A Quasi-Monte Carlo Solver for Partial Inductances in IC Interconnect Structures

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Abstract— With operating frequencies reaching the multi-GHz range, the role of on-chip inductance is becoming increasingly significant. The inclusion of inductance in the interconnect model is particularly necessary in clock distribution networks and also in signal and power lines, which have wide wires and hence low resistance. The principal complexity in the extraction of inductance is that one needs to have the knowledge of the currents in advance. However, the current distribution in today’s complicated interconnect structures depends on the device and interconnect resistances, inductances and capacitances. Therefore, the modeling of the current distribution is a difficult proposition. The conventional approaches to inductance extraction involve “loop inductance” models, which make various simplifying assumptions in determining the current distribution. A radically different approach to the modeling of inductance has been suggested in literature, which precludes the need to determine the current distribution in advance. This approach is based on the Partial Element Equivalent Circuit (PEEC) method. In this approach, the interconnect lines are divided into wire segments and self and mutual inducances are extracted for these “partial elements.” It has been demonstrated in literature that this PEEC-based approach is more accurate than the loop inductance models.

In a previous work [1], we developed a Monte Carlo algorithm for the stochastic extraction of the mutual inducances of these “partial elements.” In this work, the mutual inductance between two “partial elements” was formulated as a six-dimensional integral under the “zero-frequency approximation,” and this six-dimensional integral was estimated through Monte Carlo integration. However, this integration was performed with pseudorandom numbers and the statistical sampling error was of the order of \( N^{-1/2} \), \( N \) being the number of integration samples. In this work, we improve our previously-developed algorithm through the use of quasirandom numbers. We present our work for three quasirandom (Halton, Sobol and Niederreiter) sequences where the statistical error of integration is observed to be of the order of \( N^{-1} \). The increased convergence rate coupled with the almost linear rate of parallelization for the Monte Carlo method makes this algorithm very attractive for the extraction of partial inducances of IC interconnect structures.

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