

A Buck-Boost Hybrid Converter with a Common Capacitor

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Abstract: DC-DC converters are important electronic switching parts that are used in many different ways to control and change DC voltage levels. The hybrid buck-boost converter proposed in this study differs from conventional buck-boost converters in that it can change voltage in both directions while maintaining a constant modulation index. This makes it more flexible and useful in a wider range of situations. We provide in-depth details about the converter's circuit structure and its operational principles. We test the proposed converter with resistive loads and compare its performance to that of traditional buck-boost configurations to assess its effectiveness. The simulation results show that the proposed hybrid converter not only achieves higher and more variable voltage conversion ratios, but it also operates steadily without changing the switching duty cycle. One of the main benefits of the proposed design is that it can control voltage on both sides of the load. This makes it useful for systems that need to exchange energy dynamically, such as battery management systems, integrating renewable energy sources, and electric vehicles. On the other hand, regular converters typically only support one-way conversion, making them less flexible. Overall, the suggested hybrid buck-boost converter is a suitable choice for modern power electronic applications, as it offers improved performance, easier control, and the ability to adapt to various situations.

Keywords: DC-DC Converters; Hybrid Buck Boost Converter; PWM Controller; Common Capacitor; Voltage Conversion Ratios; Battery Management Systems; One-Way Conversion; Exchange Energy.

Cite as: P. Srinivasan, K. Arulvendhan, S. Anirudh, and B. Asaithambi, "A Buck-Boost Hybrid Converter with a Common Capacitor," *AVE Trends in Intelligent Energy Letters*, vol. 1, no. 1, pp. 39–51, 2025.

Journal Homepage: <https://www.avepubs.com/user/journals/details/ATIEL>

Received on: 03/10/2024, **Revised on:** 25/11/2024, **Accepted on:** 27/12/2024, **Published on:** 07/06/2025

DOI: <https://doi.org/10.64091/ATIEL.2025.000124>

1. Introduction

In the field of electronic circuit design, DC converters play a critical role in modifying and controlling DC voltage levels for various applications. Among these, the hybrid buck-boost DC-DC converter emerges as a versatile and innovative solution, surpassing traditional designs with unique operational advantages. Unlike conventional one-way converters, which operate within a limited ratio and direction, the hybrid buck-boost converter offers bidirectional capability with an extended operating range. This is achieved through its ability to step up or step down voltage efficiently, facilitated by a constant modulation index. The inclusion of a common capacitor further enhances its functionality, ensuring stable operation and energy storage across varying conditions [1]. This paper examines the design, operation, and potential applications of the hybrid buck-boost converter, highlighting its capability to optimise energy conversion in modern power systems. By leveraging this topology, the converter

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provides a reliable solution for diverse energy conversion challenges, paving the way for advancements in power electronics [2]. A Buck-Boost hybrid converter with a common capacitor is a power electronics circuit that combines the functionalities of both buck and boost converters, utilising a common capacitor for energy storage [4]. These converters are typically used when there is a need for both step-up (boost) and step-down (buck) voltage regulation in the same system, such as in renewable energy systems, battery management, or DC-DC converters for electronics that need variable input or output voltages [5]. The Key Components are used as follows:

- **Inductor:** Stores energy when current flows through it and releases it when the circuit changes state. It's critical for energy transfer between the input and the output.
- **Switches:** Control the flow of current through different parts of the circuit. These are essential in switching between buck and boost modes.
- **Diodes:** Ensure current flows in the correct direction during switching operations to prevent reverse current that could damage components.
- **Capacitor:** A common capacitor is shared between the buck and boost stages, smoothing out voltage ripples and helping to maintain a stable output voltage. Its size and placement are crucial for efficiency and performance.

1.1. Controller (PWM Controller)

Modulates the duty cycle to adjust the voltage by controlling the switching action of the MOSFETs or other semiconductor devices [3]; [4]. The following are the benefits of using a Common Capacitor.

- **Size Reduction:** By using a single capacitor for both the buck and boost stages, the size and complexity of the converter are reduced.
- **Cost Efficiency:** The use of fewer components results in lower manufacturing costs.
- **Simplicity in Control:** A common capacitor can simplify the control circuitry needed to manage both the buck and boost stages.
- **Reduced Ripple:** The common capacitor helps reduce voltage ripple by providing continuous smoothing action across both operating modes.

The proposed conversion switch has a constant operating relationship between 0 and 1. By administering bidirectional energy levels to the network switch, another generator (pulse width modulation) is employed, along with the switch, and a relationship with the converter structure switch is established [10]. A mathematical explanation of the building, operation, and characteristics of the proposed converter circuit is provided. Matlab/Simulink is used to test circuit functions and performance. The hardware results are very detailed [6]. The results achieved with the recommended methodology are compared to those obtained with the standard procedures by monitoring the current and voltage on the loads. Nevertheless, it's essential to highlight the groundbreaking feature of the proposed converter, which is its ability to adjust voltage in both directions [7]. This bidirectional voltage adjustment capability opens up a wide array of possibilities for applications where precise voltage control is essential [8]. The hybrid buck-boost DC-DC converter is an innovative and promising device that may be used to adapt to various voltage requirements without the need for additional converters [9]. This study highlights a significant advancement in the field of DC converters, specifically the hybrid buck-boost DC-DC converter [11]. While acknowledging its viability and novel bidirectional voltage adjustment capability, the study also acknowledges certain performance trade-offs when compared to traditional converters. The insights gained from this research contribute to our understanding of DC-DC converters' diverse capabilities and pave the way for further advancements in this critical electronic component domain [12]; [13].

