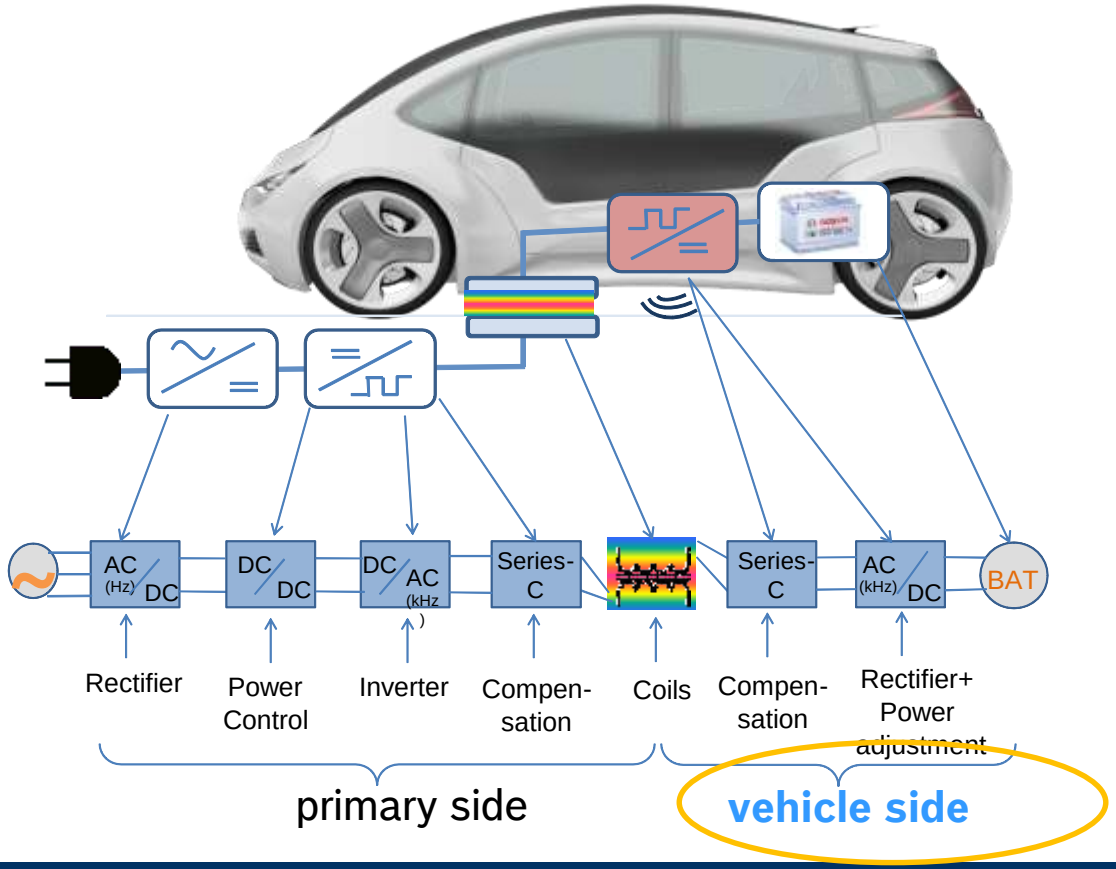
IQPC: Thermal Management for EV/HEV

Agenda

- System overview
- Power losses distribution
- Thermal challenges and measures
  - Component distribution
  - Heat sink optimization
  - Capacitor design
- Summary

