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A Transformer less Buck Boost Converter with Positive Output Voltage

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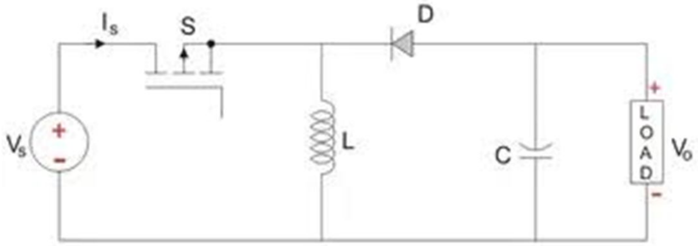
Abstract: Some industrial applications require high step-up and step-down voltage gain. The transformer less buck-boost converter has high voltage gain than that of traditional buck-boost converter without extreme duty cycles. A transformer less buck-boost converter with simple structure is obtained by inserting an additional switched network into the traditional buck-boost converter. The two power switches of the buck-boost converter operate synchronously. The operating principles of the buck-boost converter operating in continuous conduction modes are presented. A new buck- boost converter is presented by providing a feedback to the converter. By this, constant output voltage can be maintained under varying load conditions in both buck and boost operation. The output voltage of 40V (step—up mode)/8V (step down mode) is obtained with input voltage 18V and the outcomes are approved through recreation using PSIM MODEL.

I. INTRODUCTION

Switched-mode power supply is the core of modern power conversion technology which is widely used in electrical power, communication system, house hold appliances and many other fields. The basis of switched-mode power supply are the converter topologies and many converter topologies have been proposed for the construction of Smashed operating principle for the steady state analysis of the buck-boost converter which is operating in continuous conduction mode is presented in detail. In this proposed system an additional switched network is inserted into the traditional buck-boost converter to obtain the proposed system. The important feature of the proposed buck-boost converter is that its voltage gain is quadratic of the traditional buck-boost converter so that it can operate in a wide range of output voltages, that is the proposed system can achieve high or low voltage gain without extreme duty cycle.

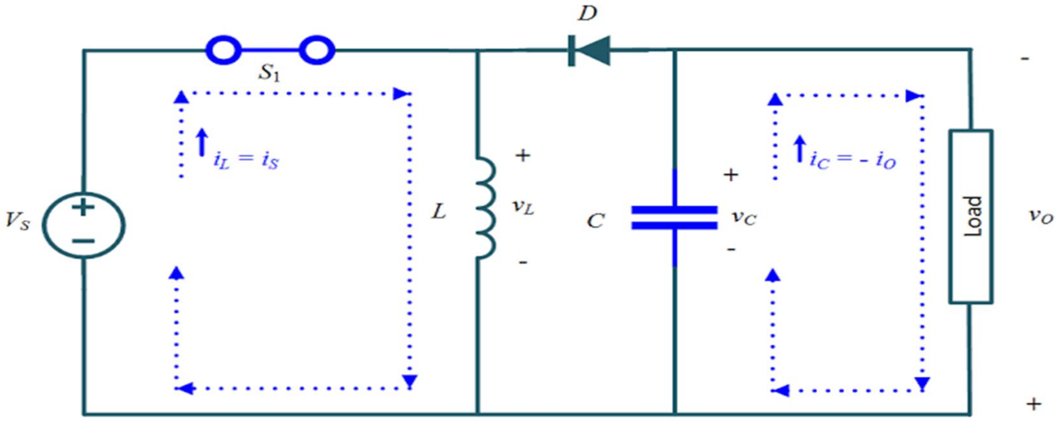
Parameter	Value
Input Voltage	18v
Switching Frequency	20kHz
Duty Cycle	0.4 - 0.6
Inductor1	1mH
Inductor 2	3mH
Charge Pump Capacitor	10μF
Output Capacitor	20μF
Output Voltage	40v (step-up), 8v (step-down)

II. CONVENTIONAL BUCK-BOOST CONVERTER



1) *MODE 1: Switch is ON, Diode is OFF*

The Switch is ON and therefore represents a short circuit ideally offering zero resistance to the flow of current so when the switch is ON all the current will flow through the switch and the inductor and back to the DC input source. The inductor stores charge during the time the switch is ON and when the solid state switch is OFF the polarity of the Inductor reverses so that current flows through the load and through the diode and back to the inductor. So, the direction of current through the inductor remains the same.



