2026 Volume: 02 Issue: 03 www.ijrpa.com ISSN 2456-9995 Review Article

International Journal Research Publication Analysis

Page: 01-12

SINGLE SOURCE NINE LEVEL BOOST INVERTER FOR PV APPLICATONS

***Anuradha K., Deva Dharshini K., Logapriya A., Venmadhi B.**

UG Students, Department of Electrical and Electronics Engineering, P. A. College of Engineering and Technology, Pollachi, Tamil Nadu, India.

Article Received: 13 February 2026
Article Revised: 04 March 2026
Published on: 24 March 2026

***Corresponding Author: Anuradha K.**
UG Students, Department of Electrical and Electronics Engineering, P. A. College of Engineering and Technology, Pollachi, Tamil Nadu, India.
DOI: https://doi-doi.org/101555/ijrpa.8369

ABSTRACT

For solar applications, a single-source nine-level boost inverter is created and put into use to transform low DC power into a multilevel AC output. The system generates numerous voltage levels from a single DC source and achieves voltage boosting using a switched capacitor approach. A PIC16F877The necessary switching pulses for managing the power switches are generated by a microcontroller. The stepped voltage waveform produced by the inverter has nine different levels and is more akin to a sinusoidal output. Both positive and negative output cycles are obtained by using an H-bridge arrangement. The hardware implementation shows better output waveform quality and fewer components. The technology is appropriate for small-scale renewable energy applications and offers effective performance.

INDEX TERMS: Multilevel Inverter, Boost Inverter, Photovoltaic System, Switched Capacitor, Nine-Level Output, Microcontroller Control, Embedded C, H-Bridge, Renewable Energy, Power Electronics.

INTRODUCTION

For photovoltaic applications, a single-source, nine-level boost inverter is designed to transform low DC voltage into a high-quality, useful multilevel AC output. Efficient conversion is crucial since the generated DC voltage in renewable energy systems, particularly solar-based systems, is frequently low and erratic. The suggested solution eliminates the need for numerous power supply by using a switched capacitor technique to increase the input voltage and produce several stepped voltage levels from a single DC source. Higher voltage gain can be achieved with fewer components thanks to this method.The control unit, a PIC16F877A microcontroller, uses programmable logic to produce precise switching pulses for the power MOSFETs. The inverter's correct operation and the production of nine different voltage levels are guaranteed by these switching signals. By lowering harmonic distortion and bringing the output waveform closer to a sinusoidal wave, multilayer topology enhances it. This is crucial for the effective operation of electrical loads.Additionally, the system has an H-bridge structure that allows the stepped DC voltage to be converted into an AC output by flipping the polarity. A CRO/DSO is used to test and analyze the output waveform utilizing a resistive load. Because of its straightforward, economical, and effective design, it can be used for home power systems, small-scale solar applications, and educational initiatives. The project shows how a multilevel inverter with better performance and less complexity may be implemented practically utilizing a single DC source.

a) Literature review

J. Rodriguez et al. (2010) proposed multilevel inverter topologies for high-power applications, focusing on improved output waveform quality and reduced harmonic distortion. However, the design required multiple DC sources and a large number of switches, increasing system complexity and cost. [1].M. Malinowski et al. (2012) developed a cascaded H-bridge multilevel inverter for renewable energy systems. The system provided better efficiency and modularity, but it required separate DC sources for each level, making it less suitable for single-source applications. [2].E. Babaei et al. (2014) introduced a new multilevel inverter topology with a reduced number of switches and DC sources. The design improved efficiency and reduced hardware requirements, but the control strategy was complex and required precise switching synchronization. [3].K. Sivakumar et al. (2016) proposed a switched capacitor-based multilevel inverter to achieve voltage boosting from a single DC source. The system successfully increased output voltage levels, but capacitor balancing and switching losses remained a challenge. [4].S. Gautam et al. (2018) developed a single-phase multilevel inverter for photovoltaic applications using a switched capacitor technique. The design achieved improved voltage gain and reduced harmonic distortion, but required additional control complexity for maintaining stable capacitor voltage. [5].R. K. Nema et al. (2020) implemented a multilevel inverter with reduced components for solar applications. The system demonstrated good performance with fewer switches, but the output waveform quality was limited due to fewer voltage levels. [6].P. Roshankumar et al. (2022) designed a single-source multilevel inverter with improved boosting capability and reduced switch count. Although efficient, the system required careful switching control to avoid voltage imbalance issues. [7].A. Kumar et al. (2024) proposed an advanced switched capacitor multilevel inverter for renewable energy systems with improved voltage gain and reduced harmonic distortion. However, the design complexity and control requirements increased with higher levels. [8].B. Singh et al. (2021) proposed a multilevel inverter for renewable energy applications using a reduced number of power switches. The system achieved improved efficiency and lower switching losses, but the voltage boosting capability was limited compared to switched capacitor-based designs. [9].H. Abu-Rub et al. (2023) developed a high-gain switched capacitor multilevel inverter for photovoltaic systems. The design provided enhanced voltage boosting and improved output waveform quality; however, it required complex control techniques and precise timing for capacitor balancing. [10].

