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DESIGN OF TAPPED INDUCTOR BASED BUCK-BOOST CONVERTER FOR DC MOTOR

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Abstract

In today's world, many applications call for high step-up Dc to DC converters that do not require isolation. Some DC to DC converters can provide high step up voltage gain, but with the penalty of either an extreme duty ratio or a large amount of circulating energy. DC to DC converter with coupled inductor can provide high voltage, but their efficiency is degraded by the losses associated with leakage inductor. Converters with active clamp recycled the leakage energy at the price of increasing topology complexity. This paper presents a new wide-input–wide-output dc–dc converter, which is an integration of buck and boost converters via a tapped inductor. Coherent transition between step-down and step-up modes is achieved by a proper control scheme. Also a modification of the circuit with the implementation of a PI filter in order to avoid ripple voltage is done. This method overcomes the disadvantage of pulsating input and output current which cause high conduction losses, extreme duty cycle increase the voltage stress of the switch diode reverse recovery problem and finally reduce the efficiency of buck–boost converter. The circuit is simulated using MATLAB. The proposed circuit is implemented using PIC controller.

Keywords: DC to DC, Converters, MATLAB, PIC controller

I. INTRODUCTION

The buck, boost, buck–boost, and Cuk converters are the four basic dc–dc non isolating converters that have found wide applications in industry. The buck converter can step down the dc voltage, whereas the boost converter is capable to perform a step-up function. In applications where both step-up and step-down conversion ratios are required, the buck–boost and Cuk converters can be used.

Simplicity and robustness are among the advantages of the buck–boost converter. However, the pulsating input and output currents cause high conduction losses, and thus, impair the efficiency of buck–boost. Furthermore,the buck–boost converter uses the inductor to store the energy from the input source, and then, release the stored energy to the output. For this reason, the magnetic components of buck– boost are subjected to a significant stress. These disadvantages limit the applications of the buck–boost converter mainly to low power level. The isolated version of buck–boost, referred to as the fly back converter, can achieve greater step-up or step-down conversion ratio utilizing a transformer, possibly, with multiple outputs.

As compared with the buck–boost converter, the Cuk converter has higher efficiency and smaller ripples in input and output currents. A significant improvement of the Cuk converter performance can be achieved by applying the zero ripple concept . The Cuk converters can be found in many high-performance power applications.

In theory buck and boost converters can generate almost any voltage, in practice the output voltage range is limited by component stresses that increase at the extreme duty cycle. Consequently, buck converter losses mount at low duty cycle, whereas boost converter efficiency deteriorates when the duty cycle tends to unity. Accordingly, voltage conversion range of the buck converter below 0.1–0.15 becomes impractical whereas that of the boost converters' is limited to below 8–10.voltages and higher frequencies.

II. THEORY OF buck-boost converter

A buck converter is a step-down DC to DC converter is a switched mode power supply that uses two switches (a transistor and a diode), an inductor and a capacitor.

The simplest way to reduce the voltage of a DC supply is to use a linear regulator(such as a 7805), but linear regulators waste energy as they operate by dissipating excess power as heat.

Buck converters, on the other hand, can be remarkably efficient (95% or higher for integrated circuits), making them useful for tasks such as converting the main voltage in a computer (12 V in a desktop, 12-24 V in a laptop) down to the 0.8-1.8 volts needed by the processor

2.2.1THEORY OF OPERATION

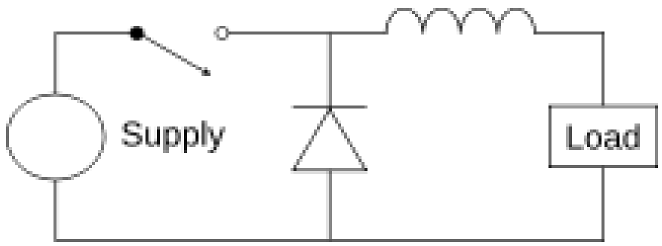

Figure 2.1: Buck converter circuit diagram.

