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Reducing range anxiety by reducing harness weight using power modules

Nicolas Richard – Director Automotive Europe

Vicor Corporation

VICOR

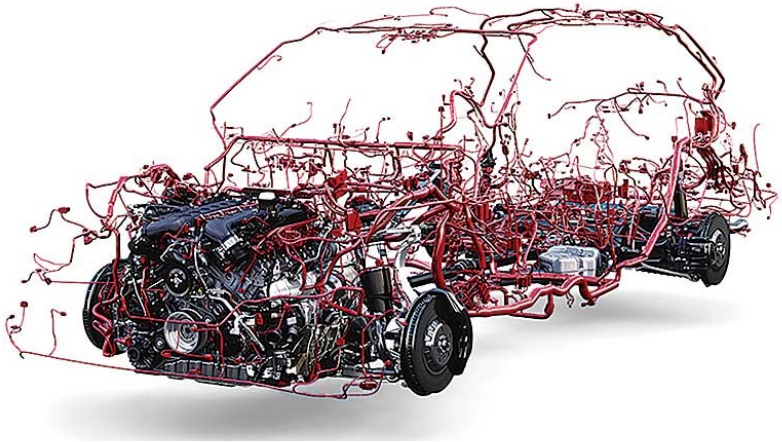
The challenge: Wire harness weight and inefficiency underestimated

The wire harness is one of the three heaviest subsystems in today's vehicles

- 2,000 copper wires totaling 1 mile in length
- 150lbs in highly contented vehicles

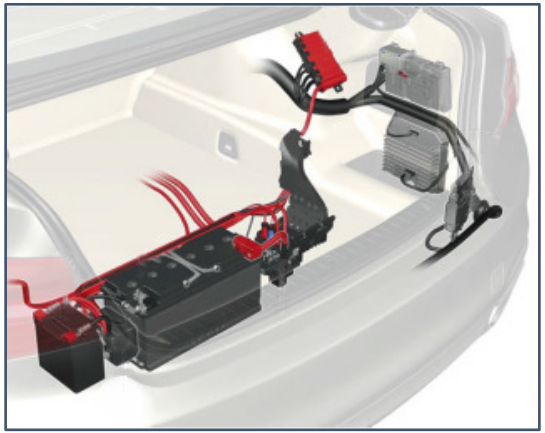
"We didn't know that our wiring harness for Mach-E was 1.6 kilometer longer than it needed to be. We didn't know it's 70 pounds heavier and that that's [cost an extra] $300 a battery"

