Industry-Academic Forum on EMC 2026

Practical EMI Troubleshooting of Power Electronic Devices – A Methodical Approach

Stefan Hoffmann

Fraunhofer IZM

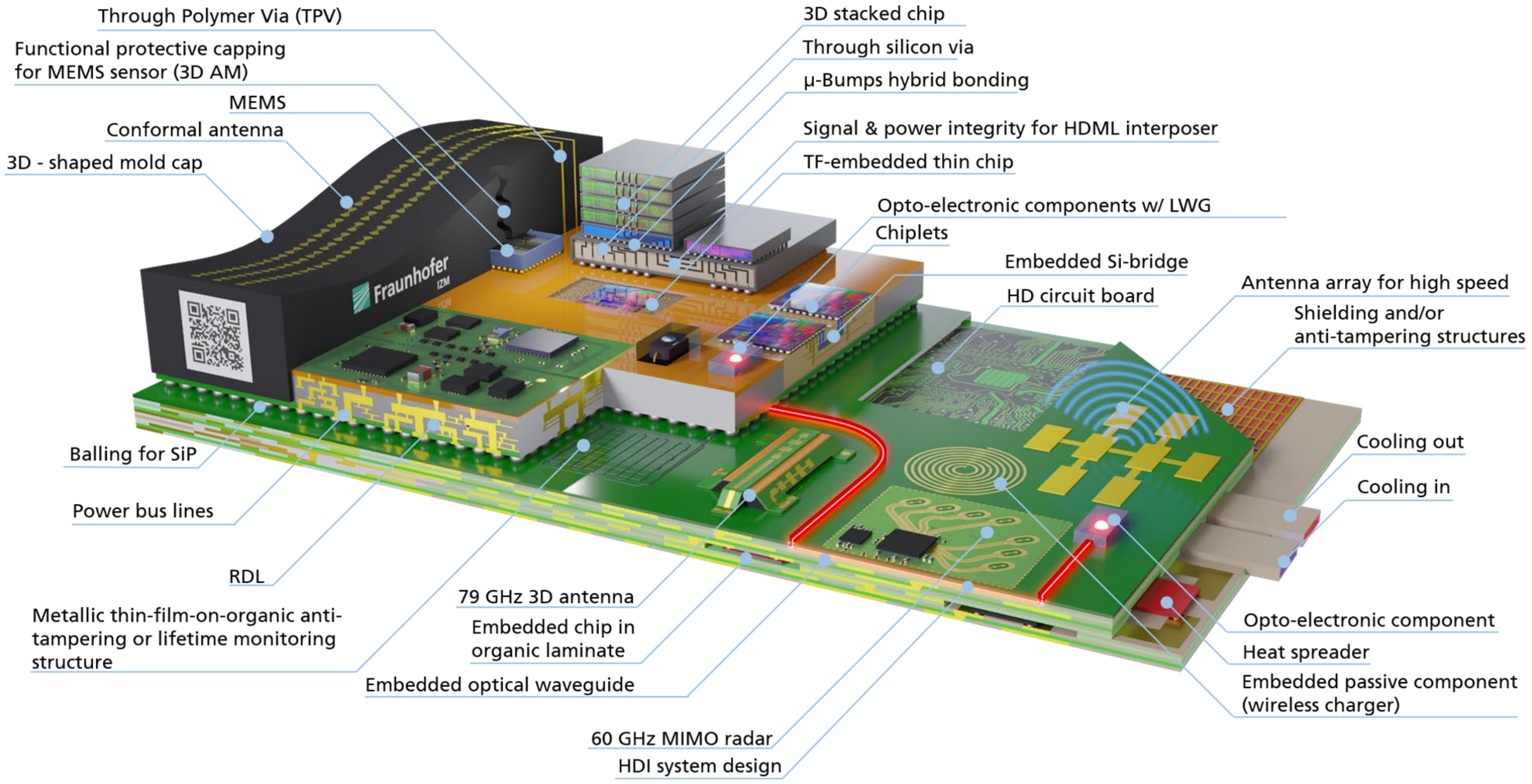
Fraunhofer Institute for Reliability and Microintegration IZM

EMC Forum

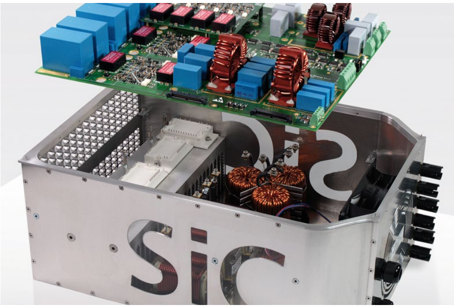
Sønderborg,
29th June 2026

Fraunhofer IZM

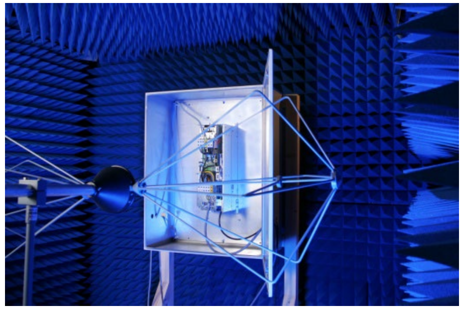
- A wide range of technologies available
- 30 years' experience with innovative technological solutions developed in collaboration with partners from industry and academia
- Some figures:
  - 430 employees
  - ~ €40 million turnover
  - 5,374 m² of laboratory space