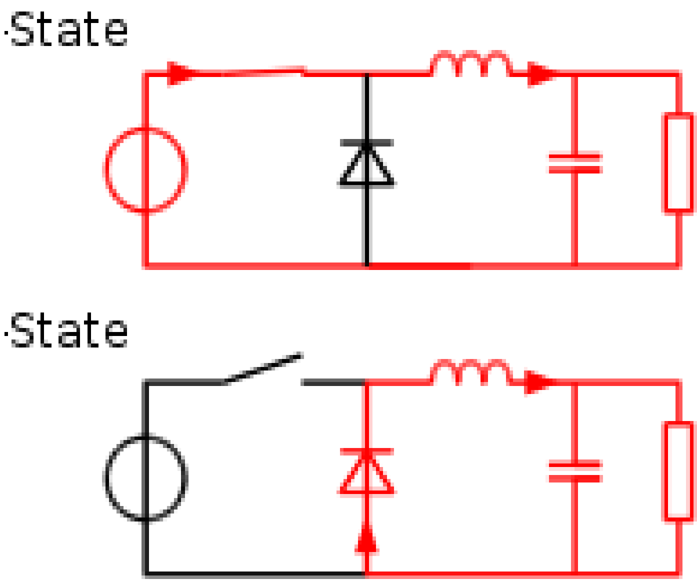

Figure 2.2: Two circuit configurations of a buck converter :(On-state, and Off-state)

The operation of the buck converter is fairly simple, with an inductor and two switches (usually a transistor and a diode) that control the inductor. It alternates between connecting the inductor to source voltage to store energy in the inductor and discharging the inductor into the load.

For the purposes of analysis it is useful to consider an idealised buck converter. In the idealised converter, all the components are considered to be perfect. Specifically, the switch and the diode have zero voltage drop when on and zero current flow when off and the inductor has zero series resistance. Further, it is assumed that the input and output voltages do not change over the course of a cycle (this would imply the output capacitance being infinitely large).

2.2.2.CONTINUOUS MODE

- When the switch pictured above is closed (On-state, top of figure 2), the voltage across the inductor is $V_L = V_i - V_o$. The current through the inductor rises linearly. As the diode is reverse-biased by the voltage source V, no current flows through it;
- When the switch is opened (off state, bottom of figure 2), the diode is forward biased. The voltage across the inductor is $V_L = -V_o$(neglecting diode drop). Current I_L decreases.

The energy stored in inductor L is

$$E = \frac{1}{2} L \times I_L^2$$

Therefore, it can be seen that the energy stored in L increases during On-time (as I_L increases) and then decreases during the Off-state. L is used to transfer energy from the input to the output of the converter.

2.3 BOOST CONVERTER:

A boost converter (step-up converter) is a DC-DC converter with an output voltage greater than its input voltage. It is a class of switched mode power supply (SMPS) containing at least two semiconductor switches (a diode and a transistor) and at least one energy storage element, a capacitor, or the two in combination. Filters made of capacitors (sometimes in combination with inductors) are normally added to the output of the converter to reduce output voltage ripple.

Power for the boost converter can come from any suitable 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 Dcwith 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 ($P = VI$) must be conserved, the output current is lower than the source current.

2.3.1 THEORY OF OPERATION

The key principle that drives the boost converter is the tendency of an inductorto resist changes in current. In a boost converter, the output voltage is always higher than the input voltage. A schematic of a boost power stage is shown in Figure 1. When the switch is turned-ON, the current flows through the inductor and energy is stored in it. When the switch is turned-OFF, the stored energy in the inductor tends

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to collapse and its polarity changes such that it adds to the input voltage. Thus, the voltage across the inductor and the input voltage are in series and together charge the output capacitor to a voltage higher than the input voltage.

