

Preface

Motivation

This book is intended as a text for senior undergraduates and first-year graduate students in Computer Engineering, Computer Science and Electrical Engineering. It is also a good reference book for CAD practitioners.

VLSI design is now recognized as an important area of Computer/Electrical Engineering and Computer Science. VLSI design is a very complex process. The design of a VLSI system is unthinkable without the use of numerous computer aided design (CAD) tools, which automate most of the design tasks. Except for the initial specification of the system, every other step of the design process has been either automated or made easy through user-friendly CAD tools/programs. The first paper on CAD appeared in 1955. CAD started being recognized as indispensable as early as 1960. Now for nearly two decades, CAD of digital systems has become a mature area. Almost every engineering school offers at least one graduate-level course in VLSI design and VLSI design automation. Computer Science departments offer courses in VLSI computation and design automation.

There are three general aspects of CAD: (1) synthesis, (2) verification, (3) design management. This book deals with the first aspect, that is, the synthesis aspect. Synthesis is known as the problem of obtaining a lower level representation of a digital system from a higher level representation of the same system. When the higher level representation is a behavioral description and the lower level is a structural description, the synthesis process from the higher level to the lower level is known as high-level synthesis. When both the higher and lower levels are structural representations, the

process is called physical synthesis. In this book, we are mostly concerned with physical synthesis, i.e., partitioning, floorplanning, placement, and routing. However, high-level synthesis aspects are also addressed in the context of silicon compilation.

This book is suitable for senior undergraduate students and first year graduate students who may not have been exposed to many of the mathematical ideas from graph theory and algorithms. The book makes up for this lack of exposure through the use of a large number of illustrative examples and solved exercises. The only pre-requisite assumed is the knowledge of basic logic design and computer architecture.

Organization of the Book

The book is organized into 9 chapters. The chapters are organized in a sequence similar to the physical design process itself.

Chapter 1, the introductory chapter, motivates the student towards a study of physical design automation of integrated circuits. Layout is examined in the backdrop of the entire design automation process. Basic terminology is introduced, and the important subproblems of layout are identified. The fact that many layout subproblems are “hard” is brought out with illustrative examples.

Chapters 2 through 7 examine the different subproblems in IC layout. Chapter 2 covers the problem of circuit partitioning. Chapter 3 discusses floorplanning. In chapter 4 we present the problem of module placement. Chapter 5 through 7 are on wiring. We discuss grid/maze routing, global routing, and channel routing in chapters 5, 6, and 7 respectively.

In Chapter 8, we consider the problem of silicon compilation and automatic generation of cells. Three different cell styles are examined, namely, Standard cell, Gate Matrix and PLA. Algorithms for automatic generation of layout in the above cell styles are covered.

In Chapter 9, layout editors are considered and techniques for hand-drawing of layouts are examined. The importance of *compaction* in hand layouts is explained, and the two main compaction approaches together with their related algorithms are described.

In order to achieve uniformity in treatment, each of these topics is examined in the following light. *Problem Definition* introduces the reader to the essence of the layout subproblem, its graph theoretic formulation, and the notation associated with the treatment of the problem. Under

Cost Functions and Constraints, we examine the problem as a constrained optimization problem and explain the possible cost functions which must be minimized subject to practical constraints. Next, we examine the various *approaches* that researchers and engineers in CAD have adopted to solve the concerned optimization problem. Such optimization algorithms include graph theoretic, numerical, and stochastic techniques. The algorithms are illustrated with examples and exercises. Finally, a section on latest developments in the problem area guides the reader/student to open research problems. An *annotated bibliography* is provided at the end of each chapter, followed by *exercises*. The exercises are classified into *routine exercises* which typically include applying an algorithm to a problem instance. *Challenging exercises* include programming projects and research-oriented problems (indicated by (*)).

The book contains an appendix which covers an overview of combinatorial optimization, and some basic definitions in algorithms and graph theory, as they apply to the book.

A Solutions Manual is available and can be obtained from the publisher or authors.