2. Hybrid Buck-Boost Converter

The circuit diagram of the hybrid buck-boost converter is shown in Figure 1.

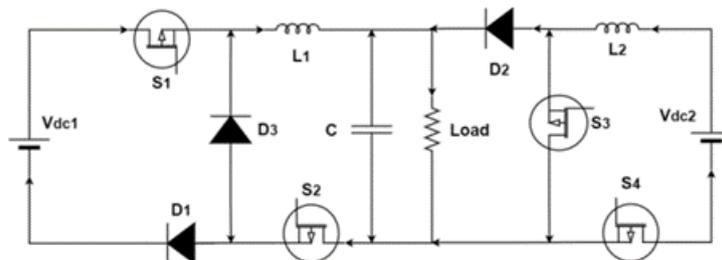


Figure 1: Multilevel as a conditioning unit in a grid-connected PV system

Three diodes from D1 to D3, two inductors from L1 to L2, two sources from Vdc1 to Vdc2, four power switches from S1 to S4, and a capacitor as C comprise the circuit.

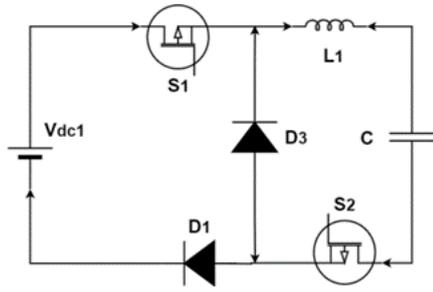


Figure 2: Buck mode at DT

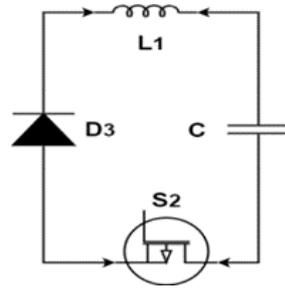


Figure 3: Buck mode at (1-D) T

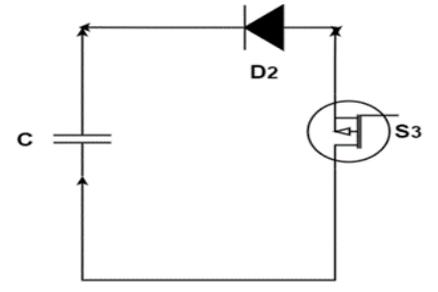


Figure 4: Buck mode at DT

Figure 2 shows a lossless DC-DC converter circuit during continuous delivery. D , divided by t , and values from 0 to 1 are the power switch [3]. The circuit is given two modes. The first mode (Figure 3) is shown between 0 and $0-DT$. The D1, S1, and S2 diodes are distorted in the forward direction. The D3 diode is blocking (Figure 5). The primary function of a D3 diode is to block leaks from other sources; however, the hybrid buck-boost converter transitions between reduction and increasing modes. At period $0 < (1-D) T$, the counter operation is displayed in (Figure 4).

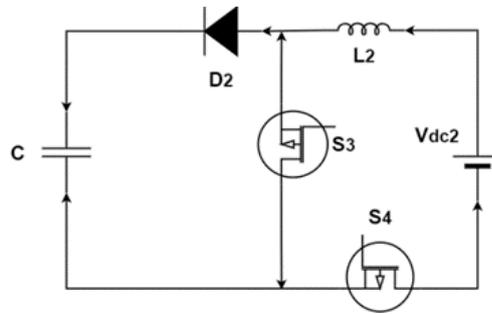


Figure 5: Boost mode of the suggested hybrid buck-boost converter at (1-D) T

D3 is turned on, and S1 is blocked. $V_O + V_C$ is the output voltage. The tension size that this process creates is explained in the following equation:

$$\frac{V_o}{V_{dc1}} = D \cdot t_1 \quad (1)$$

$$V_O = V_{dc1} D \cdot t_1 \quad (2)$$

A second time is called t_2 in an increasing state, where the occupancy rates remain constant. In the case when $k \in \mathbb{Z}^+ = \{1, 2, 3, \dots\}$, the expression for the circuit's running time, t , may be computed as follows.

$$t = t_1 + t_2 \quad (3)$$

$$t_1 = kt_2 \quad (4)$$

The second stage of the circuit also has two modes. The first stage, driven between 0 and t_2 , is shown. For the time interval $0 < (1-D) T < T < t_2$, the contrapositive mode is seen. The size of the voltage achieved by this process can be represented as:

$$\frac{v_o}{V_{dc2}} = \frac{t_2}{(1-D)} \quad (5)$$

$$V_O = \frac{V_{dc2} \cdot t_2}{(1-D)} \quad (6)$$

The mean multiplicity value over the entire time interval t can be found using the formula: $V_{dc2} = V_{dc1} = V_{dc}$:

$$V_o = [V_{dc}D \cdot t_1 + \frac{V_{dc} \cdot t_2}{(1-D)}] / (t_1 + t_2) \quad (7)$$

$$V_o = [V_{dc}D \cdot kt_2 + \frac{V_{dc} \cdot t_2}{(1-D)}] / (kt_2 + t_2) \quad (8)$$

$$V_o = [V_{dc}D \cdot k + \frac{V_{dc}}{(1-D)}] / (k + 1) \quad (9)$$

The efficiency of the stream is calculated by dividing the total power by the power obtained at the circuit's output. The estimation of power component losses is conducted using recommended techniques based on the operational state of the MOSFET power switch. When the switch is on, the resistor contributes to a conduction loss of P_{on-h} , while OFF, the loss is expressed as P_{on-l} . The output current is I_o , the MOSFET resistance is R_{on-h} , the low input breakdown is R_{on-l} , the input voltage is DC, and the output voltage is V_o .

