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A High Gain Single Input Multiple Output Boost Converter

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Abstract: **This converter is a newly designed single input multiple output DC-DC converters with coupled inductor. This converter uses only one power switch .This topology has two boost converters. One is a high gain converter and other is a normal boost converter. The techniques of voltage clamping is used to reduce the switching loss and conduction loss. For the high gain converter the energy stored in the leakage inductance of coupled inductor is efficiently recycled to the output. As a result high voltage conversion ratio is obtained. By using this converter, high efficiency power conversion, high step up ratio, and various output voltages with different levels can be obtained. The simulation is carried out in MATLAB/SIMULINK.**

Keywords: **Boost converter, coupled inductor, high gain converter, voltage clamp circuit, voltage doubler cell, voltage stress.**

I. INTRODUCTION

There are various single-input single-output DC-DC converters with different voltage gains are combined to satisfy the requirement of various voltage levels, so that its system control is more complicated and the corresponding cost is more expensive. The motivation of this study is to design a single-input multiple-output (SIMO) converter for increasing the conversion efficiency and voltage gain, reducing the control complexity, and saving the manufacturing cost.

This high gain converter can boost the voltage of a low voltage input power source to a controllable high-voltage DC and middle-voltage output terminals. The high voltage DC can be taken as the main power for a high-voltage DC load or the front terminal of a DC-AC inverter. Moreover, middle voltage output terminals can supply powers for individual middle-voltage DC loads or for charging auxiliary power sources (e.g., battery modules)[6]. In this study, a coupled-inductor based DC-DC converter scheme utilizes only one power switch with the properties of voltage clamping and the corresponding device specifications are adequately designed.

II. HIGH GAIN SINGLE INPUT MULTIPLE OUTPUT BOOST CONVERTER

This converter has two boost converters. One is a high gain converter and the other is a middle voltage converter. This converter makes use of a single power switch Q, an input inductor L_1 and a coupled inductor, diodes D_1,D_2, D_4 and D_0, a storage energy capacitor C_1 and a output capacitor C_{01} and C_{02}, a clamp circuit including diode D_3 and capacitor C_2 , an extended voltage doubler cell comprising regeneration diode D_r and capacitor C_3, and the secondary side of the coupled inductor. The dual-winding coupled inductor is modeled as an ideal transformer with a turn ratio N (n_2 /n_1), a parallel magnetizing inductance L_m and primary and secondary leakage inductance L_{k1} and L_{k2} respectively. Figure 2 shows the detailed circuit diagram of the high gain converter.

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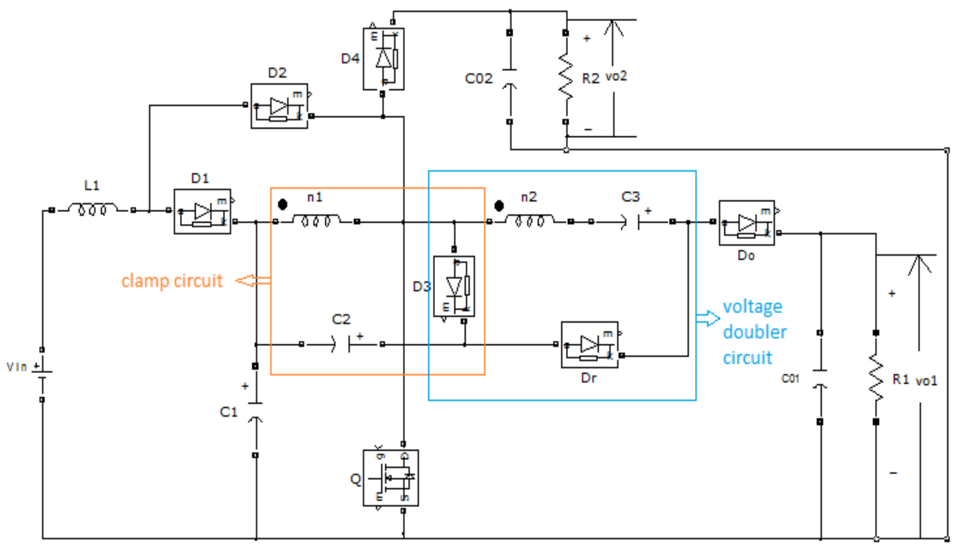


