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

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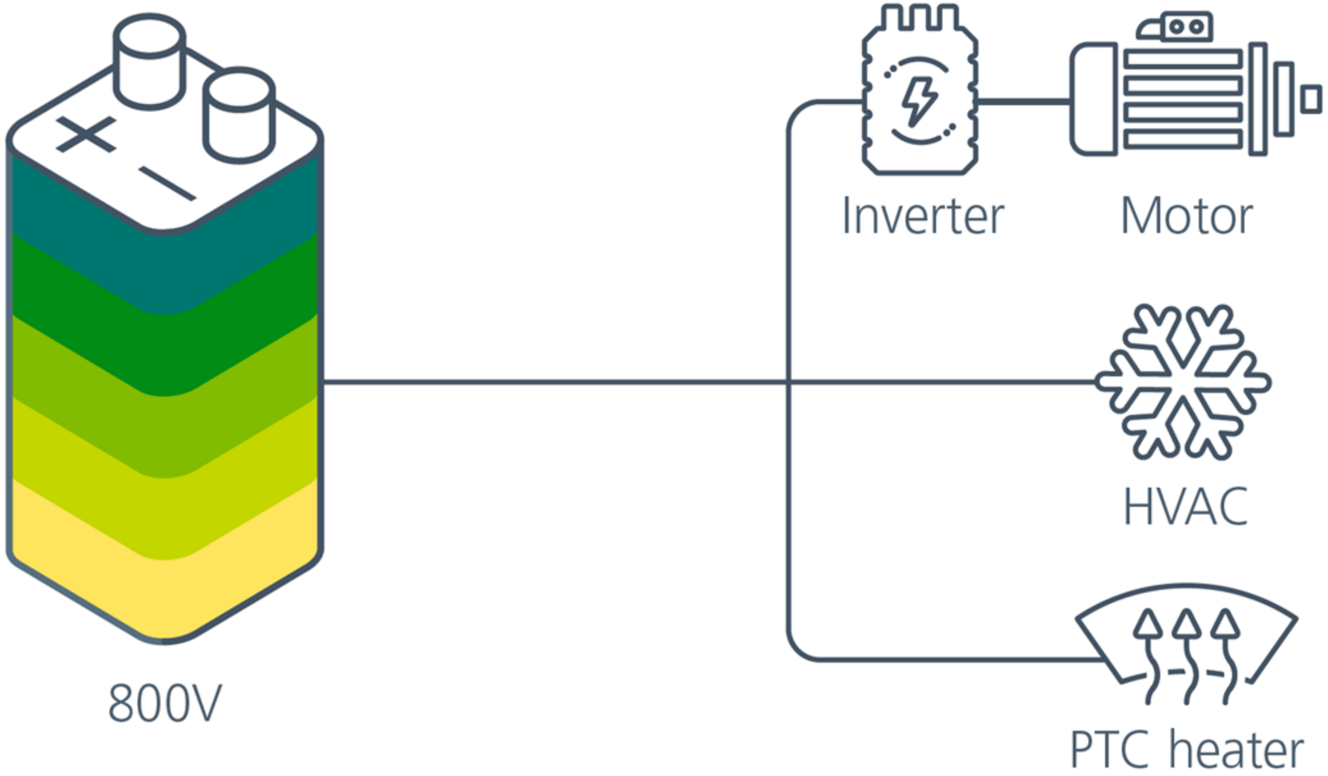
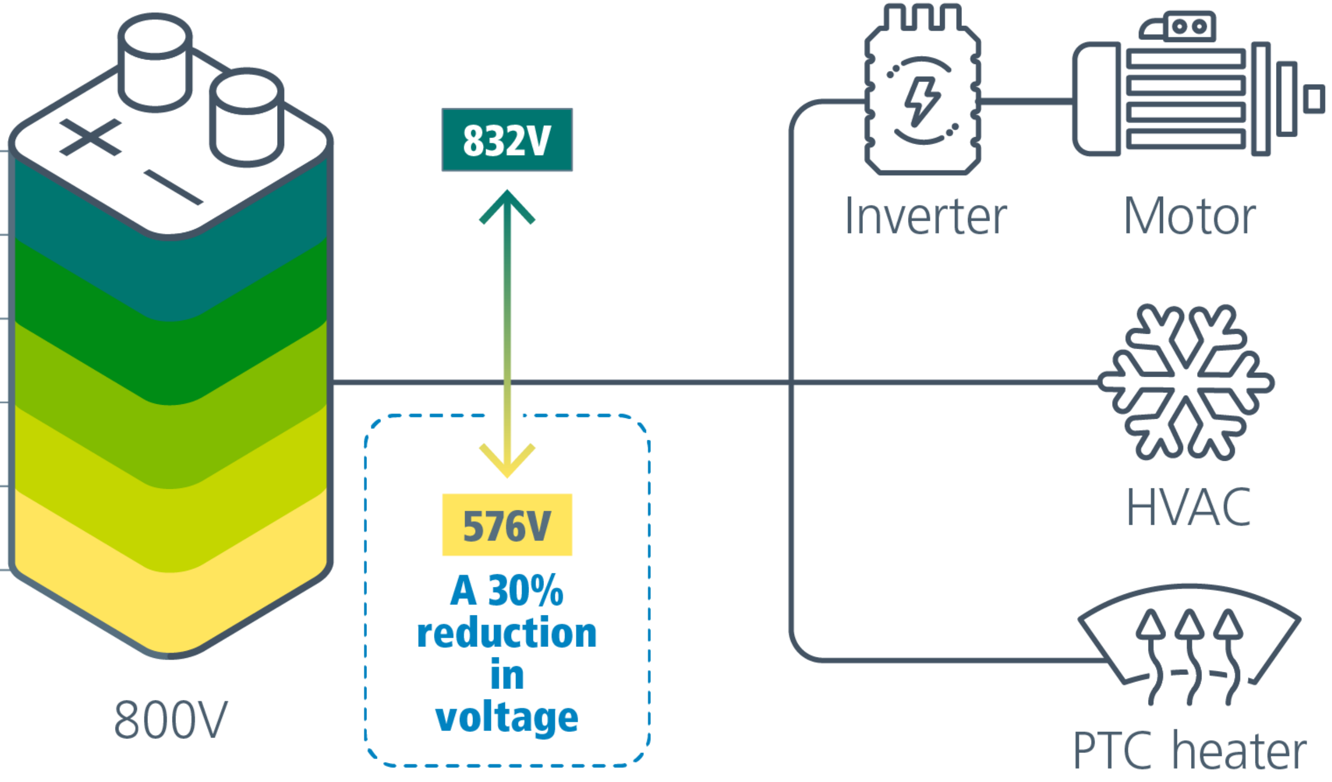
# BEV HV architecture



