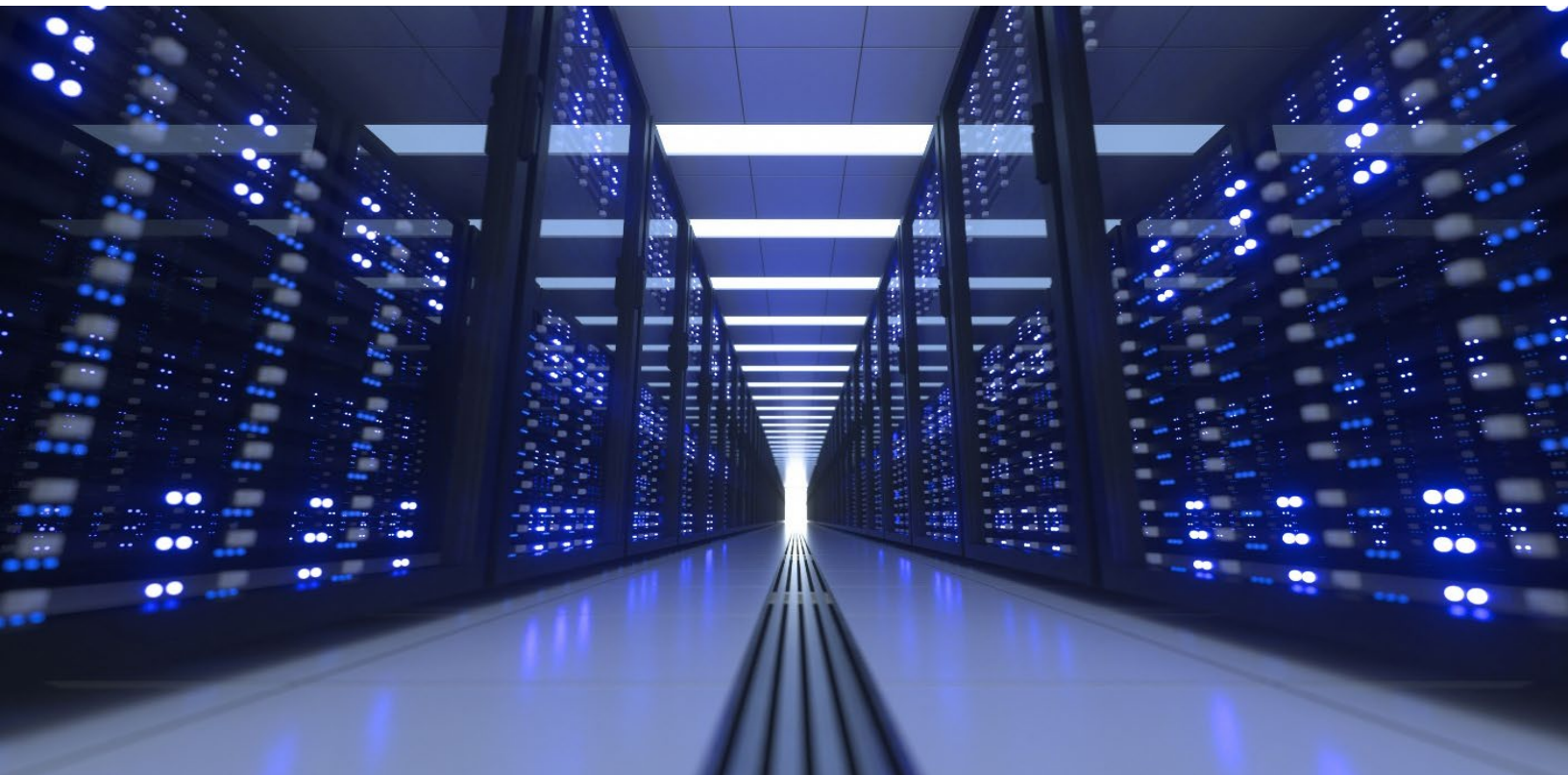


Powering Tomorrow: The Rising Power Demands of Modern Data Centers

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Introduction

This paper highlights the rapidly evolving power demands within modern data centers and the engineering challenges that come with them, from rising power density and the transition to 48V architectures to the adoption of fast-switching GaN and SiC devices.

It outlines why traditional current-sensing and power-delivery methods are reaching their limits and illustrates how advanced magnetic current sensors and high-voltage gate drivers are emerging as key technologies for improving efficiency, protection, and system reliability in next-generation datacenter designs.

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Why Data Centers Are Demanding More

Data centers stand as a unique and indispensable feature of our modern age, silently powering everything from artificial intelligence and cloud computing to the myriad connected devices that shape our daily lives. They're not merely calculating; they are the very engine making the future a reality. This foundational role means that the relentless drive for more data translates directly into an insatiable hunger for power. It's a demand that pushes traditional power delivery to approach their absolute limits.

This escalating need for energy isn't just about raw wattage; it's profoundly about power density, operational efficiency, and unwavering reliability. Engineers are constantly challenged to pack more computing power into smaller footprints, which necessitates innovative solutions for managing the electrical currents.

Each datacenter rack may contain dozens of current sensors or isolated gate drivers, controlling the conversion and distribution of power. Every milliwatt saved, every degree of heat dissipated, and every nanosecond of response time gained contributes significantly to the overall performance and sustainability of these critical infrastructures.



The Evolving Data Center: Where the Rubber Meets the Road (and the Silicon)

The 48V Revolution

As data centers continue to expand their computational muscle, the traditional 12V power distribution architecture has begun to show its limitations. The sheer amount of current required at 12V to deliver the necessary power leads to significant resistive losses. This creates a tangible pain point for engineers: their existing 12V systems are simply struggling to keep pace with the escalating power requirements of modern servers and AI accelerators. The quest for greater efficiency and reduced infrastructure costs has, therefore, driven a profound shift towards higher voltage distribution.

The move to a 48V power architecture represents a transformative leap in datacenter design. By quadrupling the voltage, the current required to deliver the same amount of power is reduced by a factor of four. This seemingly simple change has cascading benefits that directly address critical design challenges. Lower currents translate directly into significantly reduced power losses across the distribution network, minimizing wasted energy and mitigating heat generation within the racks.

While the shift from 12V to 48V significantly reduces the current flow for a given power level, it doesn't necessarily simplify the current sensing challenge. In fact, it often makes it more challenging. Designers working with 48V systems still require highly accurate current measurement, but now often across a wider dynamic range. The higher operating voltage also places increased emphasis on robust galvanic isolation for both current sensors and high voltage gate drivers, which interface with power transistors and manage switching events. These components must provide superior isolation capabilities without compromising performance.

Every Millimeter Counts

"Every millimeter counts" is not just a figure of speech; it's a design imperative. As the demand for computational power continues to climb, engineers are under immense pressure to pack more robust power delivery into the same constrained physical space. Server racks, with their standardized dimensions, offer finite room, meaning that every component selected must justify its footprint by contributing significantly to overall system performance and density.

In modern datacenter power supplies, traditional current sensing methods like current transformers (CTs) and isolated amplifiers are increasingly becoming a bottleneck. These conventional approaches often require multiple discrete components, complex layouts, and additional isolation barriers, all of which consume precious real estate on the printed circuit board and can define the overall volume of the system due to their large footprint and height. The need for compact, efficient, and integrated current sensing is therefore paramount. Solutions that can perform accurate, isolated current measurement within a small, single-chip footprint not only free up critical board space but also contribute to overall system efficiency and reliability.

The Need for Speed (and Protection)

The pursuit of higher power density and greater efficiency in datacenter power supplies has ushered in wide-bandgap semiconductors, specifically Gallium Nitride (GaN) and Silicon Carbide (SiC). These materials possess inherent characteristics that allow them to switch at significantly higher frequencies than traditional silicon-based devices. This capability is a game-changer for power supply designers: it directly enables the miniaturization of passive components like inductors and transformers. Smaller magnetics mean more compact designs, reduced material costs, and ultimately, greater power density within the fixed server power supply form factors.

