



COMPUTER ORGANIZATION AND DESIGN

THE HARDWARE/SOFTWARE INTERFACE



THIRD
3
EDIT

DAVID A. PATTERSON
JOHN L. HENNESSY



DOCKET
ALARM

Find authenticated court documents without watermarks at docketalarm.com.

ACKNOWLEDGEMENTS

Figures 1.9, 1.15 Courtesy of Intel.

Figure 1.11 Courtesy of Storage Technology Corp.

Figures 1.7.1, 1.7.2, 6.13.2 Courtesy of the Charles Babbage Institute, University of Minnesota Libraries, Minneapolis.

Figures 1.7.3, 6.13.1, 6.13.3, 7.9.3, 8.11.2 Courtesy of IBM.

Figure 1.7.4 Courtesy of Cray Inc.

Figure 1.7.5 Courtesy of Apple Computer, Inc.

Figure 1.7.6 Courtesy of the Computer History Museum.

Figure 7.33 Courtesy of AMD.

Figures 7.9.1, 7.9.2 Courtesy of Museum of Science, Boston.

Figure 7.9.4 Courtesy of MIPS Technologies, Inc.

Figure 8.3 ©Peg Skorpinski.

Figure 8.11.1 Courtesy of the Computer Museum of America.

Figure 8.11.3 Courtesy of the Commercial Computing Museum.

Figures 9.11.2, 9.11.3 Courtesy of NASA Ames Research Center.

Figure 9.11.4 Courtesy of Lawrence Livermore National Laboratory.

Computers in the Real World:

Photo of "A Laotian villager," courtesy of David Sanger.

Photo of an "Indian villager," property of Encore Software, Inc.

Photos of "Block and students" and "a pop-up archival storage" courtesy of Professor Barbara Block. Photos by Scott Taylor.

Photos of "Professor Dawson and student" and "the Mica" courtesy of AP/World Wide Photos.

Photos of "images of pottery fragments" and "a computer simulation," courtesy of Andrew Willis and David B. Cooper, Brown University Division of Engineering.

Photo of "the Eurostar TGV train," by Jos van der Kolk.

Photo of "the interior of a Eurostar TGV cab," by Andy Veitch.

Photo of "firefighter Ken Whitten," courtesy of World Economic Forum. Graphic of an "artificial retina," © The San Francisco Chronicle. Reprinted by permission.

Image of "A laser scan of Michelangelo's statue of David," by Marc Levoy and Dr. Franca Falletti, director of the Galleria dell'Accademia, Italy.

"An image from the Sistine Chapel," courtesy of Luca Pezzani, recorded using the scanner for IR reflectography of the INO Institute for Applied Optics, <http://arte.ino.it>) at the Opificio delle Pietre Dure in Florence.

Senior Editor	Denise E. M. Penrose
Publishing Services Manager	Simon Crump
Editorial Assistant	Summer Block
Cover Design	Ross Caron Design
Cover and Chapter Illustration	Chris Asimoudis
Text Design	GGs Book Services
Composition	Nancy Logan and Dartmouth Publishing, Inc.
Technical Illustration	Dartmouth Publishing, Inc.
Copyeditor	Ken DellaPenta
Proofreader	Jacqui Brownstein
Indexer	Linda Buskus
Interior printer	Courier
Cover printer	Courier

Morgan Kaufmann Publishers is an imprint of Elsevier.
500 Sansome Street, Suite 400, San Francisco, CA 94111

This book is printed on acid-free paper.

© 2005 by Elsevier Inc. All rights reserved.

Designations used by companies to distinguish their products are often claimed as trademarks. In all instances in which Morgan Kaufmann Publishers is aware of a claim, the product name will appear in initial capital or all capital letters. Readers, however, should contact the appropriate company for more complete information regarding trademarks and registration.

No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form or by any means—electronic, mechanical, photocopying, scanning, or otherwise—without prior permission of the publisher.

Permissions may be sought directly from Elsevier's Science & Technology Rights Department. UK: phone: (+44) 1865 843830, fax: (+44) 1865 853333, e-mail: permissions@elsevier.com. You can also complete your request on-line via the Elsevier homepage (<http://elsevier.com>) by selecting "Support" and then "Obtaining Permissions."

Library of Congress Cataloging-in-Publication Data
Application submitted

ISBN: 1-55860-604-1

For information on all Morgan Kaufmann publications,
visit our Web site at www.mkp.com.

