Types And Design Analysis Of DC-DC Converter

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ABSTRACT

Over last few years DC to DC converters are most interesting subject because of its utilization in different applications. A review on power DC to DC converters is presented in this paper. The study is focused on its Design, Types and applications in different fields. We discussed two types of DC to DC converters that are isolated and Non-isolated and further they are subdivided into their types. Furthermore each type of converter is addressed in detail with their equivalent circuits. Working Operation of Buck converter, Boost converter and Buck-Boost converter has explained in detail with waveforms. Fly back and forward converters are also added in paper. Comparison has done with circuits and components between Isolated and Non-isolated converters. Modes of operation in Buck-Boost converters are given. Finally we addressed some applications of DC to DC converters in modern world.

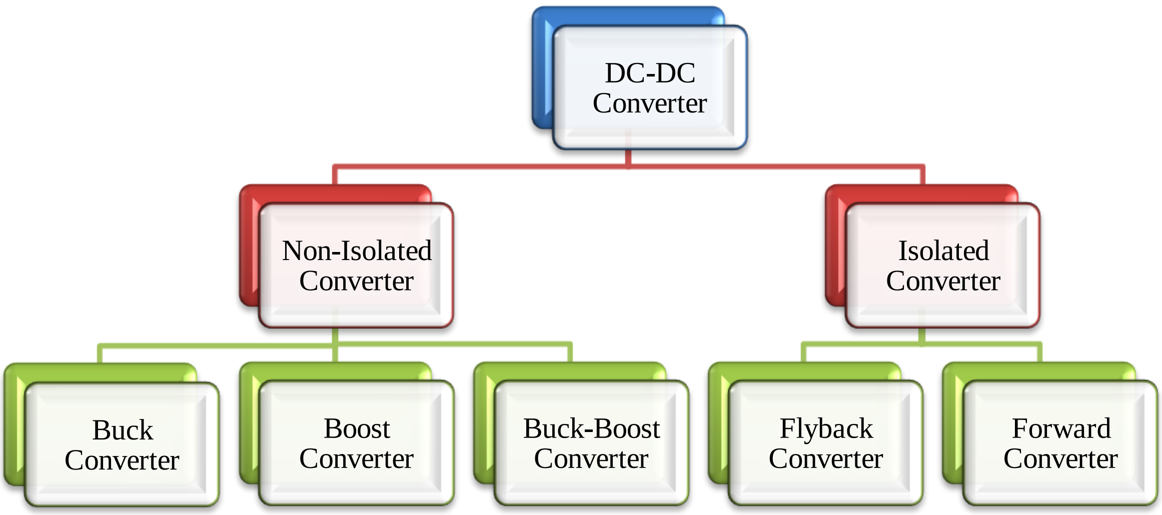
Keywords: circuits, Buck converter, Boost converter and Buck-Boost converter etc.

Introduction:

A circuit is used to convert direct current (DC) from one voltage to another is a DC-DC converter. It is necessary to convert electric power from one form to another and for this switching characteristics are in demand [1]. Switching conversion save power while linear voltage regulation liberates unwanted power as heat. Power conversion are performed by the static power converters [2]. As demand of power system is increasing so engineers have worked on the development of efficient conversion techniques and this research has resulted in growth of interdisciplinary field of power electronics. This field of research has faced so many challenges while working with the combination of two main branches of electrical engineering i.e. electronics and power.

A dc-dc converter can be considered as dc equivalent to an ac transformer with a continuously variable turn's ratio [3].

Converters Related To Switching Conversion:



1) Non Isolated Converters:-

Non-isolated converters are used when the change in the voltage is small. The input and output terminals share a common ground in this circuit. The following are the different types of converters in this group. The disadvantage is cannot give protection from high electrical voltages and has more noise.

1.1.Step Down (Buck) Converter:

A Buck Converter is a voltage step down and current step up converter. Buck converter is the most basic SMPS topology. It is widely used throughout the industry to convert a higher input voltage into a lower output voltage. The Buck Converter is used in SMPS circuits where the DC output voltage needs to be lower than the DC input voltage. It is useful where electrical isolation is not needed between the switching circuit and the output, but where the input is from a rectified AC source, isolation between the AC source and the rectifier could be provided by a mains isolating transformer.

