UPGRADING AND REPAIRING PCs
21st Edition

Contents at a Glance

Introduction 1
1 Development of the PC 5
2 PC Components, Features, and System Design 19
3 Processor Types and Specifications 29
4 Motherboards and Buses 155
5 BIOS 263
6 Memory 325
7 The ATA/IDE Interface 377
8 Magnetic Storage Principles 439
9 Hard Disk Storage 461
10 Flash and Removable Storage 507
11 Optical Storage 525
12 Video Hardware 609
13 Audio Hardware 679
14 External I/O Interfaces 703
15 Input Devices 739
16 Internet Connectivity 775
17 Local Area Networking 799
18 Power Supplies 845
19 Building or Upgrading Systems 929
20 PC Diagnostics, Testing, and Maintenance 975
Index 1035

Scott Mueller
Contents

Introduction 1

1 Development of the PC 5

Computer History: Before Personal Computers 5
Timeline 5
Electronic Computers 10
Modern Computers 10
From Tubes to Transistors 11
Integrated Circuits 13
History of the PC 14
Birth of the Personal Computer 14
The IBM Personal Computer 15
The PC Industry 30 Years Later 16

2 PC Components, Features, and System Design 19

What Is a PC? 19
Who Controls PC Software? 20
Who Controls PC Hardware? 23
White-Box Systems 26
System Types 26
System Components 28

3 Processor Types and Specifications 29

Microprocessor History 29
The First Microprocessor 29
PC Processor Evolution 32
16-Bit to 64-Bit Architecture Evolution 34
Processor Specifications 35
Data I/O Bus 42
Address Bus 42
Internal Registers (Internal Data Bus) 44
Processor Modes 44
Processor Benchmarks 49
Comparing Processor Performance 49
Cache Memory 53
Processor Features 60
System Management Mode (SMM) 60
Superscalar Execution 61
MMX Technology 62
Dynamic Execution 64
Dual Independent Bus Architecture 65
HT Technology 65
Multicore Technology 66
Hardware-Assisted Virtualization Support 68

Processor Manufacturing 69
Processor Re-Marking 74
PGA Chip Packaging 74
Single Edge Contact and Single Edge Processor Packaging 75
Processor Socket and Slot Types 75
Socket 478 78
Socket LGA775 79
Socket LGA1156 80
Socket LGA1366 81
Socket LGA1155 82
Socket LGA2011 83
Socket 939 and 940 83
Socket AM2/AM2+/AM3/AM3+ 84
Socket F (1207FX) 86
Socket FM1 86
Socket FM2 86
CPU Operating Voltages 87
Math Coprocessors (Floating-Point Units) 87
Processor Bugs and Steppings 88
Processor Code Names 88
P1 (086) Processors 89
P2 (286) Processors 90
P3 (386) Processors 91
P4 (486) Processors 92
P5 (586) Processors 93
AMD-K5 96
Intel P6 (686) Processors 96
Pentium Pro Processors 97
Pentium II Processors 97
Pentium III 99
Celeron 100
Intel Pentium 4 Processors 101
Pentium 4 Extreme Edition 104
Intel Pentium D and Pentium Extreme Edition 106
Intel Core Processors 108
Intel Core 2 Family 108
Intel (Nehalem) Core i Processors 110
AMD K6 Processors 114
NexGen Nx586 114
AMD-K6 Series 116
AMD K7 Processors 117
AMD Athlon 117
AMD Duron 118
4 Motherboards and Buses 155

Motherboard Form Factors 155
   Obsolete Form Factors 156
   ATX and Other Modern Form Factors 167
Processor Sockets/Slots 178

Chipsets 181
   Chipset Evolution 181
   Intel Chipsets 183
   Intel Chipset Model Numbers 184
   Intel Integrated Graphics Architecture 185
   AMD Integrated Graphics
      Architecture 185
   Traditional North/South Bridge
      Architecture 185
   Hub Architecture 187
   HyperTransport and Other Processor/
      Chipset Interconnects 188
Intel’s Early 386/486 Chipsets 190

Fifth-Generation (P5 Pentium Class)
   Chipsets 190

Sixth-Generation (P6 Pentium Pro/II/III Class)
   Chipsets 192

Seventh/Eighth-Generation (Pentium 4/D,
   Core 2, and Core i) Chipsets 195
   Intel 915 Family 202
   Intel 925X Family 203
   Intel 945 Express Family 203
   Intel 955X and 975X Family 204

Intel 96x Series 204
Intel 3x and 4x Series Chipsets 205
Intel 5x Series Chipsets 208
Intel 6x Series Chipsets 211
Intel 7x Series Chipsets 213

Third-Party Chipsets for Intel Processors 215
   SiS Chipsets 215
   ULi Electronics Chipsets 215
   ATI Chipsets 216
   VIA Chipsets 216
   NVIDIA Chipsets for Intel Processors 216

Chipsets for AMD Processors 217
   AMD Athlon Chipsets 217
   AMD Athlon 64 Chipsets 218
   AMD K8 Processors 219
   AMD Athlon 64 and 64 FX 220
   AMD Sempron 220
   AMD (Formerly ATI) Chipsets for Athlon
      64, Sempron, Phenom 220
   Third-Party Chipsets for AMD
      Processors 226
   VIA Chipsets 226
   SiS Chipsets 227
   NVIDIA Chipsets 227
   Super I/O Chips 228
   Motherboard Connectors 228
   System Bus Types, Functions, and
      Features 239
   The Processor Bus (FSB) 245

Types of I/O Buses 245
   The ISA Bus 245
   The Micro Channel Bus 246
   The EISA Bus 246
   Local Buses (VESA, PCI, PCI Express, AGP) 246

System Resources 254
   Interrupts 254
   DMA Channels 259
   I/O Port Addresses 259
   Motherboard Selection Criteria (Knowing
      What to Look For) 260
   Chipset Documentation 262

5 BIOS 263

BIOS Basics 263
Motherboard ROM BIOS 267
   ROM Hardware 267
   ROM Shadowing 269
   ROM Chip Types 269
   ROM BIOS Manufacturers 273
   BIOS Hardware/Software 274

Upgrading the BIOS 274
   Where to Get Your BIOS Update 275
   Determining Your BIOS Version 275
   Checking the BIOS Date 275
6 Memory 325

Memory Basics 325
- ROM 327
- DRAM 327
  - Cache Memory: SRAM 329
Memory Standards 331

Speed and Performance 332
- Fast Page Mode DRAM 335
- Extended Data Out RAM 336
- SDRAM 337
- DDR SDRAM 338
- DDR2 SDRAM 340
- DDR3 SDRAM 342
- DDR4 SDRAM 344
- RDRAM 345

Memory Modules 346
- Registered Modules 351
- SDR DIMM Details 352
- DDR DIMM Details 353
- DDR2 DIMM Details 353
- DDR3 DIMM Details 353

Determining a Memory Module’s Size and Features 354

Memory Banks 356

Memory Module Speed 357

Parity and ECC 357
- Parity Checking 359
- How Parity Checking Works 359
- ECC 360

RAM Upgrades 361
- Upgrade Options and Strategies 362
- Purchasing Memory 364
- Replacing Modules with Higher-Capacity Versions 366
- Installing Memory Modules 366

Troubleshooting Memory 368

Memory Defect Isolation Procedures 372

The System Logical Memory Layout 374

7 The ATA/IDE Interface 377

An Overview of the IDE Interface 377
- Precursors to IDE 377
- IDE Origins 378
- Origins of ATA 379

ATA Standards 380
- ATA-1 (ATA Interface for Disk Drives) 382
- ATA-2 (ATA Interface with Extensions-2) 382
- ATA-3 (ATA Interface-3) 383
- ATA/ATAPI-4 (ATA with Packet Interface Extension-4) 383
- ATA/ATAPI-5 (ATA with Packet Interface-5) 384
- ATA/ATAPI-6 (ATA with Packet Interface-6) 385
- ATA/ATAPI-7 (ATA with Packet Interface-7) 386
- ATA/ATAPI-8 386

PATA 387
- PATA I/O Connector 387
- PATA I/O Cable 390
- Longer or Rounded Cables 392
- PATA Signals 392
- PATA Dual-Drive Configurations 393
- PATA PIO Transfer Modes 396
- PATA DMA Transfer Modes 396

SATA 398
- SATA Standards and Performance 398
- SATA Express 399
- SATA Cables and Connectors 401
- eSATA 404
- SATA Configuration 407
- Advanced Host Controller Interface (AHCI) 408
- Non-Volatile Memory Express (NVMe) 409
- SATA Transfer Modes 409
ATA Features 410
ATA Commands 410
ATA Security Mode 411
Host Protected Area 412
ATAPI 413
ATA Drive Capacity Limitations 413
Prefixes for Decimal and Binary Multiples 414
BIOS Limitations 415
CHS Versus LBA 416
CHS/LBA and LBA/CHS Conversions 417
BIOS Commands Versus ATA Commands 418
CHS Limitations (the 528MB Barrier) 419
CHS Translation (Breaking the 528MB Barrier) 421
The 2.1GB and 4.2GB Barriers 423
LBA-Assist Translation 425
The 8.4GB Barrier 427
The 137GB Barrier and Beyond 429
Operating System and Other Software Limitations 430
GPT and the 2.2TB Barrier 432
PATA/SATA RAID 434
Software RAID 436

8 Magnetic Storage Principles 439
Magnetic Storage 439
History of Magnetic Storage 439
How Magnetic Fields Are Used to Store Data 440
Read/Write Head Designs 443
Ferrite 444
Metal-In-Gap 444
Thin-Film 444
Magneto-Resistive Heads 445
Giant Magneto-Resistive Heads 446
Head Sliders 448
Data-Encoding Schemes 450
Frequency Modulation Encoding 451
Modified FM Encoding 451
Run Length Limited Encoding 452
Encoding Scheme Comparisons 453
Partial-Response, Maximum-Likelihood Decoders 455
Capacity Measurements 455
Areal Density 456
Perpendicular Magnetic Recording 458

9 Hard Disk Storage 461
Definition of a Hard Disk 461
Hard Drive Advancements 462

Form Factors 463
5 1/4-Inch Drive 464
3 1/2-Inch Drive 465
2 1/2-Inch Drive 465
1.8-Inch Drive 466
1-Inch Drives 466
HDD Operation 466
The Ultimate HDD Analogy 469
Tracks and Sectors 470
ECC 472
Disk Formatting 477
Basic HDD Components 482
Hard Disk Platters (Disks) 483
Recording Media 484
Read/Write Heads 485
Head Actuator Mechanisms 487
Air Filters 494
Hard Disk Temperature Acclimation 495
Spindle Motors 495
Logic Boards 496
Cables and Connectors 497
Configuration Items 497
Hard Disk Features 498
Capacity 498
Performance 500
Reliability 504

10 Flash and Removable Storage 507
Alternative Storage Devices 507
Flash Memory Devices 507
CompactFlash 509
SmartMedia 509
MultiMediaCard 510
SecureDigital 510
Sony Memory Stick 510
ATA Flash PC Card 511
xD-Picture Card 511
SSD (Solid-State Drive) 511
USB Flash Drives 516
Comparing Flash Memory Devices 517
SD Cards Speed Class and UHS Speed Class Markings 519
File Systems Used by Flash Memory 520
Flash Card Readers 520
Card Readers 520
ReadyBoost Support 521
Cloud-Based Storage 522
Floppy Disk Drives 523
Tape Drives 523
11 Optical Storage  525

   Optical Technology  525
   CD-Based Optical Technology  526
   CDs: A Brief History  526
   CD Construction and Technology  527
   Mass-Producing CDs  527
   Writable CDs  539
   MultiRead Specifications  545
   MultiPlay and MultiAudio  547

   DVD  547
   DVD History  548
   DVD Construction and Technology  549
   DVD Tracks and Sectors  550
   Handling DVD Errors  554
   DVD Capacity (Sides and Layers)  555
   Data Encoding on the DVD Disc  558
   Recordable DVD Standards  559
   Multiformat Rewritable DVD Drives  566

   BD  567
   HD-DVD  569

   Optical Disc Formats  570
   CD Formats  570
   DVD Formats and Standards  578
   Optical Disc File Systems  582
   Ripping/Copying Discs  587
   “For Music Use Only” CD-R/RW Discs  588
   CD Copy Protection  588
   CD Digital Rights Management  589
   DVD and Blu-ray Copy Protection  589

   Optical Drive Performance Specifications  593
   CD Data Transfer Rate  593
   CD Drive Speed  593
   DVD Drive Speed  595
   Access Time  598
   Buffer/Cache  598
   Direct Memory Access and Ultra-DMA  598
   Interface  598
   Loading Mechanism  599
   Other Drive Features  600

   How to Reliably Record Optical Discs  600
   Booting from a Floppy Disk with Optical Drive Support  601
   Bootable Optical Discs—El Torito  601
   LightScribe and LabelFlash  602

12 Video Hardware  609

   Display Adapters and Monitors  609
   Video Display Adapters  610
   Video Adapter Types  610
   Integrated Video/Motherboard Chipsets  611
   CPUs with Integrated Video  616
   Video Adapter Components  617
   Identifying the Video and System Chipsets  619
   Video RAM  620
   The DAC  624
   Video Display Interfaces  624
   The System Interface  624
   The Display Interface  626
   TV Display Interfaces  641

   3D Graphics Accelerators  642
   How 3D Accelerators Work  642
   APIs  645
   Dual-GPU Scene Rendering  648

   Monitors  650
   Display Specifications  650
   LCD Technology  661
   LED Backlit Technology  663
   CRT Display Technology  663
   Plasma Display Technology  665
   LCD and DLP Projectors  666

   Using Multiple Monitors  667
   Dualview  667
   Homogeneous Adapters  668
   Heterogeneous Adapters  668

   Choosing the Best Display Hardware for a Particular Task  668

   Video Troubleshooting and Maintenance  669
   Troubleshooting Video Cards and Drivers  670
   Video Drivers  672
   Maintaining Monitors  672
   Testing Monitors  673
   Adjusting Monitors  674
   Bad Pixels  675
   Troubleshooting Monitors  676
   Repairing Monitors  677

13 Audio Hardware  679

   Audio Hardware Concepts and Terms  680
   The Nature of Sound  680
   Evaluating the Quality of Your Audio Hardware  680
   Sampling  681
Contents

Early PC Sound Cards 682
- Limitations of Sound Blaster Pro Compatibility 682
- Microsoft Windows and Audio Support 682
- DirectX and Audio Support Hardware 683
- Core Audio APIs for Windows 683
- 3D Gaming Audio Standards 684
- Legacy Audio Support Through Virtualization 685
Audio Hardware Features 686
- Basic Connectors 686
- Audio Signal Processing Methods 688
- Advanced Audio Features 688
- Volume Control 690
- MIDI Support Features 691
- Data Compression 692
- Sound Drivers 693
- Sound Cards for Sound Producers 693
Motherboard Chipsets with Integrated Audio 694
- Intel “Azalia” HD Audio 694
Troubleshooting PC Audio Problems 694
- Sound Card and Onboard Audio Problems 695
Speakers 698
- Speaker Selection Criteria 698
- Theater and Surround Sound Considerations 699
- Microphones 700

14 External I/O Interfaces 703
- Introduction to Input/Output Ports 703
- Serial Versus Parallel 703
- Universal Serial Bus (USB) 704
- IEEE 1394 (FireWire or i.LINK) 718
- Comparing USB and IEEE 1394 (FireWire) 722
- Thunderbolt Technology 728
- Low-Speed External Connections 729
- Serial Ports 730
- Parallel Ports 734

15 Input Devices 739
- Keyboards 739
- Enhanced 101-Key Keyboard 739
- 103/104-Key Windows Keyboard 740
- Keyboard Technology 742
- Keyswitch Design 742
- The “Keyboard Interface” 747
- Typematic Functions 749
- Keyboard Scan Codes 749
- International Keyboard Layouts 750

16 Internet Connectivity 775
- Internet Connectivity Trends 775
- Broadband Internet Access Types 775
- Cable TV 776
- Digital Subscriber Line 779
- Wireless Broadband 783
- Cellular Broadband 3G and 4G Services 783
- Satellite Broadband 784
- ISDN 787
- Leased Lines 788
- Comparing High-Speed Internet Access 789
- Dial-Up Modems 790
- 56Kbps Modems 791
- Internet Connection Security 794
- Having a Backup Plan in Case of Service Interruptions 795
- Sharing Your Internet Connection 795
- Routers for Internet Sharing 796
- Modem/Router Status LEDs 797

17 Local Area Networking 799
- Defining a Network 799
- Types of Networks 800
- Requirements for a Network 801
- Client/Server Versus Peer Networks 801
- Client/Server Networks 802
- Peer-to-Peer Networks 803
- Comparing Client/Server and Peer-to-Peer Networks 804
Connecting the Power Supply 958
Connecting I/O and Other Cables to the Motherboard 961
Installing the Drives 962
Installing a Video Card 967
Installing Additional Expansion Cards 969
Replacing the Cover and Connecting External Cables 969
System Startup 969
Installing the OS 971
Troubleshooting New Installations 972

20 PC Diagnostics, Testing, and Maintenance 975

PC Diagnostics 975
Diagnostics Software 975
The POST 976
Peripheral Diagnostics 989
Operating System Diagnostics 989
Commercial Diagnostics Software 990
Free/User Supported Diagnostics 991
The Boot Process 991
The Hardware Boot Process: Operating System Independent 992
The DOS Boot Process 996
The Windows 9x/Me Boot Process 997
Windows 2000/XP Startup 997
Windows Vista/7 Startup 998
Windows 8 Startup 998
PC Maintenance Tools 999
Hand Tools 1000
Safety 1003
Test Equipment 1004
Special Tools for the Enthusiast 1009
Preventive Maintenance 1011
Active Preventive Maintenance Procedures 1011
Passive Preventive Maintenance Procedures 1016
Troubleshooting Tips and Techniques 1021
Repair or Replace? 1021
Basic Troubleshooting Steps 1021
Troubleshooting by Replacing Parts 1022
Troubleshooting by the Bootstrap Approach 1023
Problems During the POST 1024
Problems Running Software 1024
Problems with Adapter Cards 1025
Top Troubleshooting Problems 1025

Index 1035
Dedication

In memory of Mark Reddin. His wonderful technical input and insight over the years have made a tremendous impact on this and many other books. You will be missed.
About the Author

Scott Mueller is the president of Mueller Technical Research (MTR), an international research and corporate training firm. Since 1982, MTR has produced the industry’s most in-depth, accurate, and effective seminars, books, articles, videos, and FAQs covering PC hardware and data recovery. MTR maintains a client list that includes Fortune 500 companies, the U.S. and foreign governments, major software and hardware corporations, as well as PC enthusiasts and entrepreneurs. Scott's seminars have been presented to several thousands of PC support professionals throughout the world.

Scott personally teaches seminars nationwide covering all aspects of PC hardware (including troubleshooting, maintenance, repair, and upgrade), A+ Certification, and data recovery/forensics. He has a knack for making technical topics not only understandable, but entertaining; his classes are never boring! If you have ten or more people to train, Scott can design and present a custom seminar for your organization.

Although he has taught classes virtually nonstop since 1982, Scott is best known as the author of the longest-running, most popular, and most comprehensive PC hardware book in the world, **Upgrading and Repairing PCs**, which has become the core of an entire series of books, including **Upgrading and Repairing PCs**, **Upgrading and Repairing Laptops**, and **Upgrading and Repairing Windows**.

Scott’s premiere work, *Upgrading and Repairing PCs*, has sold more than two million copies, making it by far the most popular and longest-running PC hardware book on the market today. Scott has been featured in *Forbes* magazine and has written several articles for *PC World* magazine, *Maximum PC* magazine, the Scott Mueller Forum, various computer and automotive newsletters, and the Upgrading and Repairing PCs website.

Contact MTR directly if you have a unique book, article, or video project in mind or if you want Scott to conduct a custom PC troubleshooting, repair, maintenance, upgrade, or data-recovery seminar tailored for your organization:

Mueller Technical Research

Web: www.muellertech.com
Email: info@muellertech.com
Forum: www.forum.scottmueller.com

Scott has a forum exclusively for his readers at www.forum.scottmueller.com. Anybody can view the forum, but posting is only available to registered members.

If you have suggestions or comments about the book or new book or article topics you would like to see covered, send them to info@muellertech.com.
I must give a very special thanks to Rick Kughen at Que. Through the years, Rick is the number-one person responsible for championing this book and the *Upgrading and Repairing* series. I cannot say enough about Rick and what he means to all the *Upgrading and Repairing* books. With all that he’s been through on this book, I have a feeling I might be responsible for a few gray hairs. (Sorry!)

I’d also like to thank Todd Brakke for doing the development editing for this edition, which was fairly substantial considering all the rewrites and new material. His excellent tips and suggestions really helped to keep the material concise and up-to-date.

Special thanks also go to Sheri Cain, who helped tremendously with the editing, and to Mandie Frank, for shepherding the manuscripts through a tight publishing schedule. I’d also like to thank the proofreader, illustrator, designer, and indexer, who worked so hard to complete the finished product and get this book out the door! They are a wonderful team that produces clearly the best computer books on the market. I am happy and proud to be closely associated with all the people at Que.

I also want to say thanks to my publisher, Greg Wiegand, who has stood behind all the *Upgrading and Repairing* book and video projects. Greg is a fellow motorcycle enthusiast—someday, hopefully, we can go riding together.

All the people at Que make me feel as if we are on the same team, and they are just as dedicated as I am to producing the best books possible.

I would like to thank both my wife Lynn and my son Emerson for helping to produce the DVD that comes with the book. Emerson did the camera work, and Lynn did all of the editing, rendering, and DVD production using the very machine that you see me build in the video. I hope you enjoy the DVD as much as we enjoyed producing it.

Many readers write me with suggestions and even corrections for the book, for which I am especially grateful. I welcome any and all of your comments and even your criticisms. I take them seriously and apply them to the continuous improvement of this book. Interaction with my readers is the primary force that helps maintain this book as the most up-to-date and relevant work available anywhere on the subject of PC hardware.

Finally, I want to thank the thousands of people who have attended my seminars; you have no idea how much I learn from each of you and all of your questions!
Accessing the Media Included with this Book

Don’t forget about the free bonus content available online! You’ll find a cache of helpful material to go along with this book, including 90 minutes of video. You’ll also find complete PDF copies of the 19th and 20th editions, as well as many pages of valuable reference material that’s particularly useful for those maintaining legacy equipment.

Register this eBook to unlock the companion files that are included in the Print edition DVD. Follow the steps below:

1. Go to quepublishing.com/register and log in or create a new account.
2. Enter the ISBN: 9780133105377
3. Enter the following code when prompted: URPCSDVD21E
4. Click on the “Access Bonus Content” link in the Registered Products section of your account page, to be taken to the page where your content is available. The video files will play in your browser. Click the links to the 19th and 20th edition PDFs, and other materials to view them, or right-click and choose to save the file to your computer.

Note

If you would like to download the videos to your computer, simply right-click the video and choose Save As. Note that the video files are large and will download slowly.
We Want to Hear from You!

As the reader of this book, you are our most important critic and commentator. We value your opinion and want to know what we’re doing right, what we could do better, what areas you’d like to see us publish in, and any other words of wisdom you’re willing to pass our way.

We welcome your comments. You can email or write to let us know what you did or didn’t like about this book—as well as what we can do to make our books better.

Please note that we cannot help you with technical problems related to the topic of this book.

When you write, please be sure to include this book’s title and author as well as your name and email address. We will carefully review your comments and share them with the author and editors who worked on the book.

Email: feedback@quepublishing.com

Mail: Que Publishing
      ATTN: Reader Feedback
      800 East 96th Street
      Indianapolis, IN 46240 USA

Reader Services

Visit our website and register this book at quepublishing.com/register for convenient access to any updates, downloads, or errata that might be available for this book.
Introduction

Welcome to *Upgrading and Repairing PCs*, 21st Edition. Since debuting as the first book of its kind on the market in 1988, no other book on PC hardware has matched the depth and quality of the information found in this tome. This edition continues *Upgrading and Repairing PCs*’ role as not only the best-selling book of its type, but also the most comprehensive and complete PC hardware reference available. This book examines PCs in depth, outlines the differences among them, and presents options for configuring each system.

The 21st edition of *Upgrading and Repairing PCs* provides you with the in-depth knowledge you need to work with the most recent systems and components and gives you an unexcelled resource for understanding older systems. As with previous editions, we worked to make this book keep pace with the rapid changes in the PC industry so that it continues to be the most accurate, complete, and in-depth book of its kind on the market today.

I wrote this book for all PC enthusiasts who want to know everything about their PCs: how they originated; how they’ve evolved; how to upgrade, troubleshoot, and repair them; and everything in between. This book covers the full gamut of PC-compatible systems, from the oldest 8-bit machines to the latest high-end 64-bit multicore processors and systems. If you need to know everything about PC hardware from the original to the latest technology on the market today, this book and the accompanying information-packed disc is definitely for you.

*Upgrading and Repairing PCs* also doesn’t ignore the less glamorous PC components. Every part of your PC plays a critical role in its stability and performance. Over the course of this book, you’ll find out exactly why your motherboard’s chipset might just be the most important part of your PC and what can go wrong when you settle for a run-of-the-mill power supply that can’t get enough juice to that monster graphics card you just bought. You’ll also find in-depth coverage of technologies such as new Intel Ivy Bridge and AMD Trinity core processors (including those with integrated graphics), new DDR3 memory, high-performance graphics cards based on AMD and NVIDIA GPUs for the fastest 3D gaming and the latest developments in OpenGL and DirectX 3D APIs, SATA 6Gbps and upcoming SATA Express interfaces, Thunderbolt and USB 3.0 interfaces in the latest motherboards, advances in solid-state drives, the benefits of 80 PLUS power supplies, and more—it’s all in here, right down to the guts-level analysis of your mouse and keyboard.

Book Objectives

*Upgrading and Repairing PCs* focuses on several objectives. The primary objective is to help you learn how to maintain, upgrade, and troubleshoot your PC system. To that end, *Upgrading and Repairing PCs* helps you fully understand the family of computers that has grown from the original IBM PC, including all PC-compatible systems. This book discusses all areas of system improvement, such as motherboards, processors, memory, and even case and power-supply improvements. It covers proper system and component care, specifies the most failure-prone items in various PC systems, and tells you how to locate and identify a failing component. You’ll learn about powerful diagnostics hardware and software that help you determine the cause of a problem and know how to repair it.

As always, PCs are moving forward rapidly in power and capabilities. Processor performance increases with every new chip design. *Upgrading and Repairing PCs* helps you gain an understanding of all the processors used in PC-compatible computer systems.
This book covers the important differences between major system architectures, from the original Industry Standard Architecture (ISA) to the latest PCI Express interface standards. *Upgrading and Repairing PCs* covers each of these system architectures and their adapter boards to help you make decisions about which type of system you want to buy in the future and help you upgrade and troubleshoot such systems.

The amount of storage space available to modern PCs is increasing geometrically. *Upgrading and Repairing PCs* covers storage options ranging from larger, faster hard drives to state-of-the-art solid-state storage devices.

When you finish reading this book, you will have the knowledge to upgrade, troubleshoot, and repair almost any system and component.

**The 21st Edition DVD-ROM**

The 21st edition of *Upgrading and Repairing PCs* includes a DVD that contains valuable content that greatly enhances this book!

There’s the all-new DVD video with new segments showing a detailed tour of a high-end Z77 chipset motherboard, a detailed comparison of SSD (solid-state drive) to HDD (hard disk drive) technology, plus information about choosing a case and power supply. There are in-depth segments showing how to build a system using these components from scratch, including motherboard and chassis preparation, component installation, and finally cabling, including the dreaded front-panel connections.

The DVD-ROM content includes my venerable Technical Reference material, a repository of reference information that has appeared in previous editions of *Upgrading and Repairing PCs* but has been moved to the disc to make room for coverage of newer technologies. The DVD-ROM also includes the complete 19th edition of this book, the complete 20th edition of the book, a detailed list of acronyms, and much more available in printable PDF format. There’s more PC hardware content and knowledge here than you’re likely to find from any other single source.

**My Website: upgradingandrepairingpcs.com**

Don’t forget about Que’s dedicated *Upgrading and Repairing PCs* website! Here, you’ll find a cache of helpful material to go along with the book you’re holding. I’ve loaded this site with tons of material—mine as well as from other authors—ranging from video clips to book content and technology updates.

If you discover that the video on this book’s disc isn’t enough, you’ll find even more of my previously recorded videos on the website. Not to mention that it is the best place to look for information on all of Que’s *Upgrading and Repairing* titles.

I also have a private forum (www.forum.scottmueller.com) designed exclusively to support those who have purchased my recent books and DVDs. I use the forum to answer questions and otherwise help my loyal readers. If you own one of my current books or DVDs, feel free to join in and post questions. I endeavor to answer each question personally, but I also encourage knowledgeable members to respond. Anybody can view the forum without registering, but to post a question of your own you need to join. Even if you don’t join in, the forum is a tremendous resource because you can still benefit from all the reader questions I have answered over the years.

Be sure to check the informit.com/upgrading website for more information on all my latest books, videos, articles, FAQs, and more!
A Personal Note

When asked which was his favorite Corvette, Dave McLellan, former manager of the Corvette platform at General Motors, always said, “Next year’s model.” Now with the new 21st edition, next year’s model has just become this year’s model, until next year that is….

I believe that this book is absolutely the best book of its kind on the market, and that is due in large part to the extensive feedback I have received from both my seminar attendees and book readers. I am so grateful to everyone who has helped me with this book through each edition, as well as all the loyal readers who have been using this book, many of you since the first edition was published. I have had personal contact with many thousands of you in the seminars I have been teaching since 1982, and I enjoy your comments and even your criticisms tremendously. Using this book in a teaching environment has been a major factor in its development. Some of you might be interested to know that I originally began writing this book in early 1985; back then it was self-published and used exclusively in my PC hardware seminars before being professionally published by Que in 1988.

In one way or another, I have been writing and rewriting this book for almost 30 years! In that time, Upgrading and Repairing PCs has proven to be not only the first, but also the most comprehensive and yet approachable and easy-to-understand book of its kind. With this new edition, it is even better than ever. Your comments, suggestions, and support have helped this book to become the best PC hardware book on the market. I look forward to hearing your comments after you see this exciting new edition.

—Scott
Chapter 7

The ATA/IDE Interface

An Overview of the IDE Interface

The interface used to connect disk drives to a PC is typically called IDE (Integrated Drive Electronics); however, the official name of this interface is ATA (AT Attachment). The ATA designation refers to the fact that this interface was originally designed to connect a combined drive and controller directly to the 16-bit bus found in the 1984 vintage IBM PC-AT (Advanced Technology) and compatible computers. The AT bus is otherwise known as the ISA (Industry Standard Architecture) bus. Although ATA is the official name of the interface, IDE is a marketing term originated by some of the drive manufacturers to describe the drive/controller combination used in drives with the ATA interface. Integrated Drive Electronics refers to the fact that the interface electronics or controller is built into the drive and is not a separate board, as it was with earlier drive interfaces. Although the correct name for the particular IDE interface we most commonly use is technically ATA, many persist in using the IDE designation today. If you are being picky, you could say that IDE refers generically to any drive interface in which the controller is built into the drive, whereas ATA refers to the specific implementation of IDE that is used in most PCs.

ATA was originally a 16-bit parallel interface, meaning that 16 bits are transmitted simultaneously down the interface cable. A newer interface called Serial ATA (SATA) was officially introduced in late 2000 and was adopted in desktop systems starting in 2003 and in laptops starting in late 2005. SATA sends one bit down the cable at a time, enabling thinner and smaller cables to be used, as well as providing higher performance due to the higher cycling speeds it enables. Although SATA is a completely different physical interface design, it is backward compatible on the software level with Parallel ATA (PATA). Throughout this book, ATA refers to both the parallel and serial versions. PATA refers specifically to the parallel version, and SATA refers specifically to the serial version.

Precursors to IDE

Several types of hard disk interfaces have been used for PC hard disks over the years, as shown in Table 7.1. As time has passed, the number of choices has increased; however, many of the older interface standards are obsolete and no longer viable in newer systems.
Table 7.1  PC Drive Interfaces

<table>
<thead>
<tr>
<th>Interface</th>
<th>When Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>ST-506/412</td>
<td>1978–1989 (obsolete)</td>
</tr>
<tr>
<td>ESDI</td>
<td>1983–1991 (obsolete)</td>
</tr>
<tr>
<td>Non-ATA IDE</td>
<td>1987–1993 (obsolete)</td>
</tr>
<tr>
<td>SCSI</td>
<td>1986–present</td>
</tr>
<tr>
<td>PATA (IDE)</td>
<td>1986–present</td>
</tr>
<tr>
<td>SATA</td>
<td>2003–present</td>
</tr>
</tbody>
</table>

ST = Seagate Technology  
ESDI = Enhanced Small Device Interface  
IDE = Integrated Drive Electronics  
SCSI = Small Computer Systems Interface  
ATA = AT (Advanced Technology) Attachment

Of these interfaces, only ST-506/412 and ESDI are what you could call true disk-controller-to-drive interfaces, and they are obsolete. Non-ATA versions of IDE were used primarily in the IBM PS/2 systems and are also obsolete. Current SCSI, ATA, and SATA are system-level interfaces that usually internally incorporate a chipset-based controller interface. For example, many SCSI, PATA, and SATA drives incorporate the same basic controller circuitry inside the actual drive. The SCSI interface then adds another layer that connects between the drive controller and the PCI (or ISA) bus, whereas PATA and SATA have a more direct connection from the controller to the AT bus attachment interface. Despite their differences, we call a SCSI, PATA, or SATA card a host interface adapter instead of a controller card because the actual controllers are inside the drives. Virtually all modern disk drives use SATA or PATA interfaces to connect to a system.

IDE Origins

Any drive with an integrated controller could be called an IDE drive, although normally when we say IDE, we really mean the specific version of IDE called ATA. No matter what you call it, combining the drive and controller greatly simplifies installation because no separate power or signal cables run from the controller to the drive. Also, when the controller and drive are assembled as a unit, the number of total components is reduced, signal paths are shorter, and the electrical connections are more noise-resistant. This results in a more reliable and less expensive design than is possible when a separate controller, connected to the drive by cables, is used.

Placing the controller, including the digital-to-analog encoder/decoder (endec), on the drive offers an inherent reliability advantage over interfaces with separate controllers such as ST506 and ESDI. Reliability is increased because the data encoding, from digital to analog, is performed directly on the drive in a tight noise-free environment. The timing-sensitive analog information does not have to travel along crude ribbon cables that are likely to pick up noise and insert propagation delays into the signals. The integrated configuration enables increases in the clock rate of the encoder and the storage density of the drive.

The earliest IDE drives were called hardcards and were nothing more than hard disks and controller cards bolted directly together and plugged into a slot as a single unit. Companies such as the Plus Development Division of Quantum took small 3 1/2-inch drives (either ST-506/412 or ESDI) and attached them directly to a standard controller card. The drive/controller assembly then was plugged into an ISA bus slot as though it were a normal disk controller card. Unfortunately, the mounting of
a heavy, vibrating hard disk in an expansion slot with nothing but a single screw to hold it in place left a lot to be desired—not to mention the physical interference with adjacent cards, because many of these units were much thicker than a controller card alone.

Several companies got the idea to redesign the controller to replace the logic board assembly on a standard hard disk and then mount it in a standard drive bay just like any other drive. Because the built-in controller in these drives still needed to plug directly into the expansion bus just like any other controller, a cable was run between the drive and one of the slots. This was the origin of IDE.

**Origins of ATA**

Control Data Corporation (CDC; its disk drive division was later called Imprimis), Western Digital, and Compaq actually created what could be called the first ATA IDE interface drive and were the first to establish the 40-pin ATA connector pinout. The first ATA IDE drive was a 5 1/4-inch half-height CDC Wren II 40MB drive with an integrated WD controller and was initially used in the first Compaq 386 systems in 1986. I remember seeing this drive for the first time in 1986 at the fall COMDEX show. Besides the (at the time) unique 40-pin ribbon cable, I remember being surprised by the green activity LED on the front bezel. (Most drives up until then used red LEDs.)

Compaq was the first to incorporate a special bus adapter in its system to adapt the 98-pin AT-bus (also known as ISA) edge connector on the motherboard to a smaller 40-pin, header-style connector into which the drive would plug. The 40-pin connector was all that was necessary because it was known that a disk controller never would need more than 40 of the ISA bus lines. Smaller 2 1/2-inch ATA drives found in laptop computers use a superset 44-pin or 50-pin connection, which includes additional pins for power and configuration. The pins from the original ISA bus used in ATA are the only signal pins required by a standard-type AT hard disk controller. For example, because a primary AT-style disk controller uses only interrupt request (IRQ) line 14, the primary motherboard ATA connector supplies only that IRQ line; no other IRQ lines are necessary. Even if your ATA interface is integrated within the motherboard chipset South Bridge or I/O Controller Hub chip (as it would be in newer systems) and runs at higher bus speeds, the pinout and functions of the pins are still the same as the original design taken right off the ISA bus.

See the Chapter 4 section, “Motherboard Connectors,” p. 228.

See the Chapter 4 section, “The ISA Bus,” p. 245.

**Note**

Many people who use systems with ATA connectors on the motherboard believe that a hard disk controller is built into their motherboards, but in a technical sense the controller is actually in the drive. Although the integrated ATA ports on a motherboard often are referred to as controllers, they are more accurately called host adapters (although you’ll rarely hear this term). You can think of a host adapter as a device that connects a controller to a bus.

Eventually, the 40-pin ATA connector and drive interface design was placed before one of the ANSI standards committees that, in conjunction with drive manufacturers, ironed out some deficiencies, tied up some loose ends, and then published what was known as the CAM ATA (Common Access Method AT Attachment) interface. The CAM ATA Committee was formed in October 1988, and the first working document of the ATA interface was introduced in March 1989. Before the CAM ATA standard, many companies, such as Conner Peripherals (which later merged with Seagate Technology), made proprietary changes to the original interface as designed by CDC. As a result, many older ATA drives from the late 1980s are difficult to integrate into a dual-drive setup because minor differences in the interfaces can cause compatibility problems among the drives. By the early 1990s, most drive manufacturers brought their drives into full compliance with the official standard, which eliminated many of these compatibility problems.
Some areas of the ATA standard have been left open for vendor-specific commands and functions. These vendor-specific commands and functions are the reason it is important to use the OEM-specific programs for testing ATA drives. To work to full capability, the diagnostic program you are using typically must know the specific vendor-unique commands for remapping defects. Unfortunately, these and other specific drive commands differ from OEM to OEM, thus clouding the standard somewhat. Most ATA drive manufacturers publish their drive-formatting/initialization software on their websites.

As I noted at the start of this chapter, PATA is a 16-bit parallel interface that has been largely phased out in favor of the serial interface of SATA. SATA’s thinner and smaller cables provide higher performance due to the higher cycling speeds allowed and are considerably easier to work with than the wide PATA ribbon cables. Figure 7.1 shows how the power and data cables SATA uses compare in size to those PATA uses.

![Figure 7.1](image)

**FIGURE 7.1** SATA data cables are much smaller than those used by PATA, whereas the power cables are similar in size.

### ATA Standards

Today, the ATA interface is controlled by an independent group of representatives from major PC, drive, and component manufacturers. This group is called Technical Committee T13 (www.t13.org) and is responsible for all standards relating to the Parallel and Serial ATA storage interfaces. T13 is a part of the International Committee on Information Technology Standards (INCITS), which operates under rules approved by the American National Standards Institute (ANSI), a governing body that sets rules that control nonproprietary standards in the computer industry as well as many other industries. A second group called the Serial ATA International Organization (www.serialata.org) was formed to initially create the SATA standards, which are then passed on to the T13 Committee for refinement and official publication under ANSI. The ATA-7 and ATA-8 standards incorporate both parallel and serial interfaces.

The rules these committees operate under are designed to ensure that voluntary industry standards are developed by the consensus of people and organizations in the affected industry. INCITS specifically develops information processing system standards, whereas ANSI approves the process under which these standards are developed and then publishes them. Because T13 is essentially a public organization, all the working drafts, discussions, and meetings of T13 are open for all to see.
Copies of any of the published standards can be purchased from ANSI (www.ansi.org) or the IHS Standards Store (formerly Global Engineering Documents, http://global.ihs.com). Draft versions of the standards can be downloaded from the T13 Committee or Serial ATA International Organization (SATA-IO) website.

Each newer version of ATA is backward compatible with the previous versions. In other words, older ATA-1 and ATA-2 devices work fine on ATA-7 and ATA-8 interfaces. ATA-7 and ATA-8 include both PATA and SATA. Newer versions of ATA are normally built on older versions, and with few exceptions can be thought of as extensions of the previous versions. This means that ATA-8, for example, is generally considered equal to ATA-7 with the addition of some features.

Table 7.2 breaks down the various ATA standards. The following sections describe recent ATA versions in more detail.

### Table 7.2 ATA Standards

<table>
<thead>
<tr>
<th>Standard</th>
<th>Proposed</th>
<th>Published</th>
<th>Withdrawn</th>
<th>PIO Modes</th>
<th>DMA Modes</th>
<th>UDMA Modes</th>
<th>Parallel Speed (MBps)</th>
<th>Serial Speed (MBps)</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATA-1</td>
<td>1988</td>
<td>1994</td>
<td>1999</td>
<td>0–2</td>
<td>0</td>
<td>—</td>
<td>8.33</td>
<td>—</td>
<td>Drives support up to 136.9GB; BIOS issues not addressed.</td>
</tr>
<tr>
<td>ATA-2</td>
<td>1993</td>
<td>1996</td>
<td>2001</td>
<td>0–4</td>
<td>0–2</td>
<td>—</td>
<td>16.67</td>
<td>—</td>
<td>Faster PIO modes; CHS/LBA BIOS translation defined up to 8.4GB; PC-Card.</td>
</tr>
<tr>
<td>ATA-3</td>
<td>1995</td>
<td>1997</td>
<td>2002</td>
<td>0–4</td>
<td>0–2</td>
<td>—</td>
<td>16.67</td>
<td>—</td>
<td>S.M.A.R.T.; improved signal integrity; LBA support mandatory; eliminated single-word DMA modes.</td>
</tr>
<tr>
<td>ATA-4</td>
<td>1996</td>
<td>1998</td>
<td>2012</td>
<td>0–4</td>
<td>0–2</td>
<td>0–2</td>
<td>33.33</td>
<td>—</td>
<td>Ultra-DMA modes; ATAPI Packet Interface; BIOS support up to 136.9GB.</td>
</tr>
<tr>
<td>ATA-5</td>
<td>1998</td>
<td>2000</td>
<td>—</td>
<td>0–4</td>
<td>0–2</td>
<td>0–4</td>
<td>66.67</td>
<td>—</td>
<td>Faster UDMA modes; 80-pin cable with auto-detection.</td>
</tr>
<tr>
<td>ATA-6</td>
<td>2000</td>
<td>2002</td>
<td>—</td>
<td>0–4</td>
<td>0–2</td>
<td>0–5</td>
<td>100</td>
<td>—</td>
<td>100MBps UDMA mode; extended drive and BIOS support up to 144PB.</td>
</tr>
<tr>
<td>ATA-7</td>
<td>2001</td>
<td>2004</td>
<td>—</td>
<td>0–4</td>
<td>0–2</td>
<td>0–6</td>
<td>133</td>
<td>150</td>
<td>133MBps UDMA mode; SATA.</td>
</tr>
<tr>
<td>ATA-8</td>
<td>2004</td>
<td>—</td>
<td>—</td>
<td>0–4</td>
<td>0–2</td>
<td>0–6</td>
<td>133</td>
<td>600</td>
<td>Minor revisions for PATA, includes SATA 2.x and 3.x.</td>
</tr>
</tbody>
</table>

**S.M.A.R.T.** = Self-Monitoring, Analysis, and Reporting Technology  
**ATAPI** = AT Attachment Packet Interface  
**MB** = Megabyte; million bytes  
**GB** = Gigabyte; billion bytes  
**PB** = Petabyte; quadrillion bytes  
**CHS** = Cylinder, Head, Sector  
**LBA** = Logical block address  
**PIO** = Programmed I/O  
**DMA** = direct memory access  
**UDMA** = Ultra DMA (direct memory access)
ATA-1 (ATA Interface for Disk Drives)
ATA-1 defined the original ATA interface, which was an integrated bus interface between disk drives and host systems based on the ISA (AT) bus. These major features were introduced and documented in the ATA-1 specification:

- 40/44-pin connectors and cabling
- Master/slave or cable select drive configuration options
- Signal timing for basic Programmed I/O (PIO) and direct memory access (DMA) modes
- Cylinder, head, sector (CHS) and logical block address (LBA) drive parameter translations supporting drive capacities up to $2^{28} - 2^{20} (267,386,880)$ sectors, or 136.9GB

Although ATA-1 had been in use since 1986, work on turning it into an official standard began in 1988 under the Common Access Method (CAM) committee. The ATA-1 standard was finished and officially published in 1994 as “ANSI X3.221-1994, AT Attachment Interface for Disk Drives.” ATA-1 was officially withdrawn as a standard on August 6, 1999.

Although ATA-1 supported theoretical drive capacities up to 136.9GB ($2^{28} - 2^{20} = 267,386,880$ sectors), it did not address BIOS limitations that stopped at 528MB ($1024 \times 16 \times 63 = 1,032,192$ sectors). The BIOS limitations would be addressed in subsequent ATA versions because, at the time, no drives larger than 528MB existed.

ATA-2 (ATA Interface with Extensions-2)
ATA-2 was a major upgrade to the original ATA standard. Perhaps the biggest change was almost a philosophical one. ATA-2 was updated to define an interface between host systems and storage devices in general and not only disk drives. The major features added to ATA-2 compared to the original ATA standard include the following:

- Faster PIO and DMA transfer modes
- Support for power management
- Support for removable devices
- PCMCIA (PC Card) device support
- Identify Drive command that reports more information
- Defined standard CHS/LBA translation methods for drives up to 8.4GB in capacity

The most important additions in ATA-2 were the support for faster PIO and DMA modes, as well as methods to enable BIOS support up to 8.4GB. The BIOS support was necessary because although ATA-1 was designed to support drives of up to 136.9GB in capacity, the PC BIOS could originally handle drives of up to 528MB. Adding parameter-translation capability now allowed the BIOS to handle drives up to 8.4GB. This is discussed in more detail later in this chapter.

ATA-2 also featured improvements in the Identify Drive command that enabled a drive to tell the software exactly what its characteristics are; this is essential for both Plug and Play (PnP) and compatibility with future revisions of the standard.

ATA-2 was also known by unofficial marketing terms, such as Fast-ATA or Fast-ATA-2 (Seagate/Quantum) and EIDE (Enhanced IDE, Western Digital).

Although work on ATA-2 began in 1993, the standard was not officially published until 1996 as “ANSI X3.279-1996 AT Attachment Interface with Extensions.” ATA-2 was officially withdrawn in 2001.
**ATA-3 (ATA Interface-3)**

ATA-3 was a comparatively minor revision to the ATA-2 standard that preceded it. It consisted of a general cleanup of the specification and had mostly minor clarifications and revisions. The most major changes included the following:

- Eliminated single-word (8-bit) DMA transfer protocols
- Added S.M.A.R.T. (Self-Monitoring, Analysis, and Reporting Technology) support for prediction of device performance degradation
- Made LBA mode support mandatory (previously, it had been optional)
- Added ATA Security mode, allowing password protection for device access
- Provided recommendations for source and receiver bus termination to solve noise issues at higher transfer speeds

ATA-3 built on ATA-2, adding improved reliability, especially of the faster PIO mode 4 transfers; however, ATA-3 did not define faster modes. ATA-3 did add a simple password-based security scheme, more sophisticated power management, and S.M.A.R.T. This enables a drive to keep track of problems that might result in a failure and thus avoid data loss. S.M.A.R.T. is a reliability prediction technology that IBM initially developed.

Work on ATA-3 began in 1995, and the standard was finished and officially published in 1997 as “ANSI X3.298-1997, AT Attachment 3 Interface.” ATA-3 was officially withdrawn in 2002.

**ATA/ATAPI-4 (ATA with Packet Interface Extension-4)**

ATA-4 included several important additions to the standard. It included the Packet Command feature known as the AT Attachment Packet Interface (ATAPI), which allowed devices such as CD-ROM and CD-RW drives, LS-120 SuperDisk floppy drives, Zip drives, tape drives, and other types of storage devices to be attached through a common interface. Until ATA-4 came out, ATAPI was a separately published standard. ATA-4 also added the 33MB per second (MBps) transfer mode known as Ultra-DMA or Ultra-ATA. ATA-4 is backward compatible with ATA-3 and earlier definitions of the ATAPI.


The major revisions added in ATA-4 were as follows:

- Ultra-DMA (UDMA) or Ultra-ATA/33) transfer modes up to Mode 2, which is 33MBps (called UDMA/33 or Ultra-ATA/33)
- Integral ATAPI support
- Advanced power management support
- An optional 80-conductor, 40-pin cable defined for improved noise resistance
- Host protected area (HPA) support
- Compact Flash Adapter (CFA) support
- Enhanced BIOS support for drives over 9.4ZB (zettabytes or trillion gigabytes) in size (even though ATA was still limited to 136.9GB)

The speed and level of ATA support in your system is mainly dictated by your motherboard chipset. Most motherboard chipsets come with a component called either a South Bridge or an I/O Controller
Hub that provides the ATA interface (as well as other functions) in the system. Check the specifications for your motherboard or chipset to see whether yours supports the faster ATA/33, ATA/66, ATA/100, or ATA/133 mode. One indication is to enter the BIOS Setup, put the hard disk on manual parameter settings (user defined), and see which (if any) Ultra-DMA modes are listed. Most boards built in 1998 support ATA/33. In 2000 they began to support ATA/66, and by late 2000 most started supporting ATA/100. ATA/133 support became widespread in mid-2002.

ATA-4 made ATAPI support a full part of the ATA standard; therefore, ATAPI was no longer an auxiliary interface to ATA but merged completely within it. Thus, ATA-4 promoted ATA for use as an interface for many other types of devices. ATA-4 also added support for new Ultra-DMA modes (also called Ultra-ATA) for even faster data transfer. The highest-performance mode, called UDMA/33, had 33MBps bandwidth—twice that of the fastest programmed I/O mode or DMA mode previously supported. In addition to the higher transfer rate, because UDMA modes relieve the load on the processor, further performance gains were realized.

An optional 80-conductor cable (with cable select) is defined for UDMA/33 transfers. Although this cable was originally defined as optional, it would later be required for the faster ATA/66, ATA/100, and ATA/133 modes in ATA-5 and later.

Support for a reserved area on the drive called the HPA was added via an optional SET MAX ADDRESS command. This enables an area of the drive to be reserved for recovery software.