System Overview: Power Transfer



Focus on vehicle power electronics

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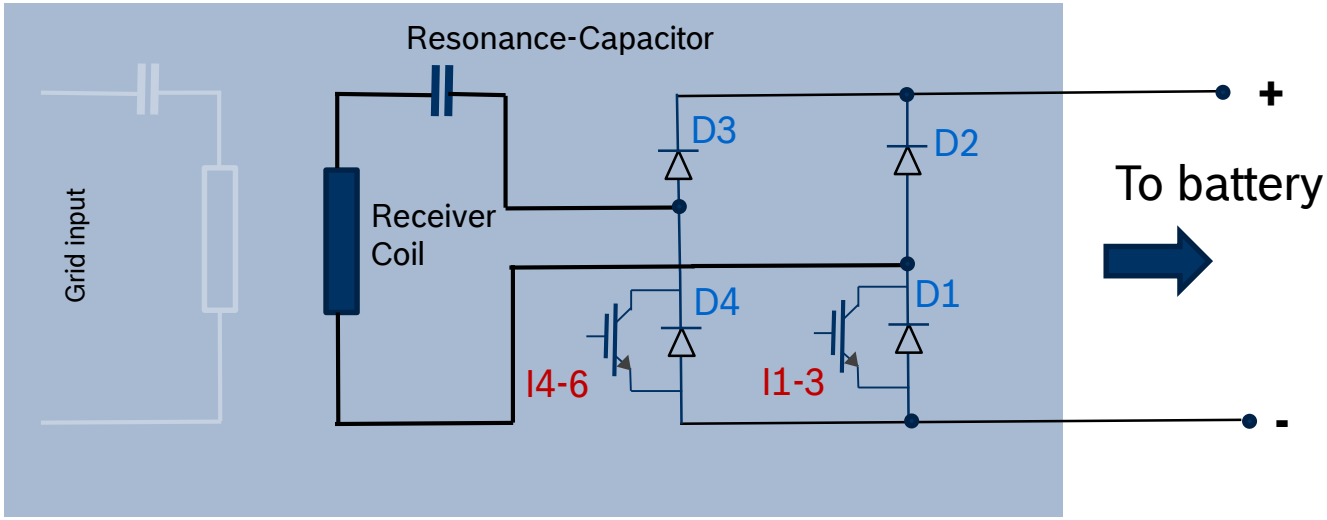
Vehicle Side of Wireless Charging

(series compensation under normal operation)



Power losses are analyzed under worst case conditions (emergency short circuit)

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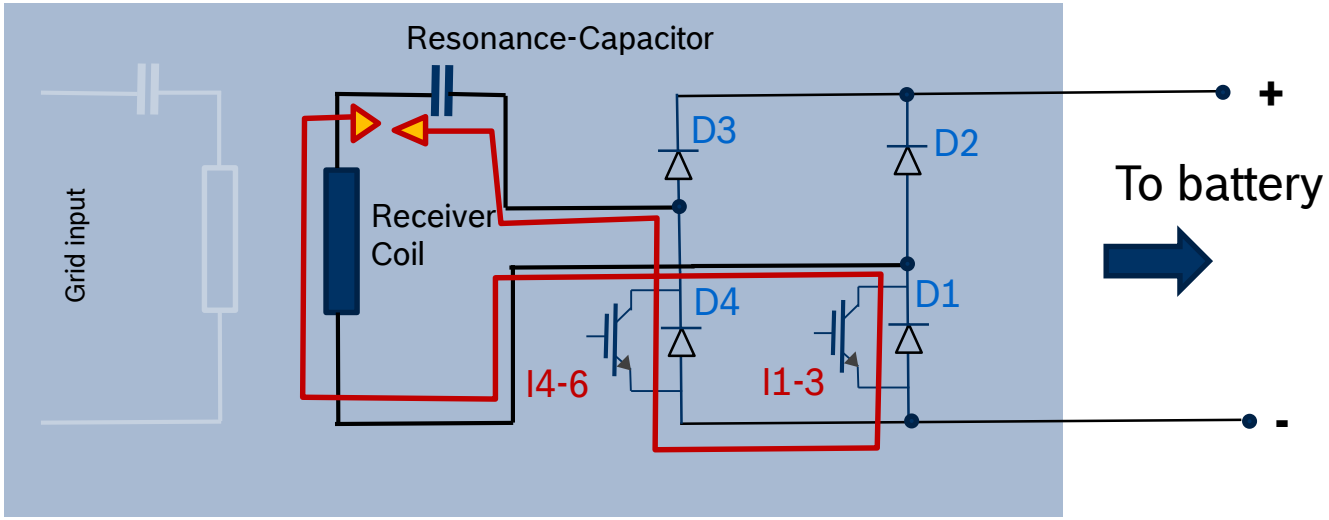
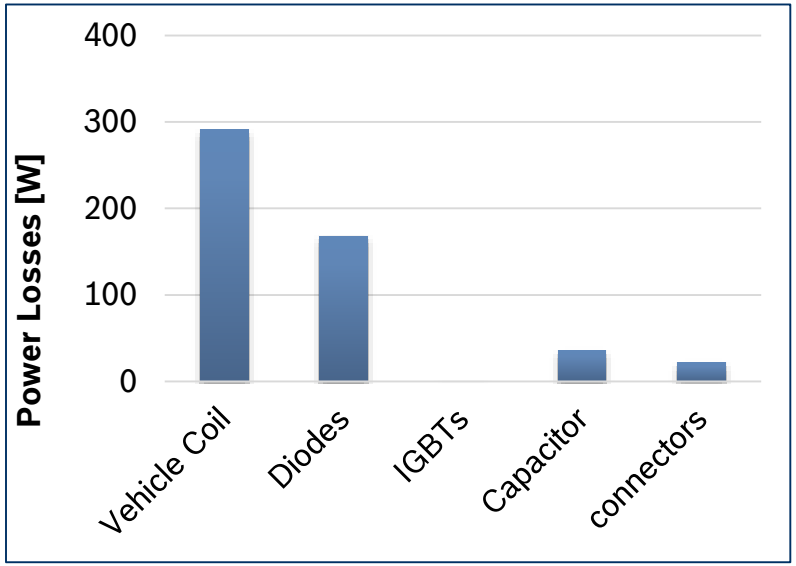
Vehicle Side of Wireless Charging
(emergency shut down)