# 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 |



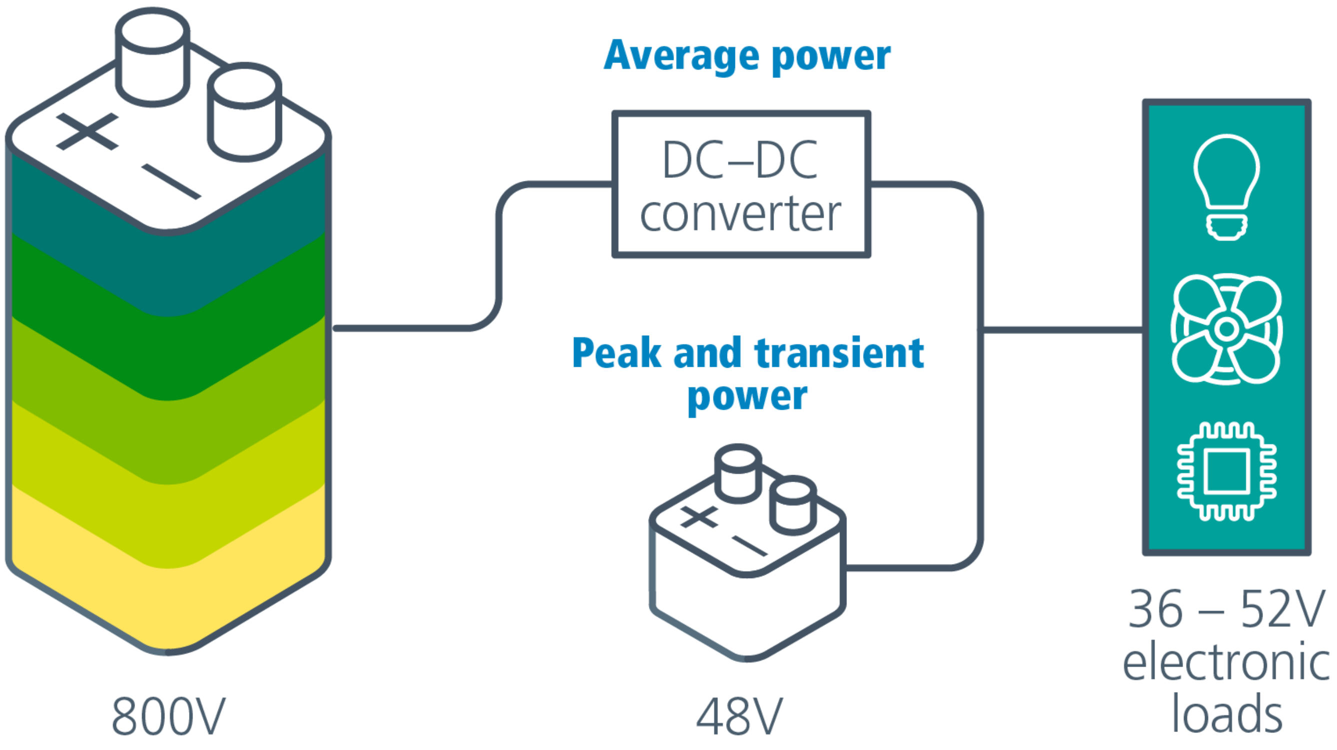
# 48V – main low voltage bus for future architectures

- Started with 48V BSG and battery
- Now DC-DC and battery
- Typical loads, require more power (pumps, motors, heaters)
  - Benefit compared to HV supply is safety
  - Benefit compared to 12V is 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?

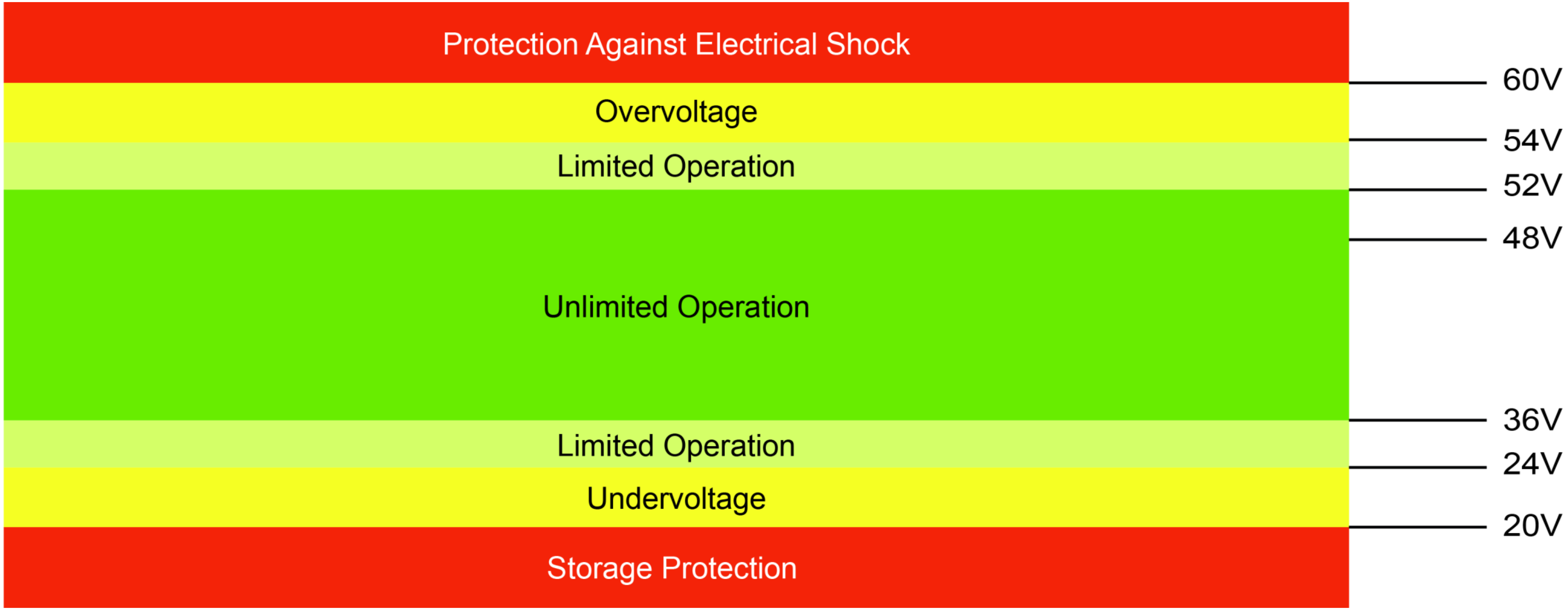
# Current 48V bus solutions for xEV

Challenges:

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



# VDA 320 – reminder that current 48V bus is defined with voltage range



# Proposed solution: Sine Amplitude Converter (SAC™)

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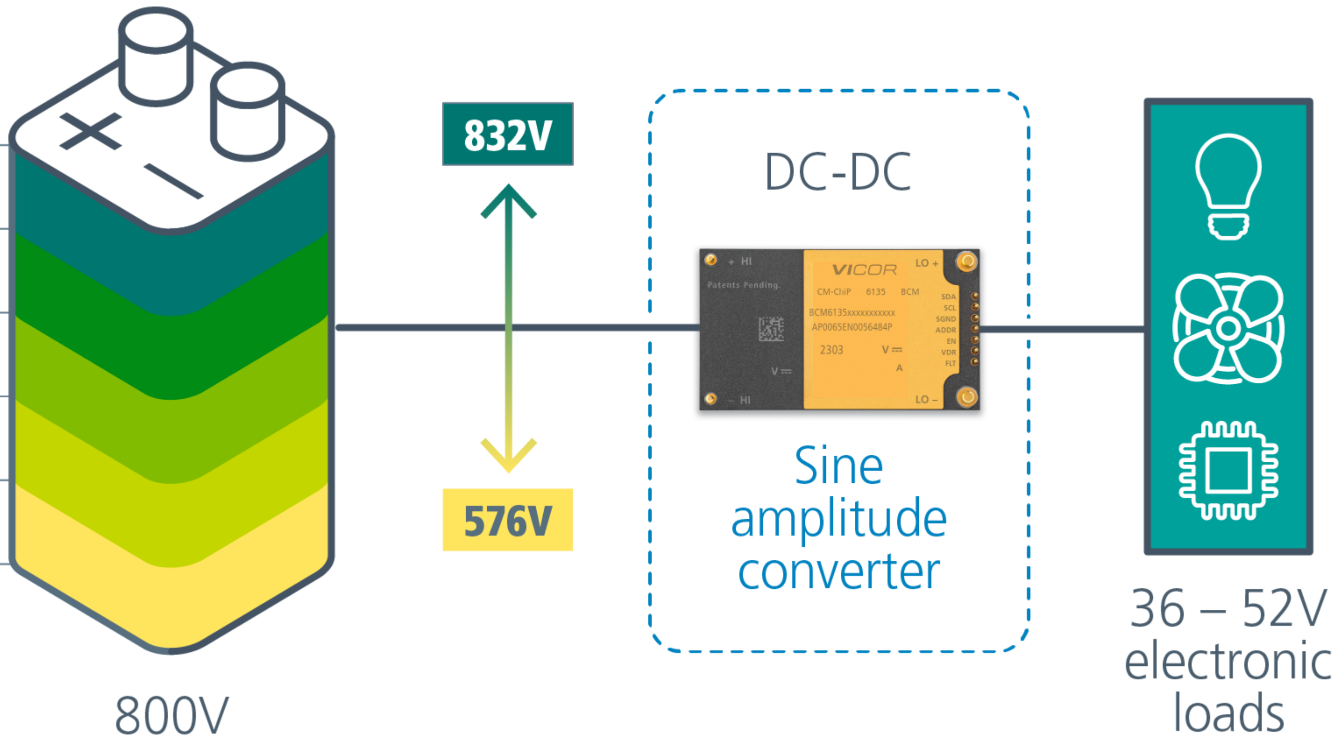
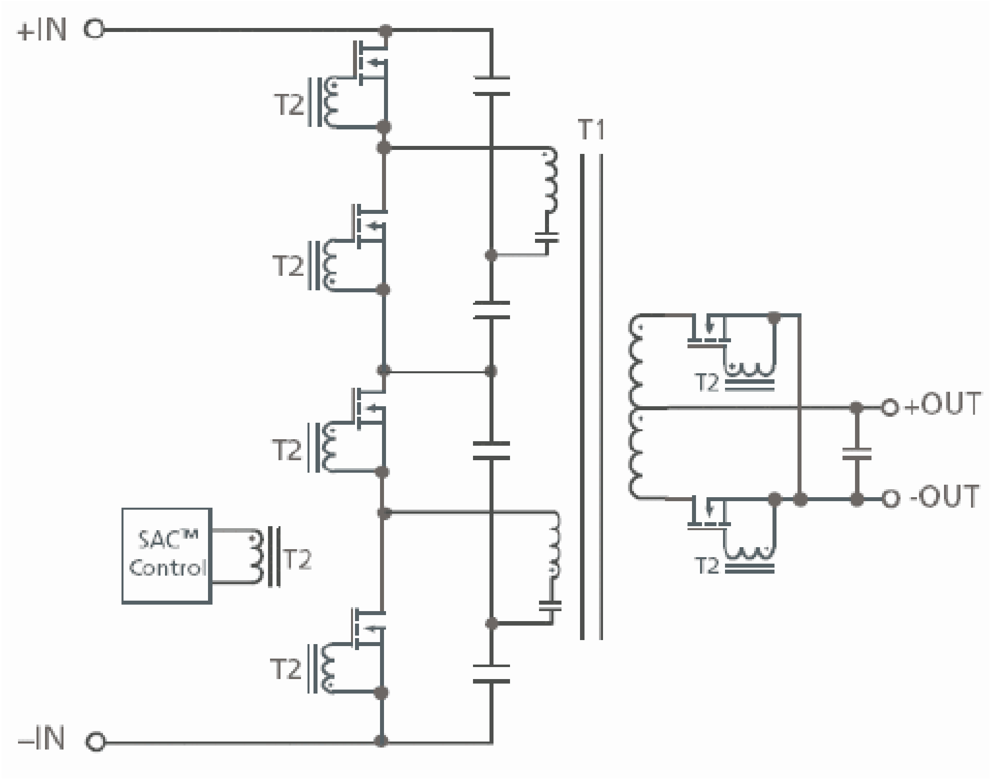
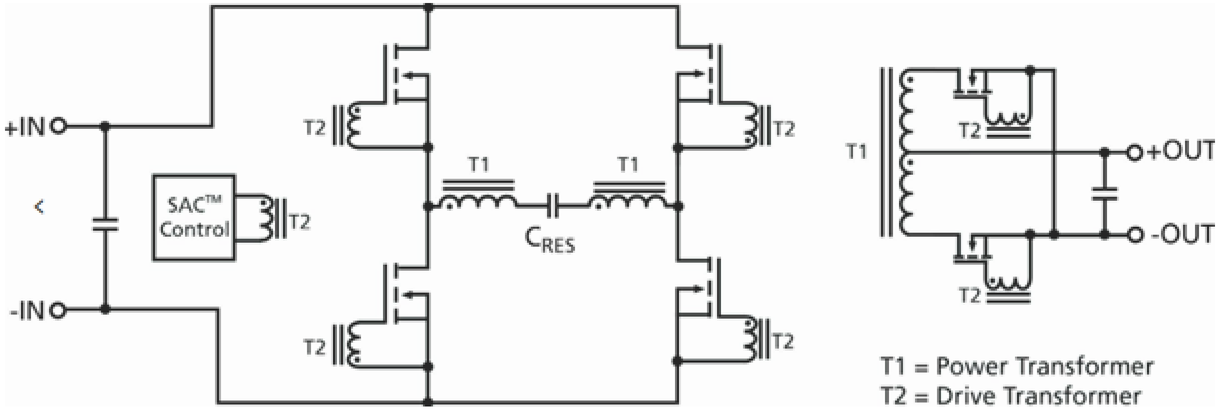


# Proposed solution: Sine Amplitude Converter

- 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

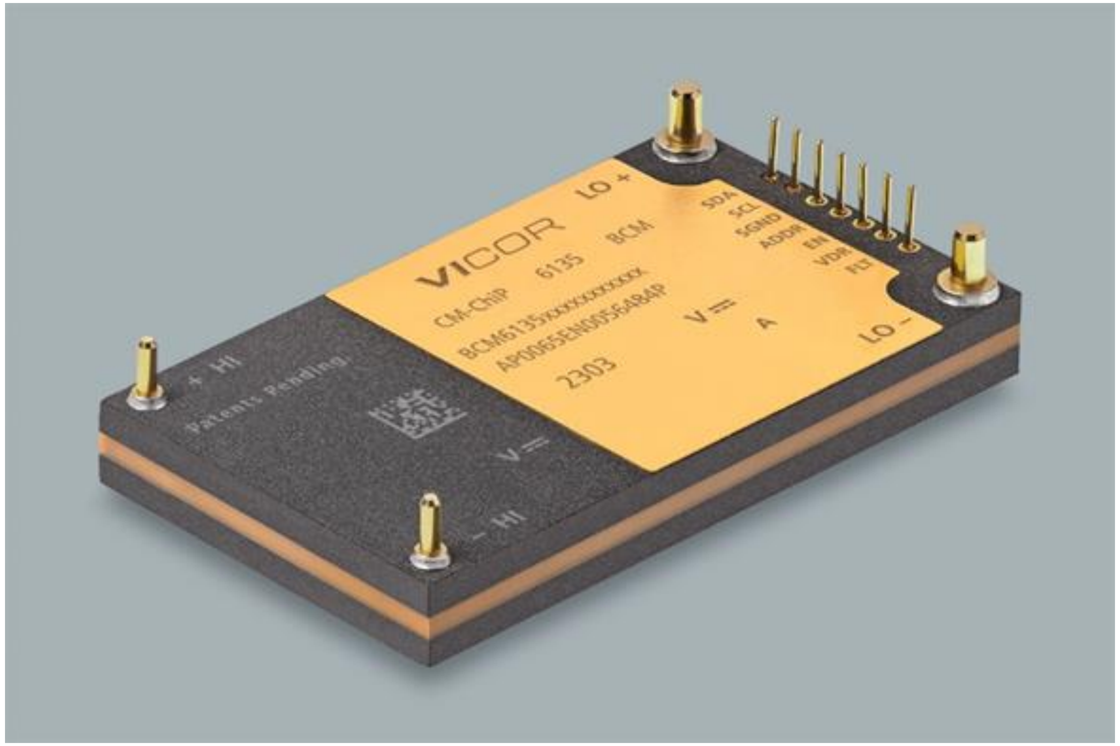
# Topology example of SAC implementation – BCM



