The Impact of Miniaturized Power Modules on Electrification

Reduce the Weight and Volume of the Power Electronics

VICOR

Introduction

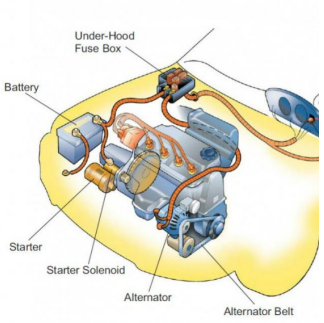
Migration to xEV has increased the electrical power used in the vehicle

Heavy Duty ICE Vehicle

14.5V Alternator

2.5 – 4.5 kW for accessory power

Direct Supply at 12V

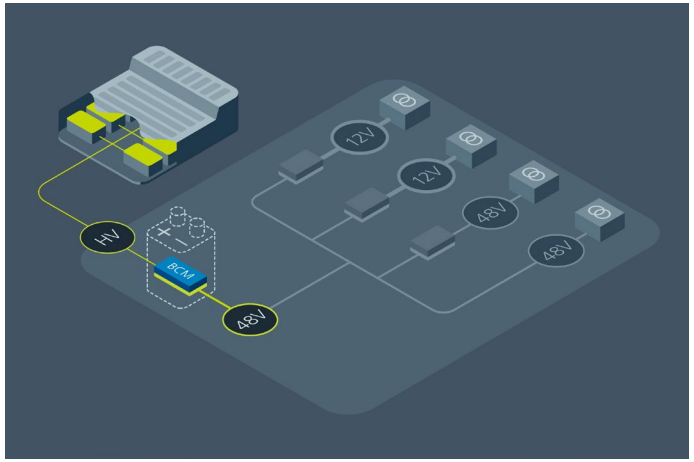


BEV Vehicle

800V / 400V Battery

100 kW power req't (4kw for accessory power)

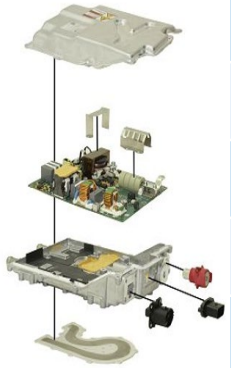
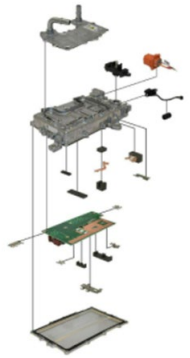
DC/DC Conversion to 12V



DCDC conversion systems are heavy and large, improvement in lower density is desired