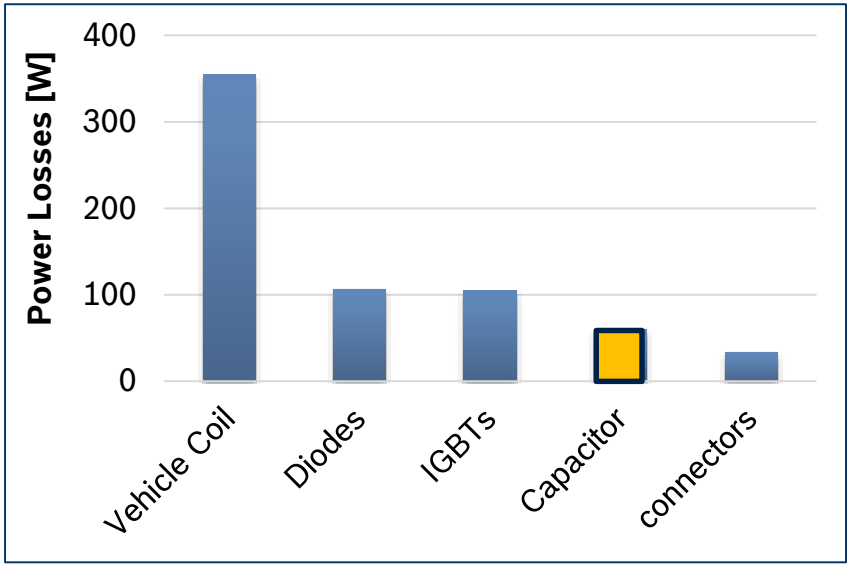
Power losses are analyzed under worst case conditions (emergency short circuit)

Power Losses Estimation

Normal operation (approx. 520W)



Emergency shut down (approx. 650W)



To be cooled in
vehicle power electronics

Resonance Capacitor is most critical component (T_{max} < 105°C)

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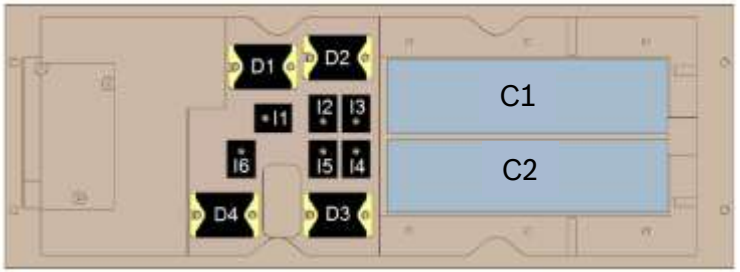
First Measure:
Splitting up Losses Over Components



- 3 IGBT per half bridge
- 2 capacitors

Part	Type	Package	Power loss [W] Emergency power off
D1	Diode	SOT-227	80
D2	Diode	SOT-228	0
D3	Diode	SOT-229	0
D4	Diode	SOT-230	80
I1	IGBT	PG-TO-247	26.67
I2	IGBT	PG-TO-248	26.67
I3	IGBT	PG-TO-249	26.67
I4	IGBT	PG-TO-250	26.67
I5	IGBT	PG-TO-251	26.67
I6	IGBT	PG-TO-252	26.67
C1	Foil Capacitor		30
C2	Foil Capacitor		30

