

Contents

Introduction 1

1 Development of the PC 5

- Computer History: Before Personal Computers 5
- Timeline 5
- Electronic Computers 10
- Modern Computers 11
 - From Tubes to Transistors 11
 - Integrated Circuits 14
- History of the PC 15
 - Birth of the Personal Computer 15
 - The IBM Personal Computer 16
 - The PC Industry 34 Years Later 17

2 PC Components, Features, and System Design 21

- What Is a PC? 21
 - Who Controls PC Software? 23
 - Who Controls PC Hardware? 26
 - White-Box Systems 28
- System Types 29
- System Components 30

3 Processor Types and Specifications 33

- Microprocessor History 33
 - The First Microprocessor 33
 - PC Processor Evolution 36
 - 16-Bit to 64-Bit Architecture Evolution 39
- Processor Specifications 40
 - Data I/O Bus 48
 - Address Bus 48
 - Internal Registers (Internal Data Bus) 49
 - Processor Modes 49
 - Processor Benchmarks 54
 - Comparing Processor Performance 55
 - Cache Memory 58
- Processor Features 65
 - System Management Mode 65
 - Superscalar Execution 66
 - MMX Technology 67
 - Dynamic Execution 69
 - Dual Independent Bus Architecture 70
 - HT Technology (Hyperthreading) 70
 - Multicore Technology 72
 - Hardware-Assisted Virtualization Support 73

- Processor Manufacturing 74
 - PGA Chip Packaging 78
 - Single Edge Contact and Single Edge Processor Packaging 80
- Processor Socket and Slot Types 81
 - Socket LGA775 84
 - Socket LGA1156 85
 - Socket LGA1366 86
 - Socket LGA1155 87
 - Socket LGA2011 87
 - Socket LGA1150 89
 - Socket AM2/AM2+/AM3/AM3+ 89
 - Socket F (1207FX) 91
 - Socket FM1 92
 - Socket FM2 92
 - Socket FM2+ 92
 - Socket AM1 (Socket FS1B) 92
- CPU Operating Voltages 93
- Math Coprocessors (Floating-Point Units) 94
- Processor Bugs and Steppings 94
- Processor Code Names 95
 - P1 (086) Processors 95
 - P2 (286) Processors 97
 - P3 (386) Processors 98
 - P4 (486) Processors 99
 - P5 (586) Processors 100
 - AMD-K5 102
 - Intel P6 (686) Processors 103
 - Pentium Pro Processors 103
 - Pentium II Processors 104
 - Pentium III 106
 - Celeron 107
 - Intel Pentium 4 and Extreme Edition Processors 108
 - Intel Pentium D and Pentium Extreme Edition 110
 - Intel Core Processors 112
 - Intel Core 2 Family 112
 - Intel (Nehalem) Core i Processors 116
 - AMD K6 Processors 121
 - AMD K7 Processors 122
 - AMD Athlon 122
 - AMD Duron 123
 - AMD Athlon XP 124
 - Athlon MP 124

AMD K8 Processors	124
AMD Athlon 64 and 64 FX	124
AMD Sempron	128
AMD Athlon X2, 64 X2, and 64 FX	128
AMD K10 Processors (Phenom, Phenom II, Athlon II, Athlon X2, Sempron)	130
AMD Bulldozer, Piledriver, Steamroller, and Excavator FX Processors	134
AMD Fusion/HSA APUs	137
Processor Upgrades	139
Overclocking	142
Quartz Crystals	142
Modern PC Clocks	145
Overclocking Tips	147
Unlocking Cores	148
Bus Speeds and Multipliers	149
Processor Cooling	152
Heatsinks	152
Liquid Cooling	158
Thermally Advantaged Chassis	159
Processor Troubleshooting Techniques	161

