# Low Cost and Low Profile 800 VDC to 12.5 V DC-DC Converter Using Low Voltage GaN in an ISOP Topology

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## Overview

Power delivery to tomorrow's megawatt-scale server racks will require a major disruption to the architecture from today's kilowatt-scale systems. To efficiently deliver higher power, the server rack and system bussing must operate at higher voltages than the traditional 54 V and reduce the number of conversion stages. Current AI systems combine four power conversion stages, from the AC mains down to the core voltage, in the same rack as the GPUs and CPUs. The first two, AC to 400 VDC and 400 VDC to 54 VDC are grouped in power supply units, and along with battery backup units, located in dedicated power shelves. From there, the 54 VDC is distributed down the rack to the compute trays or shelves, where the last two stages convert the 54 VDC into 12 VDC, and finally the 12 VDC into the core voltage. This is illustrated in figure 1.

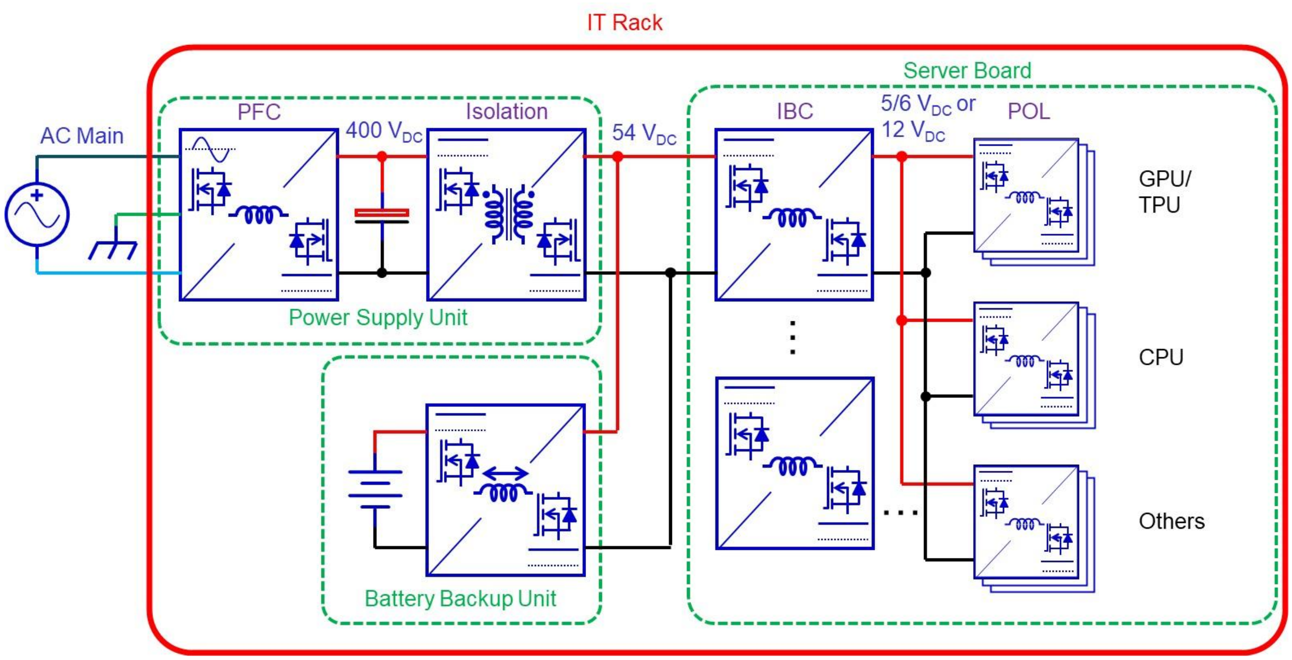


*Figure 1: Kilowatt server rack architecture configuration showing voltage details.*

The power architecture disruption begins by increasing the output voltage of the first stage from 400 VDC to 800 VDC and relocating it to a separate power rack. The 800 VDC is then delivered to the AI racks and distributed directly to the compute trays, where it is immediately converted down to 12.5 V. This stage is physically located close to the final point of load, thereby reducing bussing losses. This approach also eliminates the 54 VDC to 12 VDC conversion stage present in today's kilowatt-scale server systems. In addition, this reconfiguration of the power architecture creates more space in the AI rack for additional computing loads. This new power architecture configuration is illustrated in figure 2. This paper discusses the on-board conversion from 800 VDC to 12.5 V.

