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Design and Analysis of a New Soft-Switching Multi-Output Fly-Back Converter

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ABSTRACT: This paper presents a new multi output converter. Demand for multiple output power supplies with low voltage and high current has increased. A multi output converters needs to satisfy these conditions such as efficiency, voltage regulation, isolation and size. The fly back converter is the most attractive because of its relative simplicity compared with other topologies used in low power applications and we get multiple outputs. The proposed fly back converter operated at zero-voltage-switching (ZVS) turn-on and zero-current-switching (ZCS) turn-off process. The operational principle, analysis, and design considerations of the proposed converter are presented in this paper.

KEYWORDS: Fly-back converter, Multi output, Zero Current Switching [ZCS], Zero Voltage Switching [ZVS].

I.INTRODUCTION

The Utilization demand for multiple-output power supplies with low voltage and high current has increased [1] – [5], specifically in medical application that is therapeutic ultrasound. A multi-output converter needs to satisfy these conditions such as high efficiency at any load condition, voltage regulation, isolation and compact size. The Fly-back topology is the most attractive because of its relative simplicity compared with other topologies used in low power applications and we can easily achieve multiple outputs. The high frequency Fly-back transformer [6] serves the dual purpose of providing energy storage as well as converter isolation and minimizing the magnetic component count when compared with the forward converter. The Conventional Fly-back converter has found to be suitable for low input voltage and low-medium-power applications.

In recently many of the soft switching techniques are developed [7]-[14]. The soft switching schemes [7]-[8] with variable switching frequency have been proposes to reduce the size of power converters and switching losses on power semiconductors. The many techniques were developed in [9]- [11] to achieve zero voltage switching, and zero current switching [12]-[14] turn-on. In half bridge fly-back converter proposed in [5] [10] the voltage across the switches is not greater than the input voltage, causing the short circuit of the auxiliary switch snubber capacitor during turn on. The switch current is limited by only it's on state resistance, which would damage the switch during turn on due to the flow of large current at the instant of turn on.

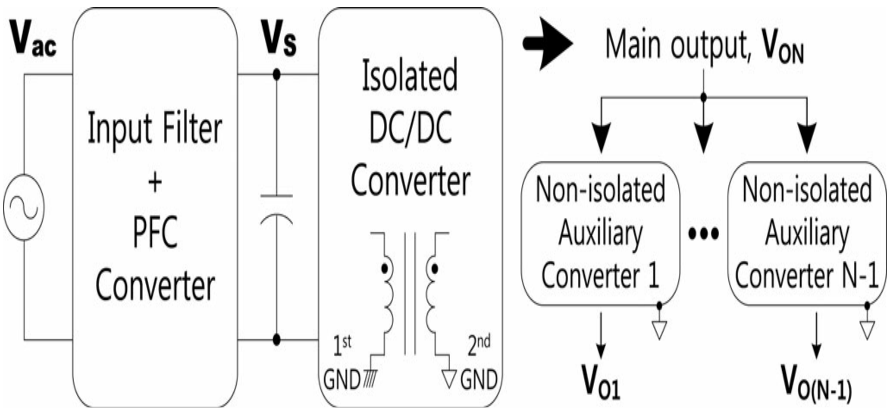

Fig.1: Block diagram of N multi output power supply with nonisolated auxiliary converter

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Fig1 shows the block diagram of typical *N* multi output power supply with nonisolated converters. The isolated dc/dc converter has dc input voltage *VS,* which comes from the input filter and power factor correction converter in ac line. It has the main output and, from this, auxiliary ones are made with a same ground. A new isolated multi output dc/dc converter is proposed. The proposed converter is based on the half-bridge fly back converter for the main output and buck converters for the auxiliary outputs.

The proposed converter integrated with the secondary fly back rectifier. This integration makes simple structure, and lower transformer size, and of main switch is operates at zero voltage- switching turn-on and zero-current-switching turn-off condition are achieved to gate control without additional components. In addition, cross regulation problems among the outputs do not occur.The auxiliary switch and the other semiconductor devices are operate at zero-current-switching turn-on and turn-off condition. The principle of operation, theoretical analysis of the proposed multi-output Fly-back converter rated 130W and operating at 100 kHz, provided to verify its performance.

