Design Of Single Input Multiple Output (SIMO) DC-DC Converter

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***Abstract*—The rapid expansion of electric vehicles, renewable energy systems, and multi-voltage portable electronics has intensified the demand for compact, efficient, and cost-effective power distribution architectures. Single-Input Multiple-Output (SIMO) DC-DC converters offer a practical solution for deriving multiple regulated voltage levels from a single source; however, conventional topologies frequently suffer from high switch counts, complex control schemes, unbalanced thermal stress, and increased manufacturing costs. To address these limitations, this paper presents a novel single-input three-output DC-DC buck converter topology. Compared to traditional SIMO designs, the proposed architecture eliminates two switching devices, significantly reducing system cost, simplifying gate-drive requirements, and promoting a more balanced distribution of power losses across the active switches. A comprehensive analytical framework is developed, encompassing steady-state operation, detailed small-signal modeling, and optimized multi-output control strategies with PWM implementation. The static and dynamic performance of the converter is rigorously evaluated through MATLAB/Simulink simulations, demonstrating stable voltage regulation, fast transient response, and high operational efficiency under varying load conditions. These simulation outcomes are corroborated by experimental prototype testing, validating the accuracy of the theoretical models and the practical feasibility of the design. The results confirm that the proposed SIMO buck converter is highly suitable for electric vehicle battery management, renewable energy integration, and multi-rail power systems. By delivering a structurally simplified, cost-efficient, and thermally balanced alternative to existing topologies, this work provides a scalable foundation for next-generation power electronic applications.**

***Index Terms*—SIMO DC-DC converter; Single-input multiple-output; Buck converter; Small-signal modeling; Control strategies; Electric vehicle applications.**

I. INTRODUCTION

The growing global energy demand and the depletion of fossil fuel sources have driven interest in alternative energy sources such as solar power, fuel cells, and other clean energy technologies, which are generally environmentally friendly [1]. DC-DC converters are primarily used in uninterruptible power supplies, battery charging/discharging systems, hybrid electric vehicles, and renewable energy systems [2–7]. In a typical buck converter, the freewheeling diode is sometimes replaced by an active power switch [8]. A topology capable of simultaneously providing boost, buck, and inverted outputs has been reported in the literature; however, it requires three switches for a single output and is suitable only for low-power applications with limited output voltage. Another study examines multi-output DC-DC boost converters, where output voltage is shared between high- and low-power applications, but two switches are needed for one output and the control scheme is complex. Kumar and Omar present a Single-Input Multiple-Output (SIMO) synchronous DC-DC buck converter for electric vehicle battery applications, as shown in Figure 1. The main objective of this converter is to step down the battery voltage to supply various components. The proposed topology offers the advantage of using only three switches for two outputs. Additionally, control strategies, design principles, and small-signal analysis are included. The system is simulated in MATLAB/Simulink. Ultimately, this SIMO buck converter system is expected not only to deepen understanding of the technology but also to serve as a practical, cost-effective solution for efficient power distribution in diverse electronic applications.

II. METHODOLOGIES

Designing a Single-Input Multiple-Output (SIMO) DC-DC converter involves several key steps. The following is a high-level overview of the design process:

1. Define Requirements –
Specify input voltage range, output voltage levels, load currents, efficiency targets, and other relevant parameters.

2. Select Topology –
Choose the appropriate DC-DC converter topology (e.g., Buck, Boost, Buck-Boost, Cuk, SEPIC) based on the application.

3. Select Components –
Choose inductors, capacitors, diodes, and switching devices (typically MOSFETs) capable of handling the required voltage, current, and switching frequency.

4. Define Control Strategy –
Decide on voltage-mode or current-mode control; each output may require a separate controller.

5. Design Transformer (if isolated) –
Determine turns ratio, core material, and winding specifications.

6. Design Feedback and Control Loops –
Implement individual or multi-loop feedback regulation for each output voltage.

7. Simulate and Analyze –
Use tools like SPICE or PLECS to evaluate performance, efficiency, and transient response; adjust component values and control parameters as needed.

