The Case for 48V Centric Power Modules Has Never Been Stronger

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Advancing semiconductor technology and global competitive forces have resulted in a stunning increase in the power density of numerous equipment types in the industrial, automotive, aerospace and high-performance computing markets over the last ten years. The vast energy required to power generative AI computing data centers is at the forefront of this megatrend.

If power systems engineers do not consider new approaches to address these exponential increases, power supplies will become an ever-greater contributor to increased system size (specifically volume), weight and cost.

Furthermore, all other things being equal, the rise in equipment power demands will see an equivalent rise in thermal management requirements, contributing to the expansion of power system form factors and recurring costs. Clearly, new approaches (including architectures, topologies and packaging methods) and innovative solutions are urgently needed.

48V-centric power modules with high conversion efficiency and power density have arrived to meet these intertwined and complex challenges.

Evolution from 12V to 48V Power Delivery Networks

The transition across numerous markets from 12V toward 48V power delivery networks (PDN's) is accelerating. For example, the first 48V PDN electric vehicles are on the road today with many in development, and 48V distribution within data center racks among Hyperscalers is now commonplace. Power system design engineers should weigh the relative merits of 48V PDNs as a logical starting point for the power delivery architecture of their electrical power subsystem.

The transition to 48V-centric power distribution is not without challenges. The 12V centric power component ecosystem offers maturity and know-how accumulated over about 75 years. There is a multiplicity of 12V optimized power component and power supply options available on the market, and power system designers are typically comfortable with this technology in all its facets. By comparison, the 48V-centric power components and subsystems are less established, with wide 48V adoption in data center server racks first appearing in 2021.

Power system engineers are less familiar with power components and subsystems needed to support a 48V-centric PDN design, and have relatively less development experience with 48V distribution hub architectures. However, by sourcing 48V DC-DC converter power modules, with integrated magnetics can eliminate areas of technical and commercial risk and uncertainty, as the module manufacturer assumes all design, sourcing, testing, quality and reliability responsibilities, shielding the end system designer from this ecosystem immaturity (Figure 1).

Additionally, many existing 12V subsystem loads are fully cost-optimized and are not financially or functionally sensible to replace in the short to medium term, so bridging between a 48V and 12V centric PDN can achieve the optimal system design. Importantly, both 12V and 48V are considered SELV (Safety Extra Low Voltage) levels, so moving to 48V power distribution hubs does not compromise human safety.

Types of 48V-Centric Power Modules

There are many types of power modules that offer a full DC-DC converter function, with high power density and some that incorporate integrated magnetics. High voltage (up to 920VDC) BCM's (fixed-ratio DC-DC bus converter modules), are typically galvanically isolated (4,242V is typical and a conversion ratio of K = 1/8 yields 50VOUT from 400VIN for example and a K = 1/16 yields 50VOUT from 800VIN).

NBM's (low-voltage non-isolated fixed-ratio bus converters) are also available (K = 1/4 yields 12V from 48VIN) and enable the bridging function between the 48V and 12V centric PDN's. Regulated DC-DC converters are also available. A good example of a regulated fixed-ratio converter is the DCM3735, a 2kW, 160A, 48V to 12V converter (Figure 2).

Power system engineers can take advantage of these power modules by utilizing higher system bus distribution voltages requiring lower current to deliver