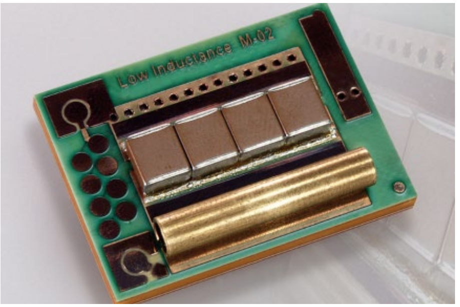
Power Electronics group @ Fraunhofer IZM



- Power Electronic systems
  - Development
  - Production
  - Qualification



- Electromagnetic Compatibility
  - Research
  - Product development support
  - Education



- Packaging Power Semiconductors
  - Design of embedded modules
  - Manufacturing Technologies
  - Research

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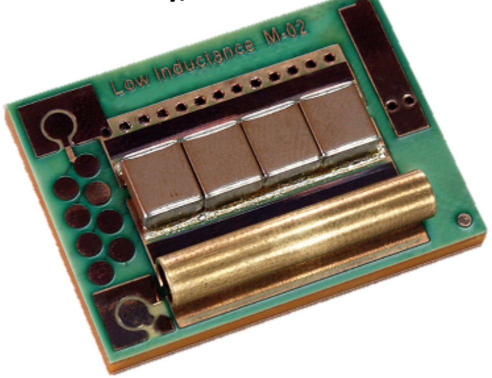
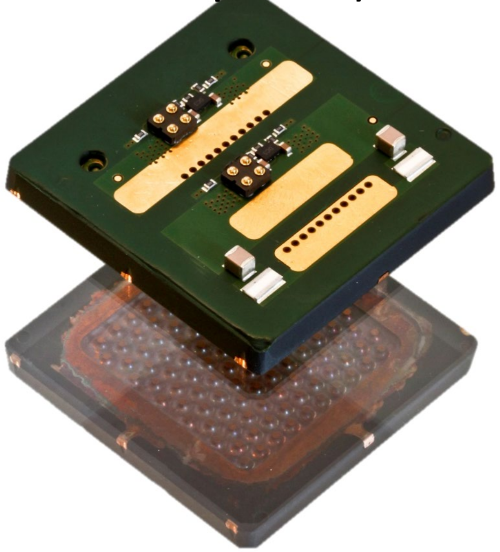
- A short selection of power modules…

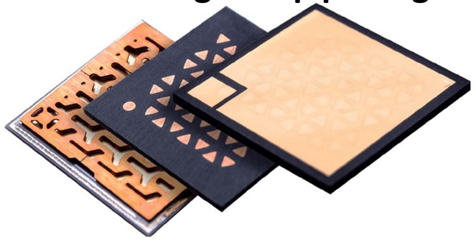
PCB embedded: low inductance (world record), current measurement



Molded package, whole switching cell, EMC optimized (shielded with DC link potential)

