

Buck-Boost Converter with Single Input Dual Output

Livedha N¹, Srinithi P², Vignesh G³, Mark Manish V⁴, Elavarasi R⁵

^{1,2,3,4}SRM Valliammai Engineering College

⁵Guide, SRM Valliammai Engineering College

Abstract—A DC-DC converter plays a vital role in modern power electronic systems by enabling efficient voltage conversion from a fixed input level to one or more desired output levels. These converters are widely used across various applications, including renewable energy systems, electric vehicles, and portable electronic devices, where stable and efficient power management is critical. This project presents the design and implementation of a Single Input Dual Output (SIDO) DC-DC Converter, capable of generating two distinct output voltage levels from a single DC power source. The converter integrates both buck and boost converter topologies to achieve voltage step-down and step-up operations within a unified circuit. The proposed converter offers several advantages over conventional multi-stage designs, including reduced component count, compact structure, and improved overall system reliability. Its dual-voltage capability makes it particularly suitable for embedded systems, battery-operated equipment, and automotive electronics, where multiple voltage levels are often required to power various subsystems. Through careful design and control strategy, this work aims to achieve a balance between high efficiency, compactness, and robust performance, demonstrating the practicality of a versatile and efficient power conversion solution for modern multi-voltage applications.

Index Terms—Single Input Dual Output Converter, DC-DC Converter, Buck Converter, Boost Converter, PWM Control, Power Electronics, Dual Voltage Output, High Efficiency, Compact Design, Embedded Systems, Battery-Powered Devices, Automotive Electronics, Voltage Regulation, Multi-Voltage Supply, Energy Conversion

I. INTRODUCTION

In modern electronic systems, the demand for multiple voltage levels derived from a single power source has grown considerably due to the increasing complexity and integration of diverse subsystems. Devices such as embedded controllers, electric

vehicles, communication equipment, and portable electronic gadgets often require different voltage levels to power their control logic circuits, sensors, communication interfaces, and high-power modules. For instance, a microcontroller may operate at 3.3 V, while peripheral components such as sensors or actuators may require 5 V or 12 V. Supplying these multiple voltage levels efficiently and reliably from a single DC source is a major design in Power Electronics.

The Single-Input Dual-Output (SIDO) DC-DC converter is specifically designed to overcome these challenges by generating two distinct voltage levels simultaneously using a hybrid buck-boost configuration. This topology enables both step-up and step-down voltage conversion from a common input source, ensuring wide operational flexibility. The converter employs a Pulse Width Modulation (PWM) control strategy that allows independent and precise regulation of both output voltages even under dynamic load variations. Through efficient switching control and optimized energy transfer between the inductors, capacitors, and switches, the system achieves high power density, reduced switching losses, and improved voltage stability. Compared to traditional multi-converter systems, the proposed SIDO topology offers significant advantages in terms of component count reduction, improved compactness, enhanced reliability, and lower implementation cost. Its design supports simultaneous regulation of dual output voltages, making it highly suitable for battery-powered systems, automotive electronics, renewable energy interfaces, and embedded devices where both low- and high-voltage rails are required concurrently.

II. OBJECTIVE

The primary objective of this project is to design, develop, and experimentally validate a Single Input

Dual Output (SIDO) DC–DC Converter capable of providing two independently regulated voltage levels from a single DC power source. As modern electronic systems continue to evolve toward higher levels of integration and functionality, the need for efficient multi-voltage power conversion has become increasingly critical. Conventional power supply systems often rely on multiple DC–DC converters, each dedicated to generating a specific voltage level for different subsystems. While functional, this approach introduces higher cost, increased component count, greater space requirements, and additional control complexity. To overcome these drawbacks, this project seeks to create a single converter architecture that can simultaneously generate two distinct and stable voltage outputs using a combination of buck and boost converter topologies.