380W

Power losses density > 100W/l

High Power density due to packaging restriction

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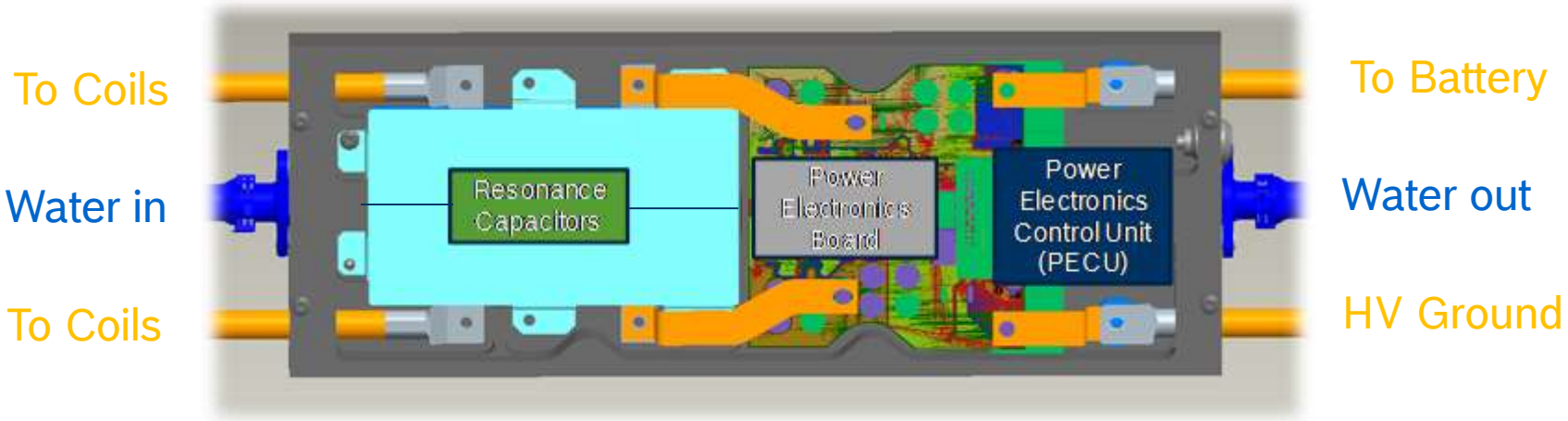
3D Package



22 kW power electronics including resonance capacitors fit into 3,5 liter

22kW vehicle electronics designed to be integrated into exhaust pipe tunnel

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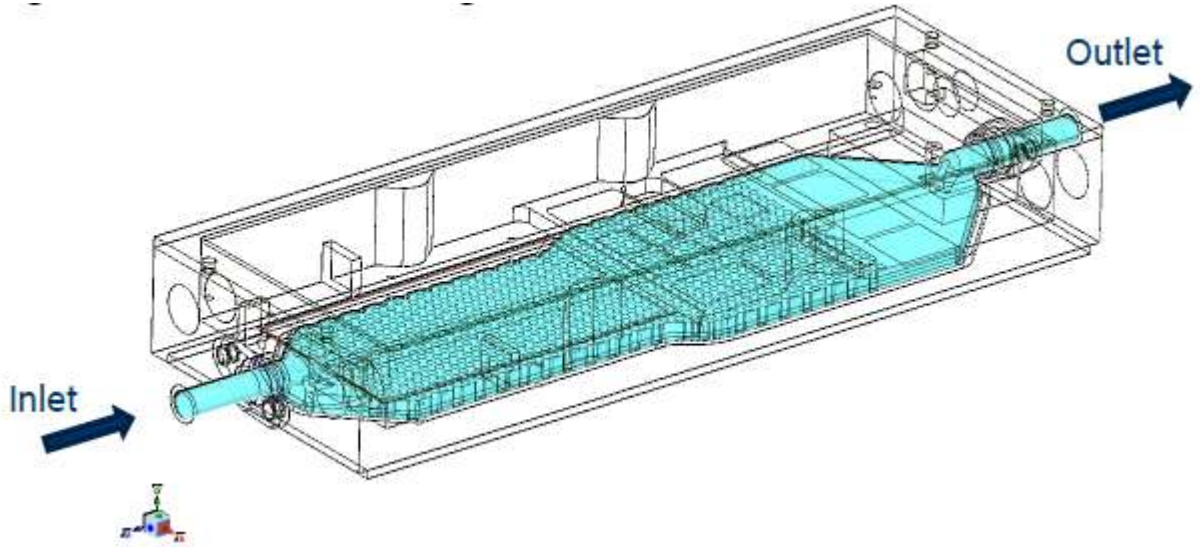
Second measure:
Optimized Water Cooled Heat Sink Design



