

# ZVS Boost Converter with an Auxiliary Resonant Circuit

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**Abstract**— This paper presents a zero voltage Switching DC-DC boost Converter with an Auxiliary resonant Circuit. The circuit consists of Boost Converter and in additional it has a auxiliary circuit which has a inductor, switch, diode and capacitor. With the help of an auxiliary circuit ZVS can be achieved and switching losses of a Boost Converter can be reduced. Generally in boost converters switching losses are dissipated in external passive resistors when a snubber circuit is used. This is called hard switching. In the given method the switching losses are avoided by forcing voltage (ZVS) to zero during switching. The switching losses are reduced by reducing the switching losses. MATLAB/Simulink simulations are performed to verify the theoretical analysis.

**Keywords**— Zero voltage switching, Boost, Efficiency, soft switching, DC-DC converter, switching losses, Simulation.

## INTRODUCTION

In conventional PWM converters operating in hard switching, where the voltage and current pulses goes from low to high value or from high to low value during the transition period, switching loss will occur. It also generates a substantial amount of Electromagnetic interference [3] [6]. These losses arise mainly because of output capacitance of the transistor, diode reverse recovery and capacitance of diode. By observation, it is seen that switching losses is directly proportional to switching frequency [4]. So switching frequency is limited by the switching losses. Because of the wide spectral range of harmonics present in PWM waveforms, a high Electro Magnetic Interference will occur [2]. Current spikes created by Diode recovery can also result in this electromagnetic interference.

Soft switching can reduce the Electromagnetic interference and switching losses by putting some stress on the devices [1] [5] [7] [11]. When either voltage or current is zero during the turn OFF or turn ON period, then the product of the current and voltage becomes zero, which leads to reduced power loss [9] [10] [12]. Therefore the switching loss can be reduced and the device can operate at high switching frequency [8]. Size and weight of the device is also reduced as the heat sink is not required.

