Design and Implementation of Buck Converter and Quasi Square Wave Converter

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ABSTRACT

As the DC-DC converter playing an important role in electrical energy system in this paper design and implementation of buck converter is presented. This DC-DC converter is designed and simulated in Matlab. To verify the desired result, also discussion on Quasi Square wave (QSW) converter is done in this paper. This paper contains theoretical analysis and simulation result of this buck converter and quasi square wave converter.

I. INTRODUCTION

Buck converter are step down DC-DC converter that are widely being used in different electronic devices like laptops, cell phones and also electric vehicles to obtain different level of voltages. Because buck converter are highly efficient and self regulating therefore these converter are most popular. The converter circuits which employ zero voltage and zero current switching are known as resonant converter. In most of these converter L-C resonance is used that is why these are known as resonant converters. Like switch mode dc-dc converter resonant converters are used to convert DC-DC through an additional conversion stage in which dc signal is converted to high frequency ac signal.

A DC-DC converter is a device that takes a dc input voltage and produces a dc output voltage. A buck converter is the simplest DC-DC power electronic converter whose aim is to step down dc voltage. The easiest way to reduce the voltage of a dc supply is to use a linear regulator but linear regulator waste energy by dissipating excess power as heat. On the other hand buck converter are highly efficient, self regulating by which it convert 12v to 24v typical battery

voltage in a laptop down to the few volts which needed by the processor. Buck converter uses SMPS topologies this topology is also called a down converter because in this output voltage is lower than the input voltage. Buck converter uses non isolated topologies means the input and output voltages share a common ground. The buck converter consists of an inductor, diode, switch and capacitor. The converter also uses one capacitor and one inductor to store and transfer energy from input to output. [1-2]

II. BUCK CONVERTER OPERATION

The operation of a buck converter is simple with an inductor and two switches that control the inductor input current Fig.1. It alternates between connecting the inductor to source voltage to store energy in the inductor and discharging the inductor into the load. In practical application a MOSFET or bipolar transistor replaces the S1 and a diode replaces the S2
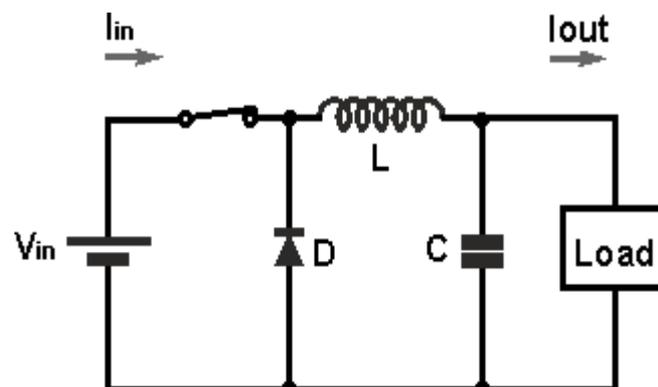

Fig. 1 Schematic diagram of Buck converter.

When the switch in the buck regulator is on – the voltage is v_{in}- v_{out}.using the inductor equation the current will rise at a rate $(v_{in}-v_{out})/L$. in this diode is reverse biased and does not conduct. When the switch is open – current still flows through the inductor and the load. With switch open the polarity of the voltage is reversed. [3-5]. We assume that the converter is in the continuous mode, meaning that the inductor's current never goes to zero. The relationship of voltage and current for an inductor is:

$$V = L\frac{di}{dt}$$,or

$$i = \frac{1}{L}\int_0^t V dt + i_o$$

For a constant rectangular pulse:

$$i = \frac{Vt}{L} + i_o$$

$$V_{out} = DV_{in}$$

So it is clear that the output voltage is related directly to the duty cycle of the pulses. The inductance is inversely Do not mix complete proportional to the ripple current. In other words, if you want to reduce the ripple, then use a larger inductor. Thus, in practice a ripple current is decided upon which will give a reason. For higher efficiency the diode should be an ultra fast recovery diode. In the diagram of the current waveforms for the buck converter / switching regulator, it can be seen that the inductor current is the sum of the diode and input / switch current. Current either flows through switch or the diode. that is also worth noting that the average input current is less than the average output current. This is to be expected because the buck converter circuit is very efficient and the input voltage is greater than the output voltage. Assuming a perfect circuit, then power in would equal power out, i.e. Vin · In = Vout · Iout. While in a real circuit there will be some losses, efficiency levels greater than 85% are to be expected for a well-designed circuit.