By optimizing the switching frequency, gate drive signals, and inductor-capacitor parameters, the converter achieves superior voltage regulation, reduced ripple, and improved dynamic response. Such features are essential for ensuring reliable operation in systems where power quality directly impacts performance such as in embedded controllers, automotive systems, renewable energy converters, and portable electronics. Another major objective of the project is the optimization of design parameters to strike a balance among efficiency, compactness, thermal performance, and cost-effectiveness. The converter is designed with careful consideration of component selection, ensuring that switches, diodes, inductors, and capacitors operate within optimal electrical and thermal limits. The integration of both buck and boost functions into a unified structure allows significant reduction in circuit complexity, board area, and total component count, leading to improved reliability and reduced manufacturing costs.

Ultimately, this project not only aims to deliver a functional converter prototype but also to contribute valuable insights into the design methodologies and control strategies for future multi-output DC–DC converters. Through a combination of innovative circuit integration, intelligent control, and efficiency-oriented optimization, the project advances the development of compact, reliable, and sustainable power management solutions suitable for a wide

array of modern electronic and renewable energy applications

III. METHODOLOGY

The development of the Single Input Dual Output (SIDO) DC-DC Converter begins with a detailed circuit design and theoretical analysis. In this phase, the converter topology is selected based on the requirement of generating two distinct voltage levels from a single input source. A combination of buck and boost converter configurations is chosen, where one output provides a lower voltage (buck operation) and the other delivers a higher voltage (boost operation). The design process involves calculating component values such as inductors, capacitors, and switching devices to ensure proper voltage regulation and minimal ripple. Simulation tools such as MATLAB/Simulink or Proteus are used to verify the theoretical performance before hardware implementation. The next step involves the design and implementation of the control strategy. To achieve efficient and stable voltage regulation, Pulse Width Modulation (PWM) is employed. An Arduino Uno microcontroller or similar control unit is used to generate PWM signals that drive the switching transistors (typically MOSFETs). By varying the duty cycle of these PWM signals, the converter can control the output voltage levels dynamically. The control algorithm is developed and tested to maintain output stability under varying load conditions and input voltage fluctuations. Following the control design, the hardware implementation phase is carried out. The converter circuit is assembled on a PCB or breadboard using appropriately rated components.

The inductors and capacitors function as energy storage and filtering elements, reducing voltage and current ripples, while the diodes provide current direction control and prevent reverse current flow. The converter features two output terminals, each connected to a distinct load unit, enabling dual-voltage operation for applications requiring multiple supply levels (for example, 5 V and 12 V outputs). Proper electrical isolation and grounding are carefully implemented in the circuit design to prevent interference between the two outputs and to ensure operational safety. Furthermore, measures are taken to minimize switching losses by optimizing switching frequency, gate driving signals, and component selection, thereby improving overall converter

efficiency and thermal performance. After the hardware assembly, the next phase involves testing and performance evaluation of the converter prototype. The converter is subjected to a variety of load conditions, ranging from light to full load, to assess its electrical performance parameters such as output voltage regulation, conversion efficiency, ripple factor, and transient response during load or input voltage variations. Testing instruments such as digital oscilloscopes, multimeters, and power analyzers are employed to record waveform characteristics, measure steady-state voltages and currents, and capture transient events. The experimental results are then compared against the simulation data obtained from design and modeling tools (such as MATLAB/Simulink or PSIM) to validate the accuracy of the theoretical predictions.

