Third Edition

Eastern Economy Edition

Basic VLSI Design

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Edition

Douglas
Kamran
Depart ical
and ele eering
Univer de

2009-2010

Prentice-Hall of India Private Limited
New Delhi

This Indian Reprint—Rs. 275.00
(Original Australian Edition—Rs. 2568.00)

BASIC VLSI DESIGN, 3rd Ed.
by Douglas A. Pucknell and Kamran Eshraghian

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ISBN-81-203-0986-3

For sale in India, Bangladesh, Bhutan, Combodia, China, Fiji, Laos, Malaysia, Maldives, Myanmar, Nepal, Pakistan, Phillippines, Singapore, South Korea, Sri Lanka, Taiwan, Thailand and Vietnam.

Published by Asoke K. Ghosh, Prentice-Hall of India Private Limited, M-97, Connaught Circus, New Delhi-110001 and Printed by Syndicate Binders, B-167, Okhla Industrial Area, Phase I, New Delhi-110020.

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Preface

The microscopic dimensions of current silicon-integrated circuitry make possible the design of digital circuits which may be very complex and yet extremely economical in space, power requirements and cost, and potentially very fast. The space, power and cost aspects have made silicon the dominant fabrication technology for electronics in very wide ranging areas of application. The combination of complexity and speed is finding ready applications for VLSI systems in digital processing, and particularly in those application areas requiring sophisticated high speed digital processing. Although silicon MOS-based circuitry will meet most requirements in such systems and the technology is still being enhanced by ongoing improvements in fabrication, there are ultimate limitations associated with the velocity of electrons (and holes) in silicon which will make MOS circuitry unsuitable for some ultra fast systems that are now being contemplated. Thus, other techniques are being actively investigated to complement silicon technology, including the use of materials other than silicon for the production of integrated circuits. One promising technology is the production of very fast circuits in gallium arsenide.

The overwhelming majority of VLSI systems in silicon utilize nMOS, CMOS or BiCMOS technology and, although nMOS designs are now mostly outmoded, it is advantageous to understand the processes and to be able to design or analyze nMOS circuits as the need arises. This added learning load is no real burden since the three technologies are closely interrelated and design is based on common concepts. It is further possible to relate some silicon design methodology and nMOS circuit concepts to the design of gallium arsenide circuits.

A significant feature of this edition is the expansion of CMOS circuitry to include bipolar transistors — the BiCMOS process. This is of particular interest, for example, where larger capacitive loads must be driven. The nature and characteristics of the relevant bipolar devices are dealt with and design rules for an n-well BiCMOS process appear in the text and are used in design examples.

Essential matters for nMOS, CMOS and BiCMOS digital circuit design are covered in Chapters 1 to 9, including numerous illustrative design exercises over Chapters 6 to 9. Learning to design circuits in silicon is essentially a 'hands-on' process and further exercises are set as tutorial work in Chapters 2, 3, 4, 6, 7, 8 and 9, and more demanding work is set out in the six CMOS design projects that comprise Chapter 11. Lambda-based design rules (Mead and Conway style*) are used in most design exercises since they are easily understood, easily remembered and applied, and can be used for fabrication. The rule set given covers both nMOS and p-well-based CMOS. However, more effective designs may be based on 'real-world' micron-based rule sets and two such rule sets are included in this text. Both are from Orbit Semiconductor Inc. of California, USA: one rule set covers a 2 micron double metal, double polysilicon n-well BiCMOS process and the second set is for a 1.2 micron n-well double metal, single polysilicon CMOS process.

An extended coverage of digital arithmetic circuitry is now included in Chapter 8 and a large part of Chapter 10 is devoted to an expanded treatment of testability considerations.

Chapter 11 is devoted entirely to project work designed to illustrate typical approaches to the design of a variety of system requirements.

Chapter 12 builds on the earlier chapters to introduce gallium arsenide (GaAs) technology and establishes suitable encoding, notation, design rules and basic design methodology. Some GaAs logic circuit arrangements are examined.

We have been particularly careful to ensure that this third edition does not omit essential material from the second edition and maintains the format and approach with which users of the earlier editions have become familiar.

Although much new material has been included, all the core material from the second edition appears in roughly the same order as before, with the exception of the chapter dealing with PLAs and finite state machines. This subject, rightly or wrongly, we now feel belongs more appropriately in texts covering digital logic in general and combinational and sequential logic in particular. One such text now forms part of this Silicon Engineering Series of texts**. However, in order to maintain a coverage of the PLA, we have included the essential material as Appendix C.

Thus, those who have based coursework on the first or second editions of this text should not be seriously affected by any omissions and should benefit substantially from the additional material presented in this new edition.

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* Mead, C. A. & Conway, L. A. *Introduction to VLSI systems*, Addison-Wesley, USA, 1980.

** Pucknell, D. A. *Fundamentals of Digital Logic Design*, Prentice Hall, Australia, 1990.

In conclusion, the authors have set out to present a balanced and structured course covering the 'technologies of the nineties'. The book covers the design of circuits in silicon and introduces the newer GaAs technology in a way that is compatible with design in silicon. We have set out to present this text in a form that is readily used and easily assimilated. Most of the material presented is based on coursework taught over a number of years and is therefore 'tried and trusted'.

Douglas Pucknell and Kamran Eshraghian
Adelaide, February 1994