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

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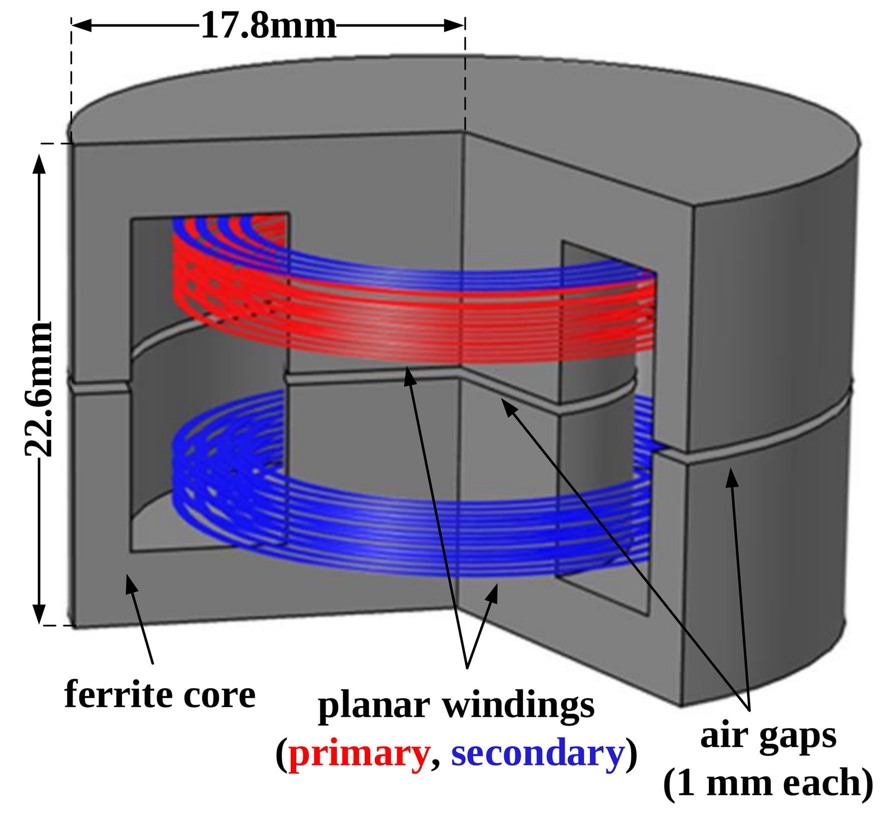
Magnetic inductors and transformers are the fundamental components for PE devices:

- 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)

The analysed planar transformer:

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



Fundamental parameters of 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

Figure 1. Geometry of the multilayer planar transformer

Parameters of transformer windings:

