eMobility eBook

Extend runtime with high density power conversion

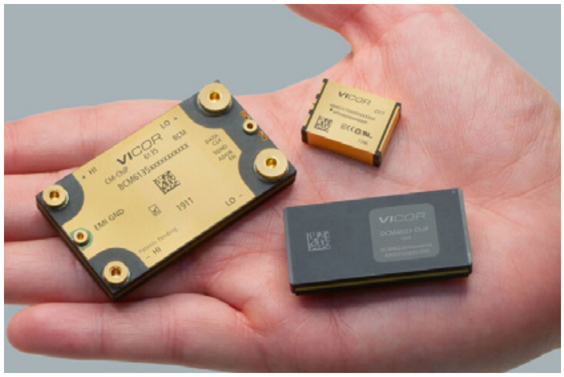
VICOR

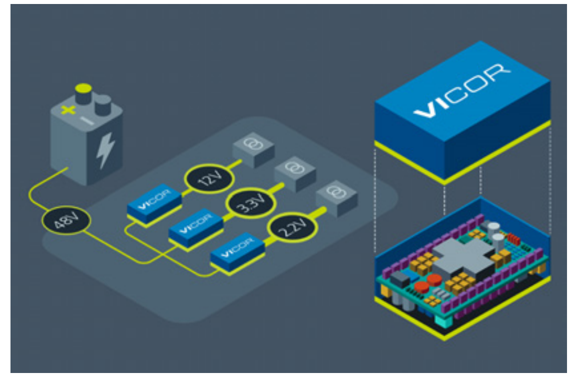
Introduction

This eBook provides a guide to developing better power delivery networks to enhance the performance, efficiency, and reliability of eMobility products. Traditional discrete power solutions often fall short in meeting demanding requirements such as compact size, high efficiency, and thermal management. You will learn how to leverage high performance power modules to overcome design challenges and shorten time-to-market.

Contents

High performance power modules optimized for 48V power delivery





Kilowatts of power in a small space

Vicor high performance power modules require dramatically less space than traditional discrete power solutions while providing high efficiency and power density. This enables longer uptime for recreation vehicles and productivity for commercial vehicles without sacrificing any features.

Advanced power architectures

By adopting the modular approach power modules can be paralleled or swapped, allowing designs to accommodate new loads or changes in power. This enables easy scaling to meet different power needs without a complete redesign, allowing for easy customization and aftermarket additions to vehicles.

Fast transient response

The ability to rapidly respond to changing load demands is crucial in EVs, especially during acceleration, braking, and other dynamic driving conditions. Vicor modules excel in this regard, ensuring smooth and efficient power delivery, optimizing energy usage.