4 Motherboards and Buses 165

Motherboard Form Factors	165
Obsolete Form Factors	166
ATX and Other Modern Form Factors	177
Processor Sockets/Slots	189
Chipsets	192
Chipset Evolution	193
Intel Chipsets	195
Intel Chipset Model Numbers	195
Intel Integrated Graphics Architecture	197
AMD Integrated Graphics Architecture	197
Traditional North/southbridge Architecture	197
Hub Architecture	199
HyperTransport and Other Processor/Chipset Interconnects	201
Intel's Early 386/486 Chipsets	201
Fifth-Generation (P5 Pentium Class) Chipsets	202
Sixth-Generation (P6 Pentium Pro/II/III Class) Chipsets	203
Seventh/Eighth-Generation (Pentium 4/D, Core 2, and Core i) Chipsets	207
Intel 915 Family	215
Intel 925X Family	215
Intel 945 Express Family	216
Intel 955X and 975X Family	217
Intel 96x Series	217

Intel 3x and 4x Series Chipsets	218
Intel 5x Series Chipsets	220
Intel 6x Series Chipsets	224
Intel 7x Series Chipsets	225
Intel 8x Series Chipsets	227
Intel 9x Series Chipsets	229
Third-Party Chipsets for Intel Processors	231
SiS Chipsets	231
ULi Electronics Chipsets	231
ATI Chipsets	231
VIA Chipsets	232
NVIDIA Chipsets for Intel Processors	232
Chipsets for AMD Processors	232
AMD Athlon Chipsets	233
AMD Athlon 64 Chipsets	234
AMD 8000 (8151) Chipset	234
AMD (Formerly ATI) Chipsets for Athlon 64, Sempron, Phenom	235
Third-Party Chipsets for AMD Processors	242
VIA Chipsets	242
SiS Chipsets	242
NVIDIA Chipsets	243
Super I/O Chips	244
Motherboard Connectors	244
System Bus Types, Functions, and Features	255
The Processor Bus (FSB)	261
Types of I/O Buses	262
The ISA Bus	262
The Micro Channel Bus	262
The EISA Bus	263
Local Buses (VESA, PCI, PCI Express, AGP)	263
System Resources	270
Interrupts	271
DMA Channels	276
I/O Port Addresses	276
Motherboard Selection Criteria (Knowing What to Look For)	278
Chipset Documentation	279

5 BIOS 281

BIOS Basics	281
Motherboard ROM BIOS	285
ROM Hardware	285
ROM Shadowing	287
ROM Chip Types	287
ROM BIOS Manufacturers	291
BIOS Hardware/Software	292
Upgrading the BIOS	292
Where to Get Your BIOS Update	293
Determining Your BIOS Version	293

Backing Up Your BIOS	293
Backing Up Your BIOS Setup (CMOS RAM) Settings	294
Upgrading a Flash BIOS	295
Motherboard CMOS RAM Addresses	303
Preboot Environment	305
Unified Extensible Firmware Interface	307
UEFI and BIOS Limitations	307
UEFI Support	309
BIOS Setup	309
Running or Accessing the BIOS Setup Program	310
BIOS Setup Menus	310
Maintenance Menu	311
Main Menu	313
Exit Menu	345
AMD-Specific BIOS Settings	346
PnP BIOS	347
PnP Device IDs	347
ACPI	347
BIOS/MBR Error Messages	348
BIOS Boot Error Messages	349
MBR Boot Error Messages	352

6 Memory 355

Memory Basics	355
ROM	357
DRAM	357
Cache Memory: SRAM	359
Memory Standards	361
Speed and Performance	362
Fast Page Mode DRAM	365
Extended Data Out RAM	366
SDRAM	367
DDR SDRAM	368
DDR2 SDRAM	370
DDR3 SDRAM	372
DDR4 SDRAM	374
RDRAM	375
Memory Modules	375
Registered Modules	382
SDR DIMM Details	383
DDR DIMM Details	384
DDR2 DIMM Details	384
DDR3 DIMM Details	384
DDR4 DIMM Details	384
Determining a Memory Module's Size and Features	385
Memory Banks	387
Memory Module Speed	388
Parity and ECC	388
Parity Checking	390
How Parity Checking Works	391
ECC	391
RAM Upgrades	392
Upgrade Options and Strategies	393
Purchasing Memory	395
Replacing Modules with Higher-Capacity Versions	397
Installing Memory Modules	397
Troubleshooting Memory	399
Memory Defect Isolation Procedures	403
The System Logical Memory Layout	405

