ELECTROTHERMAL ANALYSIS OF VLSI SYSTEMS

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Preface

With increasing complexity of VLSI chips, the task of developing state-of-the-art VLSI systems has become a highly challenging multidisciplinary task. Although in early days of MOS technology, silicon compilation looked promising, it has become difficult to fully automate the entire design flow from high-level design to mask generation due to many difficult physical design problems, including timing closure, power constraint, crosstalk, signal integrity, testability and reliability issues. In particular, the conventional practice of treating reliability qualification as a backend process has become no longer acceptable in view of excessive cost for design iterations. Attempts are under way to include reliability verification in the design flow so that expensive design iterations due to reliability problems can be avoided.

With foresight Semiconductor Research Corporation has provided strong support on our research of "design for reliability" at the University of Illinois at Urbana-Champaign for over a decade. New models and CAD capabilities have been developed and transferred to industry to address some of the serious reliability problems such as electromigration (EM) in metallic interconnects and electrostatic discharge (ESD) damages to I/O pads. With increasing concerns for on-chip power dissipation due to high packing density and high-frequency operation, electrothermal analysis has become critically important for accurate assessment of thermally activated device and circuit failures, and for timing analysis.

In this book we have attempted to provide in-depth coverage of important subjects required for electrothermal analysis of MOS VLSI circuits in an orderly manner. The underlying principles of circuit models and simulation algorithms in reliability CAD tools such as ILLIADS-T and iTEM are described in detail. For verification of design tool capability, chip design and bench test results are presented for electrothermal analysis of ring oscillators operating under digitally controlled thermal environment. We also present a "thermally skewed timing failure" phenomenon with detailed simulation result. This subject has

not been discussed in any literature to our best knowledge, but such failures have been noticed by practicing VLSl design engineers.

It is our sincere desire that readers will find the contents of this book useful for practice and also for furtherance of research in this challenging field.

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To ECE and CSL of the University of Illinois at Urbana-Champaign, and to Semiconductor Research Corporation

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Foreword

Continuing increases in the levels of circuit integration and concomitant increases in performance are sustaining the trend of increasing power dissipation in VLSI systems. A consequence is that the impact of temperature on the successful operation and reliability of devices must be comprehended during the design process. For the past decade, the authors have led an effort to provide a framework, accompanied by tools, for the electrothermal analysis and design of integrated circuits and systems. This is a challenging field driven by the enormous complexity of integrated circuits and by the need for tractable, predictive, and executable models of electrical and thermal interaction physics.

This text provides a comprehensive formulation of the electrothermal analysis problem beginning with a summary of the sources of power dissipation in CMOS circuits and followed by a formulation of the effect of temperature on MOS devices. A general framework for thermal simulation of integrated circuits and packages is presented and then the fast timing electrothermal simulator, ILLIADS-T, is described. Applications include the study of temperature dependent electromigration reliability, captured in the simulator iTEM, and the placement of cells so as to mitigate temperature effects. The text concludes with the description of a methodology to predict the effects of temperature on the timing of integrated circuits.

The tools and methods described herein are finding widespread use in industrial applications by SRC members. We at the SRC are pleased to acknowledge the important contributions that have been made by the authors and expect that readers who are involved in electrothermal modeling will find the integrated perspective of this text to be very useful.

Dr. Ralph K. Cavin, Vice President
Semiconductor Research Corporation
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