II.PRICIPLE OF OPERATION

In conventional circuit have the two outputs and two switches in the both fly back converter and transformer secondary side which causes additional losses the operation is divided into six modes. The main operation for the both conventional and proposed operated one on duty cycle D and other one is compliment to it of the primary side. On the secondary side switches are removed and transformer turns are increased to get the multiple outputs.

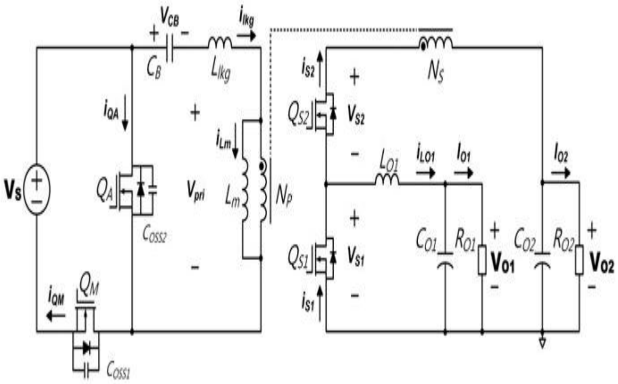

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Fig.2: Conventional Fly back converter with two outputs

The proposed multi output Fly-back converter shown in Fig.3. The circuit can divided in two parts. The first part is a conventional Fly-back converter, which is responsible for power transferred into the load. It is composed of an isolated Multi-winding transformer, a main switch Qm, output diodes D01, D02, D03& D04, and output filter C01, C02, C03 & C04. The Second part is commutation cell to provide the ZVS-ZCS to the main switch Qm. It is composed of the resonant inductor L1kg, the resonant capacitor CB, and auxiliary switch Qa, This section provides the soft-commutation functions to the power semiconductor devices of the Fly-back Converter.

The proposed Fly-back converter transformer is total five Windings, one primary winding and four secondary windings. In these four secondary windings, three windings are for positive voltage outputs and connected in series to reduce the number of turns and height of transformer, but it will increase the thickness of the wire. Fourth winding is for negative voltage. The input voltage is 30V and the output ratings are +38V/1.25A,+18V/2A, +5V/1.25A and -18V/2A. The three dynamic equivalent circuits of the proposed Fly back converter during one switching period is explained below.

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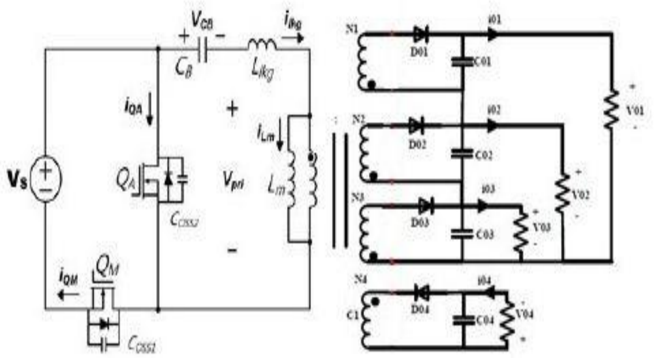


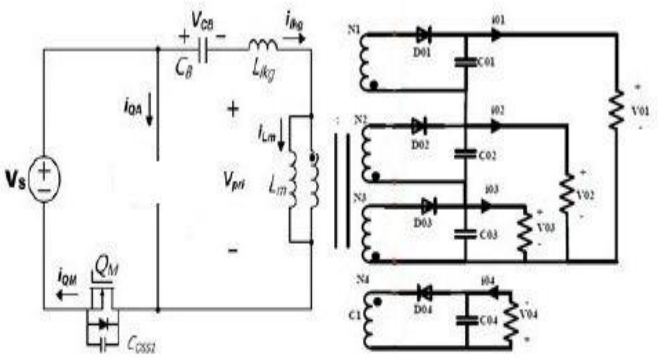
Fig.3: Block diagram of proposed Multi output Fly back converter

