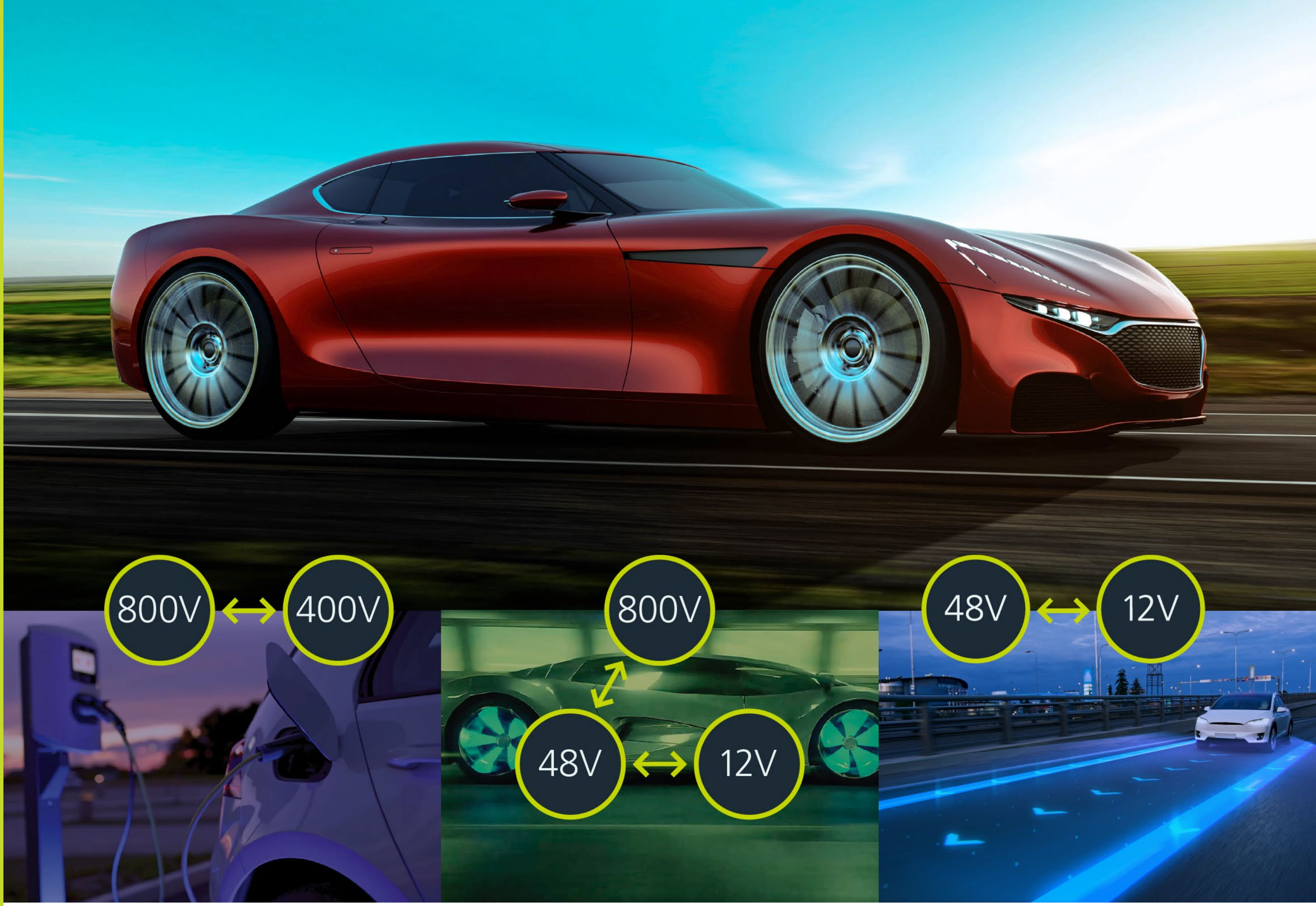


Automotive eBook

# High density power conversion: more power in less space

VICOR

# Introduction

This eBook provides a guide to developing better power delivery to meet the needs of today's EVs. Starting with application examples, you'll learn how high density power conversion can optimize vehicle power from the high voltage battery to an efficient, lightweight 48V zonal architecture. Next, case studies will demonstrate how other companies have leveraged Vicor technology to overcome design challenges. Next, in-depth articles will guide you through the key advantages of power modules over traditional discrete power solutions.

# Contents

# Application examples

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Application example:
400/800V charging
compatibility

# Efficient, high-power onboard conversion using high performance power modules

Compact and lightweight

Flexible placement of power modules

Scalable to meet changing requirements

High efficiency

## 37kW of power in a small space

Vicor high performance power modules require dramatically less space than traditional discrete power solutions. This allows for flexible placement of power conversion within the vehicle where the alternatives simply would not fit. High efficiency conversion reduces the impact to the cooling system, which can be smaller and lighter as well.

## Scalable power architecture

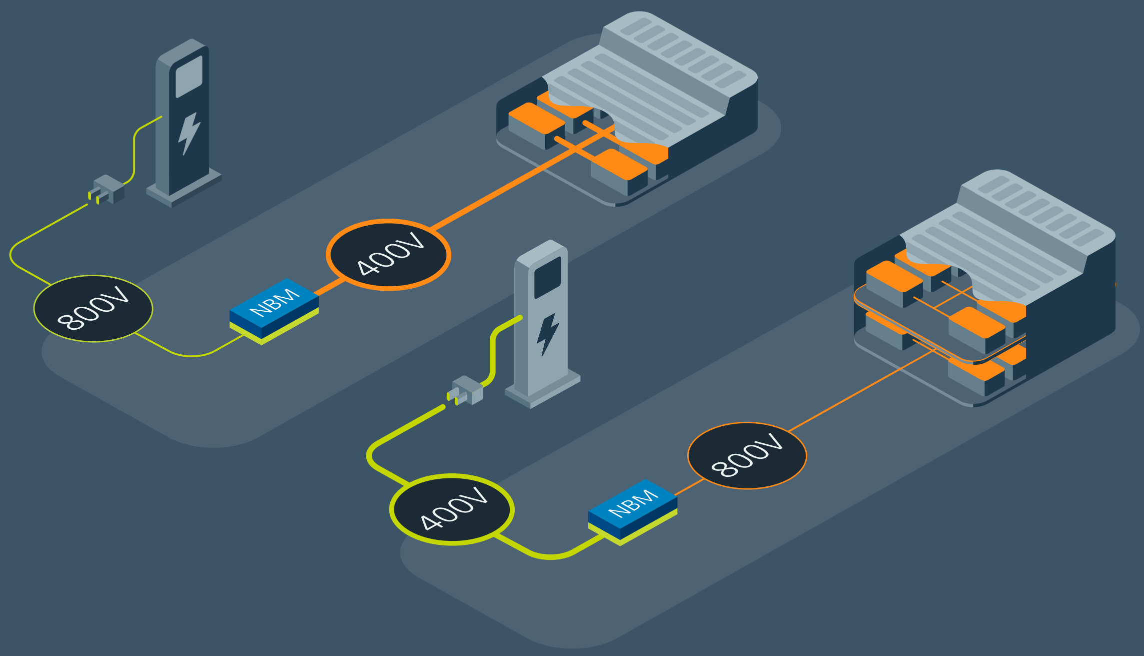
By adopting the modular approach, easily scale power to meet requirements by simply adding another module or swapping for a different module. This allows for the same power architecture to be deployed across vehicle platforms.

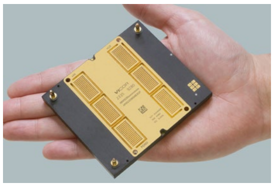
## Tailored solutions

Our team of engineers collaborates with customers to tailor our modules to support specific needs and to architect new, efficient, modular power delivery networks that take full advantage of our modules. Using just a few power modules, possible solutions support hundreds of unique power network designs to achieving the best mix of power, weight, and package space.

## The Power Delivery Network

The NBM9280 provides 37kW of 400V and 800V fixed-ratio conversion, enabling a high-efficiency and high-density scalable onboard solution for compatibility between EV batteries and roadside DC fast-charging stations. With a fixed-voltage conversion ratio of 1:2, this converter makes the battery voltage of an 800V vehicle appear to be half the voltage (400V). The same is true for a 400V vehicle: the bidirectional capability of the NBM9280 allows the same module to be used for either step-up or step-down conversion. It can also provide a 400V source for air conditioning and cabin electronics during 800V charging, minimizing battery balancing circuitry.

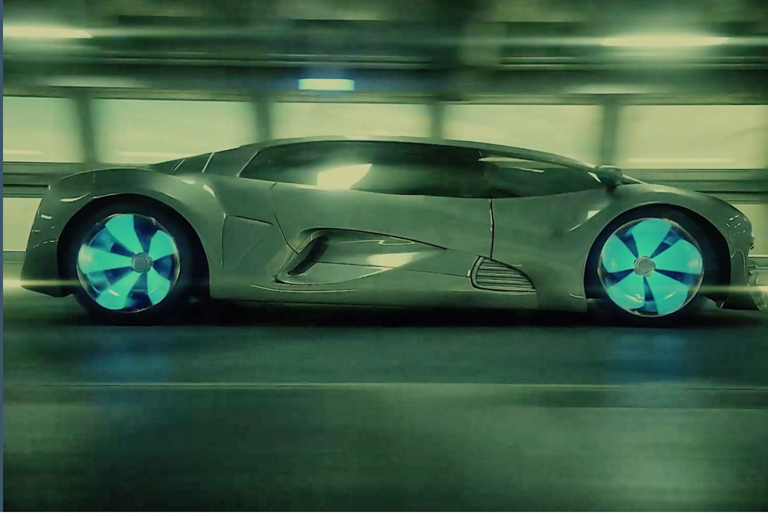


### NBM9280

| |
|---|
| Non-Isolated, fixed-ratio |
| Input: 400 – 920V |
| Output: 200 – 460V |
| Current: Up to 75A |
| Power: 37kW |
| Peak efficiency: 99.0% |
| 92.2 x 80.0 x 7.5mm |

VICOR



Application example:
400/800V conversion to 48V

# The most efficient way to get from high voltage to a 48V power delivery network

Compact and lightweight

Fast transient response

Isolated and bidirectional

Power 48V loads right off the HV battery

## 2.5 kilowatts of power in a small space

Vicor high performance power modules require dramatically less space than traditional discrete power solutions. This allows for flexible placement of power conversion within the vehicle where the alternatives simply would not fit.