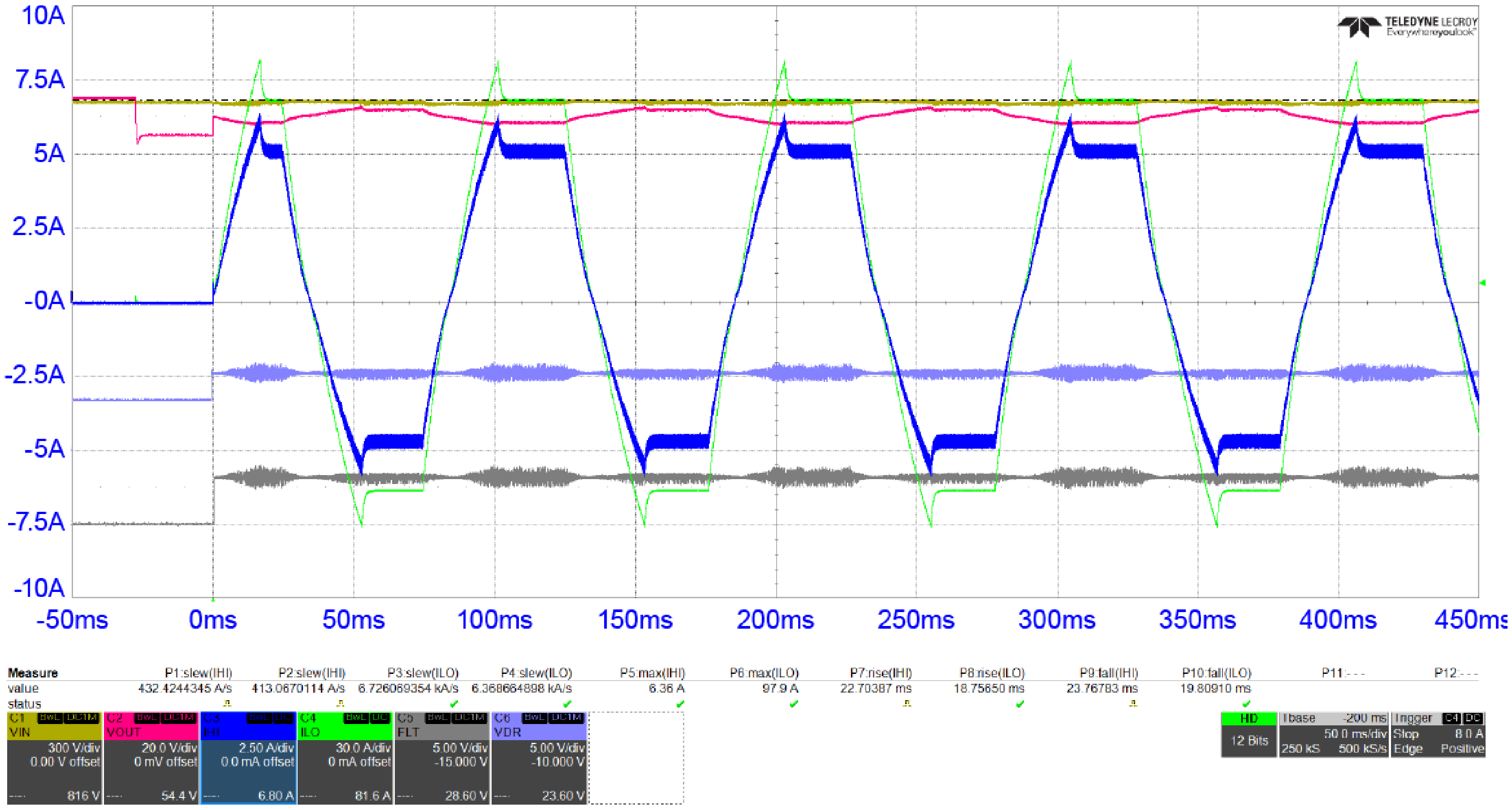



# Example of SAC implementation – BCM

- 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

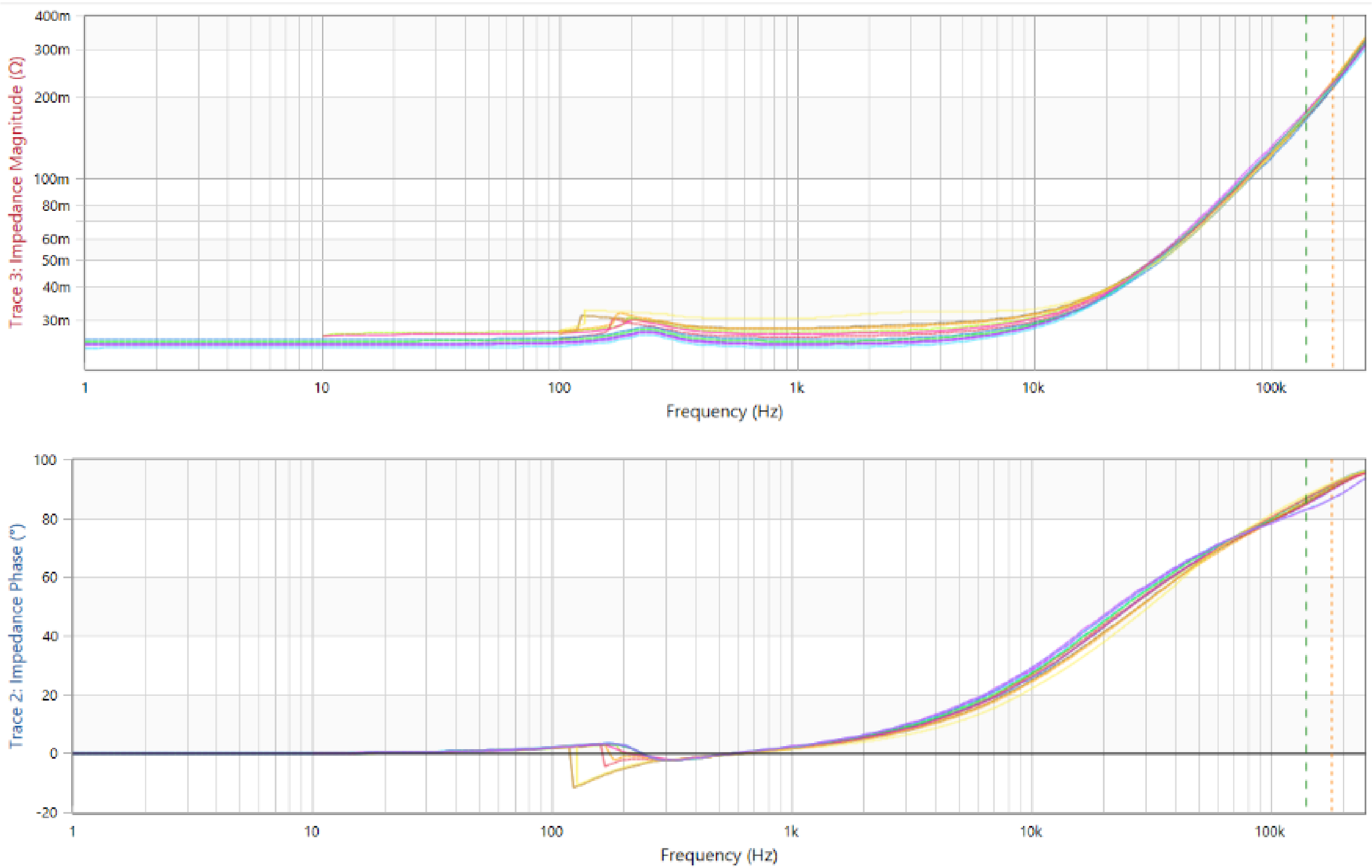


# Bidirectional current flow and bandwidth




| | | |
|---|---|---|
| C1 VIN | 300 V/div, 0.00 V offset, 816 V | High-side voltage |
| C2 VOUT | 20.0 V/div, 0 mV offset, 54.4 V | Low-side voltage |
| C3 IHI | 2.50 A/div, 0.0 mA offset, 6.80 A | High-side current |
| C4 ILO | 30.0 A/div, 0 mA offset, 81.6 A | Low-side current |
| C5 FLT | 5.00 V/div, -15.000 V, 28.60 V | Fault output voltage |
| C6 VDR | 5.00 V/div, -10.000 V, 23.60 V | Internal bias voltage |

