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片上系统的设计和描述语言

Advances in Design and Specification Languages for SoCs

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内 容 简 介

本书主要针对数模混合系统在计算模型中遇到的问题进行了分析。通过对基于 UML 系统的分析以及 C/C++等语言的使用，可以很方便的进行系统的说明和设计，加速了系统的检验和仿真。本书同时对工业自动化设计有一定的指导意义。

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《国外电子信息精品著作》序

20世纪90年代以来，信息科学技术成为世界经济的中坚力量。随着经济全球化的进一步发展，以微电子、计算机、通信和网络技术为代表的信息技术，成为人类社会进步过程中发展最快、渗透性最强、应用面最广的关键技术。信息技术的发展带动了微电子、计算机、通信、网络、超导等产业的发展，促进了生命科学、新材料、能源、航空航天等高新技术产业的成长。信息产业的发展水平不仅是社会物质生产、文化进步的基本要素和必备条件，也是衡量一个国家的综合国力、国际竞争力和发展水平的重要标志。在中国，信息产业在国民经济发展中占有举足轻重的地位，成为国民经济重要支柱产业。然而，中国的信息科学支持技术发展的力度不够，信息技术还处于比较落后的水平，因此，快速发展信息科学技术成为我国迫在眉睫的大事。

要使我国的信息技术更好地发展起来，需要科学工作者和工程技术人员付出艰辛的努力。此外，我们要从客观上为科学工作者和工程技术人员创造更有利于发展的环境，加强对信息技术的支持与投资力度，其中也包括与信息技术相关的图书出版工作。

从出版的角度考虑，除了较好较快地出版具有自主知识产权的成果外，引进国外的优秀出版物是大有裨益的。洋为中用，将国外的优秀著作引进到国内，促进最新的科技成就迅速转化为我们自己的智力成果，无疑是值得高度重视的。科学出版社引进一批国外知名出版社的优秀著作，使我国从事信息技术的广大科学工作者和工程技术人员能以较低的价格购买，对于推动我国信息技术领域的科研与教学是十分有益的事。

此次科学出版社在广泛征求专家意见的基础上，经过反复论证、仔细遴选，共引进了接近30本外版书，大体上可以分为两类，第一类是基础理论著作，第二类是工程应用方面的著作。所有的著作都涉及信息领域的最新成果，大多数是2005年后出版的，力求“层次高、内

容新、参考性强”。在内容和形式上都体现了科学出版社一贯奉行的严谨作风。

当然，这批书只能涵盖信息科学技术的一部分，所以这项工作还应该继续下去。对于一些读者面较广、观点新颖、国内缺乏的好书还应该翻译成中文出版，这有利于知识更好更快地传播。同时，我也希望广大读者提出好的建议，以改进和完善丛书的出版工作。

总之，我对科学出版社引进外版书这一举措表示热烈的支持，并盼望这一工作取得更大的成绩。

王越

中国科学院院士

中国工程院院士

2006 年 12 月

Preface

This book is the sixth in the ChDL (Chip Design Languages) series. Year 2004 has seen many efforts in the field of electronic and mixed technology circuit design languages. The industry has recognized the need for system level design as a way to enable the design of the next generation of embedded systems. This is demonstrated by the "ESL Now!" campaign that many companies are promoting. This year has also seen many interesting standardization efforts for system level design, such as SystemC TLM (`http://www.systemc.org/`) for transactional level modeling with SystemC, AUTOSAR (`http://www.autosar.org/`) for automotive embedded system applications, or SPIRIT (`http://www.spiritconsortium.org/`) for IP interchange. In the field of modeling languages, the Model Driven Architecture of the OMG (`http://www.omg.org/mda/`) has given rise to model driven engineering, which is a more general way of software engineering based on model transformations. As embedded systems are more and more programmable and as the design abstraction level rises, model driven methodologies are also considered for electronic system level design. In this context, the OMG has recently published a call for propositions for a UML 2.0 profile for Modeling and Analysis of Real-Time and Embedded systems (MARTE).

The constraints on the design process of these next generation embedded systems are considerable: Real-time, power consumption, complexity, mixed technology integration, correctness, time to market, cost, ..., all contribute to the now famous "design gap". The existing tools are pushed to their limits when designing complex systems-on-chip (SoCs) and reuse has become one of the major ways to fill the gap.

In this very exciting moment in the field of electronic system design languages, the Forum on Specification and Design Languages (FDL'04) has been once again the main European event for this community. This book is a collection of the best papers from FDL'04 selected by the program chairs, Alain Vachoux, Piet van der Putten, Eugenio Villar and Wolfgang Müller.