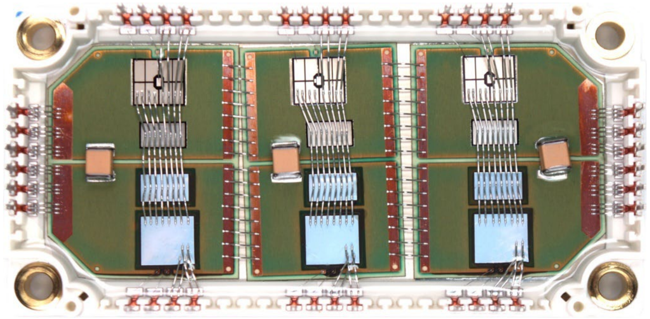


Molded single chip package

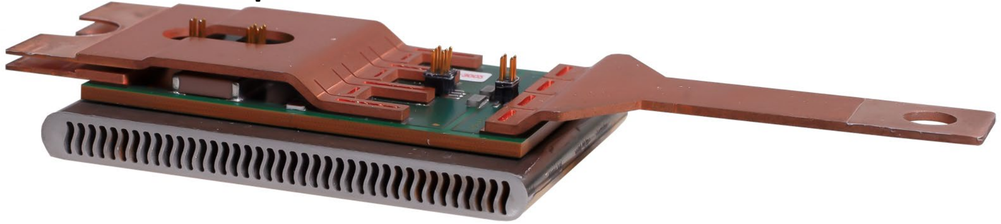


Power module for formula 1 for highest power density and optimized cooling

EMC optimized: Flip Chip, sym-metrized parasitics, DC snubber



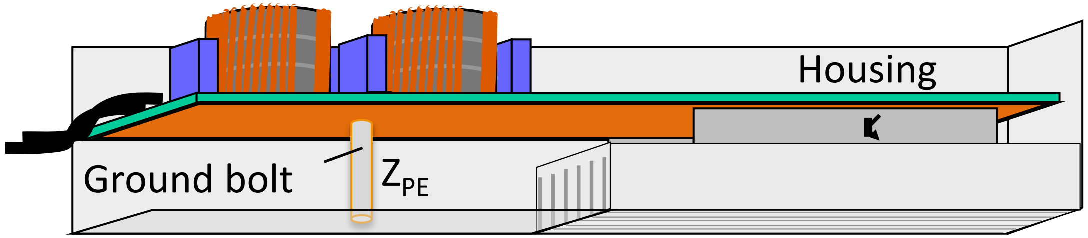
PCB embedded for very high current (1000V, 500A) and optimized thermal behavior



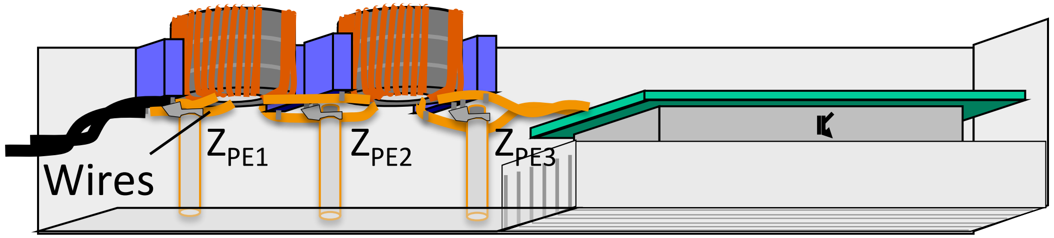
Problem: How can EMI limit exceedances be predicted?

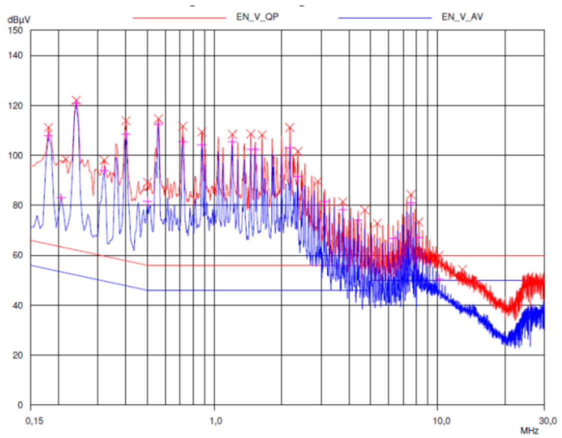
- Practical example: modification of the mains filter for a plug-in hybrid charger
- Filter topology: two current-compensated chokes for high attenuation with low leakage currents, low-capacitance Y-capacitors

Initial prototype:

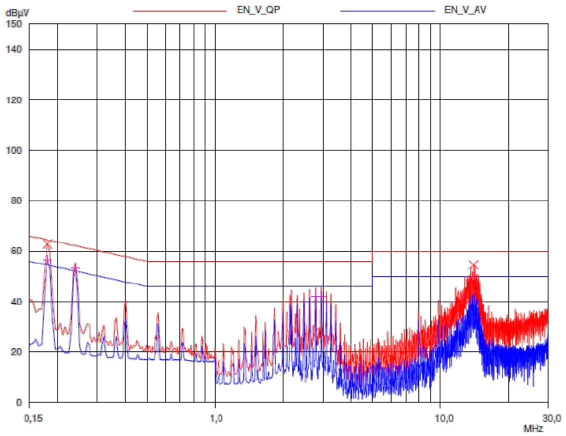


Modified prototype:





- Interference well above the limit values
- Main reasons are capacitive coupling via the GND plane and galvanic coupling at the ground bolt