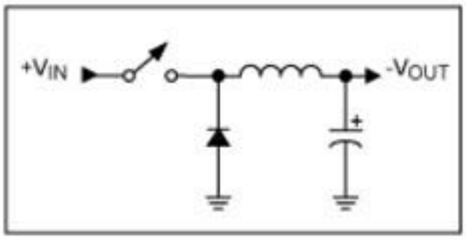


Fig. 1 Buck Converter

1.1.1. Operation of Buck Converter:

The basic operation of the buck converter has the current in an inductor controlled by two switches (usually a transistor and a diode). In the idealized 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 as being infinite).

1.1.2 Ideal circuit analysis:

In a buck converter, the average output V_a is less than the input voltage, V_S. The circuit diagram of a buck regulator has shown below and this is like a step-down converter.

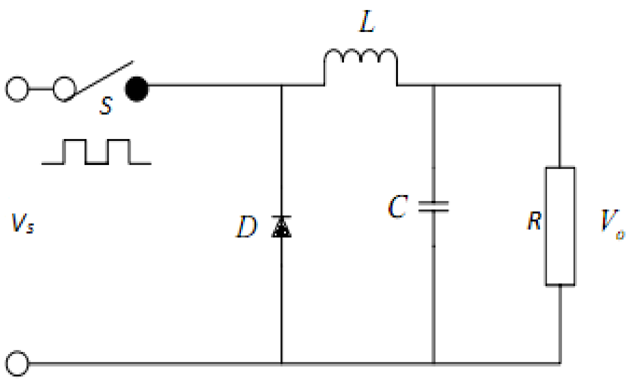


Figure 2: Circuit diagram of an ideal buck regulator.

The freewheeling diode *D* conducts due to energy stored in the inductor; and the inductor current continues to flow through inductor (*L*), capacitor (*C*), load and diode (*D*). The inductor current falls until transistor *S* is switched on again in the next cycle.

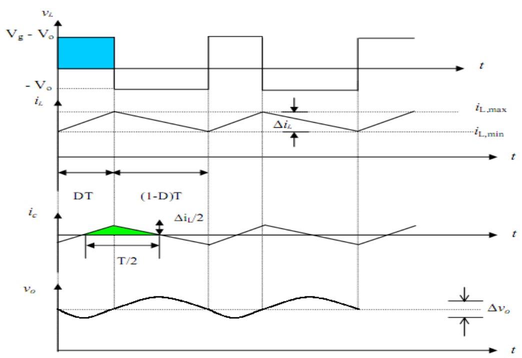


Figure 3: Waveforms of voltage and current of buck converter

1.2.Step up (Boost) Converter:

A Boost converter is a switch mode DC to DC converter in which the output voltage is greater than the input voltage. It is also called as step up converter. The name step up converter comes from the fact that analogous to step up transformer the input voltage is stepped up to a level greater than the input voltage. By law of conservation of energy the input power has to be equal to output power (assuming no losses in the circuit).

$$\text{Input power } (P_{in}) = \text{output power } (P_{out})$$

Since$V_{in} < V_{out}$ in a boost converter, it follows then that the output current is less than the input current. Therefore in boost converter

$$V_{in} < V_{out} \text{ and } I_{in} > I_{out}$$

1.2.1. Operation of Boost converter:

The main working principle of boost converter is that the inductor in the input circuit resists sudden variations in input current. When switch is OFF the inductor stores energy in the form of magnetic energy and discharges it when switch is closed. The capacitor in the output circuit is assumed large enough that the time constant of RC circuit in the output stage is high. The large time constant compared to switching period ensures a constant output voltage $V_o(t) = V_o$(constant)

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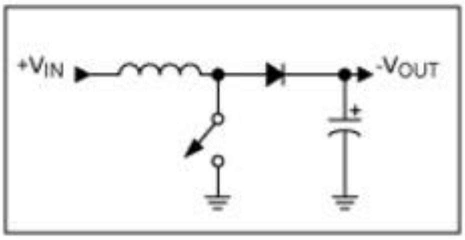

Fig. 4: Boost Converter

1.2.2. Ideal Circuit Analysis:

In a boost regulator the output voltage is larger than the input voltage hence the name ‘boost’. A boost regulator using a power MOSFET is shown in figure.