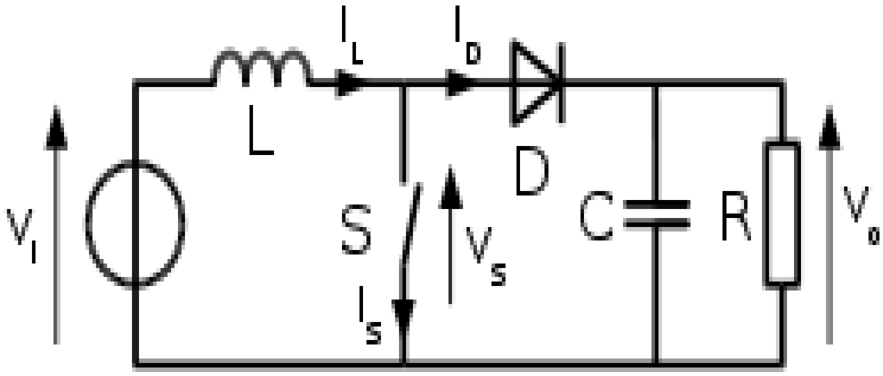


Figure 2.4: Boost converter circuit diagram

The basic principle of a Boost converter consists of 2 distinct states

- In the On-state, the switch S (see figure 1) is closed, resulting in an increase in the inductor current;
- In the Off-state, the switch is open and the only path offered to inductor current is through the flyback diode D, the capacitor C and the load R.This results in transferring the energy accumulated during the On-state into the capacitor.
- The input current is the same as the inductor current as can be seen in figure 2. So it is not discontinuous as in the buck converter the requirements on the input filter are relaxed compared to a buck converter.

2.3.2 CONTINUOUS MODE

When a boost converter operates in continuous mode, the current through the inductor (I_L) never falls to zero. Figure 2.6 shows the typical waveforms of currents and voltages in a converter operating in this mode. The output voltage can be calculated as follows, in the case of an ideal converter (i.e. using components with an ideal behaviour) operating in steady conditions

2.3.3 DISCONTINUOUS MODE

If the ripple amplitude of the current is too high, the inductor may be completely discharged before the end of a whole commutation cycle. This commonly occurs under light loads. In this case, the current through the inductor falls to zero during part of the period although slight; the difference has a strong effect on the output voltage equation. It can be calculated as follows:

As the inductor current at the beginning of the cycle is zero, its maximum value $I_{L_{Max}}$(at $t = DT$) is

$$I_{L_{Max}} = \frac{V_i DT}{L}$$

2.4 BUCK-BOOST CONVERTER

The direct dc to dc converters offer basic conversion functions. The limitations that $V_{out}< V_{in}$ for the buck, and $V_{out}> V_{in}$ for the boost are the most obvious restrictions. How can we create a more complete dc transformer function, one way is to cascade the two direct converters to form a simple indirect converter. The two converters can be adjusted independently to give any desired output ratio.

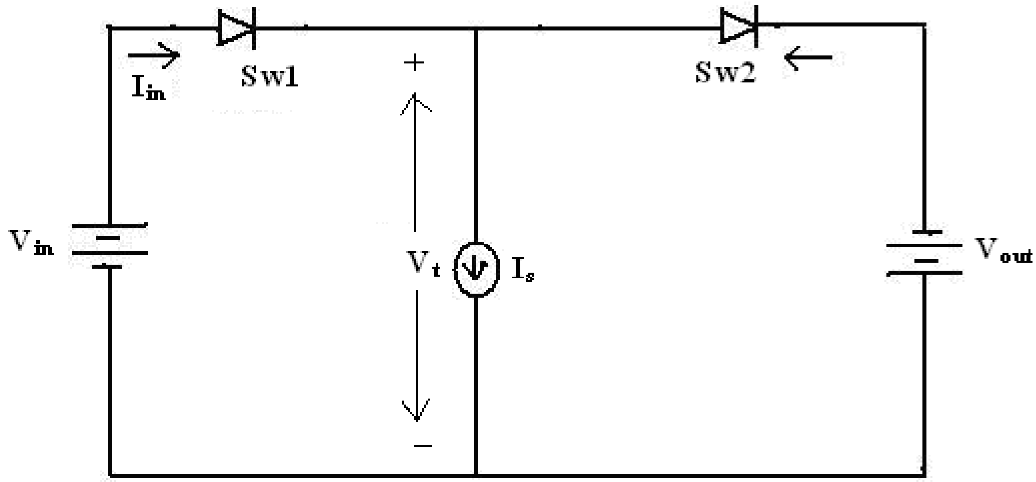


Figure 2.7 Buck Boost Converter

Some of the switches in the cascade arc redundant and can be removed. Other switches can be eliminated by recognizing that we do not wish to consume average power in the transfer current source. In fact, only two switches arc needed in the final result, This is referred to as a buck-boost converter or up-down converter since output any magnitude is possible.