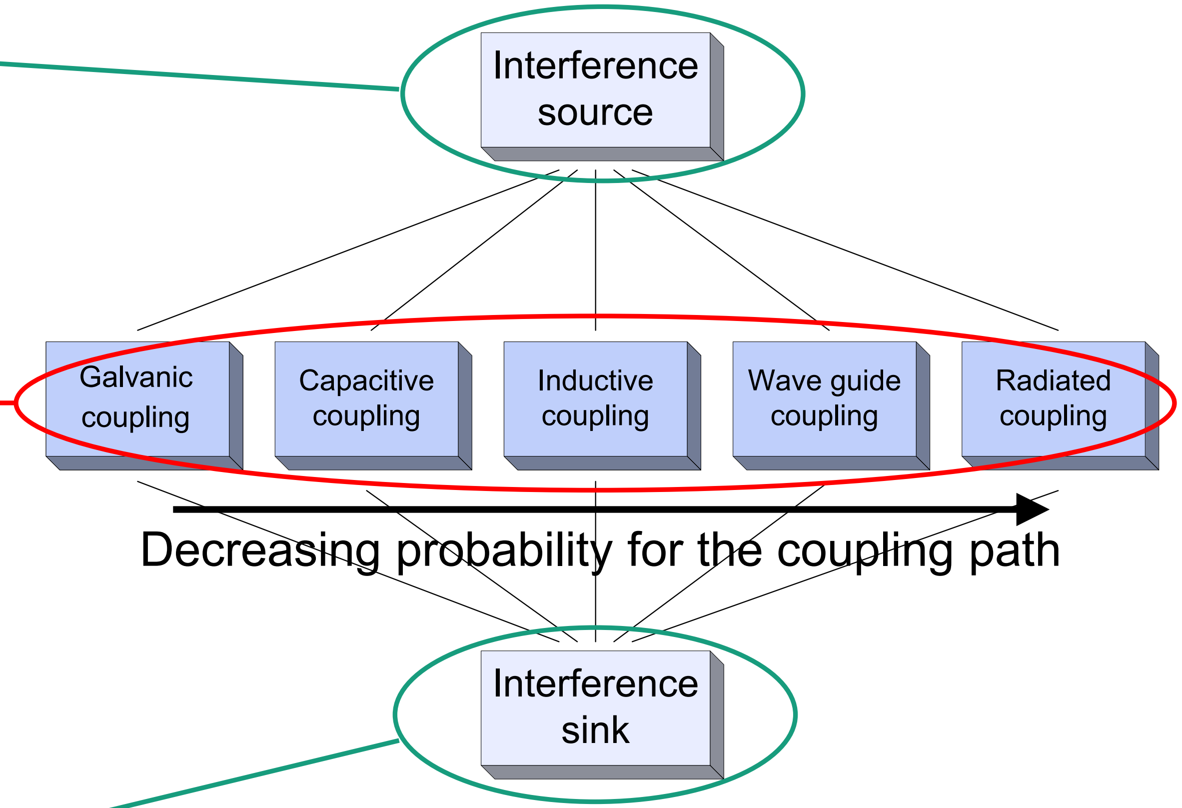


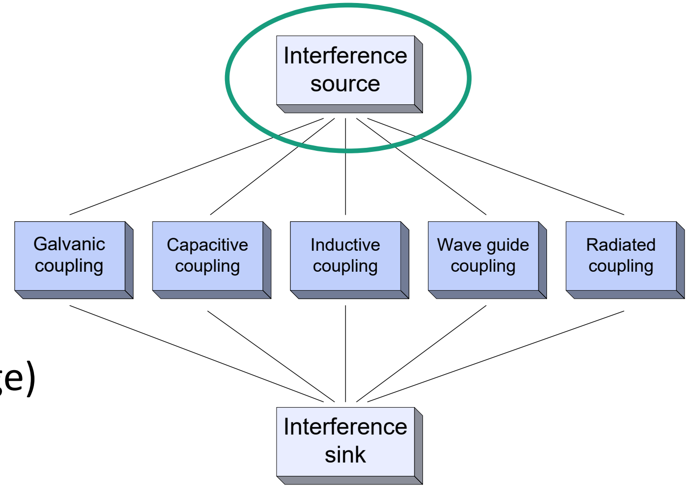
- Loose wires instead of a printed circuit board (can also be implemented using a PCB) and three connections to the housing
- Electromagnetic interference is reduced by more than 50 dB

- **What is the reasoning behind this conclusion?**

EMC propagation model

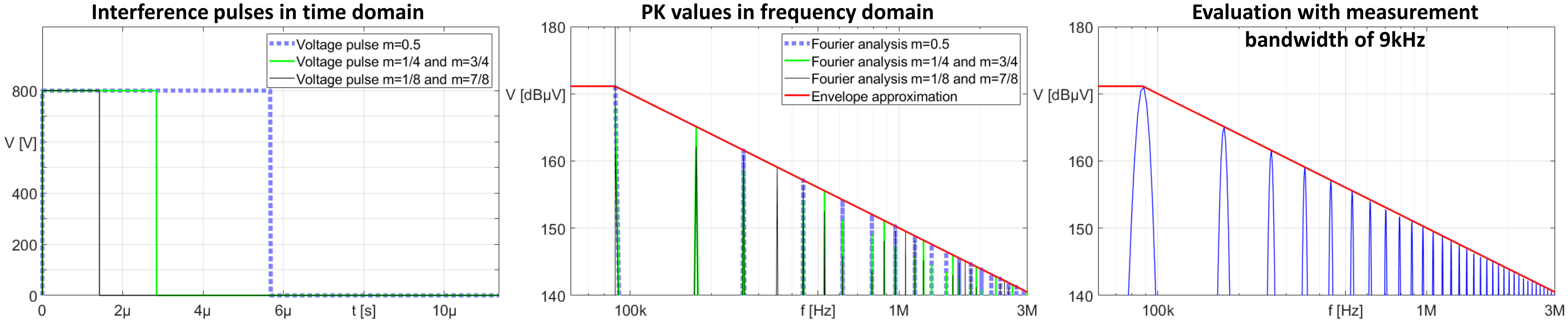
- Propagation of interference can be described using the propagation model (s. next slide)
- EMC phenomena often have something 'mysterious' about them, because the coupling path is frequently difficult to identify and remains undetected
- Although these phenomena can be explained well, the complex geometries of the assemblies and increasing frequencies make it difficult to identify the coupling
- Coupling paths are often regarded as a series connection of several couplings
- Couplings have to be identified by layout reviews on PCB and device level
- EMC sink is well defined (s. the one after next slides)





