

计算机组成 结构化方法

新版

(英文版·第5版)

Pearson International Edition

**Structured Computer
Organization**

FIFTH EDITION

ANDREW S. TANENBAUM

(荷) Andrew S. Tanenbaum 著

经典原版书库

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Structured Computer Organization
(Fifth Edition)

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(荷) Andrew S. Tanenbaum 著



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出版者的话

文艺复兴以降，源远流长的科学精神和逐步形成的学术规范，使西方国家在自然科学的各个领域取得了垄断性的优势；也正是这样的传统，使美国在信息技术发展的六十多年间名家辈出、独领风骚。在商业化的进程中，美国的产业界与教育界越来越紧密地结合，计算机学科中的许多泰山北斗同时身处科研和教学的最前线，由此而产生的经典科学著作，不仅擘划了研究的范畴，还揭橥了学术的源变，既遵循学术规范，又自有学者个性，其价值并不会因年月的流逝而减退。

近年，在全球信息化大潮的推动下，我国的计算机产业发展迅猛，对专业人才的需求日益迫切。这对计算机教育界和出版界都既是机遇，也是挑战；而专业教材的建设在教育战略上显得举足轻重。在我国信息技术发展时间较短、从业人员较少的现状下，美国等发达国家在其计算机科学发展的几十年间积淀的经典教材仍有许多值得借鉴之处。因此，引进一批国外优秀计算机教材将对我国计算机教育事业的发展起积极的推动作用，也是与世界接轨、建设真正的世界一流大学的必由之路。

机械工业出版社华章图文信息有限公司较早意识到“出版要为教育服务”。自1998年开始，华章公司就将工作重点放在了遴选、移译国外优秀教材上。经过几年的不懈努力，我们与Prentice Hall, Addison-Wesley, McGraw-Hill, Morgan Kaufmann等世界著名出版公司建立了良好的合作关系，从它们现有的数百种教材中甄选出Tanenbaum, Stroustrup, Kernighan, Jim Gray等大师名家的一批经典作品，以“计算机科学丛书”为总称出版，供读者学习、研究及度藏。大理石纹理的封面，也正体现了这套丛书的品位和格调。

“计算机科学丛书”的出版工作得到了国内外学者的鼎力襄助，国内的专家不仅提供了中肯的选题指导，还不辞劳苦地担任了翻译和审校的工作；而原书的作者也相当关注其作品在中国的传播，有的还专程为其书的中译本作序。迄今，“计算机科学丛书”已经出版了近百个品种，这些书籍在读者中树立了良好的口碑，并被许多高校采用为正式教材和参考书籍，为进一步推广与发展打下了坚实的基础。

随着学科建设的初步完善和教材改革的逐渐深化，教育界对国外计算机教材的需求和应用都步入一个新的阶段。为此，华章公司将加大引进教材的力度，在“华章教育”的总规划之下出版三个系列的计算机教材：除“计算机科学丛书”之外，对影印版的教材，则单独开辟出“经典原版书库”；同时，引进全美通行的教学辅导书“Schaum's Outlines”系列组成“全美经典学习指导系列”。为了保证这三套丛书的权威性，同时也为了更好地为学校和老师门服务，华章公司聘请了中国科学院、北京大

学、清华大学、国防科技大学、复旦大学、上海交通大学、南京大学、浙江大学、中国科技大学、哈尔滨工业大学、西安交通大学、中国人民大学、北京航空航天大学、北京邮电大学、中山大学、解放军理工大学、郑州大学、湖北工学院、中国国家信息安全测评认证中心等国内重点大学和科研机构在计算机的各个领域的著名学者组成“专家指导委员会”，为我们提供选题意见和出版监督。

这三套丛书是响应教育部提出的使用外版教材的号召，为国内高校的计算机及相关专业的教学度身订造的。其中许多教材均已为M. I. T., Stanford, U.C. Berkeley, C. M. U. 等世界名牌大学所采用。不仅涵盖了程序设计、数据结构、操作系统、计算机体系结构、数据库、编译原理、软件工程、图形学、通信与网络、离散数学等国内大学计算机专业普遍开设的核心课程，而且各具特色——有的出自语言设计者之手、有的历经三十年而不衰、有的已被全世界的几百所高校采用。在这些圆熟通博的名师大作的指引之下，读者必将在计算机科学的宫殿中由登堂而入室。

权威的作者、经典的教材、一流的译者、严格的审校、精细的编辑，这些因素使我们的图书有了质量的保证，但我们的目标是尽善尽美，而反馈的意见正是我们达到这一终极目标的重要帮助。教材的出版只是我们的后续服务的起点。华章公司欢迎老师和读者对我们的工作提出建议或给予指正，我们的联系方式如下：

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To Suzanne, Barbara, Marvin, and the memory of Sweetie π and Bram

PREFACE

The first four editions of this book were based on the idea that a computer can be regarded as a hierarchy of levels, each one performing some well-defined function. This fundamental concept is as valid today as it was when the first edition came out, so it has been retained as the basis for the fifth edition. As in the first four editions, the digital logic level, the microarchitecture level, the instruction set architecture level, the operating system machine level, and the assembly language level are all discussed in detail.

