CONTENTS

Preface xxiii
About the Authors xxix

PART I AN OVERVIEW OF COMPUTER SYSTEMS

1 COMPUTERS AND SYSTEMS 4

- 1.0 Introduction, 5
- 1.1 The Starting Point, 8
- 1.2 Components of the Computer System, 10

The Hardware Component, 13

The Software Component, 15

The Communication Component, 17

The Computer System, 17

- 1.3 The Concept of Virtualization, 19
- 1.4 Protocols and Standards, 20
- **1.5** Overview of This Book, 21
- 1.6 A Brief Architectural History of the Computer, 22

Early Work, 23

Computer Hardware, 24

Operating Systems, 27

Communication, Networks, and the Internet, 31

Summary and Review, 32

For Further Reading, 33

Key Concepts and Terms, 33

Reading Review Questions, 33

Exercises, 34

2 AN INTRODUCTION TO SYSTEM CONCEPTS AND SYSTEMS

ARCHITECTURE 36

- 2.0 Introduction, 37
- **2.1** The General Concept of Systems, 37
- 2.2 IT System Architectures, 44

The Role of the System Architect, 46

Summary and Review, 48

For Further Reading, 48

xii CONTENTS

Key Concepts and Terms, 49 Reading Review Questions, 49 Exercises, 49

PART II DATA IN THE COMPUTER

Number Systems 52

- 3.0 Introduction, 53
- 3.1 Numbers as a Physical Representation, 53
- 3.2 Counting in Different Bases, 54
- 3.3 Performing Arithmetic in Different Number Bases, 59
- **3.4** Numeric Conversion Between Number Bases, 63 Alternative Conversion Methods, 65
- **3.5** A Special Conversion Case—Number Bases That Are Related, 67
- **3.6** Fractions, 68 Fractional Conversion Methods, 71
- 3.7 Mixed Number Conversions, 73

Summary and Review, 73

For Further Reading, 74

Key Concepts and Terms, 74

Reading Review Questions, 74

Exercises, 75

4 Data Formats 78

- 4.0 Introduction, 79
- **4.1** General Considerations, 79
- 4.2 Alphanumeric Character Data, 82
- 4.3 Visual Data, 88

Bitmap Images, 89

Object Images, 93

Representing Characters as Images, 96

Video Images, 96

- **4.4** Audio Data, 97
- 4.5 Data Compression, 100
- **4.6** Page Description Languages, 102
- 4.7 Internal Computer Data Format, 102Numerical Character to Integer Conversion, 104

Summary and Review, 105

For Further Reading, 106

Key Concepts and Terms, 106

Reading Review Questions, 106

Exercises, 107

CONTENTS xiii

5 Representing Numerical Data 110

- 5.0 Introduction, 111
- 5.1 Unsigned Binary and Binary-Coded Decimal Representations, 111
- 5.2 Representations for Signed Integers, 115

Sign-and-Magnitude Representation, 115

Nine's Decimal and 1's Binary Complementary Representations, 117

Ten's Complement and 2's Complement, 124

Overflow and Carry Conditions, 126

Other Bases, 127

Summary of Rules for Complementary Numbers, 128

5.3 Real Numbers, 128

A Review of Exponential Notation, 128

Floating Point Format, 130

Normalization and Formatting of Floating Point Numbers, 133

A Programming Example, 135

Floating Point Calculations, 136

Floating Point in the Computer, 139

Conversion between Base 10 and Base 2, 141

5.4 Programming Considerations, 142

Summary and Review, 143

For Further Reading, 144

Key Concepts and Terms, 144

Reading Review Questions, 144

Exercises, 145

PART III COMPUTER ARCHITECTURE AND HARDWARE OPERATION

THE LITTLE MAN COMPUTER 152

- 6.0 Introduction, 153
- **6.1** Layout of the Little Man Computer, 154
- 6.2 Operation of the LMC, 154
- 6.3 A Simple Program, 156
- **6.4** An Extended Instruction Set, 157
- **6.5** The Instruction Cycle, 160
- **6.6** A Note Regarding Computer Architectures, 162

Summary and Review, 163

Key Concepts and Terms, 163

Reading Review Questions, 164

Exercises, 164

7 THE CPU AND MEMORY 166

- 7.0 Introduction, 167
- 7.1 The Components of the CPU, 168
- 7.2 The Concept of Registers, 169

xiv CONTENTS

7.3 The Memory Unit, 171

The Operation of Memory, 171

Memory Capacity and Addressing Limitations, 175

Primary Memory Characteristics and Implementation, 176

- 7.4 The Fetch–Execute Instruction Cycle, 178
- **7.5** Classification of Instructions, 181