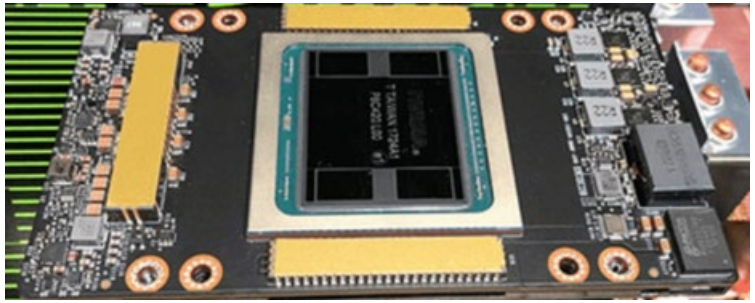
Benchmarking DCDC Converters

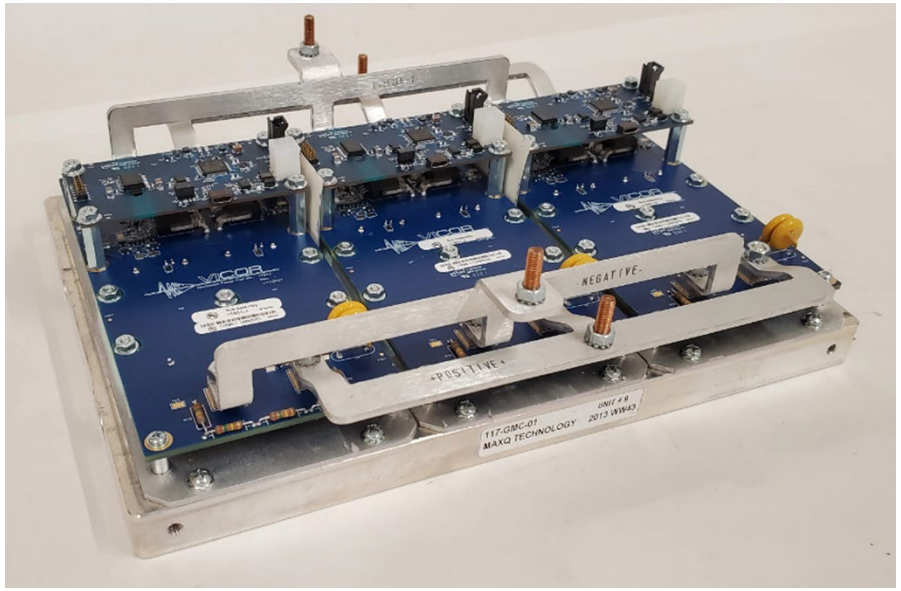
400V to 12V

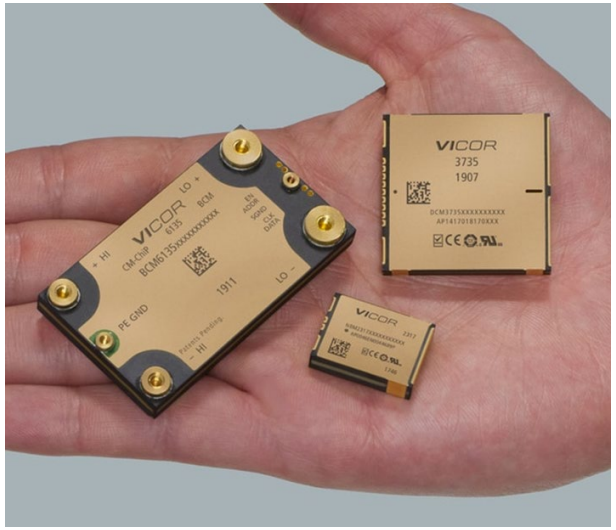
	Tesla Model X P90		Ford Mach-e		Chevy Bolt	
DCDC Power Rating	2300W		3400W		2500W	
DCDC Converter Mass	2.776 kg		2.301 kg		3.432 kg	
DCDC Volume L	4.4L		4.03 L		5.62 L	
Power Density – Mass	0.83 kW / kg		1.5 kW / kg		0.73 kW / kg	
Power Density - Volume	0.52 kW / L		0.84 kW / L		0.44 kW / L	

Miniature Power Conversion Devices

- Benefits of Sine Amplification Conversion
- BCM6135 efficiency data
- NBM6123 efficiency data

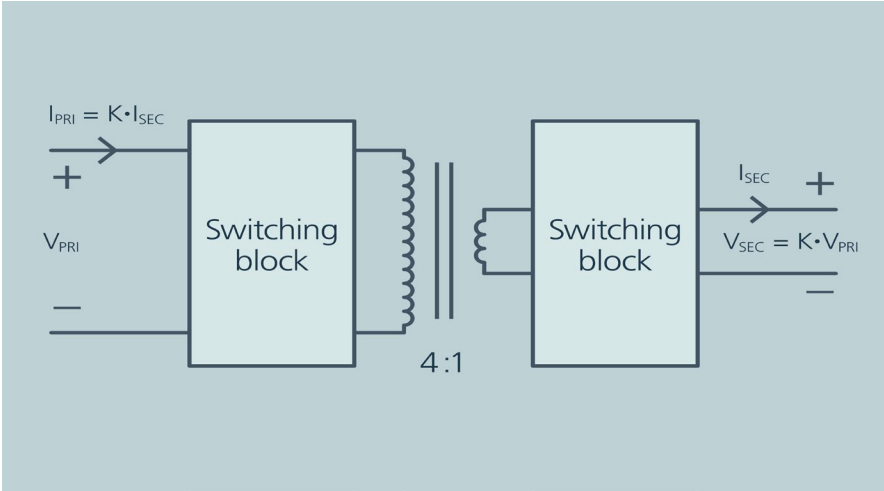






Fixed Ratio Converter

- Sine Amplitude Converter topology :
  - Zero Voltage Switching
  - Zero Current Switching
- Fixed Ratio Conversion :
  - Divide/Multiply the Voltage/Current
- Up to 2X transient current capability
- Ideal transformer behavior
- No inductor usage
- Not dependent on internal energy storage



