

Attracting Tomorrow



IEEE PSMA Capacitor Committee Workshop 2020

Innovative film capacitor technologies for wide band-gap semiconductors

Advanced design features for high-frequency applications

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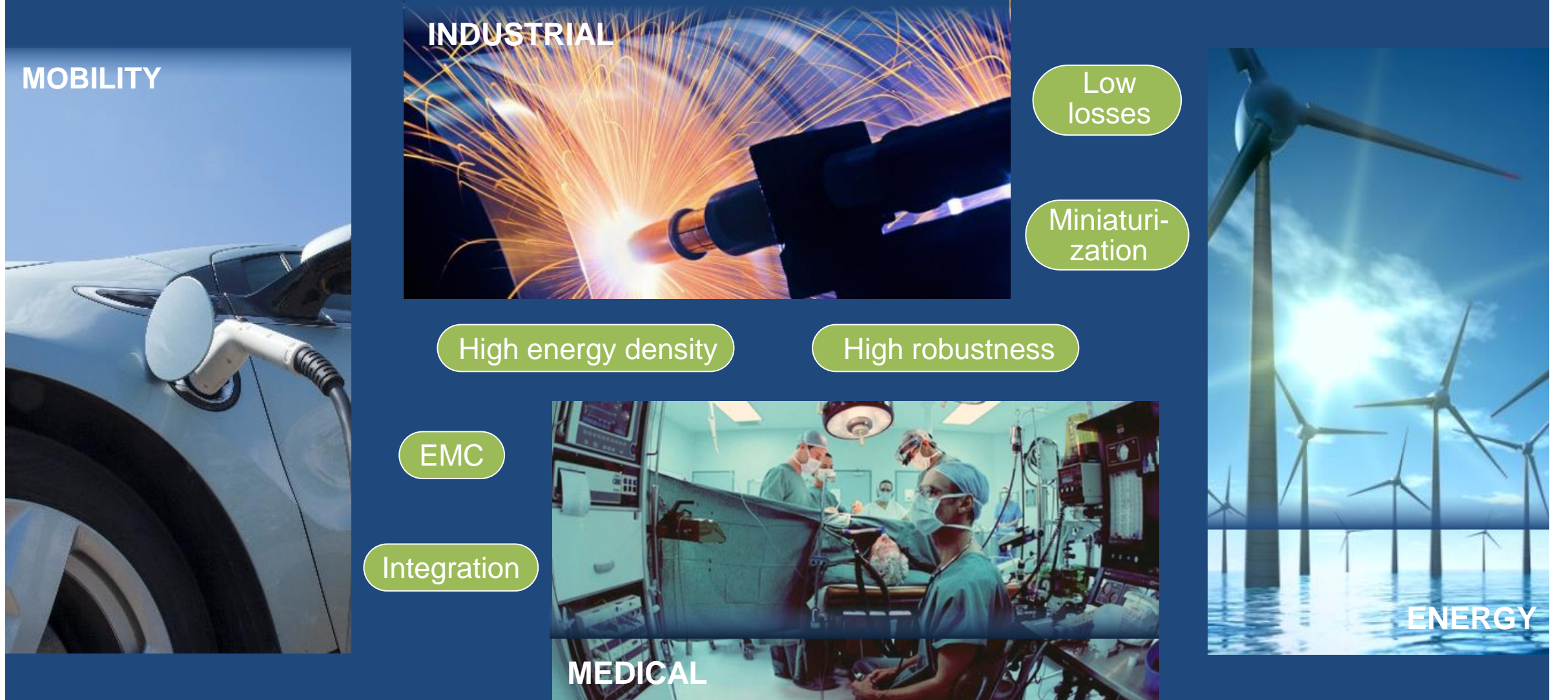
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Growing demands challenging power electronics



MOBILITY

INDUSTRIAL

MEDICAL

ENERGY

Low losses

Miniaturization

High energy density

High robustness

EMC

Integration

Advanced semiconductors put high demands on the DC link



Challenge for passive components: Not be the bottleneck in new power electronics designs

Design goals for high-frequency capacitors

High operating temperature

- High temperature dielectric
- Handle heat coming from the semiconductor busbar
- High current capability

Low ESR vs frequency

- Minimized losses
- Wider operation bandwidth up to the MHz range
- Good performance close and above the resonance frequency

Low ESL of <10 nH

- Internal design for high dV/dt levels
- Make snubber capacitors unnecessary



New dielectric for high temperature is needed

Polypropylene (PP) is a commonly used standard dielectric in film capacitors.

PP is transformed into a **biaxially oriented PP (BOPP)** film in a sequential stretching process

