# Reducing range anxiety by reducing harness weight using power modules

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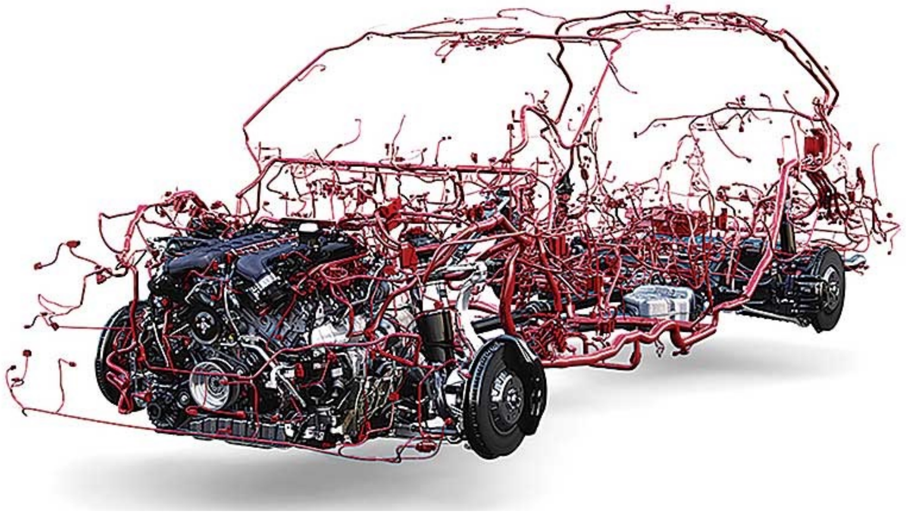
# The challenge: Wire harness weight and inefficiency underestimated

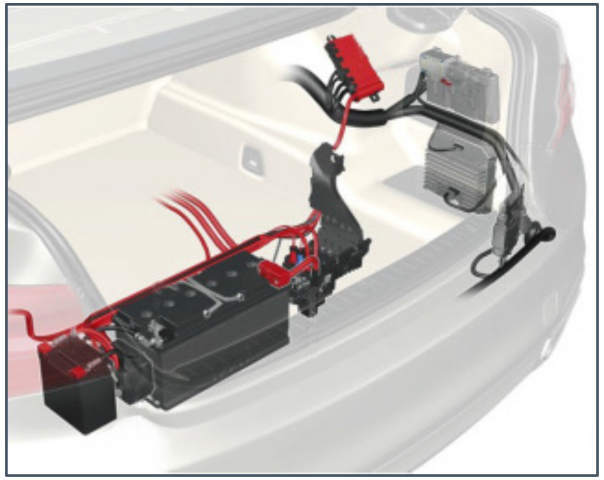
- The wire harness is one of the three heaviest subsystems in today's vehicles
- 2,000 copper wires totaling 1 mile in length
- 150lbs in highly contented vehicles

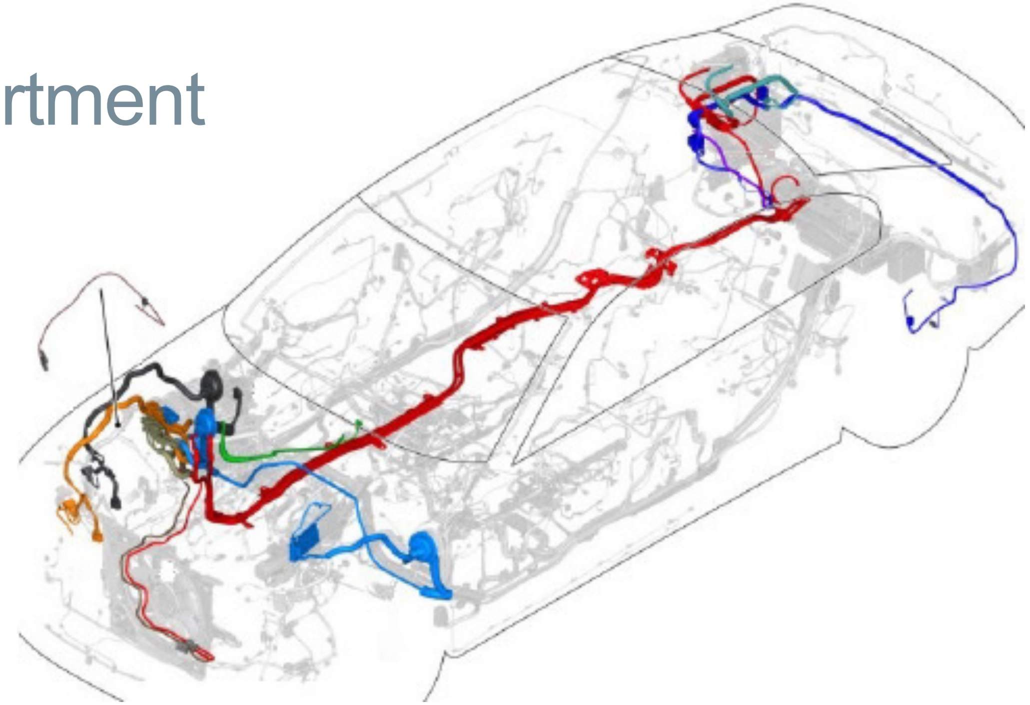
> "We didn't know that our wiring harness for Mach-E was 1.6 kilometer longer than it needed to be. We didn't know it's 70 pounds heavier and that that's [cost an extra] $300 a battery"
>
> — *Ford CEO Jim Farley*



