eBook

Accelerate your move to a high performance 48V power delivery network

VICOR

Introduction

This eBook provides guidance on designing 48V power delivery networks to enhance the performance, efficiency, and reliability of industrial products. You will learn how the 48V PDN evolved, how to overcome power design challenges, and examples of how others have implemented successful power delivery. You will also learn how to leverage high performance power modules to quickly prototype and implement a 48V PDN.

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The evolution of 48V: Powering the next generation of innovation

Power system design engineers across numerous industries are under constant pressure to deliver higher system performance and functionality. To meet the challenge, system power levels have been rising at an exponential rate while pressures mount to reduce system size and weight for added functionality, to increase efficiency and to manage increasingly complex thermal designs. This ongoing challenge—doing more with less—is driving a generational evolution in power delivery networks (PDNs). At the heart of this evolution is the transition from legacy 12V systems to high-efficiency, scalable 48V architectures that can unlock new power system capabilities and innovation.

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Originally adopted in the telecommunications industry decades ago, 48V architectures later gained a foothold in advanced high-performance computing (HPC), in electric vehicles (xEVs) and in an increasingly broad set of industrial applications. In each case, the strong technical and business merits of 48V brought clear competitive advantages. Compared to 12V systems, 48V PDNs reduce conduction losses by 16x and simplify power distribution.

Why move to 48V?

The efficiency gain and other advantages of 48V are rooted in a well-known and fundamental electrical principle—Ohm's Law—which governs the relationships between voltage, current, and resistance. Power is the product of voltage and current, VI, but the power loss due to resistance in conductors is proportional to the square of the current (i.e., I^2R loss). For the same power level, increasing the system voltage from 12V to 48V reduces the current by a factor of four, which results in a 16x (42) reduction in I^2R conduction thermal dissipation losses. The power system design benefits of such a significant reduction in power loss include:

- Lower heat dissipation
- Enhanced overall efficiency
- Thinner, lighter power distribution cables and smaller connectors
- Increased system reliability

For systems with power requirements exceeding several kilowatts, this shift isn't just beneficial—it's often a practical necessity to achieve evolving system performance goals.

The early adopter: telecom industry pioneers the use of 48V

The earliest adoption of 48V systems occurred in telecommunications infrastructure more than a hundred years ago. For decades, central offices, cell towers, and network nodes have relied on 48V battery-backed systems due to its ideal balance of safety, signaling range, and efficiency. This voltage level enables systems to remain comfortably below the safety extra-low voltage (SELV) limit of 60V, as defined by standards such as IEC 60335, while minimizing distribution losses over long cable runs.

This approach has allowed telecom operators to deploy scalable, reliable power systems across wide geographic areas. As telecom networks grew in complexity and size, 48V has proven to be robust and adaptable, establishing the foundation for its broader adoption in other industries.

48V in high-performance computing

The second major wave of 48V adoption came with the rise of high-performance computing and hyper-scale data centers over the last decade. The explosion of cloud computing, generative AI model training and inferencing, and machine learning has created massive power demands at the server rack, compute cluster and data center levels. Traditional 12V power distribution became a prohibitively limiting factor due to high current requirements, excessive copper usage, and snowballing thermal management issues. Power delivery entails not just the distribution of power but also end-to-end conversion efficiency, solution size and cost, and thermal management overhead (whether forced air or liquid cooled). Data centers have realized a 16x reduction in PDN distribution losses by switching to a 48V power architecture.

Moving from 12V to 48V PDNs is enabling data centers to:

- Improve rack-level energy efficiency
- Deliver higher power levels with thinner copper wiring
- Simplify bus-bar power distribution within server racks
- Reduce total cost of ownership (TCO) by reducing energy usage

Driven by the dynamic needs of their hyper-scale data center customers, server OEMs have adopted 48V PDNs. The Open Compute Project (OCP) was an early promoter of 48V de facto standards and over the past five years, 48V PDNs have been instrumental to the development of high-density, high-efficiency compute platforms capable of supporting modern GenAI workloads.

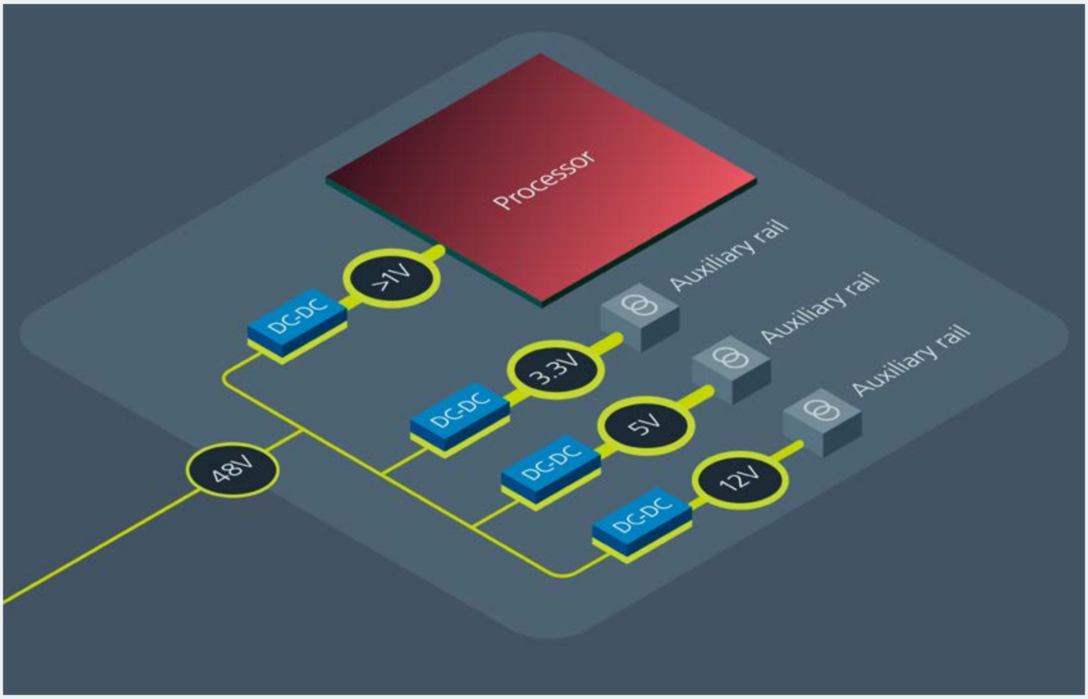
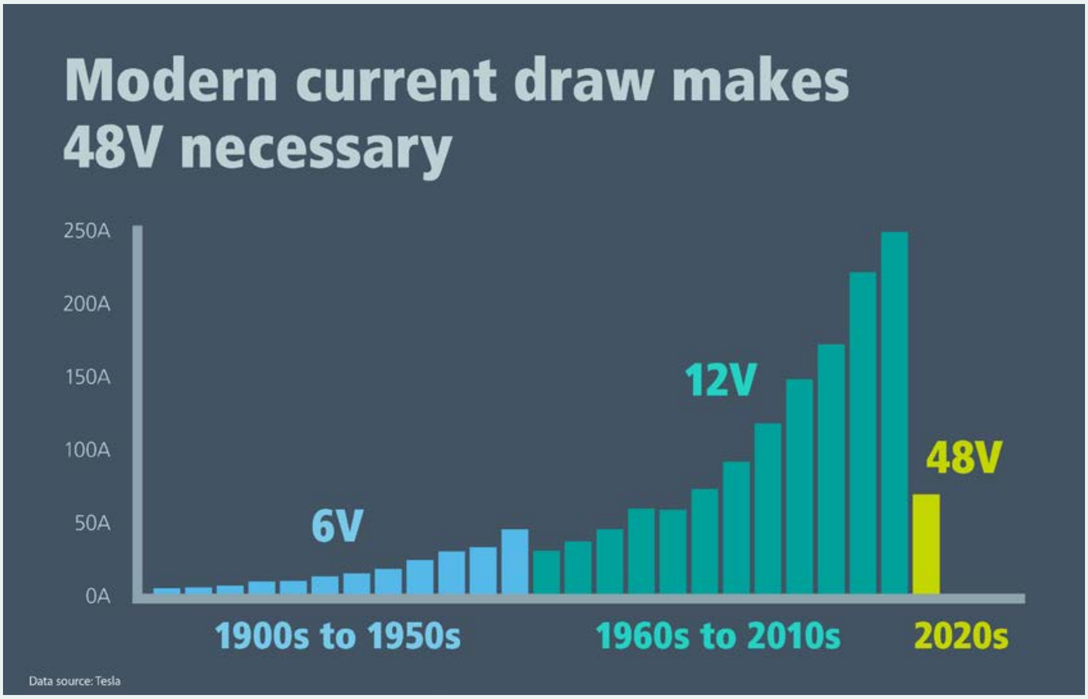


Figure 1: High-performance computing systems distribute 48V across server rack busbars for delivery to compute blades, network switches and storage trays. The 48V rail is regulated to 12V, 5V, 3.3V for auxiliary loads, and to 1V and below for the high-current processor core rail.

Rapid adoption of 48V in automotive applications

The automotive industry is undergoing a profound transformation as many vehicles evolve into electrified platforms, not only requiring more electrical power but also broader distribution of that power throughout the vehicle. Advanced driver-assistance systems (ADAS), infotainment, electric power steering and active suspension systems all place heavy demands on PDN architectures.



Data source: Tesla

Figure 2: 6V power delivery met the needs of vehicles and industrial equipment for five decades. For the rest of the 20th century and early 21st century, 12V power sources and subsystems were adequate, but rapidly rising current levels made the transition to a higher system voltage inevitable. With a quadrupling of voltage (and 16 times less conductive loss to deliver the same power), 48V is the optimal choice when SELV compliance is required.

Traditional 12V power systems were simply not intended to handle these growing electrical loads; the required current cannot be efficiently delivered using 12V networks alone. Consequently, automakers are transitioning to dual-voltage 12V/48V architectures that offer several key benefits:

- Improved fuel efficiency internal combustion engines (ICEs) through hybridization
- Reduced emissions via start-stop systems and regenerative braking and active suspension systems
- Support for high-power subsystems like infrared cabin heaters, instantly-heated windows, and heat pump HVAC
- Electrification of previously belt-driven systems, reducing mechanical complexity and boosting overall vehicle performance and reliability
- ADAS systems with braking-by-wire and steering-by-wire

The rise of 48V in industrial markets

Test and measurement, robotics, drones, medical equipment and factory automation are all industrial segments benefiting from the transition to 48V PDNs.

