Bridgeless Flyback PFC Rectifier Using Single Magnetic Core and Dual Output Windings

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Abstract

In this paper, a bridgeless flyback power factor correction (PFC) rectifier which uses single magnetic core is proposed. The proposed PFC rectifiers utilize bidirectional switch to handle both positive and negative input voltage without bridge diodes. A transformer with dual output windings enables the rectifier dispense with any additional magnetic component. The operation of the proposed flyback PFC rectifier is analyzed, and its higher efficiency than its conventional counterpart is verified by experiment.

1. Introduction

The requirements for high-efficiency power conversion system are becoming more significant due to the environmental concern [1]. Bridgeless PFC rectifier as a front-end power stage is spotlighted as a good candidate to improve the efficiency. It reduces the number of slow-recovery bridge diodes in power path to minimize the conduction loss. Conventional bridgeless PFC rectifiers those are derived from single-ended converter topologies are reported in [2]-[3]. Reference [4] utilizes two flyback rectifiers by connecting them back-to-back. However, though they employ two non-isolated DC/DC converters to handle positive and negative line voltage, they cannot fully eliminate the bridge diodes. One slow-recovery diode as well as switch carries the input current in the switch conduction interval in their topologies.

In this paper, a bridgeless flyback isolated rectifier is proposed. By utilizing a bidirectional switch and dual output windings of transformer, the proposed rectifier does not need any slow-recovery diode and additional magnetic component. The proposed flyback rectifier obtains both input current shaping and isolation with single magnetic component. Experimental results by 125-W prototype circuit verify the performance of the proposed rectifier.

2. Implementation of Control Circuit

The proposed bridgeless flyback rectifier is presented in Fig. 1. Conventional controller provides the gate signal for the bidirectional switch S because DC voltage gain and dynamic

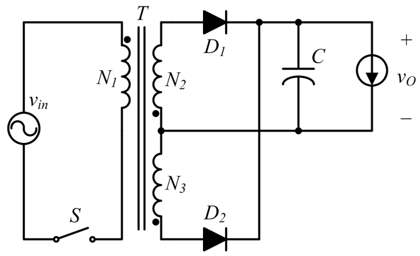

Fig. 1. Proposed bridgeless isolated flyback rectifier.

characteristic of the proposed rectifier are similar with those of the conventional counterpart. Flyback transformer T contains two output windings, N_2 and N_3. Secondary winding N_2 and output diode D_1 operate when input voltage v_{in} is positive, while tertiary winding N_3 and D_2 conduct when v_{in} is negative.

Fig. 2 shows the operational modes of the proposed circuit in continuous conduction mode. Output capacitor C and load is approximated as an ideal voltage source v_O, and leakage and magnetizing inductances of transformer T are assumed to be zero and L respectively. Figs. 2(a) and 2(b) show the circuit operation when input voltage is positive, i.e., $v_{in} > 0$. When S turns on, v_{in} charges the magnetizing inductance L as in Fig. 3(a). When S turns off in Fig. 3(b), magnetic flux in L discharges through N_2 and D_1 to load. Tertiary winding N_3 and output diode D_2 does not participate in the operation. On the contrary, when v_{in} turns negative, $v_{in} < 0$, N_3 and D_2 operates as in Figs. 3(c) and 3(d). Negative v_{in} charges L with the opposite direction when S is on (Fig. 3(c)). If S turns off, the flux in L will discharge through N_3 and D_2 (Fig. 3(d)). D_1 is reverse-biased and N_2 does not carry any current.

Turn ratio of windings of T should be properly selected to guarantee the stable operation of the rectifier. The turn ratio of N_2 to N_3 is designed to be unity to meet the voltage gain whether the polarity of v_{in} is positive or negative. The ratio of primary side and secondary side windings should be designed to satisfy (1):

$$\frac{N_2}{N_1} v_{in\_pk} = \frac{N_3}{N_1} v_{in\_pk} < v_O , \tag{1}$$

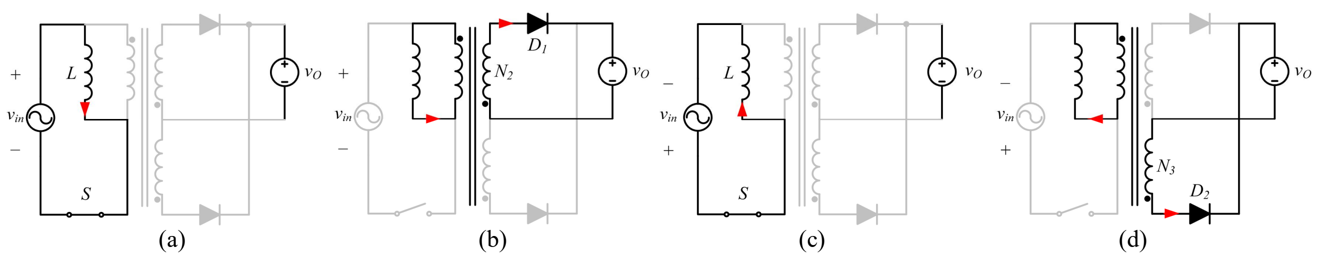

Fig. 2. Operational modes of the proposed bridgeless flyback rectifier in CCM.

