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Simulation and Implementation of the Two Switch Serial Input Interleaved Forward Converter

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Abstract

The high voltage DC available in the telecommunication systems has to be converted into low voltage DC for battery charging etc. This paper deals with simulation and implementation of two switch Interleaved Forward Converter for such application. The DC input is converted into high frequency AC using the Forward Converter. The secondary AC is rectified using a half-wave rectifier. Experimental results obtained from the hardware prototype confirm the theoretical analysis and the performance of the proposed converter. The experimental results are compared with those of the simulation.

Keywords: DC-DC Converter, Interleaved Forward Converter, Matlab, Microcontroller

1. Introduction

Many industrial applications require DC power and there is a great need for the stepping down of the voltage of DC in many an electronic gadget such as mobile phones, laptops, etc. This kind of conversion of the voltage of the same type of current is achieved by what is called DC to DC converter which is an Electronic Converter that converts DC voltage from one level to another. DC to DC converters (with isolation) effectuate the conversion, by storing the input energy temporarily and then releasing it to the output at a different voltage level. This temporary storing of the energy is performed by/in magnetic field storage components (inductors, transformers) or electric field storage components (capacitors). This conversion method is more efficient than linear voltage regulation in which the unwanted power is dissipated as heat energy. The efficiency can be enhanced by the use of power FETs, which operate at high frequency and are more efficient than power bipolar transistors. DC to DC converters are indispensable in portable electronic devices such as cellular phones and computers which get their power from their batteries.

DC to DC converters (with isolation) use what is called Galvanic isolation. It is the principle of isolating functional sections of electrical system by preventing the flow of charge carrying particles from one section to another, i.e., there is electric current flowing directly from one section to the next. Energy and/or information can still be exchanged between the sections by other means such as capacitance, inductance, electromagnetic waves, and optical, acoustic or mechanical means. Converters with galvanic isolation are of two types, namely Flyback converter and Forward converter. Forward converter is a popular Switched Mode Power Supply (SMPS) circuit that is used for producing isolated and controlled DC voltage from the unregulated DC input supply. Forward converters find applications in Power supply for DC motor, Battery charging, Battery operated Electric vehicle, Telecom industry etc.

The input DC supply for a Forward converter is often derived after rectifying (and little filtering) the AC voltage. The Forward converter, when compared with the Flyback circuit, is generally more energy efficient and is used in high power output applications (in the range of 100 watts to 200 watts), while the Flyback converter is used in low power applications, i.e., below 100 watts. The Forward converter is simple and retains many features of the buck converter. With a proper choice of the transformer turns ratio, the Forward Converter can attain wide step down

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voltage which is useful in offline applications. Moreover, this Forward converter is quite easy to control. These advantages make the Forward converter more suitable for low to medium isolated offline power applications.

Series-input interleaved forward converter with a shared switching leg for wide Input Voltage Range Application is given by Xu[1]. The analysis and design of the Forward converter with energy regenerative snubber is given by Smedley[2]. A novel ZVS resonant reset dual switch forward DC-DC converter is given by Gu[3]. Reducing common-mode noise in two-switch forward converter is given by Kong[4]. High efficiency active clamp forward converter for sustaining power module of plasma display panel is given by Kim[5]. Zero-voltage switching post regulation scheme for multi output forward converter with synchronous switches is given by Kim[6]. RCD reset dual switch forward DC/DC converter is given by Gu[7]. The Two switch active clamp forward converter with one clamp diode and delayed turnoff gate signal is given by Park[8]. A new Interleaved Series Input Parallel Output (ISIPO) forward converter with inherent demagnetizing features is given by Jin[9]. Analysis, design, and experimentation of a double forward converter with soft switching characteristics for all switches are given by De Souza Oliveira[10].

As the literature cited above does not give instances of studies comparing simulation and experimental results of two switch interleaved forward converter, this work chooses to compare the experimental results with those of simulation. The implementation of two switch forward converter using PIC controller is also not available in the reports of recent research. Hence this work proposes embedded controller for the control of TSFC system.