Industrial systems often face similar space, weight and thermal constraints as their counterparts in other markets. By adopting 48V PDNs, designers deliver more power in smaller footprints while simplifying cable routing and reducing cooling costs. Consider the semiconductor test and measurement market, where automated testers for high-performance memory and processors face the same pressing challenges as data centers with respect to supplying power-hungry AI processors in a compact space.

The 48V PDN benefits for industrial equipment mirror those in telecom, HPC and automotive markets:

- Smaller, lighter power delivery systems
- Better thermal characteristics and higher energy efficiency
- Increased power capacity and overall system performance

Additionally, the availability of purpose-built and scalable 48V power modules makes it straightforward to rapidly design and prototype low-noise and power-dense systems for a wide variety of applications.

Understanding the 48V ecosystem

The transition to 48V is best considered as a transition from a 12V ecosystem to a 48V ecosystem. The 12V ecosystem has existed for decades, with an enormous installed base infrastructure backed by decades of investment and practical experience. The 48V ecosystem, in comparison, is still developing and evolving. Fortunately, advanced modular power solutions exist today that simplify the design and implementation of 48V PDNs.

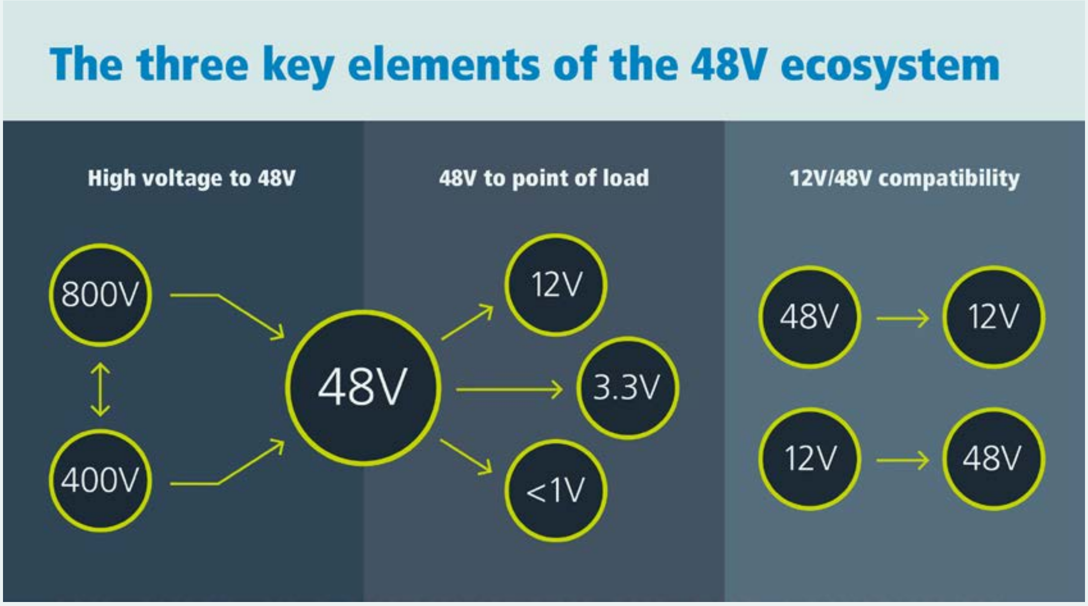


Figure 3: The 3 key elements include all conversion steps, from the source to the point of load.

To simplify the transition away from 12V power delivery, consider the three key PDN elements of the 48V ecosystem. High voltage to 48V conversion is essential as electric vehicles establish a long-term trend towards cost-optimized 800V and 400V batteries. Semiconductors (particularly processor and memories) generally use relatively low voltages at current levels that vary widely but are trending higher. Cost-efficient and lower-performance 12V subsystems are still common in electronic equipment of all types, so efficient bridging from 48V to 12V and 12V to 48V (for regenerative braking for example) are essential. By keeping these three PDN elements in mind, it is possible to rapidly design and prototype a new 48V-centric PDN, achieving the highest power and current density. Scalable modular power components future-proof 48V PDNs, while reducing power losses and simplifying thermal management. Lastly, integrated low-noise solutions simplify input and output EMI filter design.

Converting high voltage to 48V efficiently

In many systems—particularly those with mains AC or high-voltage DC inputs—the first stage is stepping down from a high-voltage source (e.g., 380V, 400V or 800V) to create a 48V bus. This is best achieved using high-efficiency, isolated bus converters. These front-end modules offer:

- High power density to minimize solution size
- Extremely high conversion efficiency to reduce operating energy cost
- Best-in-class thermal performance to minimize heat removal overhead
- Regulatory compliance to ensure low consulting engineering expense
- Electrical isolation to ensure end user safety and avoid liability

A successful design within this element lays the foundation for a robust 48V PDN that can power all defined loads downstream. Typically, high voltage to SELV conversion presents size, weight and efficiency compromises. Identifying a suitable DC-DC converter presents a variety of challenges, including size, weight, packaging, design tool availability, etc. Highly integrated and power-dense DC-DC converter modules offer many benefits for designs which are space-constrained and require flexibility and scalability.

Converting power to the point of load directly from 48V

Once a central 48V bus is established, power must be delivered to the various subsystems of the equipment design—processors, sensors, actuators, motors, LEDs—at precise voltages and with fast transient response if needed. These conversion and regulation stages must offer high efficiency when converting to low voltages (e.g., sub 1V, 3.3V, 5V), offer small form factors and precise voltage regulation to meet the demands of modern digital and analog subsystems.

Non-isolated bus converters are ideal for stepping down 48V to 12V. These fixed-ratio DC-DC converters offer high efficiency and power density. To convert 12V to the point-of-load rails, a factorized power architecture (FPA™) solution is well suited to the task, where a regulator (typically placed relatively distant from the load) feeds a voltage transformation current multiplier (typically placed very close to the load). This arrangement enables the delivery of up to hundreds of amps at low voltage, while minimizing PCB resistive losses.

Bridging 48V-centric systems to legacy 12V peripherals

High-efficiency, fixed-ratio bus converters enable seamless coexistence between the 48V backbone and existing 12V loads. This architectural flexibility is critical for:

- Gradual system design upgrades due to constrained engineering resources
- Situations in which low volume 12V subsystems are unlikely to be redesigned for 48V native operation
- Compatibility with existing high volume 12V off-the-shelf components and subsystems

By leveraging bidirectional K = 1/4 fixed-ratio bus converters, designers can migrate to a 48V PDN and continue to support legacy 12V subsystems as required.

The challenges of adopting 48V

While the benefits of 48V power are clear, adoption does come with challenges. For decades, 12V systems have enjoyed a vast ecosystem of components, tools and engineering expertise. In contrast, 48V design requires:

- Understanding new safety and isolation standards
- Selecting optimized components including efficiency, performance, size, weight and cost
- Managing EMI and thermal dissipation
- Developing new PCB layout practices
- Designing power scalability

The Vicor 48V power delivery ecosystem

To help accelerate the adoption of 48V PDNs, Vicor has developed a comprehensive ecosystem of power modules optimized for 48V applications. These modules are characterized by high power density (W/in^3) and high current density (A/mm^2). The Vicor modular approach enables designers to architect end-to-end 48V systems using building blocks that are:

- Extremely compact and power dense to enable form factor flexibility
- Highly efficient across a wide load range to minimize end user operating costs
- Electrically isolated where needed to ensure safety standards compliance
- Thermally optimized using modern packaging to minimize heat removal hardware

Thermally adept module packages, combined with high functional integration shortens design cycles, reduces engineering risk and enables scalable designs across a wide range of power levels.

The Vicor portfolio includes solutions for all three elements of the 48V ecosystem:

- Converting high-voltage to 48V: BCM® and DCM™ modules for efficient front-end conversion
- Converting 48V to PoL voltages: DCM modules, ZVS buck regulators, and VTM™ and PRM™ modules (supporting Factorized Power Architecture)
- Bridging 48V and legacy 12V systems: DCM, NBM™ and ZVS buck-boost regulators that enable single and bidirectional DC-DC conversion

48V is the new 12V

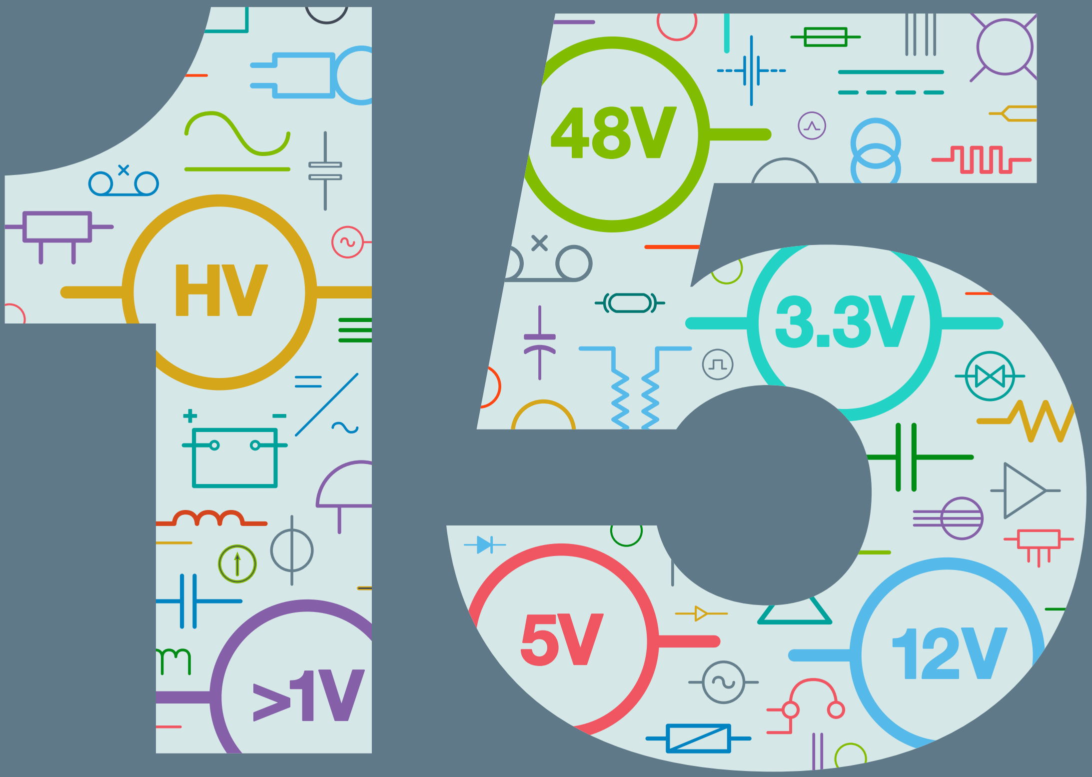
From its roots in telecommunications to its expanding presence in the computing, automotive and industrial sectors, 48V is transforming how power is delivered in modern electronic systems.