## BOOST CIRCUIT WITH AN AUXILIARY RESONANT CIRCUIT

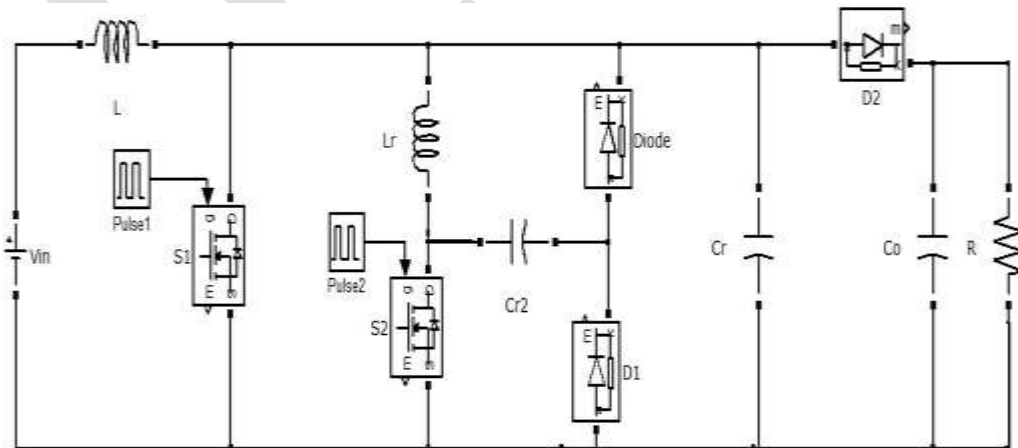


Fig 1 Boost circuit with an auxiliary circuit

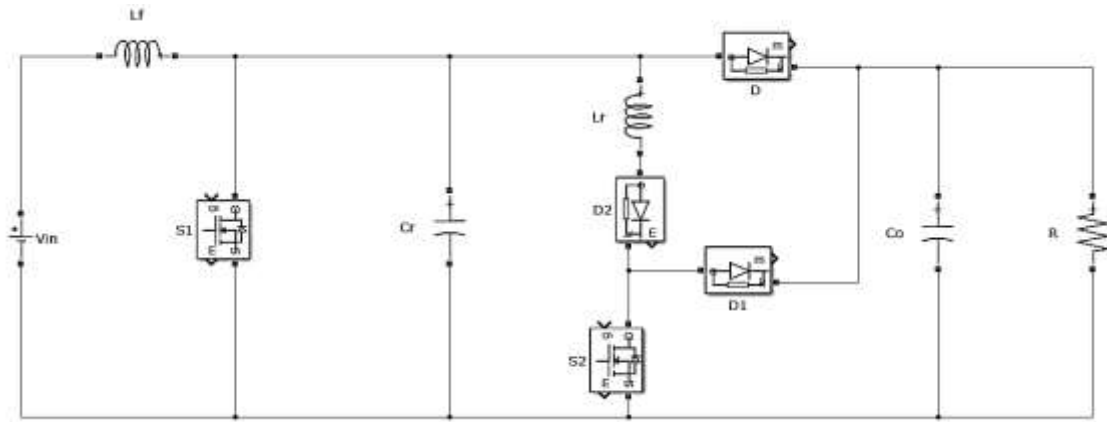


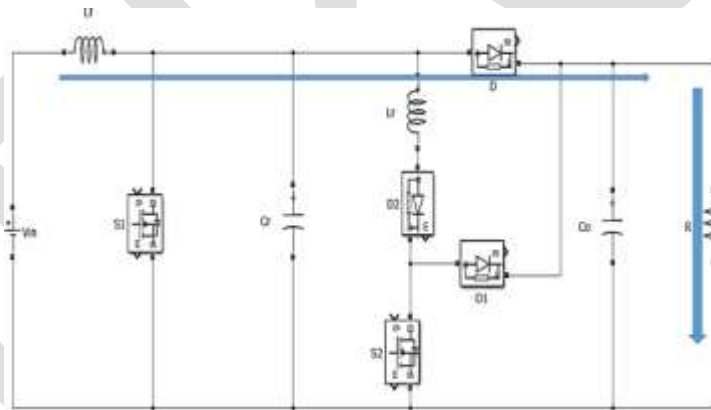
Fig 2 Boost circuit with improved auxiliary circuit

The converter consists of 2 MOSFETs  $S_1$ ,  $S_2$ . MOSFET  $S_1$  is the main MOSFET responsible for the output voltage and power.  $S_2$  is the auxiliary MOSFET which is responsible for soft switching of the main MOSFET  $S_1$ .  $S_2$  is the MOSFET which replaces the diode in order to provide low resistance path. The output capacitor acts as filter circuit providing only the DC component and filtering the AC component. The  $S_1$  is turned ON/OFF at zero voltage condition.

**WORKING OF THE CONVERTER**

**Mode 1**

Switches  $S_1$  and  $S_2$  turned off prior to time  $t_0$ . In this mode diode  $D$  conducts and at time  $t_0$ ,  $S_2$  turns on and  $i_{Lr}$  increases



linearly.

Fig 3 Mode 1 operation of the converter

**Mode 2**

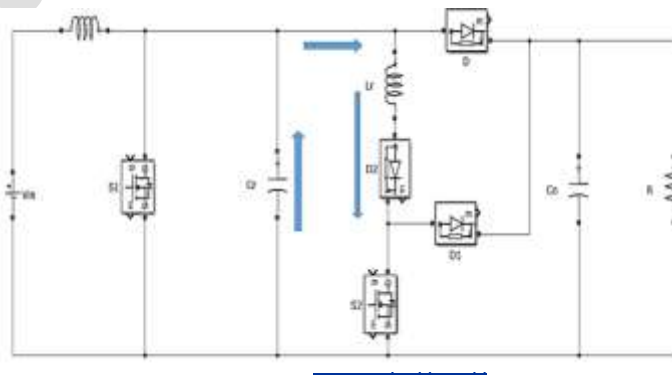


Fig 4 Mode 2 operation of the converter

In this mode  $i_{Lr}$  continues to increase and capacitor  $C_r$  discharges to zero at the end of the mode.