2. Forward Converter

The block diagram of Forward converter system is shown in Figure 1. This converter converts unregulated DC power to regulated DC power. It comprises high frequency transformer which is also called isolation transformer. This provides isolation between the load and the main circuit. As the frequency increases, the size of the transformer decreases. This is because the flux decreases with the increase in the frequency of the transformer.

2.1 DC Load

The output power is regulated DC power which can be used in applications like speed control of the motor,

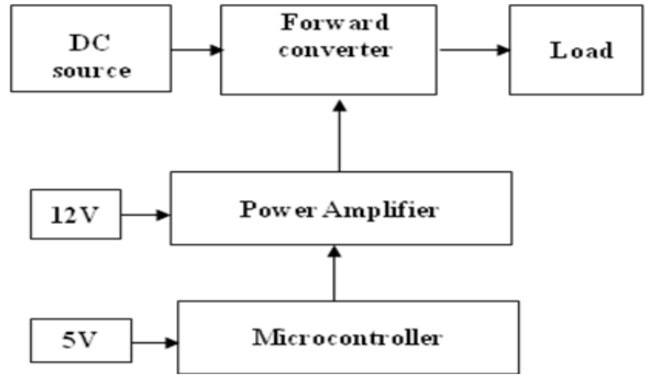


Figure 1. Block diagram of forward converter system.

battery charging, telecommunication, computers, cellular phones, electrical drives, and other applications which need DC power.

2.2 Micro Controller

Micro controller is used to generate triggering pulses for the MOSFETs. The triggering pulses are of same width and have equal intervals of time. It is also used to control the output of the Forward converter by varying the pulse width applied to the MOSFET. Microcontrollers have more advantages like fast response, low cost, small size, and improved reliability etc., compared with the analog circuits.

2.3 Power Amplifier

Power amplifier is used to amplify the pulse produced by the microcontroller and pass on the amplified pulse to the MOSFET in the main circuit. It also provides isolation between the microcontroller and the power circuit. It is neccessary to provide isolation between the power circuit (main circuit) and the microcontroller. Driver IC operates at 12V which is obtained from the AC mains using a step-down transformer and a rectifier.

The design calculations are done based on the following assumptions:

Flux Φ_m=20μwb.
Frequency f=10KHz.
$E_1=4.44N_1\Phi_m f$ volts.
E_1=Primary voltage of transformer.
E_2=Secondary voltage of transformer.
N_1=Primary turns of transformer.
N_2=Secondary turns of transformer.
From,
$N_1 = E_1/(4.44\Phi_m f)$, we get

N_1=337.8≈338 turns.
From,
$N_2 = E_2/(4.44\Phi_m f)$, we get
N_2=28.1≈28 turns.
$r = \sqrt{3}\ /12\omega^2 L_1\ C_3$.
With r =1.7*10^{-9} & C_3 = 470mF, we get
L_1 = 46mH.
Time T=1/f_1.
T=1/10,000 =100μs.
Therefore,
The Pulse Width is 50μs.

The specifications of the components used for simulation are as follows:

Capacitance C, C_1, C_2, and C_3 = 330mF, 330mF, 360mF, and 470mF respectively.
Switching Frequency=10KHz.
Inductance L=35mH and L_1=46mH.
Load Resistance R=5Ω.

3. Simulation Result

The circuit was modelled using the elements of simulink and the simulation was performed using MATLAB. Two switch serial input interleaved forward converter is shown in Figure 2a. The energy in the upper capacitor is transferred to transformer T1 and the energy in the lower capacitor is transferred to transformer T2. They step up the voltage and the secondary voltage is rectified using an uncontrolled rectifier.

DC input voltage is shown in Figure 2b and its value is 300volts.