This book is structured in four parts:

- Part I, Analog and Mixed-Signal Systems, presents five chapters covering issues in mixed-signal modeling.
- Part II, UML-Based System Specification and Design, is composed of five chapters with emphasis on model transformation approaches to system modeling.
- Part III, C/C++-Based System Design, is also structured as five chapters with SystemC as its main topic.
- Part IV, Invited Contributions, concludes the book with two invited chapters presenting the important topic of system verification, and the AUTOSAR initiative.

Together, the 17 chapters of this book present recent research advances in design and specification languages for SoCs. I hope that this book will be a thought provoking read to researchers, students and practitioners in the field of languages for electronic system design.

PIERRE BOULET
General Chair of FDL'04
Université des Sciences et Technologies de Lille
Lille, France, April 2005

Previous books

Christoph Grimm (Editor), "Languages for System Specification", Kluwer, 2004.

Eugenio Villar & Jean Mermet (Editors), "System Specification & Design Languages", Kluwer, 2003.

Anne Mignotte, Eugenio Villar & Lynn Horobin (Editors), "System on Chip Design Languages", Kluwer, 2002.

Jean Mermet (Editor), "Electronic Chips & Systems Design Languages", Kluwer, 2001.

Jean Mermet, Peter Ashenden and Ralf Seepold (Editors), "System-on-Chip Methodologies ans Design Languages", Kluwer, 2001.

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Part IV Invited Contributions

I

ANALOG AND MIXED-SIGNAL SYSTEMS

Introduction

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This part includes a selection of five papers that have been presented in the AMS workshop of the FDL'04 conference. The papers have been revised to achieve book level quality and provide a good coverage of up-to-date mixed-signal modeling issues.

The first paper, "Refinement of Mixed-Signal Systems: Between HEAVEN and HELL", from Christoph Grimm et al., presents a mixed-signal design framework supporting the modeling of signal processing systems through a consistent refinement process from abstract descriptions (executable specifications) to pin-accurate models. The framework is based on a prototype extension of SystemC that supports the modeling and the simulation of mixed-signal systems. It uses the object-oriented capabilities of the language to provide so-called polymorphic signals, i.e. signals that may have different semantic interpretations depending on the level of abstraction or the model of computation considered (e.g., single-rate or multi-rate dataflow, continuous-time signal flow, discrete-event). The major benefits of the approach are twofold: artificial converters are no more required to couple modules in the modeled system and the complexity of coupling different models of computations or simulation kernels can be hidden from the modeler. The paper illustrates the approach with a case study from the automotive domain.

The second paper, "Mixed Nets, Conversion Models, and VHDL-AMS", from John Shields and Ernst Christen, addresses a similar issue but deliberately limited to the use of the VHDL-AMS language when it comes to develop mixed-signal structural models. The current definition of the VHDL-AMS language does not provide specific language elements and semantics to efficiently describe hierarchical structures involving components from different signal domains (i.e. continuous-time and event-driven), although it does provide all the elements to describe converter components and conversion behavior. The paper discusses possible modeling strategies and details one proposal that could be eventually formally integrated in the VHDL-AMS language definition. Interestingly enough, the proposal defines a new object, called a wire, that has some similarities with the polymorphic signals discussed in the first paper, essentially since there is a separation between module's behavior and communication.

The third paper, "Monte Carlo Simulation Using VHDL-AMS", from Ekkehart-Peter Wagner and Joachim Haase, proposes the development of VHDL-AMS packages to support statistical simulation of VHDL-AMS models. Re-

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quirements to support statistical modeling and simulation have been defined during the VHDL-AMS language definition phase but they appeared to not require the support of specific language elements. This paper presents a first implementation of some of these requirements and discusses issues related to the support of different statistical continuous-time and discrete distributions as well as correlations between statistical values. Some remaining open issues have to be addressed at the simulation tool level (e.g. multi simulation runs, post-processing capabilities), but a solid foundation can be built by providing specific VHDL-AMS declarations and subprograms. Such a proposal could even be developed further to culminate as a new VHDL-AMS companion standard.

The fourth paper, "Prediction of Conducted-Mode Emission of Complex IC's", from Anne-Marie Trullemans-Anckaert et al., presents a top-down design methodology that allows for taking into account physical effects due to the distribution of power in integrated circuits in order to meet electromagnetic compatibility (EMC) compliance as early as possible in the design phase. The approach uses behavioral VHDL-AMS models to allow full-chip simulations (including IOs) in a reasonable amount of time by abstracting the real behavior, but still allowing the modeling of physical effects such as current distribution and current spike density. The paper validates the methodology through its application to the design of an 8-bit microcontroller. One interesting outcome of the approach is the definition of modeling guidelines for developing IP blocks that may be included in a library and reused in many designs without the need to use detailed transistor-level netlists and to perform long electrical simulations.

