Integrated Circuit Design and Technology

TUTORIAL GUIDES IN ELECTRONIC ENGINEERING

This series is aimed at first- and second-year undergraduate courses. Each text is complete in itself, although linked with others in the series. Where possible, the trend towards a 'systems' approach is acknowledged, but classical fundamental areas of study have not been excluded. Worked examples feature prominently and indicate, where appropriate, a number of approaches to the same problem.

A format providing marginal notes has been adopted to allow the authors to include ideas and material to support the main text. These notes include references to standard mainstream texts and commentary on the applicability of solution methods, aimed particularly at covering points normally found difficult. Graded problems are provided at the end of each chapter, with answers at the end of the book.

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Contents

Preface

Until a few years ago, all integrated circuits were designed by specialists behind the closed doors of the semiconductor industry, manufactured only in enormous quantities, and sold as standard products. A remarkable change has been brought about by the development of semi-custom design techniques and CAD tools that nowadays enable all electronics engineers to design their own **application-specific integrated circuits** (ASICs) and get them made economically in small quantities. As a result, ASICs have become the key components in electronic products of all types.

This is a book about integrated circuit design and its fundamentals in silicon technology. It is **not** a manual of how to do design using any particular CAD tools, but rather, the background for all of them. IC design started to become an academic subject with the publication in 1980 of the famous book by Mead and Conway which led to the first postgraduate courses in full-custom design in the UK. Since then, ASIC design has rapidly moved into the core of many higher education courses in electronics, aided by the provision of CAD hardware and software that nowadays enable undergraduates to gain practical design experience. With such a rapid development, courses in IC design inevitably contain a rather diverse mixture of computer techniques and parts of more traditional digital and circuit design courses with EA1 and EA2 undertones! It is, of course, all these and more.

ASICs are very often designed using semi-custom methods which require absolutely no knowledge of circuits or silicon. However, the view taken in this book is that the *educated* engineer should understand at least the fundamentals of the circuit and fabrication technologies that have an impact on design and underlie all design decisions. It therefore attempts to fit integrated circuit design into a coherent framework based on the outstanding achievements of silicon technology. IC design provides an excellent opportunity for bringing together interests in semiconductors, digital and analogue circuits, and systems. Although the book tries to be self-contained, it is therefore based on the background of digital and circuit electronics that most students acquire in the first year of a degree or higher certificate course.

The core of the book in Chapters 7–9 describes the essential steps in both semi-custom and full-custom design, and the use and features of the CAD tools required to turn a chip specification into a verified, testable circuit on silicon. The earlier chapters are on IC device structures and how they are made on silicon. Chapter 4 presents the fundamentals of MOS circuits, which can be regarded either as background for semi-custom or the basis of full-custom design. Emphasis is placed on digital CMOS circuits and their design which are most likely to be met in practice, but the book also includes an introduction to analogue CMOS design for mixed analogue–digital circuits. Chapter 5 gives the background of bipolar circuits that will never be completely overshadowed by CMOS.

The book is intended to be an introductory guide to the subject in a rather different sense from other volumes in this Series. It is a guidebook to a country and, for the parts you want to visit, you will need the more detailed information given in CAD manuals, ASIC data books, and more specialized textbooks. In visiting any new country it is useful to know some of the language and I have

deliberately introduced some of the established jargon of the semiconductor and CAD industries. I have also had to use centimetre rather than metre units because they are universally used in the industry.

Large parts of this book are descriptive rather than quantitative. It therefore differs from others in the Series in having only a few problems at the ends of chapters. I have omitted problems rather than trying to pretend that short hand calculations can make any real contribution to IC design. Lecturers should have no difficulty in devising CAD projects tailored to the particular hardware and software available and the students' competence in using them. Semiconductor data books can suggest design projects of any difficulty from a few gates to LSI functions, and it is particularly instructive to try to improve on the speed of standard TTL functions by designing them in CMOS. Other design projects will be suggested by courses in communications, computer systems and instrumentation.

My view of IC design, as presented in this book, has developed over the last nine years of teaching the subject in an M.Eng/M.Sc course to which the students and many leading electronics companies have contributed greatly. Too many people have been involved to thank all of them by name, but Simon Johnson has been particularly helpful, not least by providing the well-tried design exercise and some of the figures. I also wish to thank Professor Peter Hicks of the Electronics and Electrical Engineering Department, UMIST, and Professor Tony Dorey, the Consulting Editor, for many constructive comments. Parts of the book were written while I was a Senior Research Fellow at the University of York and I would particularly like to thank the Electronics Department there for their hospitality.