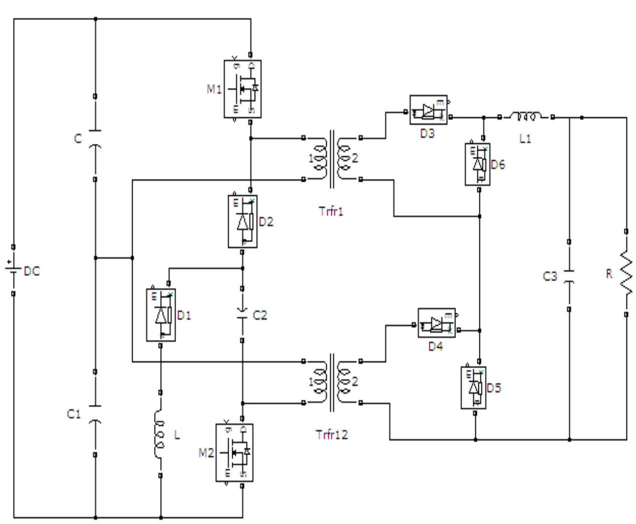


Figure 2. (a) Circuit diagram of two switch forward converter.

The input voltage and the voltage across the MOSFET M1 are shown in Figure 2c. The output voltage is the complement of the input voltage.

The switching pulses for MOSFETs M1and M2 are shown in Figure 2d.

The volages across the primary and the secondary of transformer 1 are shown in Figure 2e. The transients

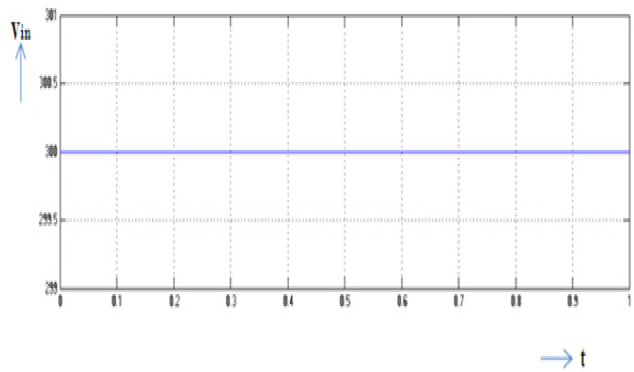


Figure 2. (b) Input voltage.

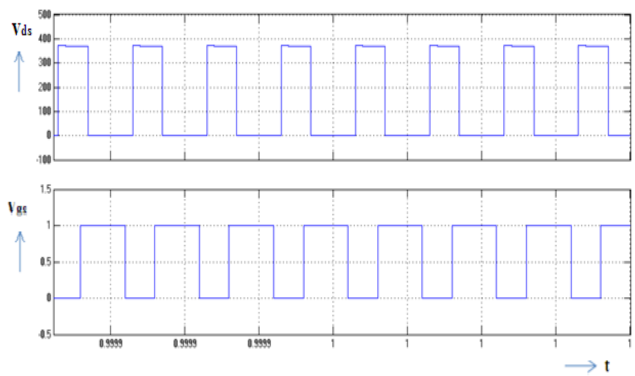


Figure 2. (c) Drain to source voltage and switching pulse.

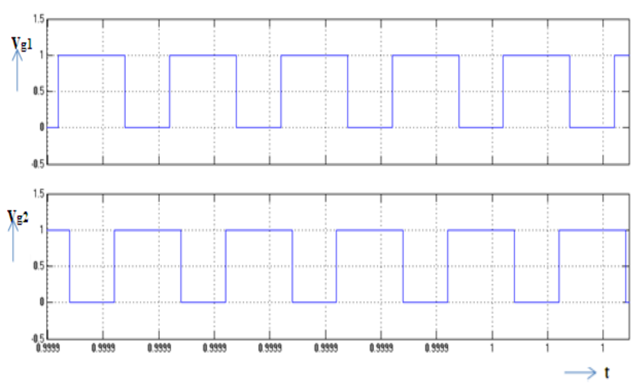


Figure 2. (d) Switching pulses for M1 and M2.

in the secondary are due to the presence of L&C in the output side.