$$P_{oh-h} = I_o^2 \cdot R_{on-h} \left[\frac{V_o}{V_{dc}} \right] \quad (10)$$

$$P_{oh-l} = I_o^2 \cdot R_{on-l} \left[1 - \frac{V_o}{V_{dc}} \right] \quad (11)$$

ΔI_L represents the inductor ripple current, f_s denotes the switching frequency, and L signifies the inductance value. The design of the ripple current is outlined below:

$$\Delta I_L = (V_{dc} - V_o) \cdot f_s \cdot L \cdot V_o / V_{dc} \quad (12)$$

$$I_{min} = I_o \quad (13)$$

$$I_{max} = I_o + \Delta I_L \quad (14)$$

PCA can be calculated using the formulas below.

$$P_{CA} = I_o \cdot (V_{dc} - V_o)^{1/2} \cdot V_o / V_{dc} \quad (15)$$

$$P_{CA} = I_{CA} \cdot (RMS)^2 \cdot R_{es} \quad (16)$$

3. Simulation Analysis and Discussion

In this discussion, the resistive load conditions of the hybrid buck-boost converter are discussed. A 50V DC source is used to supply the resistor R , whose value is chosen as 20Ω (Figure 6).

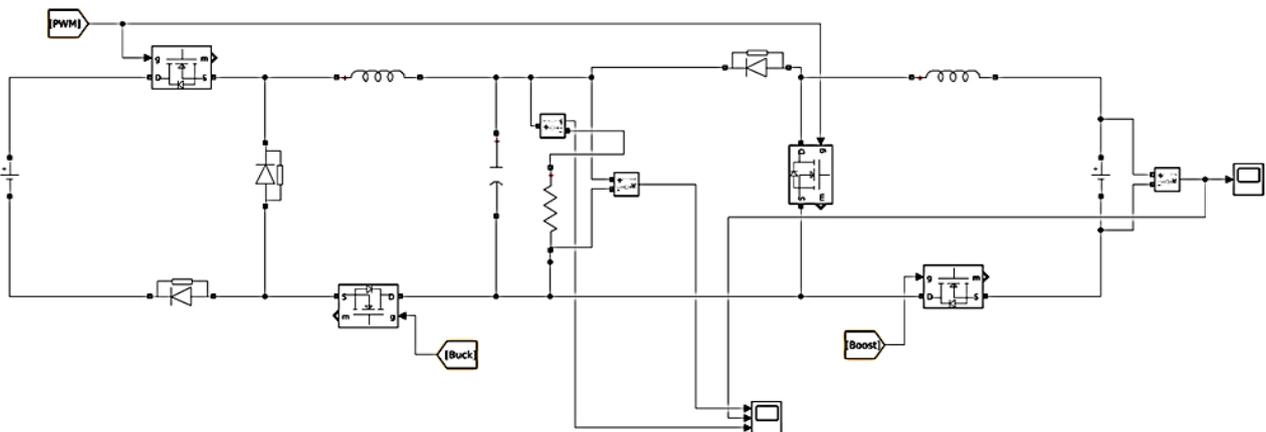


Figure 6: Circuit design of DC-DC hybrid converter designed using MATLAB/Simulink

The simulation is run at a speed of 0.1 milliseconds and with a switching time of 0.00005 seconds. The component values of the circuit are given in Table 1.

Table 1: The components used in the simulation

No.	Component	Range
1	L1	0.001H
2	L2	0.000005H
3	C	2200 μ fd
4	R	20 Ω
5	Vdc1	50V
6	Vdc2	50V

The circuit was simulated with a 20 Ω load, and the MATLAB/Simulink representation of the DC-DC hybrid converter circuit is presented. This paper presents an analysis of a typical capacitor hybrid buck-boost converter. The four-stage circuit topology and working operations are shown in the circuit elements, and the work order is complete. Circuit R is evaluated by selecting the switch operating rate at 0.4, 0.5, 0.6, 0.7, and 0.8. The load voltage is 19 V, and the operating frequency is 0.4 Hz. The voltage creates a current of 0.97 through the load. In the second stage, the load is 150 V and the current is 7.5 A. The load supply voltage is 24 V, and the employment relationship is 0.5. When a voltage of 24 V is applied, a load current of 1.16 A is generated (Figure 7).

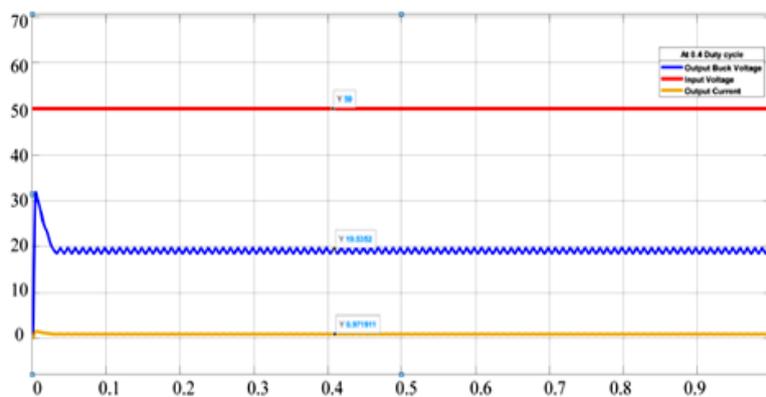


Figure 7: Input voltage of 50 V, 0.4 of D, and buck voltage of 19 V

The electricity is 8.33 A, and the load voltage is 169 V after the switch is reversed in rising mode for the same employment relationship. The operating rate is 0.6, so the load voltage increases to 29 V. A load voltage of 29 V corresponds to a current of 1.4 A (Figure 8).