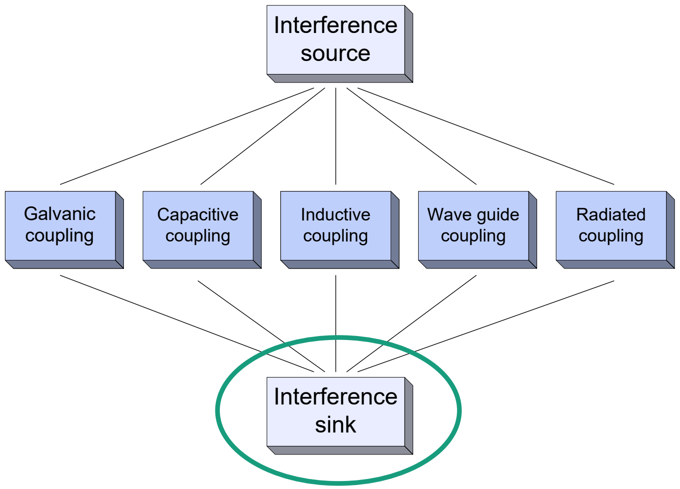
Interference source

- Switching pulse: f_S=88kHz, DC link voltage V_{DC}=800V
- Interference voltage decreases with 20dB per decade in the frequency range up to 3MHz (slope of the voltage pulse, over-voltages and oscillations can be neglected in this frequency range)
- Considering all occurring switching pulses (duty cycle changes during one mains period) each harmonic is excited with the maximum interference voltage
- To evaluate the interference spectrum with measurement bandwidth f_{BW} following equation can be applied (Δf: derivation from the frequency of the respective harmonic): $V_{noise} = \frac{\sqrt{2} \cdot V_{DC}}{\pi \cdot round\left({}^{f}/_{f_S}\right)} \cdot e^{-\frac{\sqrt{ln2} \cdot \Delta f}{\frac{f_{BW}}{2}}}$

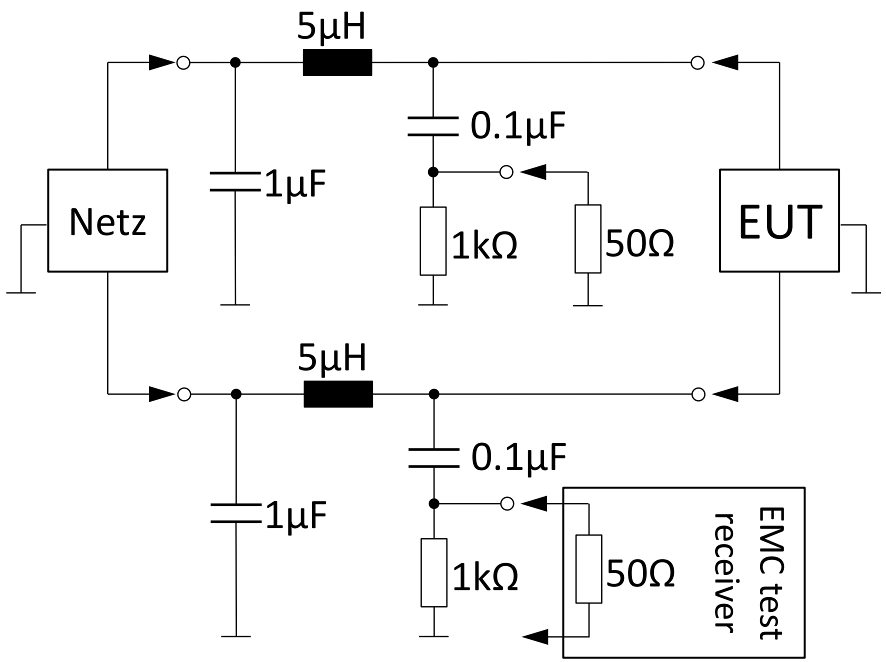


Interference sink

- Interference sinks
  - LISNs or antennas
  - LISNs can usually be described very well using simulation parameters