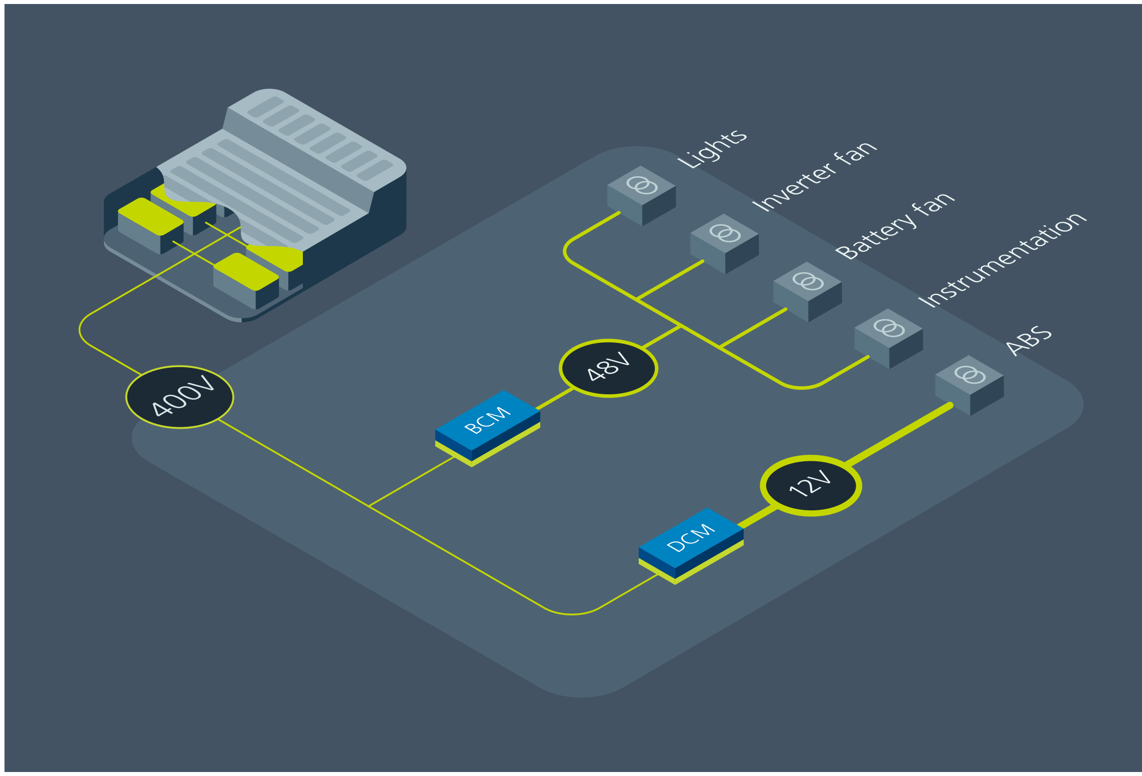
Quickly implement a power solution

Vicor provides tested and qualified power modules to build power delivery networks that can be designed quickly without all the wasted time and effort to test and certify a new discrete design. This enables our customers to get to market faster, giving them a distinct advantage over their competition.

Benefits of Vicor modules

- High power density
- High efficiency with easier thermal management
- Fast transient response
- Low EMI

The power delivery network



Isolated, high-density BCM fixed-ratio converters safely and reliably convert a high voltage input into standard safety extra low voltage (SELV) 48Vbus output voltages to power 48V loads. BCMs are parallelable to achieve the power level necessary to support all the vehicle's accessory loads. Vicor DCM4623 DC-DC converter modules convert high voltage batteries to efficiently power 12V vehicle loads such as ABS. Vicor power modules excel in both efficiency and power density, crucial factors for maximizing range and minimizing charging times in LEV. Their compact footprint allows for optimized packaging within the vehicle's limited space, while their high reliability ensures long-term performance and durability. Their soft-switching topologies allow for DC-DC voltage transformation without the generation of harmonics, high-frequency components that are often very difficult to filter. Additionally, the high-frequency operation allows for a reduction in the size of the EMI filter components.

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Case study: Lightning Motorcycles electric bikes

Making a global impact and setting record breaking speeds for electric bikes

Customer's challenge

Motorcycle electrification is challenged by stringent standards for a minimum range of 100 miles and charge times under one hour for 70 miles of range. Electric motorcycles require an extremely power-dense and reliable power delivery network that mitigates electrical noise (EMI) and manages a wide range of battery voltages while negotiating rugged, unpredictable conditions. The key goals for Lightning Motocycles were:

- Dramatically extend range and decrease charge times
- Compact and lightweight solution
- Capable of handling the different voltage input ranges from different battery chemistries