Optimized linear cooler design

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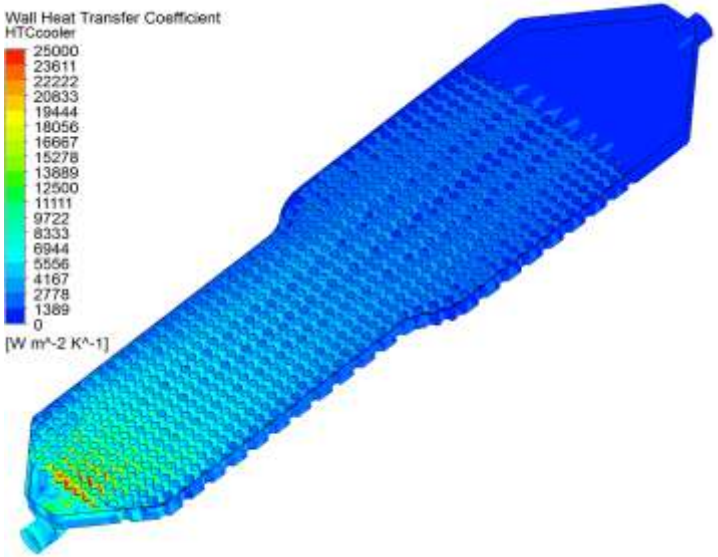
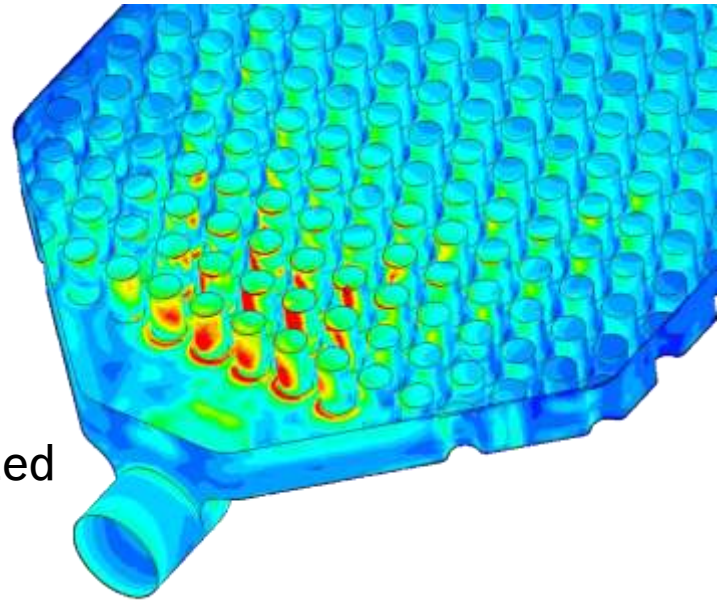
3D CFD Simulation of Pin Fin Heat Sink





High average heat transfer coefficient realized
2970 W/(m²K)