Advantages of BOPP film

State-of-the-art dielectric



Excellent self-healing properties



Low losses



Low price



Disadvantages of BOPP film



Limited performance at high temperatures



$T_{max} = 105\text{ °C}$ for high crystalline BOPP



$T_{max} = 125\text{ °C}$ for some special BOPP grades – with derating

Classic high temperature alternatives to PP



Limited self-healing



Difficult to process



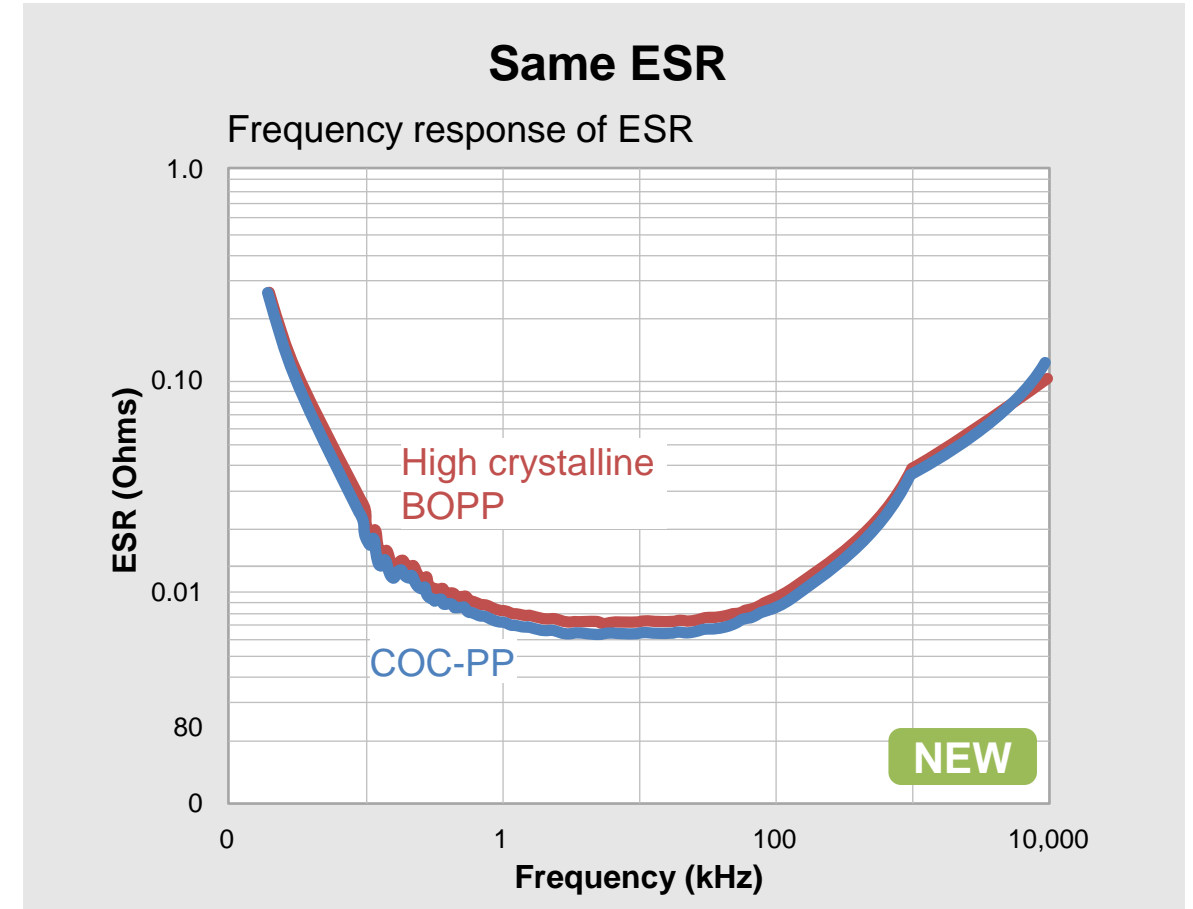
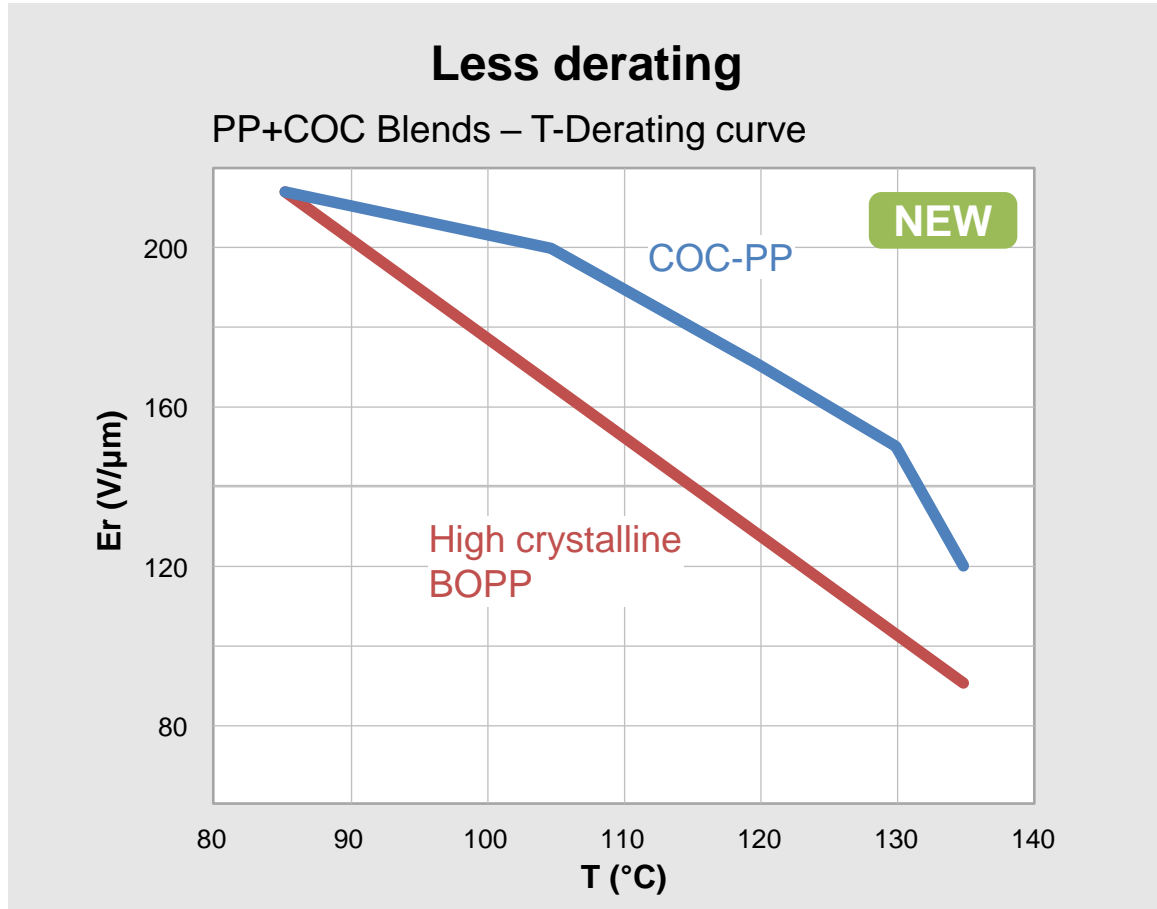
Expensive

Polypropylene is reaching its limits due to the rising demands of new wide band-gap semiconductors, especially in high-temperature applications

New material blend for high temperatures



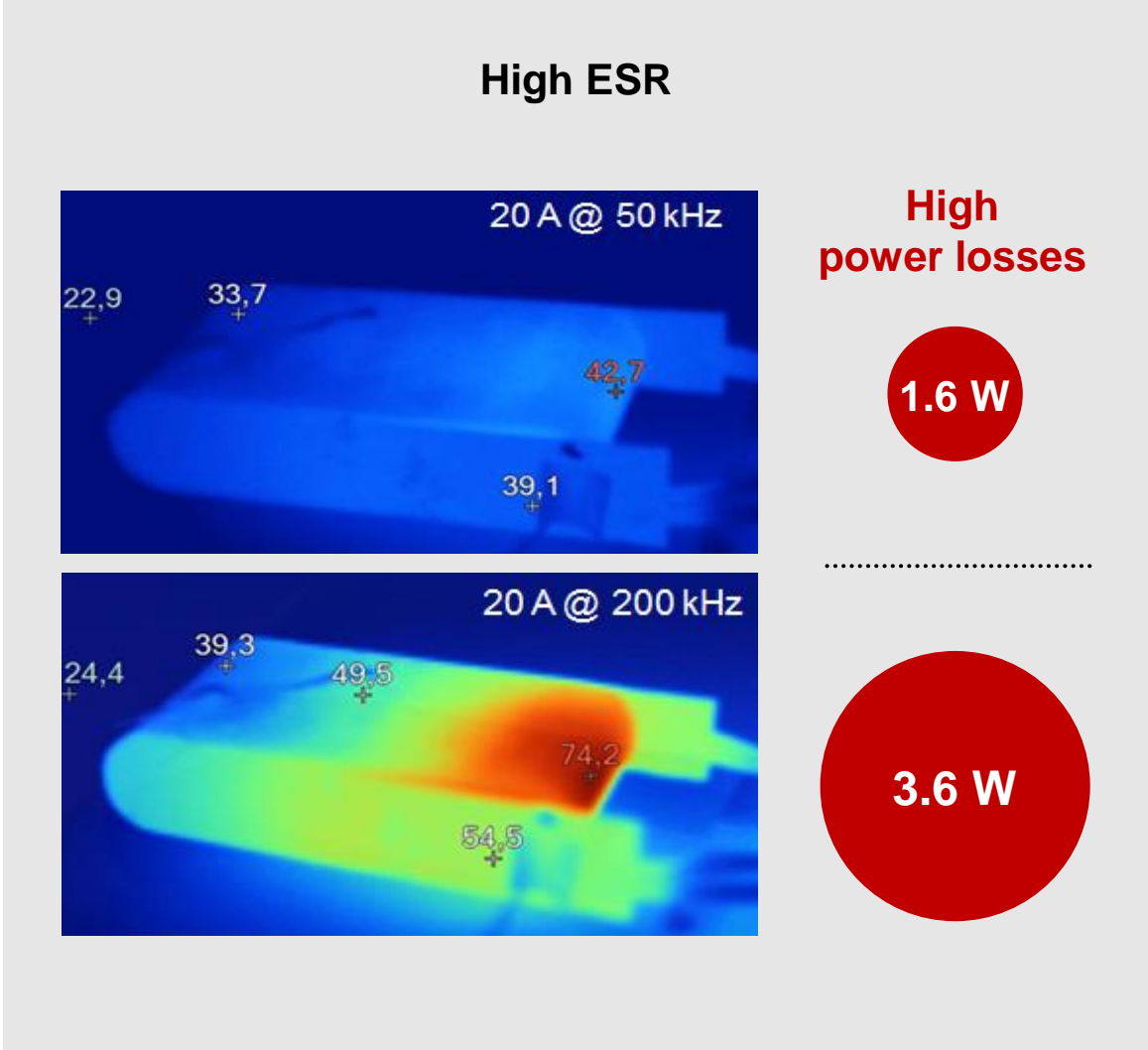
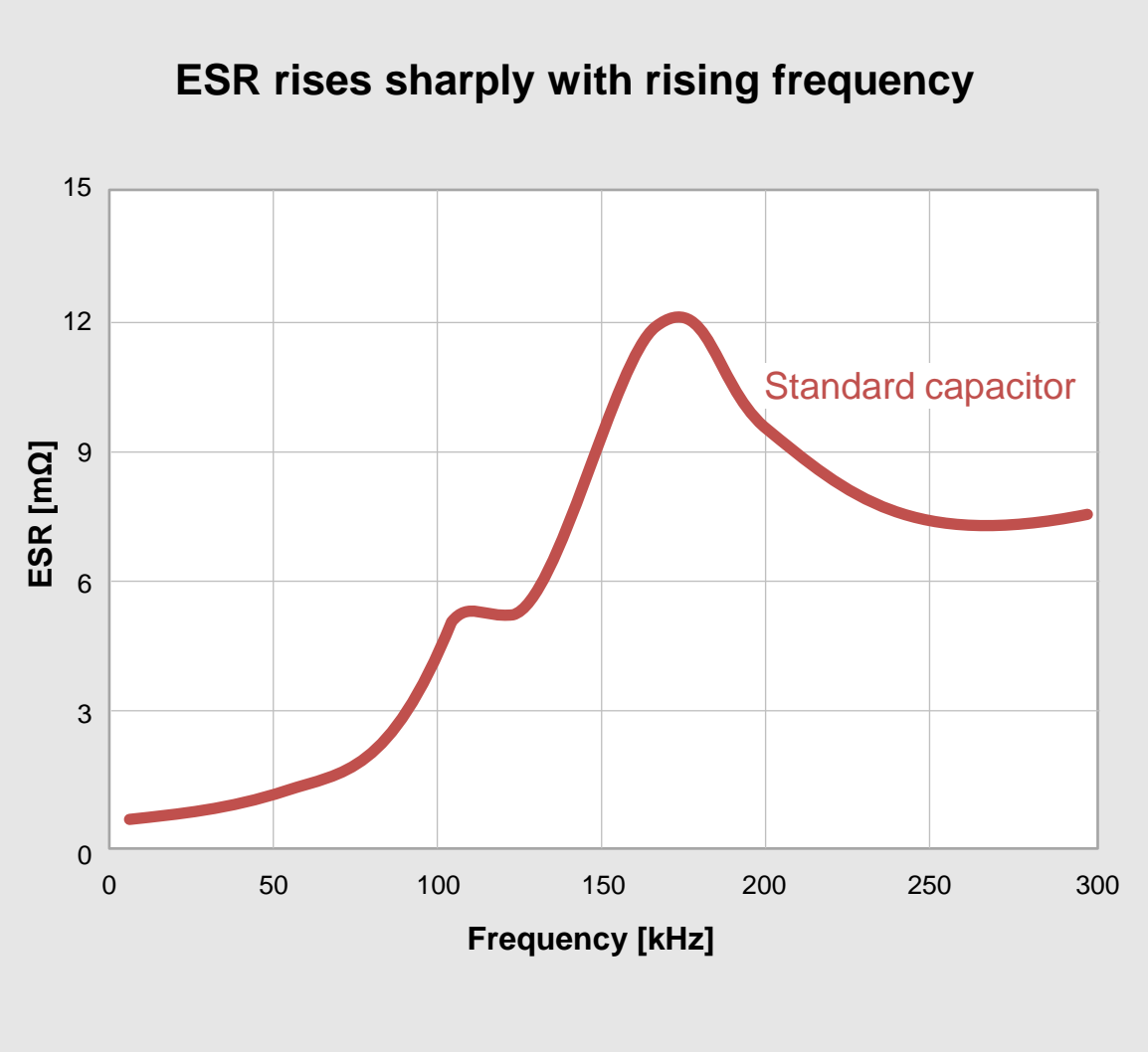
Improved performance at high temperatures



Best of both worlds

- Aging and failure mechanism similar to BOPP
- Similar self-healing properties
- Stable performance at up to 125 °C

Standard power capacitors have unfavorable ESR characteristics

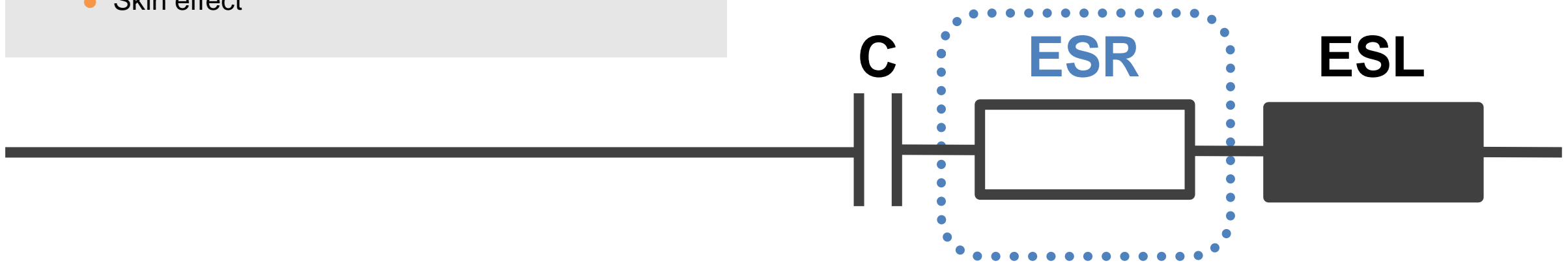


Root causes of increasing ESR

- Inhomogeneous impedance and internal resonances
- Negative electromagnetic interaction

Factors offering most potential for improvement!

- Winding geometry and metal profile
- Skin effect



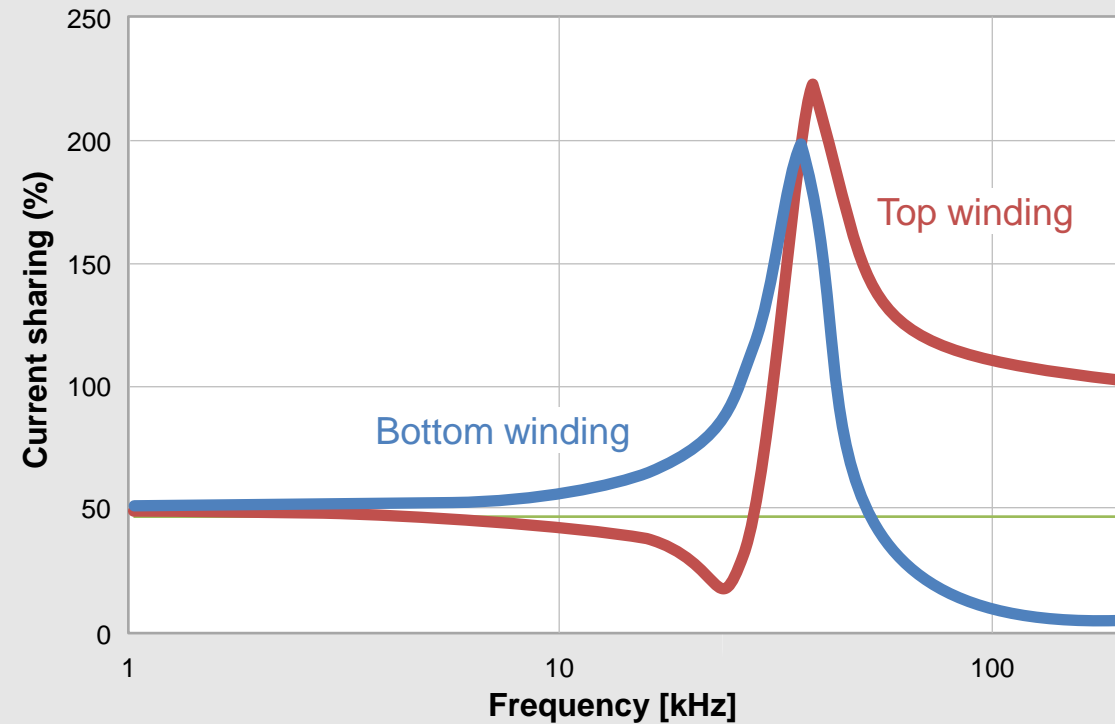
Power capacitors must be fundamentally redesigned in order to operate reliably at higher frequencies

Standard capacitors are limited at high frequencies

Standard power capacitor

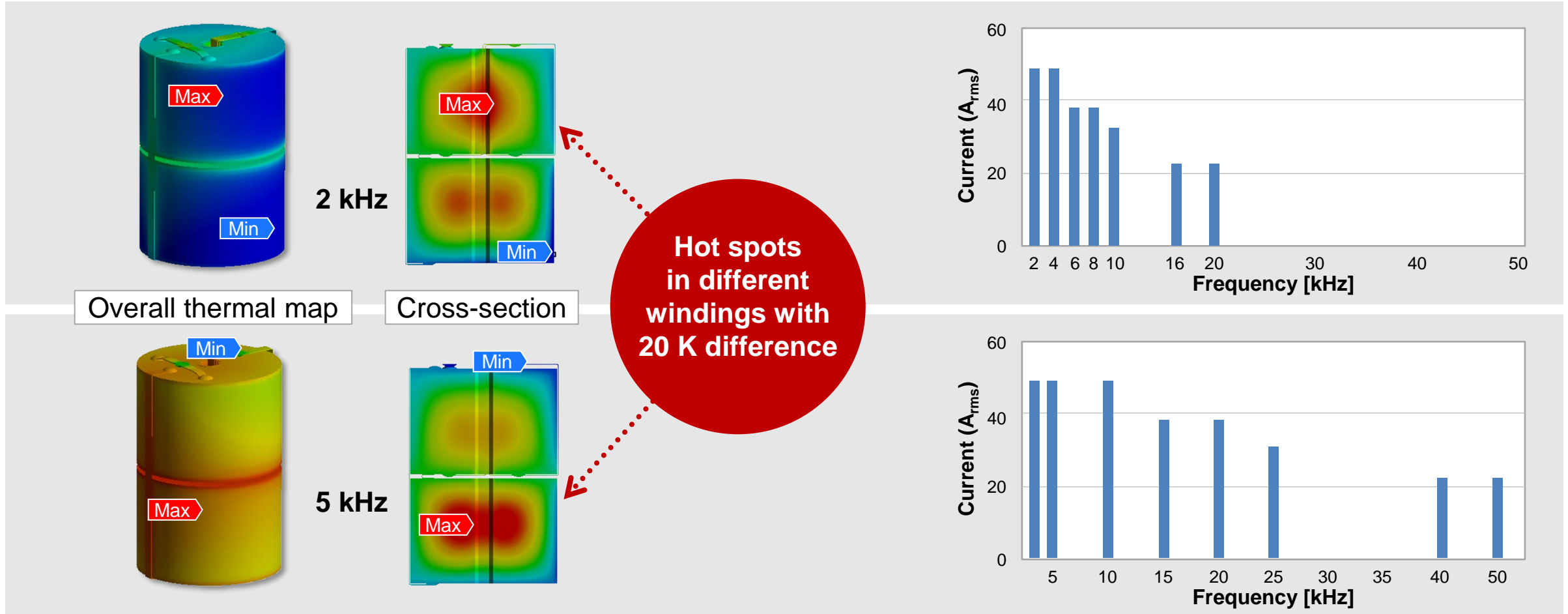


Effects of inhomogeneous impedance and internal resonances



Standard capacitors are not ready for high frequencies

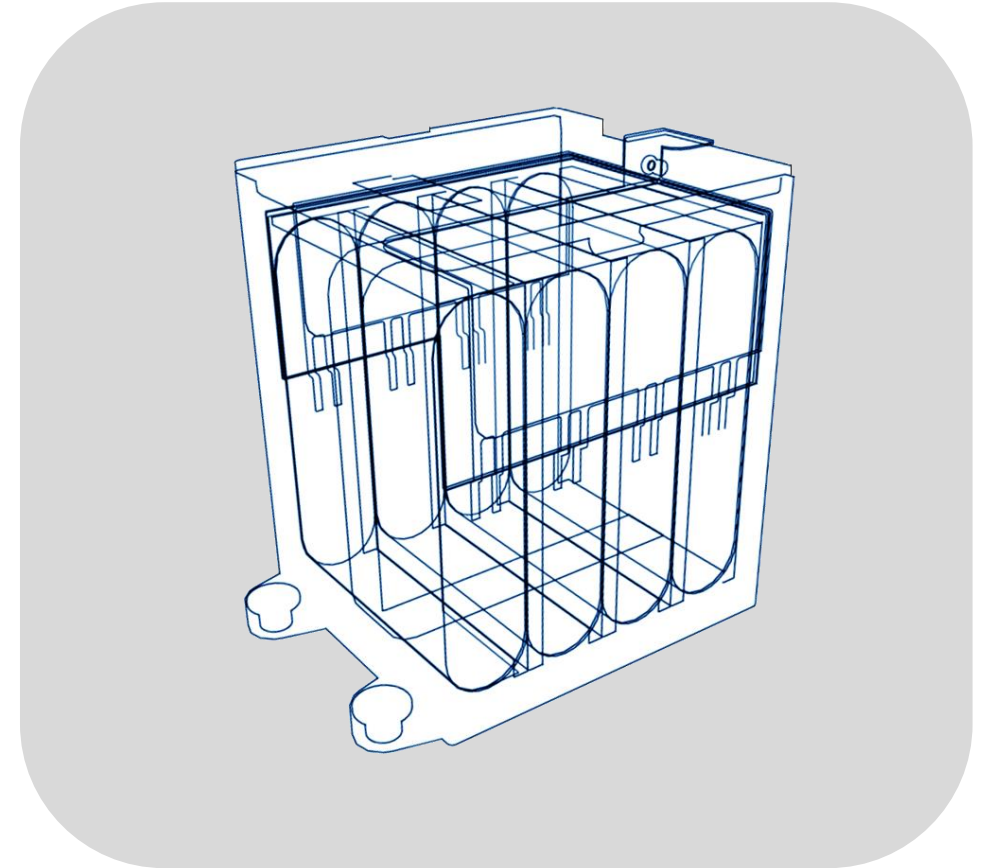
High ESR has thermal consequences



Higher switching frequencies cause unbalanced thermal behavior

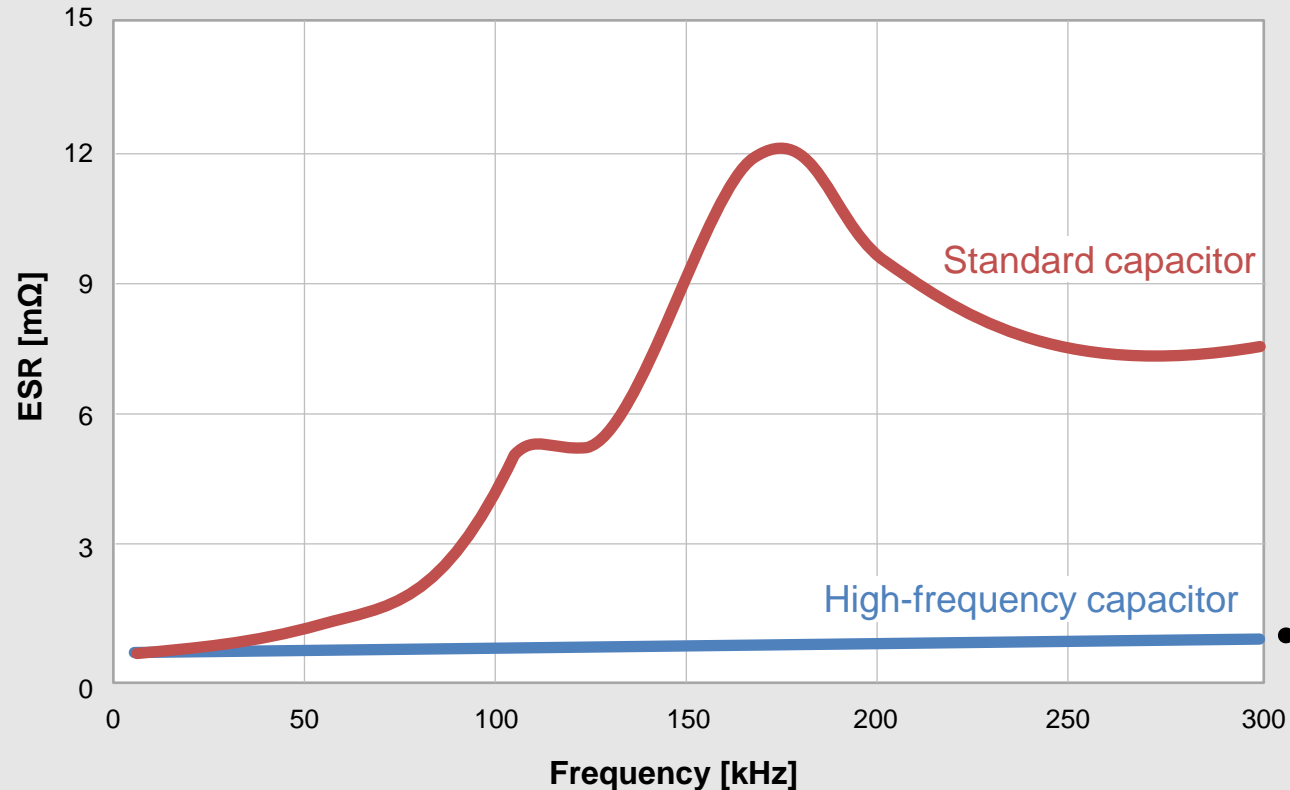
Design rules for high-frequency capacitors

- **Same impedance** of all internal capacitive elements above, below and close to capacitor resonance frequency
- **Avoid negative electromagnetic interactions** between conductors (FEA electromagnetic software)
- **Overlapped busbar** from terminals to winding connection point is required in order to minimize the inductance



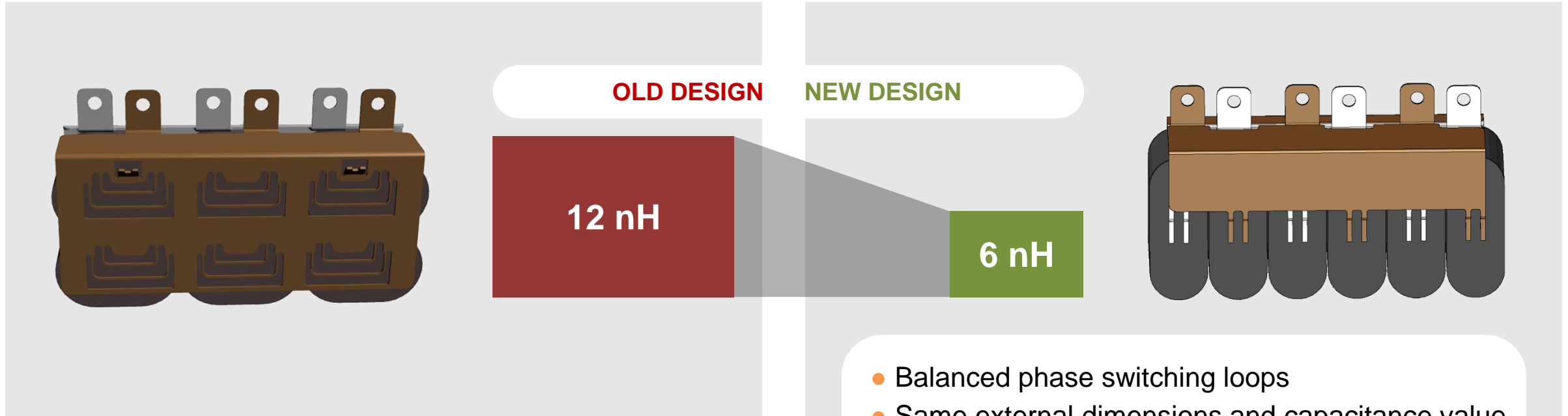
Current must be homogeneously distributed at all frequencies

Design of high-frequency capacitors focused on low ESR



New design must deliver low and stable ESR across the critical frequency range

Optimized design enables lowest ESL



- Balanced phase switching loops
- Same external dimensions and capacitance value
- Same metallized film and capacitive elements
- Lighter weight copper strips
- Significantly lower voltage overshoots

Makes snubber capacitors unnecessary in most cases

Introducing the new Modular film DCR series

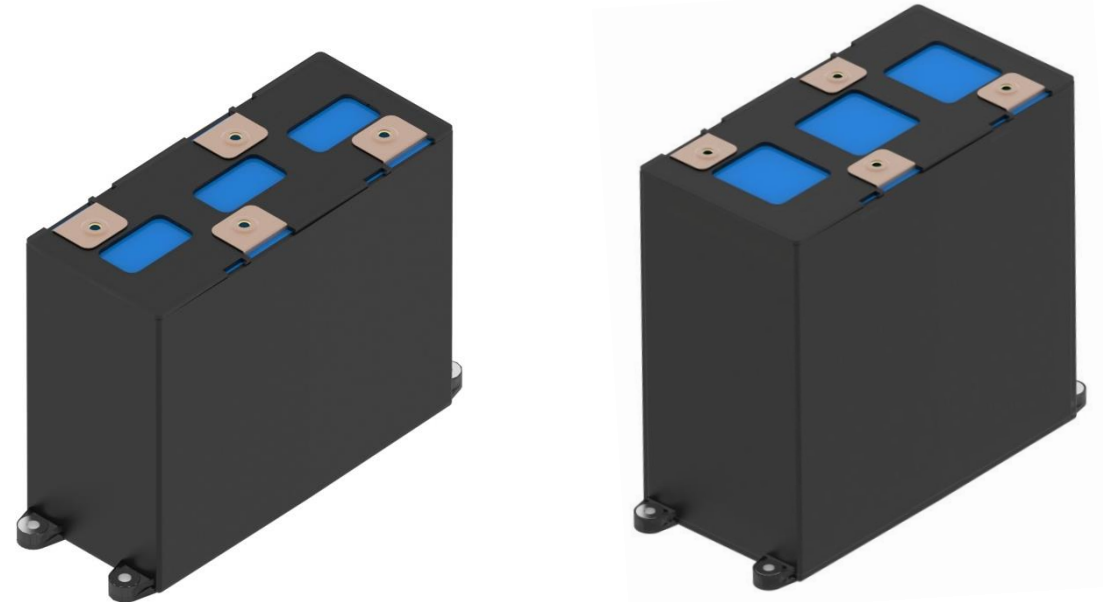
Under development

Ready for standard DC-Link optimization

- High energy density
- Voltage range from 900V to 2400V:
 - Case 1: from 2100 μ F@900V to 340 μ F@2400V
 - Case 2: from 3700 μ F@900V to 600 μ F@2400V
- Modular concept for parallelization
- Operating temperature: +85°C
- Frequency operation range up to 100 kHz
- Low ESR vs frequency
- Snubber avoidance / low voltage overshoot
- Low ESL 14 nH
- Dimensions:
 - Case 1: 205 x 170 x 90 mm (l x h x w) 3.7kg
 - Case 2: 220 x 215 x 115 mm (l x h x w) 6.1kg
- Resin-filled plastic case
- EN 45545 HL3 R23 (fire and smoke)

Expected release: 2020 Q2
Samples: available under request

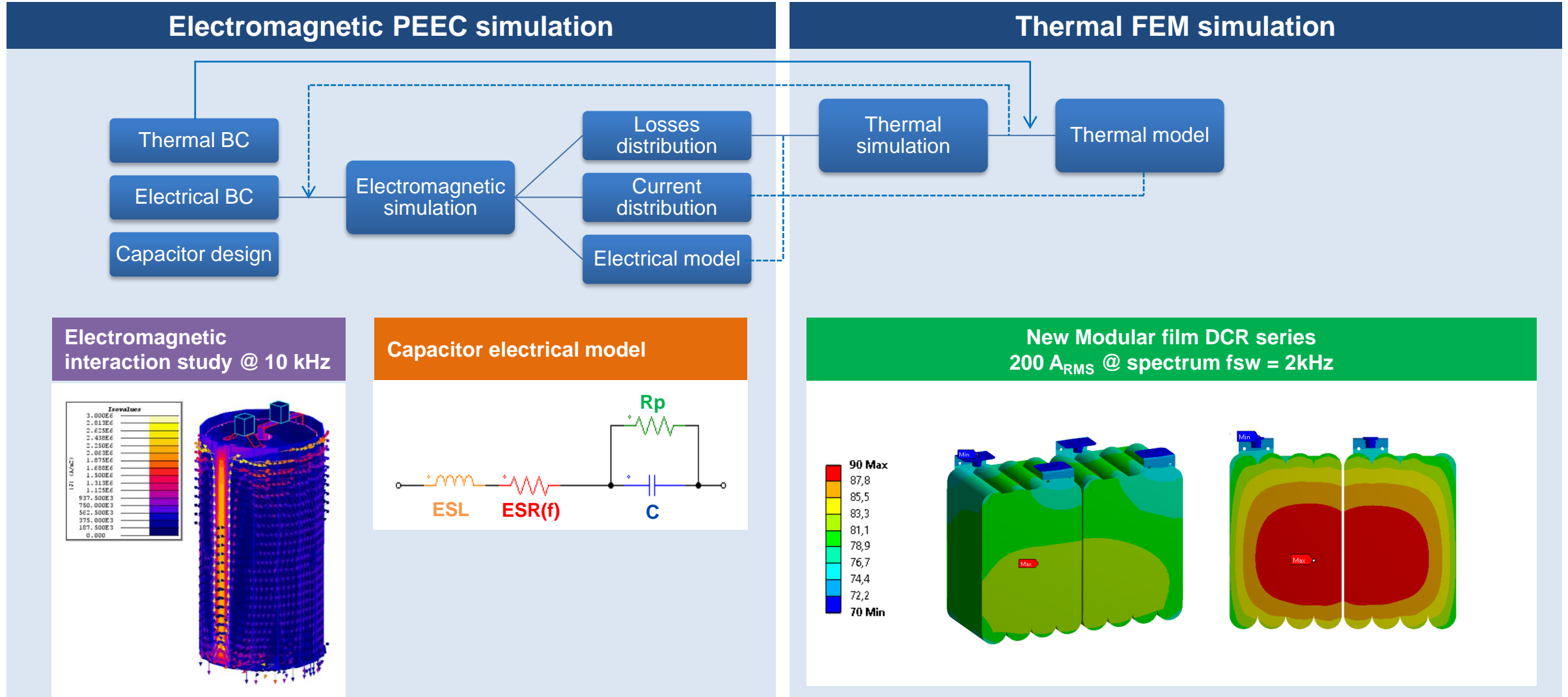
NEW



Applications

Traction, industrial drives, renewable power

Electromagnetic & thermal simulation Standard Product – Customized solution



Introducing the new HF Modular film DCR series

Under development

Fully compatible with SiC and advanced Si semiconductors

- High power density
- Suitable for higher ambient temperatures
- Suitable for fast transients (dV/dt) and ringing effects
- Modular and suitable for parallel connection
- Snubber avoidance / low voltage overshoot
- Compact and lightweight, enables lighter cooling system

Expected release: 2020 Q4
Samples: available under request

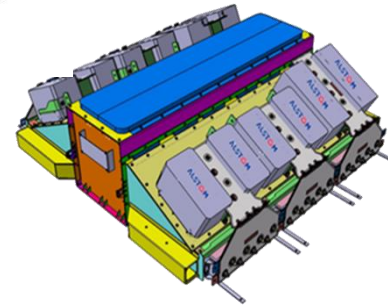
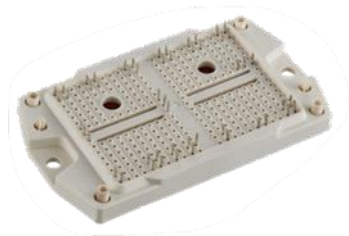


Applications

Traction, industrial drives, renewable power

- Operating temperature
 - Standard polypropylene: +105 °C
 - Advanced COC-PP dielectric: +125 °C (in development)
- 560 Vdc / 1520 μ F to 2280Vdc/ 175 μ F
- Frequency operation range up to 2 MHz
- Extremely low ESR vs frequency
- ESL of 16 nH with 1 pair of terminals
- High current density of up to 206 A/mF @ 560 Vdc and 1286 A/mF @ 2280Vdc
- Compact dimensions (2 sizes):
 - 210 x 130 x 70 mm (l x h x w) 2.8kg
 - 210 x 130 x 95 mm 3.1kg
- Resin-filled plastic case
- EN 45545 HL3 R23 / HL2 R22 (fire and smoke)

Selected development projects with new HF modular film capacitor series



Infineon Technologies AG:

- Solar 1500V Demonstrator
- Easy 3B module: 1200V TRENCHSTOP™ IGBT7 + 1200V CoolSiC™ MOSFET

TDK Electronics:

- Hybrid DC-Link capacitor: New HF film PCB+ aluminum electrolytic

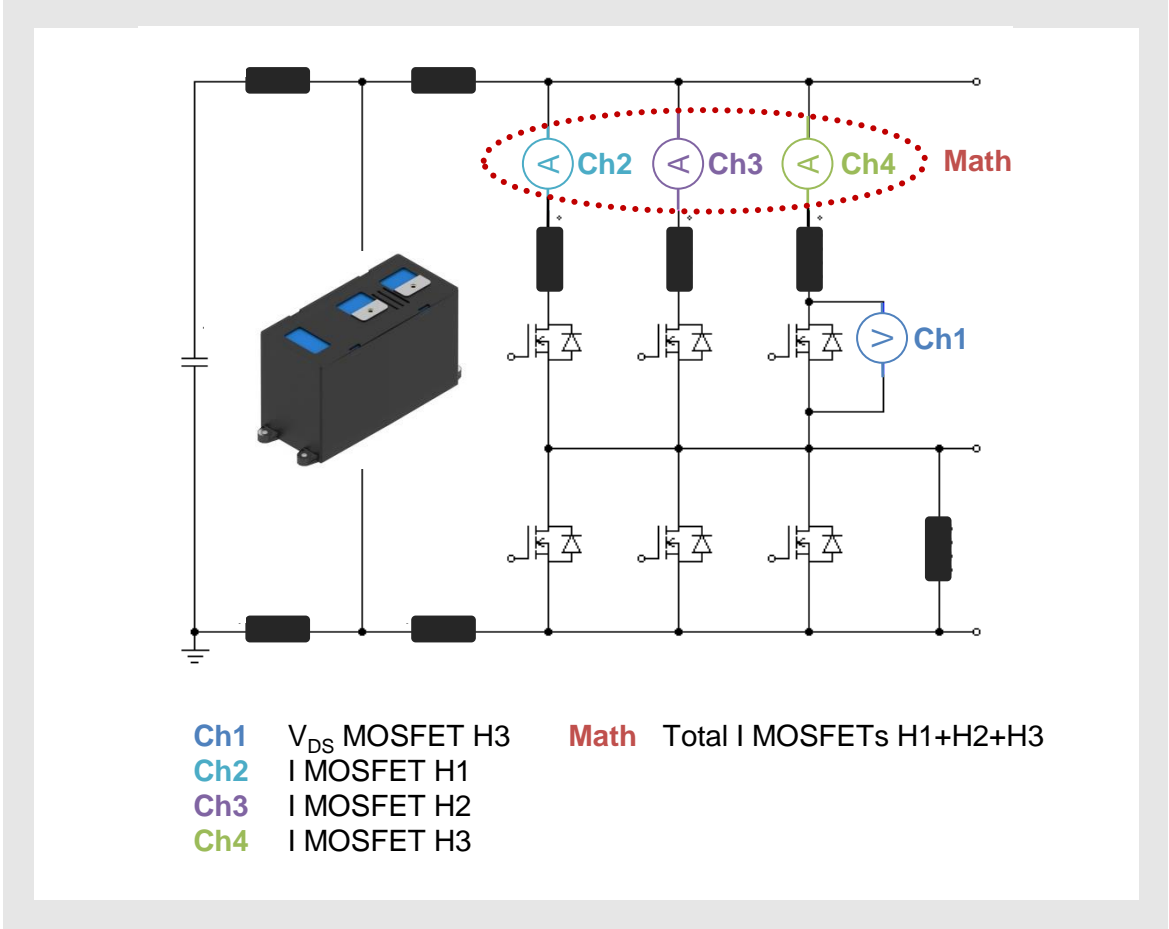
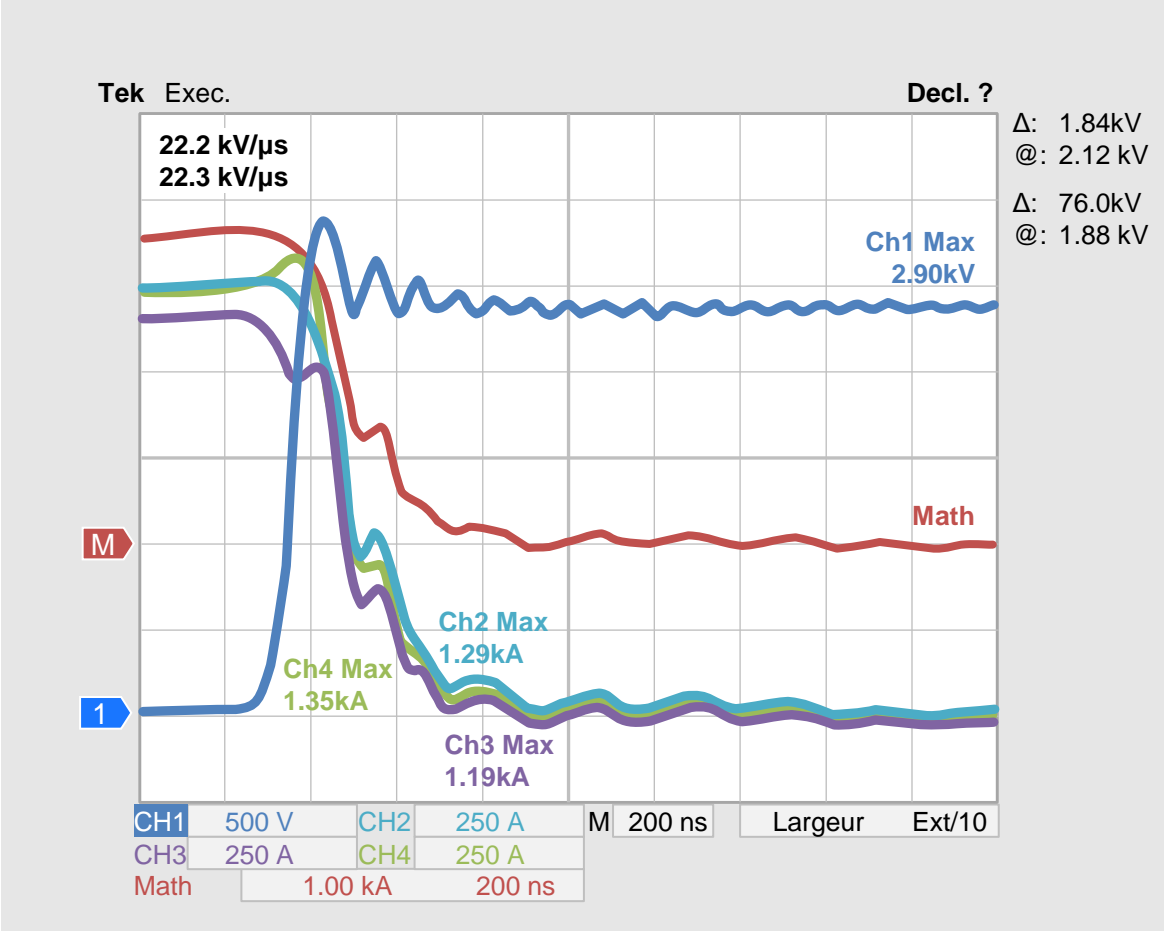
ALSTOM traction converter

- 3.3-kV SiC MOSFET
- New TDK HF film capacitor series

Traction power module (reference)

- Mitsubishi LV100 3.3kV SiC MOSFET
- New TDK HF film power capacitor
- Parallelization
- Extension to Infineon XHP2 (1.7 kV and 3.3 kV): Ongoing

HF modular film capacitor series: Ready for hard switching



New HF film capacitor series with extremely low voltage overshoot and ringing



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