Operating modes and analysis:

Mode 1[t_o-t_1]: Mode 1 begins when S1 is ON S2 is OFF current flows from Switch S1 to primary of transformer. During this mode diodes D_{01}, D02, D03 and D_{04} are forward biased.

$$i_{lkg}(t) = i_{Lm}(t) + i_{LO1}(t)/n,$$

$$i_{Lm}(t) = \frac{V_S - V_{CB}}{L_m + L_{lkg}}(t - t_0) + i_{Lm}(t_0),$$



$$W_s = \frac{1}{\sqrt{LrCeq}} \text{ and } C_{eq} = \frac{C1Cr}{C1 + Cr}$$

Mode 2[t_1-t_2]: During this Mode Switch S1 is OFF S2 is ON the diodes D_{01}, D02, D03 and D_{04} are reverse biased. During this period the capacitors power to load.

$$i_{lkg}(t) = -\frac{V_{CB} - nV_{O2}}{L_{lkg}}(t - t_3) + i_{lkg}(t_3),$$

$$i_{Lm}(t) = -\frac{nV_{O2}}{L_m}(t - t_3) + i_{Lm}(t_3),$$

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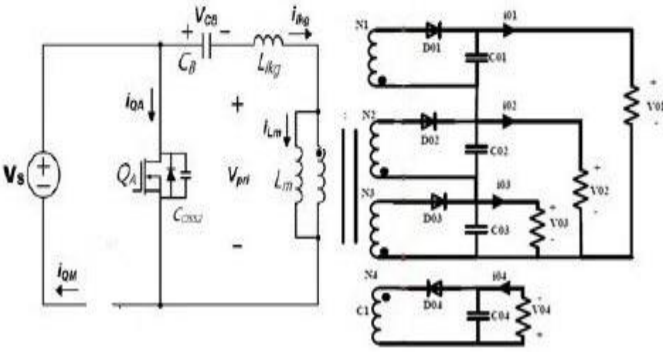
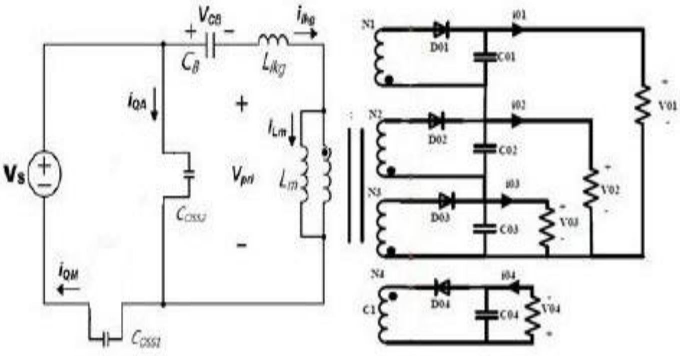


$$W_S = \frac{1}{\sqrt{L_r C_{eq}}} \text{ and } C_{eq} = \frac{C_1 C_r}{C_1 + C_r}$$

Mode 3[t_2-t_3]: During Mode 3 both S1 and S2 is turned OFF current stored by magnetizing inductor is discharged through primary wining of transformer. Due to this the diodes D_{01}, D02, D03 and D_{04} are forward biased.



$$\omega = \frac{1}{\sqrt{2L_{lkg}C_{OSS}}},$$

$$Z = \sqrt{\frac{L_{lkg}}{2C_{OSS}}}.$$

III.DESIGN CONSIDERATIONS

The gating signals for the primary side switches of the converter are given below which operate system correctly.