**Mode 3**

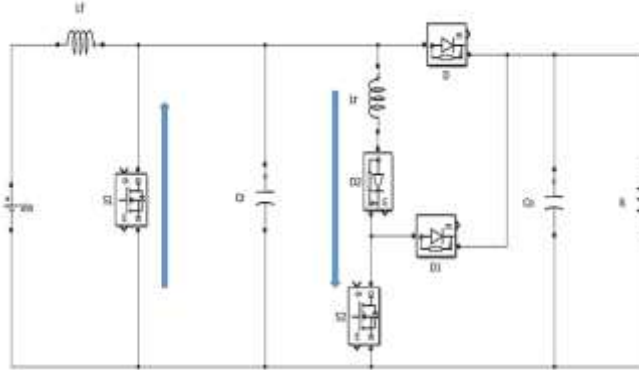


Fig 5 Mode 3 operation of the converter

At the starting of this mode body diode of  $S_1$  becomes ON and a current would flow through the body diode and voltage across the main switch becomes zero and we would get an ideal situation to turn ON the main switch at zero voltage condition.

**Mode 4**

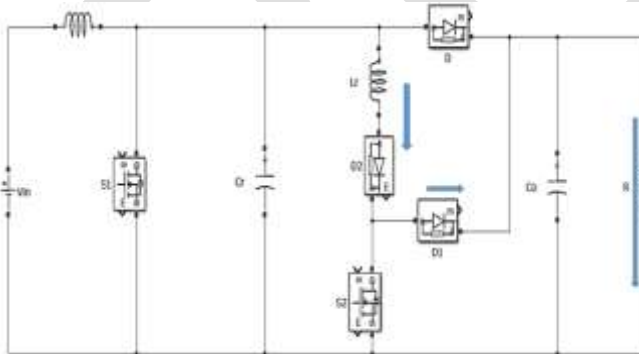


Fig 6 Mode 4 operation of the converter

In this mode switch  $S_2$  is turned off at zero voltage condition.

**Mode 5**

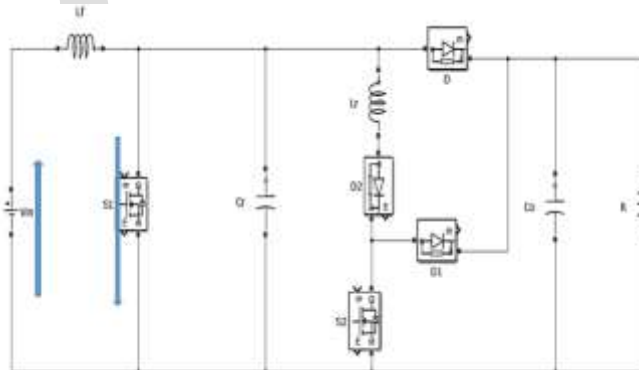


Fig 7 Mode 5 operation of the converter

$D_1$  is turned off and  $S_1$  is turned on at zero voltage condition

**Mode 6**

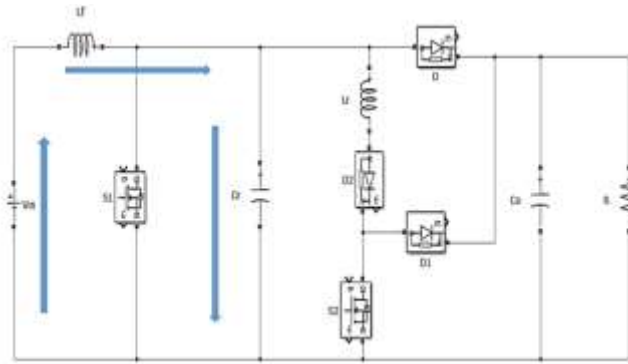


Fig 8 Mode 6 operation of the converter

$S_1$  is turned off and the capacitor  $c_r$  would get charged to input voltage  $V_{in}$ .