However, this incredible speed comes with its own set of challenges. Their rapid switching capability that makes GaN and SiC so appealing also makes them exceptionally vulnerable. These devices can transition from on to off, or vice versa, in mere nanoseconds. If an overcurrent event occurs, or if there's an unexpected transient event, the speed at which these devices can be damaged is equally fast. Without adequate protection, these advanced semiconductors can quickly succumb to thermal stress, leading to a phenomenon colloquially known as "magic smoke" – a costly and disruptive failure that underscores the critical need for immediate intervention. Component failure leads to server down time, which is a consequence that needs prevention.

To harness the full potential of GaN and SiC, power supply designers must pair current sensors with faster response times and high voltage gate drivers (HVGDs) capable of handling rapid switching events with precision. The system needs to detect and react to transient overcurrents in a few microseconds, or even nanoseconds. Such rapid detection is essential to trigger protective mechanisms, preventing thermal runaway and safeguarding these sensitive, high-performance components. HVGDs provide the necessary isolation and dv/dt immunity to protect against high-frequency transients, ensuring reliable operation even under extreme conditions.

Keeping the Power On (and Knowing Why)

Uninterrupted power is not a convenience; it is a requirement in Data center power. Unexpected downtime can translate into significant cost implications. Consequently, the focus for data center engineers extends far beyond simply delivering power; it encompasses a comprehensive strategy for preventing failures and, crucially, predicting when systems need maintenance. This necessitates robust protective measures coupled with the ability to provide detailed telemetry that paints a complete picture of system health.

Modern data center power architectures require sophisticated telemetry, offering real-time insights into voltage, current, power consumption, and thermal conditions across various points in the system. This rich data enables engineers to move beyond reactive troubleshooting, allowing them to monitor performance trends, predict potential issues before they escalate into failures, and optimize power distribution for maximum efficiency. In essence, it's about transforming raw electrical data into actionable intelligence, ensuring that the power stays on, and providing the crucial "why" behind every operational decision.



Current Sensor Solutions to Meet Evolving Data Center Demands

Isolation Innovation

In the densely packed and high-power environment of modern data centers, robust electrical isolation is not merely a feature; it's a fundamental safety and performance imperative. As power supplies transition to higher voltages, such as with a 48V architecture, the need for reliable voltage withstand capabilities become more pronounced. Traditional solutions relying on discrete components cannot scale from 12V up to 48V without negatively impacting solution size, component count, and solution cost. Magnetic current sensors, on the other hand, offer a solution which is inherently robust across both 12V and 48V supplies due to non-contacting technology.

Even higher voltages are needed within power supply PFC inputs and isolated DC-DC converters, where both advanced magnetic current sensors and isolated gate drivers play essential roles. Advanced magnetic current sensors offer integrated isolation as a transformative advantage. By incorporating isolation directly into the sensor package, achieving levels up to 500 VRMS reinforced or 1000 VRMS basic, these devices dramatically simplify the design process. They eliminate the need for external isolators and components, shrinking the overall PCB footprint, and streamlining assembly. All these things contribute to a lower overall system cost.

Similarly, advanced isolated gate drivers simplify SiC-based power supply unit (PSU) designs by eliminating the need for external bias supplies and reducing PCB footprint. Their integrated bias generation and low common-mode capacitance architecture minimize EMI at the source, enabling cleaner switching and easier compliance with EMI standards. These capabilities are especially critical in the high voltage, high frequency environments of modern data centers.

Power Density Powerhouse

In the relentless pursuit of higher power density, the traditional shunt resistor presents a significant hurdle. While seemingly simple, a shunt resistor generates heat as current flows through it, leading to power losses. This wasted energy must then be dissipated, often requiring thermal management components such as heatsinks, which further consume board space and add to the overall system size. This direct trade-off between current measurement and thermal management creates a constant design challenge, especially as power levels increase and form factors remain fixed.

