DESIGN SWITCHING MODE POWER SUPPLY USING BOOST CONVERTER CONTINUOUS MODE

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DESIGN SWITCHING MODE POWER SUPPLY USING A BOOST CONVERTER TOPOLOGY (CONTINUOUS MODE)

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This Report Is Submitted In partial Fulfillment Of Requirements For The Degree of Bachelor In Electrical Engineering (Power Electronic And Drive)

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"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)"

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Date : 8/5/07

"I hereby declared that this report is a result of my own work except for the excerpts that have been cited clearly in the references."

Signature :

Name : MASRUL BIN MASRAN

Date : 16 APRIL 2007

For my beloved father, mother, and sister

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I would like to take this opportunity to thank my PSM supervisor, Encik Azziddin bin Mohamad Razali for his guidance throughout the period of PSM I and PSM II. I am much appreciating his assistance and all the valuable knowledge provided in helping me to complete the documentation. To my parents and lecturers, thank you so much for keep on supporting me to accomplish this project successfully.

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ABSTRACT

The SMPS that has been designed is using a topology of boost converter that will step up a 12V dc input into 24V dc of output. Firstly, SMPS is smaller than linear power supply, and yet also, it has a higher efficiency, which is up to 85%. The linear regulator can, therefore, tend to be very inefficient. The switch mode power supply, however, uses a high frequency switch (in practice a transistor) with varying duty cycle to maintain the output voltage. The ripple output voltage caused by the switching are filtered out by an LC filter. SMPS can be used to step-down a supply voltage, just as linear supplies do. Unlike a linear regulator, however, an SMPS can also provide a step-up function and an inverted output function. The mode operation of this project is continuous mode, by then, the inductor used must be large enough than minimum value of calculated inductor to ensure the inductor current is continuous. Since this is a high frequency converter, a MOSFET is used as a switch to meet the requirement of the SMPS. The output voltage is larger than the input level. All the input will be in dc form and an appropriate value of capacitor is used to minimize the ripple voltage. Before implementing the topology into hardware, the simulation process will be done to c,mpare the result with the hand calculation. The basic operation of SMPS is also describe and presented in this report paper. For the design solution, the implementation of DC/DC boost converter contains two subsystems – a conventional PWM boost converter, and a PWM control circuit. An ic UC3525A is used to produce the gating signals and drives the Metal-Oxide-Semiconductor Field Effect Transistors (MOSFET), allowing the converter's output to be kept steady at 24V through pulse width modulation. A switching frequency of 50 KHz is used.

ABSTRAK

Projek ini memfokuskan bidang penciptaan dan penghasilan *switch mode power supply* (SMPS). SMPS mempunyai beberapa kelebihan berbanding dengan *linear power supply*. Pertamanya, ia lebih ringan, tambahan pula ianya mempunyai nilai kecekapan yang tinggi, melebihi 85%. Linear power supply juga begitu cenderung untuk mempunyai nilai kecekapan yang rendah. SMPS menggunakan suis berfrekuensi tinggi, nilai kitar tugas*(duty cycle)* yang boleh diubah untuk mengekalkan keluaran voltan yang stabil. *Ripple* pada keluaran voltan yang disebabkan oleh proses pensuisan akan ditapis oleh litar *filter*. SMPS juga boleh menurunkan nilai bekalan kuasa yang dibekalkan kepadanya, sama seperti *linear power supply*. Walau bagaimanapun, SMPS boleh meningkatkan nilai keluaran daripada bekalan kuasa yang dibekalkan, dan menukarkan fungsi keluaran. Cara penoperasian litar bekalan kuasa ini adalah *continuous*. Nilai induktor yang digunakan mestilah jauh lebih besar daripada nilai minimum induktor yang dikira itu sendiri bagi memastikan arus keluaran pada induktor adalah berterusan. Disebabkab litar bekalan kuasa ini merupakan litar penukar dc-dc menggunakan frekuensi pensuisan yang tinggi, MOSFET akan digunakan sebagai suis. Voltan keluaran adalah lebih tinggi berbanding voltan masukan. Kesemua bekalan masukan ke litar kuasa ini adalah berbentuk arus terus, dc. Nilai yang sepatutnya untuk kapasitor telah digunakan untuk meminimumkan nilai *ripple* pada voltan keluaran. Sebelum litar kuasa ini dihasilkan dalam bentuk *hardware*, ujian simulasi telah dijalankan untuk membuat perbandingan antara keputusan pengiraan teori dengan keputusan simulasi ataupun eksperimen. Proses keberfungsian litar ini ada dinyatakan dengan jelasnya di dalam laporan ini. Bagi menyempurnaka projek ini, litar kuasa ini mempunyai dua subsistem iaitu: *PWM boost converter,* dan juga litar kawalan PWM. UC3525A telah digunakan untuk menghasilkan isyarat yang mana akan memacu terminal *gate* MOSFET itu sendiri, untuk membolehkan keluaran kuasa adalah tetap pada kadar 24V, menerusi PWM. Nilai frekuensi suis yang digunakan ialah 50 KHz.

