Voltage conversion with Sine Amplitude Converter: performance, benefits and applications

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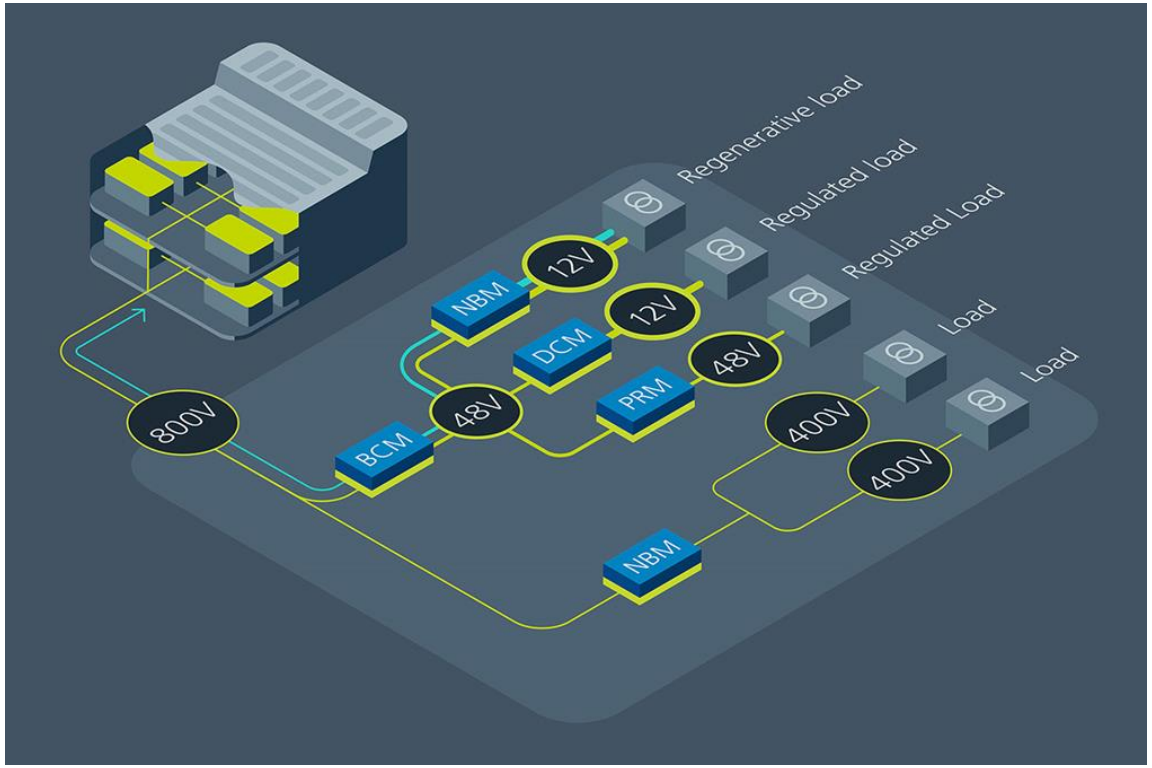
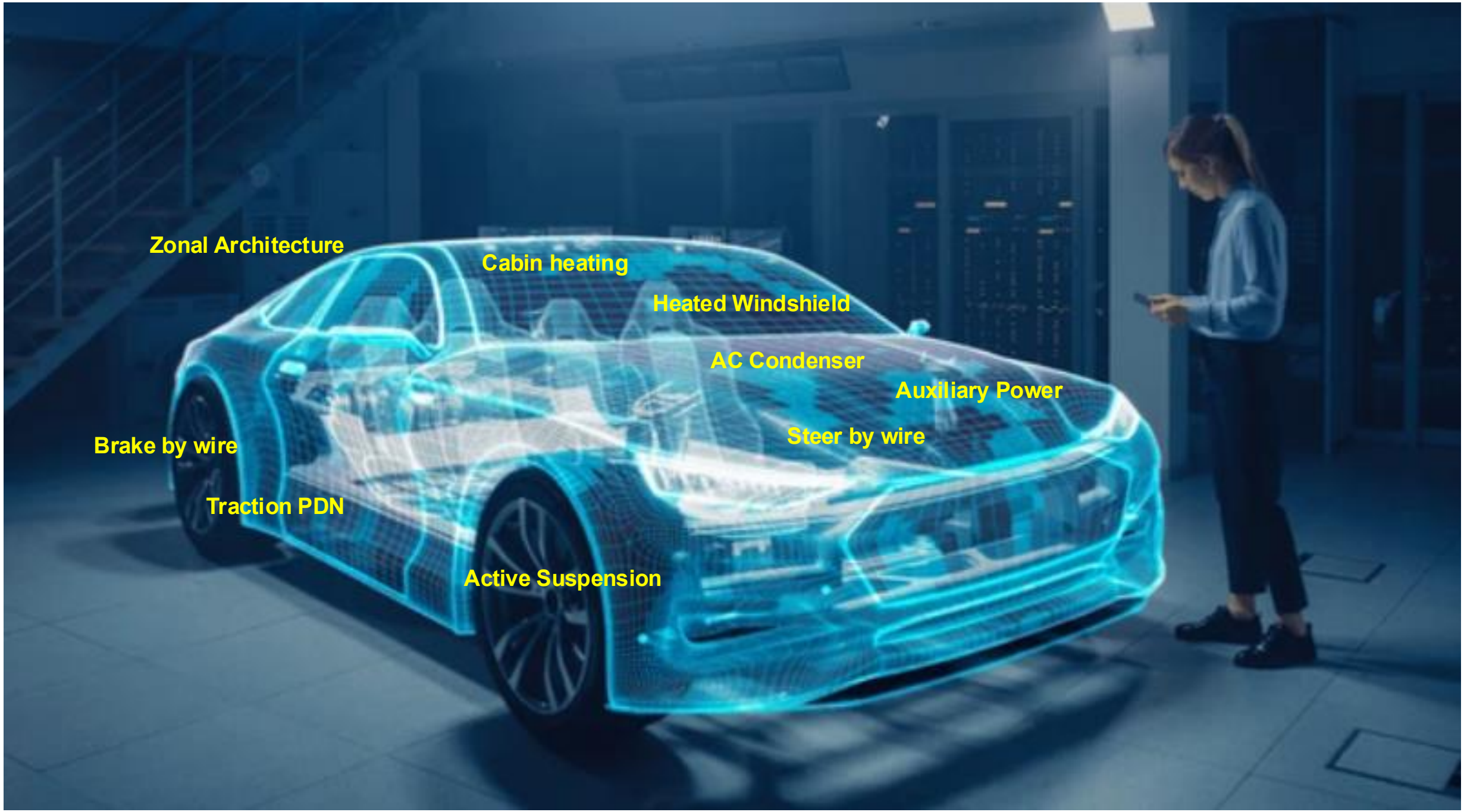
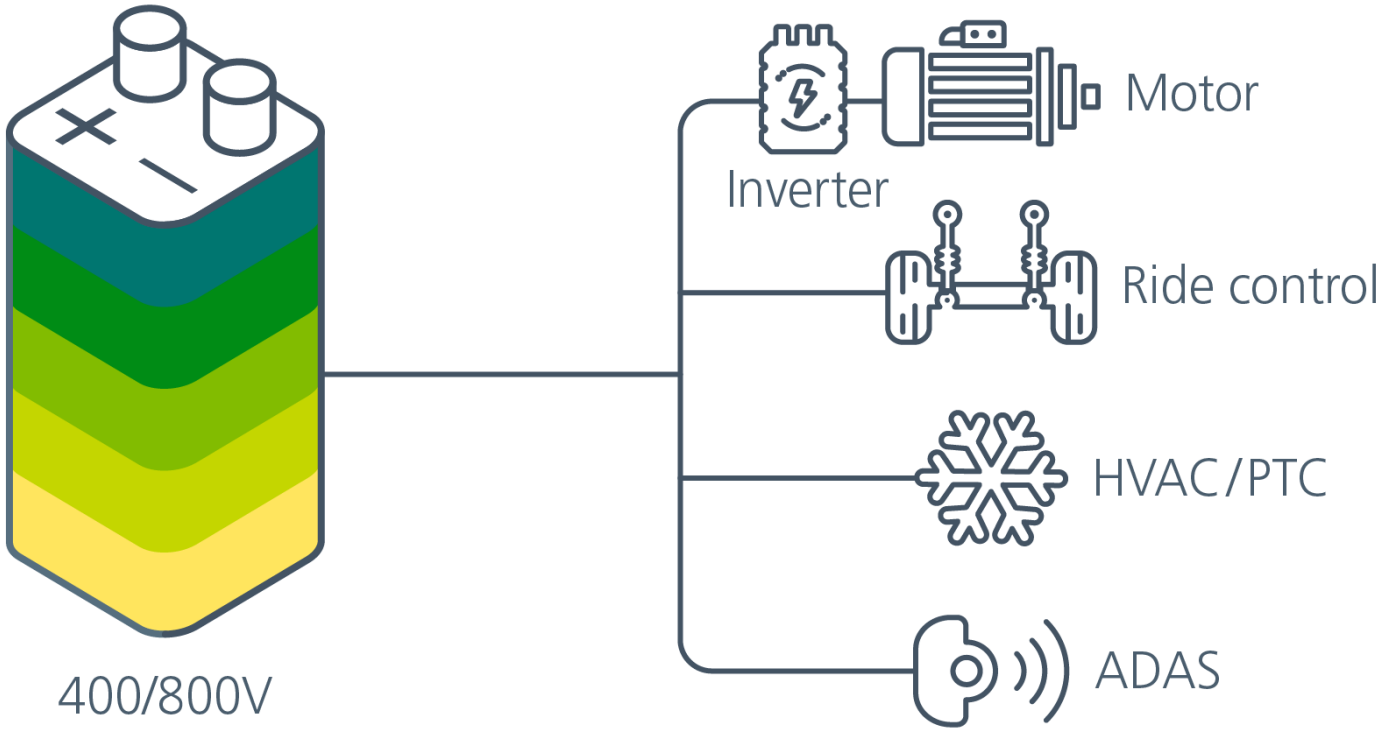
Overview