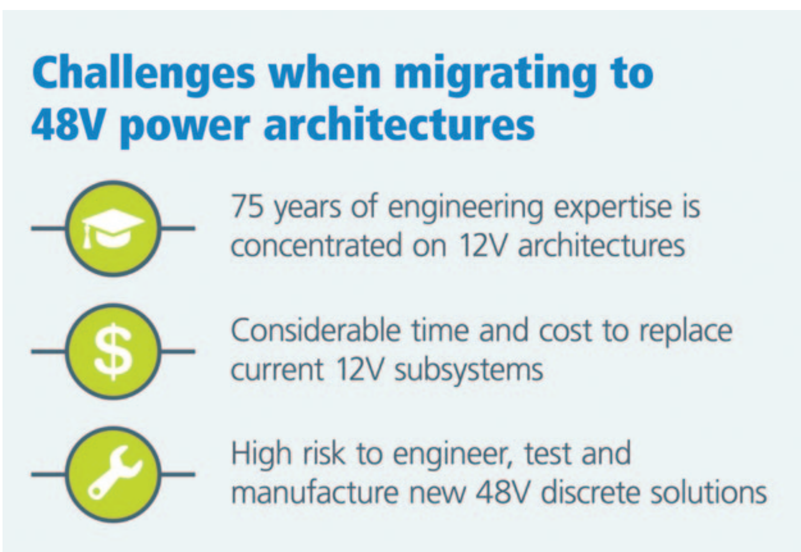

Figure 1: The 12V ecosystem is well established and in many cases is fully cost-optimized. So bridging between a 48V and 12V-centric power delivery network using DC-DC converter modules is the optimal solution to ease the path to 48V power designs.

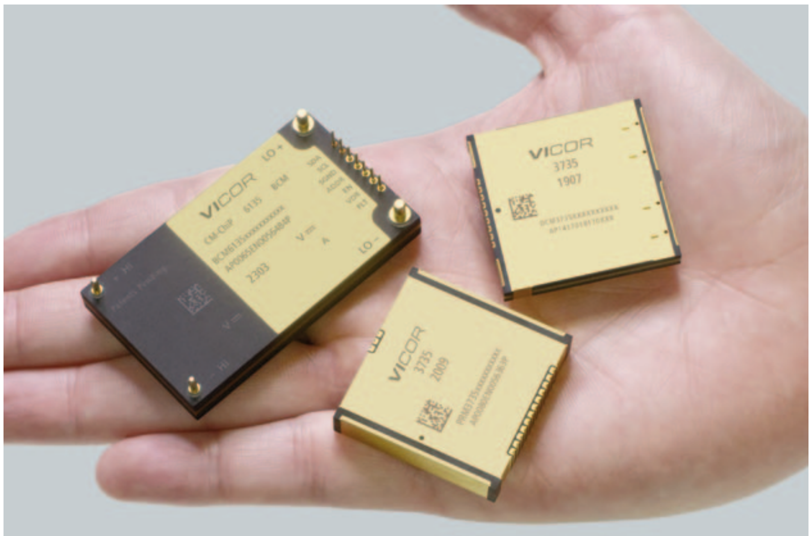

Figure 2: Vicor automotive grade BCM6135, DCM3735 and PRM3735 power modules have set a new standard for power density in the automotive industry. Collectively they solve complex conversion challenges with 800V, 400V, 48V and 12V systems for xEVs power systems.

the same power. For OEMs, this consequence of Ohm's Law can yield superior electrical, mechanical and thermal performance, higher overall system efficiency and significant economic benefits.

Important Attributes to Look for in a Power Module

A top-level attribute of best-in-class 48V-centric power modules is high volumetric power density (continuous output power per cubic inch or W/in3), achieved through innovative circuit structures and topologies, as well as state-of-the-art thermal and mechanical packaging. A related distinguishing characteristic of power modules is package thickness, which can be as thin as 7mm in advanced products. Thin packages enable lower thermal resistance, and three-dimensional electroplating (i.e., bottom, top and sides) provides a coplanar thermal conduction interface perfectly suited for heat sinks and coldplates (Figure 3).

Due to increasing equipment electrification across broad sectors of the global economy and the rising power demands across numerous end-market equipment types, liquid cooling solutions are increasingly more popular. This trend is synergistic with overmolded, high power density, thin power modules, which are exceptionally thermally adept (i.e., high thermal conductivity as measured in watts per meter per Kelvins). Designers should also consider overmolded 48V-centric power modules with integrated magnetics, as an easier way to present a planar thermal interface of all power dissipative components to heat sinks, heat pipes or coldplates.