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

Fixed Ratio Converter

Fast Transient Response

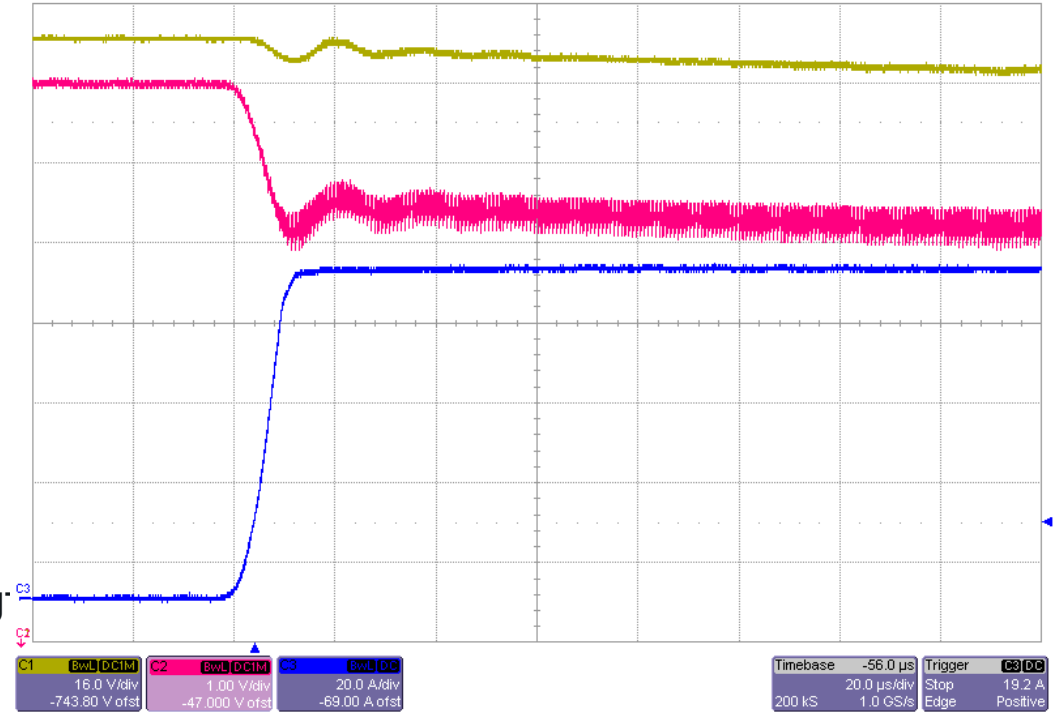
High frequency switching
- Smaller magnetic components
- Smaller path lengths for turns