**Mode 7**

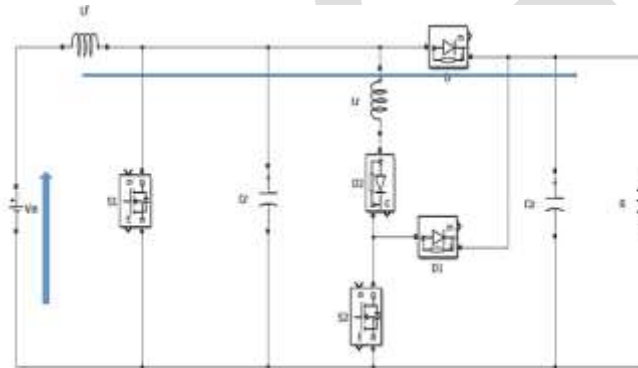


Fig 9 Mode 7 operation of the converter

In mode 7 the current would flow through the diode  $D$  to the load as shown in fig 9.

**DESIGN**

Output resistance and output current

$$V_{in} = 4V$$

$$V_{out} = 90V$$

$$P_0 = V_0 I_0$$

For a conventional boost converter,

$$\frac{V_0}{V_{in}} = \frac{1}{1 - D}$$

where,  $D = D_{main} + D_{aux}$

$$D = 57.5\%$$

$$D_{main} = 50\% \text{ and } D_{aux} = 7.5\%$$

Design of inductor and capacitor

$$L_{min} \geq \frac{(1 - D)^2 * DR}{2f}$$

$$C \geq \frac{DV_0}{\Delta V_0 R f}$$

$$C = 7.187 \mu F$$

**MATLAB/SIMULINK MODEL**

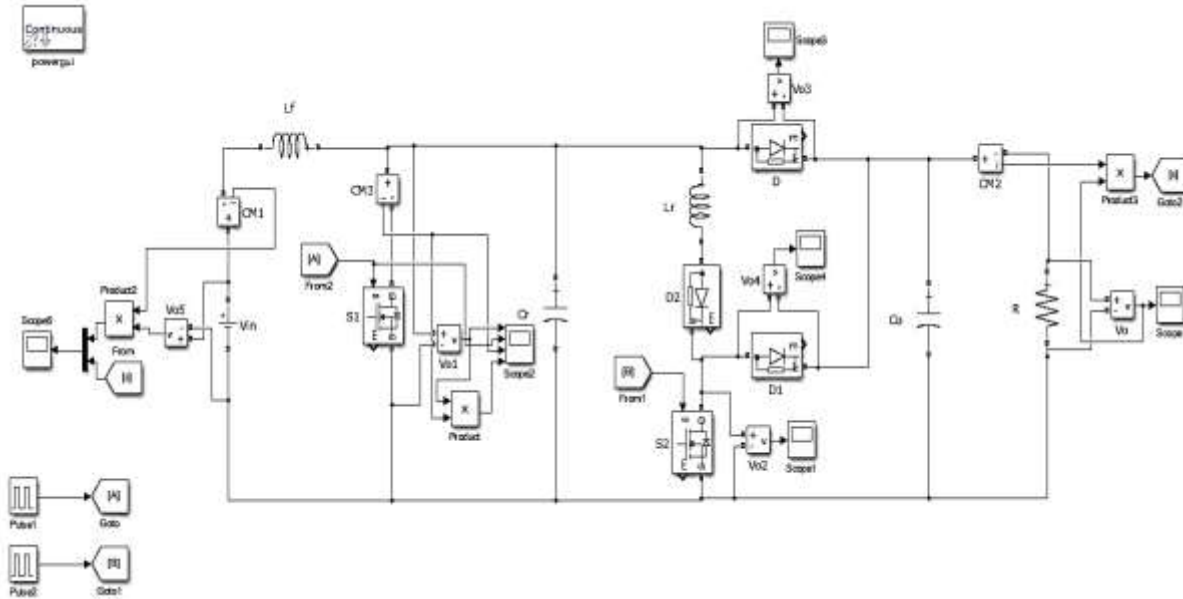


Fig 9 MATLAB/Simulink model of the converter

This section depicts the performance of the boost circuit with auxiliary resonance circuit in MATLAB/Simulink environment. The MATLAB/Simulink model is simulated and soft switching of switches is verified.

TABLE XIII  
 SIMULATION PARAMETERS

COMPONENTS	PARAMETER
Input voltage	4V
L	47 μH
Cr	7 μF