7 The ATA/IDE Interface 409

An Overview of the IDE Interface	409
Precursors to IDE	409
IDE Origins	410
Origins of ATA	411
ATA Standards	412
ATA-1 (ATA Interface for Disk Drives)	414
ATA-2 (ATA Interface with Extensions-2)	415
ATA-3 (ATA Interface-3)	415
ATA/ATAPI-4 (ATA with Packet Interface Extension-4)	416
ATA/ATAPI-5 (ATA with Packet Interface-5)	417
ATA/ATAPI-6 (ATA with Packet Interface-6)	417
ATA/ATAPI-7 (ATA with Packet Interface-7)	418
ATA/ATAPI-8	419
PATA	419
PATA I/O Connector	419
PATA I/O Cable	423
Longer or Rounded Cables	425
PATA Signals	425
PATA Dual-Drive Configurations	426
PATA PIO Transfer Modes	429
PATA DMA Transfer Modes	429
SATA	431
SATA Standards and Performance	431
SATA Express	432
SATA Cables and Connectors	434
eSATA	439
SATA Configuration	443
Advanced Host Controller Interface	444
Non-Volatile Memory Express	445
SATA Transfer Modes	445
ATA Features	446
ATA Commands	446
ATA Security Mode	447
Host Protected Area	448
ATAPI	449
ATA Drive Capacity Limitations	450

