SWITCHING MODE POWER SUPPLY USING
BOOST CONVERTER-
DISCONTINOUS CURRENT MODE

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DESIGN SWITCH MODE POWER SUPPLY USING DISCONTINUOUS CURRENT MODE USING BOOST CONVERTER TOPOLOGY

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"Saya akui laporan saya ini adalah hasil kerja saya sendiri kecuali ringkasan dan petikan yang tiap-tiap satunya saya jelaskan sumbernya."

Tandatangan : ....

Nama : WAN MOHD IRHAM B. WAN AHMAD

Tarikh : ....9/5/2007..

"Saya akui telah membaca karya ini, pada pandangan saya karya ini adalah memadai dari segi skop dan kualiti untuk penganugerahan ijazah sarjana muda Elektrik(Elektronik Kuasa & Pemacu)"

Tandatangan :..
Nama Penyelia :EN MOHD AZZIDDIN B. MOHD RAZALI
Tarikh :.........9/5/07...

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ABSTRACT

In this report, a development of a high efficiency Boost converter in DCM is presented in simulation and calculation. The design aimed to create a regulated output DC from unregulated input. Initial goal to produce smooth 24Vdc from fluctuating 12Vdc.The typical application of boost converter to provide DC power supply to inverter and generated braking for DC motor. This boost converter contains 3 subsystem boost converter , PWM circuit , and feedback circuit. An Unitrode IC – UC3525AN is used for triggering MOSFET.To perform the optimum operation for the design, software ORCAD will be utilized. The converter has been developed with less than 5% of output ripple voltage, and capable to achieve efficiency more than 80%.

ABSTRAK

Di dalam laporan ini,peningkatan prestasi penukar tinggi ditunjukkan di dalam simulation dan calculation.Rekaan bertujuan menghasilkan voltan output yang stabil daripada voltan input yang berayun-ayun.Sasaran permulaan adalah menghasilkan voltan 24Vdc yang licin daripada 12Vdc.Kebiasaannya, aplikasi untuk alat ini adalah membekalkan kuasa DC kepada Penukar AC dan penghasilan brek kepada motor DC.penukar tinggi mempunyai tiga bahagian utama iaitu litar penukar tinggi,litar PWM,dan litar maklumbalas. IC unitrode UC3525AN digunakan untuk memacu MOSFET .Untuk hasil yang memuaskan aturcara ORCAD digunakan.Penukar yang dihasilkan akan mempunyai voltan riak yang kurang dari 5% dan mempunyai prestasi kerja 80%

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Many people have contributed to this report.I am truly acknowledge their tremendous effort making this report comprehensive. Then, I want to thank to all who contributed, directly or indirectly.

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CHAPTER 1

INTRODUCTION

1.0 Background

PSM is one of term to achieve Bachelor in Engineering at all IPTA in Malaysia. This PSM required a great commitment and discipline before the project is complete. It can be divided into 2 types, PSM1 & PSM2.PSM1 is all about design a parameter and simulate a circuit design using software, and PSM2 will proceed on how to build hardware. My 1'st PSM project is about "Design Switch Mode Power Supply Using Discontinuous Mode Boost Converter".

Pulse width modulated (PWM) DC/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 the 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. This report documents a student project where the goal is to design and build a zero voltage transition, pulse width modulated DC-DC boost converter with a fixed output of 24VDC.

The snubber cell used to implement the soft switching techniques is relatively new where the main transistor is switched under zero voltage and the auxiliary transistor is switched under zero current. The snubber cell is also relatively low cost.

1.1 Objective

The objective of this project is to design and build a snubber circuit, Pulse Width Modulated DC-DC boost converter with the following ideal specifications:
Input Voltage : 12VDC
Output Voltage: 24VDC
Output Power: 50W
Switching Frequency: 50kHz
Efficiency >80%

Compatible parameter will be design using equation before simulate using ORCAD. Comparison will be made between calculation, simulation, and practical until define the correct value.

