# Isolated bidirectional full-bridge dc-dc converter with fly back snubber for high-power applications

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## Abstract

This paper introduces a flyback snubber to recycle the absorbed energy in the clamping capacitor. The flyback snubber can be operated independently to regulate the voltage of the clamping capacitor; therefore, it can clamp the voltage to a desired level just slightly higher than the voltage across the low-side transformer winding. Since the current does not circulate through the full-bridge switches, their current stresses can be reduced dramatically under heavyload condition, thus improving system reliability significantly.

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***Index terms***— flyback snubber, clamping capacitor, transformer winding, full-bridge switches, system reliability.

## 1 Introduction

ower electronic converters are used extensively in personal electronics, power systems, hybrid electric vehicles (HEVs), and many other applications to provide dc voltage sources and manage power flow by switching actions .To obtain high power quality, switching control strategies that can achieve high performances are attracting more and more attention . [1] Many advanced control strategies, such as fuzzy-neural control or sliding-mode control, have been proposed to enhance the steady-state and dynamic performance of power electronic systems. Although these control strategies are predicted to be promising in more complex-structured converters, such as dualactive-bridge (DAB) and dc-dc converters. Most of the present applications are still confined to simple structured circuits, such as buck, boost, and half-bridge converters. [1] Compared to traditional dc-dc converter circuits, isolated bidirectional DAB dc-dc converters have many advantages, such as electrical isolation, high reliability, ease of realizing soft-switching control, and bidirectional energy flow. [1] A double-phase-shift control for a unidirectional three-level converter is proposed in. The phase shift is implemented on the primary side. A start-up circuit to suppress the inrush current with a set of auxiliary circuits is proposed. [2] The dc-dc converter is a key component in hybrid electric vehicles (HEVs) to manage power flow and maintain battery health. Electrical isolation may be required to provide safe operation for the equipment operated on the hybrid battery, such as in military applications. State-of-the-art isolated dc-dc converters are generally based on single-phase full-bridge topologies with isolation transformers. An isolated bidirectional dc-dc converter, which consists of dual Hbridges located on the primary and secondary sides of an isolated transformer, respectively. [3] In traditional unidirectional dc-dc converters, the power ratings are generally low, and the switching frequency is relatively high (for MOSFET or Si C, turning on and off processes are both in the nanosecond level). Therefore, there is, generally, no need to deal with dead band effect. However, in high-voltage and high-power isolated bidirectional dc-dc converters, the dead band and phase-shift error will greatly affect the operation of the converter, both in steady-state and transient processes. These issues generally deteriorate the operational performance, or even damage the system under some specific switching conditions because of large unexpected current and voltage spikes. [4] A few integrated multi-port dc-dc converter topologies are found in the literature. There are two categories for the integrated isolated multi-port converter. One type of converter involves a transformer in which there is a separate winding for each port, therefore all ports are fully electrically isolated. The other type has a reduced parts count where some windings are absent, if the system allows the corresponding ports to share a common ground. [4] A dual active full bridge dc-dc converter was proposed for high power BDC , which employs two voltage-fed inverters to drive each sides of a transformer. Its symmetric structure enables the bidirectional power flow and ZVS for all switches. A dual active half bridge current-voltage-fed soft-switching bidirectional dc-dc converter was proposed with reduced power components however, the current-fed half bridge suffers from a high voltage spike because of the leakage inductance of the transformer. When the voltage amplitude of the two sides of the transformer is not matched, the current stresses and circulating conduction losses become higher. [5] In addition, these converters cannot achieve ZVS in low-load condition. These disadvantages make it not suitable for large variation of input or output voltage condition. An asymmetry bidirectional dc-dc converter with Phase shift plus PWM (PSP) control was proposed in, the circulating conduction loss is reduced. The converter with an active clamping branch avoids the voltage spike, achieves Zero Voltage Switching and restrains the start-inrush current. [6] The demands of a bidirectional dc/dc converter are high frequency, high power density, high efficiency and high reliability. Nevertheless, the conventional bidirectional dc/dc converters still have some drawbacks: Electric insulation and soft switching is difficult to realize, and the reverse-recovery effect of the rectifier diode restricts the switching speed. These defects limit the high-frequency power conversion applied in a bidirectional dc/dc converter. Therefore, an isolated bidirectional dc/dc converter with soft switching is the best way to meet the previously mentioned demands. [7] II.