Switching frequency	16kHz
R0	270Ω
D	57.5%
Lr	10 μH

**SIMULATION RESULTS**

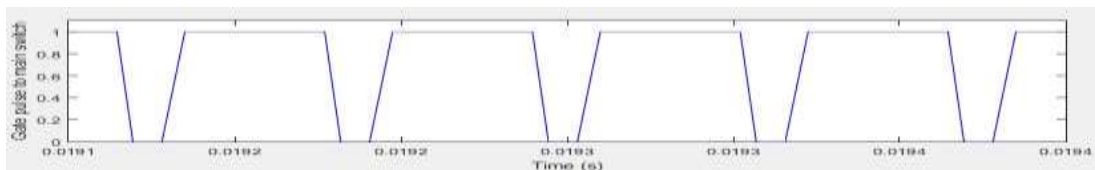


Fig 10 Gate pulse given to main switch

The above figure shows the gate pulse given to the main switch. This pulse is applied after attaining zero voltage condition at  $S_1$ . This condition is achieved by applying a pulse at the auxiliary switch.

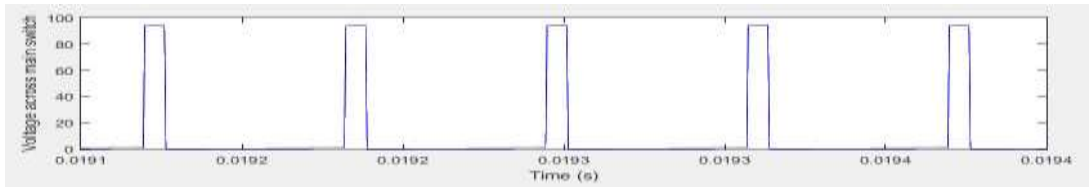


Fig 11 Gate pulse given to auxiliary switch

The above figure shows the gate pulse given to auxiliary circuit. This pulse is given before the main pulse is given and zero voltage condition is achieved at main switch so that main switch can be turned on at zero voltage conditions

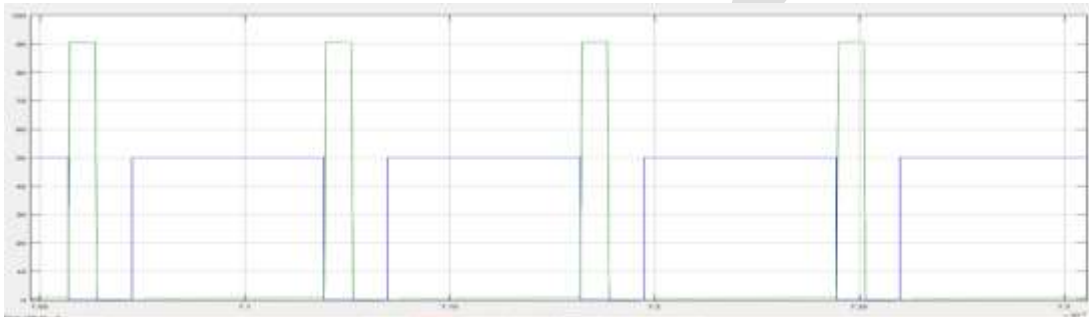


Fig 12 soft switching of main switch

In the above figure the soft switching of main switch is clearly shown. The tall wave is the voltage across the switch and the short wave is the gate pulse to the main switch. It is clear that the gate pulse is given at zero voltage conditions.