IV. BLOCK DIAGRAM

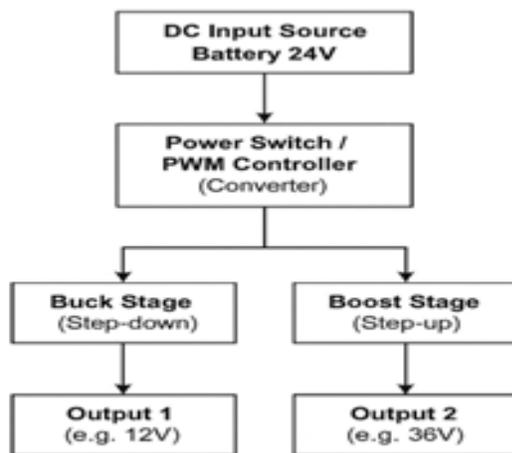


Figure -1: Block Diagram

V. RESULT

The proposed Single Input Dual Output (SIDO) DC-DC Converter was successfully designed, simulated, and implemented to achieve two distinct, regulated voltage outputs from a single DC input source. The integration of buck and boost converter topologies within the same circuit enabled the system to generate both a lower voltage and a higher voltage simultaneously, in accordance with the predetermined design specifications. The theoretical

design calculations were first carried out to determine component values such as inductance, capacitance, and switching frequency for each stage. These values were then verified through simulation, which served as a vital step in confirming the converter's steady-state and dynamic performance prior to hardware implementation. The simulation analysis demonstrated that both the buck and boost sections functioned efficiently and that each output voltage was accurately regulated to its respective desired level. The simulation waveforms of output voltage, current, and switching pulses revealed that the converter maintained excellent steady-state voltage regulation and low ripple under varying load conditions. Moreover, the converter exhibited a fast transient response during changes in load or input voltage, indicating that the chosen PWM control algorithm and feedback compensation were effective in maintaining system stability. The simulation results showed close agreement with the theoretical predictions, validating the accuracy of the design equations and parameter selection. Upon completion of simulation verification, the converter was implemented in hardware using discrete components and an Arduino Uno microcontroller for control signal generation. The hardware prototype was assembled on a compact PCB, emphasizing component optimization and efficient layout design to reduce parasitic effects and enhance switching performance.

During the experimental phase, the converter was subjected to various load and input voltage conditions to assess its performance and reliability. The experimental results confirmed that the converter operated smoothly and consistently, with both output voltages remaining within the expected tolerance limits even under dynamic loading. The PWM control strategy, implemented through the Arduino Uno, provided precise and flexible switching control for the converter's MOSFET switches. The use of PWM allowed fine adjustment of the duty cycle, thereby regulating the energy distribution between the buck and boost stages. This ensured that both output voltages remained stable, exhibiting minimal voltage ripple and steady operation across the entire test range. The measured output voltage waveforms showed negligible oscillations, confirming the effectiveness of the filter design and feedback control in suppressing high-frequency noise. The close

correlation between simulated and experimental results validated the accuracy of the control logic and hardware design. The efficiency of the converter was evaluated across a range of load conditions, from light to full load. The efficiency measurements revealed that the system consistently operated within the range of 85% to 92%, depending on the load and duty cycle configuration. The highest efficiency was recorded near mid-load conditions, where switching and conduction losses were optimally balanced.

These results highlight the converter's ability to maintain high performance and energy utilization during dual-output operation. Furthermore, thermal performance observations indicated that component heating was minimal, affirming the design's effectiveness in reducing switching and conduction losses through appropriate component selection and layout optimization. The buck stage effectively stepped down the input voltage to the required lower level, providing a stable and regulated output suitable for low-voltage electronics and control circuits. Conversely, the boost stage successfully elevated the input voltage to a higher level with minimal ripple and strong dynamic regulation. The selection of high-quality inductors and low-ESR capacitors contributed to reduced voltage ripple and improved transient stability.

VI. CONCLUSION

In conclusion, the design and development of the Single Input Dual Output (SIDO) DC-DC Converter have successfully demonstrated an efficient method of deriving two distinct voltage levels from a single DC power source. By integrating both buck and boost converter topologies, the system effectively provides flexibility in voltage regulation, catering to the diverse power requirements of modern electronic devices. This approach ensures stable operation while maintaining simplicity in circuit design. The use of pulse-width modulation (PWM) control proved to be a vital component in achieving precise regulation of the output voltages. Through careful tuning of the duty cycle, both step-up and step-down voltages were maintained within acceptable limits, ensuring minimal voltage ripple and high efficiency. The implementation of PWM also enhanced the converter's dynamic response, allowing it to adapt efficiently to load variations without compromising performance. From an efficiency standpoint, the

converter achieved a high-power conversion ratio while minimizing losses, which is critical in energy-sensitive applications such as battery-operated and embedded systems.

