10W SYNCHRONOUS BUCK CONVERTER

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To my beloved mom, dad, lecturers and fellow friends..

DECLARATION

"I, hereby declare that this thesis entitled, 10W SYNCHRONOUS BUCK CONVERTER is a result of my own research idea concept for works that have been cited clearly in the references."

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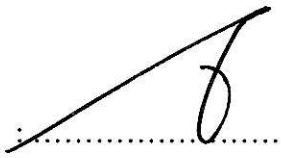
Signature : 

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ABSTRACT

To step down DC input voltage to DC output voltage for power supply, Buck Converter is developed. Since electrical and electronic products today are required to be lighter and smaller, use less power, and cost less, pulse width modulation(PWM) have been apply in power supply to control the semiconductor switch, MOSFET. Nowadays, switched regulator uses a pulse-width modulator integrator circuit as the switch controller. This project will design the Buck Converter which will obtain 10W of output power from 12V input voltage by applying PWM Controller TL5001QD as semiconductor switch controller.

ABSTRAK

Kaedah untuk mendapatkan pengeluaran voltan yang lebih kecil berbanding jumlah penerimaan voltan terhadap sesebuah litar elektronik telah membawa kepada perencanaan litar Buck Converter. Memandangkan produk-produk elektrik dan elektronik pada hari ini sangat mementingkan saiz dan berat yang kurang, kos yang murah dan penggunaan kuasa yang lebih kecil, teori elektronik "Pulse Width Modulation(PWM)" telah diguna-pakai dalam litar ini untuk mengendalikan suis semikonduktor, MOSFET. Projek ini akan membincangkan bagaimana untuk membangunkan Buck Converter yang akan menghasilkan kuasa sebanyak 10watt dengan penerimaan voltan sebanyak 12volt dengan penggunaan komponen TL5001QD sebagai pengendali suis MOSFET

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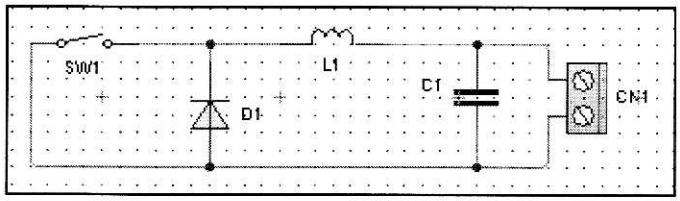
INTRODUCTION

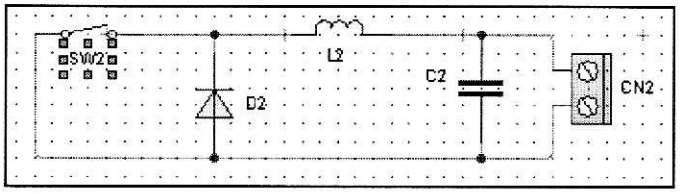
1.1 Project Introduction

Electrical and electronic products today are required to be lighter and smaller, use less power, and cost less. Because of these requirements, manufacturers are turning more to small high-frequency dc-to-dc converters for power-supply solutions. The TL5001 is a pulse-width-modulation (PWM) control integrated circuit, which with a few external components can be used to implement such converters that can operate at frequencies up to 400 kHz.

The buck converter is a popular non-isolated power stage topology, sometimes called a step down power stage. 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 it is a switched-mode power supply that uses two switches (a transistor and a diode) and an inductor and a capacitor.



On state



Off State

Figure 1.1: Buck converter Basic Operation

Buck Converter basic operation can be described as the two circuit configurations of a Buck Converter at Figure 1.1: On state, when the switch is closed, and Off-state, when the switch is open.

As we know, the simplest way to reduce a DC voltage is to use a voltage divider circuit. In electronics, a voltage divider (also known as a potential divider) is a simple linear circuit that produces an output voltage (V_{out}) that is a fraction of its input voltage (V_{in}). Voltage division refers to the partitioning of a voltage among the components of the divider.

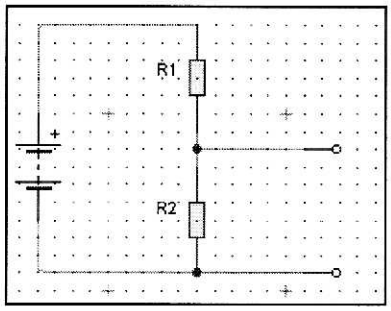


Figure 1.2

Power supply designers choose the buck power stage because the required output is always less than the input voltage. The input current for a buck power stage is discontinuous, or pulsating, because the power switch current that pulses from zero to I_o every switching cycle. The output current for a buck power stage is continuous or non-pulsating because the output current is supplied by the output inductor/capacitor combination.