## Scalable power architecture that eliminates the intermediate battery

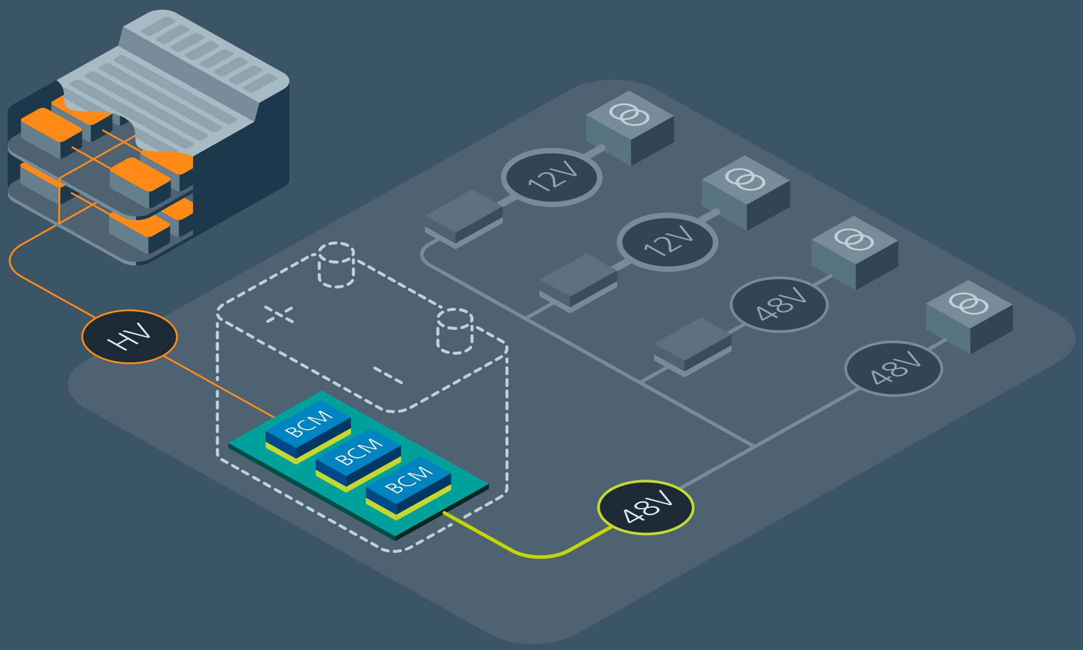
By adopting the modular approach, easily scale power to meet requirements by simply adding another module or swapping for a different module. This allows for the same power architecture to be deployed across vehicle platforms. Preserve the advantages of high-voltage energy storage by using a Vicor module to deliver power within a SELV range. It provides the fast response time required to meet the power drawn by the wide variety of subsystems.

## Tailored solutions

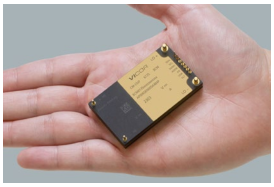
Our team of engineers collaborates with customers to tailor our modules to support specific needs and to architect new, efficient, modular power delivery networks that take full advantage of our modules. Using just a few power modules, designs achieve the best mix of power, weight, and package space.

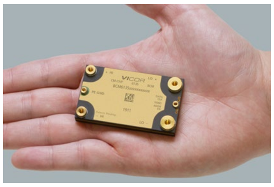
## The Power Delivery Network

Vicor BCM6135 power modules enable 800V and 400V batteries to supply 48V power delivery networks, while reducing weight and space consumption. Power level can be increased and decreased by 2.5kW simply by adding or removing a module. As shown, three BCM6135s provide 7.5kW of power. The BCM6135 provides bidirectional power conversion and fast transient response, eliminating the need for intermediate energy storage at 48V. The BCM6135 can virtualize the HV battery to look like a 48V battery within the system without the space and weight associated with a physical 48V battery – something a discrete solution cannot do.




| 800V/48V BCM6135 | 400V/480V BCM6135 |
|---|---|
| Isolated converter | Isolated converter |
| Input: 520 – 920V | Input: 260 – 410V |
| Output: 32.5 – 57.5V | Output: 32.5 – 51.3V |
| Current: Up to 80A | Current: Up to 65A |
| Power: 2.5kW | Power: 2.5kW |
| Peak efficiency: 98.0% | Peak efficiency: 98.6% |
| 61 x 35 x 7.4mm | 61 x 35 x 7.4mm |





VICOR

Application example:
Bridging 48V and 12V in
zonal architectures

# 48V zonal architecture made easy using power modules

Compact and lightweight

Passive cooling

Scalable across platforms

Flexible placement in the vehicle

## Up to 2 kilowatts of power in a small space

Vicor high performance power modules require dramatically less space than traditional discrete power solutions. This allows for flexible placement of power conversion within the vehicle where the alternatives simply would not fit.

## Simple thermal management

The low heat dissipation and planer surface of power modules allows for passive cooling instead of liquid cooling, a significant weight and complexity gain.

## Easy to implement redundancy

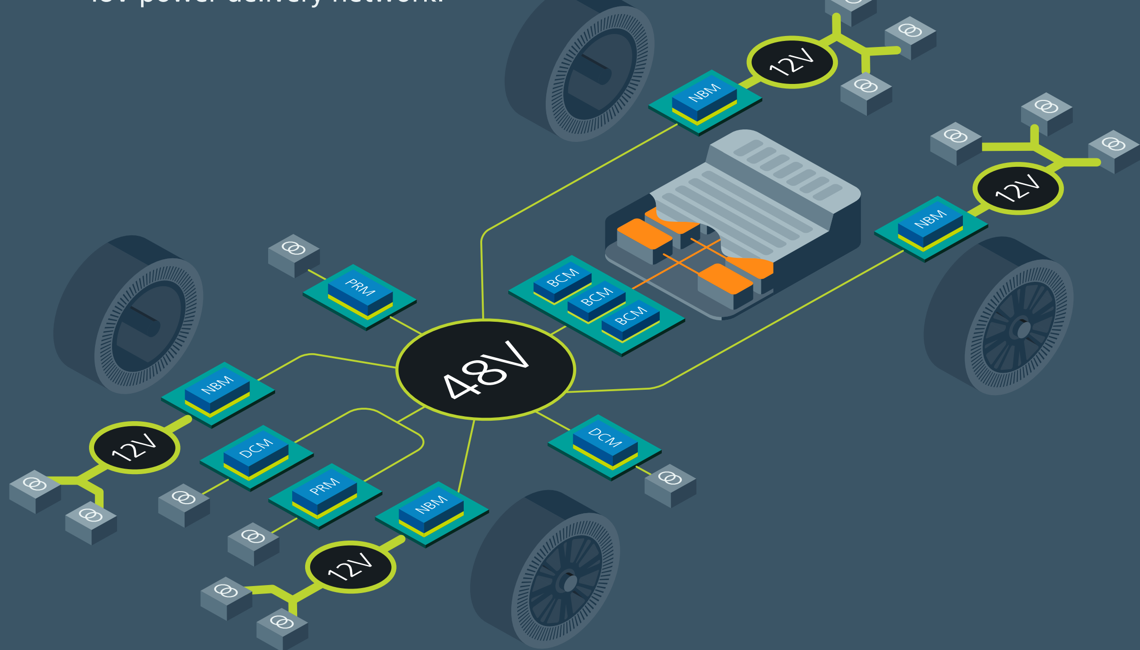
It's faster and easier to incorporate duplicate power modules than to undergo the complexity of designing-in redundancy within a discrete system.

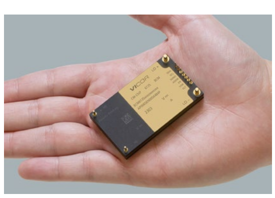
## Tailored solutions

Our team of engineers collaborates with customers to tailor our modules to support specific needs and to architect new, efficient, modular power delivery networks that take full advantage of our modules. Using just a few power modules, designs achieve the best mix of power, weight, and package space.

## The Power Delivery Network

Providing power to the growing number of loads in a 48V zonal architecture requires high-density modules, since larger and bulkier discrete solutions add much more bulk and weight. Compact power modules can be located close to the points of load, in tight spaces where alternatives would never fit. The Vicor NBM2317 provides 48V to 12V fixed ratio conversion to power legacy 12V loads at 98% efficiency. When regulation is required, the Vicor DCM3735 supports 12V loads and the Vicor PRM3735 supports 48V loads. With unprecedented density and no need for liquid cooling, these converters can be deployed throughout the vehicle, creating a much more efficient
48V power delivery network.



### 800/48V BCM6135

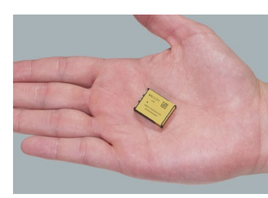
- Isolated converter
- Input: 520 – 920V
- Output: 32.5 – 57.5V
- Current: Up to 80A
- Power: 2.5kW
- Efficiency: Up to 98%
- 61.3 x 35.4 x 7.3mm

### 48/48V PRM3735

- Non-Isolated, regulated
- Input: 31 – 58V
- Output: 36 – 54V
- Power: 2.5kW
- Efficiency: Up to 99.2%
- 36.6 x 35.4 x 7.4mm

### 48/12V DCM3735

- Non-Isolated, regulated
- Input: 35 – 58V
- Output: 8 – 16V
- Power: 2kW
- Efficiency: Up to 96.5%
- 36.6 x 35.4 x 5.2mm



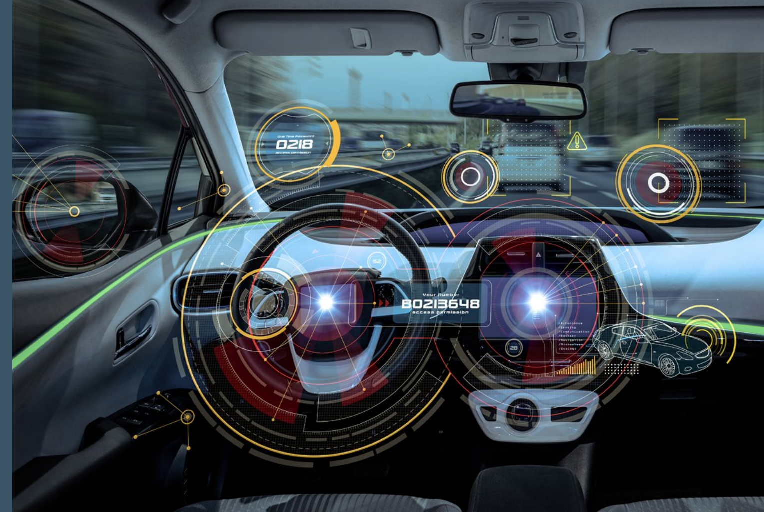
### 48/12V NBM2317

- Non-Isolated
- Input: 40 – 60V
- Output: 10 – 15V
- Power: 1kW
- Efficiency: Up to 98%
- 23 x 17 x 7.4mm