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

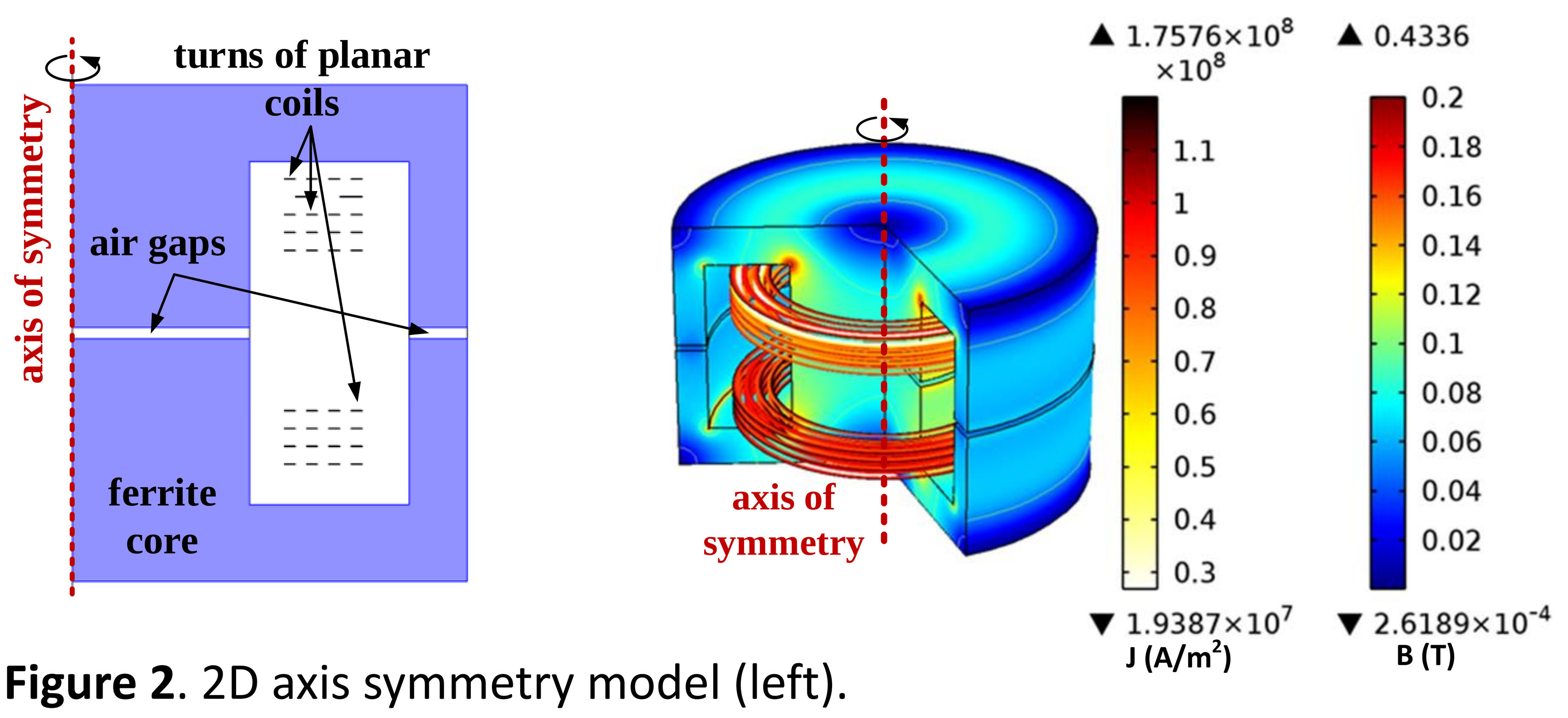


Figure 2. 2D axis symmetry model (left).
Densities of the magnetic flux and the current in a 3D revolution of the model (right).

Parametric study helps to manage the simulation parameters.

