ScuDo

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XXXIV Cycle

Stability and passivity preserving modeling techniques for fast power integrity simulations

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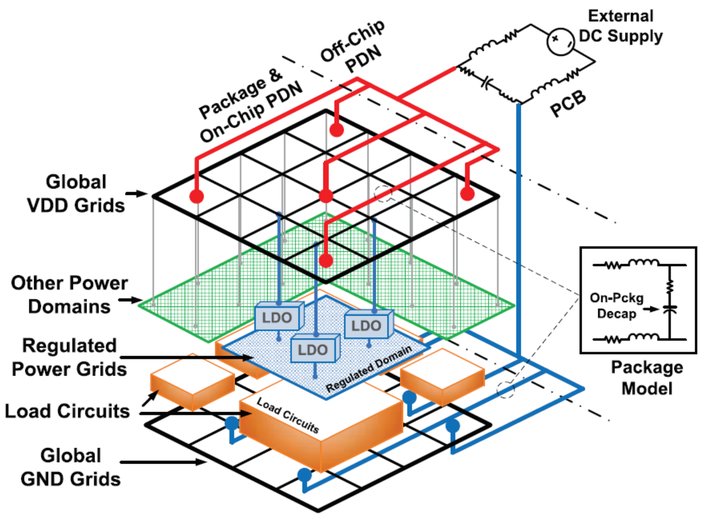
Research context and motivation

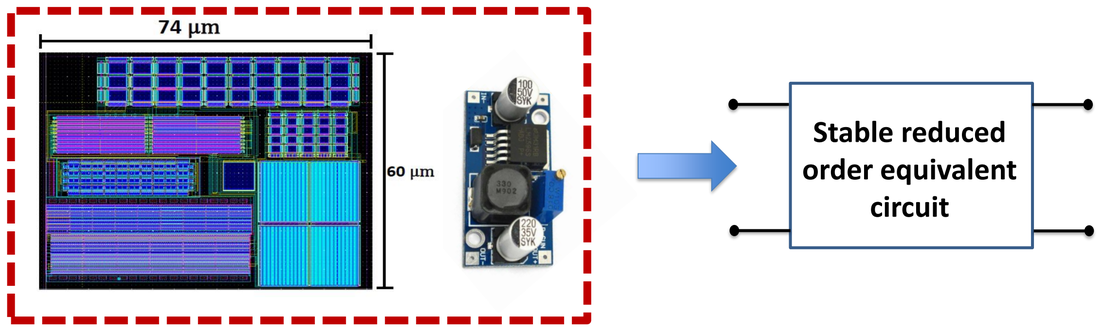
- **Power integrity assessment** is a fundamental step in electronic systems design.
- Must be performed through accurate system-level **transient analyses**.
- The **computational burden** required by these simulations is **overwhelming** due to the complexity of the involved systems.
- **Alternative simulation frameworks** are required, so that detailed circuit-level SPICE simulations can be avoided.
- Modeling techniques must be developed in order to obtain guaranteed **stable and reliable simulations** of complete power distribution systems, **including distributed voltage regulators**.
- **Behavioral reduced-order models** are very promising for such application.



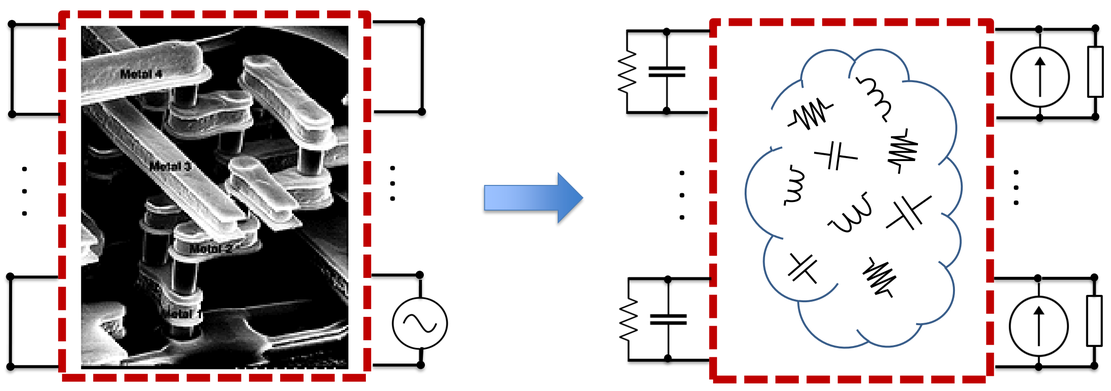
A PDN scheme from : S.Lai, B. Yai; P.Li. ‘’*Stability assurance and design optimization of large power delivery networks with multiple on-chip voltage regulators”,* IEEE ICCAD, San Jose, 5-8 November 2012 pp. 247-254.

