Journal of Power Electronics and Drives
Volume 8, Issue 1, January-April 2023

Loss Analysis and Efficiency Optimization of Half-Bridge DC-DC Converters in High-Current and Low-Voltage Applications

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Abstract
This research paper presents a detailed analysis of the losses in half-bridge DC-DC converters in high-current and low-voltage applications. Half-bridge DC-DC converters are widely used in power electronic systems due to their excellent performance characteristics. However, in high-current and low-voltage applications, the losses in the converter become significant, reducing the efficiency of the system. In this paper, we discuss the conduction losses, switching losses, and gate drive losses in the converter. We also analyze the efficiency of the converter and discuss various techniques to improve the efficiency. The analysis presented in this paper can be used to design high-performance power electronic systems that utilize half-bridge DC-DC converters.

Keywords: *Half-bridge DC-DC converter, High-current, Low-voltage, Conduction losses, Switching losses, Gate drive losses, Efficiency.*

INTRODUCTION

DC-DC converters have become an essential component in modern electronic systems due to their ability to provide voltage regulation, isolation, and voltage conversion. Half-bridge DC-DC converters are widely used in high current and low voltage applications because of their simplicity, low cost, and high efficiency. However, losses in these converters significantly affect their efficiency, which directly impacts the power conversion capability of the system. Therefore, loss analysis of half-bridge DC-

DC converters is essential to design high-performance power electronic systems. In this paper, we will present a detailed analysis of the losses in half-bridge DC-DC converters in high current and low voltage applications.

Half-Bridge DC-DC Converter Topology:

The half-bridge DC-DC converter consists of two switches, a high-side switch, and a low-side switch, connected in series with the load. The load is connected between the two switches, and a DC input voltage is applied across the switches. The high-side switch is usually a MOSFET or an IGBT, while the low-side switch is usually a MOSFET. The switches are controlled by a PWM signal generated by a controller.

The working of the half-bridge DC-DC converter is as follows: during the first half-cycle, the high-side switch is turned on, and the low-side switch is turned off, allowing the input voltage to pass through the load. During the second half-cycle, the high-side switch is turned off, and the low-side switch is turned on, allowing the load current to flow through the low-side switch. By alternating the switches' states, a voltage lower than the input voltage can be obtained across the load.

Loss Analysis:

The losses in the half-bridge DC-DC converter can be classified into two categories: conduction losses and switching losses. Conduction losses occur when the switches are conducting current, and switching losses occur when the switches are switching on or off.

Conduction Losses:

Conduction losses are the power losses that occur when the switches are conducting current. The conduction losses can be calculated using the following equation:

P_con = I^2 x R_ds

Where P_con is the conduction losses, I is the current flowing through the switch, and R_ds is the on-state resistance of the switch. The on-state resistance of the switch is an essential parameter that determines the conduction losses. MOSFETs have lower on-state resistance than IGBTs, resulting in lower conduction losses. However, MOSFETs have higher gate capacitance, which results in higher switching losses.

Switching Losses:

Switching losses occur when the switches are switching on or off. The switching losses can be further classified into three categories: turn-on losses, turn-off losses, and gate drive losses.

Turn-on losses occur when the high-side switch is turned on. During turn-on, the input voltage is applied across the switch, and the switch's capacitance is charged. The energy required to charge the switch's capacitance is dissipated as turn-on losses. Turn-on losses can be calculated using the following equation:

$$P_{on} = 0.5 \times C_{iss} \times V_{in}^2 \times (dV/dt)$$

Where P_{on} is the turn-on losses, C_{iss} is the input capacitance of the switch, V_{in} is the input voltage, and dV/dt is the rate of change of the input voltage.

Turn-off losses occur when the low-side switch is turned off. During turn-off, the switch's energy is stored in the parasitic inductance of the switch and is dissipated as turn-off losses. Turn-off losses can be calculated using the following equation:

$$P_{off} = 0.5 \times L_s \times I_{pk}^2$$

Where P_{off} is the turn-off losses, L_s is the parasitic inductance of the switch, and I_{pk} is the peak current through the switch during turn-off.

Gate drive losses occur due to the power dissipated in the gate driver circuitry. The gate driver circuitry is used to control the switches and provide sufficient voltage and current to switch the devices on and off. The gate drive losses can be calculated using the following equation:

$$P_{gate} = V_{gate} \times I_{gate} \times t_{on} + V_{gate} \times I_{gate} \times t_{off}$$

Where P_{gate} is the gate drive losses, V_{gate} is the gate voltage, I_{gate} is the gate current, and t_{on} and t_{off} are the turn-on and turn-off times of the switch, respectively.

Losses in High-Current and Low-Voltage Applications:

In high-current and low-voltage applications, the conduction losses are significant due to the high current flowing through the switches. The on-state resistance of the switch plays a crucial role in determining the conduction losses. MOSFETs are preferred over IGBTs in high-current and low-voltage applications due to their lower on-state resistance.

The switching losses are also significant in high-current and low-voltage applications. The turn-on and turn-off losses increase with increasing current and decreasing voltage. The parasitic inductance of the switch increases with increasing current, resulting in higher turn-off losses. The turn-on losses increase with decreasing voltage due to the higher rate of change of the input voltage.

The gate drive losses are also significant in high-current and low-voltage applications. The gate driver circuitry has to provide high current to switch the devices on and off quickly. This results in higher power dissipation in the gate driver circuitry.

Efficiency Analysis:

The efficiency of the half-bridge DC-DC converter can be calculated using the following equation:

Efficiency = P_out / P_in

Where P_out is the output power, and P_in is the input power. The output power can be calculated using the following equation:

P_out = V_out x I_out

Where V_out is the output voltage, and I_out is the output current. The input power can be calculated using the following equation:

P_in = V_in x I_in

Where V_in is the input voltage, and I_in is the input current.

The losses in the half-bridge DC-DC converter reduce the efficiency of the converter. Therefore, it is essential to minimize the losses to achieve high efficiency. The efficiency of the converter can be improved by using low on-state resistance switches, reducing the parasitic inductance of the switch, and optimizing the gate driver circuitry.

CONCLUSION

In this paper, we presented a detailed analysis of the losses in half-bridge DC-DC converters in high-current and low-voltage applications. We discussed the conduction losses, switching losses, and gate drive losses in the converter. We also analyzed the efficiency of the converter and discussed various techniques to improve the efficiency. The analysis presented in this paper can be used to design high-performance power electronic systems that utilize half-bridge DC-DC converters.

REFERENCES

1. Rashid, M. H. (2013). Power Electronics Handbook: Devices, Circuits, and Applications. Elsevier.

2. Boldea, I., & Nasar, S. A. (2006). Electric drives. CRC Press.
3. Zhang, C., & Shen, Y. (2016). A comparative study of DC/DC converters for low-voltage, high-current applications. IEEE Transactions on Power Electronics, 31(4), 3124-3136.
4. Zhang, C., & Shen, Y. (2017). Design and analysis of a high-frequency, high-efficiency, and low-profile isolated DC/DC converter for low-voltage, high-current applications. IEEE Transactions on Industrial Electronics, 64(5), 4135-4145.
5. Zhang, H., & Qian, Z. (2020). Loss analysis and optimization of half-bridge DC-DC converters for electric vehicle battery chargers. Energies, 13(19), 5154.
6. Shen, Y., & Zhang, C. (2016). A comprehensive loss analysis and optimization of high-frequency, high-efficiency, and low-profile DC/DC converters. IEEE Transactions on Power Electronics, 32(3), 2125-2137.