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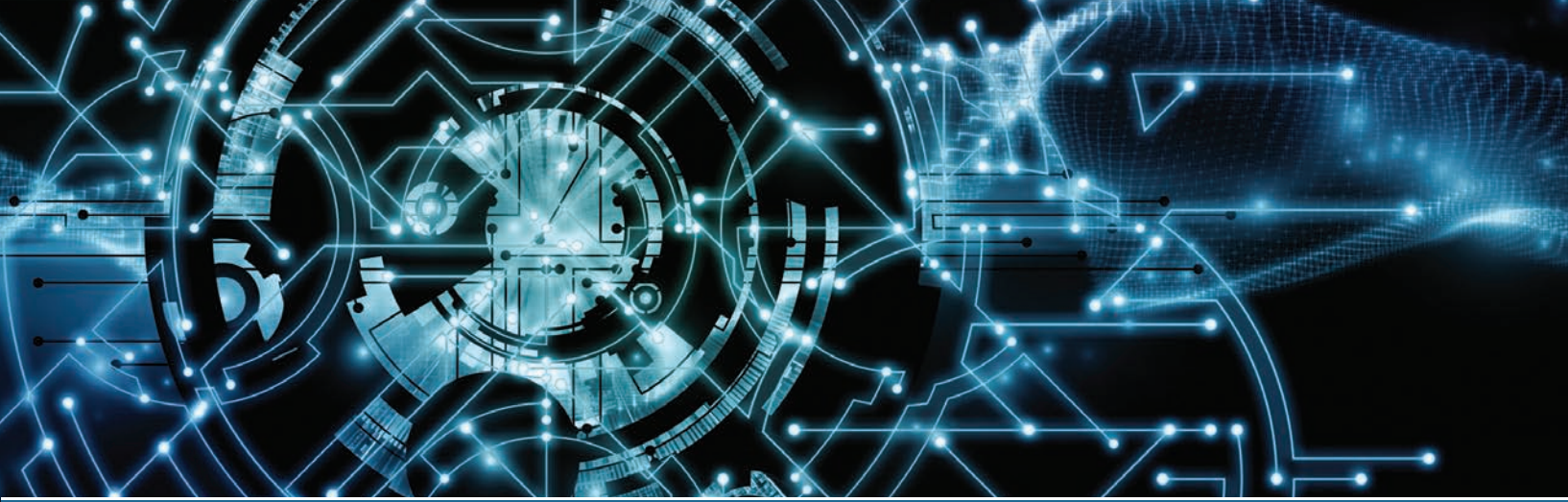
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# COMPLETE A+ GUIDE TO IT HARDWARE AND SOFTWARE

CompTIA® A+ Exams 220-1101 & 220-1102

CHERYL A. SCHMIDT  
CHRISTOPHER A. LEE



# Complete A+ Guide to IT Hardware and Software

A CompTIA® A+ Core 1 (220-1101) &  
CompTIA A+ Core 2 (220-1102) Textbook

NINTH EDITION

CHERYL A. SCHMIDT  
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FLORIDA STATE COLLEGE AT JACKSONVILLE

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# Complete A+ Guide to IT Hardware and Software, Ninth Edition

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ISBN-13: 978-0-13-767044-4

ISBN-10: 0-13-767044-3

Library of Congress Control Number: 2022906025

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## About the Authors

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## Dedications

### *A Note to Instructors from Cheryl:*

I was a teacher long before I had the title professor. Sharing what I know has always been as natural as walking to me, but sitting still to write what I know is not as natural, so composing this text has been one of my greatest challenges. Thank you so much for choosing this text. I thank you for sharing your knowledge and experience with your students. Your dedication to education is what makes the student experience so valuable.

### *A Note to Students:*

Writing a textbook is really different from teaching class. I have said for years that my students are like my children, except that I don't have to pay to send them through college. I am happy to claim any of you who have this text. I wish that I could be in each classroom with you as you start your IT career. How exciting!

IT support is an ever-changing field. You have to be excited about the never-ending changes to be good in this field. You can never stop learning, or you will not be very good anymore. I offer this important piece of advice:

Consistent, high-quality service boils down to two equally important things: caring and competence.  
—Chip R. Bell and Ron Zemke

## Acknowledgments

### *From Cheryl Schmidt:*

I am so thankful for the support of my family during the production of this book. My husband, Karl, daughters, Raina and Karalina, and son-in-law, Marc, were such a source of inspiration and encouragement. My grandsons, Gavin, Riley, Logan, and Liam, and my granddaughters, Brie and Liv, are a constant source of wonderment for me. Thanks to my mother who recently passed away, Barbara Cansler, who taught me to love words, and my brother, Jeff Cansler, for just listening. Thanks to my walking buddy, Kellie, for the miles of letting me work through knotty sections. Thanks to my colleagues, adjuncts, and students at my college who offered numerous valuable suggestions for improvement and testing the new material. Thanks to my colleagues Pamela Brauda and David Singletary for inspiring me as a teacher. Finally, I want to thank my co-author and a great teacher, Chris Lee, as well as my personal technical team, Justin Ache, Raina Durrence, Marc Durrence, and Jeff Burns.

Many thanks are also due the folks at Pearson. The professionalism and support given during this edition was stellar. Thank you so much, Pearson team, especially James Manly, Eleanor Bru, Kitty Wilson, Mandie Frank, and Chris Crayton. I thank the whole team so much for your conscientious efforts.

Finally, thank you to the students who have taken the time to share their recommendations for improvement. You are the reason I write this book each time. Please send me any ideas and comments you may have. I love hearing from you and of your successes. I may be reached at [cheryl.schmidt@fscj.edu](mailto:cheryl.schmidt@fscj.edu).

### *From Chris Lee:*

I am thankful for the lifetime of support and guidance that have allowed me to achieve my dreams and contribute to this book. My parents, Brenda McClinton and Herman Brown, have always encouraged me to follow my own path. They have also been my favorite remote “clients,” as they have embraced computer technology whereas many of their peers find it intimidating. My grandparents, Roosevelt and Bettye Nelson, are my biggest cheerleaders; they're always excited to hear about my latest projects during our weekly phone calls. I appreciate the patience and motivation from my son, Jawara, as he discovers his own niche within the world of computer science and in life itself.

Some very special teachers also deserve recognition. Mr. William Marshall at the Phyllis Wheatley Community Center allowed me to make or build whatever I wanted in the Arts and Crafts room. He saw the budding engineer in me and allowed me to discover my passion. Mrs. Linda Dillard at Duncan Chapel Elementary School instilled the discipline that I needed to stay focused amid so many distractions. Mrs. Jeanne Perkinson at Wade Hampton High School took my B.A.S.I.C. programming to the next level and introduced me to structured programming. Dr. George Lee Cain helped me weather my first term at Georgia Tech. OMED Student Services and Dr. Gary S. May at Georgia Tech gave me numerous resources to navigate college life and exposed me to several opportunities to develop my skills and serve my community.



## 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.

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Email: [community@informit.com](mailto:community@informit.com)

# Introduction

*Complete A+ Guide to IT Hardware and Software*, ninth edition, is a textbook and optional lab manual intended for one or more courses geared toward CompTIA A+ Certification and computer repair. It covers all the material needed for the CompTIA A+ Core 1 (220-1101) and CompTIA A+ Core 2 (220-1102) exams. The book is written so that it is easy to read and understand, with concepts presented in building-block fashion. The book focuses on hardware, software, mobile devices, virtualization, basic networking, and security.

Some of the best features of the book include the coverage of difficult subjects in a step-by-step manner, carefully developed graphics that illustrate concepts, photographs that demonstrate various technologies, reinforcement questions, critical thinking skills, soft skills, and hands-on exercises at the end of each chapter. Also, this book is written by teachers who understand the value of a textbook as we both are very active in the classroom and community.

## What's New in the Ninth Edition?

This edition has been revised to include more relevant coverage of hardware, including SSD migration and a few new network concepts, such as updated wireless standards, updated browser security settings, and DNS material. Some references to Windows 7 were left where it is quite different from Windows 8, 10, or 11. More scripting is included as well. The following are a few of the many new features of this edition:

- > This book conforms with the latest CompTIA A+ exam requirements, including those of the CompTIA A+ Core 1 (220-1101) and CompTIA A+ Core 2 (220-1102) exams.
- > Chapter 2 now includes information on Cat 8 and direct burial cable, as well as updated graphics showing motherboard ports.
- > Chapter 3 now includes information regarding ARM processors.
- > The video information in Chapter 4 has been moved to Chapter 8. Chapter 4 introduces TPM, which is covered in more depth in Chapter 18.
- > The book has always been filled with graphics and photos, but even more have been added to target those naturally drawn to the IT field. This edition is full color.
- > There are questions at the end of each chapter, and even more questions are available in the test bank available from the Pearson Instructor Resource Center.

## Organization of the Text

The text is organized to allow thorough coverage of all topics and also to be a flexible teaching tool. It is not necessary to cover all the chapters, nor do the chapters have to be covered in order.

- > **Chapter 1** provides an introduction to IT and careers that need the information in this book. It identifies computer parts. Chapter 1 does not have a specific soft skills section, as do the other chapters. Instead, it focuses on common technician qualities that are explored in greater detail in the soft skills sections of later chapters. Finally, Chapter 1 provides a great introduction to using Notepad, the Windows Snipping Tool, and internet search techniques.
- > **Chapter 2** is about connecting things to a computer and port identification. Details are provided on video, USB, and sound ports. The soft skills section is on using appropriate titles.
- > **Chapter 3** details components, features, and concepts related to motherboards, including processors, caches, expansion slots, and chipsets. Active listening skills are the focus of the soft skills section.
- > **Chapter 4** deals with system configuration basics. BIOS options, UEFI BIOS, and system resources are key topics. The soft skills section covers the importance of doing one thing at a time when replacing components.

- > **Chapter 5** steps through how to disassemble and reassemble a computer. Tools, ESD, EMI, and preventive maintenance are discussed. Subsequent chapters also include preventive maintenance topics. Basic electronics and computer power concepts are also included in this chapter. The soft skills section involves written communication.
- > **Chapter 6** covers memory installation, preparation, and troubleshooting. The importance of teamwork is emphasized as the soft skill.
- > **Chapter 7** deals with storage devices, including SATA SCSI, SAS, and SSDs. RAID is also covered. Phone communication skills are covered in the soft skills section of this chapter.
- > **Chapter 8** covers video and multimedia devices, including optical drives, sound cards, cameras, scanners, and speakers. The chapter ends with a section on having a positive, proactive attitude.
- > **Chapter 9** provides details on printers and multifunction devices. A discussion of work ethics finishes the chapter.
- > **Chapter 10** is on mobile devices, including details on mobile device operating systems, configuration, backup, security, and troubleshooting. The soft skills section takes a brief foray into professional appearance.
- > **Chapter 11** covers computer design. Not only are the specialized computers and components needed within the types of systems covered, but computer subsystem design is also included. Because design and troubleshooting use higher levels of critical thinking skills, the chapter also includes a review of troubleshooting, including logic, error codes, and troubleshooting flowcharts. The soft skills section provides recommendations for dealing with irate customers.
- > **Chapter 12** handles internet connectivity, virtualization, and cloud technologies. It covers internet browser configuration, along with the soft skill mentoring.
- > **Chapter 13** introduces networking. Basic concepts, terminology, and exercises make this chapter a favorite. Appendix A provides an introduction to subnetting that can be used in conjunction with this chapter. The focus of the soft skills section is being proactive instead of reactive.
- > **Chapter 14** provides an introduction to operating systems in general and discusses basic differences between the Windows versions and how to function in the various Windows environments. The soft skills section includes tips on how to stay current in this fast-paced field.
- > **Chapter 15** provides an introduction to scripting and includes how to function from the command prompt and the basics of scripting in Python, JavaScript, shell scripting, VBScript, batch files, and PowerShell. The soft skills section discusses looking at a problem from the user's perspective and being more empathetic.
- > **Chapter 16** covers Windows 8, 10, and 11. Details include how to install, configure, and troubleshoot the environment. Avoiding burnout is the soft skill discussed in this chapter.
- > **Chapter 17** discusses the basics of macOS and Linux. It provides a basic introduction to these two environments to help a technician become familiar with the environment and a few tools. The soft skills section talks about being humble.
- > **Chapter 18** describes computer, mobile device, and network security. The soft skills section is on building customer trust.
- > **Chapter 19** guides the student through operational procedures such as workplace safety, recycling, disposal, a review of power protection, change management, and soft skills.
- > **Appendix A** is an introduction to subnetting and variable length subnet mask (VLSM).

## Features of This Book

The following key features of the book are designed to enable a better learning experience:

- > **Objectives:** Each chapter begins with both chapter objectives and the CompTIA A+ exam objectives.
- > **Graphics and photographs:** Many more full-color images and all-new graphics have been added to better illustrate the concepts.
- > **Tech Tips:** The chapters are filled with Tech Tips that highlight technical issues and certification exam topics.
- > **Key terms in context:** As you read the chapter, terms that appear in blue are considered key terms and are defined in the glossary.

- > **Key Terms list:** At the end of the chapter, all key terms are listed, along with page numbers to which to refer for context.
- > **Soft Skills:** Technology is not the only thing you must learn and practice; each chapter offers advice, activities, and examples of how to be a good tech, an ethical tech, a good work mate, a good communicator, and so on.
- > **Chapter Summary:** The summary recaps the key concepts of the chapter, and you can use it for review to ensure that you've mastered the chapter's learning objectives.
- > **A+ Certification Exam Tips:** Read through these tips on the CompTIA A+ exams so you aren't caught off guard when you sit for the exam.
- > **Review Questions:** Hundreds of review questions, including true/false, multiple choice, matching, fill-in-the-blank, and open-ended questions, assess your knowledge of the topics taught in each chapter.
- > **Applying your knowledge:** This book provides hundreds of exercises and activities to help you put into practice what you are learning:
  - > **Exercises:** Sometimes called "paper labs," the exercises need no lab devices to complete in the classroom or for homework.
  - > **Activities:** The activities provide extensive practice with internet discovery, soft skills, and critical thinking skills to round out your technical knowledge so that you can be prepared for IT work. These can be used to "Flip the Classroom" so that instruction is interactive and in the hands of the students.
- > **Lab Exercises:** The separate companion *Complete A+ Guide to IT Hardware and Software Lab Manual* (on the companion web page) contains more than 140 labs in total. These hands-on labs enable you to link theory to practical experience.

## Companion Website

Register this book to get access to the **lab manual** plus additional bonus content to help you succeed with this course and the certification exam. Check this site regularly for any updates or errata that might become available for this book. Be sure to check the box indicating that you would like to hear from us to receive news of updates and exclusive discounts on related products.

To access this companion website, follow the steps below:

1. Go to [www.pearsonITcertification.com/register](http://www.pearsonITcertification.com/register) and log in or create a new account.
2. Enter the ISBN 9780137670444.
3. Answer the challenge question as proof of purchase.
4. Click the *Access Bonus Content* link in the Registered Products section of your account page to be taken to the page where your downloadable content is available.

Please note that many of our companion content files can be very large, especially image and video files.

If you are unable to locate the files for this title by following the steps above, please visit [www.pearsonITcertification.com/contact](http://www.pearsonITcertification.com/contact) and select the *Site Problems/Comments* option. Our customer service representatives will assist you.

## CompTIA A+ Exam Objectives

To earn CompTIA A+ certification, you must pass both the CompTIA A+ Core 1 (220-1101) and CompTIA A+ Core 2 (220-1102) certification exams.

Tables I.1 and I.2 summarize the domain content for each exam.

**TABLE I.1** CompTIA A+ Core 1 (220-1101) exam

Domain	Percentage of examination
1.0 Mobile Devices	15%
2.0 Networking	20%
3.0 Hardware	25%
4.0 Virtualization and Cloud Computing	11%
5.0 Hardware and Network Troubleshooting	29%
Total	100%

**TABLE I.2** CompTIA A+ Core 2 (220-1102) exam

Domain	Percentage of examination
1.0 Operating Systems	31%
2.0 Security	25%
3.0 Software Troubleshooting	22%
4.0 Operational Procedures	22%
Total	100%

Table I.3 shows a summary of the exam domains addressed in each chapter. Each chapter lists the certification objectives it covers in the chapter opener. See Appendix B on the companion website for a detailed table that identifies where you can find all the CompTIA A+ exam objectives covered in this book.

**TABLE I.3** Summary of exam domains by chapter

Table of contents	220-1101 domains	220-1102 domains
Chapter 1: Introduction to the World of IT	3	4
Chapter 2: Connectivity	1, 2, 3	4
Chapter 3: On the Motherboard	3, 5	4
Chapter 4: Introduction to Configuration	3, 5	
Chapter 5: Disassembly and Power	3, 5	4
Chapter 6: Memory	3, 5	1
Chapter 7: Storage Devices	3, 5	1, 2, 3, 4
Chapter 8: Video and Multimedia Devices	3	1, 4
Chapter 9: Printers and Multifunction Devices	2, 3, 5	1, 3, 4
Chapter 10: Mobile Devices	1, 2, 3, 5	1, 2, 3
Chapter 11: Computer Design and Troubleshooting Review	3, 5	4
Chapter 12: Internet Connectivity, Virtualization, and Cloud Technologies	2, 3, 4	1, 2, 3
Chapter 13: Networking	2, 3, 4, 5	1, 2, 3, 4
Chapter 14: Introduction to Operating Systems		1, 2, 3



<b>Table of contents</b>	<b>220-1101 domains</b>	<b>220-1102 domains</b>
Chapter 15: Introduction to Scripting		1, 3, 4
Chapter 16: Advanced Windows		1, 2, 3, 4
Chapter 17: macOS and Linux Operating Systems		1, 3
Chapter 18: Computer and Network Security	2, 3	1, 2, 3, 4
Chapter 19: Operational Procedures		4

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# 1

# Introduction to the World of IT



## In this chapter you will learn:

- > Qualities a technician should have
- > Basic skills needed to function in the Windows environment and in the technical world
- > Important computer parts
- > Basic computer terms

## CompTIA Exam Objectives:

- ✓ 1101-3.1 Explain basic cable types and their connectors, features, and purposes.
- ✓ 1101-3.6 Given a scenario, deploy and configure multifunction devices/printers and settings.
- ✓ 1102-4.4 Given a scenario, use common safety procedures.
- ✓ 1102-4.7 Given a scenario, use proper communication techniques and professionalism.

## Who Needs This Book?

More types of people than you might first think need this book. People who obviously need this information are those who will fix computers or work on a help desk or support desk. However, there are other types of users who might not be so obvious. Many folks who break into the information technology (IT) world do so through jobs that require the A+ certification. Consider medical electronics technicians who repair common equipment used in hospitals. These technicians need this material because many medical devices connect to a PC or have PC-based software that controls the device. Further, the medical devices commonly attach to wired and wireless networks.

Look at Figure 1.1 to see the types of jobs and people who need the information in this book. It might also give you ideas about something you might like to do for a career.

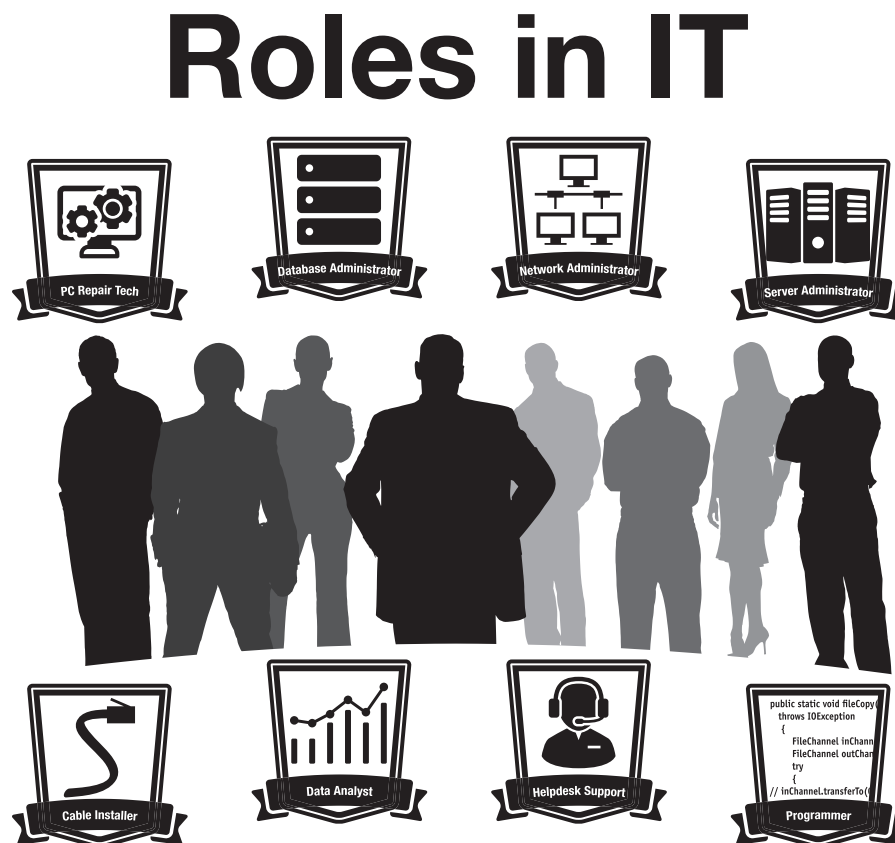
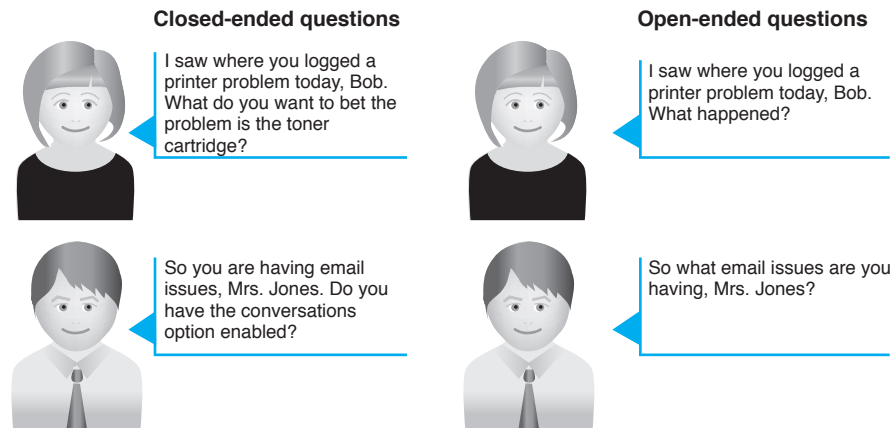


FIGURE 1.1 IT roles

## Technician Qualities

Each chapter includes a small bit of space on qualities a technician should possess or strive toward. Spending a little brain power on improving what many call your “soft skills” will pay off in promotions. Three of the most important qualities of a technician are active listening skills, a good attitude, and logic. Active listening means that you truly listen to what a person is saying. **Active listening skills** involve good eye contact, nodding your head every now and then to show that you are following the conversation, taking notes on important details, and avoiding distractions such as incoming calls or text messages. **Clarify customer statements** by asking pertinent questions and avoid interrupting. Listen to the entire problem. Ask **open-ended questions**—questions that

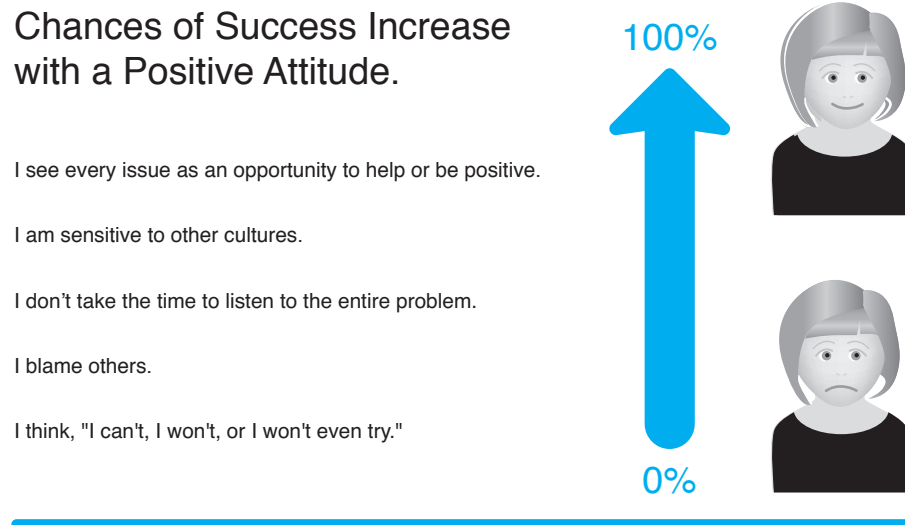
allow the user to expand on the answer rather than answer with a single word, such as *yes* or *no*. Figure 1.2 illustrates this point.