High thermal heat transfer allows efficient cooling

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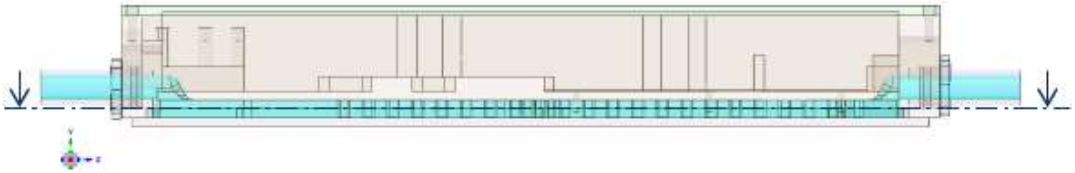
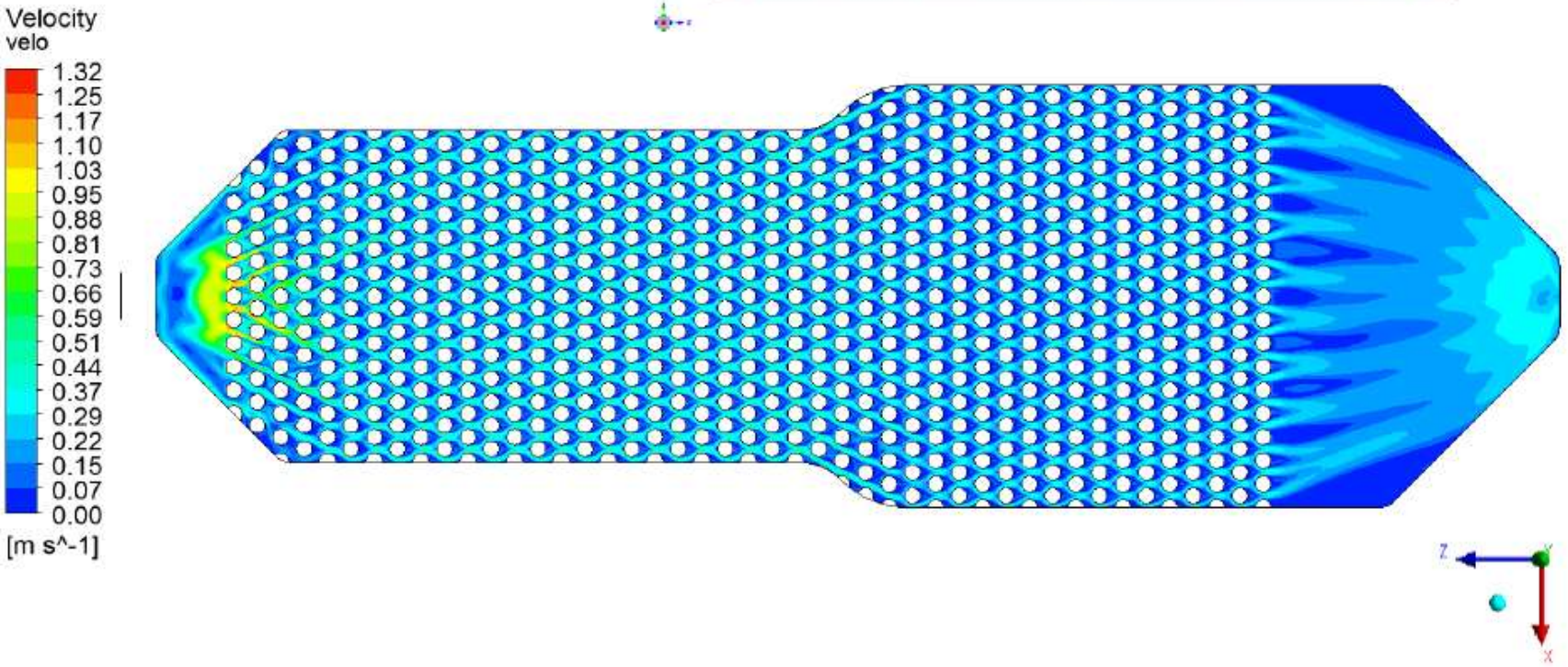
Water Velocity

- Velocity plot in center XZ plane





Homogeneous water flow in the entire cooler

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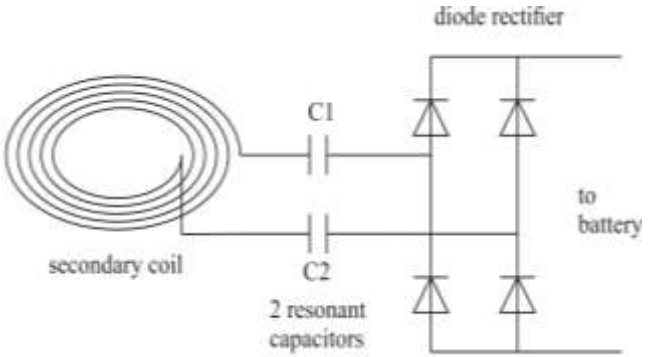
Power Losses in Capacitor

- Requirements:
  - Ambient temperature without ventilation
  - High current/voltage rating
  - High frequency
  - Very small size and weight constrain

- Low loss and good heat dissipation required



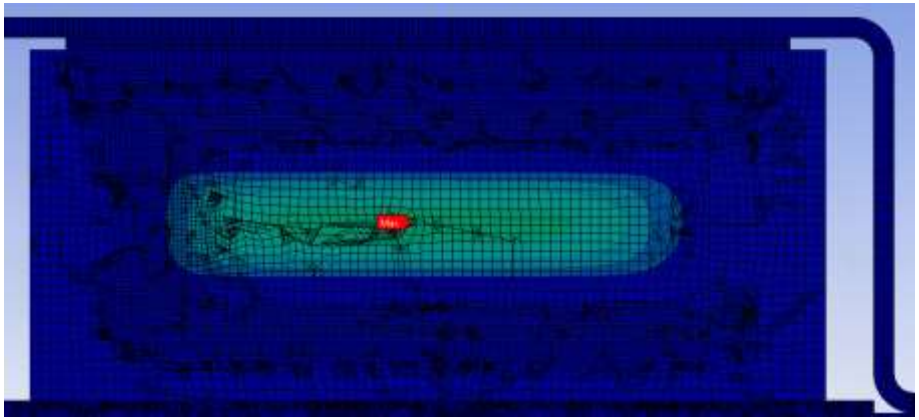
- **Challenges:**
  - **up to 1,8 kV per capacitor**
  - **85 kHz switching frequency**
  - **Full swing application : 150 kVA**