Power conversion efficiency is a critically important performance parameter. At high output power levels, the power loss heat load is substantial, even when continuous conversion efficiency is relatively high. For example, at 2.4kW (50AOUT at 48VOUT) at 98% efficiency is still 48W of power loss that must be continuously thermally managed. Therefore modules should offer very high DC-DC conversion efficiency across operating temperature to simplify thermal management solutions.

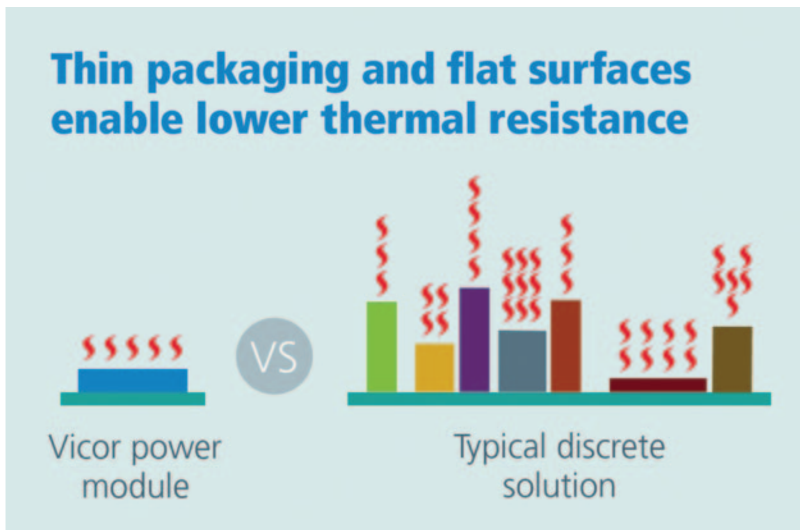

Figure 3: The thermal engineering of modern electronic systems has become a key design consideration. Discrete power designs are typically more complicated arrangements and are more challenging to cool compared to modular solutions that are thinner, more uniform designs. Thin packages enable lower thermal resistance, and three-dimensional electroplating (i.e., bottom, top and sides) provides a coplanar thermal conduction interface perfectly suited for heat sinks and coldplates.

Robust and Simplified System Designs

Overmolded power modules are also mechanically robust and more thermally adept easing the thermal management design challenge. Modules that offer full DC-DC converter solutions with integrated magnetics also minimize external circuitry, easing the system design process. For systems requiring industrial grade, military grade or automotive grade, modules are qualified by their manufacturer to rigorous electrical, mechanical and environmental standards, including temperature cycling, humidity exposure and shock/vibration testing, and are automatically production tested (i.e., using ATE) as a complete system to well-specified performance limits. This eliminates the need for the OEM to conduct separate qualification and performance characterization tests.

From the OEM perspective, power modules are a single bill of materials (BOM) item (Figure 4). The fact that there are dozens of components within the module is opaque to the end customer. By contrast, a discretely implemented power supply has a multiplicity of components that must be purchased, kitted, assembled, tested and managed (due to potential product obsolescence) over the lifetime of the equipment that utilizes the power supply. The use of a system-level DC-DC converter power module therefore effectively eliminates numerous points of failure, increasing end-product quality. The purchasing effort and inventory management costs of power modules are significantly lower than discrete component power systems. This allows power systems engineers to leverage their trusted supplier's cutting-edge materials science, circuit design and conversion topological innovation with little to no learning curve overhead.