1.2 Scope

The scope of the project

- To design Boost converter to operate in DCM operation
- Close loop feedback to maintain fixes 24Vdc.
- Load as inverter

1.3 Methodology

1.3.1 Study various kind of SMPS topology.

At the first, I had study various kind of SMPS topology. There is very important to understand the concept of SMPS. SMPS is using the same component such as MOSFET, inductor, diode and capacitor but in different sequence. The sequence meaning the placing of component is design to produce require desired output During this study, I have understood what of the purpose using boost converter. There are many kind of SMPS use in different field of applications. That is why SMPS are design in different kind of sequences to full fill this application.

Table 1.0: Field of application

(a)	Residential	Refrigeration, space heating, air conditioning , cooking, lighting , etc
(b)	Commercial	UPS , elevator,
(c)	Industrial	Pumps ,compressors , blowers and fans , Machine tools ,lasers
(d)	Transportation	Traction control of electrical vehicles , Battery chargers for electrical vehicles, electric locomotives, automotives electronic
(e)	Utility system	High Voltage DC transmission (HVDC),static Var compensation (SVC),Supplemental energy source(wind ,photovoltaic , full cells)
(f)	Aerospace	Space shuttle power systems, Satellite power system.
(g)	Telecommunication	Battery chargers, power supplies (dc and UPS).

Basically, Boost converter is design to solve battery problem. Boost converter can produce high output voltage than input voltage. For example using 3 VDC that equal to 2 batteries AA that can operate 5 VDC devices. This application can decrease the use of battery, and the same time reduces the size of device. Nowadays we can the application boost converter are wide than ever, used in automotive, electronic and electrical,etc. See Table 1.0

1.3.2 Gate Drive Study

Gate drive is important to trigger mosfet turn-on and turn-off. This PWM circuit must be able to create pulse with desire duty cycle (D).After study, I had found using IC is more easy to control and advantage. My suggestion is to use IC-UC3525AN for PSM2 that has special features than others IC.

IC- UC3525AN

- Low start up current (<1mA)
- Automatic feed forward compensation
- Pulse by pulse current limiting
- Enhanced load response characteristics
- High current Totem Pole output.
- Optimized for offline and DC to DC converter
- Under-voltages lockout with hysteresis
- Internally trimmed band gap reference
- Can operate below 500kHz operation

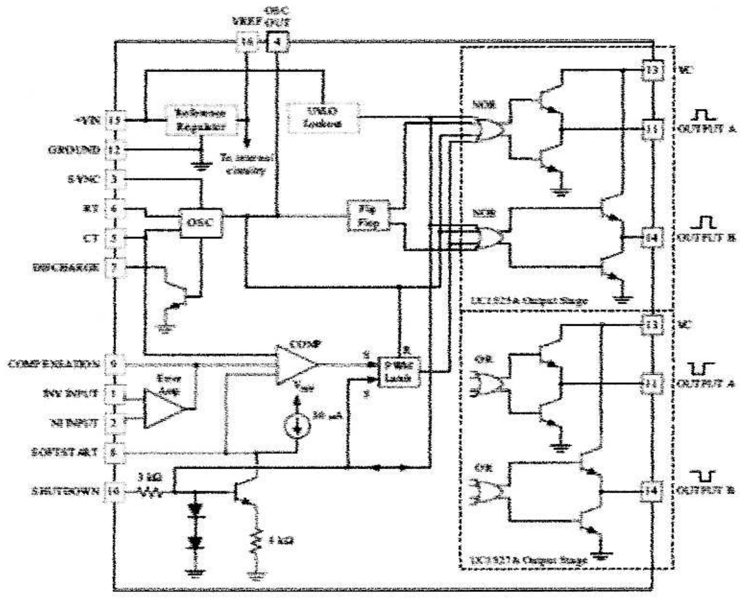


Figure 1.0: UC3525AN block diagram

1.3.3 Study magnetic Component

This sub chapter is about building an inductor. After study I had found that inductor must meet seven electrical criteria:

1. Value.

The inductance value must be low enough to store adequate energy at the worst case low input voltages, but high enough to avoid excessive current at worst case high-on-time

2. Saturation.

The coil must show the correct value of inductance at high peak operating current

3. Dielectric strength

The winding insulation must be able to withstand the inductors flyback voltage

4. DC resistance

The winding resistance must not cause excessive self heating and degraded load regulation

5. Adequate Q.

Inductor core losses must not effects low efficiency

6. Electromagnetic interference (EMI).

EMI must not affect IC and other circuit nearby.