The volages across the primary and the secondary of transformer 2 are shown in Figure 2f.

The DC output voltage is shown in Figure 2g. The output voltage is 53V.

The output current and the output power are shown in Figures 2h and 2i respectively. The output current is 10A and the output power is 530 Watts.

4. Hardware Investigations

The hardware set-up of ILFC system is shown in Figure 3a. The hardware consists of control circuit and power circuit. The DC input voltage is shown in Figure 3b. The Switching pulse1 and the output of driver1 are shown in

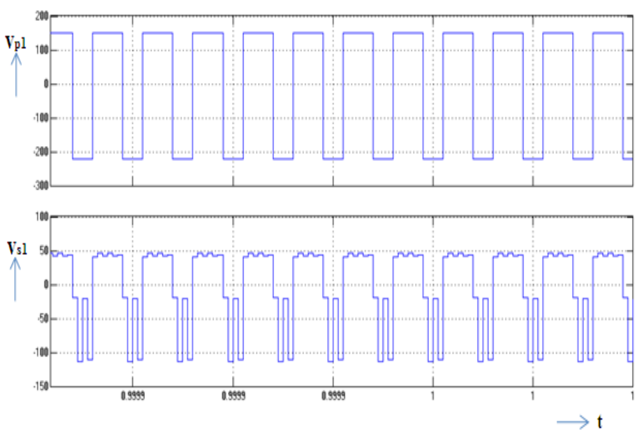


Figure 2. (e) Primary and secondary voltages of the Transformer1.

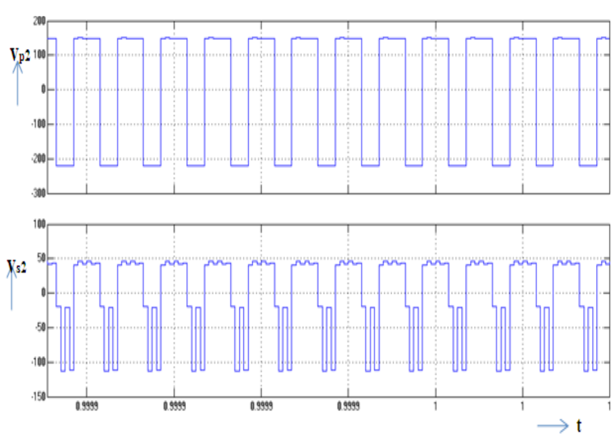


Figure 2. (f) Primary and secondary voltages of Transformer2.

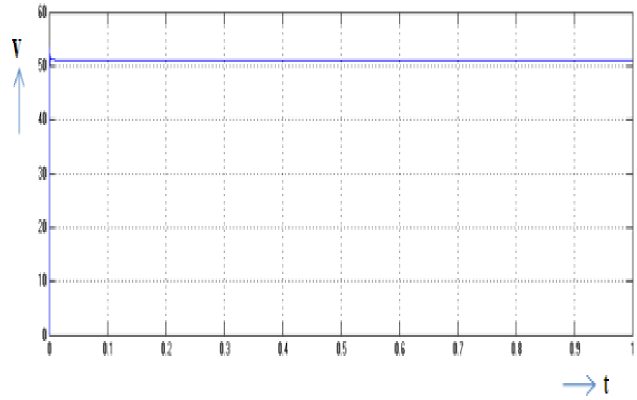


Figure 2. (g) Output voltage.

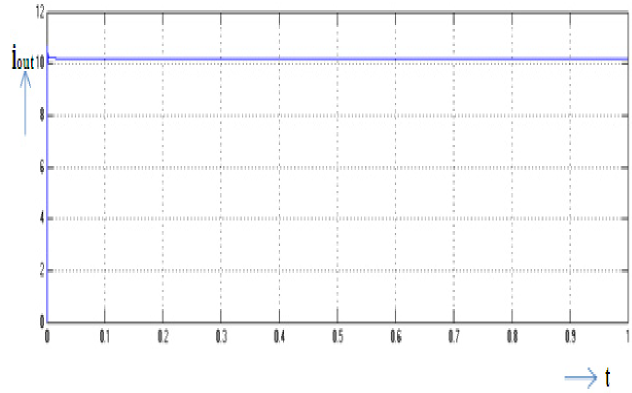


Figure 2. (h) Output current.