Allow the users to state the problem without leading them toward a solution. Restate the problem to ensure understanding and ask questions for clarity and to narrow your understanding.

**FIGURE 1.2** Asking technical questions

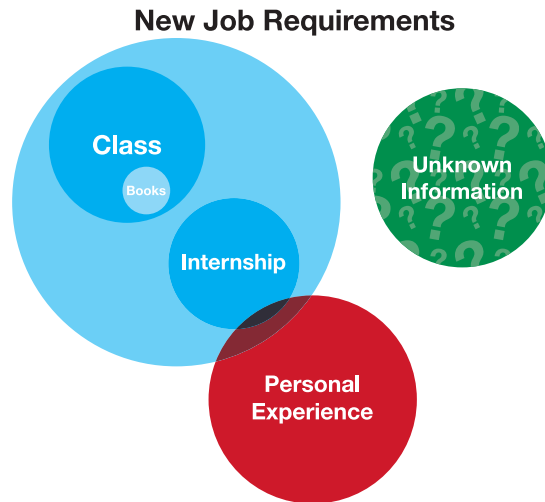
A positive attitude is probably the best quality a technician can possess. A technician with a positive attitude does not diminish the customer's problem; every problem is equally important to the computer user. A positive attitude is critical for being successful in the computer service industry. Figure 1.3 shows how negative attitudes affect your success.



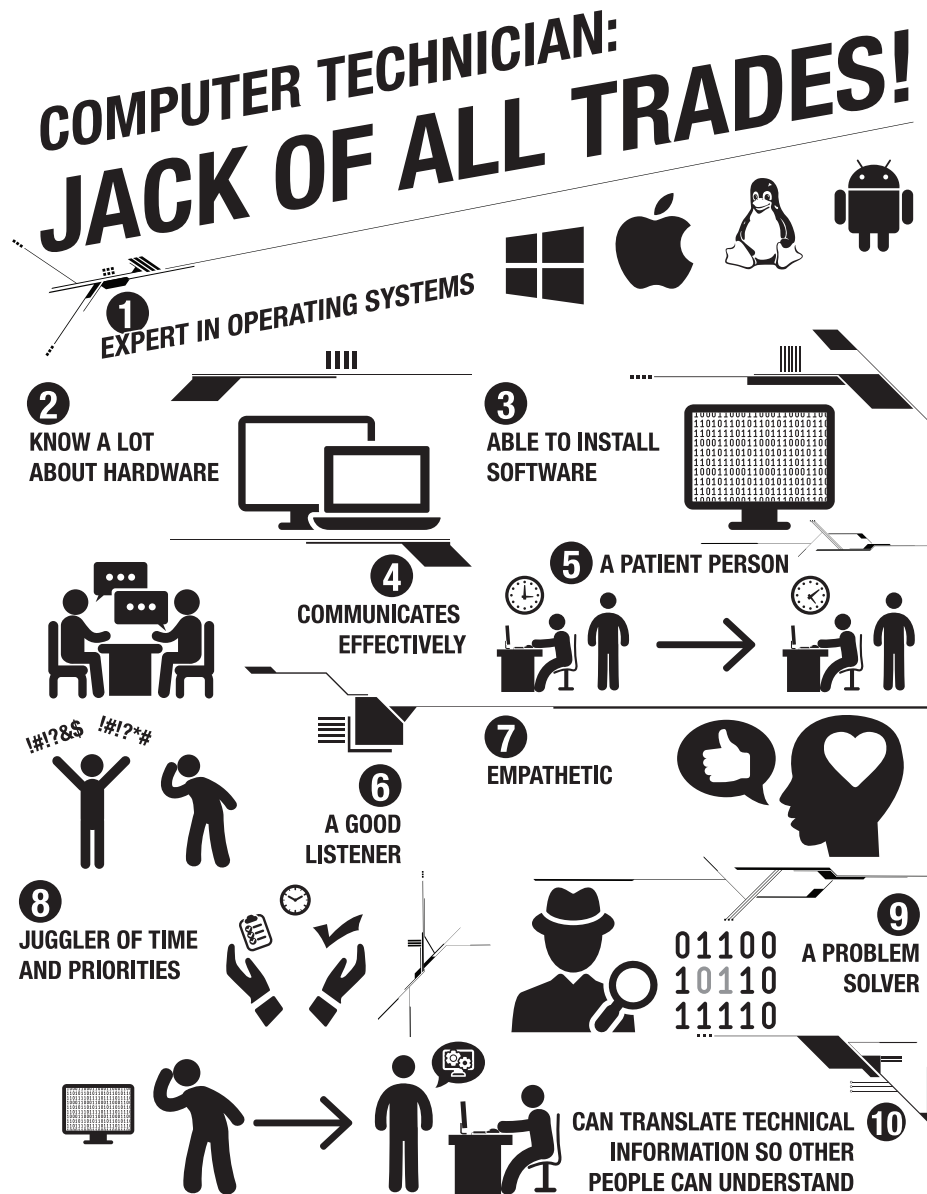
**FIGURE 1.3** Have a positive attitude

Avoid developing tunnel vision (that is, thinking that there is only one answer to a problem). Step back and look at the problem so that all possible issues can be evaluated. Be logical in your assessment and the methods used to troubleshoot and repair. This book will help you with all of this by explaining computer terminology in easy-to-understand terms and providing analogies that can be used when dealing with customers.

Before delving into computer topics, you should remember that a class can't fully prepare you for every aspect of a job. You must learn things on your own and constantly strive to update your skills so you do not become obsolete. The IT field changes rapidly. Figure 1.4 illustrates this concept. Finally, you will find that you must be a jack of all trades, as shown in Figure 1.5.



**FIGURE 1.4** Preparing for IT job requirements



**FIGURE 1.5** Computer technician skills



## Breaking into IT with the CompTIA A+ Certification

Many IT-related jobs require the A+ certification. Even if not required, the certification shows that you have a good understanding of how computers work. This certification does not guarantee you a job, but it does open doors in that a company may interview you if you lack IT experience but have the A+ certification.

A+ certification requires that you take two exams: Core 1 (220-1101) and Core 2 (220-1102). Each of these exams covers specific material. Tables 1.1 and 1.2 show the major categories (domains) for each exam and the extent to which they are represented.

**TABLE 1.1** CompTIA Core 1 (220-1101) A+ certification domains

Domain	Percentage of examination	Chapter(s)
1.0 Mobile Devices	15%	10
2.0 Networking	20%	12–13
3.0 Hardware	25%	1–9, 11
4.0 Virtualization and Cloud Computing	11%	3, 12
5.0 Hardware and Network Troubleshooting	29%	1–13

**TABLE 1.2** CompTIA Core 2 (220-1102) A+ certification domains

Domain	Percentage of examination	Chapter(s)
1.0 Operating Systems	31%	14–17
2.0 Security	25%	18
3.0 Software Troubleshooting	22%	14–18
4.0 Operational Procedures	22%	19

“What are the exams like?” you might ask. The exams include multiple-choice and performance-based questions. A performance-based question might be a drag-and-drop scenario or might ask you to do something specific on a particular device or within a particular operating system environment. Each exam is 90 minutes long and contains a maximum of 90 questions. The testing system allows you to bookmark questions that you might want to return to at the end if you have time. More information can be found on the CompTIA website ([www.comptia.org](http://www.comptia.org)).

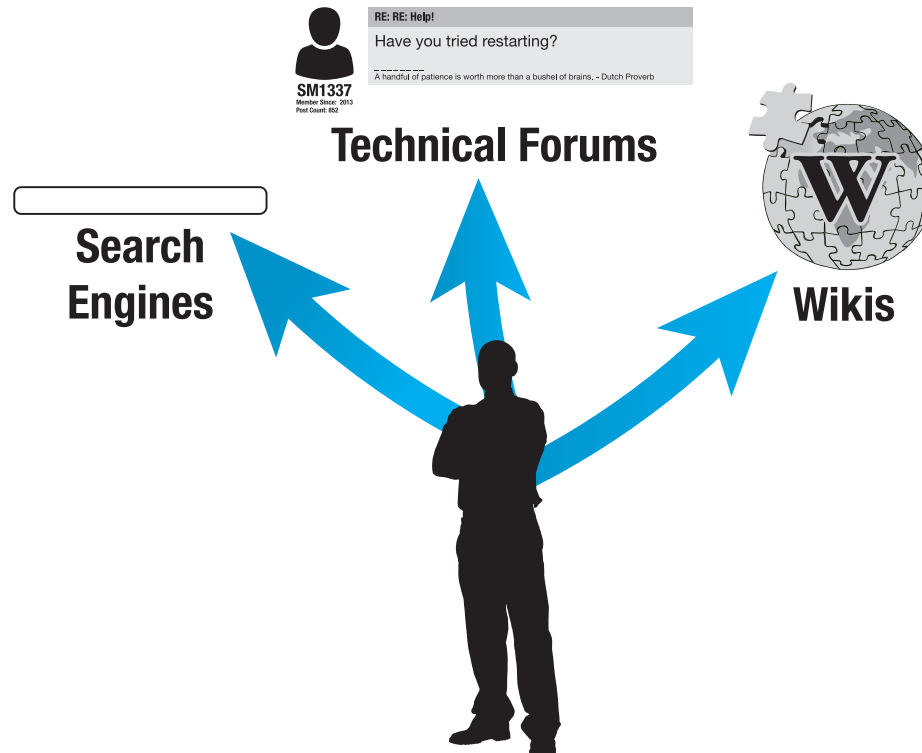
At the beginning of each chapter, you will see a list of the CompTIA A+ exam objectives that are covered in that chapter. At the end of each chapter, we’ve provided some A+ certification exam tips—tips to definitely pay attention to if you plan on taking the A+ exams. I recommend that you review the exam objectives, study material specific to them, and take some practice exams. Pearson IT Certification, the publisher of this book, develops many different certification exam prep resources that suit various study styles. Go to <http://pearsonitcertification.com/aplus> to browse the options.

## Basic Skills for This Course

In order to repair a computer, you need a few basic skills that include being familiar with the keyboard and inputting information, searching for information on the internet, and capturing information. Just because you may not be a good typist does not mean that you will not be good in an IT-related field.

## Searching for Information on the Internet

IT people need to use all available resources, including online resources. As noted, you need to be capable of searching for information online. Figure 1.6 illustrates various online resources that IT people search all the time.



**FIGURE 1.6** Search skills


Each chapter in the book has an activity at the end of it that enables you to practice searching the internet for information relevant to the chapter. Tips for searching include the following:

- > Search engines use different algorithms, so if one does not work, try another one. Examples of search engines are Google, Bing, Yahoo, and Ask. To access a search engine, open a web browser and type one of the search engine names followed by **.com**. Figure 1.7 shows where you enter the search engine name in the address bar.






**FIGURE 1.7** Web browser address bar

- > Use descriptive key words.
- > Do not include common words like *the*, *in*, *at*, or *for* because search engines tend to skip these words anyway. If you do want to use one of them, put a plus sign (+) in front of the word.

- > Avoid using a complex version, plural, or past tense of a word to avoid eliminating pages that are relevant. For example, to search for how to install a Bluetooth headset, avoid using the word *installation*, *installed*, or *installing* in the search window. Simply include the word *install*.
- > If several words are used together (an exact phrase), such as Windows 10, put quotation marks around the phrase—"Windows 10".
- > Use as many distinguishing words as possible.
- > If two words have the same meaning and are commonly used, use the word *or* in the search. For example, to search for generic information on a dot matrix printer, which is sometimes called an impact printer, you might search as follows: "dot matrix" or "impact printer". Note that the vertical bar (|), which is the key above the  key, can be used instead of the word *or*, as follows: "dot matrix" | "impact printer".
- > If a particular term can have two meanings (such as the word *memory* relating to something inside a computer or else relating to a brain function), you can use the minus sign in order to keep some information from being displayed. `memory -brain`, for example, would be a search for memory without any brain function results included.
- > If a particular term (such as *memory*) is generic, you can add a word and use the word *AND* in order to clarify the search, such as `computer AND memory`.
- > When searching for technical information, include the hardware or software manufacturer. A search for `Microsoft Windows 10` provides different results than a search for `Windows 10`.
- > If nothing relevant is on the first page of links, change the key words used in your search.

Consider the situation of a keyboard that intermittently works on a Microsoft Surface computer. The keyboard does not come standard as part of a Surface purchase. You do not own a Surface yourself and are unfamiliar with the tablet but must support it. An example of what might be typed into a search engine is `Microsoft Surface intermittent keyboard`.

## Screen Capturing

Sometimes, part of technical documentation is being able to capture what is on the screen. Windows versions come with the Snipping Tool and Snip & Sketch; you can access these tools by holding down the  key, pressing and holding the  key, and pressing the  key. This makes documenting problems easy, and you can copy what you capture into other applications. It doesn't matter what IT job you may have when you enter the workforce; documentation is a part of all IT jobs.

## Creating a Text File

Another part of documentation might involve creating or using a text file, known as a .txt file. You might need to send it as an attachment, or you might need to create a text file as part of the job. Sometimes a text file is the easiest type of file to create, especially on a mobile device. Text files can be created using a word processor and the *Save As* process, or they can be created using an app. Text files are popular because they can be opened by many apps. Text files commonly include only text, without multiple fonts or graphics. Windows has Notepad, and Apple has TextEdit, which can be used to create or open text files.

## Types of Computers

The simplest place to start to learn about technical support is with the devices themselves. The **PC**, or personal computer, comes in desktop, tower, and all-in-one models, as well as mobile models such as laptops, smartphones, and tablets. Figure 1.8 shows some of the devices technical staff are expected to support.



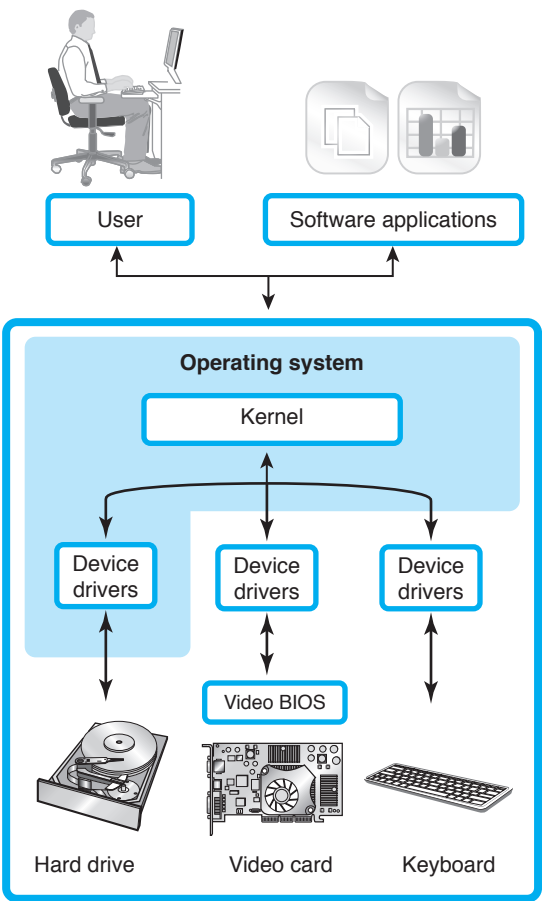
**FIGURE 1.8** Types of computers

## Basic Computer Hardware

Computer systems include hardware, software, and firmware. **Hardware** is something you can touch and feel, like the physical computer and the parts inside the computer. The monitor, keyboard, and mouse are hardware components. **Software** interacts with the hardware. Windows, Linux, macOS, Microsoft 365, Google Chrome, Adobe Acrobat Reader, Intuit TurboTax, and WordPerfect are examples of software.

Without software that directs the hardware to do something, a computer is useless. Every computer needs an important piece of software called an **operating system**, which coordinates the interaction between hardware and software applications. The operating system also handles the interaction between a user and the computer. Examples of operating systems include Windows 10 and 11, macOS, and various Linux systems, such as Red Hat and Ubuntu.

A **device driver** enables the operating system to recognize, control, and use a hardware component. Device drivers are hardware and operating system specific. For example, a printer requires a specific device driver when connected to a computer that used to have Windows 7 installed. The same printer might require a different device driver when using Windows 10 or 11. That Windows print driver would not work on an Apple computer. Each piece of installed hardware requires a device driver for the operating system being used. Figure 1.9 shows how hardware and software must work together.



**FIGURE 1.9** Hardware and software

Notice in Figure 1.9 the operating system kernel. The kernel is the central part of an operating system. The kernel is the connection between hardware and the applications being used.

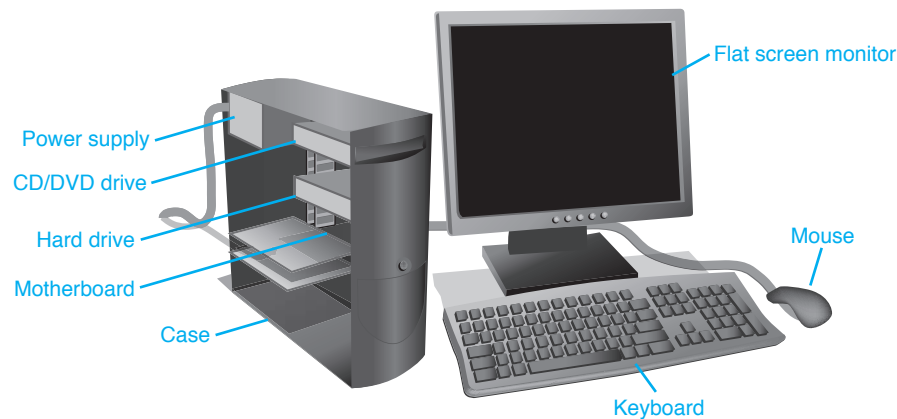
A PC typically consists of a case (chassis), a keyboard that allows users to provide input into the computer, a **monitor** that outputs or displays information (shown in Figure 1.10), and a mouse that allows data input or is used to select menus and options. Figure 1.10 shows a computer monitor, which may also be called a flat panel, display, or screen.



**FIGURE 1.10** Computer monitor

When the computer cover or side is opened or removed, the parts inside can be identified. The easiest part to identify is the **power supply**, which is the metal box normally located in a back corner of a case. A power cord connects the power supply to a wall outlet or surge strip. One purpose of the power supply is to convert the outlet AC voltage to DC voltage used internally in the PC. The power supply distributes this DC voltage using cables that connect to the various internal computer parts. A fan located inside the power supply keeps the computer cool to prevent damage to the components.

A PC usually has a device to store software applications and files. Two examples of storage devices are the hard drive and optical drive. The **hard drive**, sometimes called the hard disk, is a rectangular box normally inside the computer's case that is sealed to keep out dust and dirt. The hard drive has no external opening. The computer must be opened in order to access an internal hard drive. An **optical drive** holds discs (compact discs, or CDs), digital versatile discs (DVDs), or Blu-ray discs (BDs) that have data, music, video, or software applications on them. The front of the optical drive has a tray that ejects outward so a disc may be inserted. Figure 1.11 shows the major components of a tower computer. Figures 1.12 through 1.14 show components as they would look before being installed. Figure 1.12 shows a hard drive. Figure 1.13 shows an optical drive. Figure 1.14 shows a power supply. Figure 1.15 shows a tower computer case.