Addressed research questions/problems

- How to obtain **robust behavioral models** of linear (power distribution network with all post-layout parasitics) and non-linear (voltage regulators) circuit blocks.



- How to guarantee the reliability of large MIMO behavioral models of passive structures under **different feedback interconnection** conditions.



- How to guarantee the properties of **passivity** (if required) and **stability** of the derived models and their interconnections

Future work

- Guarantee the **stability of linear time-varying** behavioral models of active circuit blocks
- Systematically generate behavioral models for passive electrical structures with **low sensitivity to the loading conditions**
- Fast and accurate simulation of **switching circuits**

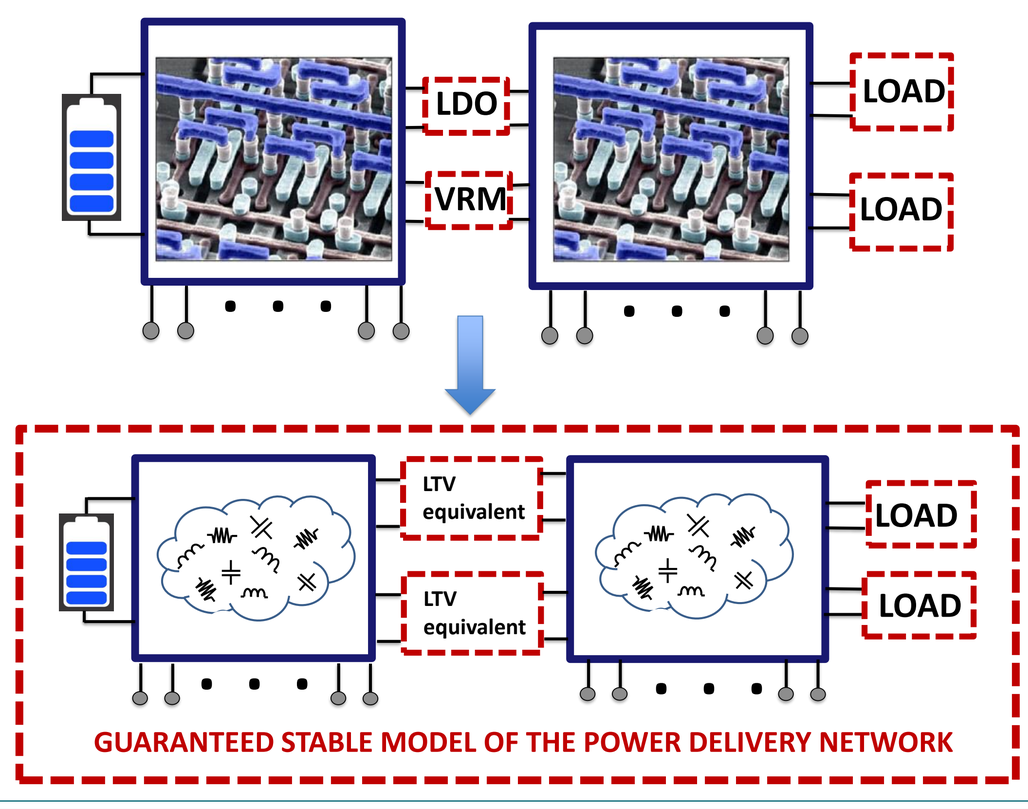
List of attended classes

- 01QRQRV – Compressed sensing: theory and applications (28/08/2019, 4)
- 01LCPRV – Experimental modeling: costruzione di modelli da dati sperimentali (08/04/2019, 6)
- 01QTEIU – Data mining concepts and algorithms (14/12/2018, 4)
- 01SQKNG – Ottimizzazione per machine learning (02/09/2019, 6)
- 01ROCRT– Scomposizione di tensori: algebra, geometria e matematica computazionale (19/09/2019, 4)
- 01TCORV – Surrogate and compact modeling: theory for the user (12/07/2019, 4)