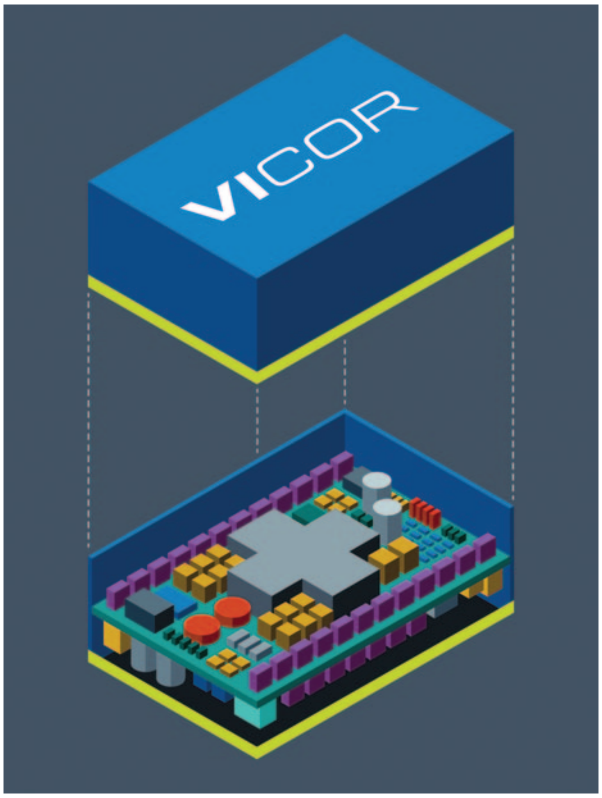

Figure 4: Pre-qualified miniaturized power modules offer a number of benefits over discrete designs. Power modules are a single bill of material (BOM) item and eliminate numerous points of failure. The fact that there are dozens of components internal to the module is opaque to the end customer. By contrast, a discretely implemented power supply has many components that must be purchased, kitted, assembled, tested and managed over the lifetime of the equipment.

Ease of Use and Power Scaling Considerations

For power scaling needs and achieving a faster design time, power modules should be capable of operating in current-shared parallel arrays. As the power system demands increase, it is possible to double or quadruple the output power through a relatively easy subsystem redesign.

An important characteristic of modern PDNs is reverse (or bidirectional) operation. The classic example is electric vehicle regenerative braking, where energy is returned to the battery pack from the traction motor inverters during braking. Bidirectional operation appears in many electrification use cases, and best-in-class power modules will offer either instantaneous reverse power conversion or reverse power conversion under digital control. Fixed-ratio BCMs and NBMs are inherently bidirectional and enable new depths of innovation.

In some specific cases, modules are designed to comply with a variety of standards, including FCC/EU EMI (conducted and radiated), as well as safety and environmental standards administered by CE, ECHA RoHS, CSA, UKCA, TUV and UL/IEC. High voltage isolated power modules should have also undergone high potential (HIPOT) safety testing. This is a significant reduction in engineering operating expense (otherwise frequently outsourced) and the capital expense of related test equipment, as well as a valuable project schedule risk reduction mitigation. Additionally, module-level product safety certifications are vital for gaining power-subsystem-level regulatory approvals.

A trusted supplier should provide comprehensive technical support and collateral, including complete data sheets, application notes, electrical, 3D mechanical and thermal simulation models, design guides and evaluation board systems. These are essential tools for design engineering success.

Electric Vehicles Save Weight and Capitalize on Transient Response with Power Modules

Automotive BEV and recreational light electric vehicle (LEV) OEMs need to show continuous performance improvement aspects beyond those of their gasoline-powered progenitors to continue to win new customers. Vehicle acceleration and battery life (i.e., vehicle range) are critical performance elements that often influence the buying decisions of EV consumers.

Small size and weight, high volumetric power density and simple, inexpensive, robust passive cooling solutions are of vital consumer marketing value to OEMs. Additionally, the use of a module-level PDN solutions frees the vehicle system designers to focus on other product development tasks because modules with high power density can solve the size and weight problems of a design.

Superior load transient response of topologies such as the Vicor SAC™ (Sine Amplitude Converter) enables numerous innovative applications in electric vehicles, including active suspension, drive-by-wire, steer-by-wire, 12V and 48V battery and supercapacitor elimination. Best-in-class modules offer industry-leading efficiency and power density, delivering outstanding electrical performance even when de-rated for use with passive heat sinks (or in some chassis or body mount applications). The robust mechanical construction of overmolded modules is well suited to the harsh environments of rugged electric recreational vehicles.