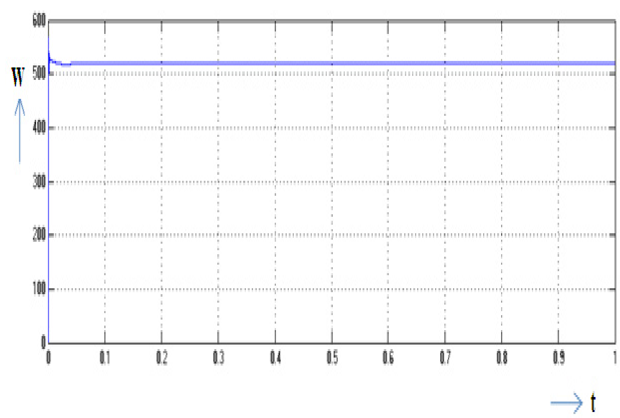
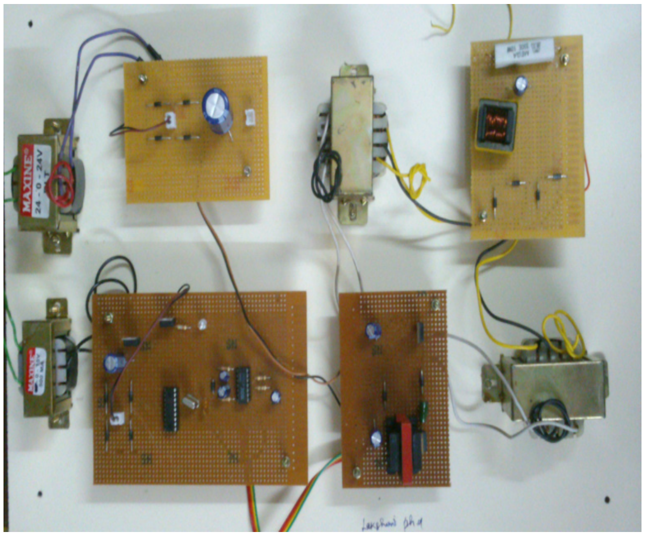


Figure 2. (i) Output power.

Figures 3c & 3d respectively. The switching pulse2 and the output of driver2 are shown in Figures 3e & 3f respectively. Transformer-primary and secondary-voltages are shown in Figures 3g & 3h respectively. The DC output voltage is shown in Figures 3i.



Figures 3. (a) Hardware set-up.

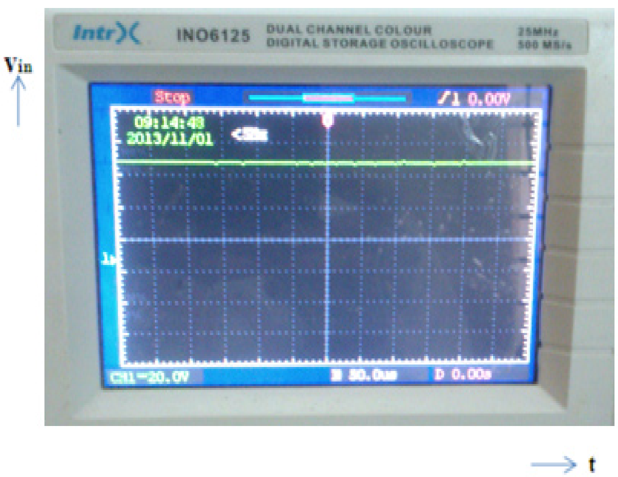


Figure 3. (b) Input voltage.

