

PREFACE

The performance of microprocessors has increased exponentially since their introduction in the early 1970s. This growth has been made possible by dramatic technical advances in semiconductor manufacturing, circuit design, computer architecture, and CAD tools. Although many technical problems have been resolved along the way, many new challenges emerge as transistors are counted in billions, and clock frequencies in gigahertz.

This book discusses the design of the next generation of microprocessors in deep submicron CMOS technologies. The topics in the book were chosen to cover the essence of high-performance design. The chapters were written by some of the world's leading technologists, designers, and researchers who are pushing the state of the art as they grapple daily with the technical hurdles that must be overcome before the microprocessors of tomorrow are shipped. All levels of system abstraction are covered, but the emphasis rests squarely on circuit design. Examples are drawn from processors designed at AMD, Digital/Compaq, IBM, Intel, MIPS, Mitsubishi, Motorola and Toshiba.

The book was written for students of VLSI design as well as practicing circuit designers, architects, system designers, CAD tool developers, process technologists, and researchers. It assumes a basic knowledge of digital circuit design and device operation, and covers a broad range of circuit styles and VLSI design techniques. Each chapter stands alone so the reader can pick and choose topics of interest and read them in any order.

The 25 chapters are grouped into eight sections:

- Section I discusses the impact of physical technology on architectural choices.
- Section II deals with technology and covers CMOS scaling, leakage current reduction, low-voltage devices, silicon on insulator, and models of process variations.
- Section III explores contemporary circuit design styles including a survey of logic families, robust dynamic circuit design, asynchronous logic, self-timed pipelines, and high-speed arithmetic units.
- Section IV deals with clocks, including edge triggered flip-flops, level-sensitive and pulse latches; phase-locked and delay-locked loops; and on-chip clock distribution schemes.
- Section V considers memory design, including register files and caches as well as embedded DRAM—structures that occupy a large portion of real estate on today's microprocessors. The limited speed of signal transmission both on and off chip has emerged as a serious performance bottleneck.
- Section VI covers techniques for driving on-chip interconnect, I/O and pad design, ESD, and high-speed signaling in general.
- Section VII deals with the realities of wear out mechanisms, such as electromigration and hot carriers, the necessity of considering these phenomena at the design stage, and their overall impact on device reliability.
- Section VIII provides a broad overview of the CAD tools needed for high-

performance microprocessor design, including timing verification, and the analysis of power distribution schemes. The book concludes with a chapter on testing.

We would like to acknowledge the many people who contributed to the completion of this book. First we would like to thank the authors of the chapters. The preparation of the text often required the authors to work long nights and weekends, while still meeting their demanding commitments at work.

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