ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

A DC Distribution System with High-Efficiency Isolated Bidirectional AC–DC Converter Operation

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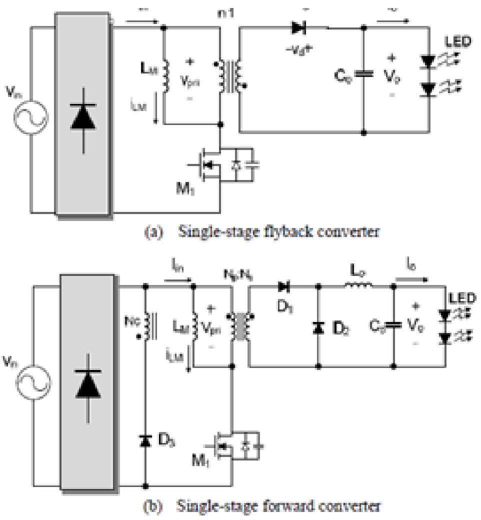
ABSTRACT: ***In this paper, a high efficiency and high power factor single-stage balanced forward-flyback converter merging a forward and flyback converter topologies is proposed. The conventional AC/DC flyback converter can achieve a good power factor but it has a high offset current through the transformer magnetizing inductor, which results in a large core loss and low power conversion efficiency. And, the conventional forward converter can achieve the good power conversion efficiency with the aid of the low core loss but the input current dead zone near zero cross AC input voltage deteriorates the power factor. On the other hand, since the proposed converter can operate as the forward and flyback converters during switch on and off periods, respectively, it cannot only perform the power transfer during an entire switching period but also achieve the high power factor due to the flyback operation. Moreover, since the current balanced capacitor can minimize the offset current through the transformer magnetizing inductor regardless of the AC input voltage, the core loss and volume of the transformer can be minimized. Therefore, the proposed converter features a high efficiency and high power factor. To confirm the validity of the proposed converter, theoretical analysis and experimental results from a prototype of 24W LED driver are presented.***

Keywords—single stage; forward-flyback; LED driver;

INTRODUCTION:

Recently, light-emitting diodes (LEDs) have become one of the most promising candidates for displays and lighting applications, because LEDs have several favorable advantages such as a high efficiency, long life time and echo-friendliness. Therefore, traditional lighting devices such as a light bulb and fluorescent lamp tend to be replaced by LEDs [1, 2]. To drive LEDs, two types of drivers are generally used, that are a linear and switch-mode regulators [3]. Although the linear driver features a simple circuit configuration, fast transient response and accurate current regulation, it has fatal drawbacks such as a low efficiency and serious heat generation. Therefore, the switch-mode driver is widely used in LED applications due to its high efficiency and high power density . Meanwhile, since drivers for LED lightings have been composed of two power conversion stages (ie. a power factor corrector and isolated DC/DC converter) [6]. The first stage provides a near unity power factor and low total harmonic distortion (THD) over an entire range of universal inputvoltage (90-270 Vrms) and the second DC/DC stage is used.



(a) Single-stage flyback converter

(b) Single-stage forward converter

Fig. 1. Conventional single-stage PFC converter circuits

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Existing System:

As shown in this figure, its primary side is exactly same as that of the conventional flyback converter consisting of one power switch (M1) and one transformer. On the other hand, its secondary side consists of one output inductor (Lo) for forward operation, one DC blocking capacitor (Cb) for balancing operation and three output Diodes (D1, D2, D3). When M1 is conducting, the proposed converter operates as a forward converter as shown in Fig 7. On the other hand, when M1 is blocked, the proposed converter operates as a flyback converter as shown in Fig 8. However, if it is assumed that the proposed converter has no balancing capacitor Cb, abovementioned forward operation is possible only when the reflected primary voltage Vin/n to the transformer secondary side is higher than the output voltage Vo. This is because the forward converter is originated from the buck converter. Therefore, the forward-flyback converter operates only as a flyback converter over the range of Vin/n < Vo. Especially, at the minimum input voltage near Vin=90Vrms, Vin/n is lower than Vo during most of periods and thus, the transformer has a large magnetizing offset current similar to the conventional flyback converter. In this case, the transformer core loss.

Proposed System:

As can be seen in this figure, the higher turn ratio can more decrease the diode voltage stress but more increase the switch voltage stress, and vice versa. Especially, the switch voltage stress of the proposed converter is somewhat higher than that of the conventional one due to the balanced capacitor voltage Vcb. Therefore, in designing the transformer turn ratio, the switch voltage stress must be carefully considered.