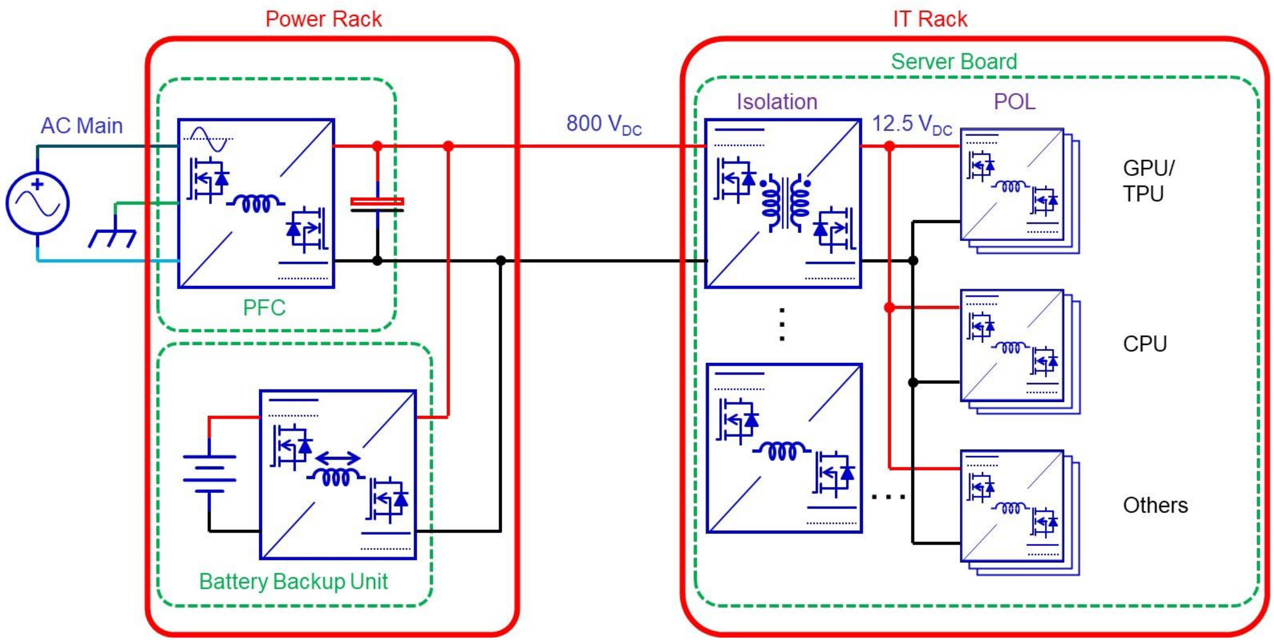


*Figure 2: Megawatt server rack architecture configuration showing voltage details.*

Converting 800 V 12.5 V on the AI computing board challenges existing converter topologies due to efficiency, size and height constraints. EPC has collaborated with NVIDIA to develop a low-cost, low-profile, 6 kW 800 VDC to 12.5 V converter utilizing EPCs most advanced 150 V and 40 V GaN technology occupying under 5,000 $mm^2$ and 8 mm in height and achieving over 97% efficiency.

**ISOP Solution**

The 6 kW 800 VDC to 12.5 V converter supports 800 VDC power distribution in AI infrastructure by using an LLC topology in an input-series, output-parallel (ISOP) configuration [1]. This configuration uses a modular approach where the input voltage and output current are divided over eight blocks, where each block only experiences 1/8$^{th}$ of the input voltage and produces 1/8$^{th}$ of the output current. As a result, the original converter specification of 800 VDC to 12 VDC (64:1 conversion ratio) is reduced to a much simpler 100 VDC to 12.5 VDC (8:1 ratio) with 750 W output power rating for each module.

Each module is configured with a half-bridge input and center tap output transformer with a turns ratio of 4:1:1. This transformer is cost effective because it is easily constructed as a planar transformer with the windings integrated into a PCB. The center tap secondary has the additional benefit of requiring only a single FET in the high-current path as opposed to two in series when using a full-bridge rectifier. The block diagram of the ISOP converter and the topology of the 100 VDC to 12.5 VDC LLC module are shown in figure 3.