Also included was support for queuing commands, similar to those provided in SCSI-2. This enabled better multitasking as multiple programs request ATA transfers.

Another standard approved by the T13 committee in 1998 was “ANSI NCITS 316-1998 1394 to AT Attachment - Tailgate,” which is a bridge protocol between the IEEE 1394 (i.LINK/FireWire) bus and ATA that enables ATA drives to be adapted to FireWire. A tailgate is an adapter device (basically a small circuit board) that converts IEEE 1394 (i.LINK or FireWire) to ATA, essentially allowing ATA drives to be plugged into a FireWire bus. This enabled vendors to quickly develop IEEE 1394 (FireWire) external drives for backup and high-capacity removable data storage. Inside almost any external FireWire drive enclosure you will find the tailgate device and a standard ATA drive.

ATA/ATAPI-5 (ATA with Packet Interface-5)

ATA-5 was built on the previous ATA-4 interface. ATA-5 includes Ultra-ATA/66 (also called Ultra-DMA or UDMA/66), which doubles the Ultra-ATA burst transfer rate by reducing setup times and increasing the clock rate. The faster clock rate increases interference, which causes problems with the standard 40-pin cable used by ATA and Ultra-ATA. To eliminate noise and interference, the newer 40-pin, 80-conductor cable was made mandatory for drives running in UDMA/66 or faster modes. This cable adds 40 additional ground lines between each of the original 40 ground and signal lines, which helps shield the signals from interference. Note that this cable works with older, non-Ultra-ATA devices as well because it still has the same 40-pin connectors.


The major additions in the ATA-5 standard include the following:

- Ultra-DMA (UDMA) transfer modes up to Mode 4, which is 66MBps (called UDMA/66 or Ultra-ATA/66).
- The 80-conductor cable now mandatory for UDMA/66 operation.
• Automatic detection of 40- or 80-conductor cables.
• UDMA modes faster than UDMA/33 enabled only if an 80-conductor cable is detected.

The 40-pin, 80-conductor cables support the cable select feature and have color-coded connectors. The blue (end) connector should be connected to the ATA host interface (usually the motherboard). The black (opposite end) connector is known as the master position, which is where the primary drive plugs in. The gray (middle) connector is for slave devices.

To use either the UDMA/33 or the UDMA/66 mode, your ATA interface, drive, BIOS, and cable must be capable of supporting the mode you want to use. The operating system also must be capable of handling direct memory access. Windows 95 OSR2 and later versions are ready out of the box, but older versions of Windows 95 and NT (prior to Service Pack 3) require additional or updated drivers to fully exploit these faster modes. Contact the motherboard or system vendor for the latest drivers.

For reliability, Ultra-DMA modes incorporate an error-detection mechanism known as cyclical redundancy checking (CRC). CRC is an algorithm that calculates a checksum used to detect errors in a stream of data. Both the host (controller) and the drive calculate a CRC value for each Ultra-DMA transfer. After the data is sent, the drive calculates a CRC value, and this is compared to the original host CRC value. If a difference is reported, the host might be required to select a slower transfer mode and retry the original request for data.

**ATA/ATAPI-6 (ATA with Packet Interface-6)**

ATA-6 includes Ultra-ATA/100 (also called Ultra-DMA or UDMA/100), which increases the Ultra-ATA burst transfer rate by reducing setup times and increasing the clock rate. As with ATA-5, the faster modes require the improved 80-conductor cable. Using the ATA/100 mode requires both a drive and motherboard interface that supports that mode.

Work on ATA-6 began in 2000, and the standard was finished and officially published in 2002 as “ANSI NCITS 361-2002, AT Attachment - 6 with Packet Interface.”

The major changes or additions in the standard include the following:

• Ultra-DMA (UDMA) Mode 5 added, which allows 100MBps (called UDMA/100, Ultra-ATA/100, or just ATA/100) transfers.
• Sector count per command increased from 8 bits (256 sectors, or 131KB) to 16 bits (65,536 sectors, or 33.5MB), allowing larger files to be transferred more efficiently.
• LBA addressing extended from 228 to 248 (281,474,976,710,656 sectors) sectors, supporting drives up to 144.12PB (petabytes = quadrillion bytes). This feature is often referred to as 48-bit LBA or greater than 137GB support by vendors; Maxtor referred to this feature as Big Drive.
• CHS addressing was made obsolete; drives must use 28-bit or 48-bit LBA addressing only.

Besides adding the 100MBps UDMA Mode 5 transfer rate, ATA-6 extended drive capacity greatly, and just in time. ATA-5 and earlier standards supported drives of up to only 137GB in capacity, which became a limitation as larger drives were becoming available. Commercially available 3 1/2-inch drives exceeding 137GB were introduced in 2001, but they were originally available only in SCSI versions because SCSI doesn’t have the same limitations as ATA. With ATA-6, the sector addressing limit has been extended from 228 sectors to 248 sectors. What this means is that LBA addressing previously could use only 28-bit numbers, but with ATA-6, LBA addressing can use larger 48-bit numbers if necessary. With 512 bytes per sector, this raises the maximum supported drive capacity to 144.12PB. That is equal to more than 144.12 quadrillion bytes! Note that the 48-bit addressing is optional and necessary only for drives larger than 137GB. Drives 137GB or smaller can use either 28-bit or 48-bit addressing.
ATA/ATAPI-7 (ATA with Packet Interface-7)

Work on ATA-7, which began late in 2001, was completed and officially published in 2004. As with the previous ATA standards, ATA-7 is built on the standard that preceded it (ATA-6), with some additions.

The primary additions to ATA-7 include the following:

- Ultra-DMA (UDMA) Mode 6 was added. This allows for 133MBps transfers (called UDMA/133, Ultra-ATA/133, or just ATA/133). As with UDMA Mode 5 (100MBps) and UDMA Mode 4 (66MBps), the use of an 80-conductor cable is required.
- Added support for long physical sectors. This allows a device to be formatted so that there are multiple logical sectors per physical sector. Each physical sector stores an ECC field, so long physical sectors allow increased format efficiency with fewer ECC bytes used overall.
- Added support for long logical sectors. This enables additional data bytes to be used per sector (520 or 528 bytes instead of 512 bytes) for server applications. Devices using long logical sectors are not backward compatible with devices or applications that use 512-byte sectors, such as standard desktop and laptop systems.
- SATA 1.0 incorporated as part of the ATA-7 standard. This includes the SATA physical interconnection as well as the related features and commands.
- The ATA-7 document split into three volumes. Volume 1 covers the command set and logical registers, which apply to both Serial and Parallel ATA. Volume 2 covers the parallel transport protocols and interconnects (PATA), and Volume 3 covers the serial transport protocols and interconnects (SATA).

The ATA/133 transfer mode was originally proposed by Maxtor, and only a few other drive and chipset manufacturers adopted it. Among the chipset manufacturers, VIA, ALi, and SiS added ATA/133 support to their chipsets, prior to moving on to SATA, but Intel decided from the outset to skip ATA/133 in its chipsets in lieu of adding SATA (150MBps or 300MBps). This means the majority of systems that utilize PATA do not support ATA/133; however, all ATA/133 drives do work in ATA/100 mode.

ATA/ATAPI-8

Work on ATA-8 began in 2004, and some initial parts of the standard were published in 2006 and 2008. Other parts are still in progress and continue to be revised as of 2013. As with the previous ATA standards, ATA-8 is built on the standard that preceded it, with some additions. As with the previous version, ATA-8 includes SATA but adds the newer 2.x and 3.x versions of the SATA specification.

The primary features added to ATA-8 include the following:

- The inclusion of SATA 2.x and 3.x for serial transport (physical) and command set functions
- The replacement of read long/write long functions
- Improved HPA management via additional HPA-related commands
- Defined IDENTIFY DEVICE word 217 to report drive rotational speed (rpm), where a value of 1 indicates nonrotating media (solid-state drive)
- Addition of the TRIM command for flash-based solid-state drives (SSDs). This allows the system to inform an SSD which blocks are no longer in use so they can be erased in preparation for future writes

As the development of ATA progresses, it is expected that newer features designed by the SATA-IO committee will be incorporated.
PATA

Parallel ATA was the most widely used drive interface for many years; however, currently it has been almost completely replaced by SATA for new systems. Even so, some new motherboards and drives are still available with PATA support, and many older systems, motherboards, and drives still in service use PATA as well. PATA has unique specifications and requirements regarding the physical interface, cabling, and connectors compared to SATA. The following sections detail the unique features of PATA.

PATA I/O Connector

The PATA interface connector is normally a 40-pin header-type connector with pins spaced 0.1 inch (2.54mm) apart. Generally, it is keyed to prevent the possibility of installing it upside down (see Figures 7.2 and 7.3). To create a keyed connector, the manufacturer usually removes pin 20 from the male connector and blocks pin 20 on the female cable connector, which prevents the user from installing the cable backward. Some cables also incorporate a protrusion on the top of the female cable connector that fits into a notch in the shroud surrounding the mating male connector on the device. The use of keyed connectors and cables is highly recommended. Plugging an ATA cable in backward normally doesn’t cause permanent damage; however, it can lock up the system and prevent it from running.

FIGURE 7.2 Typical PATA (IDE) hard drive connectors.

Table 7.3 shows the standard 40-pin PATA (IDE) interface connector pinout.
**FIGURE 7.3**  PATA (IDE) 40-pin interface connector detail.

<table>
<thead>
<tr>
<th>Signal Name</th>
<th>Pin</th>
<th>Pin</th>
<th>Signal Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>-RESET</td>
<td>1</td>
<td>2</td>
<td>GROUND</td>
</tr>
<tr>
<td>Data Bit 7</td>
<td>3</td>
<td>4</td>
<td>Data Bit 8</td>
</tr>
<tr>
<td>Data Bit 6</td>
<td>5</td>
<td>6</td>
<td>Data Bit 9</td>
</tr>
<tr>
<td>Data Bit 5</td>
<td>7</td>
<td>8</td>
<td>Data Bit 10</td>
</tr>
<tr>
<td>Data Bit 4</td>
<td>9</td>
<td>10</td>
<td>Data Bit 11</td>
</tr>
<tr>
<td>Data Bit 3</td>
<td>11</td>
<td>12</td>
<td>Data Bit 12</td>
</tr>
<tr>
<td>Data Bit 2</td>
<td>13</td>
<td>14</td>
<td>Data Bit 13</td>
</tr>
<tr>
<td>Data Bit 1</td>
<td>15</td>
<td>16</td>
<td>Data Bit 14</td>
</tr>
<tr>
<td>Data Bit 0</td>
<td>17</td>
<td>18</td>
<td>Data Bit 15</td>
</tr>
<tr>
<td>GROUND</td>
<td>19</td>
<td>20</td>
<td>KEY (pin missing)</td>
</tr>
<tr>
<td>DRQ 3</td>
<td>21</td>
<td>22</td>
<td>GROUND</td>
</tr>
<tr>
<td>-IOW</td>
<td>23</td>
<td>24</td>
<td>GROUND</td>
</tr>
<tr>
<td>-IOR</td>
<td>25</td>
<td>26</td>
<td>GROUND</td>
</tr>
<tr>
<td>I/O CH RDY</td>
<td>27</td>
<td>28</td>
<td>CSEL:SPSYNC&lt;sup&gt;1&lt;/sup&gt;</td>
</tr>
<tr>
<td>-DACK 3</td>
<td>29</td>
<td>30</td>
<td>GROUND</td>
</tr>
<tr>
<td>IRQ 14</td>
<td>31</td>
<td>32</td>
<td>Reserved&lt;sup&gt;2&lt;/sup&gt;</td>
</tr>
<tr>
<td>Address Bit 1</td>
<td>33</td>
<td>34</td>
<td>-PDIAG</td>
</tr>
<tr>
<td>Address Bit 0</td>
<td>35</td>
<td>36</td>
<td>Address Bit 2</td>
</tr>
<tr>
<td>-CS1FX</td>
<td>37</td>
<td>38</td>
<td>-CS3FX</td>
</tr>
<tr>
<td>-DA/SP</td>
<td>39</td>
<td>40</td>
<td>GROUND</td>
</tr>
</tbody>
</table>

1 Pin 28 is usually cable select, but some older drives could use it for spindle synchronization between multiple drives.
2 Pin 32 was defined as -IOCS16 in ATA-2 but is no longer used.

Note that - preceding a signal name (such as -RESET) indicates the signal is “active low.”
Chapter 7

The 2 1/2-inch drives found in notebook/laptop-size computers typically use a smaller unitized 50-pin header connector with pins spaced only 2.0mm (0.079 inches) apart. The main 40-pin part of the connector is the same as the standard PATA connector (except for the physical pin spacing), but there are added pins for power and jumpering. The cable that plugs into this connector typically has 44 pins, carrying power as well as the standard ATA signals. The jumper pins usually have a jumper on them (the jumper position controls cable select, master, or slave settings). Figure 7.4 shows the unitized 50-pin connector used on the 2 1/2-inch PATA drives in laptop or notebook computers.

**FIGURE 7.4** The 50-pin unitized PATA connector detail (used on 2 1/2-inch notebook/laptop PATA drives with a 44-pin cable).

Note the jumper pins at positions A–D; also notice that the pins at positions E and F are removed. A jumper usually is placed between positions B and D to set the drive for cable select operation. On this connector, pin 41 provides +5V power to the drive logic (circuit board), pin 42 provides +5V power to the motor (2 1/2-inch drives use 5V motors, unlike larger drives that typically use 12V motors), and pin 43 provides a power ground. The last pin (44) is reserved and not used.

Table 7.4 shows the 50-pin unitized PATA interface connector pinout as used on most 2 1/2-inch (laptop or notebook computer) drives.

**Table 7.4 The 50-Pin Unitized PATA 2 1/2-Inch (Notebook/Laptop Drive) Connector Pinout**

<table>
<thead>
<tr>
<th>Signal Name</th>
<th>Pin</th>
<th>Pin</th>
<th>Signal Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jumper pin</td>
<td>A</td>
<td>B</td>
<td>Jumper pin</td>
</tr>
<tr>
<td>Jumper pin</td>
<td>C</td>
<td>D</td>
<td>Jumper pin</td>
</tr>
<tr>
<td>KEY (pin missing)</td>
<td>E</td>
<td>F</td>
<td>KEY (pin missing)</td>
</tr>
<tr>
<td>-RESET</td>
<td>1</td>
<td>2</td>
<td>GROUND</td>
</tr>
<tr>
<td>Data Bit 7</td>
<td>3</td>
<td>4</td>
<td>Data Bit 8</td>
</tr>
<tr>
<td>Data Bit 6</td>
<td>5</td>
<td>6</td>
<td>Data Bit 9</td>
</tr>
<tr>
<td>Data Bit 5</td>
<td>7</td>
<td>8</td>
<td>Data Bit 10</td>
</tr>
<tr>
<td>Data Bit 4</td>
<td>9</td>
<td>10</td>
<td>Data Bit 11</td>
</tr>
<tr>
<td>Data Bit 3</td>
<td>11</td>
<td>12</td>
<td>Data Bit 12</td>
</tr>
<tr>
<td>Data Bit 2</td>
<td>13</td>
<td>14</td>
<td>Data Bit 13</td>
</tr>
<tr>
<td>Data Bit 1</td>
<td>15</td>
<td>16</td>
<td>Data Bit 14</td>
</tr>
<tr>
<td>Data Bit 0</td>
<td>17</td>
<td>18</td>
<td>Data Bit 15</td>
</tr>
<tr>
<td>GROUND</td>
<td>19</td>
<td>20</td>
<td>KEY (pin missing)</td>
</tr>
</tbody>
</table>
### Table 7.4 Continued

<table>
<thead>
<tr>
<th>Signal Name</th>
<th>Pin</th>
<th>Pin</th>
<th>Signal Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>DRQ 3</td>
<td>21</td>
<td>22</td>
<td>GROUND</td>
</tr>
<tr>
<td>-IOW</td>
<td>23</td>
<td>24</td>
<td>GROUND</td>
</tr>
<tr>
<td>-IOR</td>
<td>25</td>
<td>26</td>
<td>GROUND</td>
</tr>
<tr>
<td>I/O CH RDY</td>
<td>27</td>
<td>28</td>
<td>CSEL</td>
</tr>
<tr>
<td>-DACK 3</td>
<td>29</td>
<td>30</td>
<td>GROUND</td>
</tr>
<tr>
<td>IRQ 14</td>
<td>31</td>
<td>32</td>
<td>Reserved</td>
</tr>
<tr>
<td>Address Bit 1</td>
<td>33</td>
<td>34</td>
<td>-PDIAG</td>
</tr>
<tr>
<td>Address Bit 0</td>
<td>35</td>
<td>36</td>
<td>Address Bit 2</td>
</tr>
<tr>
<td>-CS1FX</td>
<td>37</td>
<td>38</td>
<td>-CS3FX</td>
</tr>
<tr>
<td>-DA/SP</td>
<td>39</td>
<td>40</td>
<td>GROUND</td>
</tr>
<tr>
<td>+5V (Logic)</td>
<td>41</td>
<td>42</td>
<td>+5V (Motor)</td>
</tr>
<tr>
<td>GROUND</td>
<td>43</td>
<td>44</td>
<td>Reserved</td>
</tr>
</tbody>
</table>

### Note

Many lower-cost board and cable manufacturers leave out the keying. Cheaper motherboards often don’t have pin 20 removed on their ATA connectors; consequently, they don’t supply a cable with pin 20 blocked. If they don’t use a shrouded connector with a notch and a corresponding protrusion on the cable connector, no keying exists and the cables can be inserted backward. Fortunately, the only consequence of this in most cases is that the device won’t work until the cable is attached with the correct orientation.

Note that some systems do not display video until the ATA drives respond to a spin-up command, which they can’t receive if the cable is connected backward. So, if you connect an unkeyed ATA drive to your computer, turn on the computer, and it seems as if the system is locked up (you don’t see anything on the screen), check the ATA cable. (See Figure 7.6 for examples of unkeyed and keyed ATA cables.)

In rare situations in which you are mixing and matching items, you might encounter a cable with pin 20 blocked (as it should be) and a board with pin 20 still present. In that case, you can break off pin 20 from the board—or for the more squeamish, remove the block from the cable or replace the cable with one without the blocked pin. Some cables have the block permanently installed as part of the connector housing, in which case you must break off pin 20 on the board or device end or use a different cable.

The simple rule of thumb is that pin 1 should be oriented toward the power connector on the device, which normally corresponds to the stripe on the cable.

### PATA I/O Cable

A 40-conductor ribbon cable is specified to carry signals between the bus adapter circuits and the drive (controller). To maximize signal integrity and eliminate potential timing and noise problems, the cable should not be longer than 18 inches (0.46 meters), although testing shows that you can reliably use 80-conductor cables up to 27 inches (0.69 meters) in length.
Note that ATA drives supporting the higher-speed transfer modes, such as PIO Mode 4 or any of the Ultra-DMA (UDMA) modes, are especially susceptible to cable integrity problems. If the cable is too long, you can experience data corruption and other errors that can be maddening. This is manifested in problems reading from or writing to the drive. In addition, any drive using UDMA Mode 5 (66MBps transfer rate), Mode 6 (100MBps transfer rate), or Mode 7 (133MBps transfer rate) must use a special, higher-quality 80-conductor cable. I also recommend this type of cable if your drive is running at UDMA Mode 2 (33MBps) or slower because it can’t hurt and can only help. I always keep a high-quality 80-conductor ATA cable in my toolbox for testing drives where I suspect cable integrity or cable length problems. Figure 7.5 shows the typical ATA cable layout and dimensions.

![Diagram of PATA (IDE) cable layout and dimensions](image)

**FIGURE 7.5** PATA (IDE) cable, with 40-pin connectors and either 40- or 80-conductor cables (additional wires are grounded in 80-conductor versions).

**Note**

Most 40-conductor cables do not have color-coded connectors, whereas all 80-conductor cables have color-coded connectors.

The two primary variations of PATA cables in use today—one with 40 conductors and the other with 80 conductors—are shown in Figure 7.6. As you can see, both use 40-pin connectors, and the additional wires in the 80-conductor version are simply wired to ground. The additional conductors are designed to reduce noise and interference and are required when setting the interface to run at 66MBps (ATA/66) or faster. The drive and host adapter are designed to disable the higher-speed ATA/66, ATA/100, and ATA/133 modes if an 80-conductor cable is not detected. In such cases, you might see a warning message when you start your computer if an ATA/66 or faster drive is connected to a 40-conductor cable. You can also use the 80-conductor cable at lower speeds to improve signal integrity. Therefore, it is the recommended version no matter which drive you use.

I once had a student ask me how to tell an 80-conductor cable from a 40-conductor cable. The simple answer is to count the ridges (conductors) in the cable. If you count only 40, it must be a 40-conductor cable, and if you count to 80...well, you get the idea! If you observe them side by side, the difference is clear: The 80-conductor cable has an obviously smoother, less ridged appearance than the 40-conductor cable.
Chapter 7

The ATA/IDE Interface

FIGURE 7.6 A 40-conductor PATA cable (left) and a 80-conductor PATA cable (right).

Note the keying on the 80-conductor cable that is designed to prevent backward installation. Note also that the poorly constructed 40-conductor cable shown in Figure 7.6 lacks keying. Most good 40-conductor cables include the keying; however, because it is optional, many cheaply constructed versions do not include it. Keying was made mandatory for all 80-conductor cables as part of the standard.

Longer or Rounded Cables
The official PATA standard limits cable length to 18 inches (0.46 meters); however, many of the cables sold are longer, up to 36 inches (0.91 meters) or more in length. I’ve had many readers write me questioning the length, asking, “Why would people sell cables longer than 18 inches if the standard doesn’t allow it?” Well, just because something is for sale doesn’t mean it conforms to the standards and will work properly! I see improperly designed, poorly manufactured, and nonconforming items for sale all the time. Many people have used the longer cables and their systems seem to work fine, but I’ve also documented numerous cases where using longer cables has caused problems, so I decided to investigate this issue more thoroughly.

What I discovered is that you can use longer 80-conductor cables reliably up to 27 inches (0.69 meters) in length, but 40-conductor cables should remain limited to 18 inches, just as the standard indicates.

In fact, an attempt was made to change the PATA standard to allow 27-inch cables. If you read www.t13.org/Documents/UploadedDocuments/technical/e00151r0.pdf, you’ll see data from a proposal that shows “negligible differences in Ultra DMA Mode 5 signal integrity between a 27-inch, 80-conductor cable and an 18-inch, 80-conductor cable.” This extended cable design was actually proposed back in October 2000, but it was never incorporated into the standard. Even though it was never officially approved, I take the information presented in this proposal as empirical evidence for allowing the use of 80-conductor cables up to 27 inches in length without problems.

To that, I would add another recommendation, which is that in general I do not recommend “rounded” ATA cables. A rounded design has not been approved in the ATA standard, and there is some evidence that it can cause problems with crosstalk and noise. The design of 80-conductor cables is such that a ground wire is interspersed between each data wire in the ribbon, and rounding the cable causes some of the data lines to run parallel or adjacent to each other at random, thereby causing crosstalk and noise and resulting in signal errors.

Of course, many people use rounded cables with success, but my knowledge of electrical engineering as well as the ATA standard has always made me somewhat uncomfortable with their use.

PATA Signals
This section describes in more detail some of the most important PATA signals having to do with drive configuration and installation. This information can help you understand how the cable select feature works, for example.
Pin 20 is used as a key pin for cable orientation and is not connected to the interface. This pin should be missing from any ATA connectors, and the cable should have the pin-20 hole in the connector plugged off to prevent the cable from being plugged in backward.

Pin 39 carries the drive active/slave present (DASP) signal, which is a dual-purpose, time-multiplexed signal. During power-on initialization, this signal indicates whether a slave drive is present on the interface. After that, each drive asserts the signal to indicate that it is active. Early drives could not multiplex these functions and required special jumper settings to work with other drives. Standardizing this function to allow for compatible dual-drive installations is one of the features of the ATA standard. This is why some drives require a slave present (SP) jumper, whereas others do not.

Pin 28 carries the cable select signal (CSEL). In some older drives, it could also carry a spindle synchronization signal (SPSYNC), but that is not commonly found on newer drives. The CSEL function is the most widely used and is designed to control the designation of a drive as master (drive 0) or slave (drive 1) without requiring jumper settings on the drives. If a drive sees the CSEL as being grounded, the drive is a master; if CSEL is open, the drive is a slave.

You can install special cabling to ground CSEL selectively. This installation usually is accomplished through a cable that has pin 28 missing from the middle connector but present in the connectors on each end. In that arrangement, with one end plugged into the motherboard and two drives set to cable select, the drive plugged into the end connector is automatically configured as master, whereas the drive attached to the middle connector is configured as slave. Note that although this is the most common arrangement, it is also possible to make cables where the middle connector is master (and the end is slave), or even to use a Y-cable arrangement, with the motherboard ATA bus connector in the middle, and each drive at opposite ends of the cable. In this arrangement, one leg of the Y would have the CSEL line connected through (master), and the other leg would have the CSEL line open (conductor interrupted or removed), making the drive at that end the slave.

## PATA Dual-Drive Configurations

Dual-drive PATA installations can be problematic because each drive has its own controller, and both controllers must function while being connected to the same bus. There has to be a way to ensure that only one of the two controllers responds to a command at a time.

The ATA standard provides the option of operating on the AT bus with two drives in a daisy-chained configuration. The primary drive (drive 0) is called the master, and the secondary drive (drive 1) is called the slave. You designate a drive as being master or slave by setting a jumper or switch on the drive or by using a special line in the interface called the cable select (CS) pin and setting the CS jumper on the drive.

When only one drive is installed, the controller responds to all commands from the system. When two drives (and, therefore, two controllers) are installed, both controllers receive all commands from the system. Each controller then must be set up to respond only to commands for itself. In this situation, one controller must be designated as the master and the other as the slave. When the system sends a command for a specific drive, the controller on the other drive must remain silent while the selected controller and drive are functioning. Setting the jumper to master or slave enables discrimination between the two controllers by setting a special bit (the DRV bit) in the drive/head register of a command block.

Configuring ATA drives can be simple, as is the case with most single-drive installations. Or it can be troublesome, especially when it comes to mixing two older drives from different manufacturers on a single cable.
You can configure most ATA drives with four possible settings:

- Master (single drive)
- Master (dual drive)
- Slave (dual drive)
- Cable select

Most drives simplify this to three settings: master, slave, and cable select. Because each ATA drive has its own controller, you must specifically tell one drive to be the master and the other to be the slave. No functional difference exists between the two, except that the drive that’s specified as the slave asserts a signal called DASP after a system reset informs the master that a slave drive is present in the system. The master drive then pays attention to the drive select line, which it otherwise ignores. Telling a drive that it’s the slave also usually causes it to delay its spin-up for several seconds to allow the master to get going and thus to lessen the load on the system’s power supply.

Until the ATA specification, no common implementation for drive configuration was in use. Some drive companies even used different master/slave methods for different models of drives. Because of these incompatibilities, some drives work together only in a specific master/slave or slave/master order. This situation mostly affects older IDE drives introduced before the ATA specification.

Most drives that fully follow the ATA specification now need only one jumper (master/slave) for configuration. A few also need a slave present jumper. Table 7.5 shows the jumper settings that most ATA drives require.

<table>
<thead>
<tr>
<th>Jumper Name</th>
<th>Single-Drive</th>
<th>Dual-Drive Master</th>
<th>Dual-Drive Slave</th>
</tr>
</thead>
<tbody>
<tr>
<td>Master (M/S)</td>
<td>On</td>
<td>On</td>
<td>Off</td>
</tr>
<tr>
<td>Slave Present (SP)</td>
<td>Off</td>
<td>On</td>
<td>Off</td>
</tr>
<tr>
<td>Cable Select (CS)</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
</tr>
</tbody>
</table>

**Note**

If a cable select cable is used, the CS jumper should be set to On and all others should be set to Off. The cable connector then determines which drive will be master or slave.

Figure 7.7 shows the jumpers on a typical ATA drive.

The master jumper indicates that the drive is a master or a slave. Some drives also require a slave present jumper, which is used only in a dual-drive setup and then installed only on the master drive, which is somewhat confusing. This jumper tells the master that a slave drive is attached. With many PATA drives, the master jumper is optional and can be left off. Installing this jumper doesn’t hurt in these cases and can eliminate confusion; I recommend that you install the jumpers listed here.

**Note**

Some drives have these jumpers on the drive circuit board on the bottom of the drive, and as such they might not be visible on the rear.
To eliminate confusion over master/slave settings, most newer systems now use the cable select option. This involves two things. The first is having a special PATA cable that has all the wires except pin 28 running from the motherboard connector to both drive connectors. Pin 28 is used for cable select and is connected to one of the drive connectors (labeled master) and not to the other (labeled slave). Both drives are then configured in cable select mode via the CS jumper on each drive.

<table>
<thead>
<tr>
<th>Master Drive Configuration (standard cable)</th>
<th>Slave Drive Configuration (standard cable)</th>
<th>Cable Select Drive Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use the Master Drive Configuration for the first (or only) drive on a standard (non-cable select) cable.</td>
<td>Use the Slave Drive Configuration for the second drive on a standard (non-cable select) cable; note that for a Slave Configuration, the jumper can be stored in the PK (Jumper Park) position, removed entirely, or stored on one of the DS Pins in a flag arrangement.</td>
<td>For Cable Select Drive Configurations, one or both drives are configured the same; the cable automatically determines which is Master or Slave by which connector the drive is plugged into.</td>
</tr>
</tbody>
</table>

**FIGURE 7.7** PATA (IDE) drive jumpers for most drives.

With cable select, the drive that receives signals on pin 28 automatically becomes the master, and the other becomes the slave. Most cables implement this by removing the metal insulation displacement bit from the pin-28 hole, which can be difficult to see at a glance. Other cables have a section of pin 28 visibly cut from the cable somewhere along the ribbon. Because this is such a minor modification to the cable and can be difficult to see, cable select cables typically have the connectors labeled master, slave, and system, indicating that the cable controls these options rather than the drive. All 80-conductor Ultra-ATA cables are designed to use cable select.

With cable select, you simply set the CS jumper on all drives and then plug the drive you want to be the master into the connector labeled master on the cable and the drive you want to be the slave into the connector labeled slave.

The only downside I see to using cable select is that it can restrict how the cable is routed or where you mount the drive that is to be master versus slave because they must be plugged into specific cable connector positions.
PATA PIO Transfer Modes

ATA-2 and ATA-3 defined the first of several higher-performance modes for transferring data over the PATA interface, to and from the drive. These faster modes were the main part of the newer specifications and were the main reason they were initially developed. The following section discusses these modes.

The PIO (programmed I/O) mode determines how fast data is transferred to and from the drive using PIO transfers. In the slowest possible mode—PIO Mode 0—the data cycle time can't exceed 600 nanoseconds (ns). In a single cycle, 16 bits are transferred into or out of the drive, making the theoretical transfer rate of PIO Mode 0 (600ns cycle time) 3.3MBps, whereas PIO Mode 4 (120ns cycle time) achieves a 16.6MBps transfer rate.

Most motherboards with ATA-2 or greater support have dual ATA connectors on the motherboard. Most of the motherboard chipsets include the ATA interface in their South Bridge components, which in most systems is tied into the PCI bus.

Older 486 and some early Pentium boards have only the primary connector running through the system's PCI local bus. The secondary connector on those boards usually runs through the ISA bus and therefore supports up to Mode 2 operation only.

When interrogated with an Identify Drive command, a hard disk returns, among other things, information about the PIO and DMA modes it is capable of using. Most BIOSs automatically set the correct mode to match the capabilities of the drive. If you set a mode faster than the drive can handle, data corruption results.

ATA-2 and newer drives also perform Block Mode PIO, which means they use the Read/Write Multiple commands that greatly reduce the number of interrupts sent to the host processor. This lowers the overhead, and the resulting transfers are even faster.

PATA DMA Transfer Modes

ATA drives support two types of transfers: programmed input/output (PIO), and direct memory access (DMA) transfers. DMA means that the data is transferred directly between drive and memory without using the CPU as an intermediary, as opposed to PIO. This offloads much of the work of transferring data from the processor, in effect allowing the processor to do other things while the transfer is taking place. DMA transfers are much faster than PIO transfers and are supported by all modern ATA devices.

There are two distinct types of direct memory access: singleword (8-bit) and multiword (16-bit). Singleword DMA modes were removed from the ATA-3 and later specifications and are obsolete. DMA modes are also sometimes called busmaster ATA modes because they use a host adapter that supports bus mastering. Ordinary DMA relies on the legacy DMA controller on the motherboard to perform the complex task of arbitration, grabbing the system bus and transferring the data. In the case of bus mastering DMA, all this is done by a higher-speed logic chip in the host adapter interface (which is also on the motherboard).

Systems using the Intel PIIX (PCI IDE ISA eXcelerator) and later South Bridge chips (or equivalent) can support busmaster ATA. The singleword and multiword busmaster ATA modes and transfer rates are shown in Tables 7.6 and 7.7, respectively.
### Table 7.6 Singleword (8-Bit) DMA Modes and Transfer Rates

<table>
<thead>
<tr>
<th>8-Bit DMA Mode</th>
<th>Bus Width (Bits)</th>
<th>Cycle Speed (ns)</th>
<th>Bus Speed (MHz)</th>
<th>Cycles per Clock</th>
<th>Transfer Rate (MBps)</th>
<th>ATA Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>16</td>
<td>960</td>
<td>1.04</td>
<td>1</td>
<td>2.08</td>
<td>ATA-1*</td>
</tr>
<tr>
<td>1</td>
<td>16</td>
<td>480</td>
<td>2.08</td>
<td>1</td>
<td>4.17</td>
<td>ATA-1*</td>
</tr>
<tr>
<td>2</td>
<td>16</td>
<td>240</td>
<td>4.17</td>
<td>1</td>
<td>8.33</td>
<td>ATA-1*</td>
</tr>
</tbody>
</table>

*Singleword (8-bit) DMA modes were removed from the ATA-3 and later specifications.

### Table 7.7 Multiword (16-Bit) DMA Modes and Transfer Rates

<table>
<thead>
<tr>
<th>16-Bit DMA Mode</th>
<th>Bus Width (Bits)</th>
<th>Cycle Speed (ns)</th>
<th>Bus Speed (MHz)</th>
<th>Cycles per Clock</th>
<th>Transfer Rate (MBps)</th>
<th>ATA Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>16</td>
<td>480</td>
<td>2.08</td>
<td>1</td>
<td>4.17</td>
<td>ATA-1</td>
</tr>
<tr>
<td>1</td>
<td>16</td>
<td>150</td>
<td>6.67</td>
<td>1</td>
<td>13.33</td>
<td>ATA-2*</td>
</tr>
<tr>
<td>2</td>
<td>16</td>
<td>120</td>
<td>8.33</td>
<td>1</td>
<td>16.67</td>
<td>ATA-2*</td>
</tr>
</tbody>
</table>

*ATA-2 was also referred to as EIDE (Enhanced IDE) or Fast-ATA.

Note that multiword DMA modes are also called busmaster DMA modes by some manufacturers. Unfortunately, even the fastest multiword DMA Mode 2 results in the same 16.67MBps transfer speed as PIO Mode 4. However, even though the transfer speed is the same as PIO, because DMA offloads much of the work from the processor, overall system performance is higher. Even so, multiword DMA modes were never very popular and have been superseded by the newer Ultra-DMA modes supported in devices that are compatible with ATA-4 through ATA-7.

Table 7.8 shows the Ultra-DMA modes now supported in the ATA-4 through ATA-7 specifications. Note that you need to install the correct drivers for your host adapter and version of Windows to use this feature.

### Table 7.8 Ultra-DMA Support in ATA-4 Through ATA-7

<table>
<thead>
<tr>
<th>Ultra DMA Mode</th>
<th>Bus Width (Bits)</th>
<th>Cycle Speed (ns)</th>
<th>Bus Speed (MHz)</th>
<th>Cycles per Clock</th>
<th>Transfer Rate (MBps)</th>
<th>ATA Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>16</td>
<td>240</td>
<td>4.17</td>
<td>2</td>
<td>16.67</td>
<td>ATA-4</td>
</tr>
<tr>
<td>1</td>
<td>16</td>
<td>160</td>
<td>6.25</td>
<td>2</td>
<td>25.00</td>
<td>ATA-4</td>
</tr>
<tr>
<td>2</td>
<td>16</td>
<td>120</td>
<td>8.33</td>
<td>2</td>
<td>33.33</td>
<td>ATA-4</td>
</tr>
<tr>
<td>3</td>
<td>16</td>
<td>90</td>
<td>11.11</td>
<td>2</td>
<td>44.44</td>
<td>ATA-5</td>
</tr>
<tr>
<td>4</td>
<td>16</td>
<td>60</td>
<td>16.67</td>
<td>2</td>
<td>66.67</td>
<td>ATA-5</td>
</tr>
<tr>
<td>5</td>
<td>16</td>
<td>40</td>
<td>25.00</td>
<td>2</td>
<td>100.00</td>
<td>ATA-6</td>
</tr>
<tr>
<td>6</td>
<td>16</td>
<td>30</td>
<td>33.00</td>
<td>2</td>
<td>133.00</td>
<td>ATA-7</td>
</tr>
</tbody>
</table>

ATA-4 UDMA Mode 2 is sometimes called Ultra-ATA/33 or ATA-33.
ATA-5 UDMA Mode 4 is sometimes called Ultra-ATA/66 or ATA-66.
ATA-6 UDMA Mode 5 is sometimes called Ultra-ATA/100 or ATA-100.
ATA-7 UDMA Mode 6 is sometimes called Ultra-ATA/133 or ATA-133.
SATA

The development of ATA-8 marked the beginning of the end for the PATA standard that has been in use since 1986. Sending data at rates faster than 133MBps down a parallel ribbon cable originally designed for only 8.3Mbps is fraught with all kinds of problems because of signal timing, electromagnetic interference (EMI), and other integrity problems. The solution, Serial ATA, is an evolutionary replacement for the venerable PATA physical storage interface. When set in non-AHCI/RAID modes (in other words, IDE or legacy mode), SATA is software-compatible with PATA, which means it emulates all the commands, registers, and controls so existing software can run without changes. In other words, the existing BIOSs, operating systems, and utilities that work on PATA also work with SATA.

Of course, they do differ physically—that is, you can’t plug PATA drives into SATA host adapters, and vice versa, although signal converters do make that possible. The physical changes are all for the better because SATA uses much smaller and thinner cables with only seven conductors that are easier to route inside the PC and easier to plug in with smaller, redesigned cable connectors. The interface chip designs also are improved, with far fewer pins and lower voltages. All these improvements are designed to eliminate the design problems inherent in PATA.

Figure 7.8 shows the official Serial ATA International Organization working group logo that identifies most SATA devices.

![Serial ATA official logo, which identifies SATA devices.](image)

Although SATA didn’t immediately replace PATA, most systems sold following SATA’s standardization included SATA interfaces alongside PATA interfaces. Over time, SATA has predominantly replaced PATA as the de facto standard internal storage device interface found in PCs, and most current systems lack PATA support. However, some motherboards and devices with PATA support are still available, and where repairs are considered they will likely remain available at a minimum level for some time.

SATA Standards and Performance

Development for SATA started when the Serial ATA Working Group effort was announced at the Intel Developer Forum in February 2000. The initial members of the Serial ATA Working Group included APT Technologies, Dell, IBM, Intel, Maxtor, Quantum, and Seagate. The original group later became known as the Serial ATA II Working Group, and finally in July 2004, it became the Serial ATA International Organization. These groups have released the following SATA specifications:

- The first SATA 1.0 draft specification was released in November 2000 and was officially published as a final specification in August 2001.
- The first SATA II Working Group extensions to this specification, which made SATA suitable for network storage, were released in October 2002.
- SATA Revision 2 was released in April 2004. It added the 3Gbps (300MBps) signaling speed.
SATA Revision 2.5 was released in August 2005. It added Native Command Queuing (NCQ), staggered spin-up, hot plug, port multiplier, and eSATA support.

SATA Revision 2.6 was released in March 2007. It added new internal Slimline and Micro cables and connectors as well as modifications to NCQ.

SATA Revision 3.0 was released in 2009. It added the 6Gbps (600MBps) signaling speed.

SATA Revision 3.1 was released in 2011. It added improvements in power management, hardware control, and a Queued Trim Command for improving SSD performance.

SATA Revision 3.2 was released in 2013. It adds a new interface called SATA Express, which uses SATA commands over a PCIe hardware interface for transfer speeds up to 16Gbps.

You can download the specifications from the Serial ATA International Organization website at www.serialata.org. Since forming, the group has grown to include more than 200 contributor and adopter companies from all areas of industry.

Systems using SATA were released in late 2002 using discrete PCI interface boards and chips. SATA was integrated directly into motherboard chipsets in April 2003 with the introduction of the Intel ICH5 chipset component. Since then, virtually all new motherboard chipsets have included SATA.

The performance of SATA is impressive, although current hard drive designs can’t fully take advantage of its bandwidth. Solid State Drives (SSDs), on the other hand, can and do take advantage of all of the bandwidth that SATA has to offer and are the driving force for the introduction of even higher bandwidth standards. Three main variations of the original standard use the same cables and connectors; they differ only in transfer rate performance. SATA Express, in contrast, uses new cables and connectors for dramatically increased throughput. Table 7.9 shows the bandwidth specifications; devices supporting the second-generation 300MBps (3Gbps) version became available in 2005, and devices supporting the third-generation 600MBps (6Gbps) versions became available in 2011. SATA Express devices are expected to be available in 2014.

<table>
<thead>
<tr>
<th>SATA Type</th>
<th>Signal Rate (Gbps)</th>
<th>Bus Width (Bits)</th>
<th>Bus Speed (MHz)</th>
<th>Data Cycles per Clock</th>
<th>Throughput</th>
</tr>
</thead>
<tbody>
<tr>
<td>SATA-150</td>
<td>1.5</td>
<td>1</td>
<td>1,500</td>
<td>1</td>
<td>150</td>
</tr>
<tr>
<td>SATA-300</td>
<td>3.0</td>
<td>1</td>
<td>3,000</td>
<td>1</td>
<td>300</td>
</tr>
<tr>
<td>SATA-600</td>
<td>6.0</td>
<td>1</td>
<td>6,000</td>
<td>1</td>
<td>600</td>
</tr>
<tr>
<td>SATA Express</td>
<td>8.0</td>
<td>2</td>
<td>16,000</td>
<td>1</td>
<td>1,969*</td>
</tr>
</tbody>
</table>

*Note SATA Express uses 128b/130b encoding, which is 98.5% efficient vs. the 80% efficient 8b/10b encoding used by SATA.

SATA Express

The advent of high-performance SSD (solid-state drive) storage has pushed the need for greater and greater interface bandwidth. SATA 3.0 offers up to 600MBps throughput, which by 2011 many SSDs could deliver. Since then the development of faster and faster drives has been mostly limited by the interface bandwidth, and that SATA had become the bottleneck. To eliminate this bottleneck, the Serial ATA International Organization (SATA-IO) first studied doubling the SATA 6Gbps rate to 12Gbps;
however, they found that doing so required extensive (and expensive) changes in cabling and signaling, not to mention that development would take some time. Instead, they decided to take a much easier way out by using the existing PCI Express interface. SATA-IO first announced in 2011 that it was developing a faster version of SATA called SATA Express, which was finally completed and published in 2013 as part of the SATA 3.2 specification.

SATA Express combines PCI Express signaling with the SATA software protocol (command set), plus a new set of cables and connectors that are backward compatible with SATA. When using PCIe 3.0 signaling, SATA Express offers up to 16Gbps in raw data throughput, which translates to nearly 2 gigabytes per second of actual data bandwidth. That is nearly 3.3 times faster than conventional SATA at 600MBps.

Not only is the SATA Express signaling speed much faster, but it is also more efficient, resulting in even higher bandwidths than the raw signaling rate would imply. Conventional SATA uses 8b/10b encoding, which is 80% efficient. That means that 8 out of every 10 bits (or 80%) in the raw data stream are actual data; the other 2 bits (or 20%) are overhead. SATA Express uses the more advanced 128b/130b encoding scheme found in PCI Express 3.0, which is an incredible 98.5% efficient, with only 1.5% overhead. This is achieved by scrambling the raw data to be sent using a known binary polynomial and then unscrambling it at the other end using the inverse polynomial. Because SATA Express uses two PCIe lanes with up to 8Gbps per lane, combined with the more efficient encoding, the end result is a whopping 1,969MBps maximum throughput as compared to 600MBps for conventional SATA.

SATA Express uses a wider cable with 18 conductors vs. the 7 conductors in a standard SATA cable. SATA Express motherboard connectors are backward compatible with SATA, meaning you can plug one or two standard SATA cables into a single SATA Express connector (see Figure 7.9). Connecting conventional SATA drives to a SATA Express port causes the port to shift down to conventional SATA mode.

**FIGURE 7.9** SATA Express motherboard and cable connectors, showing backward compatibility with conventional SATA.
With SATA Express offering more than three times the throughput of conventional SATA, high-performance storage devices like SSDs will become even faster in the future.

**SATA Cables and Connectors**

From Table 7.9, you can see that conventional SATA sends data only a single bit at a time, while SATA Express sends 2 bits. The cable used for SATA has only seven wires (four signal and three ground) and is a thin design, with keyed connectors only 14mm (0.55 inches) wide on each end. This eliminates problems with airflow compared to the wider PATA ribbon cables. Each cable has connectors only at each end, and each cable connects the device directly to the host adapter (typically on the motherboard). There are no master/slave settings because each cable supports only a single device. The cable ends are interchangeable; the connector on the motherboard is the same as on the device, and both cable ends are identical. Maximum SATA cable length is 1 meter (39.37 inches), which is considerably longer than the 18-inch maximum for PATA.

Although SATA-600 uses the same cables and connectors as the previous (slower) versions, it does place higher demands for quality, so some manufacturers will mark higher quality cables with a rating like “SATA 6Gbps.” One issue that becomes more of a problem is bending cables. Data moving at the higher 3Gbps and 6Gbps rates can be corrupted when encountering a severe right-angle bend, so it is recommended that when routing SATA cables you do not crimp or bend them sharply with a pliers; use more gradual curves or bends instead. Note that this does not apply to cables with right-angle connectors; the wires in the connectors have multiple bends or curve instead.

SATA uses a special encoding scheme called 8b/10b to encode and decode data sent along the cable. IBM initially developed (and patented) the 8b/10b transmission code in the early 1980s for use in high-speed data communications. Many high-speed data transmission standards, including Gigabit Ethernet, Fibre Channel, FireWire, and others, use this encoding scheme. The main purpose of the 8b/10b encoding scheme is to guarantee that never more than four 0s (or 1s) are transmitted consecutively. This is a form of Run Length Limited (RLL) encoding called RLL 0,4, in which the 0 represents the minimum and the 4 represents the maximum number of consecutive 0s or 1s in each encoded character.

The 8b/10b encoding also ensures that there are never more than six or fewer than four 0s (or 1s) in a single encoded 10-bit character. Because 1s and 0s are sent as voltage changes on a wire, this ensures that the spacing between the voltage transitions sent by the transmitter is fairly balanced, with a more regular and steady stream of pulses. This presents a steadier load on the circuits, increasing reliability. The conversion from 8-bit data to 10-bit encoded characters for transmission leaves several 10-bit patterns unused. Many of these additional patterns provide flow control, delimit packets of data, perform error checking, or perform other special functions.

The physical transmission scheme for SATA uses *differential NRZ* (Non Return to Zero). This uses a balanced pair of wires, each carrying +0.25V (one-quarter volt). The signals are sent differentially: If one wire in the pair carries +0.25V, the other wire carries –0.25V, where the differential voltage between the two wires is always 0.5V (one-half volt). So, for a given voltage waveform, the opposite voltage waveform is sent along the adjacent wire. Differential transmission minimizes electromagnetic radiation and makes the signals easier to read on the receiving end.

A 15-pin power cable and power connector is optional with SATA, providing 3.3V power in addition to the 5V and 12V provided via the industry-standard 4-pin device power connectors. Although it has 15 pins, this new power connector design is only 24mm (0.945 inches). With 3 pins designated for each of the 3.3V, 5V, and 12V power levels, enough capacity exists for up to 4.5 amps of current at each voltage, which is plenty for even the most power-hungry drives. For compatibility with existing power supplies, SATA drives can be made with the original, standard 4-pin device power connector or the...
new 15-pin SATA power connector (or both). If the drive doesn’t have the type of connector you need, adapters are available to convert from one type to the other.

Figure 7.10 shows what the SATA signal and power connectors look like, and Figure 7.11 shows SATA and PATA host adapters on a typical motherboard.

![Diagram of SATA signal and power connectors](image1)

**FIGURE 7.10** SATA signal and power connectors on a typical SATA hard drive.

![Diagram of motherboard with SATA and PATA host adapters](image2)

**FIGURE 7.11** A motherboard with SATA and PATA host adapters.

The pinouts for the SATA data and optional power connectors are shown in Tables 7.10 and 7.11, respectively.

### Table 7.10 SATA Data Connector Pinout

<table>
<thead>
<tr>
<th>Signal Pin</th>
<th>Signal</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>Gnd</td>
<td>First mate</td>
</tr>
<tr>
<td>S2</td>
<td>A+</td>
<td>Host Transmit +</td>
</tr>
<tr>
<td>S3</td>
<td>A-</td>
<td>Host Transmit −</td>
</tr>
</tbody>
</table>
### Table 7.11 SATA Optional Power Connector Pinout

<table>
<thead>
<tr>
<th>Signal Pin</th>
<th>Signal</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>+3.3V</td>
<td>3.3V power</td>
</tr>
<tr>
<td>P2</td>
<td>+3.3V</td>
<td>3.3V power</td>
</tr>
<tr>
<td>P3</td>
<td>+3.3V</td>
<td>3.3V power</td>
</tr>
<tr>
<td>P4</td>
<td>Gnd</td>
<td>First mate</td>
</tr>
<tr>
<td>P5</td>
<td>Gnd</td>
<td>First mate</td>
</tr>
<tr>
<td>P6</td>
<td>Gnd</td>
<td>First mate</td>
</tr>
<tr>
<td>P7</td>
<td>+5V</td>
<td>5V power</td>
</tr>
<tr>
<td>P8</td>
<td>+5V</td>
<td>5V power</td>
</tr>
<tr>
<td>P9</td>
<td>+5V</td>
<td>5V power</td>
</tr>
<tr>
<td>P10</td>
<td>Gnd</td>
<td>First mate</td>
</tr>
<tr>
<td>P11</td>
<td>Gnd</td>
<td>First mate</td>
</tr>
<tr>
<td>P12</td>
<td>Gnd</td>
<td>First mate</td>
</tr>
<tr>
<td>P13</td>
<td>+12V</td>
<td>12V power</td>
</tr>
<tr>
<td>P14</td>
<td>+12V</td>
<td>12V power</td>
</tr>
<tr>
<td>P15</td>
<td>+12V</td>
<td>12V power</td>
</tr>
</tbody>
</table>

All pins are in a single row spaced 1.27mm (.050 inches) apart.
All ground pins are longer so they will make contact before the signal/power pins to allow hot-plugging.