# Case studies

VICOR

Case study:
Central DC-DC converter




# Significantly reducing the size and weight of DC-DC conversion

## Customer's challenge

A traditional silver box power supply is large. It's difficult to fit in tight spaces and its heavy weight inhibits engineers' goals to increase driving range between charges. The supply and other silver boxes – on board charger and inverter – all require liquid cooling that adds more weight and complexity. A discrete solution likely won't work on a different platform, and re-engineering to scale power up and down requires significant cost and time frames. The key challenges were:

- Volume of space required to power all loads in an EV
- Hundreds of potential fail points in soldering and connections
- Reduce weight from the boxes

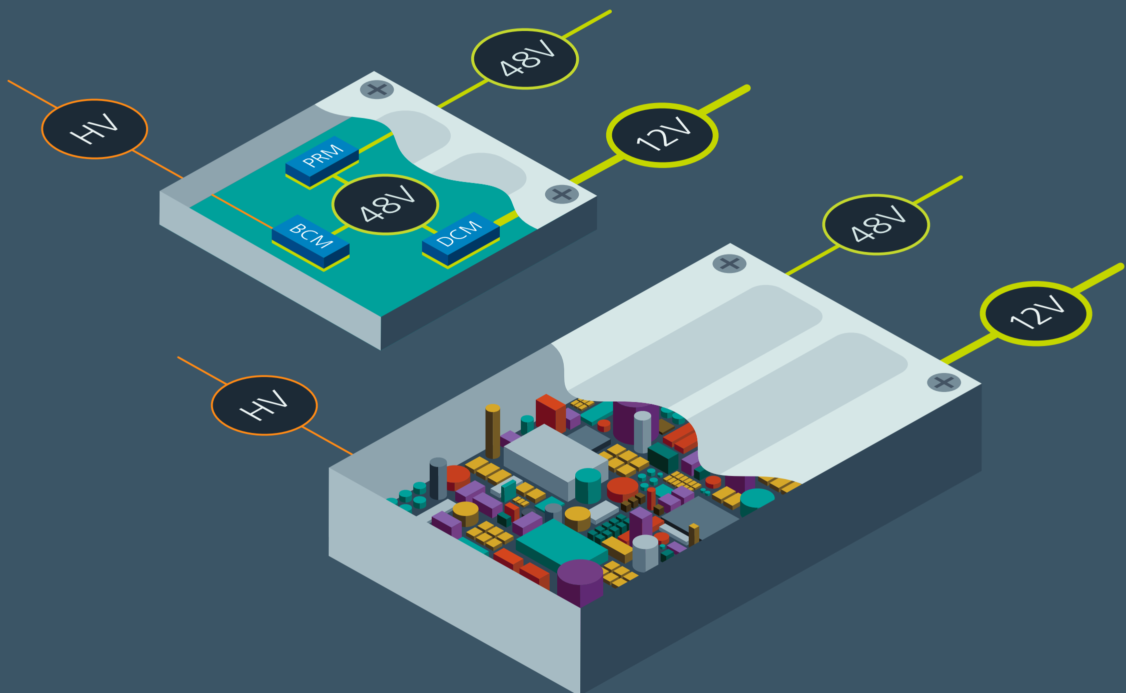
## The Vicor solution

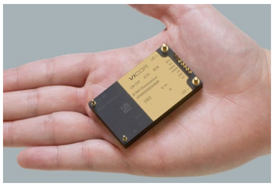
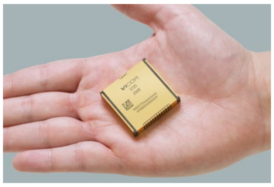
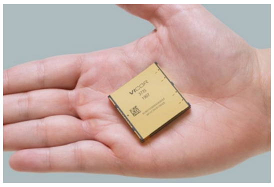
Vicor power modules are industry leading in high density power conversion. Their packaging protects inside components from harsh environmental conditions, eliminating creepage and clearance issues that make discrete solutions so large and heavy. Power modules provide conversion that's already tested, with simple passive thermal management, and are easy to adapt for use in different vehicle platforms. Their much smaller volume also makes it feasible to combine DC-DC conversion, on board charging and inverter into one box. Key benefits were:

- Up to 20kW of power in a very compact, lightweight solution
- Isolation incorporated within the module eliminates extra components, further reducing weight

## Lightweight, power-dense modules downsize EV power conversion

The BCM6135 power module converts the high voltage battery power down to a 48V SELV at 98% efficiency. The PRM3735 is used to provide a regulated 48V rail, while the DCM3735 converts 48V to a 12V regulated rail. Modules can be easily paralleled to provide as much power as is needed downstream. With the miniature dimensions of power modules, the resulting overall volume of the power supply is small enough to be located within tight spaces in the vehicle engine compartment where a bulky, heavy discrete power supply simply would not fit.



| 800/48V BCM6135 | 48/48V PRM3735 | 48/12V DCM3735 |
|---|---|---|
| Isolated converter | Non-Isolated, regulated | Non-Isolated, regulated |
| Input: 520 – 920V | Input: 31 – 58V | Input: 35 – 58V |
| Output: 32.5 – 57.5V | Output: 36 – 54V | Output: 8 – 16V |
| Current: Up to 80A | Power: 2.5kW | Power: 2kW |
| Power: 2.5kW | Efficiency: up to 99.2% | Efficiency: up to 96.5% |
| Efficiency: Up to 98% | 36.6 x 35.4 x 7.4mm | 36.6 x 35.4 x 5.2mm |
| 61.3 x 35.4 x 7.3mm | | |

Case study: Powering 400V accessory loads


# Supporting legacy accessories in new 800V architectures

## Customer's challenge

As the 800V traction battery becomes more common among EVs, loads that were powered directly from a 400V battery are now incompatible. The investment in cost and time frames to engineer 800V versions is prohibitive. Yet converting voltage for these high power loads – compressors, pumps for cooling and HVAC, etc. – needs to be as efficient and lightweight as possible to continue to maximize the driving range of EVs. The key challenges were:

- Avoiding the cost penalty of adding a discrete based 800 to 400V converter
- Do not add substantial weight to the vehicle
- Find a relatively inexpensive, quick to market solution to power 400V loads

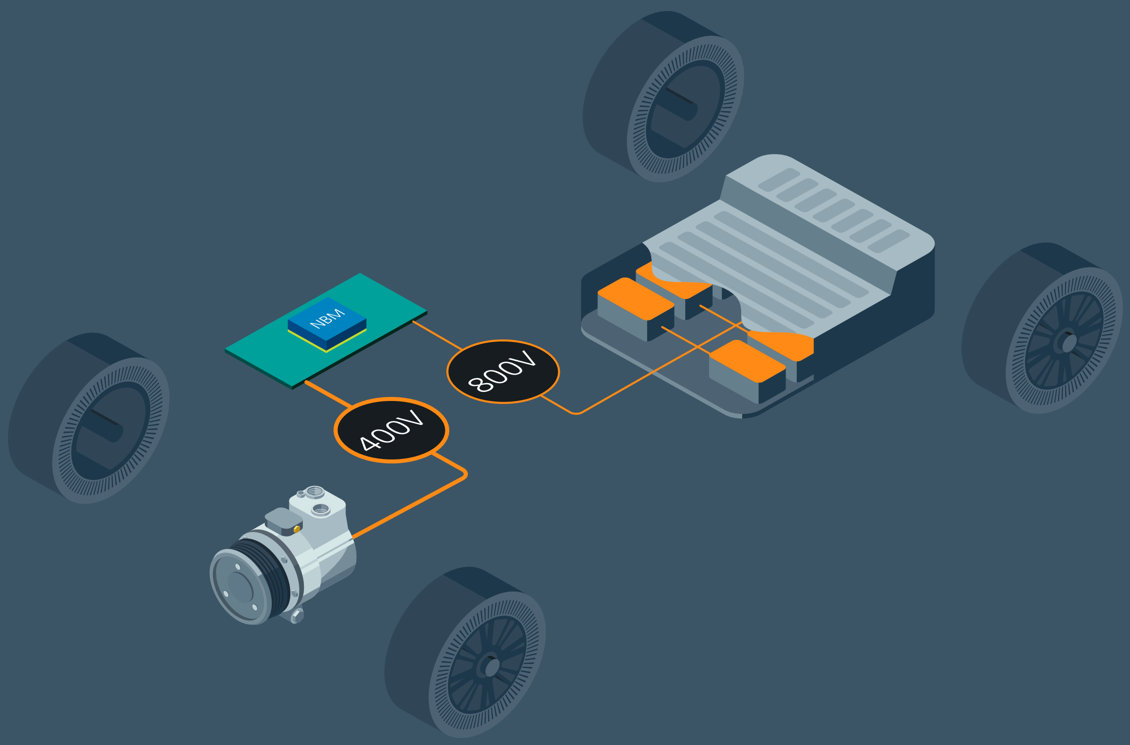
## The Vicor solution

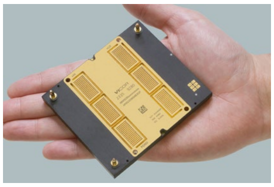
High density power conversion using a single Vicor power module provides the solution with the smallest volume, lightest weight, and highest efficiency. Power modules are already tested, often only require passive cooling, and are easy to package virtually anywhere in the power system compartment. With this modular approach, it's easy to adapt the solution to meet specifications for use in different vehicle platform. Key benefits were:

- A single power module provides up to 37kW
- A very compact, lightweight solution
- High power output can support up to 17kW with passive cooling

## Lightweight, power-dense module provides a high power rail

A single, compact NBM9280 can power a 37kW, 400V rail to power accessories from the 800V battery. With a peak efficiency of 99.0%, the NBM is a high-density power converter that weighs only 200g. It can be packaged for flexible placement within tight spaces in the vehicle engine compartment where a bulky, heavy discrete power supply simply would not fit.