The fifth and last paper in this part, "Practical Case Example of Inertial MEMS Modeling with VHDL-AMS", from Elena Martin et al., shows how to use a model-based top-down design methodology to design complex integrated systems including non-electrical parts such as sensors or actuators. Similarly to the previous paper, this paper discusses the modeling of physical effects, here mechanical and thermal effects, in abstract behavioral models of a microsystem and its associated electrical front-end and interface with a central processing unit. The use of a mixed-signal multi-domain hardware description language such as VHDL-AMS allows for obtaining a consistent model of the complete system, evaluating the influence of physical effects and adding proper compensation. The paper raises the need to develop model libraries which include multi-domain parameterized component models at various abstraction levels which can be characterizable from physical realizations.

It is my hope that this short introduction will incite you to go through the details of these five very interesting papers and to keep an attentive eye, or even contribute, to future editions of the AMS workshop in the FDL conference.

Chapter 1

REFINEMENT OF MIXED-SIGNAL SYSTEMS: BETWEEN HEAVEN AND HELL[1]

Christoph Grimm, Rüdiger Schroll, Klaus Waldschmidt
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Abstract Very complex system are designed by stepwise refinement. This means that an abstract model is successively augmented with components and properties of an implementation. For signal processing, mixed-signal systems the refinement from block diagram level to analog or digital circuit requires a significant modeling effort: The means for description of abstract models (e.g. synchronous dataflow) and physical implementation (e.g. networks) are different and cannot be combined in a direct way. In this chapter, we introduce polymorphic signals which solve this problem, and give an overview of a framework for the refinement of Mixed-Signal Systems: HEAVEN/HELL.

Keywords: Mixed-Signal Systems, Design Methodology, Refinement.

1. Introduction

A key issue of system design is the analysis of different architectures. Especially for signal processing systems the 'design space' is often huge. Design issues such as partitioning (analog, digital ASIC, DSP+Software), determination of sample frequencies, bit widths, or precision of analog components determine quality, performance and costs of the system. In order to analyze and to verify the behavior of different architectures, models of each architecture are created and simulated. Unfortunately, this is a time consuming issue.

In *model based design*, the availability of many different modeling platforms (models of computation, MoCs) simplify the creation of models. A model of computation can be seen as an 'abstract processor' that can be programmed by a 'language', and that defines means for communication and synchronisation.

[1]This work has been partially supported by funds of the BMBF/edacentrum Project SAMS under Reference Number 01M3070D.

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Examples for MoCs are finite state machines which are 'programmed' by states and transitions, or electrical networks that are programmed by components that are connected with nodes. Particular research on the use of different MoCs has been done within the design framework Ptolemy [Lee et al., 2003]. Although model based design supports the creation of new models, it does not support the re-use and modification of models within a design process.

The idea of *refinement* is to support the interactive, stepwise design process that leads from an abstract, executable specification to an implementation by

- integrating and modifying existing components, and
- augmenting the abstract, executable specification with new properties.

Figure 1.1 gives an overview of the design framework HEAVEN (**HE**terogeneous Systems Refinement, **A**nalysis and **V**erification **EN**vironment) that is used to demonstrate refinement of block diagram to a mixed-signal system, and which allows evalutation of different partitioning, bit widths, sample frequencies, noise and nonlinearities of analog circuits, etc. HEAVEN is supported by HELL (**HE**terogeneous Systems modeling **L**ibrary; figure 1.1 right). HELL provides behavioral models of physical effects that can be added to the 'ideal' behavior assumed in HEAVEN.

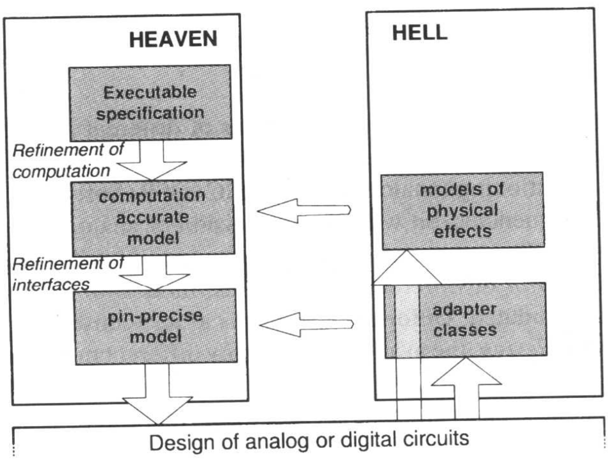

Figure 1.1. Refinement of signal processing applications to mixed-signal circuits with HEAVEN/HELL.

In HEAVEN/HELL, refinement of signal processing systems is enabled by polymorphic signals and adapter classes. Polymorphic signals automatically translate communication mechanisms used in the MoCs applied for modeling different realizations at different levels of abstraction. Therefore, polymorphic