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Electronic Design

Overcome Data-Center Power Challenges with GaN

Sponsored by Texas Instruments: To satiate the power demands of data centers using AI, engineers are turning to gallium-nitride-based high-voltage solutions.

With the onset of artificial intelligence (AI), the scale as well as the degree of power usage in data centers continue to escalate. AI-ready data centers require significantly more power than traditional data centers, particularly those involving GPUs and accelerated servers.

Specialized hardware is used to dramatically speed up work, employing parallel processing that bundles frequently occurring tasks. This translates to higher power densities per rack, with AI data centers potentially requiring 40 to 110 kW per rack, compared to 10 to 12 kW in traditional data centers.

And all of that current must be shoved through very tiny pieces of copper. Put another way, the energy requirement is going up tenfold, but the size of the chip is shrinking.

The Move to "High Voltage"

To even be able to deliver larger amounts of power, higher and higher voltages are needed to reduce the current, and there's a fundamental I^2R loss. Since power loss is directly proportional to the square of the current ($P = I^2R$), reducing the current significantly minimizes power loss.

Why high voltage? As the worldwide automotive electrification trend continues to gain momentum, efficient energy transfer at higher power levels becomes an important consideration. Increasing the voltages used to transmit and de-

TI's GaN devices are utilized in server systems that support storage, cloud-based applications, and more. (Source: TI) liver power reduces the required current for the same power level and helps minimize losses through heat.

For example, electric-vehicle batteries currently deliver 400 V. However, they're increasingly trending toward 800 V to enable more instantaneous power transfer to the traction inverter for better acceleration performance. As a result, AI is forcing designers to rethink data-center power architecture and take creative approaches to addressing the challenges.

Operating under a higher voltage brings system efficiency benefits for power conversion as well as proper galvanic isolation and insulation, which are essential in developing a safe human interface.

With power supplies now taking up too much space and generating too much heat, the designer has to move them into what's being called a "power sidecar." This is a supplemental system, often employing liquid cooling, which works alongside high-performance AI chips to manage the intense heat they generate and efficiently deliver the necessary power for operation.

The Solution: GaN Switches

When you need components functioning at a high voltage, the preferred switch for the task employs gallium nitride (GaN) *(see figure)*. GaN processes power more efficiently than silicon-only solutions, reducing power loss by 80% in power converters and minimizing the need for added cooling components. GaN quite simply takes the least amount of energy to turn on and the least amount of energy to turn reliably off.

The existence of wide-bandgap (WBG) FETs can also help solve reverse-recovered charge (Q_{rr})-related loss issues via totem-pole bridgeless PFC topology. WBG FETs have very low or even no Q_{rr}. When combining component and topology innovations, you can achieve over 99% efficiency.

What's more, almost all other parasitics, including gate charge and output capacitance, are much lower in WBG FETs than silicon MOSFETs, leading to much faster switching speeds. And faster switching speeds reduce switching losses.

While efficiency gains have been achieved by minimizing component-by-component losses, certain elements in the data-center energy-efficiency strategy require a higher-level solution—specifically selecting the right topology. Without innovations such as the isolated gate driver and digital controller, you won't be able to fully realize efficiency improvements in your designs.

Furthermore, a closed-loop system generally requires signal communication across the isolation boundaries. Add in magnetic circuit design, electromagnetic-interference considerations, operating modes, thermal management, and layout and control optimizations, and you begin to understand some of the significant design challenges when working with high-voltage systems.

Selecting the Right Gate Drivers

WBG FETs require companion devices such as isolated gate drivers and digital controllers for optimum performance. The appropriate gate driver will be capable of rapidly charging and discharging the gate capacitance. Traditional silicon MOSFET gate drivers may not offer proper voltage regulation or be able to handle the high common-mode voltage transient in a WBG design.

Faster switching means lower switching losses, but it can also lead to unwanted voltage ringing and common-mode noise issues. Not only is there parasitic inductance of the two devices themselves, but also the printed-circuit-board (PCB) trace inductance.

Dedicated digital controls manage these diverse high-performance requirements. These controllers need to operate in real-time, accurately measuring system parameters (such as voltage, current, and temperature); applying control algorithms to calculate the output commands; and supporting the high frequencies needed to improve power density. The key to real-time control is to minimize the time between sensing, processing and control functions.

By partnering with TI, you gain the advantage of a company now in its 10th generation BCD process (BCD chips combine bipolar, CMOS, and DMOS technologies, hence the name). It's very experienced in mixed-signal design very well, which results in high density with lots of intelligence diagnostic information put into a switch in a very small area.

TI's power-management solutions include a family of monolithic power-stage devices that come in thermally enhanced packaging. In addition, there are scalable controllers, which offer fast load-transient response, advanced telemetry, and protection features, plus point-of-load regulators and converters hot-swap controllers, and more.

Caption: