WHITE PAPER

Solving automotive electrification challenges via a decentralized 48V power architecture

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Manufacturers of cars, trucks, buses and motorcycles are rapidly electrifying their vehicles to increase the fuel efficiency of internal combustion engines and reduce CO^2 emissions. There are many electrification choices, but most manufacturers are opting for a 48-volt mild-hybrid system rather than a full-hybrid powertrain. In the mild-hybrid system, a 48-volt battery is added alongside the traditional 12V battery.

This increases power capability by 4x (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 while saving on fuel. The additional power can support steering, braking and suspension systems, plus add new safety, entertainment and comfort features.

Introducing a 48-volt mild hybrid system has tremendous upside once designed-in. Overcoming the hesitancy to modify the long-standing 12-volt power delivery network (PDN) may be the biggest challenge. Changes in power delivery often require new technologies that need extensive testing and may require new suppliers that can deliver on the automotive industry’s high safety and quality standards.

But the advantages far outweigh the conversion cost as the data center industry is discovering as it moves to a 48V PDN. For the automotive industry 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 CO^2 emissions.

How to maximize a 48V power delivery network

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 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 to the 12V loads. 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.

Figure 1
Traditional 12V centralized architecture

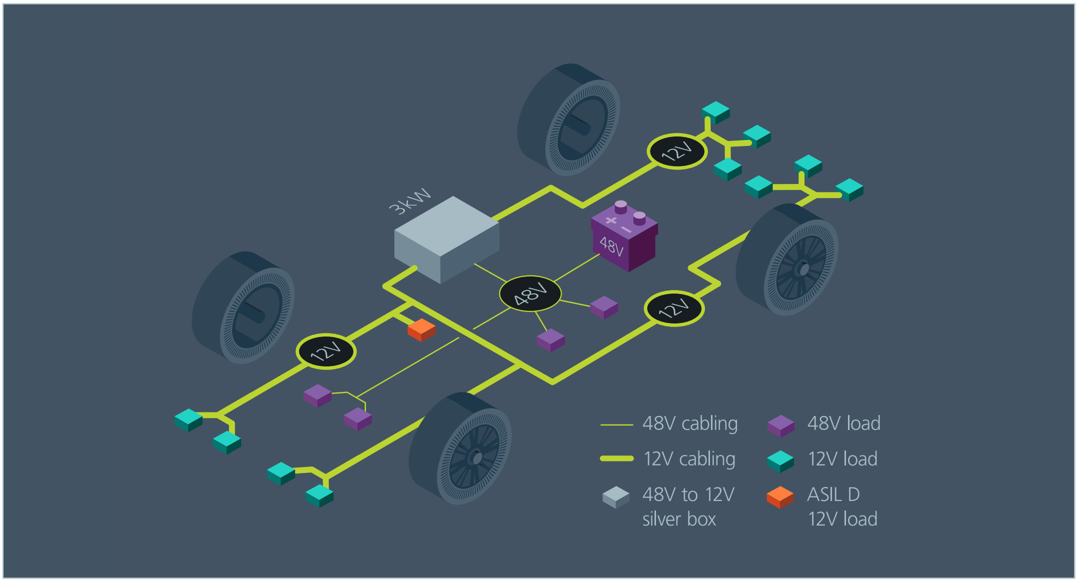
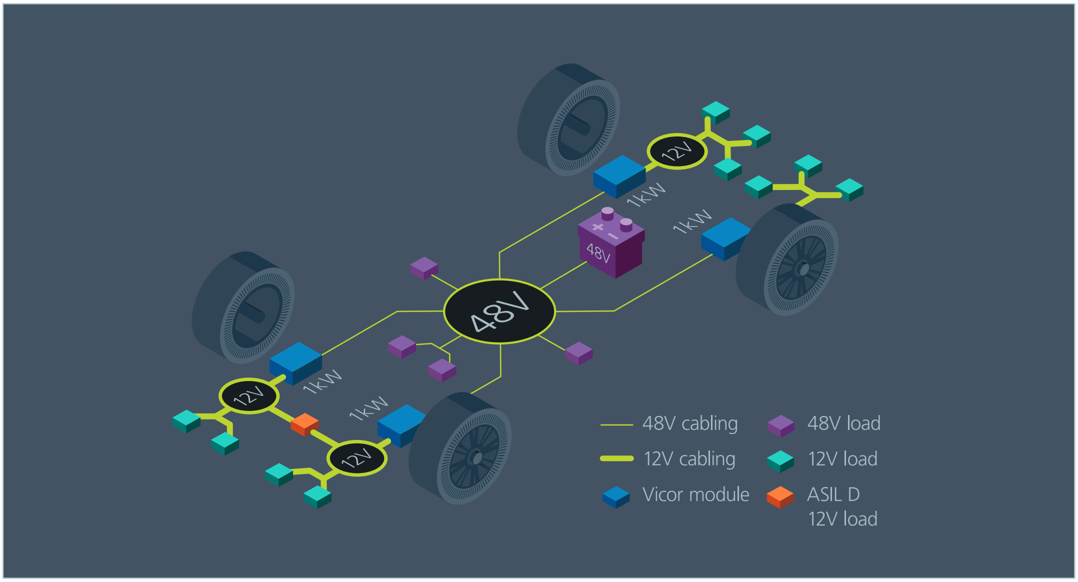


Figure 2
48V decentralized architecture



The vast majority of these centralized DC-DC converters (Figure 1) are bulky and heavy, since they use older low-frequency switching PWM 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 48V-to-12V converters, distributed throughout the vehicle close to the 12V loads. The simple power equations P = V • I and $P_{LOSS} = I^2R$ 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 16x lower losses. At quarter 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).