60W power losses in the resonance capacitor are crucial for the thermal design

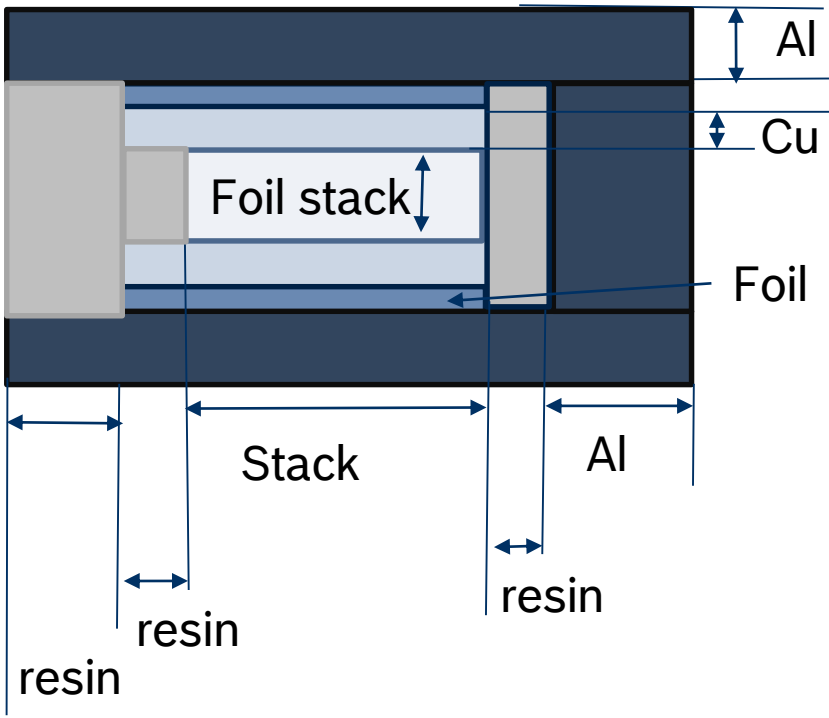
[1] Simulation of the eff. voltage and current in the coils:
Battery voltage 285..415V, charging power 3..22kW, coupling factor 0.2..0.3