Printed in the United States of America
04 05 06 07 08 5 4 3 2 1


Contents

Preface ix

CHAPTERS

1

Computer Abstractions and Technology 2


- 1.1 Introduction 3
- 1.2 Below Your Program 11
- 1.3 Under the Covers 15
- 1.4 Real Stuff: Manufacturing Pentium 4 Chips 28
- 1.5 Fallacies and Pitfalls 33
- 1.6 Concluding Remarks 35
-  1.7 Historical Perspective and Further Reading 36
- 1.8 Exercises 36

COMPUTERS IN THE REAL WORLD

Information Technology for the 4 Billion without IT 44

2

Instructions: Language of the Computer 46

- 2.1 Introduction 48
- 2.2 Operations of the Computer Hardware 49
- 2.3 Operands of the Computer Hardware 52
- 2.4 Representing Instructions in the Computer 60
- 2.5 Logical Operations 68
- 2.6 Instructions for Making Decisions 72
- 2.7 Supporting Procedures in Computer Hardware 79
- 2.8 Communicating with People 90
- 2.9 MIPS Addressing for 32-Bit Immediates and Addresses 95
- 2.10 Translating and Starting a Program 106
- 2.11 How Compilers Optimize 116
-  2.12 How Compilers Work: An Introduction 121

- 2.13 A C Sort Example to Put It All Together 121
- 2.14 Implementing an Object-Oriented Language 130
- 2.15 Arrays versus Pointers 130
- 2.16 Real Stuff: IA-32 Instructions 134
- 2.17 Fallacies and Pitfalls 143
- 2.18 Concluding Remarks 145
- 2.19 Historical Perspective and Further Reading 147
- 2.20 Exercises 147

COMPUTERS IN THE REAL WORLD

Helping Save Our Environment with Data 156

3

Arithmetic for Computers 158

- 3.1 Introduction 160
- 3.2 Signed and Unsigned Numbers 160
- 3.3 Addition and Subtraction 170
- 3.4 Multiplication 176
- 3.5 Division 183
- 3.6 Floating Point 189
- 3.7 Real Stuff: Floating Point in the IA-32 217
- 3.8 Fallacies and Pitfalls 220
- 3.9 Concluding Remarks 225
- 3.10 Historical Perspective and Further Reading 229
- 3.11 Exercises 229

COMPUTERS IN THE REAL WORLD

Reconstructing the Ancient World 236

4

Assessing and Understanding Performance

- 4.1 Introduction 240
- 4.2 CPU Performance and Its Factors 246
- 4.3 Evaluating Performance 254
- 4.4 Real Stuff: Two SPEC Benchmarks and the Performance of Intel Processors 259
- 4.5 Fallacies and Pitfalls 266
- 4.6 Concluding Remarks 270
- 4.7 Historical Perspective and Further Reading 272
- 4.8 Exercises 272

COMPUTERS IN THE REAL WORLD

Moving People Faster and More Safely 280

Explore Litigation Insights

Docket Alarm provides insights to develop a more informed litigation strategy and the peace of mind of knowing you're on top of things.

Real-Time Litigation Alerts



Keep your litigation team up-to-date with **real-time alerts** and advanced team management tools built for the enterprise, all while greatly reducing PACER spend.

Our comprehensive service means we can handle Federal, State, and Administrative courts across the country.

Advanced Docket Research



With over 230 million records, Docket Alarm's cloud-native docket research platform finds what other services can't. Coverage includes Federal, State, plus PTAB, TTAB, ITC and NLRB decisions, all in one place.

Identify arguments that have been successful in the past with full text, pinpoint searching. Link to case law cited within any court document via Fastcase.

Analytics At Your Fingertips



Learn what happened the last time a particular judge, opposing counsel or company faced cases similar to yours.

Advanced out-of-the-box PTAB and TTAB analytics are always at your fingertips.

API

Docket Alarm offers a powerful API (application programming interface) to developers that want to integrate case filings into their apps.

LAW FIRMS

Build custom dashboards for your attorneys and clients with live data direct from the court.

Automate many repetitive legal tasks like conflict checks, document management, and marketing.

FINANCIAL INSTITUTIONS

Litigation and bankruptcy checks for companies and debtors.

E-DISCOVERY AND LEGAL VENDORS

Sync your system to PACER to automate legal marketing.