**FIGURE 1.11** Tower computer



**FIGURE 1.12** Hard drive





**FIGURE 1.13** DVD or optical drive



**FIGURE 1.14** Power supply

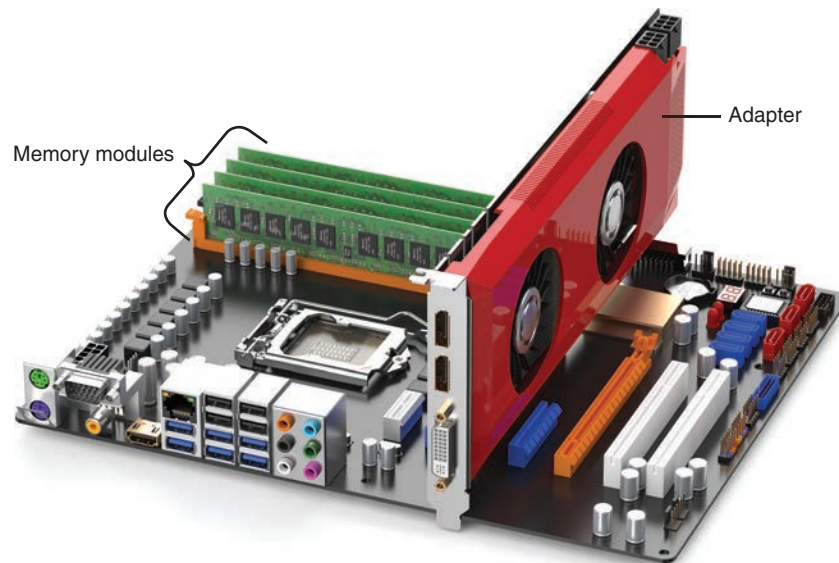


**FIGURE 1.15** Tower case

The **motherboard** is the main circuit board inside a PC and contains the most electronics. It is normally located on the bottom of a desktop or laptop computer and mounted on the side of a tower computer. Other names for the motherboard include mainboard, planar, or system board. External



devices connect directly to the back of the motherboard or ports on the front of the computer. Figure 1.16 shows a motherboard when it is not installed inside a computer as well as memory and an adapter, which are covered next.



**FIGURE 1.16** Computer motherboard

The motherboard holds memory modules. **Memory** modules hold applications, part of the operating system, and user documents. Random-access memory (**RAM**) is the most common type of memory on the motherboard and is volatile; that is, the data inside the module is lost when power is removed. When a user types a document in a word processing program, both the word processing application and the document are in RAM. If the user turns the computer off without saving the document to removable media or the hard drive, the document is lost because the information does not stay in RAM. (Note that some applications have the ability to periodically save a document, but this is not a guarantee that it has the latest information.) Figure 1.17 shows memory modules when they are not installed into the motherboard memory slots. Memory is covered in great detail in Chapter 6, “Memory.”



**FIGURE 1.17** Memory modules

A device may have a cable that connects the device to the motherboard. Other devices require an adapter. An **adapter** is an electronic card that plugs into an **expansion slot** on the motherboard. Other names for an adapter are controller, card, controller card, circuit card, circuit board, and adapter board. Adapters allow someone to add functionality or an enhancement that is not provided through the ports on the motherboard, such as better sound or video graphics or additional ports of some type in order to connect external devices. Figure 1.18 shows an adapter. Notice how the contacts at the bottom are a particular shape. Chapter 3, “On the Motherboard,” goes into more detail about the types of expansion slots and adapters. You can also look back to Figure 1.16 to see a video card/adapter installed into a motherboard expansion slot.



**FIGURE 1.18** Adapter

### TECH TIP

#### How to identify an adapter's function

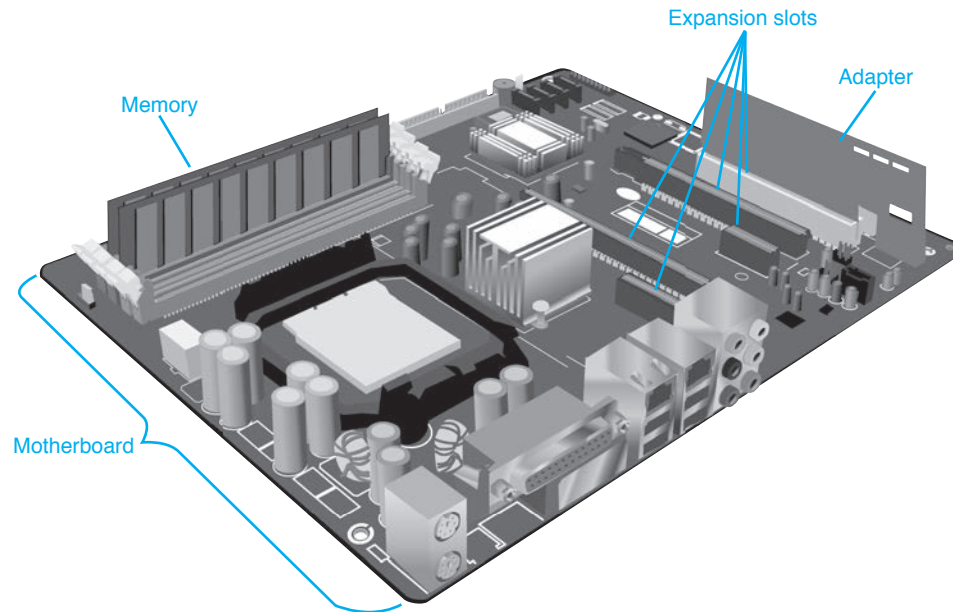
Tracing the cable attached to an adapter or looking at the device connected to an adapter can help identify the adapter's function.

The following are the generic steps for installing adapters:

- Step 1.** Always follow the manufacturer's installation directions. Use an antistatic wrist strap when handling adapters. Electrostatic discharge (ESD) can damage electronic parts. (See Chapter 5, “Disassembly and Power,” for more details on ESD.)
- Step 2.** Be sure the computer is powered off and unplugged.
- Step 3.** Remove any brackets from the case or plastic covers from the rear of the computer that may prevent adapter installation. Install the adapter in a free expansion slot and reattach any securing hardware.
- Step 4.** Attach any internal device cables that connect to the adapter, as well as any cables that go to an external port on the adapter.

- Step 5.** Attach any internal or external devices to the opposite ends of the cable, if necessary.
- Step 6.** Power on any external devices connected to the adapter, if applicable.
- Step 7.** Reattach the computer power cord and power on the computer.
- Step 8.** Load any application software or device drivers needed for the devices attached to the adapter.
- Step 9.** Test the device connected to the adapter.

See Figure 1.19 for an illustration of a motherboard, expansion slots, memory, and an adapter in an expansion slot.



**FIGURE 1.19** Motherboard with expansion slots and an adapter

## Mice and Keyboards

Input devices, such as the mouse and keyboard, attach to the motherboard. The most common type of **mouse** is an optical mouse, which has optical sensors that detect the direction in which the mouse moves. It uses reflections from light-emitting diodes (LEDs) from almost any surface to detect the mouse location. Mice commonly can be adjusted for sensitivity—how far you have to move the mouse to move the cursor on the screen a desired amount. Figure 1.20 shows a photo of the bottom of an optical mouse.

A **keyboard** is an input device that connects to a port on the motherboard or attaches wirelessly. Features users look for in a keyboard include a separate numeric keypad for those who have to input a great deal of numbers, adjustable tilt legs, and spill resistance. Figure 1.21 shows the type of keyboard and mouse that are commonly used with a tower, desktop, or all-in-one computer.



**FIGURE 1.20** Optical mouse



**FIGURE 1.21** Keyboard and mouse

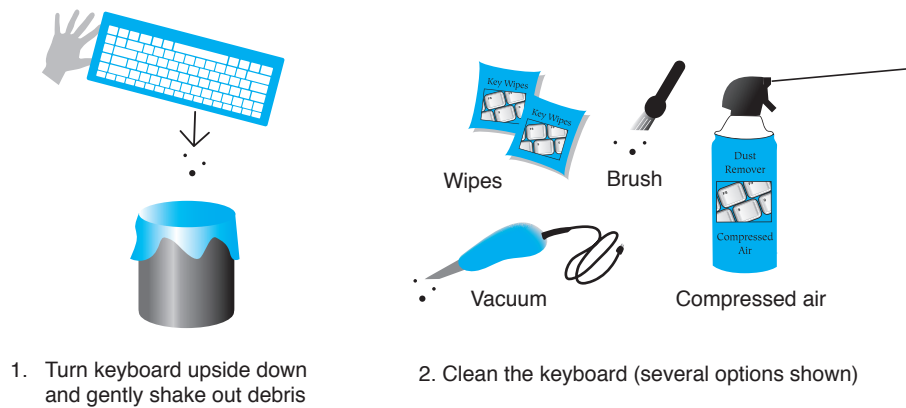
## Mouse and Keyboard Preventive Maintenance

Mouse cleaning kits are available in computer stores, but normal household supplies also work. Use the following procedures to clean an optical mouse:

**Step 1.** Wipe the bottom with a damp, lint-free cloth.



**Step 2.** Use compressed air to clean the optical sensors.

Keyboards also need periodic cleaning. Figure 1.22 shows keyboard cleaning techniques.






**FIGURE 1.22** Keyboard cleaning techniques

Keyboard/Mouse Troubleshooting

One of the easiest ways to determine whether a keyboard is working is to press the  or  key and watch to see if the keyboard light illuminates. Sometimes an application setting may be causing what appears to be a keyboard problem. Use another application to see if the keyboard is the problem. Keyboards can have LED lights that indicate particular functions. Table 1.3 lists the most common lights. Note that different vendors label the lights in various ways.

**TABLE 1.3** Common keyboard lights

Associated toggle key	Keyboard light	Description
	Number lock (NUM LOCK)	Toggles the 10-key pad between digits 0 through 9 and various functions, such as HOME, PG UP, PG DOWN, END, and various arrow keys.
	Capital letters lock (CAPS LOCK)	Toggles between all uppercase and lowercase letters.
	Scroll lock	A rarely used key used to prevent scrolling and use of the arrow keys to progress through information displayed.

TECH TIP

One key doesn't work

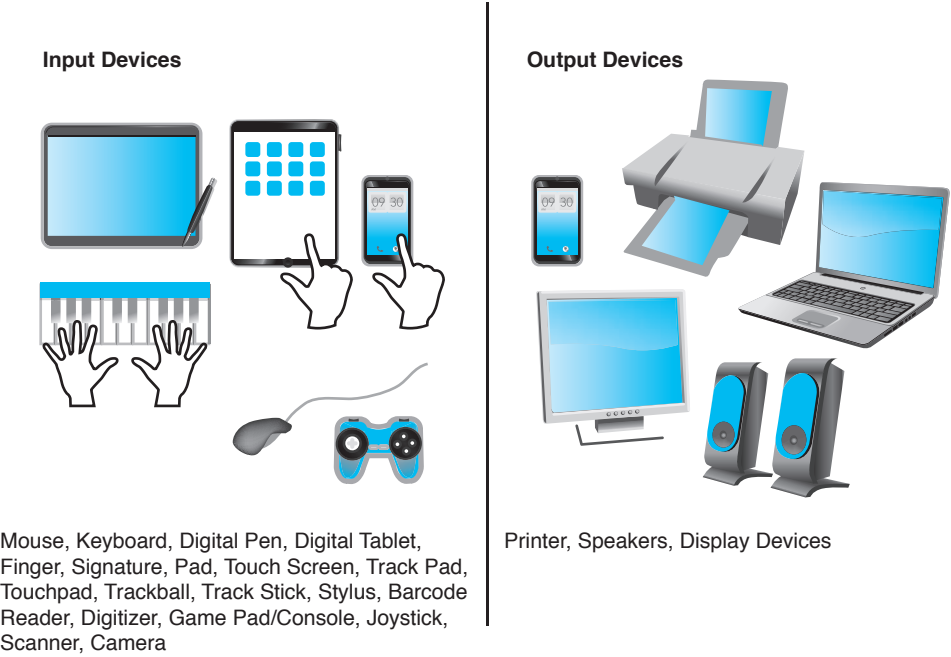
If a particular key is not working properly, remove the key cap. A small, flat-tipped screwdriver can assist with this. After removing the key cap, use compressed air around the sticky or malfunctioning key.

If coffee or another liquid spills into a PC keyboard, all is not lost, but unplug it quickly and away from the computer, turn it over. Use paper towels to get up what water you can. Afterward, the keyboard can be disassembled and/or scrubbed with lint-free swabs or cloths. However, PC keyboards and mice are normally considered throw-away technology. It is cheaper to get a new one than to spend a lot of time trying to repair a keyboard or mouse.



## Common Peripherals

Many devices connect to a computer to provide input, such as a mouse or keyboard, or output, such as a display. Some devices can be both input and output devices, such as smart TVs, Musical Instrument Digital Interface– (MIDI–) enabled devices (which are electronic musical devices), touch screens, or printers. In the case of a printer, data is sent from a computer to the printer, and the printer can send data (information), such as an out-of-ink message, back to the computer. Figure 1.23 shows some common input and output devices.



**FIGURE 1.23** Input and output devices

Table 1.4 lists various peripherals that you will see used and attached to computers today. We will be examining some of these devices in more depth and learn how to configure them, but this is a good chapter to get the basics.

**TABLE 1.4** Common peripherals

Peripheral	Description
<b>Printer</b>	An output device that transfers information such as text and graphics from a computer onto paper or other media (see Figure 1.24).
<b>Flatbed scanner</b>	An input device that digitizes words or graphics and can be used as a copier. A scanner may have an automatic document feeder ( <b>ADF</b> ) that allows one or more documents to be fed into the scanner (see Figure 1.24).
<b>All-in-one printer</b>	A device that has a printer, scanner, copier, and sometimes fax capabilities. Sometimes known as a multifunction printer (see Figure 1.24).
<b>Camera/webcam</b>	An input device used to provide live video feed such as when you participate in a video conference or capture video images or motion (see Figure 1.25). More information can be found in Chapter 8, “Video and Multimedia Devices.”
<b>Microphone</b>	An input device used to capture sound (see Figure 1.25). More information can be found in Chapter 8.
<b>Headset</b>	An input/output device that commonly has a microphone and headphones, as shown in Figure 1.25.



FIGURE 1.24 Printer, scanner, and all-in-one printer

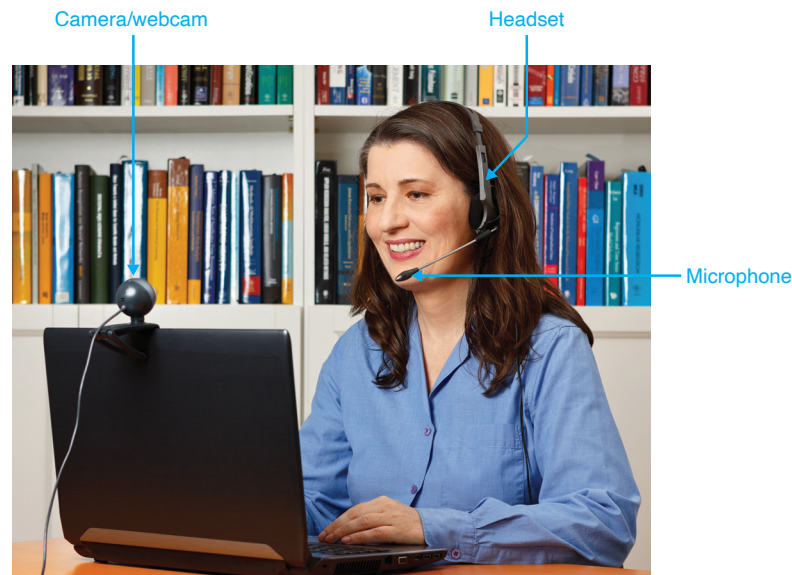


FIGURE 1.25 Camera/webcam, headset, and microphone

### 1s and 0s

Computers are digital devices. That means they understand 1s and 0s. One 1 or one 0 is known as a **bit**. In actuality, a 1 is simply a voltage level. So, when we type characters into a word processing application, the keyboard translates those characters into voltage levels. Figure 1.26 shows this concept. Notice that each letter is represented by a combination of eight 1s and 0s. Each 1 is a voltage level sent to the motherboard (and components on it). Each 0 is simply the absence of a voltage level.



		D	E	A	R	[space]	M	O	M
What we see		01000100	01000101	01000001	01010010	00100000	01001101	01010010	01001101
What a computer sees		⚡ ⚡	⚡ ⚡ ⚡	⚡ ⚡ ⚡	⚡ ⚡ ⚡	⚡	⚡ ⚡ ⚡ ⚡	⚡ ⚡ ⚡ ⚡	⚡ ⚡ ⚡ ⚡

FIGURE 1.26 Binary bits



Technicians need to be able to describe capacities such as hard drive capacities and available drive space. Eight bits grouped together are a **byte**. Figure 1.27 shows a hot dog divided into eight sections (which make a big old “byte”).

Approximately 1,000 bytes is a **kilobyte** (kB), as shown in Figure 1.28. 1 kB is 1,024 bytes to be exact, but industry folks simply round off the number to the nearest thousand for ease of calculation. Approximately 1 million bytes is a **megabyte** (MB), but a true megabyte is 1,048,576 bytes. 540 megabytes is abbreviated 540 MB, or 540 M. Notice in Figure 1.29 that a megabyte stores a lot more 1s and 0s than a kilobyte.

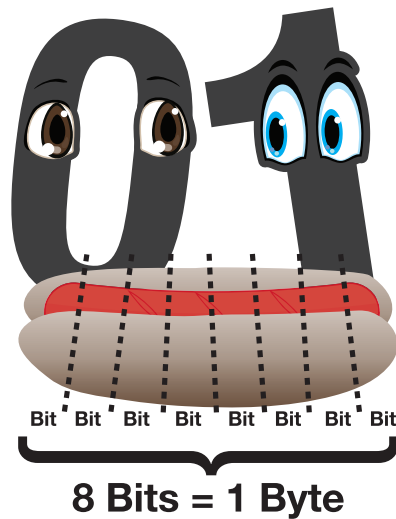


FIGURE 1.27 A byte

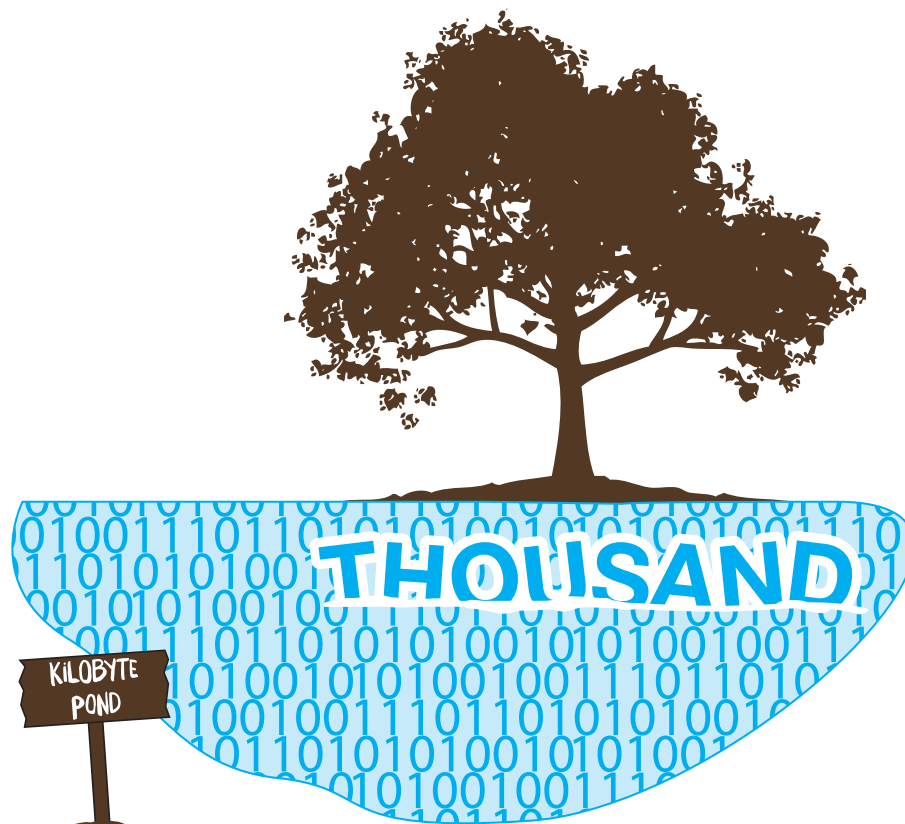
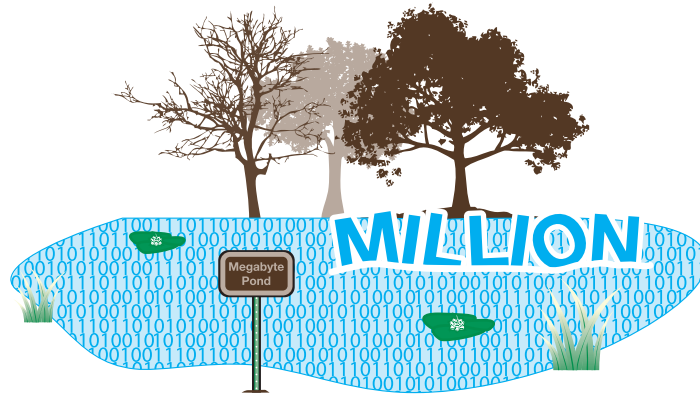
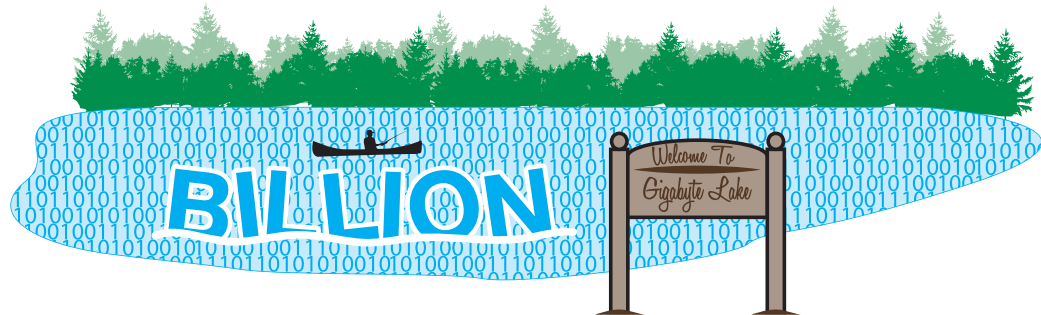


FIGURE 1.28 A kilobyte

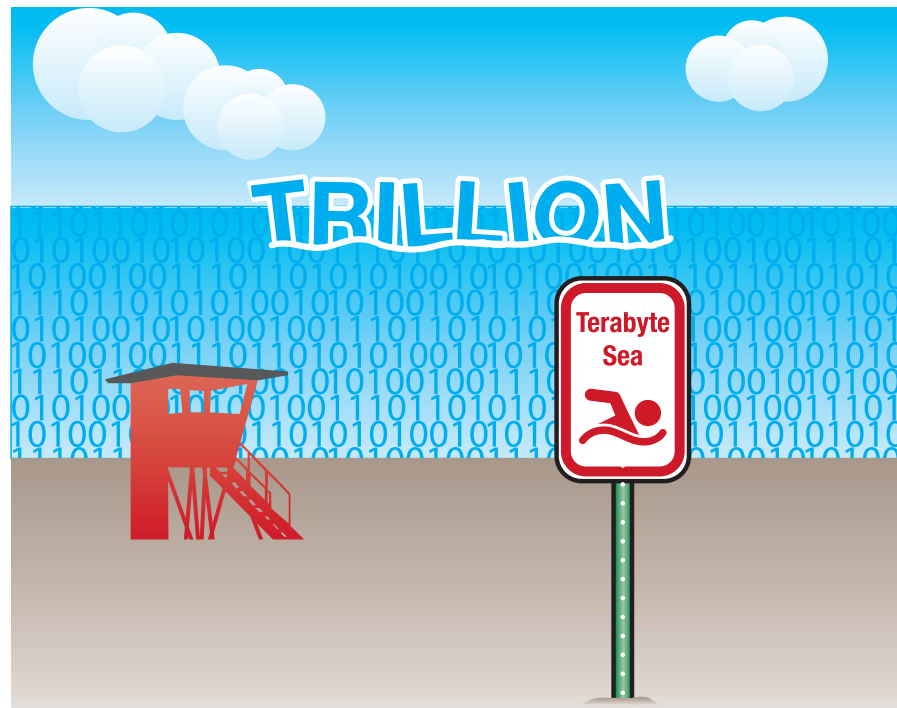


**FIGURE 1.29** A megabyte

Approximately 1 billion bytes (1,073,741,824 bytes) is a **gigabyte** (GB), which is shown as 1 GB or 1 G. Approximately 1 trillion bytes (1,099,511,627,776 bytes) is a **terabyte**, which is shown as 1 TB or 1 T. Figures 1.30 and 1.31 show how storage capacities get larger.