b) Background And Motivation

Photovoltaic (PV) systems are now widely used due to the growing need for renewable energy. For practical application, however, the low and variable DC voltage produced by PV sources needs to be effectively converted into AC. High harmonic distortion and low output quality are produced by conventional inverters. By producing stepped voltage levels that resemble sine waves, multilevel inverters enhance the quality of waveforms.

The goal of this project is to use a single DC supply to create a straightforward and effective nine-level boost inverter. To raise voltage without the need for additional sources, a switched capacitor approach is employed. The PIC16F877A microcontroller, which controls the system, makes the design affordable and appropriate for small-scale photovoltaic applications.

SYSTEM BLOCK DIAGRAM

The total configuration of the single-source, nine-level boost inverter created for this project is shown in the system block diagram. The DC input for the system is provided by a pre-charged battery and a photovoltaic (PV) panel. The necessary switching pulses for the power devices are produced by the control unit, which is based on a PIC16F877A microcontroller. The switching network, which is made up of MOSFETs, capacitors, and diodes, receives these pulses.By increasing the input voltage and producing several stepped voltage levels, the switching network carries out the inverter's primary function. While the MOSFETs regulate the current flow in response to input signals from the microcontroller, the capacitors store and transmit energy during switching to raise the voltage level. After that, the H-bridge section receives the created stepped DC output.By reversing the polarity at each half cycle, the H-bridge transforms the stepped DC voltage into an AC output. For testing and analysis, the output is linked to a resistive load. A CRO or DSO is used to view the output voltage waveform, which yields a nine-level stepped waveform.In order to accomplish effective voltage boosting and multilevel AC output generation, this configuration guarantees appropriate coordination between all blocks.

a) Operational and Element Description

The DC input from the photovoltaic (PV) panel and the pre-charged battery, which together supply a steady input voltage to the inverter, initiates the system's operation. The primary conversion step occurs in the switching network, which receives this DC supply. The PIC16F877 was used to implement the control unit.A microcontroller uses a preprogrammed sequence to produce accurate switching pulses. The gate driver circuit receives these pulses and amplifies them so that the MOSFET switches are correctly driven.MOSFETs, capacitors, and diodes make up the switching network, and each is essential to the functioning of the system. The MOSFETs function as fast switches that regulate the current flow in various directions. In order to increase the input voltage and produce numerous voltage levels, the capacitors are employed to store electrical energy and release it when switching. By preventing reverse current flow and ensuring that current only flows in one direction, the diodes aid in the correct charging and discharging of the capacitors.The system creates stepped DC voltage levels from a single DC source by working the switches in a predetermined order. The H-bridge portion is then subjected to these voltage levels. By reversing the voltage's polarity, the H-bridge's four switches transform stepped DC into an AC output waveform. Both positive and negative half cycles can be produced thanks to the polarity reversal.

For testing and examination, the inverter's output is linked to a resistive load. A nine-level stepped waveform is obtained by using a CRO or DSO to observe the waveform. Proper voltage boosting, regulated switching, and effective conversion of DC power into a multilevel AC output are ensured by the coordinated action of all components.