Package has very low parasitic inductance on input/output connections

Response is flat as a function of R_{OU} from DC to over 1.0 MHz

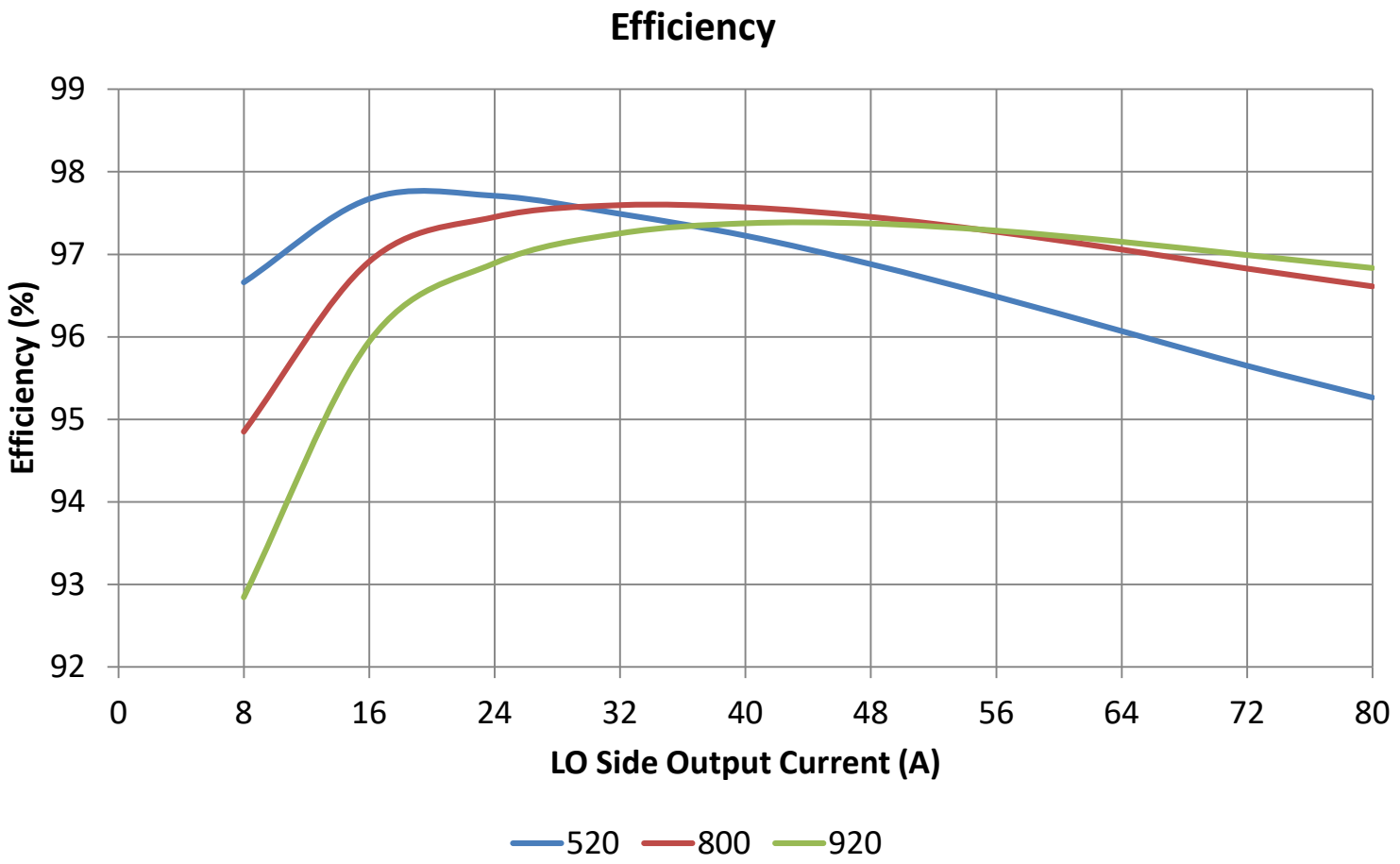
BCM6135 Load Step Transient

V_{HI} = 800V, I_{LO} step from 0A – 80A, $di_{LO}/dt \approx 8.6A/\mu s$ (8.6MA/s), No C_{LO}