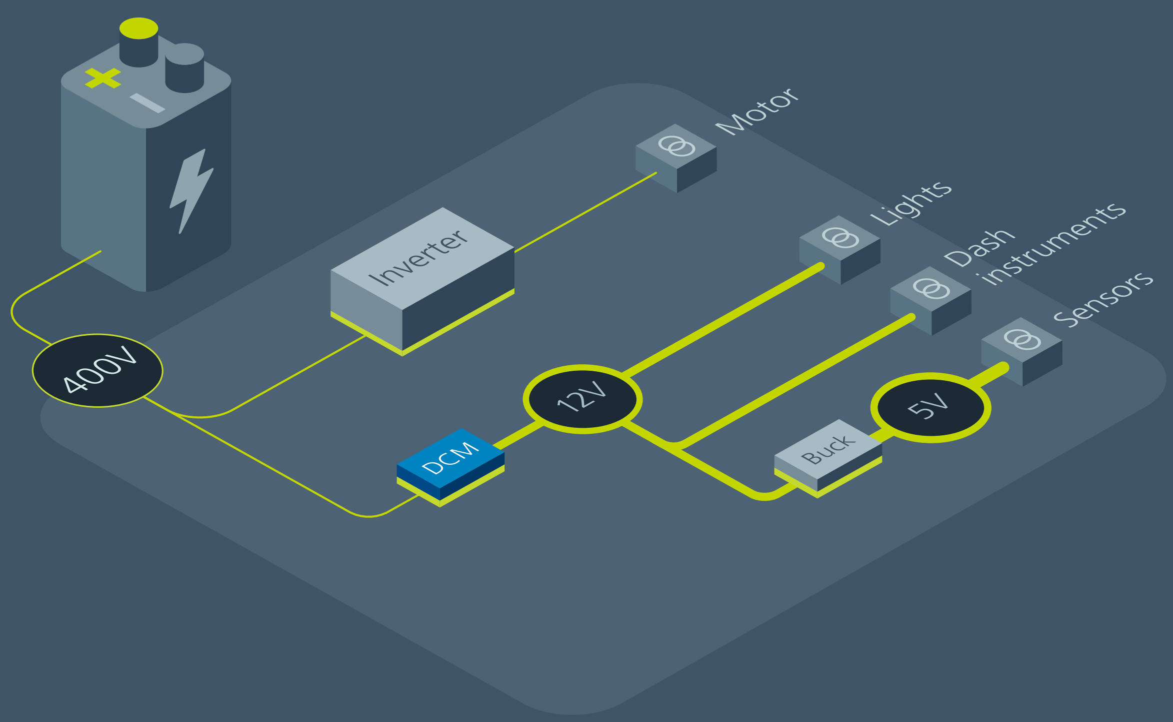
The Vicor solution

To achieve peak operational performance of world-class electric motorcycles, Lightning turned to Vicor for the smallest and most power-dense solution with the widest input range that offers flexibility to switch between Lithium-Iron-Phosphate packs, which provide 200 – 400V, and Nickel-Manganese-Cobalt or Nickel-Cobalt-Aluminum Oxide chemistries, which typically range between 250 – 420V. Key benefits were:

- Safely converts high-voltage power (400V) to SELV (12V)
- DCM™ best-in-class power density
- The integrated module packaging offers a more robust solution that can handle extreme environmental conditions

Power dense and compact power modules safely convert high voltages to 12V supply

Vicor DCM™ power modules convert the high voltage battery down to 12V to power the bike's control electronics including dash instrumentation, lighting, and sensors. The DCM4623 is a power-dense, lightweight and cost-effective DC-DC converter that generates a clean 12V supply from a very wide high voltage input range. The input range of the DCM4623 is wide enough to support different voltages from commonly used battery chemistries.



DCM DC-DC converters

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

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Case study: Fuel-cell eVTOL

A lightweight solution providing kilowatts of power for auxiliary systems

Customer's challenge

eVTOLs can be used for a variety of purposes, such as urban air mobility, cargo delivery, and emergency response. They are electric vehicles by nature, but they don't necessarily use traditional batteries: they can also use fuel cells to power the aircraft. This reduces overall weight and allows for longer flight times. However, propulsion fuel cell stacks require a substantial auxiliary power system for pumps, fans, cooling fans, and other controls that require kilowatts of power without adding bulk. The main challenges were:

- Test and implement power solutions quickly and easily to gain competitive time to market
- Manage kilowatts of power without adding much space and weight
- Ensure the highest reliability under extreme operating conditions

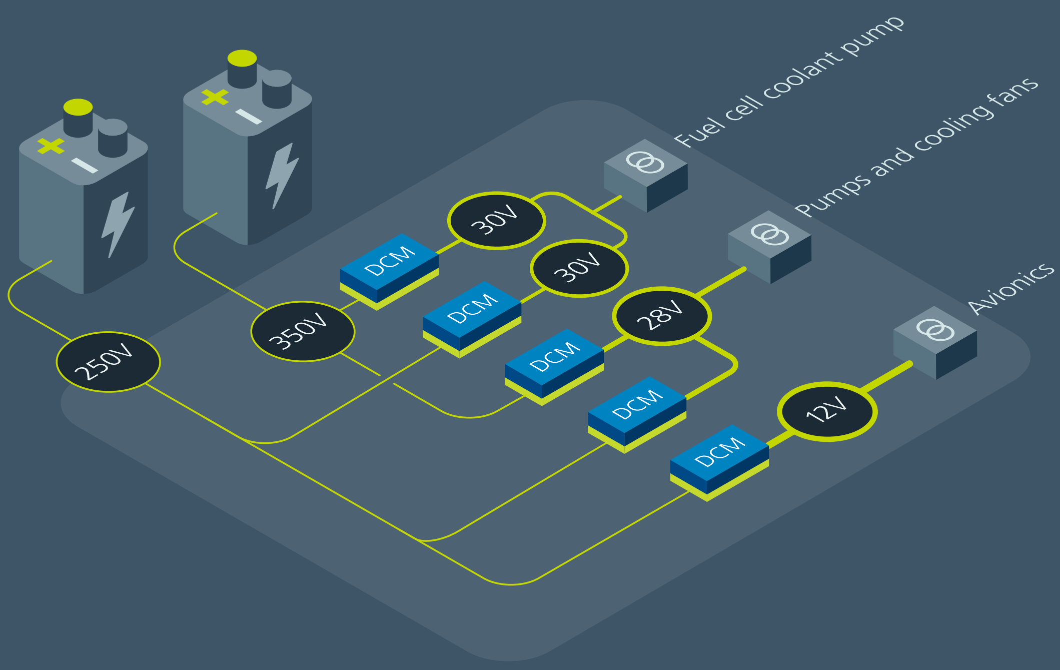
The Vicor solution

Vicor high-density power modules effectively manage kilowatts of power within limited space. Their light weight reduces energy needed for flight and optimize battery usage, providing the manufacturer more flexibility when designing aircraft. Power modules allow for quick testing and implementation and easily adapt to changing power requirements, accelerating time to market. The key benefits are:

- One design using power modules can meet diverse requirements, or be scaled to meet high power requirements, resulting in less design effort
- Compact power modules optimizes space and weight on the vehicle
- Rugged and highly integrated power modules for high reliability

The Power Delivery Network

Uninterrupted operation of critical auxiliary systems is ensured by leveraging a redundant battery system feeding a 40kW auxiliary power supply. The power delivery network utilizes arrays of Vicor DCM™ DC-DC converters connected in parallel, delivering over 10kW of power. Two sets of DCMs with 30V outputs are connected in series for higher power 60V pumps, utilizing the same part number product for most of the 40kw of auxiliary power, be it 24V, 28V or 60V. With up to 97% efficiency, DCMs reduce heat generation significantly, leading to improved thermal management and reliability. They maintain perfect output current sharing, even when connected to different input voltages, ensuring balanced load distribution and optimal performance. An additional Vicor DCM powers the sensitive avionics systems, providing a stable and regulated power source.



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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

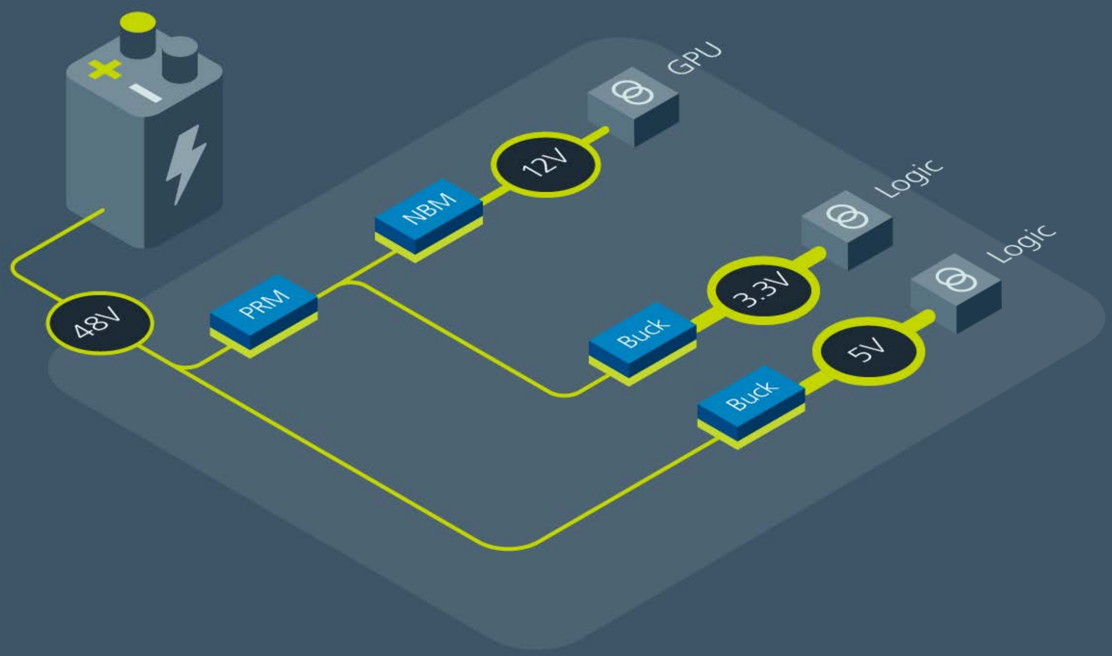
The Vicor solution

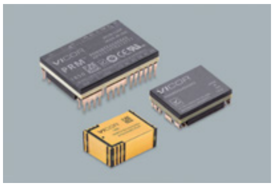
Vicor high-efficiency power modules ensure minimal heat dissipation, reducing the need for complex cooling solutions and maximizing power. This translates into higher available power and increased system reliability critical for safety. The high power density of Vicor modules saves space and weight to 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 1,200 watts, 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.