The use of a 48V zonal architecture results in much thinner cabling throughout the vehicle, which is a substantial weight and cost savings (Figure 5). Furthermore, thinner distribution power bus wires are easier to route, giving vehicle chassis and body designers more freedom from three dimensional design constraints. The reduced cable power dissipation at 48V also yields improved vehicle range.

The automotive EV designs are migrating rapidly to 48V distribution hubs with 12V zones for legacy subsystems. The global auto industry supply chain will drive rapid cost reduction of the components of this “zonal architecture” to the benefit of LEV developers.

Consider choosing a 48V module supplier that can offer automotive-grade modules with APQP process and AECQ-100 qualification attributes. These automotive grade modules are also available to LEV platform developers in the event they require AECQ-100 level reliability.

Factory Automation Equipment Benefits from Thinner Wiring and “massimetric power density”

Industrial robots are evolving to include autonomous (untethered and battery-powered) capabilities and integrated genAI inferencing processors.

Importantly, 48V cabling saves robot weight and cost versus 12V cabling, and is far easier to route mechanically, which is helpful for anthropogenic (humanoid) robots designs that are relatively trim.

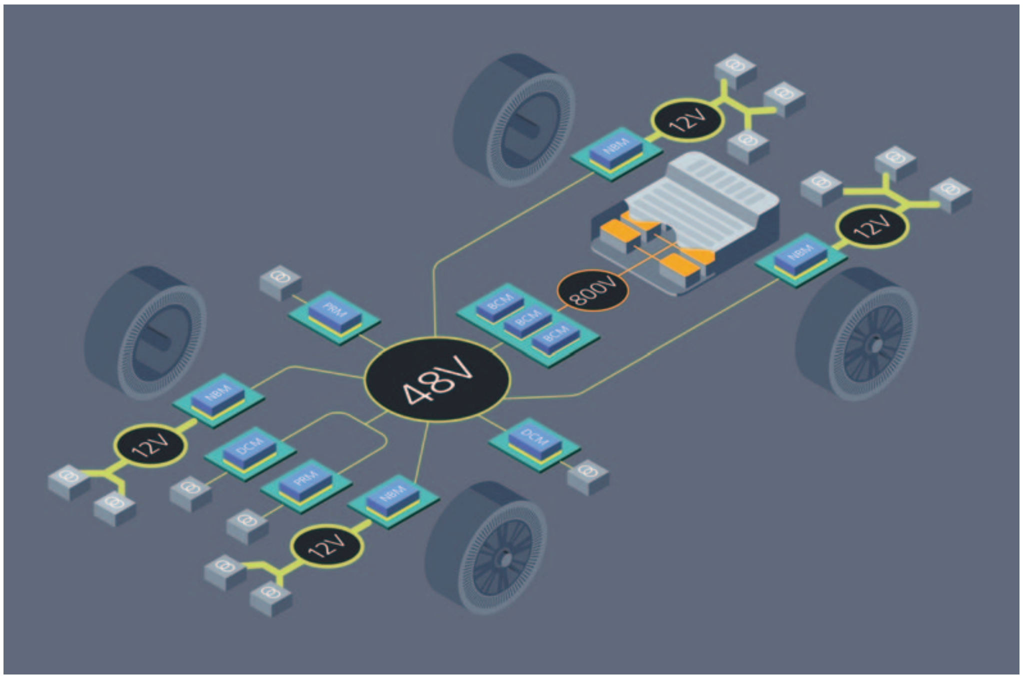

Figure 5: EVs are migrating toward 48V power delivery networks with 12V zones to accommodate legacy subsystems. Vicor compact, lightweight DC-DC converters make point of load conversion easy and highly efficient.

Some industrial mobile robots are quite small, so small 48V power modules and thinner wire harnesses are clearly advantageous for these designs (Figure 6).

