CASA-Report 10-41
July 2010

Predicting 'parasitic effects' in large-scale circuits

by

E.J.W. ter Maten, J. Rommes
Smaller transistors allow electronics companies to produce faster, more energy-efficient chips and devices. Simulation tools capable of predicting the so-called ‘parasitic effects’ which emerge in such chips are crucial to their commercial viability, say Dr Jan ter Maten and Dr Joost Rommes.

Predicting ‘parasitic effects’ in large-scale circuits

Reducing physical circuit size is a goal of enormous relevance to the electronics industry. Smaller circuits allow developers to put more functionality on the same area, meaning the eventual device is faster, more energy-efficient and produces less heat. However, the use of smaller circuits is not without its problems, and their effectiveness in commercial applications depends on rigorous research into their underlying structure. “Smaller, faster components generate what we call parasitic effects. Because everything is closer together you get undesired coupling between components. It is important to understand these effects before producing a device, because correcting them afterwards costs a lot of time and money – if these failures appear in the product then they have to be
completely redesigned. We want to develop tools to predict these undesired parasitic effects,” explains Dr Joost Rommes of the O-MOORE-NICE project. An EU-funded initiative bringing together both academic and industrial partners, O-MOORE-NICE is focused primarily on commercial problems. “One of the main goals of our project is to reduce simulation time, while we are also working to generate more precise results on circuit behaviour,” says Dr Jan ter Maten, another key figure within the project. “There is always a trade-off between these two considerations; reducing simulation time can be achieved by simplifying specific building blocks, but at the same time we must be able to guarantee that the outside of that block will still behave in the required way.”

Industrial problems
Sophisticated mathematical models capable of accurately describing the dynamical processes and interactions of electrical devices have gone a long way to addressing this issue. However, this is work which the commercial sector has, until now, not fully capitalised upon, a point on which Dr ter Maten is keen to expand. “We aim to extend several techniques so as to make them applicable to industrial problems. Several of these techniques were developed as long as 25 years ago, but industry is only slowly picking them up. The main techniques were developed for linear problems; hence we started by solving linear problems efficiently, but also wanted to use the techniques for non-linear problems and in optimisation and statistical environments, which require parameter variability,” he outlines. The project was faced with several new challenges in this work. “Our blocks had several terminals,” says Dr ter Maten. “But the theory at first was established only for two pins – where we put one pin in and took one pin out. On the surface it looked like a very simple situation, but we had several pins – that was a big problem, but we have since solved it.”

This is work which keeps the wider agenda of industrial development firmly in mind. Software has been developed, modified and tested on several industrial problems, reflecting the project’s commitment to practically-focused research, something which brings real benefits to all the O-MOORE-NICE partners. “There is often a gap between what is being developed by universities and what is being used and/or needed by industry. Our applications are usually quite a way ahead of the methods that are being developed. One of the main things we wanted to work on was bringing industry and academia closer together,” says Dr Rommes. “On the one hand commerce benefits from the development of methods in academia that can be tailored to its needs, and on the other commerce can deliver problems and real-life examples to academia for which they can develop and enhance methods.”

The mutually beneficial nature of this relationship shows that the academic and commercial sectors can work together effectively. Knowledge transfer forms a key part of the project’s agenda, with research into both the behaviour of entire systems and their individual components ongoing. “The typical design of an electronic device starts at the top level; then you have functional requirements, then your system, right down to the physical layout level, where you have a verification step. Ideally you would do this verification at the top level where you have all the details. This is a significant challenge – in some cases you cannot do it, so at some point you have to stop and predict the results of the complete system based on the results of the sub-systems,” explains Dr Rommes. A number of methods have been developed that take the verification level one step higher, so that parasitic effects can be included together with functional performance; behavioural model order reduction provides a clear example. “Behavioural model order reduction applies to a complex system but we are only interested in a few of its properties. We want to make a black box of that system, and then only model the behaviour that we’re interested in,” says Dr Rommes. “There are oscillator coupling problems in many chips for example: if there are multiple complex devices then they start to interact with each other. Now we can model this interaction relatively easily without needing to take the whole system into account.”

Behavioural models
These behavioural models can be used to accurately describe oscillator interaction, to illustrate just one
potential application, a much faster approach than using an exact model. While this is an important part of the project's work, other methods are also being developed, including model order reduction, which differs from behavioural model order reduction largely in terms of the number of elements involved. “The oscillator is basically a very small system, but because it is non-linear it is very difficult to simulate it. But that is on what we call the schematic level – now if you want to include parasitic effects then these oscillators become very large models, because you have to include all these parasitic effects, or side-effects. These side-effects are typically linear. That’s where we use model order reduction; we make a model for the side-effects,” says Dr Rommes. A third method focused on response surface modelling of RF building blocks. A black box abstraction was tuned to give for certain inputs accurate output clear specifications if they are to meet commercial needs. “Several technologies and transistor sizes are available, the question of which particular type is applied depends on the needs of the end user. The automotive and aerospace industries typically use quite old technologies and reliability is their key criteria, whereas mobile phones – which require very small semiconductors – use more advanced technologies,” says Dr Rommes. “If a chip doesn’t function well