Prefixes for Decimal and Binary

Multiples 451

BIOS Limitations 451

CHS Versus LBA 452

CHS/LBA and LBA/CHS Conversions 453

BIOS Commands Versus ATA

Commands 454

CHS Limitations (the 528MB Barrier) 455

CHS Translation (Breaking the 528MB Barrier) 457

The 2.1GB and 4.2GB Barriers 459

LBA-Assist Translation 462

The 8.4GB Barrier 465

The 137GB Barrier and Beyond 466

Operating System and Other Software Limitations 468

GPT and the 2.2TB Barrier 470

PATA/SATA RAID 471

Software RAID 474

8 Magnetic Storage 475

Magnetic Storage 475

History of Magnetic Storage 475

How Magnetic Fields Are Used to Store Data 476

Read/Write Head Designs 479

Ferrite 480

Metal-In-Gap 480

Thin-Film 480

Magneto-Resistive Heads 481

Giant Magneto-Resistive Heads 482

Head Sliders 483

Data-Encoding Schemes 486

Frequency Modulation Encoding 487

Modified FM Encoding 487

Run Length Limited Encoding 488

Encoding Scheme Comparisons 489

Partial-Response, Maximum-Likelihood Decoders 490

Capacity Measurements 491

Areal Density 492

Perpendicular Magnetic Recording 495

Helium-Filled Drives 497

Shingled Magnetic Recording 497

Definition of a Hard Disk 498

Hard Drive Advancements 499

Form Factors 500

5 1/4-Inch Drive 502

3 1/2-Inch Drive 502

2 1/2-Inch Drive 502

1.8-Inch Drive 503

1-Inch Drives 503

HDD Operation 503

Data Recovery Options 505

The Ultimate HDD Analogy 506

Tracks and Sectors 507

ECC 510

Disk Formatting 515

Basic HDD Components 521

Hard Disk Platters (Disks) 522

Recording Media 522

Read/Write Heads 524

Head Actuator Mechanisms 526

Air Filters 532

Hard Disk Temperature Acclimation 534

Spindle Motors 534

Logic Boards 535

Cables and Connectors 536

Configuration Items 536

Hard Disk Features 536

Capacity 537

Performance 538

Reliability 543

9 Flash and Removable Storage 547

Alternative Storage Devices 547

Flash Memory Devices 547

CompactFlash, XQD, and CFast 549

SmartMedia 551

MultiMediaCard 551

SecureDigital 552

Sony Memory Stick 552

ATA Flash PC Card 553

Card-Picture Card 553

Solid-State Drives 553

Virtual SSD (RAMdisk) 554

Flash-Based SSDs 554

USB Flash Drives 558

Comparing Flash Memory Devices 559

SD Cards Speed Class and UHS Speed Class

Markings 561

File Systems Used by Flash Memory 563

Flash Card Readers 563

Card Readers 563

ReadyBoost Support 564

Cloud-Based Storage 565

Floppy Disk Drives 566

Tape Drives 567

10 Optical Storage 569

Optical Technology 569

CD-Based Optical Technology 570

CDs: A Brief History 570

CD Construction and Technology 571

Mass-Producing CDs 571

Writable CDs 583

MultiRead Specifications 590

MultiPlay and MultiAudio 592

DVD 592

DVD History 593

DVD Construction and Technology 593

DVD Tracks and Sectors 595

Handling DVD Errors 599

DVD Capacity (Sides and Layers) 601

Data Encoding on the DVD Disc 604

Recordable DVD Standards 604

Multiformat Rewritable DVD Drives 612

BD 613

HD-DVD 616

Optical Disc Formats 616

CD Formats 616

DVD Formats and Standards 625

Optical Disc File Systems 628

Ripping/Copying Discs 634

"For Music Use Only" CD-R/RW

Discs 635

CD Copy Protection 635

CD Digital Rights Management 636

DVD and Blu-ray Copy Protection 636

Optical Drive Performance

Specifications 640

CD Data Transfer Rate 640

CD Drive Speed 640

DVD Drive Speed 641

BD Drive Speed 644

Access Time 645

Buffer/Cache 646

Direct Memory Access and

Ultra-DMA 646

Interface 646

Loading Mechanism 647

Other Drive Features 648

How to Reliably Record Optical Discs 648

Bootable Optical Discs—El Torito 649

LightScribe and LabelFlash 649

Troubleshooting Optical Drives 649

Caring for Optical Media 653

Updating the Firmware in an Optical Drive 654

11 Video Hardware 657

Display Adapters and Monitors 657

Video Display Adapters 658

Video Adapter Types 658

Integrated Video/Motherboard

Chipsets 659

CPUs with Integrated Video 663

Intel Processors with Integrated

Graphics 664

AMD Desktop APUs 667

Video Adapter Components 671

Identifying the Video and System

Chipsets 673

Video RAM 674

The DAC 678

Video Display Interfaces 678

The System Interface 678