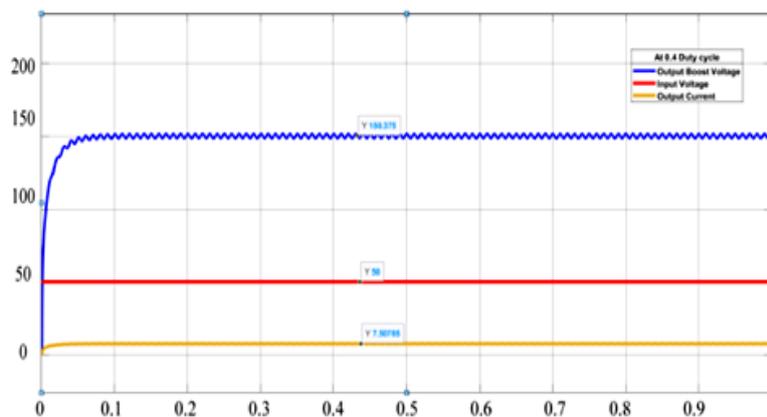


Figure 8: Input voltage of 50 V, 0.4 of D, and boost voltage of 150 V

The load current is 184 V and 9.27 A after starting at the same operating rate as the switched switch in circuit mode. If the operating rate is determined to be 0.7, the load voltage increases to 34 V (Figure 9).

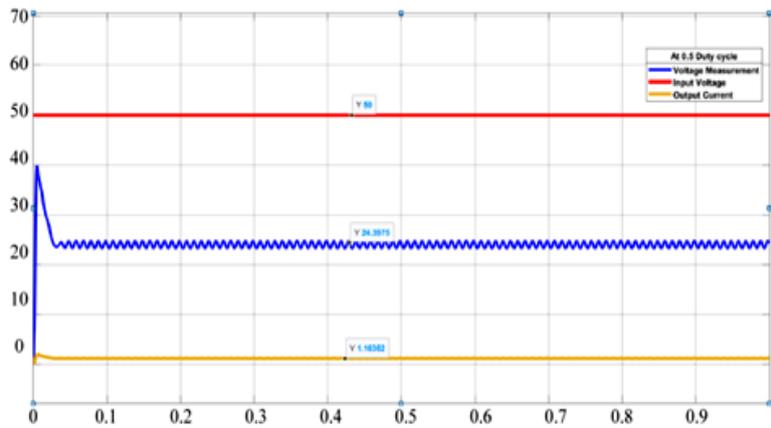


Figure 9: Input voltage of 50 V, 0.5 of D, and buck voltage of 24 V

The 34 V voltage provides 1.73 A of current through the load. The electricity is 9.85 A, and the load voltage is 196 V. The employment relationship is 0.8, and the load voltage is 39 V. As mentioned, a voltage of 39 V draws a current of 1.99 A against the load (Figure 10).

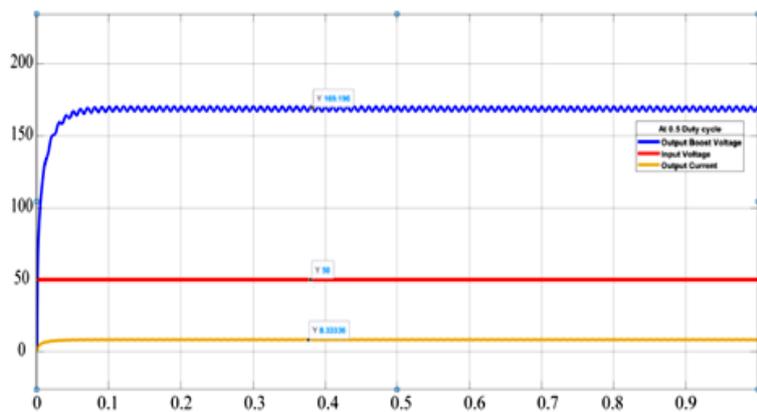


Figure 10: Input voltage of 50 V, 0.5 of D, and boost voltage of 169 V

The load voltage is 206 V, and the current is 10.4 A after transition to the increase mode in the same employment relationship of the switch as described (Figures 11 to 16).