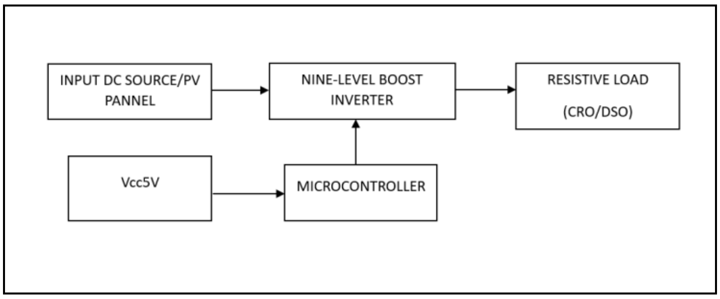

Figure .1 Block diagram of the prototype system.

b) Circuit Design and its Explanation

The system's design is based on a switched capacitor single-source nine-level boost inverter. A network of MOSFET switches, capacitors, and diodes receives the input DC voltage from the PV panel and batteries. The arrangement of the capacitors allows them to store and transfer energy at various switching intervals. The input voltage is increased and several voltage levels are produced from a single DC source by regulating the charging and discharging of these capacitors.A PIC16F877A microcontroller, which generates switching signals according to a predetermined sequence, controls the operation. The gate driver circuit applies these signals to the MOSFETs, guaranteeing appropriate and secure switching. The voltage levels at the switching network's output vary depending on which switches are turned on.The H-bridge part receives the generated stepped DC voltage after that. The H-bridge creates an AC output waveform by periodically reversing the polarity of the voltage. By lowering harmonic distortion, the switching sequence's nine-level stepped waveform enhances output quality.The overall goal of the design is to provide greater performance and higher voltage gain with fewer components.

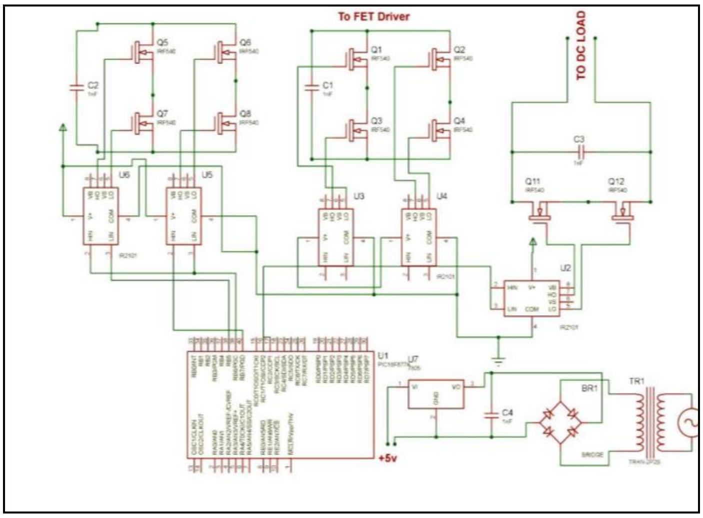

Figure.2 circuit diagram representation.

c) Switching Circuit and Switching Table

Switches T1 through T6, diodes, and capacitors C1 and C2 make up the switching circuit depicted, which is set up to provide several voltage levels from a single DC source. To achieve larger output levels, the capacitors are charged to various voltage values and their voltages are added to the input through appropriate switching. Switches T5 and T6 assist in choosing the proper voltage path to the output, while switches T1–T4 primarily regulate the capacitors' charging and discharging paths. By altering the polarity across the load, the H-bridge—which is made up of switches H1, H2, H3, and H4—converts the stepped DC voltage into AC.The ON (1) and OFF (0) states of every switch used to generate each voltage level are specified in the switching table. Switches H1 and H3 are activated at positive levels, which let current to pass through the load in a forward direction. The input source and capacitor voltages are combined to produce various voltage levels, including 1Vdc, 2Vdc, 3Vdc, and 4Vdc, depending on which of the switches T1–T6 are turned on. A particular set of switches is utilized at the zero level in order to prevent any voltage from appearing across the load. Switches H2 and H4 are activated for negative levels, reversing the direction of the current and producing −1Vdc, −2Vdc, −3Vdc, and −4Vdc.The inverter produces a nine-level stepped waveform between -4Vdc and +4Vdc by following the order specified in the switching table. The seamless transition between voltage levels, decreased harmonic distortion, and enhanced output waveform quality are all guaranteed by this step-by-step switching.