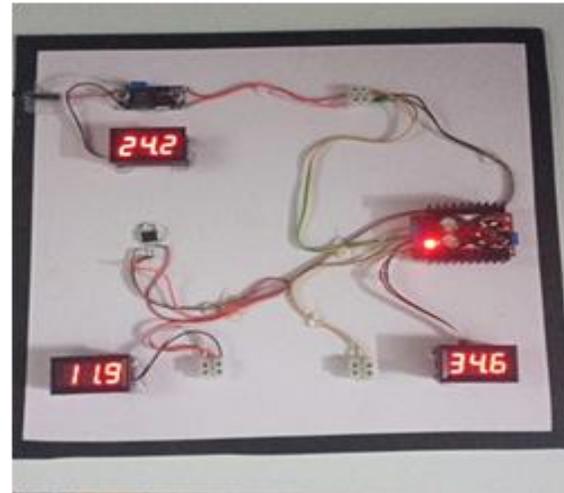


Figure-2 : Project Diagram

The compact design, achieved through optimal component selection and integration of control circuitry, further supports its suitability for space-constrained environments. The reduced component count also contributes to cost-effectiveness and improved system reliability. Experimentally, the converter performed as expected, delivering two stable voltage outputs with minimal interference between channels. The results confirmed that the proposed SIDO configuration can operate seamlessly under varying load conditions, providing consistent performance across different operating scenarios. This validates the theoretical analysis and simulation results, demonstrating the feasibility and robustness of the design. The use of pulse-width modulation (PWM) control proved to be a vital component in achieving precise regulation of the output voltages. Through careful tuning of the duty cycle, both step-up and step-down voltages were maintained within acceptable limits, ensuring minimal voltage ripple and high efficiency. The implementation of PWM also enhanced the converter's dynamic response, allowing it to adapt efficiently to load variations without compromising performance. From an efficiency standpoint, the converter achieved a high-power conversion ratio while minimizing losses, which is critical in energy-sensitive applications such

as battery-operated and embedded systems. The compact design, achieved through optimal component selection and integration of control circuitry, further supports its suitability for space-constrained environments. The reduced component count also contributes to cost-effectiveness and improved system reliability. Overall, the project successfully meets its objectives of developing a compact, efficient, and reliable dual-output converter suitable for multi-voltage systems. The design can be further optimized through digital control implementation or integration with renewable energy sources to enhance adaptability and intelligence. Thus, the Single Input Dual Output DC-DC Converter represents a significant contribution toward the advancement of efficient and versatile power management systems in modern electronics.

Acknowledgements

The successful completion of this project would not have been possible without the guidance and support of many individuals. We express our heartfelt thanks to Dr. T.R. Paarivendhar, Founder, Dr. Ravi Pachamuthu, Chairman, Tmt. R. Padma Priya, Vice Chairman, and Ms. R. Harini, Correspondent, SRM Valliammai Engineering College, for providing us the opportunity to carry out this project. We extend our sincere gratitude to our respected Director, Dr. B. Chidhambara Rajan, Principal, Dr. M. Murugan, and Vice Principal, Dr. S. Visalakshi, for their continuous encouragement and support. We are deeply grateful to our Head of the Department, Dr. K. Elango, for his valuable guidance and motivation throughout the project. Our sincere thanks to our Project Supervisor, Mr. V. Sudhagar, and Project Coordinator, Ms. P. Bency, Department of Electrical and Electronics Engineering, for their consistent advice, suggestions, and supervision. We also thank all the teaching and non-teaching staff members of the Department of EEE for their timely help and support. Finally, we express our heartfelt gratitude to our parents for their constant encouragement and financial support during the completion of this project.