CHAPTER 1

INTRODUCTION

This project goal is to design and build pulse width modulated dc to dc boost converter with a fixed output of 24VDC. When discussing SMPS circuits, the different topologies are often referred to as 'forward' or 'flyback'. A feed forward SMPS circuit will supply energy to the output capacitor when the switching element (transistor) is switched on. A flyback SMPS circuit transfers energy (from an inductor) to the output capacitor when the switching element (transistor) is switched off. This report details the design method used to meet the project specifications. It also analyzes the functionality, efficiency, and recommends changes for future implementations. Pulse width modulated (PWM) dc to dc converters are widely used in a variety of applications due to their ease of control and modification, however their use in higher frequency applications are limited due to their significant amount of noise interference and losses that occur. Because of this, soft-switching techniques have become popular to reduce these losses at higher frequencies.

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1.1 Objective

The main objective of this project is to design and build a high efficiency DC/DC boost converter continuous mode operation starting from calculating the performance parameter values, simulation process, and hardware implementation with the following ideal specifications:

- Input Voltage: 12 V dc
- Output Voltage: 24 V dc
- Switching Frequency: 50 kHz

The other objectives are to determine a correct value and rating of the converter's components and switching frequency. It is natural that there must be a different at least a bit, between hand calculation and experimental or simulation result, and it is among of my project's objective, to compare the both hand calculation and simulation with experimental results.

1.2 Scope

In the process of development this boost converter SMPS, firstly I have to determine the scope of my project. My scope of project for the first semester will begin from design the performance parameter, defining exact value for the circuit components, rating of switching frequency, duty cycle, and running the simulation using software Or Cad P-Spice .For the second semester, the circuit will be implemented into hardware prototype and test the completed hardware until the correct output voltage is obtained. The scope of my project also just included an open-loop circuit, without any feedback. Since the scope of this project is limited to open loop test, the output voltage is not always regulated, it is depends to the input voltage, if the input voltage is varied in certain amount, the output voltage also will be varies (not regulate).