7. Stray capacitance.

The inductor self resonant frequency (SRF) must be 10 times greater than switching frequency.

All of problem above can be prevent, if we using the suitable material and right winding. Size of wire also influence all factor above.

The table shows the frequency limits for core materials.

Table 1.1: core materials limit.

To 100kHz	Standard iron powers and steels tape
To 200kHz	Low permeability, high-frequency iron powders
To 400kHz	High flux MPP
To 500kHz	Standard MPP
To 1MHz	Manganese-Zinc ferrite
To 10MHz	Nickel Zinc ferrite

So, choose the correct materials are important because some materials that suitable with the application and some don't. My suggestion is to use High Flux MPP cores. Ordinary MPP cores (for radio frequency [RF] applications) contain 80% nickel, plus iron and molybdenum. High flux MPP contains 50% nickel, which not good for RF but good for switching application.

1.3.4 Study on snubber circuit.

The snubber circuits are used in combination with the boost converter circuit to decreases switching losses. The converter's semiconductor devices are turned on and off under near zero voltage transition (ZVT) and / or zero current transition (ZCT). Because of this, there are no additional voltage and current stresses on the main switch and main diode. Additional benefits of this active snubber circuit are its simple structure, relatively low cost, ease of control, and the stresses on the auxiliary components stay at allowable levels for operation. Furthermore, the converter behaves like a boost converter during the majority of the time because the time period the snubber cell is active is very short.

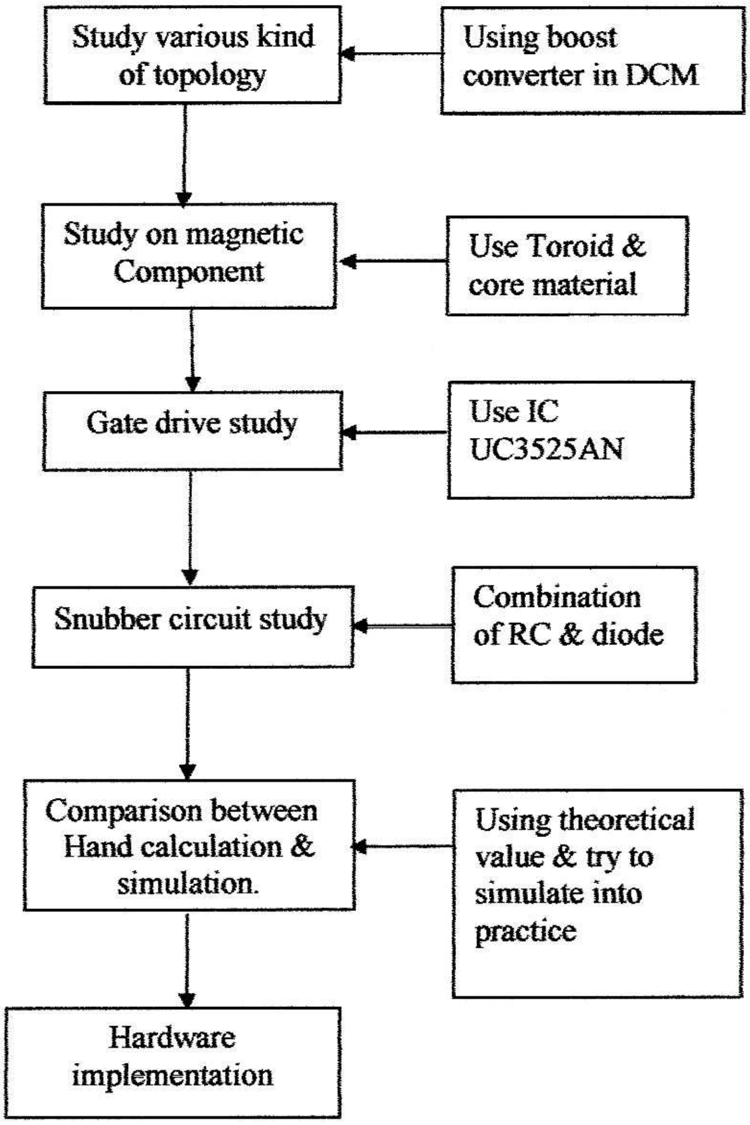
1.3.5 Comparison between hand calculation, simulation, and practical.