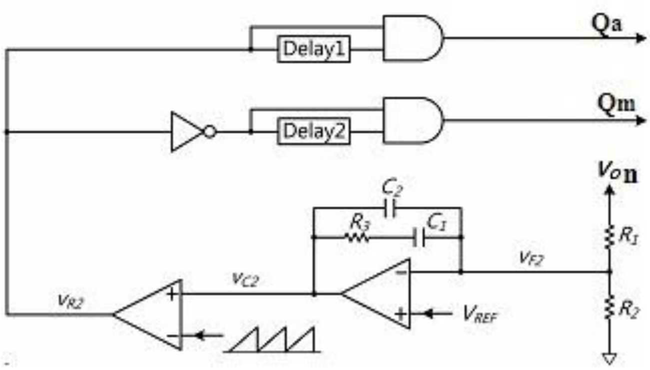


Fig 4. Gate signals

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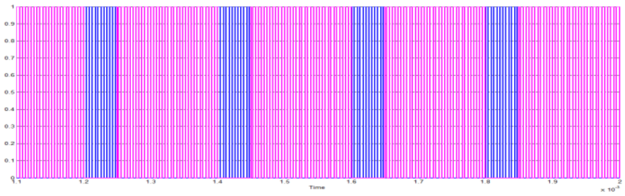

Fig 5.Gate Signals S1 & S2 of Proposed Converter

A. Design of voltage Transformer Ratio:

The turn's ratio design of proposed converter is similar to the conventional Fly-back converter. The transformer voltages ratios are 1:N1, 1:N2, 1:N3, 1:N4. The turn's ratio can calculated as follows.

$$V_{03}=\frac{N3*D}{(1-D)}*V_{in}$$

$$V_{02}=V_{03}+\frac{N2*D}{(1-D)}*V_{in}$$

$$V_{01}=V_{03}+\frac{N1*D}{(1-D)}*V_{in}$$

$$V_{04}=\frac{N4*D}{(1-D)}*V_{in}$$

B. Design of transformer magnetizing inductance:

The Fly-back transformer magnetizing inductance design is similar to the traditional Fly-back converter and can be calculated as follows

$$\frac{2Lm}{N2Ro}<(1-D)T_s$$

Where R0 is the total equivalent resistance referred to primary side of transformer $R'0 = N2R0$

$$\frac{2Lm}{R''o}<(1-D)T_s$$

C. Design of output filter capacitance:

Design of the output filter capacitor is based on the output Voltage ripples specifications.

$$C_o=\frac{Dvo}{FsRo\Delta V}$$

Where ΔV is the peak – peak ripple voltage ac component of the voltage across the capacitor.

D. Design of resonant components:

The resonant inductance selected based on the maximum value of the auxiliary switch current. To turn ON auxiliary switch with ZCS, the required series inductor Lr is can be calculated as follows.

$$\frac{(Vin+nvo+Vcro)}{Lr}t_{ro}\leq I_{imax}$$

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Here, tr0 is rise time of the auxiliary switch Vcro is the initial voltage of resonant capacitor and *lk L* is the leakage inductance of the transformer. The resonant capacitor *Cr* is determined depending on the transient intervals. The sum of the transient intervals selected to be smaller than 30% of the switching period. The transient intervals are t0-t6.

$$T_r = 2\pi\sqrt{LrCr}$$

The inductance Ls is selected maximum value of the current through it.

IV.SIMULATION RESULTS

The simulation results are shown in Fig.3. The specification of the converter is 100 KHz switching frequency. The main switch is turn on under ZVS and turn off under ZCS condition. The auxiliary switch and other semiconductor devices are operated under ZCS condition are shown in Fig.3.