Novel contributions

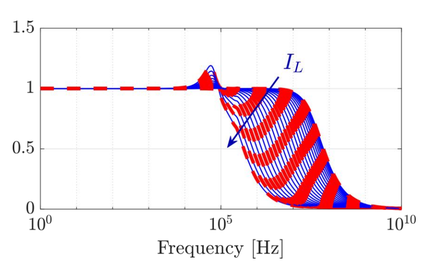
Development of a novel **simulation framework**

- for **large-scale power delivery** system analysis
- based on guaranteed stable **interconnection of behavioral models**
- based on reduced-order parameterized linear time-varying approximations to replace non-linear components (**LDOs**, **switching power converters**)
- allowing for **fast transient simulation** of large MIMO systems under different working conditions, including sensitivity, what-if, and optimization.

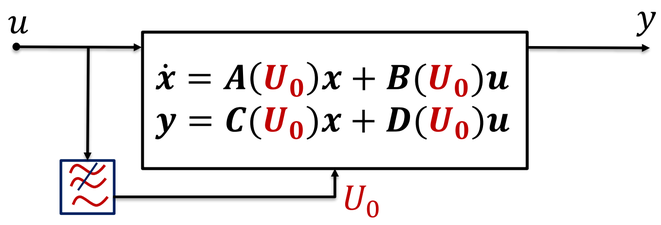


Adopted methodologies

- **Parameterized Macromodeling** (Parameterized Sanathanan-Koerner iteration)



- **Bias Dependent Equivalent Circuits**
  Published results: speedup **675X** in runtime for a real LDO circuit



- Bilinear Matrix Inequalities for the **energetic characterization of linearized models**
- **Modal Vector Fitting**

Submitted and published works

- **Journal**: T. Bradde, S. Grivet -Talocia, G. C. Calafiore, A. Proskurnikov, Z. Mahmood, L. Daniel , “*Bounded Input Dissipativity of Linearized Circuit Models*”, IEEE TCAS I. Submitted 7th August 2019.
- **Journal**: A. Zanco, S. Grivet-Talocia, T. Bradde, M. De Stefano. “*Enforcing passivity of parameterized LTI macromodels via Hamiltonian-driven multivariate adaptive sampling*”. IEEE TCAD, 2018 (early access), pp. 1-14.
- **Journal:** E. Fevola, A. Zanco, S. Grivet-Talocia, T. Bradde, M. De Stefano. “*An Adaptive Sampling Process for Automated Multivariate Macromodeling Based on Hamiltonian-Based Passivity Metrics*”. IEEE TCPMT, 2019 (early access), pp. 1-14.
- **Conference**: A. Zanco, S. Grivet-Talocia, T. Bradde, M. De Stefano. “*Multivariate macromodeling with stability and passivity constraints*”. In: IEEE SPI2018, Brest, 22-25 May 2018. pp. 1-4.
- **Conference**: A. Zanco, S. Grivet-Talocia, T. Bradde, M. De Stefano, “*On stabilization of parameterized macromodeling*”. In: IEEE SPI 2019, Chambery, 18-21 June 2019. pp. 1-4. **BEST STUDENT PAPER AWARD**
- **Conference**: E. Fevola, A. Zanco, S. Grivet-Talocia, T. Bradde, M. De Stefano,” *A 3D passivity-based adaptive algorithm for automated parameterized macromodeling of electromagnetic structures”*. ICEAA 2019, Granada, 9-13 September 2019, pp. 1-4.
- **Conference**: T. Bradde, S. Grivet-Talocia, M. De Stefano, A. Zanco,” *A Scalable Reduced-Order Modeling Algorithm for the Construction of Parameterized Interconnect Macromodels from Scattering Responses*”. IEEE EMC SI- PI 2018. Long Beach, 30 July – 3 August 2018. pp. 650-655. **BEST PAPER AWARD**
- **Conference**: M. De Stefano, S. Grivet-Talocia, T. Bradde, A. Zanco, “*A framework for the generation of guaranteed stable small-signal bias-dependent behavioral models*”. In: IEEE EuMIC 2018, Madrid, 23-25 September 2018. pp. 142-145.
- **Conference**: T. Bradde, P. Toledo, M. De Stefano, A. Zanco, S. Grivet-Talocia, P. Crovetti, “*Enabling fast power integrity transient analysis through parameterized small-signal macromodels*”, EMC Europe, Barcelona, 2-6 September 2019, pp.1-6

POLITECNICO DI TORINO

PhD program in
Electrical, Electronics and Communications Engineering