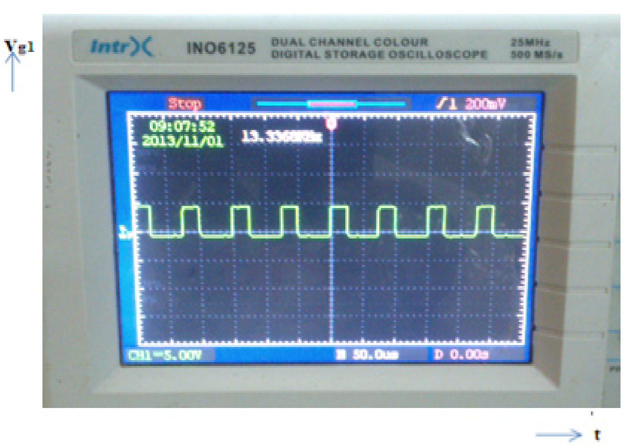


Figure 3. (c) Switching pulse for M1.

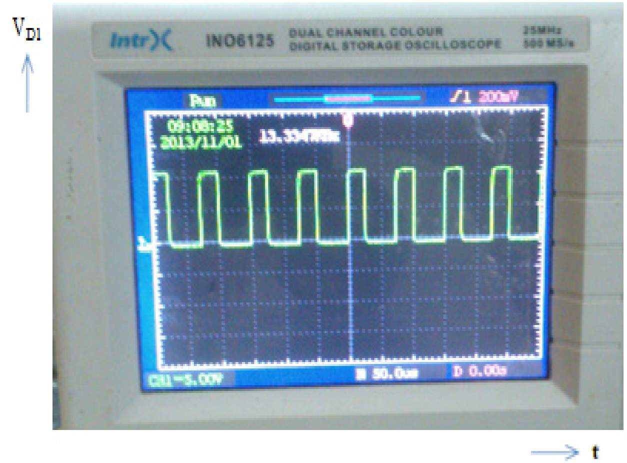


Figure 3. (d) Output of the Driver1.

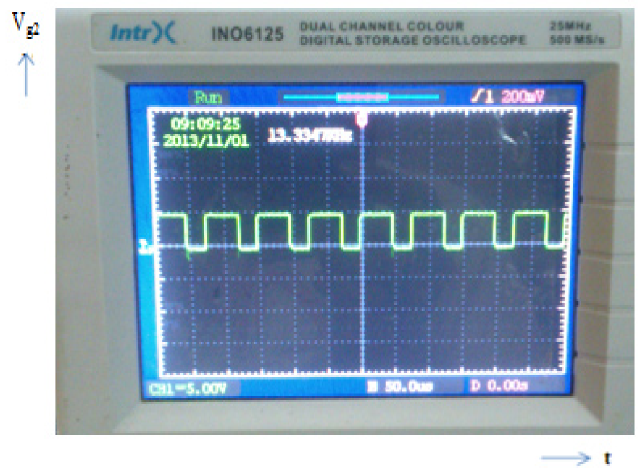


Figure 3. (e) Switching pulse for M2.

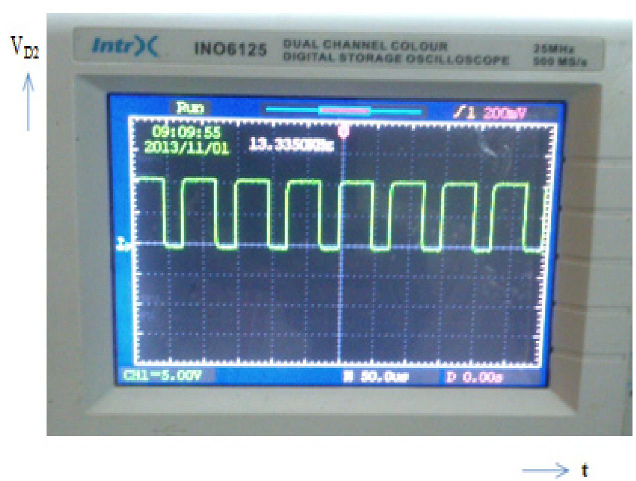


Figure 3. (f) Output of the Driver2.