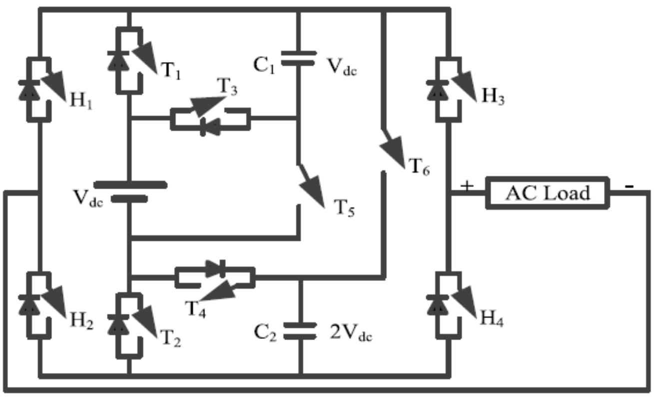

Figure 3 Switching circuit representation.

T_1	T_2	T_3	T_4	T_5	T_6	H_1	H_2	H_3	H_4	$V_o(xV_{dc})$
0	0	1	1	0	0	0	1	1	0	4
1	0	0	1	1	0	0	1	1	0	3
0	1	1	0	0	1	0	1	1	0	2
1	1	0	0	1	0	0	1	1	0	1
1	0	0	0	1	0	1	0	1	0	Zero
1	0	0	0	1	0	0	1	0	1	
1	1	0	0	1	0	1	0	0	1	-1
0	1	1	0	0	1	1	0	0	1	-2
1	0	0	1	1	0	1	0	0	1	-3
0	0	1	1	0	0	1	0	0	1	-4

Figure 4 Switching table.

SOFTWARE REQUIREMENTS

The programming tools and environment utilized to regulate the suggested inverter system's functioning are specified in the software requirements. A preset control logic is used to switch MOSFETs and create the nine-level output waveform. The PIC16F877A microcontroller is used to run the software, which was written in embedded C. The MPLAB environment, which guarantees correct code creation and dependable system operation, is used for software development and debugging.

a) Embedded c

The single-source, nine-level boost inverter in this project is controlled by Embedded C. For MOSFETs to generate a stepped nine-level output, the program produces exact switching pulses. It is designed for the PIC16F877A microcontroller, which serves as the system's control unit.

The switching sequence specified in the software determines whether each MOSFET switch is switched ON or OFF. In order to ensure smooth transitions and accurate waveform creation, delay functions are incorporated to maintain appropriate time between levels. To produce the AC output via the H-bridge, the program constantly cycles through all nine levels.Accurate timing control, simple sequence change, and dependable inverter operation are all made possible by embedded C. It guarantees proper level generation, capacitor charging, and voltage boosting. As a result, there is less harmonic distortion and a consistent nine-level stepped waveform. All things considered, Embedded C offers efficiency, accuracy, and flexibility for managing the inverter system.

b) MPLAB Development Environment

The PIC16F877A microcontroller was programmed in this project using the MPLAB IDE development platform. It offers a comprehensive environment for Embedded C code creation, compilation, and debugging.The control program in this project is written, compiled, and error-checked using the MPLAB IDE. It creates the HEX file needed to program the microcontroller. Additionally, the IDE enables program simulation to confirm appropriate operation prior to hardware implementation, including timing and switching sequence generation.MPLAB facilitates simple code modification, allowing you the flexibility to modify delay durations, switching patterns, or sequences as necessary. Additionally, it offers debugging tools to find and fix code flaws so the system runs dependably. The MPLAB IDE makes software development more structured, effective, and error-free.

The MPLAB IDE and Embedded C programming together provide accurate inverter control, appropriate level production, and smooth waveform output. It ensures that the nine-level boost inverter system operates effectively and steadily.