## 2 Configuration & Operation

The proposed isolated bidirectional full-bridge dc-dc converter with a fly back snubber is shown in Fig. 1 The converter is operated in two modes: buck mode and boost mode. Fig. 1 consists of a current-fed switch bridge, a fly back snubber at the low-voltage side, and a voltage-fed bridge at the high-voltage side.

Inductor Lm performs output filtering when power flows from the high-voltage side to the batteries, which is denoted as a buck mode. On the other hand, it works in boost mode when power is transferred from the batteries to the high-voltage side. Furthermore, clamp branch capacitor CC and diode DC are used to absorb the current difference between current-fed inductor Lm and leakage inductance Lll and Llh of isolation transformer Tx during switching commutation. The fly back snubber can be independently controlled to regulate VC to the desired value, which is just slightly higher than V AB . Thus, the voltage stress of switchesM1-M 4 can be limited to a low level. The major merits of the proposed converter configuration include no spike current circulating through the power switches and clamping the voltage across switches M 1-M 4, improving system reliability significantly. Note that high spike current can result in charge migration, over current density, and extra magnetic force, which will deteriorate in MOSFET carrier density, channel width, and wire bonding and, in turn, increase its conduction resistance. A bidirectional dc-dc converter has two types of conversions: step-up conversion (boost mode) and step-down conversion (buck mode). In boost mode, switches M1-M4 are controlled, and the body diodes of switches M 5-M 8 are used as a rectifier. In buck mode, switches M 5-M 8 are controlled, and the body diodes of switches M1-M 4 operate as a rectifier. To simplify the steady-state analysis, several assumptions are made, which are as follows.

1. All components are ideal. The transformer is treated as an ideal transformer associated with leakage inductance.

2. Inductor Lm is large enough to keep current iL constant over a switching period.

Clamping capacitor CC is much larger than parasitic capacitance of switches M1-M 8 [7] III.

## 3 Step-up Conversion

In boost mode, switches M1-M4 are operated like a boost converter, where switch pairs (M 1 , M 2 ) and (M 3 , M 4 ) are turned ON to store energy in Lm. At the high-voltage side, the body diodes of switches M 5-M 8 will conduct to transfer power to VHV . When switch pair (M 1 , M 2) or (M 3 , M 4 ) is switched to (M 1 , M 4) or (M 2 , M 3 ), the current difference iC (= iL ip ) will charge capacitor CC , and then, raise ip up to iL . The clamp VC (R ) stands for a regulated VC voltage, which is close to (VHV (NP /NS )), fs is the switching frequency, and Lm _Leq. Power PC will be transferred to the high-side voltage source through the fly back snubber, and the snubber will regulate clamping capacitor voltage VC to VC (R ) within one switching cycle Ts (=1/fs ). Note that the fly back snubber does not operate over the interval of inductance current ip increasing toward iL. The processed power PC by the fly back snubber is typically around 5% of the full-load power for low-voltage applications. With the fly back snubber, the energy absorbed in CC will not flow through switches M1-M4, which can reduce their current stress dramatically when Leq is significant. Theoretically, it can reduce the current stress from 2iL to iL . The peak voltage VC (P ) of VC will impose on M1-M 4 and it can be determined as follows:

Where iL (M) is the maximum inductor current of iL, which is related to the maximum load condition. At t4, capacitor voltage VC has been regulated to VC (R) , and the snubber is idle. Over this interval, the main power stage is still transferring power from VLV to VHV. It stops at t5 and completes a half-switching cycle operation. [7]The equivalent circuit is shown in Fig. 5 Isolated bidirectional full-bridge dc-dc converter with fly back snubber for high-power applications IV.