1.3 Project Methodology

There are several stages that I have to go through in order to complete this project successfully. The first stage is about studying the various types of SMPS with different kind of topologies and functions. In this first stage also I have to study about my project focused, boost converter, in detail. Since in this topology has a several part with different function, I do research on it one by one. Firstly, studying about MOSFET and its gate driver, PWM. In MOSFET, it have a switching frequency that has to be choose wisely to ensure its value is affordable to support this kind of high switching application of power supply. The frequency also cannot be too high, since the frequency is too high, there will be more losses included the output voltage and output power, in term of power efficiency, it is not good. The circuit that responsible to drive the gate MOSFET is known as Pulse Width Modulator, PWM. This PWM will generate a compatible signal and this signal we called as a pulse. In order to determine the compatible signal with the gate MOSFET, its pulse width must generate using the duty ratio that I obtained in calculation. The UC3525 was used as my PWM chip controller due to its less external components requirement, and easy circuit making. The complete circuit of this PWM included its external components I state in the next chapter in this report. After got a good understanding about this PWM, I continue my literature review by studying on magnetic component design, inductor. In the process of making an inductor, there are several factors need to be consider, it is about the number of turns of the core, the core's diameter, the reluctance of the core, and the material used by the manufacturer of the core, ferrite or cooper or else. After finishing the theoretical study, I continued on hand calculation and performance parameter included the component calculation value, input and output voltage, current and power. This stage is important for to determine the correct value of the circuit components so I can meet the topology requirement. After find out all the necessary values, I proceed on circuit simulation. In this simulation process, I will observe the output waveform of inductor current, output voltage, drain-to-source voltage of the MOSFET, and the output power. If these waveforms is not similar with the theoretical waveform, I have to recalculate the related component value until I obtain the actual waveform. This simulation results should be almost the same with my final results of this project, and after completing this part, I will implement the circuit into hardware. The process of hardware implementation is executes part by part of the topology. Starting from the PWM circuit, followed by the basic topology of the boost converter. If the output signal from the PWM circuit is perfectly correct in term of the peak-to-peak and mean value, and also the square wave accuracy, the boost converter circuit will be connected to this PWM circuit. After this combination circuit already done, the complete testing can be implement, to display the output voltage, inductor current, and output current. Since these waveforms are obtained, all the necessary analysis should be progress to identify the power quality delivered by this SMPS and yet also to determine the type of operation of this boost converter in continuous current mode. The inaccuracy of output result have to be troubleshoot by identifying again the calculation performance parameter, suitability of components used, and the way connection applied in this hardware until the desired output waveform obtained.