### NBM9280

- Non-Isolated, fixed-ratio
- Input: 400 – 920V
- Output: 200 – 460V
- Current: Up to 75A
- Power: 37kW
- Peak efficiency: 99.0%
- 92.2 x 80.0 x 7.5mm

VICOR

Case study:
Automotive active suspension

# High density power conversion makes active suspensions viable

## Customer's challenge

xEV customers expect the improved ride and safety that active suspensions provide. It's been difficult to implement because 12V actuators are so large they won't fit at all 4 wheels. Native 48V actuators would be necessary. The resulting power solution would need to regenerate power when the shock returns to its neutral position and react instantly to changes in power load and direction. The key challenges were:

- Existing 12V systems cannot provide adequate power
- 800V is too dangerous to route through the vehicle body
- Traditional converters cannot change direction or boost power as quickly as necessary

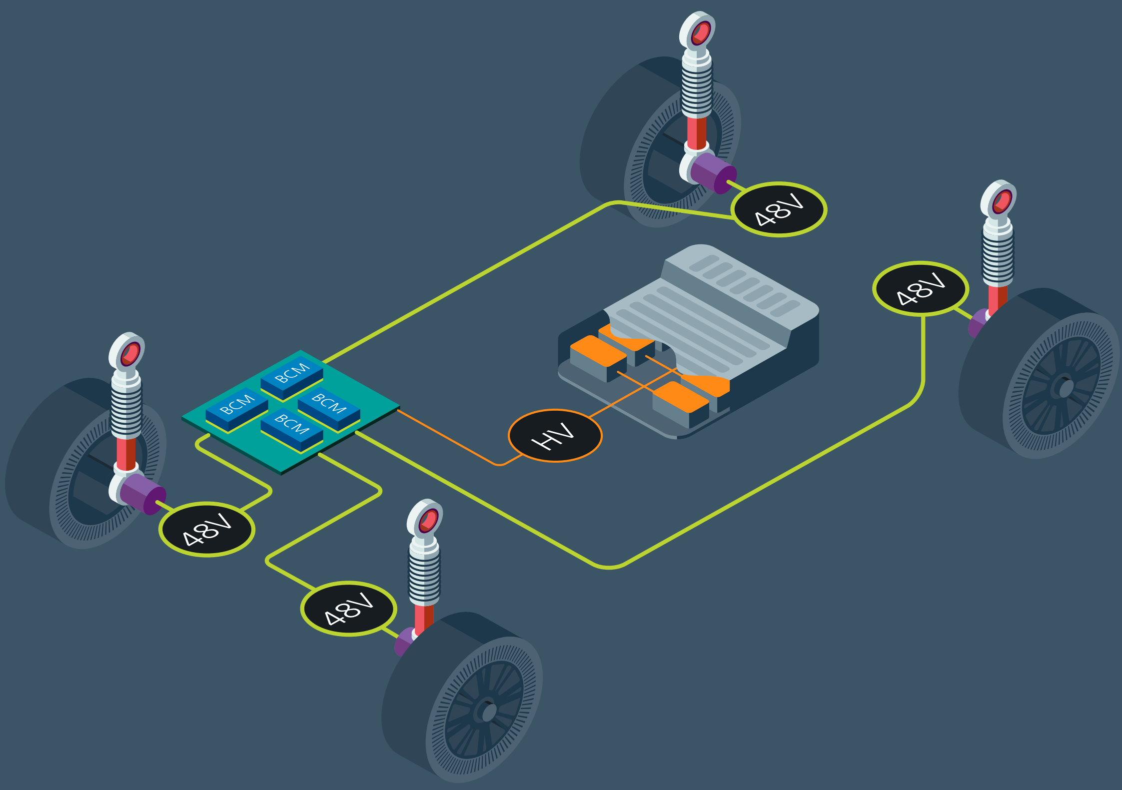
## The Vicor solution

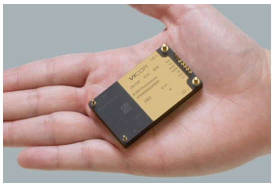
With their compact size, Vicor power modules can be easily packaged near the high voltage traction battery, making it feasible to implement active suspension by efficiently sending power to 48V actuators at all 4 wheels. The bidirectional power modules can provide the power necessary (4 to 6kW) to bring the shock down – and unlike discrete solutions – can respond instantly to provide the same amount of regenerative power back to the battery as the shock returns to its neutral position. Key benefits were:

- Power modules can both boost and buck the amount of power necessary
- Fast transient response
- Power modules provide conversion that's tested, with simple thermal management, and easy to adapt for use in different vehicle platforms

## Power dense and compact power modules safely convert high voltages to provide high power at 48V

BCM6135 bidirectional power modules convert the HV coming from the EV battery to a safe 48V SELV which is then routed to each wheel's suspension system. Each BCM provides 2.5kW of power, allowing each wheel to function – consuming or regenerating power back to the battery – independently of each other.



BCM6135

| |
|---|
| Isolated converter |
| Input: 520 – 920V |
| Output: 32.5 – 57.5V |
| Current: Up to 80A |
| Power: 2.5kW |
| 61 x 35 x 7.4mm |

# Articles

Article by Noa Margolin, R&D Engineer

# BEVs have a weight problem that can't be solved with traditional approaches

This article was originally published by Power Systems Design.

## High-density power modules enable 48V systems that reduce weight and power loss

Battery-electric vehicles (BEVs) have a serious weight problem and not the type Weight Watchers® can fix. Many BEVs are as much as 33% heavier than their internal combustion engine vehicle (ICE) counterparts. The chair of the National Transportation Safety Board noted "The Ford F-150 Lightning is between 2,000 and 3,000 pounds heavier than the non-electric version." Furthermore, the National Bureau of Economic Research found that adding 1,000 extra pounds to a vehicle increases accident fatality risk by about 47%.

Deploying a zonal architecture supported by high-density power modules will reduce weight in three ways:

Wire harness: ~85% weight reduction

Auxiliary battery elimination: ~100% weight reduction

Power system optimization: ~33% weight reduction

Consequently, automotive OEMs face severe constraints in trying to design BEVs with enhanced range, safety and electronic content. It is one of the most formidable R&D challenges the industry has ever faced.

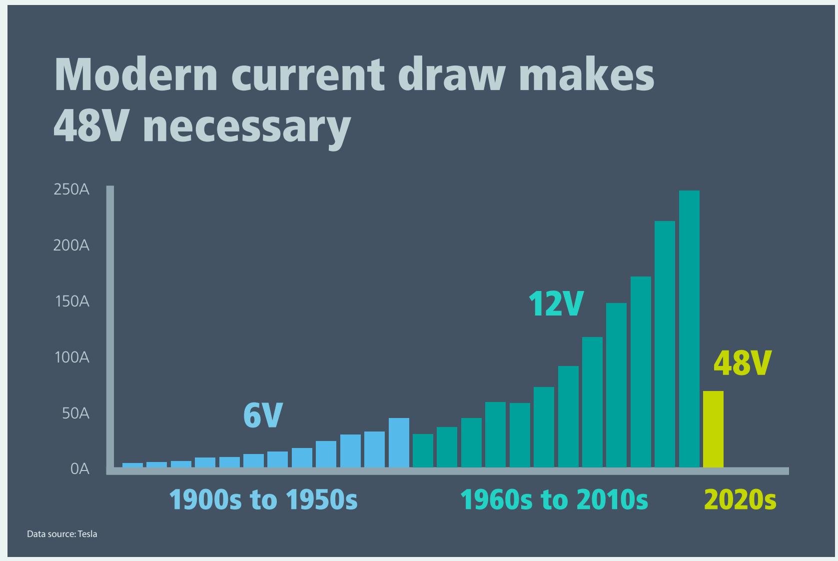
Despite the immensity of the challenge, these concerns for OEMs, consumers and legislators can be mitigated if the conventional overweight power delivery network (PDN) in EVs is replaced by 48V zonal architecture in which a 48V bus replaces legacy 12V system. Deploying a zonal architecture supported by high-density power modules will reduce weight in three ways. This new architecture will enable the transition from thick wire harnesses to a much thinner one, reducing harness weight up to 85%. Additionally, low-voltage auxiliary batteries can be removed and virtualized with power modules, completely eliminating the battery's weight. Lastly, the PDN upgrade using power modules optimizes the thermal management system, reducing its weight by up to 33%.

So, transitioning to a zonal architecture, an alternative to traditional centralized architecture, significantly reduces weight and improves overall power system efficiency.

## Moving to 48V: an obvious improvement and overdue for BEVs

New electronics like safety, security and autonomy have been added to new vehicles in every design cycle. Every additional feature increases the power draw and with a fixed, standardized battery, that has translated into an exponential increase in current. Evidenced by the trends in current (Figure 1), the centralized architecture PDN is unsustainable. The only way to support the ever-growing need for power while bringing back sustainable current levels and minimizing the wire harness weight is to increase the operating voltage to 48V using a zonal architecture.

Figure 1: Conversion to 48V system reduces vehicle total current draw from over 250A to under 75A without impacting the electrical content of the vehicle. Since 1908, the current demand in automobiles has grown exponentially with the addition of vehicle electronics. In the 1960s OEMs increased voltage from 6V to 12V, causing current to drop for the first time in 60 years. Today, most OEMs still use the 12V bus, despite the demand for more current. In 2023 Tesla became the first OEM to announce a full transition to busing 48V throughout the vehicle, which will dramatically drop current demands.




Today's BEVs are powered by a primary high-voltage battery (typically 400V or 800V) that needs to deliver power not only to the electric traction motor but also to a myriad of low voltage loads, like the air conditioner, heated seats and infotainment systems. A PDN steps-down the high voltage to the 48V and 12V auxiliary batteries that energize these subsystems.

Moving to a 48 zonal architecture presents an opportunity enabled by Ohms Law: Power=Current×Voltage. For the same power delivery, a 12V source requires four times as much current as a 48V source. Thus, the 12V wire also is generally four times thicker than a 48V wire.

## The demise of the 12V centralized architecture

The 12V centralized system has been the traditional power architecture used in automobiles since the 1960s. This architecture consists of one bulky silver box housing which contains a set of discrete components, including all the DC-DC converters, high-voltage (HV) to 48V to 12V. Thick and heavy wires are required to carry the 12V current to the points-of-load. Moreover, due to legacy DC-DC conversion inefficiency, this centralized power system generates significant heat from the silver box, often requiring intensive liquid cooling, which adds more weight.

To transition to 48V high-density power modules can be used at the endpoints to efficiently convert to 12V at the points-of-load. This enables the OEM the flexibility to gradually transition the 12V load devices to 48V over time. This helps rapidly achieve the benefits of using 48V with minimal disruption to the system architecture.

## 48V zonal architecture reduces heat loss and current

This novel 48V zonal architecture system capitalizes on Ohm's Law and is a paradigm shift for the industry, in which DC-DC conversion occurs closer to the points-of-load, rather than inside the centralized silver box. In this approach, HV-to-48V conversion enables safe 48V to be bussed throughout the vehicle. 48V-to-12V conversion occurs at the point-of-load. By carrying current at 48V instead of 12V, wires can be thinner, lighter and significantly cheaper (Figure 2). This smaller, more flexible wire is also easier to route within the vehicle. Additionally, this approach evenly distributes the heat losses associated with DC-DC converters throughout the vehicle, enabling the potential use of chassis-mounted heat conduction and convective air cooling.

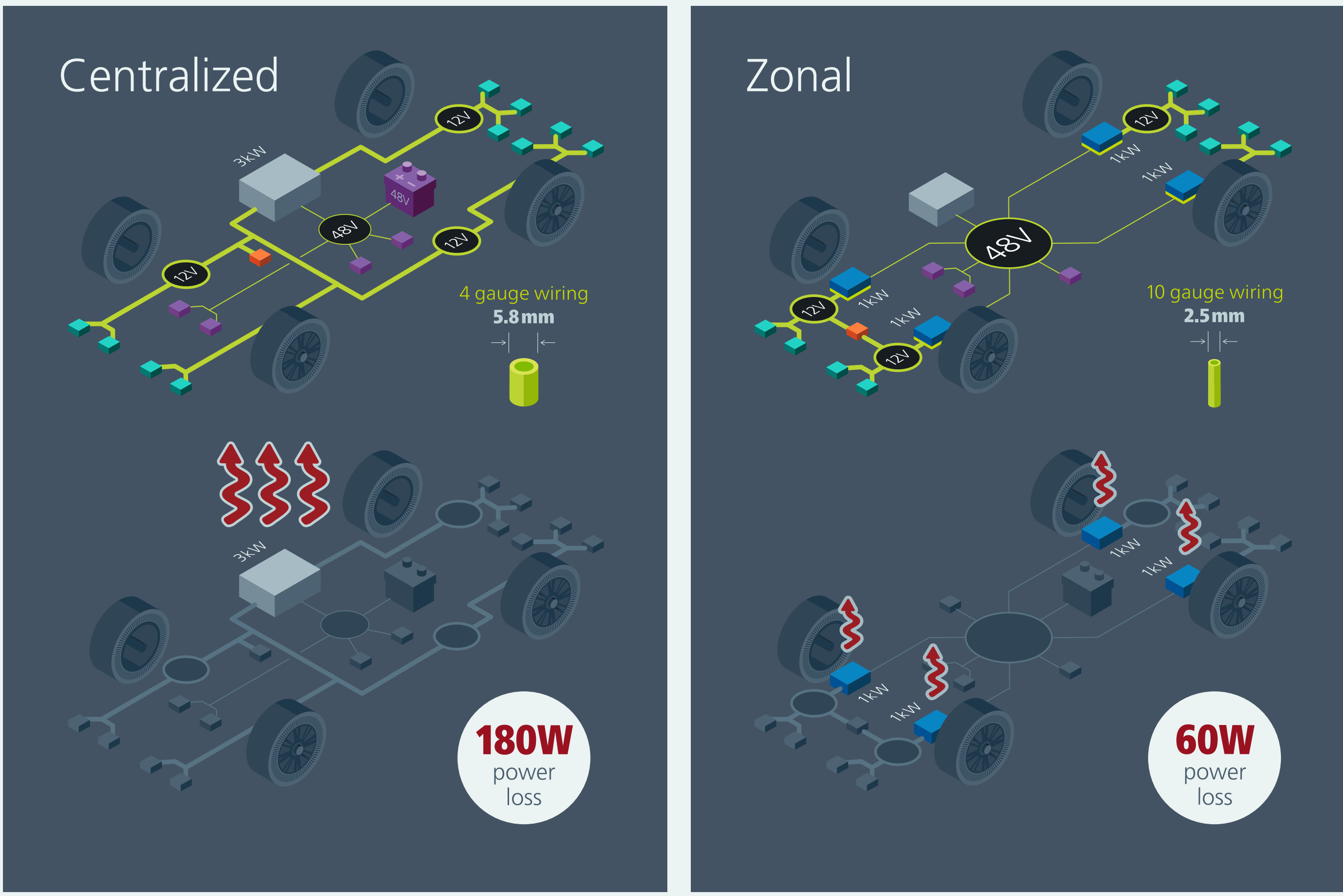



Figure 2: There are two distinct PDNs used in automobiles today. The 12V centralized architecture and fast-growing 48V zonal architecture. The former depends on the thick 12V wire harness, while the latter draws upon the thin 48V wire harness, which is far lighter, reduces heat loss and reduces current by a factor of four.

## Counting up the weight savings

The 48V zonal architecture better supports the increasing power demand in BEVs, while simultaneously lowering vehicle weight in three ways.

- Wire harness: ~85% weight reduction

  The upgrade to 48V zonal architecture means traditional 12V, 4-gauge wires at 273g/m, will be replaced with 48V, 10-gauge wires at 27g/m. This reduces the wire weight by approximately 85%.

- Auxiliary battery elimination: ~100% weight reduction

  A zonal architecture with power modules enables an acceleration of the DC-DC converter's transient response, which creates a virtual battery. Therefore, zonal 12V/48V power modules replicate the characteristics of 12/48V low-voltage batteries, while completely eliminating the physical 12V battery, saving 100% of the weight.

- Power system optimization: ~33% weight reduction

  Substituting the zonal system for the centralized system moves the 48V-to-12V power conversion out of the silver box to the points-of-load. The revised power system box using high-density power modules to provide 48V output will be up to 33% smaller. Therefore, the housing weight can be reduced by up to one third (33%).

In the traditional 12V centralized system, discrete components create a high ambient temperature inside their silver box housing. The power system box using high-density power modules creates less heat, and the point-of-load modules can be efficiently air-cooled on the chassis. These improvements enable the liquid-cooling system to slim down by up to 7%.

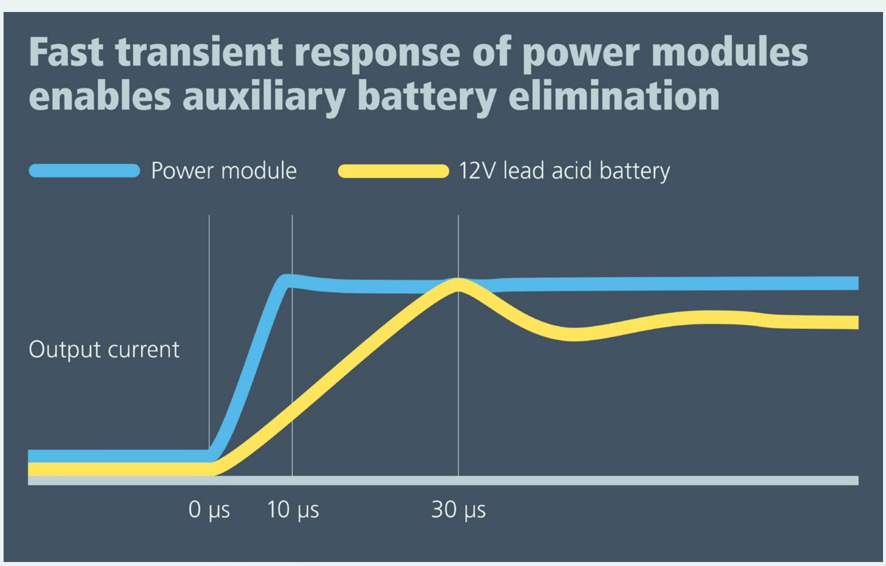


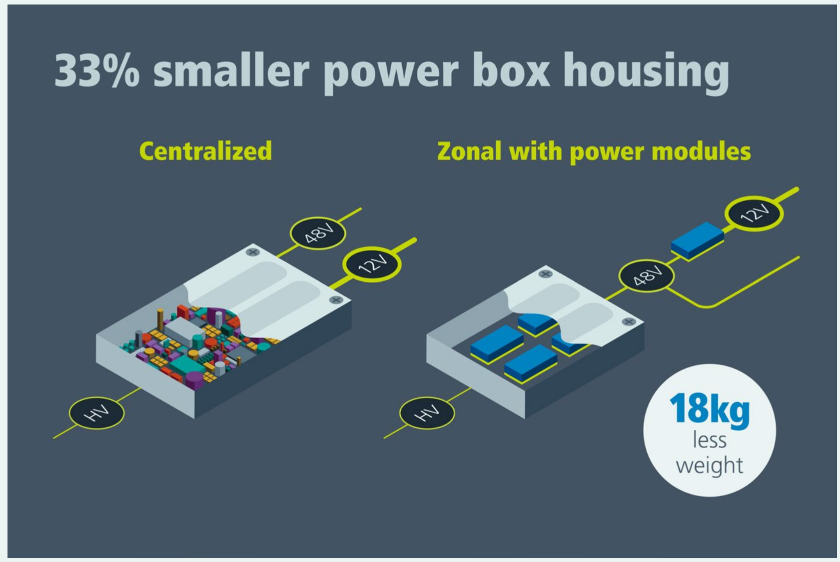

Figure 3: Power modules deliver a faster transient response than 12V lead acid batteries creating a virtual battery that can replace the legacy, heavy 12V battery.

## Transforming weight into opportunity

OEMs accrue a variety of benefits by using a zonal architecture. To illustrate, consider the impact weight reduction will have on increasing range. Heavier vehicles tax power consumption and range.

However, extra weight can mitigate the impact on range if it is used to increase battery size. The additional battery provides more energy storage, improving range.

Figure 4: The centralized housing can be reduced when using power modules and a zonal architecture because heat can be dissipated more efficiently at the endpoints where 48V is converted to 12V loads.




In a study conducted by Vicor, zonal architecture supported by high-density power modules can reduce vehicle weight up to 40 pounds (Table 1). When this weight is replaced with 40 pounds of battery cells, the EV driving range can increase up to 4,000 miles per year, with no net weight gain. This is significant because the average American drives 14,263 miles per year, according to the Federal Highway Administration in 2023. Therefore, utilization of the 48V zonal architecture can reduce yearly recharging time by up to 30% (Table 2) and increase the distance the vehicle can travel on one charge.

### Weight reduction realized with zonal architecture

| | | Weight reduction |
|---|---|---|
| Wiring harness | Using 10 gauge wire (48V) | 2.5 kg |
| Auxiliary battery | Eliminated | 13.0 kg |
| Cooling system | 45 lbs, reduced by 7% | 1.5 kg |
| Power box housing | 6 lbs, reduced by 33% | 1 kg |
| | | **18 kg** |

Table 1: A 48V zonal architecture used in conjunction with high-density power modules will save about 18kgs (40 pounds) in compact electric SUVs.

### 30% less recharging time annually

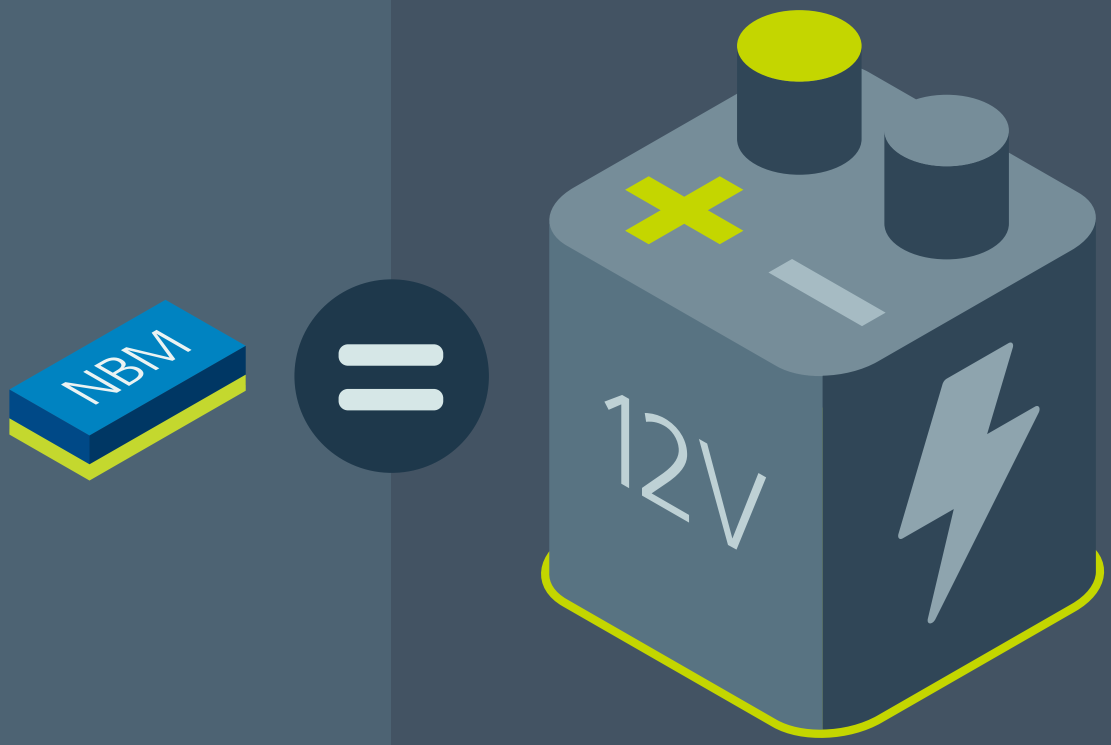
| | Average EV | Most efficent EV |
|---|---|---|
| Range per charge | 571 km | 805 km |
| Range per charge with zonal weight loss | 602 km | 848 km |
| Increase in range with zonal weight loss | 31 km | 43 km |
| Increase in range, x3 recharges/week | 93 km | 129 km |
| Increase in range, x52 weeks/year | **4836 km** | **6708 km** |
| Recharging time saved | **21%** | **30%** |

Table 2: Enhanced range offers drivers more distance per charge, reducing the charges needed per year.

## Innovate to eliminate

Electric vehicles are overweight and this trend is neither sustainable nor beneficial to the overall growth of EVs. The 12V centralized architecture, with its legacy silver box and discrete components, needs to upgrade to 48V zonal architecture to optimize the EV power delivery network and thermal management system. Going zonal can increase range up to 4000mi/year or can be used for additional safety or electronic features. The most efficient zonal architectures use small, lightweight converters at the point-of-load. Highly efficient power-dense modules are the best choice for 48V-to-12V conversion. Given the complexity of the automotive power electronics today, OEMs need to be creative to save weight while increasing performance. Vicor, the leader in high-performance power modules, enables innovation and creativity. Vicor compact power modules, architectures and topologies offer automotive OEMs flexible, scalable power solutions for high-voltage power conversion throughout the vehicle. Easy-to-deploy power modules are the alternative to the traditional discrete designs used in a legacy centralized power system. Small, compact power modules also are the obvious choice and natural complement to a 48V zonal architecture, which is the future power delivery network for the automotive industry.

This article was originally published by Power Systems Design.




Article by Pat Kowalyk,
North American Automotive Principal Field Applications Engineer

# Eliminate the 12V battery and increase EV performance

This article was originally published by Power Systems Design.

## Power module transient response is 3x faster than 12V battery

Look under the hood of an electric vehicle and you may be surprised to find a conventional 12V lead-acid battery, or an additional 48V battery. You may wonder why does an EV need a conventional battery when there's a 400V or 800V battery already in the vehicle to power the motors? Today the 12V or 48V batteries power all the other systems in the vehicle, but they add cost and weight and take up valuable space. Why not remove the 12V battery and use the 400 – 800V battery to power everything in the car?

The simple answer is that many automotive systems, especially safety systems, must respond quickly to sudden changes in power, and batteries historically have much better response times than DC-DC power converters. Until recently, power systems engineers have not had options for safely and reliably converting 800V or 400V down to 48V or even 12V with a fast transient response and without adding unwanted volume or weight.

Additionally new EV's consume up to 20x more power (going from 3kW to over 50kW) than combustion engines which puts significant strain on the power delivery network, when using hard switching DC-DC converter topologies, resulting in a hefty increase in conventional power electronics that consume space, increase weight and limit range.

Because of EV power requirements, it is time to take a fresh look at how to best deliver the power needed rather than trying to retrofit the internal combustion engine (ICE) power delivery architecture. Using traditional DC-DC power converters EVs cannot handle the associated ~20x increase in power without making performance and functionality compromises which diminish their appeal. This fresh look is not a light remodeling exercise. It is a knock-down and rebuild project that needs to be explored through the lens of innovation, not convention.

The conventional progress achieved toward electrification has been driven by adding more and higher-powered batteries to cars. These batteries are heavy and large. The latest models are touting 800V batteries, but the same vehicle is also hauling a 12V and maybe even a 48V battery. With package space and weight at a premium, three batteries is inefficient and unnecessary.

Where conventional approaches add batteries, a fresh, innovative approach removes a battery, frees package space and reduces weight, all while increasing much need power transient response.

## The end of the road for 12V batteries?

High-performance power conversion is essential to removing a battery. More specifically, faster transient response from a converter is the most important variable. If a high-performance power converter can deliver the rapid response equal to or better than a 12V battery (250A/ms), then removing the 12V battery and its associated weight and packing space becomes plausible.

The most essential role of the 12V battery has been to provide a reservoir of power for loads that require a lot of power. The typical load in a vehicle will have two types of current draw—one for start- and one for steady-state operation. When power is initially applied to a particular load, either raw power is applied or the power is already present and only an enable signal is needed.

The loads that use raw power will draw a large amount of current either to charge a capacitor or to turn an armature. Then, after the load is energized (start-up), the current drops down and the load operates continuously (steady state). This initial current draw is what makes the battery a good option for a legacy ICE vehicle, but not for an EV where weight dramatically impacts range and performance.

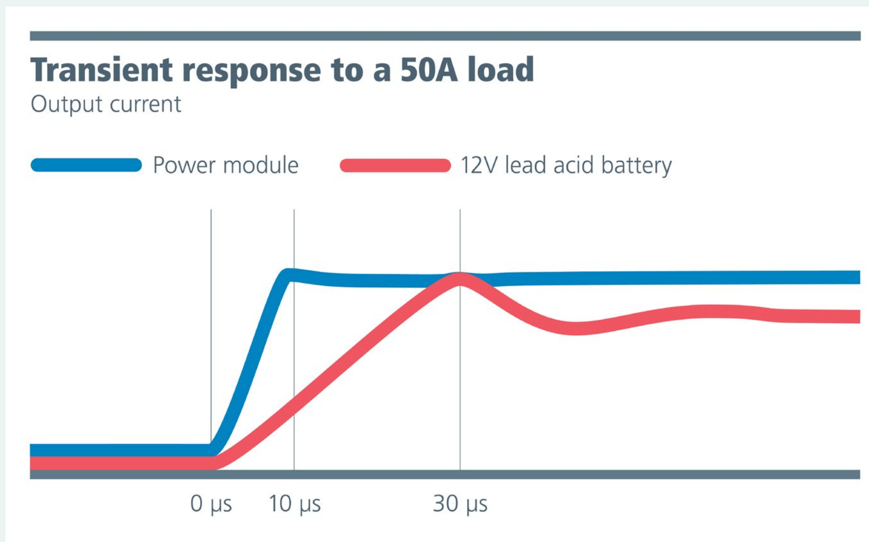
So it makes sense to eliminate the heavy lead-acid or lithium 12V battery and replace it with a lighter, compact and high-performance DC-DC converter that delivers very fast transient response.

## 12V battery vs. high-performance power modules

Replacing the 12V battery in a vehicle with a traditional converter may cause the load voltage to drop low enough that the load turns off, thus causing a reboot in a vehicle. A key parameter to look at is the load voltage deviation during a change in current relative to time. This is referred to as the transient response; the lower the voltage deviation, the higher the performance of the system.

When designing a new electric vehicle, one needs to consider a great number of new high-tech solutions. A modular power approach combined with topologies like the proprietary Vicor Sine Amplitude Converter (SAC™) allows one to far exceed the slew rate—the transient response—of a 12V lead-acid battery. A modular approach leveraging SAC can process thousands of amperes from the high voltage battery to the load eliminating any dips or loads falling out of regulation. Bench testing shows that modular power can deliver a response three times faster than a typical 12V battery (Figure 1) .

Figure 1: Transient test comparison: 48V-to-12V at 75A compared to a 12V battery. The NBM2317 power module response to a 50A load is three times faster than a standard 12V battery.




Automobile manufacturers typically require 250A/ms for their fastest loads, which 12V batteries can achieve (75A/30µs). The Vicor modular approach can provide faster transient response (75A/10µs), creating a "virtual battery" that responds three times faster than 12V.

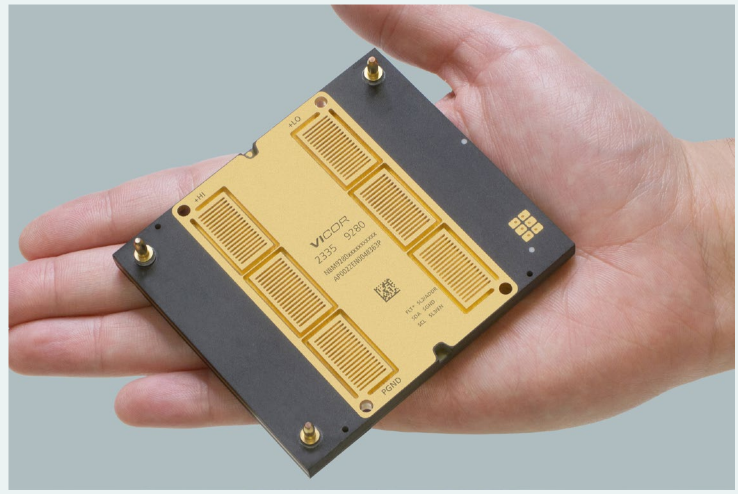
| Power source | di/dt |
|---|---|
| 660CCA, 12V car battery | 75A/30µs |
| 48V to 12V SAC at 80A | 75A/10µs |

## Replacing 12V battery with a faster, lighter and smaller high-performance power converter

Modular power combined with SAC is part of what makes this solution optimal for automotive power. The SAC has a turns ratio, called the K-factor that is a ratio of the primary to secondary turns. A key advantage of this topology is that any primary-side capacitance is multiplied by the K-factor squared. For a 12V-to-48V conversion, the K-factor is ¼, which means the effective secondary capacitance is four squared, or 16 times the primary capacitance.