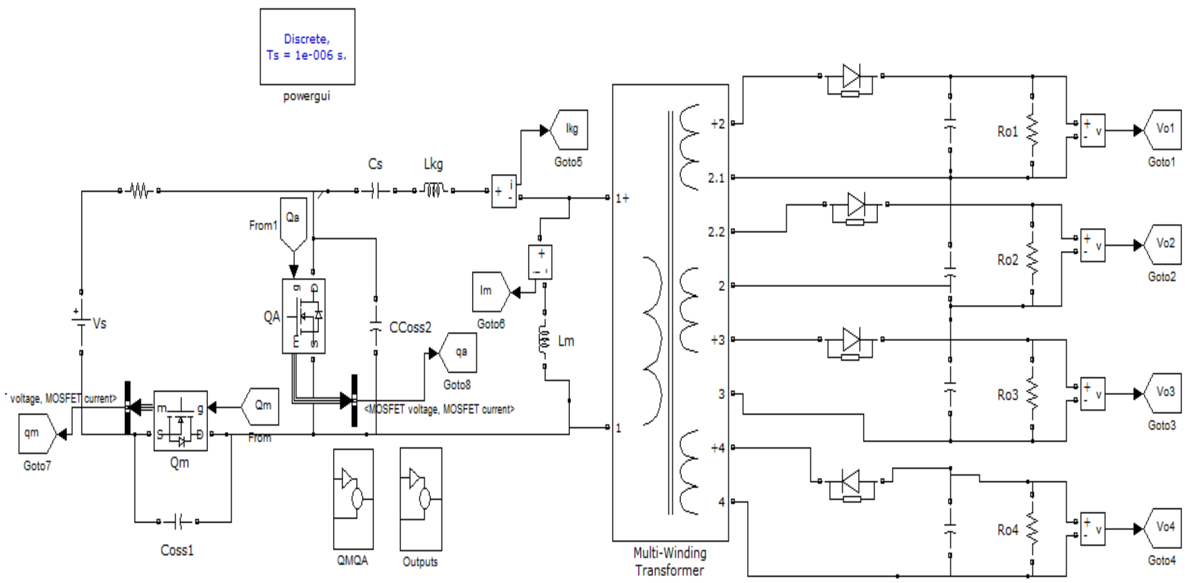

Fig 6 Matlab/Simulink Diagram

Fig 6 shows the simulink diagram of the proposed topology in which ZCS-ZVS is used for Turn ON-Turn OFF purpose and switches are eliminated.

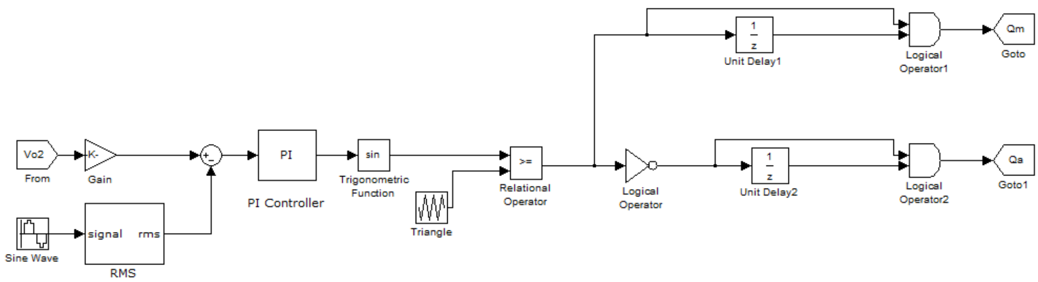

Fig 7. S1 &S2 Control Circuit of Proposed Converter

Fig 7 shows the pulse generation for the switches on the primary side of the circuit according to the pulse the switches are going to operate correctly for the required operation.

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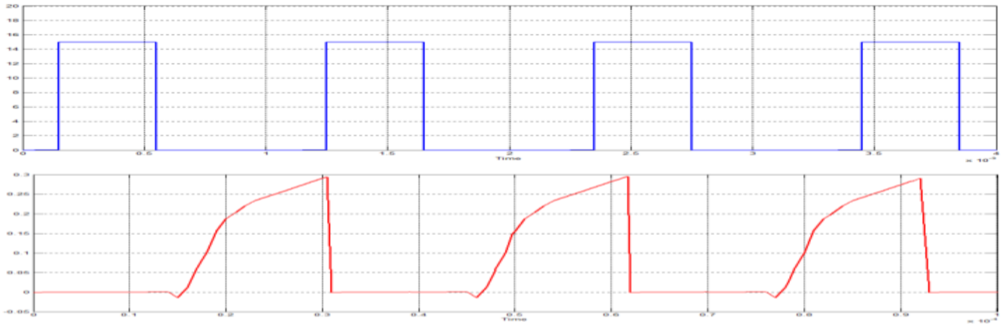

Fig 8.Apply ZVS on S1 & S2 switches of Proposed Converter

Fig 8 gives the information about the Zero Voltage Switching (ZVS) operation of the circuit which shows the current is going to vary linearly when the voltage is off condition.