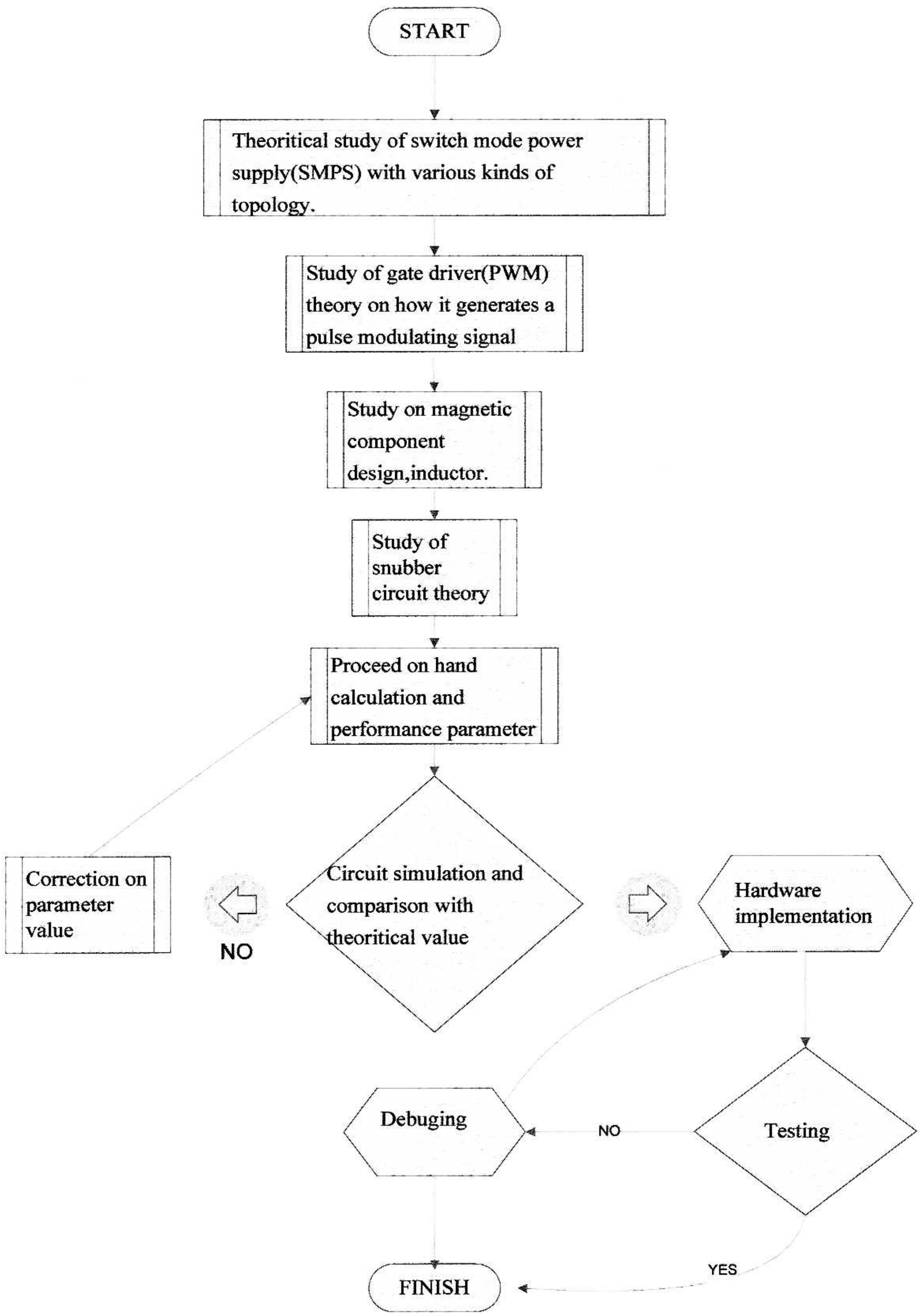

Figure1.0: The methodology flowing works

1.4 Problem statement

The problems faced in previous years of power linear supply encouraged me to do this project. Those things included heat dissipation problem that decrease efficiency on linear power supply, to achieve the high efficiency, whereas up to 85%, to maintain stability of output voltage supply to load, and term of physical construction, the linear power supply is heavier compared to switching mode power supply.

CHAPTER 2 :

LITERATURE REVIEW

This chapter will be divided into six subtopics. Those subtopics are:

2.1 SMPS with various topology

2.2 Boost converter topology CCM and DCM

2.3 Circuit operation

2.4 Circuit analysis

2.5 MOSFET gate driver(PWM)

2.6 Magnetic component design

2.1 Various topology of SMPS

In switch mode power supply, there are various type of topology together with different operation and function, only one relationship for those topologies, they are divided into two mode operation, Continuous Current Mode(CCM) and Discontinuous Current Mode(DCM). For the **boost converter** topology (Figure 2.10), it simply means to produce an average output voltage that is higher than the input source voltage. The basic boost converter usually consists of a PWM, a MOSFET switch, an inductor, a diode and a capacitor. If the PWM generate a 200 KHz (1ms) square wave at 50% duty cycle, this will cause the MOSFET to be switch on for 0.5us and off for the next 0.5us. When the MOSFET switch is on, the diode will be reverse bias, thus isolating the load from the input source voltage and charges up the inductor current. When the MOSFET switch is off, the inductor begins to discharge and will induce a negative voltage drop across the inductor. Because one terminal of the diode is driven by the input source voltage, the other terminal will have a higher voltage level. In this way, the output load will receives energy from both the inductor and the input source voltage thus boosting the output voltage up. As for the capacitor, it is used as a low-pass filter to reduce output voltage ripple cause by the fluctuating inductor current.