Let us examine the operation of this circuit with a focus on the transfer source, since its voltage is entirely determined by the switch action. The KVL and KCL restrictions require that one and only one switch be on at a time. The voltage across the transfer source value is I_s. To meet the basic objectives of power electronics, the transfer source should not consume energy, so Pt=O. The relationships are

$$q_1 + q_2 = 1$$

$$V_t=q_t*V_{in}-q_2.V_{out}$$

$$P_t=V_t.I_s=q_l* V_{in}I_s -Q_2. V_{out}*I_s$$

$$(P_t)= D_1*V_{in} I_s -D_2*V_{out}*I_s = O$$

The last part of above equation can be satisfied for nonzero is if

$D_1V_{in}= D_2V_{out}$. Since we expect $D_1+D_2=1$, this can be written

$$V_{out} = \frac{D_1}{\quad} V_{in}$$

$$1\text{-}D_1$$

The other variables determined by switch action include the input and output currents. These bring about the relationships

$$I_{in} = q_1 * I_s, \quad \langle I_{in} \rangle = D_1 * I_s$$

$$I_{out} = q_2 * I_s, \quad \langle I_{out} \rangle = D_2 * I_s$$

$$\langle I_{in} \rangle + \langle I_{out} \rangle = I_s$$

$$D_1 * \langle I_{out} \rangle = D_2 * \langle I_{in} \rangle$$

The cascade process required the polarity of the output boost converter to be inverted the buck-boost converter produce a negative voltage with respect to the input, as we have seen previously in polarity reversal examples. The output in principle can range from *0* to infinite. It is zero if D_1= and infinite if D_1=1. When D_1=0.5, the output magnitude is equal to the input. Except for the reversed polarity of V_{out}, the buck-boost converter provides a good transformer function.

The devices in the circuit can be determined with brief analysis. Switch I_s when on and blocks $V_{in} + V_{out}$ when off. A forward carrying forward blocking device is needed. The second switch can be a diode. The output load requires a capacitor to give it voltage source properties. What about the transfer current source it must maintain constant current without power loss. There is no power dissipated in an inductor, so it is just the device needed. We do not require a special current source only an inductor.

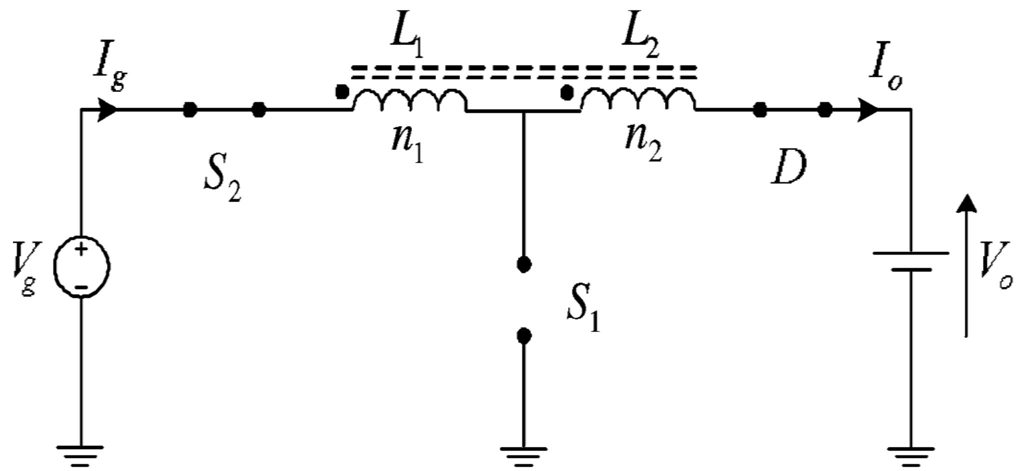
3.2 STEADY STATE OPERATION

In the following, the steady-state operation of the proposed WIWO converter is described. The analysis is performed assuming that the circuit is comprised of ideal components. The coupling coefficient of the tapped inductor is assumed to be unity. Under continuous inductor current (CCM) condition, the proposed WIWO converter exhibits four topological states, as shown in Fig. Here, the large output filter capacitor is replaced by an ideal voltage source.