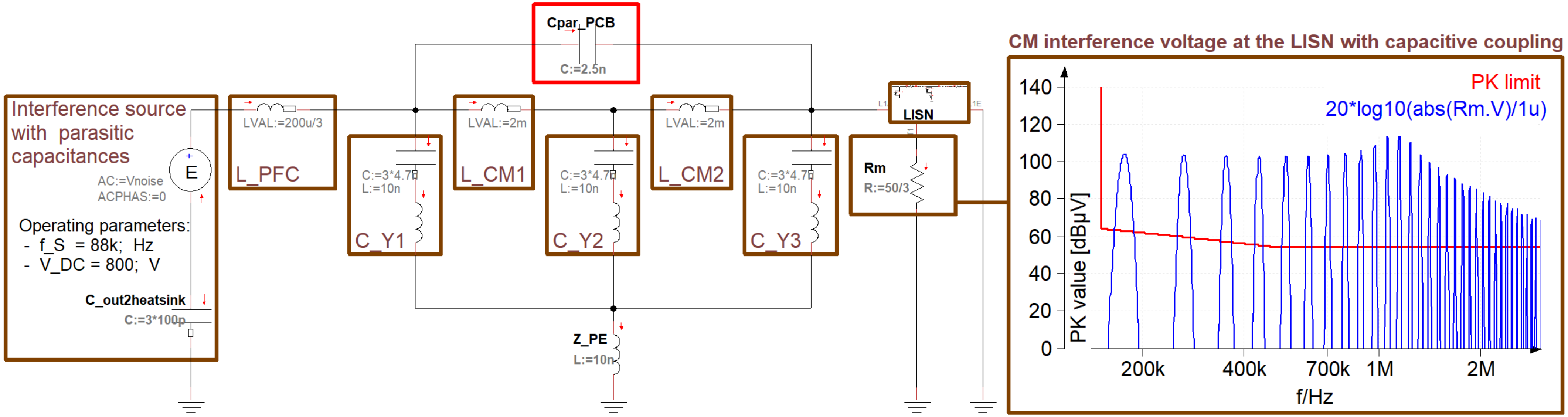


Circuit model of an automotive LISN



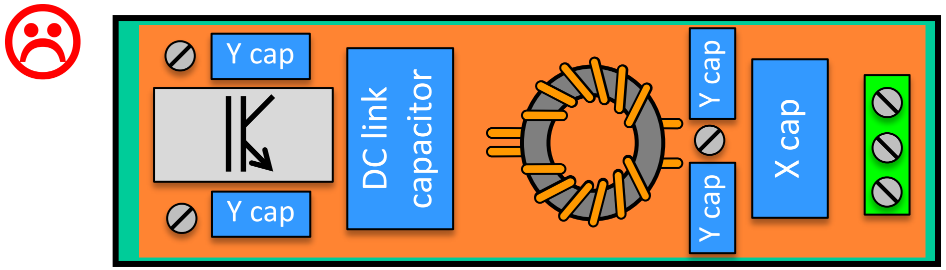
Capacitive coupling between filter stages

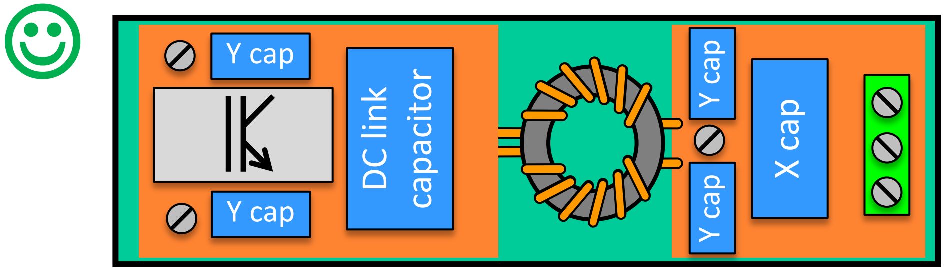
- In accordance with standard practice, a ground plane is often placed across the entire printed circuit board, which can lead to capacitive coupling between filter stages with different interference potentials and reduce the filter attenuation
- In this example, this coupling is the dominant effect



Capacitive coupling between filter stages

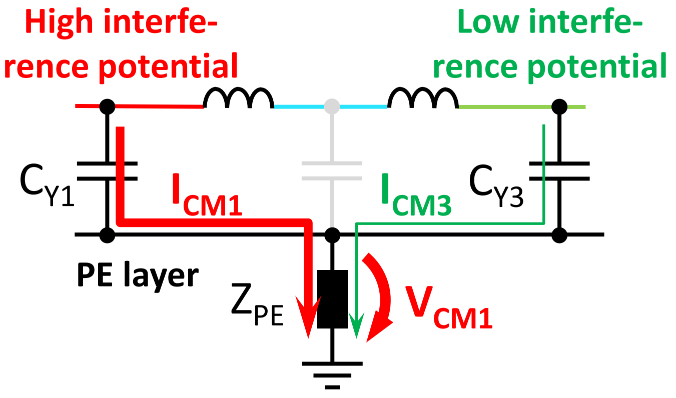
- Each filter stage should have its own ground plane separated from the filter chokes
- Copper placed beneath inductive components increases the effective winding capacitance