Figure 3
Standard DC-DC converter is 94% efficient

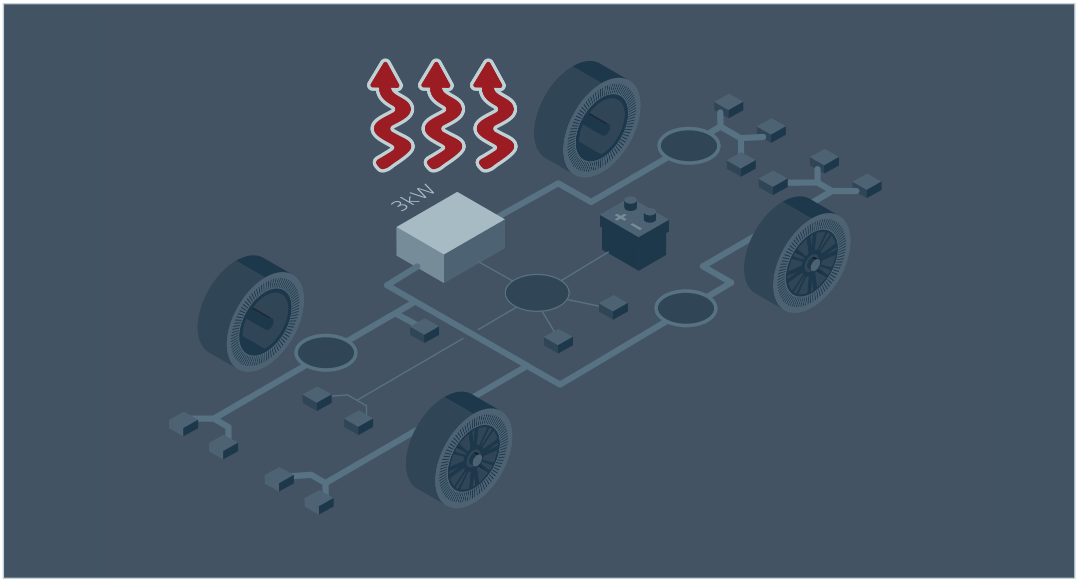
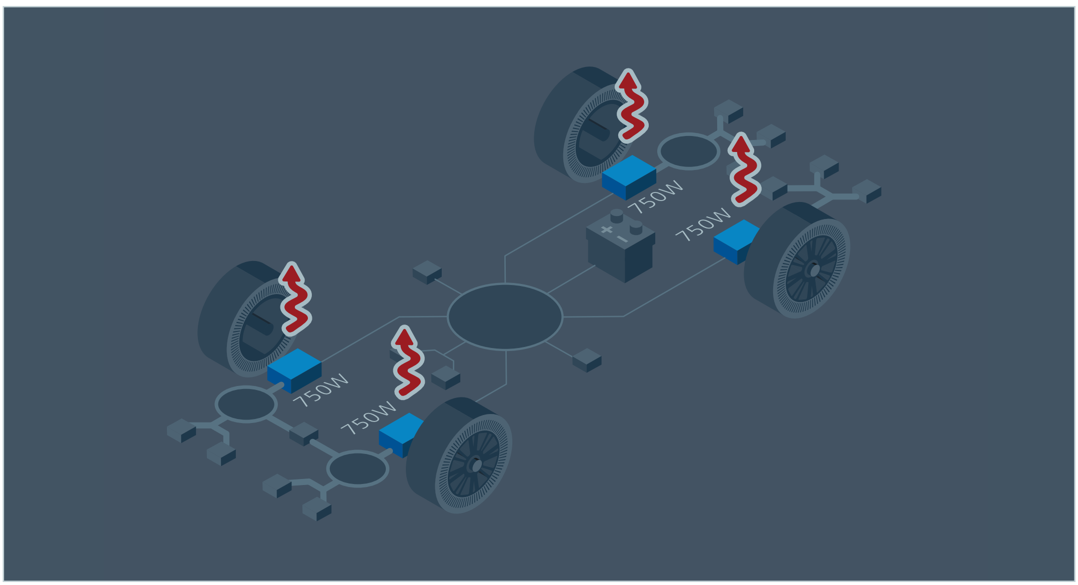


