantial improvement in efficiency, size, and cost over the conventional cascade of UPS and SMPS due to single voltage conversion, high frequency switching, and removal of design redundancy. The operation, design, analysis, and experimental results of the converter are presented.

## 1.7 Project Organization

The project's chapters are organized as follows:

**Chapter 1:** Explanation the introduction of the project and comprises the overall experimental works and the objectives and problem statement of this project. Literature review also been included for the learning purposes.

**Chapter 2:** Reviews the fundamental behind the project design. This chapter explains the basic of Switch-Mode Power Supply (SMPS) theory, the DC-DC switch mode converters and consideration of the transformer design.

**Chapter 3:** Describes the hardware implementing components that have been used. Setting up all the components for hardware and testing the circuit.

**Chapter 4:** Explanation on the results of the project.

**Chapter 5:** Discussed the problems and constrains during the project

**Chapter 6:** Gives the conclusions and suggestions to the project.

# CHAPTER 2

# FUNDAMENTAL BEHIND THE PROJECT DESIGN

## 2.1 Introduction

An effective course in switch-mode power supply (SMPS) should ideally contain an element of hands-on design and experimental work in addition to the study of the theory and simulations. This element should complement the study of the theory of SMPS and simulation of their operation.

The proposed course structure reduces the costs and the staffing or space commitments while still maintaining a very strong emphasis on practical design and experimental work.

The purpose of this chapter is to review the basic of switch-mode power supply that are essential to the understanding the dc-dc switch mode converters.

## 2.2 Theory of switch mode power supply (SMPS)

The switch-mode power supply (SMPS) transfers the energy to the load discontinuously. The SMPS offers a lower cost of ownership solution because it:

- extends the battery life by maintaining a lower battery temperature, and
- reduces the maintenance due to better reliability.

These benefits derive from the higher efficiency of the SMPS (cooler operation). The SMPS is also powered from the line, but it stores energy in an input capacitor and transfers it to the load as needed, in high-frequency increments, by switching on and off. A solid-state switch, controlled by a pulse-width modulation (PWM) controller, accomplishes the switching.

The transformer has a ferrite core that is a much smaller and lighter than the linear's iron-core counterpart, making the UPS design easier. Also, a SMPS can be used worldwide because it accepts universal input voltages.

## 2.3 Power Electronic Converters

Power electronics deals with four forms of power conversion.

1. ac-dc conversion (rectifier)
2. ac-ac conversion
3. dc-ac conversion (inverters)
4. dc-dc conversion (converters)

DC-DC converters were referred to as choppers earlier, when SCRs were used. Nowadays, IGBTs and MOSFETs are the devices used for dc-dc conversion and these circuits can be classified as switch mode power supply circuits. The abbreviation or acronym for switch mode power supply is SMPS.

A switch mode power supply circuit is versatile. It can be used to:

1. step down an unregulated dc input voltage to produce a regulated dc output voltage using a circuit known as buck converter or step-down SMPS,
2. step up an unregulated dc input voltage to produce a regulated dc output voltage using a circuit known as boost converter or step-up SMPS,
3. step up or step down an unregulated dc input voltage to produce a regulated dc output voltage ,
4. invert the input dc voltage using usually a circuit such as the Cuk converter, and

5. produce multiple dc outputs using a circuit such as the flyback converter.

A switch mode power supply is a widely used circuit nowadays and it is used in a system such as a computer, television receiver, battery charger etc. The switching frequency is usually above 20 kHz, so that the noise produced by it is above the audio range. It is also used to provide a variable dc voltage to armature of a dc motor in a variable speed drive. It is used in a high-frequency unity-power factor circuit.

## 2.4 DC-DC Switch-Mode Converters

The dc-dc converters are widely used in regulated switch-mode dc power supplies and in dc motor drive applications. As shown in Fig 2-1, often the input to these converters is an unregulated dc voltage, which is obtained by rectifying the line voltage and therefore it will fluctuate due to changes in the line-voltage magnitude. Switch-mode dc-to-dc converters are used to convert the unregulated dc input into a controlled dc output at a desired voltage level.

Looking ahead to the applications of these converters, we find that these converters are very often used with in electrical isolation transformer in the switch-mode dc power supplies and almost always without an isolation transformer in case of dc motor drives. The following dc-dc converters are:

1. Step-down (buck) converter
2. Step-up (boost) converter
3. Step-down/step-up (buck-boost) converter
4. Cuk converter
5. Full-bridge converter

All these five converters, only the step-down and the step-up are the basic converter topologies. Both the buck-boost and the cuk converters are combinations of the two basic topologies. The full-bridge converter is derived from the step-down converter.

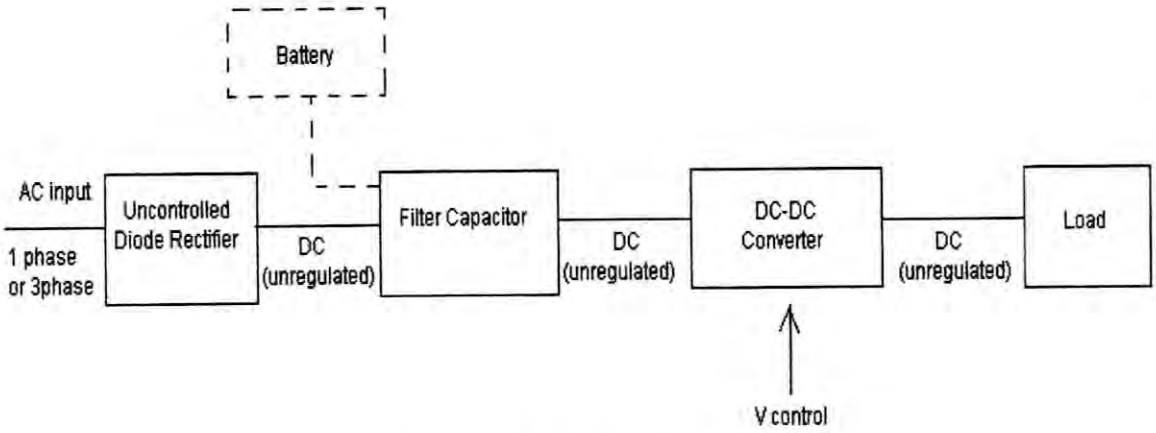


Figure 2.1: A dc-dc converter system

### 2.4.1 Step-down (buck) converter

A buck converter is a step-down DC to DC converter. Its design is similar to the step-up boost converter, and like the boost converter is a switched-mode power supply that uses two switches and an inductor, and optionally a capacitor to buffer the output.

The simplest way to reduce a DC voltage is to use a voltage divider circuit, but voltage dividers waste energy, since they operate by bleeding off excess voltage as heat. A buck converter, on the other hand, can be remarkably efficient (easily up to 95% for integrated circuits,) and self-regulating, making them useful for tasks such as converting the 12-24V typical battery voltage in a laptop down to the several volts needed by the processor.