With project timeline schedules shrinking, the simplicity of using power-efficient scalable modules to implement a 48V power architecture is becoming even more compelling.

The generational evolution from 12V to 48V power delivery is more than a simple voltage change. It is an acknowledgment that electronics system design generally is evolving – more capability and capacity is needed to support emerging end-customer requirements and expectations.

48V PDNs empower engineers to develop more compact, efficient, and reliable equipment designs able to meet the demands of advanced technologies. The comprehensive solutions, topologies, architectures and technical support from companies like Vicor enable a straightforward and successful migration process.

While some challenges remain, the ecosystem around 48V power is rapidly maturing. The design tools, resources, components and application engineering support needed for success are now available. As design engineers confront increasing power demands in constrained form factors, 48V PDNs will serve as a critical enabling technology ingredient — powering future system innovation.



Article

15 technical challenges to consider and conquer when designing a 48V power delivery network

The benefits of moving to 48V power delivery networks are well documented. However, the technical challenges are not as evident. As development engineers embark on their first 48V designs, questions naturally arise. To help you better prepare for your 48V migration consider the following 15 challenges.

1 Producing the highest efficiency at the first conversion stage

An important element of the high voltage (HV) to 48V power delivery network (PDN) design is providing isolation that complies with regulatory safety standards.

Regulation often is not required in the first stage of conversion, which allows the use of advanced topologies, specifically fixed-ratio Sine Amplitude Conversion (SAC™). Fixed-ratio SAC bus converters use a resonant circuit architecture that minimizes transformer leakage inductance, maximizing conversion efficiency. Additionally, the use of zero-voltage and zero-current soft switching minimizes switching-dependent switching losses, further enhancing efficiency. SAC bus converters provide strong (typically more than 4,000V) galvanic isolation, bidirectional operation and very high transient response. Fixed-ratio 800V and 400V SAC bus converters are available in small modular form factors, offering full compliance to creepage and clearance standards.

2 Reducing noise near sensitive loads

As power systems become more compact, it becomes increasingly important to protect loads that are sensitive to noise by using converter topologies that possess low inherent switching noise. Converters that use a high switching frequency shift the conversion noise byproducts into higher frequency bands where they can be more easily filtered, causing less disruption to sensitive loads. Soft MOSFET switching methods such as zero-voltage switching (ZVS) and zero-current switching (ZCS) emit less EMI noise and thus minimize disturbances that might otherwise affect noise-sensitive loads.

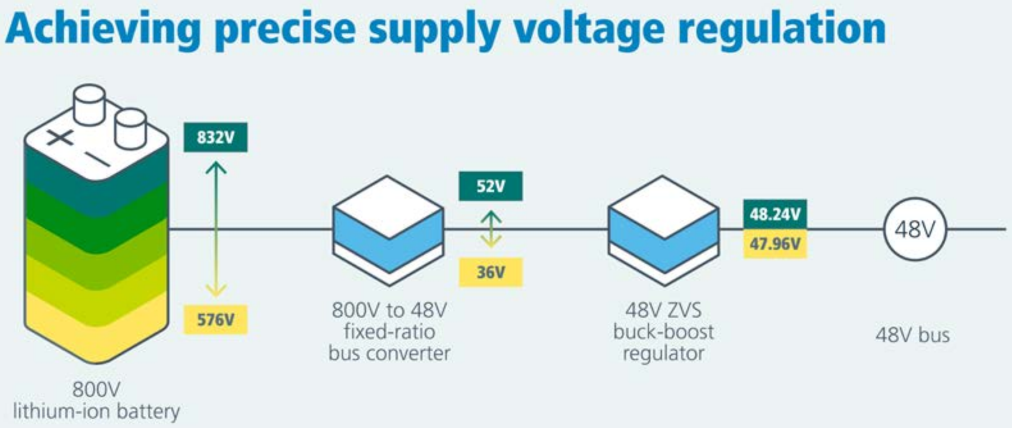


Figure 1: The output voltage of an 800V battery might range from 576 to 832V, due to state of charge, age, temperature and other factors. A high-efficiency fixed-ratio bus converter outputs a nominal 48V but reflects this wide range. A second-stage ZVS buck-boost converter regulates this range to a precise 48V for use downstream.

3 Providing a tightly regulated 48V bus

Some subsystems and peripherals have migrated to native 48V operation, particularly those with power requirements higher than what 12V supplies can reasonably provide. While some of these subsystems do not require a tightly regulated 48V rail, others do need precise supply voltage regulation.

The need for a regulated 48V bus can arise when converting high-voltage DC source to 48V with an isolating fixed-ratio bus converter, which typically does not have a regulated output. If the bus converter is being fed by a 400V or 800V battery, the bus converter's output can vary widely depending on the battery state of charge, as well as ambient temperature, battery age and the specific load characteristics. For example, the output voltage of an 800V battery might range from 576 to 832V. With a K = 1/16 bus converter, this input voltage range corresponds to an output voltage range of 36 – 52V.

In this case, the use of a ZVS buck-boost DC-DC converter stage can be helpful. For example, a typical 800W ZVS buck-boost converter might offer a wide input voltage range (such as 38 – 60V, 48V nominal), and a nominal 48V output trimmable from 30 to 54V. The output voltage load regulation of a ZVS buck-boost converter of this class might be 0.3% and the typical conversion efficiency might be 97.7% at full load. This level of performance is likely to meet the requirements of the most demanding 48V loads.

4 Identifying the optimal place for power regulation – upstream or down?

Where to regulate the 48V rail depends on the system design. If there are no 48V "native" subsystems, and all the loads operate at 12V, 5V, 3.3V or sub-1V, there is no practical need to regulate the 48V power bus. In this case, the regulation can occur in the "bridging" conversion to 12V or in the point-of-load conversion from 48V to low voltage using a buck regulator.

For 48V to 12V bridging applications, a regulated non-isolated DC-DC converter is appropriate, with the continuous and peak output power scaled to the load requirements. The input voltage range should be wide enough to support any variability on the 48V bus. The 12V regulation tolerance depends on system requirements; ZVS buck regulators might have a typical output voltage load regulation limit of 0.1%.

For 5V, 3.3V, 1.8V and sub-1V regulated point-of-load processor power applications, it can be advantageous to split the regulation function and the current multiplication function. This functional partitioning is referred to as factorized power architecture (FPA™). FPA defines a precise regulation stage followed by a voltage transformation stage or a current multiplier stage that delivers high current levels at precisely regulated supply voltages. The current multiplier transformation "K factor" determines the output voltage, for example K = 1/48 delivers 1V to the load. The level of current provided by the 48V source is correspondingly multiplied by 48. Factorized power architecture allows the regulator stage and the current multiplier stage to be physically separated, to reduce component "congestion" or crowding around the processor.

5 Powering high-current loads

A significant challenge with powering high-current loads is minimizing conduction losses in the printed circuit board copper traces or tracks. One approach to powering high-current, low-voltage loads (such as AI processors) is factorized power architecture (FPA™). In this architecture, a high-power regulator stage converts 54V to 48V with high efficiency. This regulator stage can be placed at the periphery of the accelerator PCB, to avoid contention with other functions, including memory and high-speed serial I/O. The regulator stage tightly regulates the 48V supply, making further downstream regulation unnecessary.

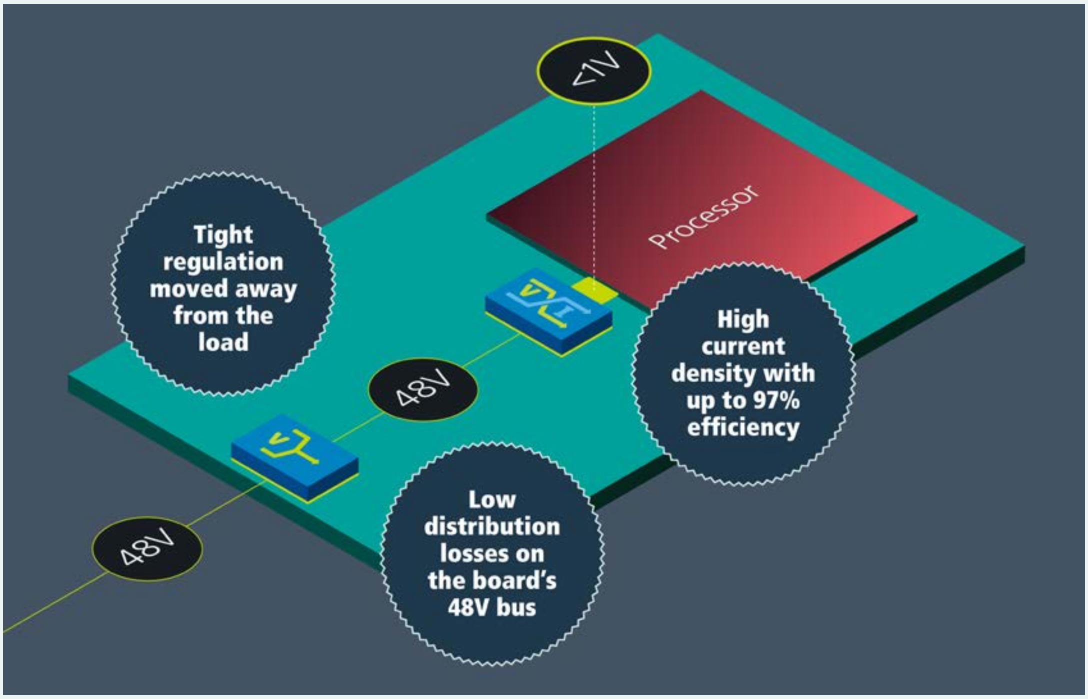


Figure 2: In a factorized power architecture, the first-stage regulator is relatively remote from the processor, freeing board area for other critical functions. The second stage current multiplier uses high efficiency fixed-ratio conversion to transform 48V to 1V (or other low voltages) and can be placed either laterally or vertically beneath the processor to limit PCB conduction losses.