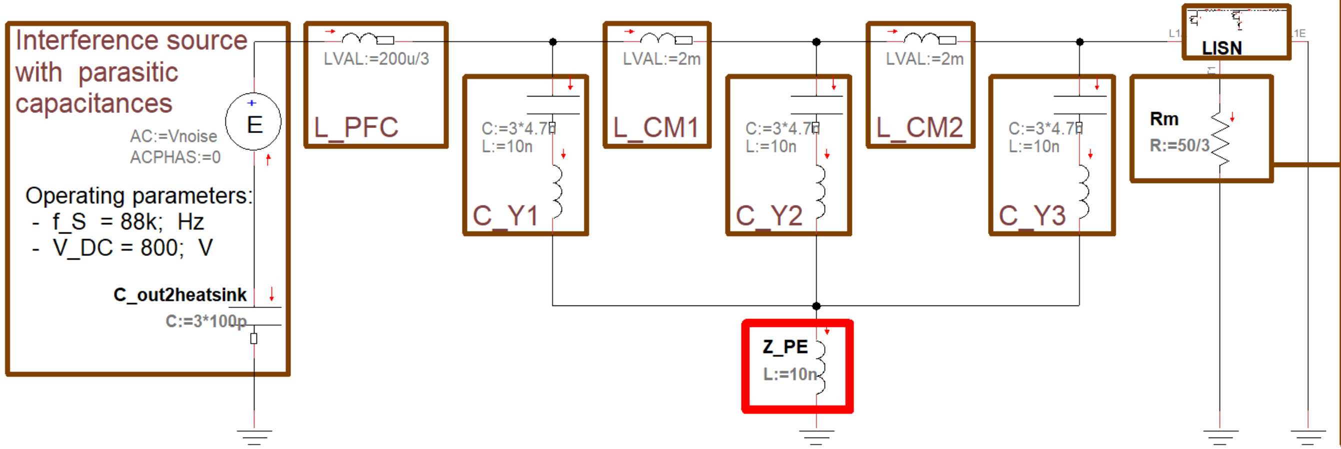


Galvanic coupling via the ground bolt

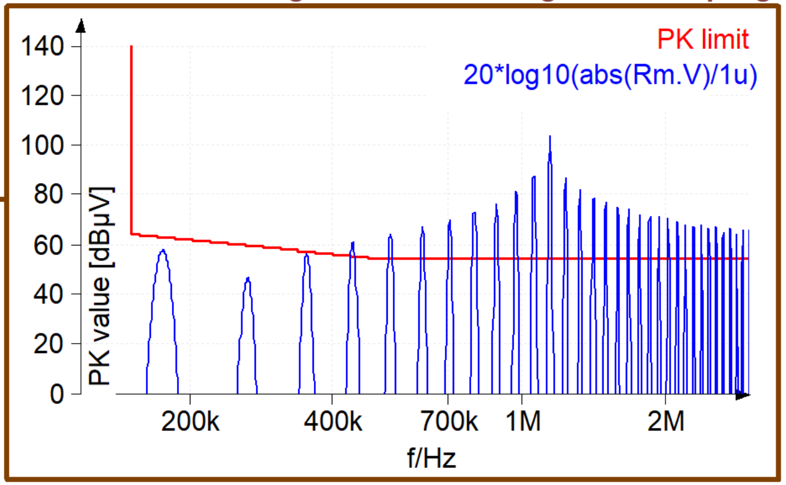
- Explanation of the galvanic coupling effect
  - PCB areas with high and low interference levels are galvanically coupled via the PE layer through the shared inductance of the ground bolt
  - The PE layer does not have an ideal connection to the chassis (Z_{PE}), and can therefore be subject to interference
  - Simulation shows the influence on CM interference emissions due to this effect (from 300 kHz, the voltages at the simulated mains supply rise)



- Interference currents with different interference potentials via a ground connection should be avoided



