

Heaven's Light is Our Guide
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Lab Report 7:
Study of Buck Converter Using Simulink

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Study of Buck Converter Using Simulink

Theory

The Buck Converter is a DC-DC power electronic circuit that steps down the input voltage to a lower output voltage while maintaining high efficiency. It is widely used in applications such as power supplies, battery chargers, and voltage regulation in electronic devices [1].

Working Principle

The Buck Converter operates by switching a transistor on and off at high frequency. When the transistor is on, the input voltage is applied to the inductor, causing the current to increase. When the transistor is off, the inductor maintains the current flow through a diode and the load. The output voltage is determined by the duty cycle of the switching signal [2].

Key Components

- Switching Transistor: Controls the on/off state of the circuit.
- Diode: Provides a path for the inductor current when the transistor is off.
- Inductor: Stores energy and smooths the current.
- Capacitor: Reduces voltage ripple at the output.
- Pulse Width Modulation (PWM) Controller: Regulates the duty cycle to achieve the desired output voltage.

Operation Modes

- Continuous Conduction Mode (CCM): The inductor current never falls to zero during operation.
- Discontinuous Conduction Mode (DCM): The inductor current falls to zero during part of the switching cycle.

Applications

- Voltage regulation in electronic devices
- Battery-powered systems
- Renewable energy systems
- Automotive electronics

MATLAB/Simulink simulations provide a powerful tool for analyzing the performance of the Buck Converter under various operating conditions, enabling optimization for specific applications [3].

Required Equipments/Software

- MATLAB/Simulink
- AC Voltage Source
- Thyristors (2 in anti-parallel configuration)
- Resistive Load (R)
- Inductive Load (RL)
- Pulse Generator for firing angle control
- Measurement Blocks (Voltage and Current)
- Scope for waveform visualization

Circuit Diagrams

Figure 1: DC-DC Buck Converter Circuit Diagram

Observations

- For the Buck Converter, the output voltage is directly proportional to the duty cycle of the PWM signal.
- Increasing the duty cycle results in a higher output voltage, while decreasing it reduces the output voltage.
- In Continuous Conduction Mode (CCM), the inductor current never falls to zero, ensuring smooth operation and reduced ripple.

- In Discontinuous Conduction Mode (DCM), the inductor current falls to zero during part of the switching cycle, leading to increased ripple.
- MATLAB/Simulink simulations demonstrate the relationship between duty cycle, output voltage, and inductor current under various load conditions.
- The circuit effectively steps down the input voltage to the desired level with high efficiency.
- The results highlight the importance of proper component selection and PWM control for optimal performance in Buck Converter applications.

Outputs

Figure 2: Simulation Output for R Load, Controlled Rectifier, No Delay

Figure 3: Simulation Output for RL Load, Controlled Rectifier, No Delay

Figure 4: Simulation Output for R Load, AC-AC Bidirectional Voltage Controller

Figure 5: Simulation Output for RL Load, AC-AC Bidirectional Voltage Controller

Discussion

The Buck Converter is a versatile DC-DC power electronic circuit widely used in various applications. Through MATLAB/Simulink simulations, we analyzed the relationship between the duty cycle of the PWM signal and the output voltage. The results demonstrate that the output voltage is directly proportional to the duty cycle, with higher duty cycles resulting in higher output voltages. For Continuous Conduction Mode (CCM), the inductor current remains smooth and does not fall to zero, ensuring efficient operation. In Discontinuous Conduction Mode (DCM), the inductor current falls to zero during part of the switching cycle, leading to increased ripple and reduced efficiency. These observations highlight the importance of proper component selection and PWM control for achieving optimal performance in Buck Converter applications.

Conclusion

The study of the Buck Converter using MATLAB/Simulink simulations provides valuable insights into its operation and performance. The simulations confirm the theoretical principles of the Buck Converter, including the relationship between duty cycle, output voltage, and inductor current. The circuit effectively steps down the input voltage to the desired level with high efficiency, making it suitable for applications such as power supplies, battery chargers, and voltage regulation in electronic devices. The results emphasize the importance of understanding the operating modes and selecting appropriate components to optimize the converter's performance for specific applications.

References

- [1] M. H. Rashid, *Power Electronics: Circuits, Devices, and Applications*, 4th ed. Pearson, 2013.
- [2] P. C. Sen, *Principles of Electric Machines and Power Electronics*. Wiley, 1987.
- [3] MathWorks, *Simulink User's Guide*, 2023, available at <https://www.mathworks.com/products/simulink.html>.