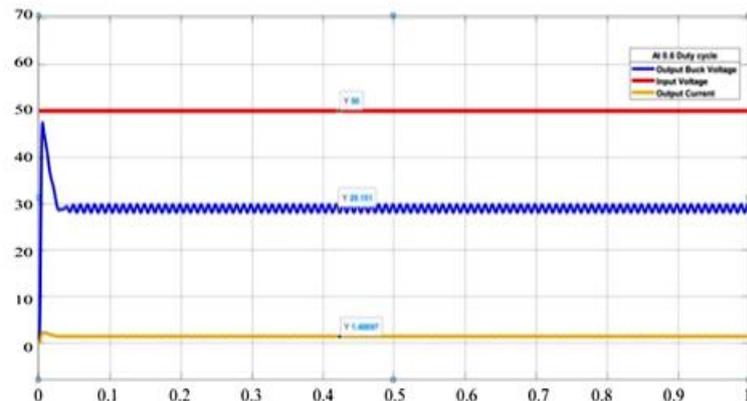


Figure 11: Input voltage of 50 V, 0.6 of D, and buck voltage of 29 V

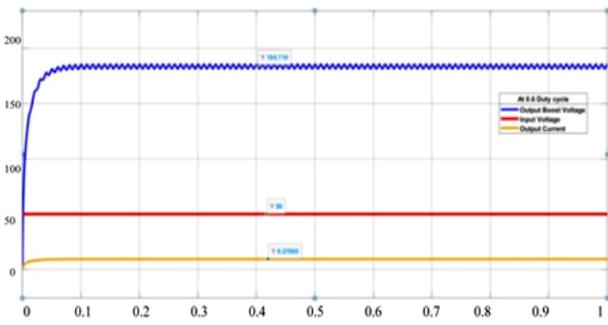


Figure 12: Input voltage of 50 V, 0.6 of D, and boost voltage of 184

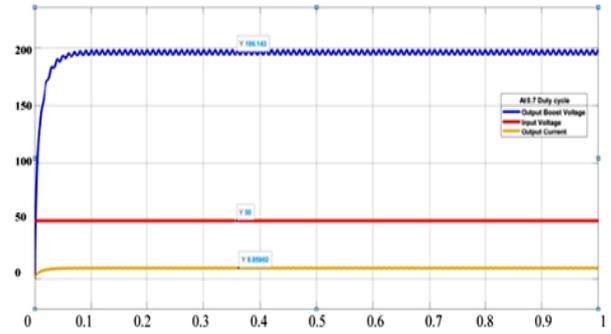


Figure 14: Input voltage of 50 V, 0.7 of D, and boost voltage of 196 V

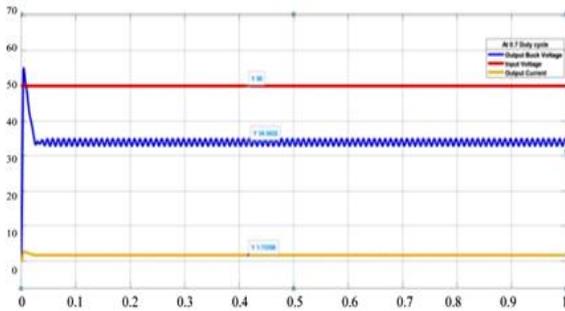


Figure 13: Input voltage of 50 V, 0.7 of D, and buck voltage of 34 V

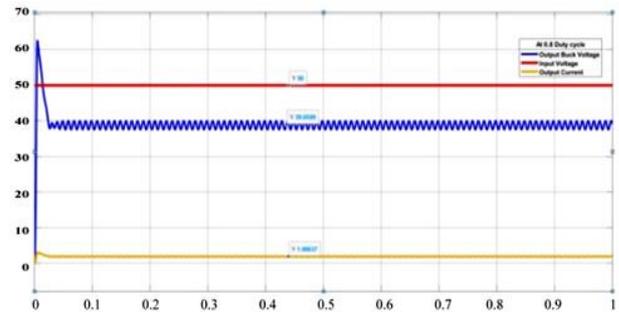


Figure 15: Input voltage of 50 V, 0.8 of D, and buck voltage of 39 V

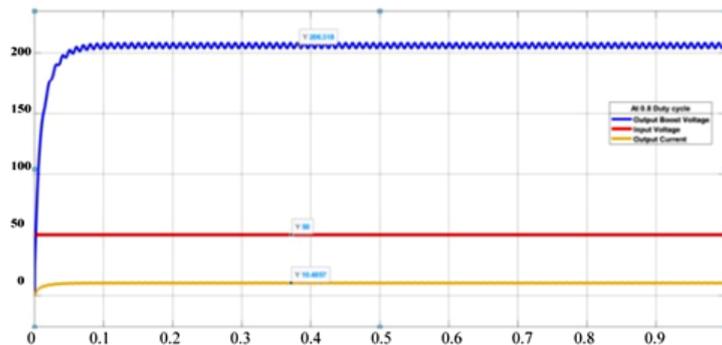


Figure 16: Input voltage of 50 V, 0.8 of D, and boost voltage of 206 V

The built-up circuit demonstrated consistent and effective operation at a rate of 0.4, indicating that it could achieve different output voltage levels in various modes of operation. The converter worked well in buck mode, lowering the voltage from 50 volts to 19 volts. This demonstrates that it can quickly and easily lower the voltage. In boost mode, on the other hand, the converter was able to raise the voltage to 150 volts under the same input voltage condition. This shows that the converter has a very high step-up ratio and can handle a wide range of voltage conversions. These operational features demonstrate that the proposed converter design is robust and can be adapted to meet various needs.

Additional tests in boost mode demonstrated that the output voltage reached an impressive 169 volts when the circuit was operated at a modulation index of 0.6. This shows that the converter can handle operations with high gain. This accomplishment surpasses standard expectations and demonstrates how the proposed hybrid converter can generate higher voltages with slightly longer duty cycles. In a different setup, the same circuit produced an intermediate hinge mode output of 29 volts, which effectively connects the buck and boost regions.

This hinge point enables you to switch between operational modes without compromising system stability or requiring extensive reconfiguration. Also, the circuit's performance was tested with a modulation index of 0.8, which is even higher than before. When it was in this mode, the converter produced 39 volts of power in buck mode and 206 volts of power in boost mode. These results clearly demonstrate that the converter excels at delivering high-voltage outputs while maintaining control accuracy and operational reliability. The significant rise in output voltage, especially at higher duty cycles, demonstrates that the converter can handle heavy loads and provide applications that require substantial voltage amplification.

