일체형 자성체를 적용한 8.4kW/L, 3kW PSFB LDC

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8.4kW/L, 3kW PSFB LDC with All-in-One Magnetics

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ABSTRACT

This paper proposes an all-in-one magnetic that integrates leakage inductor, two filter inductors, and transformer into single planar core for PSFB converter with current doubler. This integration reduces number of cores required, as well as volume, and magnetic loss, resulting in significantly reduced cost and increased efficiency. FEA Maxwell simulation is performed to verify design value. A prototype of 3kW, 800V-12V converter achieved a peak efficiency of 95.5% and a power density of 8.4kW/L.

1. Introduction

The low voltage DC-DC converter (LDC) is one of main electrical components in electrical vehicles, which provides power for 14-V load and charge to 14-V auxiliary battery. Due to the room limitation in the vehicles, the LDC required very high power density. The phase shift full bridge (PSFB) with current doubler is widely used for LDC due to the advantage of simplicity and wide voltage range. In order to increase the power density of the converter, magnetic integration is the effective method [1-2]. In this paper, a new all-in-one magnetic structure is proposed to integrated all magnetic components into single core, which results reduce the costs, minimizes volume and loss, and simplifies manufacturing processes as shown in Fig. 1.

2. Proposed all-in-one magnetic structure

In Fig. 1, the PSFB converter is shown with the separated magnetic structure and the proposed all-on-one magnetic structure. By the magnetic integration, the required number of core is reduced that reduces costs and simplified manufacturing process. Fig.2 shows the key waveform comparison of the conventional and

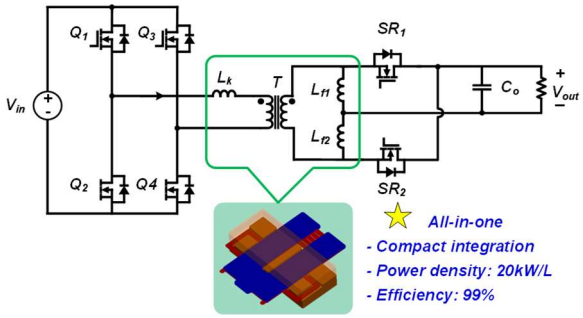


Fig.1 Phase shift full bridge current doubler converter with proposed all-in-one magnetic.

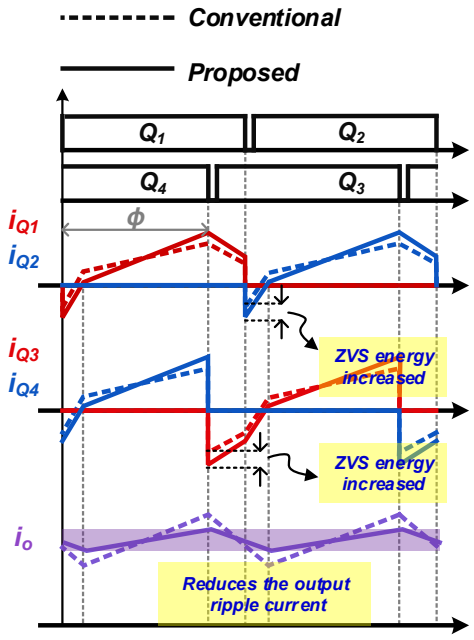
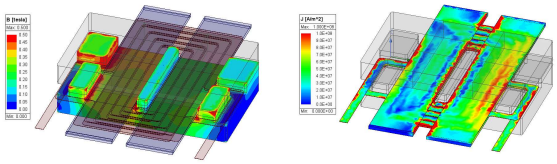


Fig.2 Key waveform comparisons of the conventional and proposed magnetics.

proposed magnetic. It can be seen that the ZVS turn-on energy is increase and the output current ripple is reduced. It can be reduce the output capacitor rating. In order to verify the design, a FEA



(a) (b)

Fig.3 FEA simulation result of the proposed all-in-one core: (a) Flux distribution, (b) current distribution

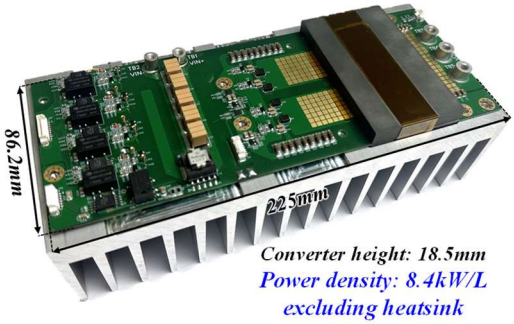


Fig.4 3kW 800V-12V PSFB converter prototype with the all-in-one core.