**Mini-SATA (mSATA)**

Mini-SATA (mSATA) is a form factor specification developed by Intel for very small solid-state drives (SSDs), primarily in laptop or tablet systems. The mSATA form factor is virtually identical to Mini-PCI Express, which is the form factor used for mobile WLAN (wireless local area network or WiFi) and WWAN (wireless wide-area network) adapters. By using the same card size and shape but with a slightly modified connector design, a Mini-PCIe socket can function in both Mini-PCIe and mSATA modes.
mSATA drives are significantly smaller than the standard 2.5-inch drives used in most laptops (see Figure 7.12).

![mSATA SSD and 2.5-inch SSD](image)

**FIGURE 7.12** An mSATA drive compared to a standard 2.5-inch drive.

Tablet devices typically have a dedicated mSATA connector internally, which is designed solely for mSATA SSDs. Many laptops, however, have an internal combination mSATA/WWAN connector, which can accept either an mSATA SSD or a WWAN interface card. Depending on which type of device is installed, the port will automatically switch to the proper mode.

mSATA SSDs are not available in nearly as high capacities as 2.5-inch SSDs, but they are also physically smaller and less expensive. Laptops with mSATA/WWAN ports can have a high-performance mSATA SSD installed as the boot drive, and then use a much cheaper and higher capacity conventional HDD as a data storage drive.

**eSATA**

When SATA was first released, the ability to run longer cables of up to 1 meter (3.3 ft.) made people think about running cables out of the system to external drives. Some companies jumped on this demand, creating a market for proprietary cable and connector designs allowing SATA drives to be run in external enclosures. Unfortunately, the designs were proprietary, and since SATA cables lacked the shielding and other design criteria to allow external operation, some of the designs were unreliable. Realizing that there was a market for external SATA, the Serial ATA International Organization (SATA-IO) released the official standard for external SATA called eSATA in 2004.

eSATA is a variation on SATA specifically designed for external connections. The main differences between SATA and eSATA are in the cables. eSATA allows for longer cables of up to 2 meters (6.6 ft.), and the cables have extra shielding. The connectors are different both electrically and mechanically as well. They have deeper contacts, metal springs for shielding and mechanical retention, and are designed for up to 5,000 mating cycles vs. only 50 for internal cables. The eSATA cable and port connectors are shown in Figure 7.13.
eSATA supports all SATA transfer speeds up to 6Gbps rate (600MBps); however, some are limited to 3Gbps (300MBps) or less. Even at 300MBps, eSATA is significantly faster than other popular external interfaces such as 1394a/FireWire 400 (50MBps) and USB 2.0 (60MBps). In fact, with 300MBps or 600MBps of bandwidth, eSATA is three to six times faster than 1394b/FireWire 800 (100MBps), and even the 3Gbps (300MBps) mode of eSATA is faster than USB 3.0 (5Gbps or 500MBps). How can 300MBps eSATA be faster than 500GBps USB 3.0? One reason is that there is a large amount of overhead in the USB specification to allow for even longer cable lengths (5 meters or 16 ft.), which drops the actual data throughput to well under 400MBps, but the other reality is that any external drive connected via USB 3.0 consists of a SATA drive plus circuitry converting the data from SATA to USB 3.0 inside the enclosure, thereby reducing efficiency even more. When using eSATA, there is no signal conversion inside the external enclosure (eSATA is SATA, after all) making the interface much more efficient. In short, eSATA is just about the ideal connection for external drives, allowing them to work just as if they were internal to the system.

If your system doesn’t have an eSATA port built in, you can easily add one using a very inexpensive cable and bracket assembly. The cable will plug into one of your motherboard-based SATA ports, and the other end of the cable will be an eSATA connector mounted in an expansion card bracket (see Figure 7.14). Brackets are available with one or two ports as necessary.

**Power Over eSATA (eSATAp)**

One drawback to eSATA over USB is that eSATA does not provide power. To rectify this, several manufacturers got together and informally created the eSATA USB Hybrid Port (EUHP) that combines USB and eSATA ports into a single physical connector. The SATA International Organization (SATA-IO) is working to make this an official standard called the Power Over eSATA (eSATAp) specification.

An eSATAp port is basically both a USB port and an eSATA port combined in one single connector (see Figure 7.15). These ports will normally be identified with an “eSATA + USB” notation. They accept standard USB or eSATA cables, and when attached, the proper connections will be made for the desired interface to function. A third option is to plug in an eSATAp cable, which will combine the eSATA and USB signals with +5V or +12V power, allowing the connection of USB, SATA, or eSATAp devices with no separate power adapter necessary. eSATAp ports have become very popular in laptops for connecting high-speed external drives, and you can get bracket adapters to add them to desktop systems (see Figure 7.16).
FIGURE 7.14 SATA to eSATA bracket assembly for adding eSATA ports to a system.

FIGURE 7.15 An eSATAP (Power Over eSATA) combination eSATA and USB connector.

FIGURE 7.16 An eSATAp (Power Over eSATA) bracket showing optional USB 3.0/2.0, eSATAp, and eSATA connections.
There are several variations on eSATAp ports. The USB part of eSATAp can be either USB 2.0 or 3.0, depending on the specific implementation. Just as with standard USB only ports, if the eSATAp port is blue in color, that indicates USB 3.0 capability. Another variation is the eSATA speed. Some supply the full 6Gbps (600MBps) rate of SATA 3.0, while others allow only 3Gbps (300MBps) mode. Finally, another variation is in the power. In most laptop systems, an eSATAp port will only supply +5V power, which is fine for powering external 2.5-inch drives. Desktop versions of eSATAp can supply both +5V and +12V power, allowing external 3.5-inch drives to be powered as well.

Besides allowing faster data transfer than even USB 3.0, connecting external drives using eSATA or eSATAp has another major advantage over USB, and that is bootability. Windows does not allow booting from USB drives; however, drives connected via eSATA or eSATAp do not have that restriction. Windows will treat them the same as if they were internally connected. Using eSATA or eSATAp, one can use and easily swap external bootable drives, a feature especially useful for diagnostics and testing purposes.

**SATA Configuration**

Configuration of SATA devices is also much simpler because the master/slave or cable select jumper settings used with PATA are no longer necessary.

BIOS setup for SATA drives is also quite simple. Because SATA is based on ATA, autodetection of drive settings on systems with SATA connectors is performed in the same way as on PATA systems. Depending on the system, SATA interfaces will support legacy (usually called “IDE”), AHCI (Advanced Host Controller Interface) or RAID (redundant array of independent disks) modes. In most cases you will want to set AHCI mode for the SATA host adapter to run in its native, most fully featured mode. RAID mode is a superset of AHCI and allows multiple drives to be configured in an array to act as a single drive. (See Chapter 5, “BIOS,” for details.)

If you want to use SATA drives but don’t want to install a new motherboard with SATA host adapters already included, you can install a separate SATA host adapter into a PCI or PCIe expansion slot (see Figure 7.17). Many of these adapters include RAID capability as well.

**FIGURE 7.17** Typical 4-port SATA RAID host adapter.
Advanced Host Controller Interface (AHCI)

SATA was designed not only as a replacement for PATA, but as an interface that would evolve into something with many more capabilities and features than its predecessor. Initially, compatibility with PATA was one of the most important features of SATA because it enabled a smooth and easy transition from one to the other. This compatibility extends to the driver level, allowing SATA devices to use the same BIOS-level drivers and software as legacy PATA devices.

Although the intent of SATA was to allow an easy transition from PATA, it was also designed to allow future growth and expansion of capabilities. To accomplish this, an enhanced software interface called the Advanced Host Controller Interface (AHCI) was initially developed by the AHCI Contributor Group, a group chaired by Intel and originally consisting of AMD, Dell, Marvell, Maxtor, Microsoft, Red Hat, Seagate, and StorageGear. The AHCI Contributor Group released a preliminary version of AHCI v0.95 in May 2003 and released the 1.0 version of the specification in April 2004. You can download the latest version (1.3, released in 2008) from Intel at www.intel.com/technology/serialata/ahci.htm.

AHCI provides an industry-standard, high-performance interface to system driver/OS software for discovering and implementing such advanced SATA features as command queuing, hot-plugging, and power management. AHCI was integrated into SATA-supporting chipsets in 2004 and is supported by AHCI drivers for Windows. The main idea behind AHCI is to have a single driver-level interface supported by all advanced SATA host adapters. This greatly simplifies the installation of operating systems, eliminating the need for custom SATA drivers for each manufacturer's SATA host adapter. For example, Windows Vista and later include AHCI drivers and automatically support any advanced SATA host adapters that are AHCI compatible.

Unfortunately, AHCI drivers are not included by default on the Windows XP and earlier installation CDs, because AHCI was developed long after XP was released. This means, for example, that if you install Windows XP on a system with an integrated SATA host adapter set to AHCI mode, you will probably need to press the F6 key at the beginning of the installation and provide a floppy disk with the AHCI drivers; otherwise, Windows XP will not be able to recognize the drives. The implication here is that the system must include a floppy drive, and you must have copied the drivers to a floppy disk in advance. But what if your system doesn’t even include a floppy drive? Fortunately, several solutions are available.

One option is to keep a spare floppy drive in your toolkit and temporarily connect it during the installation. Just open the case, plug in a floppy cable from the floppy drive connector (FDC) on the motherboard to the drive, and connect power to the drive. There is no need to actually mount the drive in the chassis because you will only need to read the disk once at the beginning of the installation.

Another option is to set the SATA host adapter to ATA/IDE compatibility mode (disable AHCI/RAID) in the BIOS Setup, after which you can boot from a standard Windows XP CD and install Windows without requiring special drivers. You could leave the adapter in compatibility mode, but you might be missing out on the performance offered by the advanced capabilities your hard drives support.

Although the first two options can work in most situations, I think the best overall solution is to simply create a custom Windows XP installation disc that already has the SATA AHCI (and even RAID) drivers preinstalled. This can be accomplished via a somewhat tedious manual integration process for each set of drivers, but to make things really easy you can use the menu-driven BTS DriverPacks from www.driverpacks.net to integrate virtually all the popular mass storage drivers directly into your Windows XP install disc. The DriverPacks allow you to easily add all kinds of drivers to your Windows XP installation discs. For example, in addition to the mass storage drivers, I like to integrate the various processor, chipset, and network (both wired and wireless) drivers because all of these still fit on a CD. If you are willing to move to a DVD instead of a CD, you can fit Windows XP and all of the available XP DriverPacks on a single DVD.
Non-Volatile Memory Express (NVMe)

The Advanced Host Controller Interface (AHCI) has long been the preferred software interface for SATA devices. AHCI can be used with conventional SATA as well as SATA Express devices, allowing both to use the same software interface and therefore the same drivers. While using AHCI mode with SATA Express allows for maximum compatibility, it does not allow for maximum performance when interfacing with low-latency devices like solid-state drives (SSDs), which internally behave more like RAM than a spinning disk. To improve the performance of SSDs connected via high-speed PCI Express–based interfaces like SATA Express, a new software interface called the Non-Volatile Memory Host Controller Interface (NVMHCI) was first defined in 2007 by the NVMHCI Workgroup (www.nvmexpress.org), a group including more than 75 major companies from the computing and storage industries. Owing to its intention on being used in combination with PCIe and SATA Express devices, the NVMHCI specification was subsequently named NVM Express (NVMe), and the NVMe specification 1.0 was published in 2011.

Like AHCI before it, NVMe is a software interface specification that defines the commands and functions for communicating with PCIe or SATA Express devices. SSDs are by nature very low latency devices, a characteristic that NVMe is designed to fully exploit. NVMe is also designed to more fully utilize the parallelism built in to modern systems such as multicore hyper-threaded processors, multi-lane buses, and multi-tasking operating systems. The biggest technical difference between AHCI and NVMe is that AHCI supports a single command queue with up to 32 commands, while NVMe supports up to 64K queues with up to 64K commands per queue. Having many more and much deeper queues allows for commands to be far more rapidly delivered to SSDs, where due to their low-latency characteristics they can be processed more rapidly than drives with spinning disks.

SATA Express host adapters support both AHCI and NVMe modes. Using AHCI mode will allow for backward compatibility with existing AHCI drivers, while choosing NVMe mode will require new NVMe drivers. Since NVMe drivers were not included by default with Windows 8 and earlier versions, NVMe drivers will need to be supplied during the OS installation procedure for Windows to recognize any devices connected to SATA Express host adapters in NVMe mode. Using AHCI mode instead, you can install Windows Vista and later on SATA Express drives right out of the box, with no additional drivers necessary; however, there will be some loss in performance.

SATA Transfer Modes

SATA transfers data in a completely different manner from PATA. As indicated previously, the transfer rates are 1.5Gbps (150MBps), 3Gbps (300MBps), and 6Gbps (600MBps), with most drives today supporting the 3Gbps or 6Gbps rates. Note that speeds are backward compatible—for example, drives supporting the 6Gbps rate also work at 3Gbps or 1.5Gbps. Note that because SATA is designed to be backward compatible with PATA, some confusion can result because the BIOS and drives can report speeds and modes that emulate PATA settings for backward compatibility.

For example, many motherboards detect and report a SATA drive as supporting Ultra DMA Mode 5 (ATA/100), which is a PATA mode operating at 100MBps. This is obviously incorrect because even the slowest SATA mode (1.5Gbps) is 150MBps, and Ultra DMA modes simply do not apply to SATA drives.

PATA and SATA are completely different electrical and physical specifications, but SATA does emulate PATA in a way that makes it completely software transparent. In fact, the PATA emulation in SATA specifically conforms to the ATA-5 specification.

This is especially apparent in the IDENTIFY DEVICE command that the autodetect routines use in the BIOS to read the drive parameters. The SATA specification indicates that many of the items returned by IDENTIFY DEVICE are to be “set as indicated in ATA/ATAPI-5,” including available UDMA modes and settings.
The SATA 1 specification also says,

Emulation of parallel ATA device behavior, as perceived by the host BIOS or software driver, is a cooperative effort between the device and the SATA host adapter hardware. The behavior of Command and Control Block registers, PIO and DMA data transfers, resets, and interrupts are emulated. The host adapter contains a set of registers that shadow the contents of the traditional device registers, referred to as the Shadow Register Block. All SATA devices behave like Device 0 devices. Devices shall ignore the DEV bit in the Device/Head field of received Register FISs, and it is the responsibility of the host adapter to gate transmission of Register FISs to devices, as appropriate, based on the value of the DEV bit.

This means the shadow register blocks are “fake” PATA registers, allowing all ATA commands, modes, and so on to be emulated. SATA was designed to be fully software compatible with ATA/ATAPI-5, which is why a SATA drive can report in some ways as if it were PATA or running in PATA modes, even though it isn’t.

**ATA Features**

The ATA standards have gone a long way toward eliminating incompatibilities and problems with interfacing SATA and PATA drives to systems. The ATA specifications define the signals on the cables and connectors, the functions and timings of these signals, the cable specifications, the supported commands, the features, and so on. The following section lists some of the elements and functions the ATA specifications define.

**ATA Commands**

One of the best features of the ATA interface is the enhanced command set. The ATA command interface was modeled after the WD1003 controller IBM used in the original AT system. All ATA drives must support the original WD command set (eight commands) with no exceptions, which is why ATA drives are so easy to install in systems today. All IBM-compatible systems have built-in ROM BIOS support for the WD1003, so they essentially support ATA as well.

In addition to supporting all the WD1003 commands, the ATA specification added numerous other commands to enhance performance and capabilities. These commands are an optional part of the ATA interface, but several of them are used in most drives available today and are important to the performance and use of ATA drives in general.

Perhaps the most important is the `IDENTIFY DEVICE` command. This command causes the drive to transmit a 512-byte block of data that provides all details about the drive. Through this command, any program (including the system BIOS) can find out exactly which type of drive is connected, including the drive manufacturer, model number, operating parameters, and even serial number of the drive. Many modern BIOSs use this information to automatically receive and enter the drive’s parameters into Complementary Metal Oxide Semiconductor (CMOS) memory, eliminating the need for the user to enter these parameters manually during system configuration. This arrangement helps prevent mistakes that can later lead to data loss when the user no longer remembers what parameters he used during setup.

The `IDENTIFY DEVICE` data can tell you many things about your drive, including the following:

- Whether the drive has rotating media (and if so, how fast), or whether it is a solid-state drive (SSD) instead
- Whether the `TRIM` command is supported (or not) on SSDs
- Number of logical block addresses available using LBA mode
ATA Features

- Number of physical cylinders, heads, and sectors available in P-CHS mode
- Number of logical cylinders, heads, and sectors in the current translation L-CHS mode
- Transfer modes (and speeds) supported
- Manufacturer and model number
- Internal firmware revision
- Serial number
- Buffer type/size, indicating sector buffering or caching capabilities
- What security functions are available, and much, much more

Several freely available programs such as HWiNFO (www.hwinfo.com) or CrystalDiskInfo (www.crystalmark.info) can execute this command, then translate and report the information onscreen.

Many other enhanced commands are available, including room for a given drive manufacturer to implement what are called vendor-unique commands. Certain vendors often use these commands for features unique to that vendor. Often, vendor-unique commands control features such as low-level formatting and defect management. This is why low-level format or initialization programs can be so specific to a particular manufacturer's ATA drives and why many manufacturers make their own LLF programs available.

ATA Security Mode

Support for drive passwords (called ATA Security Mode) was added to the ATA-3 specification in 1995. The proposal adopted in the ATA specification was originally from IBM, which had developed this capability and had already begun incorporating it into ThinkPad systems and IBM 2.5-inch drives. Because it was then incorporated into the official ATA-3 standard (finally published in 1997), most other drive and system manufacturers have also adopted this, especially for laptop systems and 2.5-inch and smaller drives. Note that these passwords are very secure. If you lose or forget them, they usually cannot be recovered, and you will never be able to access the data on the drive.

More recently, ATA security has been augmented by drives that support internal encryption/decryption using the Advanced Encryption Standard (AES). Drives supporting AES automatically encrypt all data that is written and automatically decrypt the data when it is read. When combined with a password set via ATA Security mode commands, the data on the drive will be unrecoverable even if the HDD password is bypassed or the media (that is, platters or flash memory chips) are removed from the drive and read directly. When AES encryption is employed on a drive with a strong HDD password, without knowing the HDD password there is essentially no way to recover the data. This type of security is recommended for laptops that can easily be lost or stolen.

Drive security passwords are set via the BIOS Setup, but not all systems support this feature. Most laptops support drive security, but many desktops do not. If supported, two types of drive passwords can be set, called user and master. The user password locks and unlocks the drive, whereas the master password is used only to unlock. You can set a user password only, or you can set user+master, but you cannot set a master password alone.

When a user password is set (with no master), or when both user+master passwords are set, access to the drive is prevented (even if the drive is moved to a different system), unless the user (or master) password is entered upon system startup.

The master password is designed to be an alternative or backup password for system administrators as a master unlock. With both master and user passwords set, the user is told the user password but not the master password. Subsequently, the user can change the user password as desired; however, a system administrator can still gain access by using the master password.
If a user or user+master password is set, the disk must be unlocked at boot time via a BIOS-generated password prompt. The appearance of the prompt varies from system to system. For example, in ThinkPad systems, an icon consisting of a cylinder with a number above it (indicating the drive number) next to a padlock appears onscreen. If the drive password prompt appears, you must enter it; otherwise, you will be denied access to the drive, and the system will not boot.

As with many security features, a workaround might be possible if you forget your password. In this case, at least one company can either restore the drive to operation (with all the data lost) or restore the drive and the data. That company is Nortek. (See www.nortek.on.ca for more information.) The password-removal procedure is relatively expensive (more than the cost of a new drive in most cases), and you must provide proof of ownership when you send in the drive. As you can see, password restoring is worthwhile only if you absolutely need the data back. Note that even this will not work if the drive employs internal AES encryption. In that case, without the password, the data simply cannot be recovered.

Passwords are not preset on a new drive, but they might be preset if you are buying a used drive or if the people or company you purchased the drive or system from entered them. This is a common ploy when selling drives or systems (especially laptops) on eBay—for example, the seller might set supervisor or drive passwords and hold them until payment is received. Or he might be selling a used (possibly stolen) product “as is,” for which he doesn’t have the passwords, which renders them useless to the purchaser. Be sure that you do not purchase a used laptop or drive unless you are certain that no supervisor or drive passwords are set.

Most systems also support other power-on or supervisor passwords in the BIOS Setup. In most systems, when you set a supervisor password, it automatically sets the drive password to the same value. In most cases, if a supervisor password is set and it matches the drive user or master password, when you enter the supervisor password, the BIOS automatically enters the drive password at the same time. This means that even though a drive password is set, you might not even know it because the drive password is entered automatically at the same time that you enter the supervisor password; therefore, you won’t see a separate prompt for the drive password. However, if the drive is later separated from the system, it will not work on another system or be readable until you enter the correct drive password. Without the services of a company such as Nortek, you can remove a drive password only if you know the password to begin with.

**Host Protected Area**

Most PCs sold on the market today include some form of automated product recovery or restoration feature that allows a user to easily restore the operating system and other software on the system to the state it was in when the system was new. Originally, this was accomplished via one or more product-recovery discs containing automated scripts that reinstalled all the software that came preinstalled on the system when it was new.

Unfortunately, the discs could be lost or damaged, they were often problematic to use, and including them by default cost manufacturers a lot of money. This prompted PC manufacturers to move the recovery software to a hidden partition of the boot hard drive. However, this does waste some space on the drive—usually several gigabytes. With 60GB or larger drives, this amounts to 5% or less of the total space. Still, even the hidden partition was less than satisfactory because the partition could easily be damaged or overwritten by partitioning software or other utilities, so there was no way to make it secure.

In 1996, Gateway proposed a change to the ATA-4 standard under development that would allow the HPA to be reserved on a drive. This change was ratified, and the HPA feature set was incorporated into the ATA-4 specification that was finally published in 1998. A separate BIOS firmware interface specification called Protected Area Run Time Interface Extension Services (PARTIES) was initiated in
1999 that defined services an operating system could use to access the HPA. The PARTIES standard was completed and published in 2001 as “NCITS 346-2001, Protected Area Run Time Interface Extension Services.”

The HPA works by using the optional ATA SET MAX ADDRESS command to make the drive appear to the system as slightly smaller. Anything from the new max address (the newly reported end of the drive) to the true end of the drive is considered the HPA and is accessible only using PARTIES commands. This is more secure than a hidden partition because any data past the end of the drive simply cannot be seen by a normal application or even a partitioning utility. Still, if you want to remove the HPA, you can use some options in the BIOS Setup or separate commands to reset the max address, thus exposing the HPA. At that point, you can run something such as Parted Magic or Partition Commander to resize the adjacent partition to include the extra space that was formerly hidden and unavailable.

Starting in 2003, some systems using Phoenix BIOS have included recovery software and diagnostics in the HPA. Most if not all current drives support the HPA command set; however, because of the complexity in dealing with the hidden area, I have seen most manufacturers back away from using the HPA and revert to a more standard (and easier to deal with) hidden partition instead.

For more information on the HPA and what might be stored there, see the Chapter 5 section, “Preboot Environment,” p. 287.

**ATAPI**

ATAPI is a standard designed to provide the commands necessary for devices such as optical drives, removable media drives such as SuperDisk and Zip, and tape drives that plug into an ordinary SATA or PATA (IDE) connector. Although ATAPI optical drives use the hard disk interface, they don’t necessarily look like ordinary hard disks. To the contrary, from a software point of view, they are a completely different kind of animal. They most closely resemble a SCSI device. All modern ATA optical drives support the ATAPI protocols, and generally the terms are synonymous. In other words, an ATAPI optical drive is an ATA optical drive, and vice versa.

**Caution**

Most systems starting in 1998 began supporting the Phoenix El Torito specification, which enables booting from ATAPI CD or DVD drives. Systems without El Torito support in the BIOS can’t boot from an ATAPI CD or DVD drive. Even with ATAPI support in the BIOS, you still must load a driver to use ATAPI under DOS or Windows. Windows 95 and later (including 98 and Me) and Windows NT (including Windows 2000 forward) have native ATAPI support. Some versions of the Windows 98 and Me CD-ROMs are bootable, whereas all Windows NT, 2000, and newer discs are directly bootable on those systems, thus greatly easing installation.

**ATA Drive Capacity Limitations**

ATA interface versions up through ATA-5 suffered from a drive capacity limitation of about 137GB (billion bytes). Depending on the BIOS used, you can further reduce this limitation to 8.4GB, or even as low as 528MB (million bytes). This is due to limitations in both the BIOS and the ATA interface, which when combined create even further limitations. To understand these limits, you have to look at the BIOS (software) and ATA (hardware) interfaces together.

**Note**

In addition to the BIOS/ATA limitations discussed in this section, various operating system limitations exist. These are described later in this chapter.
The limitations when dealing with ATA drives are those of the ATA interface as well as the BIOS interface used to talk to the drive. A summary of the limitations is shown in Table 7.12.

<table>
<thead>
<tr>
<th>Sector Addressing Method</th>
<th>Total Sectors Calculation</th>
<th>Maximum Total Sectors</th>
<th>Maximum Capacity (Bytes)</th>
<th>Capacity (Decimal)</th>
<th>Capacity (Binary)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHS: BIOS w/o TL</td>
<td>1024 \times 16 \times 63</td>
<td>1,032,192</td>
<td>528,482,304</td>
<td>528.48MB</td>
<td>504.00MiB</td>
</tr>
<tr>
<td>CHS: BIOS w/ bit-shift TL</td>
<td>1024 \times 240 \times 63</td>
<td>15,482,880</td>
<td>7,927,234,560</td>
<td>7.93GB</td>
<td>7.38GiB</td>
</tr>
<tr>
<td>CHS: BIOS w/ LBA-assist TL</td>
<td>1024 \times 255 \times 63</td>
<td>16,450,560</td>
<td>8,422,686,720</td>
<td>8.42GB</td>
<td>7.84GiB</td>
</tr>
<tr>
<td>CHS: BIOS INT13h</td>
<td>1024 \times 256 \times 63</td>
<td>16,515,072</td>
<td>8,455,716,864</td>
<td>8.46GB</td>
<td>7.88GiB</td>
</tr>
<tr>
<td>CHS: ATA-1/ATA-5</td>
<td>65536 \times 16 \times 255</td>
<td>267,386,880</td>
<td>136,902,082,560</td>
<td>136.90GB</td>
<td>127.50GiB</td>
</tr>
<tr>
<td>LBA: ATA-1/ATA-5</td>
<td>$2^{28}$</td>
<td>268,435,456</td>
<td>137,438,953,472</td>
<td>137.44GB</td>
<td>128.00GiB</td>
</tr>
<tr>
<td>LBA: ATA-6+</td>
<td>$2^{48}$</td>
<td>281,474,976,710,655</td>
<td>144,115,188,075,855,872</td>
<td>144.12PB</td>
<td>128.00PiB</td>
</tr>
<tr>
<td>LBA: EDD BIOS</td>
<td>$2^{64}$</td>
<td>18,446,744,073,709,551,616</td>
<td>9,444,732,965,739,290,427,392</td>
<td>9.44ZB</td>
<td>8.00ZiB</td>
</tr>
</tbody>
</table>

**Prefixes for Decimal and Binary Multiples**

Many readers are unfamiliar with the MiB (mebibyte), GiB (gibibyte), and so on designations I am using in this section and throughout the book. These are part of a standard designed to eliminate confusion between decimal- and binary-based multiples, especially in computer systems. Standard SI (system international or metric system) units are based on multiples of 10. This worked well for most things, but not for computers, which operate in a binary world where most numbers are based on powers of 2. This has resulted in different meanings being assigned to the same prefix—for example, 1KB (kilobyte) could mean either 1,000 (10³) bytes or 1,024 (2¹⁰) bytes. To eliminate confusion, in December 1998 the International Electrotechnical Commission (IEC) approved as an international
standard the prefix names and symbols for binary multiples used in data processing and transmission. Some of these prefixes are shown in Table 7.13.

### Table 7.13 Standard Prefix Names and Symbols for Decimal and Binary Multiples

<table>
<thead>
<tr>
<th>Binary Prefixes:</th>
<th>Binary Prefixes:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Factor Symbol</strong></td>
<td><strong>Symbol Name</strong></td>
</tr>
<tr>
<td>$10^3$</td>
<td>k</td>
</tr>
<tr>
<td>$10^6$</td>
<td>M</td>
</tr>
<tr>
<td>$10^9$</td>
<td>G</td>
</tr>
<tr>
<td>$10^{12}$</td>
<td>T</td>
</tr>
<tr>
<td>$10^{15}$</td>
<td>P</td>
</tr>
<tr>
<td>$10^{18}$</td>
<td>E</td>
</tr>
<tr>
<td>$10^{21}$</td>
<td>Z</td>
</tr>
<tr>
<td>$2^{10}$</td>
<td>Ki</td>
</tr>
<tr>
<td>$2^{20}$</td>
<td>Mi</td>
</tr>
<tr>
<td>$2^{30}$</td>
<td>Gi</td>
</tr>
<tr>
<td>$2^{40}$</td>
<td>Ti</td>
</tr>
<tr>
<td>$2^{50}$</td>
<td>Pi</td>
</tr>
<tr>
<td>$2^{60}$</td>
<td>Ei</td>
</tr>
<tr>
<td>$2^{70}$</td>
<td>Zi</td>
</tr>
</tbody>
</table>

The symbol for kilo (k) is in lowercase (which is technically correct according to the SI standard), whereas all other decimal prefixes are uppercase.

Under this standard terminology, a megabyte would be 1,000,000 bytes, whereas a mebibyte would be 1,048,576 bytes.

**Note**
For more information on these industry-standard decimal and binary prefixes, check out the National Institute for Standards and Technology (NIST) website at [http://physics.nist.gov/cuu/Units/prefixes.html](http://physics.nist.gov/cuu/Units/prefixes.html).

### BIOS Limitations
Motherboard ROM BIOSs have been updated throughout the years to support larger and larger drives. Table 7.14 shows the most important relative dates when drive capacity limits were changed.

### Table 7.14 Dates of Changes to Drive Capacity Limitations in the ROM BIOS

<table>
<thead>
<tr>
<th>BIOS Date</th>
<th>Capacity Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>August 1994</td>
<td>528MB</td>
</tr>
<tr>
<td>January 1998</td>
<td>8.4GB</td>
</tr>
<tr>
<td>September 2002</td>
<td>137GB</td>
</tr>
<tr>
<td>January 2011</td>
<td>2.2TB*</td>
</tr>
</tbody>
</table>

*Note: A UEFI BIOS or enabled UEFI Boot option is required to boot from 2.2TB or larger drives. Some BIOS, had this capability as early as 2006, but it wasn’t widespread until 2011.*

These dates are when the limits were broken, such that BIOSs older than August 1994 are generally limited to drives of up to 528MB, whereas BIOSs older than January 1998 are generally limited to 8.4GB. Most BIOSs dated 1998 or newer support drives up to 137GB, and those dated September 2002
or newer should support drives larger than 137GB. These are only general guidelines, though; to accurately determine this for a specific system, you should check with your motherboard manufacturer. You can also use the System Information for Windows (SIW) utility from http://gtopala.com/, which tells you the BIOS date from your system and specifically whether your system supports the Enhanced Disk Drive specification (which means drives over 8.4GB).

If your BIOS does not support EDD (drives over 8.4GB), the three possible solutions are as follows:

- Upgrade your motherboard BIOS to a 1998 or newer version that supports >8.4GB.
- Install a BIOS upgrade card, such as the UltraATA cards from www.siig.com.
- Install a software patch to add >8.4GB support.

Of these, the first one is the most desirable because it is usually free. Visit your motherboard manufacturer’s website to see whether it has newer BIOSs available for your motherboard that support large drives. If it doesn’t, the next best thing is to use a card such as one of the UltraATA cards from SIIG (www.siig.com). I almost never recommend the software-only solution because it merely installs a software patch in the boot sector area of the hard drive, which can result in numerous problems when booting from different drives, installing new drives, or recovering data.

The most recent 2.2TB barrier is not a true BIOS barrier in the same way that the previous barriers were. The issue here is not that the BIOS can’t recognize drives 2.2TB or larger; the problem is that it can’t normally boot from them. Booting from a 2.2TB or larger drive requires a UEFI (Unified Extensible Firmware Interface) BIOS, or at a minimum one with an enabled UEFI Boot option. Drives larger than 2.2TB can be used as data drives even without a UEFI BIOS. Finally, note that both booting from and recognizing a 2.2TB or larger drive as a data drive also requires that the drive be formatted using a GPT (GUID Partition Table). The operating system must have GPT support as well.

**CHS Versus LBA**

There are two primary methods to address (or number) sectors on an ATA drive. The first method is called CHS (cylinder head sector) after the three respective coordinate numbers used to address each sector of the drive. The second method is called LBA (logical block address) and uses a single number to address each sector on a drive. CHS was derived from the physical way drives were constructed (and is how they work internally), whereas LBA evolved as a simpler and more logical way to number the sectors regardless of the internal physical construction.

For more information on cylinders, heads, and sectors as they are used internally within the drive, see the Chapter 9 section, “HDD Operation,” p. 466.

The process of reading a drive sequentially in CHS mode starts with cylinder 0, head 0, and sector 1 (which is the first sector on the disk). Next, all the remaining sectors on that first track are read; then the next head is selected; and then all the sectors on that track are read. This goes on until all the heads on the first cylinder are read. Then the next cylinder is selected, and the sequence starts again. Think of CHS as an odometer of sorts: The sector numbers must roll over before the head number can change, and the head numbers must roll over before the cylinder can change.

The process of reading a drive sequentially in LBA mode starts with sector 0, then 1, then 2, and so on. The first sector on the drive in CHS mode would be 0,0,1, and the same sector in LBA mode would be 0.

As an example, imagine a drive with one platter, two heads (both sides of the platter are used), two tracks on each platter (cylinders), and two sectors on each track. We would say the drive has two cylinders (tracks per side), two heads (sides), and two sectors per track. This would result in a total capacity of eight (2 × 2 × 2) sectors. Noting that cylinders and heads begin numbering from 0—whereas
physical sectors on a track number from 1. Using CHS addressing, we would say the first sector on
the drive is cylinder 0, head 0, sector 1 (0,0,1); the second sector is 0,0,2; the third sector is 0,1,1; the
fourth sector is 0,1,2; and so on until we get to the last sector, which would be 1,1,2.

Now imagine that we could take the eight sectors and—rather than refer directly to the physical cyl-
inder, head, and sector—number the sectors in order from 0 to 7. Thus, if we wanted to address
the fourth sector on the drive, we could reference it as sector 0,1,2 in CHS mode or as sector 3 in LBA
mode. Table 7.15 shows the correspondence between CHS and LBA sector numbers for this eight-
sector imaginary drive.

### Table 7.15 CHS and LBA Sector Numbers for an Imaginary Drive with Two
Cylinders, Two Heads, and Two Sectors per Track (Eight Sectors Total)

<table>
<thead>
<tr>
<th>Mode</th>
<th>Equivalent Sector Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHS:</td>
<td>0,0,1 0,0,2 0,1,1 0,1,2 1,0,1 1,0,2 1,1,1 1,1,2</td>
</tr>
<tr>
<td>LBA:</td>
<td>0 1 2 3 4 5 6 7</td>
</tr>
</tbody>
</table>

As you can see from this example, using LBA numbers is simpler and generally easier to handle; how-
ever, when the PC was first developed, all BIOS and ATA drive-level addressing was done using CHS
addressing.

### CHS/LBA and LBA/CHS Conversions

You can address the same sectors in either CHS or LBA mode. The conversion from CHS to LBA is
always consistent in that for a given drive, a particular CHS address always converts to a given LBA
address, and vice versa. The ATA-1 document specifies a simple formula that can be used to convert
CHS parameters to LBA:

\[
LBA = (((C \times HPC) + H) \times SPT) + S - 1
\]

By reversing this formula, you can convert the other way—that is, from LBA back to CHS:

\[
C = \text{int} \left( \frac{LBA}{SPT} / HPC \right)
\]

\[
H = \text{int} \left( \left( \frac{LBA}{SPT} \right) \mod HPC \right)
\]

\[
S = (LBA \mod SPT) + 1
\]

For these formulas, the abbreviations are defined as follows:

- \(LBA\) = Logical block address
- \(C\) = Cylinder
- \(H\) = Head
- \(S\) = Sector
- \(HPC\) = Heads per cylinder (total number of heads)
- \(SPT\) = Sectors per track
- \(\text{int} X\) = Integer portion of \(X\)
- \(X \mod Y\) = Modulus (remainder) of \(X/Y\)
Using these formulas, you can calculate the LBA for any given CHS address, and vice versa. Given a drive of 16,383 cylinders, 16 heads, and 63 sectors per track, Table 7.16 shows the equivalent CHS and LBA addresses.

<table>
<thead>
<tr>
<th>Cylinder</th>
<th>Head</th>
<th>Sector</th>
<th>LBA</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>63</td>
<td>62</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
<td>63</td>
</tr>
<tr>
<td>999</td>
<td>15</td>
<td>63</td>
<td>1,007,999</td>
</tr>
<tr>
<td>1,000</td>
<td>0</td>
<td>1</td>
<td>1,008,000</td>
</tr>
<tr>
<td>9,999</td>
<td>15</td>
<td>63</td>
<td>10,079,999</td>
</tr>
<tr>
<td>10,000</td>
<td>0</td>
<td>1</td>
<td>10,080,000</td>
</tr>
<tr>
<td>16,382</td>
<td>15</td>
<td>63</td>
<td>16,514,063</td>
</tr>
</tbody>
</table>

**BIOS Commands Versus ATA Commands**

In addition to the two methods of sector addressing (CHS or LBA), there are two levels of interface where sector addressing occurs. One interface is where the operating system talks to the BIOS (using driver commands); the other is where the BIOS talks to the drive (using ATA commands). The specific commands at these levels are different, but both support CHS and LBA modes. Figure 7.18 illustrates the two interface levels.

When the operating system talks to the BIOS to read or write sectors, it issues commands via software interrupt (not the same as an IRQ) INT13h, which is how the BIOS subroutines for disk access are called. Various INT13h subfunctions allow sectors to be read or written using either CHS or LBA addressing. The BIOS routines then convert the BIOS commands into ATA hardware-level commands, which are sent over the bus I/O ports to the drive controller. Commands at the ATA hardware level can also use either CHS or LBA addressing, although the limitations are different. Whether your BIOS...
and drive use CHS or LBA addressing depends on the drive capacity, age of the BIOS and drive, BIOS Setup settings used, and operating system used.

**CHS Limitations (the 528MB Barrier)**

The original BIOS-based driver for hard disks is accessed via software interrupt 13h (13 hex) and offers functions for reading and writing drives at the sector level. Standard INT13h functions require that a particular sector be addressed by its cylinder, head, and sector location—otherwise known as CHS addressing. This interface is used by the operating system and low-level disk utilities to access the drive. IBM originally wrote the INT13h interface for the BIOS on the PC XT hard disk controller in 1983, and in 1984 the company incorporated it into the AT motherboard BIOS. This interface used numbers to define the particular cylinder, head, and sector being addressed. Table 7.17, which shows the standard INT13h BIOS CHS parameter limits, includes the maximum values for these numbers.

<table>
<thead>
<tr>
<th>Table 7.17</th>
<th>INT13h BIOS CHS Parameter Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field</td>
<td>Field Size</td>
</tr>
<tr>
<td>Cylinder</td>
<td>10 bits</td>
</tr>
<tr>
<td>Head</td>
<td>8 bits</td>
</tr>
<tr>
<td>Sector</td>
<td>6 bits</td>
</tr>
</tbody>
</table>

The concept of a maximum value given a number of digits is simple: If you had, for example, a hotel with two-digit decimal room numbers, you could have only 100 (10^2) rooms, numbered 0–99. The CHS numbers used by the standard BIOS INT13h interface are binary, and with a 10-bit number being used to count cylinders, you can have only 1,024 (2^10) maximum, numbered 0–1,023. Because the head is identified by an 8-bit number, the maximum number of heads is 256 (2^8), numbered 0–255. Finally, with sectors per track there is a minor difference. Sectors on a track are identified by a 6-bit number, which would normally allow a maximum of 64 (2^6) sectors; however, because sectors are numbered starting with 1 (instead of 0), the range is limited to 1–63, which means a total of 63 sectors per track is the maximum the BIOS can handle.

These BIOS limitations are true for all BIOS versions or programs that rely on CHS addressing. Using the maximum numbers possible for CHS at the BIOS level, you can address a drive with 1,024 cylinders, 256 heads, and 63 sectors per track. Because each sector is 512 bytes, the math works out as follows:

```
Max. Values

Cylinders          1,024
Heads              256
Sectors/Track      63

Total Sectors      16,515,072

Total Bytes        8,455,716,864
Megabytes (MB)     8,456
Mebibytes (MiB)    8,064
Gigabytes (GB)     8.4
Gibibytes (GiB)    7.8
```
From these calculations, you can see that the maximum capacity drive addressable via the standard BIOS INT13h interface is about 8.4GB (where GB equals roughly 1 billion bytes), or 7.8GiB (where GiB means gigabinarybytes).

Unfortunately, the BIOS INT13h limits are not the only limitations that apply. Limits also exist in the ATA interface. The ATA CHS limits are shown in Table 7.18.

<table>
<thead>
<tr>
<th>Field</th>
<th>Field Size</th>
<th>Maximum Value</th>
<th>Range</th>
<th>Total Usable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cylinder</td>
<td>16 bits</td>
<td>65,536</td>
<td>0–65,535</td>
<td>65,536</td>
</tr>
<tr>
<td>Head</td>
<td>4 bits</td>
<td>16</td>
<td>0–15</td>
<td>16</td>
</tr>
<tr>
<td>Sector</td>
<td>8 bits</td>
<td>256</td>
<td>1–255</td>
<td>255</td>
</tr>
</tbody>
</table>

As you can see, the ATA interface uses different-sized fields to store CHS values. Note that the ATA limits are higher than the BIOS limits for cylinders and sectors but lower than the BIOS limit for heads. The CHS limits for capacity according to the ATA-1 through ATA-5 specification are as follows:

Max. Values

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cylinders</td>
<td>65,536</td>
</tr>
<tr>
<td>Heads</td>
<td>16</td>
</tr>
<tr>
<td>Sectors/Track</td>
<td>255</td>
</tr>
<tr>
<td>Total Sectors</td>
<td>267,386,880</td>
</tr>
<tr>
<td>Total Bytes</td>
<td>136,902,082,560</td>
</tr>
<tr>
<td>Megabytes (MB)</td>
<td>136,902</td>
</tr>
<tr>
<td>Mebibytes (MiB)</td>
<td>130,560</td>
</tr>
<tr>
<td>Gigabytes (GB)</td>
<td>136.9</td>
</tr>
<tr>
<td>Gibibytes (GiB)</td>
<td>127.5</td>
</tr>
</tbody>
</table>

When you combine the limitations of the BIOS and ATA CHS parameters, you end up with the situation shown in Table 7.19.

<table>
<thead>
<tr>
<th>BIOS CHS Parameter</th>
<th>ATA CHS Parameter</th>
<th>Combined CHS Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limits</td>
<td>Limits</td>
<td>Field Limits</td>
</tr>
<tr>
<td>Cylinder</td>
<td>1,024</td>
<td>65,536</td>
</tr>
<tr>
<td>Head</td>
<td>256</td>
<td>16</td>
</tr>
<tr>
<td>Sector</td>
<td>63</td>
<td>255</td>
</tr>
<tr>
<td>Total sectors</td>
<td>16,515,072</td>
<td>267,386,880</td>
</tr>
<tr>
<td>Maximum capacity</td>
<td>8.4GB</td>
<td>136.9GB</td>
</tr>
</tbody>
</table>
As you can see, the lowest common denominator of the combined CHS limits results in maximum usable parameters of 1,024 cylinders, 16 heads, and 63 sectors, which results in a maximum drive capacity of 528MB. This became known as the 528MB barrier (also called the 504MiB barrier), and it affects virtually all PCs built in 1993 or earlier.

**CHS Translation (Breaking the 528MB Barrier)**

Having a barrier limiting drive capacity to 528MB or less wasn’t a problem when the largest drives available were smaller than that. But by 1994, drive technology had developed such that making drives larger than what the combined BIOS and ATA limitations could address was possible. Clearly a fix for the problem was needed.

Starting in 1993, the BIOS developer Phoenix Technologies began working on BIOS extensions to work around the combined CHS limits. In January of 1994, the company released the “BIOS Enhanced Disk Drive (EDD) Specification,” which was later republished by the T13 committee (also responsible for ATA) as “BIOS Enhanced Disk Drive Services (EDD).” The EDD documents detail several methods for circumventing the limitations of older BIOSs without causing compatibility problems with existing software. These include the following:

- BIOS INT13h extensions supporting 64-bit LBA
- Bit-shift geometric CHS translation
- LBA-assist geometric CHS translation

The method for dealing with the CHS problem was called translation because it enabled additional subroutines in the BIOS to translate CHS parameters from ATA maximums to BIOS maximums (and vice versa). In an effort to make its methods standard among the entire PC industry, Phoenix released the EDD document publicly and allowed the technology to be used free of charge, even among its competitors such as AMI and Award. The T-13 committee in charge of ATA subsequently adopted the EDD standard and incorporated it into official ATA documents.

Starting in 1994, most BIOSs began implementing the Phoenix-designed CHS translation methods, which enabled drives up to the BIOS limit of 8.4GB to be supported. The fix involved what is termed parameter translation at the BIOS level, which adapted or translated the cylinder, head, and sector numbers to fit within the allowable BIOS parameters. There are two types of translation: One works via a technique called CHS bit-shift (usually called “Large” or “Extended CHS” in the BIOS Setup), and the other uses a technique called LBA-assist (usually called “LBA” in the BIOS Setup). These refer to the different mathematical methods of doing essentially the same thing: converting one set of CHS numbers to another.

CHS bit-shift translation manipulates the cylinder and head numbers but does not change the sector number. It begins with the physical (drive reported) cylinders and heads and, using some simple division and multiplication, comes up with altered numbers for the cylinders and heads. The sectors-per-track value is not translated and is passed unaltered. The term bit-shift is used because the division and multiplication math is actually done in the BIOS software by shifting bits in the CHS address.

With CHS bit-shift translation, the drive reported (physical) parameters are referred to as P-CHS, and the BIOS-altered logical parameters are referred to as L-CHS. After the settings are made in the BIOS Setup, L-CHS addresses are automatically translated to P-CHS at the BIOS level. This enables the operating system to send commands to the BIOS using L-CHS parameters, which the BIOS automatically converts to P-CHS when it talks to the drive using ATA commands. Table 7.20 shows the rules for calculating CHS bit-shift translation.

CHS bit-shift translation is based on dividing the physical cylinder count by a power of 2 to bring it under the 1,024 cylinder BIOS INT13h limit and then multiplying the heads by the same power of 2, leaving the sector count unchanged. The power of 2 used depends on the cylinder count, as indicated in Table 7.20.
Table 7.20  CHS Bit-Shift Translation Rules

<table>
<thead>
<tr>
<th>Physical (Drive Reported) Cylinders</th>
<th>Physical Heads</th>
<th>Logical Cylinders</th>
<th>Logical Heads</th>
<th>Maximum Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 &lt; C &lt;= 1,024</td>
<td>1 &lt; H &lt;= 16</td>
<td>C = C</td>
<td>H = H</td>
<td>528MB</td>
</tr>
<tr>
<td>1,024 &lt; C &lt;= 2,048</td>
<td>1 &lt; H &lt;= 16</td>
<td>C = C/2</td>
<td>H = H × 2</td>
<td>1GB</td>
</tr>
<tr>
<td>2,048 &lt; C &lt;= 4,096</td>
<td>1 &lt; H &lt;= 16</td>
<td>C = C/4</td>
<td>H = H × 4</td>
<td>2.1GB</td>
</tr>
<tr>
<td>4,096 &lt; C &lt;= 8,192</td>
<td>1 &lt; H &lt;= 16</td>
<td>C = C/8</td>
<td>H = H × 8</td>
<td>4.2GB</td>
</tr>
<tr>
<td>8,192 &lt; C &lt;= 16,384</td>
<td>1 &lt; H &lt;= 16</td>
<td>C = C/16</td>
<td>H = H × 16</td>
<td>8.4GB</td>
</tr>
</tbody>
</table>

The drive reported sector count is not translated.
The logical heads value can't exceed 255 with some operating systems, such as DOS/Win9x/Me.

Here is an example of CHS bit-shift translation:

<table>
<thead>
<tr>
<th>Bit-shift</th>
<th>P-CHS Parameters</th>
<th>L-CHS Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cylinders</td>
<td>8,000</td>
<td>1,000</td>
</tr>
<tr>
<td>Heads</td>
<td>16</td>
<td>128</td>
</tr>
<tr>
<td>Sectors/Track</td>
<td>63</td>
<td>63</td>
</tr>
<tr>
<td>Total Sectors</td>
<td>8,064,000</td>
<td>8,064,000</td>
</tr>
</tbody>
</table>

Total Bytes 4,128,768,000 4,128,768,000
Megabytes (MB) 4,129 4,129
Mebibytes (MiB) 3,938 3,938
Gigabytes (GB) 4.13 4.13
Gibibytes (GiB) 3.85 3.85

This example shows a drive with 8,000 cylinders and 16 heads. The physical cylinder count is way above the BIOS limit of 1,024, so if CHS bit-shift translation is selected in the BIOS Setup, the BIOS then divides the cylinder count by 2, 4, 8, or 16 to bring it below 1,024. In this case, it would divide by 8, which results in a new logical cylinder count of 1,000—which is below the 1,024 maximum. Because the cylinder count is divided by 8, the head count is then multiplied by the same number, resulting in 128 logical heads, which is also below the limit the BIOS can handle.

So, although the drive reports having 8,000 cylinders and 16 heads, the BIOS and all software (including the operating system) instead see the drive as having 1,000 cylinders and 128 heads. Note that the 63 sectors/track figure is simply carried over without change. The result is that by using the logical parameters, the BIOS can see the entire 4.13GB drive and won't be limited to just the first 528MB.