**FIGURE 1.30** A gigabyte



**FIGURE 1.31** A terabyte

When information needs to be expressed exactly, binary prefixes are used. For example, when describing the value  $2^{10}$  (1,024), instead of saying this is 1 kilobyte, which people tend to think of as approximately 1,000 bytes, the term kibibyte (KiB) is used. When describing the value  $2^{20}$ , or 1,048,576, the term mebibyte (MiB) is used. Table 1.5 shows the terms used with computer storage capacity and binary prefixes when exact measurements are needed.

TABLE 1.5 Storage terms and binary prefixes

Term	Abbreviation	Description
Kilobyte/kibibyte	kB/KiB	~1 thousand bytes/ $2^{10}$ bytes
Megabyte/mebibyte	MB/MiB	~1 million bytes/ $2^{20}$ bytes
Gigabyte/gibibyte	GB/GiB	~1 billion bytes/ $2^{30}$ bytes
Terabyte/tebibyte	TB/TiB	~1 trillion bytes/ $2^{40}$ bytes
Petabyte/pebibyte	PB/PiB	~1,000 trillion bytes/ $2^{50}$ bytes
Exabyte/exbibyte	EB/EiB	~1 quintillion bytes/ $2^{60}$ bytes
Zettabyte/zebibyte	ZB/ZiB	~1,000 exabytes/ $2^{70}$ bytes
Yottabyte/yobibyte	YB/YiB	~1 million exabytes/ $2^{80}$ bytes

Frequencies are also important measurements in computers because people want to know how fast their computers, processors, memory, and other parts are operating. Frequencies are shown in similar measurements, but instead of bits (b) or bytes (B), speeds are shown in hertz (Hz). A hertz is a measurement of cycles per second. Something that operates at approximately 1 million cycles per second is said to operate at 1 megahertz (1 MHz). For 1 billion cycles per second, the measurement is known as 1 gigahertz, or 1 GHz. Transfer speeds are commonly shown in bits per second, such as gigabits per second, or Gb/s, or bytes per second, such as in megabytes per second, or MB/s. Notice the capital letter B to indicate bytes as compared to the lowercase b to indicate bits. These measurements are used in a lot of IT-related hardware and software.

### Safety Notes

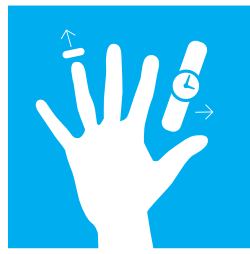
Safety is covered in each chapter, especially in Chapter 5, but no book on computer repair can begin without stating that both the technician and the computer can be harmed by poor safety habits. Before beginning any PC service, remove jewelry. To protect yourself and the computer, make sure to power off the computer and remove the power cord when disassembling, installing, or removing hardware or when doing preventive maintenance (cleaning).

#### TECH TIP

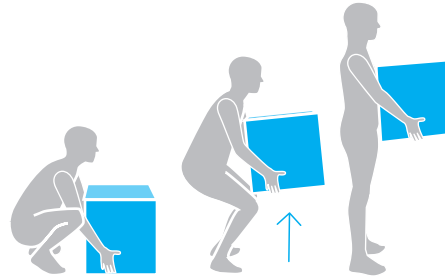
##### Some things should be left alone

Never take apart an older cathode ray tube (CRT) monitor or any power supply unless you have been specifically trained on these components.

Technicians can also be harmed when doing menial tasks such as lifting a computer or heavy laser printer. Lifting is a common requirement listed in IT job advertisements and explained during interviews. Technical jobs frequently specify a maximum lifting requirement of 40 to 50 pounds. Use proper safety precautions, such as those shown in Figure 1.32.



Remove jewelry  
before working  
inside of a computer



- Bend at the knees
- Use your legs to lift
- Use lifting aids when possible
- Ask for assistance when possible

**FIGURE 1.32** Safety tips

## Chapter Summary

- > Many IT roles require detailed knowledge of PC hardware and software.
- > Computer technicians should actively listen, have a positive attitude, and use logic when solving problems.
- > The CompTIA A+ certification requires two exams: Core 1 (220-1101) and Core 2 (220-1102). Many people break into the IT field with this certification.
- > IT staff must be proficient at searching for information on the internet, capturing files, and documenting technical information.
- > Computers consist of hardware (the physical parts) and software (the operating system and applications).
- > A technician needs to be able to identify important computer parts installed in a computer and as standalone parts: case, keyboard, mouse, motherboard, monitor, power supply, hard drive, optical drive, adapter, and memory.
- > A technician needs to know the purposes of common peripherals used in the industry: printer, flatbed scanner with ADF, camera/webcam, microphone, and headset.
- > Mice and keyboards are important input devices. To clean a keyboard, turn it over to remove debris. Then use a vacuum, compressed air, or wipes to clean it.
- > Safety is important when working on a computer. Power it down and remove the power cord before working inside it.
- > Use proper lifting techniques when servicing equipment.

## A+ CERTIFICATION EXAM TIPS

- ✓ Get a good night's rest the night before the exam.
- ✓ Ensure that you are knowledgeable about and proficient with all of the terms and technologies listed in the official CompTIA A+ exam objectives. Some students study for a particular exam by going through the objectives one by one and reviewing the material as they go through.
- ✓ Ensure that you can identify the basic parts of a computer and explain the purpose of each one. Ensure that you know the following parts: hard drive, optical drive, power supply, motherboard, and RAM.
- ✓ Know common hardware so you will be familiar with future chapters that go into the details of installing, configuring, and troubleshooting these devices: printer, flatbed scanner, ADF, monitor, optical drive, mouse, keyboard, trackpad, drawing pad, camera/webcam, microphone, speakers, and headset.
- ✓ Know the following safety procedures: disconnect power, remove jewelry, lifting techniques, and weight limitations.
- ✓ Review the "Soft Skills" section at the end of the chapter. Make sure you know what open-ended questions are.

## Key Terms

active listening skills	2	hard drive	10	open-ended question	2
adapter	13	hardware	8	operating system	8
ADF	17	headset	17	optical drive	10
bit	18	keyboard	14	PC	8
byte	19	kilobyte	19	power supply	10
camera	17	megabyte	19	printer	17
clarify customer statements	2	memory	12	RAM	12
device driver	8	microphone	17	software	8
expansion slot	13	monitor	9	terabyte	20
flatbed scanner	17	motherboard	11	webcam	17
gigabyte	20	mouse	14		

## Review Questions

1. Match each part to the appropriate description.

____ motherboard	a. Converts AC to DC
____ RAM	b. Holds the most data
____ DVD drive	c. Has the most electronics
____ hard drive	d. Fits in an expansion slot
____ adapter	e. Contents disappear when power is off
____ power supply	f. Holds a disc
2. A technician has been asked to provide support to an administrative assistant who is participating in a video conferencing session. Which peripheral would be used in video conferencing more so than in normal daily operational tasks?  
[ mouse | webcam | all-in-one-printer | hard drive ]
3. Which of the following are important suggested internet search tips? (Choose two.)
  - a. Try another search engine if the first one does not provide satisfactory results.
  - b. Use as many common words as possible, like the, in, at, or for.
  - c. Put quotation marks around two or more words that might be found consecutively in output.
  - d. Use as few words as possible.
  - e. Avoid using the name of the equipment manufacturer.
4. What is the acronym used to describe memory that is commonly found on a motherboard?  

---
5. When lifting a heavy computer, you should squat, bend at the knees, and use your legs to lift. [ T | F ]
6. How many tests must a person take in order to be A+ certified?  
[ 0 | 1 | 2 | 3 | 4 ]
7. Is the following question open ended or closed ended? You say your computer has been running slowly since Monday. Which applications have you installed this week? [ open ended | closed ended ]
8. List one example of having a positive attitude.  

---
9. Which of the following devices are common output devices? (Select all that apply.)  
[ digital piano | speakers | display | stylus | track stick | barcode reader | printer ]
10. People who work with computers might be expected to lift up to how many pounds?  
[ 10 to 20 | 20 to 30 | 30 to 40 | 40 to 50 ]
11. Which Microsoft Windows application could be used to create a text file?  
[ Textpad | Notepad | WriteIt | NoteIt ]
12. Which Windows tool can be used to capture the screen?  
[ Notepad | Bluetooth | Microsoft Edge | Snip & Sketch ]

13. Rewrite the following conversation into an open-ended question.

Technician: Good morning. I have a service log that states you are getting an error message whenever you access a PDF file. Have you done your Acrobat updates lately?

---



---



---

14. List one procedure you would do to help an erratic optical mouse.

---



---

15. Match the capacity to the description.

___ bit	a. 8 bits
___ kilobyte	b. a 1 or a 0
___ megabyte	c. approximately 1,000 bytes
___ byte	d. approximately 1 million bytes
___ gigabyte	e. approximately 1 trillion bytes
___ terabyte	f. approximately 1 billion bytes

16. Match the device to the description. Note that each description will best fit only one answer.

___ flatbed scanner	a. has an ADF
___ adapter	b. used to feed multiple sheets of paper one page at a time
___ ADF	c. used to capture video
___ power supply	d. inserts into an expansion slot
___ webcam	e. converts AC to DC

17. Which of the following is a feature of an optical mouse?

- a. LED
- b. contacts
- c. volatility
- d. electrical conversion

18. Which device is normally found inside a computer?

[ ADF | printer | headset | hard drive ]

19. Which device normally can be seen if looking inside a desktop computer with the cover off and when normally looking at the front of a desktop computer?

[ hard drive | motherboard | optical drive | RAM ]

20. Where can you find the motherboard in a tower computer?

- a. inside the power supply
- b. on the side of the case
- c. below the hard drive
- d. beside the RAM

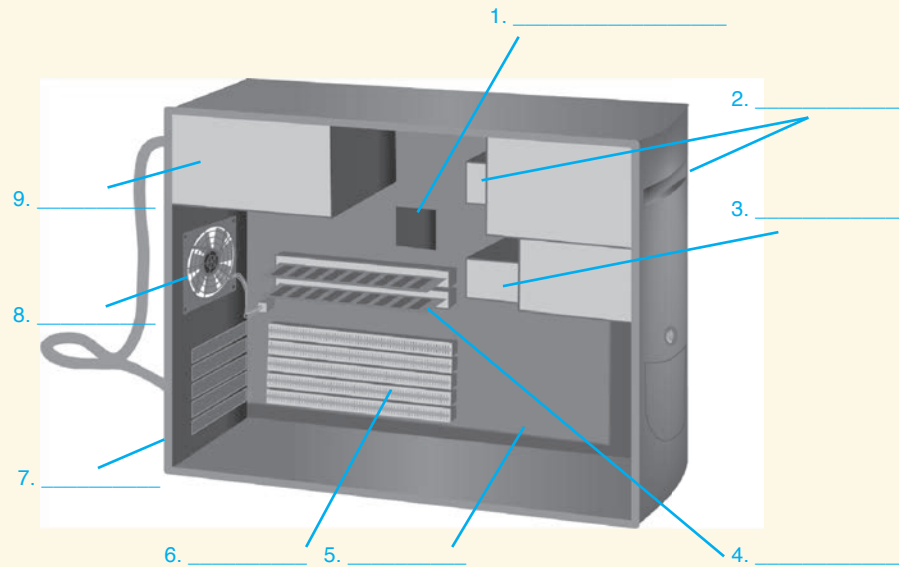


## Exercises

### Exercise 1.1 Identifying Tower Computer Parts

**Objective:** To identify various computer parts correctly

**Procedure:** Identify each computer part in Figure 1.33. Match the part to the number in Figure 1.34.



**FIGURE 1.33** Tower computer parts identification

1. \_\_\_\_\_
2. \_\_\_\_\_
3. \_\_\_\_\_
4. \_\_\_\_\_
5. \_\_\_\_\_
6. \_\_\_\_\_
7. \_\_\_\_\_
8. \_\_\_\_\_
9. \_\_\_\_\_



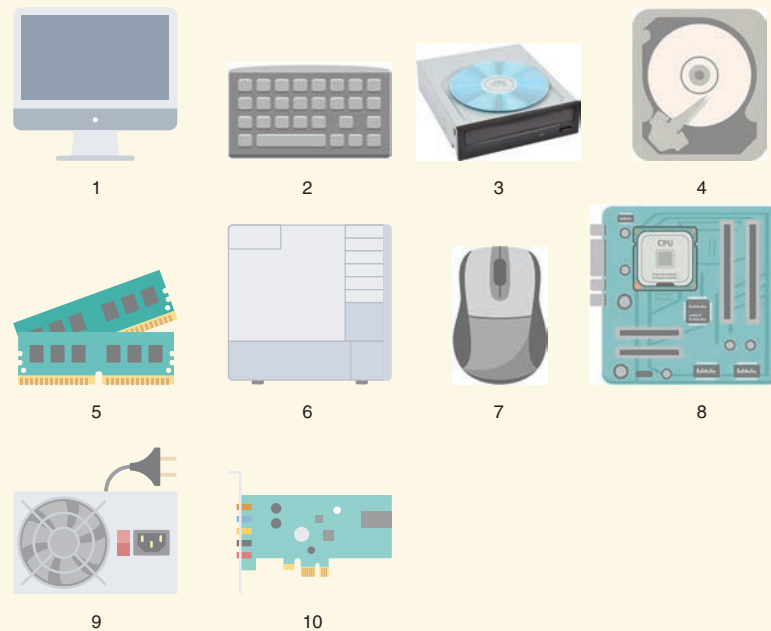
**FIGURE 1.34** Second tower computer parts identification

- |    |       |                  |
|----|-------|------------------|
| 1. | _____ | a. Motherboard   |
| 2. | _____ | b. RAM           |
| 3. | _____ | c. Power supply  |
| 4. | _____ | d. Case fan      |
| 5. | _____ | e. Adapter       |
| 6. | _____ | f. Optical drive |
| 7. | _____ | g. Case          |

## Exercise 1.2 Identifying Computer Parts

**Objective:** To identify various computer parts correctly

**Procedure:** Identify each computer part in Figure 1.35.



**FIGURE 1.35** Computer parts identification

1. \_\_\_\_\_
2. \_\_\_\_\_
3. \_\_\_\_\_
4. \_\_\_\_\_
5. \_\_\_\_\_
6. \_\_\_\_\_
7. \_\_\_\_\_
8. \_\_\_\_\_
9. \_\_\_\_\_
10. \_\_\_\_\_

## Activities



### Internet Discovery

**Objective:** To obtain specific information from the internet regarding a computer or its associated parts

**Parts:** Computer with internet access

**Procedure:** Using the internet, locate technical information about a computer. Answer the following questions based on the retrieved information. Note that you may need to open more than one document in order to answer the questions.

**Questions:**

1. What is the name of the computer for which you found technical information?  
\_\_\_\_\_
2. How much RAM comes with the computer?  
\_\_\_\_\_
3. Which URL did you use to find this information?  
\_\_\_\_\_
4. Which search term(s) would you use for the following scenario? An HP Windows 10 computer has a Samsung ML-2160 laser printer attached. This printer supports both wired and wireless printing. The computer that is wired to the printer can print just fine, but no wireless devices in the house can access or even see the printer.  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_
5. Which search term(s) would you use in a search engine to help a friend who has accidentally deleted a file on a Windows 10 computer?  
\_\_\_\_\_
6. Which search terms would you use to find a video that shows you how to add an application to a Windows 10 desktop computer?  
\_\_\_\_\_

**Soft Skills**

**Objective:** To enhance and fine-tune a future technician's ability to listen, communicate in both written and oral forms, and support people who use computers in a professional manner

**Procedure:**

1. In a team environment, list three qualities that are important in a computer technician. Create scenarios that demonstrate these qualities. Share these findings in a clear and concise way with the class.
2. In a team environment, list three qualities that are not good practices for computer technicians. Create scenarios that demonstrate these qualities. Share these findings in a clear and concise way with the class.

**Critical Thinking Skills**

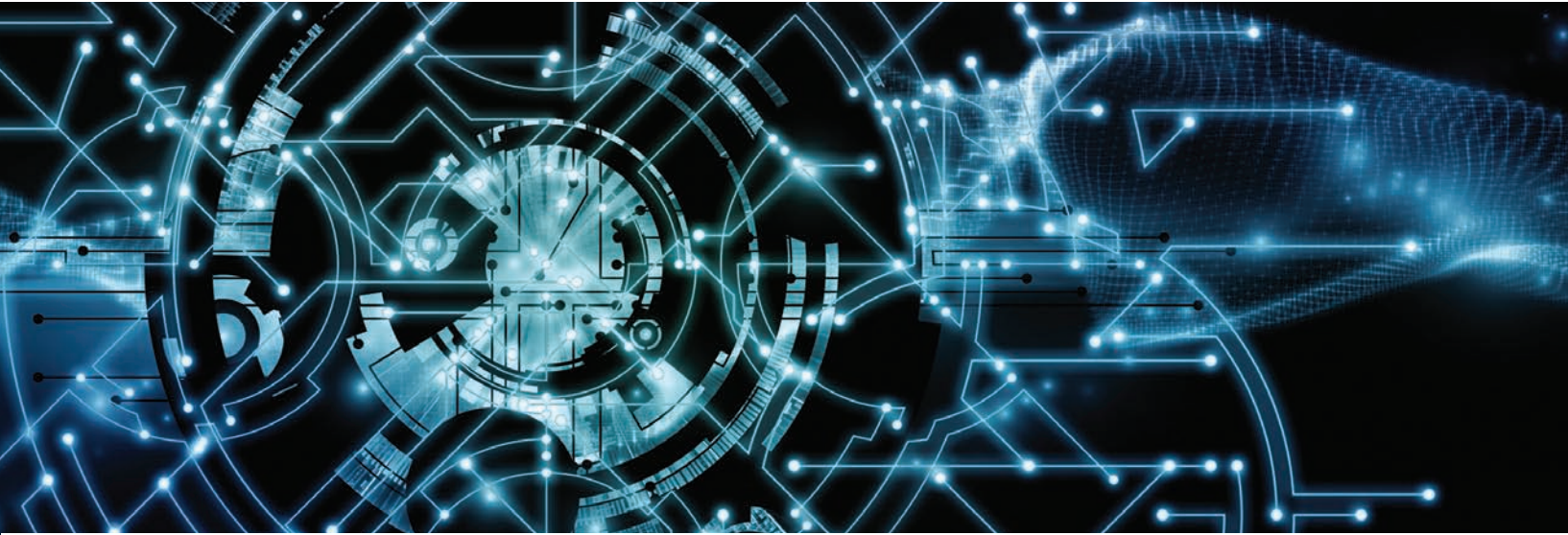
**Objective:** To analyze and evaluate information as well as apply learned information to new or different situations

**Procedure:**

1. Find an advertisement for a computer in a local computer flyer, in a newspaper, in a magazine, in a book, or on the internet. List the components you know in one column and the components you do not know in another column. Select one component you do not know and research that component. On a separate piece of paper, write a description of the component, based on your research, and then share it with at least one other person. Write the name of the person with whom you shared.
2. Why do you think that many computer components are considered "throw-away" technology? List your reasoning. In groups of three or four, share your thoughts. Nominate a spokesperson to share your group reaction in two sentences or less.
3. One device touts a transfer speed of 1 Gb/s, whereas another device advertises 100 MB/s. Compare the two devices' transfer speeds and indicate which one is faster. Locate a component you have or would like to have. Compare products paying particular attention to the transfer speed. Document your findings.

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# 2 Connectivity



## In this chapter you will learn:

- > The purposes of various computer ports
- > What to do if you don't have a particular port
- > Different types of connectors and cables
- > What types of devices connect to specific ports

## CompTIA Exam Objectives:

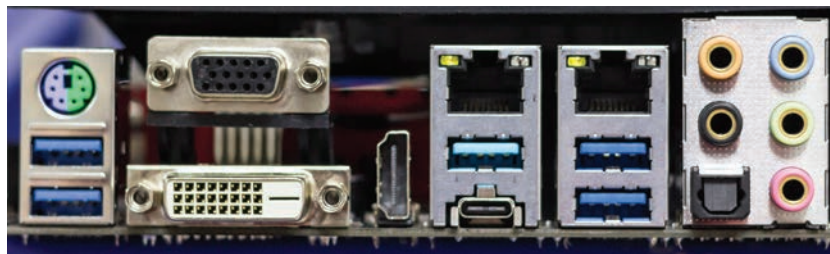
- ✓ 1101-3.1 Explain basic cable types and their connectors, features, and purposes.
- ✓ 1101-3.4 Given a scenario, install and configure motherboards, central processing units (CPUs), and add-on cards.
- ✓ 1102-4.7 Given a scenario, use proper communication techniques and professionalism.