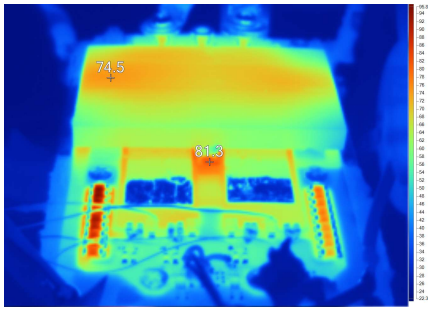
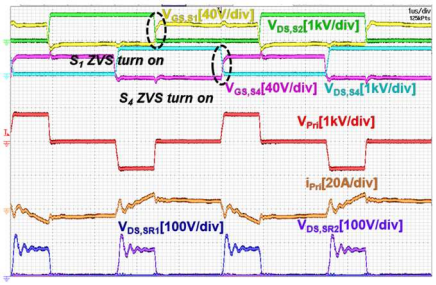


Fig.5 Thermal photograph of the proposed all-in-one core.

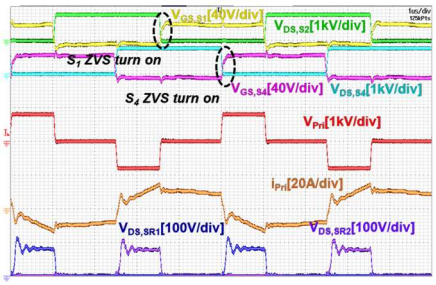
Maxwell simulation are performed. It shows that the simulation of maximum flux density and current density are 0.3T and 40A/mm^2, respectively, closed to the designed values.

3. Experimental results

Fig. 4 shows a 3kW 800V 12V PSFB converter was built to verify the proposed all-in-one core structure. The prototype achieve 8.4kW/L of power density with the converter height of 18.5mm. The prototype utilizes the AIMCQ120R060M1T switch on the primary side and the IAUTN12S5N018T switch on the secondary side, both of which are the sample switches provided by Infineon. The converter can operate under wide voltage range: V_{in} = 340V-800V and V_o = 11.6V-15.3V. The thermal graph of the proposed all-in-one magnetic are shown in Fig. 5. The maximum winding temperature is 81.3°C and core temperature is 74.5°C. In Fig. 6, the experimental waveforms at highest input voltage are shown that all switch can achieve ZVS under wide entire power range.



(a)



(b)

Fig.6 Experiment results at Vin = 800V, Vo = 14V conditions with (a) Po = 1kW; (b) Po = 3kW.

4. Conclusions

An all-in-one magnetic structure has been proposed to integrate all the magnetic components in the current doubler rectifier circuit. By the proposed integrated technique, the ZVS energy is increased and output current is reduced. In order to validate the effectiveness of the proposed core structure, a 3kW 800V 12V prototype of PSFB current doubler rectifier with the proposed all-in-one magnetic core structure has been built. The prototype converter achieved peak efficiency of 95.5% and power density of 8.4kW/L.

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References

[1] H. -P. Kieu, D. B. -H. Nguyen, D. Lee and S. Choi, "All-in-one Magnetic Structure for PSFB converter with Current Doubler Rectifier," 2024 IEEE Applied Power Electronics Conference and Exposition (APEC), Long Beach, CA, USA, 2024, pp. 875-880, doi: 10.1109/APEC48139.2024.10509124.

[2] S. Choi, H.P. Kieu, "Integrated Transformer", Korean patent pending 2023.