High Frequency Characterization and Modeling of On-Chip Interconnects and RF IC Wire Bonds

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Continuous scaling of transistors combined with increased chip area results in the ratio of global wire delay to gate delay increasing at a super-linear rate. For sub-0.25 μm technology and gigahertz clock frequency VLSI, interconnects exhibit transmission line behavior and parasitic inductance of the wires cannot be ignored. This inductance causes additional net delays, over-shooting waveforms, inductive cross talk, and increased ground bounce effects. Simple RC models are no longer adequate for simulation of modern VLSI circuits. In addition, parasitic inductance of IC packages, such as bonding wires, imposes a limit on the performance of circuits at high frequencies. For radio frequency (RF) circuit design, bonding wires are also used as components in the matching network. Therefore, it is necessary that these inductance effects involving on-chip and off-chip interconnects be correctly extracted and their electrical performance be modeled accurately.

In this work, 3D geometry-based physical extraction is exploited in the modeling of on/off-chip inductance and capacitance. The process can be fully automated and IC layout design and processing flow are used as input data. Electromagnetics field solvers are used in the extraction process. Analytical formulae for self/mutual inductance are derived to estimate inductance in order to establish guidelines for circuit designs as well as for screening of inductance effects in CAD tools. The accuracy of these formulae has been established by comparison with numerical simulation and measured data from test chips. Design insight for minimizing interconnect inductance is demonstrated.

Modeling of on-chip inductance for real chips with power/ground lines and grids is presented. Equivalent circuits for on-chip inductance and bonding wires are developed and verified by measurement of fabricated chips. Excellent agreement between modeled and measured data is achieved for frequencies up to 10 GHz.