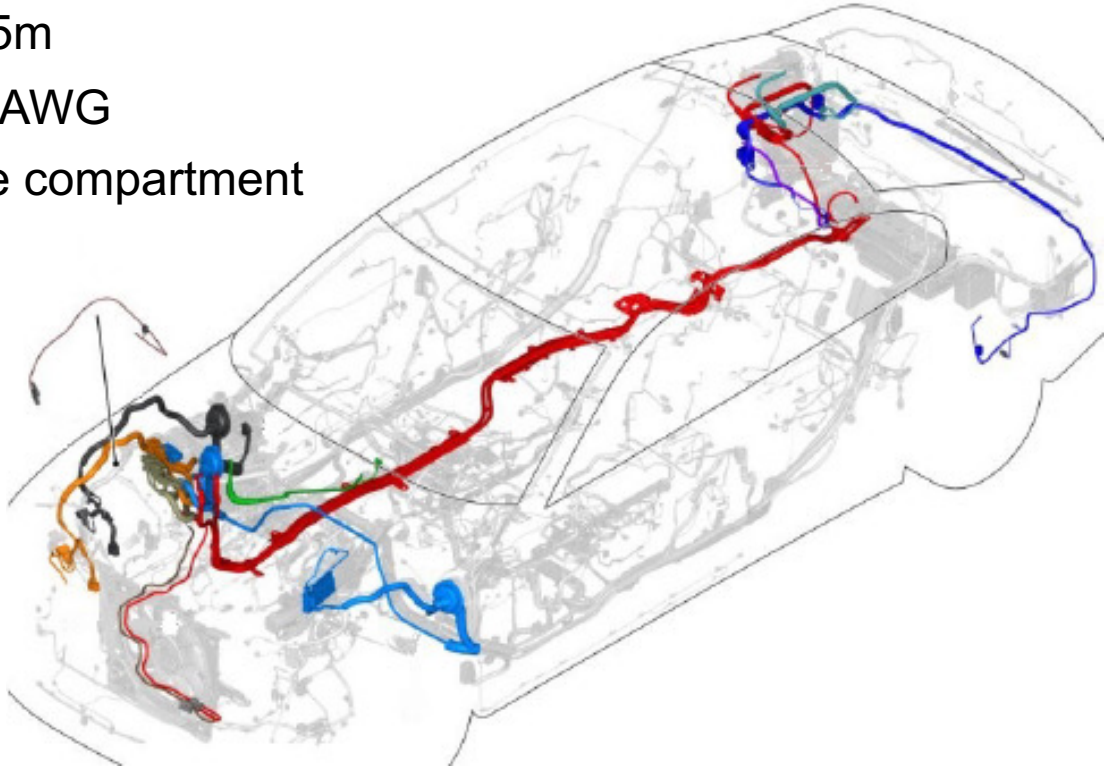
—Ford CEO Jim Farley



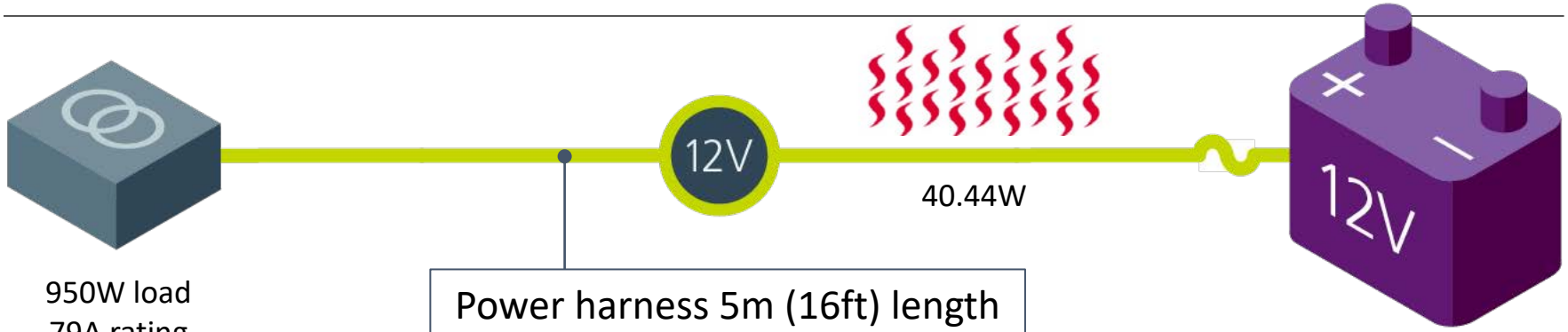
BMW 7 series G12 – complexity of wiring routing

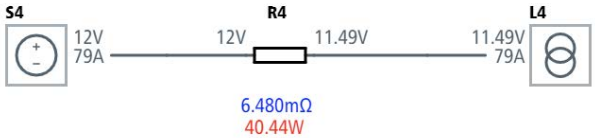
- 12V power harness length: 5m
- 12V power net : 27mm^2 or 4AWG
- Several 1kW loads in engine compartment
  - 12V @ 80A





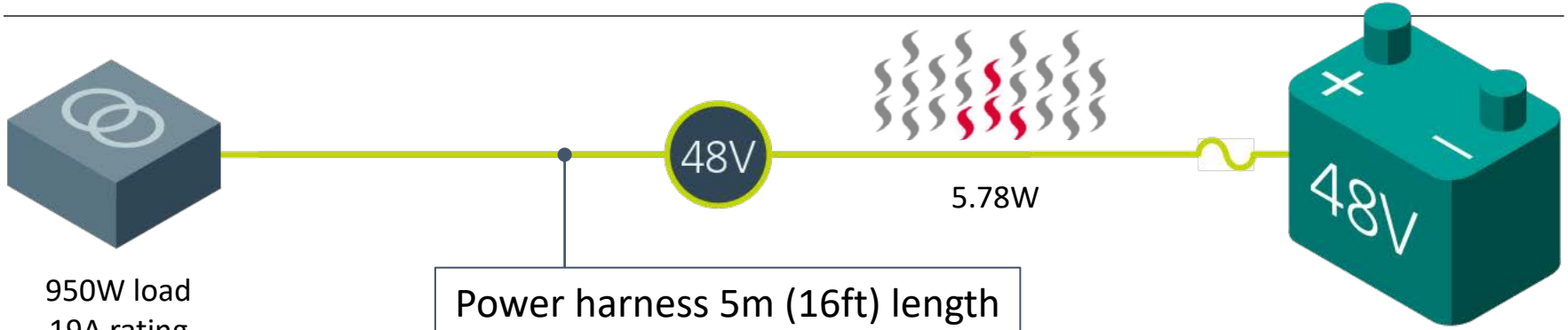
Power delivery on typical 12V architecture