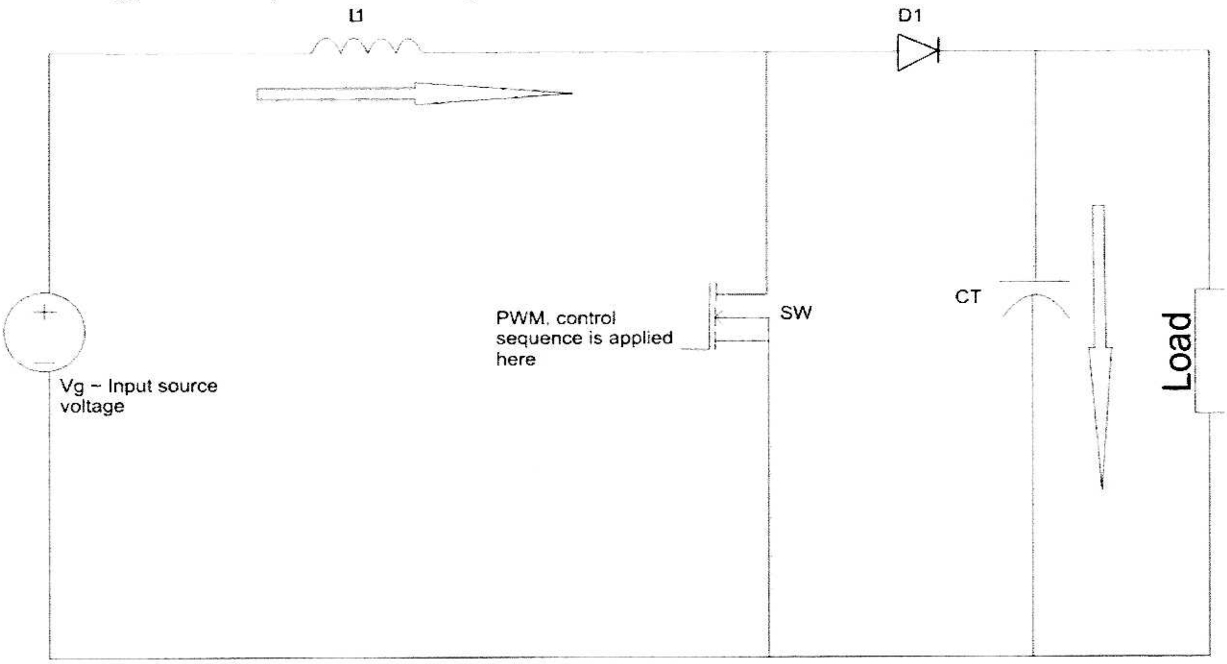

Figure 2.10 : Basic Boost converter topology

For the **buck-boost converter** topology (Figure2.11), it allows voltage to be step down or up using the same minimal components but different arrangement. When the MOSFET switch is on, the diode is reverse bias, thus charging the inductor current up. When the MOSFET switch is off, the inductor provides energy to the output load through the ground node by discharging the current and therefore induces a negative voltage drop across the inductor. Because one terminal of the inductor is tied to ground, the other terminal will have a lower voltage level compared to ground, resulting in the negative output supply voltage level across the load.