- The amount of Safety Electrical Low Voltage (SELV) at 12V or 48V is increasing due to electrification and ADAS loads
  - New vehicles require fast responding power supplies
  - Bidirectional power is needed for regeneration from key loads
  - Multiple batteries can be required for SELV Loads
- DC-DC convertor-based Sine Amplitude Conversion (SAC) can provide optimum conversion from high voltage to SELV with fast transient and full power regeneration capability



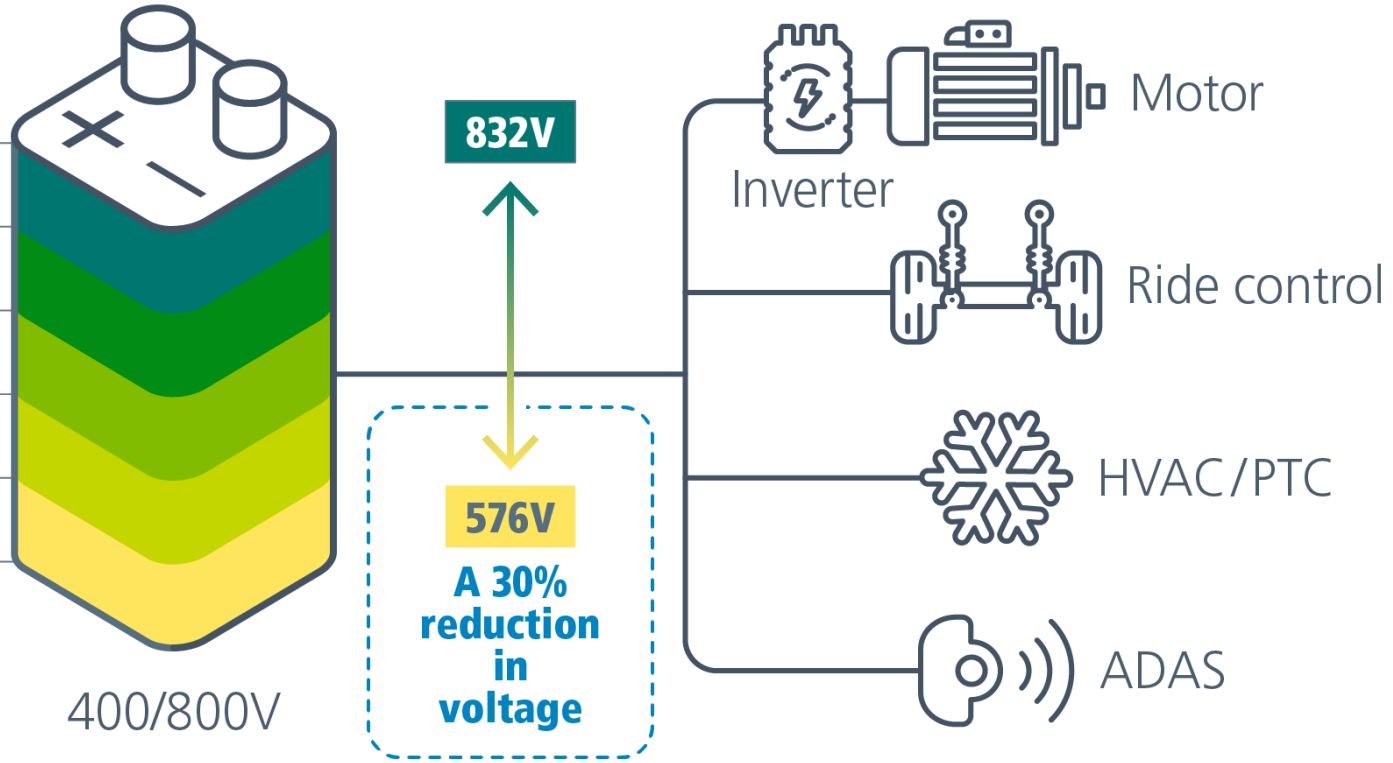

Zonal Architecture
Cabin heating
Heated Windshield
AC Condenser
Auxiliary Power
Steer by wire
Brake by wire
Traction PDN
Active Suspension