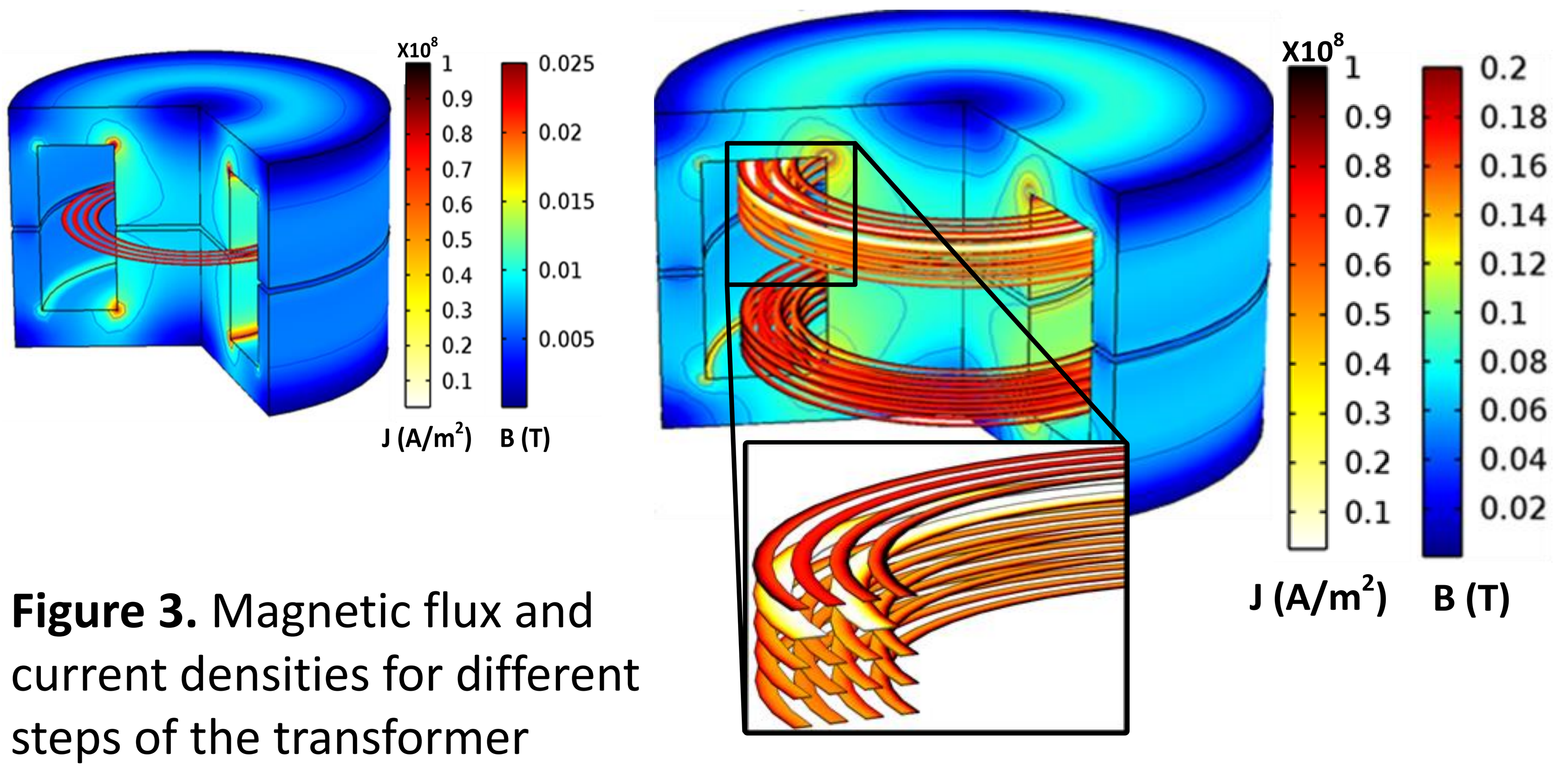


Figure 3. Magnetic flux and current densities for different steps of the transformer geometry analysis: model with one winding layer (left) and with complete layers of primary and secondary winding

Steps of the analysis:

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

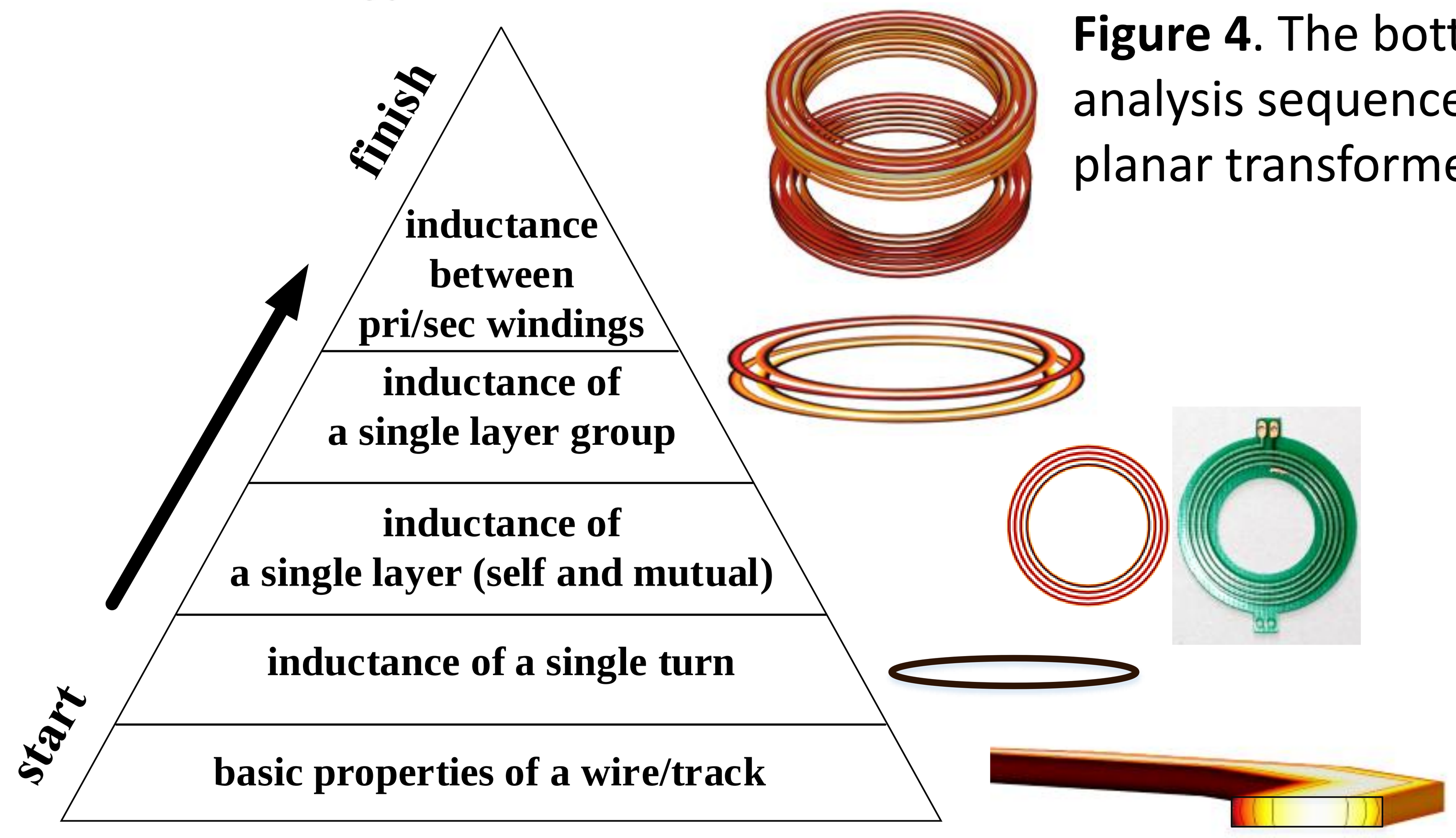


Figure 4. The bottom-up analysis sequence of the planar transformer

Parameters of the prototype:

- ferrite P-core 3622; material: N49 (MnZn)
- windings made of spiral tracks on a PCB
- scale 1:1 (FEM model to prototype)