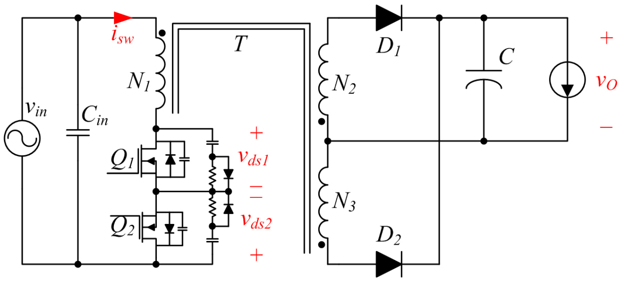

Fig. 3. Implementation of the proposed flyback rectifier.

where v_{in_pk} is maximum instantaneous input voltage and v_O is output voltage. Unless the design criterion in (1) is met, one of the output diode will be short-circuited and the operation of the rectifier will be unstable. For example, in Fig. 3(a), D_2 may turn on unexpectedly and experience excessive current when

$$\frac{N_3}{N_1} v_{in\_pk} > v_O .$$

3. Experimental Results

Practical implementation of the proposed bridgeless flyback rectifier is illustrated in Fig. 3. The prototype circuit is designed to output 125-W 80-V in discontinuous conduction mode (DCM) to avoid complicated input voltage and input current sensing. Two MOSFETs, Q_1 and Q_2, are connected back-to-back and operated with same gate signal. Snubbers are added to suppress the voltage spike induced by the leakage inductance of the transformer and parasitic capacitances of the MOFSETs. Circuit parameters of the prototype circuit are summarized in Table I.

Fig. 4(a) shows the steady state operation of the proposed flyback rectifier when 115VAC/60Hz line voltage and 60% load is applied. Traces represent output voltage, v_O, input current, i_{sw}, and drain-source voltage across Q_1, v_{ds1}, from the top respectively. Efficiency comparison between the proposed bridgeless flyback rectifier and its conventional counterpart is shown in Fig. 4(b). Except its bridge diodes, the conventional circuit is built by using same semiconductor devices and transformer with the proposed circuit for fair comparison. The proposed rectifier shows better efficiency than conventional one.

Table I. Circuit Parameters in Fig. 4

Device	Description
T	PQ32/20 PC44, 1-mm air gap at outer legs, N_1:N_2:N_3 = 15:4:4
Q_1, Q_2	SPW11N80C3 from Infineon
D_1, D_2	RURG3020CC from Fairchild
C_{in}	33nF/630V film
C	220uF/100V electrolytic 5EA parallel
Snubber	100Ω, 1nF/1600V film 2EA parallel, 1N5408

4. Conclusion

Bridgeless flyback PFC rectifier that fully eliminates the slow-recovery bridge diodes has been presented. The rectifier is derived by modifying switch and output winding of conventional DC/DC converter while not increasing the part count of magnetic component. The rectifier has proved its higher efficiency than its conventional counterpart by experimental results.

References

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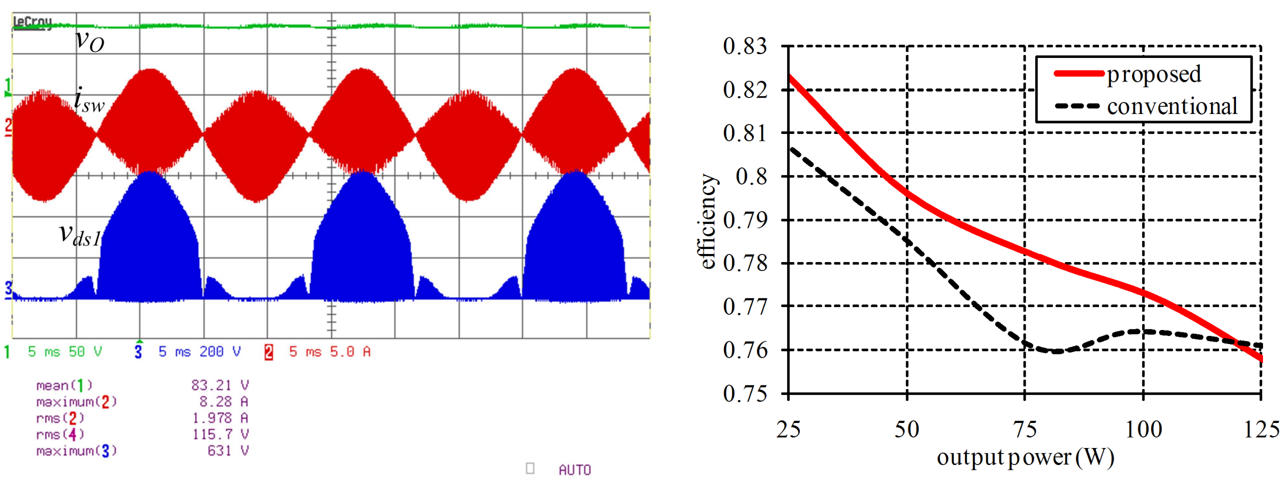

(a) (b)

Fig. 4. Experimental results: (a) Waveform of the proposed flyback rectifier. (b) Efficiency comparison.