Figure.1: Circuit diagram of high gain single input multiple output boost converter

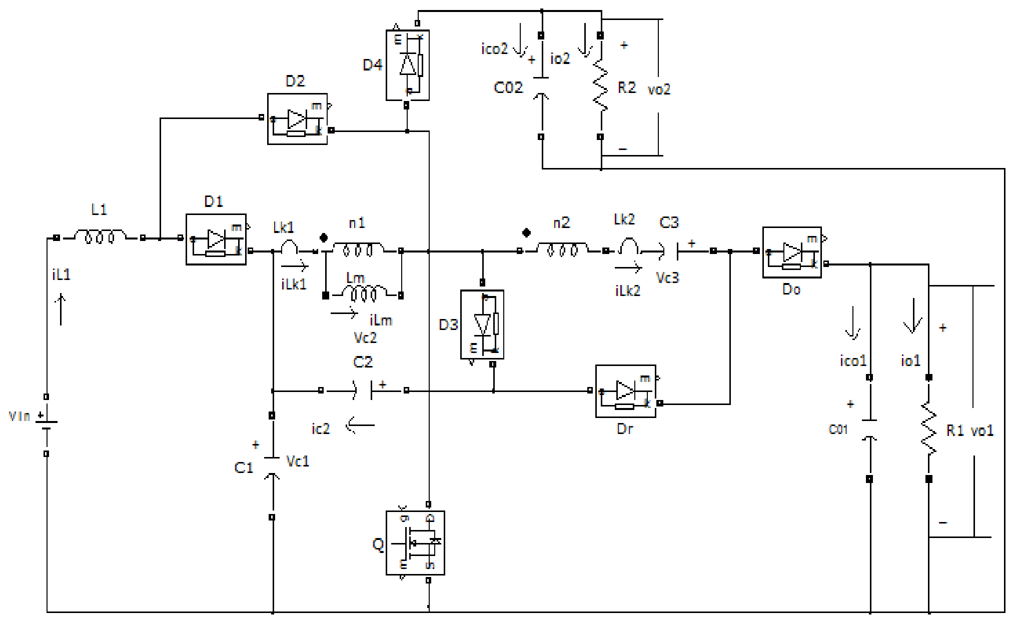
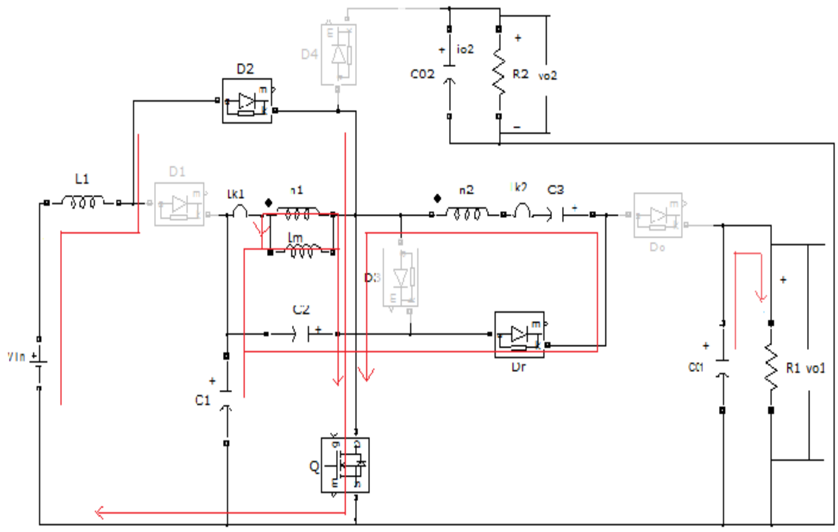


Figure 2: Circuit diagram of high gain converter in detail For analysis of the converter, the assumptions are input inductance L_1 is very large enough so that i_{L1} is continuous.

