Advance to the Next Level of Mobility

As the mobility environment becomes more complex and time-to-market pressures rise, there’s only one place you can access the latest trends, professional development, and knowledgeable contacts you need to overcome today’s mobility challenges and those yet to arrive: 2022 WCX™ SAE World Congress Experience.

Adapting 400V and 800V Architectures – Bidirectional Conversion

Matthew Jenks – Director Automotive North America

Livonia, Michigan, USA
The problem: transitioning and mixing 400V and 800V architectures

Percentage of OEM EV fleet over time
Source: Public statements as of June 2021

- 100%
- 50%

2025  2030  2035  2040
The problem: transitioning and mixing 400V and 800V architectures

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

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

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

Bucks or boosts voltage

Boosts voltage up

Bucks voltage down

Buck or boosts voltage

Vehicle to other charging
Definition of boost and buck converters

**Buck 800V to 400V**

- **800V** to **400V**
- Buck converter
- Ratio: 1/2

**Boost 400V to 800V**

- **400V** to **800V**
- Boost converter
- Ratio: 2/1
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 selectable
- Reconfigurable
- Power density
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
Enabling reuse of existing 400V systems

- Heaters
- Compressors
- Pumps
- Chillers
- DC-DC 12V Converters
Improving system efficiency with lower voltage drive capability

• 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%.
Providing additional V2V and V2X capability

As part of a system with DC-DC for regulation

Vehicle to other charging

Vehicle to vehicle (V2V) charging
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-efficiency module to create a SELV bus.
Enabling technology to bridge the voltages

Highly integrated DC-DC converters

- Extended variety of input and output voltages available
- Isolation, regulation, conversion and transformation integrated in different combinations
- Hundreds of components are tightly arranged within a miniature footprint

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

<table>
<thead>
<tr>
<th>K factor</th>
<th>1/16</th>
<th>1/4</th>
<th>2/1</th>
<th>4/1</th>
</tr>
</thead>
<tbody>
<tr>
<td>( V_{PRI} )</td>
<td>800</td>
<td>48</td>
<td>800</td>
<td>12</td>
</tr>
<tr>
<td>( V_{SEC} )</td>
<td>48</td>
<td>12</td>
<td>400</td>
<td>48</td>
</tr>
<tr>
<td>( I_{PRI} )</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>( I_{SEC} )</td>
<td>16</td>
<td>4</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>
Bi-directionality of sine amplitude converter

Notes:

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

$I_{OUT} = 1.4A$

$Ch2 = PI3740 \ V_{OUT}$
$Ch4 = \text{Capacitor current}$
Recapture energy – bi-directional

- Bi-Directional no delay

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

$I_{OUT} = 1.4A$

$Ch2 = PI3740$ $V_{OUT}$

$Ch4 = Capacitor current$
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
**Enhancing packaging technology to bridge the voltages**

Enhanced thermal packaging designs and methods

<table>
<thead>
<tr>
<th>Steps</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bare panel</td>
</tr>
<tr>
<td></td>
<td>The process begins with a bare panel, ready for multiple instances of the same high-performance module, analogous to a silicon wafer.</td>
</tr>
<tr>
<td>2</td>
<td>Surface mounting</td>
</tr>
<tr>
<td></td>
<td>High-quality power components, including magnetics, are mounted and soldered via state-of-the-art pick-and-place tools.</td>
</tr>
<tr>
<td>3</td>
<td>Overmolding</td>
</tr>
<tr>
<td></td>
<td>A plastic compound encases the panel, protecting the components and creating a flat surface that makes the final product easier to handle.</td>
</tr>
<tr>
<td>4</td>
<td>Plating</td>
</tr>
<tr>
<td></td>
<td>Heat conducting metals are plated onto the panel to enable a thermally efficient and reliable finished product.</td>
</tr>
<tr>
<td>5</td>
<td>CHiP modules</td>
</tr>
<tr>
<td></td>
<td>The panels are singulated into individual modules and tested for conformance to data sheet specifications.</td>
</tr>
</tbody>
</table>
Convert 800V roadside chargers to onboard 400V battery

Bucks voltage down

Boosts voltage up

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

30kW

Bucks voltage down

Buck or boosts voltage

Vehicle to vehicle charging and vehicle to other charging

Condensers, pumps, chillers, inverters
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
# 400V and 800V systems and subsystems interoperability

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