Hand calculations are finds from all study in literature review. Using this equation, all parameter of component is defined. Then, these parameter is simulates using Pspice-ORCAD. Comparison between these two methods will be made.

1.3.6 Hardware Implementation.

Hardware will be implements after, final result is achieve in simulation and hand calculation. The details of hardware will be discussed in PSM2.

Flow diagram of methodology



1.4 Problem Statement.

The expand market demand for power electronics due to several problem;

1. To minimize power losses in linear power supply.
2. To achieve high efficiency, up to 85%.
3. Advances in microelectronics fabrication technology , that required regulated dc power supply.

CHAPTER 2

LITERATURE REVIEW

2.1 Linear Electronic vs Power Electronic

In any power conversion process, a small power loss and high energy efficiency is important because of two reasons.

1. The cost of wasted energy.
2. Difficulty in removing heat generated due to dissipated energy.

The above objective cannot be met by linear regulator where the semiconductor devices are operated in their linear (active) region and line frequency transformer is used for electrical isolation. As an example in figure below

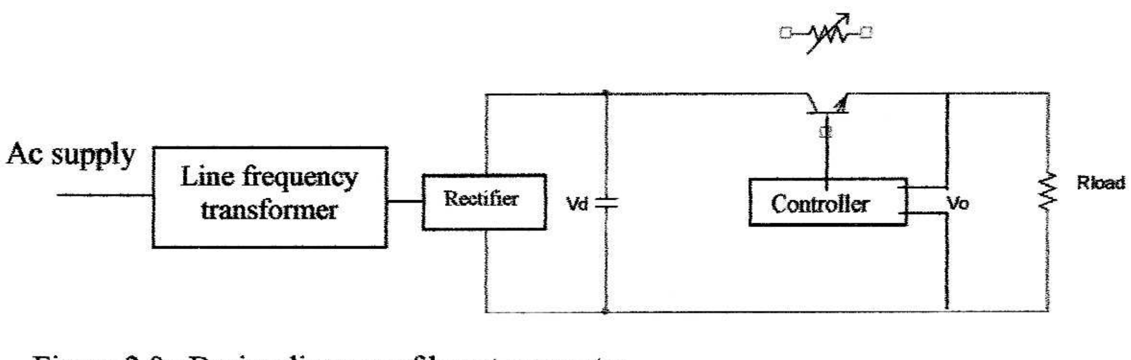


Figure 2.0 : Basics diagram of boost converter.

In linear regulator, a line frequency transformer is used to provide electrical isolation and stepping down the line voltage. The rectifier converts the alternating current (ac) to dc. The filter capacitor reduces the ripple in the dc voltage before transfer to transistor. For an input voltage, the transistor is controlled to absorb the voltage different between Vd and Vo to provide regulated output. The transistor operates in its active region as an adjustable resistor, resulting low energy efficiency.

In power electronic, above voltage regulation and isolation are achieved without line frequency transformer. By operating transistor in switch mode, at some high frequency (>50 kHz), the dc voltage(Vin),is converted into an ac voltage at switching frequency. These allow a high frequency transformer to be use for stepping down the voltage and providing isolation for the circuit. High frequency transformer is more light and small,require a small space in power supply. Since the transistor operates as a switch, the power losses are minimized. Although, there is an energy loss each time transistor switch from one state to other state through it active region. This switching power loss is usually much lower than power loss in linear regulated power supplies. From these, we can conclude that switching frequency is proportionally linear with power losses that decrease the efficiency. The losses can be reduce using snubber circuit that will be discusses in other chapter.

2.2 Basics switching (SMPS) regulator function

Figure 1 shows the block diagram of basics switching regulator. The function of circuit is to convert unregulated input DC to regulated output DC.