Pulse-width modulation (PWM) of a signal or power source involves the modulation of its duty cycle, to either convey information over a communications channel or control the amount of power sent to a load. Pulse-width modulation uses a square wave whose pulse width is modulated resulting in the variation of the average value of the wave form.

The simplest way to generate a PWM signal is the interceptive method, which requires only a saw tooth or a triangle waveform (easily generated using a simple oscillator) and a comparator.

A simple method to generate the PWM pulse train corresponding to a given signal is the interceptive PWM: the signal is compared with a saw tooth waveform. When the latter is less than the former, the PWM signal is in high state. Otherwise it is in the low state.

The TL5001 integrated circuit(IC) incorporates all the PWM-control functions in a compact 8-pin package, including:

- Oscillator/triangle-wave generator
- PWM comparator with adjustable dead-time control input
- Open-collector output-drive transistor
- 1-V temperature-stable reference
- Wide-bandwidth error amplifier
- Short-circuit protection (SCP)
- Under voltage lockout (UVLO)

In addition, the TL5001 operates over a 40-kHz to 400-kHz frequency range with supply voltages ranging from 3.6V to 40V and typically consumes only 1 mA of supply current. This report demonstrates the design of three simple step-down (buck) converters. The designs can convert 12-15V to 3.3V at 3A using the TL5001 and a few external components.

1.2 Objective Project

The main objective of this project is to design the 10W synchronous buck converter that can function as switch mode power supply or switching power supply.

A buck converter is a step down DC to DC converter. The design example shows how to include synchronous rectifiers in the power supply. In designing this switching power supply, the important tasks are choosing the suitable ICs to matching with the circuit. The suitable ICs will give high efficiency in supplying power and minimizing the circuit's space. Its design is similar to the step-up boost converter, and like the boost converter is a switch mode power supply that uses two switches (a transistor and a diode) and an inductor and a capacitor.

The challenge to this project are to design maximum efficiency in supplying desire voltage, smaller size of circuit and easy build switching power supply and, also to apply and re-design pulse width modulation technique into switching power supply to produce power of 10W, by using buck converter as voltage divider and one synchronous rectifier.

To design the 10W buck converter, I try to decrease 10V-14V input voltage to around 3.3V output voltage with 3A output current. The multiply of 3.3V with 3A will be around 9-10Watt output power.

Specifications:

Input voltage range, V_I= 10V to 14V
Output voltage, V_O = 3.3V
Output current, I_O = 0A to 3A

1.3 Problem Statement

The main reason of study and designing a buck converter power supply is to improve the efficiency of desired output voltage and make all things about power supply becomes better since there are several problems occurs with the common power supply design.

The commons power supply was lack of overall efficiency in maintaining supplying desire voltage. This is because; most of the common designs used linear regulator to control and supply power. Then, the size of common power supply is bigger than switching power supply. They also were difficult to design because they use complicated ICs and they also radiate more electromagnetic interference.

1.4 Project Scope

Throughout this project, there are several guidelines and specification that must be followed to make sure the project progresses within the scope. The scope of this project is to design to design the 10W buck converter which perhaps will decrease 10V-14V input voltage to around 3.3V output voltage with 3A output current. The multiply of 3.3V with 3A will be around 9-10Watt output power.

Then, the elaboration of why buck converter must be the best method to design power supply instead of applying other methods such as voltage divider or voltage regulator by analyzing the advantages and disadvantages.

Next, applying and choose correct power supply Integrated Circuit (IC) to desired buck converter circuit with PWM controller as the circuit's switch controller. Also start designing the circuit of buck converter and make simulation of the buck converter circuit using Multisim and PCB Wizard before apply to the real circuit. Last but not least, make some testing and troubleshooting if need before precede the final report about all works done along progress this project.

1.5 Methodology

This buck converter circuit will be design to step down the higher input DC voltage to lower output. When 10-14V voltage supplied, the buck converter will decrease the voltage value as output at around 3V. The circuit will be design by applying pulse width modulation (PWM) controller IC to control the switch, which will be MOSFET transistor.

The pulse-width modulator circuit consists of a saw-tooth generator, an error amplifier, and a comparator. The frequency of saw-tooth generator can usually be set by choosing proper values of an RC network. The error amplifier compares the reference

voltage and the feedback signal. The feedback signal is obtained using a voltage divider network across the output of the buck converter circuit.

The transistor switch is the heart of the switched supply and it controls the power supplied to the load. By applying this method to step down the DC input voltage, desire circuit's size can be smaller because core inductor will replace the transformer as voltage step down device.

After design the circuit, software simulation will be made; a complete circuit in software will be design and run the simulation to check the continuity and result before design it to the real printed circuit board, PCB. Lastly is making a demonstration and testing.

CHAPTER II

LITERATURE REVIEW

2.1 What is Buck Converter?

Buck converter or step down DC-to-DC converter is a device that accepts a higher DC input voltage and produces a lower DC output voltage than input voltage value. 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 and power bus regulation.