PRM buck-boost regulators

- 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

NBM DC-DC converters

- 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 regulators

- 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

Products used in eMobility power delivery networks

DCM DC-DC converters

Isolated regulated

Input: 9 – 420V

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

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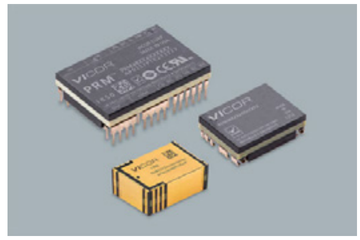
vicorpower.com/dcm



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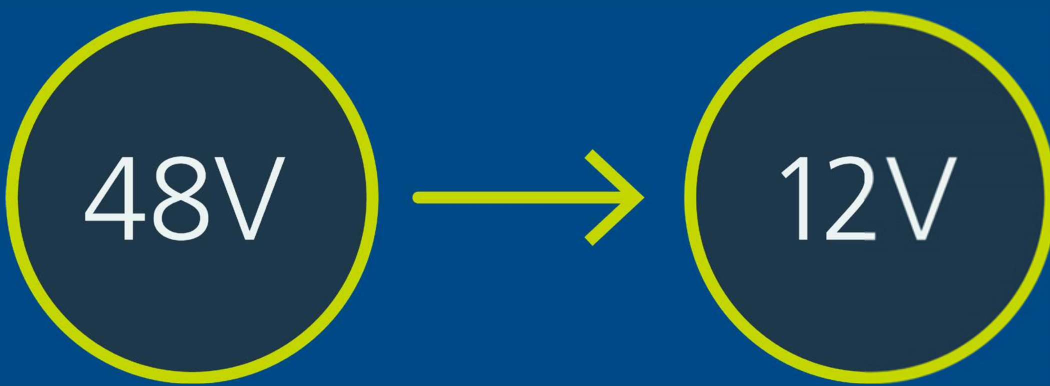

This article was originally published by Electronics World

Modular approach solves 48V power architecture electrification challenges

Tesla recently announced that 48V low-voltage systems will be used in all future electric vehicles. As the industry moves in this direction it poses an opportunity and a challenge for OEMs and Tier Ones to adapt. Adopting a zonal architecture that is decentralized, where 48V is being converted to 12V at the load, is the most efficient way to architect this type of system. Vicor small, power dense modules make it easy to design and build a zonal architecture to support xEVs.

Cars, trucks, buses and motorcycles makers are rapidly electrifying their vehicles to increase the fuel efficiency of internal combustion engines and reduce CO2 emissions. There are many electrification choices, but most opt for a 48V mild-hybrid system rather than a full-hybrid powertrain. In the mild-hybrid system, a 48V battery is added alongside the traditional 12V battery. This increases power capacity by 4 x (P = V • I), which can be used for heavier loads, such as the air conditioner and catalytic converter at start up. To increase vehicle performance, the 48V system can power a hybrid motor that is used for faster, smoother acceleration whilst saving on fuel. The additional power can also support steering, braking and suspension systems, plus new safety, entertainment and comfort features. A 48V mild-hybrid system provides a way to rapidly introduce new vehicles with lower emissions, longer range and higher gas mileage. It also delivers new and exciting design options for higher performance and features while still reducing CO2 emissions.

However, there's a general hesitancy to modify the long-standing 12V power delivery network (PDN). Changes often require new technologies that need extensive testing and may require new suppliers that can deliver automotive industry's high safety and quality standards.

Maximizing a 48V PDN

Adding a 48V battery to power the heavier powertrain and chassis system loads provides options to engineers. Now there is a choice of adding systems that can deal directly with a 48V input, or to

