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# Soft Switched Flyback DC-DC Converter for External Power Supply

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**ABSTRACT:** In this paper introduce soft switched flyback dc-dc converter for improving the performance in terms of average efficiency. Variable frequency control is used for this purpose. In order to provide soft switching two small ac capacitors are placed in both sides of flyback transformer. The switching pulses are generated by measuring the magnetizing voltage and current. This method provides zero-voltage switching during turn on and turn off periods even at light load condition. The regulated output is obtained by input reference current control. The new converter has four modes of operation which is described in this paper. The overall size of the system is reduced by increasing switching frequency. The simulation results under various load conditions are provided for verify the performance of the new converter.

**KEYWORDS:** flyback converter, resonant converters, soft switching

## I. INTRODUCTION

Flyback topology is widely used because of their relative simplicity and ability to handle multiple isolated outputs, and the ease of optimizing their duty cycle by selecting the transformer turns ratio compared to other topologies [1]. The flyback "transformer" minimizes the magnetic component compared with forward converter by performing dual purpose of energy storage element and converter isolation [2]. The power density of PWM converters can be increased by increasing switching frequency. But the issue related to high switching frequency is increased switching losses and electromagnetic interference (EMI) [3]. In order to overcome these problems, soft switching methods are employed.

Many numbers of resonant topologies, such as quasi-resonant, multi resonant, resonant transition, active clamp, phase controlled and resonant load converters, has been developed for achieving the soft switching in dc-dc converter. In these converters, zero-voltage or zero-current switching is achieved by shaping the voltage or current waveform with the help of resonant tank circuit [4]-[15].The concept of quasi resonant converter (QRC) is introduced in [9], [10]. In QRCs, soft switching is achieved with the help of high frequency resonant tank in order to shape voltage or current in quasi sinusoidal form. They provide high voltage and current stress during wide load variation and also cause oscillations due to junction capacitance of diode. To overcome these problems multi resonant converters are employed, in which resonant elements includes transistor output capacitance, diode junction capacitance and transformer leakage inductance are arranged in such a way that it absorbs all major parasitic in the circuit. The circulating energy produced by continuous resonance limits wide range of application. Resonant transition dc-dc converters use resonant active snubbers or auxiliary switches for shaping voltage or current waveform [10]. In these converters ZCS or ZVS occurs only a short period time provided by resonance. For this reason, most of the time converters act as PWM converter [4]-[7]. For flyback topology clamping circuit is necessary for dissipating leakage energy during turn off periods. In this topology the clamp circuit uses leakage energy of the inductor for achieving soft switching. The converter has good performance only at full load [13]. By moving to the phase shift control at fixed frequency, output voltage is regulated and ZVS is obtained with the help of inductive load [14]-[15].

In view of energy conservation, average efficiency is more important than full load efficiency. Therefore it is necessary for the converter to provide better performance at both light and full load conditions. The conventional resonant converters have constant frequency control, which results in poor efficiency at light load condition. Another drawback of conventional soft switching dc-dc converters is that the performance of converter depends on the load values and switching frequency. Thus variable frequency control is necessary for providing soft switching for wide load values, which in turn results in increased efficiency [15]-[17].

This paper presents a new control strategy for the soft switched flyback converter to obtain good performance over wide input voltage and load range. In the new converter, two small ac capacitors are placed on both side of transformer for achieving soft switching.

The new soft switched flyback converter will be presented in the next section. In section III, the converter operation and relative waveform are analyzed. Further analysis of converter is done in section III and section IV consists of control method adopted for the converter. Finally, analysis of results are done in section V

## II. SOFT SWITCHED FLYBACK DC-DC CONVERTER

Fig. 1 shows the soft switched flyback converter; in this secondary side consist an active switch instead of a diode for achieving variable switching frequency. Soft switching is achieved with the help of two capacitors $C_1$ and $C_2$. Resonance occurs between these capacitors and magnetizing inductance of flyback transformer, although it provide as an element for energy storage and galvanic isolation between input and output.