Let us analyse the Buck Boost converter in steady state operation for mode 1 using KVL.

$$\therefore V_{in} = V_L$$

$$\therefore V_L = L\frac{di_L}{dt} = V_{in}$$

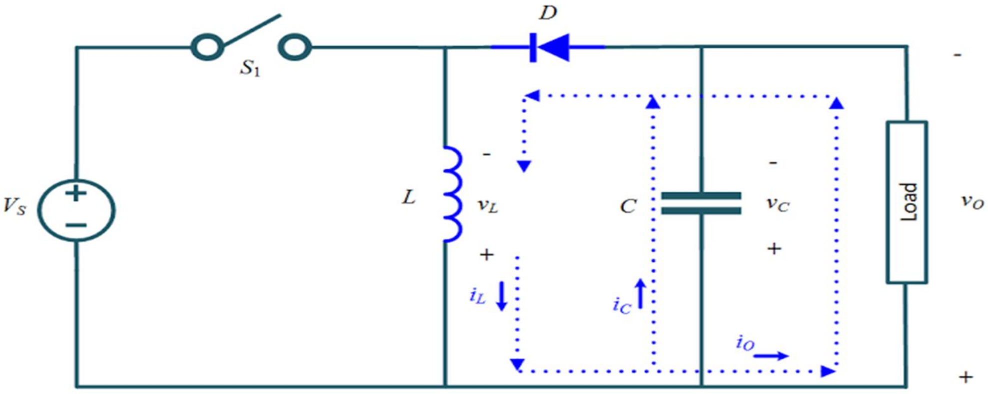
$$\frac{di_L}{dt} = \frac{\Delta i_L}{\Delta t} = \frac{\Delta i_L}{DT} = \frac{V_{in}}{L}$$

Since the switch is closed for a time $T_{ON} = DT$ we can say that $\Delta t = DT$.

$$(\Delta i_L)_{closed} = \left(\frac{V_{in}}{L}\right) DT$$

2) *MODE 2: Switch is OFF, Diode is ON*

In this mode the polarity of the inductor is reversed and the energy stored in the inductor is released and is ultimately dissipated in the load resistance and this helps to maintain the flow of current in the same direction through the load and also step-up the output voltage as the inductor is now also acting as a source in conjunction with the input source.



Let us now analyse the Buck Boost converter in steady state operation for Mode 2 using KVL.

$$\therefore V_L = V_o$$

$$\therefore V_L = L\frac{di_L}{dt} = V_o$$

$$\frac{di_L}{dt} = \frac{\Delta i_L}{\Delta t} = \frac{\Delta i_L}{(1-D)T} = \frac{V_o}{L}$$

Since the switch is open for a time

$$T_{OFF} = T - T_{ON} = T - DT = (1-D)T$$

we can say that $\Delta t = (1-D)T$

$$(\Delta i_L)_{open} = \left(\frac{V_o}{L}\right)(1-D)T$$

It is already established that the net change of the inductor current over any one complete cycle is zero.

$$\therefore (\Delta i_L)_{closed} + (\Delta i_L)_{open} = 0$$

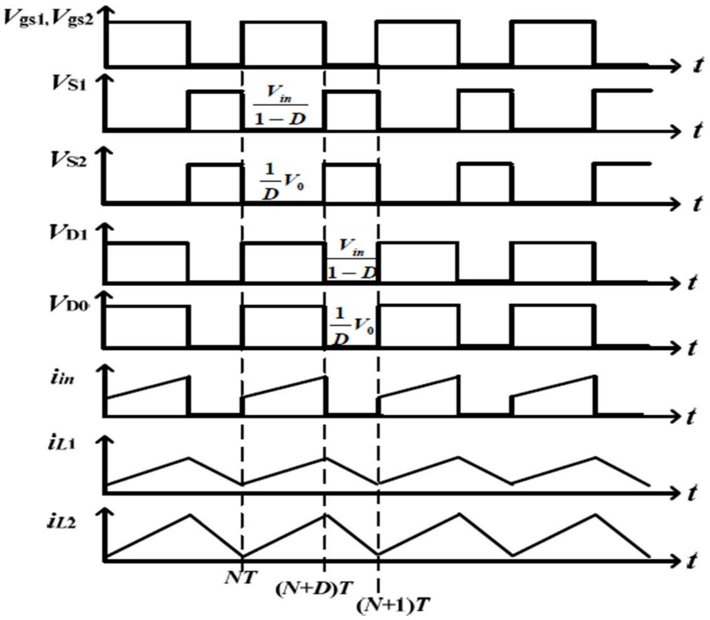
$$\left(\frac{V_o}{L}\right)(1-D)T + \left(\frac{V_{in}}{L}\right)DT = 0$$