Data Movement Instructions (LOAD, STORE, and Other Moves), 183

Arithmetic Instructions, 183

Boolean Logic Instructions, 184

Single Operand Manipulation Instructions, 184

Bit Manipulation Instructions, 184

Shift and Rotate Instructions, 185

Program Control Instructions, 186

Stack Instructions, 187

Multiple Data Instructions, 189

Other Instructions, 190

- 7.6 Instruction Word Formats, 190
- 7.7 Instruction Word Requirements and Constraints, 192

Summary and Review, 195

For Further Reading, 195

Key Concepts and Terms, 195

Reading Review Questions, 196

Exercises, 197

8 CPU AND MEMORY: DESIGN, ENHANCEMENT, AND IMPLEMENTATION 200

- 8.0 Introduction, 201
- 8.1 CPU Architectures, 202

Overview, 202

Traditional Modern Architectures, 202

8.2 CPU Features and Enhancements, 203

Introduction, 203

Fetch-Execute Cycle Timing Issues, 204

A Model for Improved CPU Performance, 206

Scalar and Superscalar Processor Organization, 210

8.3 Memory Enhancements, 213

Wide Path Memory Access, 214

Memory Interleaving, 214

Cache Memory, 215

- 8.4 The Compleat Modern Superscalar CPU, 219
- **8.5** Multiprocessing, 221
- **8.6** A Few Comments on Implementation, 225

Summary and Review, 225

For Further Reading, 226

CONTENTS XV

Key Concepts and Terms, 227 Reading Review Questions, 227 Exercises, 228

9 INPUT/OUTPUT AND BUSES 230

- 9.0 Introduction, 231
- 9.1 Characteristics of Typical I/O Devices, 232
- **9.2** Programmed I/O, 237
- **9.3** Interrupts, 239

Servicing Interrupts, 239

The Uses of Interrupts, 241

Multiple Interrupts and Prioritization, 245

- 9.4 Direct Memory Access, 249
- **9.5** I/O Controllers, 252
- **9.6** Buses, 254

Bus Characteristics, 254

Summary and Review, 258

For Further Reading, 259

Key Concepts and Terms, 259

Reading Review Questions, 259

Exercises, 260

10 Computer Peripherals 262

- 10.0 Introduction, 263
- **10.1** The Hierarchy of Storage, 264
- 10.2 Solid-State Memory, 266

10.4 Optical Disk Storage, 274

- 10.3 Magnetic Disks, 267
- Disk Arrays, 272
- **10.5** Magnetic Tape, 276
- **10.6** Displays, 277

Basic Display Design, 277

Graphical Processing Units (GPUs), 279

Liquid Crystal Display Technology, 282

OLED Display Technology, 283

10.7 Printers, 284

Laser Printers, 285

Inkjet Printers, 285

10.8 User Input Devices, 286

Keyboards, 287

Pointing Devices, 287

Alternative Sources of Alphanumeric Input, 288

Scanners, 291

xvi CONTENTS

Multimedia Input, 291 Mobile Devices, 292

10.9 Network Communication Devices, 293

Summary and Review, 293

For Further Reading, 294

Key Concepts and Terms, 294

Reading Review Questions, 295

Exercises, 295

11 COMPUTER SYSTEM ORGANIZATION 298

- 11.0 Introduction, 299
- 11.1 Putting the Pieces Together, 300
- 11.2 System Architecture, 305

Basic System Interconnection Requirements, 305

Bus I/O, 307

Channel Architecture, 311

Blurring the Line, 313

Summary and Review, 313

For Further Reading, 313

Key Concepts and Terms, 314

Reading Review Questions, 314

Exercises, 314

PART IV NETWORKS, DATA COMMUNICATIONS, AND NETWORKED COMPUTER SYSTEMS

12 Networks and Data Communications—An Overview

- **12.0** Introduction, 319
- **12.1** The Impact of Networking on Business Processes and User Access to Knowledge and Services, 320

318

- 12.2 A Simple View of Data Communications, 321
- **12.3** Basic Data Communication Concepts, 324

Messages, 324

Packets, 325

General Channel Characteristics, 326

12.4 Networks, 330

Network Topology, 330

Types of Networks, 334

Network Interconnection, 347

12.5 Standards, 351

Summary and Review, 352

For Further Reading, 352

Key Concepts and Terms, 352

Reading Review Questions, 353

Exercises, 353

CONTENTS xvii

13 ETHERNET AND TCP/IP NETWORKING 356

- 13.0 Introduction, 357
- 13.1 TCP/IP, OSI, and Other Communication Protocol Models, 357
- **13.2** Program Applications versus Network Applications, 362
- 13.3 The Physical and Data Link Layers, 362