It will also be seen that there is a smoothing capacitor placed on the output. This serves to ensure that the voltage does not vary appreciable, especially during and switch transition times. It will also be required to smooth any switching spikes that occur.Quasi square wave converter- quasi square wave resonant converter also known as quasi resonant converter allow the design of fly-back The subscript for SMPS with a reduced and an improved efficiency at full load. However as the switching frequency when load decrease the frequency excursion must be limited to avoid additional switching losses.
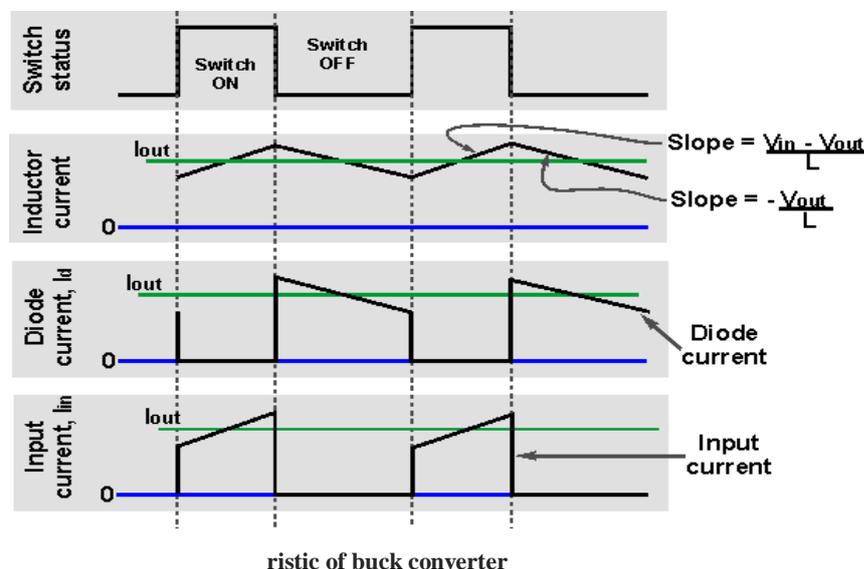

Fig. 2: Characte ristic of buck converter

III. QUASI SQUARE WAVE CONVERTER

Recently resonant power converter has attracted much more attention because of their ability to operate efficiently at higher switching frequency. There is QSW resonant power supplies generally refereed as QR power supplies and these are generally used in notebook adapters or in TV power supplier. Resonant converter uses a resonant circuit in which L and C components are used. These resonant converters are used for switching the transistor when they are at the zero current or zero voltage point by this it reduces the stress on the transistor on which we are providing the switching and reduces the radio interferences. There are many different types of resonant converter for example the resonant circuit can be placed at the primary or secondary side and another alternative is that a series and a parallel resonant and it depend on whether it is required to turn off the transistor when the current or voltage is zero. Resonant converter provides better sinusoidal waveform. Resonant converter also provides natural commutation of switches which results in low switching power dissipation and achieves power efficiency. Higher operating frequency which results in reduced size and reduction in EMI. Resonant converter also uses natural oscillation to achieve zero current switching with this it eliminates switching losses. Resonant converter use LCC components so this is soft switching and soft switching can be of two types. [5-6]

    1. ZVS
    2. ZCS

The feature of this converter is the ZVS operation with the help of this it allows the reduction of switching loss an helps to soften the EMI. By nature QR power supplies has highly variable switching frequency which depends on input and output leading condition. As the switching frequency increases load decreases and these topologies are generated by addition of resonant elements to a PWM converter. QR converter allows smooth quasi sinusoidal waveforms and switching transition at zero voltage or zero current. For examples in ZC topology the switch is turned on & off at zero current while the switch S is turned on and off at zero voltage. So power losses will be reduced. There are several implementation of ZVS QSW converter this is buck, flyback & Boost converter. In each case the resonant elements are L&C .ZVS topology is applicable to all switching topology & this topology have several benefits like zero power lossless switching transitions reduced EMI/RFI at transitions .No power loss due to discharging, No higher peak current High efficiency, with voltage input at any frequency. [7-8]

