Rahva Teknik ve Sosyal Araştırmalar Dergisi
Cilt: 1, Sayı:1, 2021, Sayfa: 1-5

Rahva Journal of Technical and Social Studies
Vol: 1, Issue:1, 2021, Page: 1-5

Analysis and Simulation of Novel RCD Passive Snubber Cell for Flyback Dc-Dc Converters

Yakup ŞAHİN[1, a, ✉]

[1]Bitlis Eren Univesity, Engineering and Architecture Faculty, Electrical Electronics Engineering, Bitlis, Turkey
[a]ORCID: 0000-0001-6792-2550

[✉]Corresponding Author: ysahin@beu.edu.tr

Abstract: Pulse Width Modulation (PWM) flyback dc-dc converters are pretty popular and have wide range application in the industry. Nevertheless, the leakage inductance issues cause high voltage spikes on the semiconductor switch when it is turned off. Consequently, passive or active snubber cells are needed at turned-off process for limiting the voltage spikes. In this paper, a novel passive snubber cell is proposed for PWM flyback dc-dc converter. The proposed snubber cell has low cost, ease of control and simple structure features. The detailed theoretical analysis of converter is presented and the analysis is demonstrated by a simulation setup in the paper. All analyses and simulation setup is made under 100 kHz switching frequency and 16 W output power conditions.

Keywords: Dc-Dc converters, Flyback, Leakage inductance, Snubber Cells.

Flyback Da-Da Dönüştürücüler için Yeni Bir RCD Pasif Bastırma Hücresinin Analiz ve Benzetimi

Özet: Darbe Genişlik Modülasyonlu (DGM) flyback da-da dönüştürücüler oldukça popüler olmalarının yanı sıra endüstride geniş bir yelpazede kullanım alanı bulurlar. Ancak bu dönüştürücülerde yarıiletken anahtar kesime girdiğinde, kaçak endüktanstan ötürü yarıiletken anahtar üzerinde gerilim pikleri oluşur. Bu nedenle kesime grime aşamasında gerilim piklerinin değerini sınırlamak için pasif ya da aktif bastırma hücreleri gerekir. Bu makalede flyback da-da dönüştürücüler için yeni bir pasif bastırma hücresi sunulmuştur. Önerilen bastırma hücresi düşük maliyet, kontrol kolaylığı ve basit yapı özelliklerine sahiptir. Makalede, dönüştürücünün detaylı analizi sunulmuş ve analizler benzetim çalışması ile doğrulanmıştır. Bütün analizler ve benzetim çalışması 100 kHz anahtarlama frekansı ve 16 W çıkış gücünde gerçekleştirilmiştir.

Anahtar sözcükler: Da-Da dönüştürücüler, Flyback, Kaçak endüktans, Bastırma hücreleri.

1. Introduction

Pulse width modulation (PWM) flyback dc-dc converters are widely used in industrial application as solar power systems, light emitted diode (LED) drivers, battery chargers etc. due to its isolated buck-boost converter feature and simple structure. Flyback converters suffers from the leakage inductance in coupled inductance. The leakage inductance leads voltage spikes on the semiconductor switch. Also, the leakage inductance leads power losses and decrease total efficiency of converter. In addition, the resonance between leakage inductance and parasitic capacitance of semiconductor switch cause electromagnetic interference (EMI). Because of leakage inductance issues can damage semiconductor switch and effect converter performance, the leakage inductance issues on the semiconductor switch must be reduced by active or passive (RCD) snubber.

Many flyback snubber cells are introduced to literature as active or passive snubber cells in the past decades. Active flyback snubber cells are called non-dissipative snubber cells and they are used LC snubber (Rezai et al., 2016; Papanikolaou & Tatakis, 2004; Ting et al, 2015; Ting et al, 2017; Zhang et al, 2010; Skesh et al, 2014). LC snubber uses an auxiliary switch and force the leakage energy to input stage or output stage. Active snubber cells has higher cost compared with passive snubber cells since auxiliary switch and extra control circuit. Furthermore, the converter has complexity of control because both main switch and auxiliary switch. Despite these issues, the actives snubber cells have better converter efficiency compared passive snubber cells. Active snubber cells are suitable for high power levels in flyback converter.