The Physical Layer, 363

The Data Link Layer, 364

Hub-Based Ethernet, 366

Switched Ethernet. 366

Wireless Ethernet (Wi-Fi), 367

- 13.4 The Network Layer, 368
- 13.5 The Transport Layer, 372
- **13.6** IP Addresses, 376 IPv4 and DHCP, 376 IPv6, 379
- 13.7 Domain Names and DNS Services, 380
- 13.8 Quality of Service, 385
- 13.9 Network Security, 386

Physical and Logical Access Restriction, 386 Encryption, 387

13.10 Alternative Protocols, 387

A Comparison of TCP/IP and OSI, 388

Other Protocol Suites and Components, 388

SCSI Over IP, 389

Cellular Technology, 389

MPLS, 390

Summary and Review, 390

For Further Reading, 391

Key Concepts and Terms, 391

Reading Review Questions, 392

Exercises, 392

14 COMMUNICATION CHANNEL TECHNOLOGY 396

- 14.0 Introduction, 397
- **14.1** Communication Channel Technology, 398
- 14.2 The Fundamentals of Signaling Technology, 400

Analog Signaling, 401

Digital Signaling, 411

Modems, 416

Two Examples of Alternative Advanced Technologies, 416

- 14.3 Transmission Media and Signaling Methods, 418
- 14.4 Wireless Technologies, 420

Cellular Technology, 421

Wi-Fi, 421

Bluetooth, 421

xviii CONTENTS

Summary and Review, 422 For Further Reading, 423 Key Concepts and Terms, 423 Reading Review Questions, 423 Exercises, 424

15 Modern Networked Computer Systems 426

- **15.0** Introduction, 427
- 15.1 Distributed Systems, 428
- 15.2 Client-Server Computing, 430
- **15.3** Web-Based Computing, 433
- 15.4 Peer-to-Peer Computing, 435
- 15.5 Clusters, 436Overview, 436Classification and Configuration, 437Beowulf Clusters, 438
- 15.6 Storage Area Networks, 440
- 15.7 Cloud Computing, 441
- **15.8** Supercomputing, 443 Grid Computing, 444
- **15.9** Networked Computer System Architecture Examples, 444
 Google: A System Architecture Example, 445
 Another Example: Facebook's Application Architecture, 448

Summary and Review, 449
For Further Reading, 450
Key Concepts and Terms, 450
Reading Review Questions, 450
Exercises, 451

PART V THE SOFTWARE COMPONENT

16 OPERATING SYSTEMS: AN OVERVIEW 454

- **16.0** Introduction, 455
- **16.1** The Barebones Computer System, 456
- 16.2 The Operating Systems Concept: An Introduction, 457
- 16.3 Services and Facilities, 463

User Interface and Command Execution Services, 464

File Management, 465

Input/Output Services, 466

Process Control Management, 467

Memory Management, 468

Scheduling and Dispatch, 468

Secondary Storage Management, 471

Network and Communications Support Services, 471

CONTENTS xix

Security and Protection Services, 472 System Administration Support, 473

16.4 Organization, 476

16.5 Types of Computer Systems, 479

Summary and Review, 483

For Further Reading, 483

Key Concepts and Terms, 483

Reading Review Questions, 484

Exercises, 484

17 THE USER VIEW OF OPERATING SYSTEMS 486

17.0 Introduction, 487

17.1 Purpose of the User Interface, 488

17.2 User Functions and Program Services, 490

Program Execution, 490

File Commands, 491

Disk and Other I/O Device Commands, 492

Security and Data Integrity Protection, 492

Interuser Communication and Data Sharing Operations, 493

System Status Information and User Administration, 494

Program Services, 495

17.3 Types of User Interface, 495

The Command Line Interface, 496

Batch System Commands, 498

Graphical User Interfaces, 499

Touchless Gesture- and Voice-Based Interfaces, 504

Trade-Offs in the User Interface. 505

Software Considerations, 506

17.4 X Window and Other Graphics Display Methodologies, 507

17.5 Command and Scripting Languages, 510

The Elements of a Command Language, 512

The Command Language Start-Up Sequence Files, 512

17.6 Services to Programs, 513

Summary and Review, 515

For Further Reading, 515

Key Concepts and Terms, 515

Reading Review Questions, 516

Exercises, 516

18 FILE MANAGEMENT 518

18.0 Introduction, 519

18.1 The Logical and Physical View of Files, 519

18.2 The Role of the File Management System, 524

18.3 Logical File Access Methods, 528 Sequential File Access, 529

XX CONTENTS

Random Access, 529

Indexed Access, 530

18.4 Physical File Storage, 531

Contiguous Storage Allocation, 531

Noncontiguous Storage Allocation, 532

Indexed Allocation, 534

Free Space Management, 537

Tape Allocation, 539

Optical and Flash Drive Allocation, 539

- **18.5** File Systems, Volumes, Disks, Partitions, and Storage Pools, 539
- 18.6 The Directory Structure, 542