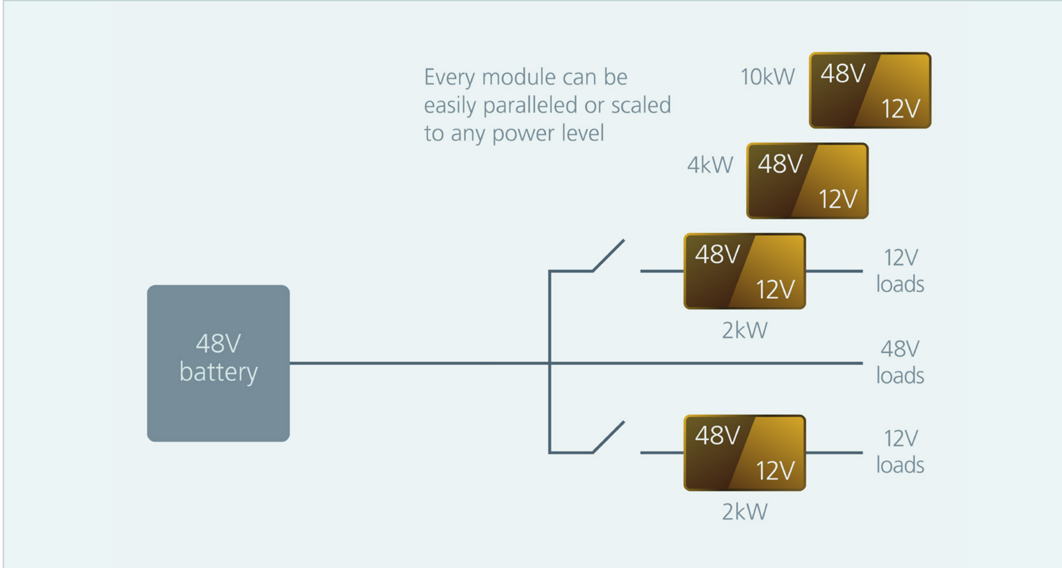
Figure 4
Vicor DC-DC converter is 98% efficient



Modular component benefits for decentralized architectures

A modular approach to a decentralized power delivery (Figure 5) is highly scalable.

Figure 5
A modular approach to a hybrid electric vehicle

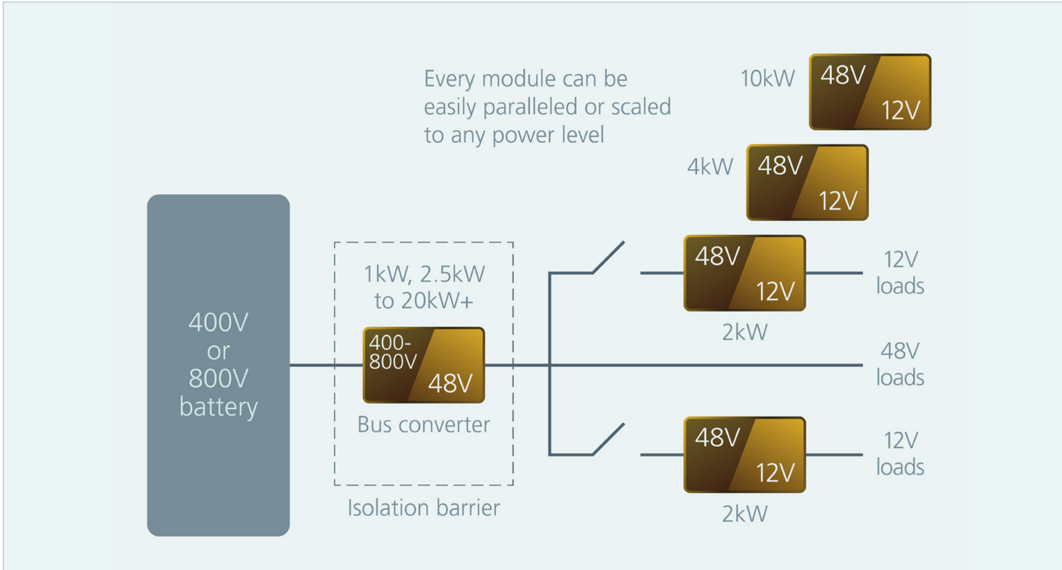


The 48V output from the battery is distributed to the various high-power loads in the vehicle, maximizing the benefits of lower current (4x) and lower losses (16x) resulting in a physically smaller and lower weight PDN. Depending on a load power analysis of the various distributed loads, one module can be designed and qualified for the right power granularity and scale to be 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 has advantages if 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. Another design advantage is reduced development time as the module is already approved and qualified.

Implementing a decentralized, modular 48V architecture in higher voltage battery systems

Figure 6
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- or 400V-to-48V conversion.

This high-power DC-DC converter also requires isolation but not regulation. Better voltage regulation is one benefit of decentralizing the placement of 48V-to-12V converters. 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 (Figure 6). Using a regulated converter over this range is very inefficient and presents a large thermal management problem.

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 fixed-ratio bus converters (BCM®) 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.

Conclusion

Vicor is a supplier to the automotive market, delivering the most advanced and innovative 48V solutions. A decentralized modular approach to automotive power delivery architectures simplifies complex power delivery challenges, increasing performance, productivity and time to market. A leader in 48V power conversion, Vicor is constantly innovating power delivery architectures, power conversion topologies, control systems and packaging.

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