A. DIFFERENT MODES OF OPERATION:

MODE 1:

During this time interval $[t_0,t_1]$,the switch Q is conducting at $t = t_0$. Diodes D_1,D_3 and D_0 are reverse-biased by V_{c1},$V_{c1}+V_{c2}$ and V_0- V_{c1}- V_{c2} respectively. Diode D_4 is also in off condition. Only Diodes D_2 and D_r are turned ON. Figure 3 shows the current flow path. The dc source V_{in} energy is transferred to the inductor L_1 through D_2 and Q. Therefore, current i_{L1} is increasing linearly. The primary voltage of the coupled inductor including magnetizing inductor Lm and leakage L_{k1} is V_{c1} and the capacitor C1 is discharging its energy to the magnetizing inductor L_m and primary leakage inductor L_{k1} through Q.



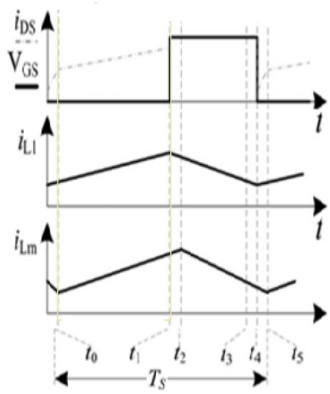


Figure 3: Current flow path in mode 1 **Figure 4: Theoretical waveforms**

Then currents i_{D2}, i_{Lm}, and i_{k1} are increasing. Meanwhile, the energy stored in C_2 and C_1 is released to C_3 through D_r. The loads R_1 and R_2 are supplied by the output capacitors C_{01} and C_{02} respectively. This stage ends at $t = t_1$.

MODE 2:

In this interval, Q is turned off at $t = t_1$, the current through Q is forced to flow through D_3. At the same time, the energy stored in inductor L_1 flows through diode D_1 to charge capacitor C_1 instantaneously and also through diode D_4. The inductor current i_{L1} declines linearly. Thus, the diode D_2 is reverse biased by V_{c2} .A part of inductor current i_{L1} also flows

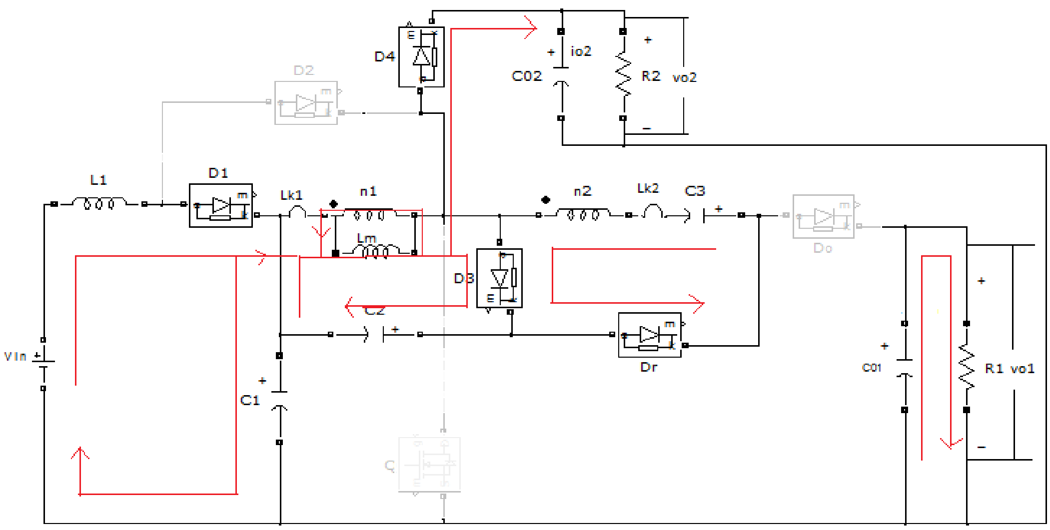


Figure 5. Current flow path in mode 2

through D_4 .The diode D_0 is still reverse biased by V_0- V_{c1}- V_{c2}. The energy stored in inductor L_{k1} flows through diode D_3 to charge capacitor C_2 .Therefore, the energy stored in Lk1 is recycled to C_2. The L_{k2} keeps the same current direction for charging capacitor C_3 through diode D_3 and regeneration-diode Dr. The load energy is supplied by the output capacitors C_{01}.Figure 4 shows the current flow path of this mode.