c) Nine level Generation and MOSFETcontrl

Ten MOSFET switches, a transformer, capacitors, diodes, transistors, a battery, and solar input are used in the nine-level boost inverter to produce several stepped voltage levels. The MOSFETs themselves create the H-bridge in this design, which allows for both positive and negative voltage levels by reversing polarity at alternate intervals to transform the stepped DC voltage into AC. In order to increase the input voltage and produce precise stepped output levels, the capacitors are charged and discharged in time with the switching sequence.A microcontroller with an Embedded C software controls the MOSFETs. Four positive, one zero, and four negative levels are produced when each MOSFET is turned ON or OFF in accordance with the predetermined switching table. The program ensures safe and dependable operation by preventing simultaneous ON states that could result in short circuits through proper timing and delay operations.the transformer is used to separate the load from the source and increase the voltage to the necessary level. With the right gate signals, transistors help drive the MOSFETs effectively. The device ensures constant output even when solar input varies because it can run on both solar energy and a charged battery.The nine-level waveform is precisely generated by adhering to the switching table. To confirm waveform quality and decreased harmonic distortion, the output is connected to a resistive load and viewed using a CRO or DSO. Because of the design's flexibility, it can be easily modified for upcoming extensions or higher-level inverters. All things considered, the combination of MOSFETs (which constitute the H-bridge), transformer, capacitors, transistors, batteries, and solar input guarantees accurate nine-level generation, steady AC output, and effective operation of the inveter system.

IV. EXPERIMENTAL SETUP

a) Prototype Implementation

Ten MOSFETs, capacitors, diodes, transistors, a transformer, a battery, and a solar panel are used in the construction of the single-source nine-level boost inverter prototype. The nine stepped voltage levels are produced by the H-bridge and switching network formed by the arrangement of the MOSFETs. Voltage boosting and precise level creation are made possible by the circuit's connection of capacitors, which store and release energy in time with the switching sequence.The MOSFETs are controlled by the microcontroller, which is programmed in Embedded C, in accordance with the predetermined switching table. The program's delay routines make sure that switching activities are timed correctly, avoiding simultaneous ON states that could harm the system. The transformer is used to separate the load from the source and increase the voltage to the necessary level. The MOSFETs are effectively driven by transistors.Because the system can run on both solar energy and a fully charged battery, it can produce continuously even when solar input varies. To evaluate performance, the prototype is attached to a resistive load. The proper nine-level waveform, seamless transitions, and decreased harmonic distortion are verified by looking at the output on a CRO.This prototype demonstrates the practical implementation of the inverter, combining hardware configuration and software control to produce stable, efficient, and reliable nine-level AC output.

Figure 5. Experimental Setup.

b) Output Waveform Representation using CRO/DSO

A Cathode Ray Oscilloscope (CRO) or Digital Storage Oscilloscope (DSO) is used to view the output voltage waveform of the suggested nine-level boost inverter. To see the voltage waveform in the time domain, the measuring device is connected across the inverter's output terminals.The produced waveform unmistakably displays a nine-level stepped output, confirming the inverter's correct operation. There are several distinct voltage levels in the waveform, such as positive, zero, and negative levels. These voltage levels are produced by controlled switching of MOSFETs based on the switching logic implemented in the microcontroller.Each step in the output waveform, which resembles a staircase, represents a distinct switching state. After progressively rising to the positive peak, the voltage symmetrically falls toward the negative peak. The periodic waveform closely resembles an AC sinusoidal waveform.The CRO/DSO experimental observation confirms that:Nine different voltage levels are produced by the inverter.The waveform is periodic and symmetrical.The switching sequence is executed successfully.With less distortion, the output resembles an AC waveform.

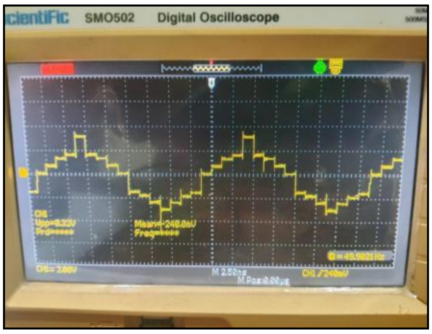

Figure.6 Output representation.

V. CONCLUSION

The proposed nine-level boost inverter system was successfully designed and implemented using suitable power electronic components and a control circuit. The main objective of the project was to convert a DC input source into a stepped AC output with multiple voltage levels. The switching pulses required for the inverter operation were generated using the PIC16F877A microcontroller, which controlled the switching devices according to the programmed sequence. By properly controlling the switches and capacitors in the inverter circuit, multiple voltage levels were generated at the output.The hardware implementation of the system demonstrated that the inverter is capable of producing a nine-level stepped output waveform. The output waveform was observed using a Digital Storage Oscilloscope, which confirmed the proper functioning of the switching circuit and the multilevel inverter operation. The stepped waveform obtained from the inverter was closer to a sinusoidal waveform compared to a conventional two-level inverter. This helps in reducing harmonic distortion and improving the overall quality of the output voltage.Thus, the proposed nine-level boost inverter provides better performance in terms of waveform quality and efficient DC-to-AC power conversion. The system can be effectively used in power electronics and renewable energy applications such as solar power systems where improved output voltage quality is required. The successful hardware implementation and experimental verification prove the effectiveness and reliability of the proposed inverter design.