Passive snubber cells include Resistance-Capacitance-Diode (RCD) and they are called dissipative snubber cells (Abramovitz et al, 2013; Jung &Chou, 2014; Gacio et al, 2011; Xie, 2012; Spiazzi et al, 2000; Meng et al, 2010). They are dissipative because they consume the leakage energy on the resistance. These snubber cells have ease of control and simple structure features since they do not include an auxiliary switch. Compared by active snubber cells, the passive snubber cells lower converter efficiency and they are suitable for low power level in flyback converter.

In this paper a passive snubber cell for PWM flyback dc-dc converter is presented to overcome the leakage inductance issues. By aid of introduced snubber cell, the voltage spikes on the semiconductor switch is reduced to acceptable level and resonance between leakage inductance and parasitic capacitance is eliminated. Finally, the EMI in the flyback converter is eliminated.

2. Analysis and Operational Principle

The main circuit scheme of proposed converter is illustrated in Fig. 1. In the main circuit D_{B1}, D_{B2}, D_{B3} and D_{B4} are input bridge diode, C_i is filter capacitance, V_i is input voltage, S is semiconductor switch, D_o is output diode, C_o is output filter capacitance, R_L is resistive load, V_o is output voltage, Tr is coupled inductor, N_p is primary windings and N_s is secondary windings, L_{lk} is leakage inductance of coupled inductor, a is turn ratio. In the proposed RCD snubber cell, R_{S1} and R_{S2} are snubber resistances, C_S snubber capacitance and D_S is snubber diode.

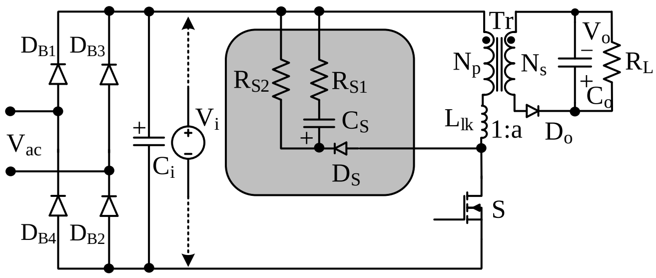


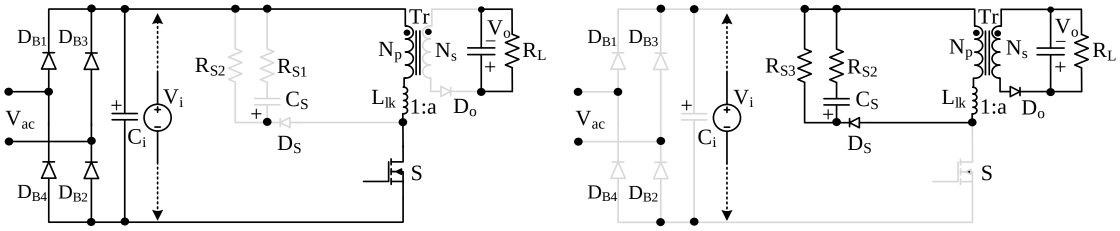
Figure 1 Proposed RCD snubber PWM flyback dc-dc converter.

2.1. Operational Modes of Proposed Converter

The operational modes of proposed converter include two modes and their equivalent circuit schemes are introduced in Fig. 2.

Operational Mode 1 ***[Fig. 2(a)]:***

This mode is started when the gate signal is applied to semiconductor switch S. the primary windings are exposed to input voltage V_i and the current of primary inductance is started to increase. The secondary inductance is at off-state during this mode and the output voltage level is decreased a little bit since resistive load R_L is exposed to V_o. When the current of primary inductance is reached maximum level, this mode is finished and the gate signal of semiconductor switch is removed.



(a) (b)

Figure 2 Equivalent circuit schemes of operational modes.

Operational Mode 2 *[Fig. 2(b)]:*

When the gate signal of semiconductor switch is removed, this mode is started. The stored energy in the primary inductance is transferred to the secondary inductance and secondary inductance increases the output voltage. Besides, the stored energy in the leakage inductance is transferred to RCD snubber cell throughout this mode and the voltage of snubber capacitance is increased. When the current of secondary inductance falls to zero, this mode is finished and it is returned to Mode 1.