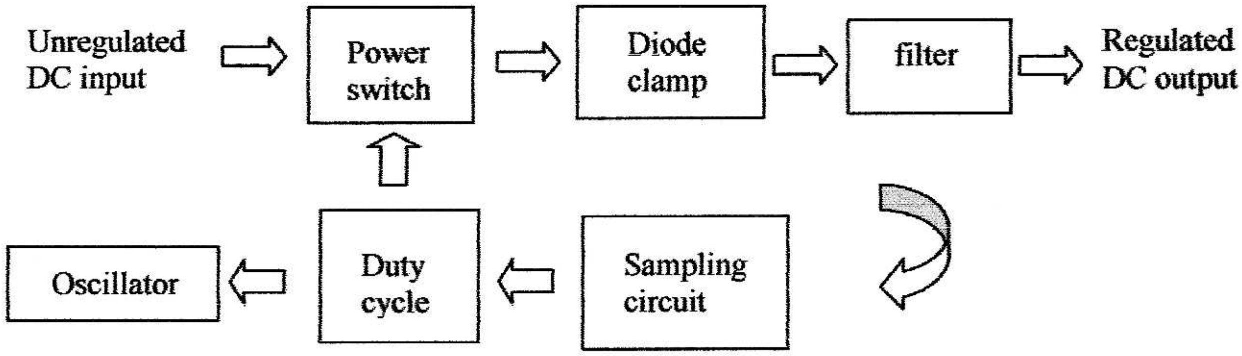


Figure 2.1: Block diagram of SMPS function

In switching regulator (SMPS), the power transistor is used in a switching (turn on/off) rather than continuous mode in linear supply. As result, switching regulator efficiency increase in range 70% - 90%.In addition of increasing efficiency, switching regulator can provide output greater than input. SMPS can provide twice of efficiency than linear regulator

2.3 Switching Regulator Problem

Often SMPS offer a good quality in efficiency but it still has a special problem. In addition of complex circuit, SMPS produce electromagnetic interference (EMI).But with proper design, EMI can be minimize into accepted levels.

2.4 Basics topology of various kind of SMPS

A DC-to-DC converter is a device that accepts a DC input voltage and produces a DC output voltage. Typically the output produced is at a different voltage level than the input. In addition, DC-to-DC converters are used to provide noise isolation, power bus regulation, etc. This is a summary of basics DC-to-DC converter topologies:

- Boost converter
- Buck converter
- Buck-Boost converter

1. BUCK CONVERTER STEP-DOWN CONVERTER (CCM operation)

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.

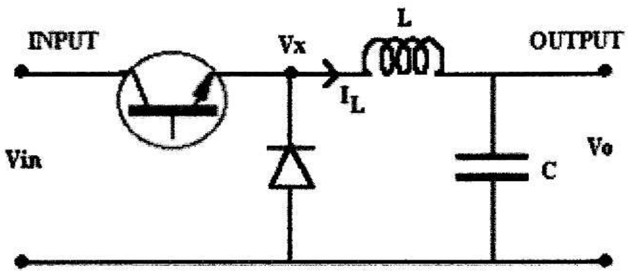


Fig. 2.2: Buck Converter

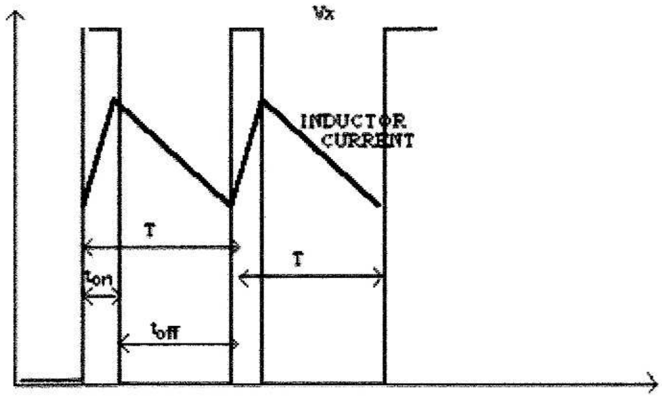


Fig. 2.3: Voltage and current changes

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

$$V_x - V_o = L\frac{di}{dt} \tag{2.1}$$

the change of current satisfies

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

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 Vx=Vin and in the OFF Vx=0. Thus

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

Which simplifies to,

(2.4)