Its design is similar to the step-up boost converter, and like the boost converter it is a switched-mode power supply that uses two switches (a transistor and a diode) and an inductor and a capacitor.

In circuit from Figure 2.1, the transistor turning ON will put voltage V_I 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 V_X will now be only the voltage across the conducting diode during the full OFF time. The average voltage at V_X will depend on the average ON time of the transistor provided the inductor current is continuous.

Figure 2.1 shows a simplified schematic of the buck power stage. Inductor L and capacitor C make up the effective output filter. This is the single state LC design. The capacitor equivalent series resistance (ESR), RC, and the inductor dc resistance, RL, are included in the analysis.

Resistor R represents the load seen by the power supply output. The diode D_1 is usually called the catch diode, or freewheeling diode.

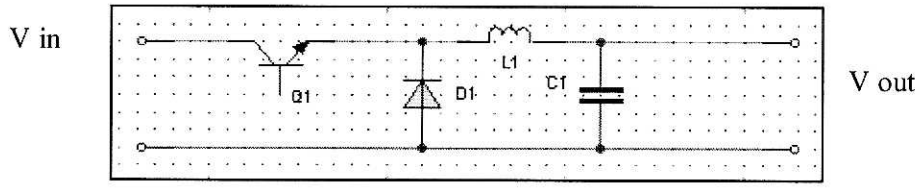


Figure 2.1 Single State LC design

2.2 Different of Buck Converter with Step Up Boost Converter

As stated above, the design of buck converter was similar with boost converter (step-up converter), which is a power converter with an output dc voltage greater than its input dc voltage. It is a class of switching-mode power supply (SMPS) containing at least two semiconductor switches (a diode and a transistor) and at least one energy storage element. Filters made of inductor and capacitor combinations are often added to a converter's output to improve performance as show in Figure 2.2

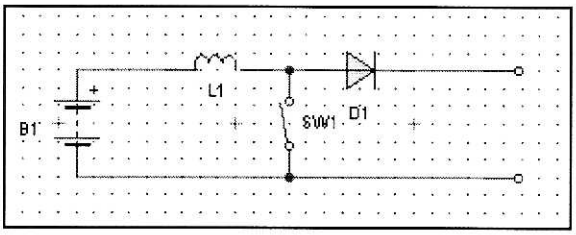


Figure 2.2

Power can also come from DC sources such as batteries, solar panels, rectifiers, and DC generators. A process that changes one DC voltage to a different DC voltage is called dc to dc conversion. A boost converter is a DC to DC converter with an output voltage greater than the source voltage. A boost converter is sometimes called a step-up converter since it "steps up" the source voltage. Since power (V×I) must be conserved, the output current is lower than the source current.

2.3 Switched-mode power supply (SMPS)

For high efficiency, the SMPS switch must turn on and off quickly and have low losses. The advent of a commercial semiconductor switch in the 1950's represented a major milestone that made SMPSs such as the boost converter possible. Semiconductor switches turned on and off more quickly and lasted longer than other switches such as vacuum tubes and electromechanical relays.

This simplification reduced two systems into one. The new model led to insightful design equations which helped SMPS growth.

Figure 2.3 shows interior view of an ATX switched-mode power supply.

A - Bridge rectifier
B - input filter capacitors
C - transformer
D - output filter coil
E - output filter capacitors

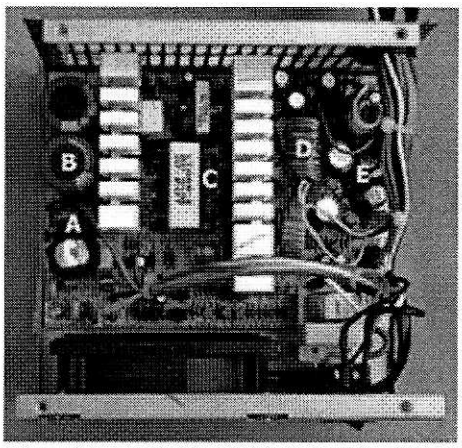


Figure 2.3: ATX switched-mode power supply

A switched-mode power supply, switching-mode power supply or SMPS, is an electronic power supply unit (PSU) that incorporates a switching regulator. While a linear regulator maintains the desired output voltage by dissipating excess power in a "pass" power transistor, the SMPS rapidly switches a power transistor between saturation (full on) and cutoff (completely off) with a variable duty cycle whose average is the desired output voltage.

Other advantages include smaller size and lighter weight (from the elimination of low frequency transformers which have a high weight) and lower heat generation from the higher efficiency. Disadvantages include greater complexity, the generation of high amplitude, high frequency energy that the low-pass filter must block to avoid EMI, and a ripple voltage at the switching frequency and the harmonic frequencies thereof.