8. Optimize Efficiency –
Minimize switching and component losses through appropriate control strategies.

9. Implement Protection and Safety –
Include overcurrent, overvoltage, and overtemperature protection.

10. Design PCB Layout –
Create a well-structured layout to reduce noise, parasitic elements, and optimize thermal performance.

11. Test and Validate
Prototype and test under various operating conditions to verify compliance with design specifications.

12. Iterate and Refine
Adjust design, components, or control strategies based on test results and repeat as necessary.

13. Document
Record schematics, bill of materials (BOM), and application notes for future reference.

Designing a SIMO DC-DC converter is complex, and the methodology depends on the unique requirements and constraints of each application. Success requires a solid understanding of power electronics, control theory, and practical design experience.

III. BUCK CONVERTER (STEP-DOWN CONVERTER):

1. Operation:
The buck converter reduces the input voltage to a lower output voltage. It operates in continuous or discontinuous conduction modes, depending on the load and component values.

2. Design Considerations:
- Determine the desired output voltage levels and current requirements for each output.
- Calculate the duty cycle (D) for each output using the relationship Vout = Vin * D.
- Select appropriate inductors, capacitors, and diodes for each output to meet the voltage and current requirements.
- Consider component stress, such as current ratings, voltage ratings, and power dissipation.

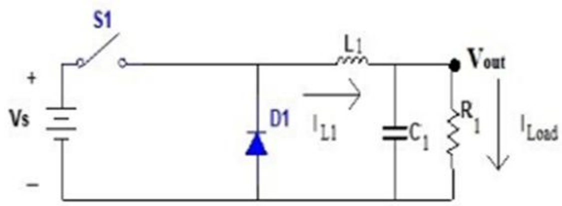


Figure.1: Basic Buck Converter

3. Advantages:

- Efficient for reducing voltage levels.
- Suitable for applications where some outputs require a lower voltage than the input.

IV. BOOST CONVERTER (STEP-UP CONVERTER):

1. Operation:

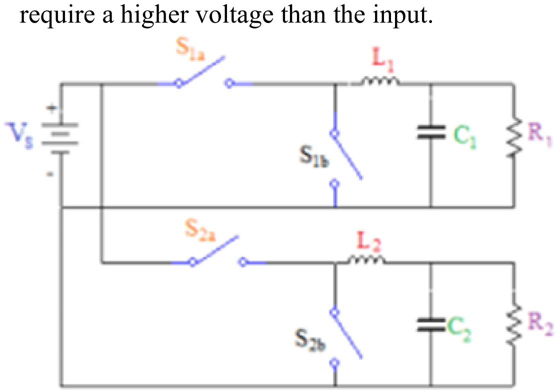
The boost converter increases the input voltage to a higher output voltage. It also operates in continuous or discontinuous conduction modes.

2. Design Considerations:

- Determine the desired output voltage levels and current requirements for each output.
- Calculate the duty cycle (D) for each output using the relationship Vout = Vin / (1 - D).
- Select appropriate inductors, capacitors, and diodes for each output to meet the voltage and current requirements.
- Consider component stress, such as current ratings, voltage ratings, and power dissipation.

3. Advantages:

- Efficient for raising voltage levels.
- Suitable for applications where some outputs require a higher voltage than the input.



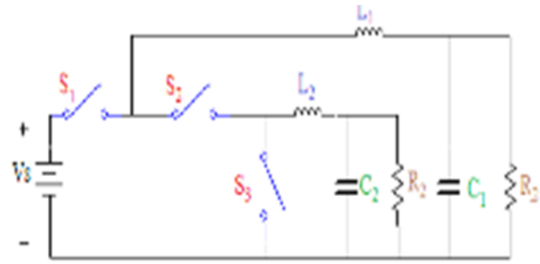


Figure.2: Bi-directional SIMO DC-DC buck converter: (i) Parallel solution, (ii) Implemented solution

With the values of

P = 100 W, V_O= 12 V, V_{in} = 48 V

I_{in} = P / V_{in} (4.1)

I_O = P / V_O (4.2)

