Analysis on Technical Trends and Challenges of Switching Power Supply

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Abstract: Switching power supply technology has rapidly evolved over the last few decades, bringing substantial improvements in efficiency, power density, and cost. The aim of this paper is to provide an overview of the technical trends in switching power supply and the challenges that come with them. This paper analyzes the technical trends in switching power supply, including high-frequency switching power supply, multi-phase switching power supply, digital control of switching power supply,and wide bandgap semiconductor switching power supply. The future trends and challenges in switching power supply, including miniaturization of switching power supply, high power density switching power supply, increasing efficiency of switching power supply, and integration of switching power supply are also discussed.This paper is hoped to provide assistance to relevant staff in developing switching power supplies.
Keywords: Switching Power Supply; Technical Trends; Efficiency

1. Introduction

Switching power supply is a widely used technology for converting electrical power from one form to another. It is a type of power supply that utilizes a switching regulator to control the conversion of electrical energy. The switching regulator is responsible for efficiently converting electrical energy from a power source to a load, usually through a power switch that is turned on and off at high frequencies. Switching power supply technology has evolved over the years, with new advancements providing improvements in efficiency, power density, and cost. This paper analyzes the technical trends in switching power supply and the challenges that come with them.

2. Technical Trends in Switching Power Supply

The field of switching power supply is continually evolving to meet the increasing demand for high-efficiency, compact, and reliable power supplies. In this section, we will analyze some of the major technical trends in switching power supply technology.At the same time, the following technical trends have mutual influence and promotion. For example, high-frequency technology often requires the support of digital control and wide bandgap devices, while multi-phase control often requires more advanced digital control capabilities.

2.1 High-Frequency Switching Power Supply

High-frequency switching power supply is one of the primary trends in the field of switching power supply technology. By operating at high frequencies, these power supplies can achieve higher power densities and efficiencies. They can be used in various applications, such as data centers, telecommunications, and consumer electronics.However, the primary challenge of high-frequency switching power supplies is the switching losses that occur during each switching cycle. Researchers have been developing new topologies and control techniques to reduce these losses and improve the overall efficiency. Soft-switching techniques, such as zero-voltage switching (ZVS) and zero-current switching (ZCS), have been widely used to minimize switching losses in high-frequency power supplies.For example ,LLC resonant converter can realize both zero voltage switching (ZVS) on primary side and zero current switching (ZCS) on secondary side[1].

2.2 Multi-Phase Switching Power Supply

Multi-phase switching power supplies are gaining popularity due to their ability to handle high currents and provide better power density. In a multi-phase power supply, several identical power phases are connected in parallel, which allows the load current to be shared among the phases. This results in a more efficient and reliable power supply.Another advantage of multi-phase switching power supplies is their ability to reduce output voltage ripple. By interleaving the switching of the phases, the output voltage ripple can be minimized without increasing the switching frequency. This makes multi-phase power supplies ideal for applications that require low output voltage ripple, such as microprocessors and other sensitive electronics.

2.3 Digital Control of Switching Power Supply

Digital control of switching power supplies is another emerging trend in power supply technology. Digital control techniques can provide better accuracy, stability, and flexibility compared to traditional analog control techniques. In addition, digital control can be easily integrated with other digital systems, such as microcontrollers and field-programmable gate arrays (FPGAs).One of the primary challenges in digital control of switching power supplies is the latency and jitter introduced by the digital control system. To address this issue, researchers have been developing new digital control techniques like predictive control that can provide fast and accurate control without introducing significant latency or jitter. Adaptive digital control is a control technique that adjusts the control parameters in real-time to adapt to changes in the load or input voltage. This technique can greatly improve the stability and performance of switching power supplies under varying operating conditions.