When you compare the performance of this hybrid buck-boost converter to that of a regular buck-boost converter, the differences become even clearer. A regular converter typically outputs up to 60 volts under the same input and control conditions. This is much less than what the hybrid model can do. The primary issue with the traditional design is primarily due to architectural limitations and the lack of dynamic, bidirectional energy flow mechanisms. The proposed converter, on the other hand, gets around these problems with its advanced switching strategy and shared component topology. This allows it to operate over a wider range of voltages without losing efficiency or generating excessive voltage ripple. The study's test results demonstrate that the proposed hybrid converter offers several advantages over traditional configurations, particularly its ability to adapt and provide different output values across various operating modes. The converter's improved performance is due to its optimised switching structure, advanced control algorithms, and enhanced power transfer methods.

These components work together to maintain a steady, accurate, and responsive output voltage, capable of adapting to changes in the duty cycle or load conditions. A close examination of the experiment's results supports the claim that the hybrid converter is more effective. It can produce multiple output voltages with a single fixed input by adjusting the modulation index. This demonstrates its usefulness in systems where precision and flexibility are crucial. The converter also maintains low switching losses and high efficiency across its entire operating range. Not only does reducing losses make the converter more energy-efficient, but it also lowers thermal dissipation, which in turn extends the converter's lifespan and improves its performance.

The converter's overall performance depends significantly on using a shared capacitor and carefully selecting inductive parts and switching devices. This setup utilises fewer parts, making the design simpler, smaller, and more cost-effective. The control circuitry works together perfectly to ensure that the converter switches between modes without introducing noise, surges, or delays. This feature is crucial for sensitive electronics and embedded systems that require a clean and uninterrupted power supply. The results show that the hybrid topology consistently outperforms traditional models when their output performance is compared under the same conditions.

This design is good for renewable energy applications, battery-powered systems, and electric vehicles because it can produce high output voltages with low input and has a predictable operating index. The converter's better regulation and responsiveness make it a top choice for modern power conversion tasks. We have confirmed that the converter works in real-world applications by running numerous simulations and testing it on actual hardware. The results are very similar to what was expected based on theory and simulation, which makes the proposed design more believable and useful in the real world. The results also show that the hybrid converter not only converts voltage more efficiently, but it also makes it easier to design and control. Engineers and researchers can apply the same principles to create scalable converter designs that operate with larger systems or higher current ratings.

Table 2: Evaluation of the performance of the proposed hybrid buck-boost converter

Input Voltage	Duty Cycle	Proposed Converter	
		Buck (V)	Boost (V)
50	0.4	19	150
50	0.5	24	169
50	0.6	29	184
50	0.7	34	196
50	0.8	39	206

In short, the suggested hybrid buck-boost DC-DC converter is superior to traditional converters because it can produce higher and more flexible output voltages from a single input source, with improved efficiency and reduced ripple. The experimental setups clearly demonstrate that this design achieves significant improvements in power conversion efficiency. The converter's value and potential for future high-performance electronic and energy systems come from its ability to produce different output values from the same set of operational parameters. The performance data, as shown in Table 2, provides a clear and quantitative comparison of the proposed converter's superiority over others. This makes it a reliable and effective choice for next-generation power electronics.

4. Hardware Results and Discussion

Figure 17 illustrates a schematic of the proposed hardware implementation of the hybrid buck-boost converter, which was developed and tested in real-world applications. The implementation's buck converter setup utilises a 30-volt input voltage, which serves as a stable and reliable source for testing the circuit's ability to down-convert.

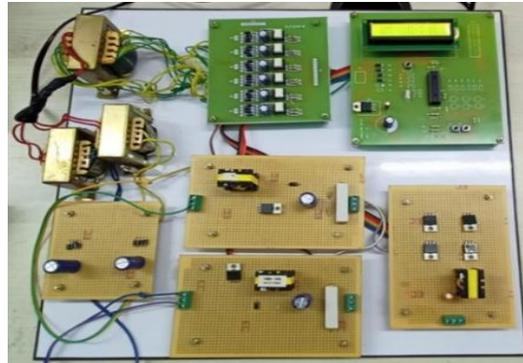


Figure 17: Hardware of the proposed system

The operation of this setup is watched and recorded under different duty cycle conditions, with special attention paid to how the voltage conversion works at different points.

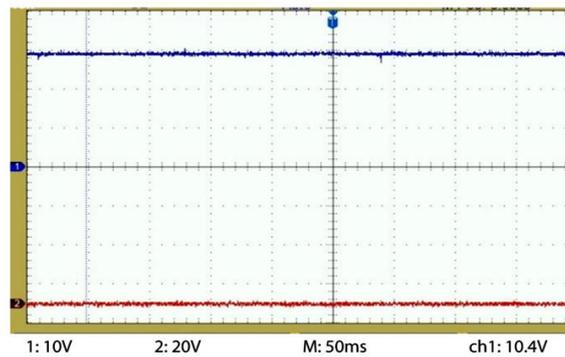


Figure 18: Buck input voltage of 30 V

Figure 18a shows, in particular, the steady application of a 30-volt input to the buck converter. When the duty cycle is maintained at 0.4, as shown in Figure 19, the system operates as expected, producing an output voltage of approximately 5 volts, as illustrated in Figure 20.