The Vicor NBM is an ideal converter to transfer the energy load from a mechanical source, which is on all the time, to an electrical source of energy that cycles on and off, allowing better control and better efficiency. The NBM in conjunction with the SAC allows an engineer to create a virtual battery that replicates the essential properties of a physical battery, complete with all the benefits of a battery but without the weight, size or temperature limitations of a battery (Figure 2).

Figure 2: Vicor power modules bundled with EMI filtering, minimal components and an enclosure could replace a 12V lead-acid or lithium-ion battery eliminating 15 – 40lbs of weight.




Using a modular approach allows the designer to split the power source into different zones. Instead of having one centralized power architecture, the designer can place an NBM in the dashboard, in the trunk and or by all four wheels. Having the power source closer to the load reduces parasitic inductances and series resistances for a high-performing power system. The same approach also applies to HV-to-48V conversion which would show similar performance, creating a 48V virtual battery (Figure 3).

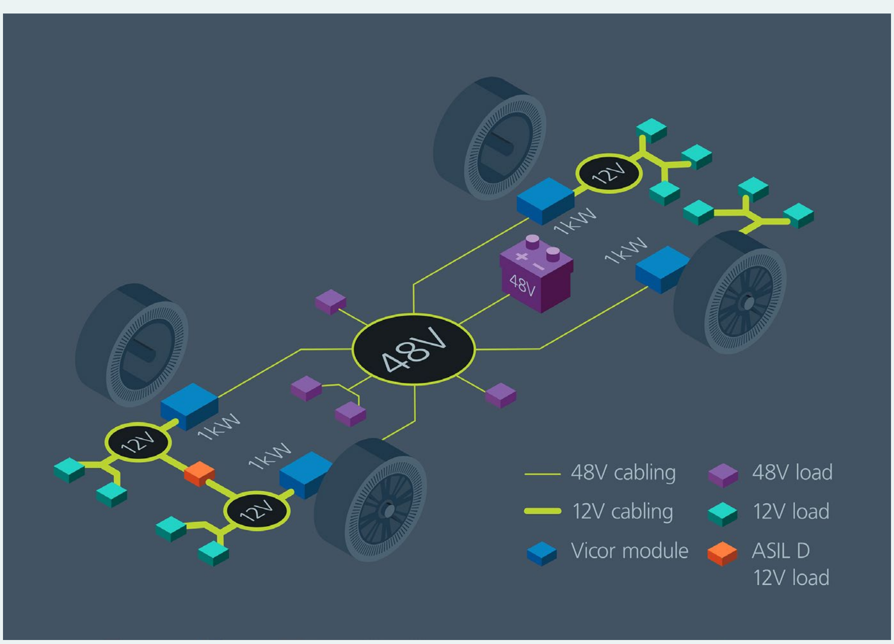



Figure 3: A Decentralized architecture offers more design flexibility and can reduce the cable and harnessing weight in the vehicle, freeing space and extending range.

It makes sense to use the traction motor battery which is the largest energy source in the vehicle to down-convert to different safe voltages. Typically, the traction motor battery in an electric vehicle is either 400V or 800V and will be quickly replaced with 1,200VDC or 1,400VDC.

A modular approach eliminates any internal series inductance on the input or output and can process easily 700,000 amperes per second or 700 amperes per millisecond. It can be easily be paralleled in an array to create a large power-processing system and has isolation from any primary bus voltages which are 60V or higher.

The NBM™ in theory is only thermally limited in terms of its power capability and if properly cooled it can process very high amount of power. It provides the added benefit of bidirectional operation and can start up in either direction.

## Revolutionize your electrification with modular power

In this new age of electrification, OEMs will benefit from taking a fresh look at how cars are electrified. By designing the power delivery network from the ground up and considering all of the vehicles' electrical needs, you can derive far more benefits and deliver far greater performance.

In short, by switching to modular power you can eliminate the 12V battery and achieve enhanced transient response, decreased weight and additional package space – all of which contribute to extended range and better overall performance.

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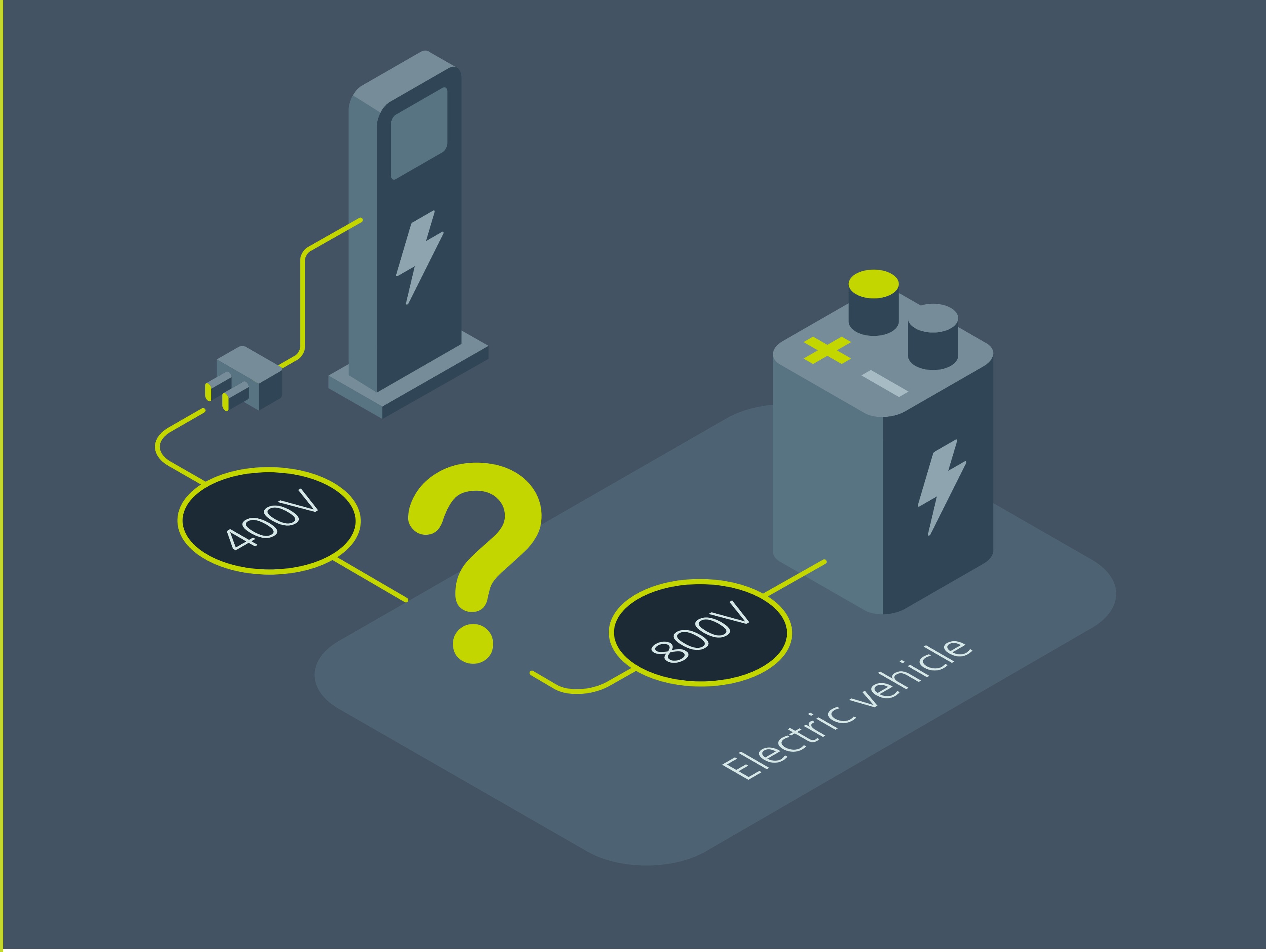
## About the Author

Patrick Kowalyk has been solving power delivery issues for over 20 years with Vicor innovative, high power, high density and high efficiency solutions. Patrick is the lead Automotive Principal Field Applications Engineer for Vicor in North America, helping power engineers architect new Automotive power delivery systems. He has a BS in Electrical Engineering from Illinois Institute of Technology.




Article by Haris Muhedinovic,
Senior Field Application Engineer

# Preparing the way ahead for a compatible EV infrastructure

This article was originally published by Electronic Specifier.

Charge anxiety is on the rise as today's EVs are increasing the primary battery voltage from 400 to 800V, even though public infrastructure is not adequate to support 800VDC fast charging. Upgrading the charging station infrastructure is not a tenable short-term solution. A faster, more holistic approach is an on board conversion solution which enables 400 or 800V compatibility. This approach can be adopted without significant capital investment and is a far easier execution.

## DC fast-charging incompatibility

The incompatibility problem is focused on DC charging, which is commonly used for long-range driving where time and access are limited. AC charging for everyday charging is not an issue because the existing grid infrastructure AC charging is fairly convenient. This type of charging is readily accessible to people who own EVs and can charge at home (overnight) or work (daytime) where charging speed is not critical. AC charging is ideal for daily use and short-range driving, and it is the cheapest and most practical solution for daily trips up to 300km.

When people are traveling long distances, however, they need to charge quickly and in public places, such as at a highway rest stop. In those cases, they can use DC fast charging stations. These stations require more than 50kW of power, reaching 150kW or 350kW at peak. While DC charging may be used less frequently than AC charging, it is very important to have a solid network of this type to reduce range anxiety. In 2020, the DC charging network totaled around 400,000 publicly-accessible fast chargers, with few of these supporting 800V vehicles. For example, in Europe, only 400 of 40,000 total charging stations support 800V vehicles.

This imbalance between 400V and 800V charging stations presents a significant problem as OEMs begin rolling out new 800V vehicles: the public infrastructure to charge them is inadequate.