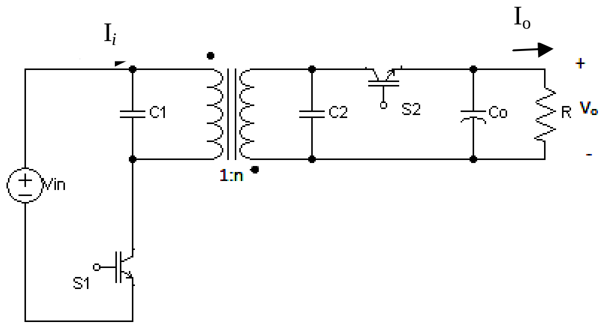


Fig. 1 Soft switched flyback dc-dc converter

## III. OPERATING PRINCIPLE

The soft switched flyback converter consists of four modes of operation in a single switching cycle; corresponding modes are represented by Fig.2. In mode 1 operation is shown in Fig.2(a), in which switch $S_1$is turned on, which cause charging of magnetizing inductance through the input. Since the switch $s_1$ is on magnetizing inductance will be charged in the positive direction. This mode continue until average input current equals to the input reference current, $i_{ref}$ and thus $S_1$ is turned off. Due to the presence of capacitors, the magnetizing voltage decreases slowly and makes the $S_1$to turn off at zero voltage. When $S_1$ is turned off, mode 2 will begins i.e. partially resonant occur between capacitors and magnetizing inductance. This mode is represented in Fig.2(b). During this mode voltage across the magnetizing inductance decreases, when this reaches to the reflected output voltage the switch $S_2$ is turned on and third mode of operation will begins. Fig.2(c) represents third mode of operation of the converter. During mode3 inductance is discharged trough the output. As a result magnetizing current decreases, when it reaches to small value or zero the switch $S_2$ is turned off and next mode is started. This is shown in Fig.2(d) In this mode, capacitor and inductance undergo resonant condition, and this will continue until mode 1 operation begins i.e. magnetizing inductance voltage reaches to input voltage and at the same time where current through inductor reaches to a small current in positive direction and this current is given by

$$I = \sqrt{\frac{C_1 + n^2 * C_2}{L_M}(V_P^2 - V_{in}^2)} \qquad \text{.................................. (1)}$$

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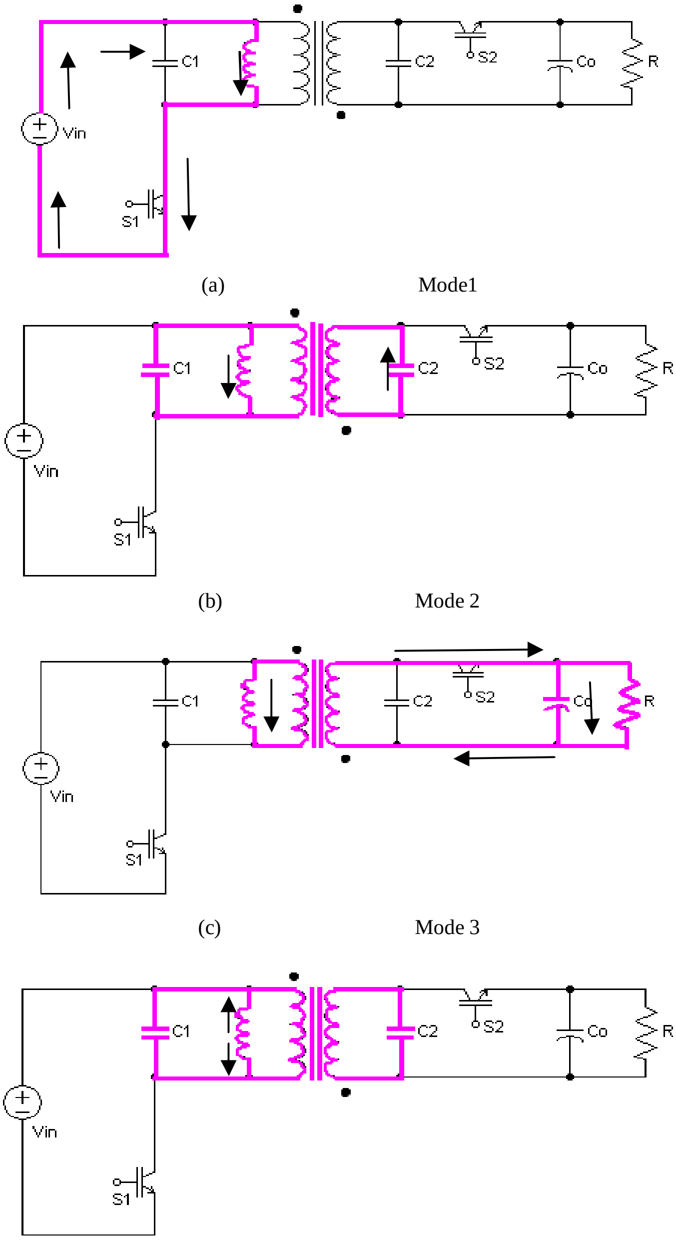


(a) Mode1

(b) Mode 2

(c) Mode 3

(d) Mode 4

Fig. 2 Modes of operations of soft switched flyback converter

## IV. CONTROL STRATEGY

Fig:3 shows the control strategy of the new converter. From the Figure it is clear that the output voltage and reference are compared and passed through PI controller for producing the reference current. The sensor A is used to measure the output voltage and B is used to measure the magnetizing voltage. The current sensor is employed to get the magnetizing current, for obtain this two current sensors are employed which sense the transformer's primary and secondary currents and properly subtracting these. By using these information pulses for the converter thus generated. For low values of reference current converter operates as buck converter and act as boost in high value of reference current.