REFERENCES

1. Aditya, K., Suresh, Y., Shiva Naik, B., Nageswar Rao, B., & Panda, A. K. (2024). A single-source nine-level boost inverter with new optimal switching scheme for EV applications. International Journal of Circuit Theory and Applications, 52(2), 954–972.
2. Barbosa, P. G., Braga, H. A. C., Rodrigues, M. D. C. B., & Teixeira, E. C. (2006). Boost current multilevel inverter and its application on single-phase grid-connected photovoltaic systems. IEEE Transactions on Power Electronics, 21(4), 1116–1124.
3. Buticchi, G., Barater, D., Lorenzani, E., Concari, C., & Franceschini, G. (2013). A nine-level grid-connected converter topology for single-phase transformerless PV systems. IEEE Transactions on Industrial Electronics, 61(8), 3951–3960.
4. Chen, M., Yang, Y., Loh, P. C., & Blaabjerg, F. (2021). A single-source nine-level boost inverter with a low switch count. IEEE Transactions on Industrial Electronics, 69(3), 2644–2658.
5. Gopinath, N. P., & Vijayakumar, K. (2022). Common ground nine-level boost inverter for grid-connected PV applications. Frontiers in Energy Research, 10, 922786.
6. Jakhar, A., Sandeep, N., & Verma, A. K. (2023). A nine-level common-ground-type boost inverter for PV applications. IEEE Journal of Emerging and Selected Topics in Industrial Electronics, 5(3), 1080–1088.
7. Lee, S. S. (2018). A single-phase single-source 7-level inverter with triple voltage boosting gain. IEEE Access, 6, 30005–30011.
8. Liu, J., Wu, J., Zeng, J., & Guo, H. (2016). A novel nine-level inverter employing one voltage source and reduced components as high-frequency AC power source. IEEE Transactions on Power Electronics, 32(4), 2939–2947.
9. Sathik, M. J., Sandeep, N., Almakhles, D. J., & Yaragatti, U. R. (2020). A five-level boosting inverter for PV application. IEEE Journal of Emerging and Selected Topics in Power Electronics, 9(4), 5016–5025.
10. Siddique, M. D., Mekhilef, S., Shah, N. M., Ali, J. S. M., Meraj, M., Iqbal, A., & Al-Hitmi, M. A. (2019). A new single phase single switched-capacitor based nine-level boost inverter topology with reduced switch count and voltage stress. IEEE Access, 7, 174178–174188.

11. Singh, A. K., Raushan, R., Mandal, R. K., & Ahmad, M. W. (2022). A new single-source nine-level quadruple boost inverter (NQBI) for PV application. IEEE Access, 10, 36246–36253.
12. Srivastava, A., & Seshadrinath, J. (2022). A new nine-level highly efficient boost inverter for transformerless grid-connected PV application. IEEE Journal of Emerging and Selected Topics in Power Electronics, 11(3), 2730–2741.
13. Srivastava, A., & Seshadrinath, J. (2022). A single-phase seven-level triple boost inverter for grid-connected transformerless PV applications. IEEE Transactions on Industrial Electronics, 70(9), 9004–9015.
14. Tayyab, M., Sarwar, A., Bakhsh, F. I., Al-Durra, A., & Siddiqui, K. M. (2025). A single-source nine-level inverter with quadratic boost ability for renewable energy applications. IET Renewable Power Generation, 19(1), e12549.
15. Zaid, M., Tayyab, M., Sarwer, Z., Ali, M., Sarwar, A., Anwar, M. N., & Khalid, M. (2024). A single-source nine-level solar-PV inverter with quadruple voltage boosting and high reliability. International Journal of Circuit Theory and Applications, 52(8), 3734–3755.