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DUAL SWITCH ENHANCED GAIN DC-DC CONVERTER

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***Abstract*—**These days, high gain DC-DC converters are re- quired due to the growing usage of solar energy resources. Low efficiency and increased voltage stress are the results of employing a traditional boost converter running at a high duty ratio to achieve high gain.The suggested converter is made to have a low duty ratio, less voltage stress, and a high gain. In order to create this construction, a voltage multiplier cell is added to the rear end of a traditional buck boost converter using a capacitor and diode. This lowers the voltage stress across the switches. Switches with low voltage ratings can thus be utilized.Additionally, a suggested converter that satisfies every need for DC-DC converters in solar applications is examined. This converter has the features of a broad voltage conversion range, constant input current, and high conversion efficiency. A detailed analysis is conducted of the converter's steady-state features and principles of operation. By modeling the converter in MATLAB/SIMULINK R2017b, results are obtained. According to the simulation findings, the converter reaches a peak efficiency of 85% and has a significant voltage gain. A TMS320F28027F microcontroller is then used to implement the hardware prototype with a 2V input, yielding an output of 8.5V.

***keywords*—**Voltage Multiplier, SEPIC, Efficiency, Photovoltaic (PV)

I. INTRODUCTION

Given the concerns raised by climate change, increased energy demand, the reduction of fossil fuel usage, global warming, and other factors, renewable energy resources are receiving a lot of attention these days. Power electronics equipment is generally essential for connecting various re- newable energy sources like fuel cells, wind energy, and photovoltaic (PV) to the demand. Furthermore, these power electronic devices maintain the load voltage in the face of wide variations in the source voltage and are utilized in a variety of applications, including battery systems, power factor correction, electric vehicles, portable gadgets, etc. In contrast, a variety of output voltages with regard to a constant source at the input end are needed for some applications, such as multifunctional switched mode power supplies.

For the aforementioned issues, a dc–dc converter with a large voltage conversion ratio emerges as a viable option. Because of their comprehensible and straightforward nature, boost and buck converters are traditional and well-established. A novel negative output (N/O) buck–boost converter is de- veloped in [2]. It may be used for applications requiring a broad range of inverse voltage. It is a buck-boost con- verter modification that offers a broad conversion ratio and inverted output voltage. This novel converter does not have sudden voltage changes; instead, it stores energy in an energy- transferring capacitor.In [3], a novel transformerless buck boost converter is developed, which involves including an extra switching network into the conventional buck-boost converter architecture. The primary advantage of the suggested buck boost converter is that it can function in a broad range of output voltages since its voltage gain is quadratic compared to the typical buck boost converter.

When operating in step-up mode [4], the voltage gain of the suggested converter surpasses that of simple non-isolated buck- boost converters like SEPIC, Cuk, Zeta, and classic buck- boost.Because there is just one power switch employed in this design, switching power losses are decreased and the control method is made simpler. Because of the extremely basic converter architecture suggested in [5], the converter control is also quite basic. Because the output voltage is greater than the pressures on the main switch and diodes, the switch loss will be lower and the converter efficiency will increase. In reference [6], a new type of buck-boost converter is suggested that has a negative output voltage and a low step-down voltage gain, equivalent to the gain of a conventional buck-boost converter.The proposal of transistor topology and the specification of switching functions, which enable a significant amount of input current ripple to be cancelled and thereby lower the size of inductors, constitute the manuscript's primary contribution. These are detailed in [7].In [8], a buck–boost converter with common ground that is based on switching capacitors is suggested for point-of-load applications.

In [9], a revolutionary power converter architecture is introduced.The output voltage can be treated with a voltage ripple canceling approach, after which the converter can be made to operate over any desired duty cycle (gain) and produce zero output voltage ripple at such an unconstrained duty cycle.By combining one traditional boost converter, one traditional buck converter, and one traditional buck-boost converter with just one power switch, the converter in [10] proposes a unique quadratic buck-boost converter.The most practical remedy for the aforementioned constraints is to offer an enhanced dual switch buck boost converter [1] with fewer components and less voltage stress on the component.