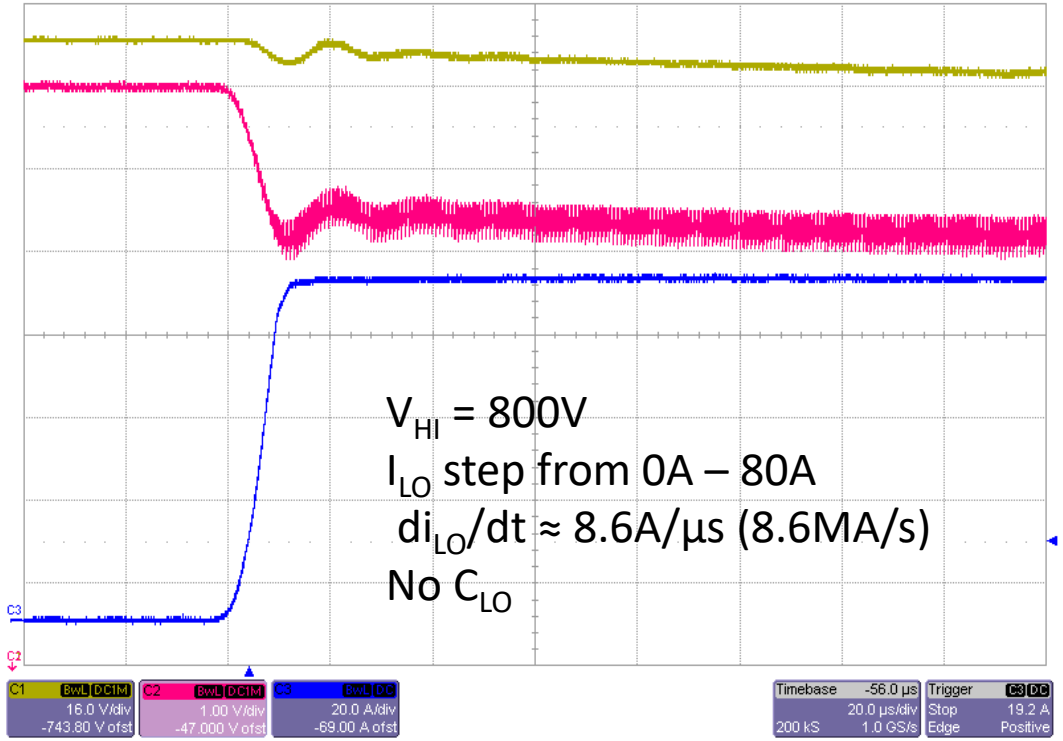


BCM6135 Efficiency

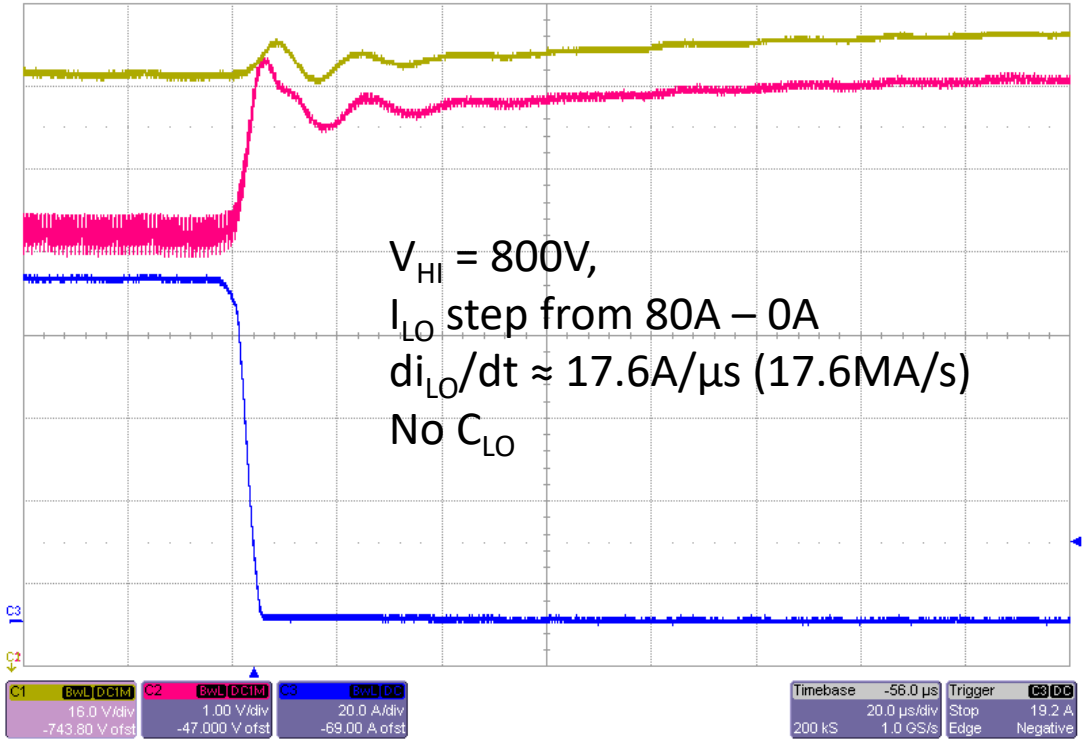
Bench measurement at 25°C ambient



BCM6135 Load Step Transient

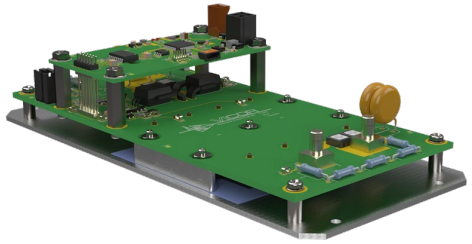


CH1 – V_{HI}: 16V/div. (DC)
CH2 – V_{LO}: 1V/div. (DC)
CH3 – I_{LO}: 20A/div. (DC)
Timebase – 20µs/div.



CH1 – V_{HI}: 16V/div. (DC)
CH2 – V_{LO}: 1V/div. (DC)
CH3 – I_{LO}: 20A/div. (DC)
Timebase – 20µs/div.