Higher volumetric power density means lower robot weight for the same level of power delivery as alternative lower power density solutions, which extends operating time between battery recharges; this is a critical end-customer purchasing consideration.

For autonomous vehicular robots, including limbed humanoid robots, an important power delivery criterion is "massimetric power density." This is measured in continuous output watts per gram (W/g). Robot weight defines many performance aspects given the physical constraints of battery size, cost and chemical power density. Every opportunity to reduce weight is valuable, including the weight of the power delivery 48V DC-DC converters. 48V DC-DC converters appropriate for robot designs are capable of delivering more than 60W per gram (2kW at 29 grams) – a solid benchmark for regulated output converters.

Power Modules Accelerate the Adoption of 48V

These two real-world market segment examples illustrate and underscore the tremendous advantages that 48V-centric (HVDC to 48V and 48V to 12V) high-power-density modules bring to a broad spectrum of industrial, high-performance computing, aerospace and defense and automotive power system designs. In aggregate, the multiplicity of technical, economic and performance-based advantages that 48V power delivery networks enable for next-generation equipment hardware designs are extremely compelling.

Vicor power modules offer industry-leading high voltage (800V/400V to 48V to 12V) zonal bridging, and low-voltage, high-current point-of-load solutions that address all modern hardware design requirements. With the world's first ChiP™ (Converter housed in Package) high volume fabrication process, and a fully vertically integrated and automated factory, Vicor is ready and able to meet today's advanced 48V power module demands.

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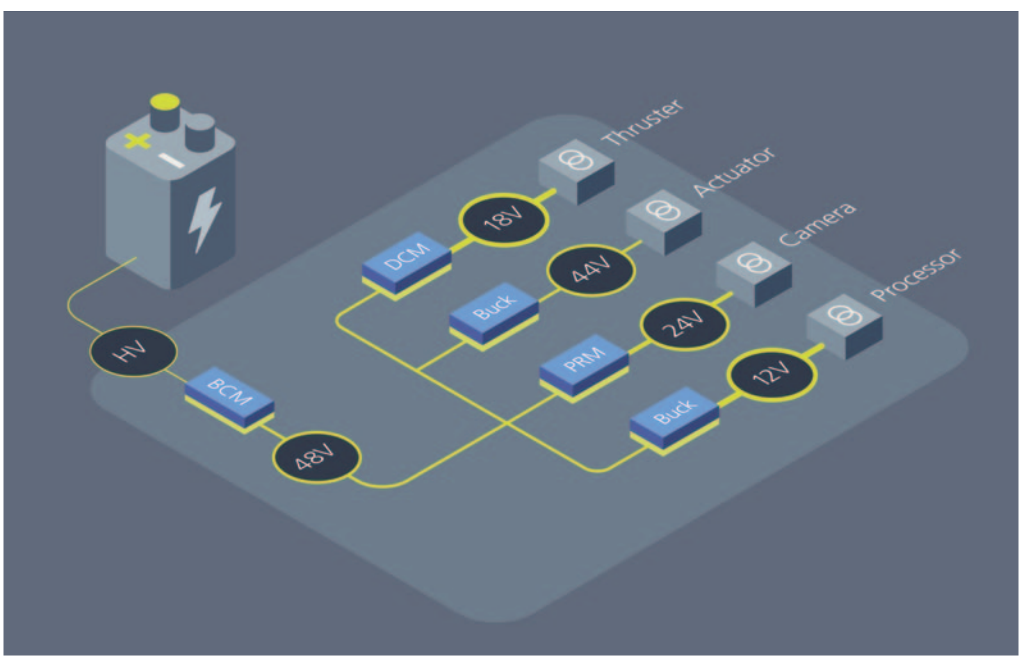

Figure 6: Humanoid robots have numerous power domains with diverse loads. Vicor's broad family of 48-centric power modules adds flexibility to the design process and can accommodate many loads with high efficiency.