When you install a drive, you don't have to perform the translation math to convert the cylinders and heads; the BIOS does that for you automatically. All you have to do is allow the BIOS to autodetect the P-CHS parameters and then enable the translation in the BIOS Setup. Selecting Large or ECHS translation in the BIOS Setup enables the CHS bit-shift. The BIOS does the rest of the work for you.
CHS bit-shift is a simple and fast (code-wise) scheme that can work with all drives, but unfortunately it can’t properly translate all theoretically possible drive geometries for drives under 8.4GB. To solve this, an addendum was added to the ATA-2 specification to specifically require drives to report certain ranges of geometries to allow bit-shift translation to work. Thus, all drives that conform to the ATA-2 specification (or higher) can be translated using this method.

The 2.1GB and 4.2GB Barriers

Some BIOSs incorrectly allocated only 12 bits for the P-CHS cylinder field, thereby allowing a maximum of 4,096 cylinders. Combined with the standard 16-head and 63-sector limits, this resulted in the inability to support any drives over 2.1GB in capacity. Fortunately, this BIOS defect affected only a limited number of systems with BIOS dates prior to about mid-1996.

Even so, some problems still existed with bit-shift translation. Because of the way DOS and Windows 9x/Me were written, they could not properly handle a drive with 256 heads. This was a problem for drives larger than 4.2GB because the CHS bit-shift translation rules typically resulted in 256 heads as a logical value, as seen in the following example:

<table>
<thead>
<tr>
<th>Bit-shift</th>
<th>P-CHS Parameters</th>
<th>L-CHS Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cylinders</td>
<td>12,000</td>
<td>750</td>
</tr>
<tr>
<td>Heads</td>
<td>16</td>
<td>256</td>
</tr>
<tr>
<td>Sectors/Track</td>
<td>63</td>
<td>63</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>------------------</td>
<td>------------------</td>
</tr>
<tr>
<td>Total Sectors</td>
<td>12,096,000</td>
<td>12,096,000</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>------------------</td>
<td>------------------</td>
</tr>
<tr>
<td>Total Bytes</td>
<td>6,193,152,000</td>
<td>6,193,152,000</td>
</tr>
<tr>
<td>Megabytes (MB)</td>
<td>6,193</td>
<td>6,193</td>
</tr>
<tr>
<td>Mebibytes (MiB)</td>
<td>5,906</td>
<td>5,906</td>
</tr>
<tr>
<td>Gigabytes (GB)</td>
<td>6.19</td>
<td>6.19</td>
</tr>
<tr>
<td>Gibibytes (GiB)</td>
<td>5.77</td>
<td>5.77</td>
</tr>
</tbody>
</table>

This scheme failed when you tried to install Windows 9x/Me (or DOS) on a drive larger than 4.2GB because the L-CHS parameters included 256 heads. Any BIOS that implemented this scheme essentially had a 4.2GB barrier, so installing a drive larger than that and selecting CHS bit-shift translation caused the drive to fail. Note that this was not a problem for Windows NT or later.

**Note**

The BIOS is not actually at fault here; the problem instead lies with the DOS/Win9x/Me file system code, which stores the sector-per-track number as an 8-bit value. The number 256 causes a problem because 256 equals 100000000b, which takes 9 bits to store. The value 255 (which equals 11111111b) is the largest value that can fit in an 8-bit binary register and is therefore the maximum number of heads those operating systems can support.

To solve this problem, CHS bit-shift translation was revised by adding a rule such that if the drive reported 16 heads and more than 8,192 cylinders (which would result in a 256-head translation), the P-CHS head value would be assumed to be 15 (instead of 16) and the P-CHS cylinder value would be multiplied by 16/15 to compensate. These adjusted cylinder and head values would then be translated. The following example shows the results:
As you can see from this example, a drive with 12,000 cylinders and 16 heads translates to 750 cylinders and 256 heads using the standard CHS bit-shift scheme. The revised CHS bit-shift scheme rule does a double translation in this case, first changing the 16 heads to 15 and then multiplying the 12,000 cylinders by 16/15, resulting in 12,800 cylinders. Then, the new cylinder value is CHS bit-shift-translated (it is divided by 16), resulting in 800 logical cylinders. Likewise, the 15 heads are multiplied by 16, resulting in 240 logical heads. If the logical cylinder count calculates to more than 1,024, it is truncated to 1,024. In this case, what started out as 12,000 cylinders and 16 heads P-CHS becomes 800 cylinders and 240 heads (instead of 750 cylinders and 256 heads) L-CHS, which works around the bug in the DOS/Win9x/Me operating systems.

So far, all my examples have been clean—that is, the L-CHS parameters have calculated to the same capacity as the P-CHS parameters. Unfortunately, it doesn’t always work out that way. The following shows a more typical example in the real world. Several 8.4GB drives from Maxtor, Quantum, Seagate, and others report 16,383 cylinders and 16 heads P-CHS. For those drives, the translations would work out as follows:

<table>
<thead>
<tr>
<th></th>
<th>Bit-shift</th>
<th>Revised Bit-shift</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P-CHS</td>
<td>L-CHS</td>
</tr>
<tr>
<td></td>
<td>Parameters</td>
<td>Parameters</td>
</tr>
<tr>
<td>Cylinders</td>
<td>16,383</td>
<td>1,023</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1,024</td>
</tr>
<tr>
<td>Heads</td>
<td>16</td>
<td>256</td>
</tr>
<tr>
<td></td>
<td></td>
<td>240</td>
</tr>
<tr>
<td>Sectors/Track</td>
<td>63</td>
<td>63</td>
</tr>
<tr>
<td></td>
<td></td>
<td>63</td>
</tr>
<tr>
<td>Total Sectors</td>
<td>16,514,064</td>
<td>16,498,944</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15,482,880</td>
</tr>
<tr>
<td>Total Bytes</td>
<td>8,455,200,768</td>
<td>8,447,459,328</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7,927,234,560</td>
</tr>
<tr>
<td>Megabytes (MB)</td>
<td>8,455</td>
<td>8,447</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7,927</td>
</tr>
<tr>
<td>Mebibytes (MiB)</td>
<td>8,064</td>
<td>8,056</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7,560</td>
</tr>
<tr>
<td>Gigabytes (GB)</td>
<td>8.46</td>
<td>8.45</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7.93</td>
</tr>
<tr>
<td>Gibibytes (GiB)</td>
<td>7.87</td>
<td>7.87</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7.38</td>
</tr>
</tbody>
</table>
Note that the revised CHS bit-shift translation rules result in supporting only 7.93GB of the 8.46GB total on the drive. In fact, the parameters shown (with 240 heads) are the absolute maximum that revised CHS bit-shift supports. Fortunately, another translation mode is available that improves this situation.

**LBA-Assist Translation**

The LBA-assist translation method places no artificial limits on the reported drive geometries, but it works only on drives that support LBA addressing at the ATA interface level. Fortunately, though, virtually all ATA drives larger than 2GB support LBA. LBA-assist translation takes the CHS parameters the drive reports, multiplies them together to get a calculated LBA maximum value (total number of sectors), and then uses this calculated LBA number to derive the translated CHS parameters. Table 7.21 shows the rules for LBA-assist translation.

**Table 7.21 LBA-Assist Translation Rules**

<table>
<thead>
<tr>
<th>Logical Cylinders</th>
<th>Logical Heads</th>
<th>Logical Sectors</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1 &lt; T \leq 1,032,192)</td>
<td>(T/1,008)</td>
<td>16</td>
</tr>
<tr>
<td>(1,032,192 &lt; T \leq 2,064,384)</td>
<td>(T/2,016)</td>
<td>32</td>
</tr>
<tr>
<td>(2,064,384 &lt; T \leq 4,128,768)</td>
<td>(T/4,032)</td>
<td>64</td>
</tr>
<tr>
<td>(4,128,768 &lt; T \leq 8,257,536)</td>
<td>(T/8,064)</td>
<td>128</td>
</tr>
<tr>
<td>(8,257,536 &lt; T \leq 16,450,560)</td>
<td>(T/16,065)</td>
<td>255</td>
</tr>
</tbody>
</table>

\(T = \text{Total sectors, calculated by multiplying the drive-reported P-CHS parameters } (C \times H \times S)\)

LBA-assist translation fixes the sectors at 63 no matter what and divides and multiplies the cylinders and heads by predetermined values depending on the total number of sectors. This results in a set of L-CHS parameters the operating system uses to communicate with the BIOS. The L-CHS numbers are then translated to LBA numbers at the ATA interface level. Because LBA mode is more flexible at translating, you should use it in most cases instead of CHS bit-shift.

Normally, both the CHS bit-shift and LBA-assist translations generate the same L-CHS geometry for a given drive. This should always be true if the drive reports 63 sectors per track and 4, 8, or 16 heads. In the following example, both translation schemes result in identical L-CHS values:

<table>
<thead>
<tr>
<th>Revised bit-shift P-CHS Parameters</th>
<th>Revised bit-shift L-CHS Parameters</th>
<th>LBA-assist L-CHS Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cylinders</td>
<td>8,192</td>
<td>1,024</td>
</tr>
<tr>
<td>Heads</td>
<td>16</td>
<td>128</td>
</tr>
<tr>
<td>Sectors/Track</td>
<td>63</td>
<td>63</td>
</tr>
<tr>
<td>Total Sectors</td>
<td>8,257,536</td>
<td>8,257,536</td>
</tr>
<tr>
<td>Total Bytes</td>
<td>4,227,858,432</td>
<td>4,227,858,432</td>
</tr>
<tr>
<td>Megabytes (MB)</td>
<td>4,228</td>
<td>4,228</td>
</tr>
<tr>
<td>Mebibytes (MiB)</td>
<td>4,032</td>
<td>4,032</td>
</tr>
<tr>
<td>Gigabytes (GB)</td>
<td>4.23</td>
<td>4.23</td>
</tr>
<tr>
<td>Gibibytes (GiB)</td>
<td>3.94</td>
<td>3.94</td>
</tr>
</tbody>
</table>
However, if the drive reports a value other than 63 sectors per track or has other than 4, 8, or 16 heads, LBA-assist translation does not result in the same parameters as CHS bit-shift translation. In the following example, different translations result:

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Revised bit-shift</th>
<th>LBA-assist</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cylinders</td>
<td>16,383</td>
<td>1,024</td>
</tr>
<tr>
<td>Heads</td>
<td>16</td>
<td>240</td>
</tr>
<tr>
<td>Sectors/Track</td>
<td>63</td>
<td>63</td>
</tr>
<tr>
<td>Total Sectors</td>
<td>16,514,064</td>
<td>15,482,880</td>
</tr>
<tr>
<td>Total Bytes</td>
<td>8,455,200,768</td>
<td>7,927,234,560</td>
</tr>
<tr>
<td>Megabytes (MB)</td>
<td>8,455</td>
<td>7,927</td>
</tr>
<tr>
<td>Mebibytes (MiB)</td>
<td>8,064</td>
<td>7,560</td>
</tr>
<tr>
<td>Gigabytes (GB)</td>
<td>8.46</td>
<td>7.93</td>
</tr>
<tr>
<td>Gibibytes (GiB)</td>
<td>7.87</td>
<td>7.38</td>
</tr>
</tbody>
</table>

The LBA-assist translation supports 8.42GB, which is nearly 500MB more than the revised CHS bit-shift translation. More importantly, these translations are different, which can result in problems if you change translation modes with data on the drive. If you were to set up and format a drive using CHS bit-shift translation and then change to LBA-assist translation, the interpreted geometry could change and the drive could then become unreadable until it is repartitioned and reformatted (which would destroy all the data). Bottom line: After you select a translation method, don’t plan on changing it unless you have your data securely backed up.

Virtually all PC BIOSs since 1994 have translation capability in the BIOS Setup, and virtually all offer both translation modes as well as an option to disable translation entirely. If both CHS bit-shift and LBA-assist translation modes are offered, you should probably choose the LBA method of translation because it is the more efficient and flexible of the two. LBA-assist translation also gets around the 4.2GB operating system bug because it is designed to allow a maximum of 255 logical heads no matter what.

You usually can tell whether your BIOS supports translation by the capability to specify more than 1,024 cylinders in the BIOS Setup, although this can be misleading. The best clue is to look for the translation setting parameters in the ATA/IDE drive setup page in the BIOS Setup. See Chapter 5 for more information on how to enter the BIOS Setup on your system. If you see drive-related settings, such as LBA or ECHS (sometimes called Large or Extended), these are telltale signs of a BIOS with translation support. Most BIOSs with a date of 1994 or later include this capability, although some AMI BIOS versions from the mid-1990s locate the LBA setting on a screen different from the hard drive configuration screen. If your system currently does not support parameter translation, you might be able to get an upgrade from your motherboard manufacturer or install a BIOS upgrade card with this capability, such as the LBA Pro card from eSupport.com.

Table 7.22 summarizes the four ways today’s BIOSs can handle addressing sectors on the drive: Standard CHS (no translation), Extended CHS translation, LBA translation, and pure LBA addressing.
ATA Drive Capacity Limitations

Chapter 7

Table 7.22 Drive Sector Addressing Methods

<table>
<thead>
<tr>
<th>BIOS Mode</th>
<th>OS to BIOS</th>
<th>BIOS to Drive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard (Normal), no translation</td>
<td>P-CHS</td>
<td>P-CHS</td>
</tr>
<tr>
<td>CHS bit-shift (ECHS) translation</td>
<td>L-CHS</td>
<td>P-CHS</td>
</tr>
<tr>
<td>LBA-assist (LBA) translation</td>
<td>L-CHS</td>
<td>LBA</td>
</tr>
<tr>
<td>Pure LBA (EDD BIOS)</td>
<td>LBA</td>
<td>LBA</td>
</tr>
</tbody>
</table>

Standard CHS has only one possible translation step internal to the drive. The drive's actual physical geometry is completely invisible from the outside with all zoned recorded ATA drives today. The cylinders, heads, and sectors printed on the label for use in the BIOS Setup are purely logical geometry and do not represent the actual physical parameters. Standard CHS addressing is limited to 16 heads and 1,024 cylinders, which provides a limit of 504MiB (528MB).

This is often called “Normal” in the BIOS Setup and causes the BIOS to behave like an old-fashioned one without translation. Use this setting if your drive has fewer than 1,024 cylinders or if you want to use the drive with an operating system that doesn’t require translation.

ECHS, or “Large” in the BIOS Setup, is CHS bit-shift, and most BIOSs from 1997 and later use the revised method (240 logical heads maximum).

LBA, as selected in the BIOS Setup, indicates LBA-assist translation, not pure LBA mode. This enables software to operate using L-CHS parameters while the BIOS talks to the drive in LBA mode.

The only way to select a pure LBA mode, from the OS to the BIOS as well as from the BIOS to the drive, is with a drive that is over 8.4GB. All drives over 137GB must be addressed via LBA at both the BIOS and drive levels, and most PC BIOSs automatically address any drive over 8.4GB in that manner, as well. In that case, no special BIOS Setup settings are necessary, other than setting the type to auto or autodetect.

Caution

A word of warning with these BIOS translation settings: If you have a drive 8.4GB or less in capacity and switch between Standard CHS, ECHS, or LBA, the BIOS can change the (translated) geometry. The same thing can happen if you transfer a disk that has been formatted on an old, non-LBA computer to a new one that uses LBA. This causes the logical CHS geometry seen by the operating system to change and the data to appear in the wrong location from where it actually is! This can cause you to lose access to your data if you are not careful. I always recommend recording the CMOS Setup screens associated with the hard disk configuration so that you can properly match the setup of a drive to the settings to which it was originally set. This does not affect drives over 8.4GB because in those cases pure LBA is automatically selected.

The 8.4GB Barrier

Although CHS translation breaks the 528MB barrier, it runs into another barrier at 8.4GB. Supporting drives larger than 8.4GB requires leaving CHS behind and changing from CHS to LBA addressing at the BIOS level. The ATA interface had always supported LBA addressing, even in the original ATA-1 specification. One problem was that LBA support at the ATA level originally was optional, but the main problem was that there was no LBA support at the BIOS interface level. You could set LBA-assist
translation in the BIOS Setup, but all that did was convert the drive LBA numbers to CHS numbers at the BIOS interface level.

Phoenix Technologies recognized that the BIOS interface needed to move from CHS to LBA early on and, beginning in 1994, published the “BIOS Enhanced Disk Drive Specification (EDD),” which addressed this problem with new extended INT13h BIOS services that worked with LBA rather than CHS addresses.

To ensure industry-wide support and compatibility for these new BIOS functions, in 1996 Phoenix turned this document over to the International Committee on Information Technology Standards (INCITS) T13 technical committee for further enhancement and certification as a standard called the “BIOS Enhanced Disk Drive Specification (EDD).” Starting in 1998, most of the other BIOS manufacturers began installing EDD support in their BIOS, enabling BIOS-level LBA mode support for ATA drives larger than 8.4GB. Coincidentally (or not), this support arrived just in time because ATA drives of that size and larger became available that same year.

The EDD document describes new extended INT13h BIOS commands that allow LBA addressing up to $2^{64}$ sectors, which results in a theoretical maximum capacity of more than 9.44ZB (zettabytes, or quadrillion bytes). That is the same as saying 9.44 trillion GB, which is $9.44 \times 10^{21}$ bytes or, to be more precise, 9,444,732,965,739,290,427,392 bytes! I say theoretical capacity because even though by 1998 the BIOS could handle up to $2^{64}$ sectors, ATA drives were still using only 28-bit addressing ($2^{28}$ sectors) at the ATA interface level. This limited an ATA drive to 268,435,456 sectors, which was a capacity of 137,438,953,472 bytes, or 137.44GB. Thus, the 8.4GB barrier had been broken, but another barrier remained at 137GB because of the 28-bit LBA addressing used in the ATA interface. The numbers work out as follows:

<table>
<thead>
<tr>
<th>Max. Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Sectors</td>
</tr>
<tr>
<td>Total Bytes</td>
</tr>
<tr>
<td>Megabytes (MB)</td>
</tr>
<tr>
<td>Mebibytes (MiB)</td>
</tr>
<tr>
<td>Gigabytes (GB)</td>
</tr>
<tr>
<td>Gibibytes (GiB)</td>
</tr>
</tbody>
</table>

By using the new extended INT13h 64-bit LBA mode commands at the BIOS level, as well as the existing 28-bit LBA mode commands at the ATA level, no translation would be required and the LBA numbers would be passed unchanged. The combination of LBA at the BIOS and the ATA interface levels meant that the clumsy CHS addressing could finally die. This also means that when you install an ATA drive larger than 8.4GB in a PC that has an EDD-capable BIOS (1998 or newer), both the BIOS and the drive are automatically set to use LBA mode.

An interesting quirk is that to allow backward compatibility when you boot an older operating system that doesn’t support LBA mode addressing (DOS or the original release of Windows 95, for example), most drives larger than 8.4GB report 16,383 cylinders, 16 heads, and 63 sectors per track, which is 8.4GB. For example, this enables a 120GB drive to be seen as an 8.4GB drive by older BIOSs or operating systems. That sounds strange, but I guess having a 120GB drive being recognized as an 8.4GB is better than not having it work at all. If you did want to install a drive larger than 8.4GB into a system dated before 1998, the recommended solution is either a motherboard BIOS upgrade or an add-on BIOS card with EDD support.
## The 137GB Barrier and Beyond

By 2001, the 137GB barrier had become a problem because 3 1/2-inch hard drives were poised to breach that capacity level. The solution came in the form of ATA-6, which was being developed during that year. To enable the addressing of drives of greater capacity, ATA-6 upgraded the LBA functions from using 28-bit numbers to using larger 48-bit numbers.

The ATA-6 specification extends the LBA interface such that it can use 48-bit sector addressing. This means that the maximum capacity is increased to 248 (2,814,749,767,106,566) total sectors. Because each sector stores 512 bytes, this results in the maximum drive capacity shown here:

<table>
<thead>
<tr>
<th>Max. Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Sectors</td>
</tr>
</tbody>
</table>

| Total Bytes | 144,115,188,075,855,872 |
|-------------|
| Megabytes (MB) | 144,115,188,076 |
| Mebibytes (MiB) | 137,438,953,472 |
| Gigabytes (GB) | 144,115,188 |
| Gibibytes (GiB) | 134,217,728 |
| Terabytes (TB) | 144,115 |
| Tebibytes (TiB) | 131,072 |
| Petabytes (PB) | 144.12 |
| Pebibytes (PiB) | 128.00 |

As you can see, the 48-bit LBA in ATA-6 allows a capacity of just over 144PB (petabytes = quadrillion bytes)!

Because the EDD BIOS functions use a 64-bit LBA number, they have a much larger limit:

<table>
<thead>
<tr>
<th>Max. Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Sectors</td>
</tr>
</tbody>
</table>

| Total Bytes | 9,444,732,965,739,290,427,392 |
|-------------|
| Megabytes (MB) | 9,444,732,965,739,290 |
| Mebibytes (MiB) | 9,007,199,254,740,992 |
| Gigabytes (GB) | 9,444,732,965,739 |
| Gibibytes (GiB) | 8,796,093,022,208 |
| Terabytes (TB) | 9,444,732,966 |
| Tebibytes (TiB) | 8,589,934,592 |
| Petabytes (PB) | 9,444,733 |
| Pebibytes (PiB) | 8,388,608 |
| Exabytes (EB) | 9,445 |
| Exbibytes (EiB) | 8,192 |
| Zettabytes (ZB) | 9.44 |
| Zebibytes (ZiB) | 8.00 |
Although the BIOS services use 64-bit LBA (allowing up to $2^{64}$ sectors) for even greater capacity, the 144 petabyte ATA-6 limitation is the lowest common denominator that would apply. Still, that should hold us for some time to come.

Because hard disk drives have been doubling in capacity every 1.5 to 2 years (a corollary of Moore’s Law), I estimate that it will take us until sometime between the years 2031 and 2041 before we reach the 144PB barrier (assuming hard disk technology hasn’t been completely replaced by then). Similarly, I estimate that the 9.44ZB EDD BIOS barrier won’t be reached until between the years 2055 and 2073! Phoenix originally claimed that the EDD specification would hold us until 2020, but it seems they were being quite conservative.

The 137GB barrier proved a bit more complicated than previous barriers because, in addition to BIOS issues, operating system issues also had to be considered.

Internal ATA drives larger than 137GB require 48-bit LBA (logical block address) support. This support absolutely needs to be provided in the OS, but it can also be provided in the BIOS. It is best if both the OS and BIOS provide this support, but it can be made to work if only the OS has the support.

Having 48-bit LBA support in the OS requires one of the following:

- Windows XP with Service Pack 1 (SP1) or later.
- Windows 2000 with Service Pack 4 (SP4) or later.
- Windows 98/98SE/Me or NT 4.0 with the Intel Application Accelerator (IAA) loaded and a motherboard with an IAA-supported chipset. See http://downloadcenter.intel.com and search for IAA.

Having 48-bit LBA support in the BIOS requires either of the following:

- A motherboard BIOS with 48-bit LBA support (most of those dated September 2002 or later)
- An ATA host adapter card with onboard BIOS that includes 48-bit LBA support

If your motherboard BIOS does not have the support and an update is not available from your motherboard manufacturer, you may be able to use a card. Promise Technology (www.promise.com) makes several PCI cards with 3Gbps SATA/eSATA interfaces as well as an onboard BIOS that adds 48-bit LBA support.

Note that if you have both BIOS and OS support, you can simply install and use the drive like any other. If you have no BIOS support, but you do have OS support, portions of the drive past 137GB are not recognized or accessible until the OS is loaded. If you are installing the OS to a blank hard drive and booting from an original XP (pre-SP1) CD or earlier, you will only be able to partition up to the first 137GB of the drive at installation time. After installing the OS and then the SP1 (or SP2/SP3) update, you can either partition the remainder of the drive as a second partition in Windows or use a free third-party partitioning program such as Parted Magic to expand the 137GB partition to use the full drive. If you are booting from an XP CD with SP1 or later integrated, Windows will recognize the entire drive during the OS installation and allow partitioning of the entire drive as a single partition greater than 137GB.

**Operating System and Other Software Limitations**

Note that if you use older software, including utilities, applications, or even operating systems that rely exclusively on CHS parameters, these items will see all drives over 8.4GB as 8.4GB only. You will need not only a newer BIOS, but also newer software designed to handle the direct LBA addressing to work with drives over 8.4GB.

Operating system limitations with respect to drives over 8.4GB are shown in Table 7.23.
### Table 7.23 Operating System Limitations for Hard Drive Size

<table>
<thead>
<tr>
<th>Operating System</th>
<th>Limitations for Hard Drive Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>DOS/Windows 3x</td>
<td>DOS 6.22 or lower can't support drives greater than 8.4GB. DOS 7.0 or higher (including with Windows 95 or later) is required to recognize a drive over 8.4GB.</td>
</tr>
<tr>
<td>Windows 9x/Me</td>
<td>Windows 95a (original version) does support the INT13h extensions, which means it does support drives over 8.4GB; however, due to limitations of the FAT16 file system, the maximum individual partition size is limited to 2GB. Windows 95B/OSR2 and later (including Windows 98/Me) support the INT13h extensions, which allow drives over 8.4GB, and they also support FAT32, which allows partition sizes up to the maximum capacity of the drive. However, Windows 95 doesn't support hard drives larger than 32GB because of limitations in its design. Windows 98 requires an update to FDISK to partition drives larger than 64GB.</td>
</tr>
<tr>
<td>Windows NT</td>
<td>Windows NT 3.5x does not support drives greater than 8.4GB. Windows NT 4.0 does support drivers greater than 8.4GB; however, when a drive larger than 8.4GB is being used as the primary bootable device, Windows NT will not recognize more than 8.4GB. Microsoft has released Service Pack 4, which corrects this problem.</td>
</tr>
<tr>
<td>Windows 2000 and later</td>
<td>All Windows 2000 SP3+, Windows XP SP1+, Windows Vista, Windows 7/8, and later systems support MBR-formatted drives up to 2.19TB by default. 64-bit versions of Windows Vista SP1+ and Windows 7/8 and later support GPT-formatted drives of 2.2TB or larger, up to a maximum of 281TB (256TiB).</td>
</tr>
<tr>
<td>Linux</td>
<td>Most versions support MBR-formatted drives up to 2.19TB by default, whereas most current versions support GPT formatted drives of 2.2TB or larger, up to 16TiB or 1EiB depending on the file system.</td>
</tr>
<tr>
<td>OS/2 Warp</td>
<td>Some versions of OS/2 are limited to a boot partition size of 3.1GB or 4.3GB. IBM has a Device Driver Pack upgrade that enables the boot partition to be as large as 8.4GB. The HPFS file system in OS/2 supports drives up to 64GB.</td>
</tr>
<tr>
<td>Novell</td>
<td>NetWare 5.0 and later support drives greater than 8.4GB.</td>
</tr>
</tbody>
</table>

In the case of operating systems that support drives over 8.4GB, the maximum drive size limitations depend on the BIOS and hard drive interface standard, not the OS. Instead, other limitations come into play for the volumes (partitions) and files that can be created and managed by the various operating systems. These limitations depend on not only the operating system involved, but also the file system that is used for the volume. Table 7.24 shows the minimum and maximum volume (partition) size and file size limitations of the various Windows operating systems. As noted in the previous section, the original version of XP, as well as Windows 2000/NT or Windows 95/98/Me, does not currently provide native support for ATA hard drives that are larger than 137GB. You need to use Windows 7/8, Vista, or XP with Service Pack 1 or later installed to use an ATA drive over 137GB. This does not affect drives attached via USB, FireWire, SCSI, or other interfaces.

### Table 7.24 Operating System Volume/File Size Limitations by File System

<table>
<thead>
<tr>
<th>OS Limitations by File System</th>
<th>FAT16</th>
<th>FAT32</th>
<th>NTFS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min. volume size (9x/Me)</td>
<td>2.092MB</td>
<td>33.554MB</td>
<td>—</td>
</tr>
<tr>
<td>Max. volume size (95)</td>
<td>2.147GB</td>
<td>33.554MB</td>
<td>—</td>
</tr>
<tr>
<td>Max. volume size (98)</td>
<td>2.147GB</td>
<td>136.902GB</td>
<td>—</td>
</tr>
</tbody>
</table>
### GPT and the 2.2TB Barrier

Although most of the previous barriers in disk capacity have been hardware related, the 2.2TB barrier is more of a software than a hardware problem. Even more specifically, it is a disk formatting and OS problem, and it’s a BIOS problem if you consider boot drives versus data drives.

This problem stems from the way hard disks have been formatted since DOS 2.0 and the first PC hard drives appeared in 1983. Back then IBM and Microsoft came up with a scheme for partitioning drives called the **MBR** (Master Boot Record). The MBR is the first sector on a disk, and it is internally defined with the ability to control four primary partitions. Each partition is described by a 16-byte table entry, with 4-byte (32-bit) fields that define the LBA (Logical Block Address) for both where the partition starts and how big it is.

The largest number that can be written using 32 binary digits is $2^{32}$, which is equal to 4,294,967,296. Because each sector is normally limited to 512 bytes, this means that the maximum amount of a drive that can be recognized is 2.2TB. Combine the MBR limitation with the fact that most PC BIOSs can only boot from MBR-formatted drives, and most older operating systems only support MBR-formatted drives for both boot drives and data drives, and you can see that the 2.2TB limitation can be a problem.

Several changes are necessary to break this barrier. The first is to develop a new partitioning scheme without the limitations the MBR imposes. This replacement is called GPT, which stands for **GUID** (globally unique identifier) Partition Table. Intel initially developed the GPT as part of its EFI (Extensible Firmware Interface) specification in 2000; since then Microsoft and other OS vendors have been incorporating it into operating systems. The GPT uses 64-bit LBA numbers, meaning disks of up to 9.4ZB (8ZiB) can be managed. That’s equal to 9.4 billion terabytes, a limit that won’t be reached any time soon.

Figure 7.19 illustrates the differences between MBR and GPT partitions.

Although GPT breaks the 2.2TB barrier from a drive formatting perspective, other elements must be in place for GPT to be usable in a PC. To format or recognize a GPT-formatted disk, you need an OS that supports GPT. That alone allows you to use GPT-formatted disks as secondary (data) disks, but to boot from a GPT-formatted drive, you also need a motherboard with a UEFI BIOS or UEFI Boot option. Table 7.25 summarizes the requirements to break the 2.2TB barrier.
FIGURE 7.19  GPT includes a backup for partition entries and the partition table header.

### Table 7.25  Operating System GPT Boot/Data Disk Support

<table>
<thead>
<tr>
<th>Operating System</th>
<th>GPT Boot Disk</th>
<th>GPT Data Disk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Windows XP (x86)</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Windows XP (x64)</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Windows Vista SP1+ (x86)</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Windows Vista SP1+ (x64)</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Windows 7/8 (x86)</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Windows 7/8 (x64)</td>
<td>Yes^2</td>
<td>Yes</td>
</tr>
<tr>
<td>Linux UBUNTU 8.04+/SUSE (x86, x64)</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

**Note:**

- x86 = 32-bit, x64 = 64-bit
- 1 Yes with third-party software such as the Paragon GPT Loader
- 2 Only on systems with a UEFI BIOS or an enabled UEFI Boot option

Drives 2.2TB or larger can also be supported externally via USB without having to resort to GPT partitioning. This is accomplished within the USB Bridge chipset firmware, which can be designed to present 2.2TB or larger drives using 4K sectors instead of the normal 512-byte sectors. USB enclosures or
drive docks with this feature can use standard MBR formatting to allow the drive to be supported in Windows XP with no special software required.

In summary, to use a 2.2TB or larger drive as an internal secondary/data drive, you need to format it using GPT, and you need to run a GPT-aware OS (Vista SP1 or later). Booting from such a drive also requires a UEFI BIOS or an enabled UEFI Boot option. You can use GPT-formatted secondary/data drives with Windows XP by installing third-party GPT support software such as the Paragon GPT Loader (www.Paragon-Software.com).

**PATA/SATA RAID**

**RAID** is an acronym for redundant array of independent (or inexpensive) disks and was designed to improve the fault tolerance and performance of computer storage systems. RAID was developed at the University of California at Berkeley in 1987 and was designed so that a group of smaller, less expensive drives could be interconnected with special hardware and software to make them appear as a single larger drive to the system. By using multiple drives to act as one drive, increases in fault tolerance and performance could be realized.

Initially, RAID was conceived to simply enable all the individual drives in the array to work together as a single, larger drive with the combined storage space of all the individual drives, which is called a **JBOD** (Just a Bunch of Disks) configuration. Unfortunately, if you had four drives connected in a JBOD array acting as one drive, you would be four times more likely to experience a drive failure than if you used just a single larger drive. And because JBOD does not use striping, performance would be no better than a single drive either. To improve both reliability and performance, the Berkeley scientists proposed six levels (corresponding to different methods) of RAID. These levels provide varying emphasis on fault tolerance (reliability), storage capacity, performance, or a combination of the three.

Although it no longer exists, an organization called the RAID Advisory Board (RAB) was formed in July 1992 to standardize, classify, and educate on the subject of RAID. The RAB developed specifications for RAID, a conformance program for the various RAID levels, and a classification program for RAID hardware.

The RAID Advisory Board defined seven standard RAID levels, called RAID 0–6. Most RAID controllers also implement a RAID 0+1 combination, which is usually called RAID 10. The levels are as follows:

- **RAID Level 0**—Striping-File data is written simultaneously to multiple drives in the array, which act as a single larger drive. This offers high read/write performance but low reliability. Requires a minimum of two drives to implement.

- **RAID Level 1**—Mirroring-Data written to one drive is duplicated on another, providing excellent fault tolerance (if one drive fails, the other is used and no is data lost) but no real increase in performance as compared to a single drive. Requires a minimum of two drives to implement (same capacity as one drive).

- **RAID Level 2**—Bit-level ECC-Data is split one bit at a time across multiple drives, and error correction codes (ECCs) are written to other drives. This is intended for storage devices that do not incorporate ECC internally. (All SCSI and ATA drives have internal ECC.) It’s a standard that theoretically provides high data rates with good fault tolerance, but seven or more drives are required for greater than 50% efficiency, and no commercial RAID 2 controllers or drives without ECC are available.

- **RAID Level 3**—Striped with parity-Combines RAID Level 0 striping with an additional drive used for parity information. This RAID level is really an adaptation of RAID Level 0 that sacrifices some capacity, for the same number of drives. However, it also achieves a high level of data integrity or fault tolerance because data usually can be rebuilt if one drive fails. Requires a minimum of three drives to implement (two or more for data and one for parity).
■ RAID Level 4—Blocked data with parity—Similar to RAID 3 except data is written in larger blocks to the independent drives, offering faster read performance with larger files. Requires a minimum of three drives to implement (two or more for data and one for parity).

■ RAID Level 5—Blocked data with distributed parity—Similar to RAID 4 but offers improved performance by distributing the parity stripes over a series of hard drives. Requires a minimum of three drives to implement (two or more for data and one for parity).

■ RAID Level 6—Blocked data with double distributed parity—Similar to RAID 5 except parity information is written twice using two parity schemes to provide even better fault tolerance in case of multiple drive failures. Requires a minimum of four drives to implement (two or more for data and two for parity).

There are also nested RAID levels created by combining several forms of RAID. The most common are as follows:

■ RAID Level 01: Mirrored stripes—Drives are first combined in striped RAID 0 sets; then the RAID 0 sets are mirrored in a RAID 1 configuration. A minimum of four drives is required, and the total number of drives must be an even number. Most PC implementations allow four drives only. The total usable storage capacity is equal to half of the number of drives in the array times the size of the lowest capacity drive. RAID 01 arrays can tolerate a single drive failure and some (but not all) combinations of multiple drive failures. This is not generally recommended because RAID 10 offers more redundancy and performance.

■ RAID Level 10: Striped mirrors—Drives are first combined in mirrored RAID 1 sets; then the RAID 1 sets are striped in a RAID 0 configuration. A minimum of four drives is required, and the total number of drives must be an even number. Most PC implementations allow four drives only. The total usable storage capacity is equal to half of the number of drives in the array times the size of the lowest capacity drive. RAID 10 arrays can tolerate a single drive failure and many (but not all) combinations of multiple drive failures. This is similar to RAID 01, except with somewhat increased reliability because more combinations of multiple drive failures can be tolerated, and rebuilding an array after a failed drive is replaced is much faster and more efficient.

Additional custom or proprietary RAID levels exist that were not originally supported by the RAID Advisory Board. For example, from 1993 through 2004, “RAID 7” was a trademarked marketing term used to describe a proprietary RAID implementation released by the (now defunct) Storage Computer Corp.

When set up for maximum performance, arrays typically run RAID Level 0, which incorporates data striping. Unfortunately, RAID 0 also sacrifices reliability such that if any one drive fails, all data in the array is lost. The advantage is in extreme performance. With RAID 0, performance generally scales up with the number of drives you add in the array. For example, with four drives you won’t necessarily have four times the performance of a single drive, but many controllers can come close to that for sustained transfers. Some overhead is still involved in the controller performing the striping, and issues still exist with latency—that is, how long it takes to find the data—but performance will be higher than any single drive can normally achieve.

When set up for reliability, arrays generally run RAID Level 1, which is simple drive mirroring. All data written to one drive is written to the other. If one drive fails, the system can continue to work on the other drive. Unfortunately, this does not increase performance, and it also means you get to use only half of the available drive capacity. In other words, you must install two drives, but you get to use only one. (The other is the mirror.) However, in an era of high capacities and low drive prices, this is not a significant issue.
Combining performance with fault tolerance requires using one of the other RAID levels, such as RAID 5 or 10. For example, virtually all professional RAID controllers used in network file servers are designed to use RAID Level 5. Controllers that implement RAID Level 5 used to be very expensive, and RAID 5 requires at least three drives to be connected, whereas RAID 10 requires four drives.

With four 500GB drives in a RAID 5 configuration, you would have 1.5TB of total storage, and you could withstand the failure of any single drive. After a drive failure, data could still be read from and written to the array. However, read/write performance would be exceptionally slow, and it would remain so until the drive was replaced and the array was rebuilt. The rebuild process could take a relatively long time, so if another drive failed before the rebuild completed, all data would be lost.

With four drives in a RAID 10 configuration, you would have only 1TB of total storage. However, you could withstand many cases of multiple drive failures. In addition, after a drive failure, data could still be read from and written to the array at full speed, with no noticeable loss in performance. In addition, once the failed drive is replaced, the rebuild process would go relatively quickly as compared to rebuilding a RAID 5 array. Because of the advantages of RAID 10, many are recommending it as an alternative to RAID 5 where maximum redundancy and performance are required.

Many motherboards include SATA RAID capability as a built-in feature. For those that don’t, or where a higher performance or more capable SATA RAID solution is desired, you can install a SATA RAID host adapter in a PCIe slot in the system. A typical PCIe SATA RAID controller enables up to four, six, or eight drives to be attached, and you can run them in RAID Level 0, 1, 5, or 10 mode. Most PCIe SATA RAID cards use a separate SATA data channel (cable) for each drive, allowing maximum performance. Motherboard-based RAID controllers almost exclusively use SATA drives.

If you are considering a SATA RAID controller (or a motherboard with an integrated SATA RAID controller), here are some things to look for:

- RAID levels supported. (Most support 0, 1, 5, and 10. A lack of RAID 5/6 or RAID 10 support indicates a very low-end product.)
- Support for four, six, or eight drives.
- Support for 6Gbps SATA transfer rates.
- PCIe card with onboard controller (provides best performance and future compatibility; note that low-cost PCIe cards are host-based and rely on the CPU).

**Software RAID**

Some operating systems include software-based RAID capability; in fact, limited RAID 0, 1, and even RAID 5 functionality has been built in to some versions of Windows since Windows 2000. When Microsoft released Windows Home Server in 2007 it greatly enhanced this capability with a feature called Drive Extender, which allowed for the creation and arbitrary expansion of an array using virtually any type of drive (SATA, PATA, USB, FireWire, etc.) in any capacity. Drive Extender creates a virtual drive that is a combination of the assigned physical drives. There is limited redundancy in that by default each file saved on a Drive Extender volume is automatically stored on two different drives such that if one drive fails it can theoretically be replaced without losing any data. If more than one drive fails, then data will be lost. Unfortunately, problems with Drive Extender caused Microsoft to remove the feature from Windows Home Server 2011.

Microsoft has included a newer and better replacement for Drive Extender in Windows 8, which is now called Storage Spaces. Just like Drive Extender, it allows you to build a virtual drive using an array of drives of just about any type or capacity. One area where Storage Spaces differs from Drive Extender is in the redundancy options. In addition to two-way redundancy where data is saved on two drives, Storage Spaces allows for three-way redundancy, meaning that data will be saved on three drives. This
also means that up to two drives can fail in the array without losing data. While the redundancy and reliability has been improved, just as with most software-based RAID, performance falls dramatically as compared to either a physical drive or hardware-based RAID, especially in write performance.

While the Storage Spaces feature in Windows 8 looks like an excellent option for a home server with multiple data drives, just like any other RAID array, it doesn't replace the need for backup, meaning you would need somewhere else to back up all of the data on the Storage Spaces virtual drive.

Normally, if you want both performance and reliability, you should look for hardware-based SATA RAID controllers that support RAID Level 5 or 10, or an external storage device with built-in RAID capability. You can install a PCIe-based RAID controller; however, many motherboards have RAID capability built in via the motherboard chipset. Another option is external storage devices like the Drobo (www.drobo.com), which can create and manage virtual drives using the various physical drives mounted in the enclosure. Because they rely on dedicated management hardware, they can offer better performance and reliability than even some hardware-based RAID setups.
Symbols

1/2-Baby motherboards, 159
0.85” drive, 466
1” hard drives, 466
1st ATAPI CD-ROM Drive setting (Boot menu), 314
1st Boot Device setting (Boot menu), 314
1st Hard Disk Drive setting (Boot menu), 314
1st Removable Device setting (Boot menu), 314
1.8” hard drives, 466
2nd Boot Device setting (Boot menu), 314
2.1 GB barrier (CHS), 423
2.1 speaker configuration, 700
2.2 TB barrier, 432-434
2/3-Baby motherboards, 159
2.5” ATA drive cables, 1003
2.5” hard drives, 465

3D gaming audio standards, 684-686
3D graphics accelerators, 642
animation, 645
antialiasing, 645
APIs (application programming interfaces), 645
DirectX, 646-647
OpenGL, 646
depth cueing, 644
dual-GPU scene rendering
AMD CrossFireX, 648-649
AMD Eyefinity, 650
NVIDIA SLI, 648
flat shading, 642
Gouraud shading, 643
history of, 643-644
image abstractions, 644
image rendering, 644-645
MIP mapping, 644
perspective correction, 644
primitives, 644
scan conversion, 645
shading, 645
software optimization, 645
texture mapping, 643-645
vertices, 644
visible surface determination, 645

3D Soundback, 684
3DNow! technology, 64
3G mobile broadband, 783
3rd Boot Device setting (Boot menu), 314
3TB drives, troubleshooting, 1032-1033
3x series chipsets (Intel), 205-208
+3.3V power sources, 846
3.5” drive enclosure, 1003
3.5” half-height drives, 465
4G mobile broadband, 783-784
4K sectors (Advanced Format), 473-475
4-pin +12V power connectors (ATX), 882-883
4-pin to 8-pin +12V power connectors (ATX), 883-884
4th Boot Device setting (Boot menu), 314
4.1 speaker configuration, 700
4.2 GB barrier (CHS), 423-425
4x series chipsets (Intel), 206-208
-5V power sources, 847-848
+5V power sources, 846
5-pin DIN keyboard connectors, 751
5.1 Surround sound, 700
5.25” hard drives, 464-465
5x series chipsets (Intel), 208-211
6-pin auxiliary power connectors (ATX), 876-877
6-pin mini-DIN keyboard connectors, 751

6.1 Surround sound, 700
6x series chipsets (Intel), 211-213
7-Zip, 281
7.1 Surround sound, 700
7x series chipsets (Intel), 213-215
8-bit (bidirectional) parallel ports, 737
8-bit ISA (Industry Standard Architecture) buses, 255
8-bit processors, 89-90
8P8C connectors, 816
8-pin +12V power connectors (ATX), 883-884
8.4 GB barrier, 427-428
9-pin serial port connectors, 732
9-pin-to-25-pin serial port connectors, 733
10BASE-T, 806
10GBASE-T, 807
12V power sources, 847-848
+12V power sources, 846
14.31818MHz crystals, 136
16-bit ISA (Industry Standard Architecture) buses, 256
16-bit processors, 89-90
16-bit to 64-bit processor architecture evolution, 34-35
20-pin main power connectors (ATX), 872-874
25-pin parallel port connectors, 734-735
25-pin serial port connectors, 732
30-pin SIMMs (single inline memory modules), 347
32-bit processors
386, 91-92
486, 92-93
Intel-compatible, 96

Pentium, 93-96
BTB (branch target buffer), 95
instruction processing, 95
math coprocessor, 95
specifications, 94
superscalar technology, 94
twin data pipelines, 94

50-pin PATA (Parallel ATA) connectors, 389-390

56Kbps modems, 791
chips, 792
limitations, 792
Modem-on-Hold feature, 793-794
PCM Upstream feature, 794
speed, 792
V.90 standard, 793
V.92 standard, 793-794

64-bit extension mode, 46-48

64-bit processors
AMD Athlon 64, 120-124
AMD Athlon 64 FX, 120-124
Celeron, 96, 100-101
Pentium II, 96-99
Pentium III, 96, 99-100
Pentium Pro, 96-97

72-pin SIMMs (single inline memory modules), 347
80 PLUS Program, 903-904
086 processors, 89
96x series chipsets (Intel), 204-205
100BASE-TX, 806
101-key keyboards, 739-740
103/104-key keyboards, 740-742
137 GB barrier, 429-430
168-pin SDRAM DIMMs, 348
184-pin DDR DIMMs, 348, 353
240-pin DDR2 DIMMs, 348, 353
240-pin DDR3 DIMMs, 349, 353
286 processors, 90
active preventative maintenance

305 RAMAC (Random Access Method of Accounting and Control), 439
386 processors, 91-92, 190
480x chipsets (AMD), 220
486 processors, 92-93
  82350 chipsets, 190
    Intel chipsets, 190
    sockets, 75-76
500 series chipsets (AMD), 220
504 MiB barrier (CHS), 421
512-byte sector on modern drive, 472
528 MB barrier (CHS), 419-421
555.2 Harmonics standard (IEC), 899
586 processors. See Pentium processors
686 processors
  Celeron, 100-101
  Pentium-compatible, 64
  Pentium II, 64-65, 96-99
  Pentium III, 99-100
  Pentium Pro, 64-65, 96-97
690 series chipsets (AMD), 221
  700 series chipsets (AMD), 221-222
  726 Tape Unit, 439
  800 series chipsets (AMD), 222
  802.11a Wi-Fi standard, 810
  802.11ac Wi-Fi standard, 812
  802.11b Wi-Fi standard, 808-810
  802.11g Wi-Fi standard, 810-811
  802.11n Wi-Fi standard, 811-812
  900 series chipsets (AMD), 223-225
  915 family chipsets (Intel), 202-203
  925X family chipsets (Intel), 203
  945 Express family chipsets (Intel), 203
  955X chipsets (Intel), 204
  975X chipsets (Intel), 204
  1000-3-2 Harmonics standard (IEC), 899
  1000-3-3 Flicker standard (IEC), 899
  1394 standard (IEEE), 718
  1394a standard (IEEE), 718-719
  1394b S3200 standard (IEEE), 721
  1394b standard (IEEE), 719-720
  4004 processor, 30
  6502 processors, 32
  8000 (8151) chipsets (AMD), 219
  8008 processor, 31
  8085 processors, 31
  8086 mode, 44-45
  8086 processors, 32, 89-90
  8088 processors, 32, 89-90
  8151 chipsets (AMD), 219
  9100A electronic calculator (Hewlett-Packard), 20
  80286 processors, 90
  80386 processors, 91-92, 190
  80486 processors, 92-93
    82350 chipsets, 190
    Intel chipsets, 190
    sockets, 75-76
  80586 processors. See Pentium processors
  80686 processors
  82C206 chips, 182
  82C836 SCAT (Single Chip AT) chipsets, 182
  82350 chipsets (Intel), 190