Current transformers (CTs), often used for high-speed isolated current measurements, present their own set of challenges. While they offer inherent isolation, their physical size can be substantial. This bulk consumes valuable board space and adds to the overall height of the power supply unit, directly impacting the ability to miniaturize designs and pack more power into a given volume. Integrating CTs often necessitates additional circuitry, further increasing component count and design complexity, all of which are working opposite to the goal of maximizing power density within the tightly constrained server environments.

Magnetic current sensors offer an innovative solution to these power density challenges, acting as an alternative to both shunt resistors and current transformers. By sensing the magnetic field generated by the current, these integrated devices lessen the power losses and heat associated with shunts, leading to significantly cooler operation and reducing the need for thermal solutions. These benefits result in higher system efficiency. At the same time, their compact, single-chip footprint directly addresses the spatial inefficiencies of current transformers. This combined efficiency and miniaturization frees up valuable board real estate, drastically reduces BOM complexity, and ultimately enables the higher power densities essential for next-generation datacenter designs.

In parallel, isolated gate drivers further advance power density goals by integrating bias generation and minimizing external component requirements. Their low common-mode capacitance architecture reduces EMI and switching losses, allowing for higher switching frequencies and smaller magnetics. Together with magnetic current sensors, these drivers form a complementary foundation for compact, efficient, and thermally optimized power conversion in modern datacenter architectures.

Warp Speed

To effectively harness the revolutionary capabilities of GaN and SiC, power supply designers are increasingly turning to advanced magnetic current sensors. Unlike traditional shunt-based solutions, which introduce parasitic inductance and resistance that can distort high-frequency signals and slow response times, magnetic sensors offer a fundamentally different approach. By sensing the magnetic field generated by the current, these devices enable ultra-fast, accurate current monitoring, ensuring that the critical feedback loop is not compromised by the very speed and high-voltage transients that characterize GaN and SiC operation.

This unique operational principle enables magnetic current sensors to deliver the lightning-fast response times crucial for protecting sensitive GaN/SiC components and enabling ultra-fast control loops. They can detect transient overcurrent events in microseconds, or even nanoseconds, providing the immediate signal necessary to trigger protective shutdowns or adjustments before thermal stress can damage these high-value semiconductors. By directly tackling the need for speed in high frequency switching applications, magnetic current sensors empower engineers to push the boundaries of efficiency and power density with confidence, knowing that their cutting-edge designs are safeguarded against rapid, unforeseen electrical events.

At the same time, high-voltage gate drivers are essential for translating those rapid control signals into precise switching actions at the device level. Their optimized propagation delay, strong drive strength, and reinforced isolation ensure clean, reliable transitions even in the presence of large common-mode voltage swings. By integrating bias generation and minimizing parasitic coupling, these drivers reduce EMI and switching losses, allowing designers to exploit the full switching speed of wide bandgap devices without sacrificing stability or robustness.

Beyond the Amp: Intelligent Monitoring

While accurate current measurement is fundamental, the demands of modern datacenter power management extend beyond reporting instantaneous values. Engineers require more than just raw data; they need actionable intelligence to optimize performance, predict failures, and ensure continuous operation. This requires a shift towards more "intelligent" current sensors that can perform critical calculations and detections at the sensor level, offloading valuable processing power from the main microcontroller (MCU). Tasks such as RMS current calculation, zero-crossing detection, and even power measurement are increasingly being integrated into the sensor itself, freeing the host MCU to focus on higher-level system control and complex algorithms, rather than being burdened with repetitive, real-time data processing.