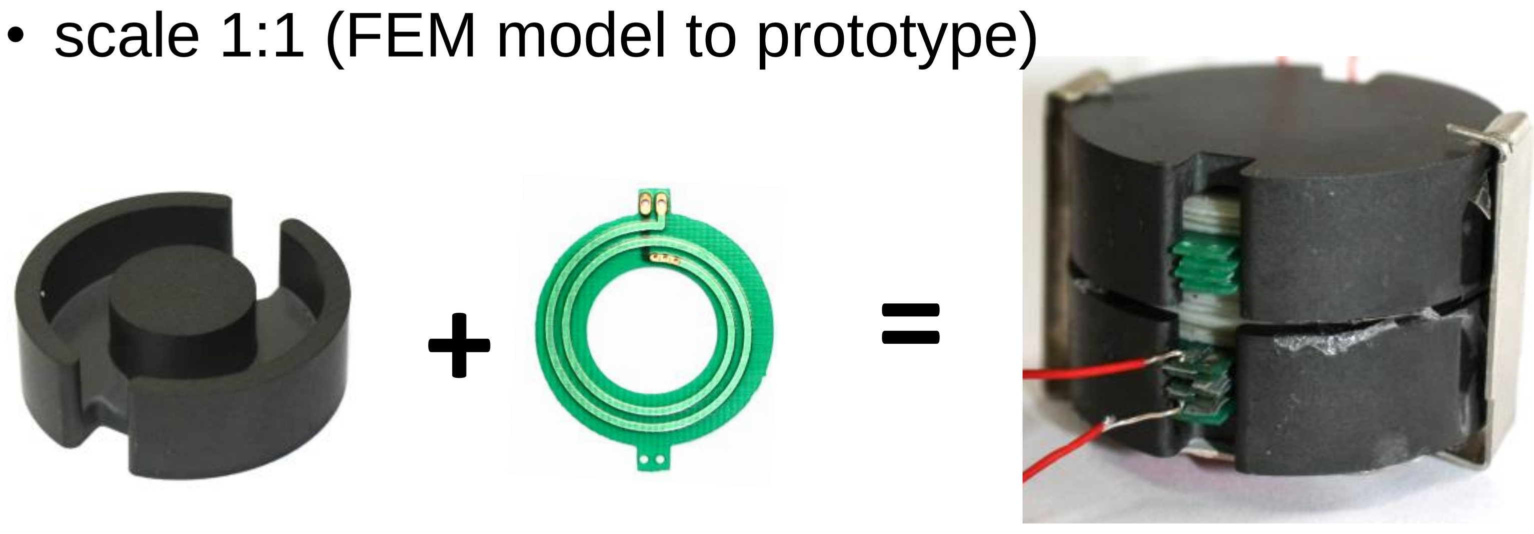


Figure 5. Prototype of the multilayer planar transformer

Comparison of the simulation and the 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

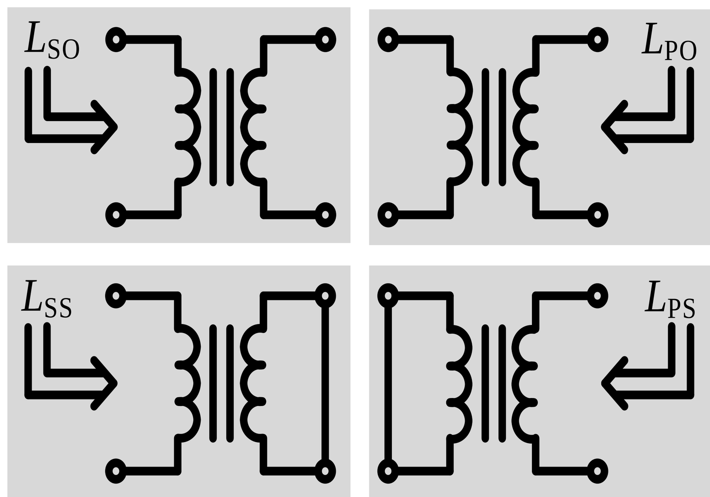


Figure 6. Windings' configurations for the impedance measurements

- 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.

References:
1. H. A. Wheeler, Simple inductance formulas for radio coils, Proc. IRE, vol 16, pp. 1398–1400 (1928)
2. Sunderarajan S Mohan, Maria del Mar Hershenson, Stephen P. Boyd, Thomas H. Lee, Simple Accurate Expressions for Planar Spiral Inductances, IEEE Journal of Solid-State Circuits, vol. 34, pp. 1419-1424 (1999)
3. Jonsenser Zhao, A new calculation for designing multilayer planar spiral inductors, EDN Europe, vol 57 (2010)
4. Ziwei Ouyang, Ole C. Thomsen, Michael A. E. Andersen, Optimal Design and Tradeoff Analysis of Planar Transformer in High-Power DC–DC Converters, IEEE Transactions on Industrial Electronics, vol. 59, pp. 2800- 2810 (2012)
5. Yu Ma, Peipei Meng, Junming Zhang, Zhaoming Qian, Detailed losses Analysis of High-Frequency Planar Power Transformer, 7th International Conference on Power Electronics and Drive Systems, PEDS '07, pp. 423-426 (2007)
6. Nitin Saxena, Electrical Engineering, pp. 191 – 194, University Science Press, New Delhi (2010)
7. SIFERRIT material N49 EPCOS Datasheet: http://www.epcos.com/blob/528856/download/3/pdf-n49.pdf (2006)
8. Agilent 4294 Datasheet: http://cp.literature.agilent.com/litweb/pdf/5968-3809E.pdf (2008)

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