3. Simulation Setup and Waveforms

To verify the theoretical analysis of proposed RCD snubber PWM dc-dc flyback converter, a simulation circuit is setup and related waveforms are introduced in this section. The simulation circuit is setup in PSIM 9.1 and presented in Fig. 3. Furthermore, the waveforms of converter devices are introduced in Fig. 4. Finally, the device parameters in the proposed converter is presented in Table 1. The leakage inductance leads high voltage spikes on the semiconductor switch. However, in the proposed converter, the voltage spikes on the semiconductor switch is reduced by proposed RCD snubber cell. It can be seen in Fig. 4 that the voltage stress on semiconductor switch about 300 V and it is very reasonable value. Besides, the output voltage is set to fixed 16 V.

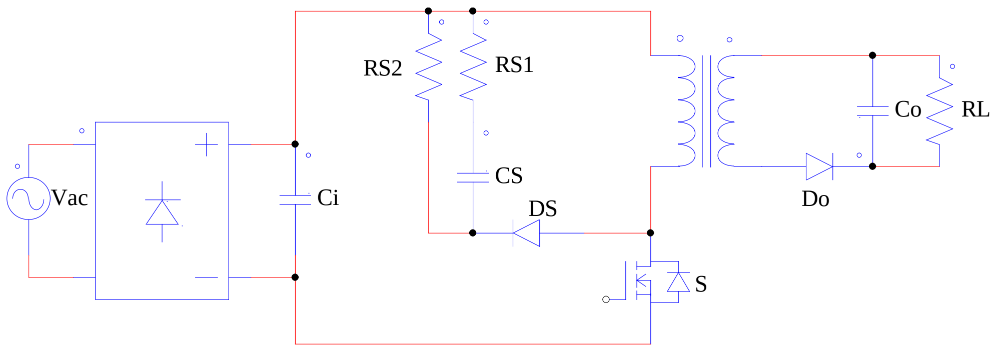


Figure 3 Simulation setup of proposed converter.

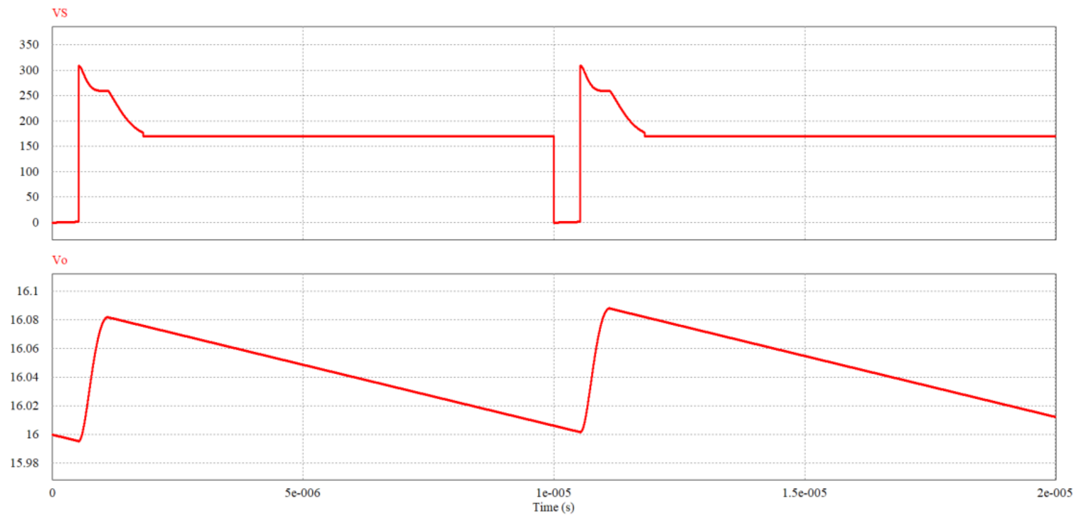


Figure 4 The voltage of switch (above) and the output voltage (below).