Although the basic structure has been maintained, this fifth edition does contain many changes, both small and large, that bring it up to date in the rapidly changing computer industry. For example, the example machines used have been brought up to date. The current examples are the Intel Pentium 4, the Sun Ultra-SPARC III, and the Intel 8051. The Pentium 4 is an example of a popular CPU used on desktop machines. The UltraSPARC III is an example of a popular server, widely used in medium and large mutiprocessors.

However, the 8051 may come as a surprise to some people. It is a venerable chip that has been around for decades. However, with the enormous growth of embedded systems, it has finally come into its own. With computers running everything from clock radios to microwave ovens, interest in embedded systems is surging, and the 8051 is a widely-used choice due to its extremely low cost (pennies), the wealth of software and peripherals for it, and the large number of 8051 programmers available.

The book has become longer over the years. Such an expansion is inevitable as a subject develops and there is more known about it. As a result, when the book is used for a course, it may not always be possible to finish the book in a single course (e.g., in a trimester system). A possible approach would be to do all of Chaps. 1, 2, and 3, the first part of Chap. 4 (up through and including Sec. 4.4), and Chap. 5 as a bare minimum. The remaining time could be filled with the rest of Chap.4, and parts of Chaps. 6, 7, and 8, depending on the interest of the instructor.

A chapter-by-chapter rundown of the major changes since the fourth edition follows. Chapter 1 still contains an historical overview of computer architecture, pointing out how we got where we are now and what the milestones were along the way. The enlarged spectrum of computers that exist is now discussed, and our three major examples (Pentium 4, UltraSPARC III, and 8051) are introduced.

In Chapter 2, the material on input/output devices has been updated, emphasizing the technology of modern devices, including digital cameras, DSL, and Internet over cable.

Chapter 3 has undergone some revision and now treats computer buses and modern I/O chips. The three new examples are described here at the chip level. New material has been added about the PCI Express bus, which is expected to replace the PCI bus shortly.

Chapter 4 has always been a popular chapter for explaining how a computer really works, so most of it is unchanged since the fourth edition. However, there are new sections discussing the microarchitecture level of Pentium 4, the Ultra-SPARC III, and the 8051.

Chapters 5, 6, and 7 have been updated using the new examples, but are otherwise relatively unchanged. Chapter 6 uses Windows XP rather than Windows NT as an example, but at the level of discussion here, the changes are minimal.

In contrast, Chapter 8 has been heavily modified to reflect all the new activity in parallel computers of all forms. It covers five different classes of parallel systems, from on-chip parallelism (instruction-level parallelism, on-chip multithreading, and single-chip multiprocessors), through coprocessors, shared-memory systems, and clusters, and ends up with a brief discussion of grids. Numerous new examples are discussed here, from the TriMedia CPU, to the BlueGene/L, Red Storm and Google clusters.

The references in Chap. 9 have been updated heavily. Computer organization is a dynamic field. Over half the references in this 5th edition are to books and papers written after the 4th edition of this book was published.

Appendices A and B are unchanged since last edition.

In addition to the assembly language tools, the Website also contains a graphical simulator to be used in conjunction with Chap. 4. This simulator was written by Prof. Richard Salter of Oberlin College. It can be used by students to help grasp the principles discussed in this chapter. My thanks to him for providing this software.

In addition, the figures used in the book and PowerPoint sheets for instructors are also available on the Website. The URL is

<http://www.prenhall.com/tanenbaum>

From there, click on the Companion Website for this book and select the page you are looking for from the menu.

Instructors using this book for a university course can obtain a manual with the solutions to the problems by contacting their Pearson Education representative.

A number of people have read (parts of) the manuscript and provided useful suggestions or have been helpful in other ways. In particular, I would like to thank Nikitas Alexandridis, Shekar Borkar, Herbert Bos, Scott Cannon, Doug Carmean, Alan Charlesworth, Eric Cota-Robles, Michael Fetterman, Quinn Jacobson, Thilo Kielmann, Iffat Kazi, Saul Levy, Ahmed Louri, Abhijit Pandya, Krist Petersen, Mark Russinovich, Ronald Schroeder, and Saim Ural for their help, for which I am most grateful. Thank you.

