EPE’23 ECCE Europe – Call for Tutorials

Planar Magnetics for On Board Chargers and others

Name(s) and Affiliation(s) of the Lecturer(s):

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Tutorial Objectives:

Magnetic components in power electronics are very often bulky and costly, handmade and not strait forward to cool. Using windings manufactured in PCB technology with ferrite cores is an alternative, but it comes along with some challenges:

- Skin- and proximity effects are very distinct in flat inductors, how to solve?
- How to design MHz windings for transformers with kW power?
- Where is the power limit for PCB windings?
- Capacitive effects are more distinct in planar magnetics, how to handle?
- Creepage und clearance requirements, how to fulfill?

The tutorial uses the example of a 22kW On Board Charger (OBC) developed at Fraunhofer IZM with only planar magnetics to explain requirements and opportunities for these components. It consists of a 1/3-phase PFC part and a DC/DC-converter part.

The PFC uses an interleaved topology together with a coupled main inductor. Thereby ripple current can be minimized and the skin losses reduce to an acceptable value. The solution will be introduced as well as the other side effects having to be considered when designing this kind of component. Especially parasitic capacitive properties also have to be controlled and minimized, as they show distinct effect in EMC behavior, ringing and losses. With frequencies in the 100kHz range and above and grid voltages capacitive losses get very harmful.

The potential separating DC/DC converter used as example operates at 1MHz with 11kW in full resonant operation. Challenges here are to design the printed circuit board in a way, that minimize skin- and proximity effects and handle capacitive coupling in a tricky way. Thereby the knowledge of the PCB production process as well as high frequency design is mandatory. The optimization requires an efficient coupling of layout tool and electromagnetic simulation tool to evaluate the loss effect of design decisions. Experience will be exchanged and examples for optimizations given.

Target Audience:

Target of this tutorial are magnetics developers as well as every one who wants to get a first hand insight on the potential of the technology as well as the issues. Target are grid connected units in the kW power range. The basics of magnetics design will not be treated, as well as how to optimize classic windings.

Topical Outline:

Introduction: (25 min)

- How does an OBC with flat magnetics look like?
- What are the ideas behind it?
- How would manufacturing look like with these kinds of components?

Effects to consider when designing planar magnetics (45min)

- Skin effect – How does it appear
- Proximity effect – What´s the difference
- Parasitic capacitance – where is it relevant
- Ferrites – some mostly unknown properties
- Creepage and clearance

The PFC inductor (45 min)

- Topology to make it attractive
- PCB technology
- LF current balancing between the windings
- Geometry and consequences: capacitive losses
- Geometry and consequences: EMC behavior and ringing

The DC/DC-converter (45min)

- Topology: the Sine Amplitude Converter
- Common mode cancellation
- Winding loss optimization
- Capacitance optimization

Conclusions (30min)

- Conclusion
- Discussion

Provisional Schedule of the Tutorial:

Schedule:

14:00 – 15:30 : Introduction / Theme 1 / Theme 2
15:30 – 15:50 : Coffee break / Lunch Break
15:50 – 17:20 : Theme 2 / Theme 3 / Conclusions

About the Lecturers:

Eckart Hoene received his Diploma in electrical engineering from Technical University Berlin in 1997. He joined the Fraunhofer Institute for Reliability and Microintegration as scientific assistant and his Ph.D. was given in 2001 by the TU Berlin. He continued at Fraunhofer as Postdoc, group leader and business development manager. In 2014 he became adjunct Professor at Aalborg University, in addition to the courses he chairs for the European Center for Power Electronics and his Fraunhofer affiliation. He now is responsible for the power electronic activities at Fraunhofer IZM. Technical focus of his work are high switching frequencies in power electronics, packaging semiconductors and EMC.

Stefan Hoffmann successfully completed his master's degree at the Technical University Berlin in 2010. At the beginning of 2011, he was assigned as a research assistant to the Power Electronics working group at Fraunhofer Institute for Reliability and Microintegration. His current research interests include designing and optimizing power electronic systems regarding efficiency, power density, and EMC. He is currently completing his Ph.D. thesis on this topic.

Andreas Kieninger received his master's degree in electrical engineering from the Technical University Berlin in 2020. Since 2020, he is working as a research assistant in the field of power electronics at the Fraunhofer Institute for Reliability and Microintegration. His main research interests are design of power electronic systems with high power denisty, resonant inverters and optimization tasks to increase the system efficiency.