Symbolic analysis and model order reduction of electronic networks with parameter disturbances

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Motivation and aim

With the trend from micro- to nanoelectronics the control of production deviations can not keep pace with the reduction of the absolute sizes of semiconductor devices. This results in a drastic increase of relative parameter variations and thus in a decreasing yield of produced circuits due to system behaviours beyond the specifications.

Therefore the aim is to assist designing of robust circuits to minimize the amount of defective circuits and therefore to increase the yield. The Fraunhofer ITWM considers electronic circuits with statistical process variations at system level using its EDA software Analog Insydes, which allows analysis and symbolic approximation of nominal analogue circuits. This has been extended to regard parameter variations as well.

By reducing a system to its most important terms while keeping the statistical properties of the parameter variations the simulation time significantly decreases and new insights in the system behaviour are generated. Both features are critical for a successful development of robust circuits and to optimize nanoelectronic systems.

Results

For the construction of a symbolic behavioural model with parameter tolerances at system level the netlist, the parameters and their distributions have to be extracted from both, device and circuit level. That can be done by the extension of the interface between Cadence (commercial software tool for design of electronic circuits) and Analog Insydes (own software for symbolic analysis of electronic circuits). This allows handling continuous and discontinuous distributions from measurements of correlated and uncorrelated parameters. The generated symbolic model equations can be used for large signal, small signal, transient or sensitivity analysis of the circuit. The latter one yields an approximation of the variation of the output behaviour depending on the parameter distributions. Additionally the model equations can be reduced with respect to parameter distributions by a mixed numeric-symbolic algorithm. This is done by taking data from sensitivity analysis to avoid using...
expensive Monte-Carlo simulations. Statistical error functions in the algorithm guarantee a good approximation of the original system. The symbolic form as well as the statistical behaviour of the model are kept. Due to its decreased complexity, the resulting behavioural model allows more efficient simulations and analysis of the system and finally leads to a deeper understanding of the system behaviour.

Example

A voltage limiter circuit, which limits the output voltage to 3.5 V, is considered here as an example of a system with parameter tolerances. The sizes of the 30 MOSFET transistors and the values of the two resistors are normal distributed with standard deviations of 1-2%. For a given rather tight error bound the numeric-symbolic reduction routine cancels 69.2% of all terms and 59.2% of the equations. This leads to a simulation time which is shortened by a factor 12, without changing the behaviour and losing system parameters.

The diagram shows the simulation results of the original (green) and the reduced model (red) for several samples of the parameter distributions. With increasing the input voltage the circuit limits the output voltage to 3.5 V. As shown in the zoomed area, the distribution of the output voltage of the original system is well approximated by the corresponding one of the reduced system.

<table>
<thead>
<tr>
<th>number of equations</th>
<th>simulation time</th>
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</thead>
<tbody>
<tr>
<td>original model</td>
<td>353</td>
</tr>
<tr>
<td>reduced model</td>
<td>144</td>
</tr>
<tr>
<td>reduced by</td>
<td>59.2%</td>
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</tbody>
</table>

References