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APRIL 18-20, 2023

DETROIT





Adapting 400V and 800V Architectures – Bidirectional Conversion

Matthew Jenks – Director Automotive North America

Livonia, Michigan, USA

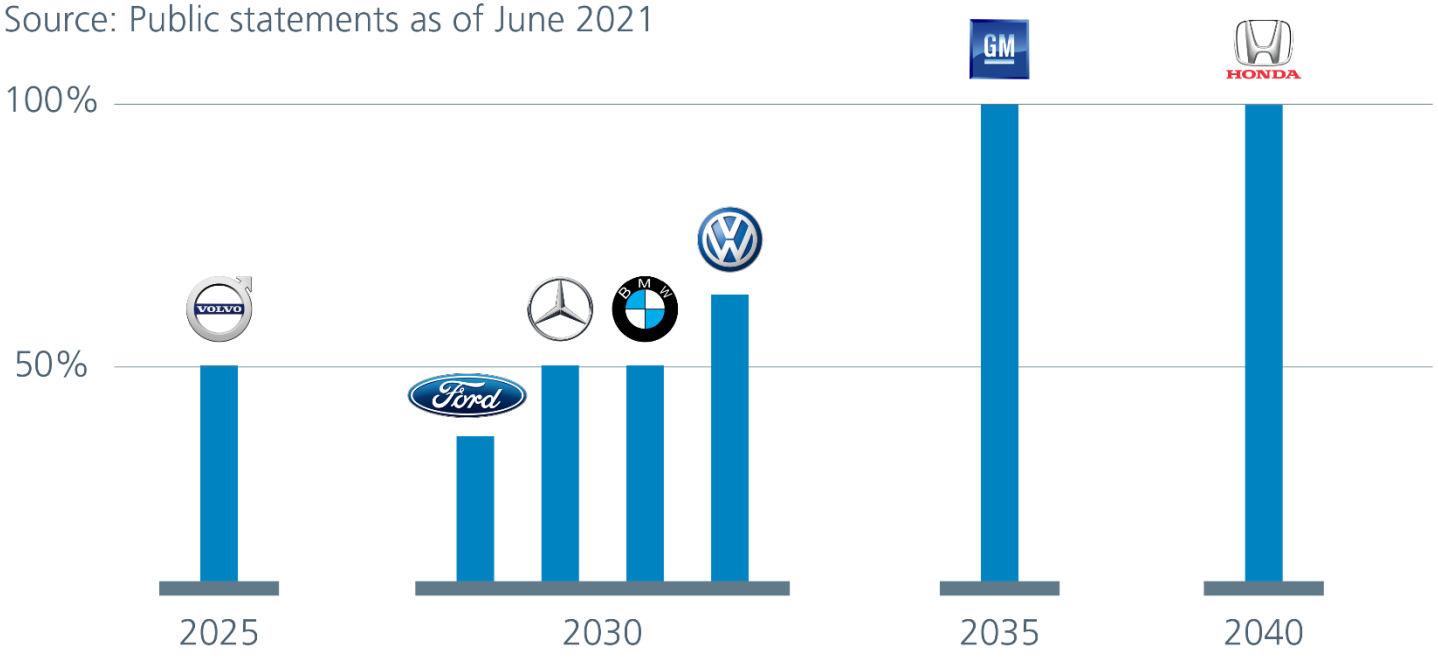
VICOR

The problem: transitioning and mixing 400V and 800V architectures



Percentage of OEM EV fleet over time

Source: Public statements as of June 2021



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The problem: transitioning and mixing 400V and 800V architectures



GIZMODO

Biden's New Vehicle Emissions Rules Could Speed the EV Revolution

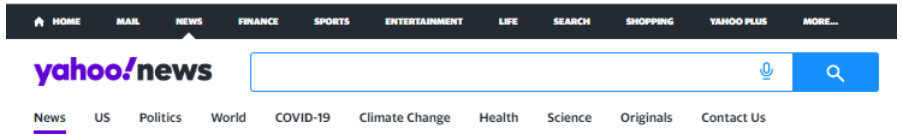
23

Jake Bittle, Grist

Thu, April 13, 2023 at 8:12 AM CDT · 5 min read



Photo: Justin Sullivan (Getty Images)



"The Biden administration has far bigger plans for the next eight years: Under a sweeping set of vehicle emissions rules unveiled by the Environmental Protection Agency on Wednesday, EVs would make up as much as *two-thirds* of all U.S. car sales by 2031 — a more than tenfold increase from current levels."

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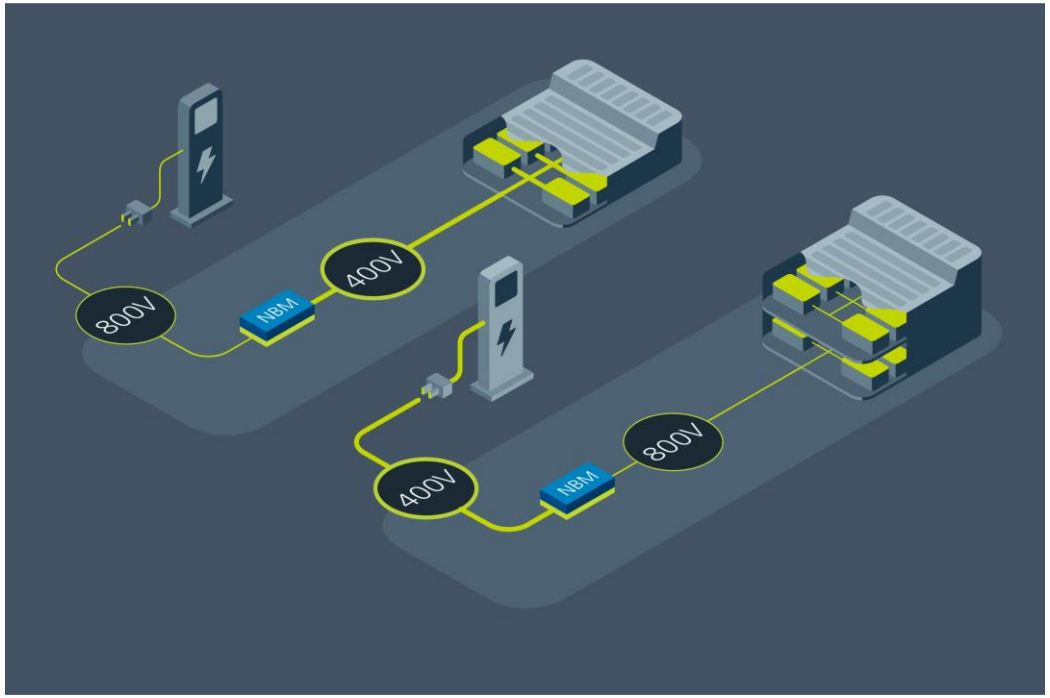
The problem: transitioning and mixing 400V and 800V architectures



As OEMs transition from 400V to 800V HV batteries, how do these architecture interact:

- Interoperability of 400V and 800V systems and subsystems
- Reuse of legacy 400V systems
- Reduce development time



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400V and 800V systems and subsystems interoperability



The right technology is required to enable and bridge the transition

- Interfacing to the existing charging infrastructure
- Enabling reuse of existing 400V systems, saving resources and time
- Improving system efficiency with lower voltage drive capability
- Providing additional V2V and V2X capability

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400V and 800V systems and subsystems interoperability



Vehicle to vehicle charging 400V to 800V and 800V to 400V



Bucks or boosts voltage

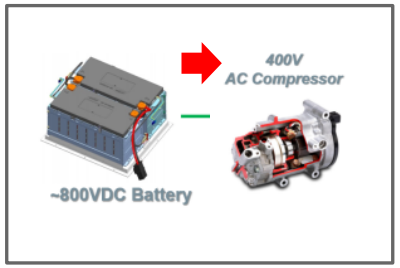


Boosts voltage up

The onboard booster enables 400V stations to charge 800V vehicles

Convert 800V battery to 400V bus voltage for condensers, pumps, chillers

Bucks voltage down



Buck or boosts voltage

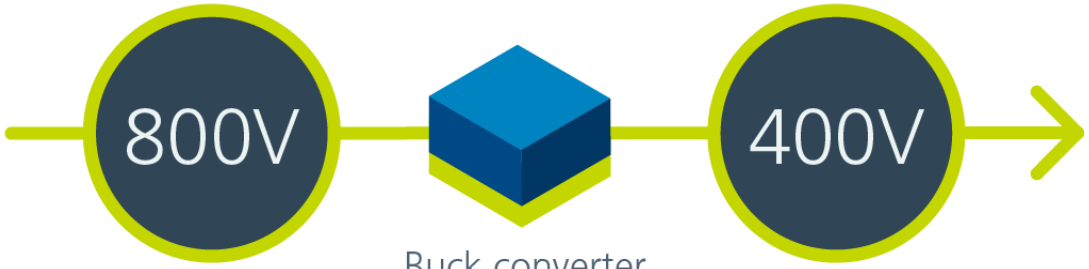


Vehicle to other charging

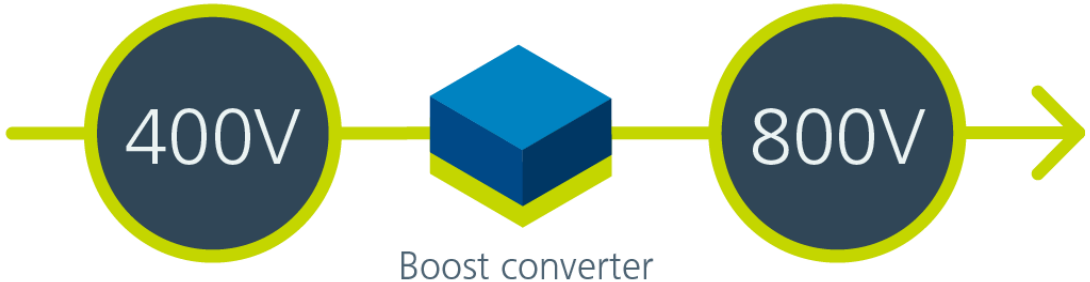
Definition of boost and buck converters



Buck 800V to 400V



Boost 400V to 800V



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What is needed to address all 4 applications?



- Bi-directional converter : Buck and Boost capability
- 400V – 800V 2:1 conversion
- Battery virtualization
- Modular
- Scalable and celectable
- Reconfigurable
- Power density

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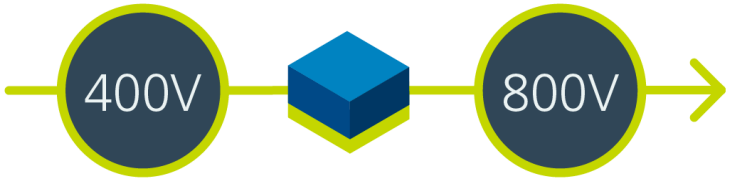
Interfacing to the existing charging infrastructure





Interface to 400V or 800V charging infrastructure

- Universal solution independent of charging station and battery configuration
- High performance and density
- Scalable



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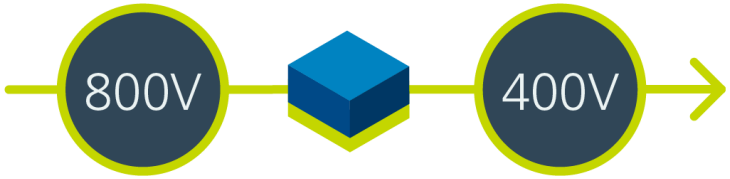
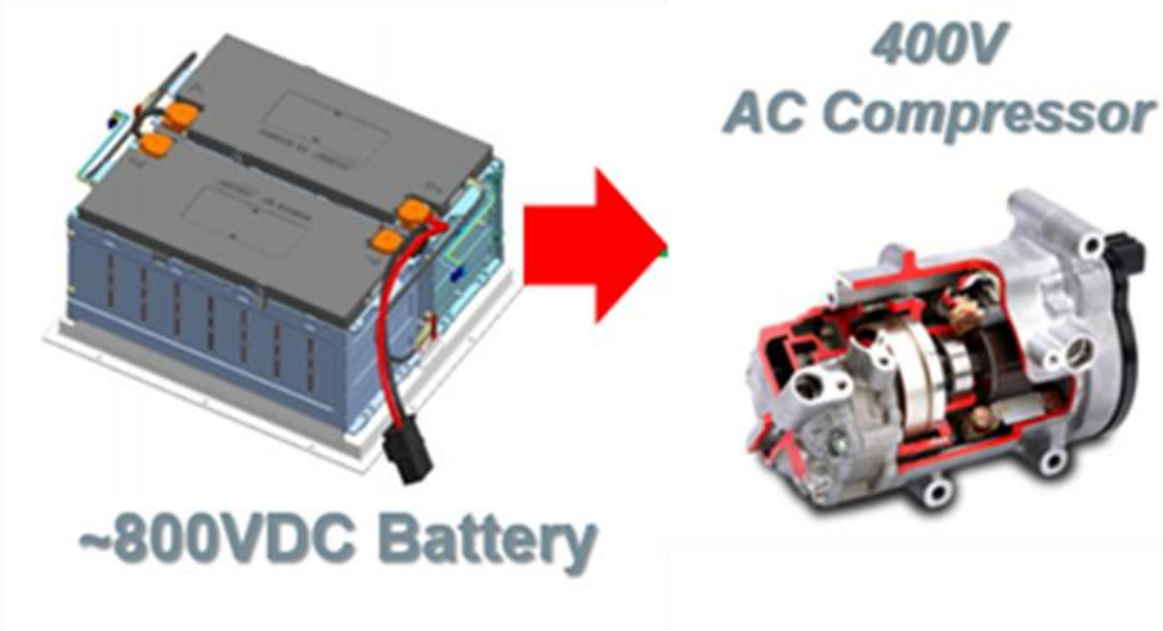
Enabling reuse of existing 400V systems





- Heaters
- Compressors
- Pumps
- Chillers
- DC-DC 12V Converters



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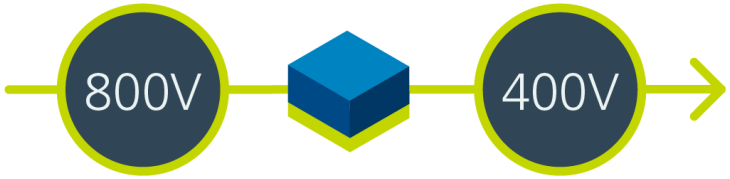
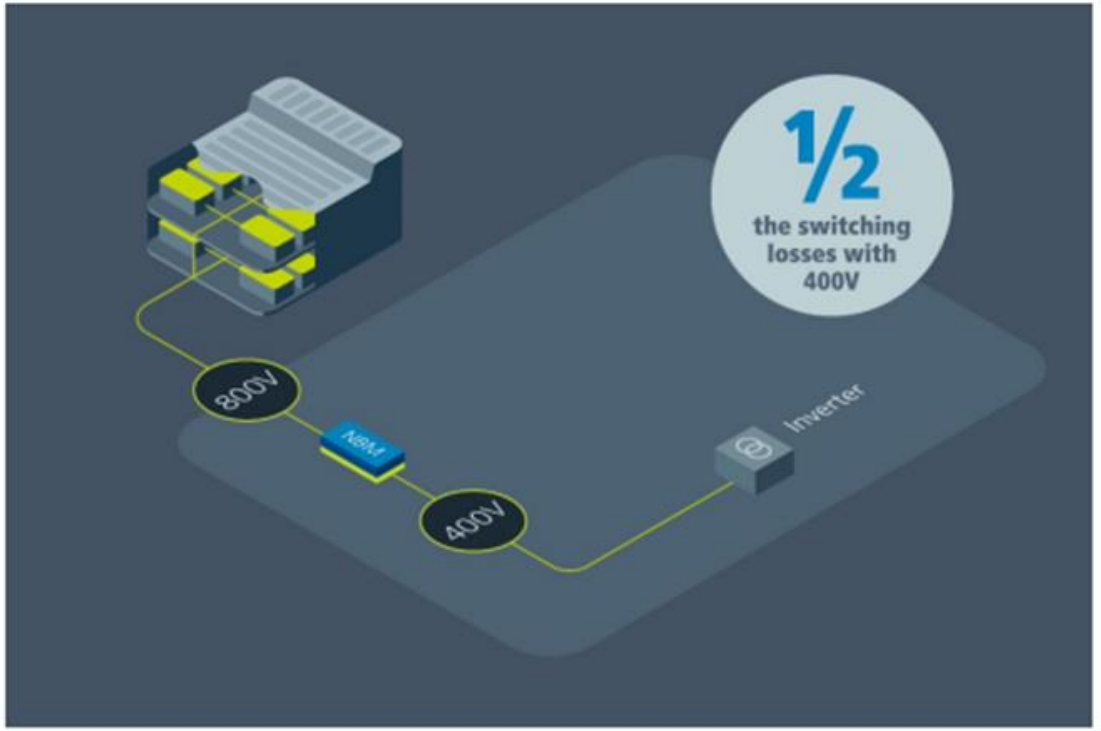
Improving system efficiency with lower voltage drive capa





- While the vehicle is in motion, same converter can be used to supply traction inverter for low RPM operation and improve powertrain efficiency up to 5%.



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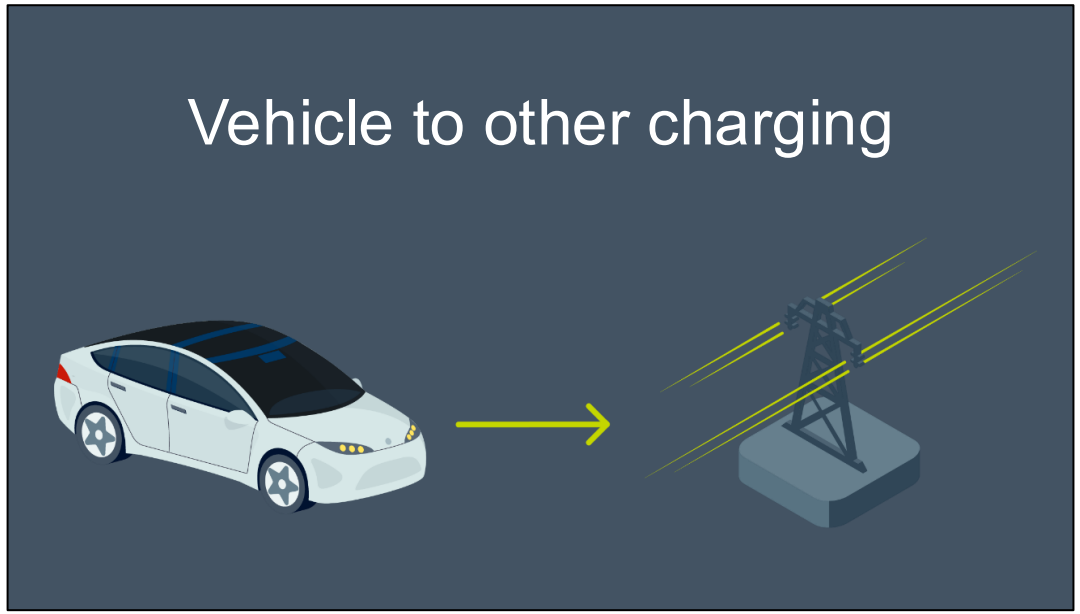
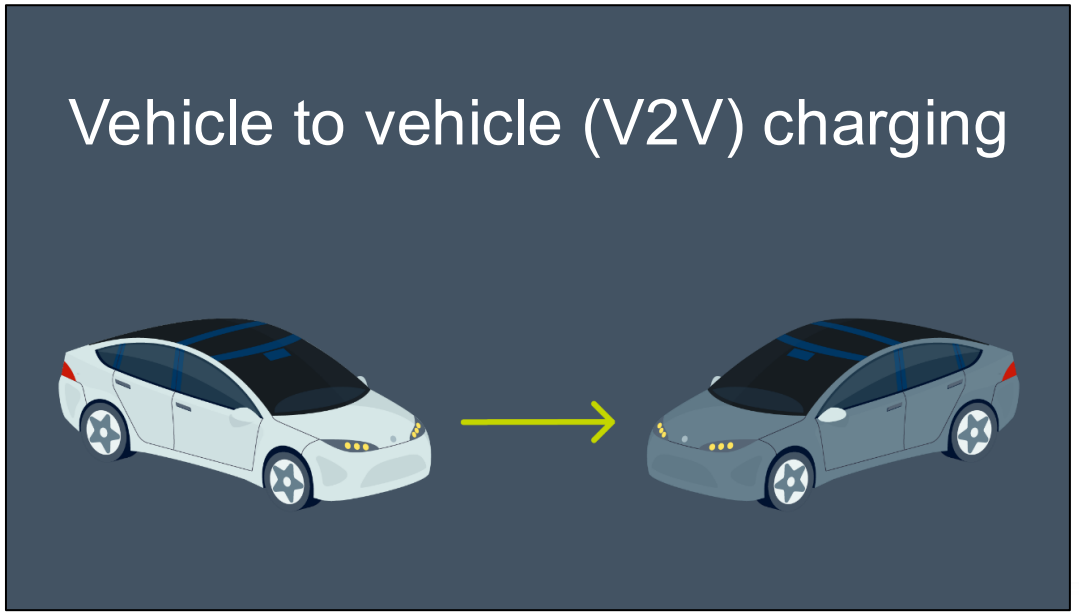
Providing additional V2V and V2X capability





As part of a system with DC-DC for regulation





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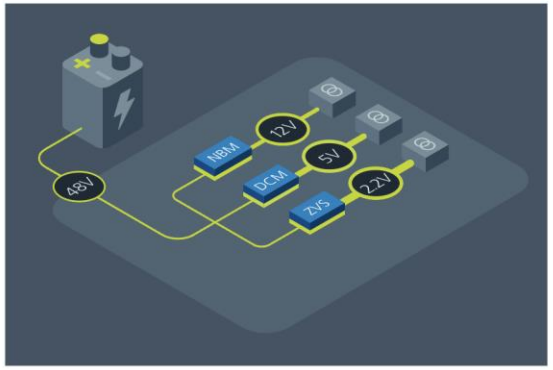
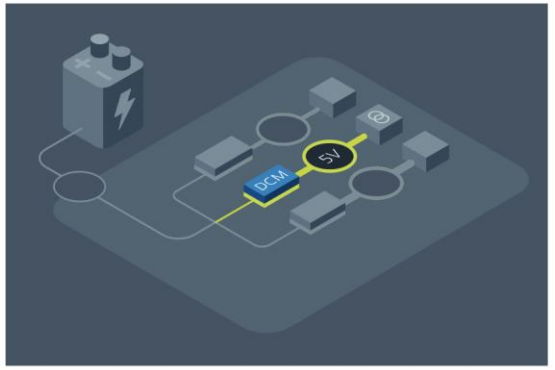
Reusable, Scalable and Reconfigurable



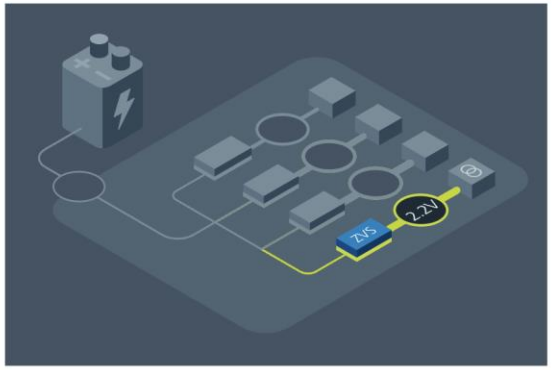
Simple, easy architecture

Individual modules perform the needed conversion at each load.



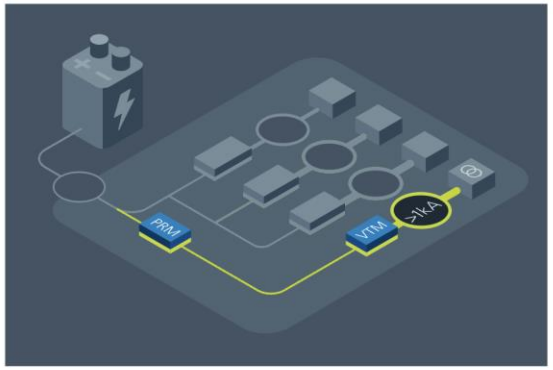
When power needs change

To accommodate a load with updated requirements, simply replace modules.



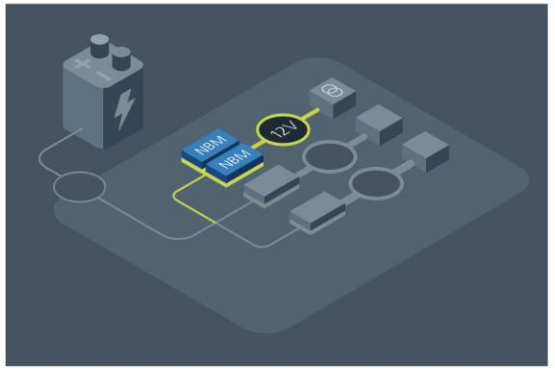
Support an additional load

When a design requires a new load, simply add another module.



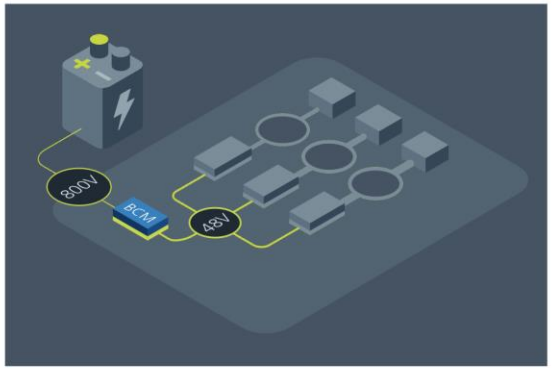
Reduce rail losses

Separate regulation and transformation functions for current multiplication using Vicor Factorized Power Architecture.



Double the power at a load

Add a second or third module to multiply the power to a load.



Create a SELV bus

When drawing from a high source, use a high-efficienc module to create a SELV bu

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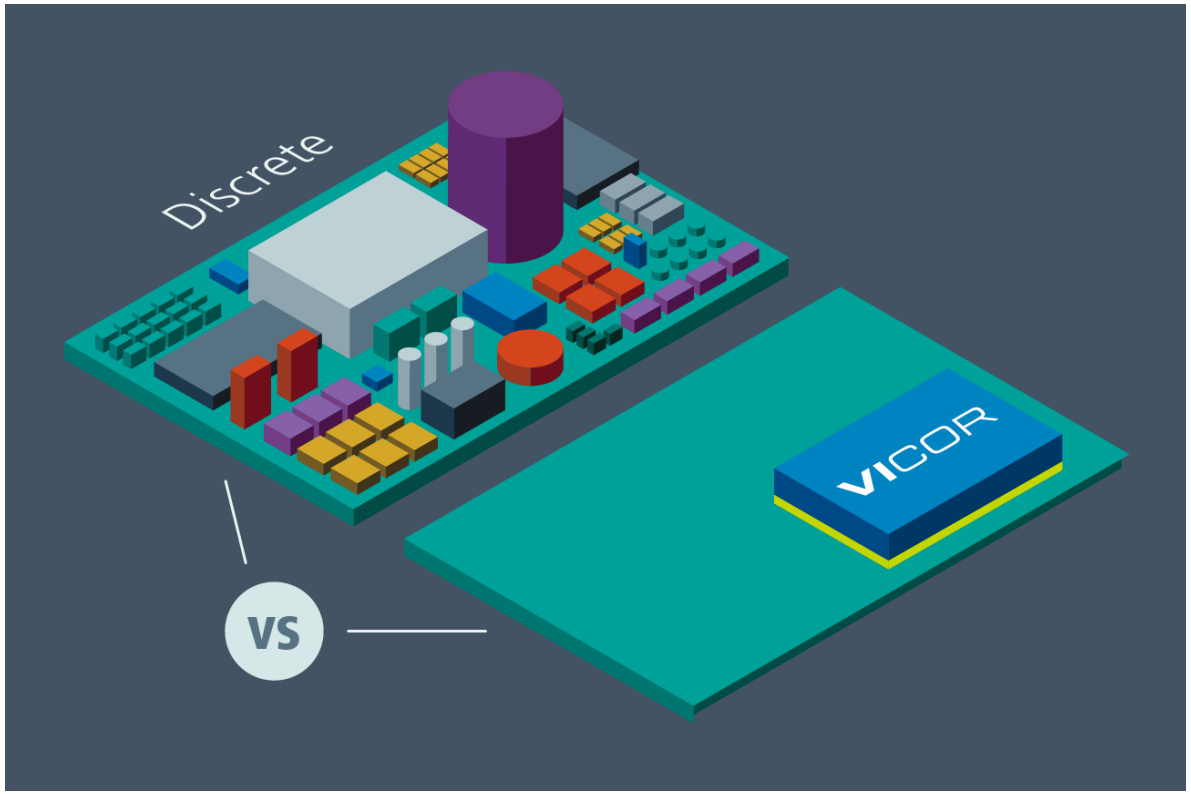
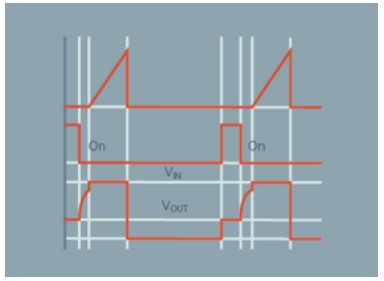
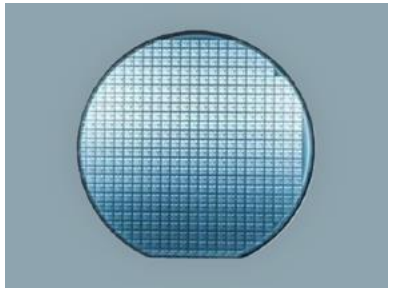
Enabling technology to bridge the voltages





SAC (Sine Amplitude Converter) topology and innovative controller designs and systems

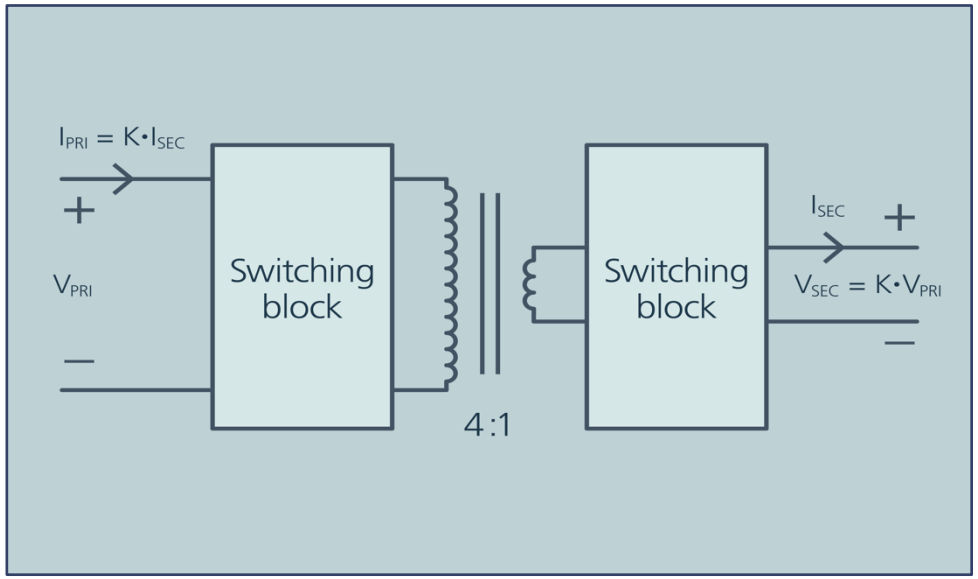




Sine amplitude converter technology/topology



- Sine Amplitude Converter topology:
  - Zero-voltage switching
  - Zero-current switching
- Fixed-ratio conversion :
  - Divide/multiply the voltage/current
- Extremely fast transient current capability
- Ideal transformer behavior
- No inductor usage
- Not dependent on internal energy storage



K factor	1/16	1/4	2/1	4/1
V_{PRI}	800	48	800	12
V_{SEC}	48	12	400	48
I_{PRI}	1	1	2	4
I_{SEC}	16	4	1	1

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Bi-directionality of sine amplitude converter

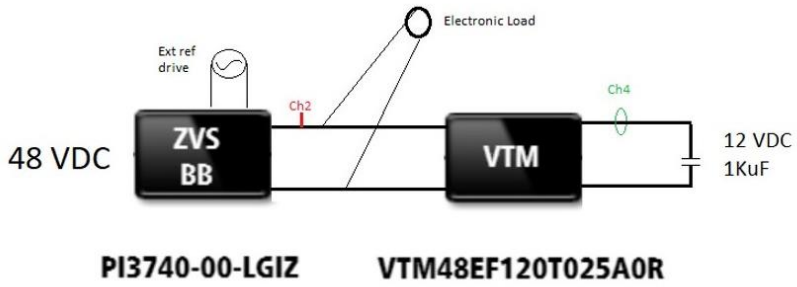


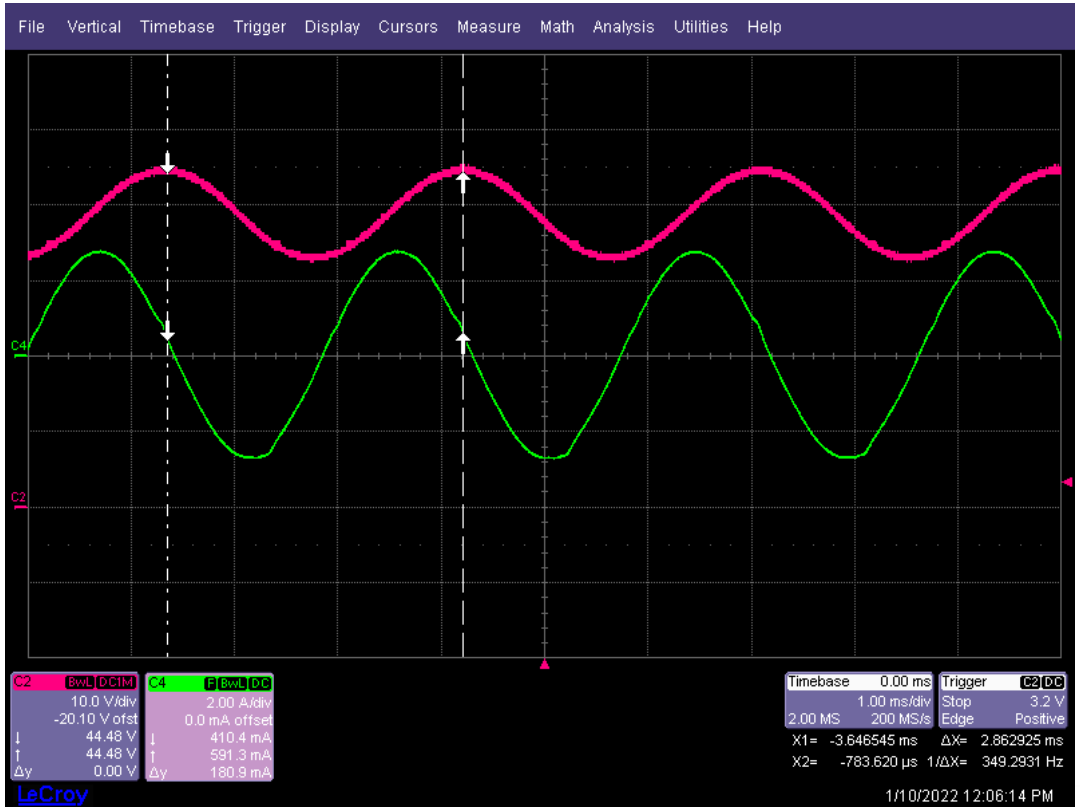
Notes:

Switching at 349Hz (Cannot go higher because of equipment limitations)

I_{OUT} = 1.4A

Ch2 = PI3740 V_{OUT}
Ch4 = Capacitor current





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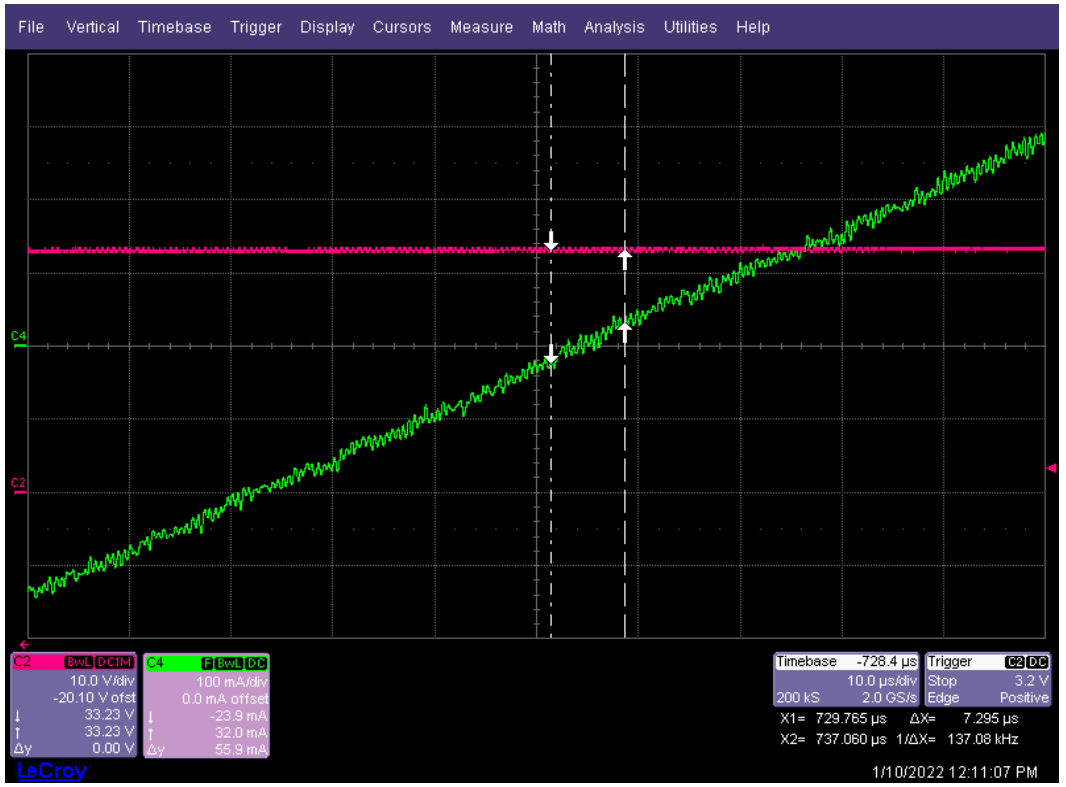
Recapture energy – bi-directional



✓ Bi-Directional no delay



Switching at 349Hz (Cannot go higher because of equipment limitations)

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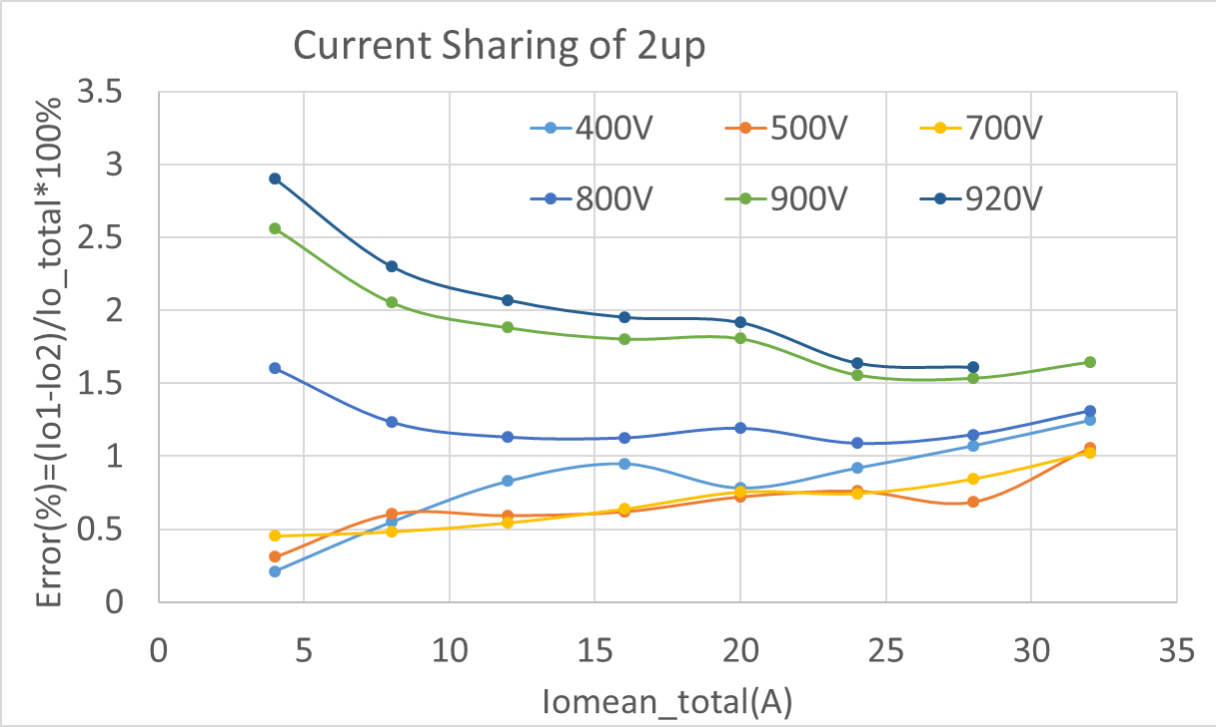
Paralleling for modular scaling



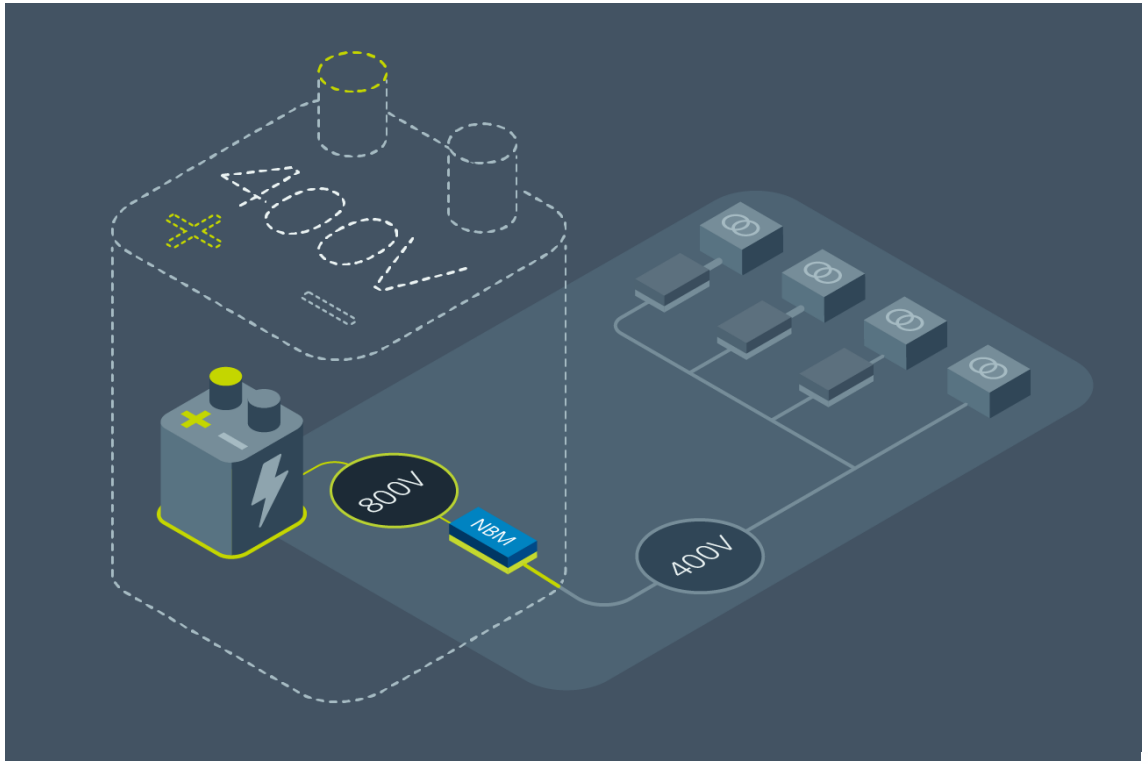
- ✓ The current sharing capability enables the scalability to higher power



Battery virtualization – virtualize a 400V battery



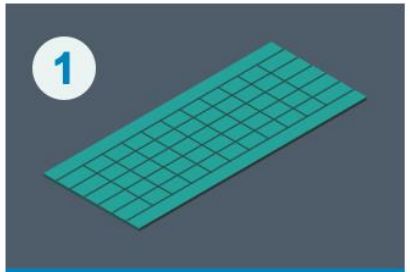
- ✓ Fast transient response, low impedance and bi-directional operation enable battery virtualization



Enabling packaging technology to bridge the voltages

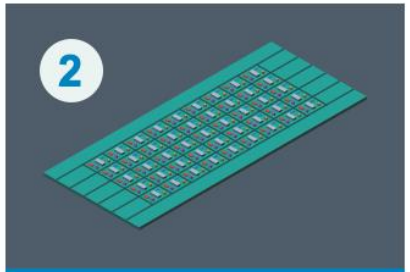


Enhanced thermal packaging designs and methods



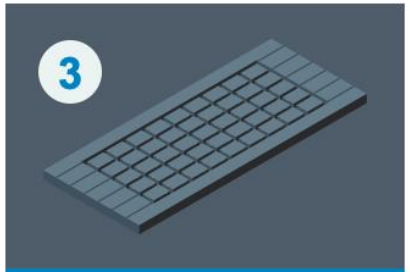
Bare panel

The process begins with a bare panel, ready for multiple instances of the same high-performance module, analogous to a silicon wafer



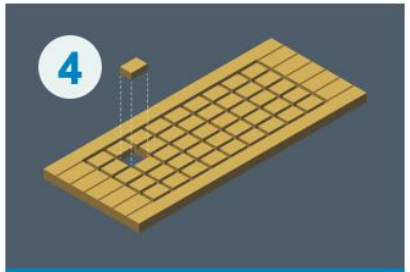
Surface mounting

High-quality power components, including magnetics, are mounted and soldered via state-of-the-art pick-and-place tools



Overmolding

A plastic compound encases the panel, protecting the components and creating a flat surface that makes the final product easier to handle



Plating

Heat conducting metals are plated onto the panel to enable a thermally efficient and reliable finished product



CHiP modules

The panels are singulated into individual modules and tested for conformance to data sheet specifications

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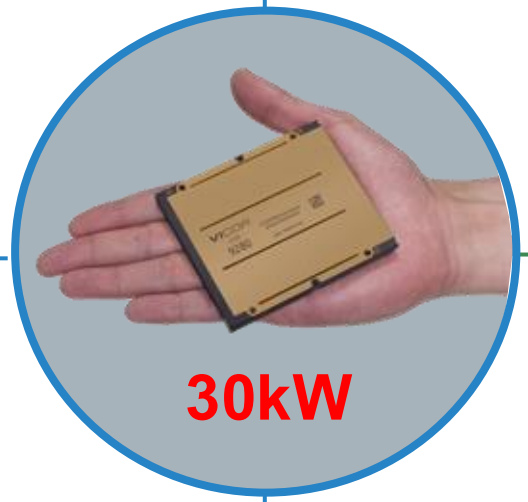
400V and 800V systems and subsystems interoperability



Convert 800V roadside chargers to onboard 400V battery

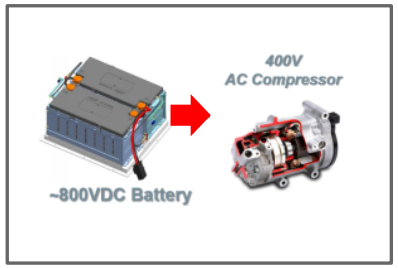


Bucks voltage down



condensers, pumps, chillers, inverters

Bucks voltage down





Boosts voltage up

The onboard booster enables 400V stations to charge 800V vehicles

Buck or boosts voltage



Vehicle to vehicle charging and vehicle to other charging

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Product solution NBM9280 : 30kW



- NBM9280 bi-directional converter
- 400V – 800V
- SAC 2:1 conversion
- Efficiency 98.3% peak
- Virtual battery
- Highly integrated
- Power dense
- Scalable and selectable
- Reconfigurable system



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400V and 800V systems and subsystems interoperability



System/Subsystem	Directionality	Vicor
Interfacing to the existing charging infrastructure	Boost	✓ Bi-Directional ✓ 2X transient capability ✓ Virtual Battery ✓ Power Density ✓ Reconfigurable ✓ Selectable ✓ Scalable
Enabling reuse of existing 400V systems, saving resources and time	Buck	
Improving system efficiency with lower voltage drive capability	Buck	
Providing additional V2V and V2X capability	Buck/Boost - Regulation	

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Matthew Jenks - author



- Thank you
- Vicor Corporation
- Matthew is the Director Automotive North America, joining Vicor in 2021 to bring Vicor technology and power modules to OEM Automotive BEV power delivery systems. Matt earned his BSEE degree at Michigan State University and lives in Livonia, Michigan.



- mjenks@vicorpower.com or 248-797-4284

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