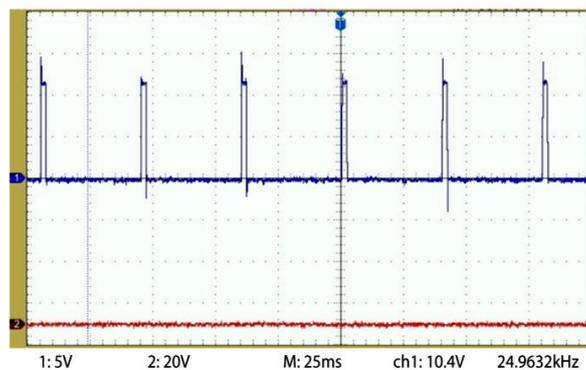


Figure 19: At 0.4 of D

The buck converter can adjust its output voltage from 2.3 volts to 25.9 volts, depending on the duty cycle setting.

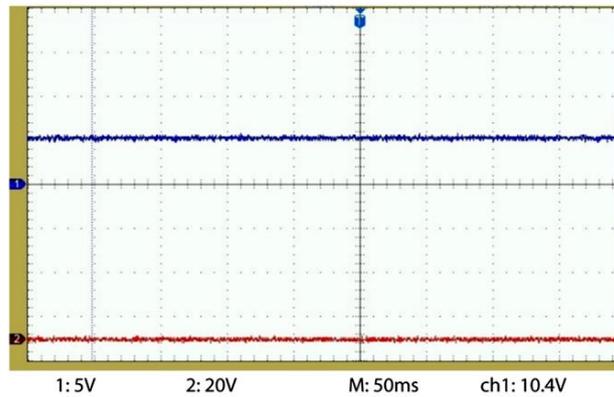


Figure 20: Buck output voltage of 5 V

This range demonstrates that the converter can efficiently lower voltages and adjust to various load and control conditions, proving it suitable for applications requiring stable low-voltage outputs (Figures 21 to 23).

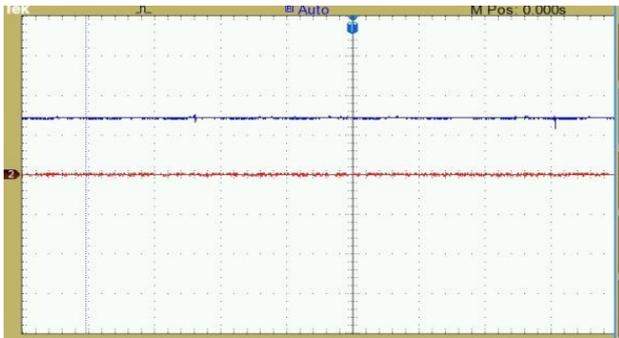


Figure 21: Boost input voltage of 13.5 V

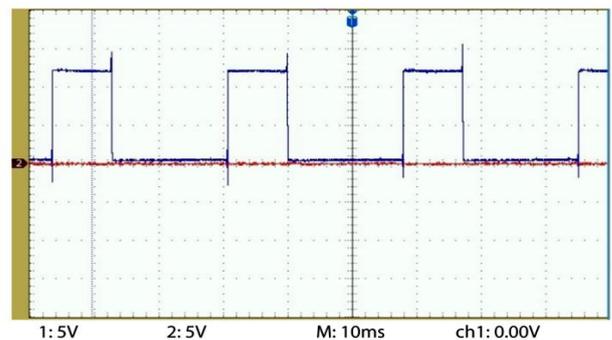


Figure 22: At 0.8 of D

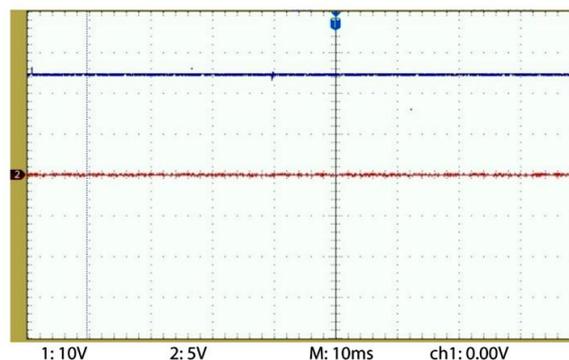


Figure 23: Boost output voltage of 24.5 V

In the next step of validation, a boost converter configuration is tested to determine how effectively it can raise the voltage while operating with various settings. A voltage of 13.5 volts is applied to this setup. The duty cycle applied to the switching signal has a big effect on how the boost converter works. Its performance is tested over a wide range of duty cycle values. The output voltage remains the same as the input voltage at a duty cycle of 0.4, indicating that the output is 13.5 volts. This illustrates the system's limit, where no significant boosting effect is observed. However, when the duty cycle is increased to 0.5, the output voltage rises slightly, reaching 15 volts. This rise demonstrates that the converter can efficiently raise the voltage even with small changes in duty cycle, a feature that is particularly useful for applications requiring precise control. When the duty cycle

increases to 0.7, the output voltage rises to 19.5 volts, indicating that the voltage gain becomes steeper as the switch-on period lengthens.

The system is tested again with a duty cycle of 0.8. When the input voltage is 13.5 volts, the output voltage is 24.5 volts. Figures 11a, 11b, and 11c show this condition visually. Together, they demonstrate that the voltage step-up behaviour remains consistent and accurate as the duty cycle increases. The boost converter can output voltages ranging from 13.5 to 29 volts, depending on the duty cycle. This is useful in situations where precise voltage control is needed across a range of operating conditions. Because it can operate over a wide range of voltages and exhibits a linear voltage gain pattern, the boost converter is highly useful for regulating DC power in renewable energy systems, battery charging modules, and DC grid interfacing applications. The results of these tests support the idea that the proposed hybrid converter hardware is both efficient and reliable. Table 3 presents a detailed list of the components used to construct the prototype, including switching elements, passive filters, capacitors, inductors, and control modules. We carefully select each part to ensure that it works optimally in both buck and boost modes. The hardware parts are checked for consistency, heat resistance, and signal fidelity. This ensures that the entire system maintains its high conversion efficiency and low voltage ripple under various load conditions.