Between the input and load side, there is a shared ground infrastructure and constant source current. Converter control is made simple by using the same PWM pulse for both switches. A dual switch enhanced gain buck boost converter with reduced voltage stress is suggested as a solution to the aforementioned issues. By including a voltage multiplier circuit, the suggested converter raises the voltage gain. In comparison to other buck boost DC-DC converters, there is also a noticeable decrease in the voltage stress between the components. The voltage gain of the suggested converter is improved by the voltage multiplier cell. As a result, the suggested converter achieves low voltage stress across the switches, constant input current without transients, and good gain across a wide duty cycle range.With two modes of operation, the converter is studied in continuous conduction mode.

II. METHODOLOGY

By altering the traditional buck boost converter and adding a voltage multiplier cell at the back end using a capacitor and diode, the dual switch enhanced gain buck boost converter is created. This lowers the voltage stress across the switches.Two synchronously controlled power switches S_1 & S_2, three inductors L_1, L_2 & L_3, four capacitors C_1 , C_2 , C_3 & C_4 and three diodes D_1, D_2, & D_3 and a load resistor R make up the circuit.

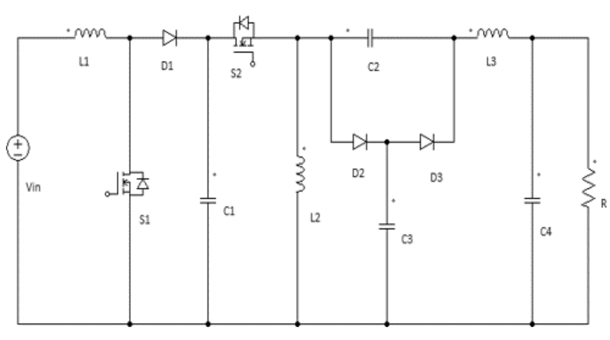


Fig. 1. Dual Switch Enhanced Gain Buck Boost Converter

A. Modes of Operation

The dual switch enhanced gain buck boost converter operates in two modes. The two power switches S_1 & S_2 operates with same duty ratio. According to the synchronised turn ON and turn OFF of two switches, the converter operation can be divided in to two modes within one switching cycle.

1) Mode 1 : In mode 1, diode D_2 is switched on together with switches S_1 & S_2, while diodes D_1, and D_3 are turned off. The inductors L_1, L_2 & L_3 are now being charged by the source. In this mode, capacitor C_3 charges and capacitors C_1, C_2 & C_4 discharges. Inductors have a linear increase in current. The load is charged by the output capacitor C_4. The mode 1 operating circuit is depicted in Figure 2.

$$V_{IN} - V_{L1} = 0 \tag{1}$$

$$V_{C1} - V_{L2} = 0 \tag{2}$$

$$V_{C1} - V_{C3} = 0 \tag{3}$$

$$V_{C2} - V_{C3} + V_{C4} - V_{L3} = 0 \tag{4}$$

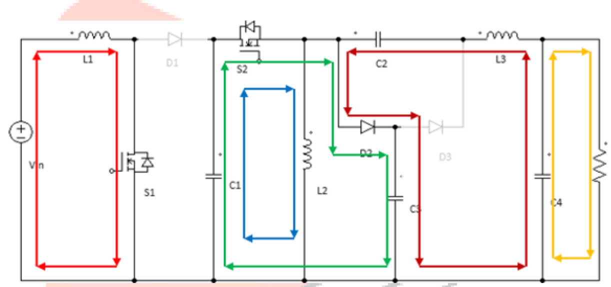


Fig. 2. Mode 1

2) Mode 2 :In mode 2, diode D_2 is switched off together with switches S_1 & S_2, while diodes D_1, and D_3 are turned on. At this point, the inductors L_1, L_2 & L_3 are now being discharged by the source. Current in inductors falls down linearly. Mode 2 of circuit is depicted in Figure 3.