Use of 48V as the intermediate bus voltage minimizes conduction losses. A voltage transformation stage or current multiplication stage is placed lateral to the processor (lateral power delivery) or ideally vertically beneath the processor (vertical power delivery). The placement minimizes the copper PCB trace length between the current multiplier and the processor power and ground connections to reduce the PCB impedance and associated resistive thermal losses. The voltage transformation and current multiplier blocks are fixed-ratio converters that can deliver hundreds of amps at sub-1V levels. The FPA approach can meet the power delivery needs of the most advanced CPUs, GPUs and network processors.

6 Attaining safe enough isolation at high voltages

High-voltage (800V and 400V) power delivery systems should provide thousands of volts of galvanic isolation. Ideally, these systems should also provide up to 100MΩ of insulation resistance, and sufficient creepage and clearance provisions to meet industry safety requirements, such as IEC 60664-1. Discrete designs based on standard switching topologies are limited in their ability to achieve high isolation ratings because of parasitic capacitance between components, inability to design with adequate creepage and clearance distances, and the difficulty of synchronizing high-speed switching while maintaining dielectric integrity across isolation barriers.

DC-DC converters based on SAC topologies can achieve extremely high voltage isolation ratings thanks to zero-voltage and zero-current switching. These soft-switching techniques reduce EMI and minimize voltage stress across the isolation barrier, which enables the use of compact magnetic structures without compromising insulation performance. As a result, SAC topology DC-DC converters can integrate high-isolation transformers and maintain efficiency even in dense, high-voltage environments where discrete component solutions often fail.

7 Designing for safe creepage and clearance when board space is tight

When high-voltage components are packed tightly on a PCB, the risk for electrical arcing (clearance) and electrical tracking (creepage) increases. Note that arcing and tracking are impacted by working voltage, pollution level, altitude, moisture and humidity, insulation material, and transient voltages. While potting approaches can help mitigate risk, fully-molded packaging is a far more effective solution. The use of a power-dense integrated solution is a better choice because the components required to implement the power system are encapsulated within the epoxy-molded package, lowering or eliminating the risk of arcing and tracking. It is important that the power solution supplier tests for creepage and clearance compliance with standards such as IEC 60664-1 and 62368-1.

8 Overcoming the lack of an extensive 48V component ecosystem

Today the 48V component and associated ecosystem is not as well developed as the 12V component ecosystem, which has developed over many decades. In many cases, 12V components and subsystems are fully cost-optimized with many sources of the same function competing on price. A reasonable system architecture choice may be to retain 12V subsystems when they can meet system performance goals and to choose 48V subsystems where the higher voltage provides key performance advantages. Because of the relative scarcity of 48V power components for discrete power supply implementation, modular 48V DC-DC converters can be an attractive option. The use of modular power converters dramatically reduces product development, test time, expert engineering resources and expense. They also enable rapid prototyping and reduce the burden of bill-of-materials procurement and component lifecycle management.

Where combining the two approaches is desirable, adopt a 48-to-12V bridging strategy. If the 48V bus is already regulated, a 48V to 12V fixed-ratio non-isolated bidirectional bus converter is ideal, as the conversion efficiency is typically extremely high. If the 48V bus is not regulated, a non-isolated zero-voltage switching (ZVS) buck DC-DC converter can provide a 12V regulated output from a 48V unregulated source.

9 Accommodating high peak power demands without overbuilding the power delivery network (PDN)

Many real-world systems exhibit periods during which the power demand peaks on an intermittent basis. But it can be a needless expense to design a power system specified for intermittent peak power (load step) demands. Point-of-load capacitors are typically used to supply energy to accommodate peak power spikes. Often power systems offer a short duration (for example 20ms) peak power capacity that can reach 50% higher than the continuous output power specification.

Fixed-ratio SAC bus converters can deliver a rapid instantaneous response (millions of amps per second) which can reduce the need to over-specify the output power rating to handle peak power demands. These converters also exhibit a unique capacitive multiplication attribute: input capacitance is multiplied by the square of the K factor, appearing as an effective output capacitance. This characteristic reduces the amount of capacitance otherwise needed to meet peak load step demands.

10 Improving the efficiency and reliability of switching devices

DC-DC converter efficiency is related to conversion topology and partitioning, MOSFET switching frequency and other factors. A converter topology that uses zero-voltage switching and zero-current switching can offer higher efficiency than alternative topologies. Factorized power architecture, with a high-efficiency regulator first stage, and a voltage transformation / current multiplier second stage offers exceptional efficiency, by virtue of the fixed-ratio current multiplier, which acts as an ideal DC-DC transformer. A high MOSFET switching frequency minimizes circuit parasitics and helps to increase conversion efficiency. Advanced packaging with low thermal resistance and coplanar top and bottom surfaces for heat sinks and coldplates increases reliability (i.e., higher MTTF) by reducing the maximum internal temperature of the power module.

11 Maintaining a very compact, cooled power delivery network

Clearly, the most effective way to keep a compact PDN cool is with the use of high-efficiency DC-DC converters. Beyond that, compact power systems must deal not only with the heat dissipation from the individual components and modules, but also with the mutual heating of the closely spaced components and modules. Generally speaking, either air-cooled or liquid-cooled hardware must be used with high power (above about 1kW) PNDs. The higher the power density (W/in^3) of the power system, the more important it is to use an active (air- or liquid-based) cooling system to ensure high reliability. Power system components with high conversion efficiency and low thermal impedance packaging are essential to a more passive approach to cooling, especially for compact PDNs.

12 Getting a stable output across a wide input range

Some electronic subsystems, such as microprocessors, memories and data converters must be provided with stable supply rails to avoid permanent internal device damage (advanced semiconductor process transistors are sensitive to supply voltage). The purpose of power regulation stages is providing, for example, a precisely regulated 48V output (~0.2% typical output voltage load regulation) from a wide-ranging input (40 – 60V is typical). This allows the first-stage regulator to work with a battery-fed bus converter where the nominal 400V battery might range from 340 to 460V depending on its state of charge, temperature and age. A K = 1/8 fixed-ratio stage converts this range to 42.5 – 57.5V, which falls within the input range of the regulator. Depending on the use case, a wide input range regulator is essential for functional compatibility.

13 Achieving high transient response

There are various electronic and electro-mechanical systems that are characterized by highly transient or instantaneous demand for power. For example, 12V and 48V batteries in automobiles serve transient current demands from different subsystems (such as from an HVAC motor) within the car. Another example are the current transients that result from changes in the algorithmic loading of a multicore data center AI processor. In both cases, the best PDN solution to handle these transients are fixed-ratio converters using the Sine Amplitude Conversion (SAC™) topology. This type of converter utilizes a high switching frequency, allowing energy to be transferred to the output more frequently, assisting with transient current demand events. They are also characterized by low output AC impedance, which helps to keep the output voltage stable during transient events. Converters leveraging SAC also act as capacitance multipliers, where the input capacitance is multiplied by the square of the transformation ratio (K) and effectively appears on the output. This capacitance multiplication effect improves the overall transient performance of the PDN.

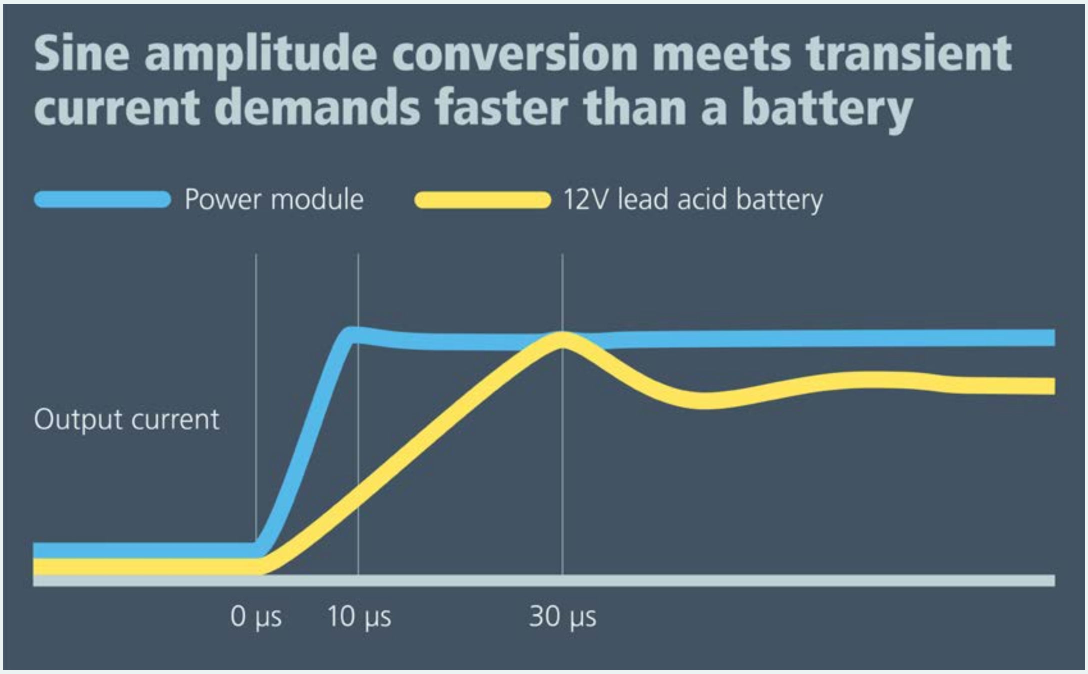


Figure 3: High switching frequency resonant Sine Amplitude Converters use soft switching (ZVS and ZCS). They are characterized by high control bandwidth, low AC output impedance and input capacitance multiplication, which all contribute to extremely high transient response, exceeding that of lead acid batteries.

14 Accommodating legacy 12V loads

Most systems will include 12V loads, for example 12VDC fans. These 12V subsystems are often cost-optimized over many years of production and may not be economically attractive to replace with 48V alternatives. For these subsystems, a 48V to 12V DC-DC converter would be ideal when a regulated supply rail is required, and a 48V to 12V non-isolated bus converter would be ideal when a non-regulated supply rail is sufficient. The non-isolated bus converter solution can provide a regulated output to the 12V subsystem if an upstream 48V DC-DC converter provides regulation.