Table 1 Converter parameters

Parameter	**Value**	**Unit**
Input Voltage	170	V
Output Voltage	16	V
Load Current	4	A
Primary Turns	24	
Secondary Turns	4	
Magnetization Inductance	280	uH
Leakage Inductance	1.5	uH
Switching Frequency	100	kHz
Snubber Resistors	5	Ω
Snubber Capacitance	22	nF
Input Capacitance	47	uF
Output Capacitance	100	uF

4. Conclusion

This paper introduces a novel RCD snubber cell for PWM flyback dc-dc converters. The leakage inductance causes high voltage spikes on the semiconductor switch however the voltage spikes are reduced by proposed RCD snubber cell. In the paper, after the presentation of novel converter, the theoretical analysis of proposed converter is introduced. Subsequently, the simulation circuit is presented and related waveforms are illustrated. As observed from waveforms, the voltage spikes on the semiconductor switch is reduced at acceptable value. The converter is operated at 100 kHz and 64 W output power. The proposed converter is suitable for low power and high switching frequency PWM flyback dc-dc converters.

References

Abramovitz, A., Liao, C-S. & Smedley, K. (2013) State-Plane Analysis of Regenerative Snubber for Flyback Converters. *IEEE Transactions On Power Electronics*, 28, 5323-5332.

Ai, T-H. (2005) A novel integrated non-dissipative Snubber for flyback converter. *Proceeding International Conference Systems and Signals*. 66–71.

Gacio, D., Alonso, J. M., Calleja, A. J., García, J. & M. Rico-Secades. (2011) A universal-input single-stage high-power-factor power supply for HB-LEDs based on integrated buck-flyback converter. *IEEE Transactions On Industrial Electronics*, 58, 589–599.

Jung, S. & Chou, G-H. (2014) Transformer Coupled Recycle Snubber for High-Efficiency Offline Isolated LED Driver With On-Chip Primary-Side Power Regulation. *IEEE Transactions On Industrial Electronics*, 61, 6710-6719.

Meng, P., Wu, X., Yang, J., Chen, H. & Qian, Z. (2010) Analysis and design considerations for EMI and losses of RCD snubber in flyback converter. *Proceeding IEEE APEC*, 642–647.

Papanikolaou, N. P. & Tatakis, E. C. (2004). Active Voltage Clamp in Flyback Converters Operating in CCM Mode Under Wide Load Variation. *IEEE Transactions On Industrial Electronics*, 51, 632-640.

Rezai, M. A., Lee, K-J. & Huang, A. Q. (2016). A High-Efficiency Flyback Micro-inverter With a New Adaptive Snubber for Photovoltaic Applications. *IEEE Transactions On Power Electronics*, 31, 318-327.

Spiazzi, G., Buso, S. & Tagliavia, D. (2000) A low-loss high-power-factor flyback rectifier for smart power integration. *Proceeding IEEE PESC'00, Galway, Ireland*, 805–810.

Sukesh, N., Pahlevaninezhad, M. & Jain, P. K. (2014) Analysis and implementation of a single-stage flyback PV microinverter with soft switching. *IEEE Transactions On Industrial Electronics*, 61, 1819–1833.

Ting, N. S., Aksoy, I., & Sahin, Y. (2015). A new ZCT-ZVT PWM interleaved DC-DC boost converter. *2015 Intl Aegean Conference on Electrical Machines & Power Electronics (ACEMP), 2015 Intl Conference on Optimization of Electrical & Electronic Equipment (OPTIM) & 2015 Intl Symposium on Advanced Electromechanical Motion Systems (ELECTROMOTION)*, 250-256.

Ting, N. S., Sahin, Y., & Aksoy, I. (2017) Analysis, design and implementation of a zero voltage-transition interleaved boost converter. Journal of Power electronics, 17(1), 47-55.

Xie, X., Wang, J., Zhao, C., Lu, Q. & Liu, S. (2012) A novel output current estimation and regulation circuit for primary side controlled high power factor single-stage flyback LED driver. *IEEE Transactions On Power Electronics*, 27, 4602–4612.

Zhang, J., Huang, X., Wu, X. & Qian, Z. (2010) A high efficiency flyback converter with new active clamp technique. *IEEE Transactions On Power Electronics*, 25, 1175-1785.