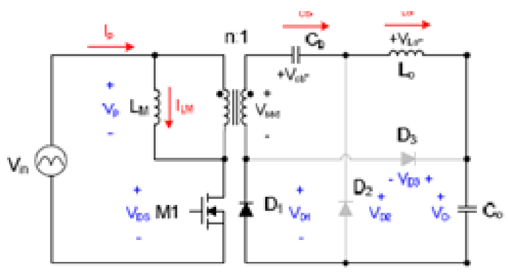


Fig. 7. Circuit operation during mode 1

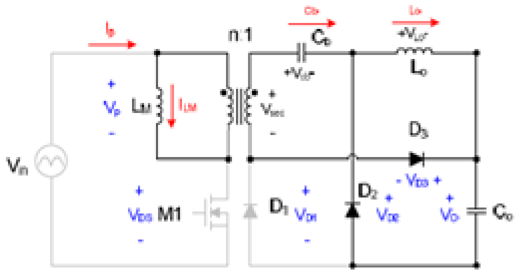


Fig. 8. Circuit operation during mode 2

ANALYSIS OF THE PROPOSED CONVERTER

A. Voltage conversion ratio

The voltage conversion ratio of the proposed converter can be obtained by applying the volt-second balance rule on LM and Lo. As can be seen in Fig. 9, the voltage across LM is Vin and n(Vo+Vcb) during t1-t0=DTS and t2-t1=(1-D)TS, respectively. Therefore, following equation can be obtained.

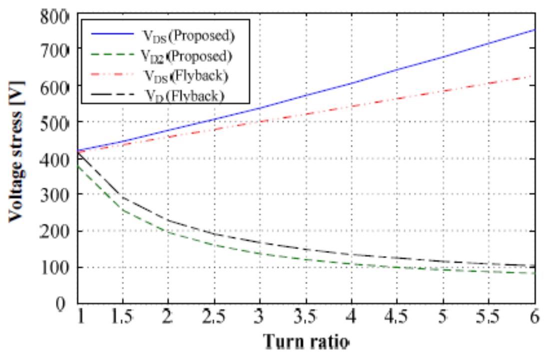


Fig. 10. Comparisons of voltage stresses between conventional flyback and proposed forward-flyback converters

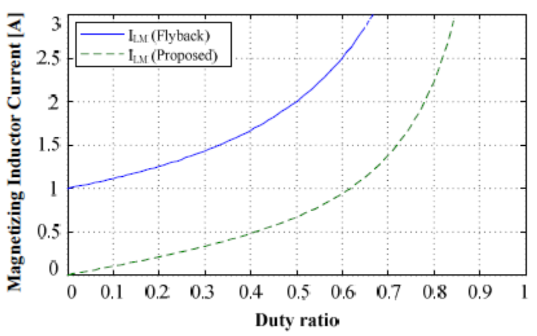
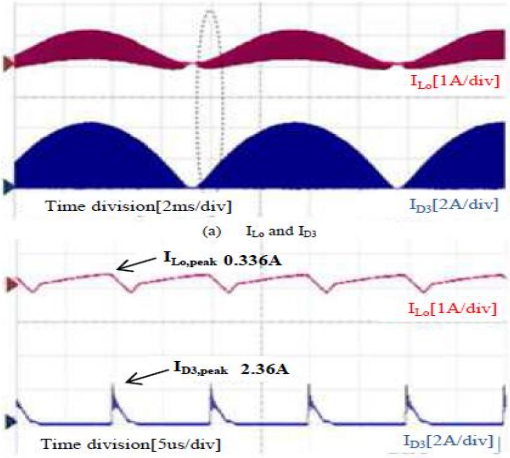


Fig. 11. Magnetizing offset currents of conventional flyback and

Experimental Results and Discussions

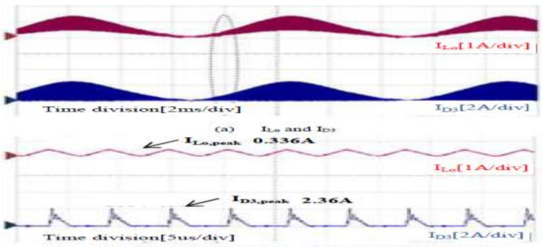
To confirm the validity of the operational principles and theoretical analysis of the proposed converter, a laboratory prototype applicable to the LED driver was implemented and tested with the following specifications. Fig. 15 shows the measured efficiency and power factor of the proposed forward-flyback and conventional flyback converters. As shown in this figure, the proposed converter has the high power factor above 95% over a wide range of input voltage.



(b) Detailed waveforms of I_{Lo} and I_{D3} at low input voltage
Fig. 13. Experimental key waveforms of proposed circuit measured at $90V_{rms}$.

CONCLUSION

A single stage power-factor-correction balanced forward flyback converter for LED application is presented, and its operation principle analyzed in this paper. The proposed forward-flyback converter with the balancing capacitor can always operate as both forward and flyback converters regardless of the input voltage. Therefore, it has a smaller magnetizing offset current, resultant smaller core loss and more reduced transformer core volume. For this reason proposed converter can be obtained high efficiency and high power factor.



(b) Detailed waveforms of I_{Lo} and I_{D3} at low input voltage
Fig. 14 Experimental key waveforms of proposed circuit measured at $264V_{rms}$.

To verify the validity of proposed circuit, experimental results from a prototype of 24W single stage power factor correction balanced forward-flyback converter for LED application are provided, which shows that the measured maximum power factor and efficiency is 0.996 and 91.21% respectively. Moreover, the proposed circuit can be perform the power transfer during an entire switching period. Therefore, the proposed circuit having these favorable advantages is expected to be well suited to various LED driver applications.

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ISSN No: 2348-4845
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