$$V_{IN} - V_{C1} - V_{L1} = 0 \tag{5}$$

$$V_{C2} - V_{L2} - V_{L3} + V_{C4} = 0 \tag{6}$$

$$V_{C4} - V_{C3} - V_{L3} = 0 \tag{7}$$

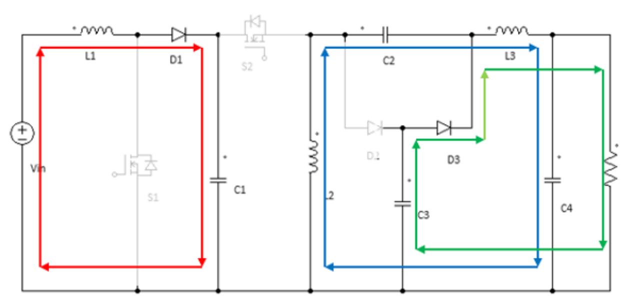


Fig. 3. Mode 2

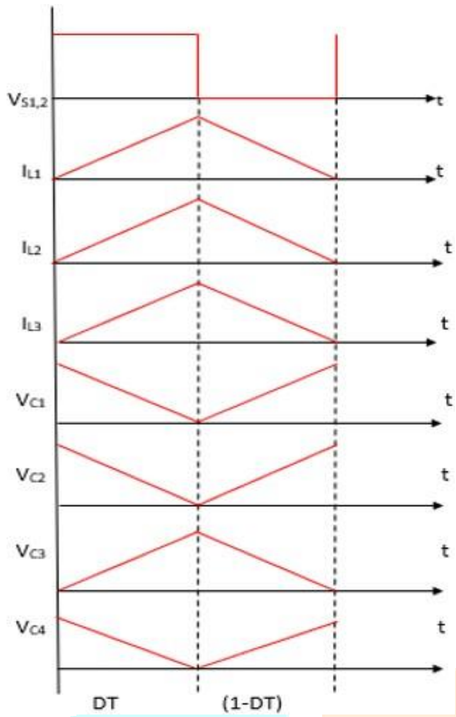


Fig. 4. Key waveform of a converter

B. Design of Components

A converter cannot operate properly unless its components are designed appropriately. The design of the buck boost converter makes a few assumptions. It consists of the inductors L_1, L_2, L_3, and L_4, as well as the load resistance design and the capacitors C_1, C_2, C_3, C_4, and C_5. We take 15 V to be the input voltage. It is assumed that the output power is 40W and the output voltage is 75V. The switching frequency is 75 kHz. The output current is equal to 0.53A after solving equation (9).

$$I_O = \frac{P_O}{V_O} \tag{8}$$

The duty ratio is found using (10) and is equivalent to 0.55. In (11) the load resistor value is set to 150Ω.

$$\frac{V_O}{V_{IN}} = \frac{1}{(1-D)^2} \tag{9}$$

$$R = \frac{V_O^2}{P_O} \tag{10}$$

The value of inductors are designed from following equations.

$$L_1 \geq \frac{D * V_{IN}}{f_s * \Delta i_{L1}} \tag{11}$$

$$L_2 \geq \frac{D * V_{IN}}{f_s * \Delta i_{L2} * (1-D)^2} \tag{12}$$

$$L_3 \geq \frac{D^2 V_{IN}}{f_s * \Delta i_{L3} * (1-D)} \tag{13}$$

The voltage stress and the maximum allowable voltage ripple across the capacitor are the two main considerations in its design. By calculating voltage ripple as 1% of the voltage across corresponding capacitors, the capacitors C_1, C_2, C_3, C_4 and C_5 are obtained. By adjusting the values in the following equations, the estimated values of capacitors for C_1 is 47µF, C_2, C_3 and C_4 is 100µF.

$$C_1 \geq \frac{I_O D}{f_s * \Delta V_{C1} * (1-D)^2} \tag{14}$$

$$C_2 \geq \frac{I_O D}{f_s * \Delta V_{C2}} \tag{15}$$

$$C_3 \geq \frac{I_O}{f_s * \Delta V_{C3} * (1-D)} \tag{16}$$

$$C_4 \geq \frac{I_O D}{f_s * \Delta V_{C4}} \tag{17}$$

III. SIMULATIONS AND RESULTS

The enhanced gain buck boost DC-DC converter is simulated using MATLAB/SIMULINK with the settings chosen from Table 1. The MOSFET switch keeps its switching frequency constant at 75kHz. The power switch is managed using a 0.55 duty ratio.

TABLE I
SIMULATION PARAMETERS OF BUCK BOOST CONVERTER

Parameters	Values
Input Voltage V_{IN}	15V
Output Load R	150Ω
Switching Frequency f_s	75 kHz
Inductors L_1,L_2,L_3	1.2 mH, 1 mH, 1.1 mH
Capacitors C_1,C_2,C_3,C_4	47 µF, 100 µF, 100 µF,100 µF
Duty Ratio	0.55

An output of 75V can be obtained with a dc input voltage of 15V. Figure 5 illustrates the display of the source voltage and current. The voltage and current of the converter's output can be observed in Figure 6. The gate pulse and switching voltage across switches are displayed in Figure 7. Switch S_1 & S_2 has a voltage stress of 33V & 71V.