15 Ensuring your 48V delivery network is scalable and easy to prototype

It is common for the power demands of various electronic systems to increase over time. For example, in computer systems, additional memory or network hardware might be added. Ideally, the ability to scale up the power delivery network capacity without a major system redesign is advantageous. This takes some advanced planning but can be accomplished.

Some modular DC-DC converters support array operation in which multiple devices operate in parallel to double or quadruple the output power. Ideally, there is a simple wire interconnect current sharing scheme to form this power array. The advantage of this approach is that a board can be laid out for two or four parallel devices, with only one populated initially. Then, if the power requirements of the system increase over time, one to three (or more) devices can be added and a few jumpers connected, enabling the power system to scale up to meet new system power requirements.

Straightforward power delivery scaling supports the fast-turn evaluation and prototyping of different design options and expands the possibility of design reuse for systems with different power requirements.

Modular power solutions are far easier to prototype with than discretely implemented alternatives. They are compact, have relatively few I/O connections, and require minimal external components. Importantly, they are pre-tested and pre-certified to industry and regulatory standards. When time-to-market is a critical project objective, power modules offer an attractive value proposition.

Due diligence eases your 48V migration and ensures top performing power delivery networks

The first widespread adoption of 48V system power can be traced back more than 100 years, when the nascent telephone industry recognized the efficiency and transmission distance benefits. More recently, the Open Compute Project has advocated for 48V power deliver within data center racks. Some electric vehicles are now employing 48V system power.

The pace of this generational change from 12V PDNs to 48V PDNs is now accelerating. It’s a question of when rather than if systems will migrate to 48V. The pressure from automotive electrification, the extreme pace of artificial intelligence computing, and the emergence of high-power industrial applications are converging on 48V power delivery networks. While power engineers have decades of experience and confidence with 12V PDNs, questions loom for design teams when migrating to higher capacity 48V PDNs. Discrete systems have been effective with 12V power designs for decades, but when set against evolving power delivery challenges, they can fall short. In many cases ongoing industry innovation – including architectures, topologies and packaging – will ease the implementation of next generation 48V challenges. This innovation will intensify the migration to 48V and help deliver scalable, high-density, future-proofed PDNs.

Article

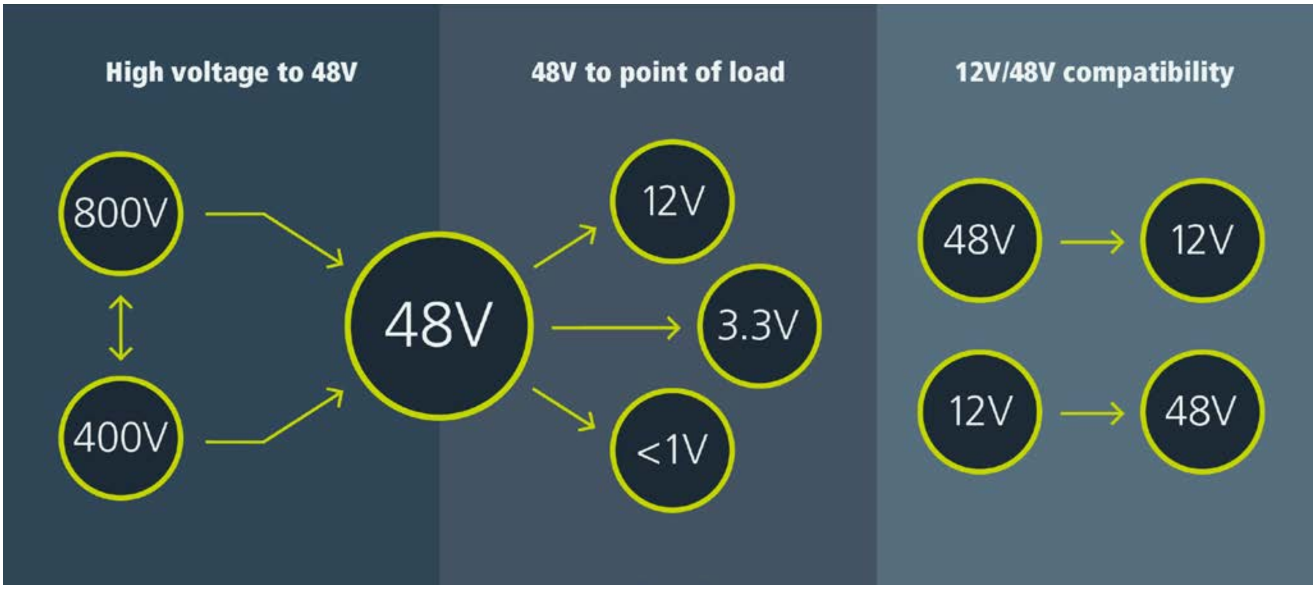
High performance power modules optimized for 48V power delivery networks

Solutions for the entire power delivery network

The transition to 48V power delivery networks is accelerating across industrial, AI/data center and automotive applications due to higher demands for more power from the same system size and weight.

Vicor high-density modular power conversion is essential in space-constrained designs that require flexibility and scalability. Power modules' low noise simplifies filter design, and their thermally-adept packaging simplifies thermal management to significantly reduce power losses. The broad Vicor ecosystem of advanced power modules, architecture and topologies simplify the transition to 48V by allowing for quick prototyping and implementation of a complete 48V power delivery network.

The three essential power system design elements in 48V power delivery networks



Element 1: Converting high voltage to 48V

Industry-leading power density and innovative architectures of Vicor power modules equip power designers with either isolated or non-isolated solutions that reduce the size and weight of power systems and enable the advantages of a 48V bus.

Element 2: Powering the point-of-load from a 48V bus

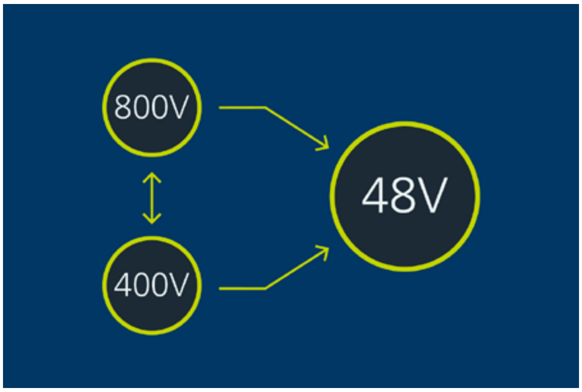
Our DC-DC converters and regulators enable efficiencies and superior size/weight performance, while also providing the flexibility and scalability the modular approach to power is known for.

Element 3: Bridging between 48V and legacy 12V systems

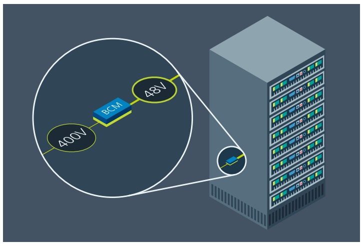
Our regulated and fixed-ratio converters are easing the transition to inherent efficient 48V power delivery while alleviating the burden of re-designing systems that for decades have been optimized around 12V architectures.

Converting high voltage to 48V

The initial element for power designs is the conversion of rectified AC or high-voltage DC inputs to 48V. Isolated, high-efficiency converters are used to step down from voltages such as 800V or 400V. Industry-leading power density and innovative architectures of Vicor power modules equip power designers with either isolated or non-isolated solutions that reduce the size and weight of power systems and provide the most efficient solution establishing a 48V bus.

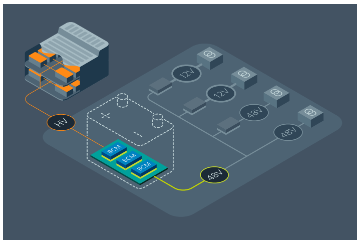


Application examples



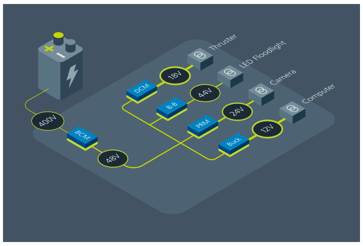
Data centers

By moving AC-DC rectification and battery backup to a central location, high voltage power distribution in data centers can increase the number of processors in each rack by fourfold.



Automotive

The fast transient response of power modules allows for the elimination of the intermediate 12V or 48V battery, reducing considerable weight and space consumption within an EV.



Robotics and UAVs

Converting a high-voltage input into a 48V bus allows robots to save valuable space and weight, enabling more productivity, functionality and increased run time.

Power modules to convert high voltage to 48V

BCM® bus converter

Isolated fixed-ratio

Input: 800 – 48V

Output: 2.4 – 55.0V

Current: Up to 150A

Peak efficiency: 98%

As small as
22.0 x 16.5 x 6.7mm

vicorpower.com/bcm

DCM™ DC-DC converter

Isolated regulated

Input: 9 – 420V

Output: 3.3, 5, 12, 13.8, 15, 24, 28, 36, 48V

Power: Up to 1300W

Peak efficiency: 96%

As small as
24.8 x 22.8 x 7.21mm

vicorpower.com/dcm

MIL-COTS DCM™ DC-DC converter

Isolated regulated

Input: 28, 30, 270V

Output: 3.3, 5, 12, 15, 24, 28, 48V

Power: Up to 1300W

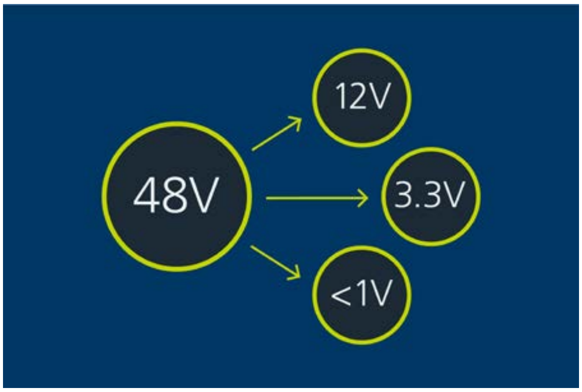
Peak efficiency: 96%

As small as
0.98 x 0.90 x 0.28in

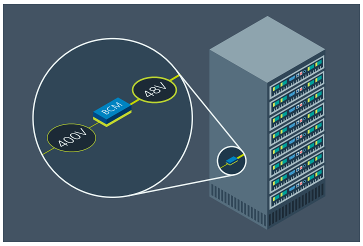
vicorpower.com/mil-cots-dcm

Powering the point-of-load from a 48V bus

48V to point-of-load converters deliver power to processors, sensors, motors and other loads. Vicor DC-DC power modules — buck and buck-boost converters, voltage regulators and fixed-ratio bus converters — provide high power at low voltages, offer fast transient response and precise voltage regulation in compact form factors with superior size and weight performance. They also provide the flexibility and scalability the modular approach to power is known for.