Power Test Setup



- Startup C_{Lomax} = 3.3 µF

- 25uF C_o on each PLA7.5K E-load

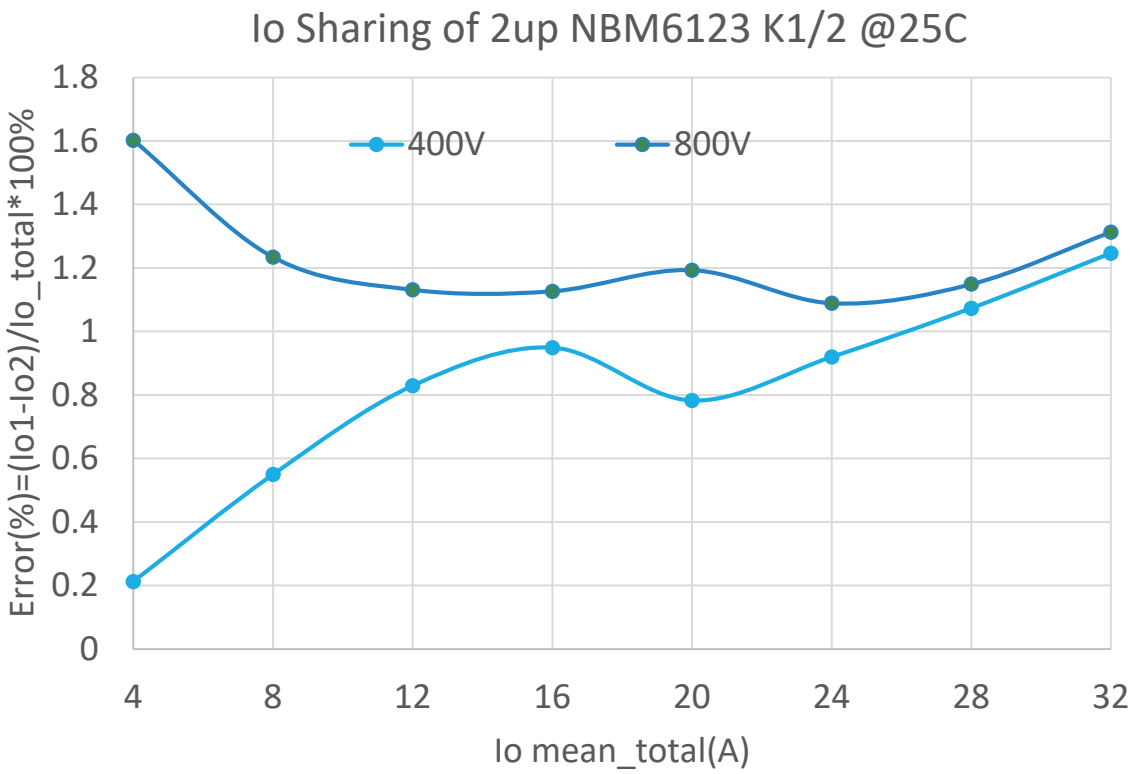
- S_2, S_3: Relay, 1000Vdc, 50A

- R_shunt = 2mΩ

This array combines 2 NBM6123 modules in Buck Mode 800V – 400V

- Each Module provides 7.5 kW
- Array provides 15kW

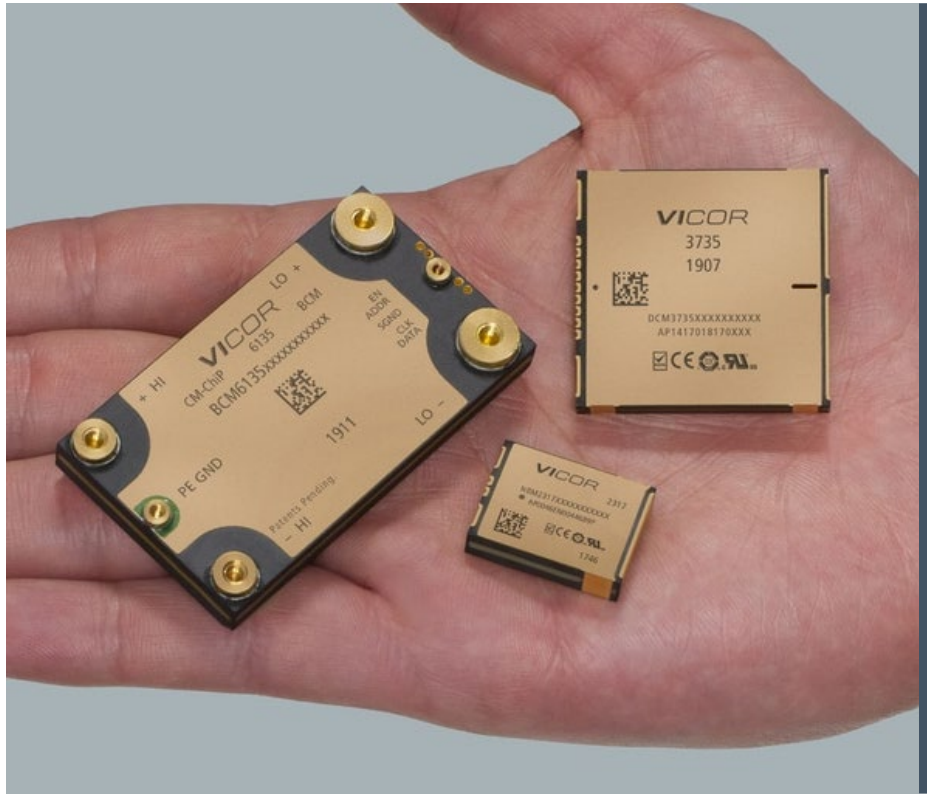
Network to Higher Power with Array of Miniature Modules