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

We know that D varies between 0 and 1. If D > 0.5, the output voltage is larger than the input; and if D < 0.5, the output is smaller than the input. But if D = 0.5 the output voltage is equal to the input voltage.

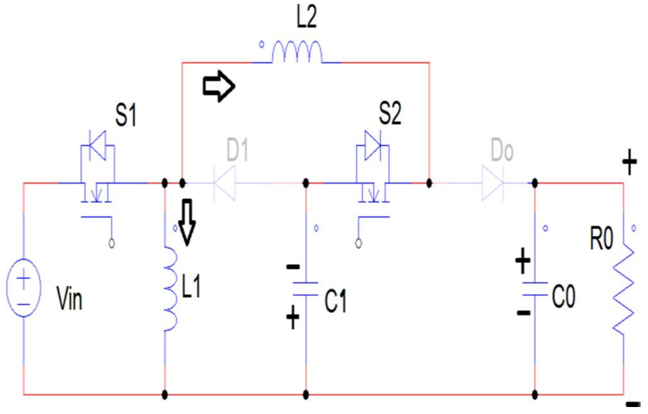
III. A TRANSFORMERLESS BUCK-BOOST CONVERTER

There are two modes, that is, mode 1 and mode 2, in the transformer less buck-boost converter when it operates in CCM operation. Mode 1 between time interval (NT<t<(N+D) T). Mode 2 between time interval ((N+D) T<t<(N+1) T).



1) *MODE 1 (NT<t<(N+D) T)*

Mode 1 is during the time interval (NT<t<(N+D) T). During this time interval, the switches S1 and S2 are turned on, while D1 and DO are reverse biased. From below figure, it is seen that L1 is magnetized from the input voltage Vin while L2 is magnetized from the input voltage Vin and the charge pump capacitor C1. Also, the output energy is supplied from the output capacitor CO.



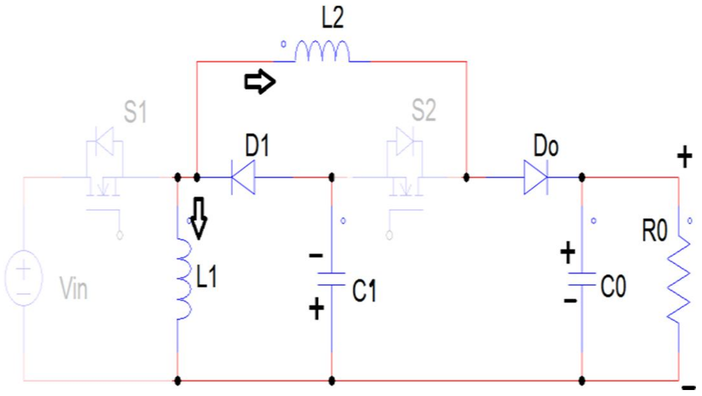
Thus, the corresponding equations can be established as,

$V_{L1}=V_{in}$……………………………... (1)

$V_{L2}= V_{in} + V_{C1}$.................................(2)

2) *MODE 2 ((N+D) T<t<(N+1) T)*

Mode 2 is during the time interval ((N+D) T<t<(N+1) T). During this time interval, the switches S1 and S2 are turned off, while D1 and DO are forward biased. From below figure, it is seen that the energy stored in the inductor L1 is released to the charge pump capacitor C1 via the diode D1. At the same time, the energy stored in the inductor L2 is released to the charge pump capacitor C1, the output capacitor CO and the resistive load R via the diodes DO and D1