How to use this book?

The book can serve as a text for one semester first year graduate course on CAD of digital systems. It will be difficult to cover all material in detail in the fifteen weeks of the semester. Our experience using early manuscript of the text was that the first seven chapters can be well covered. One week is required to introduce the topic of CAD in general and physical design in particular (Chapter 1). Approximately two weeks are spent on Chapters 2 to 7. In each chapter, several heuristics are described. Instructors may choose to cover all topics of the book by discussing only selected sections from each chapter.

As an undergraduate text, the depth and pace of coverage will be different. Only portions from each chapter could be covered. The instructors may decide as to which portions to cover. Material covered may preferably be from early portions of each chapter.

Acknowledgments

The book took about two years to write. Many people supported the book. We wish to thank all those who provided comments, corrections, and reviews for the book. We wish to thank Dr. Muhammad. S. T. Benteen, former Dean, College of Computer Sciences and Engineering, King Fahd University of Petroleum and Minerals (KFUPM), for his tremendous support. He was a wonderful consultant on matters related to UNIX and \LaTeX . We also thank Dr. Samir H. Abdul-Jauwad, former Chairman, Computer Engineering Department, the Late Dr. Ala H. Al-Rabeh, former Dean, College of Graduate Studies, and Dr. M. Y. Osman, all at KFUPM, for their encouragement and support.

We would like to gratefully acknowledge our teachers, Dr. Eugene Shragowitz, (Department of Computer Science, University of Minnesota), Dr. Manzer Masud, (formerly with Department of Computer Engineering, KFUPM, and now Engineering Vice President of Attest Software Incorporated, Santa Clara, California), who attracted us to the general area of VLSI DA and shaped/influenced many of our views.

We would also like to acknowledge Dr. Gerhard Beckhoff, (Department of Electrical Engineering, KFUPM), Dr. Farouk Kamoun, and Dr. Muhammad Ben-Ahmed (formerly with Department of Informatics, Faculty of Science, Tunis), Dr. Valdis Berzins (Professor, Naval Post Graduate School, Monterey, CA), who played a key role during our formative years.

We would like to thank Asjad M. T. Khan and Dr. C. P. Ravikumar for providing material, and exercises for parts of the book. Asjad spent an extraordinary amount of time and energy on this project and was a consultant on such matters as computer systems, text editing, typesetting in \LaTeX , etc. Dr. Ravikumar provided the Appendix. He also helped in the writing of the introductory chapter and edited early drafts of some chapters (Partitioning, Placement and Grid Routing).

We used early drafts of this book to teach a graduate course in VLSI Physical Design Automation. Our thanks and appreciation to all those students who contributed with corrections to the text, solutions to the problems, etc, namely, Talal Al-Kharroubi, Talhah Al-Jarad, Maher Al-Sharif, Munir Zahra, Usamah Abed, Muhammad Al-Akroush, Emran Ba-Abbad, Shahid Khan, Shah Edrees, and Khaled Nassar. Special thanks to (1) Talal Al-Kharroubi for his meticulous reading of the entire manuscript and for detecting many technical errors, subtle typos and formulation errors, and

(2) Shahid Khan, Khalid A. A, and Masud-ul-Hasan, for their patience in making and correcting all illustrations.

Any book writing requires a sizable amount of reference material. Mr. Shoaib A. Quraishi of KFUPM library was helpful in getting all requested material in record time.

Lastly, we are very grateful to our wives, Sumaiya Sadiq and Leila Youssef, and children Ifrah, Aakif, and Arwa Sadiq, Elias, Osama, and Amin Youssef, without whose understanding such a major undertaking and its successful completion would not have been possible.

The authors also acknowledge the support provided by King Fahd University of Petroleum and Minerals under Project Code COE/AUTOMATION/163.

The book was typeset in \LaTeX at KFUPM using the computing facilities of the College of Computer Sciences and Engineering.

Sadiq M. Sait
Dhahran, December 1998

Habib Youssef
Dhahran, December 1998