I would also like to thank Jim Goodman for his contributions to this book, especially to Chaps. 4 and 5. The idea of using the Java Virtual Machine was his and the book is better for it.

Finally, I would like to thank Suzanne once more for her love and patience. It never ends, not even after 15 books. Barbara and Marvin are always a joy and now know what professors do for a living. The Royal Netherlands Academy of Arts and Sciences granted me a much-coveted Academy Professorship in 2004, freeing me from some of the less attractive aspects of academia (such as endless boring committee meetings), for which I am eternally grateful.

Andrew S. Tanenbaum

ABOUT THE AUTHOR

Andrew S. Tanenbaum has an S.B. degree from M.I.T. and a Ph.D. from the University of California at Berkeley. He is currently a Professor of Computer Science at the Vrije Universiteit in Amsterdam, The Netherlands, where he heads the Computer Systems Group. Until stepping down in Jan. 2005, for 12 years he had been Dean of the Advanced School for Computing and Imaging, an inter-university graduate school doing research on advanced parallel, distributed, and imaging systems.

In the past, he has done research on compilers, operating systems, networking, and local-area distributed systems. His current research focuses primarily on computer security, especially in operating systems, networks, and large wide-area distributed systems. Together, all these research projects have led to over 100 refereed papers in journals and conference proceedings and five books.

Prof. Tanenbaum has also produced a considerable volume of software. He was the principal architect of the Amsterdam Compiler Kit, a widely-used toolkit for writing portable compilers, as well as of MINIX, a small UNIX clone intended for use in student programming labs. This system provided the inspiration and base on which Linux was developed. Together with his Ph.D. students and programmers, he helped design the Amoeba distributed operating system, a high-performance microkernel-based local-area distributed operating system. After that he was one of the designers of Globe, a wide-area distributed system intended to handle a billion users. This software is now available for free via the Internet.

His Ph.D. students have gone on to greater glory after getting their degrees. He is very proud of them. In this respect he resembles a mother hen.

Prof. Tanenbaum is a Fellow of the ACM, a Fellow of the the IEEE, and a member of the Royal Netherlands Academy of Arts and Sciences. He is also winner of the 1994 ACM Karl V. Karlstrom Outstanding Educator Award, winner of the 1997 ACM/SIGCSE Award for Outstanding Contributions to Computer Science Education, and winner of the 2002 Texty award for excellence in textbooks. In 2004 he was named as one of the five new Academy Professors by the Royal Academy. He is also listed in *Who's Who in the World*. His home page on the World Wide Web can be found at URL <http://www.cs.vu.nl/~ast/> .

CONTENTS

PREFACE vii

1 INTRODUCTION 1

- 1.1 STRUCTURED COMPUTER ORGANIZATION 2
 - 1.1.1 Languages, Levels, and Virtual Machines 2
 - 1.1.2 Contemporary Multilevel Machines 5
 - 1.1.3 Evolution of Multilevel Machines 8
- 1.2 MILESTONES IN COMPUTER ARCHITECTURE 13
 - 1.2.1 The Zeroth Generation-Mechanical Computers (1642-1945) 14
 - 1.2.2 The First Generation-Vacuum Tubes (1945-1955) 16
 - 1.2.3 The Second Generation-Transistors (1955-1965) 19
 - 1.2.4 The Third Generation-Integrated Circuits (1965-1980) 22
 - 1.2.5 The Fourth Generation-Very Large Scale Integration (1980-?) 23
 - 1.2.6 The Fifth Generation-Invisible Computers 26
- 1.3 THE COMPUTER ZOO 27
 - 1.3.1 Technological and Economic Forces 27
 - 1.3.2 The Computer Spectrum 29
 - 1.3.3 Disposable Computers 29
 - 1.3.4 Microcontrollers 31
 - 1.3.5 Game Computers 33

- 1.3.6 Personal Computers 34
- 1.3.7 Servers 34
- 1.3.8 Collections of Workstations 34
- 1.3.9 Mainframes 36
- 1.4 EXAMPLE COMPUTER FAMILIES 37
 - 1.4.1 Introduction to the Pentium 4 37
 - 1.4.2 Introduction to the UltraSPARC III 42
 - 1.4.3 Introduction to the 8051 44
- 1.5 METRIC UNITS 46
- 1.6 OUTLINE OF THIS BOOK 47