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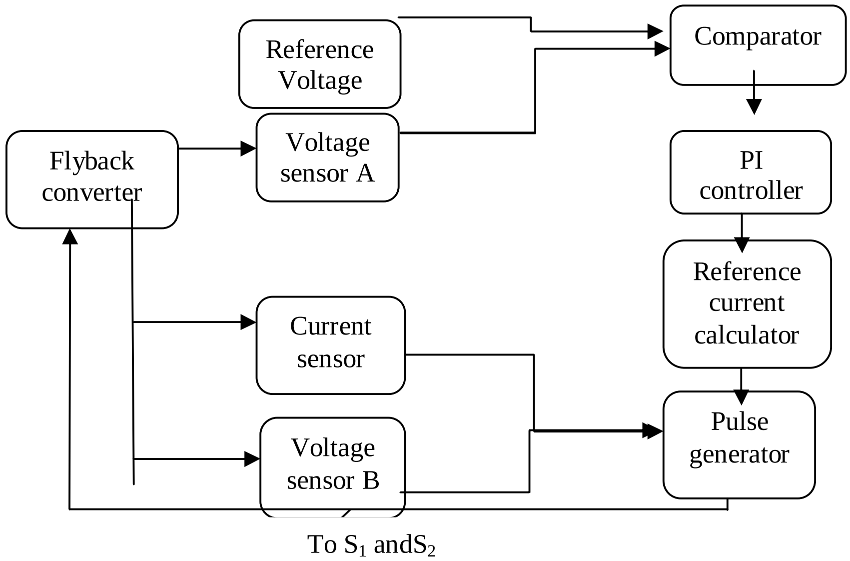


Fig.3 Block diagram of control strategy

The value of reference current is adjusted for obtaining fixed output voltage .Since reference current is calculated from load values, depending up on the load the reference current will vary. Under light load condition the value of output current is low as a result the reference current generated will be small value, as a result the duration of mode 1 and mode 3 are shortened. Which in turn result in the increasing of switching frequency of the converter from full load to light load condition.

## V. SIMULATION RESULTS

The soft switched flyback converter is simulated using MATLAB/SIMULINK model. In order to verify the performance of the converter different load conditions are chosen from full load to light load. Also for obtain regulated output reference current control is employed. The parallel combination of 42μH magnetizing inductance and 41nF total capacitance are chosen for obtaining 100 KHz switching frequency under rated load condition. The simulation is carried out at different load conditions with input voltage as 200V and 300V as output.

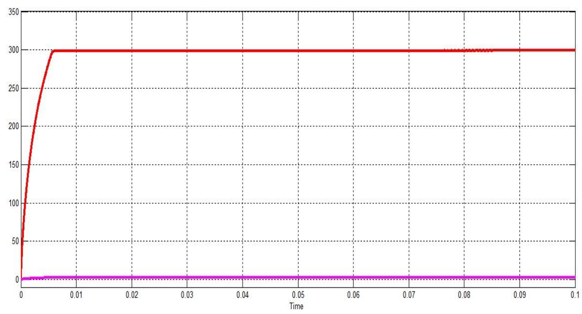

Fig.4 Output voltage and current at $V_{in}$=200V, 750W output and R=120Ω

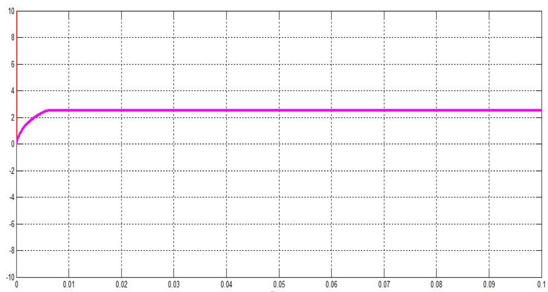

Fig.5 output current at $V_{in}$=200V, 750W output and R=120Ω

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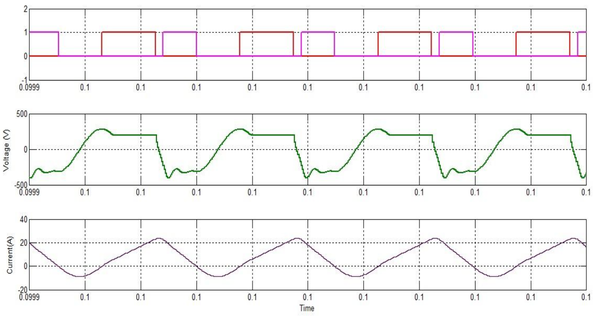