This intelligent offloading provides engineers with invaluable telemetry, transforming raw electrical signals into meaningful insights for diagnostics and predictive maintenance. By continuously monitoring and processing current, voltage, and power data directly at the point of measurement, these advanced sensors enable a granular understanding of system health and behavior. This rich, real-time information allows for the early detection of anomalies, the identification of power consumption trends, and the precise optimization of energy distribution. Ultimately, intelligent current sensors empower datacenter operators to move from reactive troubleshooting to proactive management, ensuring that the power stays on, and providing the crucial data needed to make informed decisions for maximum efficiency and reliability.

Powering the Future with Precision Sensing and Intelligent Gate Driving

The relentless pace of innovation in artificial intelligence, cloud computing, and connected technologies continue to drive an exponential demand for power within data centers. Engineers are perpetually challenged to achieve unprecedented levels of power density, operational efficiency, and unwavering reliability within static physical constraints. From the shift to 48V architectures and the adoption of lightning-fast GaN semiconductors, to the critical need for compact designs and robust protection against unforeseen electrical events, the path forward demands sensing solutions that are as advanced as the systems they monitor. Magnetic current sensors and high voltage gate drivers have emerged as a new technology, uniquely positioned to address many of these multifaceted demands, enabling the next generation of high-performance power architectures.

These innovative components offer a compelling answer to the industry's most pressing challenges. The inherent high bandwidth of magnetic current sensors provides the speed necessary to protect sensitive wide-bandgap devices and enable ultra-fast control loops, pushing the boundaries of efficiency without fear of thermal runaway. In parallel, high-voltage gate drivers deliver the precise control and reinforced isolation required to safely and efficiently switch these devices at ever-higher frequencies. Their integrated bias generation and low common-mode capacitance architecture reduce EMI and simplify design, helping engineers achieve smaller, cooler, and more reliable systems. Together, these technologies simplify power-stage design, improve reliability, and unlock new levels of performance for dense datacenter environments.

Integrated isolation within both magnetic sensors and gate drivers ensures safety in high-voltage domains while reducing component count and board complexity. Their compact, highly integrated footprints act as true power density enablers, freeing valuable PCB area and minimizing thermal and electrical constraints. Furthermore, the evolution toward intelligent sensing and driving technologies empowers engineers with richer telemetry and cleaner control, transforming raw electrical behavior into actionable insights for predictive maintenance, optimized power delivery, and long-term system resilience.

Table 1. Device Recommendations for Magnetic Current Sensors

Product	Package	Isolation	Peak Current	Features
ACS37030/32 MY	SOICW-6	500V RMS Reinforced	65A	High BW DC to 5 MHz
CT433	SOICW-16	550V RMS Reinforced	65A	High BW DC to 1 MHz
CT427	SOIC-8	560V RMS Basic	65A	High BW DC to 1 MHz
ACS37220	4x4 mm QFN	100V Functional	200A	100μΩ conductor
ACS37800	SOICW-16	565V RMS Reinforced	90A	V/I/P RMS Calculator
CT456	TSSOP-8	Field Sensor	Field Sensor	Contactless Field Sensor
ACS37611	TSSOP-8	Field Sensor	Field Sensor	Contactless Field Sensor

Table 2. Device Recommendations for Isolated Gate Drivers

Product	Integrated Transformer	Switch	Driver Power	Polarity	Working Voltage	Package
AHV85110	Yes	GaN	18 nC x 8V	Unipolar	1000	DFN-10
AHV85111	Yes	GaN	18 nC x 8V	Bipolar	1000	DFN-10
AHV85311	Yes	SiC	130 nC x 25V	Bipolar	1500	SMT-26, SOICW-24

Conclusion

For engineers navigating the complexities of modern data center power design, the message is clear: the future is being built with precision, efficiency, and intelligence, one sensor and gate driver at a time. We invite you to explore how these advanced magnetic current sensing and high-voltage gate driving solutions can transform your next-generation designs, helping you unlock higher power densities, enhance system reliability, and accelerate your time to market.

Engage with our experts to [discover how these technologies](#) can empower you to confidently push the boundaries of what’s possible in data center power.