Tree-Structured Directories, 543

Acyclic-Graph Directories, 545

- 18.7 Network File Access, 548
- 18.8 File Protection, 550
- 18.9 Journaling File Systems, 551

Summary and Review, 552

For Further Reading, 552

Key Concepts and Terms, 553

Reading Review Questions, 553

Exercises, 554

19 THE INTERNAL OPERATING SYSTEM 556

- **19.0** Introduction, 557
- **19.1** Fundamental OS Requirements, 558
 Example: A Simple Multitasking Operating System, 559
- **19.2** Starting the Computer System: The Bootstrap, 562
- **19.3** Processes and Threads, 564

Process Creation, 567

Process States, 568

Threads, 569

- 19.4 Basic Loading and Execution Operations, 570
- 19.5 CPU Scheduling and Dispatching, 572

Long-Term Scheduler, 572

Short-Term Scheduler and Dispatcher, 572

Nonpreemptive Scheduling Algorithms, 575

Preemptive Short-Term Scheduling Algorithms, 576

19.6 Memory Management, 577

Memory Partitioning, 578

19.7 Virtual Storage, 579

Overview, 579

Pages and Frames, 580

The Concept of Virtual Storage, 585

Page Faults, 586

Working Sets and the Concept of Locality, 588

Page Sharing, 588

Page Replacement Algorithms, 589

CONTENTS xxi

19.8	Thrashing, 592 Page Table Implementation, 592 Segmentation, 595 Process Separation, 596 Disk Scheduling, 596 First-Come, First-Served Scheduling, 597 Shortest Distance First Scheduling, 597 Scan Scheduling, 597			
	<i>n</i> -Step c-Scan Scheduling, 598			
19.9	Network Operating System Services, 598			
	OS Protocol Support and Other Services, 598			
19.10	Other Operating System Issues, 601			
	Deadlock, 601			
	Other Issues, 602			
19.11	Virtual Machines, 603			
Summary and Review, 605				
For Further Reading, 606				
Key Concepts and Terms, 606				
Reading Review Questions, 607				
Exercises, 608				
BLIOGRAPHY				
DEX				

B-1 BIE

INI I-1

SUPPLEMENTARY CHAPTERS

On the Web at www.wiley.com/Englander6e

An Introduction To Digital Computer SUPPLEMENTARY CHAPTER 1 Logic

S1.0	Introdu	iction
J1.U		

S1.1 Boolean Algebra

S1.2 Gates and Combinatorial Logic

\$1.3 Sequential Logic Circuits

Summary and Review

For Further Reading

Key Concepts and Terms

Reading Review Questions

Exercises

SUPPLEMENTARY CHAPTER 2 System Examples

57 N	Introd	luction

S2.1 Hardware Examples

The x86 Family

The POWER Family

The IBM System 360/370/390/zSeries Family

S2.2 Operating System Examples

The Microsoft Windows Family

xxii

CONTENTS

UNIX and Linux

The IBM z/OS Operating System

S2.3 Networking Examples

Google

Summary and Review

For Further Reading

Key Concepts and Terms

Reading Review Questions

Exercises

SUPPLEMENTARY CHAPTER 3 Instruction Addressing Modes

- **S3.0** Introduction
- **S3.1** Register Addressing
- **S3.2** Alternatives to Absolute Addressing
- **S3.3** Alternatives to Direct Addressing

Immediate Addressing

Indirect Addressing

Register Indirect Addressing

Indexed Addressing

Indirect Indexed and Indirect Indexed Addressing

Summary and Review

For Further Reading

Key Concepts and Terms

Reading Review Questions

Exercises

SUPPLEMENTARY CHAPTER 4 Programming Tools

- **S4.0** Introduction
- **S4.1** Program Editing and Entry
- **S4.2** The Concept of Program Translation
- **S4.3** Assembly Language and the Assembler

Operation of the Assembler

Assembly Language Formats

Features and Extensions

Relocatability

S4.4 Program Language Description and Rules

A Description of Written English

Programming Language Rules

Computer Language Descriptions

The Compilation Process

Interpreters

S4.5 Linking and Loading

S4.6 Debuggers

Summary and Review

For Further Reading

Key Concepts and Terms

Reading Review Questions

Exercises