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The Design of a Multilayer Planar Transformer for a DC/DC Converter with a Resonant Inverter

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Agenda

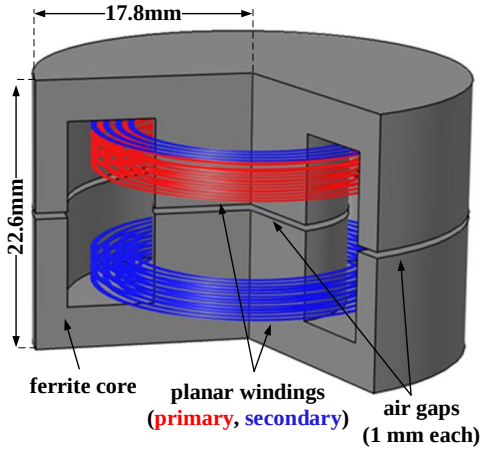
1. Introduction
2. Design requirements for the planar transformer
3. Simulation models description
4. Steps of the analysis
5. Constructed prototype and laboratory measurement results
6. Conclusions

Planar transformer
Introduction

Magnetic inductors and transformers are the fundamental components for PE devices:

- potential applications: high frequency filters, EMC chokes, energy storages, galvanic insulations, etc.
- requirements of mass production: stability of fundamental and parasitic parameters (inductances, resistances, leakage inductances, stray capacitances)
- complicated design process of inductive elements due to the complexity of a magnetic circuit and high frequency interactions between windings

Planar transformer
Design requirements



Geometry of the multilayer planar transformer

Fundamental parameters of the transformer

Item	Value
pri./sec. voltage U_1/U_2	750 V/600 V
pri./sec. current I_1/I_2	1.33 A/1.67 A
output power S_{OUT}	1.00 kVA
operation frequency f_n	500 kHz
turns @ pri./sec. N_1/N_2	14/20
maximum flux density of a magnetic core B_{MAX}	0.49 T
pri./sec. inductance L_1/L_2	48.3 µH /93.0 µH
coupling coefficient k	0.87

The analysed planar transformer:

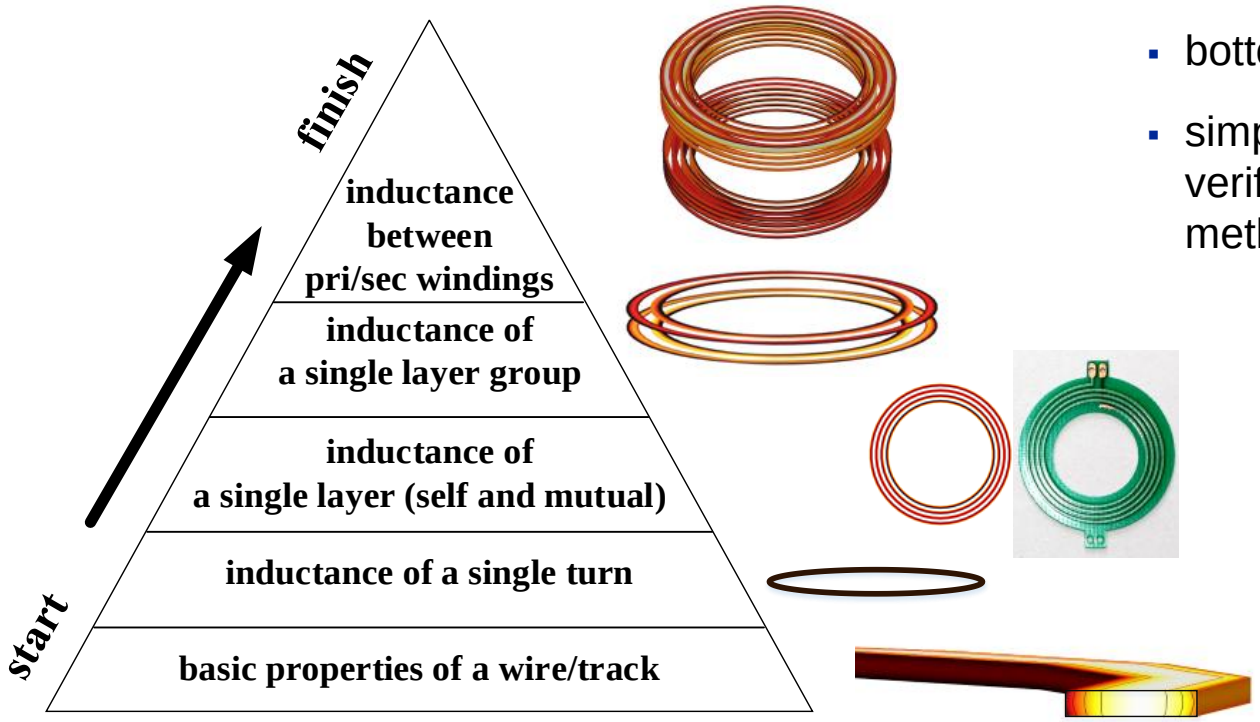
- application: DC/DC Converter with a Resonant Inverter,
- requirements of parameters: the leakage inductance strictly fitted to a load parameters.