## Introduction to Connectivity

Now that we've discussed the basic parts of a PC, we are ready to dive into the technical details. Some of the ports may be challenging at first, but it is important that people going into the IT field know how to connect devices to ports and the purpose of each port.

## External Connectivity

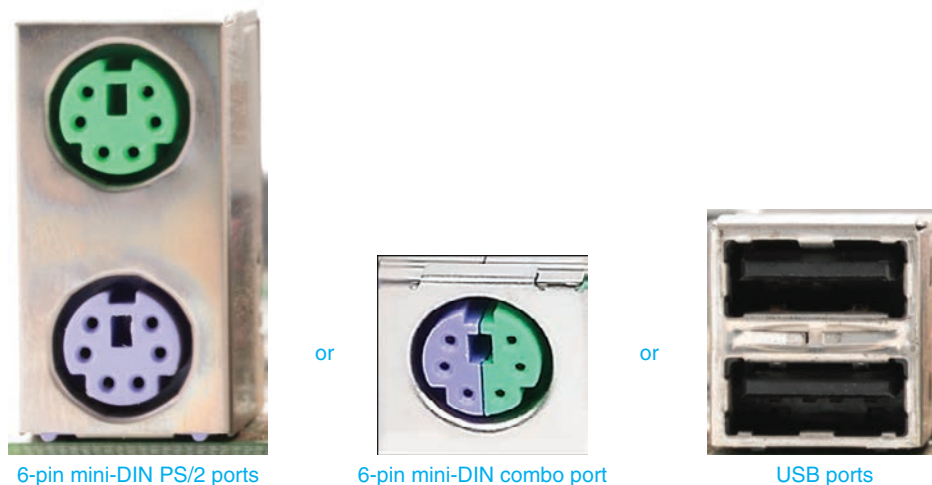
A **port** is a connector on a motherboard or on a separate adapter that allows a device to connect to a computer. Ports can be found all around a computer or mobile device. Figure 2.1 shows a motherboard with some of the ports we will be covering. See how many you can already identify and then return to this figure after finishing the chapter. IT professionals should be able to recognize and identify the common ports used today.



**FIGURE 2.1** Motherboard ports

## Mouse and Keyboard Ports

**Mouse ports** and **keyboard ports** were traditionally 6-pin **mini-DIN** ports that are sometimes called **PS/2 ports**. Most ports are keyed so the cable can only be inserted one way. Today, USB ports are more commonly used for mouse and keyboard connectivity, but some gaming motherboards still have the mini-DIN port(s). Manufacturers color code the mouse port as green and the keyboard port as purple; they may put a small diagram of a keyboard or a mouse by each connector. Figure 2.2 shows mouse and keyboard connectivity options.

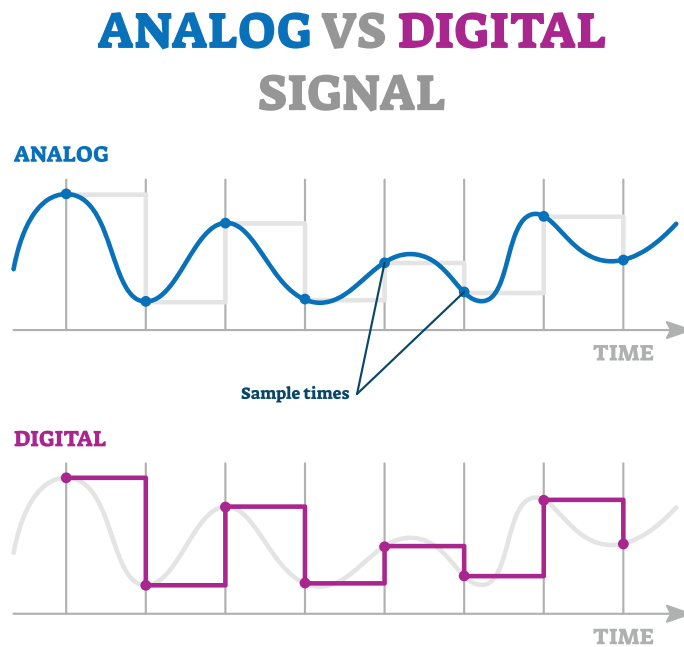


**FIGURE 2.2** Mouse and keyboard ports



## Video Ports

A video port is used to connect a monitor. Video output can be the older method of an **analog signal** (varying levels, such as seen with an audio signal) or the newer output that uses a **digital signal** (1s and 0s). Because a computer uses digital signals, sending 1s and 0s is more efficient than converting an analog signal to a digital signal. This is relevant because there are still video ports around that are designed for analog signals. Figure 2.3 shows the difference between analog and digital signals.



**FIGURE 2.3** Analog and digital signals

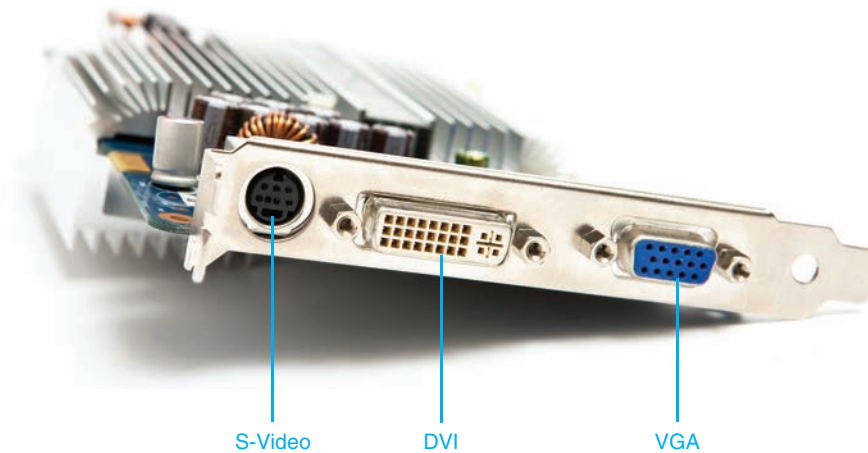
The most common video ports used today are VGA, DVI, DisplayPort, and HDMI. These are all covered in this section. In addition, multipurpose ports such as USB-C, Thunderbolt, and Lightning are also used for video. The multipurpose ports are covered separately since they can transmit more than just audio and video.

### Video Graphics Array (VGA)

The video graphics array port, or **VGA port**, was designed for analog output to an old cathode ray tube (CRT) monitor. VGA ports are easy to identify because they have three rows of holes—15 holes in total. Ports that have holes are known as female ports. The VGA port is sometimes seen in documentation as an HD15, DE15, or D-sub port. The “D” in these names comes from the VGA connector being a D-shell connector. Look at the VGA port in Figure 2.4 and imagine that port turned sideways so it looks like the letter D. The VGA cable has a DB15 male end that attaches to the DE15 female port.

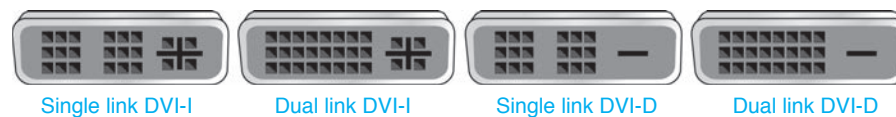
### Digital Visual Interface (DVI)

A newer port is the Digital Visual Interface port, or **DVI port**, that has three rows of square holes. Some monitors can also connect to the older VGA port. Some video adapters also enable you to connect a video device (such as a television) that has an **S-Video port**. Figure 2.4 shows a video adapter with the DVI port as the left connector, the S-Video port in the center, and a VGA port on the right.



**FIGURE 2.4** DVI, S-Video, and VGA ports

There are several types of DVI connectors. The one used depends on the type of monitor attached. Two terms used with DVI connectors are single link and dual link. A single link connection allows lower video resolutions than a dual link connection because a dual link port has more pins. The two major types of connectors are DVI-D and DVI-I. **DVI-D** is used for digital video connectivity only. **DVI-I** can be used for both digital and analog monitors, and it is the most common. A less common type is DVI-A, which is used for analog connectivity (and is not shown in Figure 2.5). Figure 2.6 shows both a DVI cable and a VGA cable.



**FIGURE 2.5** DVI connectors



**FIGURE 2.6** DVI and VGA cables

### TECH TIP

#### Match a monitor to the port type

Be careful when installing a monitor. For example, ensure that the video port matches the DVI connection type for the monitor. Converters can be purchased to adapt a monitor to a different type of port.

## DisplayPort

The **DisplayPort** developed by VESA (Video Electronics Standards Association) can send and receive video, audio, or both types of signals simultaneously to monitors, televisions, and home theaters. Figure 2.7 shows the DisplayPort and a cable that would connect to this port.



**FIGURE 2.7** DisplayPort

## HDMI

Another upgrade over DVI is High-Definition Multimedia Interface (**HDMI**), a digital interface that can carry audio and video over the same cable. HDMI ports are found on cable TV boxes, televisions, video adapters, laptops, desktops, and tablets. Smaller miniHDMI or microHDMI connectors are used with devices such as cameras, tablets, and smartphones. Figure 2.8 shows an HDMI port and cable. Table 2.1 describes the different HDMI ports.



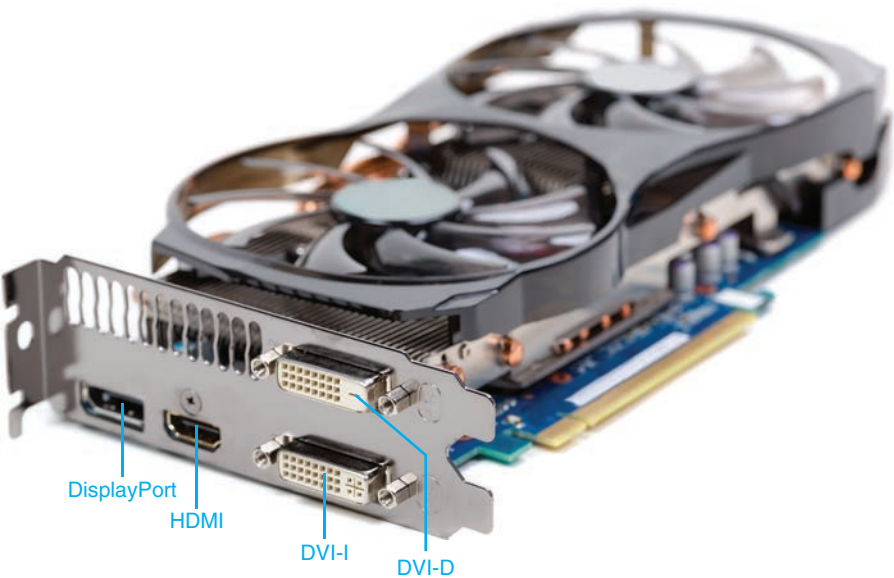
**FIGURE 2.8** HDMI port and cable

**TABLE 2.1** HDMI ports

HDMI connector type	Description
A	19-pin port found on a TV or PC that can have a Category 1 (standard) or Category 2 (high-speed) cable attached
B	29-pin port used with very high-resolution displays
C	19-pin miniHDMI port found on mobile devices
D	19-pin microHDMI port found on mobile devices

Figure 2.9 shows a video card that would be used in a gaming computer. On top is a dual link DVI-D port. On the bottom, from left to right, are a DisplayPort, an HDMI port, and a dual link DVI-I port. Table 2.2 summarizes important PC video ports. Note that Thunderbolt, Lightning, and

USB cables can also carry video signals; these ports and cables are covered in the “Multipurpose Ports” section, later in this chapter.



**FIGURE 2.9** Video ports, including a DisplayPort, an HDMI port, and two DVI ports

**TABLE 2.2** Video port summary

Port type	Analog, digital, or both	Max transfer speed	Carries audio?	Maximum cable lengths
VGA	Analog	N/A	No	Depends on resolution
DVI-D	Digital	Dual link 7.92 Gb/s	No	Up to 15 feet (4.57 m) for display resolutions up to 1920×1200
DVI-I	Both	Single or dual link	No	Not in the standards, but a general rule of thumb is up to 15 feet (4.57 m) for display resolutions up to 1920×1200
DisplayPort	Digital	80 Gb/s	Yes	9.8 feet (3 m) for passive and 108 feet (32.9 m) for active
HDMI	Digital	48 Gb/s	Yes	Not in the standards, but a general rule of thumb is up to 16 feet (4.88 m) for standard cable and up to 49 feet (14.9 m) for high-speed, good-quality cable and connectors

Video Adapters and Converters

Converters can be purchased for video ports to convert from one of the major types to another type. For example, Figure 2.10 shows a **DVI-to-HDMI adapter** (with both ends visible).



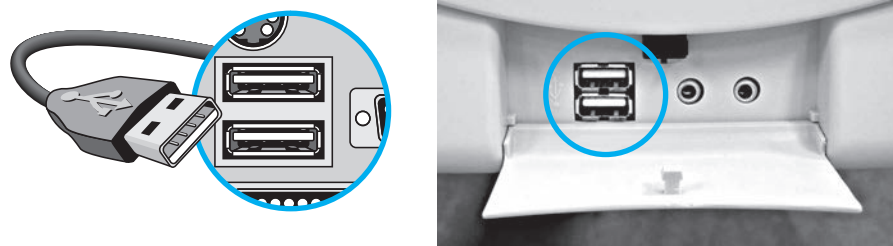
**FIGURE 2.10** DVI-to-HDMI adapter

## Multipurpose Ports

Some ports/cables can be used for multiple devices, including USB 2.0, USB 3.x, USB 4, USB-C, Thunderbolt, and Lightning. The USB port is probably the one people are most familiar with, but the Thunderbolt and Lightning ports are also considered multipurpose ports. Let's explore these ports.

## USB Ports

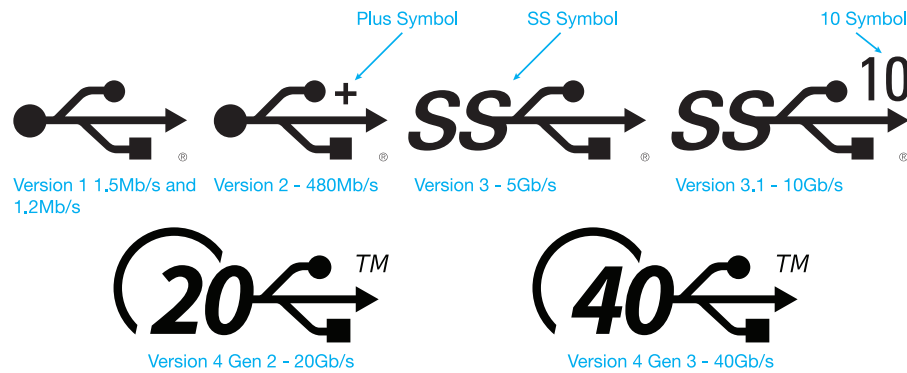
**USB** stands for Universal Serial Bus and is one of the most popular ports. A USB port allows up to 127 connected devices to transmit at speeds up to 10 Gb/s (10 billion bits per second), 20 Gb/s, or even 40 Gb/s. Devices that connect to a USB port include printers, scanners, mice, keyboards, joysticks, optical drives, game pads, cameras, modems, speakers, telephones, video phones, data gloves, and digitizers. Additional ports can sometimes be found on the front of a PC case or on the side of a mobile device. Figure 2.11 shows some USB ports.



**FIGURE 2.11** USB ports

## USB Versions

USB ports come in several versions: USB 1.0/1.1, **USB 2.0** (Hi-Speed), **USB 3.0** (3.2 Gen 1 SuperSpeed and 3.2 Gen 2 SuperSpeed+), and 4.x. Figure 2.12 shows the different USB versions and speed symbols.



**FIGURE 2.12** USB versions, speeds, and symbols

### TECH TIP

#### Documentation can be key to USB speed

A port does not have to be labeled, and sometimes looking at the technical specifications for a computer or motherboard is the only way to determine the port speed.

## USB Power Delivery (USB-PD)

USB ports have been able to provide 5V at 500mA for 2.5 watts of power to devices since version 2.0. The newest USB standard, Power Delivery (**PD** or **USB-PD**), can provide up to 20V at 5A for 100 watts of power. The standard actually has five levels of power delivery: 10W, 18W, 36W, 60W, and 100W. All USB4 connections allow charging a USB device.

## USB Cables

Each USB standard has a maximum cable length (shown in Table 2.3, later in the chapter). USB cables can be longer than these specifications, but longer cables may not work well. You can use an active USB extension cable (repeater cable) or a powered USB hub, covered later in the chapter, to go further distances.

If a USB port provides power to a device, then the maximum cable length shortens. For example, if a USB 2.0 PD device is being used, the maximum cable length is less than 13 feet (4 m). If a USB 3.1 PD device is used with a USB Type-C cable, then the cable length should be less than 3.3 feet (1 m). A PD device requires a Type-C cable, but not all ports or cables support PD.

## USB Connectors

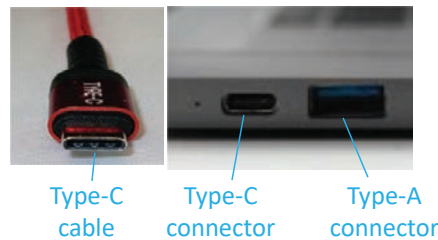
Older USB ports are commonly known as **USB Type-A** and **USB Type-B**. A USB printer cable, for example, has a Type-A male connector on one end and a Type-B male connector on the other end. The port on the computer is a Type-A port. Figure 2.13 shows Type-A and Type-B connectors.



**FIGURE 2.13** USB Type-B and Type-A connectors



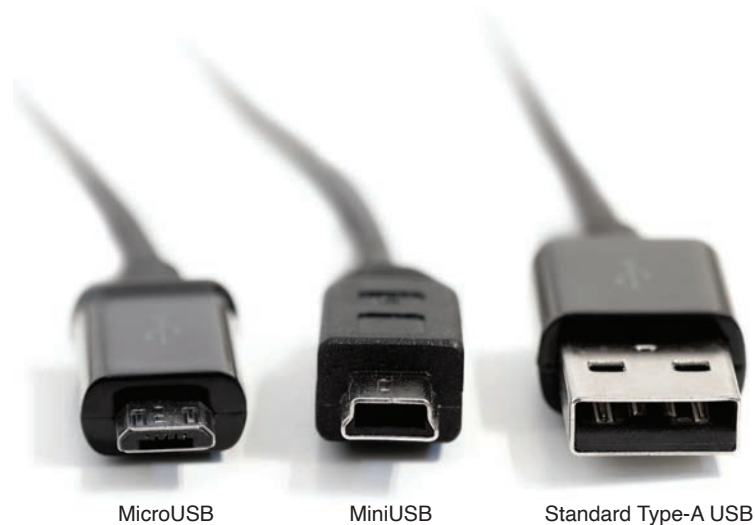
The **USB Type-C** (sometimes called **USB-C**) connector is the latest type and will eventually replace the Type-A and Type-B connectors. With older devices, it is possible to use an adapter in order to attach to a Type-C connector. Many USB 3.0 ports are Type-C connectors, but they do not have to be as USB 3.1 and higher ports require a Type-C cable. Figure 2.14 shows a USB Type-C connector and cable alongside a Type-A port. Notice in the photo of a USB Type-C connector in Figure 2.14 that the cable could be inserted into the USB-C port with either side facing up.



**FIGURE 2.14** USB Type-C cable and connector and Type-A port

### MiniUSB and MicroUSB

Two smaller USB ports used on portable devices such as hubs, external hard drives, digital cameras, and smartphones are the **miniUSB** and **microUSB** ports. There are several types of these smaller USB ports: mini-A, mini-AB, micro-B, and micro-AB. The mini-AB and micro-AB ports accept either a mini-A/micro-A or a mini-B/micro-B cable end. Figure 2-15 shows the standard Type-A USB cable that would be inserted into a PC port compared to the miniUSB and microUSB cables used with mobile devices. Figure 2.16 shows a USB 3.0 micro-B port and connector.



**FIGURE 2.15** MicroUSB, miniUSB, and USB Type-A cables

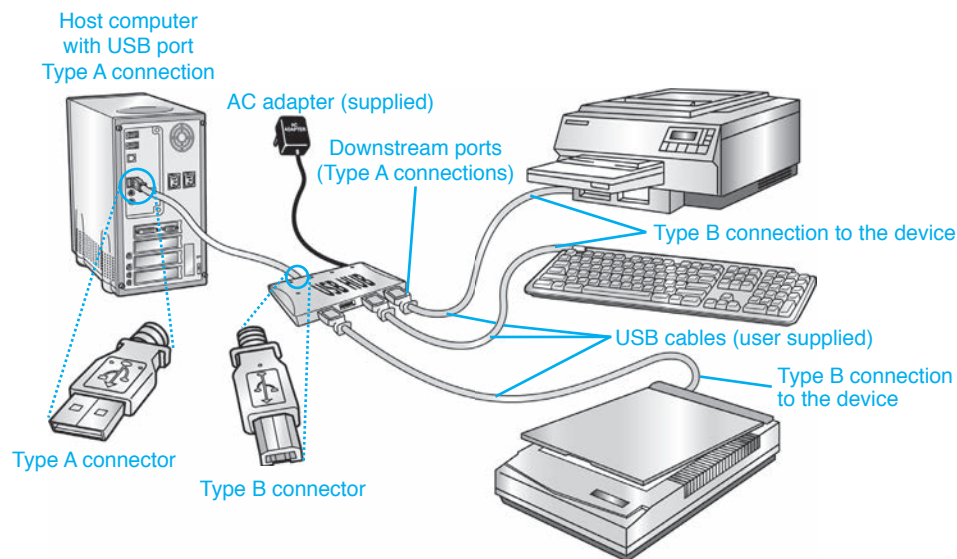




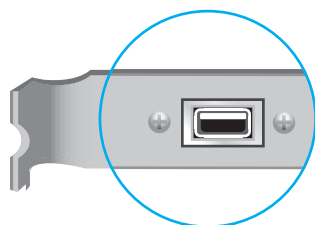
**FIGURE 2.16** USB 3.0 micro-B port and connector

## USB Hubs

A USB port can have more than one device attached to the port through the use of a USB hub. Many hubs can operate in two power modes—self-powered and bus powered. A powered hub (sometimes called a self-powered hub) has an external power supply attached. A bus-powered hub has no external power supply. Once USB devices attached to a hub are tested, the hub's power supply can be removed, and the devices can be retested. If all attached devices work properly, the power supply can be left disconnected. Figure 2.17 shows USB hub connectivity, and Figure 2.18 shows USB cabling rules.



