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Analysis and Optimization of low-Voltage and High-Current Matrix Current-Doubler Rectifiers Integrated Magnetic Components

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Abstract

All parties favour the half-bridge current-doubling rectifier circuit due to its advantages: small output current pulsation, low switching voltage stress, and high anti-unbalance ability. Further integration of the secondary inductor and the transformer further reduces the size of the converter and dramatically improves the power density. This paper carefully analyzes the existing magnetic integration schemes. Combined with the characteristics of low-voltage and high-current DC converters, the secondary winding in this paper adopts the form of one turn to further reduce the loss so as to adapt to the secondary output of high current. The way the integrated magnetics are matrixed. The winding loss, termination loss, core loss, and distribution parameters of single and matrix integrated magnetic components were compared and analyzed. Focus on optimization analysis. It focuses on the influence of matrix on the DC bias and DC loss of the current-doubling rectifier core. At the same time, the leakage inductance and winding loss of the integrated magnetic components are comprehensively considered, and a compromise design is carried out further to improve the power density of the integrated magnetic components.

Introduction

With the continuous development of modern microprocessors and communication equipment, the performance requirements for low-voltage and high-current output switching power supplies are increasing. All parties favour the half-bridge current-doubling rectifier circuit due to its advantages: small output current pulsation, low switching tube voltage stress, and high anti-unbalance capability. The converter dramatically reduces the volume of the entire converter and improves the power density of the converter

In short, this paper applies a matrix transformer to a matrix-type current-doubling magnetic integrated magnetic device with a secondary winding of 1 turn, which significantly improves the converter's power density and is beneficial further to reduce the volume and weight of the magnetic element. The winding loss, core loss, termination loss and distribution parameters of the integrated magnetics were further studied. At the same time, The DC bias of a single core on the matrix current-doubling integrated magnet is significantly reduced, and the loss of a single core is reduced. It reduces the increase of the core loss caused by the multiple pairs of magnetic cores caused by the matrix.

The Matrix Current-Doubling Integrated Magnetic Device Proposed in this Paper

The structure of the matrix-type current-doubler rectifier magnetic integrated converter is shown in figure 1. The input voltage Vin is 48V, and the output voltage is 0.8V. The switching frequency is 500KHz. The primary side adopts a half-bridge with a turns ratio of 6:1:1. In this design, the 6:1:1 transformer is divided into two distributed 3:1:1 element transformers. The primary side is connected in series, the secondary side is connected in parallel, and the secondary side winding uses eight parallel windings to handle large output currents. The primary side adopts two parallel windings and uses a 14-layer PCB board.The Matrix Current Doubler Magnetic Integrated Converter and Laminated Structures is shown in figure 2.

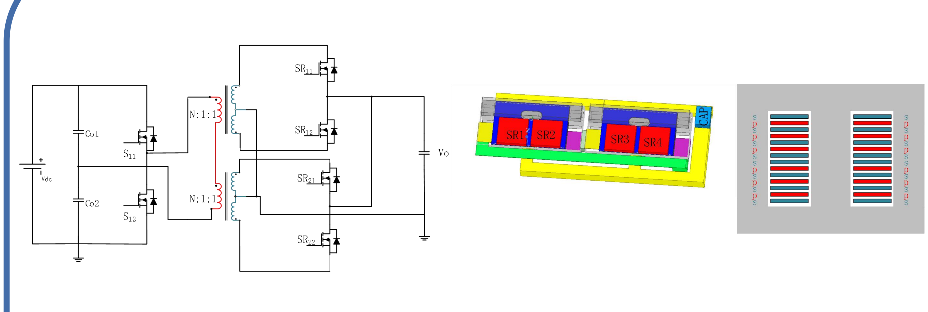

Figure 1. a) Matrix Current Doubler Magnetic Integrated Converter b) Laminated Structures

Analysis and Optimization of Magnetic Components with the One-Turn Secondary Winding

As a low-voltage high-current topology, the secondary winding loss of the current doubler rectifier converter accounts for a large proportion of the entire winding loss. This paper adopts a planar EE-type magnetic core.

14 PCB layers are used for the integrated magnetics. The secondary side uses 8 layers in parallel, but the current distribution in the 8-layer secondary side parallel winding is quite uneven. The staggered structure of the primary and secondary sides can reduce the uneven current level of the 8-layer secondary side parallel windings to a certain extent.

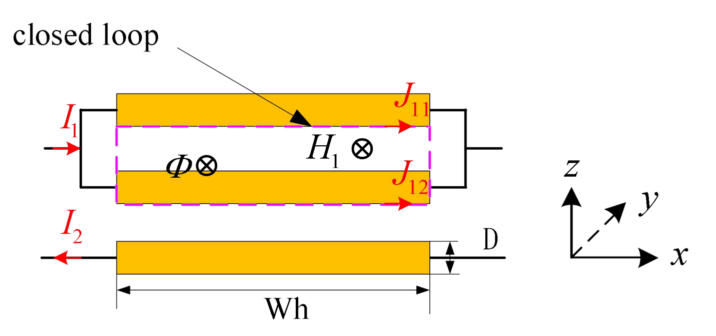

Figure 2. Xoz section of two layers of parallel windings

It is not difficult to see from table 1 and Figure 3 that the greater the degree of staggering of the primary (P) and the secondary (S), that is, the closer to a completely staggered structure, the smaller the field strength H1 and the magnetic flux Φ between the PCB copper foils, Winding losses are also more minor with integrated magnetics. Below is an example of the current distribution between the layers of SPSPSPSSPSPSPS along line 1, as shown in figure 4. It can be seen that the current distribution on the secondary side of one turn formed by 8 layers of copper foils in parallel is relatively uniform.

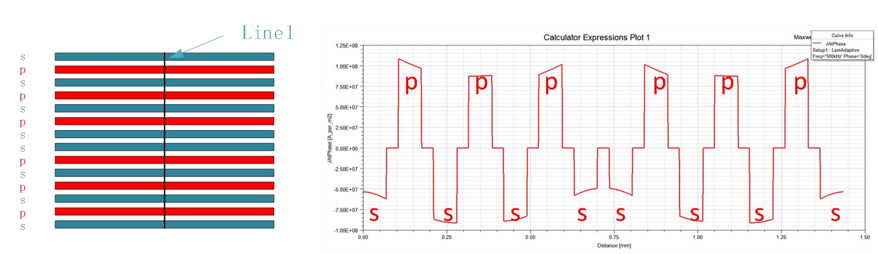

Figure 3. Current distribution along the line of the laminated structure

Conclusion

To sum up, this paper proposes a novel matrix-based current-doubling rectifier integrated magnetic device, which dramatically improves the converter's power density and is beneficial further to reduce the volume and weight of the magnetic device. The winding loss, termination loss, significant core loss caused by DC bias, and the leakage inductance of the integrated magnetic components are analyzed in detail. Integrated magnetic winding and core losses are optimized while maintaining specific volume and weight.