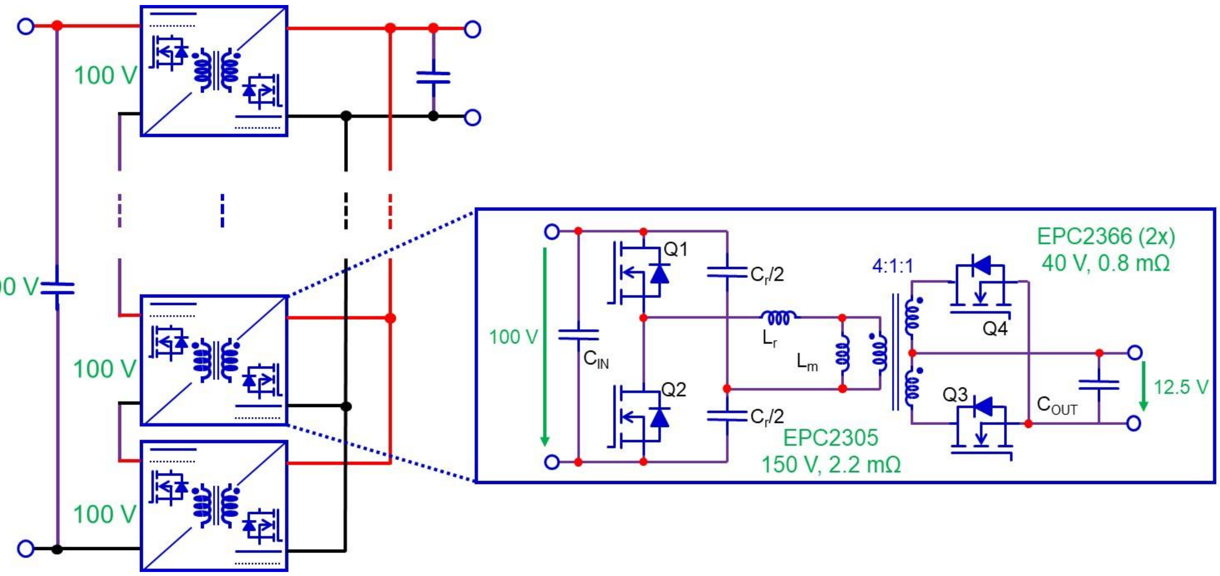

*Figure 3: 800 VDC to 12.5 VDC ISOP Converter showing details of the LV module.*

The elegance of this design is in its simplicity. The LLC modules are designed to operate at the resonant frequency, where efficiency is the highest and the gain of the resonant tank is unity. By designing $L_R << L_M$, the gain of the converter remains frequency independent around the operating frequency and over a wide range. This forces the parallel outputs to present equal voltages to each of the primaries, including, component tolerances to maintain equally divided voltages across each of the modules. Since all inputs are in series, the current through each input is identical, balancing the current on each of the outputs.

With zero-voltage, zero-current switching of the LLC, these low voltage modules are very efficient, even at high frequencies. EPC's embodiment of this solution has each module switching at 1 MHz, which enables a very small, low-profile core with a height of < 8 mm. This height is critical as it allows many AI boards to be stacked in the rack without disrupting the cooling of the processors.

*Table 1: Key parameters for EPC2305 and EPC2366 GaN FETs used in the LLC module.*

| Part Number | $V_{DS\ max}$ (V) | $R_{DS(on)\ typ}$ (mΩ) | $Q_{G\ typ}$ (nC) | $Q_{OSS\ typ}$ (nC) | $Q_{RR\ typ}$ (nC) | Size (mm) | $R_{\theta JC}$ (°C/W) |
|---|---|---|---|---|---|---|---|
| EPC2305 | 150 | 2.2 | 22 | 103 | 0 | 3 x 5 | 0.2 |
| EPC2366 | 40 | 0.8 | 13 | 20 | 0 | 2.6 x 3.3 | 0.6 |

The combination of low resistance, low capacitance and low inductance of EPC's eGaN® FETs make the high efficiency at high frequency possible [2]. The 150 V rated, 2.2 mΩ EPC2305 GaN FET is used in the primary half-bridge and is available in a 3 mm x 5 mm QFN package [3]. Two in parallel of the 40 V rated, 0.8 mΩ EPC2366 GaN FET are employed in each leg as the synchronous rectifiers and are available in a 2.6 mm x 3.3 mm QFN package [4]. The QFN packages used have exposed top technology for efficient top-side cooling. Key parameters for these devices are shown in table 1.