The equations of the mode 2 are described as follows

$V_{L1}=-V_{C1}$..(3)

$V_{L2}= -(V_{C1}+V_{O})$ ....(4)

If applying the voltage-second balance principle on the inductor L1, then the voltage across the charge pump capacitor C1 is readily obtained from equations (1) and (3) as

$V_{C1}=\{D/(1-D)\}\ V_{in}$......................................(5)

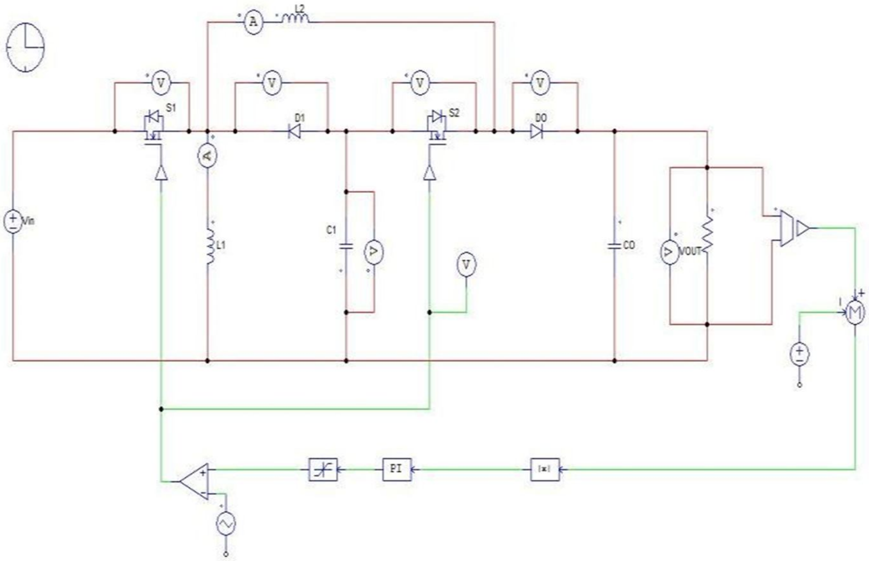
Here, D is the duty cycle, which represents the proportion of the power switches turn on time to the whole switching cycle. Similarly, by using the voltage-second balance principle on the inductor L_2, the voltage gain of the proposed buck-boost converter can be obtained from equations (2), (4), and (5) as

$M=V_O/V_{in} = (D/(1-D))^2$...................................(6)

From equation (6), it is apparent that the proposed buck-boost converter can step-up the input voltage when the duty cycle is bigger than 0.5, and step-down the input voltage when the duty cycle is smaller than 0.5.

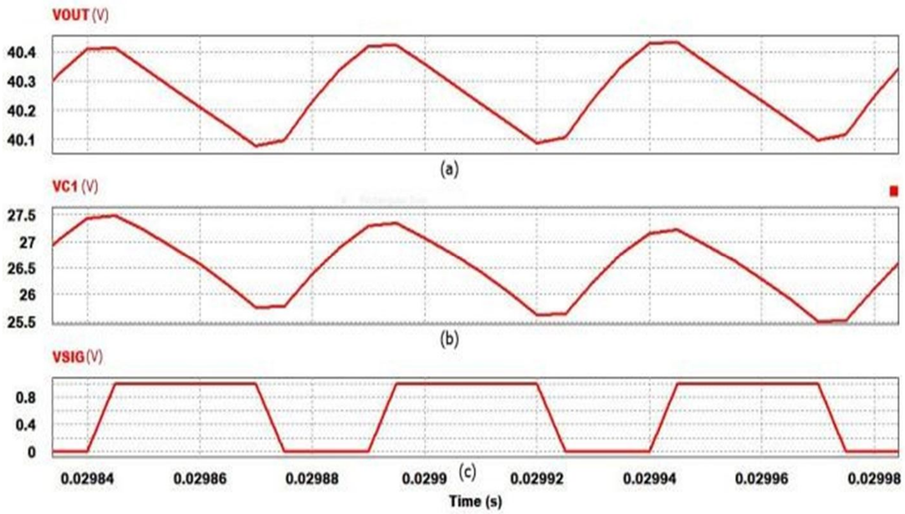
From (6), it is apparent that the proposed buck-boost converter can step-up the input voltage when the duty cycle is bigger than 0.5, and step-down the input voltage when the duty cycle is smaller than 0.5.

