Title: ISOLATED BUCK-BOOST CONVERTER

Abstract: The present invention provides an isolated buck-boost converter according to the present invention in which an input circuit is isolated from an output circuit by a transformer, wherein the input circuit comprises a DC source, a primary coil of the transformer connected in series to the DC source, and a switch which is connected in series to the primary coil of the transformer and which performs on-off switching; and wherein the output circuit comprises a secondary coil of the transformer corresponding to the primary coil of the transformer, an inductor connected in parallel to the secondary coil of the transformer, a diode of which cathode is connected to one node between the secondary coil of the transformer and the inductor, a capacitor connected to the other node between the secondary coil of the transformer and an anode of the diode, and a load resistor connected in parallel to the capacitor.
Description

ISOLATED BUCK-BOOST CONVERTER

Technical Field

[1] The present invention relates to a buck-boost converter. More particularly, the present invention relates to a new topology of isolated buck-boost converter.

[2]

Background Art

[3] Recently, a Switched-Mode Power Supply (SMPS) is widely used as a power equipment to supply a stable direct current (D.C.) power to an electronic circuit part of all of electronics and communication equipments such as portable telecom devices, telecommunication power system, power conditioning system for renewable energy etc. Since a DC-DC converter defines the characteristics of these SMPS, the type of the DC-DC converter determines the type of the SMPS.

[4] The main type of these DC-DC converters is a pulse width modulation (PWM) converter. PWM converters are divided into non-isolated DC-DC converters and isolated DC-DC converters. In non-isolated DC-DC converters, the input is not isolated from the output. In isolated DC-DC converters, the primary circuit of the transformer isolated from the secondary circuit of the transformer.

[5] There are several types of non-isolated DC-DC converter: buck converter in which output voltage is always smaller than input voltage; boost converter in which output voltage is always larger than input voltage; and buck boost converter which can step up and step down the voltage. And there are two types of the isolated converter of which main switch uses only a single one: one is a forward type which transfers power when a switch is turned on, and the other is a flyback type which transfers power when a switch is turned off.

[6] The isolated DC-DC converter is more efficient than non-isolated converter because most applications require the isolation between the input and the output. Therefore, if possible, it is desirable to make the DC-DC converter in the form of an isolated type.

[7] However, the efficiency of isolated DC-DC converters is limited because isolated DC-DC converters can transfer energy of a primary circuit to a secondary circuit only when a switch is turned on or off.

[8] Accordingly, the inventors of the present invention have developed a new type of isolated buck-boost converter which can increase the efficiency of the transformer and the output of the converter.

[9]

Disclosure of Invention
Technical Problem

[10] An object of the present invention is to provide a new type of isolated buck-boost converter.

[11] Another object of the present invention is to provide an isolated buck-boost converter which can increase the efficiency of the transformer.

[12] Yet another object of the present invention is to provide an isolated buck-boost converter which can increase the output by using energy stored in the magnetizing inductance of the transformer as the output of the converter.

[13] The objects and other advantages may be achieved by the present invention which will be discussed below.

[14] Technical Solution

[15] One isolated buck-boost converter according to the present invention in which an input circuit is isolated from an output circuit by a transformer, wherein the input circuit comprises a DC source, a primary coil of the transformer connected in series to the DC source, and a switch which is connected in series to the primary coil of the transformer and which performs on/off switching; and wherein the output circuit comprises a secondary coil of the transformer corresponding to the primary coil of the transformer, an inductor connected in parallel to the secondary coil of the transformer, a diode of which cathode is connected to one node between the secondary coil of the transformer and the inductor, a capacitor connected to the other node between the secondary coil of the transformer and an anode of the diode, and a load resistor connected in parallel to the capacitor.

[16] The other isolated buck-boost converter according to the present invention in which an input circuit is isolated from an output circuit by a transformer, wherein the transformer is (n) coil transformer using one core; wherein the input circuit comprises a DC source, a primary coil of the transformer connected in series to the DC source, and a switch which is connected in series to the primary coil of the transformer and which performs on/off switching; and wherein the output circuit forms (n-1) output circuits, each output circuit comprises a secondary coil of the transformer corresponding to the primary coil of the transformer, an inductor connected in parallel to the secondary coil of the transformer, a diode of which cathode is connected to one node between the secondary coil of the transformer and the inductor, a capacitor connected to the other node between the secondary coil of the transformer and an anode of the diode, and a resistor connected in parallel to the capacitor.

[17] The present invention will be discussed below in detail.

[18]
**Brief Description of the Drawings**

[19] Fig. 1 shows a circuit of an isolated buck-boost converter according to the first embodiment of the present invention.

[20] Fig. 2 is a graph showing the voltage and current changes for each part of the circuit when the switch of Fig. 1 is turned on and off.

[21] Fig. 3 shows a circuit when the switch of Fig. 1 is turned on.

[22] Fig. 4 shows a circuit when the switch of Fig. 1 is turned off.

[23] Fig. 5 shows a circuit of an isolated buck-boost converter according to the second embodiment of the present invention.