2 COMPUTER SYSTEMS ORGANIZATION 51

- 2.1 PROCESSORS 51
 - 2.1.1 CPU Organization 52
 - 2.1.2 Instruction Execution 54
 - 2.1.3 RISC versus CISC 58
 - 2.1.4 Design Principles for Modern Computers 59
 - 2.1.5 Instruction-Level Parallelism 61
 - 2.1.6 Processor-Level Parallelism 65
- 2.2 PRIMARY MEMORY 69
 - 2.2.1 Bits 69
 - 2.2.2 Memory Addresses 70
 - 2.2.3 Byte Ordering 71
 - 2.2.4 Error-Correcting Codes 73
 - 2.2.5 Cache Memory 77
 - 2.2.6 Memory Packaging and Types 80
- 2.3 SECONDARY MEMORY 81
 - 2.3.1 Memory Hierarchies 81
 - 2.3.2 Magnetic Disks 82
 - 2.3.3 Floppy Disks 86
 - 2.3.4 IDE Disks 86
 - 2.3.5 SCSI Disks 88
 - 2.3.6 RAID 89
 - 2.3.7 CD-ROMs 93
 - 2.3.8 CD-Recordables 97
 - 2.3.9 CD-Rewritables 99

- 2.3.10 DVD 99
- 2.3.11 Blu-Ray 102
- 2.4 INPUT/OUTPUT 102
 - 2.4.1 Buses 102
 - 2.4.2 Terminals 105
 - 2.4.3 Mice 110
 - 2.4.4 Printers 112
 - 2.4.5 Telecommunications Equipment 117
 - 2.4.6 Digital Cameras 125
 - 2.4.7 Character Codes 127
- 2.5 SUMMARY 131

3 THE DIGITAL LOGIC LEVEL 135

- 3.1 GATES AND BOOLEAN ALGEBRA 135
 - 3.1.1 Gates 136
 - 3.1.2 Boolean Algebra 138
 - 3.1.3 Implementation of Boolean Functions 140
 - 3.1.4 Circuit Equivalence 141
- 3.2 BASIC DIGITAL LOGIC CIRCUITS 146
 - 3.2.1 Integrated Circuits 146
 - 3.2.2 Combinational Circuits 147
 - 3.2.3 Arithmetic Circuits 152
 - 3.2.4 Clocks 157
- 3.3 MEMORY 159
 - 3.3.1 Latches 159
 - 3.3.2 Flip-Flops 161
 - 3.3.3 Registers 163
 - 3.3.4 Memory Organization 164
 - 3.3.5 Memory Chips 168
 - 3.3.6 RAMs and ROMs 171
- 3.4 CPU CHIPS AND BUSES 173
 - 3.4.1 CPU Chips 174
 - 3.4.2 Computer Buses 176
 - 3.4.3 Bus Width 178
 - 3.4.4 Bus Clocking 180
 - 3.4.5 Bus Arbitration 184
 - 3.4.6 Bus Operations 187

- 3.5 EXAMPLE CPU CHIPS 189
 - 3.5.1 The Pentium 4189
 - 3.5.2 The UltraSPARC III 196
 - 3.5.3 The 8051 200
- 3.6 EXAMPLE BUSES 202
 - 3.6.1 The ISA Bus 203
 - 3.6.2 The PCI Bus 204
 - 3.6.3 PCI Express 212
 - 3.6.4 The Universal Serial Bus 217
- 3.7 INTERFACING 221
 - 3.7.1 I/O Chips 221
 - 3.7.2 Address Decoding 222
- 3.8 SUMMARY 225

4 THE MICROARCHITECTURE LEVEL 231

- 4.1 AN EXAMPLE MICROARCHITECTURE 231
 - 4.1.1 The Data Path 232
 - 4.1.2 Microinstructions 239
 - 4.1.3 Microinstruction Control: The Mic-1 241
- 4.2 AN EXAMPLE ISA: IJVM 246
 - 4.2.1 Stacks 246
 - 4.2.2 The IJVM Memory Model 248
 - 4.2.3 The IJVM Instruction Set 250
 - 4.2.4 Compiling Java to IJVM 254
- 4.3 AN EXAMPLE IMPLEMENTATION 255
 - 4.3.1 Microinstructions and Notation 255
 - 4.3.2 Implementation of IJVM Using the Mic-1 260
- 4.4 DESIGN OF THE MICROARCHITECTURE LEVEL 271
 - 4.4.1 Speed versus Cost 271
 - 4.4.2 Reducing the Execution Path Length 273
 - 4.4.3 A Design with Prefetching: The Mic-2 281
 - 4.4.4 A Pipelined Design: The Mic-3 281
 - 4.4.5 A Seven-Stage Pipeline: The Mic-4 288
- 4.5 IMPROVING PERFORMANCE 292
 - 4.5.1 Cache Memory 293

