Minisymposium *Optimization and Model Order Reduction in Circuit Design*

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While during the last decades the great enhancements in the field of digital design methodologies and tools have allowed to design larger digital circuits in less time, the analog circuit design methods have not progressed at the same rate. The design of analog electrical circuits needs electronic engineers with a long experience and a wide knowledge of the theories that rule this kind of circuits. However, experimental optimization tools exist; they search the space of solutions for optimal configurations of variables sets, given a circuit netlist provided by the designers. Typical analog integrated circuit optimization problems are computationally hard and require the handling of multiple, conflicting, and non-commensurate objectives having strong nonlinear interdependence. In general it is possible to reformulate integrated circuit design as constrained multi-objective optimization problems defined in a mixed integer/discrete/continuous domain. The hereby employed traditional numerical techniques are becoming too much time-consuming for circuits of industrial complexity. The long computation time required for the optimization of a complete circuit cannot be tolerated especially in the early design stages. For tackling this complexity problem model reduction methods are a promising approach in order to achieve a faster performance evaluation in order to obtain more robust devices within a more efficient design process.

The minisymposium focused on the usage of model reduction techniques in combination with optimization methods. The results are developed in the EU Marie Curie projects SymTecO (Symbolic Techniques for Circuit Optimization) and O-Moore-Nice! (Operational Model Order Reduction for Nanoscale IC Electronics). Both projects address Transfer of Knowledge on Mathematics for Industry.

Paola Barrera from STMicroelectronics in Catania, with Thomas Halfmann and Jochen Broz from the Fraunhofer Institute (ITWM) in Kaiserslautern, presented a talk from SYMTECO on *"A Netlist Reduction Algorithm to Symbolic Circuit Analysis"*, in which new reduction algorithm in the area of symbolic circuit analysis was described. The reduction of a netlist as well as of the model order complexity are important modelling issues which help

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to speed up the process of integrated circuit design [5]. The proposed method eliminated nodes from a netlist topology assuring a user-given accuracy margin. The algorithm was based on the decision diagram derived from the circuit topology and considered low memory storage issues in order to efficiently carry out the simplification. Starting from the application of a spiral inductor test case [1] efficiency was evaluated. The reduced system complexity in terms of netlist nodes and model order encouraged the application to other industrial test cases.

Alberto Venturi from the Fraunhofer Institute (ITWM) in Kaiserslautern, with the contribution of A. Ciccazzo, S. Rinaudo from STMicroelectronics in Catania (Italy) gave a talk from SYMTECO on *"Application of optimization and model order reduction techniques"* in which he explained how given the computation time required for the analysis of a complete circuit can be too long for an adequate use of optimization methods in industrial circuit design, the use of symbolic analysis together with model order reduction techniques could reduce the computational cost and hence make optimization a practicable way in the circuit design. To evaluate the possibilities offered by this technique, a linear test case had been considered: the problem of an inductor simulation had been analyzed by introducing simplified analytical expressions and different optimization algorithms in the fitting/optimization process. Then the technique was applied to a real circuit, a voltage reference, trying to improve the stability of the reference over the temperature.

Jan ter Maten of NXP Semiconductors presented *"Parameterized Model Order Reduction for nonlinear IC models"*. This work was in cooperation with Joost Rommes (NXP) and Michael Striebel (TU Chemnitz) of the O-MOORE-NICE! project and with Tamara Bechtold(NXP), Kasra Mohaghegh (Univ. of Wuppertal) and Zoran Ilievski (TU Eindhoven) of the COMSON RTN-project. He demonstrated Model Order Reduction for a nonlinear system of differential-algebraic equations of a diode chain. While the Trajectory PieceWise Linear method (TPWL) is very fast it also is very sensitive to the change of input signals. The weighting procedure of linear models was pointed out as a key ingredient that needs further research in order to further improve the method. Proper Orthogonal Decomposition (POD) much better preserves nonlinearity, but needed significant adaptions (called Adapted Missing Point Estimation) to become comparable in speed to TPWL [7]. The resulting method also is much more accurate than TPWL and behaves better to changes of the input. The snapshots collected in POD can also be used to efficiently obtain a first impression of sensitivities of objective functions [6].

Luciano De Tommasi from Antwerp and Ghent University – IBBT, Belgium, gave a talk entitled *"Optimization in surrogate model building for RF circuit blocks"* (joint O-MOORE-NICE! project work with D. Gorissen, J. Croon and T. Dhaene). Surrogate models, also known as response surface models, have become a cost effective alternative for replacing expensive computer simulations when exploring the design space, performing what-if analysis, optimization and sensitivity analysis. Relevant aspects which have

been investigated include model type selection [2, 3], adaptive sampling [2] and optimization of model parameters [2–4] (adaptive modeling).

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