# BCM output impedance



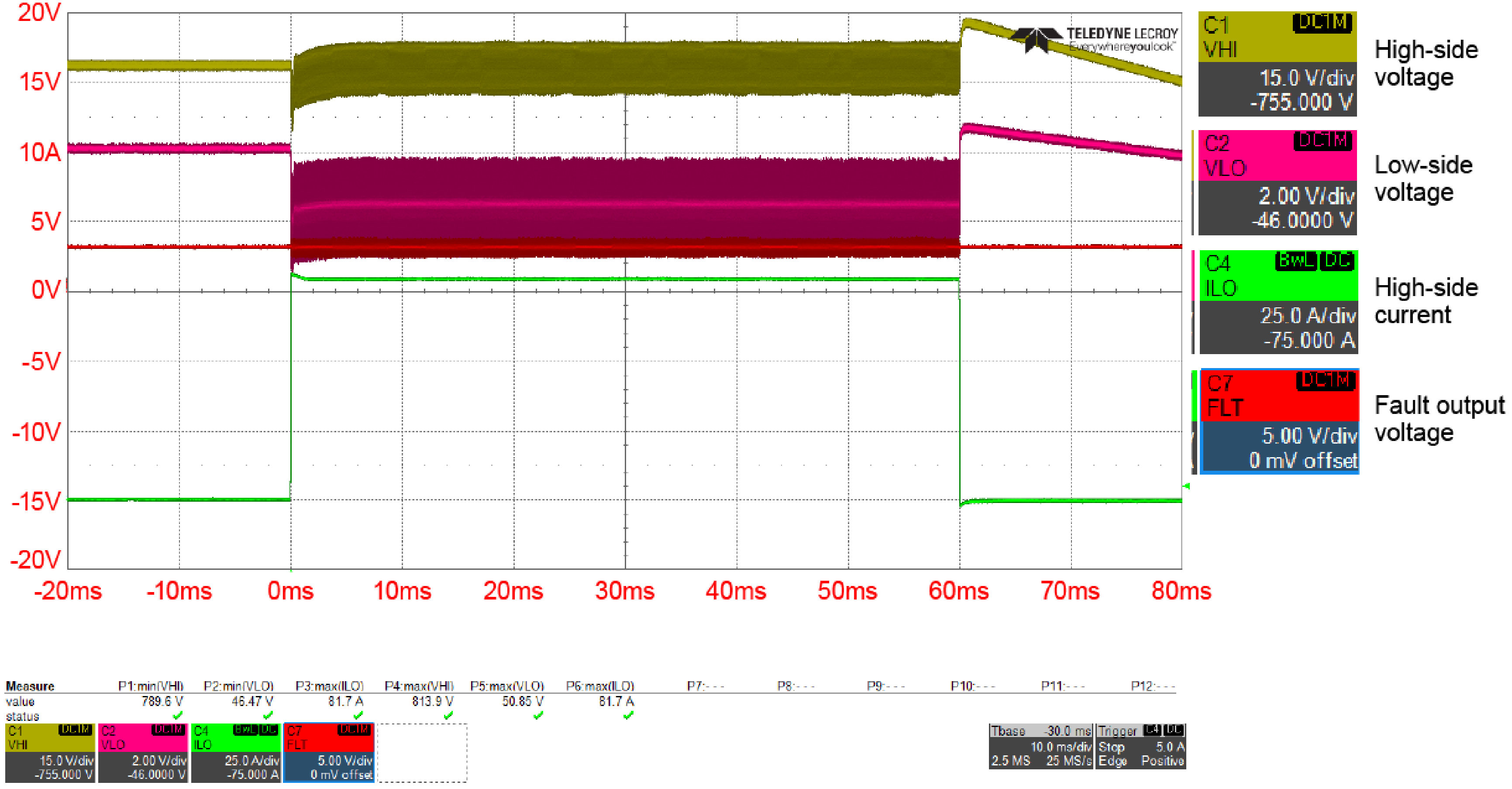

Output impedance

Measurement includes

EMI filter required

For CISPR-25 Class 5

# Peak current/power



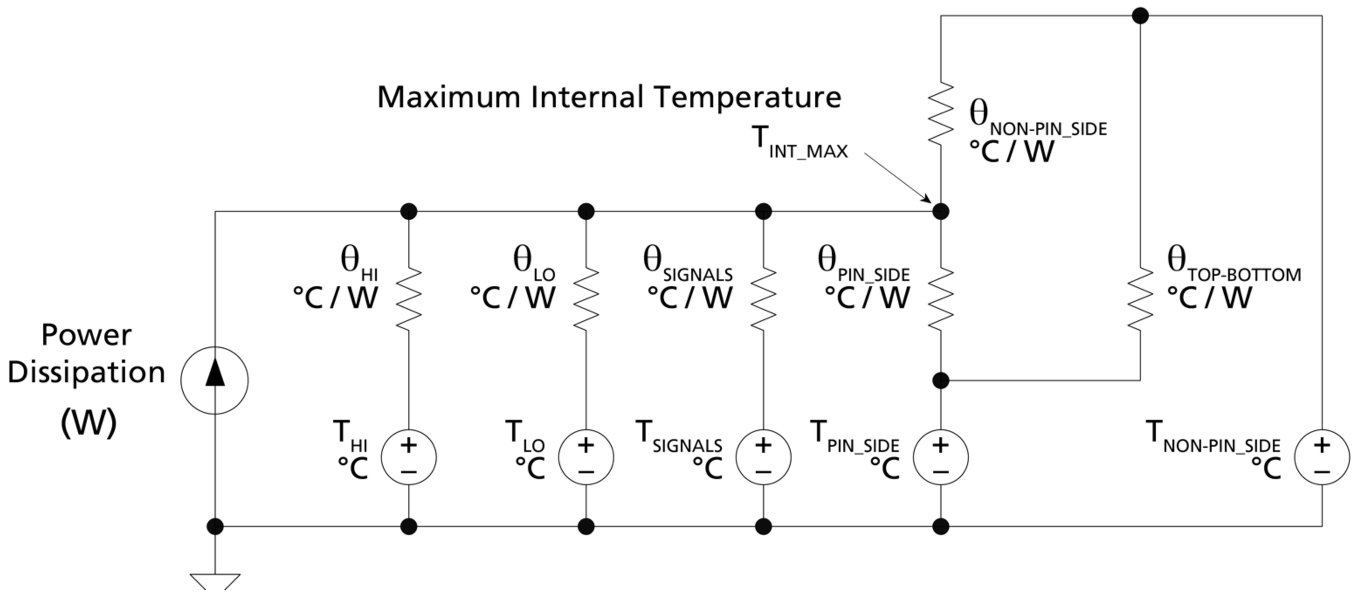

50V output

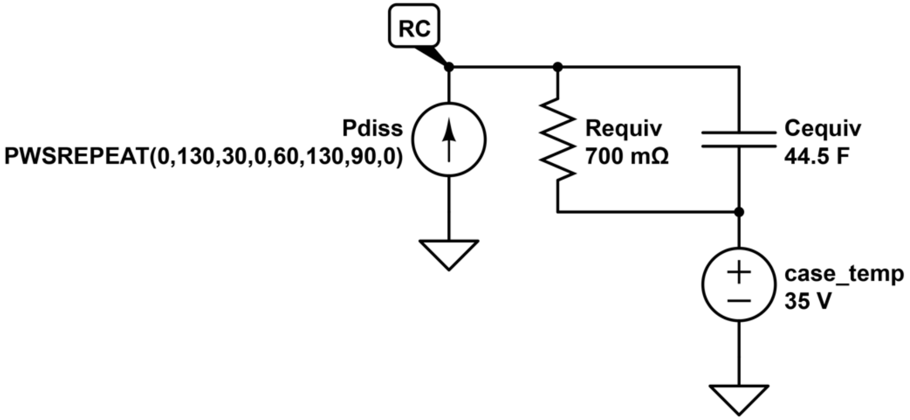
90A peak current

No heatsink

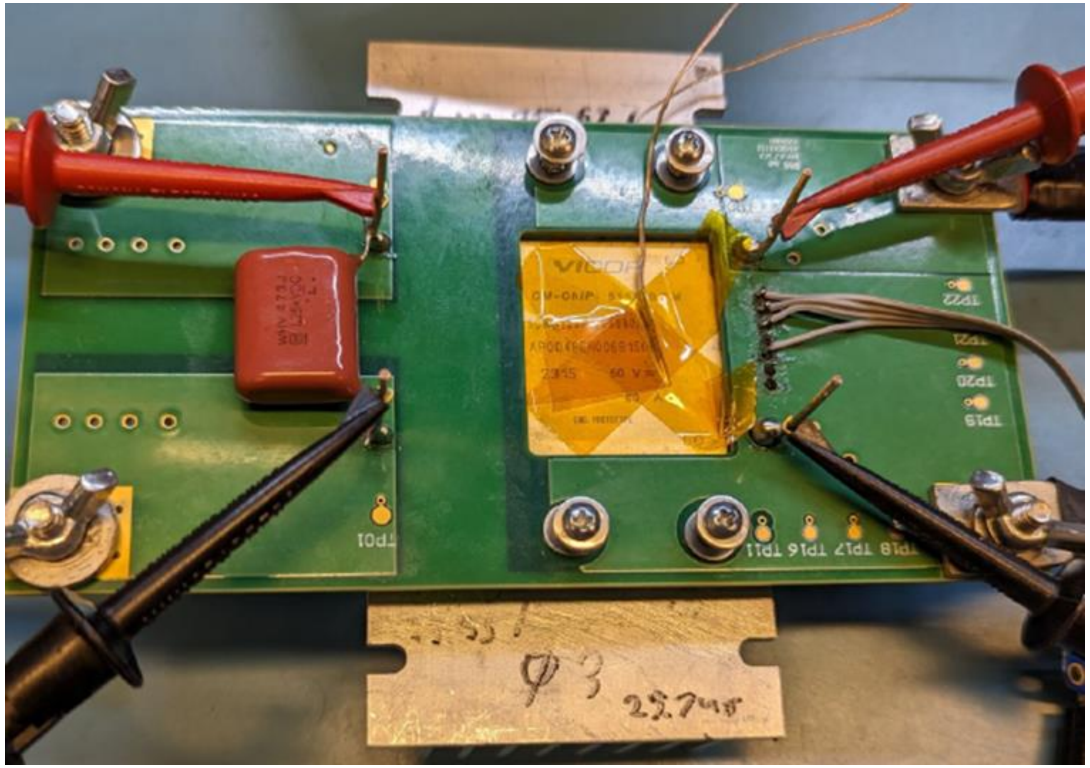
# Packaging thermal performance

Package size: 61 x 35 x 7 mm