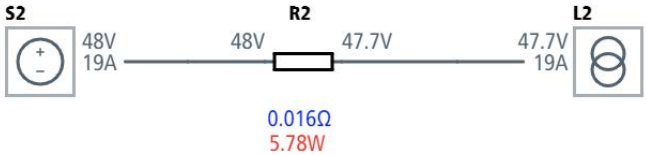




Benefits:	Drawbacks:
• Known power architecture • Easy implementation	• Weight • Routing complexity, high current connection and fuse • Wire commodity cost uncertain • Wire harness system power loss

Power delivery with 48V architecture: 85% weight reduction!





Power losses in wiring harnesses are proportional to the square of currents => 1/16

$$P = RI^2$$

Benefits:	**Drawbacks:**
• 85% weight wire harness weight over 12V system • Easier wire harness routing	• New vehicle power delivery architecture • Li-Ion Battery complexity and cost • Need DC/DC converter 48V to 12V for the 12V loads

48V power wiring harness system design advantage

Power Dissipation and Weight:

Example: all wires ≥30A @ 12V show a potential of reducing:

- Power dissipation by 5W to 10W
- Weight by approximately 2,5 kg

Assumptions:

- 20 of 130 power supply lines ≥30A
- with cross sections from 2,5mm^2 to 25mm^2

Wiring Materials – Copper vs. Aluminum.

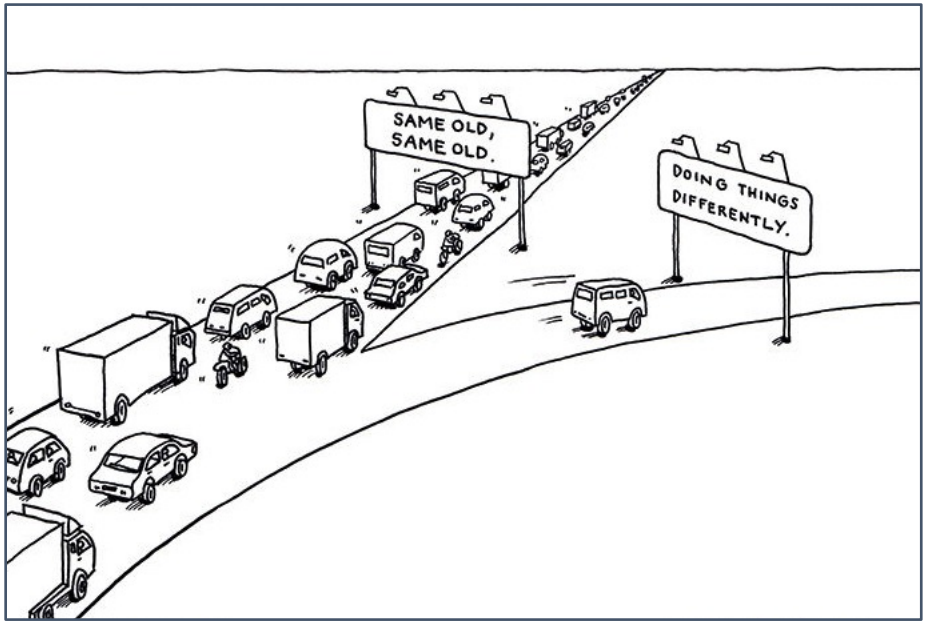
	600 W @ 12 V		600W @ 48 V	
Load Current	50 A	50 A	12,5 A	12,5 A
Material of Wires	copper	aluminum	copper	aluminum
Cross Section	10 mm^2	17 mm^2	1,5 mm^2	2,5 mm^2
Weight/Length	108 g/m	74 g/m	17 g/m	11 g/m
Power Loss/Length	4,5 W/m	3,8 W/m	1,8 W/m	1,6 W/m