BEV HV architecture



Characteristics of a HV battery

State of charge	Voltage/cell
100%	4.2V
80%	4.0V
50%	3.7V
20%	3.4V
0%	3.0V



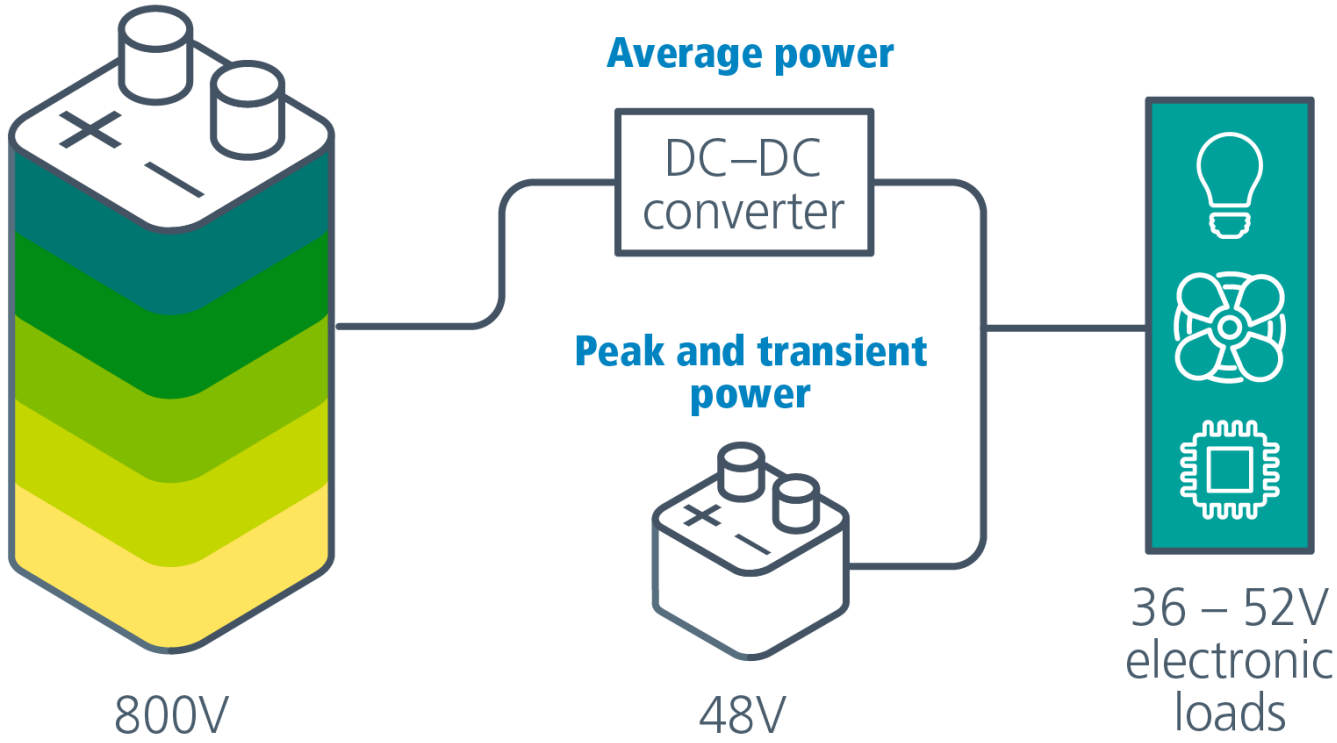
48V – main low voltage bus for future architectures

- Started with 48V BSG and battery
- Now DC-DC and battery
- Typical loads require more power (pumps, motors, heaters)
  - SELV Benefit compared to HV supply is safety
  - 48V Benefits compared to 12V are more power, more performance, less weight
- Conversion from HV requires reinforced isolation
  - Do 48V loads require stable voltage?
  - Can they operate like HV loads, with wider voltage range?

Current 48V bus solutions for xEV

Challenges:

- Weight and size
- Cost
- Maintenance efforts
- Lifetime of 48V battery



Proposed solution: Sine Amplitude Converter (SAC™)