Parameters of transformer windings:

- tracks made on a multilayer PCB,
- spiral shape of coils with precisely defined positions

View of a single-layer planar coil with four turns

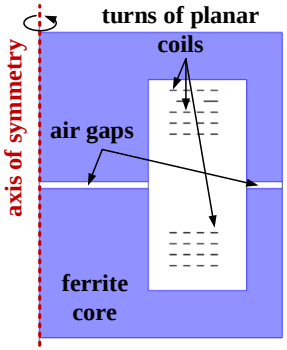
Planar transformer
Steps of the analysis



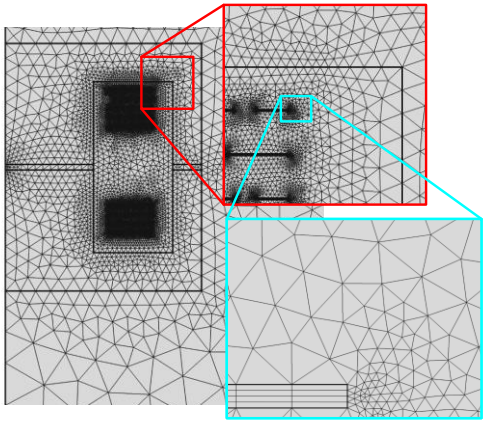
Steps of the analysis:

- bottom-up approach,
- simple models allow the verification of the modelling methodology

Planar transformer
Models description

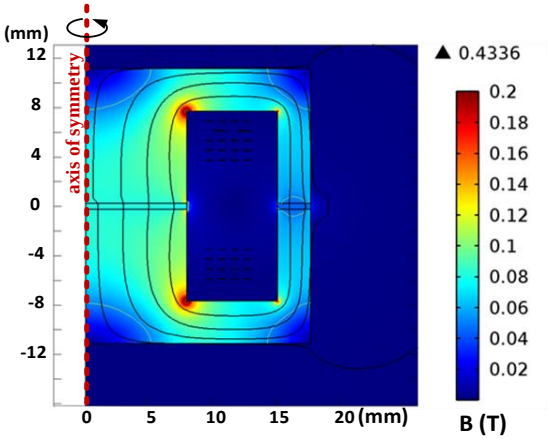


2D axis symmetry model - geometry

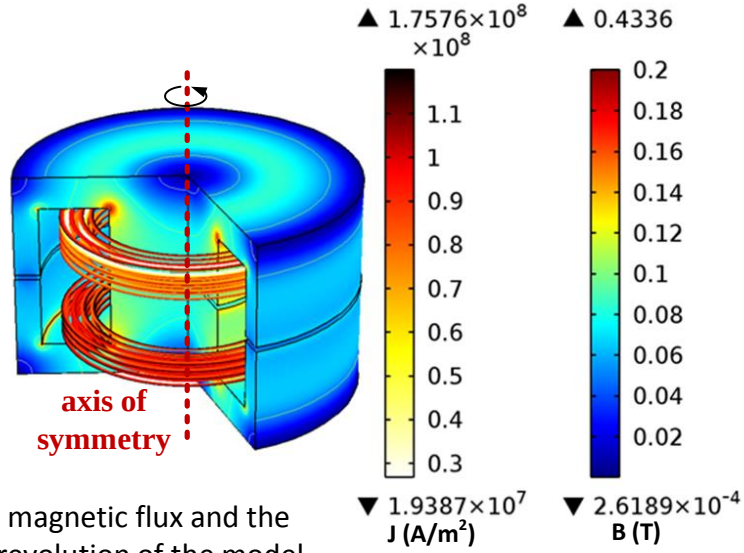


Mesh of the model domain

- All COMSOL models were prepared as a 2D axial symmetry
- AC/DC Module, Magnetic Field Interface, Electrical Circuit Interface, STCD
- Frequency Domain analysis (500 kHz)
- Geometry: parametrized dimensions
- Mesh: quads and triangulars