## Exploring the DC fast-charging solutions

Broadly speaking, there are two approaches to solving DC fast-charging problem: one focuses on making changes to the charging stations, the other on making changes to the vehicle.

Expanding the DC fast-charging network of charging stations can alleviate this problem, but it may not be the most expeditious nor cost-effective. There are two ways to expand the DC fast-charging network:

- Adding 800V stations: installing new DC fast-charging stations with wide-voltage capability (from 250 to 920V) is one solution, but it requires considerable investment in time and money. Today there are approximately 1,000 charging stations in Europe and USA that offer 800V charging, which accounts for only about 2% of all available DC charging stations. To address the growth of 800V EVs, that network would need to expand to hundreds more stations. Installing that many new stations will take years and be cost-prohibitive.
- Utilizing 400V stations: another approach is to leverage the 400V stations and upgrade them to also support 800V, but this presents its own set of challenges. Charging at ultra-high-power rates (>150kW) is not always available and not always possible (temperature, battery degradation, etc.). Also, charging times would be slower than desired for 800V.

Onboard charging with a modular DC-DC virtual battery offers flexibility and 99% efficiency. In contrast to expanding the charging network, onboard conversion solutions are a more holistic approach to enable 400 or 800V compatibility. This approach can be adopted much more quickly and with no capital investment in charging infrastructure.

The incompatibility between 800V batteries and 400V chargers can be solved through "battery virtualization." With battery virtualization, the charger "sees" a 400V battery on one side of the onboard charger even while the 800V battery is connected to the other side. This approach starts from the battery voltage and adapts it to the voltage range acceptable by charging station (Figure 1).

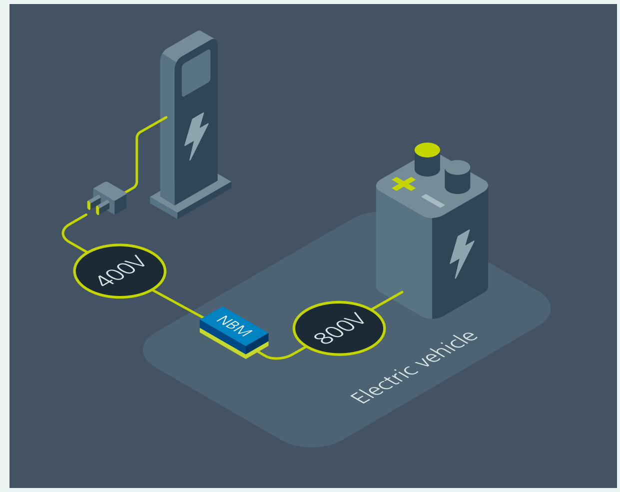



Figure 1: The incompatibility between 800V batteries and 400V chargers can be solved through "battery virtualization." With battery virtualization, the charger "sees" a 400V battery on one side of the onboard charger even while the 800V battery is connected to the other side.

This approach starts from the battery voltage and adapts it to the voltage range acceptable by charging station.

Vicor high-density, high-power modules can be used to implement a DC-DC converter onboard charging solution for battery virtualization without adding size, weight and design complexity.

Vicor NBM™ bidirectional modules convert tens of kW of power reaching 550kW/liter and 130kW/kg in power density, using power converters at least 50% smaller and lighter than discrete solutions. The Vicor proprietary SAC™ (Sine Amplitude Converter) topology ensures soft switching on primary and secondary sides, reaching 99% efficiency. This behavior implies simple EMC design and offers flexible cooling management (Figure 2).

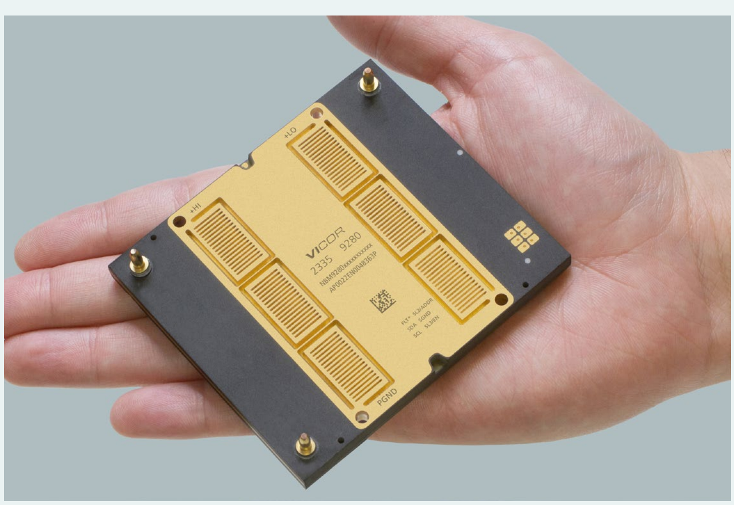



Figure 2: Vicor NBM bidirectional modules convert tens of kW of power reaching 550kW/litre and 130kW/kg in power density, using power converters at least 50% smaller and lighter than discrete solutions.

Connecting a battery to one side of an NBM module will immediately virtualize a battery on the other side, dividing or multiplying the voltage or current by constant factor. Ultimately, NBM modules extend the voltage range of charging stations (250 to 460V to 500 to 920V), thus increasing the number of overall available charging points and making an EV compatible with any DC charging station.

Flawless powertrain design and a high-bandwidth controller enable this battery virtualization. Vicor packaging technology not only simplifies assembly and manufacturing but also offers flexibility and scalability of power. OEMs can configure scalable packages of charging power from 50 to 150kW using the same module without need for additional qualification and certifications.

## Another reason to use power modules

Not only does the NBM have the capacity to offer battery virtualization for charging, it can also integrate with the traction battery to deliver higher efficiency for low-RPM driving. For example, city driving requires lower RPMs and the 800V traction inverter efficiency falls drastically by more than 15%. The NBM can be used in this ancillary manner to supply the inverter with half of the battery voltage, cutting switching losses in half and extending driving range. This is another advantage of how an integrated, modular approach to power can optimize the power delivery network, enabling partial utilization of the DC-DC converter to maintain peak efficiency.

## Eliminate range anxiety before starting up by using onboard boost conversion

While charging station infrastructure will certainly expand to support the growth of EVs, expansion alone will not resolve the 400V/800V compatibility problem. The most impactful solution to reduce range anxiety is to design onboard chargers that are compatible with any DC fast charger.

The Vicor onboard solution using high performance power modules enables full compatibility between 800V/400V vehicles and DC charging networks with minimal investment and maximum benefit. On average, the Vicor solution is half the size and weight of most discrete solutions and delivers very high efficiency and scalability. It can convert tens of kW of power reaching 550kW/liter and 130kW/kg in power density. The combination of high power density, flexibility and high efficiency make Vicor power modules an ideal onboard solution to solve 400V/800V EV charging compatibility problem.

## About the Author

Haris Muhedinovic works with OEMs and TIERs to design and develop highest performance power solutions for most demanding automotive applications. With his interest in power electronics and electronics systems, Haris is aware of new technologies and trends in industry, which allows him to implement power solutions to meet the most demanding specifications. Haris received his MSc from the University of Sarajevo and has 7 years of experience in power electronics in design and application engineering.

This article was originally published by Electronic Specifier.

# On-demand webinars

## WCX24 session: Optimize your Vehicle Power Distribution Network by Integrating the DC-DC Converter into the Battery Pack

With the move to Zonal architecture, future BEVs will have several heavy loads and safety systems using both 48V and 12V legacy power. Learn how incorporating 48V power conversion into the battery pack can eliminate substantial weight and size from the 48V power network. This integration will reduce weight, improve thermal losses, and reduce the system complexity. As a further step to reduce weight and system complexity, it will be shown how a 120kW 400V – 800V converter can be downsized to fit in the battery housing. Watch now.

## WCX24 session: Eliminating the high voltage precharge with existing hardware in BEVs

Any high-voltage bus needs to have a precharge circuit to reduce the current flow over a period of time, called the dv/dt, to protect the electronic devices in a battery electric vehicle. The challenge with a traditional solution to this age-long problem is that the precharge resistor charge time is inversely proportional to the power dissipation. A better approach is taking the power components in the battery electric vehicle and reusing them to charge the high voltage bus from a low-voltage source. Using power modules the regulator can be used in reverse, regulating the voltage and current. Watch now.

## WCX24 session: Achieving EM conducted emission compliance for high voltage conversion with switching frequency above 1.3MHz

Fixing EMI in systems employing high-frequency DC-DC converters poses a critical challenge due to the intrinsic nature of these converters. High-frequency operation and compact layouts intensify EMI concerns. The rapid switching of currents in these converters generates harmonics that can propagate through the circuit and radiate as electromagnetic waves. Mitigating EMI requires sophisticated filtering and shielding strategies, adding complexity to the design and increasing costs. Achieving effective EMI suppression without compromising the converter's performance requires a delicate balance, as aggressive filtering may hinder efficiency. Intricate trade-offs are required to develop robust systems that meet stringent EMI standards in the presence of high-frequency DC-DC converters. Watch now.

## WCX24 session: The uncertain future of aftermarket loads in a 48V world

High-power loads heavily tax the 12V system in current heavy-duty and super-duty passenger trucks, and these loads are key for the consumer to effectively use their vehicle. Converting these loads to 48V creates a diffusion of responsibility between OEMs and aftermarket suppliers. As these trucks make the switch to a 48V architecture, how will the aftermarket suppliers respond? What should you be thinking about to make the transition easier? What is the best approach now that can future-proof the ongoing transition to 48V? Flexible, scalable, and power-dense DC-DC converter modules are a key to a smooth migration for both the OEMs and aftermarket players. Watch now.

# Take full advantage of high density power conversion

Our team of engineers collaborates with customers to architect new, efficient, modular power delivery networks that take full advantage of our solutions.

## Tailor product specifications

We can work with you to reconfigure and expand the capabilities of our power modules to best suit your design. For example, we can increase input range, adjust current limits, and set regulation points to fine tune output.

## Configure the power delivery network

With just four power module models, we can deploy more than 300 different power delivery solutions. We're here to help you to optimize board layout and communication paths. We'll determine the best arrangement of power modules and how to parallel modules in arrays to delivery higher power.

## Optimize packaging efficiency

We'll help you optimize mounting, cooling, and EMI filtering. We're experts at finding the most efficient way to package our modules so that DC-DC conversion can be placed where no discrete solution would fit.

## Provide a complete solution

We also have engineers with decades of experience developing full DC-DC conversion solutions using our power modules to solve the toughest power challenges.

To learn more about Vicor in automotive, please visit our website at www.vicorpower.com/automotive. We look forward to working with you and exploring ways we can help you solve your electrification challenges.

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