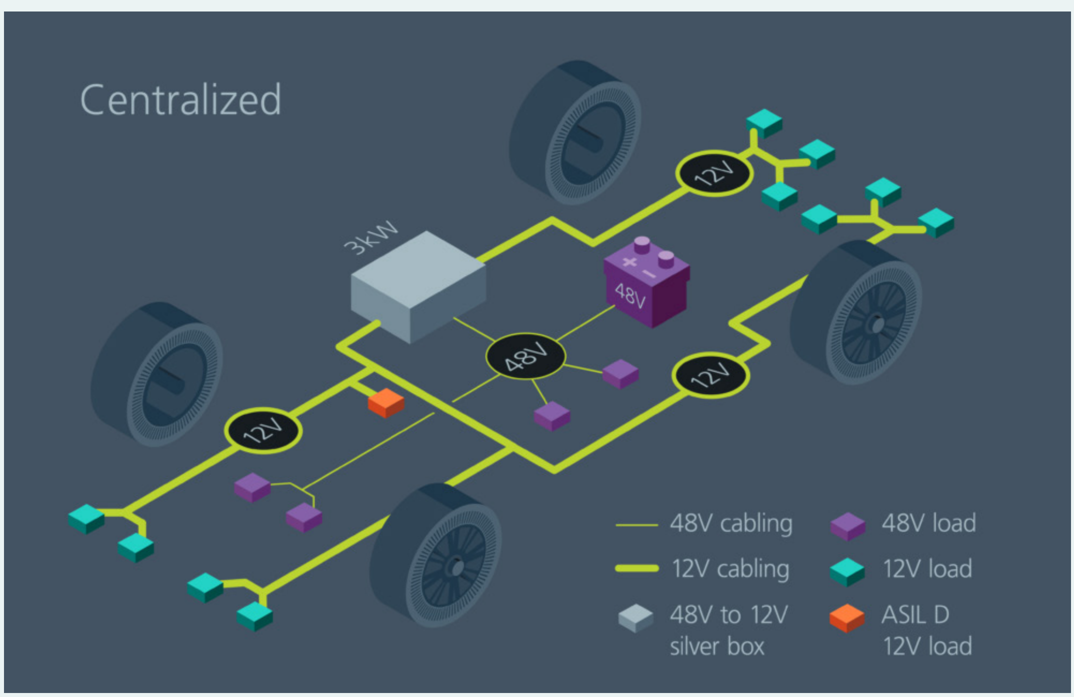

Figure 1: Traditional 12V centralized architecture.

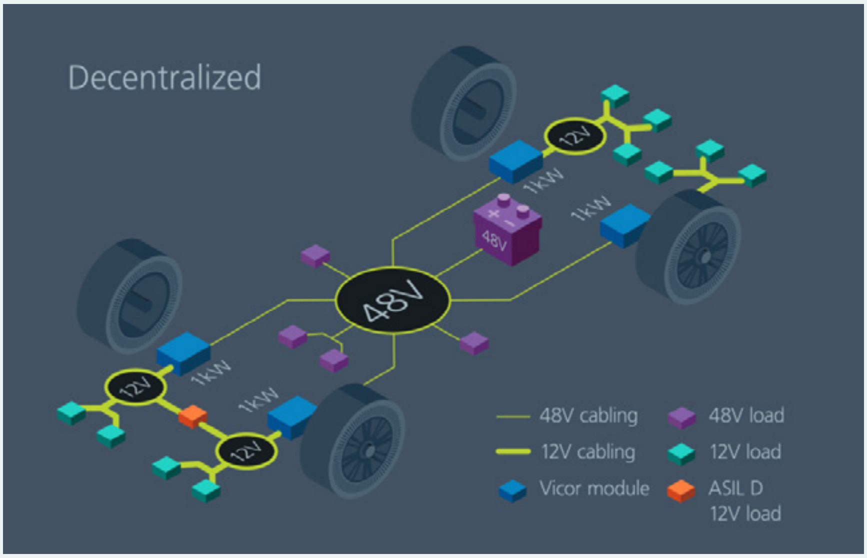

Figure 2: 48V decentralized or zonal architecture.

retain legacy 12V electromechanical loads such as pumps, fans and motors and instead convert the 48V to 12V via a regulated DC-DC converter. In order to manage change and risk, existing mild-hybrid power delivery systems are slowly adding 48V loads but still use a large centralized multi-kW 48V-to-12V converter that feeds 12V around the vehicle. However, this centralized architecture does not take the full advantage of a 48V PDN, nor does it utilize the benefits of available advanced converter topologies, control systems and packaging.

The vast majority of these centralized DC-DC converters (Figure 1) are bulky and heavy, since they use older low-frequency PWM switching topologies. They also represent a single point of failure for many critical powertrain systems.

A different architecture to consider is decentralized power delivery (Figure 2) with modular power components. This power delivery architecture uses smaller, lower-power 48-to-12V converters, distributed throughout the vehicle close to the 12V loads. The simple power equations P = V • I and