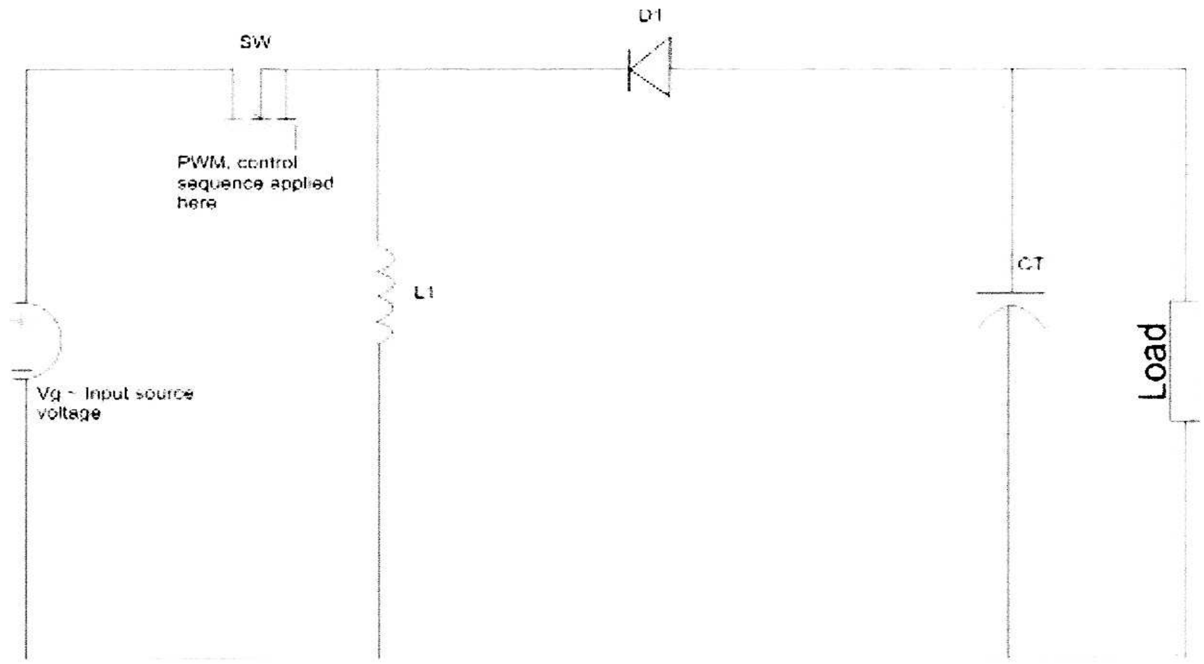

Figure 2.11: Basic Buck-Boost converter topology

For the **buck converter** topology (Figure2.12), the concept is quite similar to the boost converter except for the arrangement of the components which will result in an average output voltage lower than the input source voltage. When the MOSFET switch is on, the inductor current increases, thus inducing a positive voltage drop across the inductor and a lower output supply voltage reference to the input source voltage. When the MOSFET switch is off, the inductor current discharges, thus inducing a negative voltage drop across the inductor. Because one terminal of the diode is tied to ground, the other terminal will have a higher voltage level, which is the target output supply voltage. Like in the boost converter, the capacitor continues to act like a low-pass filter to reduce output voltage ripple cause by the fluctuating inductor current.

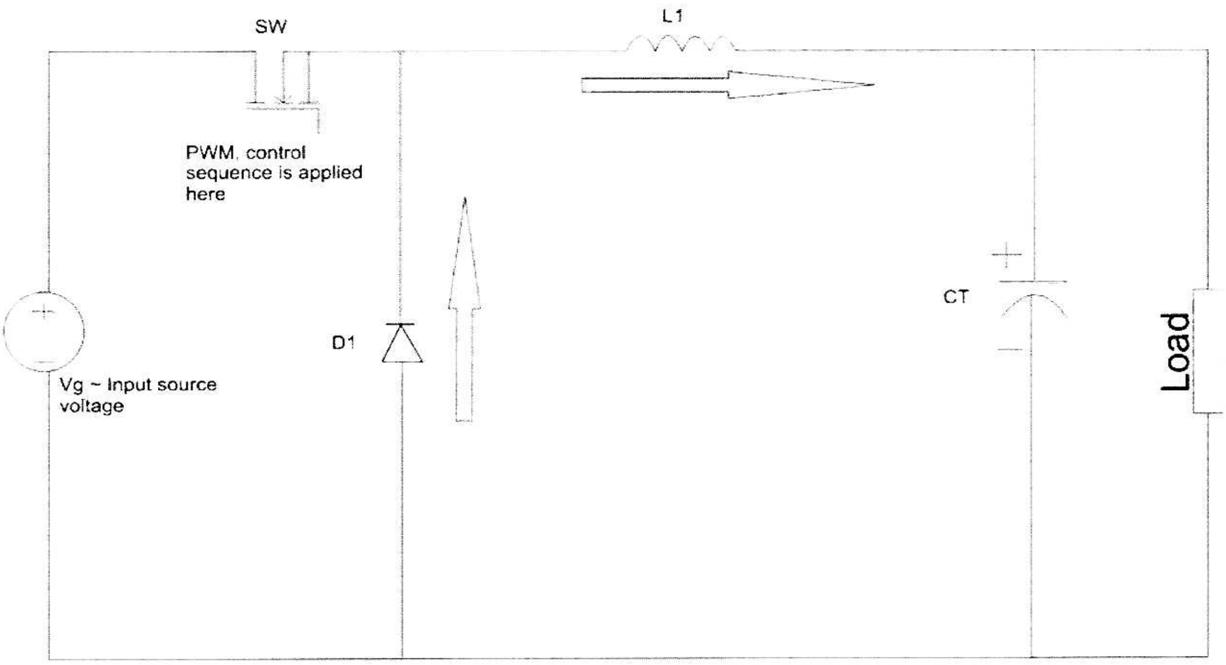

Figure 2.12: Basic Buck converter topology