A

ABC (Atanasoff-Berry Computer), 5, 10
absolute time in pre-groove (ATIP), 540
AC power switches
  front panel, 868-869
  integral, 868
AC ripple, 898
AC’97 integrated audio, 694
Accelerated Graphics Port (AGP), 253, 625-626
accelerated hub architecture (AHA), 188
accessing BIOS Setup, 292
Access Mode setting (Drive Configuration menu), 302
access points, 831, 836, 842
access times
  CD drives, 598
  DVD drives, 598
  HDDs (hard disk drives), 503
acclimating to temperatures (HDDs), 495
ACM (Adaptive Contrast Management), 660
ACPI (Advanced Configuration and Power Interface), 318-319, 905-908
ACPI suspend mode, 312, 910
Acronis True Image, 506
active heatsinks, 143-145
active low signals, 866
Active Management Technology (AMT) BIOS Setup, 306
active-matrix LCD (liquid crystal display) monitors, 661-662
active PFC (power factor correction), 899
active preventative maintenance
  cleaning, 1012
    chemical-freeze sprays, 1014
    compressed air, 1014
connectors, 1015-1016
contact cleaners/lubricants, 1013
contacts, 1015-1016
disassembly and cleaning tools, 1013
keyboards, 1016
mouse devices, 1016
swabs, 1015
system disassembly, 1015
vacuum cleaners, 1014
weekly and monthly checklists, 1011-1012
actuator mechanisms (heads), 467
servo mechanisms, 489-493
dedicated servo, 492-493
disk sweep, 491
embedded servo, 492
gray code, 490
servowriters, 490
thermal recalibration, 490
wedge servo, 491-492
stepper motors, 487-488
voice-coil actuators, 488-489
Adalin, 684
adapters. See also 3D graphics accelerators, 642
2 ½” ATA drive cables and adapters, 1003
audio adapters. See sound cards
data transfer cables and adapters, 1003
DWA (Device Wire Adapter), 717
expansion cards, 969
host interface adapters. See ATA (AT Attachment); SCSI (small computer system interface)
HWA (Host Wire Adapter), 717
integrated adapters, 938
network interface adapters, 989
NICs (network interface cards)
bus types, 815
connectors, 815-816
costs, 814
full-duplex, 815
half-duplex, 815
installation, 840-841
speed, 815
testing, 841
wireless NICs, 832
PCI (Peripheral Connect Interface) buses, 249
PS/2 Y adapter, 1003
troubleshooting, 1025, 1034
USB/FireWire cable adapter, 1003
video adapters
chipsets, 619-620
choosing, 940
components, 617-618
DAC (digital-to-analog converter), 624
definition of, 610
dual-head graphics adapters, 667
explained, 610
heterogeneous adapters, 668
homogeneous adapters, 668
installation, 967-968
integrated video/motherboard chipsets, 611-616
processors with integrated video, 616-617
removing, 968
testing, 671
troubleshooting, 670-671
types of, 610-611
UMA (unified memory architecture), 611
VGA adapters, 667
video BIOS, 618
video drivers, 672
video RAM, 620-624
Adaptive Contrast Management (ACM), 660
Adaptive Differential Pulse Code Modulation (ADPCM), 692
ADCs (analog-to-digital converters), 681
Additional System Information setting (BIOS main menu), 295
AddOn ROM Display Mode setting (Boot menu), 314
address buses, 42-44
Address Mark sector field, 470
address storing (switches), 828
addresses
CMOS RAM addresses, 285-287
MAC addresses, 814
port addresses, 259-260
addressing sectors
CHS (cylinder head sector)
2.1 GB barrier, 423
4.2 GB barrier, 423-425
8.4 GB barrier, 427-428
528 MB barrier, 419-421
BIOS commands versus ATA commands, 418-419
CHS bit-shift translation, 421-423
CHS/LBA conversions, 417-418
LBA (logical block address)
137 GB barrier and beyond, 429-430
BIOS commands versus ATA commands, 418-419
CHS/LBA conversions, 417-418
compared to CHS (cylinder head sector), 416-417
LBA-assist translation, 425-427
prefixes for decimal/binary multiples, 414-415
Adesso mechanical-switch keyboards, 743
ad hoc mode, 831
adjusting monitors, 674-675
AdLib sound card, 682
ADPCM (Adaptive Differential Pulse Code Modulation), 692
ADSL (Asymmetric DSL), 781
Advanced Configuration and Power Interface (ACPI), 318-319, 905-908
Advanced Format (4K sectors), 473-475
Advanced Host Controller Interface (AHCI), 408-409
advanced Linux sound architecture (ALSA), 693
Advanced menus (BIOS Setup)
Boot Configuration, 298
Chipset Configuration, 298-300
Drive Configuration, 302-305
Event Log Configuration, 306-307
explained, 295-296
Fan Control Configuration, 309
Floppy Configuration, 305-306
hardware monitoring display, 310
Memory Configuration, 297-298
PCI Configuration, 296
PCI Express Configuration, 296-297
Peripheral Configuration, 301-302
USB Configuration, 308-309
Video Configuration, 307-308
Advanced Optical Disc (AOD), 569-570
Advanced Power Management (APM), 312, 318, 904-905
advanced processing units (APUs), 131-132
Advanced Programmable Interrupt Controller (APIC), 258
Advanced RLL (ARLL), 452
advanced vector extensions (AVX), 64
Advanced Video Coding High Definition (AVCHD), 511
AFC (antiferromagnetically coupled) media, 485
After Power Failure setting (Power menu), 312
AGC (Automatic Gain Control), 556, 687
AGP (Accelerated Graphics Port), 253, 625-626
AGP/PCI Burn-in Mode setting (Chipset Configuration menu), 299
AHA (accelerated hub architecture), 188
AHCI (Advanced Host Controller Interface), 408-409
air bearing heads, 469
air filters, 494-495
Alderwood (925X) chipsets, 203
algorithms, ADPCM (Adaptive Differential Pulse Code Modulation), 692
ALi Corporation. See ULi Electronics chipsets
A-Link architecture, 190
Allied Electronics, 1000 allocation units, 480
alpha particles, 358
Alps Electric mechanical key-switches, 743
ALSA (advanced Linux sound architecture), 693
Altair, 19
8800 kit, 14
aluminum foil, 945
aluminum in hard disks, 441
aluminum/magnesium alloy platters, 484
AMD chipsets, 217
AMD 690 series chipsets, 221
AMD 700 series chipsets, 221-222
AMD 800 series chipsets, 222
AMD 900 series chipsets, 223-225
AMD 8000 (8151), 219
AMD A series chipsets, 225
AMD (ATI) 480x and 500 series chipsets, 220
reference table, 217-218
Clock program, 138
CPU Info program, 138
CrossFire, 893
CrossFireX, 648-649
Eyefinity, 650
Fusion/HSA (Heterogeneous Systems Architecture) APUs, 131-132
processors
Athlon, 117-118
Athlon 64, 120-124
Athlon 64 FX, 120-126
Athlon 64 X2, 125-126
Athlon MP, 120
Athlon XP, 118-119
Bulldozer FX, 128-131
code names, 88-89
development of, 33-34
Duron, 118, 185
K5, 96
K6, 64, 116-117
K10, 126-128
Piledriver FX, 128-131
Sempron, 124
specifications, 40
AMD-V, 69
American Megatrends, Inc. See AMI (American Megatrends, Inc.) BIOS
American Power Conversion (APC), 925
AMI (American Megatrends, Inc.) BIOS, 273
BIOS error messages, 322
POST error codes, 978-979
AMIDiag Suite, 990
amorphous state, 544
amplification, 698
amplitude, 680
AMR (anisotropic magneto-resistant) heads, 445-446
AMR (Audio Modem Riser), 240
AMT (Active Management Technology) BIOS Setup, 306
analog RCA sound card connectors, 689
analog-to-digital converters (ADCs), 681
Analytical Engine, 5
Andromeda Research Labs, 271
animation, 645
anisotropic magneto-resistant (AMR) heads, 445-446
antennas, 832
antialiasing, 645
antiferromagnetically coupled (AFC) media, 485
AOD (Advanced Optical Disc), 569-570
APC (American Power Conversion), 925
aperture, numerical, 568
Aperture Size setting (Video Configuration menu), 307
APIC (Advanced Programmable Interrupt Controller), 258
a-pinene, 1013
APIs (application programming interfaces), 645
definition of, 265
DirectX, 646-647
OpenGL, 646
APM (Advanced Power Management), 312, 318, 904-905
Apple
Apple I, 15
Apple II, 15
Mac OS X, 23
proprietary design, 17
shift to PC-based architecture, 18
application programming interfaces. See APIs
APUs (advanced processing units), 131-132
architecture, layered system architecture, 265-266
areal density, 456-458
ARLL (Advanced RLL), 452
ARPAnet, 6
ASCR (ASUS Smart Contrast Ratio), 660
A series chipsets (AMD), 225
ASF Support setting (Boot Configuration menu), 298
a-Si (hydrogenated amorphous silicon), 661
ASIO4ALL project, 693
aspect ratio, 652-653
assembling systems. See system assembly
ASUS Disk Unlocker, 292
ASUS Smart Contrast Ratio (ASCR), 660
Asymmetric DSL (ADSL), 781
asynchronous, 730
AT Attachment. See ATA
AT motherboards
Baby-AT, 158-159
full-size AT, 157-158
power supply connectors, 870-872
ATA (AT Attachment)
ATA-1 standard, 382
ATA-2 standard, 382
ATA-3 standard, 383
ATA/ATAPI-4 standard, 383-384
ATA/ATAPI-5 standard, 384-385
ATA/ATAPI-6 standard, 385
ATA/ATAPI-7 standard, 386
ATA/ATAPI-8 standard, 386
ATAPI (AT Attachment Packet Interface), 413
busmaster ATA, 396
CAM ATA (Common Access Method ATA), 379
capacity limitations, 498
CHS (cylinder head sector) addressing, 419-421
commands, 410-411
connectors, 385
drive capacity limitations, 413-414
2.1 GB barrier, 423
2.2 TB barrier, 432-434
4.2 GB barrier, 423-425
8.4 GB barrier, 427-428
137 GB barrier and beyond, 429-430
BIOS limitations, 415-416
BIOS versus ATA commands, 418-419
CHS bit-shift translation, 421-423
CHS/LBA conversions, 417-418
CHS limitations, 419-421
CHS versus LBA, 416-417
LBA-assist translation, 425-427
table of, 414
endecs, 378
explained, 377
GPT (GUID Partition Table), 432-434
history of, 378-380
HPAs (host protected areas), 412-413
operating system limitations, 430-432
PATA (Parallel ATA), 380
DMA (direct memory access) transfer modes, 396-397
dual-drive configurations, 393-395
I/O cables, 390-392
I/O connectors, 387-390
PIO (Programmed I/O) transfer modes, 396
signals, 392-393
precursors to, 377-378
RAID (redundant array of independent disks), 434-435
levels, 434-436
software RAID, 436-437
reliability, 378
SATA (Serial ATA)
AHCI (Advanced Host Controller Interface), 408-409
backward compatibility, 398
BIOS setup, 407
cables and connectors, 401-403
eSATA (external SATA), 404-405
eSATAp (Power Over eSATA), 405-407
explained, 398
mSATA (mini-SATA), 403-404
NVMe (Non-Volatile Memory Express), 409
power connectors, 889
SATA Express, 399-401
Serial ATA International Organization, 380, 399
standards and performance, 398-399
transfer modes, 399, 409-410
Security Mode, 411-412
standard organizations, 380-381
standard summary, 381
upgrade boards, 274
ATA IDENTIFY DEVICE command, 514
ATA/IDE Configuration setting (Drive Configuration menu), 303
Atanasoff-Berry Computer (ABC), 5, 10
Atanasoff, John V., 5, 10
ATAPI (AT Attachment Packet Interface), 413
Athlon chipsets
nForce/nForce2, 227
reference table, 217-218
SiS, 227
Athlon II (K10) processors, 126-128
Athlon 64 processors
chipsets
AMD 690 series, 221
AMD 700 series, 221-222
AMD 800 series, 222
AMD 900 series, 223-225
AMD 8000 (8151), 219
AMD A series, 225
AMD (ATI) 480x and 500 series, 220
overview, 120-124
Athlon 64 FX processors, 120-126
Athlon 64 X2 processors, 125-126
Athlon MP processors, 120
Athlon X2 (K10) processors, 126-128
Athlon XP processors, 118-119
ATI
chipsets, 190, 216
Hybrid CrossFire, 940
ATIP (absolute time in pre-groove), 540
Atom processors (Intel), 115
AT power supply connectors, 870-872
AT&T, 795
attachment unit interface (AUI), 816
AT&T U-verse, 838
ATX12V 2.x 24-pin power supply connectors, 877-879
ATX12V power supply, 852-854
ATX/ATX12V 1.x power supply connectors, 872
6-pin auxiliary power connectors, 876-877
20-pin main power connectors, 872-874
maximum power-handling capabilities, 875-876
Molex Mini-Fit Jr. power connectors, 874-875
ATX motherboards, 167-168
color coding, 172
extended ATX, 172
FlexATX, 174-175
identifying, 169
microATX, 172-174
Mini-ATX, 169
ports, 170
power supply connectors, 852-854, 872
4-pin +12V power connectors, 882-883
4-pin to 8-pin +12V power connectors, 884-885
6-pin auxiliary power connectors, 876-877
8-pin +12V power connectors, 883-884
20-pin main power connectors, 872-874
ATX12V 2.x 24-pin, 877-879
backward/forward compatibility, 885-886
Dell proprietary ATX design, 887
maximum power-handling capabilities, 875-876
Molex Mini-Fit Jr. power connectors, 874-875
PCG (Platform Compatibility Guide), 881
VRM (voltage regulator module), 879-880
specification, 172
Audacity, 682-693
audio
amplitude, 680
CDs. See CDs
explained, 679-680
frequency response, 680
front panel audio connector pinout, 236
headphones, 699
integrated audio chipsets, 694
microphones, 700-701
Microsoft Windows audio support, 682
3D gaming standards, 684-685
core audio APIs, 683-684
DirectX, 683
legacy audio support, 685-686
optimizing system for, 932
pitch, 680
POST audio error codes, 977
POST beep codes
AMI BIOS, 978-979
Award BIOS/Phoenix FirstBIOS, 979
IBM BIOS, 984
IBM/Lenovo, 987-989
Phoenix BIOS 4 and later, 983-984
Phoenix BIOS 486 and earlier, 981-983
sampling, 534, 681-682
SNR (signal-to-noise ratio), 681
sound cards
AdLib, 682
choosing, 940
connectors, 686-689
data compression, 692-693
drivers, 693
history of, 682
integrated audio chipsets, 694
MIDI support features, 691
monophonic/stereophonic, 691
signal processing methods, 688
Sound Blaster, 682
Sound Blaster Pro, 682
sound production features, 693
troubleshooting, 694
USB-based audio processors, 689-690
volume control, 690-691
speakers
amplification, 698
DBB (dynamic bass boost), 699
explained, 698
frequency response, 698
interference, 699
satellite speakers, 699
sleep feature, 699
surround sound, 699-700
total harmonic distortion, 698
volume control, 699
watts, 698
total harmonic distortion, 680
troubleshooting, 1027
advanced features, 697
with Device Manager, 698
low volume, 695-696
no sound, 695
problems playing specific file formats, 696
scratchy sound, 697
speakers, 696
startup problems, 697
audio data information
CDs, 533
DVDs, 553-554
audio endpoint devices, 683
Audio Interface Wizard, 693
Audio Modem Riser (AMR), 240
AUI (attachment unit interface), 816
AUTOEXEC.BAT file, 997
automated bootable media images, upgrading flash ROM from, 280
automatic drive detection, 966
Automatic Fan Detection setting (Fan Control Configuration menu), 309
Automatic Gain Control (AGC), 556, 687
automatic head parking, 493-494
auto-sensing, 687
auxiliary power connectors (ATX), 876-877
Auxiliary Power setting (Peripheral Configuration menu), 301
aux in sound card connectors, 688
Avant Prime mechanical-switch keyboards, 743
AVCHD (Advanced Video Coding High Definition), 511
average access times of HDDs (hard disk drives), 503
average seek times, 502
AVX (advanced vector extensions), 64
Award BIOS error messages, 322
 POST error codes, 979
 POST onscreen messages, 980-981
Azalia HD Audio, 694
azimuth, 488

Babbage, Charles, 5
Baby-AT motherboards, 158-159
backing plates, 143
backing up CMOS RAM, 276-277
back probing, 915
backup power supply
 standby power supply, 922-923
 UPS (uninterruptible power supply), 923-925
backups of ROM BIOS, 276
backward compatibility
 DVD drives, 580
 motherboard power connectors, 885-886
 SATA (Serial ATA), 398
bad pixels (LCDs), 675-676
Balanced Technology Extended (BTX) motherboards, 164-167
ball-driven mice, 758-759
bandwidth, 42
 buses, 240-245
 cable bandwidth, 778
banks (memory), 351, 356-357
BAPCo SYSmark, 49
Bardeen, John, 6, 11
Base I/O Address (for the Parallel Port) setting (Peripheral Configuration menu), 301
bench testing power supplies
digital infrared thermometers, 916
variable voltage transformers, 917

Berkeley, Edmund C., 19
Berners-Lee, Tim, 8
Berry, Clifford, 10
bidirectional (8-bit) parallel ports, 737
binary digits (bits), 11
binary multiples, prefixes for, 414-415
biometric security, 516
BIOS (basic input/output system)
 backing up, 276
 BIOS dates, 275-276
 boot ROM, 274
 bootstrap loader, 267
capacity limitations, 498-499
choosing, 936
CMOS RAM
 addresses, 285-287
 backing up, 276-277
 configuring with BIOS Setup. See Setup program (BIOS)
definition of, 266-267
diagnostic status byte codes, 287
definition of, 22, 263
error messages
 AMI BIOS messages, 322
 Award BIOS messages, 322
 Compaq BIOS messages, 322
 explained, 319-320
 IBM BIOS messages, 320-321
 MBR boot error messages, 322-324
 Phoenix BIOS messages, 322
BIOS (basic input/output system) explained, 263-266, 936
firmware, 264
flash ROM, upgrading, 277-278
  with automated bootable media images, 280
BIOS Setup executable upgrades, 279-280
emergency flash ROM recovery, 282-285
safety, 282
  with user-created bootable media, 280-281
Windows executable upgrades, 279
write protection, 278
hardware/software, 274
IPL (initial program load) ROM, 274
manufacturers, 273-274
motherboard ROM BIOS, 267
  EEPROM (electronically erasable programmable ROM), 272-273
  EPROM (erasable programmable ROM), 271-272
  flash ROM, 272-273
mask ROM, 270
PROM (programmable ROM), 270-271
ROM hardware, 267-268
ROM shadowing, 269
non-PC ROM upgrades, 272
paragraphs, 268
PnP (Plug and Play), 317
  ACPI (Advanced Configuration and Power Interface), 318-319
device IDs, 318
POST errors. See POST (power on self test)
preboot environment, 287-289
RTC/NVRAM (real-time clock/nonvolatile memory) chips, 266
SATA (Serial ATA) setup, 407
Setup program, 267
  accessing, 292
  additional setup features, 316-317
  Boot Configuration menu, 298
  Boot menu, 314-315
  Chipset Configuration menu, 298-300
  Drive Configuration menu, 302-305
  Event Log Configuration menu, 306-307
  Exit menu, 315-316
  explained, 292-293
  Fan Control Configuration menu, 309
  Floppy Configuration menu, 305-306
  hardware monitoring display, 310
  main menu, 294-295
  Maintenance menu, 293-294
  Memory Configuration menu, 297-298
  PCI Configuration menu, 296
  PCI Express Configuration menu, 296-297
  Peripheral Configuration menu, 301-302
  Power menu, 312-313
  running, 969-971
  Security menu, 311-312
  USB Configuration menu, 308-309
  Video Configuration menu, 307-308
UEFI (Unified Extensible Firmware Interface)
  BIOS limitations, 290-291
  explained, 289-290
  support for, 291-292
upgrading
  advantages of, 274-275
  BIOS versions, 275
  CMOS RAM addresses, 285-287
  CMOS RAM backups, 276-277
  CMOS RAM diagnostic status byte codes, 287
  flash ROM, 277-285
  keyboard controller chips, 277
  obtaining updates, 275
  versions, 275
BIOS RAM checksum error – System halted (error message), 980
BIOS Version setting (BIOS main menu), 295
bits (binary digits), 11
  bit cells, 442
  bit-level ECC (error correction codes), 434
  merge bits, 537
bitsetting, 566
bit-shift translation (CHS), 421-423
black power switch connector wires, 869
blanks, 134
BLER (block error rate), 535
Blinkenlights Archaeological Institute, 19
blocked data with distributed parity, 435
blocked data with double distributed parity, 435
block error rate (BLER), 535
Blue Book standard (CD EXTRA), 576-577
blue power switch connector wires, 869
Blue Ripple Sound, 684
Blue Screen Of Death (BSOD) errors, 989
Bluetooth, 772, 813-814, 833
Blu-ray Disc Founders (BDF), 567
Blu-ray discs, 567-569, 592, 606
Board ID setting (BIOS Maintenance menu), 293
bonding, 73
bootable CDs, creating, 601-602, 606
bootable DVDs, creating, 601-602
Boot Configuration menu (BIOS Setup), 298
Boot menu (BIOS Setup), 314-315
bootmgr.exe, 998
boot process
BIOS boot error messages
AMI BIOS messages, 322
Award BIOS messages, 322
Compaq BIOS messages, 322
explained, 320
IBM BIOS messages, 320-321
Phoenix BIOS messages, 322
BIOS Setup settings, 314-315
bootable CDs, 601-602, 606
boot floppy disks, 601
booting from CD-ROM, 993
DOS, 996-997
explained, 991-992
MBR boot error messages, 322-323
Error loading operating system, 323-324
Invalid partition table, 323
Missing operating system, 324
operating system independent, 992-996, 1024-1025
quiet boots, 275
troubleshooting, 1024, 1031
Windows 8, 998-999
Windows 9x/Me, 997
Windows 2000/XP, 997-998
Windows Vista/7, 998
boot ROM (read-only memory), 274
Boot to Network setting (Boot menu), 314
Boot to Optical Devices setting (Boot menu), 314
Boot to Removable Devices setting (Boot menu), 314
Boot Up Floppy Seek feature (BIOS Setup), 317
bootstrap loader, 267
bootstrap troubleshooting approach, 1023-1024
bouncing keystrokes, 747
boutique heatsinks, 146
boxed processors, 934
branch prediction, 64, 95
branch target buffer (BTB), 95
Brattain, Walter, 6, 11
Break codes, 749
bridges, wireless, 832
brightness (monitors), 659-660
broadband technology
CATV (cable TV)
cable bandwidth, 778
cable modems, 776-778
costs, 779
explained, 776
cellular broadband
3G mobile broadband, 783
4G mobile broadband, 783-784
comparison of access types, 789
DSL (digital subscriber line), 779
ADSL (Asymmetric DSL), 781
availability, 780
CAP (carrierless amplitude/phase), 780
costs, 782-783
DMT (discrete multitone), 780
DSLAM (DSL access multiplexer), 780
how it works, 779-780
low-pass filters, 780
SDSL (Symmetrical DSL), 781
security, 782
self-installing, 781-782
transceivers, 780
VDSL (Very High-Data-Rate DSL), 781
explained, 775-776
ISDN (Integrated Services Digital Network), 787
leased lines, 788
satellite broadband
explained, 784-785
HughesNet, 785
performance issues, 786-787
StarBand, 786
WildBlue, 785-786
service interruptions, 795
speeds, 789
status LEDs, 797
wireless broadband, 783
Broadwater (96x) chipsets, 204-205
brown power switch connector wires, 869
BSOD (Blue Screen Of Death) errors, 989
BTB (branch target buffer), 95
BTS DriverPacks, 408
BTX motherboards, 164-167
buckling spring keyboards, 746
buffers
buffer underruns, 601
TLB (translation lookaside buffer), 60
bugs. See also troubleshooting
    bug checks, 989
    processor bugs, 88
building systems. See system assembly
Bulldozer FX processors, 128-131
bumpless build-up layer (BBUL), 75
burning
    CDs, 541, 600-601
    ROM (read-only memory), 270
burn-in testing, 990-991
BURN-Proof technology, 601
burst EDO (BEDO), 337
bus masters, 60
bus snooping, 60
bus topology, 825
buses, 239, 245
    address buses, 42-44
    AGP (Accelerated Graphics Port), 253
    bandwidth, 240-245
    bus masters, 60
    bus snooping, 60
    definition of, 239
    DIB (Dual Independent Bus) architecture, 65
DMA (direct memory access) channels, 259
DMI (Direct Media Interface), 240
EISA (Extended Industry Standard Architecture), 246, 256
external data buses, 42
HyperTransport bus, 188
identifying, 245
internal data buses, 44
I/O port addresses, 259-260
IRQs (interrupt request channels), 254
    8-bit ISA bus interrupts, 255
16-bit ISA/EISA/MCA bus interrupts, 256-257
Advanced Programmable Interrupt Controller, 258
conflicts, 259
data edges-triggered interrupt sensing, 255
interrupt sharing, 255
maskable interrupts, 255
PCI interrupts, 257-258
PCI IRQ Steering, 255
ISA (Industry Standard Architecture), 245-246, 255-256
local buses, 246-247
MCA (microchannel architecture), 246, 256
NICs (network interface cards), 815
overclocking, 140
PCI (Peripheral Connect Interface), 239, 248-251
    adapter cards, 249
    board configurations, 250-251
    bus types, 249
    interrupts, 257
PCI Express, 239, 251-253
    specifications, 247-248
S-100 bus, 14
    speeds, 333-335
USB. See USB (Universal Serial Bus)
VESA (Video Electronics Standards Association), 247
video memory bus width, 623-624
widths, 26-27
Busicom, 30
busmaster ATA (AT Attachment), 396
busmaster DMA (direct memory access), 397
buttons (mouse), 758
byte mode (parallel ports), 737

C
C1E setting (BIOS Maintenance menu), 293
cable bandwidth, 778
Cable Detected setting (Drive Configuration menu), 303
cable modems, 776-778
cable select (CSEL) signals, 393
cable select (CS) pins, 393-395
cable TV. See CATV (cable TV)
CableLabs Certified cable modems, 776
cables, 816
cable distance limitations, 824
cable-ties, 1002
choosing, 842, 941
FIC (flex interconnect cable), 448
grounding loops, 818
hard drive cables, 497-498
installation, 961-962, 969
keyboard cables, 754
modular cables, 919
PATA (Parallel ATA) I/O cables, 390-392
SATA (Serial ATA), 401-403
testing with DMMs (digital multimeters), 754
Thicknet, 816-817
Thinnet, 817
twisted-pair
cable building, 820-824
    Category 3 cable, 818
    Category 5 cable, 819
    Category 6a cable, 819
    Category 6 cable, 819
cross-over cables, 821
STP (shielded twisted pair), 817-818
UTP (unshielded twisted pair), 817
wiring standards, 820-821
cache
bus snooping, 60
cache controllers, 60
definition of, 53, 330
direct-mapped cache, 59
explained, 329, 936-937
fully associative mapped cache, 59
hard disk drive cache programs, 503-504
hits/misses, 330
Level 1, 54, 330
cache operation, 54-56
importance of, 54
Pentium-MMX improvements, 62
Level 2, 56, 330
Level 3, 56, 331
performance and design, 57-59
set associative cache, 59
speed, 60
TLB (translation lookaside buffer), 60
write-back cache, 370
write-through cache, 60
cache controllers, 60
caddy load mechanism (CD/DVD drives), 599
Cady, Walter G., 136
calculating
power consumption, 901-903
video RAM, 622-623
calculators
9100A electronic calculator (Hewlett-Packard), 20
IBM701 Defense Calculator, 439
CAM ATA (Common Access Method ATA), 379
Canadian Standards Agency (CSA) certifications, 900
Cannon Electric, 689
Cannon, James H., 689
cannon plugs, 689
capacitive keyswitches, 746
capacity
ATA drive capacity limitations, 413-414
2.1 GB barrier, 423
2.2 TB barrier, 432-434
4.2 GB barrier, 423-425
8.4 GB barrier, 427-428
137 GB barrier and beyond, 429-430
BIOS commands versus ATA commands, 418-419
BIOS limitations, 415-416
CHS bit-shift translation, 421-423
CHS/LBA conversions, 417-418
CHS limitations, 419-421
CHS versus LBA, 416-417
GPT (GUID Partition Table), 432-434
LBA-assist translation, 425-427
table of, 414
CD-R discs, 541
CDs, 526, 536-537
DVDs, 555-558
flash memory cards, 518
HDDs (hard disk drives), 462-463
BIOS limitations, 498-499
operating system limitations, 499-500
magnetic storage, 455-456
CAP (carrierless amplitude/phase), 780
card readers, 520-521
care and maintenance. See also troubleshooting
CD/DVD drives, 600
CDs/DVDs, 527, 606-607
cleaning. See cleaning keyboards, 754-755
keyswitches, 744
mice, 765
monitors, 672-673
power-protection systems
backup power, 922
explained, 919-921
line conditioners, 922
phone line surge protectors, 922
surge protectors, 921
preventative maintenance
active/passive, 1011
cleaning. See cleaning dust, 1020-1021
heating and cooling, 1017
operating environment, 1016
pollutants, 1020-1021
power cycling, 1017-1018
power-line noise, 1018-1019
RFI (radio-frequency interference), 1019-1020
static electricity, 1018
tool/supply vendors, 1000
weekly and monthly checklists, 1011-1012
safety, 1003-1004
System Restore, 1012
tools, 999-1000
2 ½” ATA drive cables and adapters, 1003
3 ½” drive enclosure, 1003
cleaning materials, 1002
data transfer cables and adapters, 1003
DMMs (digital multimeters), 1002, 1005-1007
electrical testing equipment, 1005
electric screwdrivers, 1002, 1009
ESD (electrostatic discharge) protection kits, 1003
files, 1002
flashlights, 1002
hemostats, 1002
infrared thermometers, 1010
lithium coin cell batteries, 1003
logic probes, 1007-1008
loopback connector, 1005
markers/pens, 1002
memory testers, 1008-1009
needle-nose pliers, 1002
nut drivers, 1000
nylon cable-ties, 1002
outlet testers, 1008
parts grabbers, 1000-1011
POST crds, 1002
PS/2 Y adapter, 1003
screwdrivers, 1000
spare parts, 1003
temperature probes, 1010
Torx drivers, 1001
tweezers, 1000
USB/FireWire cable adapter, 1003
vises/clamps, 1002
Windows 98/98 SE or Me Startup floppy, 1002
Windows 98 2000/XP bootable CD, 1002
wire cutters, 1002
wire strippers, 1002
carrierless amplitude/phase (CAP), 780
CAS (column address strobe) latency, 335
cases, 933-934
  cover assembly, 969
definition of, 28
  mounting motherboards in, 953-956
  no-tool, 1001
Casper's Electronics, 271
Cassette BASIC, 321
Category 3 cables, 818
Category 5 cables, 819
Category 6 cables, 819
Category 6a cables, 819
CATV (cable TV)
  cable bandwidth, 778
  cable modems, 776-778
costs, 779
  explained, 776
CAV (constant angular velocity) technology, 593
CCleaner, 1012
CD audio connectors, 238
CD-DA, 571
CD drives, 526. See also CD drives
  access times, 598
  bootable CDs, 606
  booting, 601, 993
  buffers/cache, 598
  buffer underruns, 601
  CAV (constant angular velocity) technology, 593
  choosing, 939
  CLV (constant linear velocity) technology, 593-595
data transfer rates, 593
definition of, 28
disc read failures, 602-605
disc write failures, 604
disc drive sealing, 600
disc read errors, 603-605
disc write errors, 604
DRM (digital rights management), 589
drives, 526, 536-537
care and handling, 527
care and maintenance, 606-607
copy protection, 588-589
disc read errors, 603-605
disc write errors, 604
explained, 539
For Music Use Only discs, 588
  media color, 541-542
  media recording speed ratings, 543
CD Roller, 586
CD-ROM discs. See CDs
CD-ROM drives. See CD drives
CD-R discs, 543-545
copy protection, 588-589
disc read errors, 603-605
disc write errors, 604
DRM (digital rights management), 589
drives, 526, 536-537
care and handling, 527
care and maintenance, 606-607
CD-DA, 571
troubleshooting, 1033
  self-cleaning lenses, 600
table of CD-ROM drive speeds and transfer rates, 595
troubleshooting, 1033
disc read failures, 602-605
disc write failures, 604
problems burning discs with Windows built-in recording, 605
slow drive speeds, 604-605
CD-E. See CD-RW discs
CD EXTRA, 576-577
CD-R discs
capacity, 541
construction and technology, 540-541
copy protection, 588-589
disc read errors, 603-605
DRM (digital rights management), 589
explained, 539
For Music Use Only discs, 588
media color, 541-542
media recording speed ratings, 543
CDs. See also CD drives
audio data information, 533
Blue Book standard (CD EXTRA), 576-577
bootable CDs, 601-602, 606
burning, 600-601
capacity, 526, 536-537
care and handling, 527
care and maintenance, 606-607
CD-DA, 571
CD-R
  capacity, 541
  construction and technology, 540-541
  disc read errors, 603-605 explained, 539
  media color, 541-542
  media recording speed ratings, 543
CD-ROM, 571-572
CD-RW, 543-545
  disc read errors, 603-605
  disc write errors, 604 explained, 539
CD TEXT discs, 534-535
construction and technology, 527
copy protection, 536, 588-589
DRM (digital rights management), 589
DualDisc, 578
EFM data encoding, 537-539
file systems, 582
  HFS (Hierarchical File System), 586
  High Sierra, 583
  ISO 9660, 583-584
  Joliet, 584-585
  Rock Ridge, 586
UDF (Universal Disk Format), 585-586
form factor, 526
For Music Use Only discs, 588
frames, 533
history of, 526-527
hub clamping area, 530
Labelflash direct disc labeling system, 602
lands, 529
lead-in, 531
lead-out, 531
LightScribe direct disc labeling system, 602
mass production, 527-529
Mount Rainier standard, 586-587
multisession recording
  DAO (Disc-at-Once) recording, 573
  packet writing, 573-575
  Track-at-Once, 573
Orange Book standard, 572
PCA (power calibration area), 531
Photo CD, 575
Picture CD, 576
pits, 529
PMA (power memory area), 531
program area, 531
read errors, 535-536
ripping, 587-588
sampling rates, 534
Scarlet Book standard (SA-CD), 577-578
sectors, 533, 572
subcode bytes, 534
Super Video CDs, 576
table of CD formats, 570-571
technical parameters, 532
tracks, 530-531
troubleshooting
  disc read failures, 602-605
  disc write failures, 604
  problems burning discs with Windows built-in recording, 605
virgin CDs, 540
White Book standard (Video CD), 576
Windows 2000/XP bootable CD, 1002
CD TEXT discs, 534-535
Celeron 4 chipsets
  ATI chipsets, 216
  Intel 96x series, 204-205
  Intel 915 family, 202-203
  Intel 925X family, 203
  Intel 945 Express family, 203
  Intel 955X, 204
  Intel 975X, 204
  Intel chipsets reference tables, 196-202
  NVIDIA, 216-217
  SiS chipsets, 215
  ULi chipsets, 215-216
  VIA chipsets, 216, 226
Celeron processors, 96, 100-101
cell phones, tethering, 795
cells, bit cells, 442
cellular broadband
  3G mobile broadband, 783
  4G mobile broadband, 783-784
central processing units (CPUs). See specific processors (for example, Pentium)
central switch (CS), 780
CFX12V power supply, 860, 863
chassis
  chassis intrusion connectors, 237
definition of, 28
  thermally advantaged chassis cooling fans, 149
  maximum heatsink inlet temperatures, 150
  processor ducts, 151
  specifications, 150-151
Chassis Intrusion setting
  (Security menu), 311
checkpoint codes (POST), 977
chemical cleaners, 1013-1014
Chernobyl virus, 278
Cherry Corporation G8x-series keyboards, 745
chip creep, 346
chip on ceramic (COC) technology, 448

CD-ROM, 571-572
CD-RW, 543-545
  disc read errors, 603-605
  disc write errors, 604
  explained, 539
CD TEXT discs, 534-535
construction and technology, 527
copy protection, 536, 588-589
DRM (digital rights management), 589
DualDisc, 578
EFM data encoding, 537-539
file systems, 582
  HFS (Hierarchical File System), 586
  High Sierra, 583
  ISO 9660, 583-584
  Joliet, 584-585
  Rock Ridge, 586
UDF (Universal Disk Format), 585-586
form factor, 526
For Music Use Only discs, 588
frames, 533
history of, 526-527
hub clamping area, 530
Labelflash direct disc labeling system, 602
lands, 529
lead-in, 531
lead-out, 531
LightScribe direct disc labeling system, 602
mass production, 527-529
Mount Rainier standard, 586-587
multisession recording
  DAO (Disc-at-Once) recording, 573
  packet writing, 573-575
  Track-at-Once, 573
Orange Book standard, 572
PCA (power calibration area), 531
Photo CD, 575
Picture CD, 576
pits, 529
PMA (power memory area), 531
program area, 531
read errors, 535-536
ripping, 587-588
sampling rates, 534
Scarlet Book standard (SA-CD), 577-578
sectors, 533, 572
subcode bytes, 534
Super Video CDs, 576
table of CD formats, 570-571
technical parameters, 532
tracks, 530-531
troubleshooting
  disc read failures, 602-605
  disc write failures, 604
  problems burning discs with Windows built-in recording, 605
virgin CDs, 540
White Book standard (Video CD), 576
Windows 2000/XP bootable CD, 1002
CD TEXT discs, 534-535
Celeron 4 chipsets
  ATI chipsets, 216
  Intel 96x series, 204-205
  Intel 915 family, 202-203
  Intel 925X family, 203
  Intel 945 Express family, 203
  Intel 955X, 204
  Intel 975X, 204
  Intel chipsets reference tables, 196-202
  NVIDIA, 216-217
  SiS chipsets, 215
  ULi chipsets, 215-216
  VIA chipsets, 216, 226
Celeron processors, 96, 100-101
cell phones, tethering, 795
cells, bit cells, 442
cellular broadband
  3G mobile broadband, 783
  4G mobile broadband, 783-784
central processing units (CPUs). See specific processors (for example, Pentium)
central switch (CS), 780
CFX12V power supply, 860, 863
chassis
  chassis intrusion connectors, 237
definition of, 28
  thermally advantaged chassis cooling fans, 149
  maximum heatsink inlet temperatures, 150
  processor ducts, 151
  specifications, 150-151
Chassis Intrusion setting
  (Security menu), 311
checkpoint codes (POST), 977
chemical cleaners, 1013-1014
Chernobyl virus, 278
Cherry Corporation G8x-series keyboards, 745
chip creep, 346
chip on ceramic (COC) technology, 448
chips

CISC (Complex Instruction Set Computer), 61
EEPROM (electronically erasable programmable ROM), 272-273, 277-285
EPROM (erasable programmable ROM), 271-272
flash ROM, 272-273
keyboard controller chips, upgrading, 277
OTP (one-time programmable) chips, 270
RISC (Reduced Instruction Set Computer), 61
RTC/NVRAM (real-time clock/nonvolatile memory) chips, 266
Super I/O chips, 228

Chips and Technologies, 182
Chipset Configuration menu (BIOS Setup), 298-300
chipsets, 181
56Kbps modems, 792
82C206 chips, 182
82C836 SCAT (Single Chip AT) chipsets, 182
AMD, 217
AMD 690 series, 221
AMD 700 series, 221-222
AMD 800 series, 222
AMD 900 series, 223-225
AMD 8000 (8151), 219
AMD A series, 225
AMD (ATI) 480x and 500 series, 220
reference table, 217-218
ATI, 190, 216
AT motherboards, 182
CS8220 chipset, 182
databooks, 936
documentation, 262
explained, 935-936
history and development, 181-183
hub architecture, 187-188
HyperTransport interconnects, 188-190
industry control of, 24
integrated video/motherboard chipsets, 611
chipsets with integrated video for 64-bit AMD processors, 614-616
graphics chip market share, 612
Intel chipset integrated video, 612-613
third-party chipsets with integrated video for Intel processors, 614
Intel, 183-184
3x series, 205-208
4x series, 206-208
5x series, 208-211
6x series, 211-213
7x series, 213-215
96x series, 204-205
386/486 chipsets, 190
915 family, 202-203
925X family, 203
945 Express family, 203
955X, 204
975X, 204
82350 chipsets, 190
Extreme Graphics Architecture, 185
model numbers, 184
North Bridge, 185-187
Pentium 4 chipsets, 196-202
Pentium chipsets, 190-191
Pentium Pro chipsets, 192-195
South Bridge, 186-187
Super I/O chips, 186
NEAT (New Enhanced AT) CS8221 chipset, 182
NVIDIA Technologies, 216-217, 227
PC/XT motherboards, 182
SIS (Silicon Integrated Systems), 215
Athlon/Duron chipsets, 227
MuTIOL architecture, 189
Super I/O chips, 228
ULi, 215-216
VIA Technologies, 189, 216, 226
video adapter chipsets identifying, 619-620
video processor, 619

CHS (cylinder head sector) addressing
2.1 GB barrier, 423
4.2 GB barrier, 423-425
528 MB barrier, 419-421
CHS bit-shift translation, 421-423
CHS/LBA conversions, 417-418
compared to LBA (logical block address), 416-417

CIH virus, 278
Cinavia, 591
CIRC (cross-interleave Reed-Solomon code), 535
Cirque Glidepoint, 768-769
CISC (Complex Instruction Set Computer) chips, 61
citrus-based cleaners, 1013
clamps, 1002
Clean Boot CD package, 281
“clean room” approach to reverse-engineering software, 22
cleaning, 1012. See also care and maintenance
CD/DVD drives, 600
CDs, 606
chemical-freeze sprays, 1014
compressed air, 1014
collectors, 1015-1016
contact cleaners/lubricants, 1013
contacts, 1015-1016
disassembly and cleaning tools, 1013
erasers, 1015
keyboards, 755-756, 1016
keyswitches, 744
mice, 765, 1016
swabs, 1015
system disassembly, 1015
vacuum cleaners, 1014
Clear All DMI Event Log setting
(Event Logging menu), 306
Clear All Passwords setting
(BIOS Maintenance menu), 293
Clear Trusted Platform Module setting
(BIOS Maintenance menu), 293
Clear User Password setting
(Security menu), 311
ClickLock feature
(IntelliMouse), 763
clients, 933
client/server networks, 802-804
Clock program (AMD), 138
clocks, 136-138. See also over-clocking
clock signals, 49, 451
clock speed, 49-53, 333
closed loop feedback mechanism, 488
cloud-based storage, 522-523
clusters, 480
CLV (constant linear velocity) technology, 593-595
CMOS (Complementary Metal Oxide Semiconductor), 12
CMOS battery failed (error message), 980
CMOS checksum error – Defaults loaded (error message), 980
CMOS RAM addresses, 285-287
backing up, 276-277
batteries
modern CMOS batteries, 925-927
obsolete/unique CMOS batteries, 927-928
troubleshooting, 928
configuring with BIOS Setup. See Setup program (BIOS)
definition of, 266-267
diagnostic status byte codes, 287
CmosPpwd, 277
CMOSrest, 277
CMOSsave, 277
CNR (Communications and Networking Riser), 240
coaxial cables
Thicknet, 816-817
Thinnet, 817
coaxial PDIF sound card connectors, 688
COC (chip on ceramic) technology, 448
code-free DVD players, 592
code names for processors, 88-89
color coding
ATX motherboards, 172
power switch connectors, 869
Colossus, 5, 10
column address strobe (CAS) latency, 335
combo adapters, 815
commands. See specific commands
commercial diagnostic software, 990-991
Common Access Method ATA
(CAM ATA), 379
communication ports, 733
Communications and Networking Riser (CNR), 240
compact disc read-only memory. See CDs; CD drives
CompactFlash, 509
compact form factor (CFX12V) power supply, 860, 863
Compaq
ATA. See ATA (AT Attachment)
BIOS error messages, 322
reverse engineering of IBM software, 21-22
compatible mode (parallel ports), 737
Complementary Metal Oxide Semiconductor (CMOS), 12
Complex Instruction Set
Computer (CISC) chips, 61
Compliance Test Pattern setting
(PCI Express Configuration menu), 297
component benchmarks, 49
COM ports. See serial ports
composite ferrite heads, 444
compressed air, 755, 1014
compression of sound card data, 692-693
computer history. See history of computers
compute shaders (DirectX), 647
CONFIG.SYS file, 996
configuration documentation of, 946
hardware-assisted virtualization support, 69
HDDs (hard disk drives)
automatic drive detection, 966
explained, 962-963
network software, 842-843
parallel ports, 738
PATA (Parallel ATA), 393-395
power supply, 958-961
processor operating voltages, 87
SATA (Serial ATA), 407
serial ports, 733-734
SSDs (solid state drives), 962-963
Configure SATA as setting (Drive Configuration menu), 303

conflicts, IRQs (interrupt request channels), 259

connectors
- ATA (AT Attachment), 385
- cleaning procedures, 1015-1016
- floppy power connectors, 888-889
- hard drive connectors, 497-498
- keyboard/mouse interface connectors
  - hybrid mice, 762
  - keyboard connectors, 751-753
  - PS/2 mouse port, 761
  - serial interface, 760-761
  - troubleshooting, 755
  - USB (Universal Serial Bus), 762
- motherboard connectors, 228-234
  - alternative single-row front panel connector pinouts, 231
  - AMR (Audio Modem Riser), 240
  - ATAPI-style line-in connectors, 238
  - battery connector, 237
  - CD audio connectors, 238
  - chassis intrusion connectors, 237
  - CNR (Communications and Networking Riser), 240
  - front panel audio connector pinout, 236
  - front panel switch/LED connector pinouts, 230
  - IEEE 1394 (FireWire/i.LINK) connector, 235
  - infrared data front panel connector pinout, 237
- LED and keylock connectors, 237
- microprocessor fan power connectors, 239
- power LED indications, 231
- speaker connectors, 237
- telephony connectors, 238
- USB 1.1/2.0 USB header connector pinout, 233
- USB 3.0 header connector pinout, 234-235
- Wake on LAN connectors, 238
- Wake on Ring connectors, 238
- motherboard power connectors
  - 4-pin +12V power connectors, 882-883
  - 4-pin to 8-pin +12V power connectors, 884-885
  - 8-pin +12V power connectors, 883-884
- AT, 870-872
- ATX12V 2.x 24-pin, 877-879
- ATX/ATX12V 1.x, 872-877
- backward/forward compatibility, 885-886
- Dell proprietary ATX design, 887
- explained, 870
- PCG (Platform Compatibility Guide), 881
- power switch connectors, 866-869
- VRM (voltage regulator module), 879-880
  - parallel port connectors, 734-735
- PATA (Parallel ATA) I/O connectors, 387-390
- PCI Express x16 Graphics Power connectors, 890-893
- peripheral power connectors, 887-888
- PS/2-type connector, 159
- SATA power connectors, 401-403, 889
- sound card connectors, 686-689
  - analog RCA, 689
  - aux in, 688
  - coaxial PDIF, 688
  - HDMI (High Definition Multimedia Interface), 688
  - line in sound card connectors, 687
  - line out sound card connectors, 687
  - microphone in connectors, 687
  - MIDI in/out, 688
  - mono in connectors, 687
  - optical SPDIF out, 688
  - rear out sound card connectors, 687
  - socketed Op Amp chips, 689
  - world clock I/O, 689
  - XLR input/output, 689
- USB (Universal Serial Bus) connectors, 710-713
  - Mini/Micro A/B connectors, 712
  - mini plugs and sockets, 711
  - Series A/B connectors, 712
  - wired network adapter connectors, 815-816

Conner Peripherals, Inc. 2.5" drives, 465

constant angular velocity (CAV) technology, 593

constant linear velocity (CLV) technology, 593-595

constant voltage power supply, 845

consumption of power supply, calculating, 901-903
contact cleaners/lubricants, 1013-1016
contact start stop (CSS) design, 468
content scramble system (CSS), 590-591
contrast (monitors), 659-660
collectors. See adapters
conventional memory, 295
conventional memory barrier, 374
converting sector addresses, 417-418
Cooler Master CM Storm keyboards, 757
cooling. See heating/cooling issues
copy protection
CDs, 536, 588-589
DVDs, 589-590
breakability of, 591
Cinavia, 591
CSS (content scramble system), 590-591
ProtectDisc, 591
region codes used by Blu-ray disc, 592
RPC (regional playback control), 591-592
copyright, 21
cordless input devices. See wireless input devices
Core 2 processors
chipsets
Intel 3x series, 205-208
Intel 4x series, 206-208
overview, 108-110
core audio APIs, 683-684
Core i processors (Intel)
chipsets
Intel 5x series, 208-211
Intel 6x series, 211-213
Intel 7x series, 213-215
Intel Atom, 115
Ivy Bridge architecture, 114-115
Nehalem architecture, 110-113
overclocking, 142
Sandy Bridge architecture, 113-114
Core Multiplexing Technology setting (BIOS main menu), 295
cores, unlocking, 139-140
cosmic ray-induced errors, 358
cover assembly (cases), 969
CPC Override setting (Memory Configuration menu), 297
CPP-GMR (current perpendicular-to-the-plane giant magneto-resistive) heads, 447
CPU at nnnn (error message), 980
CPU Fan Control setting (Fan Control Configuration menu), 309
CPU Frequency Multiplier setting (BIOS Maintenance menu), 294
CPU Info program (AMD), 138
CPU Internal Cache/External Cache feature (BIOS Setup), 316
CPU Microcode Update Revision setting (BIOS Maintenance menu), 294
CPU Stepping Signature setting (BIOS Maintenance menu), 294
CPU-Z, 29, 74, 185, 275, 356
CPUs (central processing units). See specific processors (for example, Pentium)
Crashes, head crashes, 468
CRC (cyclical redundancy checking), 385
Creative Labs
OpenAL website, 684
Sound Blaster Pro sound cards, 682
Sound Blaster sound cards, 682
creep, 908
CrossFire, 890-893
CrossFireX, 648-649, 900
cross-interleave Reed-Solomon code (CIRC), 535
crossover UTP (unshielded twisted-pair) cables, 821
CRT (cathode ray tube) monitors
dot pitch, 664
electron guns, 663
persistence, 664
raster, 665
refresh rate, 664-665
refresh rates, 657-659
shadow masks, 664
slotted masks, 664
CrystalDiskInfo, 411
crystals, quartz, 134-136
CS8220 chipset, 182
CS8221 chipset, 182
CSA (Canadian Standards Agency) certifications, 900
CSA Device setting (Chipset Configuration menu), 299
CS (cable select) pins, 393-395
CS (central switch), 780
CSEL (cable select) signals, 393
CSS (contact start stop) design, 468
CSS (content scramble system), 590-591
CST, 369, 1009
current perpendicular-to-the-plane giant magneto-resistive (CPP-GMR) heads, 447
custom PC configurations, 931-933
audio/video editing systems, 932
gaming systems, 932
graphics systems, 931
Data Over Cable Service Interface Specification (DOCSIS) standards, 777
Data sector field, 470
data transfer cables, 1003
data transfer rates. See transfer rates
data zone (DVDs), 550
DB-9 connectors, 760, 815
DB-15 cable (Thicknet), 816-817
DB-25 connectors, 760
DBB (dynamic bass boost), 699
db (decibels), 680
DCMA (Digital Millennium Copyright Act), 590
DC voltages
negative voltages, 847-848
positive voltages
voltage rails, 846-847
voltage regulators, 847
DDC (Display Data Channel), 630-631
DDR DIMMs, 348, 353
DDR SDRAM, 338-340, 621, 936
DDR2 DIMMs, 348, 353
DDR2 SDRAM, 340-342
DDR2 Voltage setting (Chipset Configuration menu), 299
DDR3 DIMMs, 34, 353
DDR3 dual-channel, 80
DDR3 SDRAM, 342-344
DDR3 triple-channel, 82
DDR4 SDRAM, 344-345
DDWG (Digital Display Working Group), 630
dead pixels (LCDs), 675
debouncing keystrokes, 747
decibels (db), 680
decimal-based multiples, prefixes for, 414-415
dedicated servo mechanisms, 492-493
Default Frequency Ratio setting (BIOS Maintenance menu), 294
defered writes, 725
De Forest, Lee, 5, 11
delayed writes, 725
Dell proprietary ATX power connectors, 887
density, areal, 456-458
depot repair, 677
depth cueing, 644
designing systems. See system assembly
Desktop Form Factors website, 935
Desktop Management Interface (DMI), 306
Deutsche Industrie Norm (DIN), 740
development of computers. See history of computers
device drivers. See drivers
Device Power states, 906-908
Device Topology API, 683
Device Wire Adapter (DWA), 717
DHCP (Dynamic Host Configuration Protocol), 835-836
diagnostic status byte codes (CMOS RAM), 287
diagnostic tools. See specific tools
dialup modems. See modems
dial-up networks, 837
DIB (Dual Independent Bus) architecture, 65
dies, 71
differential NRZ (Non Return to Zero), 401
Digi-Key, 1000
digital audio extraction (DAE). See ripping CDs
digital display interfaces
DisplayPort, 636-640
DMS-59, 632
DVI (Digital Video Interface), 630-632
HDMI (High Definition Multimedia Interface), 633-636
overview, 629
Digital Display Working Group (DDWG), 630
digital infrared thermometers, 916
digital light processing (DLP) projectors, 667
digital micromirror device (DMD), 666
Digital Millennium Copyright Act (DCMA), 590
digital multimeters. See DMMs
Digital Research, 16, 22
digital rights management (DRM), 589
digital signal processor (DSP), 688
digital subscriber line. See DSL
digital versatile discs. See DVDs
digital-to-analog converters (DACs), 624, 681
Digital Video Express (DIVX), 580
Digital Video Interface (DVI), 630-632
digitized sound. See Waveform audio
DIMMs (dual inline memory modules), 346, 936
168-pin SDRAM DIMMs, 348
DDR DIMMs, 348, 353
DDR2 DIMMs, 348, 353
DDR3 DIMMs, 349
purchasing, 365
SDR DIMMs, 352
DIN (Deutsche Industrie Norm), 740
DIP (dual inline package) chips, 346
DirectCompute, 617
direct disc labeling systems, 602
direct-mapped cache, 59
Direct Media Interface (DMI), 80, 188, 240
direct memory access. See DMA
direct overwrite, 544
DirectSound wrappers, 684
DirectX, 646-647, 683
disassembly for cleaning, 1015
Discard Changes command (BIOS Exit menu), 316
Disc-at-Once (DAO) recording, 573
disc-stamping operation (CDs), 528
discrete multitone (DMT), 780
discs. See CDs; DVDs
DiskT@2, 602
DISK BOOT FAILURE (error message), 322
disk drive power connectors, 887-888
disk sweep, 491
Diskette Controller setting (Floppy Configuration menu), 306
Diskette Write Protect setting (Floppy Configuration menu), 306
DISKPART command, 481
disks, floppy. See floppy disks
Display Data Channel (DDC), 630-631
display interfaces
digital display interfaces, 629
DisplayPort, 636-640
DMS-59, 632
DVI (Digital Video Interface), 630-632
HDMI (High Definition Multimedia Interface), 633-636
overview, 626-627
TV display interfaces, 641-642
VGA (Video Graphics Array), 627-629
DisplayMate, 671
DisplayPort, 636-640
Display Power Management Signaling (DPMS), 660-661
Display Setup Prompt setting (Boot Configuration menu), 298
displays. See monitors
Display switch is set incorrectly (error message), 980
distributed parity, blocked data with, 435
DIVX (Digital Video Express), 580
d-limonene, 1013
DLP (digital light processing) projectors, 667
DMA (direct memory access)
busmaster DMA, 397
channels, 259
multiword, 397
singleword, 396-397
UDMA (Ultra-DMA), 383-386, 397
DMA Mode setting (Drive Configuration menu), 303
DMD (digital micromirror device), 666
DMI (Desktop Management Interface), 306
DMI (Direct Media Interface), 80, 188, 240
DMI Event Log setting (Event Logging menu), 306
DMMs (digital multimeters), 754, 913, 1002, 1005-1007
back probing, 915-916
buying tips, 914-915
measuring voltage with, 915-916
DMS-59, 632
DNT (digital multitone), 780
DOCSIS (Data Over Cable Service Interface Specification) standards, 777
Dolby Digital surround sound, 700

doping, 11, 70

DOS operating system
boot process, 996-997
drive limitations, 431
DOS extenders, 46
DPMI (DOS protected mode interface), 46
free and open-source DOS versions, 22
licensing, 22

dot pitch, 654, 664
dots per inch (DPI), 758
double data rate SDRAM. See DDR SDRAM
Double-Density recording, 451-452
double distributed parity, blocked data with, 435
double-sided memory modules, 346
DPI (dots per inch), 758
DPMI (DOS protected mode interface), 46
DPMS (Display Power Management Signaling), 660-661

drains (MOSFETs), 12

DRAM (dynamic RAM)
compared to SRAM, 329
DDR SDRAM (double data rate SDRAM), 338-340
DDR2 SDRAM (double data rate 2 SDRAM), 340-342
DDR3 SDRAM (double data rate 3 SDRAM), 342-344
DDR4 SDRAM (double data rate 4 SDRAM), 344-345
explained, 327-329
FPO DRAM (Fast Page Mode DRAM), 335-336
RDRAM (Rambus DRAM), 345
SDRAM (synchronous DRAM), 337-338

dual-channel memory, 356-357
dual-core processors. See multicore processors
DualDisc, 578
dual-drive PATA (Parallel ATA) configuration, 393-395
dual-GPU scene rendering
AMD CrossFireX, 648-649
AMD Eyefinity, 650
NVIDIA SLI, 648
dual-head graphics adapters, 667