Figure 3. (g) Transformer primary voltage.

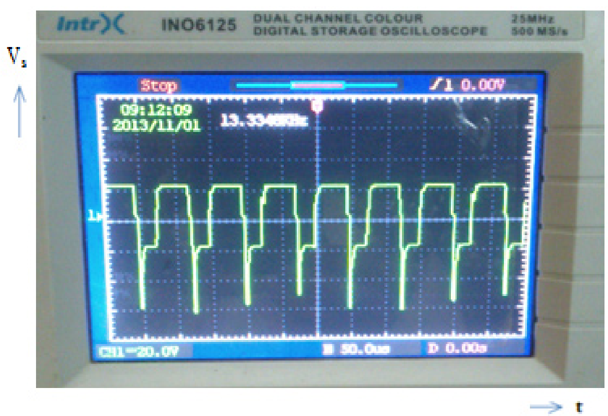


Figure 3. (h) Transformer secondary voltage.

Figure 3. (i) DC output voltage.

5. Conclusion

The two switch serial input interleaved forward converters were modeled and simulated using MATLAB Simulink. The simulation results were found to be in line with the predictions. The hardware was fabricated and tested. The experimental results obtained from the hardware prototype were found to support the theoretical analysis and the performance of the proposed converter. They are almost similar to the simulation results.

The scope of this study includes the modeling, the simulation and the implementation of open loop controlled two switch ILFC system. The closed loop system will be implemented in future.

6. References

1. Xu H, Xu P, Liu W, Xing Y. Series-input interleaved forward converter with a shared switching leg for wide Input Voltage Range Applications. IEEE Trans Ind Electron. 2013 Nov; 60(11):5029–39.
2. Abramovitz A, Cheng T, Smedley K. Analysis and design of forward converter with energy regenerative snubber. IEEE Trans Power Electron. 2010; 25(3):667–76.
3. Gu Y, Lu Z, Qian Z, Gu X, Hang L. A novel ZVS resonant reset dual switch forward DC-DC converter. IEEE Trans Power Electron. 2007 Jan; 22(1):96–103.
4. Kong P, Wang S, Lee FC, Wang Z. Reducing common-mode noise in two-switch forward converter. IEEE Trans Power Electron. 2011 May; 26(5):1522–33.
5. Kim T-S, Han S-K, Moon G-W, Youn M-J. High efficiency active clamp forward converter for sustaining power module of plasma display panel. IEEE Trans Ind Electron. 2008 Apr; 55(4):1874–6.
6. Kim J-K, Choi S-W, Moon G-W. Zero-voltage switching post regulation scheme for multi output forward converter with synchronous switches. IEEE Trans Ind Electron. 2011 Jun; 58(6):2378–86.
7. Gu Y, Gu X, Huang L, Du Y, Lu Z, Qian Z. RCD reset dual switch forward DC/DC converter. Proceedings 35th IEEE PESC; 2004. p. 1465–69.
8. Park KB, Moon GW, Youn MJ. Two switch active-clamp forward converter with one clamp diode and delayed turnoff gate signal. IEEE Trans Ind Electron. 2011 Oct; 58(10):4768–72.
9. Jin T, Zhang K, Zhang K, Smedley K. A new Interleaved Series Input Parallel Output (ISIPO) forward converter with inherent demagnetizing features. IEEE Trans Power Electron. 2008 Mar; 23(2):888–95.
10. de Souza Oliveira S, de Alencar e Silva CE, Torrico-Bascope RP, Tofoli FL, Bissochi CA, Vieira JB, Farias VJ, de Freitas LC. Analysis, design and experimentation of a double forward converter with soft switching characteristics for all switches. IEEE Trans Power Electron. 2011 Aug; 26(8):2137–48.