High Density Voltage Regulator Module for Vertical Power Delivery with Twisted Core Inductor

In just two years, in both 2022 and 2023, artificial intelligence (AI) witnessed massive growth and a large-scale expansion. Developing and maintaining AI models requires many graphic processing units (GPUs). As a result, the computational resources to train and operate AI models and applications could cause a surge in data-center electricity consumption. Research firm Semi Analysis suggested that the daily energy required to support ChatGPT, the popular AI application, is about 564 MWh. Therefore, saving even a fraction of the energy demands becomes crucial.

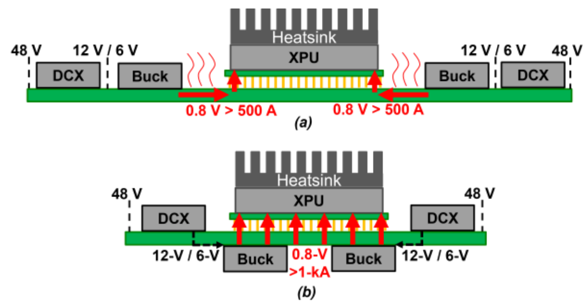

Fig.1. Processors' power delivery concepts: (a) lateral power delivery (b) vertical power delivery

A single H100 GPU from NVIDIA can continuously consume 700 W of power and much higher instantaneous peak power. Therefore, the buck converters should provide more than 1000 A current. Figure 1(a) shows the current practice of designing a processor card called lateral power delivery (LPD) architecture. In LPD architecture, the distance between the buck converters and the processors creates a significant conduction loss, given the high current demand of the processors. Thus, the processor card efficiency becomes concerning if the LPD architecture practice continues for next-generation, ultra-high-current processors. Vertical power delivery (VPD) architecture, as shown in Fig. 1(b), has emerged as a promising candidate for the next generation of ultra-high-current microprocessors. The idea is to move all buck converters directly underneath the processor to significantly reduce the high-current distance from the buck converters to the processors. Therefore, better efficiency can be achieved. However, the design of the buck converter for VPD architecture becomes significantly challenging due to the size of the power inductor, especially to conform with the size restriction in VPD architecture.

This work presents a novel planar twisted core negative coupled inductor structure, as shown in Fig. 2(a). The proposed structure enables straight and short winding, achieving an extremely small inductor winding dc-resistance (DCR) of less than 0.1 mΩ. Compared with the conventional twisted core inductor, only a single mold design is required for the proposed structure, reducing the manufacturing complexity. A three-dimensional (3D) 5 V/0.8 V voltage regulator module with 130 A peak current handling capability is built with the proposed planar twisted core inductor, as shown in Fig. 2(b), offering 1.44 A/mm^2 peak current density and 2.7kW/in^3 power density. The total converter height is 4.4 mm with 91% peak efficiency**.**

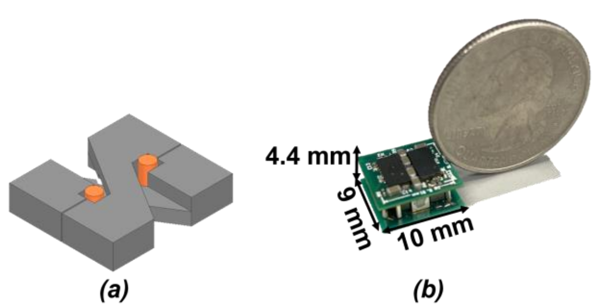

Fig. 2. Proposed twisted core inductor: (a) bare inductor (b) implementation in a 3D integrated buck converter