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# 5 Step-Down Conversion

In the analysis, leakage inductance of the transformer at the low-voltage side is reflected to the high-voltage side, as shown in Fig. **??**, in which equivalent inductance Leq equals(Llh + Ll (N 2p_N 2 s

)). This circuit is known as a phase-shift full-bridge converter. In the step-down conversion, switches M 5-M 8 are operated like a buck converter, in which switch pairs (M 5 , M 8 ) and (M 6 , M 7 ) are alternately turned ON to transfer power from VHV to VLV. SwitchesM1-M4 are operated with synchronous switching to reduce conduction loss. For alleviating leakage inductance effect on voltage spike, switchesM 5-M 8 are operated with phase-shift manner. Although, there is no need to absorb the current difference between iL and ip , capacitor CC can help to clamp the voltage ringing due to Leq equals (Ll + Llh (N 2p_N 2s )) and parasitic capacitance of M 1-M 4 .The operation waveforms of step-down conversion are shown in Fig. 12. A detailed description of a half-switching cycle operation is shown as follows. The equivalent circuit is shown in Fig. 11 where Vc,h is the maximum voltage of Vc , Vc,l is the minimum voltage of Vc , and fs is the switching frequency. [7] V.

# 6 Simulation Results

# 7 Conclusion

This paper presents an isolated bidirectional full-bridge dc-dc converter with a fly back snubber for high-power applications. The fly back snubber can alleviate the voltage spike caused by the current difference between the current-fed inductor and leakage inductance of the isolation transformer, and can reduce the current flowing through the active switches at the current fed side by 50%. Since the current does not circulate through the full-bridge switches, their current stresses can be reduced dramatically under heavy-load condition, thus improving system reliability significantly. The fly back snubber can also be controlled to achieve a soft start-up feature. It has been successful in suppressing inrush current which is usually found in a boost-mode start-up transition.

**1**

Figure 1: Fig. 1 :

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Figure 2: 2 Fig. 2 :

[1] [2] [3]

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[1] © 2012 Global Journals Inc. (US)

[2] May3.

[3] MayMode 3 [t2 t < t3 ]:

**334**

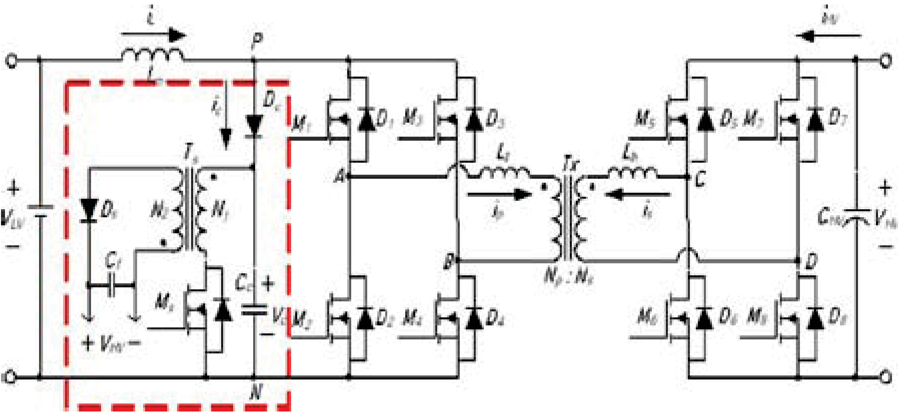
Figure 3: Fig. 3 : 3 FIG 4 :

**5**

Figure 4: FIG 5 :

**6**

Figure 5: VolumeFig. 6 :



**78**

Figure 6: Fig. 7 :Fig. 8 :

$$P_C = \frac{1}{2} C_C \left[ (i_L Z_o)^2 + 2 i_L Z_o V_{C(R)} \right] f_s \qquad (1)$$

**11**

Figure 7: Fig. 11 :

$$Z_o = \sqrt{\frac{L_{\mathrm{eq}}}{C_C}}$$

$$L_{\mathrm{eq}} = L_{ll} + L_{lh}\frac{N_p^2}{N_s^2}$$

**17**

Figure 8: Fig. 17 :

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