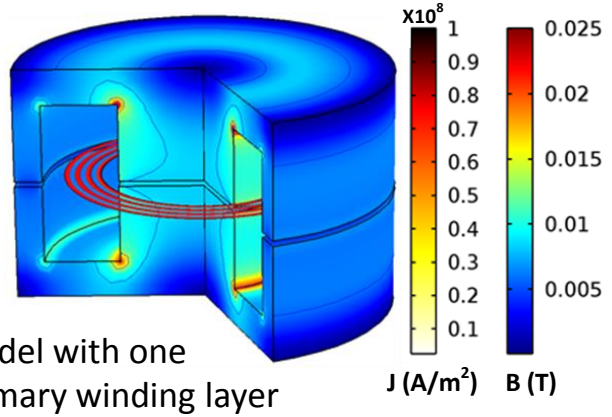
Magnetic flux density in a model



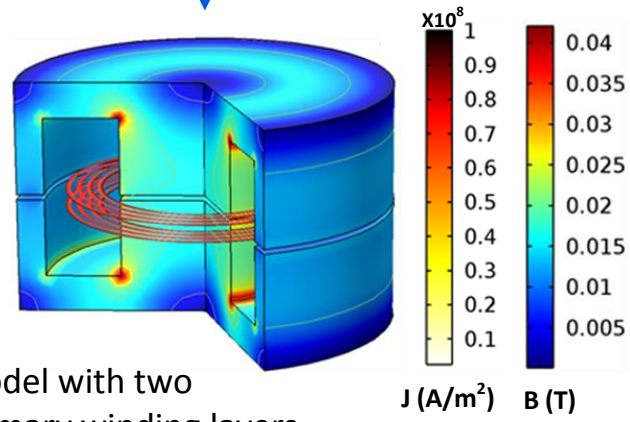
Densities of the magnetic flux and the current in a 3D revolution of the model

Planar transformer
Steps of the analysis

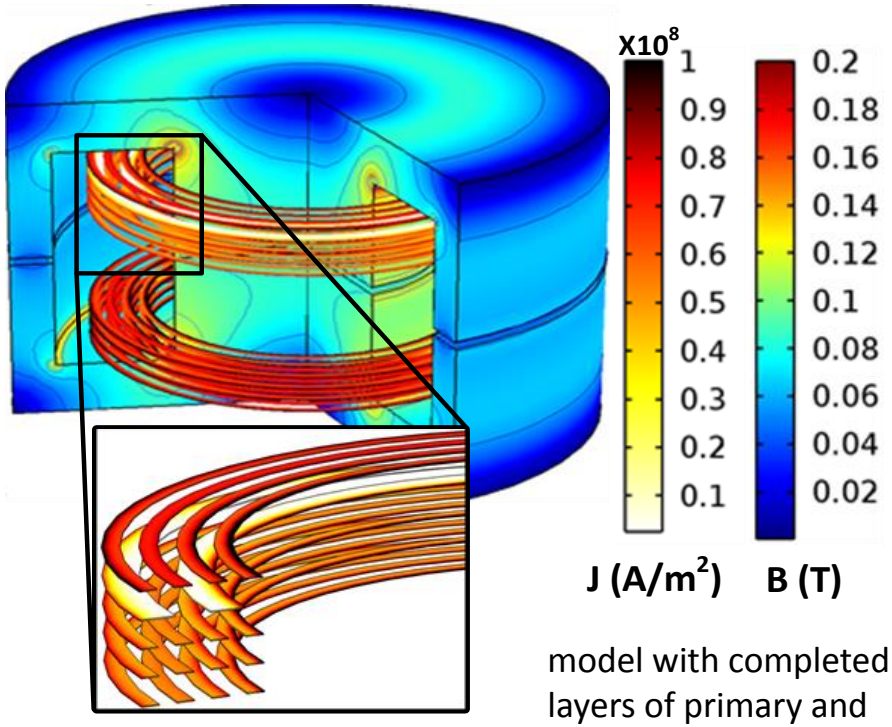
Magnetic flux and current densities for different steps of the transformer geometry analysis:



model with one primary winding layer



model with two primary winding layers

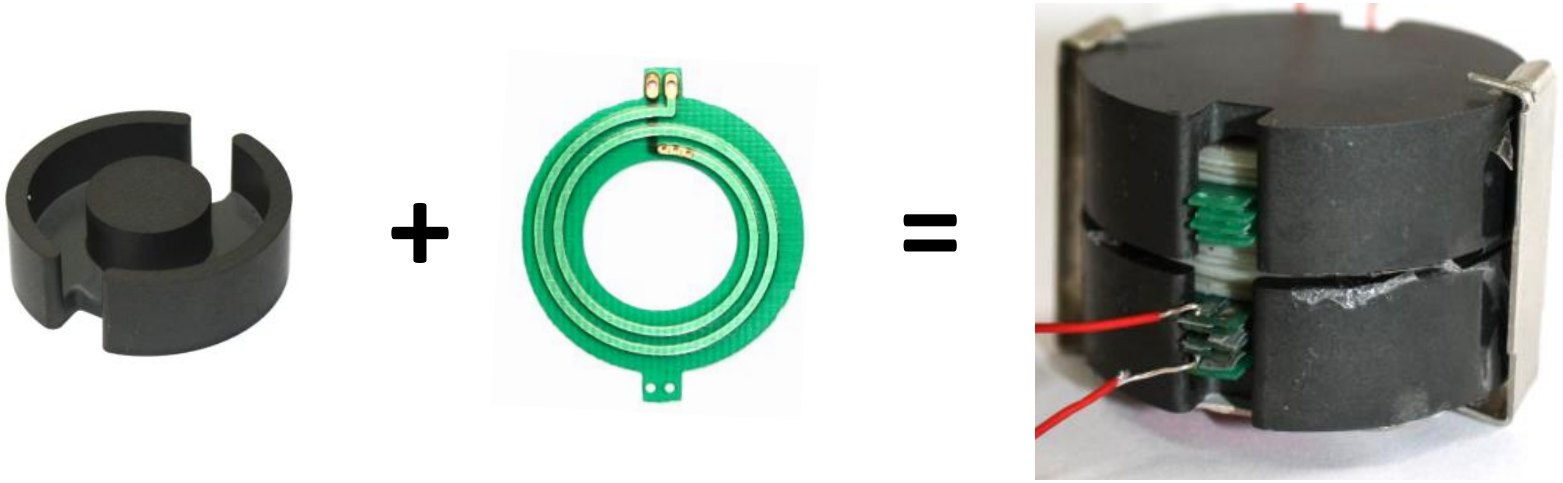


model with completed layers of primary and secondary windings

Planar transformer
Constucted prototype

Parameters of the prototype:

- ferrite P-core 3622; material: N49 (MnZn); B_{MAX} = 490 mT
- windings made of spiral tracks on PCBs
- PCBs stacked alternately with insulating spacers
- simple models allow the verification of the modelling methodology
- scale 1:1 (FEM model to prototype)

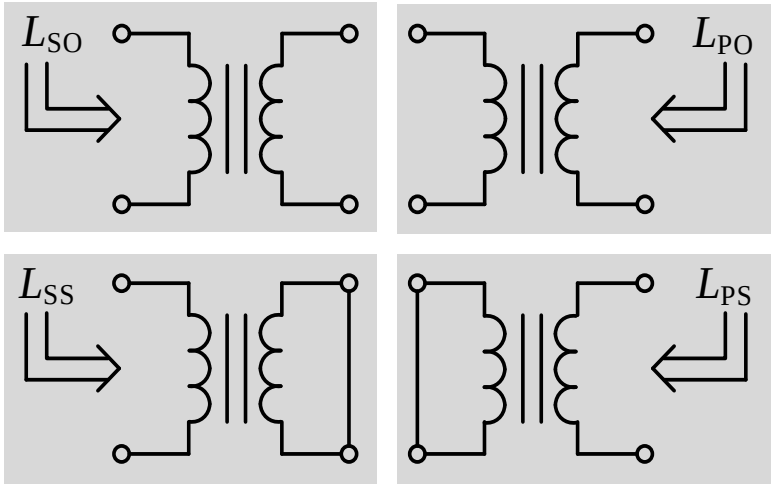


View of the prototype of the multilayer planar transformer and its components: a pot core and a planar coil

Planar transformer
Laboratory test

Comparison of simulation and laboratory test results for four specific configurations of the windings (Electrical Circuit interface used in COMSOL) :

Item	Measured	Simulation	Diff %
LSO	44.02 µH	48.42 µH	10.0
LSS	11.63 µH	13.20 µH	13.5
LPO	83.66 µH	90.02 µH	7.6
LPS	21.93 µH	24.55 µH	11.9



Windings' configurations for the impedance measurements.

Planar transformer
Conclusions

- The comparison of the FEM model results and laboratory measurements shows the reliability of the COMSOL calculations.
- Changes of the transformer windings configurations impact the magnetic field distribution in the core.
- The FEM analyses allow to determine a magnetic core point of operation and predict possible magnetic saturation,
- The FEM calculation of a current density (with skin and proximity effects) allows an optimal design of the cross-section of the transformer windings.

Thank you very much for your attention!

I also would like to invite you to see the poster: 23

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