[24] **Best Mode for Carrying Out the Invention**

[25] Fig. 1 is a circuit showing an example of an isolated buck-boost converter in accordance with the invention. As shown in Fig. 1, the isolated buck-boost converter is an isolated DC-DC converter including one transformer by which an input circuit is isolated from an output circuit. The input circuit comprises a DC source (S), a primary coil of the transformer (T₁), and a switch (Q). The switch, in which on/off switching is possible, consists of a power MOSFET and a body diode such as a free wheeling diode connected in parallel to the power MOSFET. Whether a diode is necessary or not depends on the type of a switch, thus a diode is not always necessary.

[26] Also, the output circuit of the isolated buck-boost converter comprises a secondary coil (T₂) of the transformer corresponding to the primary coil of the transformer, an inductor (L) connected in parallel to the secondary coil of the transformer, a diode (D) of which cathode is connected to one node between the secondary coil of the transformer and the inductor, a capacitor (C) connected to the other node between the secondary coil of the transformer and an anode of the diode, and a load resistor (R₀) connected in parallel to the capacitor.

[27] As for the isolated buck-boost converter of the invention, when the switch is alternately turned on (t₁) and off (t₂), the changes of gate drive voltage (V_gate) for a converter switch (Q), switch voltage (V_D), switch current (I_s1), current (I_s2) on a secondary coil of the converter, current (I_D) through a diode, and inductor current (I_L) are shown in Fig. 2.

[28] The operation of the buck-boost converter circuit when the switch (Q) is turned on/off will be described herein below. If the switch (Q) is turned on (t₁), the input voltage (V_in) is supplied to the primary portion of the transformer and the input energy is then stored in the inductor (L). Now, the diode (D) is reverse-biased and thus is turned off. Therefore, the buck-boost converter circuit is operated as shown in Fig. 3.

[29] In this case, let a voltage of DC source (S) be V_in, a switch turn-on resistor be R_on, a
transformer magnetizing inductance be \( L_M \), a magnetizing current be \( I_M \), the inductance of an inductor be \( L \), an inductor current be \( I_L \), the output voltage be \( V_0 \), and a ratio of turns of the primary coil to the secondary coil be \( N(=N_2/N_1) \), the circuit equation will be as follows:

\[
k_1 X' = A_1 X + B_1 U(t) \\
Y = C_1 X + D_1 U(t)
\]
equation (1)

Here,

\[
X(t) = \begin{bmatrix} I_M(t) \\ I_L(t) \\ V_0(t) \end{bmatrix}
\]

\[
K_1 = \begin{bmatrix} L_M & 0 & 0 \\ 0 & L & 0 \\ 0 & 0 & 0 \end{bmatrix}, \quad A_1 = \begin{bmatrix} -R_{on} & 0 & 0 \\ 0 & -N^2 R_{on} & 0 \\ 0 & 0 & -1/R_o \end{bmatrix}
\]

\[
B_1 = \begin{bmatrix} 1 \\ N \\ 0 \\ 0 \end{bmatrix}, \quad C_1 = \begin{bmatrix} 1 & 0 & 0 \\ 0 & N & 0 \\ 0 & 0 & 0 \end{bmatrix}, \quad D_1 = \begin{bmatrix} 0 & 0 \\ 0 & 0 \\ 0 & 0 \end{bmatrix}
\]

Also, when the switch (Q) is turned off (\( t_1 \)), the diode (D) is forward-biased and then is turned on. Therefore, the isolated buck-boost circuit is operated as shown in Fig. 4. In such a circuit, the energy stored in the inductor (L) is discharged to a load resistor, and also the energy stored in the magnetizing inductor (\( L_M \)) is discharged via the secondary coil of the transformer. And, the inductor current (\( I_L \)) and the current (\( I_{S_2} \)) on the secondary coil of the transformer are added to a diode current. Consequently, the following equation is established:
\[ k_2 \dot{X} = A_2 X + B_2 U(t) \]
\[ Y = C_2 X + D_2 U(t) \]

equation (2)

Here,
\[ X(t) = [I_M(t) \quad I_z(t) \quad V_o(t)] , \]

\[ K_2 = \begin{bmatrix} L_M & 0 & 0 \\ 0 & L & 0 \\ 0 & 0 & 0 \end{bmatrix} \quad A_2 = \begin{bmatrix} 0 & 0 & \frac{1}{N} \\ 0 & 0 & 1 \\ \frac{1}{N} & -1 & -\frac{1}{R_o} \end{bmatrix} \]

\[ B_2 = \begin{bmatrix} 0 & -\frac{1}{N} \\ 0 & -1 \\ 0 & 0 \end{bmatrix} \quad C_2 = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} \quad D_2 = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix} \]

In the steady state, a DC analysis by the duty ratio D (ratio between the on-time of the switch and the switching period) is as follows:

\[ X = -A^{-1} BU \]
\[ Y = (-CA^{-1} B + D)U \]

equation (3)