- 4.5.2 Branch Prediction 299
- 4.5.3 Out-of-Order Execution and Register Renaming 304
- 4.5.4 Speculative Execution 309
- 4.6 EXAMPLES OF THE MICROARCHITECTURE LEVEL 311
 - 4.6.1 The Microarchitecture of the Pentium 4 CPU 312
 - 4.6.2 The Microarchitecture of the UltraSPARC-III Cu CPU 317
 - 4.6.3 The Microarchitecture of the 8051 CPU 323
- 4.7 COMPARISON OF THE PENTIUM, ULTRASPARC,
AND 8051 325
- 4.8 SUMMARY 326

5 THE INSTRUCTION SET ARCHITECTURE LEVEL 331

- 5.1 OVERVIEW OF THE ISA LEVEL 333
 - 5.1.1 Properties of the ISA Level 333
 - 5.1.2 Memory Models 335
 - 5.1.3 Registers 337
 - 5.1.4 Instructions 339
 - 5.1.5 Overview of the Pentium 4 ISA Level 339
 - 5.1.6 Overview of the UltraSPARC III ISA Level 341
 - 5.1.7 Overview of the 8051 ISA Level 345
- 5.2 DATA TYPES 348
 - 5.2.1 Numeric Data Types 348
 - 5.2.2 Nonnumeric Data Types 349
 - 5.2.3 Data Types on the Pentium 4 350
 - 5.2.4 Data Types on the UltraSPARC III 350
 - 5.2.5 Data Types on the 8051 351
- 5.3 INSTRUCTION FORMATS 351
 - 5.3.1 Design Criteria for Instruction Formats 352
 - 5.3.2 Expanding Opcodes 354
 - 5.3.3 The Pentium 4 Instruction Formats 357
 - 5.3.4 The UltraSPARC III Instruction Formats 358
 - 5.3.5 The 8051 Instruction Formats 359
- 5.4 ADDRESSING 360
 - 5.4.1 Addressing Modes 360
 - 5.4.2 Immediate Addressing 361
 - 5.4.3 Direct Addressing 361

- 5.4.4 Register Addressing 361
- 5.4.5 Register Indirect Addressing 362
- 5.4.6 Indexed Addressing 363
- 5.4.7 Based-Indexed Addressing 365
- 5.4.8 Stack Addressing 365
- 5.4.9 Addressing Modes for Branch Instructions 369
- 5.4.10 Orthogonality of Opcodes and Addressing Modes 369
- 5.4.11 The Pentium 4 Addressing Modes 371
- 5.4.12 The UltraSPARC III Addressing Modes 373
- 5.4.13 The 8051 Addressing Modes 373
- 5.4.14 Discussion of Addressing Modes 374
- 5.5 INSTRUCTION TYPES 375
 - 5.5.1 Data Movement Instructions 375
 - 5.5.2 Dyadic Operations 376
 - 5.5.3 Monadic Operations 377
 - 5.5.4 Comparisons and Conditional Branches 379
 - 5.5.5 Procedure Call Instructions 381
 - 5.5.6 Loop Control 382
 - 5.5.7 Input/Output 383
 - 5.5.8 The Pentium 4 Instructions 386
 - 5.5.9 The UltraSPARC III Instruction 389
 - 5.5.10 The 8051 Instructions 392
 - 5.5.11 Comparison of Instruction Sets 392
- 5.6 FLOW OF CONTROL 395
 - 5.6.1 Sequential Flow of Control and Branches 395
 - 5.6.2 Procedures 396
 - 5.6.3 Coroutines 401
 - 5.6.5 Traps 404
 - 5.6.5 Interrupts 404
- 5.7 A DETAILED EXAMPLE: THE TOWERS OF HANOI 408
 - 5.7.1 The Towers of Hanoi in Pentium 4 Assembly Language 409
 - 5.7.2 The Towers of Hanoi in UltraSPARC III Assembly Language 409
- 5.8 THE IA-64 ARCHITECTURE AND THE ITANIUM 2411
 - 5.8.1 The Problem with the Pentium 4 413
 - 5.8.2 The IA-64 Model: Explicitly Parallel Instruction Computing 414
 - 5.8.3 Reducing Memory References 415
 - 5.8.4 Instruction Scheduling 416