MODE 3:

During this transition interval, switch Q remains OFF. V_{C2} is reflected to the secondary side of coupled inductor thus, regeneration-diode Dr is blocked by V_{C3} + NV_{C2}. Meanwhile, the diode D_0 starts to conduct. Figure 5 shows the current flow path of this mode. The inductance L_1 is still releasing its energy to the capacitor C_1. Thus, the current i_{L1} still declines

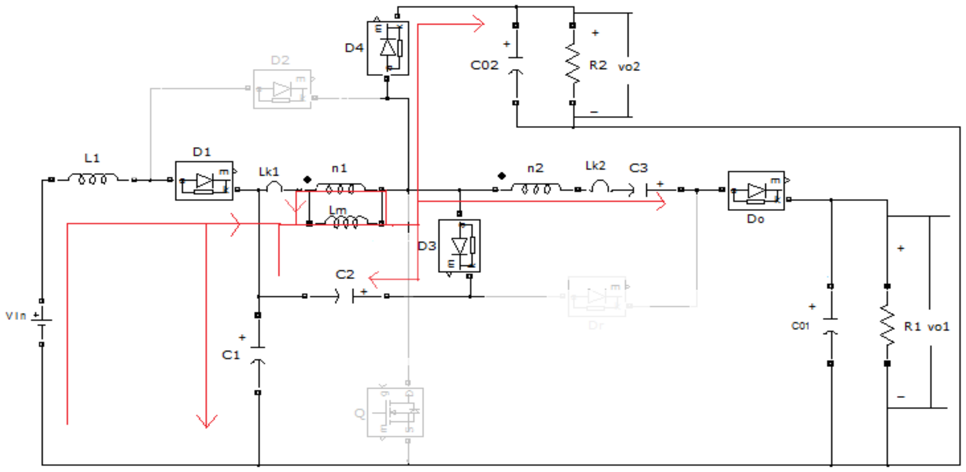


Figure.6: Current flow path in mode 3

linearly. The energy stored in L_{k1} and L_m is released to C_2.Also a part of energy stored in L_1 and L_{k1} is released to C_{02} and R_2 through D_4.Moreover,the energy stored in L_m is released to the output via n_2 and C_3. The leakage inductor energy can thus be recycled, and the voltage stress of the main switch is clamped to the summation of V_{C1} and V_{C2}.

MODE 4:

During this time interval, the switch Q, diodes D_2 and Dr is still turned OFF. Since i_{c2} reaches zero at t = t_3, the entire current of i_{LK1} flows through D_3 is blocked. The current flow path of this mode is shown in figure 6. The energy stored in an inductor L_1 flows through diode D_1 to charge capacitor C_1 continually, so the current i_{L1} is decreasing linearly. Also a part of energy stored in $L_1$and L_{k1} is released to C_{02} and R_2 through D_4. The dc source V_{in}, L_1 ,L_m ,L_{k1},the winding n_2,L_{k2} and V_{c3} are series connected to discharge their energy to capacitor C_{01} and load R_1 . This stage ends when the switch Q is turned ON at t = t_4.