Dual Independent Bus architecture (DIB), 65
dual inline memory modules. See DIMMs
dual inline package (DIP) chips, 346
dual-link DVI (Digital Video Interface), 630
dual rank memory modules, 346
dual-speed switches, 829

Dualview, 667

Duron processors
chipsets, 185
nForce/nForce2, 227
reference table, 217-218
SiS chipsets, 227
overview, 118
dust, 1014, 1020-1021

DVD-5 discs, 555
DVD-9 discs, 555
DVD-10 discs, 556
DVD-18 discs, 556

DVD CCA (DVD Copy Control Association), 589
DVD Copy Control Association (DVC CCA), 589

DVD drives. See also DVDs
access times, 598
booting from floppy disk, 601
buffers/cache, 598
choosing, 939
compatibility, 580
definition of, 28
DMA and Ultra-DMA, 598
drive sealing, 600
DVD Multi specification, 566-567
firmware updates, 607-608
interfaces, 598-599
loading mechanisms, 599-600
MultiAudio specification, 547
MultiPlay specification, 547
MultiRead specifications, 545-547
self-cleaning lenses, 600
speed, 595-597
troubleshooting, 1033
disc read failures, 602-605
disc write failures, 604
problems burning discs with Windows built-in recording, 605
slow drive speeds, 604-605

DVD Forum, 548
DVD Multi specification, 566-567
DVD-R, 562-563
DVD+R, 564-566
DVD-RAM, 560-562
DVD-R DL, 563
DVD+R DL, 566
DVD-RW, 563-564
DVD+RW, 564-566
DVD+RW Alliance, 548
DVD-Video, 548

DVDs. See also DVD drives
audio data information, 553-554
bootable DVDs, 601-602
capacity, 555-558
care and maintenance, 606-607
construction and technology, 549-550
copy protection, 589-590
breakability of, 591
Cinavia, 591
CSS (content scramble system), 590-591
region codes used by Blu-ray disc, 592
RPC (regional playback control), 591-592
copy protectionProtectDisc, 591
data zone, 550
DIVX (Digital Video Express), 580
DVD-5, 555
DVD-9, 555
DVD-10, 556
DVD-18, 556
DVD Forum, 548
DVD-R, 562-563
DVD+R, 564-566
DVD-RAM, 560-562
DVD-R DL, 563
DVD+R DL, 566
DVD-RW, 563-564
DVD+RW, 564-566
DVD+RW Alliance, 548
DVD-Video, 548
EFM+ data encoding, 558-559
error handling, 554-555
explained, 547-548
frames, 553-554
HD-DVD, 569-570
history of, 548
hub clamping area, 550
Labelflash direct disc labeling system, 602
lead-in zone, 550
lead-out zone, 550
LightScribe direct disc labeling system, 602
media compatibility, 560
OTP (opposite track path) construction, 556-557
playing on PCs, 581
PTP (parallel track path) construction, 556-557
sectors, 553-554
table of DVD formats and standards, 578-580
table of recordable DVD standards, 559
technical parameters, 551-553
tracks, 550-551
troubleshooting
disc read failures, 602-605
disc write failures, 604
problems burning discs with Windows built-in recording, 605
DVI (Digital Video Interface), 630-632
DVI-D (integrated) connector, 632
DVI-I (integrated) connector, 631
DVMT Mode setting (Video Configuration menu), 307
Dvorak, August, 754
Dvorak Simplified Keyboard (DSK), 754
DWA (Device Wire Adapter), 717
D. W. Electrochemicals, Stabilant 22a, 744
DXDIAG utility, 697
dynamic bass boost (DBB), 699
dynamic execution
dataflow analysis, 65
multiple branch prediction, 64
speculative execution, 65
Dynamic Host Configuration Protocol (DHCP), 835-836
dynamic RAM. See DRAM
Dynamic shader linkage (DirectX), 647
EarthLink, 795

EAX (environmental audio extensions), 685

ECC (error correcting code), 360-361, 434, 472-473

ECC Event Logging setting (Event Logging menu), 306

ECC sector field, 470

ECHS. See bit-shift translation

Eckert, John P., 6, 10

economy interconnection (EI) connectors, 888

ECP (Enhanced Capabilities) parallel ports, 737-738

ECP Mode Use DMA setting (Peripheral Configuration menu), 301

ED (extra-high density) floppy format, 459

EDD (Enhanced Disk Drive) specifications, 421

data encoding, 537-539

endecs, 378, 450

EndpointVolume API, 683

Energy 2000 standard, 661

Energy Lake setting (Power menu), 313

Energy Star standard, 660

ENERGY STAR systems, 904

Englebart, Douglas, 757

Enhanced 3DNow! technology, 64

Enhanced 101-key keyboards, 739-740

Enhanced Capabilities (ECP) parallel ports, 737-738

Enhanced Disk Drive. See EDD

Enhanced Parallel Port (EPP), 737

ENIAC (Electrical Numerical Integrator and Calculator), 10

electronic computers, 5

electronics, 440

electron guns (CRT), 663

electronically erasable programmable ROM (EEPROM), 272-273

electroforming, 527

electromagnetism, 440

electron guns (CRT), 663

electronically erasable programmable ROM (EEPROM), 272-273

electronic computers, 5

electrostatic discharge (ESD) protection, 945, 1003

EL Torito support, 601-602

energy savings, 282

Windows executable upgrades, 279

erasers, 272, 1015

ergonomic keyboards, 754

Ergonomic Resources, 743, 754

Error loading operating system (error message), 323-324
error messages. See also troubleshooting

ACPI (Advanced Configuration and Power Interface) error codes, 319

BIOS error messages
AMI BIOS, 322
Award BIOS, 322, 984-987
Award BIOS/Phoenix FirstBIOS, 980-981
Compaq BIOS, 322 explained, 319-320
IBM BIOS, 320-321
Phoenix BIOS, 322

CD read errors, 535-536
DVD errors, 554-555

Fatal Exception errors, 1026

MBR boot error messages, 322-323
Error loading operating system, 323-324
Invalid partition table, 323
Missing operating system, 324
memory errors, 370
Missing operating system, 1031
POST errors. See POST (power on self test)
soft errors, 328
STOP errors, 1025
eSATA (external SATA), 404-405
eSATAp (Power Over eSATA), 405-407
eSATA USB Hybrid Port (EUHP), 405

ESD (electrostatic discharge) protection, 945, 1003

Estridge, Don, 15

Ethernet, 805
10 Gigabit Ethernet (10GBASE-T), 807 cables. See cables development of, 6
explained, 806

Fast Ethernet, 806
Gigabit Ethernet, 806-807 hubs, 828-829
switches, 827-828, 842 address storing, 828 compared to hubs, 828-829 dual-speed, 829 managed/unmanaged, 828 placement of, 830-831 ports, 830 power-saving features, 829

Wi-Fi (Wireless Fidelity)
802.11a standard, 810
802.11ac standard, 812
802.11b standard, 808-810
802.11g standard, 810-811
802.11n standard, 811-812 access points, 831
DHCP support, 835-836 explained, 807-808 network speeds, 813
NICs (network interface cards), 832
point-to-point topology, 833
security, 833-835
signal boosters, 832
specialized antennas, 832
star topology, 833
users per access point, 836
wireless bridges, 832
wireless repeaters, 832

EUHP (eSATA USB Hybrid Port), 405

Event Log Capacity setting
(Event Logging menu), 306

Event Log Configuration menu
(BIOS Setup), 306-307

Event Log Validity setting
(Event Logging menu), 307

evolution of computers. See history of computers

exFAT, 480, 520

Exit Discarding Changes command
(BIOS Exit menu), 316

Exit menu (BIOS Setup), 315-316

Exit Saving Changes command
(BIOS Exit menu), 316
expansion cards, 969
extended ATX motherboards, 172
extended ATX power supply, 860

Extended Burn-in Mode setting
(Chipset Configuration menu), 299

Extended Configuration setting
(Chipset Configuration menu), 299
extended data out RAM (EDO RAM), 336-337

Extended Industry Standard Architecture (EISA) buses, 246, 256
extended memory, 295

extenders (DOS), 46
external cache, 330
external data buses, 42
external hubs, 706
external SATA (eSATA), 404-405
external speakers. See speakers extra-high density (ED) floppy format, 459
extranets, 801

Extreme Graphics Architecture, 185

Eyefinity, 617, 650

F

F7 BIOS Flash Update, 279
Face Wizard, 275
Faggin, Frederico, 30-31

Failsafe Watchdog setting (BIOS Maintenance menu), 294
failures (memory)
  hard fails, 357
  soft errors, 357-359
failures (power), troubleshooting, 911-912
  diagnostic procedures, 912
  digital infrared thermometers, 916
  DMMs (digital multimeters), 913
    back probing, 915-916
    buying tips, 914-915
    measuring voltage with, 915-916
  inadequate cooling, 913
  overloaded power supply, 912-913
  variable voltage transformers, 917
Fan Control Configuration menu (BIOS Setup), 309
fans, 149
  BIOS Setup settings, 309
  power connectors, 239
Faraday, Michael, 440
Fastchip, 272
Fast Ethernet, 806
Fast Mode parallel ports, 737
Fast Page Mode DRAM (FPO DRAM), 335-336
Fast Startup mode, 998-999
FAT32 (file allocation table, 32-bit), 480
FAT64, 480, 520
FAT (file allocation table), 480
fatal errors, 976, 1026
fathers (CDs), 527
fault tolerance
  ECC (error correcting code), 360-361
  parity checking, 359-360
FCC (Federal Communications Commission) certifications, 900
FC-PGA (flip-chip pin grid array), 75
FDDI (Fiber Distributed Data Interface), 826
FDI (Flexible Display Interface), 80
Federal Communications Commission (FCC) certifications, 900
Femto air bearing sliders, 449-450
ferrite read/write heads, 444
FHSS (frequency hopping spread spectrum), 813
Fiber Distributed Data Interface (FDDI), 826
fiber to the curb (FTTC), 781
fiber to the home (FTTH), 781
fiber to the neighborhood (FTTN), 781
fiber to the premises (FTTP), 781
FIC (flex interconnect cable), 448
fields, magnetic, 441-442
Fifth SATA Master setting (Drive Configuration menu), 304
file allocation table. See FAT file systems
  CD file systems, 582
    HFS (Hierarchical File System), 586
    High Sierra, 583
    ISO 9660, 583-584
    Joliet, 584-585
    Rock Ridge, 586
    UDF (Universal Disk Format), 585-586
  exFAT, 480
  FAT (file allocation table), 480
  FAT32 (file allocation table, 32-bit), 480
  for flash memory, 520
  NTFS (Windows NT File System), 480
files
  AUTOEXEC.BAT, 997
  CONFIG.SYS, 998
  hiberfil.sys, 996
  MSDOS.SYS, 996
  Ntbtlog.txt, 998
files (metal), 1002
filters
  air filters, 494-495
  low-pass filters, 780
  polarizing LCD filters, 661
FireWire
  compared to USB, 722-725
  explained, 718
  FireWire 400, 718-719
  FireWire 800, 718-720
  FireWire 3200, 721
  hot-plugging, 725-728
  speed of, 723-725
  tailgates, 384
firmware, 264, 273
  upgrades, 607-608, 619
“First Draft of a Report on the EDVAC” (von Neumann), 6
first-party memory modules, 364
First SATA Master setting (Drive Configuration menu), 304
Fixed Disk Boot Sector setting (BIOS Maintenance menu), 294
fixed disk drives. See HDDs (hard disk drives)
Flash-based SSDs, 512-513
flashlights, 1002
flash memory, 326, 507
  card capacities, 518
  card readers, 520-521
  CompactFlash, 509
  comparison of, 517-519
  development of, 507
  device sizes, 509
  explained, 508-509
  file systems, 520
keychain devices, 507
Lexar Memory Stick Pro, 511
Lexar Memory Stick Pro Duo, 511
MMC (MultiMediaCard), 510
NAND (Not AND), 508
NOR (Not OR), 508
PC Card, 511
ReadyBoost support, 521-522
SD (SecureDigital), 510
SmartMedia, 509, 510
Sony Memory Stick, 510
Sony Memory Stick Micro, 511
Sony Memory Stick XC, 511
speed classes, 519-520
SSD (solid-state drive) applications, 515
definition of, 511
Flash-based SSDs, 512-513
partition alignment, 515
SLC (single-level cell) versus MLC (multilevel cell), 513-514
SSD awareness in Windows, 514
TRIM command, 514-515
virtual SSD (RAMdisk), 512
thumb devices, 507
USB flash drives, 516-517
xD-Picture Card, 511
flash ROM (read-only memory), 272-273
recovering, 282-285
upgrading, 277-278
with automated bootable media images, 280
BIOS Setup executable upgrades, 279-280
safety, 282
with user-created bootable media, 280-281
Windows executable upgrades, 279
write protection, 278
Flat Panel Display-Link (FPD-Link), 629
flat shading, 642
FlexATX motherboards, 174-175
Flex ATX power supply, 864-866
Flexible Display Interface (FDI), 80
flex interconnect cable (FIC), 448
flicker (screen), 664
flicker-free refresh rates, 658
flip-chip pin grid array (FC-PGA), 75
floating point units (math coprocessors), 87
Floppy A setting (Floppy Configuration menu), 306
Floppy Configuration menu (BIOS Setup), 305-306
floppy disks
booting from, 601
ED (extra-high density) floppy format, 459
Windows 98/98SE or Me Startup floppy, 1002
Floppy disks(s) fail (error message), 980
floppy drives, 523. See also magnetic storage
BIOS Setup settings, 305-306
power connectors, 888-889
Flowers, Thomas, 5, 10
fluid dynamic bearings, 496
flux, 442
FM (Frequency Modulation) encoding, 451
FM synthesis, 691
FMA4, 64
foam element keyswitches, 743-744
ForceWare v81.85 (NVIDIA), 648
FORMAT command, 477
form factors
definition of, 933
HDDs (hard disk drives) 1” hard drives, 466
1.8” hard drives, 466
2.5” hard drives, 465
3.5” half-height drives, 465
5.25” drives, 464-465
table of, 463-464
motherboard form factors. See motherboards
power supply form factors
ATX/ATX12V, 852-854
CFX12V, 860, 863
EPS/EPS12V, 858-860
explained, 849-850
Flex ATX, 864-866
LFX12V, 863
proprietary standards, 851
PS3, 856
SFX/SFX12V, 854-858
table of, 851
TFX12V, 860
Form Factors website, 172
formatting hard drives
high-level formatting, 477, 482
low-level formatting, 477-478
standard recording, 478
ZBR (zoned-bit recording), 478-480
partitions, 480-481
For Music Use Only discs, 588
forward compatibility of motherboard power connectors, 885-886
Fourth SATA Master setting (Drive Configuration menu), 304
Fowler-Nordheim tunneling, 508
FPD-Link (Flat Panel Display-Link), 629
FPO DRAM (Fast Page Mode DRAM), 335-336
FPUs, 95
fractioned T-1 lines, 788
Frame Buffer Size setting (Video Configuration menu), 307
frames (DVDs), 553-554
fraudulent processors, 74
free diagnostic software, 991
FreeDOS, 22
free magnetic layers, 446
frequency, 810
frequency hopping spread spectrum (FHSS), 813
Frequency Modulation (FM) encoding, 451
frequency response, 680, 698
frequency synthesizers, 136
frequency timing generator (FTG), 136
Front Panel 1394 Port 1 setting (Peripheral Configuration menu), 301
Front Panel 1394 Port 2 setting (Peripheral Configuration menu), 301
front panel motherboard-controlled switches, 866-868
front panel power supply AC switches, 868-869
Front Side Bus (FSB) Frequency setting (BIOS main menu), 295
FrozenCPU.com, 941
frozen systems, troubleshooting, 1030-1034
FSB (front side bus). See buses
FSP (Fortron Source Power), 864-866
FTG (frequency timing generator), 136
FTTC (fiber to the curb), 781
FTTH (fiber to the home), 781
FTTN (fiber to the neighborhood), 781
FTTP (fiber to the premises), 781
full-duplex mode, 806, 828
full-duplex operation, 815
Full On state (APM), 904
full-size AT motherboards, 157-158
fully associative mapped cache, 59
functions (USB), 706
Fusion/HSA (Heterogeneous Systems Architecture) APUs, 131-132
FX Bulldozer chipsets, 223-225
FX processors (AMD), 128-131
G
G0 Working power state, 906
G1 Sleeping power state, 906
G2/S5 Soft Off power state, 907
G3 Mechanical Off power state, 907
G8x-series keyboards (Cherry Corporation), 745
gaming
3D graphics accelerators. See 3D graphics accelerators
APIs, 645
DirectX, 646-647
OpenGL, 646
optimizing system for, 932
ganged heads, 485
gang programmers, 270
Gap sector field, 470
Gate A20 Option feature (BIOS Setup), 317
gates (MOSFETs), 12
GDDR2 SDRAM, 621
GDDR3 SDRAM, 622
GDDR4 SDRAM, 622
GDDR5 SDRAM, 622
GeForce SLI website, 648
generic hubs, 706
generic PCs. See white-box systems
genometry, 644
ghost images (monitors), 664
gHz (gigahertz), 36, 332
GI (guard interval), 812
Giant Brains, or Machines That Think (Berkeley), 19
giant magneto-resistive (GMR) heads, 446-447
Gigabit Ethernet, 806-807
Gigabyte Face Wizard, 275
gigahertz (GHz), 36, 332
GIMPS, 991
glass in hard disks, 441
Glidepoint, 768-769
Global Engineering Documents, 381
GM Vehicle Calibration Information website, 272
GMR (giant magneto-resistive) heads, 446-447
Gouraud shading, 643
GPT (GUID Partition Table), 432-434
GPT Loader (Paragon), 434
GPU (video graphics processor), 619
GPU-Z, 620
Grantsdale (915) chipsets, 202-203
Graphene-based transistors, 13
graphics
3D graphics accelerators. See 3D graphics accelerators
Extreme Graphics Architecture, 185
optimizing system for, 931
graphics adapters. See video adapters
gray code, 490
green power switch connector wires, 869
grounding loops, 818
guard interval (GI), 812
GUID Partition Table (GPT), 432-434
 half-bridge forward converting switching power supply, 893-894
half-duplex operation, 815
Halt On setting (Boot menu), 314
hand tools
 3 ½” drive enclosure, 1003
cleaning materials, 1002
data transfer cables and adapters, 1003
electric screwdrivers, 1002
ESD (electrostatic discharge) protection kits, 1003
files, 1002
flashlights, 1002
hemostats, 1002
lithium coin cell batteries, 1003
markers/pens, 1002
needle-nose pliers, 1002
nut drivers, 1000
nylon cable ties, 1002
parts grabbers, 1000, 1011
POST cards, 1002
PS/2 Y adapter, 1003
screwdrivers, 1000
spare parts, 1003
Torx drivers, 1001
tweezers, 1000
USB/FireWire cable adapter, 1003
vises/clamps, 1002
Windows 98 Startup floppy, 1002
Windows 2000/XP bootable CD, 1002
wire cutters, 1002
wire strippers, 1002
hard disk drives. See HDDs (hard disk drives)
HARD DISK INSTALL FAILURE (error message), 980
Hard Disk Pre-Delay setting (Drive Configuration menu), 303
Hard disk(s) diagnosis fail (error message), 980
Hard Drive setting (Power menu), 313
hard error rates (HERs), 357
hard memory fails, 357
hardcards, 378
hardware monitoring display (BIOS Setup), 310
hardware resources, 942
harmonic distortion, 680, 698
Haughton, Ken, 462
HDAs (head disk assemblies), 468
HDDs (hard disk drives). See also ATA (AT Attachment);
magnetic storage; SSD (solid-state drive)
0.85” drive, 466
305 RAMAC (Random Access Method of Accounting and Control), 439
actuators, 467
air filters, 494-495
areal density, 456-458
ATA drive capacity limitations, 413-414
2.1 GB barrier, 423
2.2 TB barrier, 432-434
4.2 GB barrier, 423-425
8.4 GB barrier, 427-428
137 GB barrier and beyond, 429-430
BIOS commands versus ATA commands, 418-419
BIOS limitations, 415-416
CHS bit-shift translation, 421-423
CHS/LBA conversions, 417-418
CHS limitations, 419-421
CHS versus LBA, 416-417
GPT (GUID Partition Table), 432-434
LBA-assist translation, 425-427
table of, 414
BIOS Setup settings, 302-305
cables/connectors, 497-498
capacity, 462-463
BIOS limitations, 498-499
capacity limitations, 498
operating system limitations, 499-500
choosing, 938-939
configuration
  automatic drive detection, 966
  configuration items, 497
explained, 962-963
cooling. See heating/cooling issues
costs, 463
CSS (contact start stop) design, 468
cylinders, 467
definition of, 28, 461
dual-drive configurations (PATA), 393-395
ECC (error correction code), 472-473
form factors
  1” hard drives, 466
  1.8” hard drives, 466
  2.5” hard drives, 465
  3.5” half-height drives, 465
  5.25” drives, 464-465
table of, 463-464
head actuator mechanisms, 487
stepper motors, 487-488
voice-coil actuators, 488-489

heads, 468
air bearing, 469
automatic head parking, 493-494
HDAs (head disk assemblies), 468
head crashes, 468
head sliders, 448-450
head/medium interaction, 469-470
read/write heads, 443-444, 458-460, 485-487

recording media
AFC (antiferromagnetically coupled), 485
oxide, 484
thin-film, 484-485
read/write heads, 443-444, 445-446
GMR (giant magneto-resistive), 446-447
MIG (Metal-In-Gap), 444
MR (magneto-resistive), 445-446
PMR (perpendicular magnetic recording), 458-460
TF (thin film), 444-445

reliability
MTBF (mean time between failures), 504
PFA (Predictive Failure Analysis), 505
S.M.A.R.T. (Self-Monitoring, Analysis, and Reporting Technology), 504-506

Safe Removal settings, 726-727
sectors, 466
512-byte sector on modern drive, 472
Advanced Format (4K sectors), 473-475
data bytes, 470
fields, 470
headers/trailers, 471
numbering, 470
sector drive partition alignment, 475-477
usable space, 471
Western Digital WD1003/WD1006 (IBM AT) 512-byte sector, 471-472
Xebec 1210/1220 (IBM XT) 512-byte sector format, 471
seek times, 463

head crashes, 468
dedicated servo, 492-493
disk sweep, 491
embedded servo, 492
gray code, 490
servowriters, 490
thermal recalibration, 490
wedge servo, 491-492

spindle motors, 495-496
spin rates, 467
striping, 434-435
striping with parity, 434

HD-DVD, 569-570
HDMI (High Definition Multimedia Interface), 633-636, 688
HDMI Forum website, 636

head actuator mechanisms
servo mechanisms, 489-493
dedicated servo, 492-493
disk sweep, 491
embedded servo, 492
gray code, 490
servowriters, 490
thermal recalibration, 490
wedge servo, 491-492
stepper motors, 487-488
voice-coil actuators, 488-489

head disk assemblies (HDAs), 468

head sliders, 448-450

headphones, 699
heads
  air bearing, 469
  automatic head parking, 493-494
  cautions, 468
  HDAs (head disk assemblies), 468
  head actuator mechanisms
    stepper motors, 487-488
    voice-coil actuators, 488-489
  head crashes, 468
  head/medium interaction, 469-470
  head sliders, 448-450
  read/write heads, 440-444, 485-487
    ferrite, 444
    GMR (giant magneto-resistive), 446-447
    MIG (Metal-In-Gap), 444
    MR (magneto-resistive), 445-446
    PMR (perpendicular magnetic recording), 458-460
    TF (thin film), 444-445
  servo mechanisms, 489-493
    dedicated servo, 492-493
    disk sweep, 491
    embedded servo, 492
    gray code, 490
    servowriters, 490
    thermal recalibration, 490
    wedge servo, 491-492
heat spreaders, 75
heating/cooling issues
  hard disk temperature acclimation, 495
  heatsinks
    active heatsinks, 143-145
    boutique heatsinks, 146
    choosing, 941
    heatsink clips, 143
    installation, 147-148, 946-952
  passive heatsinks, 146
  purchasing, 146
  ratings and calculations, 146-147
  infrared thermometers, 1010
  liquid cooling, 148-149, 941
  maximum heatsink inlet temperatures, 150
  Pentium 4, 104-106
  positive-pressure-ventilation design, 852
  power supply, 913
  preventative maintenance, 1017
  temperature probes, 1010
  thermally advantaged chassis
    cooling fans, 149
    maximum heatsink inlet temperatures, 150
    processor ducts, 151
    specifications, 150-151
  troubleshooting, 1030
heatsinks, 143, 941
  active heatsinks, 143-145
  boutique heatsinks, 146
  heatsink clips, 143
  installation, 147-148, 946-952
  maximum heatsink inlet temperatures, 150
  passive heatsinks, 146
  purchasing, 146
  ratings and calculations, 146-147

Heaven DX11 benchmark utility (UniGine), 647
help. See troubleshooting
hemostats, 1002
HERs (hard error rates), 357
Hertz (Hz), 680
Hertz, Heinrich Rudolph, 49
heterogeneous adapters, 668
Heterogeneous Systems
  Architecture (HSA) APUs, 131-132
Hewlett-Packard 9100A electronic calculator, 20
HFC (hybrid fiber/coax) networks, 776
HFS (Hierarchical File System), 586
hiberfil.sys file, 998
Hibernate (S4) state, 910
Hierarchical File System (HFS), 586
High Definition Multimedia Interface (HDMI), 633-636, 688
high-level formatting, 477, 482
high memory area (HMA), 46
High Sierra file system, 583
High-Speed USB (USB 2.0)
  data rates, 709
  technical details, 705-708
highly parallel instructions, 62
history of computers
  ATA (AT Attachment), 378-380
  Atanasoff-Berry Computer, 10
  CD drives, 526-527
  CDs, 526-527
  chipsets, 181-183
  Colossus, 10
  DVDs, 548
  ENIAC (Electrical Numerical Integrator and Calculator), 10
  flash memory, 507
  floppy drives, 523
  ICs (integrated circuits), 13-14
  importance of, 20
  magnetic storage, 439
  microprocessors, 33-34
  Moore's Law, 16-17
  mouse, 757-758
  PCs (personal computers)
    Apple I, 15
    Apple II, 15
    IBM Model 5100, 14
    IBM Model 5150, 15
IBM PCs, 15-16
MITS Altair 8800 kit, 14
processors, 29-33
recent developments, 17-18
sound cards, 682
timeline, 5-9
transistors, 11-13
UNIVAC (Universal Automatic
Computer), 10
vacuum tubes, 11
Hitachi
Global Storage Technologies, 463
Super-IPS (in-place switching), 662
hits (cache), 330
HLF. See low-level formatting
HMA (high memory area), 46
Hoff, Ted, 30
hold-up time (power supply), 897
Hollerith, Herman, 439
home networks. See networks
home servers, optimizing sys-
tem for, 932-933
home theater, optimizing sys-
tem for, 932
HomePlug 1.0, 839
HomePlug AV, 840
HomePlug Powerline Alliance, 839
HomePNA, 838-839
homogeneous adapters, 668
horizontal frequency, 657
host adapters. See adapters
host-based audio signal process-
ing, 688
Host Burn-in Mode setting
(Chipset Configuration
menu), 299
Host Burn-in Mode Type set-
ting (Chipset Configuration
menu), 299
host interface adapters. See ATA
(AT Attachment); SCSI (small
computer system interface)
host protected areas (HPAs),
287-289, 384, 412-413
Host Spread Spectrum set-
ting (Chipset Configuration
menu), 299
Host Wire Adapter (HWA), 717
hot spots, 810
hot-plugging, 713, 725-728
hot-swappable drives, 727
HP (Hewlett-Packard)
KittyHawk, 466
LightScribe, 602
HPAs (host protected areas),
287-289, 384, 412-413
HPET setting (Chipset
Configuration menu), 300
HPUSBDisk.exe, 281
HSA (Heterogeneous Systems
Architecture) APUs, 131-132
HT (Hyper-Threading)
Technology, 65-66
hubs, 704-706, 828-829
AHA (accelerated hub architec-
ture), 188
chipset hub architecture,
187-188
hub clamping area
CDs, 530
DVDs, 550
ICH (I/O Controller Hub), 187
MCH (Memory Controller
Hub), 187
HughesNet, 785
HWA (Host Wire Adapter), 717
HWINFO, 356, 411
HWMonitor, 991
hybrid fiber/coax (HFC) net-
works, 776
hybrid mice, 762
hybrid processors
AMD-K6, 64, 116-117
NexGen Nx586, 114-116
hydrogenated amorphous silica
(a-Si), 661
Hyper Page mode memory,
336-337
Hyper-Threading Technology
(HT), 65-66
Hyper-Threading Technology
setting (BIOS main menu), 295
HyperStreaming, 189
Hypertech, 272
HyperTransport, 188
Hz (Hertz), 680
IA-32 mode, 45
IA-32 virtual real mode, 45-46
IA-32e 64-bit extension mode,
46-48
IA-64 processors, 35
IBM
305 RAMAC (Random Access
Method of Accounting and
Control), 439
650 magnetic drum calcula-
tor, 6
701 Defense Calculator, 439
726 Tape Unit, 439
8088 processors, 89-90
BIOS error messages, 320-321
development of magnetic stor-
age, 439
Enhanced 101-key keyboard,
739-740
history of IBM PCs, 15-16
IBM BIOS, 984-989
MicroDrive, 466
Model 5100 PC, 14
Model 5150 PC, 15
PC-AT (PC Advanced
Technology), 7
PS/2 mouse port, 761
TrackPoint, 765-768
IBM BIOS, 984-989
IBM clones, 19, 90
IBM compatibles, 19
ICH (I/O Controller Hub), 187
ICs (integrated circuits), 13-14
ID error detection (IED) codes, 553
ID sector field, 470
IDE (Integrated Drive Electronics). See ATA (AT Attachment)
IDENTIFY DRIVE command (ATA), 410
IDs, PnP (Plug and Play) device IDs, 318
IEC (International Electrotechnical Commission), 455, 899
IED (ID error detection) codes, 553
IEEE (Institute of Electrical and Electronic Engineers)
802.11a standard, 810
802.11b standard, 808-810
802.11g standard, 810-811
802.11n standard, 811-812
1284 standard, 735-736
1394 standard
1394a standard, 718-719
1394b S3200 standard, 721
1394b standard, 719-720
compared to USB, 722-725
explained, 718
hot-plugging, 725-728
speed of, 723-725
iFeel Mouse (Logitech), 759
IFLASH.EXE, 281
IHS Standards Store, 381
i.LINK. See FireWire
image abstractions, 644
image mastering application program interface (IMAPI), 574
images. See graphics
IMAPI (image mastering application program interface), 574
ImgBurn, 280-281, 284
Inactivity Timer setting (Power menu), 313
InCD Reader (Nero AG Software), 585
inductive power, 898
industry control
of PC hardware, 23-26
of PC software, 20-23
white-box systems, 26
Industry Standard Architecture. See ISA buses
infrared data front panel connector pinout, 237
infrared (IR) input devices, 771
infrared thermometers, 916, 1010
infrastructure mode, 831
initial program load (IPL) ROM, 274
Innoventions, 369
in-plane switching (IPS), 662
input devices
choosing, 939
keyboards, 739
103/104-key, 740-742
buckling spring keyboards, 746
buying tips, 756-757
cleaning, 755-756, 1016
connectors, 751-755
DSK (Dvorak Simplified Keyboard), 754
Enhanced 101-key, 739-740
ergonomic, 754
international layouts, 750-751
keyboard interface, 747-748
key matrix, 747
key numbers, 749-750
keyswitch design, 742-746
scan codes, 749-750
skins, 756
touch keyboards, 747
troubleshooting, 754-755
typematic functions, 749
USB (Universal Serial Bus), 753-754
mice
ball-driven mouse, 758-759
buttons, 758
cleaning, 765, 1016
components, 758
history of, 757-758
hybrid mice, 762
manufacturers, 758
optical mouse, 759-760
PS/2 mouse port, 761
scroll wheels, 762-763
sensitivity, 758
serial interfaces, 760-761
touch-sensitive mice, 763
troubleshooting, 764-765
USB (Universal Serial Bus), 762
touch pads, 768-769
touchscreen technology, 770-771
trackballs, 758-770
TrackPoint, 765-768
wireless
Bluetooth, 772
IR (infrared), 771
power management, 772
proprietary radio frequency, 771
troubleshooting, 773
input range (power supply), 897
inSSIDer, 1020
installation
cables, 969
CD/DVD firmware, 608
DSL (digital subscriber line), 781-782
expansion cards, 969
HDDs (hard disk drives), 963-965
heatsinks, 147-148, 946-952
memory modules, 952
motherboard cables, 961-962
motherboards, 953-956
NICs (network interface cards), 840-841
operating systems, 971-972
power supply, 958-961
processors, 946-952
RAM (random access memory), 366-367
SSDs (solid state drives), 963-965
troubleshooting, 972-973
video adapters, 967-968
Institute of Electrical and Electronic Engineers. See IEEE
instruction sets (math coprocessors), 87
INT13h
BIOS CHS parameter limits, 419
commands, 418
INTA# interrupts, 257
INTB# interrupts, 257
INTC# interrupts, 257
INTD# interrupts, 257
integral cache, 330
Integral Peripherals 1.8” hard drives, 466
integral power supply AC switches, 868
integrated adapters, 938
integrated audio chipsets, 694
integrated circuits (ICs), 13, 14
Integrated Drive Electronics (IDE). See ATA (AT Attachment)
Integrated Services Digital Network (ISDN), 787
integrated video/motherboard chipsets, 611
chipsets with integrated video for 64-bit AMD processors, 614-616
graphics chip market share, 612
Intel chipset integrated video, 612-613
third-party chipsets with integrated video for Intel processors, 614
Integrator Toolkit (Intel), 275
Intel
“Azalia” HD Audio, 694
BTX motherboards, 164-167
chipsets, 183-184
3x series, 205-208
4x series, 206-208
5x series, 208-211
6x series, 211-213
7x series, 213-215
96x series, 204-205
386/486 chipsets, 190
915 family, 202-203
925X family, 203
945 Express family, 203
955X, 204
82350 chipsets, 190
hub architecture, 187-188
integrated video, 612-613
integrated video/motherboard chipsets, 612
Intel Extreme Graphics Architecture, 185
model numbers, 184
North Bridge, 185-187
Pentium 4 chipsets, 196-202
Pentium chipsets, 190-191
Pentium Pro chipsets, 192-195
South Bridge, 186-187
Super I/O chips, 186
Chipset Identification Utility, 185
Extreme Graphics Architecture, 185
hardware industry control, 23-26
Integrator Toolkit, 275
Processor Frequency ID Utility, 138
Processor Identification Utility, 138
processors
286, 90
386, 91-92
486, 92-93
4004, 30
8085, 31
8086, 32, 89
8088, 31-32, 89-90
Celeron, 96, 100-101
code names, 88-89
Core 2, 108-110
development of, 30-34
Intel Core i, 110
Intel Atom, 115
Itanium, 35
Ivy Bridge architecture, 114-115
Nehalem architecture, 110-113
overclocking, 142
Sandy Bridge architecture, 113-114
Pentium, 93-96
Pentium II, 96-99
Pentium III, 96-100
Pentium 4, 101-106
Pentium 4 Extreme Edition, 104
Pentium D, 106-107
Pentium Pro, 96-97
specifications, 35-38
RTS2011LC cooling system, 149
Thunderbolt Technology, 728-729
Intel Chipset Identification Utility, 185
Intel Quick Resume Technology setting (Power menu), 313
Intel RAID Technology setting (Drive Configuration menu), 303
Intel Rapid BIOS Boot setting (Boot menu), 314
Intel VT-D, 69
Intel VT-x, 69
Intel-compatible processors
AMD Athlon, 117-118
AMD Athlon MP, 120
AMD Athlon XP, 118-119
AMD Duron, 118
AMD K5, 96
AMD K6, 64, 116-117
AMD Sempron, 124
NexGen Nx586, 114-116
IntelliMouse Explorer, 759
interference
RFI (radio-frequency interference), 1019
speakers, 699
interlaced mode, 659
interleave, 336, 504
internal cache, 330
internal Level 1 cache. See
Level 1 cache
internal Level 2 cache. See
Level 2 cache
internal registers, 44
International Electrotechnical Commission (IEC), 455, 899
international keyboard layouts, 750, 751
International Organization for Standardization (ISO) 9660 standard, 583-584
Internet connections, 795-796
broadband technology
CATV (cable TV), 776-779
cellular broadband, 783-784
comparison of access types, 789
DSL (digital subscriber line), 779-783
explained, 775-776
ISDN (Integrated Services Digital Network), 787
leased lines, 788
satellite broadband, 784-787
service interruptions, 795
speeds, 789
status LEDs, 797
wireless broadband, 783
dialup modems
56Kbps modems, 791-794
asynchronous versus synchronous communications, 790
data bits, 791
explained, 790-791
parity, 791
stop bits, 791
routers, 796
security
explained, 794-795
routers, 796
service interruptions, 795
shared connections, 795-796
Internet Protocol (IP), 836
Internetwork Packet Exchange (IPX), 837
interpolation, 535
Interrupt (for the Parallel Port) setting (Peripheral Configuration menu), 301
Interrupt (for the Serial Port) setting (Peripheral Configuration menu), 301
interrupt request channels. See IRQs
interrupt sharing, 255
intranets, 801
Invalid partition table (error message), 323
IOAPIC Enable setting (Chipset Configuration menu), 300
I/O buses. See buses
I/O Controller Hub (ICH), 187
IOH (I/O Hub), 81
ion bombardment, 11
IP (Internet Protocol), 836
IPL (initial program load) ROM, 274
IPS (in-plane switching), 662
IPX (Internetwork Packet Exchange), 837
IR (infrared) input devices, 771
iron oxide
in hard disks, 441
in recording media, 484
IRQs (interrupt request channels), 254
8-bit ISA bus interrupts, 255
16-bit ISA/EISA/MCA interrupts, 256-257
Advanced Programmable Interrupt Controller (APIC), 258
conflicts, 259
edge-triggered interrupt sensing, 255
interrupt sharing, 255
IRQ sharing, 258
maskable interrupts, 255
PCI interrupts, 257-258
PCI IRQ Steering, 255
IRs (infrared thermometers), 1010
ISA Enable Bit setting (Chipset Configuration menu), 300
ISA (Industry Standard Architecture) buses, 245-246, 255-256
ISDN (Integrated Services Digital Network), 787
ISO (International Organization for Standardization) 9660 standard, 583-584
IsoBuster, 586
isolating memory defects, 372-374
Itanium processors (Intel), 35
ITU (International Telecommunication Union)
  V.90 standard, 793
  V.92 standard, 793-794
ITX motherboards, 176-177
Ivy Bridge architecture (Core i), 114-115, 142
Iwasaki, Shun-ichi, 459

K
K5 processors (AMD), 96
K6 processors (AMD), 64, 116-117
K10 (Phenom) processors, 126-128
K11. See Bulldozer FX processors
K56flex chipsets, 793
Katmai New Instructions (KNI), 63
key matrix, 747
key numbers (keyboards), 749-750
keyboard controller chips, upgrading, 277
Keyboard error or no keyboard is present (error message), 980
Keyboard is locked out–Unlock the key (error message), 980
Keyboard Select setting (Power menu), 313
keyboards, 739
  104-key, 740-742
  buckling spring keyboards, 746
  buying tips, 756-757
  choosing, 939
  cleaning, 755-756
  cleaning procedures, 1016
  connectors, 751-755
  controller chips, upgrading, 277
definition of, 28
DSK (Dvorak Simplified Keyboard), 754
Enhanced 101-key, 739-740
ergonomic, 754
international layouts, 750-751
key matrix, 747
key numbers, 749-750
keyboard interface, 747-748
keyswitches
  capacitive, 746
  cleaning, 744
  foam element, 743-744
  membrane, 744-745
  pure mechanical, 742-743
  rubber dome, 744
troubleshooting, 755
scan codes, 749-750
skins, 756
touch keyboards, 747
troubleshooting, 754, 1027
  connectors, 755
  defective cables, 754-755
  stuck keyswitches, 755
typematic functions, 749
USB (Universal Serial Bus), 753-754
wireless
  Bluetooth, 772
  IR (infrared), 771
  power management, 772
  proprietary radio frequency, 771
troubleshooting, 773
keychain flash memory devices, 507
keylock connectors, 237
keystrokes, bouncing/debouncing, 747
keyswitches
  capacitive, 746
  cleaning, 744
  foam element, 743-744
  membrane, 744-745
  pure mechanical, 742-743
  rubber dome, 744
troubleshooting, 755
KeyTronicEMS, 744-745
Kilby, Jack, 6, 13
kilovolt-amperes-reactive (KVAR), 899
Kinesis mechanical-switch keyboards, 743
KittyHawk, 466
Klamath, 97
K-Lite Codec Pack, 581
KNI (Katmai New Instructions), 63
known-good spare troubleshooting technique, 1022
KVAR (kilovolt-amperes-reactive), 899