We aimed to extend several techniques so as to make them applicable to industrial problems. Several of these techniques were developed as long as 25 years ago, but industry is only slowly picking them up. The available techniques could only be used for linear problems.”

results. “When you understand the underlying problem you have to translate it into mathematical terms and can try to solve it; when you have done that you then have to report back to the owner – the designer or the electronics engineer,” outlines Dr Rommes. “In many applications we realise that we have in fact solved the wrong problem; so there is a difficulty of process, of giving feedback to both parties.”

This is an issue which further underlines the importance of close collaboration between academia and commerce. Based themselves at NXP, the Dutch semiconductor manufacturer, both Dr Rommes and Dr ter Maten say that their work is relevant to a wide range of applications, meaning researchers require it will badly affect a clients' image. Our clients insist on 100 per cent reliability,” stresses Dr ter Maten. While this grows increasingly difficult to achieve at smaller scales, Dr Rommes says there is still room for further development. “We have to make trade-offs: the physical limit of the size of a device is about 9 nanometres – you cannot make semiconductors smaller than that with current technologies. But we must also be aware that the smaller the technology the less mature it is, so there will be several effects that are not well understood,” he acknowledges. “On the one hand it gives you great potential with respect to speed, efficiency and size, but on the other you can get a lot of unexpected side-effects. We have to keep these kinds of practical issues in mind.”

At a glance

Full Project Title
Operational MOdel Order REduction for nanoscale IC Electronics (O-MOORE-NICE!)

Project Objectives
• Behavioural Modelling of main features of a complex system
• Extend Model Order Reduction to multi-terminal problems, include nonlinearity and parameterization
• Response surface modelling of RF building blocks

Project Partners
• NXP Semiconductors, Eindhoven, The Netherlands (Dr Joost Rommes, Dr Jan ter Maten)
• Chemnitz University of Technology, Germany (Dr Michael Striebel, Professor Peter Benner)
• University of Antwerp, Belgium (Dr Luciano De Tommasi, Professor Tom Dhaene)
• Eindhoven University of Technology, The Netherlands (Dr Davit Harutyunyan, Professor Wil Schilders)

Contact Details
Project Coordinators,
Joost Rommes, Dr Jan ter Maten
NXP Semiconductors
High Tech Campus 46 – 210
5656 AE Eindhoven
The Netherlands
T: +31-40-2729898
E: Joost.Rommes@nxp.com
E: Jan.ter.Maten@nxp.com
W: http://sites.google.com/site/rommes/
W: http://home.iae.nl/users/termaten/publications.html

Dr Jan ter Maten (left)
Dr Joost Rommes (right)

Project Coordinators
Dr Jan ter Maten has a Ph.D. in Mathematics (1984, Utrecht University)
Dr Joost Rommes has a Ph.D. in Mathematics (2007, Utrecht University)

Both work on methods for analogue circuit design and simulation.
PREVIOUS PUBLICATIONS IN THIS SERIES:

<table>
<thead>
<tr>
<th>Number</th>
<th>Author(s)</th>
<th>Title</th>
<th>Month</th>
</tr>
</thead>
<tbody>
<tr>
<td>10-37</td>
<td>A. Bergant</td>
<td>Water hammer and column separation due to accidental simultaneous closure of control valves in a large scale two-phase flow experimental test rig</td>
<td>July ’10</td>
</tr>
<tr>
<td></td>
<td>J.M.C. van ‘t Westende</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>T. Koppel</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>J. Gale</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Q. Hou</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Z. Pandula</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>A.S. Tijsseling</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10-38</td>
<td>A.S. Tijsseling</td>
<td>Acoustic resonance in a reservoir-pipeline-orifice system</td>
<td>July ’10</td>
</tr>
<tr>
<td></td>
<td>Q. Hou</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>B. Svingen</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>A. Bergant</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10-39</td>
<td>A. Keramat</td>
<td>Investigation of transient cavitating flow in viscoelastic pipes</td>
<td>July ’10</td>
</tr>
<tr>
<td></td>
<td>A.S. Tijsseling</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>A. Ahmadi</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10-40</td>
<td>V. Chalupecký</td>
<td>Multiscale sulfate attack on sewer pipes: Numerical study of a fast micro-macro mass transfer limit</td>
<td>July ’10</td>
</tr>
<tr>
<td></td>
<td>T. Fatima</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>A. Muntean</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10-41</td>
<td>E.J.W. ter Maten</td>
<td>Predicting 'parasitic effects' in large-scale circuits</td>
<td>July ’10</td>
</tr>
<tr>
<td></td>
<td>J. Rommes</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Ontwerp: de Tantes, Tobias Baanders, CWI