IV. SIMULATION

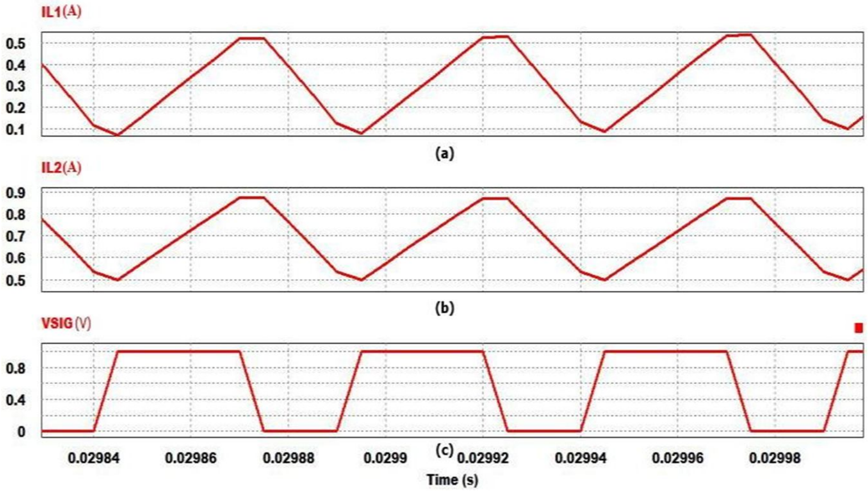


PSIM Model of Transformer less Buck-Boost Converter with Feedback

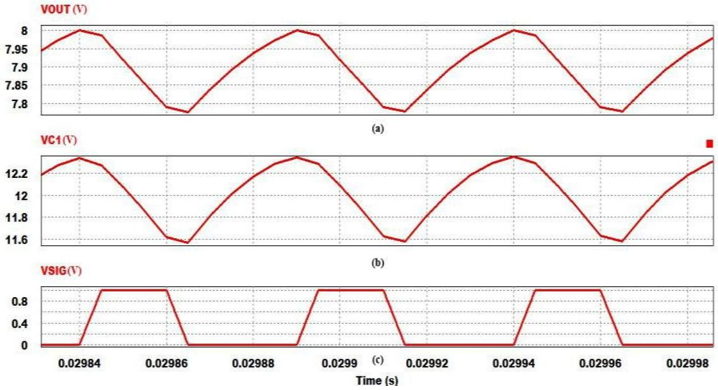
V. RESULTS



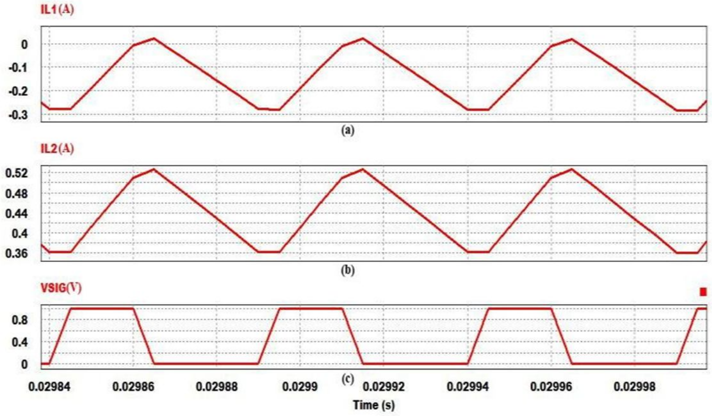
PSIM simulations for the buck-boost converter operating in step-up mode