Fig.6 Waveforms with $V_{in}$=200V, 750W output and R=120Ω,top: switching pulses, middle: magnetizing voltage, and bottom: magnetizing current

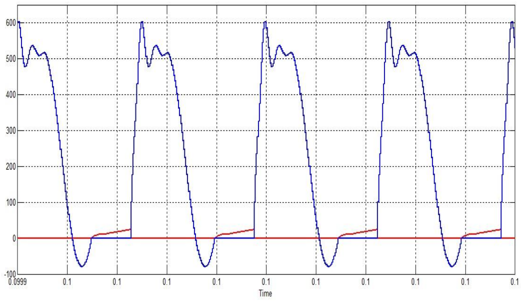

Fig.7 Voltage and current of switch $S_1$ at $V_{in}$=200V, 750W output and R=120Ω

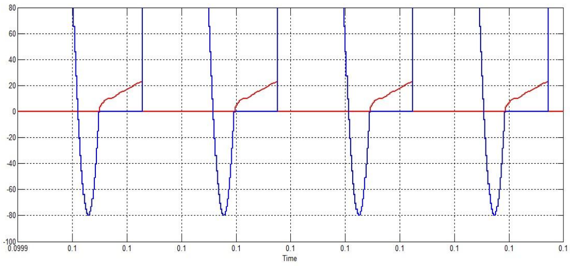

Fig.8 Close view of voltage and current of switch $S_1$ at $V_{in}$=200V, 750W output and R=120Ω

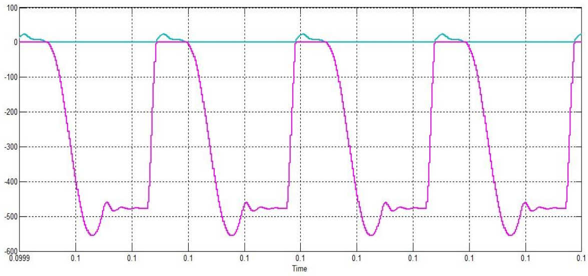

Fig.9 voltage and current of switch $S_2$ at $V_{in}$=200V, 750W

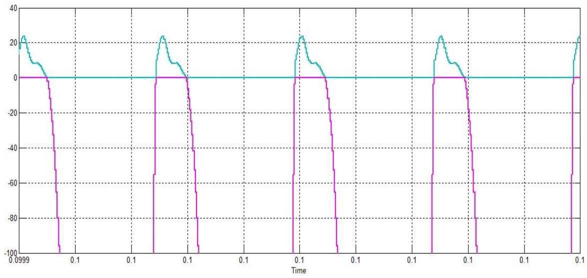

Fig.10 Close view of voltage and current of switch $S_2$ at $V_{in}$=200V, 750W

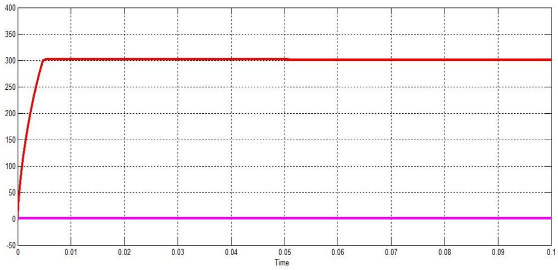

Fig.11 Output voltage and current at $V_{in}$=200Vand 75W output

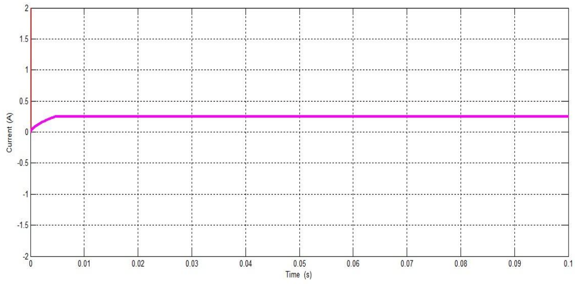

Fig.12 Output current at $V_{in}$=200Vand75W output

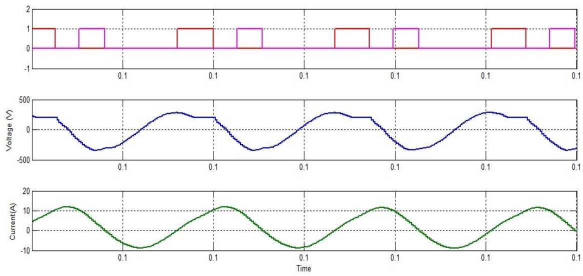

Fig.13 Waveforms with $V_{in}$=200V and 75W output, top: switching pulses, middle: Magnetizing voltage, and bottom: magnetizing current