Quasi square wave resonant converter power supplies generally referred as quasi resonant (QR) power supplies are widely used in notebook adapters or in TV power supplies. The principal feature of this architecture is the zero voltage switching (ZVS) operation which allows the reduction of switching losses and helps to soften the EMI signature.

Quasi square wave converters
The need for ever smaller 50-500W dc-dc switching supplies have led to the development of circuits that operate in the 1MHz range and above. Since the parasitic elements that normally occur in a power circuit can be very significant components at this frequency, most of this work is focused on resonant topologies. Such topologies, by actually making use of these parasitic elements, recover through resonant ringing the energy that would have been lost every switch transition in a square-wave topology [2]. The switching losses are therefore apparently reduced to a negligible value and the operating frequency can be increased without loss of efficiency. In QSW operation mode, the output inductance is much smaller so that the inductor current is reset to negative In each switching cycle, before the gate signal of the synchronous rectifier is removed. The current in the synchronous rectifier flows from the drain to the source. The body diode of the MOSFET does not carry current. Thus, the body diode reverse recovery problem is eliminated.
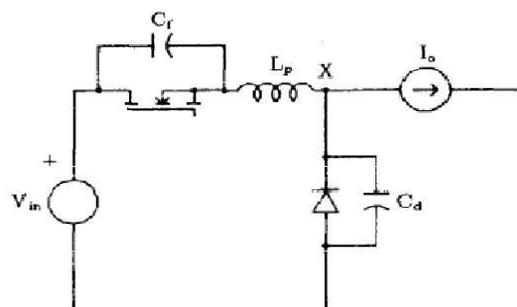

Fig. 3 Schematic diagrm of QSW converter

Quasi-square-wave converters are derived by permutation of the three-terminal networks shown in Fig.4. These networks are for obvious reasons called T and Pi sections and contain two switches and the resonant tank elements L_O and Co. The ports of the T sections are specified as voltage ports whereas those of the Pi sections are specified as current ports.
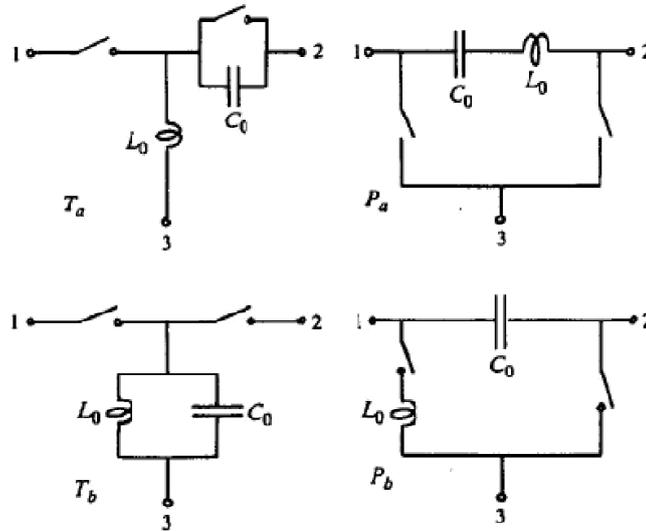

Fig. 4: QSW converter

Various converters are generated by permutation of these sections between sources and sinks. ZVS converters are obtained from T sections and ZCS converters are obtained from pi sections. However, the inductor current ripple in QSW mode is much larger than in conventional operation. If a synchronous rectifier is used, QSW increases the conduction loss by about 33%. These two drawbacks make the QSW mode rectification questionable in the full-bridge or centre-tapped rectification.

