Modeling and Co-Simulation of Power Distribution Networks for Digital and Mixed Signal Systems

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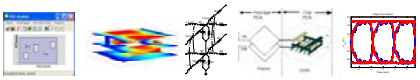
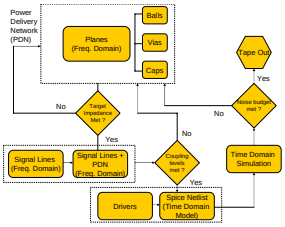
Objective

- Co-simulation of Signal And Power Delivery Networks in Integrated Microsystems
- Modeling of Electromagnetic Interference
- Mitigation of Substrate Noise



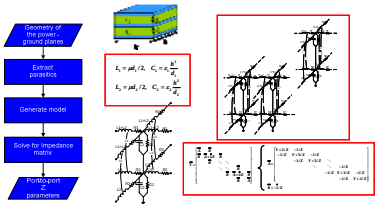
Develop Fast/accurate CAD tools | Simulation of large-scale structures | System-level Simulation | Novel designs for better performance

Co-Simulation Methodology



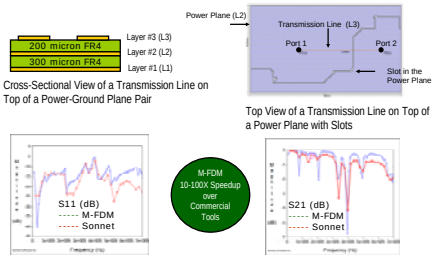
Ref: M. Swaminathan and E. Engin, "Power Integrity Modeling and Design for Semiconductors and Systems", Prentice Hall 2007.

M-FDM: Frequency-Domain Package PDN Simulator



E. Engin, K. Bharath and M. Swaminathan, "Multilayered Finite-difference Method (MFDM) for Modeling of Package and Printed Circuit Board Planes", IEEE Trans. EMC, Vol. 49, May 2007

M-FDM: Performance

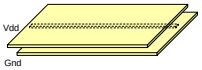


Cross-Sectional View of a Transmission Line on Top of a Power-Ground Plane Pair

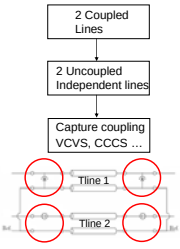
Top View of a Transmission Line on Top of a Power Plane with Slots

Modal Decomposition Method

Example: Stripline Configuration[1]



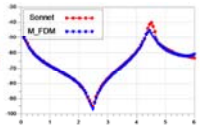
- Using multiconductor transmission line theory, transform coupled transmission lines to uncoupled lines.
- Capture the coupling using controlled sources.



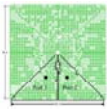
K. Bharath, E. Engin, M. Swaminathan, K. Uriu, T. Yamada, "Computationally Efficient Power Integrity Simulation for System-on-Package Applications", DAC 2007

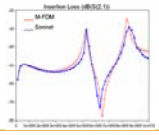
Modal Decomposition Results

Package Layouts



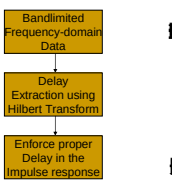
Geometry of Split Planes

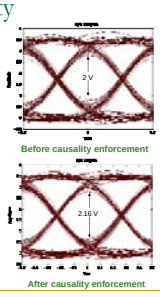




Delay Based Causality

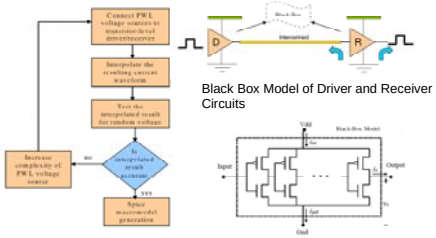
Delay Enforcement Methodology





R. Mandrekar, K. Srinivasan, E. Engin, M. Swaminathan, "Causality enforcement in transient co-simulation of signal and power delivery networks", IEEE Transactions on Adv. Packaging

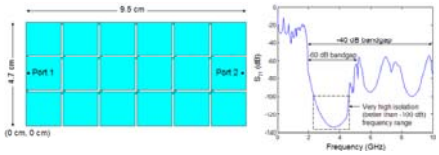
Non-Linear Driver Macromodeling



Black Box Model of Driver and Receiver Circuits

Noise Isolation

- Excellent Isolation (-100 dB ~ -140 dB)
- Broad Stopband (over 10 GHz for - 40 dB stopband)



Jinwoo Choi, Madhavan Swaminathan and Vinu Govind, "Mixed-signal systems with alternating impedance electromagnetic bandgap (AI-EBG) structures for noise suppression/isolation", US Patent 7,253,788, Aug '07

Mixed-Signal System Integration Using AI-EBG based Power Distribution Network

- Mixed-Signal System Test Vehicles
  - 3 metal layers.
  - FPGA (Digital) driving 300 MHz bus.
  - LNA (RF) operating at 2.13 GHz.
  - AI-EBG based common PDN used.

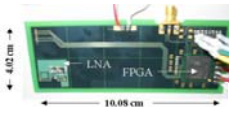
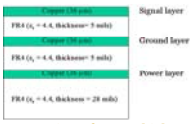
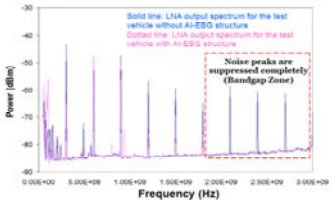


Photo of mixed-signal system with AI-EBG structure



Cross section of test vehicle

Noise Suppression using AI-EBG Structure based Power Distribution Network



Jinwoo Choi, Madhavan Swaminathan and Vinu Govind,"Electromagnetic bandgap structure for isolation in mixed-signal systems", US Patent 7,215,301, May '07

Summary

- Design of high-performance analog/digital circuits in the package or in the chip requires careful understanding of the effects of the nonideal nature of the power and signal delivery networks (PDN/SDN) in the package and in the chip
- The following topics were addressed:
  - SDN/PDN Co-Simulation using Modal Decomposition Technique
  - Accurate simulation including delay based causality enforcement
  - Noise mitigation using EBG structures
  - Non-linear Driver macromodeling
- The authors would like to thank Ege Engin and Krishna Bharath

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