Here,
\[ A = \begin{bmatrix} -DR_{on} & 0 & (1-D)/N \\ 0 & -DN^2R_{on} & (1-D) \\ (1-D)/N & -(1-D) & -1/R_o \end{bmatrix} \]
\[
B = \begin{bmatrix}
D & -(1-D)/N \\
ND & -(1-D) \\
0 & 0
\end{bmatrix}, \quad C = \begin{bmatrix}
D & 0 & 0 \\
0 & ND & 0 \\
0 & 0 & 0
\end{bmatrix}, \quad D = \begin{bmatrix}
0 & 0 \\
0 & 0
\end{bmatrix}
\]

If
\[R_{on} = 0, \quad V_D = 0\]
then

\[
0 = \frac{(1-D)}{N} V_o + D V_{in}
\]
equation (4)

\[
0 = -(1-D)\left(\frac{1}{N} I_M + I_L + \frac{1}{R_o} V\right)
\]
equation (5)

By the equations (4) and (5),

\[
V_o = -N \frac{D}{1-D} V_{in}
\]
equation (6)

\[
\frac{1}{N} I_M + I_L = -\frac{1}{R_o} V_o
\]
equation (7)

Thus the output current is
\[
I_o = -\frac{1}{R_o} V_o
\]
(here, 
\[ I_o = \frac{1}{N} I_M + I_L \]
), the output voltage is
\[ V_o = \frac{N_2}{N_1} \frac{D}{1-D} V_{in} \]
.

[56]

[57] From the above results, it is therefore understood that the isolated buck-boost converter of the invention has the rate of transformation of input/output similar to that of the prior buck-boost converter, but has an additional element \( N(N_2/N_1) \) of the transformer.

[58] Also, the output current \( (I_o) \) of the isolated buck-boost converter consists of an inductance current \((I_L)\) and a converter magnetizing current \((I_M)\). It can be understood that when \( N_1 = N_2 \), the output of the isolated buck-boost converter increases in power and the current of the buck-boost mode and the current of the flyback mode are combined into one output current of the converter.

[59] Fig. 5 shows another example of the isolated buck-boost converter according to the invention in which multiple output circuits are connected in parallel.

[60] If the output circuits are connected in parallel, each of the output voltage \((V_{o2}, V_{o3})\) can be operated independently by changing turns \((N_2, N_3)\) of each coil of the transformer.

[61] In telecommunication equipment comprising many devices that require different output energy respectively, each device can be provided with output energy suitable for each device, efficiently.

[62] Although Fig. 5 show an example in which the two output circuits are connected in parallel, it can be understood by those in the art that more than three output circuits can be connected.

[63]
Claims

[1] An isolated buck-boost converter in which an input circuit is isolated from an output circuit by a transformer, wherein the input circuit comprises a DC source, a primary coil of the transformer connected in series to the DC source, and a switch which is connected in series to the primary coil of the transformer and which performs on/off switching; and, wherein the output circuit comprises a secondary coil of the transformer corresponding to the primary coil of the transformer, an inductor connected in parallel to the secondary coil of the transformer, a diode of which cathode is connected to one node between the secondary coil of the transformer and the inductor, a capacitor connected to the other node between the secondary coil of the transformer and an anode of the diode, and a load resistor connected in parallel to the capacitor.

[2] An isolated buck-boost converter in which an input circuit is isolated from an output circuit by a transformer, wherein the transformer is (n) coil transformer using one core; wherein the input circuit comprises a DC source, a primary coil of the transformer connected in series to the DC source, and a switch which is connected in series to the primary coil of the transformer and which performs on/off switching; and wherein the output circuit forms (n-1) output circuits, each output circuit comprises a secondary coil of the transformer corresponding to the primary coil of the transformer, an inductor connected in parallel to the secondary coil of the transformer, a diode of which cathode is connected to one node between the secondary coil of the transformer and the inductor, a capacitor connected to the other node between the secondary coil of the transformer and an anode of the diode, and a resistor connected in parallel to the capacitor.

[3] The isolated buck-boost converter according to Claim 2, wherein each of (n-1) output circuit has different turns of the secondary coil of the transformer such that each of (n-1) output circuit has different output.

[4] The isolated buck-boost converter according to Claim 2, wherein the turns of the primary coil of the transformer are the same as those of the secondary coil of the transformer.

[5] The converter according to any claim of Claims 2 to 4, wherein the switch consists of a power MOSFET and a body diode such as free wheeling diode connected in parallel to the power MOSFET.
A. CLASSIFICATION OF SUBJECT MATTER

**H02M 3/28 (2006.01)**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 8: H02M 3/28, 3/335, 3/337

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean Utility models and applications for Utility Models since 1975

Japanese Utility models and applications for Utility Models since 1975

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKIPASS (KIPO internal) "converter", "buck-boost"

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
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<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
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<td>A</td>
<td>US 4455596 A (BAKER, GEORGE J.) 19 June 1984 See the abstract; figure 2</td>
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<td>1, 2</td>
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Document member of the same patent family

Date of the actual completion of the international search

13 APRIL 2007 (13.04.2007)

Date of mailing of the international search report

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