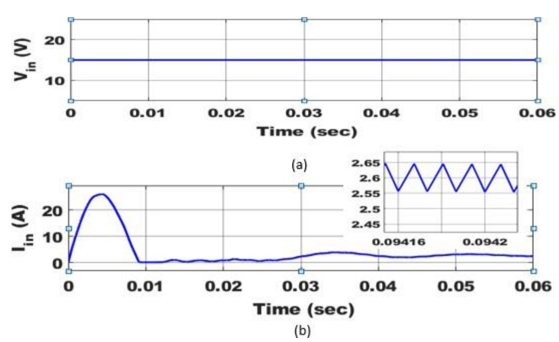


Fig. 5. (a) Input Voltage (V_{IN}) and (b) Input Current (I_{IN})

The voltage across capacitors V_{C1} is 32V ,V_{C2} is 69V, V_{C3} is 31V and V_{C4} is obtained as 75V which is shown in Figure 8.

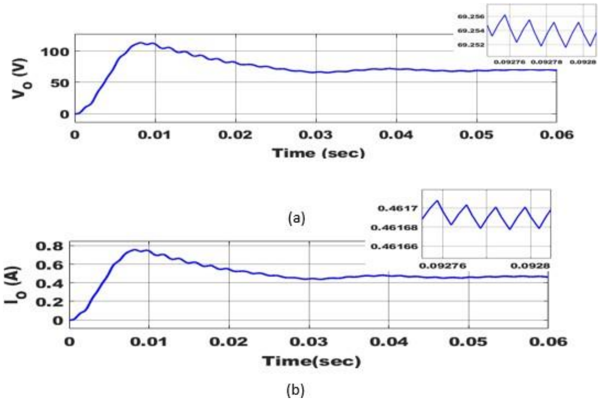


Fig. 6. (a) Output Voltage (V_O) and (b) Output Current (I_O)

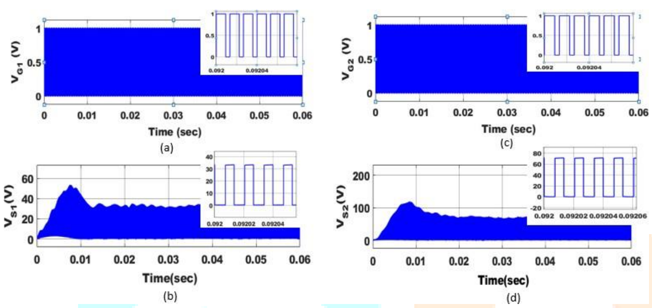


Fig. 7. (a) Gate Pulse of S_1 , (b) V_{S1}, (c) Gate Pulse of S_2 ,(b) V_{S2}

IV. PERFORMANCE ANALYSIS

The power input to output ratio of a electrical equipment determines its efficiency at various load. The efficiency versus output power for a single switch high gain buck boost DC-DC converter with R and RL loads is presented in Figure 9. For R and RL loads, the maximum converter efficiencies are 85% and 86% respectively.

The graph of Voltage gain VS duty ratio is shown in figure 10. The graph of Output voltage ripple Vs duty ratio is shown in figure 11. The graph of Output voltage ripple Vs Frequency is shown in figure 12.