The fact that both the buck and boost operations utilise the same key components, such as the capacitor, also reduces the number, size, and complexity of the physical hardware layout. This makes the converter smaller and cheaper. Table 4 shows the real-world results of using the hybrid buck-boost converter. It lists the input-output relationships, duty cycle changes, and the corresponding output voltage levels. These results not only confirm the theoretical design of the converter but also demonstrate that it can be accurately built and utilised to achieve the desired voltage profiles. The fact that the converter can switch between buck and boost modes without any problems or distortion in the waveform demonstrates the robustness of the proposed control strategy and the quality of the hardware. This feature is especially important in real-time applications, where system reliability and a steady power supply are crucial. Also, the converter's ability to handle multiple voltage levels from fixed input sources using controlled duty cycle modulation is useful in modern electronic and power systems.

Table 3: Shows the hardware components, specifications, and tasks

Component	Features	Task
Power supply unit-1	Input 220VAC to output 30VDC	Buck Input
Power supply unit-2	Input 220VAC to output 13.5VDC	Boost Input
Buck-Boost Hybrid Converter	Buck converter: Input DC: 30V, Output DC: (0-30V)	Step up or step down the DC voltage using a common capacitor
	Boost converter: Input DC: 13.5V, Output DC: (13.5-29V)	
Pulse driver	MCT2E-optocoupler	MCT2E is a phototransistor optocoupler
	Diode forward voltage is 1.25V	
	Collector-emitter voltage is 30V	
	On-state collector current is 5mA	
	Transistor HFE is 300	
	Rise time is 5us and fall time is 5us.	
Microcontroller	dsPIC 30F2010	Pulse generation to drive the switch
	24-bit wide instructions, 16-bit wide data path	
	Wide operating voltage range (2.5V to 5.5V)	
	Dual data fetch	
Inverter	Input: 13.5VDC	Converts DC-AC
	Output:230VAC, 50HZ	

It can be used in a lot of different ways, like in electric vehicles where both step-up and step-down voltages are needed at different points in the powertrain; in solar photovoltaic systems where maximum power point tracking may need dynamic voltage adaptation; and in portable electronics where voltage regulation has to stay the same even when the battery runs out. These examples demonstrate the utility and adaptability of the proposed design. The experimental testing of the hybrid buck-boost converter shows that it is very reliable, versatile, and performs well.

The fact that it worked when translated from simulation to hardware demonstrates its suitability for advanced power electronics applications. The converter's ability to respond to duty cycle modulation, its wide range of operational voltages, and its efficient performance all make it a viable, scalable, and robust solution for today's DC power conversion challenges. The voltage measurements and detailed tables demonstrate that the new design outperforms traditional converters. This makes it a suitable candidate for further development and application in various energy management systems.

Table 4: Hardware implementation of proposed hybrid buck-boost converters

S.no	Buck Input	Buck Output	Boost Input	Boost Output
1	30	25.9	13.5	13.5
2	30	22	13.5	15
3	30	17.5	13.5	17
4	30	13	13.5	19.5
5	30	8.5	13.5	21
6	30	5	13.5	24.5
7	30	2.3	13.5	29

5. Conclusion

This paper provides a standard hybrid buck-boost converter from a capacitor. First, the operation of the four stages of the circuit structure and the sequence of operation of the circuit elements were explained. The operating relationships (0.4, 0.5, 0.6, 0.7, and 0.8) were selected to perform the study on circuit R loads. The traditional buck-boost converter produced only 26 V, while the hybrid buck-boost converter, operating at a ratio of 0.4, supplied 19 V and 150 V in boost and buck modes, respectively. The constant result of the traditional buck-boost converter was 50V. However, at a ratio of 0.5, the hybrid buck-boost converter produced 24 V in buck mode and 169 V in boost mode. Traditional buck-boost converters produce a 60V output. In buck mode, the circuit built with the ratio 0.6 produced 29 V; in boost mode, it produced 184 V. The traditional buck-boost converter produced seventy volts of output. In buck mode, the circuit built with a ratio of 0.7 produced 34 V; in boost mode, it produced 196 V. The traditional buck-boost converter yielded a maximum output of 60 V. In comparison, the designed circuit operated at a ratio of 0.8, yielding an output voltage of 39 V for buck mode and 206 V for boost mode. Hardware results of the proposed hybrid buck-boost converters are presented at an input voltage of 30V for the buck mode and 13.5V for boost mode. The output duty ratio of a buck converter is in the range of 0.4 to 0.8. The maximum output voltage is 25.9V, and the minimum output voltage is 2.3V. For a duty ratio of 0.4 to 0.8, the output of the boost converter ranges from at least 13.5V to at most 29V. The new hybrid converter is shown to be more efficient in producing new output values under the same operating ratios as compared to conventional converters.

Acknowledgement: The authors would like to express their sincere gratitude to SRM Institute of Science and Technology for providing the facilities and support throughout this research work.

Data Availability Statement: The study utilizes a dataset that features a buck-boost hybrid converter with a common capacitor.

Funding Statement: The authors confirm that no funding has been obtained to help prepare this manuscript and research work.

Conflicts of Interest Statement: The authors declare that there are no conflicts of interest.

Ethics and Consent Statement: The authors obtained consent from the organization and individual participants during data collection, and ethical approval, along with participant consent, was duly obtained.

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