Third Measure: Capacitor Design with Cu Inlay

Capacitor cross section

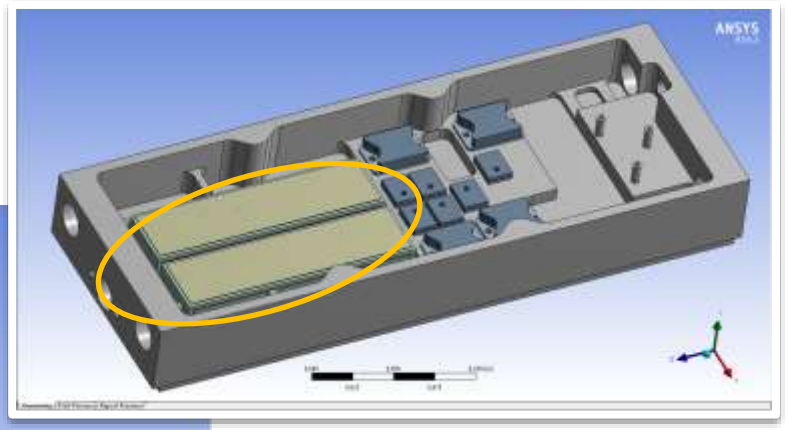


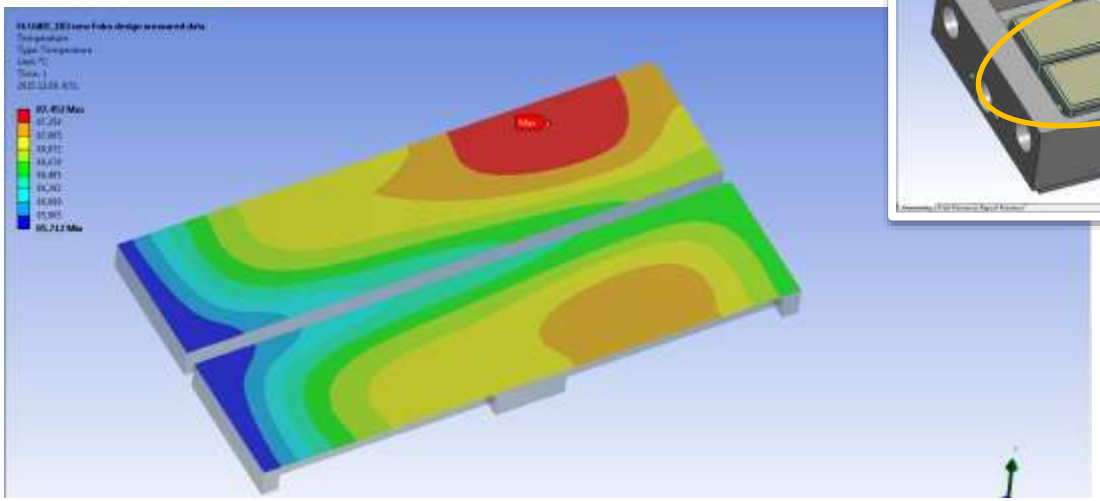
Hot spot inside of capacitor
+ approx. 30K @22kW
(P_{loss} = 2x 30W @80A)



At 65 °C water cooling temperature, the inner stack stays below 105°C @ 22kW

3D FEM Simulation of Capacitor





Simulation Settings
22kW Power transfer, 18W P_{loss} per Capacitor (@60A), 85°C water temp.

Simulations shows up to 3 K higher temperature on the Al-housing

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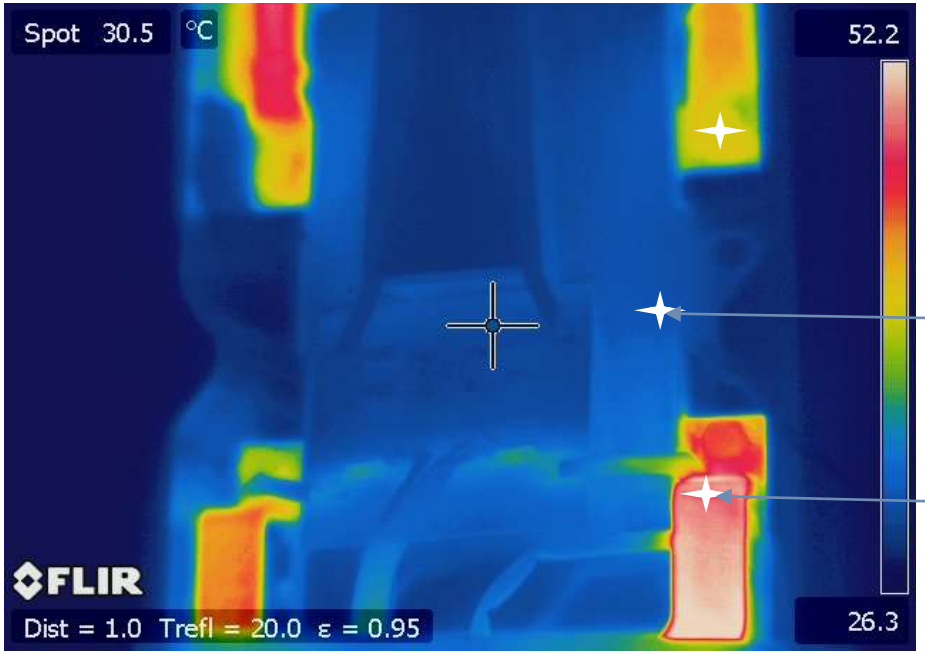
Thermography measurements of Capacitor Housing

To the coils



Measurement
Temp.: + 7K

Up to 25K higher temperature on bus bars

Measurement Settings
22kW Power transfer, 18W P_{loss} per Capacitor (@60A), 25°C water temp.

Good cooling performance:
up to 7 K higher temperature of the Al-capacitor-housing at 22kW, only

Summary and Discussion

- 22kW wireless charging vehicle electronics fit into 3,5 liter
- Design restrictions due to vehicle integration in exhaust pipe tunnel
- Wireless Charging is an interesting heat source (up to 660 W)
- Thermal management includes several measures
  - Several components operation in parallel
  - Optimized water cooling
  - Specific capacitor design
- Inner hotspot of capacitor stays in spec,

  for 22 kW power transfer and 65°C cooling water temperature

Acknowledgments

A vehicle power electronic for 22 kW inductive charging fits into <3.5L

This work is part of the project BiPoL+ and sponsored by the German Federal Ministry of Science, Research and Energy

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