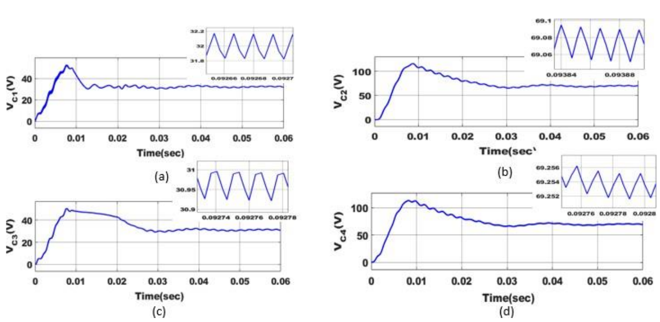


Fig. 8. Voltage across Capacitors (a)V_{C1}, (b)V_{C2}, (c)V_{C3}, (d)V_{C4}

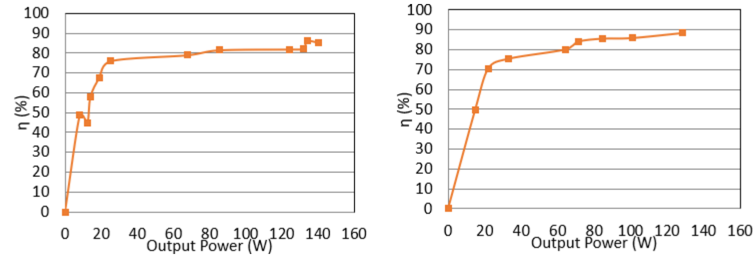


Fig. 9. Efficiency of converter Vs Output Power for (a) Resistive load, (b) Resistive-Inductive load

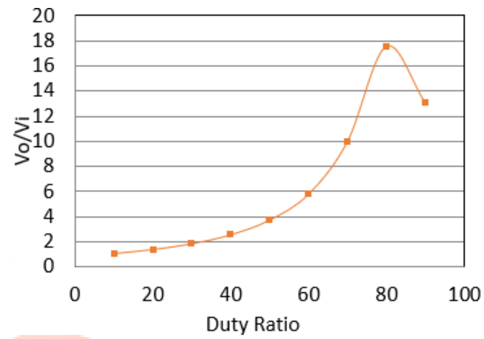


Fig. 10. Voltage Gain Vs Duty Ratio

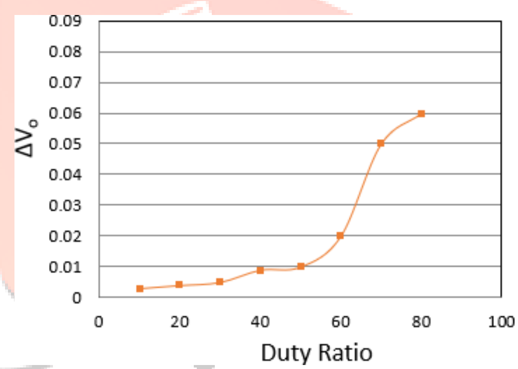


Fig. 11. Output Voltage Ripple Vs Duty Ratio

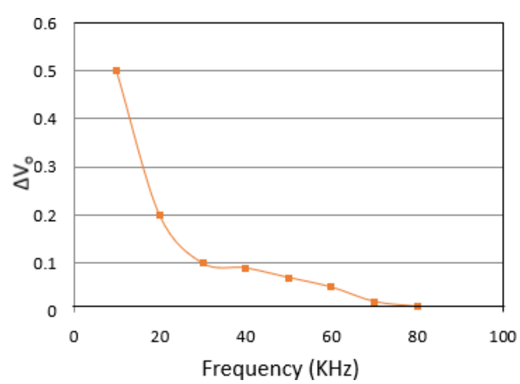


Fig. 12. Output Voltage Ripple Vs Frequency

V. COMPARITIVE STUDY

Table II presents a comparison between the basic buck boost converter and the enhanced gain buck boost converter. It is clear from the table II and III that the modified converter surpasses the standard buck boost dc-dc converter in terms of gain.

TABLE II
COMPARISON WITH BUCK BOOST CONVERTER AND ENHANCED GAIN BUCK BOOST CONVERTER

Parameters	***Dual Switch Buck Boost Converter***	***Enhanced Gain Buck Boost Converter***
Duty Ratio (D)	69%	55%
Output Voltage (V_O)	70.8V	69.4V
Output Current (I_O)	0.47A	0.46A
Input Voltage (V_{IN})	15V	15V
Input Current (I_{IN})	2.75A	2.66A
Voltage stress across switches	V_{S1} = 48V V_{S2} = 151.8V	V_{S1} = 33.2V V_{S2} = 71.3V
Efficiency	80%	80.6%
Voltage Gain	4.7	4.6
Input Current Ripple	0.1A	0.1A
Output Voltage Ripple	0.01V	0.004V
Output Current Ripple	0.00002A	0.00003A