**FIGURE 2.17** USB hub connectivity



### USB cabling rules

- 5 hubs maximum (total max range of 88.5 feet or 27 meters)
- 127 devices maximum connected to up to 5 hubs
- Maximum distance between 2 USB hubs
  - high-speed devices – 16.4 feet or 5 meters
  - low-speed devices – 9.8 feet or 3 meters

**FIGURE 2.18** USB cabling rules

USB ports have always been able to provide power to unpowered devices, such as flash drives. A **charging USB port** is a port designed to be able to provide power and charge attached devices. Note that not all USB devices can be powered on while charging. With a **sleep-and-charge USB port**, the port provides power to charge the device even when the computer is powered off. See the computing device's specifications to see if a USB port supports this feature. Table 2.3 summarizes USB types, alternate names, speeds, port colors, and cable requirements.

**TECH TIP****Safely removing USB devices**

To remove a USB device, do not simply unplug it from the port. Instead, click on the *Safely Remove Hardware* icon (Windows 7) or *Safely Remove Hardware and Eject Media* (Windows 8/10/11) from the notification area and then select the USB device to remove. On a Mac, right-click the desktop icon for the device and select *Eject x* (where *x* is the device name) or drag the desktop icon to the trash can. In Ubuntu Linux, locate the device in Files or File Explorer. Click the small eject icon. The operating system prompts when it is safe to unplug the device.

**TABLE 2.3** USB port summary

Port type and alternate name	Maximum transmission speed	Port color	Cable type/length and alternate name
USB 1.x	1.5 Mb/s and 12 Mb/s	Usually white	9.8 feet (3m) Type-A 1.0 low speed 1.1 full speed
USB 2.0	480 Mb/s	Black	9.8 feet (3m) Type-A Hi-Speed
USB 3.0	5 Gb/s	Blue	9.8 feet (3m) Type-A or Type-C SuperSpeed
USB 3.1 Gen 1	5 Gb/s	Blue	9.8 feet (3m) Type-A or Type-C SuperSpeed
USB 3.1 Gen 2	10 Gb/s	Teal	9.8 feet (3m) Type-C SuperSpeed+
USB 3.2 Gen 1 (3.2 Gen 1x1 1 lane) (3.2 Gen 1x2 2 lanes)	5 Gb/s and 10 Gb/s	Red	9.8 feet (3m) Type-C SuperSpeed USB 5Gbps SuperSpeed USB 10Gbps
USB 3.2 Gen 2 (3.2 Gen 2x1 1 lane) (3.2 Gen 2x2 2 lanes)	10 Gb/s and 20 Gb/s	Red	9.8 feet (3m) Type-C SuperSpeed USB 10Gbps SuperSpeed USB 20Gbps
USB4 Gen 2 (2 lanes)	20 Gb/s	N/A	9.8 feet (3m) Type-C
USB4 Gen 3 (2 lanes)	40 Gb/s	N/A	9.8 feet (3m) Type-C
USB sleep-and-charge	N/A	Yellow, orange, or red	N/A

**USB Converters**

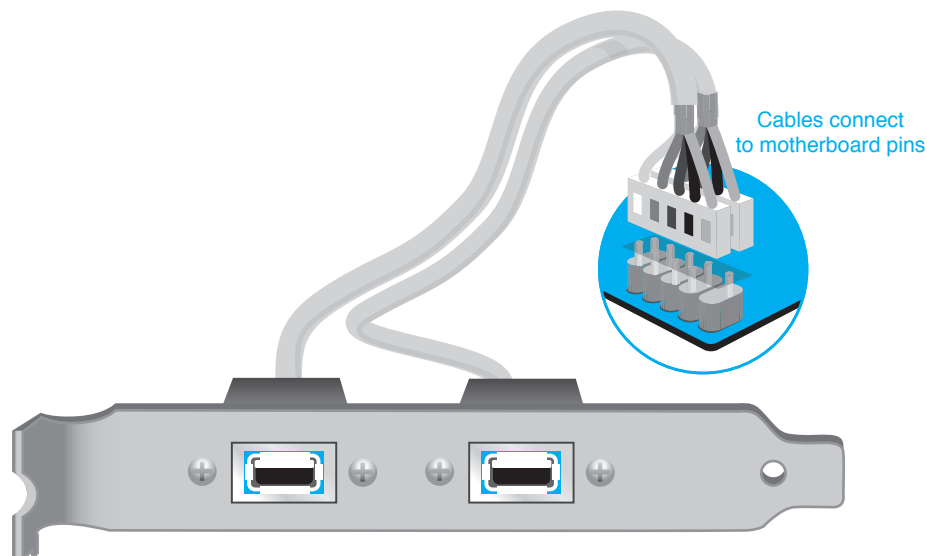
Converters are available to convert a USB port to a different type of connector (or vice versa), such as the **USB-to-Ethernet converter** used to connect a device, such as a tablet that has a USB port, to a wired Ethernet network (see Figure 2.19).



**FIGURE 2.19** USB-to-Ethernet converter

## Installing Extra USB Ports

Sometimes people want more USB ports and do not want to add another hub. Many motherboards support adding two or more USB ports by using a cable that attaches to an internal USB connector on the motherboard, also known as a USB header. The term **header** simply means a set of motherboard pins for a specific purpose, like USB 2.0, USB 3.0, USB Type-C, SATA, eSATA, RGB LEDs (lights), and TPM (Trusted Platform Module). The ports mount in an expansion slot space, but they do not have a card that plugs into an expansion slot. Even if a motherboard has such pins, the ports and cable assembly might have to be purchased separately. Figure 2.20 shows sample USB ports that attach to a motherboard.



**FIGURE 2.20** Installing extra USB ports

## Thunderbolt

A **Thunderbolt port** is a type of port that is used primarily for video, uses some of the DisplayPort video port technology, and can carry power, audio, video, and data to external storage devices. The Thunderbolt interface was developed by Intel with support from Apple. The Thunderbolt port used on Apple computers is the same connector as the miniDisplayPort; however, Thunderbolt 3 uses the USB Type-C connector, discussed earlier in this chapter, in the “USB Connectors” section. Thunderbolt 3 is the first Thunderbolt version to support USB.

A Thunderbolt cable can have data speeds up to 80 Gb/s. Thunderbolt allows daisy-chaining up to six devices. Figure 2.21 shows a Thunderbolt port and cable. Look back at Figure 2.14 to see the Type-C connector and cable that Thunderbolt 3 and 4 use.



**FIGURE 2.21** Thunderbolt cable and port

### TECH TIP

#### Can a Thunderbolt 3 or 4 device work in a USB-C port?

Even if a Thunderbolt 3 or 4 device can attach to a USB-C port, it may not work. If the device does work, it will work at USB-C speed. However, USB-C devices can function and connect to a Thunderbolt 3 or 4 port.

## Lightning

The last multipurpose port to cover is the **Lightning port** and associated cable. The Lightning port, developed by Apple, is an 8-pin port that accepts the cable with either side facing up (that is, it is reversible). The Lightning port can carry data and power from mobile devices to other devices, such as cameras, external monitors, and external storage devices. An adapter/converter can be used to allow the cable to be used with the older Apple 30-pin connector, USB, HDMI, VGA, or SD cards. The Lightning port supports USB data and USB charging, but the Lightning port or cable is not interchangeable with USB-C. Note that some MacBook computers have USB-C, not Lightning, connectors. Figure 2.22 shows a Lightning cable. Table 2.4 shows a comparison of the three multipurpose ports.



**FIGURE 2.22** Lightning cable

**TABLE 2.4** Multipurpose port comparison

Port type	Maximum transmission speed	Type of connector	Platforms	What it carries
USB4 Gen 3	40 Gb/s	USB Type-C 24-pin reversible connector	Found on Apple and PCs	Data and power
Thunderbolt 4	80 Gb/s	USB Type-C 24-pin reversible connector	Intel and Apple developed	Data and power
Lightning	Speeds up to USB 3.0, but normally 480 Mb/s	8-pin reversible connector	Apple-proprietary	Data and power

## Audio Ports

A **sound card** (sometimes called an audio card) converts digital computer signals to sound and sound to digital computer signals (see Figure 2.3). Sound ports are commonly integrated into the motherboard, but some people want better sound, and so they add a card. The most common sound ports include a port for a microphone and one or more ports for speakers. The ports can accept analog or digital signals.

The traditional analog sound ports are 3.5 mm (see Figure 2.23). The newer Sony/Phillips Digital interface (**S/PDIF**) in/out ports, on the left in Figure 2.23, are used to connect to various devices, such as digital audio tape players/recorders, DVD players/recorders, and external disc players/recorders. There are two main types of S/PDIF connectors: an **RCA** jack (last port on the left) used to connect a coaxial cable and a fiber-optic port for a **TOSLINK** cable connection (two optical ports beside the RCA/Digital Out jack in Figure 2.23). Sound cards are popular because people want better sound quality than what is available with the ports integrated into a motherboard.

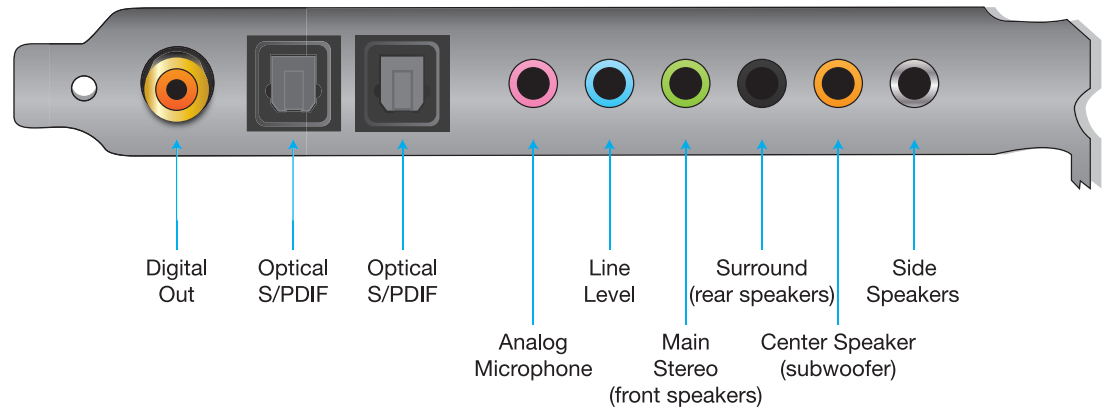


FIGURE 2.23 Sound card ports

## eSATA Ports

SATA connections are commonly used for internal and external storage devices. A 7-pin non-powered external serial AT attachment, or **eSATA**, port is used for connecting external storage. Desktop computers commonly have an SATA header so that an eSATA port can be easily added. eSATA can transfer data at 6 Gb/s. Devices can connect at a maximum of approximately 6.6 feet (2 m). If the internal SATA drive has crashed, an external drive connected to an eSATA or USB port can be used to boot and troubleshoot the system.

A variation of the eSATA port is the **eSATAp port**, which is also known as eSATA/USB, or power over eSATA. This variation can accept eSATA or USB cables and provides power when necessary. Figure 2.24 shows a standard **eSATA cable**, an eSATA port, and an eSATAp (eSATA/USB combination) port.

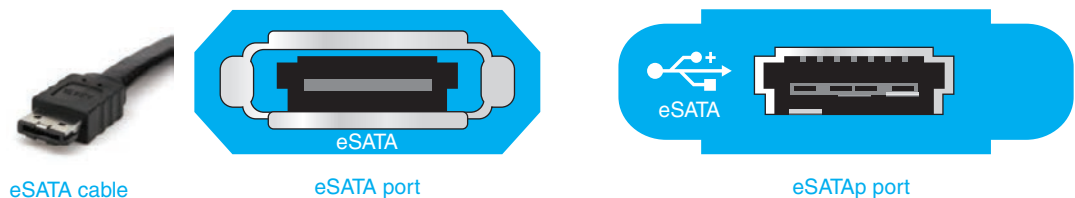


FIGURE 2.24 eSATA cable and eSATA/eSATAp ports

## Modem and Serial Ports

A modulator/demodulator, or **modem**, connects a digital computer to a different type of network, such as a phone line or an internet connection. An internal modem used to connect a computer to a phone network is an adapter that has one or two **RJ11** phone jack ports. The RJ11 port labeled *Line* is for the connection to the wall jack; the one labeled *Phone* is for a phone connection, if needed. Figure 2.25 shows an internal modem with two RJ11 ports.

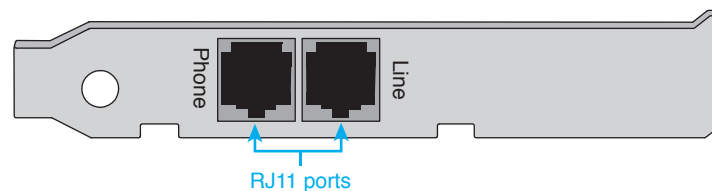


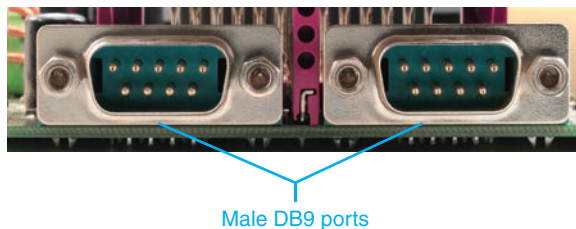
FIGURE 2.25 An internal modem with two RJ11 ports

The same type of RJ11 port with four conductors is used with a cable modem used to connect a home network to the internet, and the RJ11 port is used to connect a phone. Figure 2.26 shows this port labeled as Phone Lines 1&2.



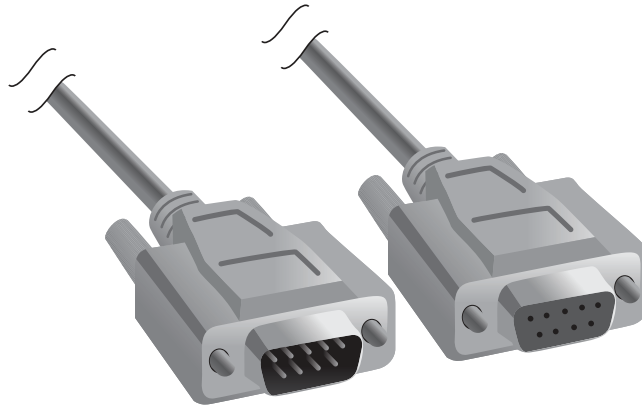
**FIGURE 2.26** Cable modem with RJ11 port

Serial ports are found on older modems and motherboards, network equipment, alarm systems, automation systems, communication systems, and single-board systems like the Raspberry Pi and ASUS Tinker Board. Serial ports are 9-pin male (that is, they have pins instead of holes) and are sometimes called **DB9** or RS-232 ports. Figure 2.27 shows the DB9 serial ports on an older computer. Figure 2.28 shows an example of a **serial cable**. The DB9 female connector would attach to the DB9 male connector on a device or motherboard. Figure 2.29 shows a USB-to-serial converter cable you might need to connect an external modem to a modern motherboard.



**FIGURE 2.27** DB9 serial ports





**FIGURE 2.28** Serial cable ends



**FIGURE 2.29** USB-to-serial port converter

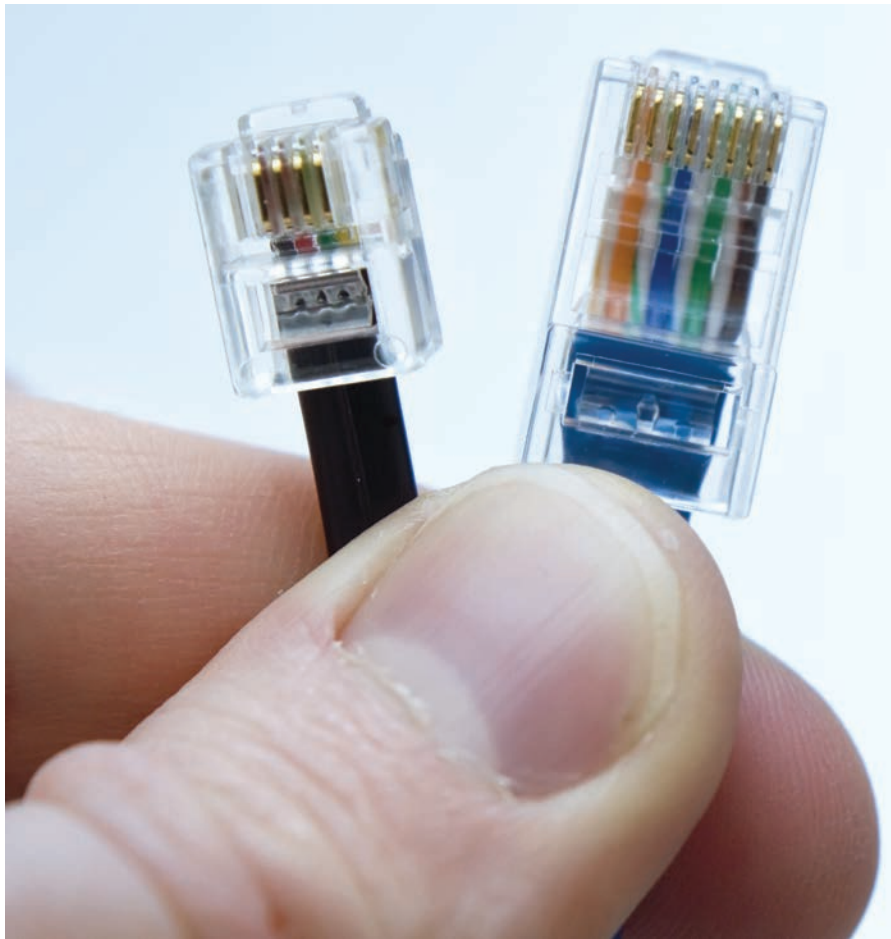
## Network Ports

A **network port** is used to connect a device such as a computer or printer to a network. The most common type of network port is an **Ethernet port**, also known as an **RJ45** port. A network cable inserts into an Ethernet port to connect a computing device to a wired network. A network port is sometimes called a **NIC** (network interface card or controller). Notice the 8 conductors (wires) in the RJ45 Ethernet port shown in Figure 2.30.



**FIGURE 2.30** An RJ45 Ethernet port

An RJ45 port looks very similar to an RJ11 phone jack (see Figures 2.25 and 2.26). However, the RJ45 connector has 8 conductors (wires) instead of 4. Look closely at the connectors in Figure 2.31 to see the difference. The RJ11 connector is on the left.



**FIGURE 2.31** RJ11 and RJ45 connectors

### TECH TIP

#### Ethernet port symbols

An Ethernet port commonly has LEDs on top or near the port to indicate data activity. This port may also have one of the following symbols:

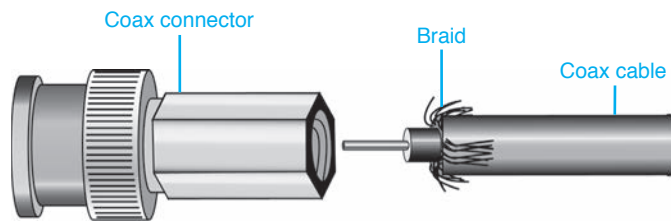


## Network Cabling

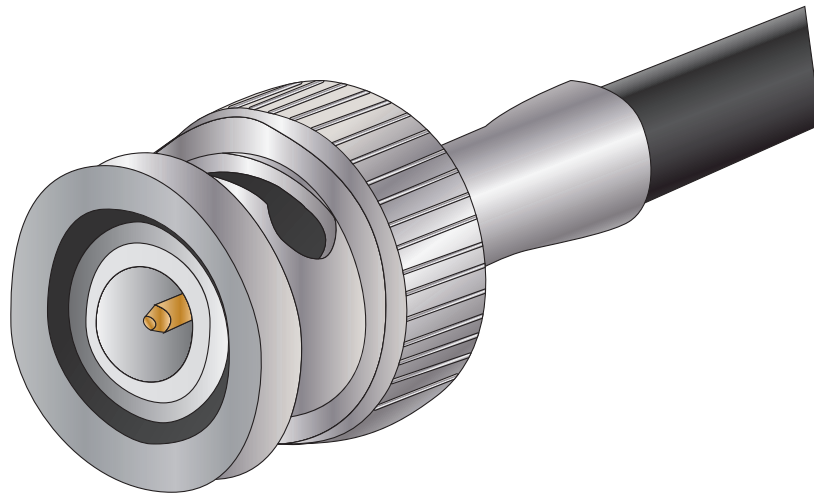
People who work in IT have all types of devices—including PCs, printers, servers, projectors, and displays—that connect to the network. This is a good time to make sure you know what type of cable might be used. We will start with **copper cabling**, which sends electrical pulses to create the digital 1s and 0s, and then look at fiber-optic cabling that uses light instead.

## Coaxial

A type of connector you might see associated with video, but more likely with cable TV or when attaching a wireless network antenna to a connector, is a Bayonet Neill–Concelman (BNC) connector. A **BNC connector** is used with a **coaxial** cable that is found in video networks such as a school where multiple TVs connect to the same distribution center or in a home that obtains TV channels through a cable provider. A BNC connector has a center conductor that pushes onto the receptacle and is surrounded by insulation. Outside the insulation is a shield of copper braid, a metallic foil, or both, to protect the center conductor from outside noises called electromagnetic interference (EMI), as shown in Figure 2.32. Figure 2.33 shows the front of a BNC connector already attached to the coax cable.