The transition from 12V to 48V allows for the continuing use of copper wiring

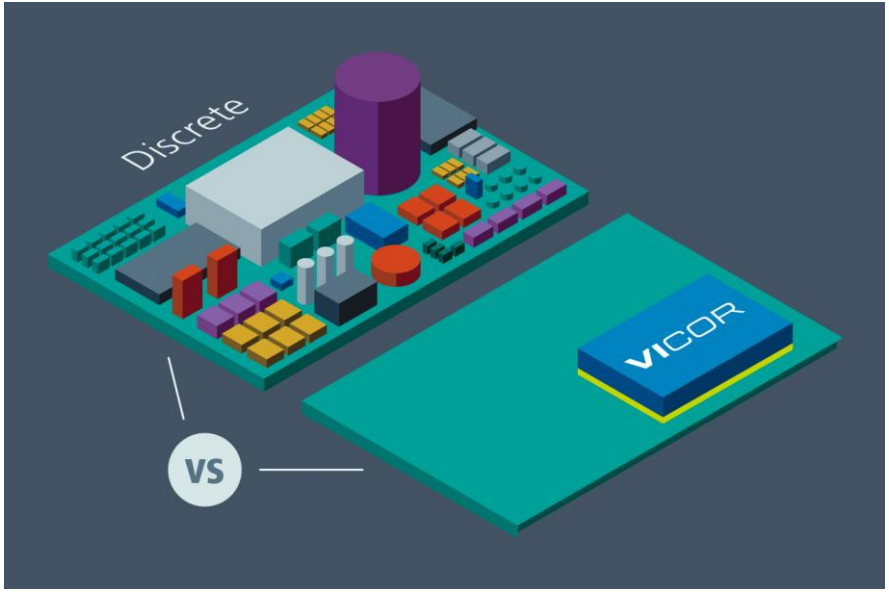
Further optimization: aluminum wiring with equivalent weight reduce power dissipation by 50%.

Doing things differently with the right technology?

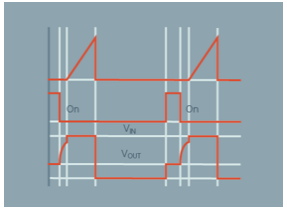
The right technology is needed to enable an increase of the overall system efficiency with optimized Power Delivery Network while beneficiating wire harness weight reduction.

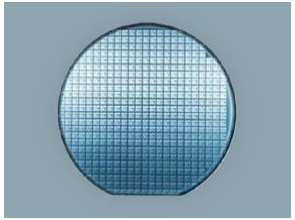


Enabling technology to bridge the voltages



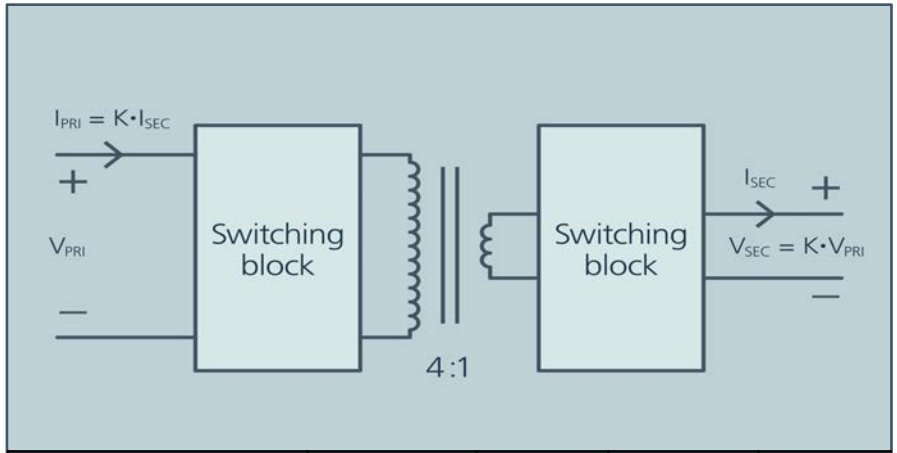
SAC (Sine Amplitude Converter) topology and innovative controller designs and systems





Sine amplitude converter – what is it?

- 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



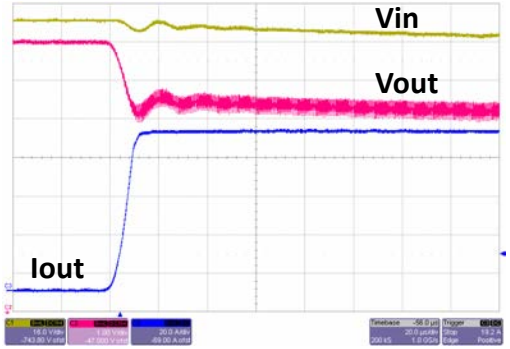
K factor	1/16	1/4	1/1	4/1
V_{PRI}	800	48	48	12
V_{SEC}	48	12	48	48
I_{PRI}	1	1	1	4
I_{SEC}	16	4	1	1