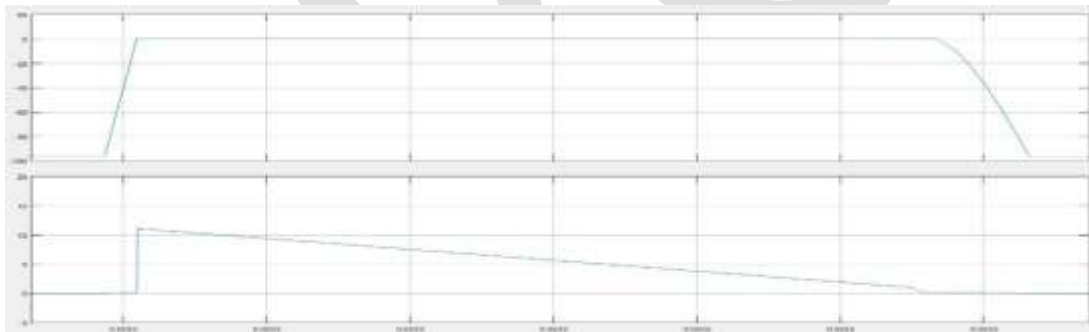


Fig 13 Zero current turn off of rectifier diode

The above figure shows the voltage across the diode at the top and current through the diode at the bottom. It is clear that diode is turned off after the current has reached zero.

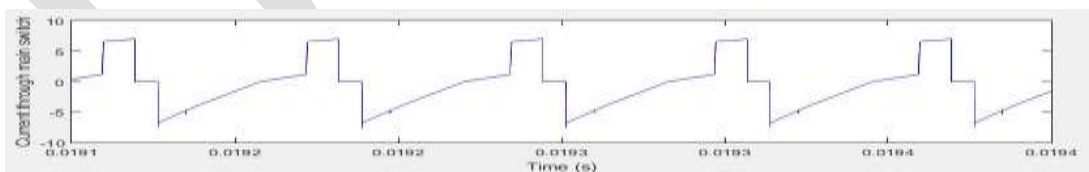


Fig 14 Current through main switch

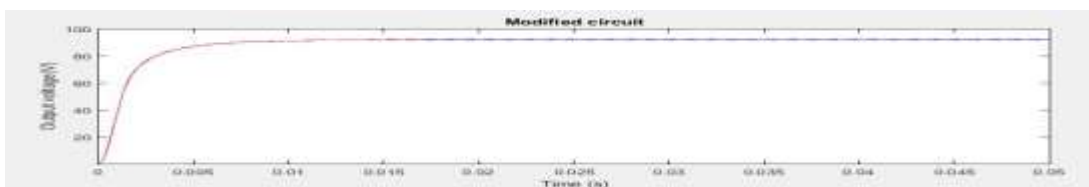


Fig 15 Output voltage

The above figure shows the output voltage obtained in the converter when an input of 4V is given. It is able to obtain an output of 90V. From the above waveforms it is clear that the performance of the converter has improved.

## CONCLUSION

In this work a ZVS Boost converter using an auxiliary resonant circuit is analysed. The circuit diagram of the converter and modes of operation are discussed. Each mode of operation is analysed by simulation using MATLAB/Simulink software. It is seen in simulation that the main switch operates in soft switching. The main switch is turned OFF and ON by the zero voltage switching (ZVS). The rectifier diode is turned off when the current through it reduces to zero. The switching losses are reduced by soft switching and efficiency of the boost converter is improved.

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