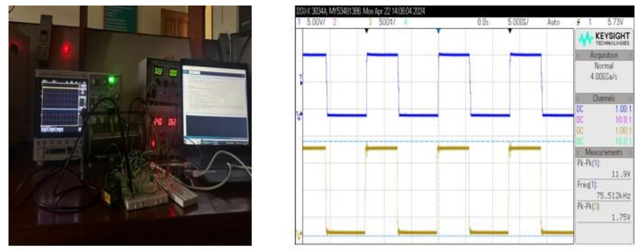
Due to the addition of a voltage multiplier circuit, the high gain buck boost converter has more components. Thus, there was a reduction in stress across the switch. The Comparison between dual switch buck boost converter and enhanced gain buck boost converter is done by keeping the same output power P_O = 40W, input voltage V_{IN} = 15V, switching frequency f_s= 50kHz and the load as constant. The utilization of a high gain converter effectively reduces the ripple exist in both the output voltage and current. Table III presents the results of a comparative analysis between various buck boost topologies and the suggested converter. After evaluating similar buck boost converters, it can be inferred that the suggested converter has exceptional performance in regards of voltage gain, switching voltage, and efficiency.

TABLE III
COMPARISON WITH HIGH GAIN BUCK BOOST CONVERTER AND DIFFERENT DC-DC CONVERTER CIRCUITS

Converters	***Buck Boost Converter in[2]***	***Buck Boost Converter in[3]***	***Dual Switch Buck Boost Converter[1]***	***Enhanced Gain Buck Boost Converter***
Switches	2	2	2	2
Diodes	2	2	2	3
Inductors	2	2	3	3
Capacitors	2	2	3	4
Voltage Gain	$\frac{D(2-D)}{(1-D)^2}$	$\frac{D^2}{(1-D)^2}$	$\frac{D^2}{(1-D)^2}$	$\frac{1}{(1-D)^2}$

VI. EXPERIMENT RESULTS

The source voltage is lowered to 2V, inorder to facilitate hardware implemention .While the TMS320F28335 controller is employed to generate the switching pulses. MOSFETIRF540 switches are utilized, and IN 5817 diodes are used. The TLP250H optocoupler, which is used to provide the necessary gating to turn on the switch and to isolate and shield the microcontroller from harm, is used to implement the driver circuit. The TLP250H is used in the development of an interface circuit to supply the gating voltage needed to activate the switches. Fig. displays the dual switch enhanced gain buck boost converter experimental setup in 13(a).Input: DC source provides a 1.57V DC supply. The TMS320F28027F microcontroller provides the switching pulses to the driver circuit.



(a) (b)

Fig. 13. (a) Experimental Setup (b) Switching Pulses

The TMS320F28027F microcontroller provides the switching pulses to the driver circuit. The TMS320F28027F controller, as shown in Figure 13(b), generates pulses that are integrated into an interface circuit, which amplifies the pulse to activate the switch. Consequently, the power circuit depicted in Figure 14 yields an output voltage of 8.5V, 75kHz. The converter's output voltage is measured using a DSO oscilloscope.

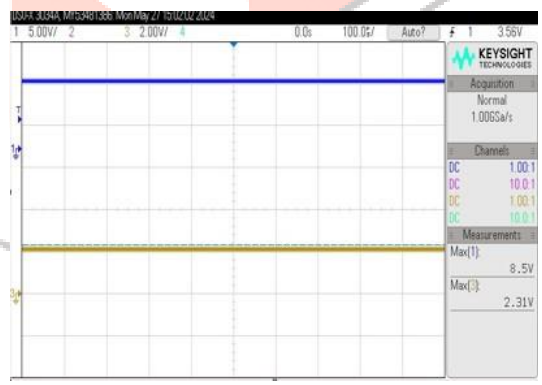


Fig. 14. Output Voltage of Converter

VII. CONCLUSION

A newly developed and improved gain buck boost converter with reduced stress on the switches is introduced and put into use. This design is created by altering the standard gain buck boost converter by incorporating a voltage multiplier component at the rear using a capacitor and diode. When pitted against other gain buck boost DC-DC converters, this new converter stands out for its high gain and reduced stress on the switching elements. The design is then subjected to simulations and analyses. The results show that the converter reaches an efficiency of 80% for an output power of 40W. Further analysis reveals that the enhanced gain buck boost converter can achieve a peak efficiency of 85.4% for an output power of 140W. The proposed design also brings several benefits, including a broad operating range for duty ratio and minimal stress on the switches. The control of this converter is realized through the use of a TMS320F28027F microcontroller. A prototype of the converter for 40W delivers the anticipated performance with an output voltage of 8.5V, despite component voltage drops. Therefore, these character- istics render the presented design an outstanding choice for photovoltaic systems.

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