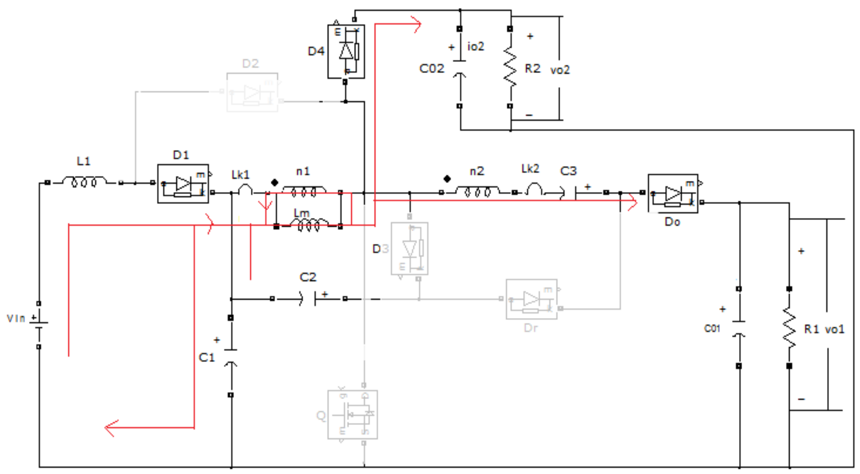


Figure 7. Current flow in mode 4

MODE 5:

The main switch Q is turned ON at t4. During this transition interval, diodes D_1,D_3,and D_r are reverse-biased V_{c1},V_{c1}+V_{c2} and V_0- V_{c1}- V_{c2} respectively.D_4 is also in off condition. The current flow path is shown in Figure 7.The inductance L_1 is charged by input voltage Vin and the current i_{L1} increases almost in a linear way. The blocking voltages V_{C1} is applied on

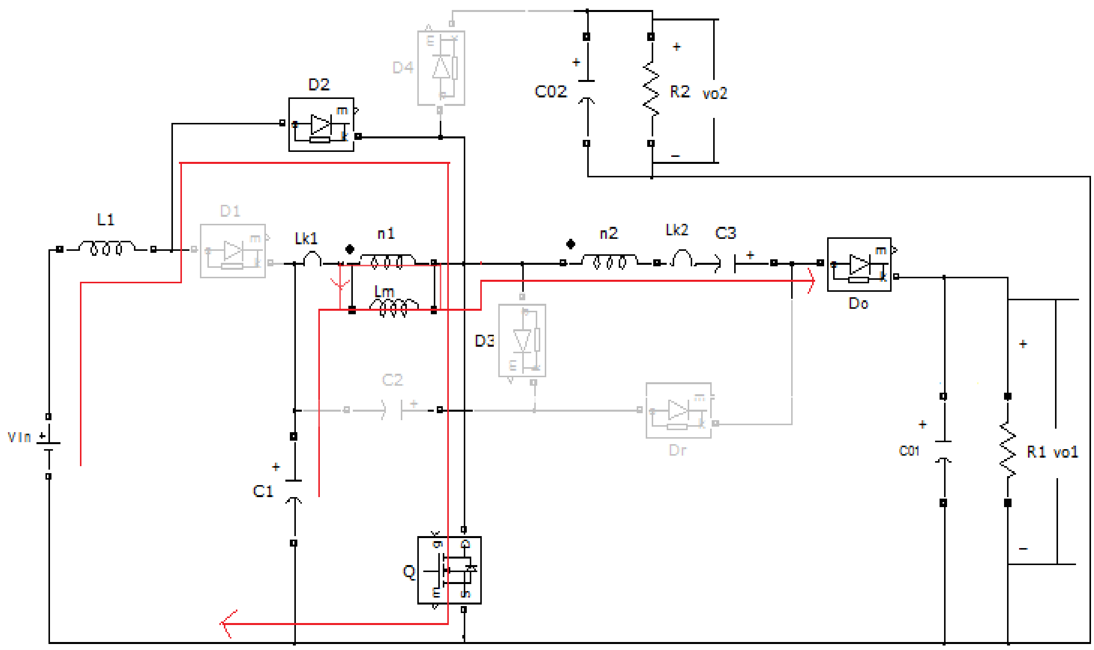


Figure 8. Current flow in mode 5

magnetizing inductor L_m and primary-side leakage L_{k1}, so the current i_{LK1} of the coupled inductor is increased rapidly. Meanwhile, the magnetizing inductor L_m keeps on transferring its energy through the secondary winding to the output capacitor C_{01} and load R_1. At the same time, the energy stored in C_3 is discharged to the output 1.R_2 is fed by C_{02}.

