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Analogue Behavioural Modelling for Electronic Circuits

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Introduction

The goal of this presentation is to illustrate the requirements for automated analogue behaviour modelling techniques from the viewpoint of the designer. In the first paragraph the reasons for using behavioural models are explained. Next the desired features of such techniques are given in general terms. Finally some of the available methods and tools are presented as an example.

Motivation for using behavioural modelling

In order to manage the design complexity of large integrated circuits a TopDown-BottomUp design flow is preferred. During the different steps from a high-level system specification down to the circuit implementation, the complete system with its analogue sub-blocks at different abstraction levels has to be simulated. This is only possible by using behavioural models to reduce the circuit size and simulation time.

In the bottom-up verification phase, the behaviour of the circuit is checked against the intended specification on different levels of abstraction. New models have to be derived from the circuit netlist that corectly represent the properties of this particular implementation. The challenge here is to reduce the circuit complexity with minimal effort while keeping only the relevant behaviour of the sub-blocks. Because this is a cumbersome task, automated modelling techniques are essential.

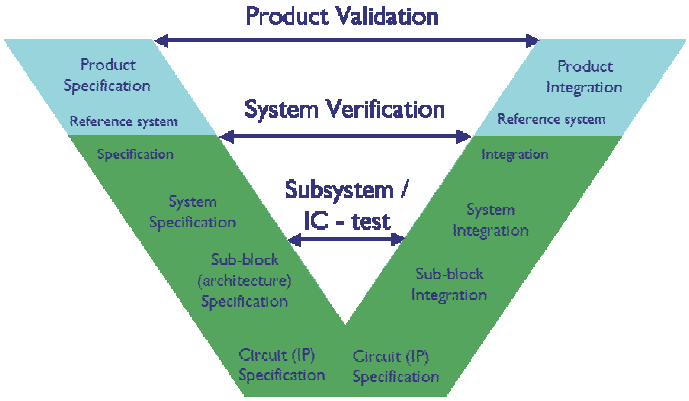


Figure 1: schematic representation of a TopDown-BottomUp design flow

Requirements for automated modelling techniques

Roughly, there are three different application modes for automated model generation. All of them are situated in the BottomUp verification phase of the design.

Either the model is created fully automated as a pre-processing step integrated in a simulation run. In this scenario, the model is re-created again for every simulation and therefore the generation has to be very fast. These techniques are already used for linear time invariant systems like the reduction of extracted parasitic elements.

The second scenario is when a model is created for the verification of a sub-block in a larger system. The major features of a good modelling method for this applicaton are

- The resulting model must simulate fast
- The accuracy must be adjustable by the designer (trade-off against speed)

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- There is flexibility with respect to which non-ideal effects should be included.
- It must be easy to generate (user friendly, quick and with limited expertise)

Finally, another situation occurs when re-usable models are genereated for the integration of IP-blocks in a system. Clearly the model should simulate fast but there are additional requirements:
- Introduce a well-chosen set of adjustable parameters (or: weakly synthesizable)
- The model must be accuracy and show complete non-ideal effects description

Note that there are some requirements that are currently not addressed by modelling techniques. An important group of circuits that cannot be modelled easily with currently available automated techniques are oscillators, circuits with internal memory or with switching topologies. In addition, most techniques are restricted to modelling standard behaviour only. Statistical behaviour or other properties like noise are not supported yet.

Experiences with automated modelling tools

Linear Model Order Reduction

Lay-out extraction of parasitic elements of a circuit results in huge RLC networks that cannot be simulated by traditional simulators anymore. Linear model order reduction methods are used to obtain smaller circuits without losing accuracy. Our experiments with commercial tools like JivaroA from edXact [1] show that they work satisfactory.

Symbolic analysis

Linear modelling problems can also arise for circuits like amplifiers or filters that are designed to stay in their linear operation region. A tool like Arana from Orora [2] will create a small-signal model using symbolic manipulation. The advantage of this technique is that it gives great insight in the circuit under investigation and allows models to have parameters. The disadvantage is that it can only be used on the small class of linear circuits.

Black-box method with neural networks

The major interest in modelling however is for non-linear circuit behaviour. Several techniques are under development for weakly non-linear circuits. A Philips propriety tool based on neural networks perfectly reproduces the behaviour of the training set. However because there is no way to predict the model behaviour outside the boundaries of this training set. This is experienced as counter-intuitive by designers. A lot of expertise is required to use this tool and to understand the resulting model.

Signal Path Analysis

A. Mantooth from the university of Arkansas takes another approach in the Signal Path Analysis method [3]. The strength of this technique is that it first analyses the circuit and then passes control back to the designer. He is presented with a list of nodes that the dominate the contribution to the simulated transfer function. Using his knowledge of the circuit, the designer can compromise between accuracy and model complexity by selecting or deselecting the nodes he wants to be included.

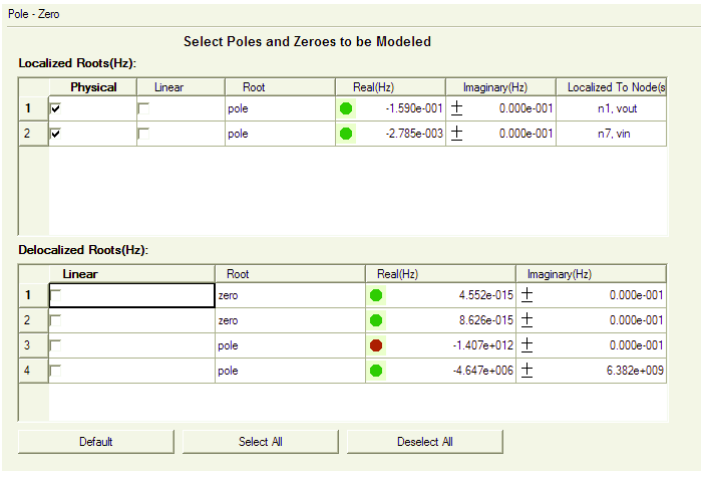


Figure 2: A selection form of Ascend where the designer can choose which nodes he wants to include for the model

In addition he can choose between a non-linear or a simpler linear modelling for these nodes.

The current implementation of this method (Ascend) requires that the circuit has well defined inputs and outputs (a signal can go through) and that it has an operation point with a main continuous operation region around that point. These conditions exclude oscillators, circuits with memory states, switches (topology changes) or circuits that show hysteresis, but still this method can be usefull for a broad range of applications.

Conclusion

The problems in designing large electronic systems are so complicated, that techniques for data reduction like behavioural modelling can't be avoided anymore. There is an enormous potential for modelling techniques, especially for automated methods that can handle non-linear behaviour. Methods that reduce the very high effort and the skill required to create models should be develloped by universities and commercialized. The best chances are for those methods that give the designer control over the model creation process and allow trade-offs between speed and accuracy.

References

1. edXact website: www.edxact.com

2. Orora website from Richard Shi: www.orora.com

3. Ascend website from Alan Mantooth: mixedsignal.eleg.uark.edu/paragon.html