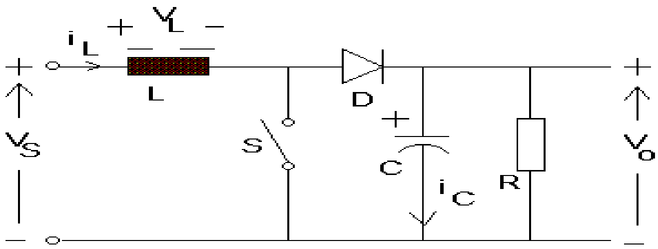

Figure 5: Circuit diagram of an ideal boost regulator.

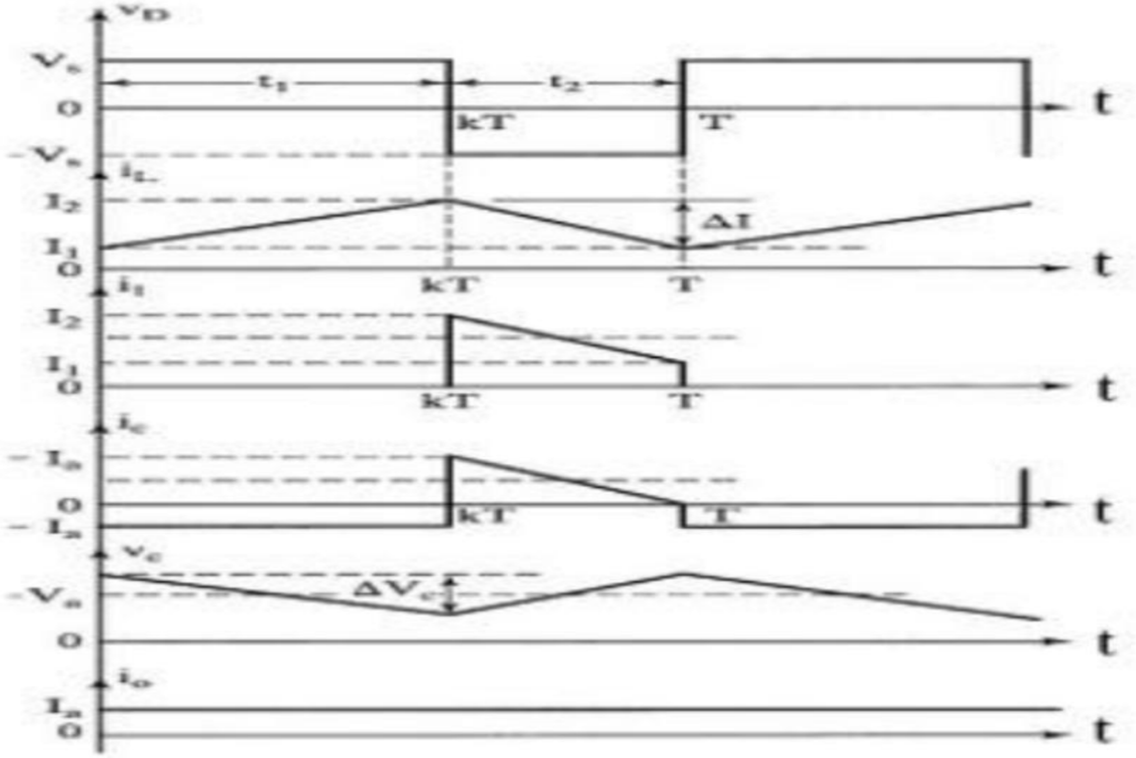

Fig.6: Wave forms of Boost Converter

1.3.Buck-Boost Converter:

It is a type of DC to DC converter and it has a magnitude of output voltage. It may be more or less than equal to the input voltage magnitude. The buck boost converter is equal to the fly back circuit and single inductor is used in the place of the transformer. There are two types of converters in the buck boost converter that are buck converter and the other one is boost converter. These converters can produce the range of output voltage than the input voltage. The following diagram shows the basic buck boost converter.