D = V_O / V_{in} (4.3)

$$L = \frac{D(1-D)V_O}{f\Delta i_L} \quad (4.4)$$

$$C = \frac{D(1-D)Vs}{8Lf^2\Delta i_L} \quad (4.5)$$

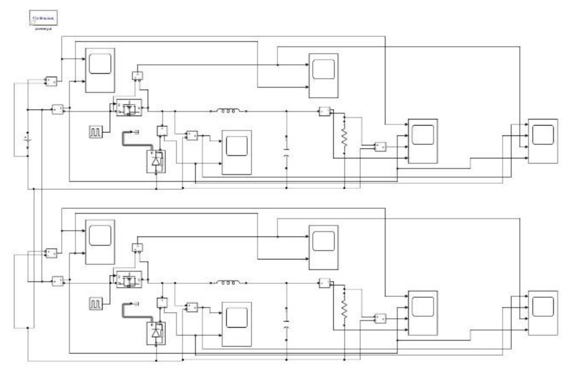


Figure.3: Simulation of buck converter

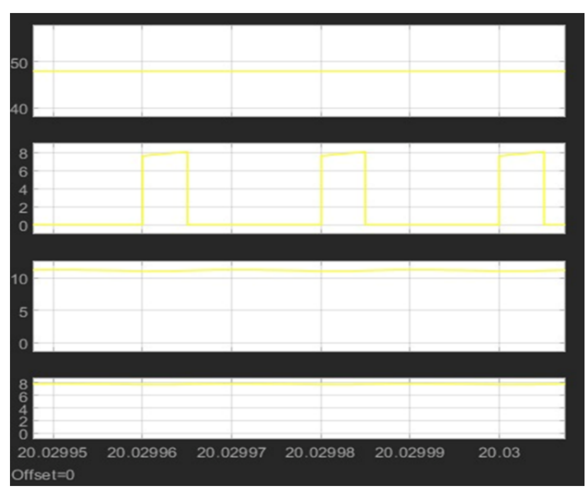


Figure.4: Simulation results

Buck converters are more efficient when stepping down voltages, while boost converters are more efficient when stepping up voltages. The choice between buck and boost converters depends on the specific requirements of the application and the desired output voltage levels.

For a SIMO DC-DC converter, you may need a combination of buck and boost converters to meet different output voltage requirements. Efficiency, component selection, and control strategy are key factors in the design of both types of converters.

In summary, the design of a SIMO DC-DC converter involves selecting the appropriate converter topology (buck or boost) for each output voltage requirement and designing the circuit with the necessary components and control strategies to meet the specifications of the multiple outputs.

V. CONCLUSION:

This study presents a structurally simplified Single-Input Multiple-Output (SIMO) DC-DC buck converter topology specifically optimized for electric vehicle (EV) power distribution architectures. By eliminating two switching devices compared to conventional multi-output designs, the proposed converter achieves notable reductions in component cost, gate-drive complexity, and overall system footprint, while simultaneously enabling a more balanced distribution of conduction and switching losses across active devices. Comprehensive steady-state analysis and a detailed small-signal dynamic model were developed to characterize the converter's operational behavior. Advanced PWM-based control strategies were formulated to ensure precise, decoupled voltage regulation across all three outputs under varying load transients. Extensive MATLAB/Simulink simulations of both static and dynamic operating conditions validate the theoretical framework, demonstrating stable cross-regulation, fast transient recovery, and high steady-state efficiency. These results strongly confirm the topology's suitability for automotive subsystems where compact, multi-rail power supplies are increasingly critical. The inherent architectural simplicity also positions this converter as a scalable solution for renewable energy interfaces, portable electronics, and battery management systems. Future work will focus on hardware prototype validation at higher power levels, optimization of switching frequencies to mitigate electromagnetic interference (EMI), and integration of wide-bandgap semiconductor devices to further enhance thermal performance and efficiency. Additionally, advanced digital control techniques, such as model predictive control and adaptive duty-cycle modulation, will be explored to improve dynamic resilience and fault tolerance. Ultimately, this research demonstrates that strategically simplified SIMO buck converters offer a highly practical, cost-effective pathway for next-generation multi-output power electronics, supporting the broader transition toward sustainable transportation and decentralized energy systems.

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