3.2.1 BUCK MODE:

State 1 ($t0 \le t < t1$):

The buck mode charging state is shown in figure below. Here, the switch S2 is turned on and S1 is turned off. The diode D conducts and the coupled inductors L1 and L2 are charged. The energy is also transferred from dc source to load.

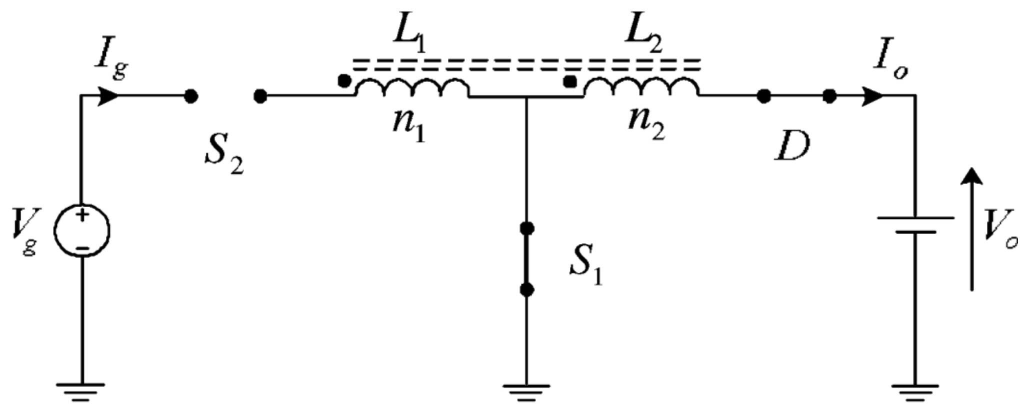


3.2 Buck Mode (Charging state)

State 2 ($t_1 \leq t \leq t_2$):

The buck-mode discharging state is shown in figure. Here, the switch S2 is turned off also cutting off the current in the L1 winding, whereas S1 is turned on and

the diode D conducts L2 current to the load.



3.3 Buck Mode (Discharging state)

3.2.2 BOOST MODE:

State 3 ($t_0 \leq t \leq t_1$):

The boost-mode charging state is shown in figure below Here, the switches S1 and S2 are turned on charging the L1 inductor. The diode D is cut off by the negative voltage induced in L2 winding. The output voltage is supported by the capacitor C.

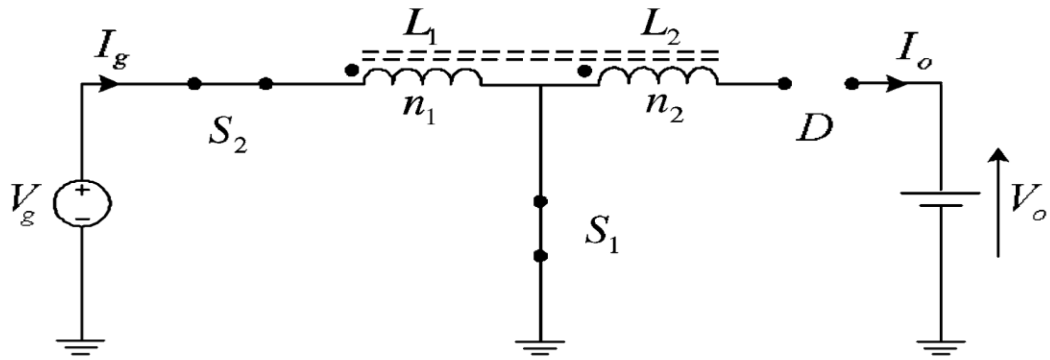


Figure 3.5 Boost mode (Charging state)

State 4 ($t_1 \leq t \leq t_2$):

The boost-mode discharging state, the switch S2 is still ON whereas S1 is turned off. Both windings L1 and L2 conduct through the diode D and discharge the stored energy to the output.

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