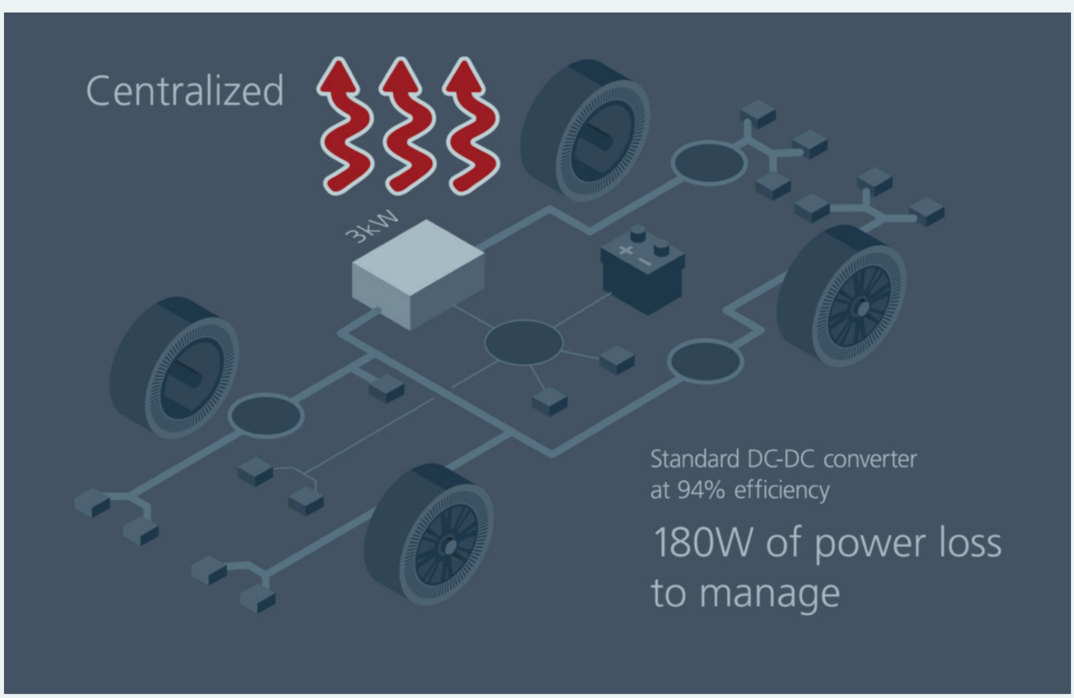

Figure 3: Standard DC-DC converter is 94% efficient.

$P_{LOSS} = I^2R$ explain why 48V is more efficient than distributing 12V.

For a given power level, the current is four times lower at 48V than in a 12V system and has 16 times lower losses (I^2R). At ¼ of the current, the cables and connectors can be smaller, lower weight and cheaper. The decentralized power architecture also has significant thermal management and power system redundancy benefits (Figure 4). It's another way of spreading kilowatts of power around the vehicle without the weight, thermal concerns and volume of a traditional DC-DC converter.

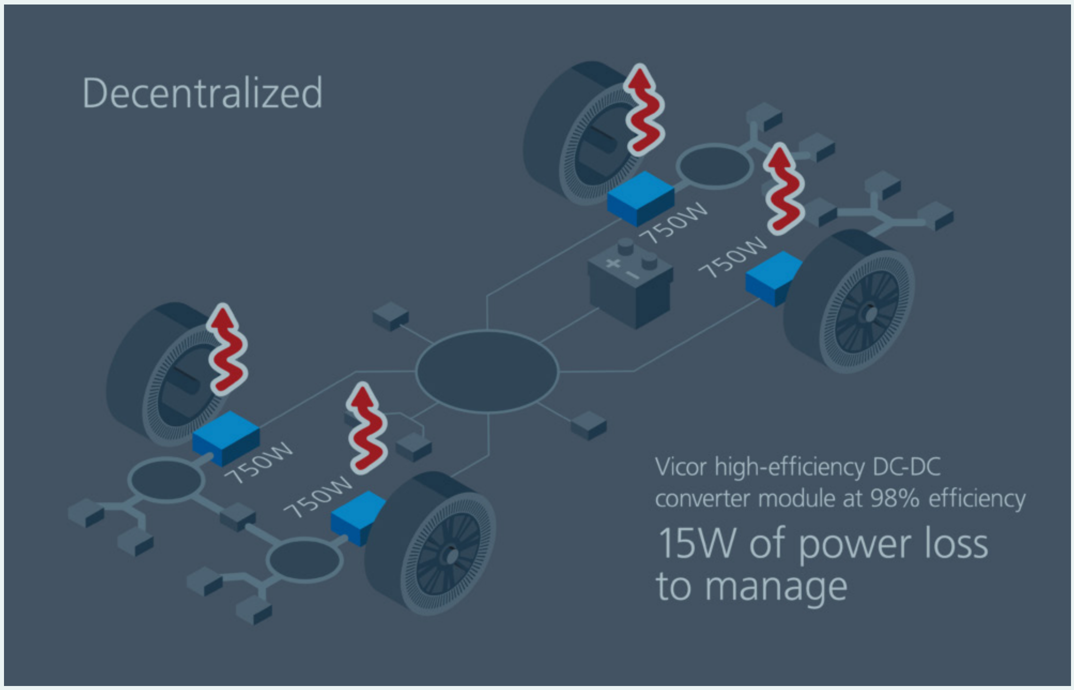

Figure 4: Vicor DC-DC converter is 98% efficient.

Modularity for decentralized or zonal architectures

A modular approach to a decentralized power delivery (Figure 4) is highly scalable.