L
L2 Cache RAM setting (BIOS main menu), 295
L2 cache. See Level 2 cache
L-CHS parameters, 421
Labelflash, 602
Lakeport chipsets (Intel), 203
Lancaster, Don, 7
lands, 79
CDs, 527-529
DVDs, 549
LANs (local area networks), 800
Larson, Earl R., 10
Laser Beam Recorder (LBR), 527
lasers (CD drives), 529
latency, 335, 503
layered architecture, 265-266
Layer Jump Recording (LJR), 563
layout (memory), 326
lazy write, 725-726
LBA (logical block address) addressing
137GB barrier and beyond, 429-430
CHS/LBA conversions, 417-418
compared to CHS (cylinder head sector), 416-417
LBA-assist translation, 425-427
LBR (Laser Beam Recorder), 527
LCC (leadless chip carrier) packaging, 79
LCD (liquid crystal display) monitors. See also video display interfaces
active-matrix displays, 661-662
advantages of, 662
bad pixels, 675-676
dead pixels, 675
how it works, 661
lack of screen flicker, 659
projectors, 666
selection criteria, 662-663
stuck pixels, 675
lead-in zone
CDs, 531
DVDs, 550
leadless chip carrier (LCC) packaging, 79
lead-out zone
CDs, 531
DVDs, 550
leased lines, 788
LED monitors
backlit technology, 663
connectors, 237
lack of screen flicker, 659
legacy audio support, 685-686
Legacy Front Panel Audio setting (Peripheral Configuration menu), 301
Legacy IDE Channels setting (Drive Configuration menu), 303
legacy support
ports, 703, 937
power management, 907
USB, 748
legal issues
copyright protection, 21
licensing
Mac OS X, 23
MS-DOS, 22
Windows 8, 930
patents, 21
Lenovo, POST display error codes, 987-989
Level 1 cache, 54, 330
cache operation, 54-56
importance of, 54
Pentium-MMX improvements, 62
Level 2 cache, 56-59, 330
Level 3 cache, 56, 331
level-sensitive interrupts, 257
levels (RAID), 434-436
Lexar
Memory Stick Pro, 511
Memory Stick Pro Duo, 511
Lexmark, 746
LFX12V power supply, 863
licensing
Mac OS X, 23
MS-DOS, 22
Windows 8, 930
LIF (low insertion force) sockets, 78
Light Peak. See Thunderbolt Technology
LightScribe, 602
Limit CPUID MaxVal setting (Boot Configuration menu), 298
linear power supply, 893-894
linear voice-coil actuators, 488-489
line conditioners, 922
line in sound card connectors, 687
line out sound card connectors, 687
line regulation (power supply), 898
Link Layer Topology Discoverer (LLTD) responder, 843
Link Stability Algorithm setting (PCI Express Configuration menu), 297
Linux
ALSA (advanced Linux sound architecture), 693
drive limitations, 431
liquid cooling, 148-149, 941
lithium coin cell batteries, 1003
LJR (Layer Jump Recording), 563
LLF. See low-level formatting
LLTD (Link Layer Topology Discoverer) responder, 843
Load Custom Defaults command (BIOS Exit menu), 316
Load Optimal Defaults command (BIOS Exit menu), 316
load regulation (power supply), 898
loading mechanisms (CD/DVD drives), 599-600
loads (power supply), 894-895
apparent power, 899
inductive, 898
load regulation, 898
maximum load current, 898
minimum load current, 898
nonlinear, 899
resistive, 898
working power, 899
load/unload head mechanism, 468
local area networks (LANs), 800
local buses, 246-247
PCI. See PCI buses
VESA local bus, 247
locations for serial ports, 730-733
locked systems, troubleshooting, 1030-1034
logical block address. See LBA addressing
logical formatting. See high-level formatting
logical mapping (memory), 326
logical memory layout, 374-376
logical ring topology, 826
logic boards, 496-497
logic probes, 1007-1008
Logitech mice, 758-759
loopback connector, 1005
Lowest System Fan Speed setting (Fan Control Configuration menu), 309
low insertion force (LIF) sockets, 78
low profile form factor (LFX12V) power supply, 863
low volume, troubleshooting, 695-696
low-level formatting, 477-478
standard recording, 478
ZBR (zoned-bit recording), 478-480
low-pass filters, 780
LPX motherboards, 160-161, 870-872
lubricants, 1013
encoding schemes
comparison of, 453-454
explained, 450-451
FM (Frequency Modulation), 451
MFM (Modified Frequency Modulation), 442, 451-452
RLL (Run Length Limited), 442, 452-453
flux, 442
head sliders, 448-450
history of, 439
magnetic fields, 441-442
overview, 439
PMR (perpendicular magnetic recording), 458-460
PRML (Partial-Response, Maximum-Likelihood), 455
read process, 442-443
read/write heads, 440, 443-444
ferrite, 444
GMR (giant magneto-resistive), 446-447
MIG (Metal-In-Gap), 444
MR (magneto-resistive), 445-446
TF (thin film), 444-445
write process, 442-443
magneto-resistive (MR) heads, 445-446
main boards. See motherboards
main memory. See RAM (random access memory)
main menu (BIOS Setup), 294-295
maintenance. See care and maintenance
Maintenance menu (BIOS Setup), 293-294
Make codes, 749
managed switches, 828
MANs (metropolitan area networks), 800
manufaturer-supplied diagnos-
tic software, 975
manufacturing
CDs, 527-529
manufacturing tests, 319
processors
.09 micron manufactur-
ing, 72
.13 micron manufactur-
ing, 71
bonding, 73
dies, 71
doping, 70
metallization layers, 71
photolithography, 70-71
processor remarking, 74
process/wafer size transi-
tions, 73
silicon, 69
silicon on insulator (SOI), 71
steppers, 71
test process, 74
wafers, 70-72
yields, 73
mapping
MIP mapping, 644
texture mapping, 645
Mark DMI Events As Read set-
ing (Event Logging menu), 307
mask ROM (read-only mem-
ory), 270
maskable interrupts, 255
mass-producing CDs, 527-529
master development (CDs), 527
master drives (ATA), 393
master position (ATA), 385
master separation (CDs), 528
Masuoka, Fujio, 507
Material Safety Data Sheets (MSDS), 1014
math coprocessors
Pentium processors, 95
processors, 87
matrix math extensions
(MMX), 62-63
Mauchly, John W., 6, 10, 20
Maximum Capacity setting (Drive Configuration menu), 303
maximum load current (power supply), 898
MBOA-SIG (Multiband OFDM
Alliance Special Interest
Group), 716
MBR boot error messages, 322-323
  Error loading operating sys-
tem, 323-324
  Invalid partition table, 323
  Missing operating system, 324
MCA (microchannel architec-
ture) buses, 246, 256
MCH (Memory Controller Hub), 187, 935
MCH Voltage Override set-
ing (Chipset Configuration
menu), 300
MCM (multichip module), 97
Mean Time Between Failures
(MTBF), 504, 897
Mean Time To Failure (MTTF), 897
measuring voltage, 915-916
mechanical keyswitches
  capacitive, 746
  foam element, 743-744
  membrane, 744-745
  pure mechanical, 742-743
  rubber dome, 744
  troubleshooting, 755
media, recording media, 484
  AFC (antiferromagnetically
coupled), 485
  media color, 541-542
  layers, 540-541
  oxide, 484
  speed ratings, 543
  thin-film, 484-485
MediaGX, 612
megahertz (MHz), 36, 332
membrane keyswitches, 744-745
MemCor, 484
memory. See flash memory;
RAM (random access memory)
Memory Configuration menu
(BIOS Setup), 297-298
Memory Controller Hub (MCH), 187, 935
Memory Frequency setting
(Memory Configuration menu), 297
Memory Mode setting (Memory
Configuration menu), 297
Memory Stick, 510
Memory Stick Micro, 511
Memory Stick Pro, 511
Memory Stick Pro Duo, 511
Memory Stick Pro XC, 511
Memory Test (error message), 980
memory testers, 1008-1009
Memory test fail (error mes-
sage), 980
Memtest86, 369, 1009
merge bits, 537
merged MR (magneto-resistive)
heads, 446
messages, error. See error mes-
ges
Metal-In-Gap (MIG) heads, 444
metallization (CDs), 528
metallization layers (proces-
sors), 71
Metal Oxide Semiconductor
Field Effect Transistors
(MOSFETs), 11-12
metal-oxide varistors (MOV), 921
Metcalfe, Robert, 6
metropolitan area networks (MANs), 800
mezzanine buses. See PCI (Peripheral Connect Interface) buses
M-Flash, 279
MFM (Modified Frequency Modulation), 442, 451-452
MHz (megahertz), 36, 332
mice
   ball-driven mouse, 758-759
   buttons, 758
   choosing, 939
   cleaning, 765, 1016
   components, 758
   definition of, 28
   history of, 757-758
   hybrid mice, 762
   manufacturers, 758
   optical mouse, 759-760
   PS/2 mouse port, 761
   scroll wheels, 762-763
   sensitivity, 758
   serial interfaces, 760-761
   touch-sensitive mice, 763
   troubleshooting, 764-765
   USB (Universal Serial Bus), 762
   wireless
      Bluetooth, 772
      IR (infrared), 771
      power management, 772
      proprietary radio frequency, 771
      troubleshooting, 773
Micro A/B connectors (USB), 712
Micro Instrumentation and Telemetry Systems, 14
micro-AT motherboards, 159
microATX motherboards, 172-174
microchannel architecture (MCA) buses, 246
microcode, reprogrammable, 88
Microcode Revision setting (BIOS Maintenance menu), 294
MicroDrive, 466
microphone in connectors, 687
microphones, 700-701
microprocessors. See specific processors (for example, Pentium)
Micro-Scope, 990
MicroSD, 510
Microsoft
   DirectX, 646-647
   mice, 758
      IntelliMouse Explorer, 759
      Microsoft Explorer Touch Mouse, 763-764
   MS-DOS
      free and open-source DOS versions, 22
      licensing, 22
      software industry control, 20-23
   Windows Memory Diagnostic, 369, 1009
Microsoft Plug and Play ID web page, 318
MIDI (Musical Instrument Digital Interface)
   in/out sound card connectors, 688
   sound card support, 691
MIDI Out Setter, 692
MIG (Metal-In-Gap) heads, 444
MIMO (multiple input, multiple output), 811
Mini A/B connectors (USB), 712
mini-AT motherboards, 159
Mini-ATX motherboards, 169
Mini-DTX motherboards, 176
Mini-ITX motherboards, 176-177
mini-LPX motherboards, 160-161
minimum load current (power supply), 898
mini-SATA (mSATA), 403-404
MiniSD, 510
mini-tower cases, 933
Mini-Winchester sliders, 448
MIO (multipurpose I/O), 648
mirroring disks, 434-435
misses (cache), 330
Missing operating system (error message), 324, 1031
MITS, Inc.
   Altair, 14, 19
   history of, 14
MLC (multilevel cell), 513-514
MMC (MultiMediaCard), 510
MMCA (MultiMediaCard Association), 510
MMDevice (Multimedia Devices) API, 683
MMX (multimedia extensions), 62-63, 87
Model 5100 PC, 14
Model 5150 PC, 15
model numbers (Intel), 184
Modem-on-Hold feature, 793-794
modems
   56kbps modems, 791
   chipsets, 792
   limitations, 792
   Modem-on-Hold feature, 793-794
   PCM Upstream feature, 794
   speed, 792
   V.90 standard, 793
   V.92 standard, 793-794
   asynchronous versus synchronous communications, 790
cable modems, 776-778
data bits, 791
definition of, 28
explained, 790-791
parity, 791
stop bits, 791
troubleshooting, 1026-1027
modes
PATA DMA (direct memory access) transfer modes, 396-397
PATA PIO (Programmed I/O) transfer modes, 396
processor modes
IA-32 mode, 45
IA-32 virtual real mode, 45-46
IA-32e 64-bit extension mode, 46-48
real mode, 44-45
Modified Frequency Modulation (MFM), 442, 451-452
modular cables, 919
modular power supplies, 958
modules (memory)
capacities, 349-351
determining module size/features, 354-355
DIMMs (dual inline memory modules), 346
168-pin SDRAM DIMM, 348
DDR DIMM, 348, 353
DDR2 DIMM, 348, 353
DDR3 DIMM, 349, 353
purchasing, 365
SDR DIMMs, 352
dual rank, 346
ECC (error correcting code), 360-361
hard fails, 357
installation, 366-367
memory banks, 351, 356-357
parity checking, 359-360
purchasing
DIMMs, 365
obsolete memory, 366
suppliers, 364-365
registered modules, 351-352
replacing with higher-capacity versions, 366
RIMMs (Rambus inline memory modules), 346, 349
SIMMs (single inline memory modules), 346
30-pin SIMM, 347
72-pin SIMM, 347
purchasing, 366
single rank, 346
soft errors, 357-359
speeds, 357
troubleshooting, 368-372
with diagnostic software, 368-369
memory defect isolation procedures, 372-374
with POST (Power On Self Test), 368
step-by-step process, 370-372
types of errors, 370
upgrading, 361-364
Molex Mini-Fit Jr. power connectors (ATX), 874-875
monitors. See also display interfaces; video adapters; video display interface
adjusting, 674-675
aspect ratio, 652-653
bad pixels, 675-676
care and maintenance, 672-673
choosing, 668-669
CRT (cathode ray tube)
dot pitch, 664
electron guns, 663
persistance, 664
raster, 665
refresh rates, 657-659, 664-665
shadow masks, 664
slotted masks, 664
dead pixels, 675
definition of, 28
display size, 650
DLP projectors, 667
horizontal frequency, 657
image brightness and contrast, 659-660
interlaced versus noninterlaced modes, 659
LCD (liquid crystal display)
active-matrix displays, 661-662
advantages of, 662
how it works, 661
lack of screen flicker, 659
projectors, 666
selection criteria, 662-663
LED
backlit technology, 663
lack of screen flicker, 659
multiple monitors
Dualview, 667
heterogeneous adapters, 668
homogeneous adapters, 668
overview, 609, 650
pixels, 653-657
plasma displays, 665
repairing, 677
resolution, 651-652
stuck pixels, 675
testing, 671-674
touchscreen technology, 770-771
troubleshooting, 676-677, 1027-1028
vertical frequency, 657
mono in connectors, 687
monophonic sound cards, 691
Moore, Gordon, 16-17, 29-30
Moore's Law, 16-17
Morris, Robert, 7
MOSFETs (Metal Oxide Semiconductor Field Effect Transistors), 11-12
MOS Technologies 6502 processor, 32
motherboards. See also BIOS (basic input/output system); buses; chipsets; PSUs (power supply units)
AT, 157-158, 870-872
ATX, 167-168
color coding, 172
identifying, 169
ports, 170
power supply, 852-854
specification, 172
Baby-AT, 158-159
BTX, 164-167
cables, 961-962
connectors, 228, 232-234
alternative single-row front panel connector pinouts, 231
amultichip module (MCM), 97
AMR (Audio Modem Riser), 240
ATAPI-style line-in connectors, 238
battery connector, 237
CD audio connectors, 238
chassis intrusion connectors, 237
CNR (Communications and Networking Riser), 240
front panel audio connector pinout, 236
front panel switch/LED connector pinouts, 230
IEEE 1394 (FireWire/i.LINK) connector pinout, 235
infrared data front panel connector pinout, 237
LED and keylock connectors, 237
microprocessor fan power connectors, 239
power LED indications, 231
speaker connectors, 237
telephony connectors, 238
USB 1.1/2.0 USB header connector pinout, 233
USB 3.0 header connector pinout, 234-235
Wake on LAN connectors, 238
Wake on Ring connectors, 238
definition of, 28
Desktop Form Factors website, 935
documentation, 262
DTX, 176
explained, 935
extended ATX, 172
FlexATX, 174-175
industry control of, 23
integrated adapters, 938
ITX, 176-177
LPX, 160-161, 870-872
memory, 936-937
DDR SDRAM (double data rate SDRAM), 936
DIMMs (dual inline memory modules), 936
installation, 952
microATX, 172-174
Mini-ATX, 169
Mini-DTX, 176
Mini-ITX, 176-177
mounting in case, 953-956
NLX motherboards, 162-163
PC motherboards, 156-157
ports, 761, 937-938
processor sockets/slots, 178-181
proprietary designs, 177
selection criteria, 260-262
summary of form factors, 155-156
Super I/O chips, 228
troubleshooting, 1034
UEFI (Unified Extensible Firmware Interface), 936
voltage regulators, 847
WTX, 164
XT, 156-157
mothers (CDs), 528
Motion Pictures Experts Group (MPEG) standard, 693
motors
spindle motors, 495-496
stepper motors, 487-488
mounting motherboards, 953-956
Mount Rainier standard, 575, 586-587
mouse devices. See mice
Mouser Electronics, 1000
MOV s (metal-oxide varistors), 921
MPEG (Motion Pictures Experts Group) standard, 693
MPEG-2 codecs, 581
MPEG-2 decoders, 581
MR (magneto-resistive) heads, 445-446
mSATA (mini-SATA), 403-404
MSAUs (multistation access units), 826
MS-DOS. See DOS operating system
MSDOS.SYS file, 996
MSDS (Material Safety Data Sheets), 1014
msinfo32.exe, 477
MTBF (Mean Time Between Failures), 504, 897
MTTF (Mean Time To Failure), 897
MultiAudio specification, 547
Multiband OFDM Alliance Special Interest Group (MBOA-SIG), 716
multichip module (MCM), 97
multicore processors, 66-68
    AMD Athlon 64 X2, 125-126
    AMD K10, 126-128
    AMD 64 FX, 125-126
    Intel Core 2, 108-110
    Intel Core i
        Intel Atom, 115
        Ivy Bridge architecture, 114-115
        Nehalem architecture, 110-113
        overclocking, 142
        Sandy Bridge architecture, 113-114
    Intel Pentium D, 106-107
multidomain vertical alignment (MVA), 662
multiformat rewritable DVD drives, 566-567
multilevel cell (MLC), 513-514
multimedia. See also monitors; video adapters
    3D graphics accelerators. See 3D graphics accelerators
    MMX (multimedia extensions), 62-63
    SSE (Streaming SIMD Extensions), 63-64
MultiMediaCard Association (MMCA), 510
MultiMediaCard (MMC), 510
Multimedia CD, 548
Multimedia Devices (MMDevice) API, 683
multimedia extensions (MMX), 62-63, 87
multimeters, 1002, 1005-1007
MultiPlay specification, 547
multiple branch prediction, 64
multiple input, multiple output (MIMO), 811
multiple monitors
    Dualview, 667
    heterogeneous adapters, 668
    homogeneous adapters, 668
    overview, 667
multiple I/O (MIO), 648
MultiRead specifications, 545-547
multisession recording (CDs)
    DAO (Disc-at-Once) recording, 573
    packet writing, 573-575
    Track-at-Once, 573
multistation access units (MSAUs), 826
multithreaded rendering (DirectX), 647
multi-touch digitizing pad, 939
multi-touch integrated pad, 939
multiword DMA (direct memory access), 397
municipal area networks (MANs), 800
music. See audio
    MuTIOL architecture, 189
    MVA (multidomain vertical alignment), 662
    Mylar, 441
N
NAND (Not AND) flash memory, 508
nanoseconds, 332
Napier, John, 5
Napier's Bones, 5
National Committee on Information Technology Standards (NCITS), 380
National Institute for Standards and Technology (NIST), 415
National Television System Committee (NTSC), 641
NCITS (National Committee on Information Technology Standards), 380
Near Field Communication (NFC), 800
NEAT (New Enhanced AT) CS8221 chipset, 182
needle-nose pliers, 1002
negative DC voltages, 847-848
negative inertia, 768
Nehalem architecture (Core i), 110-113
Nero AG Software, InCD Reader, 585
nested RAID levels, 435
NetBEUI (NetBIOS Extended User Interface), 837
NetBurst microarchitecture, 103
Network and Sharing Center, 843-844
network interface adapters, 989
network interface cards. See NICs
networks
    ad hoc mode, 831
    architecture summary, 804-805
    benefits of, 800
    Bluetooth, 813-814
broadband technology
    CATV (cable TV), 776-779
    cellular broadband, 783-784
    comparison of access types, 789
    DSL (digital subscriber line), 779-783
    explained, 775-776
    ISDN (Integrated Services Digital Network), 787
    leased lines, 788
    satellite broadband, 784-787
    service interruptions, 795
    speeds, 789
status LEDs, 797
wireless broadband, 783
cables
cable distance limitations, 824
choosing, 842
grounding loops, 818
Thicknet, 816-817
Thinnet, 817
twisted-pair, 817-824
client/server networks, 802-804
definition of, 799-800
dialup modems
56Kbps modems, 791-794
asynchronous versus synchronous communications, 790
data bits, 791
explained, 790-791
parity, 791
stop bits, 791
extranets, 801
HFC (hybrid fiber/coax) networks, 776
HomePNA, 838-839
hubs, 828-829
infrastructure mode, 831
Internet, 800
intranets, 801
LANs (local area networks), 800
MANs (metropolitan area networks), 800
minimum requirements, 801
network software configuration, 842-843
NICs (network interface cards)
business types, 815
connectors, 815-816
costs, 814
definition of, 28
full-duplex, 815
half-duplex, 815
installation, 840-841
onboard BIOS, 274
speed, 815
testing, 841
wireless NICs, 832
PANs (personal area networks), 800
peer-to-peer networks, 803-804
powerline networks, 839-840
security, 833-835
shared Internet connections, 795-796
switches, 827-828, 842
address storing, 828
compared to hubs, 828-829
dual-speed, 829
managed/unmanaged, 828
placement of, 830-831
ports, 830
power-saving features, 829
topologies
bus topology, 825
explained, 824-825
point-to-point topology, 833
ring topology, 826
star topology, 827, 833
WANs (wide area networks), 800
Wi-Fi (Wireless Fidelity)
802.11a standard, 810
802.11ac standard, 812
802.11b standard, 808-810
802.11g standard, 810-811
802.11n standard, 811-812
access points, 831, 842
antennas, 832
bridges, 832
DHCP support, 835-836
explained, 807-808
network speeds, 813
repeaters, 832
security, 833-835
signal boosters, 832
topologies, 833
users per access point, 836
wireless NICs, 832
with Windows, 843-844
wired Ethernet, 805
10 Gigabit Ethernet
(10GBASE-T), 807
cables. See cables
explained, 806
Fast Ethernet, 806
Gigabit Ethernet, 806-807
hubs, 828-829
switches, 827-831, 842
WWANs (wireless wide area networks), 800
Neumann, John von, 6, 10
New Enhanced AT (NEAT)
CS8221 chipset, 182
Newark/element14, 1000
NewEgg.com, 935
NexGen Nx586 processors, 114-116
NeXT Computer, 7
NFC (Near Field Communication), 800
NFC Forum, 800
nForce/nForce2 chipsets, 227
NFC Forum, 800
Nibble Mode memory, 335-336
nibble mode (parallel ports), 737
NICs (network interface cards), 814
bus types, 815
connectors, 815-816
costs, 814
definition of, 28
full-duplex, 815
half-duplex, 815
installation, 840-841
onboard BIOS, 274
speed, 815
testing, 841
wireless NICs, 832
Nirsoft WirelessNetView, 1020
NIST (National Institute for Standards and Technology), 415
nits, 659
NLX motherboards, 162-163
NMOS transistors, 12
Noble, David, 523
No boot device available (error message), 322
NO ROM BASIC -SYSTEM HALTED (error message), 322
No-ID sector format, 472
no-tool cases, 1001
Non Return to Zero (differential NRZ), 401
Non Return to Zero Inverted (NRZI), 705
Non-System disk or disk error (error message), 322
Non-Volatile Memory Express (NVMe), 409
Non-Volatile Memory Host Controller Interface (NVMHCI), 409
noncontact thermometers, 916
noninterlaced mode, 659
nonlinear power, 899
nonvolatile memory, 263
nonvolatile RAM (NVRAM). See CMOS RAM
nonvolatile storage, 461. See also HDDs (hard disk drives)
NOR (Not OR) flash memory, 508
North Bridge chips, 185-187, 935
Norton Ghost (Symantec), 506
Novell NetWare, 431
Noyce, Robert, 6, 13, 29-30
NRZI (Non Return to Zero Inverted), 705
Ntbtlog.txt file, 998
Ntdetect.com, 997
NTFS (Windows NT File System), 480
NTldr (NT Loader), 997-998
NTSC (National Television System Committee), 641
numbers
Intel model numbers, 184
keyboard key numbers, 749-750
numerical aperture, 568
Numlock setting (Boot Configuration menu), 298
nut drivers, 1000
NVIDIA
chipsets, 216-217, 227
ForceWare v81.85, 648
SLI, 648
NVMe (Non-Volatile Memory Express), 409
NVMHCI (Non-Volatile Memory Host Controller Interface), 409
NVMHCI Workgroup, 409
NVRAM (nonvolatile RAM). See CMOS RAM
Nx586 processors (NexGen), 114-116
nylon cable-ties, 1002
OCCT, 991
OEMs (original equipment manufacturers), 273, 934
Oersted, Hans Christian, 440
OFDM (orthogonal frequency division multiplexing), 812, 839
OFDM data encoding, 810
offline devices, SPS (standby power supply), 922-923
Off state (APM), 905
“On Computable Numbers” (Turing), 5
Onboard 1394 setting (Peripheral Configuration menu), 301
Onboard Audio setting (Peripheral Configuration menu), 301
Onboard Chip SATA setting (Drive Configuration menu), 303
Onboard LAN Boot ROM setting (Peripheral Configuration menu), 301
Onboard LAN setting (Peripheral Configuration menu), 301
Onboard Video Memory Size setting (Video Configuration menu), 307
time programmable (OTP) chips, 270
online systems, UPS (uninterruptible power supply), 923-925
onscreen messages (POST), 978
Award BIOS/Phoenix FirstBIOS, 980-981
IBM BIOS, 984-987
open sound system (OSS) API, 693
OpenAL, 684
OpenAL Soft, 684
OpenCL, 617
OpenGL, 617, 646
operating range (power supply), 897
operating system diagnostic software, 976, 989-990
operating-system-independent boot process, 992-996, 1024-1025
operating system installation, 971-972
opposite track path (OTP), 556-557
optical mice, 759-760
optical SPDIF out sound card connectors, 688
optical storage

Blu-ray discs, 567-569, 606
care and maintenance, 606-607
CD drives, 526
  access times, 598
  bootable CDs, 606
  booting from floppy disk, 601
  buffers/cache, 598
  buffer underruns, 601
CAV (constant angular velocity) technology, 593
CLV (constant linear velocity) technology, 593-595
data transfer rates, 593
DMA and Ultra-DMA, 598
drive sealing, 600
firmware updates, 607-608
history of, 526-527
interfaces, 598-599
laser operation, 529
loading mechanisms, 599-600
mechanical drive operation, 530
Mount Rainier standard, 586-587
MultiAudio specification, 547
MultiPlay specification, 547
MultiRead specifications, 545-547
self-cleaning lenses, 600
table of CD-ROM drive speeds and transfer rates, 595
troubleshooting, 602-605

CDs
  audio data information, 533
  Blue Book standard (CD EXTRA), 576-577
  bootable CDs, 601-602, 606
  burning, 541, 600-601
capacity, 526, 536-537
care and handling, 527
CD-DA, 571
CD-R, 539-543
CD-ROM, 571-572
CD-RW, 539, 543-545
CD TEXT discs, 534-535
construction and technology, 527
copy protection, 536, 588-589
DRM (digital rights management), 589
DualDisc, 578
EFM data encoding, 537-539
file systems, 582-586
form factor, 526
For Music Use Only discs, 588
frames, 533
history of, 526-527
hub clamping area, 530
Labelflash direct disc labeling system, 602
lands, 529
lead-in, 531
lead-out, 531
LightScribe direct disc labeling system, 602
mass production, 527-529
Mount Rainier standard, 586-587
multisession recording, 573-575
Orange Book standard, 572
PCA (power calibration area), 531
Photo CD, 575
Picture CD, 576
pits, 529
PMA (power memory area), 531
program area, 531
read errors, 535-536
ripping, 587-588
sampling rates, 534
Scarlet Book standard (SA-CD), 577-578
sector modes and forms, 572
sectors, 533
subcode bytes, 534
Super Video CDs, 576
table of CD formats, 570-571
technical parameters, 532
tracks, 530-531
White Book standard (Video CD), 576
choosing, 939

DVD drives
  access times, 598
  booting from floppy disk, 601
  buffers/cache, 598
  compatibility, 580
  DMA and Ultra-DMA, 598
  drive sealing, 600
  DVD Multi specification, 566-567
  firmware updates, 607-608
  interfaces, 598-599
  loading mechanisms, 599-600
  MultiAudio specification, 547
  MultiPlay specification, 547
  MultiRead specifications, 545-547
  self-cleaning lenses, 600
  speed, 595-597
  troubleshooting, 602-605

DVDs
  audio data information, 553-554
  bootable DVDs, 601-602
capacity, 555-558
construction and technology, 549-550
copy protection, 589-592
data zone, 550
DIVX (Digital Video Express), 580
DVD drive and media compatibility, 560
DVD Forum, 548
DVD-5, 555
DVD-9, 555
DVD-10, 556
DVD-18, 556
DVD-R, 562-563
DVD+R, 564-566
DVD-R DL, 563
DVD+R DL, 566
DVD-RW, 563-564
DVD+RW, 564-566
DVD+RW Alliance, 548
DVD-Video, 548
EFM+ data encoding, 558-559
error handling, 554-555
explained, 547-548
frames, 553-554
history of, 548
hub clamping area, 550
Labelflash direct disc labeling system, 602
lead-in zone, 550
lead-out zone, 550
LightScribe direct disc labeling system, 602
OTP (opposite track path) construction, 556-557
playing on PCs, 581
PTP (parallel track path) construction, 556-557
sectors, 553-554
table of DVD formats and standards, 578-580
table of recordable DVD standards, 559
technical parameters, 551-553
tracks, 550-551
explained, 525-526
HD-DVD, 569-570
troubleshooting
disc read failures, 602-605
disc write failures, 604
firmware updates, 607-608
problems burning discs with Windows built-in recording, 605
slow drive speeds, 604-605
Optical Storage Technology Association (OSTA), 585-586
optimal resolution, 658
optimizing performance. See performance
Orange Book standard, 572
original equipment manufacturers (OEMs), 273
orthogonal frequency division multiplexing (OFDM), 812, 839
OS/2 Warp, 431
Osborne, Adam, 7
OSS (open sound system) API, 693
OSTA (Optical Storage Technology Association), 585-586
OSx86 Project, 18, 23
OTP (one-time programmable) chips, 270
OTP (opposite track path), 556-557
output ratings (power supply), 895-896
overburning CDs, 541
overclocking, 133-134
CPU voltage settings, 142
bus speeds and multipliers, 140
modern PC clocks, 136-138
pitfalls, 140-142
quartz crystals, 134-136
Sandy Bridge and Ivy Bridge processors, 142
tips and guidelines, 138-139
unlocking cores, 139-140
overheating. See heating/cooling issues
overloading power supply, 912-913
Override enabled – Defaults loaded (error message), 981
overvoltage protection (power supply), 898
oxide media, 484

P

P8 power supply connectors, 870-872
P9 power supply connectors, 870-872
P-CAV (Partial-CAV) technology, 593
packaging processors
BBUL (bumpless build-up layer), 75
FC-PGA (flip-chip pin grid array), 75
PGA (pin grid array), 75
SEC (single edge contact), 75
SPGA (staggered pin grid array), 74
Packet Binary Convolutional Coding (PBCC-22), 810
packets
ATAPI (AT Attachment Packet Interface), 413
packet writing, 573-575
PAC (PCI/AGP Controller). See North Bridge chips
Page Mode memory, 335-336
paged memory, 335-336
paging, 335
pairing, 94, 814
PAL (Phase Alternate Line), 641
PanelLink, 629-630
PANs (personal area networks), 800
Paragon GPT Loader, 292, 434
paragraphs (ROM), 268
Parallel ATA. See PATA
Parallel Port Mode setting (Peripheral Configuration menu), 301
parallel ports, 703-704
25-pin parallel port connectors, 734-735
bidirectional (8-bit) parallel ports, 737
configuration, 738
ECP (Enhanced Capabilities) parallel ports, 737-738
EPP (Enhanced Parallel Port), 737
explained, 729, 734
IEEE 1284 standard, 735-736
standard parallel ports, 736-737
Parallel Port setting (Peripheral Configuration menu), 302
parallel track path (PTP), 556-557
parameter translation. See translation
PARD (Periodic and Random Deviation), 898
parity
block data with, 435
dialup modems, 791
parity bits, 359
parity checking, 359-360
parity inner (PI) bytes, 553
parity outer (PO) bytes, 553
striping with, 434
Parkinson, Cyril Northcote, 462
Parkinson’s Law (Parkinson), 462
Parted Magic, 477, 481
Partial-CAV (P-CAV) technology, 593
Partial-Response, Maximum-Likelihood (PRML), 455
PARTIES (Protected Area Run Time Interface Extension Services), 288
partitioning hard drives, 480-481
GPT (GUID Partition Table), 432-434
HDD partition alignment, 475-477
sector drive partition alignment, 475-477
SSD (solid-state drive) partition alignment needs, 515
parts grabbers, 1000, 1011
Pascal, Blaise, 5
passive heatsinks, 146
passive PFC (power factor correction), 899
passive preventative maintenance, 1011
dust, 1020-1021
heating and cooling, 1017
operating environment, 1016
pollutants, 1020-1021
power cycling, 1017-1018
power-line noise, 1018-1019
RFI (radio-frequency interference), 1019-1020
static electricity, 1018
PassMark Software, 1005
passwords, 311
PATA (Parallel ATA), 380
definition of, 377
DMA (direct memory access) transfer modes, 396-397
dual-drive configurations, 393-395
I/O cables, 390-392
I/O connectors, 387-390
PIO (Programmed I/O) transfer modes, 396
signals, 392-393
patents, 21
PBCC-22 (Packet Binary Convolutional Coding), 810
PC Advanced Technology (PC-AT), 7
PC Card, 511
PC Diag Professional Suite, 990
PC 99 Design Guide website, 686
PC133 specification, 337-338
PC-AT (PC Advanced Technology), 7
Pc-Check, 990
PC-Doctor Service Center, 990
PC-Technician, 990
PCA (power calibration area), 531
PCG (Platform Compatibility Guide), 881
PCH (Platform Controller Hub), 935
P-CHS parameters, 421
PCI (Peripheral Connect Interface) buses, 248-251
adapter cards, 249
board configurations, 250-251
bus types, 249
interrupts, 257
PCI Express, 251-253
specifications, 247-248
PCI Burn-in Mode setting (Chipset Configuration menu), 300
PCI buses, 239
PCI Configuration menu (BIOS Setup), 296
PCIe (PCI Express), 251-253, 626
PCIE x16 Link Retrain setting (PCI Express Configuration menu), 297
PCI Express (PCIe), 626
PCI Express Burn-in Mode setting (Chipset Configuration menu), 300
PCI Express bus, 239
PCI Express Configuration menu (BIOS Setup), 296-297
PCI Express x16 Graphics Power connectors, 890-893
PCI Express x16 v2.0, 80
PCI IDE Bus Master setting (Drive Configuration menu), 304
PCI IRQ Steering, 255, 258
PCI Latency Timer setting (Chipset Configuration menu), 300
PCI/VGA Palette Snoop setting (Video Configuration menu), 307
PCM Upstream, 794
PCMCIA (Personal Computer Memory Card International Association), 511
PdaNet, 795
peak inrush current (power supply), 897
peer-to-peer networks, 803-804
PEG Allow > x1 setting (Chipset Configuration menu), 300
PEG Negotiated Width setting (PCI Express Configuration menu), 297
Pentium-compatible processors
AMD Athlon, 117-118
AMD Athlon MP, 120
AMD Athlon XP, 118-119
AMD Duron, 118
AMD-K6, 64, 116-117
AMD Sempron, 124
NexGen NxS86, 114-116
Pentium processors, 93-96
BTB (branch target buffer), 95
chips, 190-191
instruction processing, 95
math coprocessor, 95
MMX (multimedia extensions), 62-63
socket specifications, 75-76
 specifications, 94
SPGA (staggered pin grid array) packaging, 74
SSE (Streaming SIMD Extensions), 63-64
 superscalar technology, 94
twin data pipelines, 94
Pentium D processors, 106-107, 215
Pentium Extreme Edition processors, 106-107
Pentium II processors, 96-99
chips, 192-195
dynamic execution
dataflow analysis, 65
multiple branch prediction, 64
speculative execution, 65
SECC (single edge contact cartridge) packaging, 75
socket specifications, 75-76
Pentium III processors, 96-100
chips, 192-195
SECC (single edge contact cartridge) packaging, 75
socket specifications, 75-76
SSE (Streaming SIMD Extensions), 63-64
Pentium 4 processors, 101-104
chips
ATI chipsets, 216
Intel 96x series, 204-205
Intel 915 family, 202-203
Intel 925X family, 203
Intel 945 Express family, 203
Intel 955X, 204
Intel 975X, 204
NVIDIA chipset, 216-217
reference tables, 196-202
SiS chipsets, 215
ULi chipsets, 215-216
VIA chipsets, 216, 226
heating/cooling issues, 104-106
NetBurst microarchitecture, 103
Pentium 4 Extreme Edition, 104
power supply issues, 104-106
 specifications, 102-104
Pentium-MMX processors, 62-63
Pentium Pro processors, 96-97
chips, 192-195
dynamic execution
dataflow analysis, 65
multiple branch prediction, 64
speculative execution, 65
socket specifications, 75-76
SPGA (staggered pin grid array) packaging, 74
per inch (TPI), 468
performance
CD drives
access times, 598
buffers/cache, 598
CAV (constant angular velocity) technology, 593
CLV (constant linear velocity) technology, 593-595
data transfer rates, 593
table of CD-ROM drive speeds and transfer rates, 595
DVD drives, 595-597
access times, 598
buffers/cache, 598
DMA and Ultra-DMA, 598
HDDs (hard disk drives)
access times, 503
average seek times, 502
cache programs, 503-504
interleave, 504
latency, 503
reliability, 504-506
transfer rates, 500-502
IEEE 1394, 723-725
memory speed
clock speeds, 333
cycle times, 333
DDR SDRAM, 339-340
DDR2 SDRAM, 341-342
DDR3 SDRAM, 343-344
DDR4 SDRAM, 345
GHz (gigahertz), 332
interleaving, 336
MHz (megahertz), 332
module speeds, 357
nanoseconds, 332
processor bus speeds, 333-335
SDRAM, 338
overclocking, 133-134
bus speeds and multipliers, 140
CPU voltage settings, 142
modern PC clocks, 136-138
pitfalls, 140-142
quartz crystals, 134-136
Sandy Bridge and Ivy Bridge processors, 142
tips and guidelines, 138-139
unlocking cores, 139-140
software, 645
USB (Universal Serial Bus), 723-725
Periodic and Random Deviation (PARD), 898
Peripheral Configuration menu (BIOS Setup), 301-302
Peripheral Connect Interface buses. See PCI buses
peripheral diagnostics software, 976
peripherals. See input devices
perpendicular magnetic recording (PMR), 458-460
persistence, 664
personal area networks (PANs), 800
Personal Computer Memory Card International Association. See PC Card
Personal Use License for System Builder license, 930
perspective correction, 644
PFA (Predictive Failure Analysis), 505
PFC (power factor correction), 898-899
PGA (pin grid array), 75
Phase Alternate Line (PAL), 641
phase-change material, 147
phase-change recording, 561
Phenom processors
chips
AMD 480x and 500 series
chips, 220
AMD 690 series chipsets, 221
AMD 700 series chipsets, 221-222
AMD 800 series chipsets, 222
AMD 900 series chipsets, 223-225
AMD A series chipsets, 225
Phenom, 126-128
Phenom II, 126-128
Philips CD-ROM design and development, 526-527
Phoenix Technologies
BIOS error codes, 322
Phoenix Award BIOS, 273
Phoenix BIOS 4 and later, 983-984
Phoenix BIOS 486 and earlier, 981-983
POST onscreen messages, 979-981
reverse engineering of IBM software, 21-22
phone line surge protectors, 922
Photo CDs, 575
photolithography, 70-71
photoresist coating (CDs), 527
physical configuration, documenting, 946
physical formatting. See low-level formatting
piconets, 813
pico sliders, 469
Picture CDs, 576
piezoelectricity, 134
Piledriver FX processors, 128-131
pin grid array (PGA), 75
pinned magnetic layers, 446
PIO (Programmed I/O) transfer modes, 396
PIO Mode setting (Drive Configuration menu), 304
PI (parity inner) bytes, 553
pitch, 680
pits
CDs, 527-529
DVDs, 549
pixels, 653-657
bad pixels, 675-676
dead pixels, 675
pixels per inch (PPI), 758
stuck pixels, 675
pixie dust, 485
planar. See motherboards
plasma displays, 665
plated thin-film media, 484-485
Platform Compatibility Guide (PCG), 881
Platform Controller Hub (PHC), 935
platters, 466, 483-484
Plextor Zero Link technology, 564
pliers, needle-nose, 1002
Plug and Play. See PnP
Plug & Play O/S setting (Boot Configuration menu), 298
PMA (power memory area), 531
PMOS transistors, 12
PMR (perpendicular magnetic recording), 458-460
PnP (Plug and Play)
hot-plugging, 713
PnP BIOS, 317
ACPI (Advanced Configuration and Power Interface), 318-319
device IDs, 318
point-contact transistor, 6
pointing devices
choosing, 939
mice
ball-driven mouse, 758-759
buttons, 758
cleaning, 765
components, 758
history of, 757-758
hybrid mice, 762
manufacturers, 758
optical mouse, 759-760
PS/2 mouse port, 761
scroll wheels, 762-763
sensitivity, 758
serial interfaces, 760-761
touch-sensitive mice, 763
troubleshooting, 764-765
USB (Universal Serial Bus), 762
touch pads, 768-769
touchscreen technology, 770-771
trackballs, 758, 769-770
TrackPoint, 765-768
wireless
Bluetooth, 772
IR (infrared), 771
power management, 772
proprietary radio frequency, 771
troubleshooting, 773
point of presence (PoP), 788
point-to-point topology, 833
polarizing filters (LCDs), 661
pollutants, 1020-1021
PO (parity outer) bytes, 553
PoP (point of presence), 788
ports
addresses
chipset-based device port addresses, 259-260
motherboard-based device port addresses, 259-260
EUHP (eSATA USB Hybrid Port), 405
explained, 703, 937-938
FireWire. See FireWire
hot-plugging, 725-728
IEEE 1394. See IEEE 1394
legacy ports, 703, 937
motherboard mouse port (PS/2), 761
on ATX motherboards, 170
parallel ports, 703-704
25-pin parallel port connectors, 734-735
bidirectional (8-bit) parallel ports, 737
configuration, 738
ECP (Enhanced Capabilities) parallel ports, 737-738
EPP (Enhanced Parallel Port), 737
explained, 729, 734
IEEE 1284 standard, 735-736
standard parallel ports, 736-737
serial ports, 703-704, 733
9-pin serial port connectors, 732
9-pin-to-25-pin serial port connectors, 733
25-pin serial port connectors, 732
configuration, 733-734
explained, 729-730
locations, 730-733
UART (Universal Asynchronous Receiver/Transmitter) chips, 733
switch ports, 830
USB. See USB (Universal Serial Bus)
POS (Power on Suspend), 910
positive DC voltages
voltage rails, 846-847
voltage regulators, 847
positive-pressure-ventilation design, 852
POST (power on self test), 267, 368
audio error codes, 977
AMI BIOS, 978-979
Award BIOS/Phoenix FirstBIOS, 979
IBM BIOS, 984
IBM/Lenovo, 987-989
Phoenix BIOS, 981-984
checkpoint codes, 977
explained, 975-976
fatal errors, 976
onscreen messages, 978
Award BIOS/Phoenix FirstBIOS, 980-981
IBM BIOS, 984-987
POST cards, 1002
troubleshooting, 1024-1025
postcodemaster.com, 977
Poulsen, Valdemar, 459
power calibration area (PCA), 531
power connectors
4-pin +12V power connectors, 882-883
4-pin to 8-pin +12V power connectors, 884-885
8-pin +12V power connectors, 883-884
AT, 870-872
ATX12V 2.x 24-pin, 877-879
ATX/ATX12V 1.x
6-pin auxiliary power connectors, 876-877
20-pin main power connectors, 872-874
maximum power-handling capabilities, 875-876
Molex Mini-Fit Jr. power connectors, 874-875
backward/forward compatibility, 885-886
Dell proprietary ATX design, 887
explained, 870
floppy power connectors, 888-889
PCG (Platform Compatibility Guide), 881
PCI Express x16 Graphics Power connectors, 890-893
peripheral power connectors, 887-888
power switch connectors
color coding, 869
front panel motherboard-controlled switches, 866-868
front panel power supply AC switches, 868-869
integral power supply AC switches, 868
powerline networks, 839-840
PPI (pixels per inch), 758
PrairieTek 2.5” hard drives, 465
preboot environment (BIOS), 287-289
Predictive Failure Analysis (PFA), 505
prefetching, 63
prefixes for decimal/binary multiples, 414-415
pre-grooves (CD-R), 540
Press ESC to skip memory test (error message), 980
Press TAB to show POST screen (error message), 981
preventative maintenance. See care and maintenance, 1011
Primary IDE Master setting (Drive Configuration menu), 304
Primary IDE Slave setting (Drive Configuration menu), 304
Primary master hard disk fail (error message), 981
Primary slave hard disk fail (error message), 981
Primary Video Adapter setting (Video Configuration menu), 308
primitives, 644
PRML (Partial-Response, Maximum-Likelihood), 455

power factor correction (PFC), 898-899
Power_Good signal, 848-849
power LED indications, 231
power-line noise, 1018-1019
power management
80 PLUS Program, 903-904
ACPI (Advanced Configuration and Power Interface), 905-908
APM (Advanced Power Management), 904-905
BIOS Power menu, 312-313
DPMS (Display Power Management Signaling), 660-661
Energy 2000 standard, 661
Energy Star standard, 660
ENERGY STAR systems, 904
legacy power management, 907
SMM (System Management Mode), 60-61
wireless input devices, 772
power memory area (PMA), 531
Power menu (BIOS Setup), 312-313
Power_OK signal, 848-849
Power on self test. See POST
Power on Suspend (POS), 910
Power Over eSATA (eSATAp), 405-407
power-protection systems
backup power
standby power supply, 922-923
UPS (uninterruptible power supply), 923-925
explained, 919-921
line conditioners, 922
phone line surge protectors, 922
surge protectors, 921
Power Supply Design Guide for Desktop Platform Form Factors, 883
power supply. See PSUs (power supply units)
power switch connectors
color coding, 869
front panel motherboard-controlled switches, 866-868
front panel power supply AC switches, 868-869
integral power supply AC switches, 868
PowerCycle Power Supply (PS) (power supply unit), 321
Power Over eSATA (eSATAp), 405-407
Power On (POST), 287-289
Press ESC to skip memory test (error message), 980
Press TAB to show POST screen (error message), 981
preventative maintenance. See care and maintenance, 1011
Primary IDE hard disk fail (error message), 981
Primary IDE master hard disk fail (error message), 981
Primary IDE slave hard disk fail (error message), 981
Primary Video Adapter setting (Video Configuration menu), 308
primitives, 644
PRML (Partial-Response, Maximum-Likelihood), 455