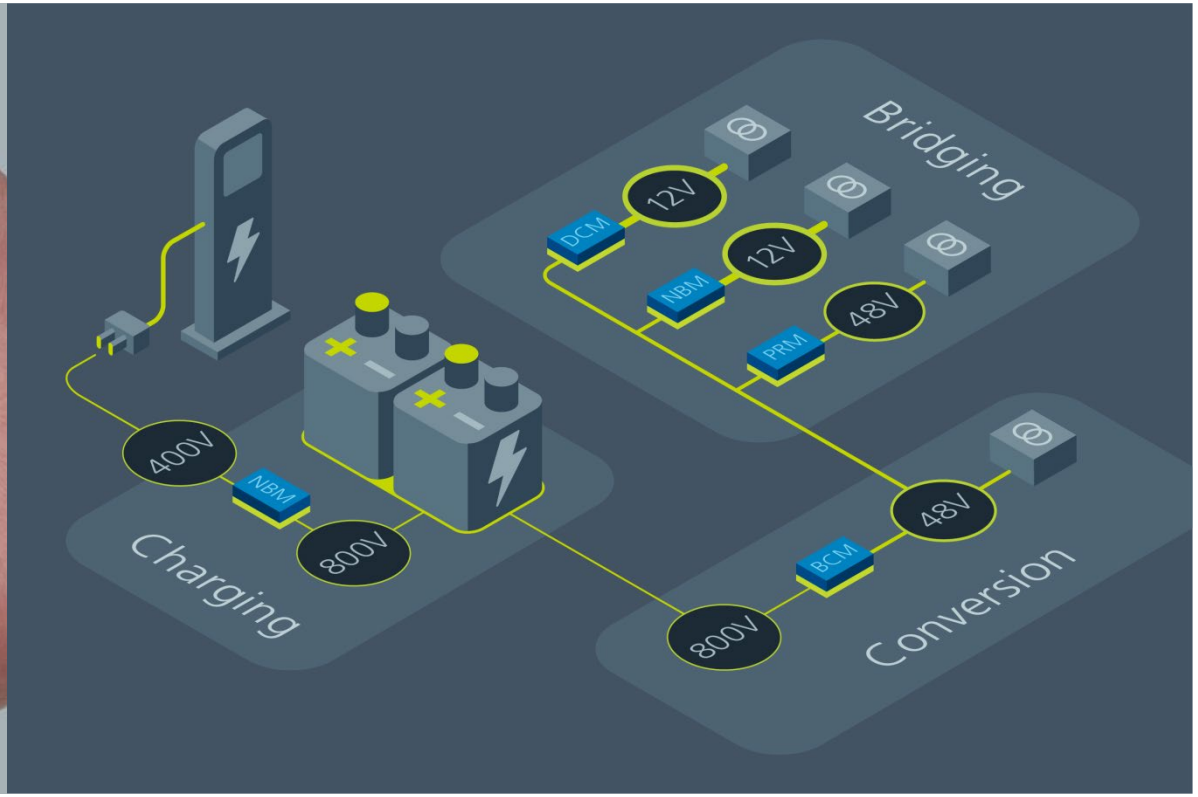


Minimal Current Sharing error which enables arrays of up to 10 modules

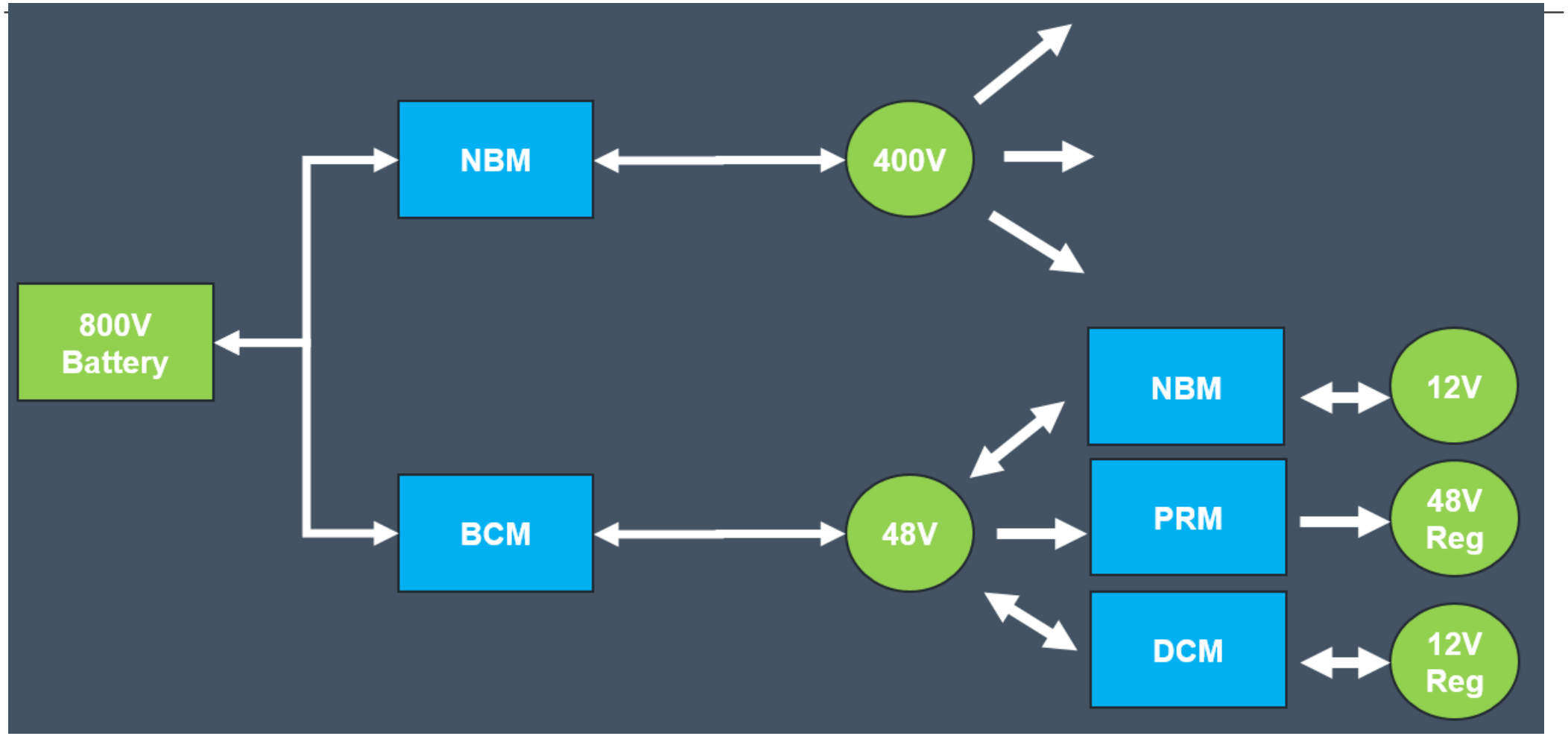
Current Sharing Error is under 1.5% for 400V and 800V