III. SIMULATION RESULTS

Table 1. Simulation Parameters

Vin	5 V
Input inductor L1	16 µH
C1,C0	100 µF
C2,C3	47 µF
Coupled inductor	
Turns ratio	13/7
Primary winding inductance	54µH
Secondary winding inductance	186 µH
Lm	100 µH
Switch	MOSFET
Switching frequency	40 kHz
Duty ratio	0.4

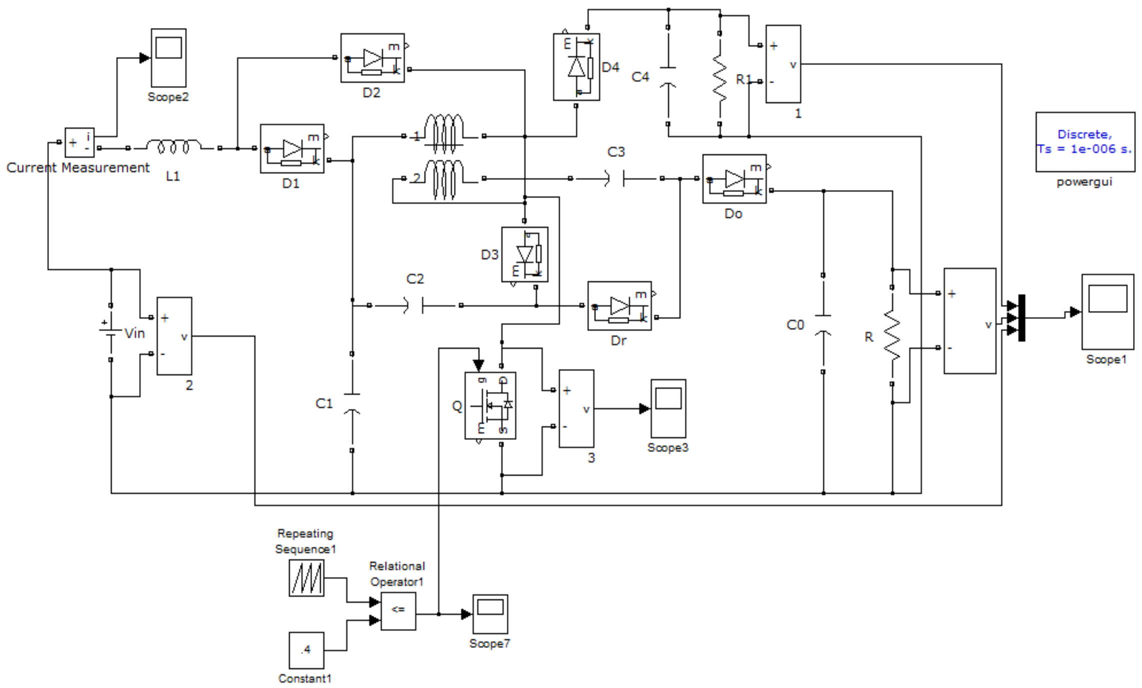


Figure 9. Simulink model of high gain single input multiple output boost converter

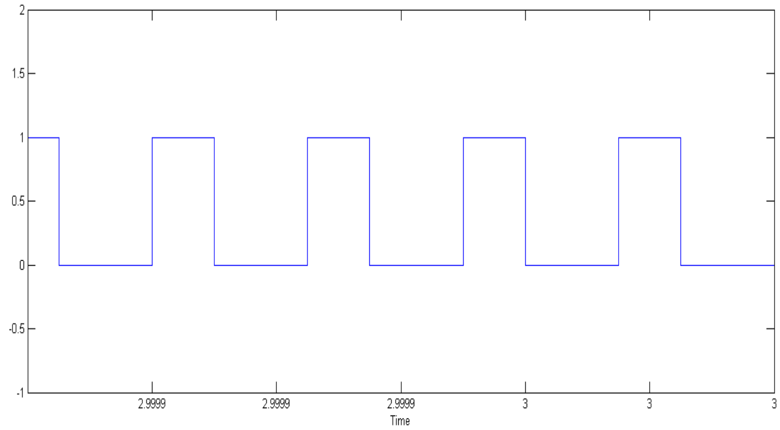


Figure 10. Gate pulse

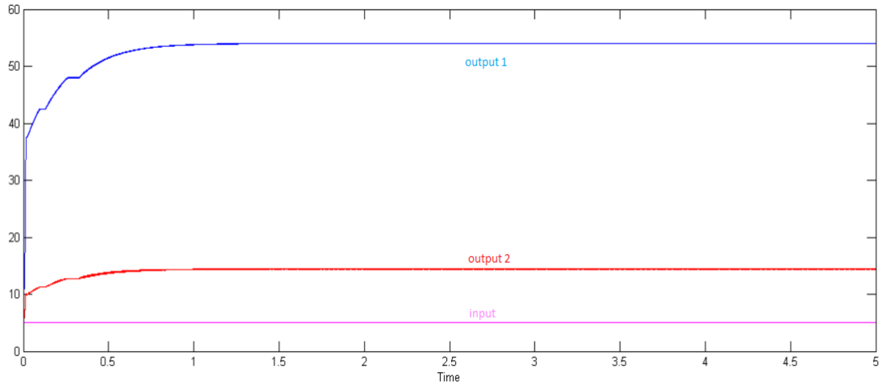


Figure 11. Converter output voltages

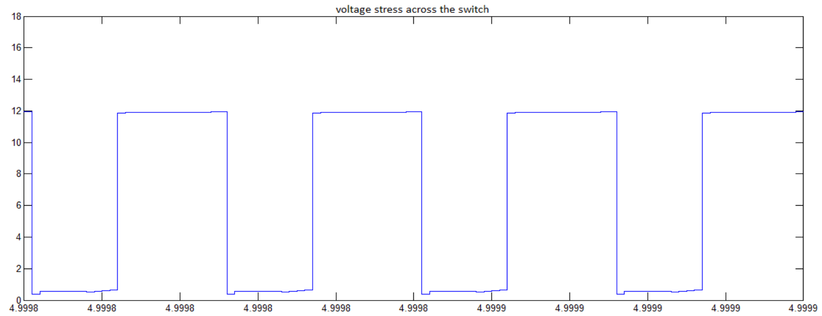


Figure 12. Voltage stress across the switch

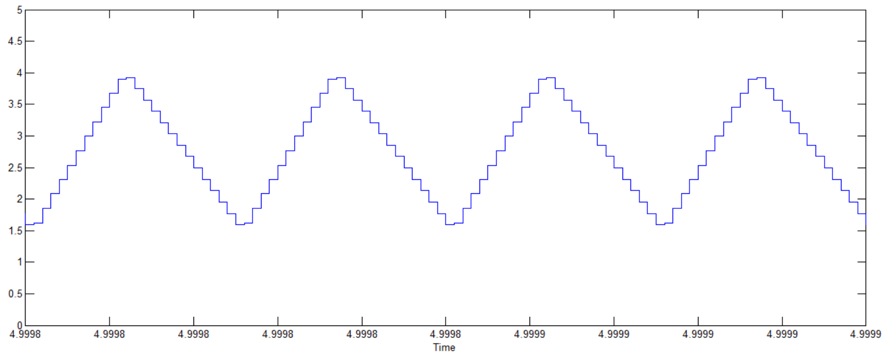


Figure 13. Current through input inductor L_1

By giving an input of 5 V, two output voltages are obtained.One is the high gain output 54 V and the other is the middle voltage output 14 V.Voltage stress across the switch is 12 V.

IV. CONCLUSIONS

A high gain single input multiple output DC-DC converter is introduced. The simulation result shows that single input power source is converted to two output terminals. This topology adopts only one power switch to achieve the objective of multiple output. The voltage stress across the switch is only 22% of the high gain output. The technique of voltage clamping is used to reduce the switching and conduction losses. The energy stored in the leakage inductance of coupled inductor efficiently recycled to one of the output. This topology provides the designers with an alternative choice for boosting a low-voltage power source to multiple outputs with different voltage levels efficiently.

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