State of charge	Voltage/cell
100%	4.2V
80%	4.0V
50%	3.7V
20%	3.4V
0%	3.0V

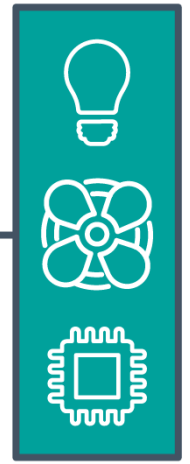
800V

832V

576V

DC-DC

Sine amplitude converter



36 – 52V electronic loads

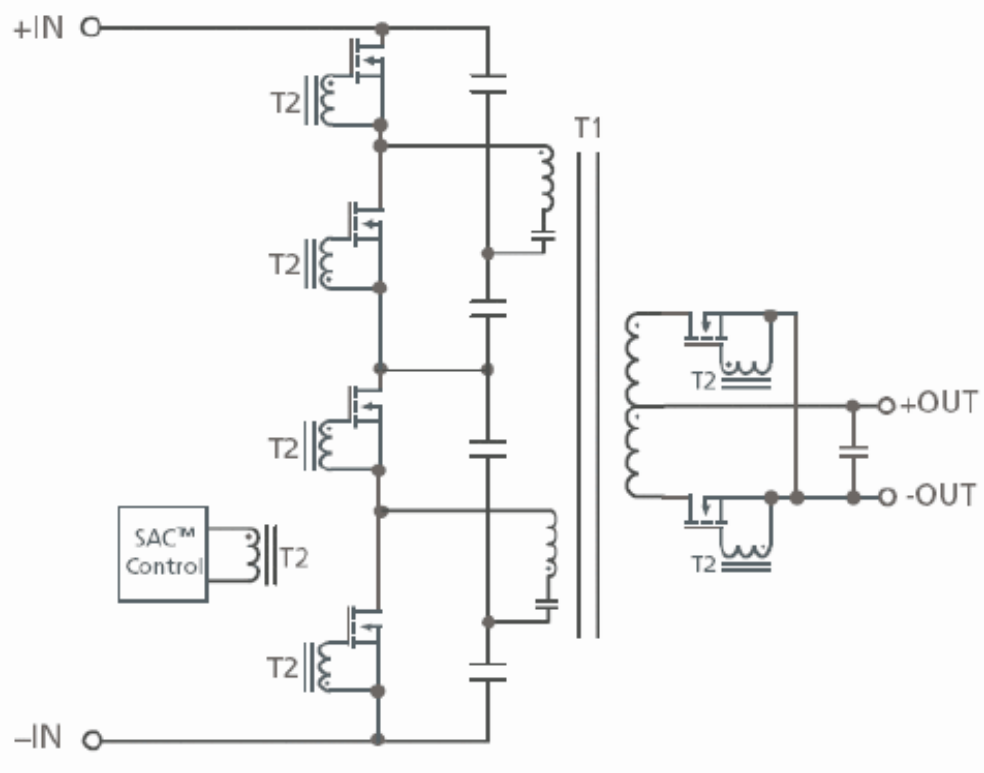
Proposed solution: Sine Amplitude Converter

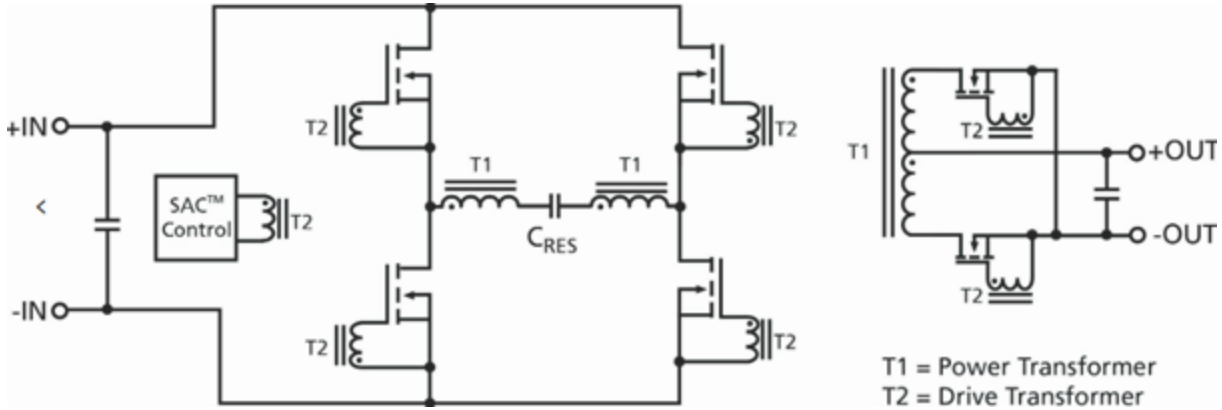
- Resonant topology
  - Operates at resonant frequency, fixed gain
- Soft switching, constant frequency/duty
  - Low EMI profile
  - Switching losses minimized
- Enables higher switching frequencies and lower volume/weight
- Transformer design, resonant circuit design, gate drives etc.
- Vicor has intellectual property to optimize design