The 48V output from the battery is distributed to the various high-power loads in the vehicle, maximizing the benefits of lower current (4x) and lower losses (16x), resulting in a physically smaller and lower weight PDN. Depending on a load power analysis of the various distributed loads, one module can be designed and qualified for the right power granularity and scale the power level of the system upwards, when used in parallel arrays.

In this example, a 2kW module is shown. As noted, the granularity and scalability are system dependent. By using distributed modules instead of a large centralized DC-DC converter, N+1 redundancy is also possible at a much lower cost. This approach also advantageous when load power changes during the vehicle development phase. Instead of implementing changes to a full ground-up custom power supply, engineers can either add or eliminate modules. In addition, the module is already approved and qualified, reducing development time.

Implementing a decentralized or zonal modular 48V architecture

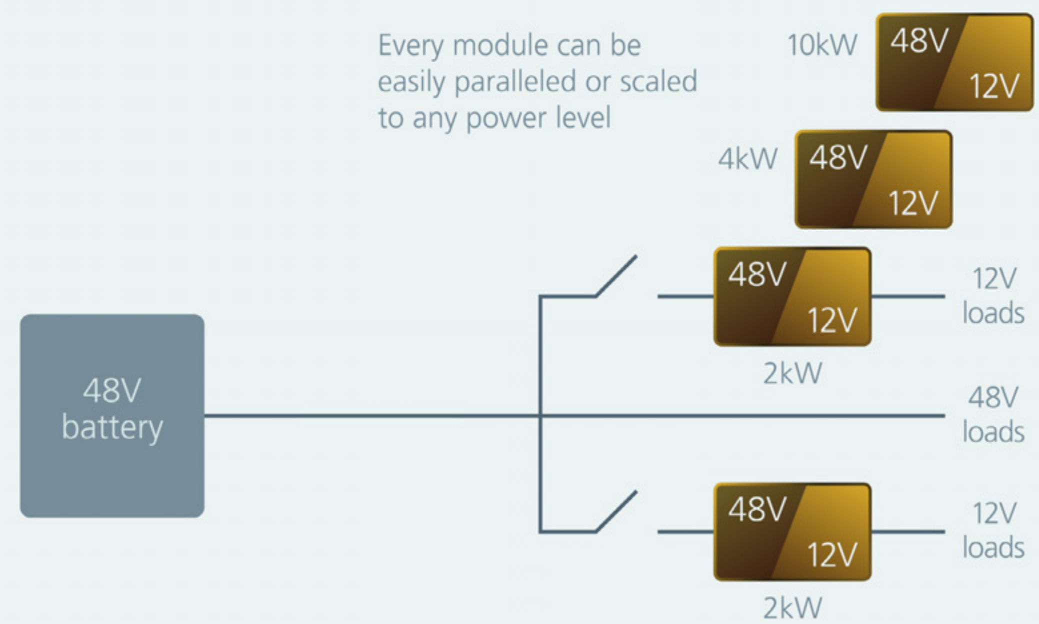

Figure 5: A modular approach to a fully electric vehicle.

In the case of pure electric vehicles or high-performance hybrid cars, high-voltage batteries are used due to the high power demands of the powertrain and chassis systems. A 48V SELV PDN still has significant benefits for OEMs, but now the power system designer has an additional challenge of a high-power 800V-to-48V or 400V-to-48V conversion.

This high-power DC-DC converter also requires isolation but not regulation. By using regulated PoL converters, the high-power upstream converter can use a fixed-ratio topology. This is extremely beneficial due to the wide input-to-output voltage range of 16:1 or 8:1 for 800/48 and 400/48, respectively; see Figure 5. Using a regulated converter over this range is very inefficient and presents a large thermal management problem. OEMs are often locating this efficient step down solution right inside the battery pack, and in some cases are able to eliminate the battery. Vicor's fixed ratio high voltage conversion products deliver rapid current delivery at fast slew rates, enabling OEMs to lose the 12-14kg of unnecessary 48V battery weight.

It would be very difficult and costly to decentralize this high-voltage isolated converter due to safety requirements in distributing the 400V or 800V. However, a high-power centralized fixed-ratio converter can be designed utilizing power modules instead of a large silver box DC-DC converter.

Power modules of the right level of granularity and scalability can be developed and then easily paralleled for a range of vehicles with differing powertrain and chassis electrification requirements. Vicor BCM fixed-ratio bus converters are also bidirectional, which supports various energy regeneration schemes. Due to the sine amplitude converter (SAC) high-frequency soft-switching topology, BCMs achieve efficiencies over 98%. They also feature power densities of 2.6kW/in^3, which significantly reduces the size of the centralized high-voltage converter.

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.

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