PSIM simulations for the buck-boost converter operating in step-up model



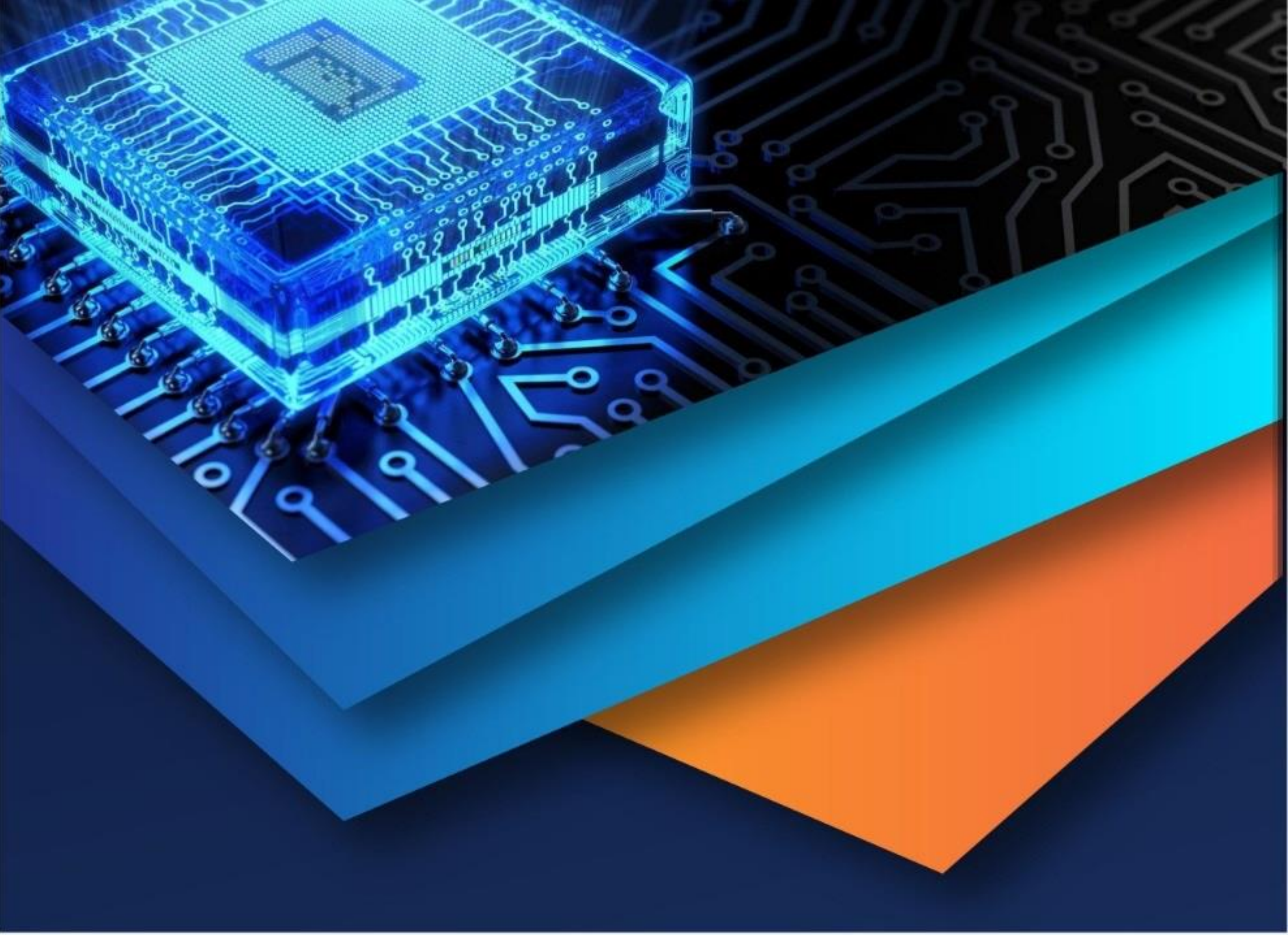
PSIM simulations for the buck-boost converter operating in step-down mode



PSIM simulations for the buck-boost converter operating in step-down mode

VI. CONCLUSION

From the PSIM simulations, it is proved that the new transformer less buck-boost converter possesses the merits such as high step-up/step-down voltage gain, positive output voltage. Hence the proposed buck-boost converter is suitable for the industrial applications requiring high step-up/step-down voltage gain. The converter operates in a wide range of output voltage without using extreme duty cycles. It provides enough gain within the duty ratio 0.4-0.6. It has simple operating modes.



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