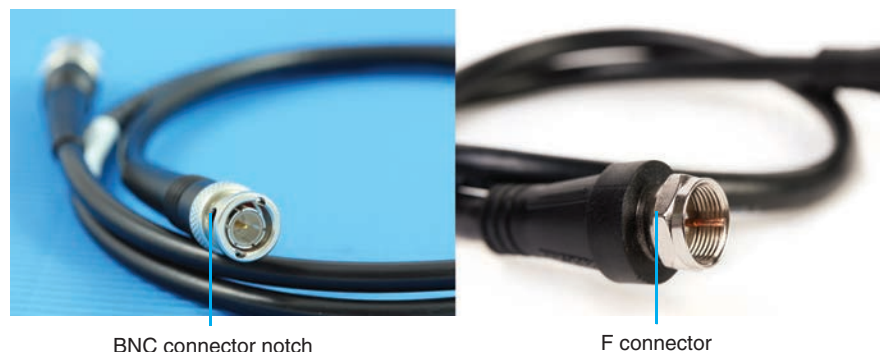


**FIGURE 2.32** Coaxial cable with a BNC connector



**FIGURE 2.33** BNC connector

Figure 2.34 shows two popular coax connectors: BNC and F. Notice that the BNC connector has a notched side to turn and twist onto the receiving connector. The **F type** connector simply screws onto the receiving connector. Table 2.5 lists types of coax cables.



**FIGURE 2.34** Coaxial BNC and F connectors

TABLE 2.5 Coax cable types

Coax cable type	Description
RG-6*	This is the type of cable least likely to be used in a network. It is a 75-ohm cable suitable for distributing signals for cable TV, satellite dishes, or rooftop antennas. It has better shielding than RG-59, so it is larger in diameter. Typical distances are 1000 feet (305 m) to 1500 feet (457 m). It can carry frequencies up to 2200 MHz.
RG-59	This type of 75-ohm cable is not used in LANs but is used in video installations. Typical distances are 750 feet (225 m) to 1000 feet (305 m). It can carry frequencies up to 1000 MHz.

\*RG stands for radio grade.

If a coaxial cable of different impedance attaches to another coaxial cable, signal loss results. Coaxial cable is rated according to whether it will be used in an interior or exterior space. Use the appropriate cable type for the installation. Be careful when bending the cable. When there is a problem and the right type of cable and connector are used, the most common issue is that the coax connector is not attached properly.

### Ethernet Cable

Ethernet is the most common type of wired network seen in homes and in companies. An Ethernet cable attaches to an RJ45 Ethernet port. The most common type of network cable is **unshielded twisted pair (UTP)**. UTP comes in several types: **Cat 5**, **Cat 5e**, **Cat 6**, and **Cat 6a**. Cat 7 and Cat 8 are also available. The *Cat* in these cable names is short for *category*.

UTP cable has 8 wires that are twisted to prevent data that is traveling along one wire from interfering with an adjacent wire; this type of interference is called *crosstalk*. Figure 2.35 shows a Cat 6 cable and a Cat 5e cable. Notice that the Cat 6 cable is thinner. Table 2.6 shows a comparison of the cable types. Cat 6a has more cable twists to reduce crosstalk. Cat 6a cabling might also have a thicker conductor and jacket.

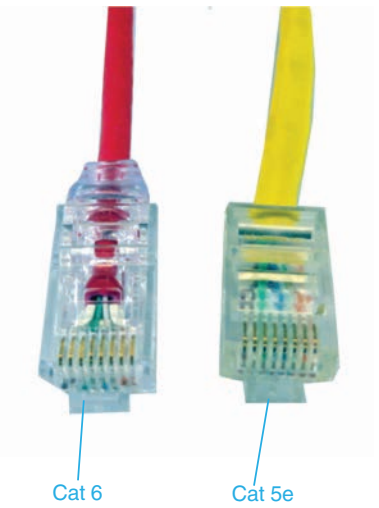


FIGURE 2.35 Cat 6 and Cat 5e cables

**TABLE 2.6** Ethernet cable comparison

Ethernet cable type	Maximum transmission speed	Bandwidth	Distance limitation
Cat 5	100 Mb/s	100 MHz	328 feet (100 m)
Cat 5e	1000 Mb/s, or 1 Gb/s	100 MHz	328 feet (100 m)
Cat 6	1000 Mb/s, or 1 Gb/s*	250 MHz	328 feet (100 m)
Cat 6a	10,000 Mb/s, or 10 Gb/s	500 MHz	328 feet (100 m)
Cat 7	10,000 Mb/s, or 10 Gb/s	600 MHz	328 feet (100 m)
Cat 8	25,000/40,000 Mb/s or 25/40 Gb/s	2000 MHz	328 feet (100 m)

\*Cat 6 can support speeds of 10 Gb/s at lengths up to 165 feet (55 m).

The alternative to UTP is **shield twisted pair (STP)** cable, which is used in manufacturing, with security alarm systems, for audio connections, between buildings, and in harsh environments where the cabling needs a little more shielding to keep the data intact. The shielding is provided by a foil wrapped around all the cables as well as around each grouping of two cables, which makes STP cabling thicker than UTP. Cat 7 and Cat 8 cabling use this type.

STP is also used with direct burial and underground cable in an outdoor environment. **Direct burial cable** is designed to be used underground without any extra protection provided (like tubing, piping, or extra covering) because this type of cabling has extra insulation, cover, and waterproofing added. UTP direct burial cable is also available and designed to protect against moisture.

Both UTP and STP use the RJ45 connector, which has a tang on one side. To remove a cable from an Ethernet port, press on the tang to release the cable from the port. When inserting the cable, ensure that the cable is oriented properly and then push the cable firmly into the port until you hear a click of the tang fitting snugly into the port. Figure 2.36 shows the top and bottom of an Ethernet cable connector.

**FIGURE 2.36** Ethernet RJ45 connector with tang

Ethernet cabling in a corporate environment makes use of a patch panel to get cabling from one part of a building to the next. On the back of a patch panel is a **punchdown block** that is also found in traditional phone networks. Figure 2.37 shows a technician using a **punchdown tool** to firmly attach a wire into a punchdown block.



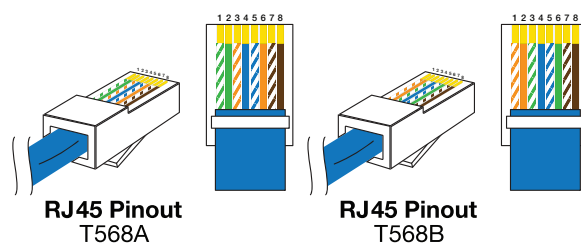


**FIGURE 2.37** Connecting a wire on a punchdown block using a punchdown tool

A special type of UTP or STP cable is **plenum cable**. A plenum is a building's air circulation space for heating and air conditioning systems. Plenum cable is treated with Teflon or alternative fire-retardant materials to reduce the fire risk. Plenum cable produces less smoke and is less toxic when it burns than regular networking cable.

An alternative to plenum cable is polyvinyl chloride (**PVC**) cable, which has a plastic cable insulation or jacket. PVC is cheaper than plenum cable, and it can have flame-retardant chemicals added to make it compliant with building codes. PVC is usually easier to install than plenum cable.

To avoid extra troubleshooting time, most businesses install their network cable according to the ANSI/TIA/EIA-568-A or 568-B (commonly shown as **T568A** and **T568B** or **568A/B**) standard. These standards specify how far the cable can extend, how to label it, what type of connectors to use, and so forth. Figure 2.38 shows that the colored wires within a connector must be in a particular order. Chapter 13, "Networking," shows how to make cables according to the T568A and T568B standards.



**FIGURE 2.38** ANSI/TIA/EIA T568A and T568AB wiring standards

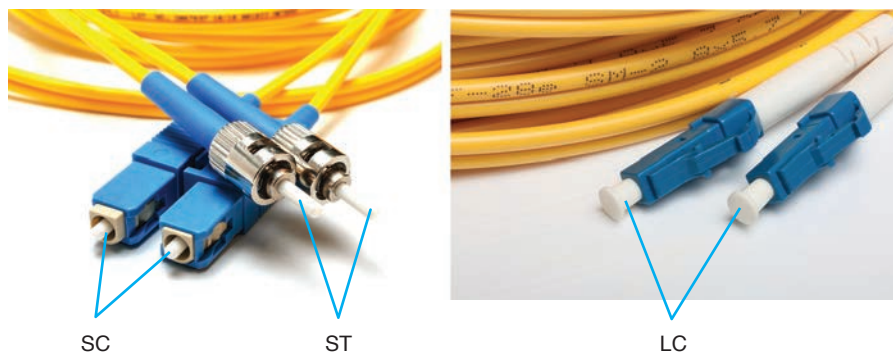
## Fiber Media

**Fiber cable**, also known as **optical cable** or fiber-optic cable, is made of glass or a type of plastic fiber and is used to carry light pulses. Fiber cable can be used to connect a workstation to another device, but in industry, the most common uses of fiber-optic cable are to connect networks forming the network backbone, networks between buildings, service provider high-speed networks, and homes to a service provider. Figure 2.39 shows fiber switch connections. Notice that the fibers are grouped in pairs.



**FIGURE 2.39** Fiber connections

There are many different types of fiber connectors, and some of them are proprietary. Four of the most common connectors used with fiber-optic cable are Mechanical Transfer Registered Jack, or MT-RJ (common in home installations), **straight tip (ST) connector**, **subscriber connector (SC)**, and **Lucent connector (LC)**. Figure 2.40 shows three of these connectors.



**FIGURE 2.40** Fiber-optic connector types

The two major classifications of fiber are single-mode and multi-mode. **Single-mode fiber** cable has only one light beam sent down the cable. **Multi-mode fiber** allows multiple light signals to be sent along the same cable. Table 2.7 describes the characteristics of the two types. (Note that fiber's maximum speeds keep increasing as technology keeps changing.)

**TABLE 2.7** Fiber cable speed and transmission characteristics

Type	Characteristic
Single-mode	Classified by the size of the fiber core and the cladding. Common sizes include 8/125 to 10/125 microns, where the first number represents the size of the core, and the second number is the size of the cladding. Single-mode cable allows for distances more than 50 miles (80 km) at speeds more than 100 Gb/s.
Multi-mode	Sizes include 50/125 and 62.5/125 microns. Can support distances more than 1 mile (2 km) and speeds up to 10 Gb/s. ST connectors are used more with multi-mode fiber than with single-mode.

### TECH TIP

#### Choosing the correct fiber type

Multi-mode fiber is cheaper and more commonly used than single-mode fiber and is good for shorter-distance applications; however, single-mode fiber can transmit a signal farther than multi-mode and supports the highest bandwidth.








## Integrated Motherboard Ports

An integrated motherboard provides expandability because ports are built in and do not require separate adapters. If a motherboard includes USB, network, sound, keyboard, mouse, and video ports, there is more space available for other adapters. The number of available expansion slots in a system depends on the motherboard manufacturer. Figure 2.41 shows integrated motherboard ports including ports to attach two Wi-Fi 6 wireless antennas.



**FIGURE 2.41** Integrated motherboard ports

Ports built into a motherboard are faster than those on an expansion board. All adapters in expansion slots run more slowly than the motherboard components. Computers with integrated motherboards are easier to set up because you do not have to install an adapter or configure the ports. Normally, systems with integrated motherboards are easier to troubleshoot because the components are on one board. The drawback is that when one port goes bad, you have to add an adapter that has the same type of port as the one that went bad. Furthermore, ports found on an adapter might be of higher quality or might have more capabilities than an integrated port. See Figure 2.42.

Integrated port	Advantages to ports on an adapter
<div> VGA</div> <div> DVI</div> <div> HDMI</div>	<ul style="list-style-type: none"><li>• RAM that is not shared with motherboard RAM</li><li>• Video GPU</li><li>• Supports higher resolutions</li><li>• Support for dual monitors</li></ul>
<div> Sound</div>	<ul style="list-style-type: none"><li>• Higher quality sound</li><li>• Sound features such as surround sound and 3D sound</li><li>• More input/output ports</li></ul>
<div> NIC</div>	<ul style="list-style-type: none"><li>• Faster connection</li><li>• Could have fiber instead of copper</li></ul>

**FIGURE 2.42** Advantages of adapters

## Getting to Know Ports

Being able to identify ports quickly and accurately is a critical skill in computer repair. Table 2.8 lists the most common computer ports.

**TABLE 2.8** Common ports

Port	Usage	Port color code	Common connector
PS/2 mouse	Mouse	Green	6-pin mini-DIN
PS/2 keyboard	Keyboard	Purple	6-pin mini-DIN
VGA	Video for an analog monitor	Blue	3-row 15-pin female D-shell or mini-VGA port
DVI	Video for a DVI digital or analog monitor	White	3-row 18- or 24-pin female DVI, mini-DVI, or micro-DVI
DVI-D	Video for a DVI digital monitor	White	3-row 18- or 24-pin female DVI, mini-DVI, or micro-DVI
DVI-A	Video for a DVI analog monitor	White	3-row 18- or 24-pin female DVI, mini-DVI, or micro-DVI
HDMI	Digital audio and video monitor	N/A	19- or 29-pin HDMI, mini-HDMI, or micro-HDMI
DisplayPort	Digital audio and video monitor	N/A	20-pin DisplayPort or mini-DisplayPort
USB	Multipurpose port for data, video, audio, and power	Black, blue, teal, or red	USB Type-A, Type-B, Type-C, miniUSB, microUSB
Thunderbolt	Multipurpose port that can carry data, video, audio, and power	N/A	20-pin DisplayPort, mini-DisplayPort, or USB Type-C connector
Lightning	Multipurpose port for Apple devices that can carry data and power	N/A	8-pin connector
Audio	Analog audio input	Light pink	1/8 inch (3.5 mm) jack
Audio	Analog line level audio input	Light blue	1/8 inch (3.5 mm) jack
Audio	Analog line level audio output from main stereo signal	Lime green	1/8 inch (3.5 mm) jack
Audio	Analog line level audio for right-to-left speaker	Brown	1/8 inch (3.5 mm) jack
S/PDIF	Audio input/output	Orange	RCA jack (coax) or TOSLINK (fiber)
RJ45	UTP Ethernet network	N/A	8-conductor
RJ11	Internal/external modem or phone	N/A	4-conductor
DB9	RS232 serial port found on older computers and some networking equipment	N/A	9-pin port
eSATA	External storage devices	N/A	7-pin nonpowered port
eSATAp	External devices	N/A	Combination eSATA/USB port

## Wireless Connectivity for Input Devices

Many input devices, such as keyboards, mice, game pads, touchpads, and headphones, have wireless connectivity. Technologies used to connect without a cord include infrared, radio, Bluetooth, and near field communication (NFC). Many computing devices, especially smartphones and other mobile devices, have cordless connectivity integrated into the device; otherwise, a transceiver is connected to a USB port to allow connectivity to the computing device. Figure 2.43 shows a wireless presenter used with a computing device and a projector.



**FIGURE 2.43** Wireless presenter

Table 2.9 summarizes the various wireless technologies used with input and output devices.

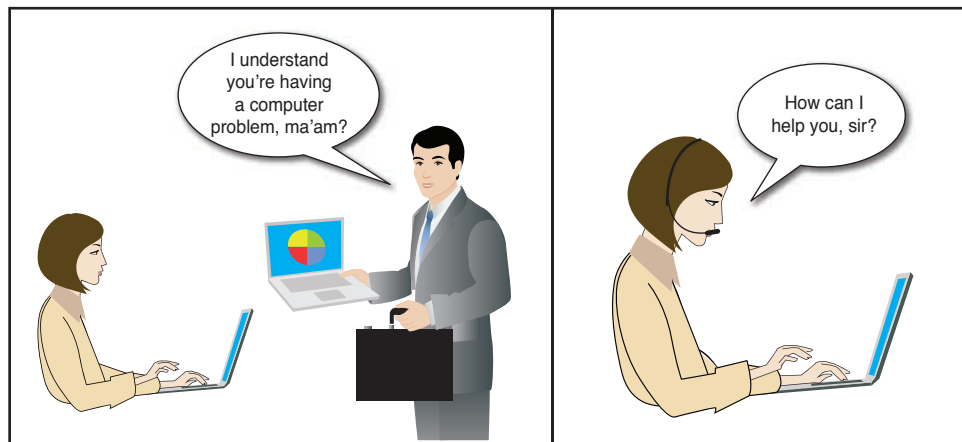
**TABLE 2.9** Wireless input/output technologies

Technology	Description
Infrared ( <b>IR</b> )	Used for very short distances. Cheaper than other technologies.
<b>Radio</b>	Works in the 27 or 900 MHz, or 2.4, 5, or 60 GHz radio frequency ranges. Longer distances are supported than with infrared.
<b>Bluetooth</b>	Includes 128-bit security and works in the 2.4 GHz range. There are four classes of devices, with ranges up to 1.6 feet (0.5 m), 3 feet (1 m), 33 feet (10 m), and 328 feet (100 m). Note that Bluetooth 5 supports a connection between two devices up to 800 feet (242 meters) away. Up to eight devices can be connected with only one device controlling the other devices.
Near field communication ( <b>NFC</b> )	Used to print from a phone or a camera or to transfer data between two smartphones that are positioned very close to one another (less than 6 inches [15.24 cm]). Also used in payment systems. Works in the 13.56 MHz range at transfer speeds up to 424 kb/s.

## SOFT SKILLS: USING APPROPRIATE TITLES

The internet and mobile devices have brought new methods of communication. In today's social media world, communication tends to be more casual, with people using colloquialisms, slang, and other language habits that aren't necessarily professional. In addition, some people regularly use acronyms, such as HAGD, LOL, BTW, NRN, TYVM, and YMMD, to communicate in emails, notes, text messages, and memos.

Many places of business are returning to the basics when it comes to customer service, and these businesses expect you as an IT professional to use professional communication methods. People expect the IT department to use more professional communication skills, and improved soft skills are therefore emphasized during the hiring process. For example, IT personnel are expected to use appropriate titles, such as Dr., Mr., Professor, and Ms. when talking to non-IT personnel, including external vendors. In the work environment, you should use a person's title, sir, or ma'am until the person you are addressing tells you otherwise. Figure 2.44 shows a couple of examples.



**FIGURE 2.44** At work, use appropriate salutations

## Chapter Summary

- > A technician must be able to identify a variety of ports, including mouse and keyboard PS/2, VGA, DVI, HDMI, DisplayPort, Thunderbolt, Lightning, USB, RJ45, RJ11, 3.5 mm sound jack, TOSLINK, RCA, DB9, eSATA, and eSATAp ports.
- > USB is the most popular connection type for adding devices to desktops, laptops, and tablets.
- > USB provides power: 10W, 18W, 36W, 60W, and 100W. All USB4 ports support charging a USB device.
- > Add additional USB ports by connecting a hub that can be self-powered or bus powered. Up to five hubs can be daisy-chained to one port.
- > Connect an internal USB cable from a motherboard connector to a metal plate that mounts in an empty expansion slot for more USB ports.
- > Adapters are available to convert between different types of display ports, such as DVI and VGA or DVI and HDMI.
- > Converters are available for USB ports, such as USB-to-Ethernet if the Ethernet port goes bad on a computer.
- > Audio ports can be analog or digital. S/PDIF ports are digital. There are two types of S/PDIF ports: TOSLINK and fiber.

- > Ethernet ports have RJ45 connectors. RJ11 ports are found on modems and devices used to connect to the internet.
- > DB9 ports can be found on modems, single-board computers, and networking equipment.
- > Ethernet ports commonly have a Cat 5e, 6, or 6a cable attached. Ethernet cables can be unshielded twisted pair or, if additional shielding is needed, shielded twisted pair. Plenum cabling is made of fire-retardant materials. A cheaper type of cable is PVC. Ethernet cables adhere to the T568A or T568B standard.
- > Fiber cabling carries data over longer distances, and coaxial (coax) cabling is used for video networks.
- > Input devices can connect to a computer by using four wireless technologies: IR, radio, Bluetooth, or NFC.
- > When speaking with others, use appropriate professional titles when appropriate.

## A+ CERTIFICATION EXAM TIPS

- ✓ Be able to identify the following connectors: RJ11, RJ45, F type, ST, LC, SC, USB, microUSB, miniUSB, USB-C, DB9, and Lightning. (On 3×5 cards, write the names of ports you have a hard time remembering. Put a picture of the port on one side and the name of the port on the other. Also include the type of connector each type of cable attaches to, such as RJ11 is a connector for a phone cable; RJ45 is a connector for a network cable; BNC is a connector for coaxial cable; and DB9 is used on a serial cable. Practice until you know them all.)
- ✓ Explain where you would see and how you would recognize a punchdown block.
- ✓ Be able to describe the following network cables and describe features of each one: Ethernet (Cat 5, Cat 5e, Cat 6, Cat 6a, plenum, shielded twisted pair, unshielded twisted pair, and the T568A/B standard), fiber, and coaxial. Know that direct burial STP cable is used between buildings without having to have piping or special conduits. (Make a chart of key characteristics for each of these types of cable. Have someone quiz you on them.)
- ✓ Be able to explain the following video cables, features, and their purposes: VGA, HDMI, DisplayPort, and DVI. (Do a web search of images for video ports and see if you can recognize these ports.)
- ✓ Be able to explain the features and purposes of the following cables: serial, Thunderbolt, USB 2.0, and USB 3.0. (Make another chart for each of these cables and characteristics of each.)
- ✓ The following communication and professionalism skills are part of the 220-1102 exam: Be culturally sensitive and use appropriate professional titles when applicable.