**EPC's 800 VDC to 12.5 VDC ISOP LLC Converter**

Figure 4 presents a photo of EPC's solution to support the 800 VDC infrastructure in the next generation of AI factories. The system features a 64:1 fixed-ratio isolated converter, implemented using an ISOP configuration of eight LLC modules. The converter bridges the 800 VDC distribution bus and the 12.5 VDC load bus, delivering up to 6 kW exceeding 97% efficiency. The key benefits of this solution are summarized below:

1. Superior semiconductor devices: Low voltage GaN devices, such as EPC2305 can be used in primary side, have much better figures of merit than 1200 V SiC or 650 V GaN FETs,
2. Simpler transformer: The design of the transformer is greatly simplified to a compact and efficient planar structure with turns ratio of 4:1:1, while achieving a 64:1 overall converter ratio,
3. Lower bus capacitance: The eight LLC modules that make up the ISOP configuration can have their switching cycles interleaved to reduce input/output voltage ripple, minimizing bus capacitance requirements,
4. Low profile components: The lower input voltage for each LLC module enables lower voltage components to be used on the input side, which in turn translates to lower profile components.
5. Distributed losses: The ISOP configuration distributes the total power losses between each of the 8 modules and uniformly over the entire area of the converter, thus simplifying the cooling solution.
6. Distributed output voltage: The output voltage is presented along two entire edges of the converter for efficient bussing of the 12.5 V to the POL converters.

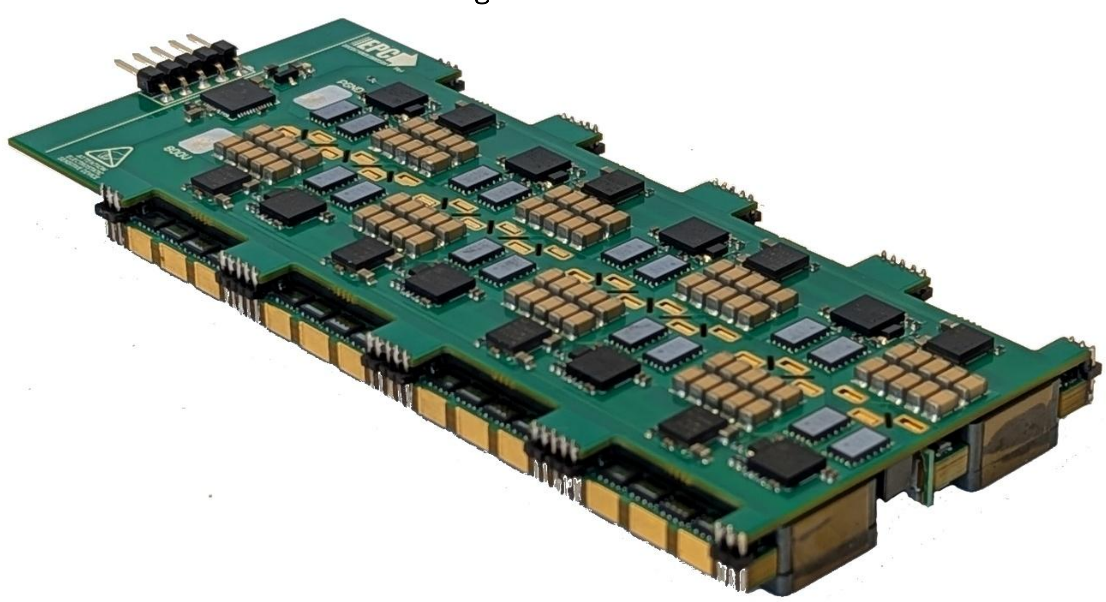

*Figure 4 Photo of EPC 800 VDC to 12.5 V, 6.5 kW converter*

## Conclusions

EPC and NVIDIA have worked together as a team to define and develop a modular solution for converting the standardized 800 VDC directly to 12.5 V at power levels that are inherently scalable and future-proof. The solution uses the ISOP topology enabling lower voltage components and much higher frequency than traditional solutions. The result is a high efficiency, low-profile conversion, putting more processor power in each rack.

## References


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