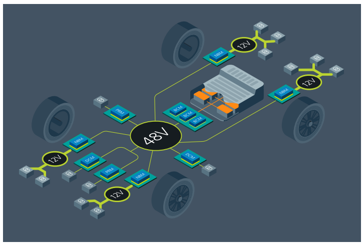


Application examples



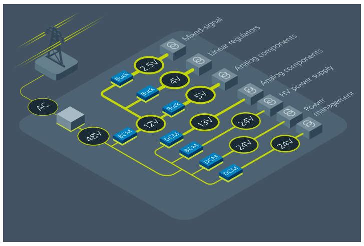
Computing

Vertical power delivery enables previously unattainable performance levels necessary for processors to fulfill the promise of high-performance applications such as AI.



Automotive

Power modules support more than 300 configurations, providing building blocks to deploy the right power to each point-of-load within a 48V zonal architecture.



ATE

Manufacturers of test equipment can readily scale power levels and support different voltages, and allow for maximum throughput in the same floorspace.

Power modules to convert 48V to the point-of-load voltage

DCM™ DC-DC converter

Isolated regulated

Input: 9 – 420V

Output: 3.3, 5, 12, 13.8, 15, 24, 28, 36, 48V

Power: Up to 1300W

Peak efficiency: 96%

As small as 24.8 x 22.8 x 7.21mm

vicorpower.com/dcm

ZVS buck regulator

Non-isolated regulated

Input:12V (8 – 18V), 24V (8 – 42V), 48V (30 – 60V)

Output: 2.2 – 16V

Current: Up to 22A

Peak efficiency: 98%

As small as 10.0 x 10.0 x 2.56mm

vicorpower.com/buck

ZVS buck-boost regulator

Non-isolated regulated

Input: 8 – 60V

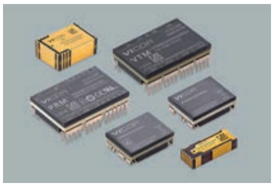
Output: 10 – 54V

Power: Up to 150W continuous

Peak efficiency: 97%

10 x 14 x 2.56mm

vicorpower.com/buck-boost



PRM™ and VTM™ modules

Isolated regulated

Input: 48V (36 – 75V)

Output: 0 – 55V

Current: Up to 130A

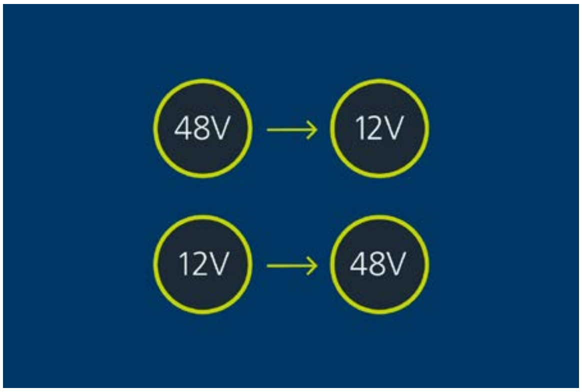
Peak efficiency: 97%

As small as 22.83 x 8.52 x 4.9mm

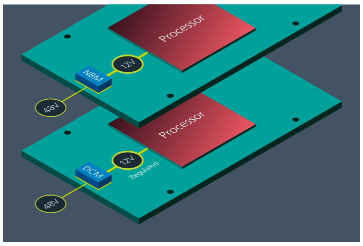
vicorpower.com/prm-vtm

Bridging between 48V and legacy 12V systems

48V and 12V compatibility eases the transition to 48V and allows legacy 12V loads to coexist with new 48V architectures. Vicor bidirectional and conventional converters support gradual upgrades that enable hybrid mixed-voltage environments and compatibility with off-the-shelf components. This alleviates the burden of completely redesigning systems that for decades have been optimized around 12V architectures.

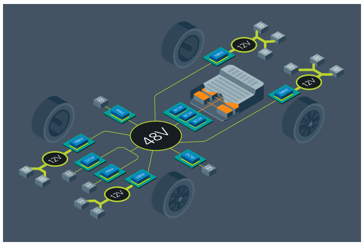


Application examples



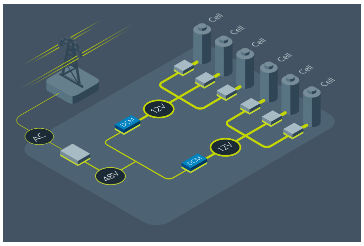
Data centers

Modules can power legacy 12V boards in a 48V data center infrastructure. Bidirectional modules can help integrate the latest GPU into a legacy 12V infrastructure.



Automotive

Power modules enable efficient 48V architectures while eliminating the gating factors of risk and timeframes re-engineering the many legacy 12V systems being used.



Battery testing

48V power delivery provides significant size, weight, and efficiency benefits while maintaining legacy 12V buses to power the cell monitor and balancing control units.

Power modules that convert 48V to 12V and 12V to 48V

DCM™ DC-DC converter

Non-isolated regulated

Input: 40 – 60V

Output: 10 – 12.5V

Power: Up to 2kW

Peak efficiency: 96.5%

As small as
36.7 x 17.3 x 5.2mm

vicorpower.com/dcm48to12V

NBM™ bus converter

Non-isolated fixed-ratio

Input: 36 – 60V

Output: 7.2 – 15.3V

Power: Up to 2400W

Peak efficiency: 98%

As small as 23 x 17 x 5.2mm

vicorpower.com/nbm

ZVS buck regulator

Non-isolated regulated

Input:12V (8 – 18V),
24V (8 – 42V), 48V (30 – 60V)

Output: 2.2 – 16V

Current: Up to 22A

Peak efficiency: 98%

As small as
10.0 x 10.0 x 2.56mm

vicorpower.com/buck

Case studies

VICOR

Case study: Autonomous electric shuttle

Advanced power module packaging optimizes available power, reliability and safety

Customer's challenge

Low-voltage (48V) autonomous electric shuttles have advanced self-driving systems that navigate complex urban environments. The GPU and sensors are vital components for autonomous operation and rely on high-performance ATX power supplies. These supplies must be compact and lightweight to fit in the vehicle, operate with high efficiency to minimize heat, and maintain exceptional reliability. To keep up with evolving needs, the power system must be scalable to accommodate increasing GPU power requirements and adapt to higher voltage batteries. The main challenges were:

- Avoid overheating and improve thermal management
- Efficiently power GPU to increase functionality and safety
- A versatile and scalable solution to adapt to evolving needs

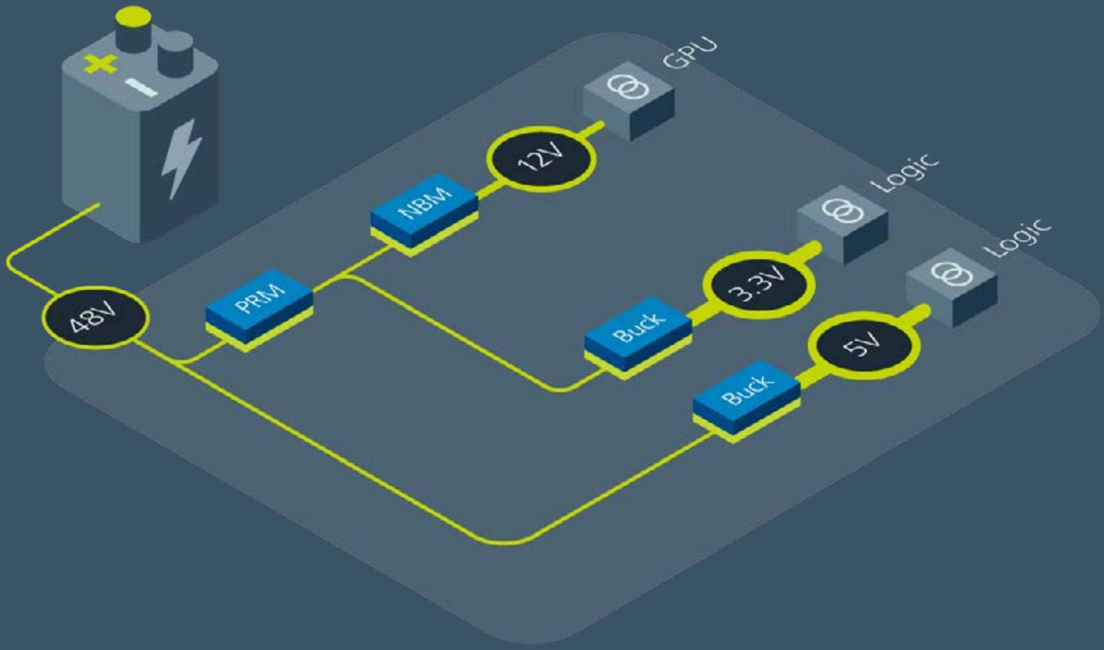
The Vicor solution

Vicor high-efficiency power modules ensure minimal heat dissipation, reducing the need for complex cooling solutions and maximizing power. This translates into higher available power and increased system reliability critical for safety. The high-power density of Vicor modules saves space and weight to enable improved vehicle run time and optimize space on board for additional GPU power and functions. Key benefits were:

- Advanced packaging and high efficiency reduce cooling needs
- Easy to scale solution adapts to different vehicles and platforms
- High performance power modules optimize power consumption increasing range and functionality

The Power Delivery Network

A combination of Vicor PRM™ and NBM™ modules – Factorized Power Architecture – efficiently steps down a 36 – 75V input to a stable 12V output. This solution offers scalable performance up to 1200W, ensuring seamless adaptation to the increasing demands of evolving processors. Vicor Zero-Voltage Switching (ZVS) buck converters provide direct, high-current (10A+) conversion from the battery to standard 5V and 3.3V logic rails. This direct conversion minimizes losses and ensures reliable power delivery to critical system components. This power delivery network allows for the vehicle to be retrofitted with a 400V battery by simply adding a bus converter module upstream of the PRM module.