The Display Interface 679

TV Display Interfaces 695

3D Graphics Accelerators 696

How 3D Accelerators Work 697

APIs 700

Dual-GPU Scene Rendering 704

Monitors 707

Display Specifications 707

LCD and LED Technology 716

Touchscreens 719

Plasma Display Technology 720

LCD and DLP Projectors 721

Using Multiple Monitors 722

Dualview 722

Homogeneous Adapters 723

Heterogeneous Adapters 723

Choosing the Best Display Hardware for a Particular Task 723

Video Troubleshooting and

Maintenance 724

Troubleshooting Video Cards and

Drivers 725

Video Drivers 727

Maintaining Monitors 728

Testing Monitors 728

Adjusting Monitors 729

Bad Pixels 730

Troubleshooting Monitors 730

Repairing Monitors 731

12 Audio Hardware 733

Audio Hardware Concepts and Terms 734

The Nature of Sound 734

Evaluating the Quality of Your Audio

Hardware 734

Sampling 735

Early PC Sound Cards 736

Limitations of Sound Blaster Pro

Compatibility 736

Microsoft Windows and Audio

Support 736

DirectX and Audio Support

Hardware 737

Core Audio APIs for Windows	737
3D Gaming Audio Standards	738
Legacy Audio Support Through Virtualization	740
Audio Hardware Features	740
Basic Connectors	740
Audio Signal Processing Methods	743
Advanced Audio Features	743
Volume Control	745
MIDI Support Features	745
Data Compression	746
Sound Drivers	747
Sound Cards for Sound Producers	748
Motherboard Chipsets with Integrated Audio	748
Intel "Azalia" HD Audio	749
Troubleshooting PC Audio Problems	749
Sound Card and Onboard Audio Problems	749
Speakers	753
Speaker Selection Criteria	753
Theater and Surround Sound Considerations	754
Microphones	755

External I/O Interfaces 757

Introduction to Input/Output Ports	757
Serial Versus Parallel	757
Universal Serial Bus	758
IEEE 1394 (FireWire or iLINK)	775
Hot-Plugging (and Unplugging)	779
Thunderbolt Technology	782
Low-Speed External Connections	784
Serial Ports	784
Parallel Ports	789

Input Devices 795

Keyboards	795
Enhanced 101-Key Keyboard	795
103/104-Key Windows Keyboard	796
Keyboard Technology	798
Keyswitch Design	798
The Keyboard Interface	804
Typematic Functions	805
Keyboard Scan Codes	806
International Keyboard Layouts	807
Keyboard/Mouse Interface	808
Connectors	808
USB Keyboards	810
Keyboards with Special Features	811
Keyboard Troubleshooting and Repair	811
Cleaning a Keyboard	812
Keyboard Recommendations	813

Pointing Devices	814
Mouse Sensitivity	815
Ball-Type Mice	815
Optical Mice	815
Pointing Device Interface Types	817
Scroll Wheels	819
Mouse Troubleshooting	821
Cleaning Your Mouse	821
Alternative Pointing Devices	821
Touchscreen Technology	826
Wireless Input Devices	827
Power Management Features of Wireless Input Devices	828
Supporting Multiple Devices with a Single Transceiver	829
Troubleshooting Wireless Input Devices	829

15 Internet Connectivity 831

Internet Connectivity Trends	831
Broadband Internet Access Types	832
Cable Internet	832
Digital Subscriber Line	836
Wireless Broadband	840
Cellular Broadband 3G and 4G Services	840
Satellite Broadband	841
ISDN	844
Leased Lines	845
Comparing High-Speed Internet Access	846
Dial-Up Modems	847
Internet Connection Security	848
Having a Backup Plan in Case of Service Interruptions	849
Sharing Your Internet Connection	850
Routers for Internet Sharing	850
Modem/Router Status LEDs	851

16 Local Area Networking 853

Defining a Network	853
Types of Networks	854
Requirements for a Network	855
Client/Server Versus Peer Networks	855
Client/Server Networks	856
Peer-to-Peer Networks	857
Comparing Client/Server and Peer-to-Peer Networks	857
Network Architecture Overview	858
Wired Ethernet	860
Wireless Ethernet	862
Bluetooth	868

Hardware Elements of Your Network	869
NICs for Wired Ethernet Networks	869
Network Cables for Wired Ethernet	871
Wired Network Topologies	880
Switches for Ethernet Networks	883
Wireless Ethernet Hardware	887
Network Protocols	892
IP and TCP/IP	892
IPX and NetBEUI	893
Other Home Networking Solutions	894
HomePNA	894
HomeGrid Forum and G.hn	895
Power Line Networking	895
Putting Your Network Together	897
Network Adapters	898
Cables and Connections Between Computers	899
Switch/Access Point	899