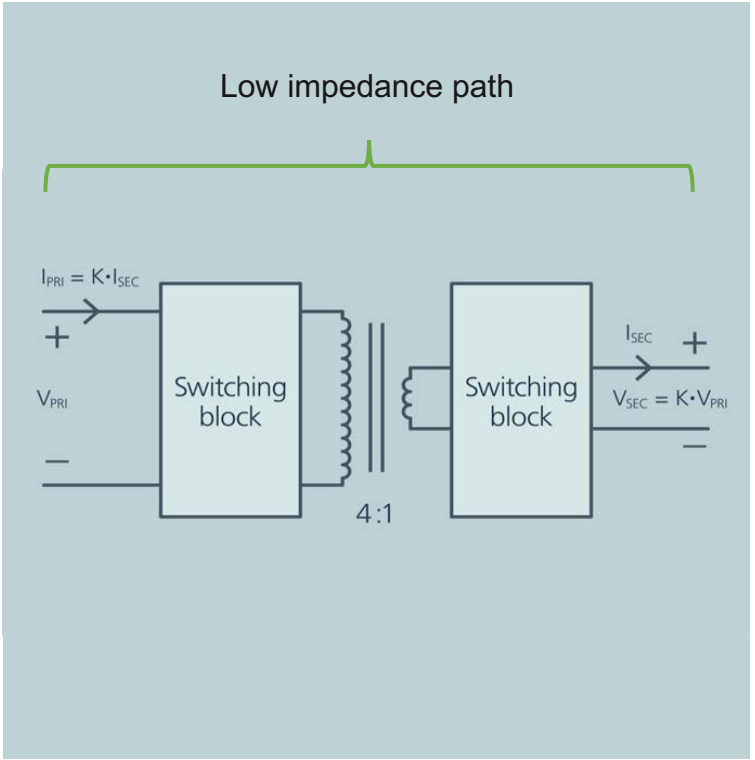
Fixed ratio converter - fast transient response

- 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 ROUT from DC to over a MHz

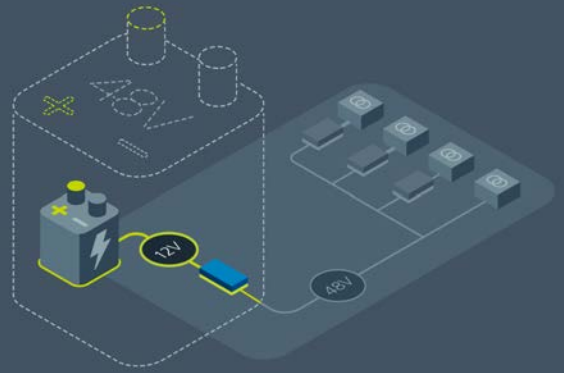
di/dt up to 10MA/s

Load step from 0A – 80A
Timebase – 20µs/div

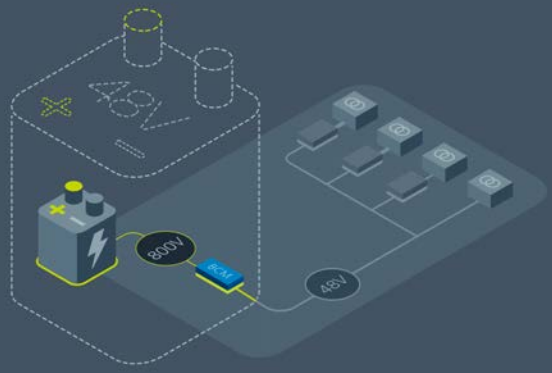




Fast transient response, low impedance and bidirectional operation enables Battery Virtualization



Virtualize a 48V battery to enable 48V load compatibility on a 12V vehicle architecture



Virtualize a 48V Battery to enable 48V loads in a BEV with isolated SAC

Scalability of the vehicle Power Delivery Network across the range ICE/BEV

Product solution : NBM2317 and NBM3523



- Input/output range: 38V - 60V_{DC} / 9.5V – 15V_{DC}
- Output current (step down): 80A – 1kW
- Fixed ratio (k=1/4)
- Peak efficiency: 98.3%
- Full power bidirectional

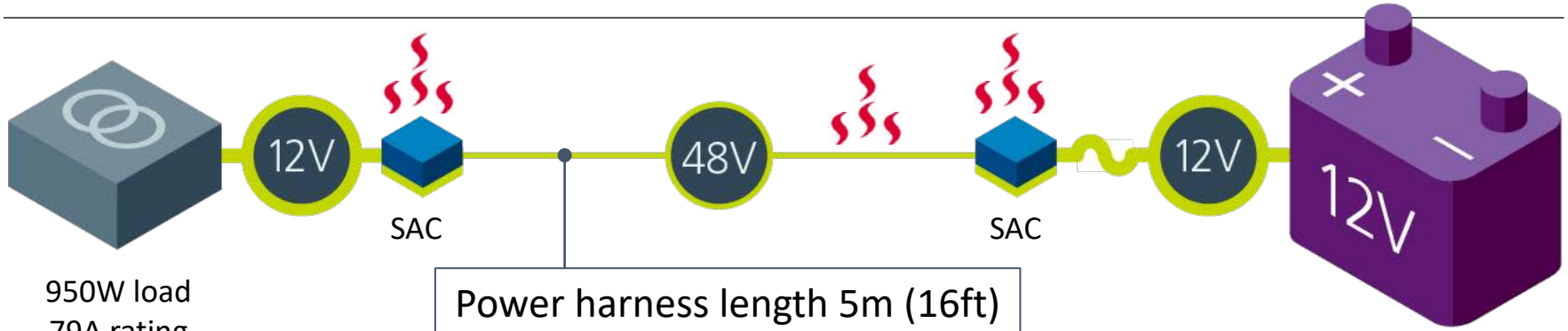
23mm x 17mm
Weigh: 8.7g

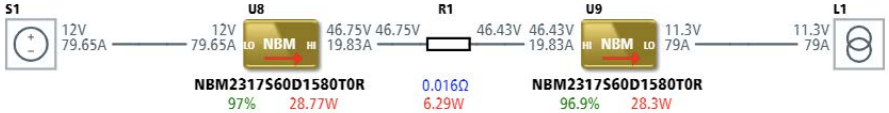


- Input/output range: 38V - 60V_{DC} / 9.5V - 15V_{DC}
- Output Current (step down) : 160A – 2kW
- Fixed ratio (k=1/4)
- Peak efficiency: 97.9%
- Full power bidirectional

35mm x 23mm
Weight: 17g

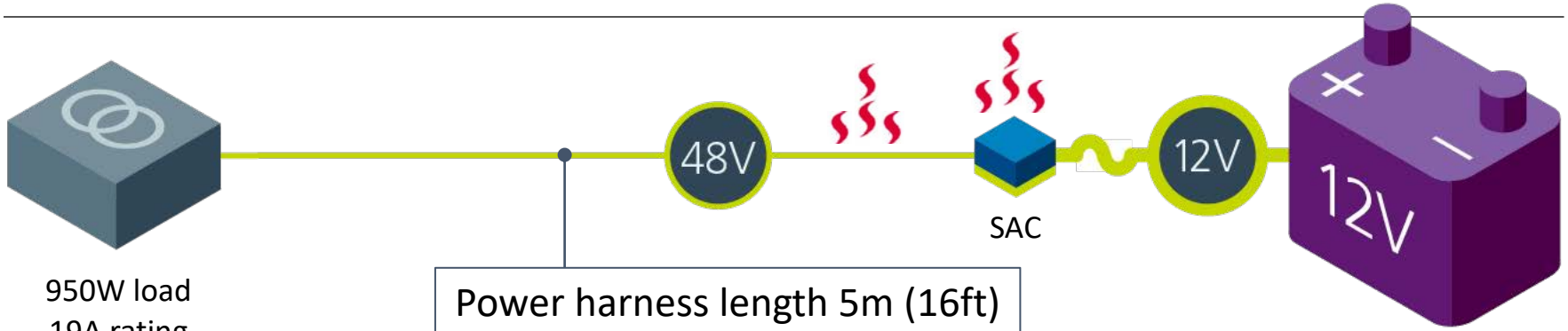
SAC technology with 12V architecture: 85% weight reduction

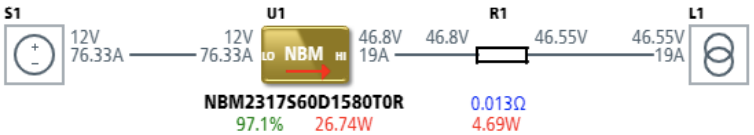




Benefits:	Drawbacks:
• Minimum architecture change • Wire harness routing • 85% wire weight reduction compared to 12V	• Not taking full advantage of higher bus voltage at the load • Additional hardware • Low efficiency

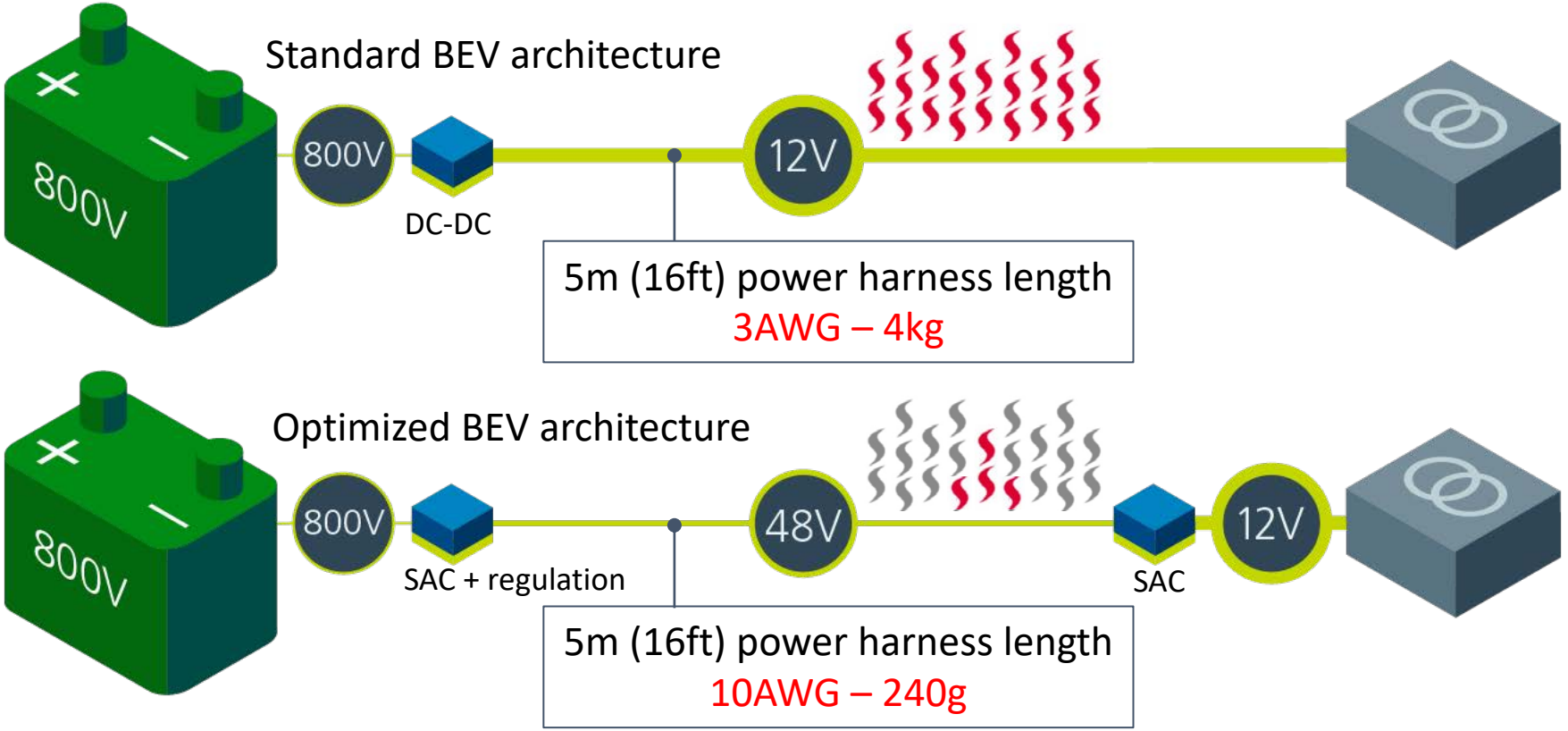
SAC enabling 48V battery virtualization: 85% weight reduction and efficiency





Benefits:	Drawbacks:
• PDN optimization • Overall system weight reduction • Scalability • System power loss minimized	• 48V load • Cost

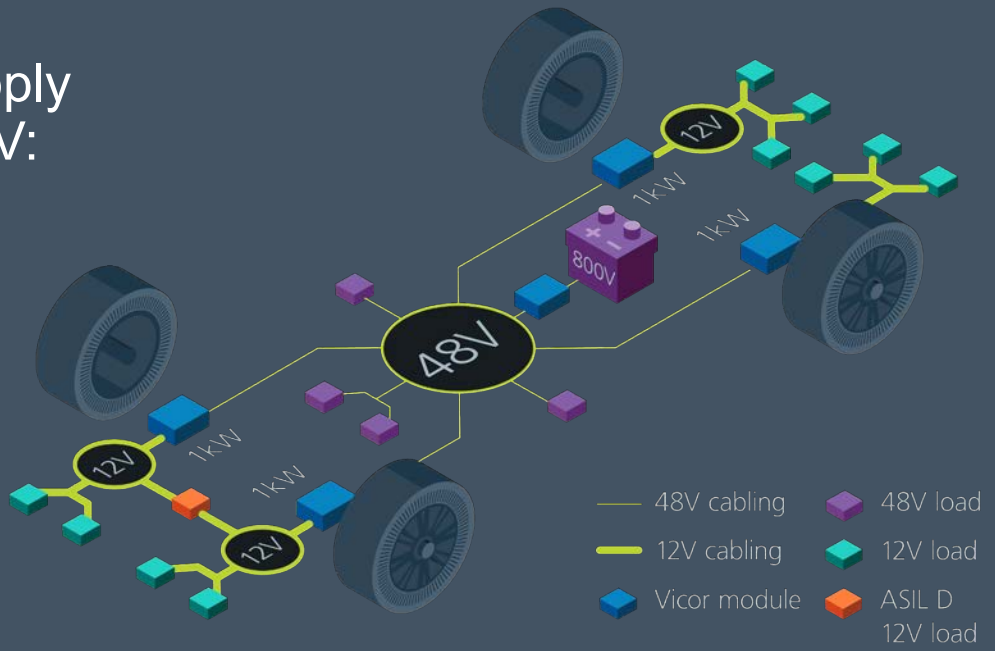
Enabling up to 85% wire harness weight reduction on a BEV architecture



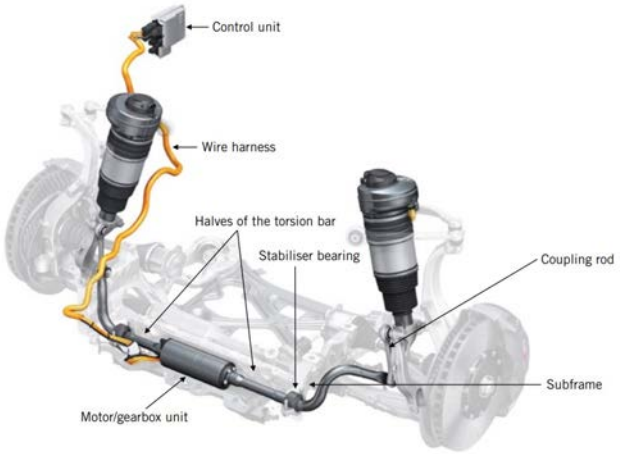
Enabling weight reduction on a BEV architecture… further

Consolidation of power supply systems in a distributed 48V:

- 12V wiring harness reduced to a minimum
- Leverage 48V and HV for high power loads and power distribution
- Fewer LV battery storage (12V / 48V)



Additional application possibilities



Enable 48V load compatibility on a 12V vehicle power architecture

(ICE for instance with 48V active suspension)



Commercial vehicle applications

(15 – 20 meters wire harness)

Conclusion – what can Vicor technology enable

- Increase the bus voltage to 48V enables up to 85% weight reduction on the power distribution wiring harness.
- Better thermal management and wiring harness routing.
- Reduction of system complexity and overall cost.
- Increase electrical efficiency from source to load.

Electrical efficiency of E/E systems to reduce CO^2 emissions or to increase electric range

100W electrical power
~ approximately 1g/km CO_2 (ICE) or 10km range (BEV)

Nicolas Richard - author

Thank you



Nicolas Richard – Vicor Corporation

Nicolas Richard is Vicor's Director for Automotive Sales and Field Application Engineering in Europe. Nicolas has 19 years of automotive experience in Infotainment, ADAS, Power electronics systems (DC/DC, Inverter, BMS) and semiconductors . He held position in Engineering, Program management, Field Application Engineering and Sales at Tiers 1 and Tiers 2 automotive companies, including Siemens VDO, Continental, Fairchild, ON Semi, IDT and Renesas. Nicolas earned his MSc in Electrical Engineering from ESIEE in France.

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References

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