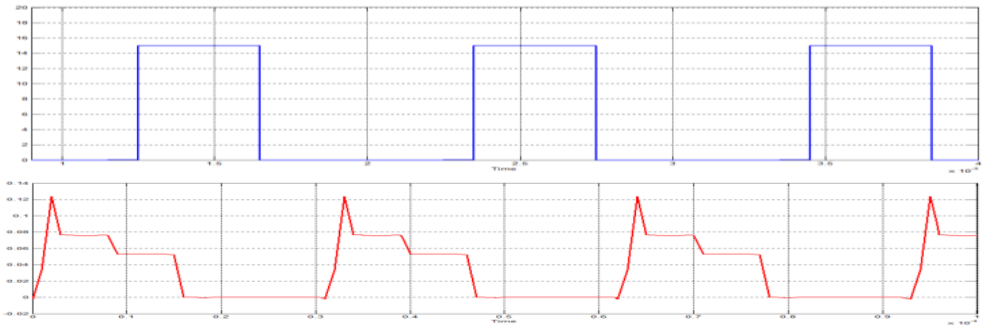

Fig 9.Apply ZCS on S1 & S2 switches of Proposed Converter

Fig 9 gives the information about the Zero Current Switching (ZCS) operation of the circuit which shows the Voltage is going to vary linearly when the Current is off condition.

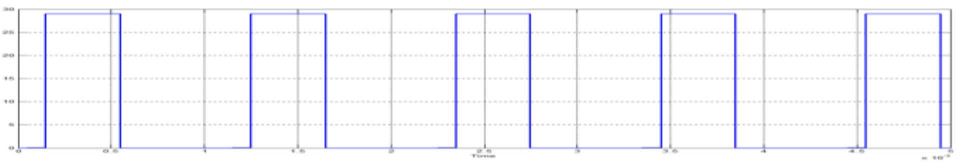

Fig 10.Transformer Primary Voltage

Fig 10 transformer primary winding voltage of the proposed circuit which is going to supplied to the system and operation depends on the switches turn on and off condition.

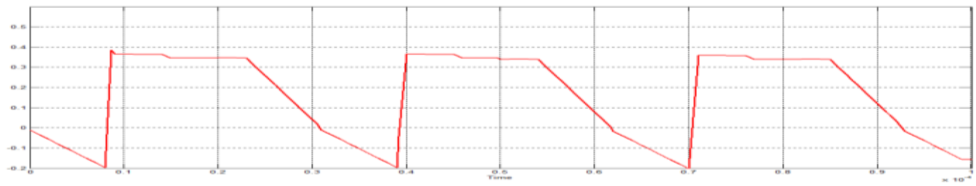

Fig 11.Leakage Current of Inductor

Fig 11 leakage currents of the proposed topology in which losses are going to reduced in its value when compared to the conventional topology.

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Table 1. TRANSFORMER PRIMARY AND SECONDARY TURNS

PRIMARY SIDE TURNS	SECONDARY SIDE TURNS
	67
53	32
	9
	32

Table 2. OUTPUT VOLTAGES

Conventional Technique	With Proposed Technique
12v	38v
	18v
24v	5v
	-18v

V.CONCLUSION

This paper presents a Complete simulation of Fly back converter with ZVS-ZCS is achieved for all the switches by gate control without additional components to get the multiple outputs. High efficiency is obtained under entire load conditions with reduced switching stress because secondary side switches are eliminated. No cross regulation problems occur. The proposed converter is suitable for multi output power supply which requires the outputs with same ground.

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