DC-DC

Sine amplitude converter

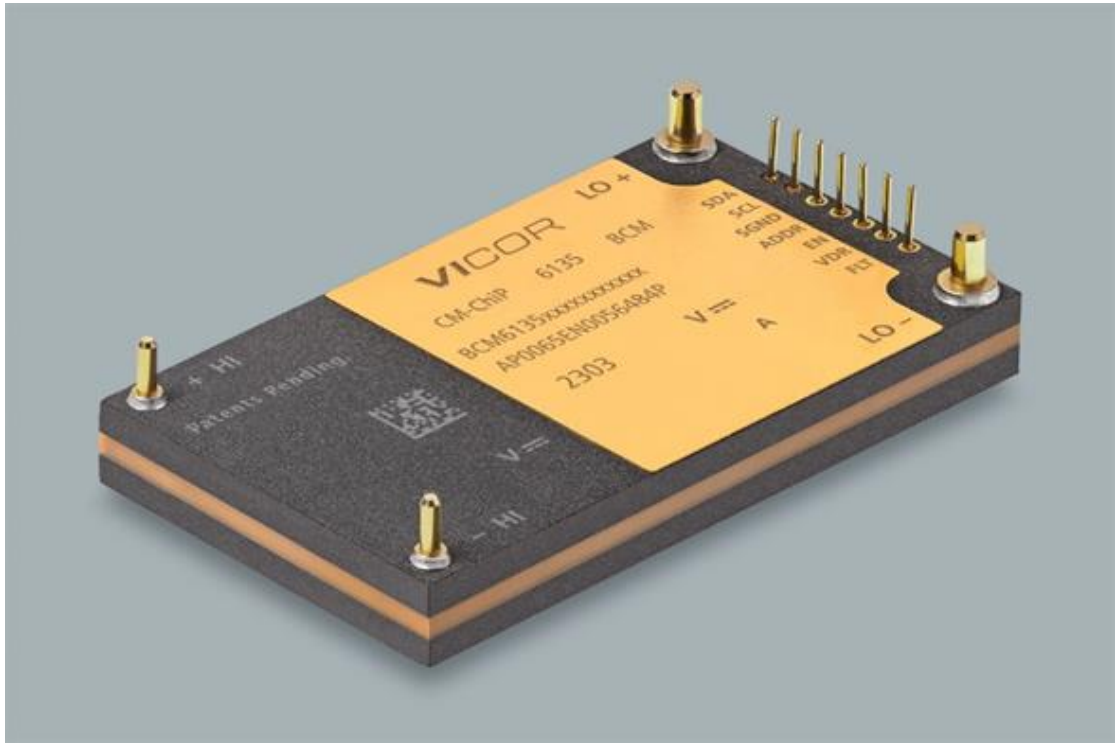
Topology example of SAC implementation – BCM





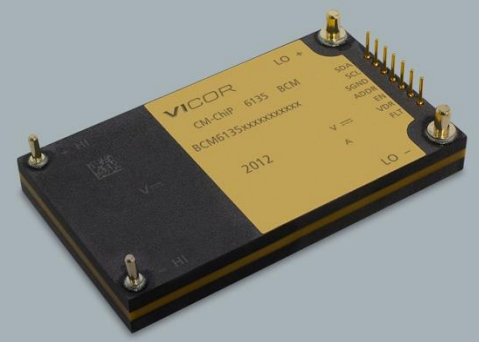
Example of SAC implementation – BCM

- Up to 5 kW peak power, or 100A peak current
- Losses and package performance
  - Peak efficiency 98.3%, full power 97.8%
  - Power losses up to 55W
- Thermal resistance 0.7K/W
- Symmetrical power flow capability
- How is it possible?
  - In house development for controller, transformer, switches and packaging
  - All parameters optimized under the same function



BCM6135 for 800V to 48V with isolation

BCM6135AJ2F5880A06



Peak Power	2.5 kW
V_{IN} Range	520 – 920V
V_{OUT} Range	32.5 – 57.5V
Peak Current	80 A
Bidirectional	Yes
Start-Up Bias	Internal

Creates 4242V input to output isolation internally

Provides 20kW of power when built in an array of 10 modules

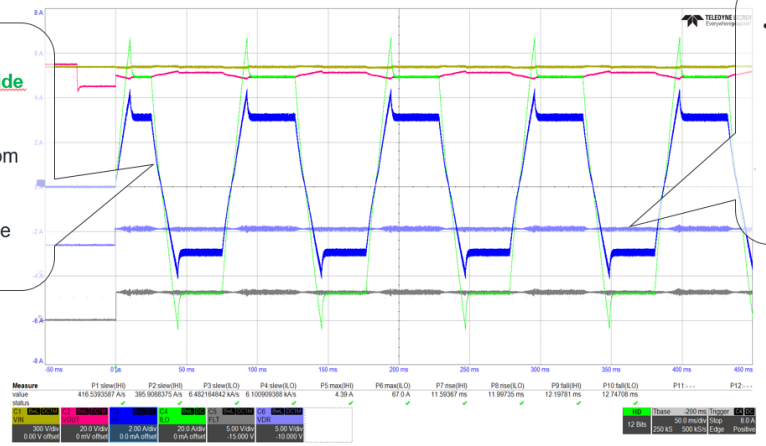
Symmetrical performance in buck or boost

Highest current change (slew) rate of 8 M A/s

System Load Transient

800VHI, 50VLO, 0 to 50A ILO, 0A to 3.125A IHI

- Hiside LoSide Currents
- Linear transition from forward to reverse
- No dead time