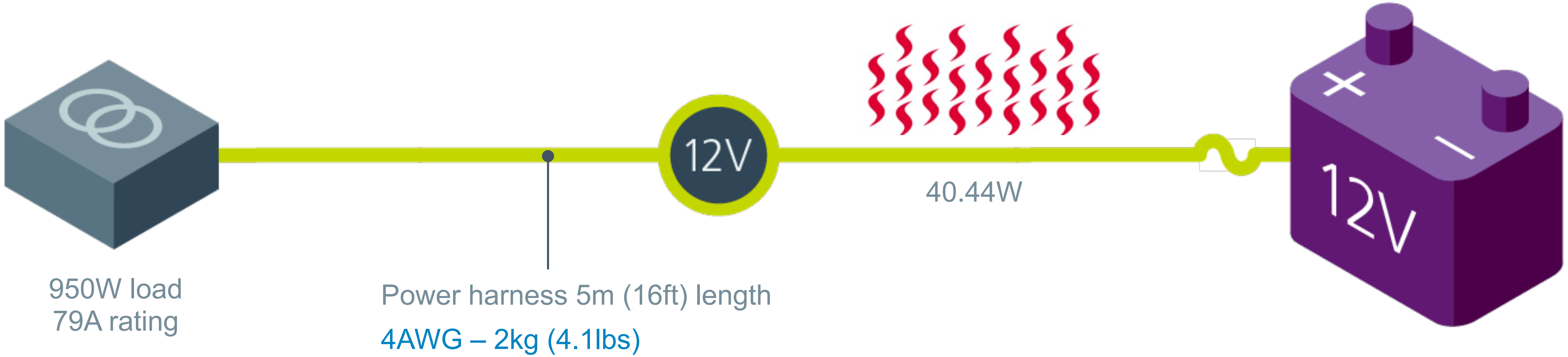
# BMW 7 series G12 – complexity of wiring routing

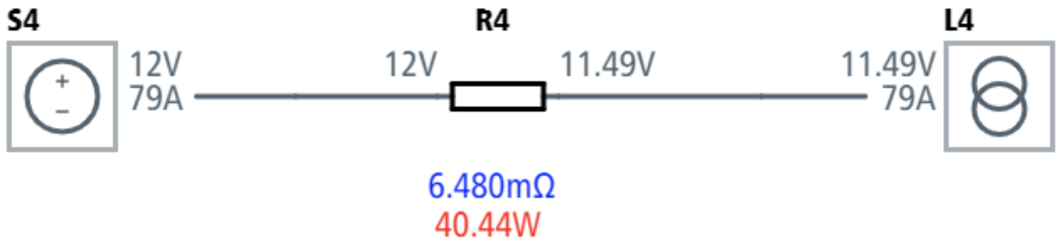
- 12V power harness length: 5m
- 12V power net : 27mm$^2$ or 4AWG
- Several 1kW loads in engine compartment
- 12V @ 80A





# Power delivery on typical 12V architecture




Benefits:
- Known power architecture
- Easy implementation

Drawbacks:
- Weight
- Routing complexity, high current connection and fuse
- Wire commodity cost uncertain
- Wire harness system power loss

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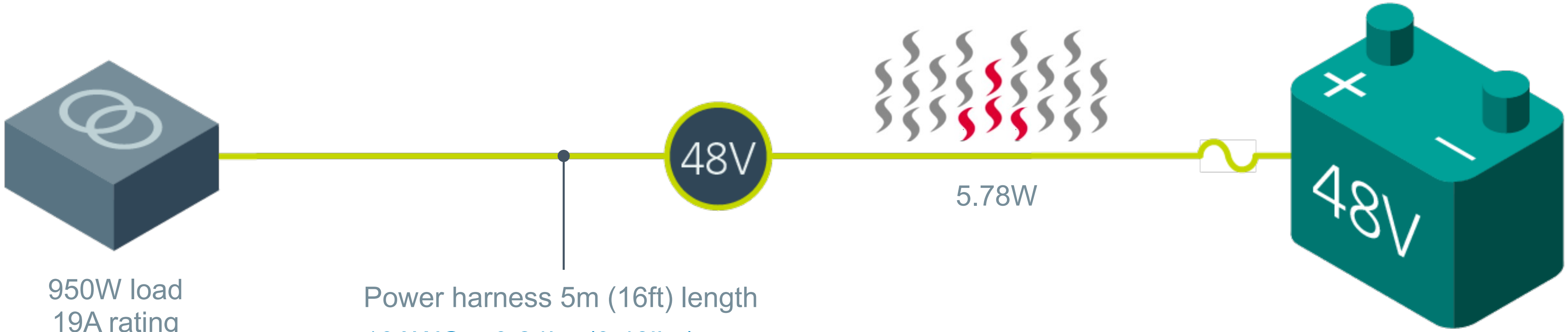
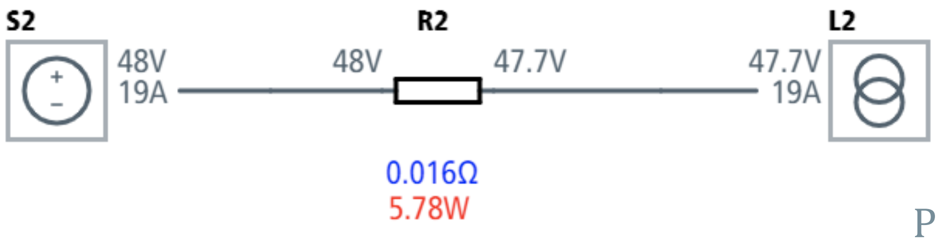
# Power delivery with 48V architecture:
# 85% weight reduction!




950W load
19A rating

Power harness 5m (16ft) length
10AWG – 0.24kg (0.48lbs)




$$\mathrm{P} = RI^2$$

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

Benefits:
- 85% weight wire harness weight over 12V system
- Easier wire harness routing

Drawbacks:
- 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$^2$

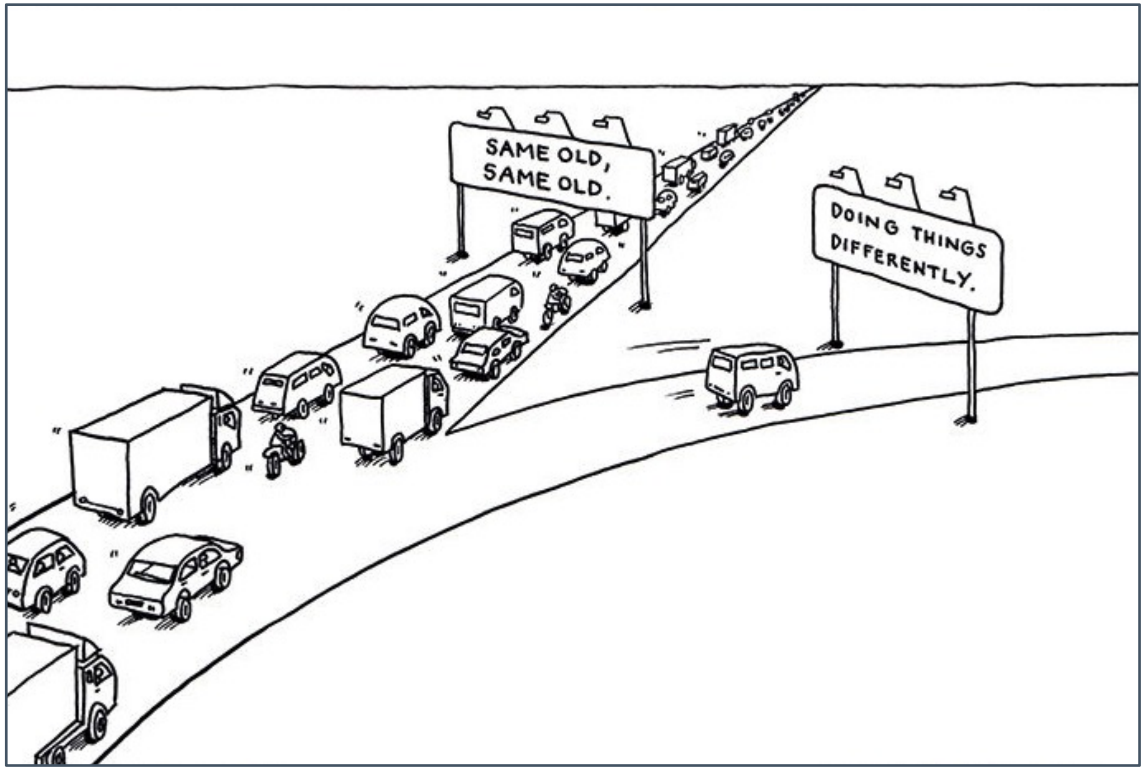
## Wiring materials – copper vs. aluminum

| | 600W @ 12V | | 600W @ 48V | |
|---|---|---|---|---|
| Load current | 50A | 50A | 12,5A | 12,5A |
| Material of wires | copper | aluminum | copper | aluminum |
| Cross section | 10mm$^2$ | 17mm$^2$ | 1,5mm$^2$ | 2,5mm$^2$ |
| Weight/length | 108g/m | 74/gm | 17g/m | 11g/m |
| Power loss/length | 4,5W/m | 3,8W/m | 1,8W/m | 1,6W/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%

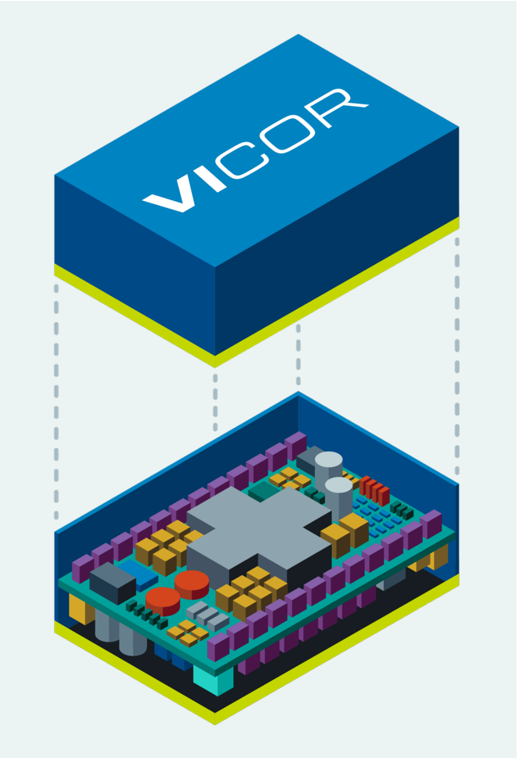
# Doing things differently with the right technology?

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.



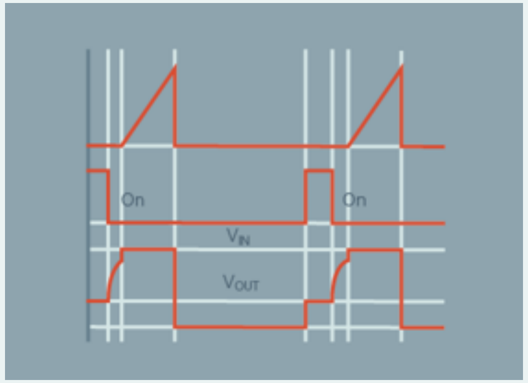
# Enabling technology to bridge the voltages

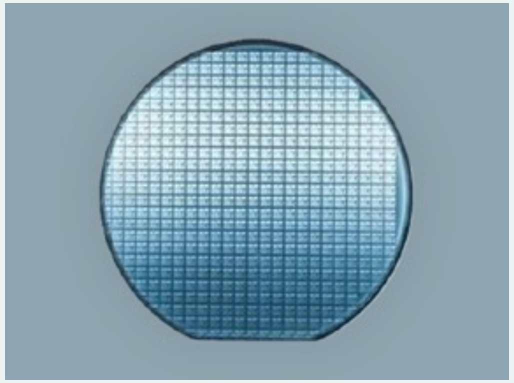
## Highly integrated DC-DC converters




- 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

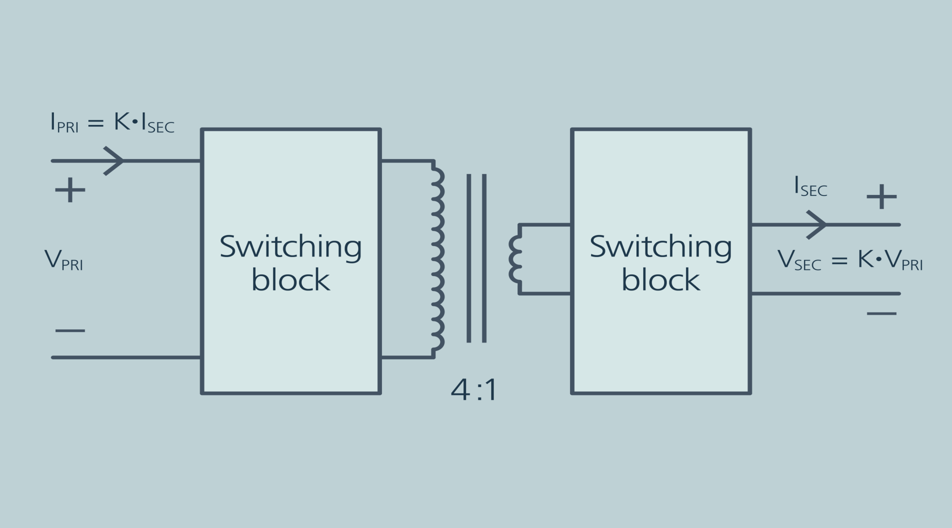
## SAC (Sine Amplitude Converter) topology and innovative controller designs and systems



# Sine amplitude converter – what is it?

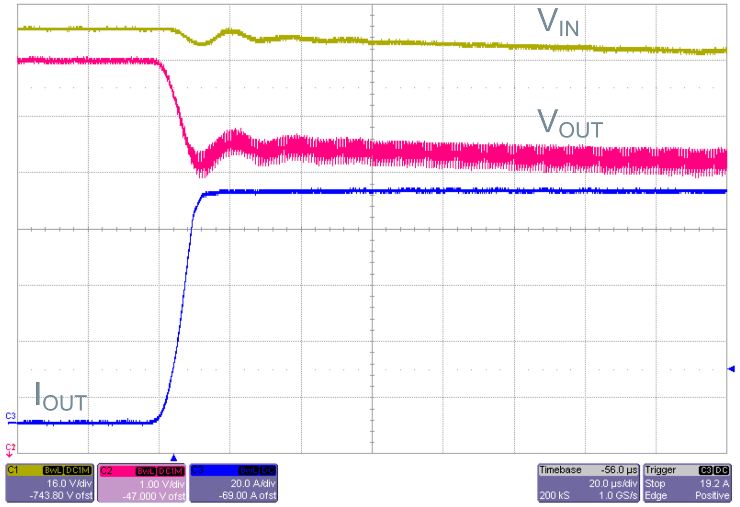
- Sine Amplitude Converter topology:
  - Zero-voltage switching
  - Zero-current switching
- Fixed-ratio conversion:
  - Divide/multiply the voltage/current
- Extremely fast transient current capability
- Ideal transformer behavior
- No inductor usage
- Not dependent on internal energy storage




| 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

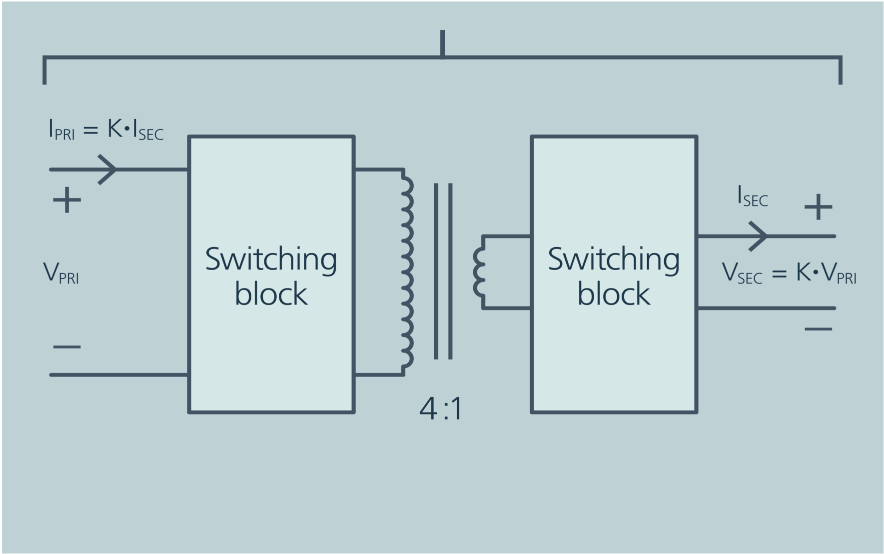
- High frequency switching
- Smaller magnetic components
- Smaller path lengths for turns
- Package has very low parasitic inductance on input/output connections
- Response is flat as a function of $R_{OUT}$ from DC to over a MHz



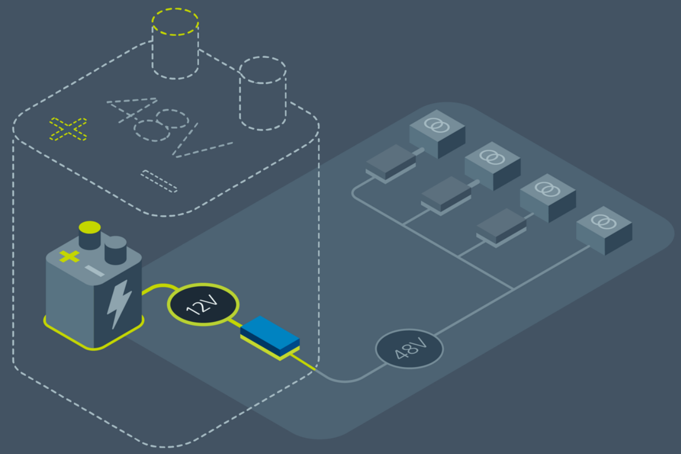

di/dt up to 10MA/s

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

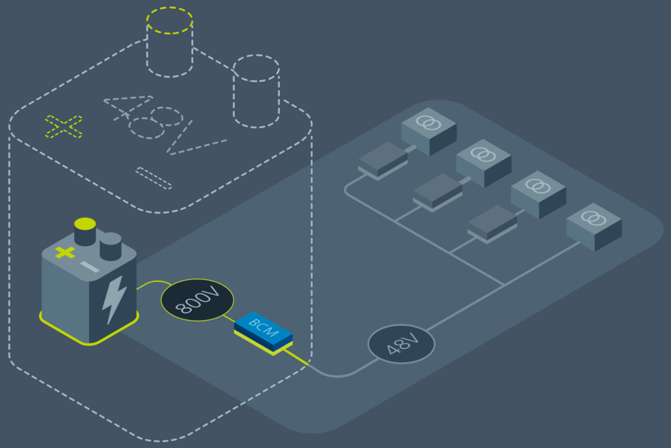
## Low impedance path



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



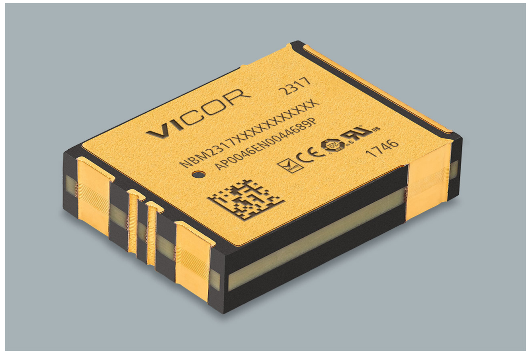

Virtualize a 48V battery to enable 48V load compatibility on a 12V vehicle architecture




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

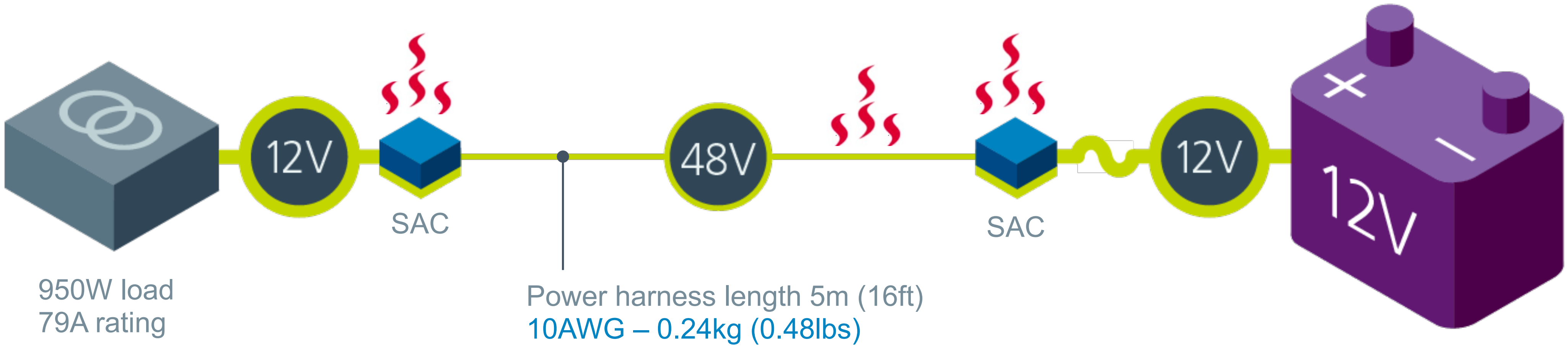
# Product solution: NBM2317 and NBM3523

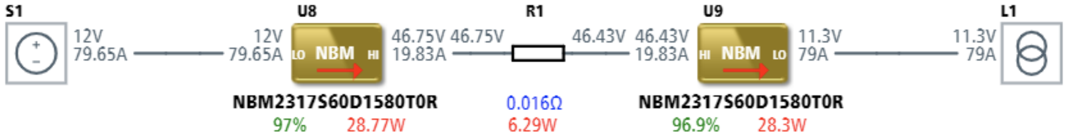



- Input/output range: 38V - 60$V_{DC}$ / 9.5V - 15$V_{DC}$
- Output Current (step down): 160A – 2kW
- Fixed ratio (k = 1/4)
- Peak efficiency: 97.9%
- Full power bidirectional


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

# SAC technology with 12V architecture:
# 85% weight reduction

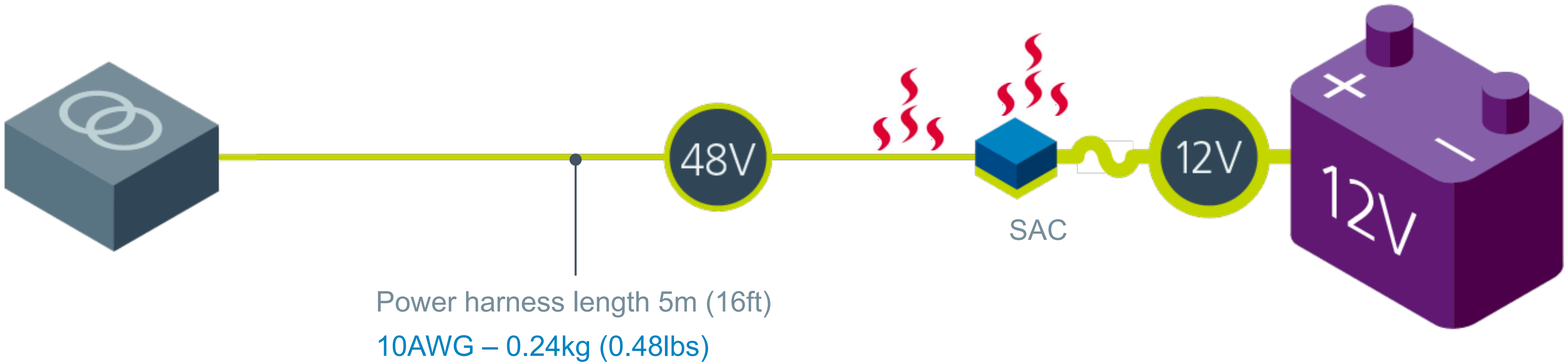


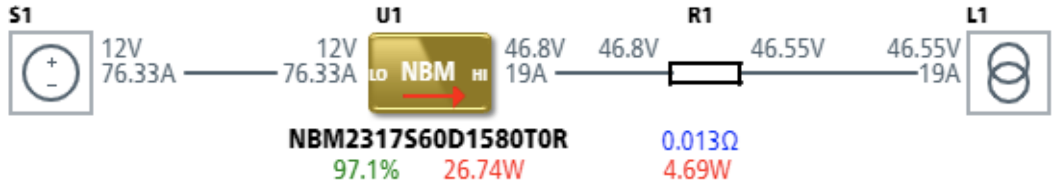




Benefits:
- Minimum architecture change
- Wire harness routing
- 85% wire weight reduction compared to 12V

Drawbacks:
- 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:
- PDN optimization
- Overall system weight reduction
- Scalability
- System power loss minimized

Drawbacks:
- 48V load
- Cost

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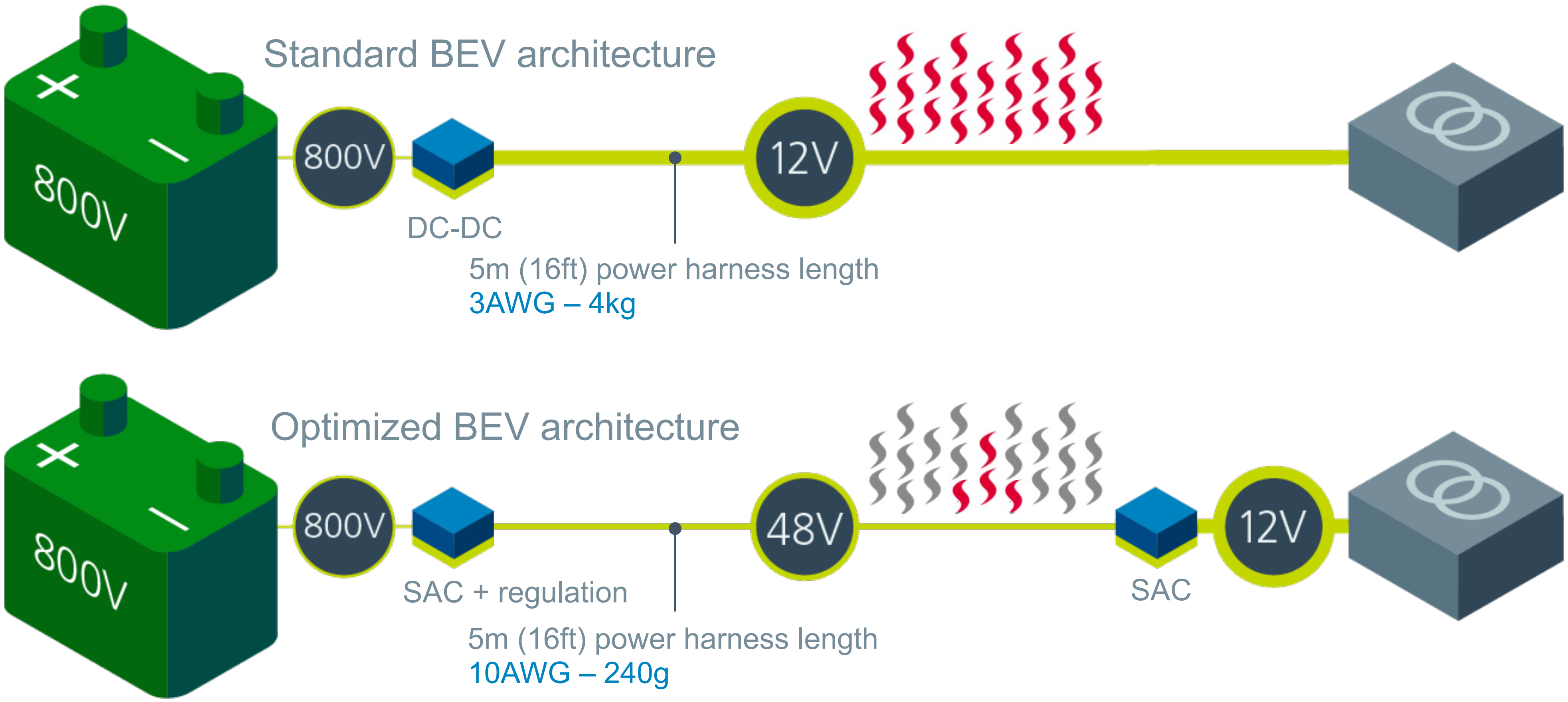
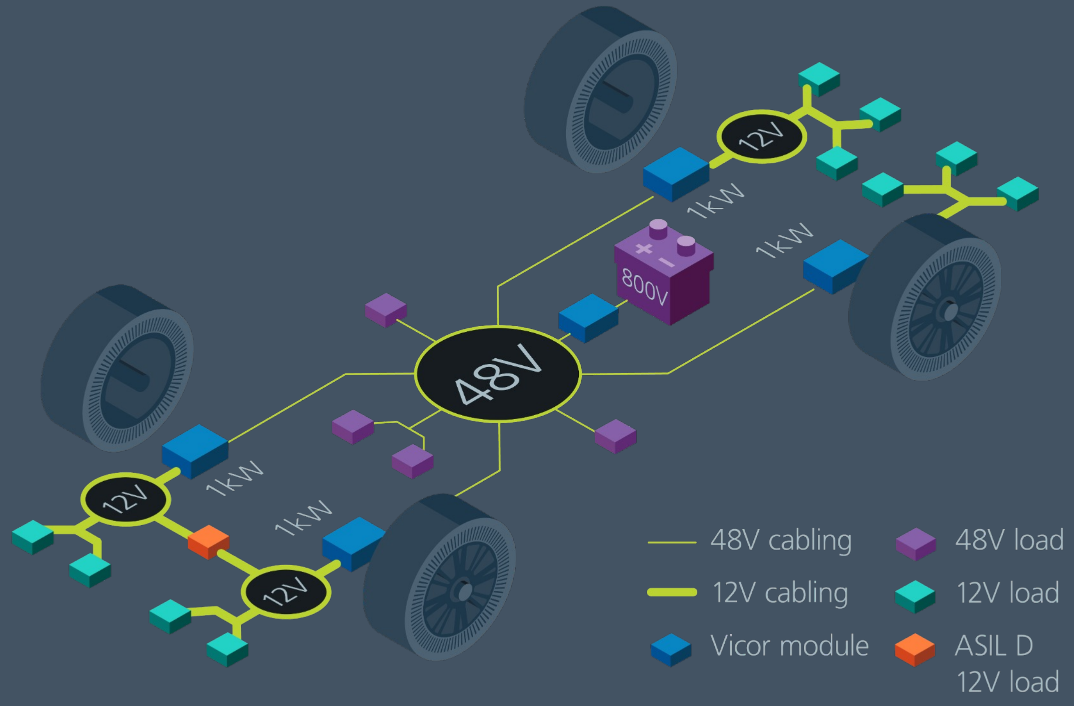
# Enabling up to 85% wire harness weight reduction on a BEV architecture



# 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)

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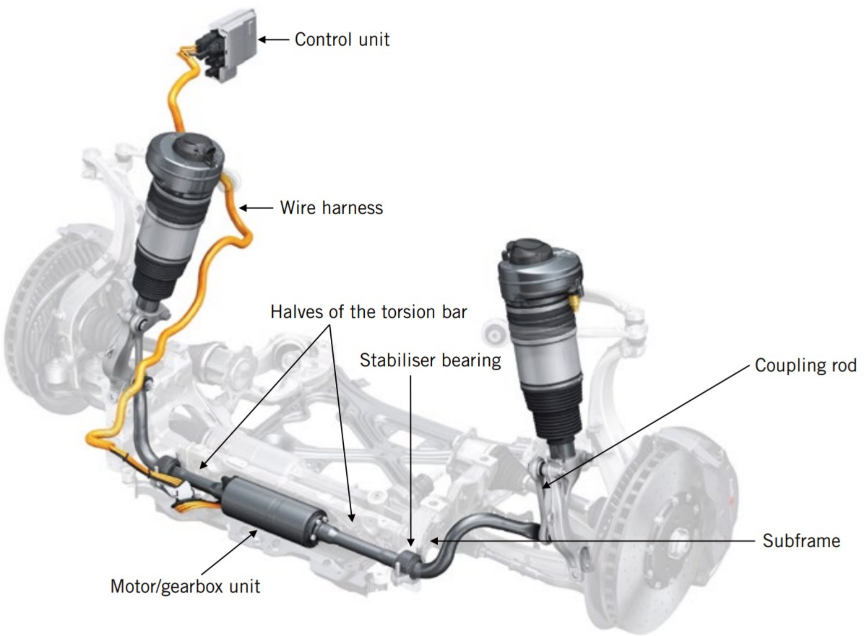
# Additional application possibilities




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)

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# 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)

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YK is the Automotive Sr. Field Application Engineer, helping power engineers architect new automotive power delivery systems. He has a MSc in Power Electronics from Konkuk University.

Scan and download the presentation

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# Thank you

## References:

BMW AG – Ottmar Sirch: *Future vehicle Power supply with 48V Nov 2019*

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