CM interference voltage at the LISN with galvanic coupling



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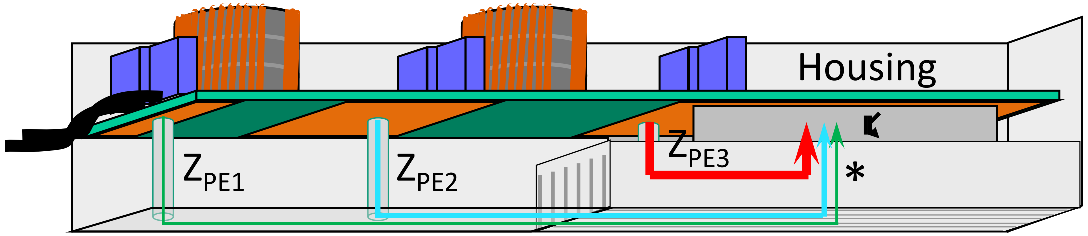
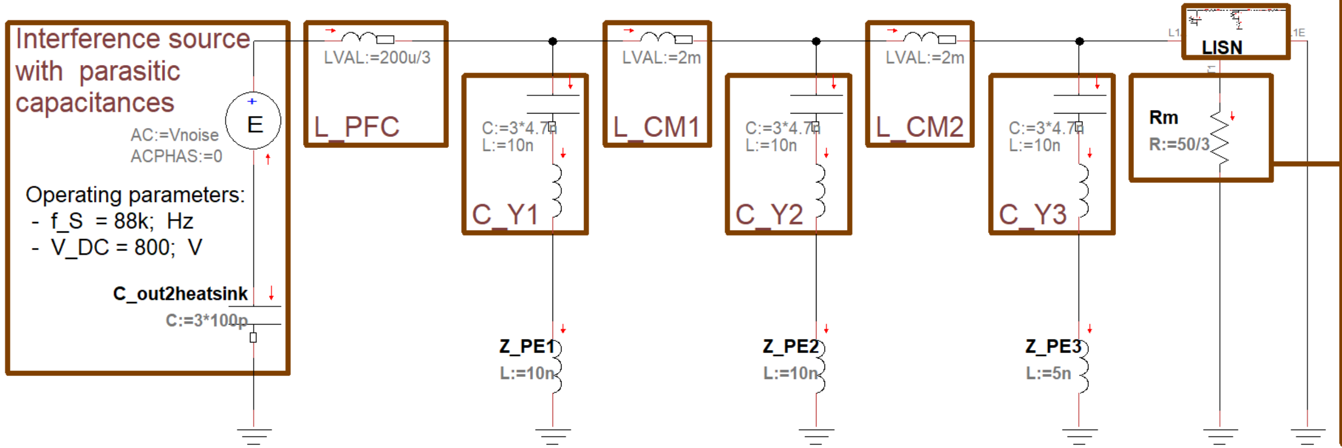
Solution

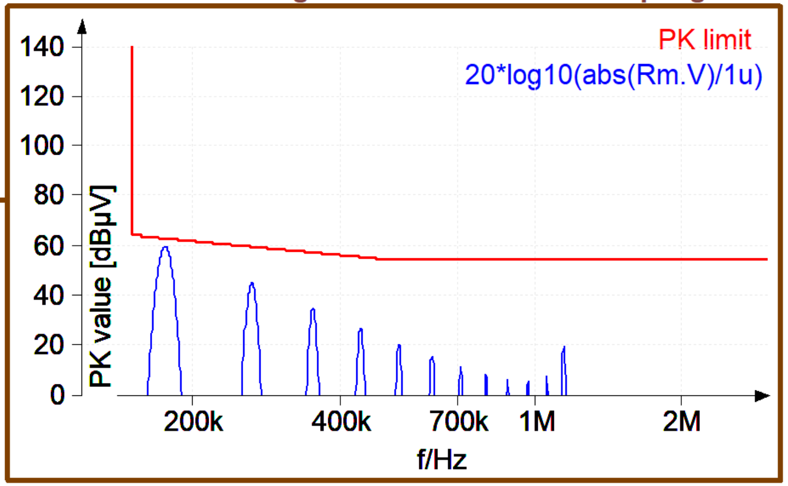
- Measures to reduce coupling
  - One ground bolt per filter stage (affects the mechanical design)
  - Split the PE layer into three separate islands
  - Reduce the parasitic inductance of the ground bolts (design them to be as short and thick as possible)
  - Keep the distance between filter stages as large as possible
  - No copper beneath filter chokes (to reduce capacitive coupling (winding capacitance); this effect is not taken into account in the simulation)



* Keep common interference current paths with varying interference potentials as low-impedance as possible



CM interference voltage at the LISN without couplings



Remark: From approximately 1 MHz onwards, the parasitic winding capacitances of the common-mode chokes must be taken into account in order to obtain more accurate predictions.

Conclusion

- EMC phenomena can be predicted using methodological approaches
- For most EMC problems, the relevant coupling path must be identified (the source and sink of interference can usually be identified more easily)
- The higher the frequency, the more difficult it is to make a prediction

Thank you for your Attention

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Fraunhofer Institute for Reliability and Microintegration IZM

Stefan Hoffmann
Tel. +49 30 – 46 403 - 142
stefan.hoffmann@izm.fraunhofer.de

Fraunhofer IZM Berlin
Gustav-Meyer-Allee 25
13355 Berlin
Germany
+49 30 46403-100

Fraunhofer IZM-ASSID
Ringstraße 12
01468 Dresden-Moritzburg
Germany
+49 351 795572-12

Fraunhofer IZM Außenstelle Cottbus
Karl-Marx-Straße 69
03044 Cottbus
Germany
+49 355 383 770-12