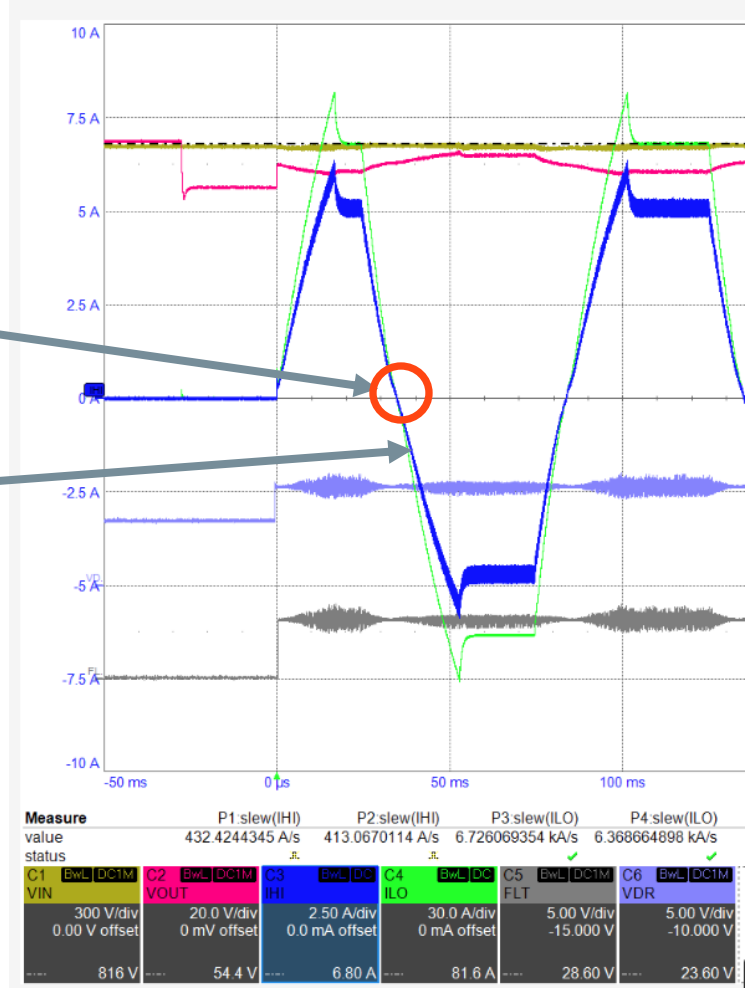


- VDR Power is constant highlighting how the powertrain behaves no different forward or reverse

Bidirectional current flow and bandwidth

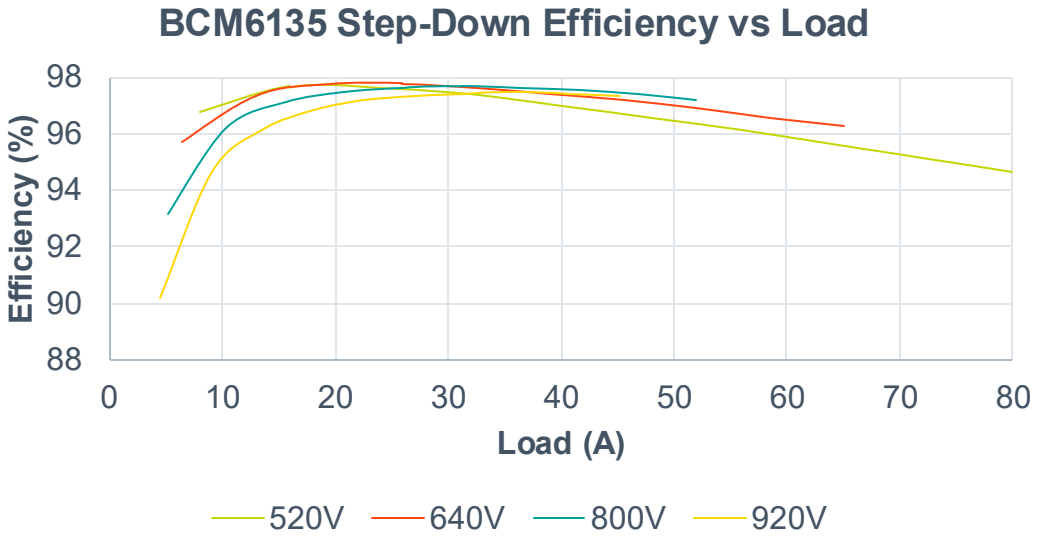
No dead zone in Transition

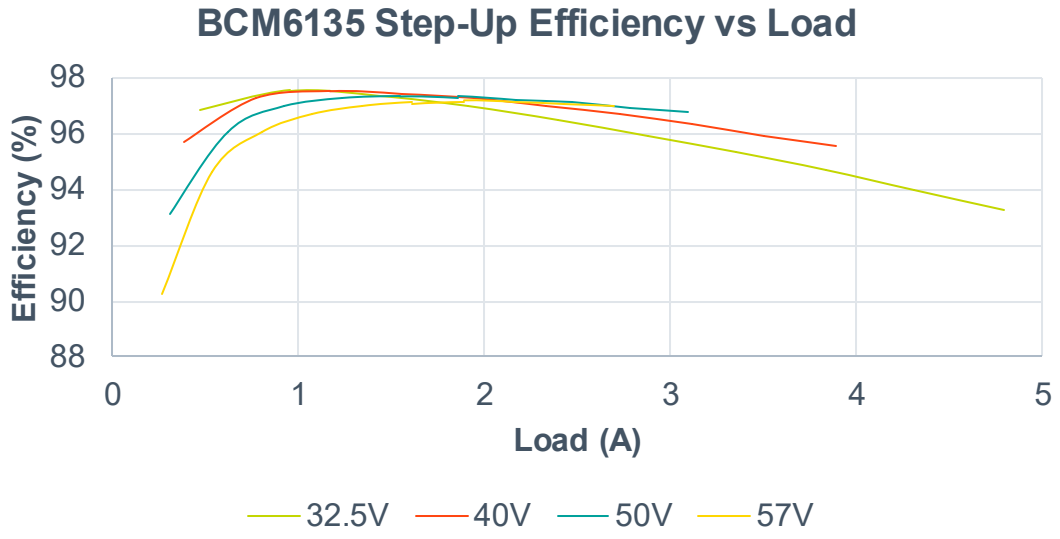
Linear Transition between forward and reverse