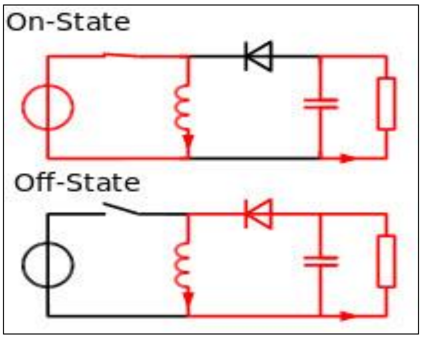

Fig.7: Buck-Boost Converter

1.3.1. Operation of Buck Boost converter:

The working operation of the DC to DC converter is the inductor in the input resistance has the unexpected variation in the input current. If the switch is ON then the inductor feed the energy from the input and it stores the energy of magnetic energy. If the switch is closed it discharges the energy. The output circuit of the capacitor is assumed as high sufficient than the time constant of an RC circuit is high on the output stage. The huge time constant is compared with the switching period and make sure that the steady state is a constant output voltage Vo(t) = Vo(constant) and present at the load terminal.

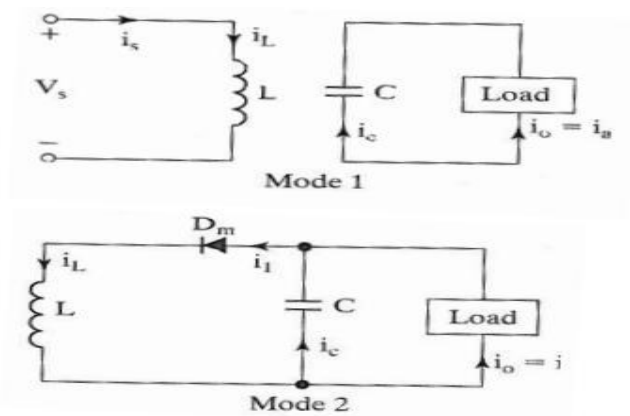

Fig. 8: Equivalent circuit of buck-boost converter.

The circuit operation divided into two modes. During mode 1, transistor *Q1* is turned on and the diode *Dm* is reversed biased. The input current, which rises, flows through inductor *L* and transistor *Q1*. During mode 2, transistor *Q1* is switched off and the current, which was flowing through inductor *L*, would flow through *L, C, Dm*, and the load. The energy stored in inductor *L* would be transferred to the load and inductor current would fall until transistor *Q1* is switched on again in the next cycle. The equivalent circuits for the modes are shown in figure 8. The waveforms for steady-state voltages and currents of the buck-boost regulator are shown in figure 9 for a continuous load current.

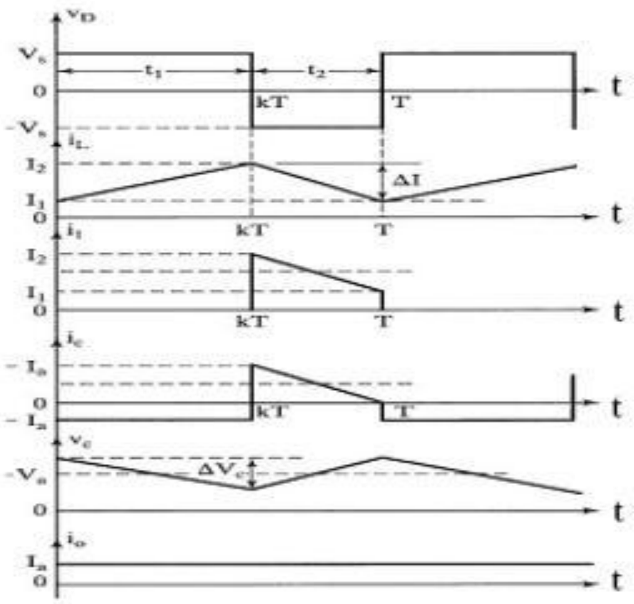

Fig. 9: Waveforms of buck-boost converter.