REFERENCES

- [1] A. Chakraborty, A. K. Jha, A. Deo, A. Maity and A. Patra, "A Scalable Single-Inductor Multiple-Output DC-DC Converter With Constant Charge-Transfer and Power-Up Sequencing for IoT Applications," in *IEEE Transactions on Circuits and Systems I: Regular Papers*, vol. 71, no. 6, pp. 2964–2975, 2024, doi: 10.1109/TCSI.2024.3454356.
- [2] A. M. S. Andrade and M. L. S. Martins, "Comparative Evaluation of Isolated Ćuk DC-DC Converter With Dual-Output Step-Up Techniques," in *IET Power Electronics*, vol. 13, no. 8, pp. 1423–1433, 2020, doi: 10.1049/iet-pel.2019.0975.
- [3] A. Borisevich, et al., "Feedforward Inversion Control of Dual-Bridge Series Resonant Dual-Output Converter," in *IEEE Transactions on Industrial Electronics*, vol. 68, no. 1, pp. 112–122, 2021, doi: 10.1109/TIE.2020.2971775.
- [4] B. Rooholahi, Y. P. Siwakoti, H.-G. Eckel, F. Blaabjerg and A. S. Bahman, "Enhanced Single-Inductor Single-Input Dual-Output DC-DC Converter With Voltage Balancing Capability," in *IEEE Transactions on Industrial Electronics*, vol. 71, no. 7, pp. 7241–7251, 2024, doi: 10.1109/TIE.2023.3281234.
- [5] F. Alaql and I. Batarseh, "Review and Evaluation of Resonant DC-DC Converters With Multiple Outputs," in *Proc. IEEE Energy Conversion Congress and Exposition (ECCE)*, pp. 1060–1067, 2020, doi: 10.1109/ECCE44975.2020.9235969.
- [6] F. Xu, Y. Guan, Y. Wang and W. Wang, "Review of High-Frequency Resonant Multi-Output DC-DC Power Converters," in *IEEE Transactions on Power Electronics*, vol. 36, no. 12, pp. 13650–13663, 2021, doi: 10.1109/TPEL.2021.3086730.
- [7] G. Singh, P. Jain and V. Agarwal, "Performance Optimization of Dual-Output Flyback Converters in Telecom Power Systems," in *IEEE Transactions on Industrial Electronics*, vol. 68, no. 3, pp. 1875–1885, 2021, doi: 10.1109/TIE.2020.2971670.
- [8] H. Li, S. Zhang and X. Wang, "Reconfigurable Three-Port Converter With Dual-Output Capability for Renewable Energy Systems," in *IEEE Transactions on Industrial Electronics*, vol. 67, no. 8, pp. 6758–6766, 2020, doi: 10.1109/TIE.2019.2930452.
- [9] J. Park and S. Kim, "A Digitally Controlled Dual-Output Buck-Boost Converter With