VDR is constant over change in current direction

Symmetrical Power Processing





Product Ratings				
Step-Down Operation	K = 1/16	V_{HI} = 800V (520 – 920V)	V_{LO} = 50V (32.5 – 57.5V) No Load	I_{LO} = 80A Max
Step-Up Operation		V_{LO} = 50V (32.5 – 57.5V)	V_{HI} = 800V (520 – 920V) No Load	I_{HI} = 5A Max

Application Examples

Just 3 SAC™ Modules enable a multitude of applications through flexibility and scalability

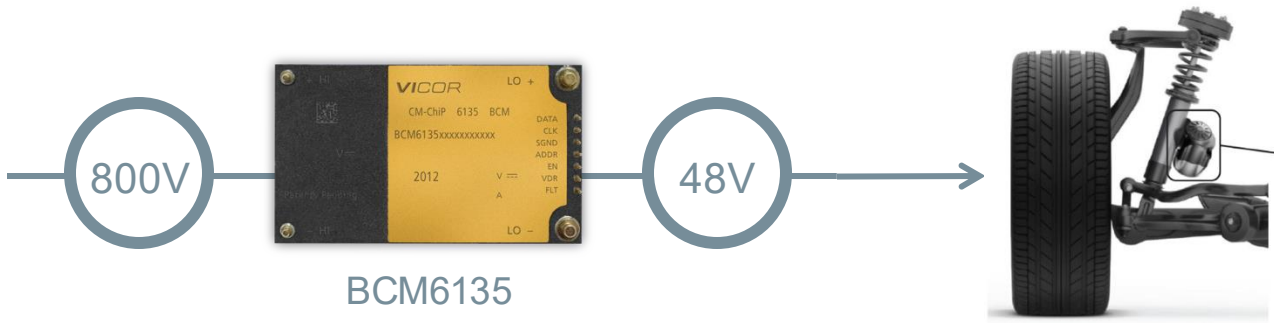
Active suspension

Power Delivery Network

IR Heating

Zonal architectures

Active roll suspension system



BCM6135

- **Dynamic response test: current slope >8A/us**

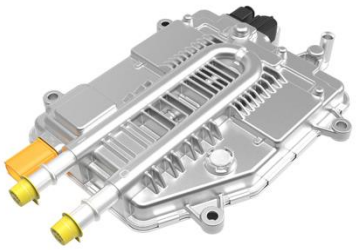
48V power is a key enabler to having correctly sized actuators for stability and roll control

Symmetrical buck/boost capability of BCM6135 perfectly aligns with the requirements of active suspension systems

BCM6135 current slew rate (speed of current changes) of 8.0M A/s allows it to match the rapid power changes created by these systems

3 – 4x improvement in power density

	Vicor Solution	Tesla Model X	Vitesco 4th Generation
Pout W (Output Power)	4000 @ 13.8V	2300 @ 12 V	3500 @ 14.5V
Weight kg	1.7	2.1	2.6
Footprint mm^2	24500	30520	50000
Volume L (w/o connectors)	1.7L (275 x 155 x 42)	1.8L (140 x 218 x 60)	2.5 L (250 x 200 x 50)
Efficiency	95%	93% Estimate	96% Estimate
Power Density kW/liter	2.35	1.3	1.34
Gravimetric Power Density kW/kg	2.35	1.1	1.5



Infrared cabin heating / windshield heating

BCM6135-A06 2.5 kW

800V to 48V

Isolated without Regulation

Heating an EV passenger compartment requires additional energy, which reduces the vehicle's range.

IR heating is a more efficient method to heat the passengers. The BCM6135 provides a high efficiency source of isolated 48V power for these applications

Conclusion

- Oversized DC-DC converters and/or batteries can be replaced.
- Independent loads/load islands on 48V can be directly powered
- Efficiently transition high power loads to 48V

Sine Amplitude Converter offers the highest performance to weight and volume ratio

Continually providing the highest density: We've learned we can deliver more power using the same package dimensions and we're currently delivering 3.5kW continuously

Thank you