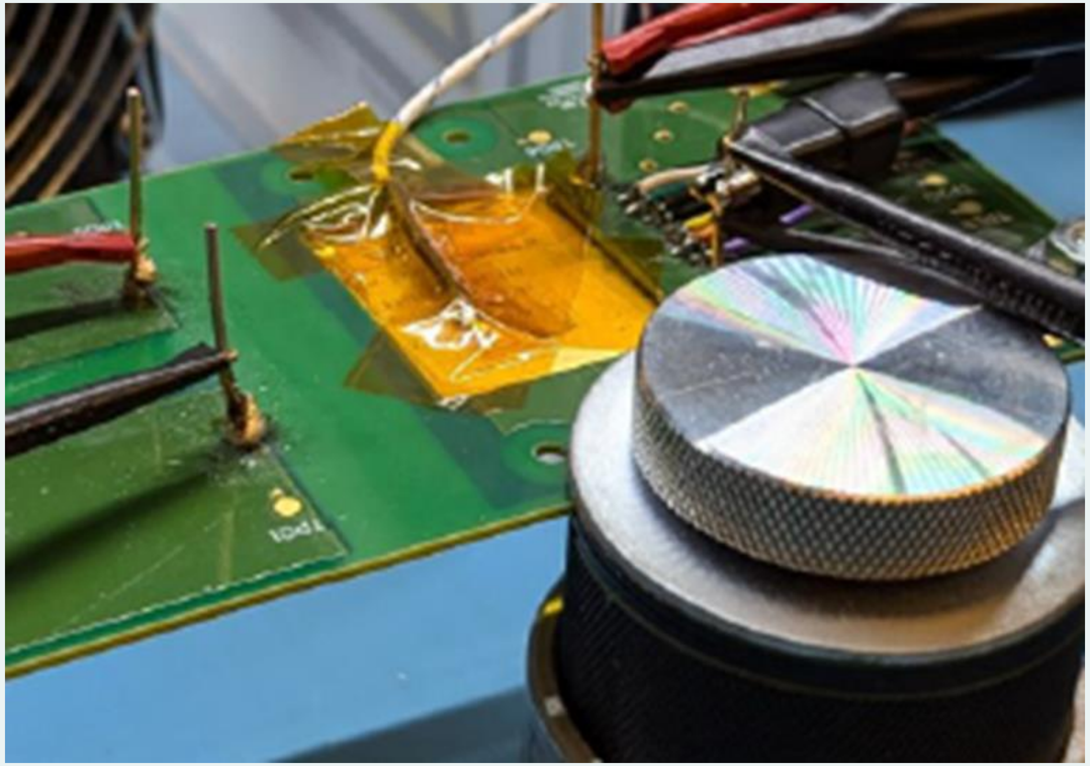



# Test setup with heat sink

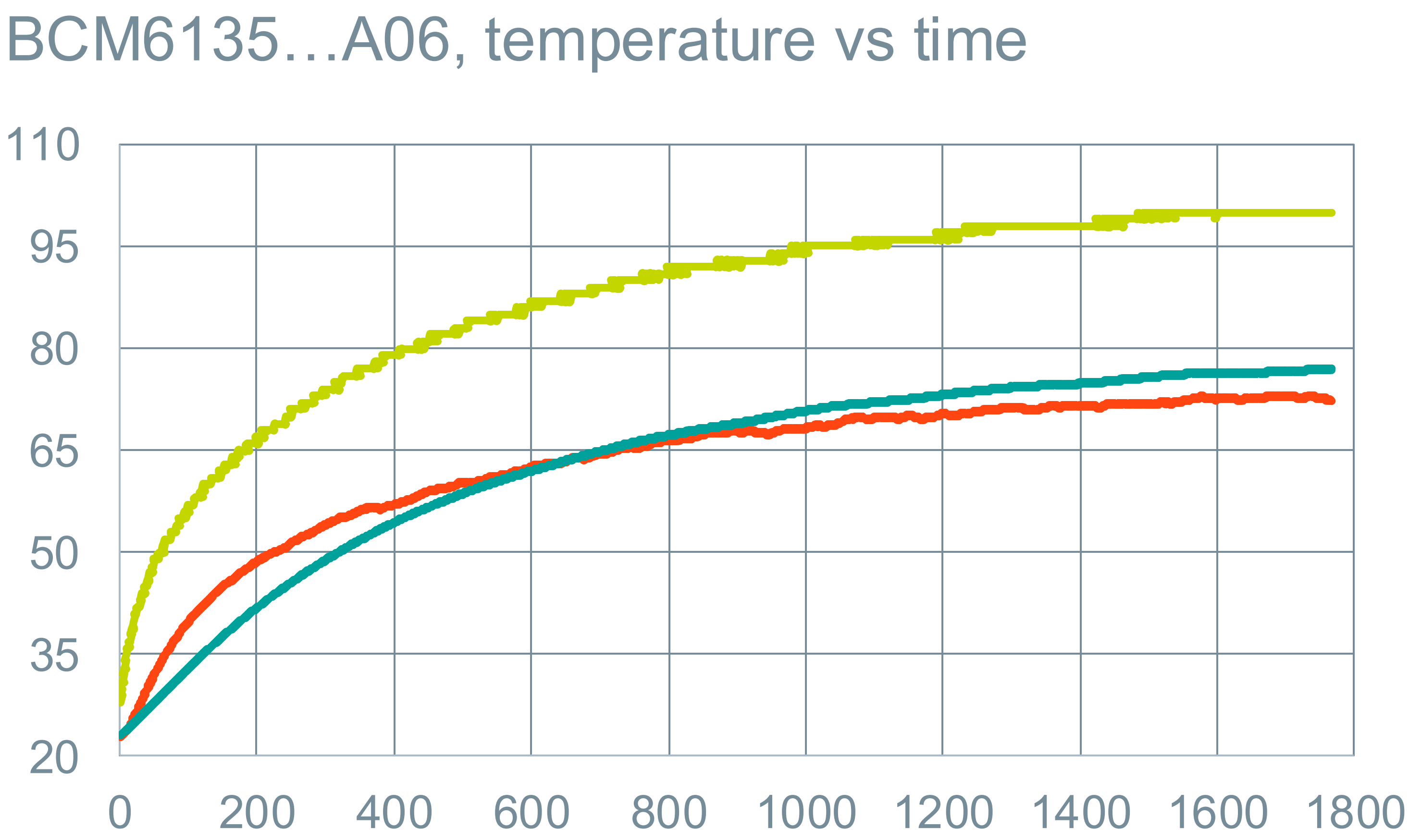


Heat sink: 120 x 60 x 25 mm

# Without heat sink

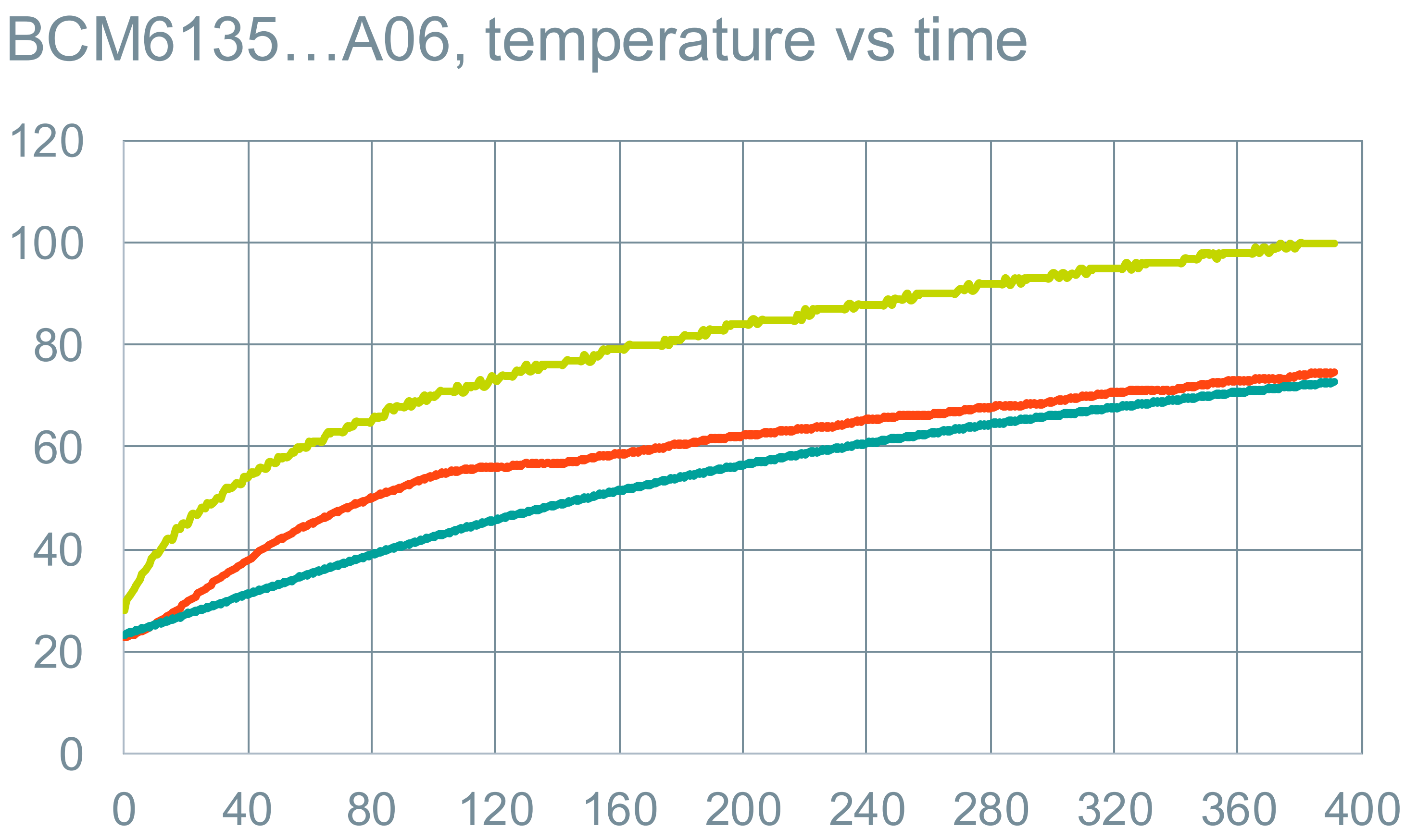


# 520V$_{HI}$, 32.5V$_{LO}$, 16 to 80A (2.5kW), with heat sink



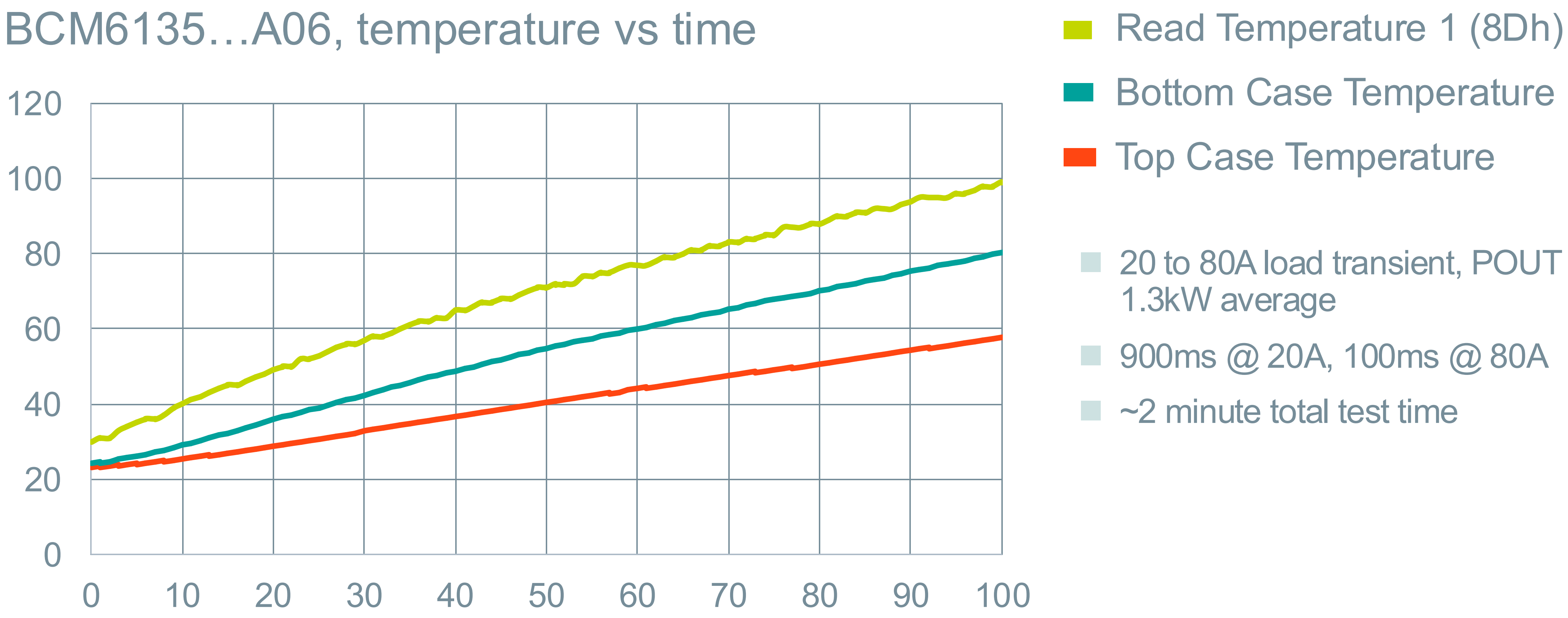

- 16 to 80A load transient, $P_{OUT}$ = 720W average
- 900ms @ 16A, 100ms @ 80A
- 30-minute total test time
- Heatsink Vicor PN: 02111
- Thermal pad: ACTPD00018A
- Thermal pad size: 68 x 41 x 1mm

# 800VHI, 50VLO, 20 to 80A (4kW), with heat sink




- 20 to 80A load transient, POUT = 1.3kW average
- 900ms @ 20A, 100ms @ 80A
- 6 minute total test time
- Heatsink Vicor PN: 02111
- Thermal pad: ACTPD00018A
- Thermal pad size: 68 x 41 x 1mm