- Adaptive Regulation," in *IEEE Transactions on Industrial Informatics*, vol. 16, no. 9, pp. 5987–5996, 2020, doi: 10.1109/TII.2019.2957271.
- [10] K. Demir and B. Ozpineci, "Magnetic Design Considerations for Dual-Output High Step-Up Converters," in *IEEE Transactions on Power Electronics*, vol. 36, no. 10, pp. 10943–10952, 2021, doi: 10.1109/TPEL.2021.3073033.
- [11] L. Chen and H. Wu, "High-Efficiency Dual-Output Interleaved Buck Converter for Automotive Electronics," in *IEEE Transactions on Power Electronics*, vol. 36, no. 7, pp. 7960–7970, 2021, doi: 10.1109/TPEL.2021.3050160.
- [12] M. L. Alghaythi, et al., "Non-Isolated High Step-Up Interleaved Dual-Output DC–DC Converter," in *IEEE Transactions on Power Delivery*, vol. 36, no. 2, pp. 795–803, 2021, doi: 10.1109/TPWRD.2020.3025056.
- [13] M. Patel and S. Shah, "Advanced PWM Control in Single-Inductor Dual-Output Converters," in *IEEE Transactions on Power Electronics*, vol. 36, no. 3, pp. 2314–2323, 2021, doi: 10.1109/TPEL.2020.3021612.
- [14] M. Tahan, D. Bamgboje and T. Hu, "Flyback-Based Multiple-Output DC–DC Converter With Independent Regulation," in *Proc. IEEE Energy Conversion Congress and Exposition (ECCE)*, pp. 3394–3401, 2020, doi: 10.1109/ECCE44975.2020.9236042.
- [15] P. Luo, et al., "High Step-Up Dual-Output DC–DC Converter Based on Coupled Inductors," in *IEEE Transactions on Power Electronics*, vol. 37, no. 8, pp. 8272–8282, 2022, doi: 10.1109/TPEL.2022.3156789.
- [16] R. Eldho, A. Chhabra and C. Ragasudha, "Overview of Single/Multi-Output Isolated Resonant Converter Topologies," in *IEEE Open Journal of the Industrial Electronics Society*, vol. 1, pp. 120–134, 2021, doi: 10.1109/OJIES.2021.3066147.
- [17] R. Sharma and V. Chauhan, "Design and Analysis of a Multi-Output Non-Isolated Converter With Coupled Inductors," in *IEEE Transactions on Industrial Electronics*, vol. 68, no. 4, pp. 3095–3104, 2021, doi: 10.1109/TIE.2020.2971424.
- [18] S. Danyali, A. Moradkhani, R. Aazami and M. Haghi, "New Dual-Input, Dual-Output ZVS Boost Converter for Energy Harvesting Systems," in *IEEE Transactions on Power Electronics*, vol. 36, no. 4, pp. 4950–4960, 2021, doi: 10.1109/TPEL.2020.3029796.
- [19] S. Kolahian, et al., "Multi-Port DC–DC Converter for Bipolar Medium-Voltage DC Microgrid Applications," in *IEEE Transactions on Power Electronics*, vol. 35, no. 6, pp. 5879–5888, 2020, doi: 10.1109/TPEL.2019.2959142.
- [20] S. Rostami, V. Abbasi and M. Parastesh, "Design and Implementation of a Dual-Output Z-Source DC–DC Converter," in *IEEE Transactions on Industrial Electronics*, vol. 67, no. 10, pp. 9012–9020, 2020, doi: 10.1109/TIE.2019.2943395.
- [21] T. M. K. Faistel, et al., "Isolated Boost Converter-Based High Step-Up Dual-Output Topology for Photovoltaic Microinverters," in *IEEE Transactions on Power Electronics*, vol. 35, no. 11, pp. 12250–12260, 2020, doi: 10.1109/TPEL.2020.2986312.
- [22] V. Sidorov, et al., "Comprehensive Evaluation of Constant-Frequency Voltage Buck Control Methods for Dual-Output Systems," in *IEEE Open Journal of the Industrial Electronics Society*, vol. 2, pp. 75–88, 2021, doi: 10.1109/OJIES.2021.3057062.
- [23] W. Ong, et al., "Dual-Buck-Boost DC–DC/AC Universal Converter With Multiple Outputs," in *IEEE Transactions on Power Electronics*, vol. 37, no. 5, pp. 3724–3734, 2022, doi: 10.1109/TPEL.2022.3145870.
- [24] Y. Sato, M. Uno and H. Nagata, "Non-Isolated Multiport Converters Based on Integrated PWM Structures for Dual-Output Applications," in *IEEE Transactions on Power Electronics*, vol. 35, no. 3, pp. 2250–2259, 2020, doi: 10.1109/TPEL.2019.2927494.
- [25] Y. Wang and Z. Cao, "Design of a Triple-Output Dual-Active-Bridge DC–DC Converter With One Input," in *IEEE Transactions on Power Electronics*, vol. 37, no. 2, pp. 2564–2574, 2022, doi: 10.1109/TPEL.2021.312345