Equivalent circuit model of QSW converter

The ZVS-QSW converter is shown in Fig. The apc terminal designations refer to active, passive, and common. It should be pointed out that the mere physical connection of two switches does not constitute a zero-current switching or zero-voltage switching three-terminal device It is indeed the implementation of this three-terminal device in various zero-current-switched or zero-voltage-switched QSC's that provides the proper external conditions on the device for it to operate as a zero current or a zero-voltage switching device. The significance of the three-terminal device lies in the fact that certain particular relationships between the terminal voltages and currents are independent of the type of converter (buck, boost, Cuk etc.) in which the device is implemented

Consequently, an equivalent circuit model representing the average voltage and current gains between any two ports of this three-terminal device can be obtained. This average equivalent circuit model can then be used to determine the conversion-ratio characteristics of the different types of converters such as the buck, boost, etc. We first derive in detail the equivalent circuit model for the zero-voltage-switched quasi-square-wave device (ZVS-QSD) and then simply state the results for the zero current- switched QSD. [9-10]
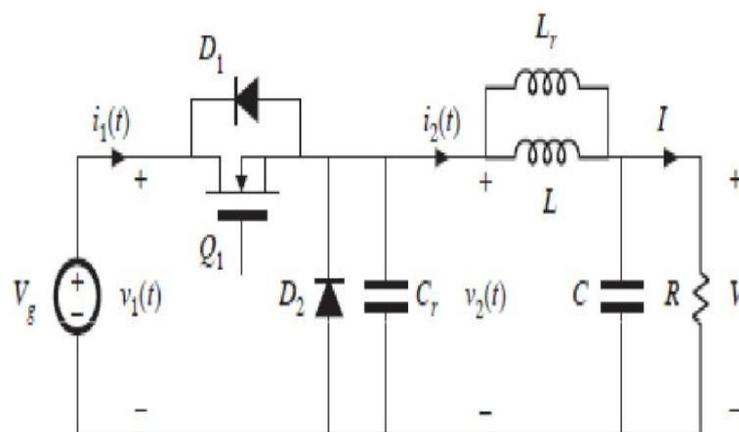
Fig. 5: LLC QSW converter
IV. SIMULATION OF BUCK CONVERTER

To evaluate the designed converter, a simulated circuit is built in MATLAB with the following specification: Vi= 48V, V$_o$= 24 V, Iout= 2.2A, f= 1MHz.

TABLE 1. Design parameter of buck converter

Parameters	Symbols	Values
Input Voltage in (Volt)	Vi	48
Output Voltage in (Volt)	Vo	24
Switching Frequency in (MHz)	fs	1
Output Power in (Watt)	Po	23.2*2.2
The voltage ripple	(Vr/Vo)	1%

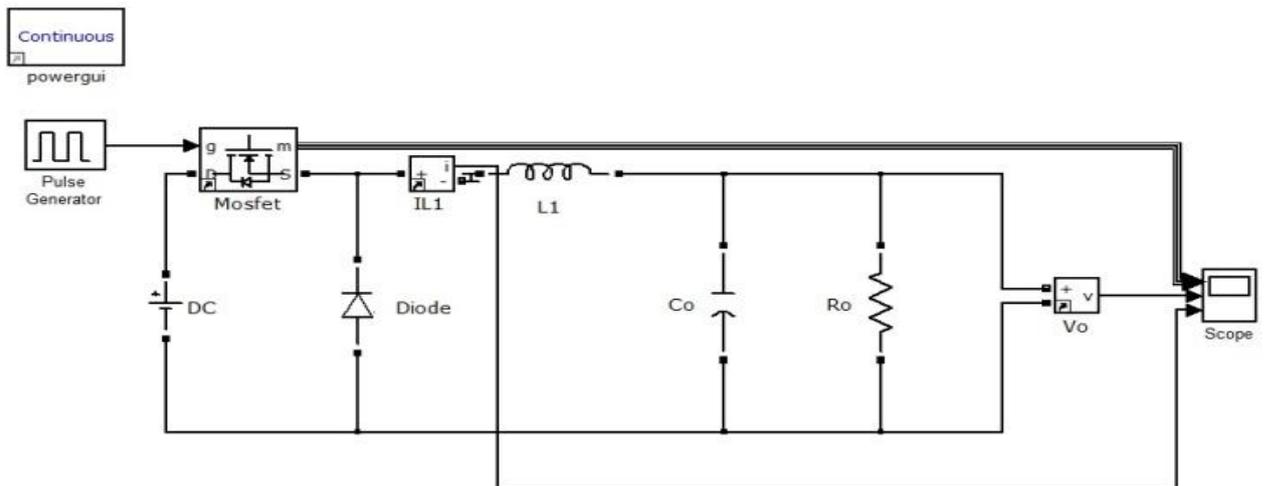Simulation model is given in Fig.6 below:

Fig. 6 Simulation model of Buck converter

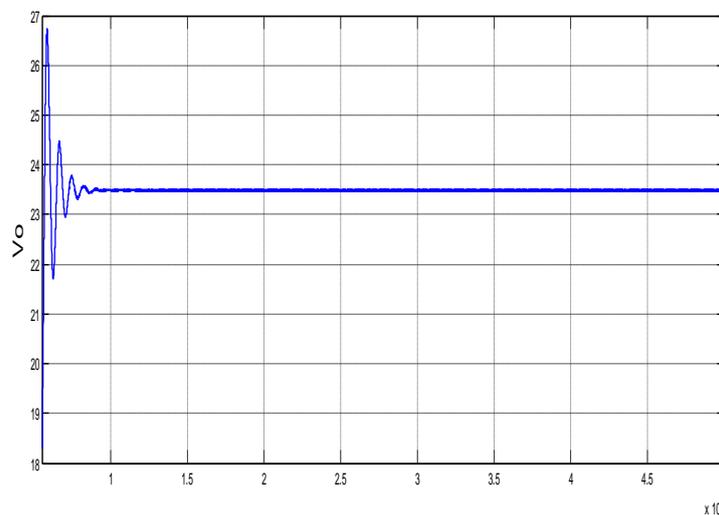The output voltage of buck converter is given in Fig. 7 below

Fig. 7 Result obtained in simulation (Output Voltage)

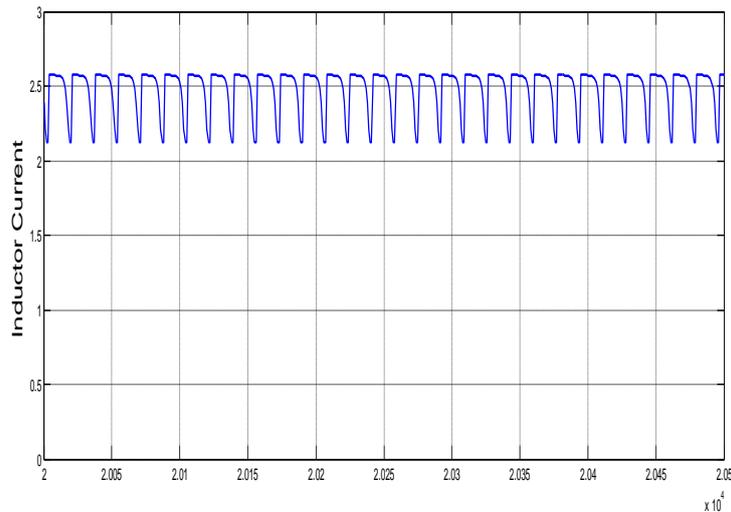The inductor current of the buck converter is given in Fig.8 below

Fig. 8 Result obtained in simulation (Inductor current)

CONCLUSION

The power supply topologies in general use and these are buck, boost and buck- boost. The power supply topologies refer to how the capacitor, inductor and switches are connected. Each topology has a unique feature. The most common and simplest topology is the buck power stage. It is sometimes called a step down power stage. The designers of power supply topology choose the buck converter because output voltage is less than the input voltage and is not isolated from the input. Buck converter uses SMPS topology this topology can be used not only to convert voltage but also suitable to act as current source depending on the control method. Buck converters are rugged, cost effective and easy to use and there is less need of external components to achieve high operating efficiency. In this paper design and simulation of 48 to 24 Volt buck converter is presented and simulation results are presented for the same system.

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