17 Power Supplies 903

The Power Supply	903
Primary Function and Operation	903
Voltage Rails	904
The Power Good Signal	906
Power Supply Form Factors	907
Modern Form Factors	910
Power Switches	925
ATX and Newer	925
PC/XT/AT and LPX Power Switches	927
Motherboard Power Connectors	928
AT/LPX Power Supply Connectors	929
ATX and ATX12V Motherboard Power Connectors	931
Backward and Forward Compatibility	944
Dell Proprietary (Nonstandard) ATX Design	946
Additional Power Connectors	946
Peripheral Power Connectors	946
Floppy (Berg) Power Connectors	947
Serial ATA Power Connectors	948
PCI Express Auxiliary Graphics Power Connectors	949
Power Supply Specifications	953
Power Supply Loading	953
Power Supply Ratings	955
Other Power Supply Specifications	956
Power Factor Correction	958
SLI-Ready and CrossFire/CrossFireX Certifications	960
Safety Certifications	960
Power-Use Calculations	961

Power Savings	963
80 Plus	963
ENERGY STAR	965
Advanced Configuration and Power Interface	966
Power Cycling	968
Power Supply Troubleshooting	972
Overloaded Power Supplies	973
Inadequate Cooling	973
Using Digital Multimeters	974
Specialized Test Equipment	977
Power Supply Recommendations	980
Modular Cables	981
Sources for Replacement Power Supplies	982
Power-Protection Systems	982
Surge Suppressors (Protectors)	984
Network and Phone Line Surge Protectors	984
Line Conditioners	985
Backup Power	985
Real-Time Clock/Nonvolatile RAM (CMOS RAM) Batteries	988
Modern CMOS Batteries	989
Obsolete or Unique CMOS Batteries	990
CMOS Battery Troubleshooting	991

18 Building or Upgrading Systems 993

System Components	993
Before You Start: How to Decide What to Build	995
Case and Power Supply	997
Processor	998
Motherboard	999
Memory	1001
I/O Ports	1001
Hard Disk/Solid-State Drives	1003
Removable Storage	1003
Input Devices	1004
Video Card and Display	1004
Audio Hardware	1005
Accessories	1005
Hardware and Software Resources	1006
System Assembly and Disassembly	1007
Assembly Preparation	1007
Installing the CPU and Heatsink	1011
Installing Memory Modules	1017
Mounting the New Motherboard in the Case	1018
Preparing a Modular Power Supply	1023
Connecting the Power Supply	1023

Connecting I/O and Other Cables to the Motherboard	1026
Installing the Drives	1027
Installing a Video Card	1031
Installing Additional Expansion Cards	1033
Replacing the Cover and Connecting External Cables	1033
System Startup	1033
Installing the OS	1035
Troubleshooting New Installations	1037

19 PC Diagnostics, Testing, and Maintenance 1039

PC Diagnostics	1039
Diagnostics Software	1039
The POST	1040
Insyde BIOS Diagnostic and Beep Codes	1053
Peripheral Diagnostics	1053
Operating System Diagnostics	1053
Commercial Diagnostics Software	1054
Free/User-Supported Diagnostics	1055
The Boot Process	1055
The Hardware Boot Process: Operating System Independent	1056
The DOS Boot Process	1061
The Windows 9x/Me Boot Process	1061
Windows 2000/XP Startup	1061
Windows Vista/7 Startup	1062
Windows 8.1/10 Startup	1063

PC Maintenance Tools	1063
Hand Tools	1064
Safety	1068
Test Equipment	1069
Special Tools for the Enthusiast	1074
Preventive Maintenance	1075
Active Preventive Maintenance Procedures	1076
Passive Preventive Maintenance Procedures	1081
Troubleshooting Tips and Techniques	1085
Repair or Replace?	1086
Basic Troubleshooting Steps	1086
Troubleshooting by Replacing Parts	1087
Troubleshooting by the Bootstrap Approach	1087
Problems During the POST	1089
Problems Running Software	1089
Problems with Adapter Cards	1089
Top Troubleshooting Problems	1090

Index 1101