2.4 Wide Bandgap Semiconductor Switching Power Supply

Wide bandgap semiconductors, such as silicon carbide (SiC) and gallium nitride (GaN), are emerging as promising materials for switching power supplies. Compared to traditional silicon-based power devices, wide bandgap semiconductors can operate at higher temperatures, voltages, and frequencies, resulting in higher power densities and efficiencies[2].One of the primary challenges in using wide bandgap semiconductors in switching power supplies is the high cost of these materials compared to traditional silicon-based devices. However, as the production of wide bandgap semiconductors increases and the cost decreases, they are expected to become more widely used in various applications, such as electric vehicles, renewable energy systems, and data centers.The wide bandgap semiconductor switching power supplies has ability to operate at higher switching frequencies, which can significantly reduce the size of passive components, such as inductors and capacitors, in the power supply circuit. This results in a more compact and lightweight power supply.

3. Challenges in Switching Power Supply

Below passages will focus on the challenges facing switching power supply design, with a particular emphasis on miniaturization, high power density, increasing efficiency, and integration.At the same time, the following technical challenges have mutual influence and promotion， such as integration technology promoting minimaturization, high efficiency means low energy and heat loss, which means does not require large heat sink, and can achieve high power density.

3.1 Miniaturization of Switching Power Supply

One of the primary goals of switching power supply technology is to achieve miniaturization while maintaining high efficiency and performance. Miniaturization of switching power supplies is essential for applications where space is limited, such as portable devices and wearable technology.To achieve miniaturization, researchers are developing new topologies and control techniques that can reduce the size of passive components, such as inductors and capacitors, and the size of the power supply circuit. One example is the use of resonant switching topologies that can achieve high efficiency and reduce the size of passive components.

3.2 High Power Density Switching Power Supply

High power density switching power supplies are essential for applications that require high power output in a limited space, such as data centers and electric vehicles. To achieve high power density, researchers are exploring new materials and device structures that can operate at higher voltages, frequencies, and temperatures.Wide bandgap semiconductors, such as SiC and GaN, are promising materials for high power density switching power supplies due to their ability to operate at higher temperatures and frequencies, resulting in higher power densities and efficiencies.Advanced Control System can be used to improve real-time detection, control of the output voltage and current of a high-power-density switching power supply,make high power density possible[3].In addition, researchers are developing new cooling techniques, such as potting cooling, that can improve the heat dissipation of the power supply circuit, enabling higher power densities.

3.3 Increasing Efficiency of Switching Power Supply

Increasing the efficiency of switching power supplies is critical for reducing energy consumption and minimizing the impact on the environment. To achieve higher efficiency, researchers are exploring new topologies and control techniques that can minimize the losses in the power supply circuit.One approach is the use of soft-switching topologies, such as resonant and quasi-resonant converters, that can reduce the switching losses in the power supply circuit. Another approach is the use of digital control techniques that can optimize the switching frequency and duty cycle of the power supply circuit, resulting in higher efficiency.In addition, researchers are developing new materials and devices that can reduce the losses in the power supply circuit. For example, the use of wide bandgap semiconductors and new magnetic materials can reduce the switching and core losses in the power supply circuit, resulting in higher efficiency.

3.4 Integration of Switching Power Supply

Integration of switching power supplies is becoming increasingly important for applications where space is limited, such as portable devices and IoT devices. Integration of switching power supplies can reduce the overall size and weight of the power supply system and improve the reliability of the system. Magnetic Integrated is another Integrating way ,for example, two inductors and power transformer can be combined into one magnetic core, which can be used to eliminate the wave current and reduce the overall size[4]. In addition,researchers are developing new integration techniques, such as power module integration, that can integrate multiple power supply circuits into a single package, reducing the overall size and weight of the power supply system.

4. Conclusion

Switching power supplies are critical components of modern electronic systems, providing the necessary energy conversion with high efficiency and low cost.The technical trends of switching power supplies include high-frequency operation, wide-bandgap semiconductors and multi-phase etc. However, the development of switching power supply technology still faces various technical challenges such as high power density, increasing efficiency, high switching frequency, integration, and miniaturization. Both challenges and problems provide innovative space for our switching power supply researchers, thus leading to the emergence of various technological trends introduced in this article.To overcome these challenges, designers need to balance the trade-offs between various design parameters and employ advanced techniques,at the same time, innovate on new technological trends.We believed that switching power supply technology will be further developed and improved in China in the future.

References

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