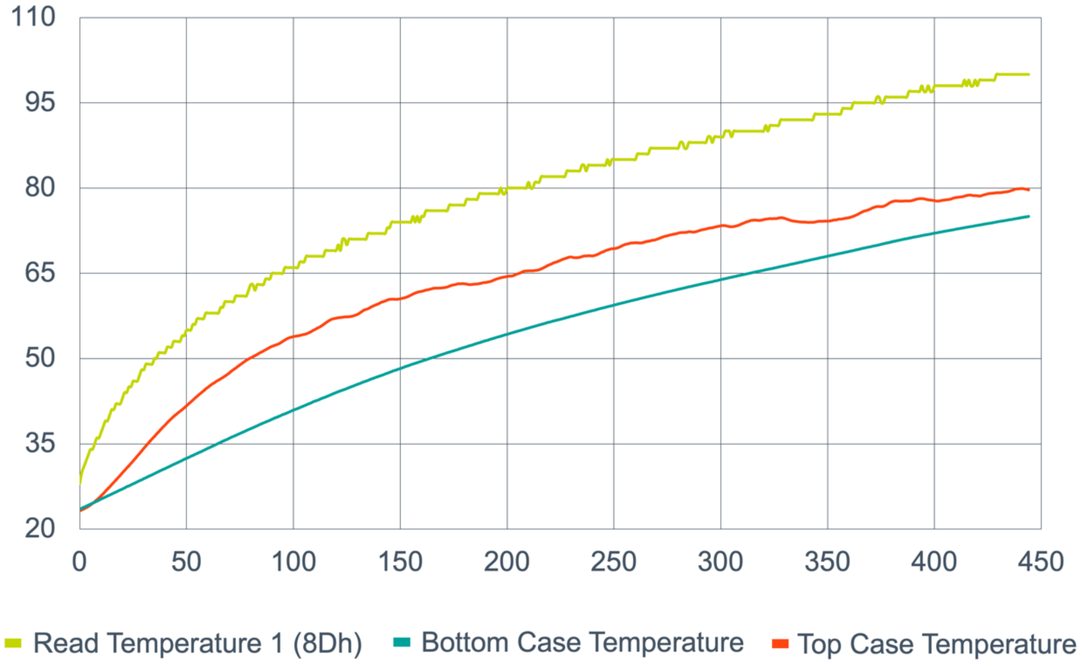
# 800VHI, 50VLO, 20 to 80A (4kW), without heat sink



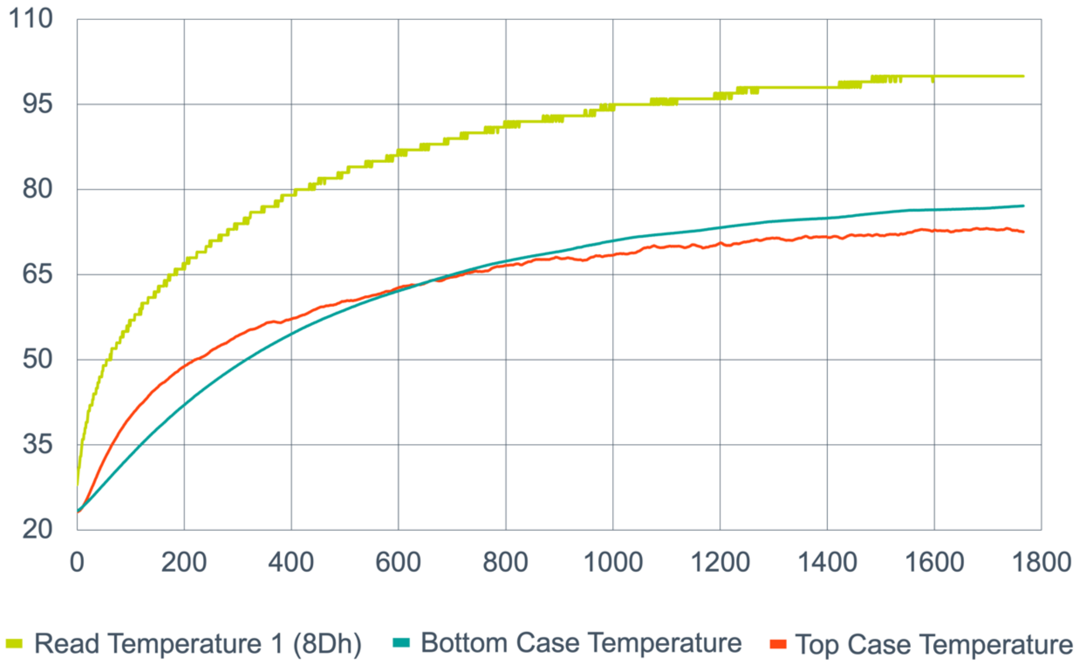

- 20 to 80A load transient, POUT = 1.3kW average
- 900ms @ 20A, 100ms @ 80A
- ~2 minute total test time

# 10% duty cycle, 16A to 80A load steps

## Without heatsink




## With heatsink

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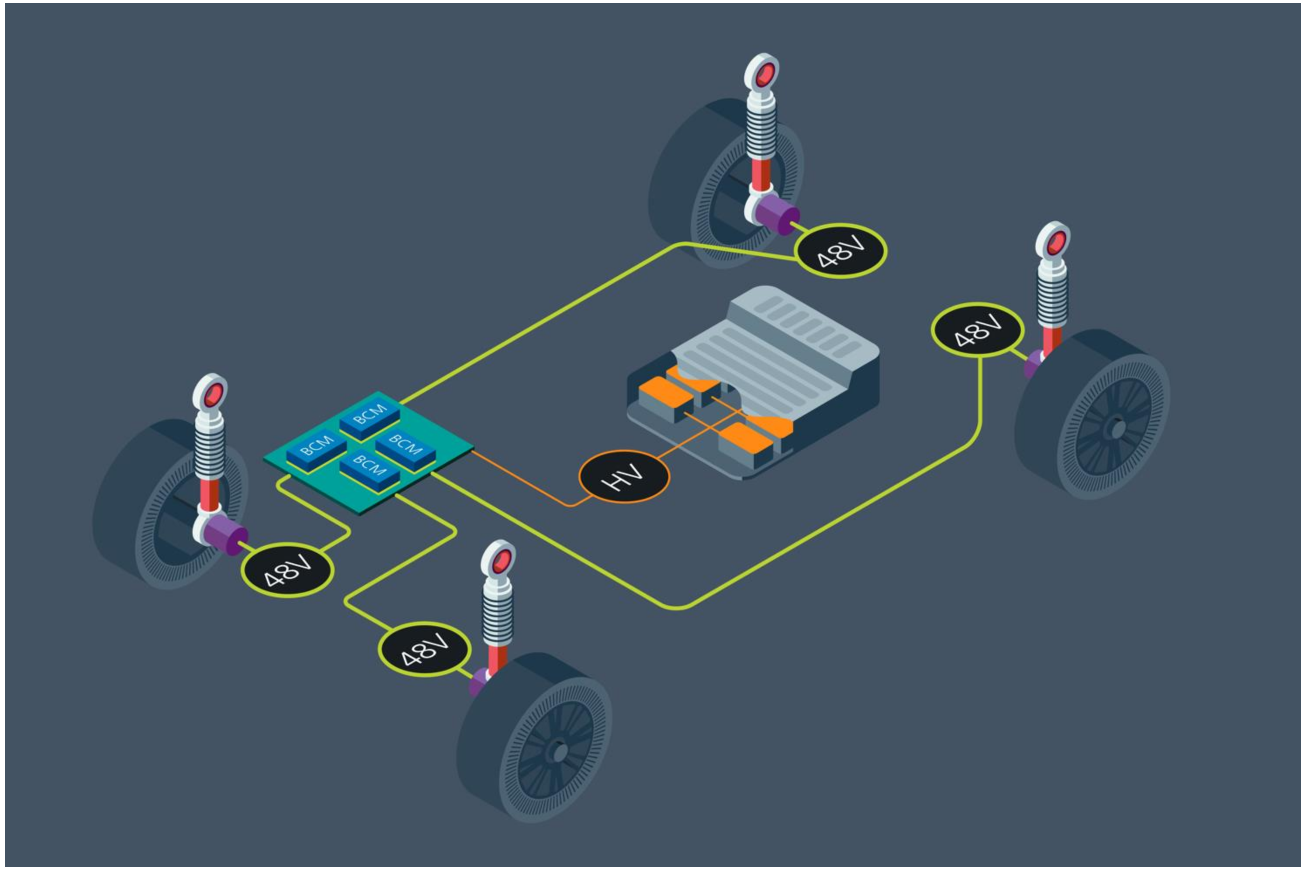
# Application examples

- Active suspension
  - High dynamic
  - Peak currents
  - Energy recuperation
  - High added value to vehicle and customer
- Other:
  - windshield heaters
  - pumps



# Summary conclusions

- Do we need oversized DC-DC converters and/or batteries?
- Can we supply independent loads/load islands on 48V?
- What can we do to 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

VICOR

# Thank you