NBM™ bus converter

Non-isolated fixed-ratio

Input: 36 – 60V

Output: 7.2 – 15.3V

Power: Up to 2400W

Peak efficiency: 98%

As small as 23 x 17 x 5.2mm

vicorpower.com/nbm

ZVS buck regulator

Non-isolated regulated

Input:12V (8 – 18V),
24V (8 – 42V), 48V (30 – 60V)

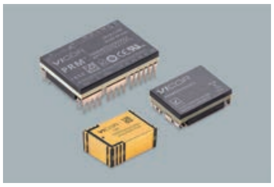
Output: 2.2 – 16V

Current: Up to 22A

Peak efficiency: 98%

As small as
10.0 x 10.0 x 2.56mm

vicorpower.com/buck



PRM™ regulator

Non-isolated regulated

Input: 48V (36 – 75V)

Output: 48V (5 – 55V)

Power: Up to 600W

Peak efficiency: 98%

As small as
22.0 x 16.5 x 6.73mm

vicorpower.com/prm

VICOR

Case study: Dragonfly Pictures unmanned multirotor aerial relay (UMAR) tethered drone

Tethered drones revolutionize remote communications

Customer's challenge

As today's navies become more sophisticated, the demand for more reliable communications and intelligence, surveillance, and reconnaissance (ISR) has grown. To withstand the harsh weather conditions, the industry has turned its attention to vertical lift-off tethered drone technology. This new technology has the potential to achieve all the desired objectives but still has challenges to overcome like time of flight, stability, and survivability. The key goals for Dragonfly Pictures were:

- Tether diameter must be kept thin for reduced weight
- Power density must be high to support higher voltage inputs
- Low EMI to improve quality of communication signal

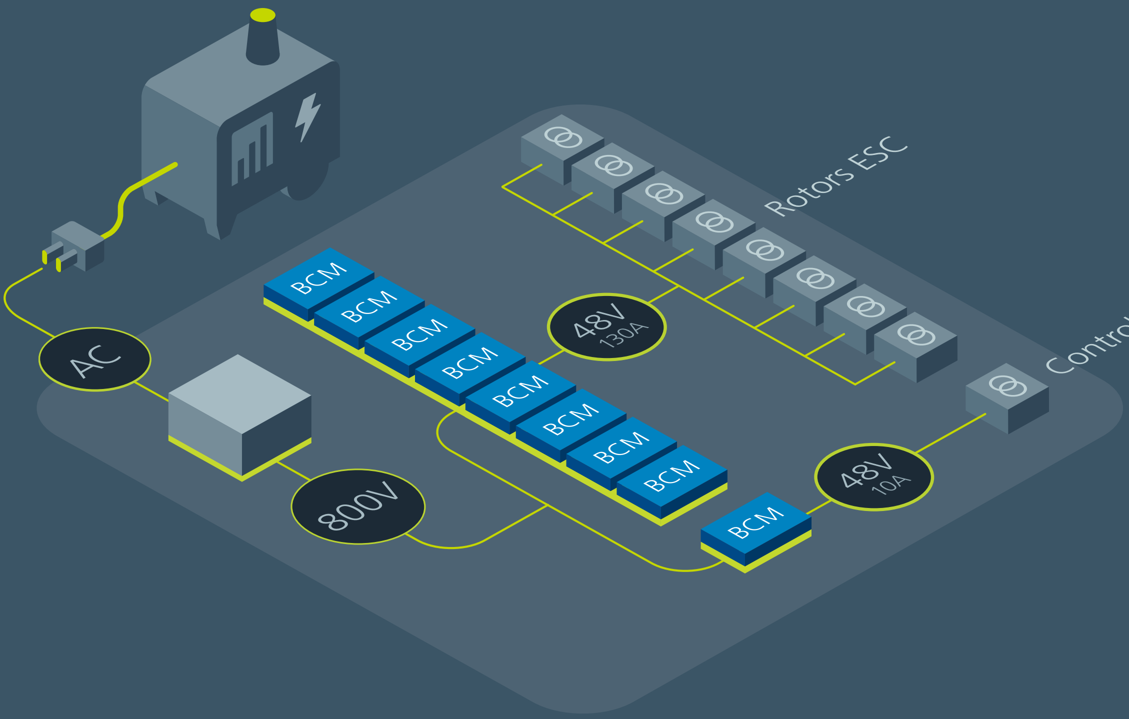
The Vicor solution

The DPI Unmanned Multirotor Aerial Relay (UMAR) tethered drone can provide 400+ hours of non-stop uptime and operations – at altitudes up to 500 feet. To achieve this, power needs to be delivered from the host vessel to the drone at extremely high voltage (500 – 800V) and low current to enable the use of the thinnest, lightest tether enabling greater drone mobility and larger airborne payloads. Also, high-voltage conversion must be achieved in the smallest possible footprint and lightweight profile. Key benefits were:

- High-power density enables smaller form factor and lower weight
- Higher voltage inputs deliver higher efficiency enabling longer flight times
- Low-noise power topologies support lower EMI and clearer communications

Power solutions enabling the thinnest, lightest tether

The Vicor high-voltage BCM4414 VIA low-profile modules used within its UMAR tethered drone enable high-efficiency power conversion (98%) from 800V to 50V. The compact footprint of the **power delivery network** is critical in achieving an extremely power-dense board configuration. There are eight Vicor BCMs® arrayed to power the DPI UMAR's eight independent rotors, with the ability to share power among the rotors in parallel for increased redundancy. The integrated filtering capability within the Vicor BCMs helped to minimize EMI noise.



MIL-COTS BCM® bus converter

Isolated fixed-ratio

Input: 200 – 400V, 400 – 700V, 500 – 800V

Current: Up to 35A

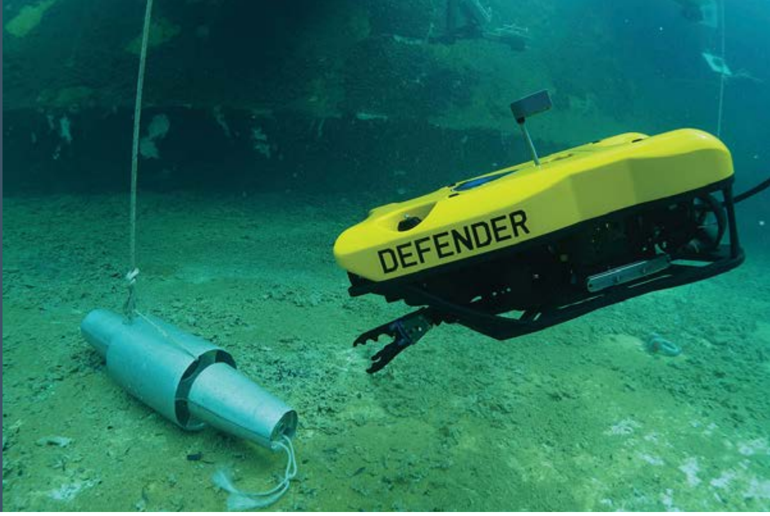
Peak efficiency: 98%

As small as
1.28 x 0.86 x 0.26in

vicorpower.com/mil-cots-bcm

VICOR

Case study: VideoRay modular multi-purpose ROV



ROVs quickly adapt to today’s most risky underwater missions

Customer’s challenge

For optimum maneuverability and to offset the drag from ocean currents, 1kW of thruster power is required over the tether of an underwater ROV, yet the tether needs be light and thin. When used in very deep water, to maximize performance, VideoRay further reduced the tether diameter by powering the ROV from an onboard 48V battery. This eliminated the power cables and their weight from the tether, enabling it to be used for communication purposes only. Key goals were:

- Scalable power so the platform could be quickly reconfigured for different use cases
- High power density and efficiency
- Low EMI to avoid interfering with video transmission on the tether