Total Power Delivery Network built using Miniaturized Modules





Power Network Possibilities



Miniaturized 400V – 12V DCDC

The contents of this system:

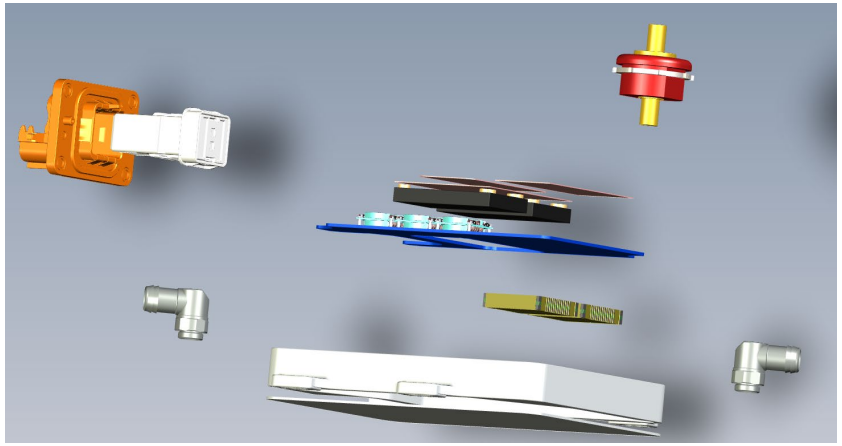
2 BCM6135 to convert 400V to 48V

2 DCM3735 to convert 48V to regulated 12V

System PCB Board with circuits for:

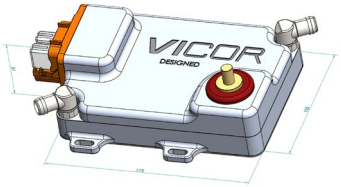
- Reverse Polarity
- VCC
- Pre-charge
- EMI Filters
- Isolator
- HV Connector
- LV Post Connector
- CAN Connector
- Cooling Plate
- Housing

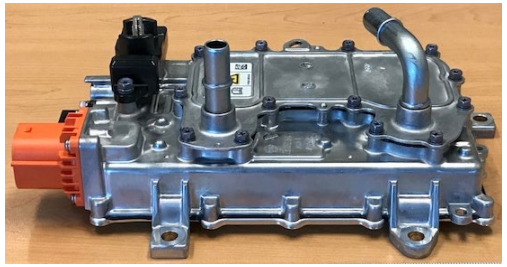
Vicor Chipset for 4 kW
Volume 0.046L = 87 kW / L
Mass 266 g = 15 kW / kg



Miniaturization achieves up to 5x Improvement in Power Density

	Vicor Concept	Tesla Model X	TDK Production Mach-E
Pout W (Output Power)	4000 @ 13.8V	2300 @ 12 V	3410 @ 15.5V
Output Current A	290	193	220
Weight kg	1.4	2.1	2.7
Size mm (w/o connectors)	0.76 L (175 x 125 x 35)	1.8L (140 x 218 x 60)	4.0 L (288 x 200 x 70)
Efficiency	95% Estimate	93% Estimate	93% Peak
Power Density kW/liter	**5.22**	**1.3**	**0.84**
Gravimetric Power Density kW/kg	**2.50**	**1.1**	**1.5**





Benefits of Miniaturized Power Modules

1. Higher Efficiency provides for less cooling loads at high power conversion
2. Higher power density for lower weight and smaller package size
3. Ability to create a virtual battery

Acknowledgements

I would like to thank these colleagues for their help with this presentation:

Dr. Patrizio Vinciarelli, CEO

Ben Chen, Applications Engineering

Su Sheng, Applications Engineering

Patrick Kowalyk, Applications Engineering

Speaker information

Thank you

Gregory Green

Director, Automotive Customer Programs

Vicor Corporation

ggreen@vicr.com