1086
PSUs (power supply units)

Index

probes (logic), 1007-1008
processor ducts, 151
Processor Frequency ID Utility, 138
Processor Identification Utility, 138
Processor Speed setting (BIOS main menu), 295
Processor Stepping setting (BIOS Maintenance menu), 294
Processor Type setting (BIOS main menu), 295
Processor Zone Response setting (Fan Control Configuration menu), 309
processors. See specific processors (for example, Pentium)
Professional 3DNow! technology, 64
program area (CDs), 531
programmable ROM (PROM), 270-271
Programmed I/O (PIO) modes, 396
projectors
DLP projectors, 667
LCD (liquid crystal display) projectors, 666
PROM (programmable ROM), 270-271
proprietary-design motherboards, 177
proprietary power supply standards, 851
proprietary radio frequency input devices, 771
ProtectDisc, 591
Protected Area Run Time Interface Extension Services (PARTIES), 288
protective coating (CDs), 528
protocols. See specific protocols
PS/2 mouse port, 761
PS/2-type connectors, 159
PS/2 Y adapter, 1003
PS3 form factor, 856
PSB (processor side bus). See buses
pseudo-open drain, 622
PS_ON signal, 848, 866
PSUs (power supply units)
-5V power sources, 847-848
-12V power sources, 847-848
+3.3V power sources, 846
+5V power sources, 846
+12V power sources, 846
backup power
standby power supply, 922-923
UPS (uninterruptible power supply), 923-925
batteries
replacing, 928
RTC/NVRAM, 925-928
buying tips, 918-919
connecting, 958-961
constant voltage, 845
CrossfireX certification, 900
definition of, 28
efficiency, 898
ESD (electrostatic discharge) protection, 945, 1003
floppy power connectors, 888-889
form factors
ATX/ATX12V, 852-854
CFX12V, 860, 863
EPS/EPS12V, 858-860
explained, 849-850
Flex ATX, 864-866
LFX12V, 863
proprietary standards, 851
PS3, 856
SFX/SFX12V, 854-858
table of, 851
TFX12V, 860
hold-up time, 897
importance of, 845
input range, 897
linear design, 893-894
line regulation, 898
loads, 894-895
apparent power, 899
inductive, 898
load regulation, 898
maximum load current, 898
minimum load current, 898
nonlinear, 899
resistive, 898
working power, 899
modular cables, 919
modular power supplies, 958
motherboard power connectors
4-pin +12V power connectors, 882-883
4-pin to 8-pin +12V power connectors, 884-885
8-pin +12V power connectors, 883-884
AT, 870-872
ATX12V 2.x 24-pin, 877-879
ATX/ATX12V 1.x, 872-877
backward/forward, 885-886
Dell proprietary ATX design, 887
explained, 870
PCG (Platform Compatibility), 881
power switch connectors, 866-869
VRM (voltage regulator), 879-880
MTBF (Mean Time Between Failures), 897
negative DC voltages, 847-848
outlet testers, 1008
output ratings, 895-896
overloading, 912-913
overvoltage protection, 898
PARD (Periodic and Random Deviation), 898
PCI Express x16 Graphics
Power connectors, 890-893
peak inrush current, 897
Pentium 4 issues, 104-106
peripheral power connectors, 887-888
PFC (power factor correction), 898-899
positive DC voltages
voltage rails, 846-847
voltage regulators, 847
Power cycling, 908-911
Power_Good signal, 848-849
powering off/on
electrical costs, 908-909
S3 (Suspend To RAM) state, 910
S4 (Hibernate) state, 910
thermal shock, 908
power management
80 PLUS Program, 903-904
ACPI (Advanced Configuration) and, 905-908
APM (Advanced Power Management), 904-905
DPMS (Display Power Management Signaling), 660-661
Energy 2000 standard, 661
Energy Star standard, 660, 904
legacy power management, 907
SMM (System Management Mode), 60-61
power-protection systems
backup power, 922
explained, 919-921
line conditioners, 922
phone line surge protectors, 922
surge protectors, 921
power-use calculations, 901-903
preventative maintenance
power cycling, 1017-1018
power-line noise, 1018-1019
static electricity, 1018
processor voltage settings, 87, 142
protective features, 896
ripple, 898
safety certifications, 900-901
SATA power connectors, 889
SLI-ready, 900
soft-power feature, 848
sources for replacement power supplies, 919
switching design, 846, 893-894
test equipment
back probing, 915-916
digital infrared thermometers, 916
DMMs (digital multimeters), 913-916
variable voltage transformers, 917
transient response, 897
troubleshooting, 911-912, 1025
diagnostic procedures, 912
inadequate cooling, 913
overloaded power supply, 912-913
universal power supplies, 896
test equipment
voltage measurements, 915-916
PTP (parallel track path), 556-557
pure mechanical keyswitches, 742-743
PWR_OK signal, 848-849
PXE Boot to LAN setting (Boot menu), 315
Q
QPI (Quick Path Interconnect), 82
QPSK/CCK data encoding, 810
quartz crystals, 134-136
QuickConnect standard, 793
Quick Path Interconnect (QPI), 82
Quick Power On Self Test feature (BIOS Setup), 316
QuickStop response (TrackPoint), 768
QuickTechPRO, 990
quiet boots, 275
R
RAB (Raid Advisory Board), 434
radio frequency input devices, 771
radio-frequency interference (RFI), 1019
RadioLabs, 1020
RadioShack, 1000
Raid Advisory Board (RAB), 434
RAID (redundant array of independent disks), 434
levels, 434-436
onboard BIOS, 274
software RAID, 436-437
rails (voltage), 846-847
RAM (random access memory)
buffer underruns, 601
cache, 936-937
bus snooping, 60
cache controllers, 60
definition of, 53, 330
direct-mapped cache, 59
explained, 329
fully associative mapped cache, 59
hard disk drive cache programs, 503-504
hits/misses, 330
Level 1, 54-56, 330
Level 2, 56, 330
Level 3, 56, 331
Pentium-MMX improvements, 62
performance and design, 57-59
set associative cache, 59
speed, 60
TLB (translation lookaside buffer), 60
write-back cache, 370
write-through cache, 60
CMOS RAM
addresses, 285-287
backing up, 276-277
configuring with BIOS Setup. See Setup program (BIOS)
definition of, 266-267
diagnostic status byte codes, 287
compared to storage, 326
DDR2 SDRAM, 340-342
DDR3 SDRAM, 342-344
DDR4 SDRAM, 344-345
DDR SDRAM, 338-340, 936
definition of, 28
DIMMs (dual inline memory modules), 346, 936
168-pin SDRAM DIMMs, 348
DDR DIMMs, 348, 353
DDR2 DIMMs, 348, 353
DDR3 DIMMs, 349
purchasing, 365
SDR DIMMs, 352
DIP (dual inline package) chips, 346
DMA (direct memory access) busmaster DMA, 397
CD/DVD drives, 598
channels, 259
multiword, 397
singleword, 396-397
Ultra-DMA, 397
DRAM (dynamic RAM)
compared to SRAM, 329
explained, 327-329
ECC (error correcting code), 360-361
EDO RAM (extended data out RAM), 336-337
explained, 325-327
FPO DRAM (Fast Page Mode DRAM), 335-336
hard fails, 357
HMA (high memory area), 46
installation, 952
layout, 326
logical mapping, 326
memory modules
capacities, 349-351
determining module size/features, 354-355
DIMMs (dual inline memory modules), 346-353, 365
dual rank, 346
installation, 366-367
memory banks, 351, 356-357
purchasing, 364-366
registered modules, 351-352
replacing with higher-capacity versions, 366
RIMMs (Rambus inline memory modules), 346, 349
SIMMs (single inline memory modules), 346-347, 366
single rank, 346
speeds, 357
memory testers, 1008-1009
parity checking, 359-360
purchasing
DIMMs, 365
obsolete memory, 366
suppliers, 364-365
RDRAM (Rambus DRAM), 345
RTC/NVRAM batteries
modern CMOS batteries, 925-927
obsolete/unique CMOS batteries, 927-928
troubleshooting, 928
SDRAM (synchronous DRAM), 337-338
soft errors, 357-359
speed
clock speeds, 333
cycle times, 333
GHz (gigahertz), 332
interleaving, 336
MHz (megahertz), 332
nanoseconds, 332
processor bus speeds, 333-335
SRAM (static RAM)
compared to DRAM, 329
explained, 329
hits/misses, 330
Level 1 cache, 330
Level 2 cache, 330
Level 3 cache, 331
system logical memory layout, 374-376
troubleshooting, 368-372, 1031-1034
with diagnostic software, 368-369
memory defect isolation procedures, 372-374
with POST (Power On Self Test), 368
step-by-step process, 370-372
types of errors, 370
Ultra-DMA, 598
upgrading, 361-364
video RAM, 620-621
  DDR SDRAM, 621
  GDDR2 SDRAM, 621
  GDDR3 SDRAM, 622
  GDDR4 SDRAM, 622
  GDDR5 SDRAM, 622
RAM calculations, 622-623
SGRAM, 621
speed, 622
video memory bus width, 623-624
VRAM, 621
WRAM, 621
volatile storage, 326
RAMAC (Random Access Method of Accounting and Control), 439
Rambus DRAM (RDRAM), 345
Rambus inline memory modules (RIMMs), 346, 349
RAMdisk, 512
Random Access Method of Accounting and Control (RAMAC), 439
ranks of memory modules, 346
raster, 665
rasterization, 644
Ratio Actual Value setting (BIOS Maintenance menu), 294
Raytek, 916
RDRAM (Rambus DRAM), 345
read errors (CDs), 535-536
read latency, 335
read-only memory. See ROM
read process
  flash memory, 520-521
  magnetic storage, 442-443
read/write heads, 440, 443-444, 485-487
  ferrite, 444
  GMR (giant magneto-resistive), 446-447
MIG (Metal-In-Gap), 444
MR (magneto-resistive), 445-446
PMR (perpendicular magnetic recording), 458-460
TF (thin film), 444-445
ReadyBoost, 521-522
real mode, 44-45
real-time clock/nonvolatile memory (RTC/NVRAM), 266
real-time clock. See RTC
rear out sound card connectors, 687
receptacle testers, 1008
recordable DVDs, 559
recording
  CDs, 541, 600-601
    buffer underruns, 601
    DAO (Disc-at-Once) recording, 573
    packet writing, 573-575
    Track-at-Once, 573
  recording media
    AFC (antiferromagnetically coupled), 485
    oxide, 484
    thin-film, 484-485
    sound sampling, 681-682
    standard recording, 478
    ZBR (zoned-bit recording), 478-480
recording media
  AFC (antiferromagnetically coupled), 485
  oxide, 484
  thin-film, 484-485
  recording media
  of flash BIOS, 282-285
  System Restore, 1012
Recuva, 482
Red Book (CD-DA format, 571
Red Hill Hardware Guide, 468
redrawing screen, 665
Reduced Instruction Set Computer (RISC), 61, 739
redundant array of independent disks. See RAID
refresh rates, 657-659, 664-665
refreshing screen, 665
region codes used by Blu-ray disc, 592
region-free DVD players, 592
regional playback control (RPC), 591-592
The Register (website), 26
registered memory modules, 351-352
regulators (voltage), 847
reinstalling components, 1021
reliability
  of ATA (AT Attachment), 378
  of HDDs (hard disk drives)
    MTBF (mean time between failures), 504
    PFA (Predictive Failure Analysis), 505
    S.M.A.R.T. (Self-Monitoring, Analysis, and Reporting Technology), 504-506
remarking processors, 74
remote power switch connectors. See power switch connectors
removable storage devices. See also flash memory
  choosing, 939
  explained, 507
  flash memory
    card capacities, 518
    card readers, 520-521
    CompactFlash, 509
    comparison of, 517-519
    development of, 507
    device sizes, 509
    explained, 508-509
    file systems, 520
    keychain devices, 507
Lexar Memory Stick Pro, 511
Lexar Memory Stick Pro Duo, 511
MMC (MultiMediaCard), 510
NAND (Not AND), 508
NOR (Not OR), 508
PC Card, 511
ReadyBoost support, 521-522
SD (SecureDigital)
SecureDigital (SD), 510
SmartMedia, 509-510
Sony Memory Stick, 510
Sony Memory Stick Micro, 511
Sony Memory Stick XC, 511
speed classes, 519-520
SSD (solid-state drive), 511-515
USB flash drives, 516-517
xD-Picture Card, 511
floppy drives, 523
tape drives, 523
removing video adapters, 968
rendering images, 644-645, 648
AMD CrossFireX, 648-649
AMD Eyefinity, 650
NVIDIA SLI, 648
repair. See troubleshooting
Repeat Delay parameter
(Windows keyboards), 749
Repeat Rate parameter
(Windows keyboards), 749
repeaters, wireless, 832
replacing
batteries, 928
components
bootstrap approach, 1023-1024
compared to reinstalling components, 1021
known-good spare technique, 1022
power supply, 919
video adapters, 968
report status command, 505
reprogrammable microcode, 88
Reset Intel AMT to default factory settings (BIOS Maintenance menu), 294
resistive power, 898
resolution
of monitors, 651-652
optimal resolution, 658
resources. See system resources
restore points, 1012
Resuming from disk, Press TAB to show POST screen (error message), 981
reverse-engineering software, 22
RF (radio frequency) input devices, 771
RFI (radio-frequency interference), 1019-1020
RG-58 cable (Thinnet), 817
RIMMs (Rambus inline memory modules), 346, 349
ring topology, 826
rippling CDs, 587-588
ripple (power supply), 898
RISC (Reduced Instruction Set Computer), 61, 739
RJ-45 connectors, 815
RLL (Run Length Limited), 442, 452-453
Roberts, Ed, 14
Rock Ridge file system, 586
Rock Ridge Interchange Protocol (RRIP), 586
ROM. See also BIOS
definition of, 267
EEPROM (electronically erasable programmable ROM), 272-273
EPROM (erasable programmable ROM), 271-272
explained, 327
flash ROM, 272-273
hardware, 267-268
manufacturers, 273-274
mask ROM, 270
 PROM (programmable ROM), 270-271
shadowing, 269
root hubs, 706
rotary voice-coil actuators, 489
routers, 796
RPC (regional playback control), 591-592
RRIP (Rock Ridge Interchange Protocol), 586
RTC (real-time clock), 266
modern CMOS batteries, 925-927
obsolete/unique CMOS batteries, 927-928
troubleshooting, 928
RTS2011LC cooling system, 149
rubber dome keyswitches, 744
Run Length Limited (RLL), 442, 452-453
Rutledge, Joseph, 766
S
S3 (Suspend To RAM) state, 910
S4 (Hibernate) state, 910
S-100 bus, 14
SA-CD (Super Audio CD), 577-578
SafeAudio, 589
Safe Removal settings (drives), 726-727
safety. See security
SAL (Soft Adjacent Layer) structure, 446
sampled sound. See Waveform audio sampling
sampling, 534, 681-682
SanDisk Corporation CompactFlash, 509
Sandy Bridge architecture (Core i), 113-114, 142
SASI (Shugart Associates System Interface). See SCSI (small computer system interface)
SATA (Serial ATA)
   AHCI (Advanced Host Controller Interface), 408-409
   backward compatibility, 398
   BIOS setup, 407
   cables and connectors, 401-403
   CD/DVD drive interfaces, 598-599
   definition of, 377
   eSATA (external SATA), 404-405
   eSATAp (Power Over eSATA), 405-407
   explained, 398
   mSATA (mini-SATA), 403-404
   NVMe (Non-Volatile Memory Express), 409
   power connectors, 889
   SATA Express, 399-401
   Serial ATA International Organization, 380, 399
   standards and performance, 398-399
   transfer modes, 399, 409-410
SATA Express, 399-401
satellite broadband
   explained, 784-785
   HughesNet, 785
   performance issues, 786-787
   StarBand, 786
   WildBlue, 785-786
satellite speakers, 699
Save Custom Defaults command (BIOS Exit menu), 316
SB 810 South Bridge chip, 222
SB 850 South Bridge chip, 222
scalable link interface (SLI), 890-893
scan codes, 749-750
scan conversion, 645
scan-line interfacing (SLI), 648
scan rates, 657-659, 664-665
Scan User Flash Area setting (Boot menu), 315
Scarlet Book standard (SA-CD), 577-578
SCAT (Single Chip AT) chipsets, 182
scientific method, applying to troubleshooting, 1021-1022
scratchy sound, troubleshooting, 697
screen flicker, 664
screwdrivers, 1000, 1002, 1009
scroll wheels (mouse), 762-763
SCSI (small computer system interface), 523
SD (SecureDigital), 510
SD (Super Density) disks, 548
SDR (single data rate) DIMMs, 352
SDRAM (synchronous DRAM), 337-338
   DDR SDRAM (double data rate SDRAM), 936
   SDRAM DIMM, 348
SDRAM CAS# Latency setting (Memory Configuration menu), 297
SDRAM Frequency setting (Memory Configuration menu), 297
SDRAM RAS Act. To Pre. setting (Memory Configuration menu), 297
SDRAM RAS# Precharge setting (Memory Configuration menu), 298
SDRAM RAS# to CAS# delay setting (Memory Configuration menu), 298
SDRAM Timing Control setting (Memory Configuration menu), 298
SDSL (Symmetrical DSL), 781
sealing CD/DVD drives, 600
SECAM (Sequential Couleur Avec Mémoire), 641
SECC (single edge contact cartridge) processor packaging, 75
SEC-DED (single-bit error-correction double-bit error detection), 360
second-party memory modules, 364
Second SATA Master setting (Drive Configuration menu), 304
secondary cache. See Level 2 cache
Secondary IDE Master setting (Drive Configuration menu), 304
Secondary IDE Slave setting (Drive Configuration menu), 304
Secondary master hard disk fail (error message), 981
Secondary SATA Controller setting (Peripheral Configuration menu), 302
Secondary slave hard disk fail (error message), 981
Secondary Video Adapter setting (Video Configuration menu), 308
sector addressing
   CHS (cylinder head sector)
      2.1 GB barrier, 423
      4.2 GB barrier, 423-425
      8.4 GB barrier, 427-428
      528 MB barrier, 419-421
   BIOS commands versus ATA commands, 418-419
   CHS bit-shift translation, 421-423
servo-controlled systems

Index

1093

CHS/LBA conversions, 417-418
compared to LBA (logical block address), 416-417
LBA (logical block address)
137 GB barrier and beyond, 429-430
BIOS commands versus ATA commands, 418-419
CHS/LBA conversions, 417-418
compared to CHS (cylinder head sector), 416-417
LBA-assist translation, 425-427
prefixes for decimal/binary multiples, 414-415
sectors, 466. See also tracks
512-byte sector on modern drive, 472
Advanced Format (4K sectors), 473-475
CDs, 533
data bytes, 470
DVDs, 553-554
fields, 470
gaps in, 470
headers/trailers, 471
numbering, 470
sector drive partition alignment, 475-477
usable space, 471
Western Digital WD1003/WD1006 (IBM AT) 512-byte sector format, 471-472
Xebec 1210/1220 (IBM XT) 512-byte sector format, 471
security
ATA (AT Attachment)
HPAs (host protected areas), 412-413
Security Mode, 411-412
biometric security, 516
BIOS Setup settings, 311-312
CD copy protection, 536, 588-589
DRM (digital rights management), 589
DSL (digital subscriber line), 782
DVD copy protection, 589-590
breakability of, 591
Cinavia, 591
CSS (content scramble system), 590-591
ProtectDisc, 591
region codes used by Blu-ray disc, 592
RPC (regional playback control), 591-592
Internet connections explained, 794-795
routers, 796
service interruptions, 795
shared connections, 795-796
passwords, 311
power-protection systems backup power, 922
explained, 919-921
line conditioners, 922
phone line surge protectors, 922
surge protectors, 921
viruses, CIH, 278
war driving, 833
WEP (wired equivalent privacy), 834-835
wireless networks, 833-835
WPA (Wi-Fi Protected Access), 834
Security menu (BIOS Setup), 311-312
Security Option setting (Security menu), 311
seek times, 463, 502
self-cleaning lenses (CD/DVD drives), 600
Self-Monitoring, Analysis, and Reporting Technology (S.M.A.R.T.), 383, 504-506
Selker, Ted, 766
semiconductors, 12, 25
semiproprietary LPX motherboards, 160
Sempron processors, 124
chipsets
AMD 480x and 500 series chipsets, 220
AMD 690 series chipsets, 221
AMD 700 series chipsets, 221-222
AMD 800 series chipsets, 222
AMD 900 series chipsets, 223-225
AMD A series chipsets, 225
overview, 126-128
sensitivity of mice, 758
SEPP (single edge processor package), 75
Sequential Couleur Avec Mémoire (SECAM), 641
Serial ATA. See SATA
Serial ATA International Organization, 380, 399
serial mouse, 760-761
serial ports, 703-704
9-pin serial port connectors, 732
9-pin-to-25-pin serial port connectors, 733
25-pin serial port connectors, 732
configuration, 733-734
explained, 729-730
locations, 730-733
UART (Universal Asynchronous Receiver/Transmitter) chips, 733
Serial Port setting (Peripheral Configuration menu), 302
Series A/B connectors (USB), 712
SERs (soft error rates), 357-359
servo-controlled systems, 488
servo mechanisms, 489-493
  dedicated servo, 492-493
disk sweep, 491
embedded servo, 492
gray code, 490
servowriters, 490
thermal recalibration, 490
wedge servo, 491-492
servowriters, 490
set associative cache, 59
SET MAX ADDRESS command (ATA), 413
Set Supervisor Password setting (Security menu), 311
setup passwords, 311
Setup program (BIOS), 267
  accessing, 292
  additional setup features, 316-317
Boot Configuration menu, 298
Boot menu, 314-315
Chipset Configuration menu, 298-300
Drive Configuration menu, 302-305
Event Log Configuration menu, 306-307
Exit menu, 315-316
explained, 292-293
Fan Control Configuration menu, 309
Floppy Configuration menu, 305-306
hardware monitoring display, 310
main menu, 294-295
Maintenance menu, 293-294
Memory Configuration menu, 297-298
PCI Configuration menu, 296
PCI Express Configuration menu, 296-297
Peripheral Configuration menu, 301-302
Power menu, 312-313
running, 969-971
Security Configuration menu, 311-312
USB Configuration menu, 308-309
Video Configuration menu, 307-308
Set User Password setting (Security menu), 311
SFX power supply, 854-858
SFX12V power supply, 854-858
SGI OpenGL, 646
SGRAM (Synchronous Graphics RAM), 621
shading, 645
  flat shading, 642
  Gouraud shading, 643
shadow masks (CRT), 664
shadowed ROM (read-only memory), 269
Shannon, Claude, 791
Shannon’s Law, 791
sharing
  Internet connections, 795-796
  interrupts, 255
shielded twisted pair (STP) cables, 817-818
Shima, Masatoshi, 30-31
Shockley, William, 6, 11
Shugart, Alan, 464, 523
Shugart Associates, 464-465
Shugart Associates System Interface (SASI). See SCSI (small computer system interface)
shutdown, troubleshooting, 1026
Shutdown.exe, 999
signals
  keyboard connector signals, 752
  PATA (Parallel ATA) signals, 392-393
  Power_Good, 848-849
  PS_ON, 848, 866
  signal boosters, 832
  signal skew, 704
  signal processing methods (audio), 688
  signal-to-noise ratio (SNR), 681
SIIG, 416
  mechanical-switch keyboards, 743
Silent Boot setting (Boot menu), 315
silicon, 69
Silicon Image PanelLink, 629-630
silicon on insulator (SOI), 71
silicon transistors, 12
SIMMs (single inline memory modules), 346
  30-pin SIMM, 347
  72-pin SIMM, 347
  purchasing, 366
Simon computer, 19
single-bit error-correction double-bit error detection (SEC-DED), 360
Single Chip AT (SCAT) chipsets, 182
single data rate (SDR) DIMMs, 352
Single-Density encoding, 451
single edge contact cartridge (SECC) packaging, 75
single edge processor package (SEPP), 75
single-gap heads, 446
single inline memory modules. See SIMMs
single-level cell (SLC), 513-514
single rank memory modules, 346
single-sided memory modules, 346
singleword DMA (direct memory access), 396-397
SiS (Silicon Integrated Systems) chipsets, 215, 227
SIV, 275
sound cards

SIW (System Information for Windows), 416, 1032
Sixth SATA Master setting (Drive Configuration menu), 304
size
   of flash memory devices, 509
   of hard disk drive platters, 483
   of video monitors, 650
skins (keyboard), 756
slave drives (ATA), 393
SLC (single-level cell), 513-514
sleep feature for speakers, 699
sliders (head), 448-450
slimline cases, 933
SLI (scalable link interface), 890-893
SLI (scan-line interfacing), 648
SLI-ready power supplies, 900
slot load mechanism (CD/DVD drives), 599
slots (processor), 178-181
slotted masks (CRT), 664
SmartMedia, 509-510
Smartronix, 1005
S.M.A.R.T. (Self-Monitoring, Analysis, and Reporting Technology), 383, 504-506
S.M.A.R.T. setting (Drive Configuration menu), 304
SMBIOS (System Management BIOS Setup), 306
SMI (System Management Interrupt), 61
SMM (System Management Mode), 60-61
snooping (bus), 60
SNR (signal-to-noise ratio), 681
Socket B, 81, 82
Socket H, 80-81
Socket H2, 82
socketed Op Amp chips, 689
sockets, 178-181
   LIF (low insertion force), 78
   Socket 478, 78-79
Sound Blaster, 682
Sound Blaster Pro, 682
sound cards
   AdLib, 682
   choosing, 940
   connectors, 686-689
      analog RCA, 689
      aux in, 688
      coaxial PDIF, 688
      HDMI (High Definition Multimedia Interface), 688
      line in sound card connectors, 687
      line out sound card connectors, 687
      microphone in connectors, 687
      MIDI in/out, 688
      mono in connectors, 687
      optical SPDIF out, 688
      rear out sound card connectors, 687
      socketed Op Amp chips, 689
      world clock I/O, 689
software
   copyright protection, 21
   industry control of, 20-23
   optimization, 645
   reverse-engineering, 22
   software RAID, 436-437
   software resources, 942
   troubleshooting, 1024
SOI (silicon on insulator), 71
solid-state drive. See SSD
solid state floppy disk card (SSFDC), 509
Sony
   3.5” half-height drives, 465
   CD-ROM design and development, 526-527
   DRM (digital rights management), 589
   Memory Stick, 510
   Memory Stick Micro, 511
   Memory Stick XC, 511
sound. See audio
Sound Blaster, 682
Sound Blaster Pro, 682
SMBIOS (System Management BIOS Setup), 306
specifications, 75-76
ZIF (zero insertion force), 74, 78
Socket T, 79
Soft Adjacent Layer (SAL) structure, 446
soft error rates (SERs), 357-359
soft errors, 328
soft memory fails, 357-359
soft-off switches, 866
Soft Power, 854
soft-power feature, 848
software
   copyright protection, 21
   industry control of, 20-23
   optimization, 645
   reverse-engineering, 22
   software RAID, 436-437
   software resources, 942
   troubleshooting, 1024
SOI (silicon on insulator), 71
solid-state drive. See SSD
solid state floppy disk card (SSFDC), 509
Sony
   3.5” half-height drives, 465
   CD-ROM design and development, 526-527
   DRM (digital rights management), 589
   Memory Stick, 510
   Memory Stick Micro, 511
   Memory Stick XC, 511
sound. See audio
Sound Blaster, 682
Sound Blaster Pro, 682
sound cards
   AdLib, 682
   choosing, 940
   connectors, 686-689
      analog RCA, 689
      aux in, 688
      coaxial PDIF, 688
      HDMI (High Definition Multimedia Interface), 688
      line in sound card connectors, 687
      line out sound card connectors, 687
      microphone in connectors, 687
      MIDI in/out, 688
      mono in connectors, 687
      optical SPDIF out, 688
      rear out sound card connectors, 687
      socketed Op Amp chips, 689
      world clock I/O, 689
XLR input/output, 689
data compression, 692-693
definition of, 28
drivers, 693
frequency response, 680
history of, 682
integrated audio chipsets, 694
Microsoft Windows audio support, 682
   3D gaming standards, 684-685
core audio APIs, 683-684
   DirectX, 683
   EAX (environmental audio extensions), 685
Index

sound cards

interference, 699
satellite speakers, 699
sleep feature, 699
surround sound, 699-700
total harmonic distortion, 698
troubleshooting, 696
volume control, 699
watts, 698

Specialized Products Company, 1004

speculative execution, 64-65

speed

56Kbps modems, 792
broadband technology, 789

CD drives
access times, 598
buffers/cache, 598
CAV (constant angular velocity) technology, 593
CLV (constant linear velocity) technology, 593-595
data transfer rates, 593
DMA and Ultra-DMA, 598
table of CD-ROM drive speeds and transfer rates, 595

CD-R, 543

HDDs (hard disk drives)
access times, 503
average seek times, 502

cache programs, 503-504
interleave, 504
latency, 503
transfer rates, 500-502

IEEE 1394, 723-725

memory speed

cache, 60
clock speeds, 333

cycle times, 333

DDR SDRAM, 339-340
DDR2 SDRAM, 341-342
DDR3 SDRAM, 343-344
DDR4 SDRAM, 345

GHz (gigahertz), 332

flash memory cards, 519-520
interleaving, 336
MHz (megahertz), 332
module speeds, 357
nanoseconds, 332

processor bus speeds, 333-335
SDRAM, 338

NICs (network interface cards), 815

overclocking, 133-134
bus speeds and multipliers, 140
CPU voltage settings, 142
modern PC clocks, 136-138
pitfalls, 140-142
quartz crystals, 134-136

Sandy Bridge and Ivy Bridge processors, 142
tips and guidelines, 138-139
unlocking cores, 139-140

processors, 49-53

speed locking, 294

SpeedFan, 991

SPGA (staggered pin grid array), 74

spills on keyboards, cleaning, 756

spin-coating process (CD-R), 540

spindle motors, 495-496

Spindle Synchronization (SPSYNC) signals, 393

spin rates (HDDs), 467

spin-valve heads, 446-447

Spitfire (Duron), 118

splash screens, 275
Sync sector field

SPS (standby power supply), 922-923
SPSYNC (Spindle Synchronization) signals, 393
sputtered thin-film media, 484-485
sputtering, 444, 485
SRAM (static RAM). See also cache
  compared to DRAM, 329
  explained, 329
  hits/misses, 330
  Level 1 cache, 330
  Level 2 cache, 330
  Level 3 cache, 331
SSDs (solid state drives)
  applications, 515
  configuration
    automatic drive detection, 966
    explained, 962-963
  definition of, 511
  Flash-based SSDs, 512-513
  installation, 963-965
  partition alignment, 515
  SLC (single-level cell) versus MLC (multilevel cell), 513-514
  SSD awareness in Windows, 514
  TRIM command, 514-515
  virtual SSD (RAMdisk), 512
SSE (Streaming SIMD Extensions), 63-64
SSFDC (solid state floppy disk card), 509
SSIDs, 834
Stabilant 22a, 744, 1014
staggered pin grid array (SPGA), 74
standard parallel ports, 736-737
standard recording, 478
standard thick client, 933
standard thin client, 933
standby power supply, 922-923
Standby state (APM), 905
Stanley Supply & Services, 1000, 1004
star topology, 827, 833
StarBand, 786
start bits, 730
start-stop communications, 790
startup process, troubleshooting, 697
Static Column memory, 335-336
static contrast ratio, 660
static electricity, 1018
static-filled sound, troubleshooting, 697
static RAM. See SRAM
status LEDs (broadband devices), 797
steppe motors, 487-488
stereophonic sound cards. See sound cards
STFT, 662
stop bits, 791
STOP errors, 1025
stored-program technique, 10
STP (shielded twisted pair) cables, 817-818
Streaming SIMD Extensions (SSE), 63-64
striping disks, 434-435
STR (Suspend to RAM), 910
stuck keyswitches, troubleshooting, 755
stuck pixels (LCDs), 675
subcode bytes (CDs), 534
substrate material, magnetic storage, 441
Super Audio CD (SA-CD), 577-578
Super Density (SD) disks, 548
Super I/O chips, 186, 228
Super-IPS (in-place switching), 662
Super Video CDs, 576
Superchips, 272
superparamagnetic limit, 485
superscalar technology, 94, 61-62
SuperSpeed USB (USB 3.0), 713-715
supertiling, 648
supervisor passwords, 311
Supervisor Password setting (Security menu), 311
surge protectors, 921
surprise removal, 725
surround sound, 699-700
Suspend state (APM), 905
Suspend to RAM (STR), 910
swabs, 1015
Swan Floppy Drive feature (BIOS Setup), 316
switches, 827-828, 842
  address storing, 828
  compared to hubs, 828-829
  dual-speeds, 829
  front panel AC switches, 868-869
  front panel motherboard-controlled, 866-868
  integral AC switches, 868
  managed/unmanaged, 828
  placement of, 830-831
  ports, 830
  power-saving features, 829
switching power supply
  loads, 894-895
    apparent power, 899
    inductive, 898
    load regulation, 898
    maximum load current, 898
    minimum load current, 898
    resistive, 898
    working power, 899
  overview, 846, 893-894
Symantec Norton Ghost, 506
Symmetrical DSL (SDSL), 781
Sync sector field, 470
synchronous DRAM (SDRAM), 337-338
Synchronous Graphics RAM (SGRAM), 621
synthetic benchmarks, 49
SYMark 2012, 52-53
system assembly
cables, 941, 969
cases, 933-934, 953-956
cover assembly, 969
custom PC configurations, 931-933
  audio/video editing systems, 932
custom PC build guide, 933
gaming systems, 932
graphics systems, 931
home server systems, 932-933
home theater systems, 932
standard thick client, 933
standard thin client, 933
virtualization systems, 932
documentation of physical configuration, 946
ESD (electrostatic discharge) protection, 945
expansion cards, 969
explained, 929-931, 942-943
hardware resources, 942
HDDs (hard disk drives)
  choosing, 938-939
  drive configuration, 962-963
  drive installation, 963-965
heatsinks, 941, 946-952
input devices, 939
memory modules, 952
miscellaneous hardware, 942
motherboards
  BIOS, 936
  cables, 961-962
  chipsets, 935-936
Desktop Form Factors website, 935
explained, 935
integrated adapters, 938
memory, 936-937
mounting in case, 953-956
ports, 937-938
UEFI (Unified Extensible Firmware Interface), 936
operating system installation, 971-972
power supply
  connecting, 958-961
  modular power supplies, 958
preparation, 943-944
processors, 934, 946-952
required tools, 943-944
software resources, 942
sound cards, 940
SSDs (solid state drives)
  automatic drive detection, 966
  drive configuration, 962-963
  drive installation, 963-965
troubleshooting, 972-973
video adapters, 940
  installation, 967-968
  removing, 968
system boards. See motherboards
system boot process. See boot process
System Bus Speed setting (BIOS main menu), 295
System Date setting (BIOS main menu), 295
System Fan Control setting (Fan Control Configuration menu), 309
System Information for Windows (SIW), 416, 1032
system interface (video)
  AGP (Accelerated Graphics Port), 625-626
  overview, 624
  PCIe (PCI Express), 626
system logical memory layout, 374-376
System Management Interrupt (SMI), 61
System Management Mode (SMM), 60-61
System Management (SMBIOS) BIOS Setup, 306
system memory. See RAM (random access memory)
System Memory Speed setting (BIOS main menu), 295
system passwords, 311
system resources, 254
  DMA (direct memory access) channels, 259
I/O port addresses
  chipset-based device port addresses, 259-260
  motherboard-based device port addresses, 259-260
IRQs (interrupt request channels), 254
  8-bit ISA bus interrupts, 255
  16-bit ISA/EISA/MCA bus interrupts, 256-257
Advanced Programmable Interrupt, 258
  conflicts, 259
edge-triggered interrupt sensing, 255
interrupt sharing, 255
maskable interrupts, 255
PCI interrupts, 257-258
PCI IRQ Steering, 255
System Restore, 1012
system startup, 969-971
System Time setting (BIOS main menu), 295
system tray, 725
system types, 26-27

T

T-1 connections, 788
tables, GPT (GUID Partition Table), 432-434
TAC Design Guide, 151
tailgates, 384
Tanisys, 369, 1009
TAO (Track-at-Once) recording, 573
tape drives, 523
TCP/IP, 837
Teal, Gordon, 6
Technical Committee T13, 380
telephony connectors, 238
temperature acclimation (HDDs), 495
temperature probes, 1010
tessellation (DirectX), 647
test equipment
  DMMs (digital multimeters), 1002, 1005-1007
electrical testing equipment, 1005
electric screwdrivers, 1009
logic probes, 1007-1008
loopback connector, 1005
memory testers, 1008-1009
outlet testers, 1008
video adapters, 671
Tether, 795
tethering, 795
texture mapping, 643-645
TF (thin film) heads, 444-445
TFT (thin film transistor) arrays, 661-662
TFX12V power supply, 860
THD (total harmonic distortion), 680, 698
theater surround sound, 699-700
thermal interface material (TIM), 949
thermal recalibration (servo mechanisms), 490
thermal resistance, 146
thermal shock, 908
thermally advantaged chassis
  cooling fans, 149
  maximum heatsink inlet temperatures, 150
  processor ducts, 151
  specifications, 150-151
thermometers
digital infrared thermometers, 916
infrared thermometers, 1010
thick Ethernet coaxial cables, 816-817
thin Ethernet coaxial cables, 817
thin film (TF) heads, 444-445
thin-film media, 484-485
thin film transistor (TFT) arrays, 661-662
thin form factor (TFX12V) power supply, 860
ThinkPad keyboards, 757
Thinnet, 817
third-party memory modules, 364
Third SATA Master setting (Drive Configuration menu), 304
Thomas, Thampy, 114
threads, 67
thumb flash memory devices, 507
Thunderbolt Technology, 728-729
Timelt utility, 724
timeline of computer history, 5-9
TIM (thermal interface material), 949
TLB (translation lookaside buffer), 60
TMDS (Transition Minimized Differential Signaling), 629-630
Token-Ring, 826
topologies
  bus topology, 825
  explained, 824-825
  point-to-point topology, 833
  ring topology, 826
  star topology, 827, 833
toroids, 1019
Torture Test (GIMPs), 991
Torx drivers, 1001
total harmonic distortion (THD), 680, 698
Total Memory setting
  BIOS main menu, 295
  Memory Configuration menu, 298
  touch keyboards, 747
  Touch Mouse (Microsoft), 763-764
  touch pads, 768-769
  touch-sensitive mice, 763
  touchscreen technology, 770-771
tower cases, 934
Track-at-Once (TAO) recording, 573
track following systems, 488
track pads, 768-769
trackballs, 758, 769-770
TrackPoint keyboards (ThinkPad), 757
TrackPoint pointing device, 765-768
tracks. See also sectors
  CDs, 530-531
  defined, 470
densities, 468
  DVDs, 550-551
  HDDs, 466
  trailers (sectors), 471
  transceivers (DSL), 780
  transfer modes (SATA), 409-410
transfer rates
  CD drives, 593
  DMA (direct memory access), 397
  HDDs (hard disk drives), 463, 500-502
  PATA DMA (direct memory access) transfer modes, 396-397
  PATA PIO (Programmed I/O) transfer modes, 396
  SATA (Serial ATA) transfer rates, 399
transient response (power supply), 897
transistors
  Graphene-based transistors, 13
  invention of, 11
  MOSFETs (Metal Oxide Semiconductor Field Effect Transistors), 11-12
  PMOS transistors, 12
  silicon transistors, 12
transition cells, 442
Transition Minimized Differential Signaling (TMDS), 629-630
translation
  CHS bit-shift translation, 421-423
  LBA-assist translation, 425-427
  TLB (translation lookaside buffer), 60
Transmission Control Protocol/Internet Protocol (TCP/IP), 837
tray load mechanism (CD/DVD drives), 599-600
tri-channel memory, 356-357
Tri-Gate transistors, 13
Triode, 11
Tripp Lite, 925
troubleshooting. See also testing
  3TB drives, 1032-1033
  adapter cards, 1025, 1034
  audio
    advanced features, 697
    with Device Manager, 698
    low volume, 695-696
    no sound, 695
    problems playing specific file formats, 696
    scratchy sound, 697
    speakers, 696
    startup problems, 697
  basic guidelines, 1021
  BD (Blu-ray), 606
  BIOS errors, 319-320
    AMI BIOS error messages, 322
    Award BIOS error messages, 322
    Compaq BIOS error messages, 322
    IBM BIOS error messages, 320-321
    Phoenix BIOS error messages, 322
  bootable CDs, 606
  boot process, 1024, 1031
  bootstrap approach, 1023-1024
  broadband service interruptions, 795
  broadband signal lights, 797
  BSOD (Blue Screen Of Death) errors, 989
  CD/DVD drives, 1033
    disc read failures, 602-605
    disc write failures, 604
    firmware, 607-608
    problems burning discs with Windows built-in recording, 605
    slow drive speeds, 604-605
  CMOS batteries, 928
  DVD errors, 554-555
  emergency flash BIOS recovery, 282-285
errors. See error messages
  ESD (electrostatic discharge), 945
  Fatal Exception errors, 1026
  frozen/locked systems, 1030-1034
  hard drives, 1030-1031
  HDDs (hard disk drives), 1032-1034
  IRQs (interrupt request channels) conflicts, 259
keyboards, 1027
  cleaning, 755-756
connectors, 755
defective cables, 754-755
stuck keyswitches, 755
known-good spare technique, 1022
maintenance tools, 999-1000
  2 ½"ATA drive cables and adapters, 1003
3 ½" drive enclosure, 1003
cleaning materials, 1002
data transfer cables and adapters, 1003
DMMs (digital multimeters), 1002, 1005-1007
electrical testing equipment, 1005
electric screwdrivers, 1002, 1009
ESD (electrostatic discharge) protection kits, 1003
files, 1002
flashlights, 1002
hemostats, 1002
infrared thermometers, 1010
lithium coin cell batteries, 1003
logic probes, 1007-1008
loopback connector, 1005
markers/pens, 1002
memory testers, 1008-1009
needle-nose pliers, 1002
nut drivers, 1000
nylon cable-ties, 1002
outlet testers, 1008
parts grabbers, 1000, 1011
POST cards, 1002
PS/2 Y adapter, 1003
safety, 1003-1004
screwdrivers, 1000
spare parts, 1003
temperature probes, 1010
torx drivers, 1001
tweezers, 1000
USB/FireWire cable adapter, 1003
vises/clamps, 1002
Windows 98/98SE or Me Startup floppy, 1002
Windows 2000/XP bootable CD, 1002
wire cutters, 1002
wire strippers, 1002
MBR errors, 319-323
  Error loading operating system, 323-324
  Invalid partition table, 323
  Missing operating system, 324
memory
  ECC (error correcting code), 360-361
  hard fails, 357
  parity checking, 359-360
  soft errors, 357-359
mouse, 764-765
microphones, 701
Missing operating system error message, 1031
modems, 1026-1027
monitors, 672-677, 1027-1028
  bad pixels, 675-676
  dead pixels, 675
  monitor adjustments, 674-675
  monitor repairs, 677
  monitor testing, 673-674
  stuck pixels, 675
motherboard installation, 1034
POST (power on self test). See POST
power supply, 911-912, 1025
diagnostic procedures, 912
with DMMs. See DMMs (digital multimeters)
inadequate cooling, 913
overloaded power supply, 912-913
processors, 88, 151-153
processor upgrades, 1029-1030
RAM (random access memory), 368-372, 1031-1034
with diagnostic software, 368-369
memory defect isolation procedures, 372-374
with POST (Power On Self Test), 368
step-by-step process, 370-372
types of errors, 370
reinstallation versus replacement, 1021
scientific method, 1021-1022
software, 1024
sound, 1027
sound cards, 694
STOP errors, 1025
system assembly, 972-973
USB (Universal Serial Bus), 1033
video adapters, 670-671
video cards, 1028-1029
video drivers, 672
Windows shutdown, 1026
wireless input devices, 773

TRS-80 Model 1 computers, 31
true ROM (read-only memory), 270
true UPS (uninterruptible power supply), 923
Trusted Platform Module setting (Peripheral Configuration menu), 302
tubes, 11
TurboCore, 617
Turing, Alan, 5
Turing Machine, 5
turning off/on systems
electrical costs, 908-909
S3 (Suspend To RAM) state, 910
S4 (Hibernate) state, 910
thermal shock, 908
TV display interfaces, 641-642
tweezers, 1000
twisted-pair cables, 817
building, 820-824
cable distance limitations, 824
Category 3 cable, 818
Category 5 cable, 819
Category 6 cable, 819
Category 6a cable, 819
crossover cables, 821
grounding loops, 818
STP (shielded twisted pair), 817-818
wiring standards, 820-821
Typematic Delay (Msec) feature (BIOS Setup), 317
typematic functions, 749
Typematic Rate feature (BIOS Setup), 317
Typematic Rate Setting feature (BIOS Setup), 317

U

u-pipes, 94
UART (Universal Asynchronous Receiver/Transmitter) chip, 733
UDF (Universal Disk Format), 574, 585-586
UDF Reader 2.5, 585
UDF Volume Reader 7.1.0.95, 585
UDMA (Ultra-DMA), 383-386
Udpixel, 676
UEFI (Unified Extensible Firmware Interface), 273, 936
BIOS limitations, 290-291
explained, 289-290
support for, 291-292
UEFI Boot setting (Boot menu), 315
UHA (Ultra High Aperture), 662
UHS (Ultra High Speed) Class marking, 520
UL (Underwriters Laboratories)
power supply safety certifications, 900
surge protector standards, 921
ULi Electronics chipsets, 215-216
Ultimate Boot CD, 369, 991
Ultra-DMA, 397 598
Ultra High Aperture (UHA), 662
Ultra High Speed (UHS) Class marking, 520
UltraNav keyboards (ThinkPad), 757
UMA (unified memory architecture), 611
«Understanding SD Association Speed Ratings» (Lexar), 520
Underwriters Laboratories (UL)
power supply safety certifications, 900
surge protector standards, 921
Unicomp, 746
Unified Extensible Firmware Interface. See UEFI
unified memory architecture (UMA), 611
UniGine Heaven DX11 benchmark utility, 647
uninterruptible power supply (UPS), 923-925
UNIVAC (Universal Automatic Computer), 10
Universal Asynchronous Receiver/Transmitter (UART) chip, 733
Universal Automatic Computer (UNIVAC), 10
Universal Disk Format (UDF), 574, 585-586
universal power supplies, 896
Universal Serial Bus. See USB
Unlock Intel(R) QST setting (Fan Control Configuration menu), 309
unlocking cores, 139-140
unmanaged switches, 828
unrecoverable errors, 472
unshielded twisted pair cables. See UTP cables
untwisted-pair cables, 817
updating
CD/DVD firmware, 607-608
processor microcode, 88
Upgrading and Repairing Servers (Mueller), 703
uplink ports, 830
UPS (uninterruptible power supply), 923-925
USB (Universal Serial Bus)
BIOS Setup settings, 308-309
CD/DVD drives, 599
compared to IEEE 1394 (FireWire), 722-725
connectors
Mini/Micro A/B connectors, 712
mini plugs and sockets, 711
Series A/B connectors, 712
explained, 704-705
functions, 706
header connector pinout, 234-235
hot-plugging, 725-728
hubs, 704-706
keyboards, 753-754
legacy support, 748
maximum cable lengths, 708
mice interfaces, 762
data, 707
speed of, 723-725
troubleshooting, 1033
USB 1.1, 707
collectors, 710-713
technical details, 705-708
USB 2.0, 707
collectors, 710-713
data rates, 709
technical details, 705-708
USB 3.0, 713-715
USB-based audio processors, 689-690
USB flash drives, 516-517
USB On-The-Go, 716
Windows USB support, 717-718
WUSB (Wireless USB), 716-717
USB 2.0 Legacy Support setting (USB Configuration menu), 308
USB 2.0 setting (USB Configuration menu), 308
USB 3.0 Controller setting (USB Configuration menu), 308
USB 3.0 Hub Presence setting (USB Configuration menu), 308
USB Boot setting (Boot menu), 315
USB Configuration menu (BIOS Setup), 308-309
USB EHCI Controller setting (USB Configuration menu), 308
USB/FireWire cable adapter, 1003
USB Function setting (USB Configuration menu), 308
USB-IF (USB Implementer's Forum), 709
USB Implementer's Forum (USB-IF), 709
USB Legacy setting (USB Configuration menu), 308
USB Mass Storage Emulation Type setting (Boot menu), 315
USB Ports setting (USB Configuration menu), 308
USB ZIP Emulation Type setting (USB Configuration menu), 308
Use Automatic Mode setting (Drive Configuration menu), 304
Use Maximum Multiplier setting (BIOS Maintenance menu), 294
User access Level setting (Security menu), 311
user-created bootable media, upgrading flash ROM from, 280-281
user passwords, 311
User Password setting (Security menu), 312
user-supported diagnostic software, 991
UTP (unshielded twisted-pair) cables, 817
building, 820-824
cable distance limitations, 824
Category 3 cable, 818
Category 5 cable, 819
Category 6 cable, 819
Category 6a cable, 819
crossover cables, 821
wiring standards, 820-821
U-verse, 838

V

V-Link architecture, 189
v-pipes, 94
V.90 modem standard, 793
V.92 modem standard, 793-794
vacuum cleaners, cleaning systems with, 755, 1014
vacuum tubes, 11
vacuum tube triode, 5
variable voltage transformers, 917
VBR (volume boot record), 1031
VCD (Video CD), 576
VDSL (Very High-Data-Rate DSL), 781
vendor-unique commands (ATA), 411
vertical blanking interval, 657
vertical frequency, 657
vertical recording, 459
vertical scan frequency, 665
vertices, 644
Very High-Data-Rate DSL (VDSL), 781
VESA (Video Electronic Standards Association), 247, 629
VGA (Video Graphics Array), 627-629, 667
VIA Technologies
chipsets, 189, 216, 226
ITX motherboards, 176-177
Mini-ITX motherboards, 176-177
VIA VT, 69
video adapters. See also 3D graphics accelerators
BIOS Setup settings, 307-308
chipsets
identifying, 619-620
video processor, 619
choosing, 940
components, 617-618
DAC (digital-to-analog converter), 624
definition of, 610
heterogeneous adapters, 668
homogeneous adapters, 668
installation, 967-968
integrated video/motherboard chipsets, 611
chipsets with integrated video for 64-bit AMD processors, 614-616
graphics chip market share, 612
Intel chipset integrated video, 612-613
third-party chipsets with integrated video for Intel processors, 614
optimizing system for, 932
overview, 610
processors with integrated video, 616-617
removing, 968
testing, 671
troubleshooting, 670-671
types of, 610-611
UMA (unified memory architecture), 611
video BIOS, 618
video drivers, 672
video RAM, 620-621
  DDR SDRAM, 621
  GDDR2 SDRAM, 621
  GDDR3 SDRAM, 622
  GDDR4 SDRAM, 622
  GDDR5 SDRAM, 622
  RAM calculations, 622-623
  SGRAM, 621
  speed, 622
  video memory bus width, 623-624
  VRAM, 621
  WRAM, 621
video BIOS, 618
video cards
  definition of, 28
  onboard BIOS, 274
troubleshooting, 1028-1029
Video CD (VCD), 576
Video Configuration menu (BIOS Setup), 307-308
video display interfaces
  AGP (Accelerated Graphics Port), 625-626
digital display interfaces
  DisplayPort, 636-640
  DMS-59, 632
  DVI (Digital Video Interface), 630-632
  HDMI (High Definition Multimedia Interface), 633-636
  overview, 629
  overview, 624-627
  PCIe (PCI Express), 626
  TV display interfaces, 641-642
  VGA (Video Graphics Array), 627-629
video drivers, 672
Video Electronic Standards Association (VESA), 247, 629
Video Graphics Array (VGA), 627-629
video monitors. See monitors
video RAM (random access memory), 620-621
  DDR SDRAM, 621
  GDDR2 SDRAM, 621
  GDDR3 SDRAM, 622
  GDDR4 SDRAM, 622
  GDDR5 SDRAM, 622
  RAM calculations, 622-623
  SGRAM, 621
  speed, 622
  video memory bus width, 623-624
  VRAM, 621
  WRAM, 621
Video Repost setting (Power menu), 313
View Event Log setting (Event Logging menu), 307
viewable image size (monitors), 650
vintagecalculators.com, 20
virgin CDs, 540
virtual PC environments, 685-686
virtual real mode, 91
virtual SSD (RAMdisk), 512
virtualization
  hardware-assisted virtualization support, 68-69
  legacy audio support, 685-686
  optimizing system for, 932
Virus Warning feature (BIOS Setup), 316
viruses, CIH, 278
vises, 1002
visible surface determination, 645
Vista/Win7 Codec Packages, 581
VL-Bus, 247
voice-coil actuators, 488-489
volatile storage, 326
voltage regulator module (VRM), 879-880
voltage settings (processors), 142
volume
  sound cards, 690-691
  speaker volume control, 699
troubleshooting, 695-696
volume boot record (VBR), 1031
VOPT, 1012
VRAM (Video RAM), 621
VRM (voltage regulator module), 879-880
VT Technology setting (Security menu), 312
W
wafers, 72
wafers (processors), 70
wait states, 49, 330
Wake on LAN connectors, 238
Wake on LAN from S5 setting (Power menu), 313
Wake on Modem Ring setting (Power menu), 313
Wake on PCI PME setting (Power menu), 313
Wake on PS/2 Mouse from S3 setting (Power menu), 313
Wake on Ring connectors, 238
WANs (wide area networks), 800. See also networks
war driving, 833
WASAPI (Windows Audio Session API) API, 683
Watchdog Timer setting (Chipset Configuration menu), 300
waterblocks, 941
watts, 698
Waveform audio sampling, 681-682
wavetable adapters, 691
WD1003 commands, 410
wear leveling, 491
WECA (Wireless Ethernet Compatibility Alliance), 808
wedge servo mechanisms, 491-492
WEP (wired equivalent privacy), 834-835
Western Digital
ATA. See ATA (AT Attachment) WD1003/WD1006 (IBM AT) 512-byte sector format, 471-472
White Book standard (Video CD), 576
white-box systems, 26
white power switch connector wires, 869
Wi-Fi Alliance, 808
Wi-Fi Protected Access (WPA), 834
Wi-Fi (Wireless Fidelity) 802.11a standard, 810 802.11ac standard, 812 802.11b standard, 808-810 802.11g standard, 810-811 802.11n standard, 811-812 access points, 831, 842 DHCP support, 835-836 explained, 807-808 network speeds, 813 NICs (network interface cards), 832 point-to-point topology, 833 security, 833-835 signal boosters, 832 specialized antennas, 832 star topology, 833 users per access point, 836 wireless bridges, 832 wireless repeaters, 832 wide area networks (WANs), 800. See also networks width data buses, 26-27 processor specifications, 35-37 WildBlue, 785-786 Wilkes, Maurice, 6 Winchester drives, 462 Window RAM (WRAM), 621 Windows 3.x drive limitations, 431 Windows 7 103/104-key keyboards, 740-742 audio 3D gaming audio standards, 684-685 core audio APIs, 683-684 EAX (environmental audio extensions), 685 legacy audio support, 685-686 OpenAL, 684 boot process, 998 drive limitations, 431 USB support, 718 Windows 8 Codec Package, 581 Windows 8 103/104-key keyboards, 740-742 audio 3D gaming audio standards, 684-685 core audio APIs, 683-684 EAX (environmental audio extensions), 685 OpenAL, 684 boot process, 998-999 drive limitations, 431 Fast Startup mode, 998-999 installation, 972 networking with, 843-844 Personal Use License for System Builder license, 930 SSD (solid-state drive) awareness, 514 USB support, 718 Windows 9x 103/104-key keyboards, 740-742 boot process, 997 drive limitations, 431 USB support, 717-718 Windows 2000 103/104-key keyboards, 740-742 boot process, 997-998 drive limitations, 431 Windows Audio Session API (WASAPI) API, 683 Windows Disk Cleanup tool, 1012 Windows executable upgrades (flash ROM), 279 Windows Me 103/104-key keyboards, 740-742 boot process, 997 drive limitations, 431
Windows Memory Diagnostic, 369, 1009
Windows NT drive limitations, 431
Windows Server 2003 Resource Kit Tools, 724
Windows Vista
  audio
    3D gaming audio standards, 684-685
core audio APIs, 683-684
EAX (environmental audio extensions), 685
legacy audio support, 685-686
OpenAL, 684
boot process, 998
networking with, 843-844
USB support, 718
Windows XP
  103/104-key keyboards, 740-742
  boot process, 997-998
  USB support, 718
  Windows XP Video Decoder Checkup Utility, 581
winload.exe, 998
wire cutters, 1002
wired equivalent privacy (WEP), 834-835
Wireless-A, 810
Wireless-AC, 812
wireless bridges, 832
wireless broadband, 783
Wireless Ethernet Compatibility Alliance (WECA), 808
Wireless Fidelity. See Wi-Fi
Wireless-G, 810-811
wireless input devices
  Bluetooth, 772
  IR (infrared), 771
  power management, 772
proprietary radio frequency, 771
troubleshooting, 773
Wireless Internet Service Providers Association (WISPA), 783
Wireless Internet Service Provider (WISP), 783
Wireless-N, 811-812
WirelessNetView (Nirsoft), 1020
wireless networks
  Bluetooth, 813-814, 833
  security, 834
topologies, 833
Wi-Fi (Wireless Fidelity)
  802.11a standard, 810
  802.11ac standard, 812
  802.11b standard, 808-810
  802.11g standard, 810-811
  802.11n standard, 811-812
  access points, 831
  antennas, 832
  bridges, 832
  DHCP support, 835-836
  explained, 807-808
  network speeds, 813
  NICs (network interface cards), 832
  repeaters, 832
  security, 833-835
  signal boosters, 832
  users per access point, 836
wireless PANs (WPANs), 800
wireless repeaters, 832
Wireless USB (WUSB), 716-717
wireless WANs (WWANs), 800
wire strippers, 1002
WISPA (Wireless Internet Service Providers Association), 783
WISP (Wireless Internet Service Provider), 783
wobbled land and groove recording, 561
working power, 899
world clock I/O sound card connectors, 689
WORM (write once, read many), 539
Wozniak, Steve, 7, 32
WPANs (wireless PANs), 800
wpa_supplicant, 835
WPA (Wi-Fi Protected Access), 834
WRAM (Window RAM), 621
wrap plugs, 1005
writable CDs. See CD-R discs; CD-RW discs
write-back cache, 370, 725
write once, read many (WORM), 539
write process, 442-443
write protection for flash ROM, 278
write-through cache, 60
write-through operations, 725
WTX motherboards, 164
WUSB (Wireless USB), 716-717
WWANs (wireless wide area networks), 800
X
  XD Technology setting
    (Security menu), 312
xD-Picture Card, 511
xDSL. See DSL (digital subscriber line)
Xebec 1210/1220 (IBM XT)
512-byte sector format, 471
XLR input/output sound card connectors, 689
XOP, 64
XT motherboards, 156-157
Y
Yellow Book (CD-ROM) standard, 571-572
yields, 73

Z
Z80 processor (Zilog), 31
ZBR (zoned-bit recording), 478-480
Z-CLV (zoned CLV) technology, 595
zero insertion force (ZIF) sockets, 74, 78
Zero Link technology, 564
Ziegler, J. F., 358
ZIF (zero insertion force) sockets, 74, 78
Zilog Z80 processor, 31
ZIP Emulation Type setting (Boot menu), 315
zoned-bit recording (ZBR), 478-480
zoned CLV (Z-CLV) technology, 595
zones, 478
Zuse, Konrad, 5