2) Isolated Converter: These converters have a separation between input and output terminals. They have high isolation voltage properties. They can block the noise and interference. This allows them to produce a cleaner DC source. An isolated DC-DC converter will have a high frequency transformer providing that barrier. This barrier can withstand anything from a few hundred volts to several thousand volts. A second advantage of an isolated converter is that the output can be configured to be either positive or negative. They are categorised into two types:

2.1. Flyback converter: This converter works similar to the buck-boost converter of the non-isolating category. The difference is it uses a transformer to store the energy instead of an inductor. This is the popular isolated converter (input and output are isolated) used in low and moderate power levels. The high frequency transformer provides the isolation between control switch and load.

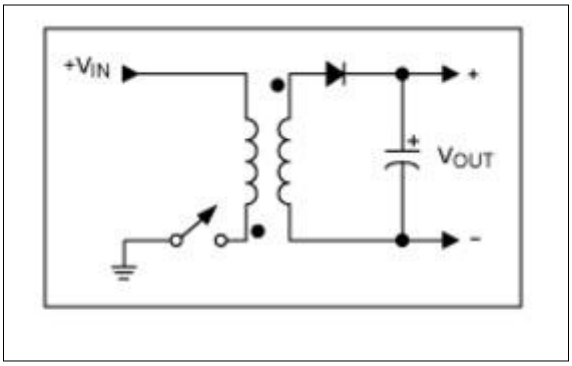

Fig. 10: Flyback Converter

2.2. Forward Converter:

This converter will use the transformer to send the energy, between the input and output in a single step. A forward converter transforms a DC voltage at the input to a DC voltage at the output. The operating principle is similar to the buck converter, but an additional transformer is used to achieve galvanic isolation of the input and output. To show the working principle of the circuit the magnetizing inductance (L_m) and a primary side demagnetizing winding are neglected for simplicity. For a flyback converter in continuous conduction mode the output voltage across resistor R is given by:

$$V_{out} = N_2/N_1 \cdot D \cdot V_{in}$$

where D is the duty cycle, and N_1 and N_2 are the turns numbers of the primary and secondary windings.

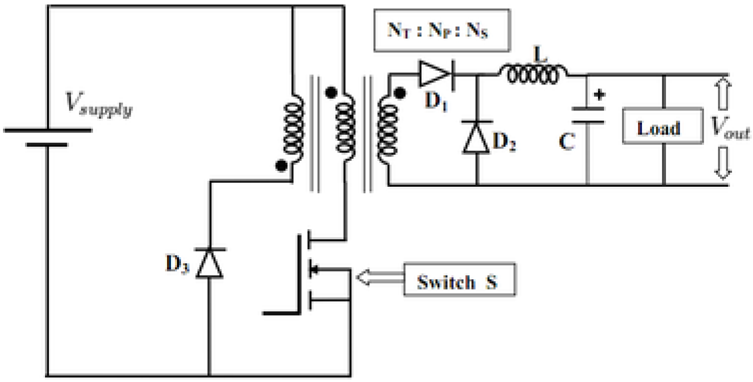

Fig.11: Forward Converter

Applications of DC-DC Converter:

1. DC to DC converters are used in mobile, phones, computers, laptops etc which work with supplied power from batteries. These types of electronic devices have sub-circuits, each circuit required different voltage which is supplied by an external source .Sometimes it required higher voltage or sometimes lower voltage comparative to input voltage. Also voltage of battery gets reduced because of the drainage of stored energy. That is why we use DC to DC converter for increasing the voltage. Use of DC/DC converter reduces the use of multiple batteries.

2. For regulating output voltage we also use DC to DC converter. In some exceptions highly efficient power source LEDs are also used which regulate the current and it contain some charge pumps for increasing output voltage up to double or triple.

3. By using DC-DC converter in photovoltaic system we can generate clean electricity and can improve power quality. For this purpose DC to DC converters (Power optimizer)are developed for wind turbines.

4. We can also use DC-DC switching techniques instead of expensive transformers. For conversion of main frequencies and for high power, transformer should be large and heavy but this makes them expensive and there are eddy current losses in their windings. DC-to-DC converter works with cheap or light inductors with small components. Plus point of these technique are that they can be used with main transformer for example Consequently these techniques are used even where a mains transformer could be used; for example; domestic electronic appliances.

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