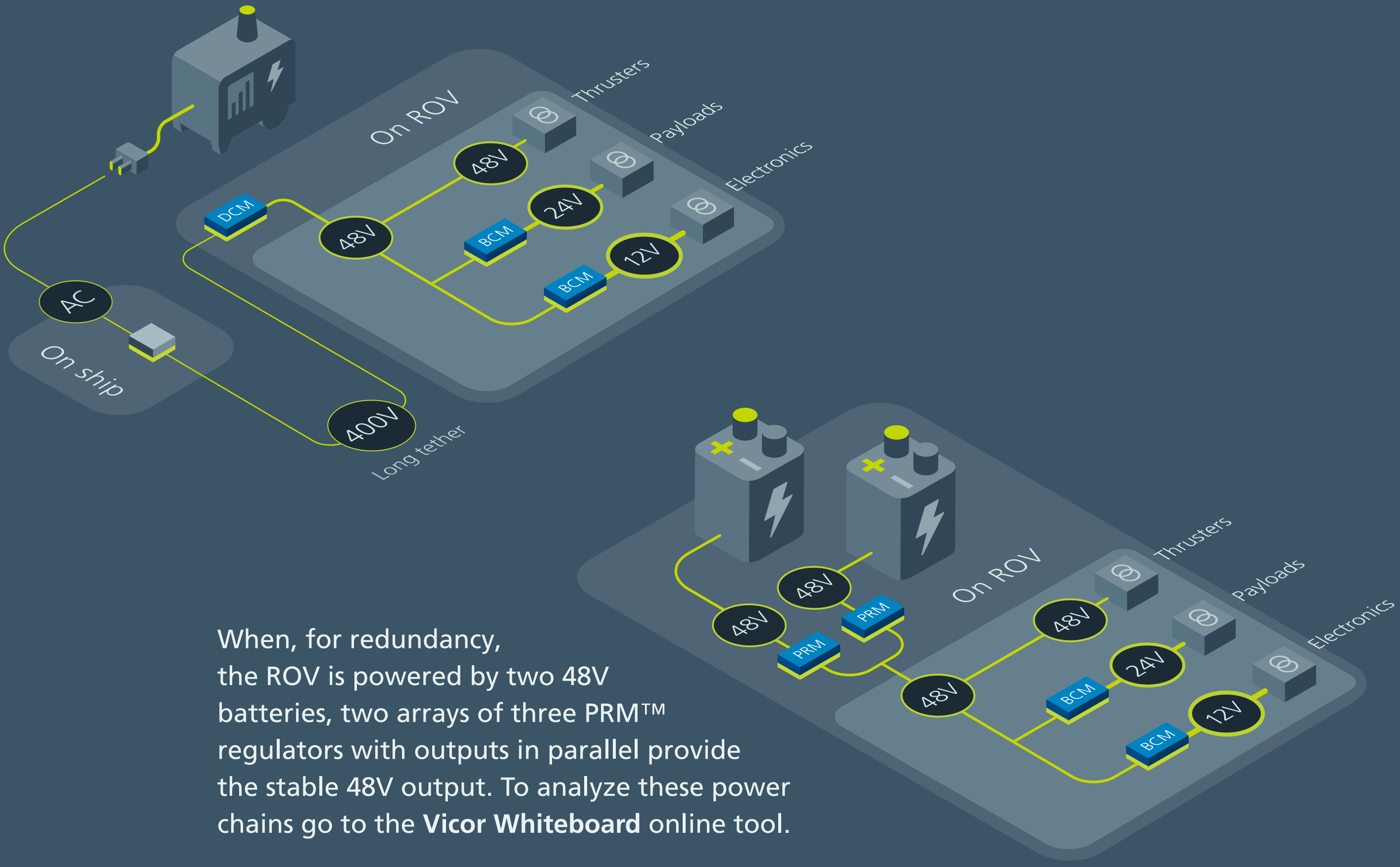
The Vicor solution

To deliver the proper performance for each mission, highly-adaptable modular power is used to meet varying payloads and demands for each different ROV. To ensure greater maneuverability at greater depths, each new configuration uses the scalable power delivery network to suit its mission, enabled by Vicor high-density, high-efficiency power modules. Key benefits were:

- Power modules can be scaled to meet diverse requirements
- Highly dense solution occupies just 25% of the space required for a brick-based solution
- Rugged, highly integrated power modules for high reliability

Flexible power components optimize conversion for multiple use cases

Power delivery network: On the ship the AC supply is rectified to provide the 400V DC tether voltage. On the ROV, the tether voltage is isolated and regulated to 48V by an array of three DCM™ DC-DC converters. The regulated 48V rail directly powers the thrusters and two BCM® DC-DC transformers with 95% efficiency provide the 24V and 12V outputs for onboard loads.



When, for redundancy, the ROV is powered by two 48V batteries, two arrays of three PRM™ regulators with outputs in parallel provide the stable 48V output. To analyze these power chains go to the **Vicor Whiteboard** online tool.

DCM™ DC-DC converter

Isolated regulated

Input: 9 – 420V

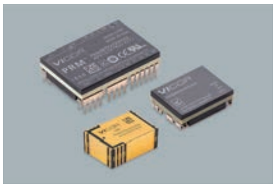
Output: 3.3, 5, 12, 13.8, 15, 24, 28, 36, 48V

Power: Up to 1300W

Peak efficiency: 96%

As small as
24.8 x 22.8 x 7.21mm

vicorpower.com/dcm



PRM™ regulator

Non-isolated regulated

Input: 48V (36 – 75V)

Output: 48V (5 – 55V)

Power: Up to 600W

Peak efficiency: 98%

As small as
22.0 x 16.5 x 6.73mm

vicorpower.com/prm

BCM® bus converter

Isolated fixed-ratio

Input: 800 – 48V

Output: 2.4 – 55.0V

Current: Up to 150A

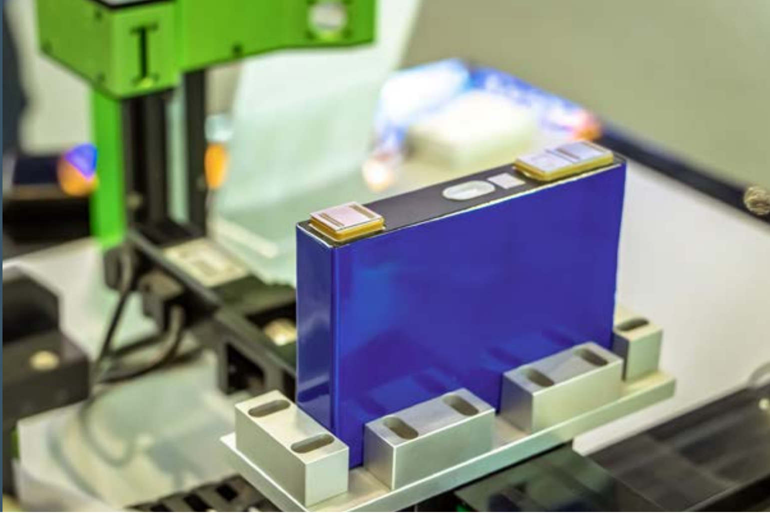
Peak efficiency: 98%

As small as
22.0 x 16.5 x 6.7mm

vicorpower.com/bcm

VICOR

Case study: battery testing



Maximizing throughput and adapting to change quickly and easily

Customer's challenge

With soaring demand for batteries, battery testing equipment manufacturers are challenged with maximizing throughput without increasing floor space or equipment dimensions. They also need to enable testing that can adapt and scale easily when supporting new or improved battery pack configurations. Equipment must manage the wide current variability in the battery testing process to maintain continued operation. Key challenges were:

- Higher density power delivery that fits within current height restrictions
- High current capability and wide input range
- A scalable and flexible solution

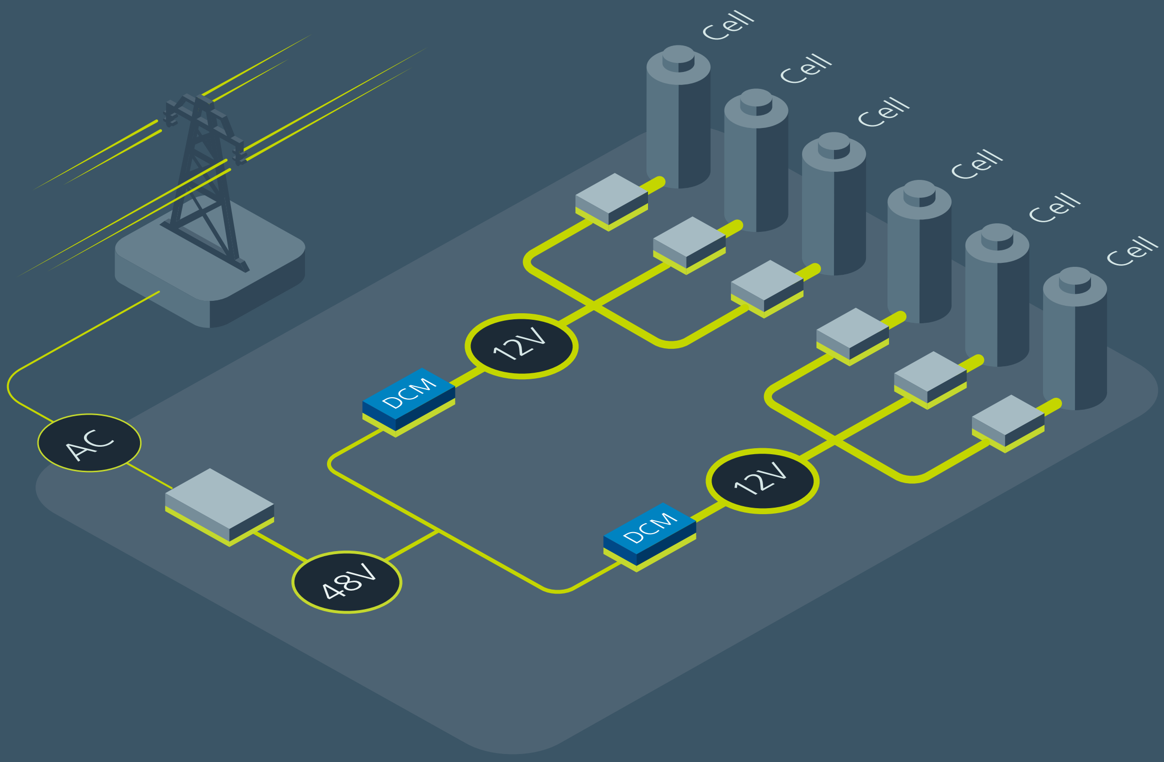
The Vicor solution

Migrating to a 48V architecture provides higher efficiency and the high density of Vicor power modules allows for higher power delivery in less space. Vicor 48V to 24V DC-DC converters enable the use of legacy 12V systems to save time and cost when developing new equipment. Vicor robust power modules are designed to handle the high – and sometimes unpredictable – currents routinely encountered in the battery testing process. Key benefits were:

- Significant size and weight reduction
- Supporting cell voltages from 0V to greater than 48V
- Ability to quickly and easily adapt to changing requirements

The power delivery network

The non-isolated, regulated Vicor DCM™ enables easy implementation of a 48V architecture by providing conversion for legacy 12V buses powering the downstream cell monitor/ balancing control units. This high-performance solution delivers significant size, weight, and efficiency benefits. This easy-to-use power module reduces design complexity and can be easily paralleled to scale power when needed.



DCM™ DC-DC converter

Non-isolated regulated

Input: 40 – 60V

Output: 10 – 12.5V

Power: Up to 2kW

Peak efficiency: 96.5%

As small as
36.7 x 17.3 x 5.2mm

vicorpower.com/dcm48to12V

Tools

This section outlines Vicor tools that provide novice and experienced engineers a digital workspace where they can design and test power module solutions to best fit their application needs.

Power System Designer

The Power System Designer is a user-friendly software which both novice and experienced system designers can utilize to architect end-to-end power delivery networks. This tool harnesses the Vicor Power Component Design Methodology to produce optimized solutions without time consuming trial and error. The Power System Designer also provides a service which is up to 75% faster than traditional methods and allows users to export the final BOM.

Whiteboard

Whiteboard is an online tool with an easy-to-use workspace where users can analyze and optimize the performance of different power chains. Users are able to find the best solution for their application needs using Vicor high density, high efficiency power modules. In addition, users can set operating conditions for each component of the power design and get loss analysis for individual components and the system overall.

www.vicorpower.com   Customer service: custserv@vicorpower.com   Technical support: apps@vicorpower.com

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