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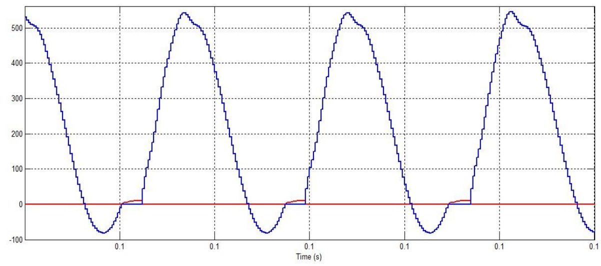


Fig.14 Voltage and current of switch $S_1$ at $V_{in}$=200V and 75W output

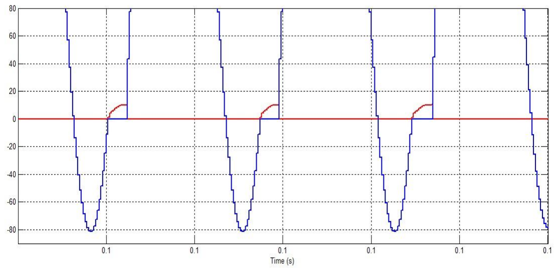


Fig.15 Close view of voltage and current of switch $S_1$ at $V_{in}$ =200Vand 75W output

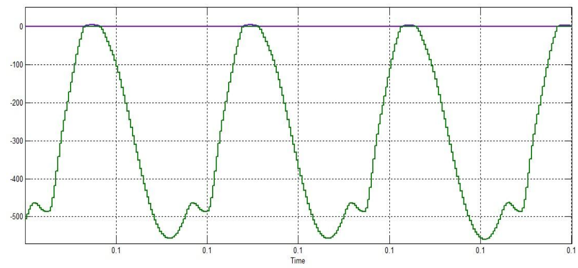


Fig.16 Voltage and current of switch $S_2$ at $V_{in}$=200V and 75W output

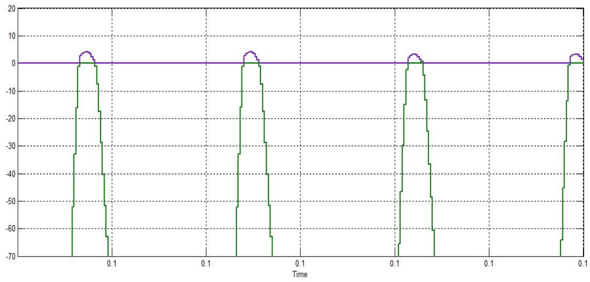


Fig.17 Close view of voltage and current of switch $S_2$ at $V_{in}$=200V and 75W output

Fig.4 and Fig.5 shows the output voltage and current of soft switched flyback converter under rated load condition. The switching pulses, magnetizing voltage and magnetizing current for the rated load are shown in Fig.6. The Fig.7 shows the voltage and current waveforms of main switch $S_1$at that load. Fig:8 is the zoomed view of Fig:7. The voltage across and current through switch $S_2$ are shown in Fig.9. Fig.10 is a zoomed view of Fig:9.

Fig.11 and Fig.12 shows the output voltage and current of soft switched flyback converter at 10% of rated load condition. Fig:13 shows the corresponding switching pulses, magnetizing voltage and magnetizing current at light load.Fig.14 shows the voltage and current waveforms of main switch $S_1$for 10% of rated load and Fig:15 is a close view of Fig:14. Fig.16 shows the voltage across and current through $S_2$ at that load condition and Fig:17 is a closed view of Fig:16. From the waveforms it is clear that soft switching is obtained even at light load condition i.e. converter provides zero voltage switching independent of load conditions.

## VI. CONCLUSION

This paper presents a soft switched flyback converter for provide good average performance in terms of efficiency, which is achieved by reducing switching losses during on and off periods even at light load condition . Two small capacitors are added on both side of the flyback transformer for achieving zero voltage switching. The advantage of this converter includes zero voltage switching over wide load conditions, low peak current compared to resonant converter. The new converter has smaller size due its increased switching frequency. Various simulation results are presented for verifying the performance of the new converter.

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