## Key Terms

- 568A/B 52
- analog signal 33
- Bluetooth 56
- BNC connector 49
- Cat 5 50
- Cat 5e 50
- Cat 6 50
- Cat 6a 50
- charging USB port 41
- coaxial 49
- copper cabling 48
- DB9 46
- digital signal 33
- direct burial cable 51
- DisplayPort 35
- DVI port 33
- DVI-to-HDMI adapter 36
- DVI-D 34
- DVI-I 34
- eSATA 45
- eSATA cable 45
- eSATAp port 45
- Ethernet port 47
- F type 49
- fiber cable 52
- HDMI 35
- header 42
- IR 56
- keyboard port 32
- Lightning port 43
- Lucent connector (LC) 53
- microUSB 39
- mini-DIN 32
- miniUSB 39
- modem 45
- mouse port 32
- multi-mode fiber 53
- network port 47
- NFC 56
- NIC 47
- optical cable 52
- PD 38
- plenum cable 52
- port 32
- PS/2 port 32
- punchdown block 51
- punchdown tool 51
- PVC 52
- radio 56
- RCA 44
- RJ11 45
- RJ45 port 47
- S/PDIF 44
- S-Video port 33
- serial cable 46
- shielded twisted pair (STP) 51
- single-mode fiber 53
- sleep-and-charge USB port 41
- sound card 44
- straight tip (ST) 53
- subscriber connector (SC) 53
- T568A 52
- T568B 52
- Thunderbolt port 43
- TOSLINK 44
- unshielded twisted pair (UTP) 50
- USB 37
- USB 2.0 37
- USB 3.0 37
- USB-C 39
- USB-PD 38
- USB-to-Ethernet converter 41
- USB Type-A 38
- USB Type-B 38
- USB Type-C 39
- VGA port 33

## Review Questions

1. Match the port to the description.

_____ DVI	a. Ethernet
_____ VGA	b. TOSLINK
_____ Thunderbolt	c. up to 127 devices
_____ USB	d. daisy-chain up to 6 devices
_____ NIC	e. older monitor
_____ S/PDIF	f. digital signals to monitor
2. Which connectors are used with fiber-optic cabling? (Choose all that apply.)  
[ BNC | DVI | ST | Lightning | LC | Thunderbolt | UTP ]
3. What is a visual indication that a port is USB version 3.0?  

---
4. Which port uses an RJ45 connector?  
[ modem | Ethernet | Lightning | S/PDIF ]
5. What feature does an eSATAp port have that makes it different from an eSATA port?  

---
6. When considering VGA, HDMI, DVI, and DisplayPort, which video port can output both digital audio and video signals and is the most technologically advanced?  
[ DisplayPort | DVI | HDMI | VGA ]
7. What is the most common DVI port?  
[ DVI-A | DVI-D | DVI-C | DVI-I ]
8. Which has the faster transfer time, a USB 3.0 or 1000 Mb/s Ethernet port?  
[ USB 3.0 | 1000 Mb/s Ethernet ]
9. What is the maximum cable length for an Ethernet UTP cable?  
[ 100 meters | 150 meters | 200 meters | 1000 meters ]
10. Which color of sound port would be used to attach a speaker?  
[ black | green | pink | white ]
11. List two titles that might be used in the workplace that are not sir or ma'am.  

---
12. You see a port on a computer that you have never seen before. There are no markings. How will you determine the purpose of the port?  

---
13. What type of port uses an RJ11 connector?  
[ Ethernet | internal modem | display | keyboard ]
14. Which port is more likely found on an Apple computer than any other type of PC?  
[ Ethernet | RJ45 | Lightning | USB-C ]
15. On which type of cable would you find an F type connector?  
[ VGA | Thunderbolt | Lightning | coaxial ]
16. On which type of card would a DB9 connector be found?  
[ serial | NIC | video | audio ]



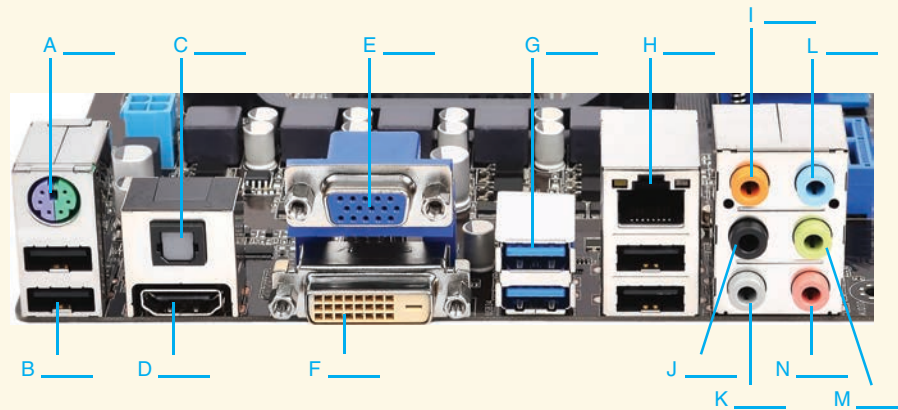
17. Which cable can carry video and audio signals and can be used to connect external storage devices?  
[ Type-A | DVI-I | Thunderbolt | mini-DIN ]
18. In which of the following situations would Bluetooth most likely be used?
  - a. To connect to a corporate wireless network
  - b. To attach a keyboard to a PC
  - c. To connect a PC to a phone line
  - d. To connect a flash drive to a camera
19. List one advantage of having an adapter rather than an integrated motherboard port.  
\_\_\_\_\_
20. What are two commonly used connectors on coaxial cable used in video distribution systems? (Choose two.)  
[ RG-6 | RG-11 | RG-59 | RJ11 | RJ45 ]

## Exercises

### Exercise 2.1 Identifying Computer Ports

**Objective:** To identify various computer ports correctly

**Procedure:** Identify each computer port in Figure 2.45.



**FIGURE 2.45** Identify motherboard ports

- |          |          |
|----------|----------|
| A. _____ | H. _____ |
| B. _____ | I. _____ |
| C. _____ | J. _____ |
| D. _____ | K. _____ |
| E. _____ | L. _____ |
| F. _____ | M. _____ |
| G. _____ | N. _____ |

Exercise 2.2 Identifying More Computer Ports

**Objective:** To identify various computer ports using graphics  
**Procedure:** Identify each computer port in Figure 2.46.

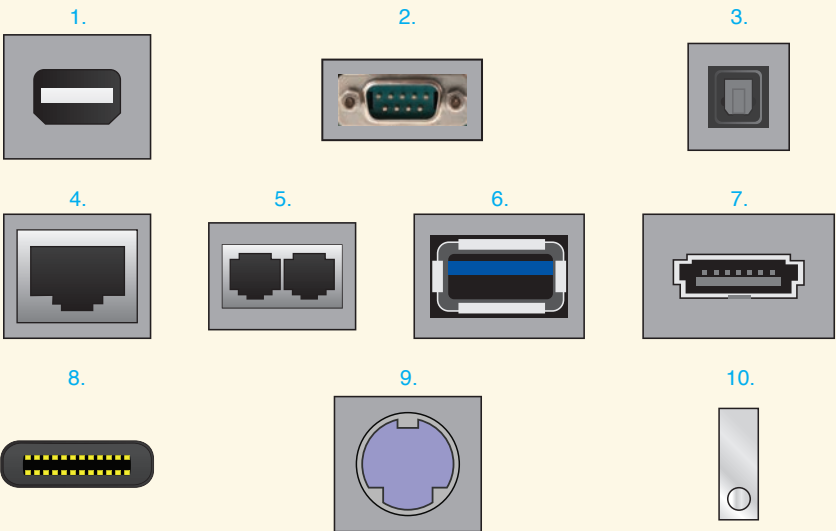


FIGURE 2.46 Identify computer ports

1. _____	6. _____
2. _____	7. _____
3. _____	8. _____
4. _____	9. _____
5. _____	10. _____

Exercise 2.3 Identifying Display Ports

**Objective:** To identify various display ports correctly  
**Procedure:** Identify each display port in Figure 2.47.



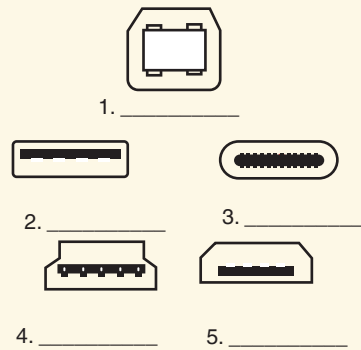
FIGURE 2.47 Identify video ports

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____

## Exercise 2.4 Identifying USB Ports

**Objective:** To identify various USB ports correctly

**Procedure:** Identify each display port in Figure 2.48.



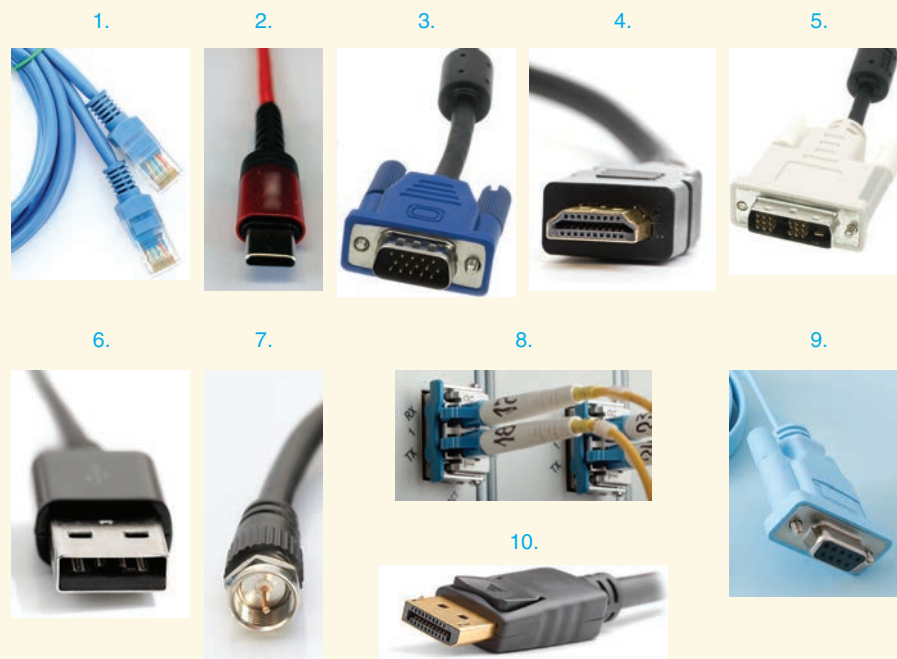
**FIGURE 2.48** Identify USB ports

- |          |          |
|----------|----------|
| 1. _____ | 4. _____ |
| 2. _____ | 5. _____ |
| 3. _____ |          |

## Exercise 2.5 Identifying Cables

**Objective:** To identify various cables

**Procedure:** Identify each cable in Figure 2.49.



**FIGURE 2.49** Identify cables

- |          |           |
|----------|-----------|
| 1. _____ | 6. _____  |
| 2. _____ | 7. _____  |
| 3. _____ | 8. _____  |
| 4. _____ | 9. _____  |
| 5. _____ | 10. _____ |

## Activities



### Internet Discovery

- Objective:** To obtain specific information from the internet regarding a computer or its associated parts
- Parts:** Computer with internet access
- Procedure:** Complete the following procedure and answer the accompanying questions.
- Questions:** For Questions 1–4: Obtain technical information about a particular computer (maybe your own computer or a model number given by the instructor). Answer the following questions based on the information. You may need to obtain more documents, or you may need to select a different computer model to answer questions. Please use only one computer model.
1. Which ports are available on the front of the computer?  

---
  2. Which ports are available on the back of the computer?  

---
  3. How many drive bays are available to install devices such as hard drives, optical drives, tape drives, and so on?  

---
  4. Were the photos in the documentation clear enough to differentiate between the different ports? If not, explain what is wrong.  

---
  5. List 10 acronyms and what they stand for that would be appropriate in a text message to a family member but inappropriate to use when communicating (even texting) with an employee from a non-IT department who is not a close friend but a professional acquaintance. Also, provide the URL(s) where this information is found.  

---
  6. Using the internet, list one fact about NFC that was not in the chapter and the URL where you found this information.  

---



### Soft Skills

- Objective:** To enhance and fine-tune a future technician's ability to listen, communicate in both written and oral forms, and support people who use computers in a professional manner
- Procedure:**
1. In teams of two, one student writes a professional note that contains internet acronyms that are commonly used for texting. The other student tries to then guess what the acronyms mean. Together, rewrite the note so it is more professional.
  2. Draft an email to a pretend computer customer that you just met yesterday for the first time. You did not have the part needed to repair the computer, but now the part has come in. Be sure you use professionalism in your email.



## Critical Thinking Skills

**Objective:** To analyze and evaluate information as well as apply learned information to new or different situations

**Procedure:**

1. Find an advertisement for a computer in a local computer flyer, in a newspaper, in a magazine, in a book, or on the internet. List which ports you know in one column and the ports you do not know in the other column. Select one port you do not know and research that component. Write the new information and share it with at least one other person.
2. Work in groups of three. As a group, do you think future computers will only have wireless connections or continue to have both wired and wireless connectivity? Why do you think this? What might be some hindrances to future computers having only have wireless connections?
3. Provide five tips that might help someone identify the different computer ports. If possible, each person in the class should state a tip without duplicating someone else's tip.

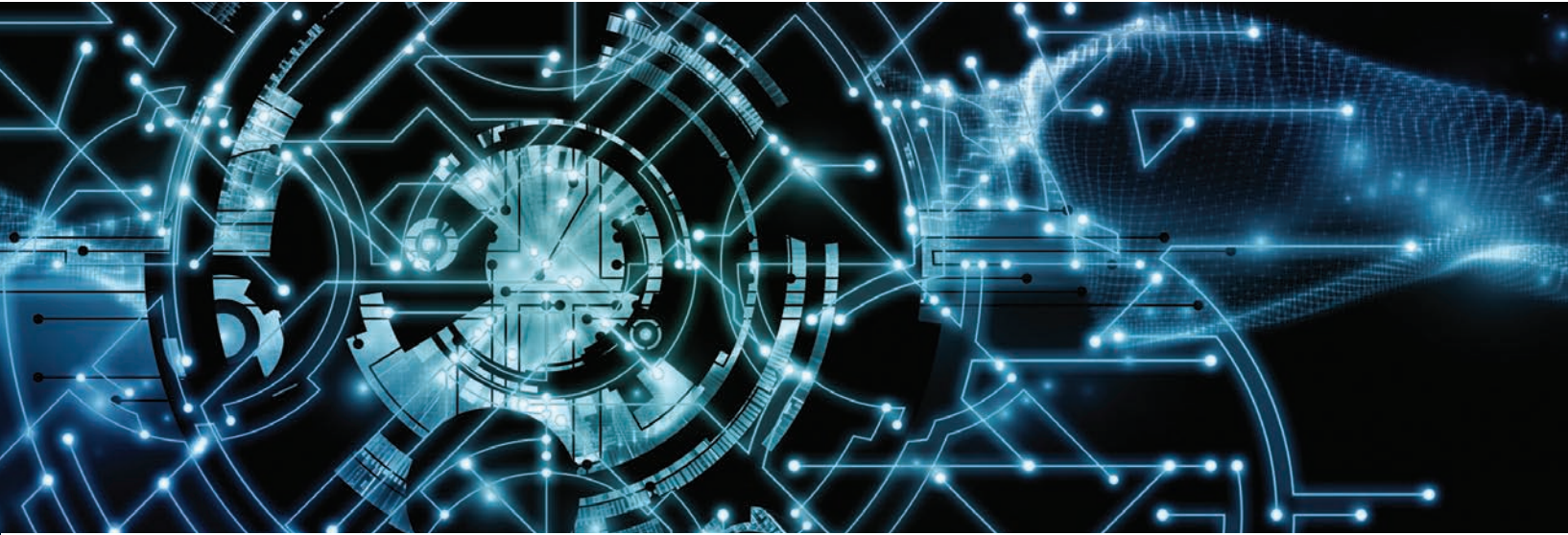
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# 3

## On the Motherboard



### In this chapter you will learn:

- > How to recognize and identify important motherboard parts
- > The basics of how a processor works
- > Issues to consider when upgrading or replacing a motherboard or processor
- > Information regarding GPUs
- > How to add cards to computers
- > The differences between PCI, AGP, and PCIe adapters and slots
- > Motherboard technologies such as HyperTransport, Hyperthreading, and multicore
- > Motherboard form factors and security options
- > Symptoms of motherboard and CPU problems
- > The benefits of active listening

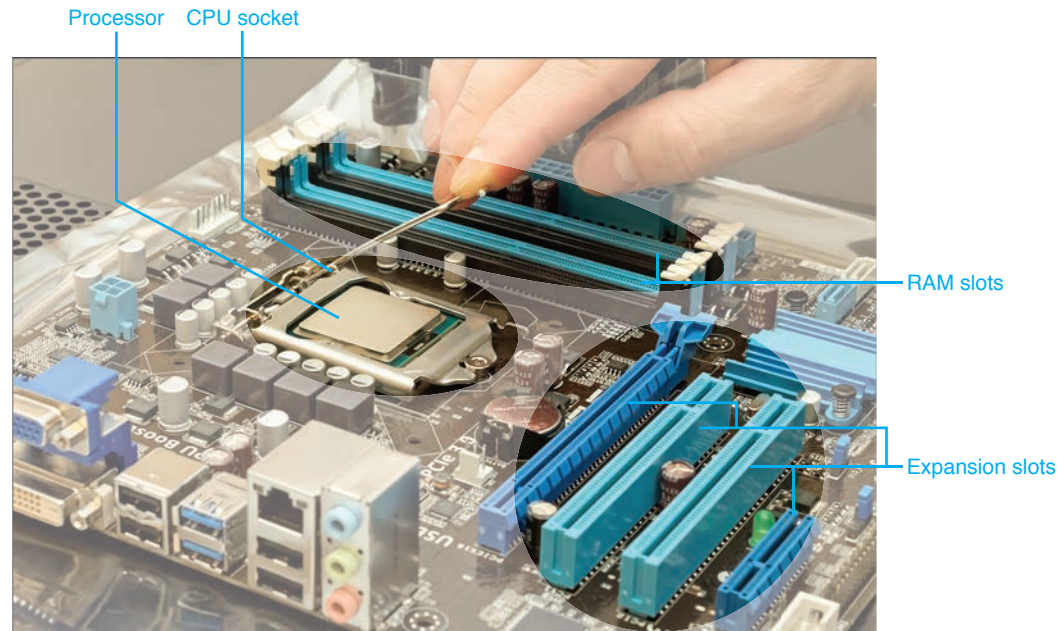
### CompTIA Exam Objectives:

- ✓ 1101-3.4 Given a scenario, install and configure motherboards, central processing units (CPUs), and add-on cards.
- ✓ 1101-5.2 Given a scenario, troubleshoot problems related to motherboards, RAM, CPU, and power.
- ✓ 1102-4.7 Given a scenario, use proper communication techniques and professionalism.



## Introduction to the Motherboard

The motherboard contains the most electronics and is important to any type of device including a computer. Figure 3.1 shows some of the key motherboard components we will be covering.



**FIGURE 3.1** Key motherboard components

## Processor Overview

At the heart of every computer is the **processor**, which determines, to a great extent, the power of the computer. The processor is also called the central processing unit (**CPU**), or microprocessor. The processor executes instructions, performs calculations, and coordinates input/output operations. Each motherboard has chips that work with the CPU and that are designed to exact specifications. The major processor manufacturers today are Intel, Motorola, VIA, Samsung, NVIDIA, Apple Inc., Qualcomm, and AMD (Advanced Micro Devices, Inc.). **Intel** and **AMD** are the predominant manufacturers for desktop and laptop processors. A term you might hear related to Intel and AMD CPUs is x86-64. The **x86** relates to the Intel 8086 processor, and the 64, or **x64**, reflects the update to a 64-bit version. Intel has its own patented CPU architecture called Intel 64, and AMD has the patented architecture AMD64.

**ARM processors** are used on mobile devices like smartphones, tablets, and laptops, but can also be used with desktop computers and servers. ARM used to be an acronym for Acorn RISC (reduced instruction set computing) Machine and then Advanced RISC Machines, but today it is just an architecture used in processors and microcontrollers. ARM processors can be 32- or 64-bit. ARM processors take less power, produce less heat, and cost less than AMD or Intel processors. The company Arm Ltd. also licenses its own designs to other companies that create their own products.

A motherboard accepts the processors of one or more specific manufacturers; for example, a motherboard that accepts an Intel processor will not support an AMD processor. Figure 3.2 shows a processor.



**FIGURE 3.2** Intel processor

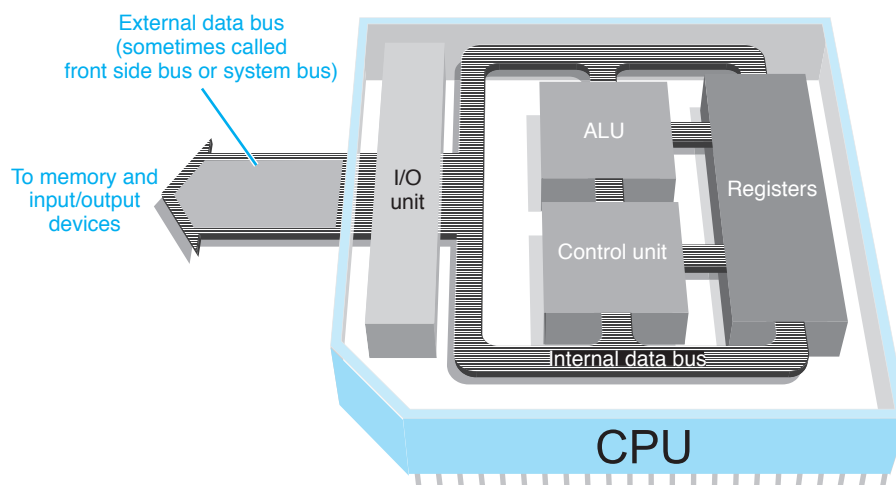
## Processor Basics

Processors come in a variety of speeds, measured in gigahertz (GHz). Hertz is a measurement of cycles per second. One hertz, written 1 Hz, equals 1 cycle per second. One gigahertz, or 1 GHz, is 1 billion cycles per second. Today's processors can run at speeds near 5 GHz.

## Buses

Processors operate on 1s and 0s. The 1s and 0s must travel from one place to another inside the processor, as well as outside to other chips. To move the 1s and 0s around, electronic lines called a bus are used. The electronic lines inside the CPU are known as the **internal data bus**, or system bus. In the Intel 8086 (from which the term x86 architecture originated), the internal data bus comprises 16 separate lines, with each line carrying a single 1 or a single 0. In today's processors, 64 or 128 internal data bus lines operate concurrently.

For a CPU to communicate with devices in the outside world, such as a printer, the 1s and 0s travel on the **external data bus**. The external data bus connects the processor to adapters, the keyboard, the mouse, storage, and other devices. You can see the external data lines by looking between the expansion slots on the motherboard. Today's processors have 64- and 128-bit external data paths. Figure 3.3 shows the internal and external data buses.



**FIGURE 3.3** Internal and external data buses

## ALUs

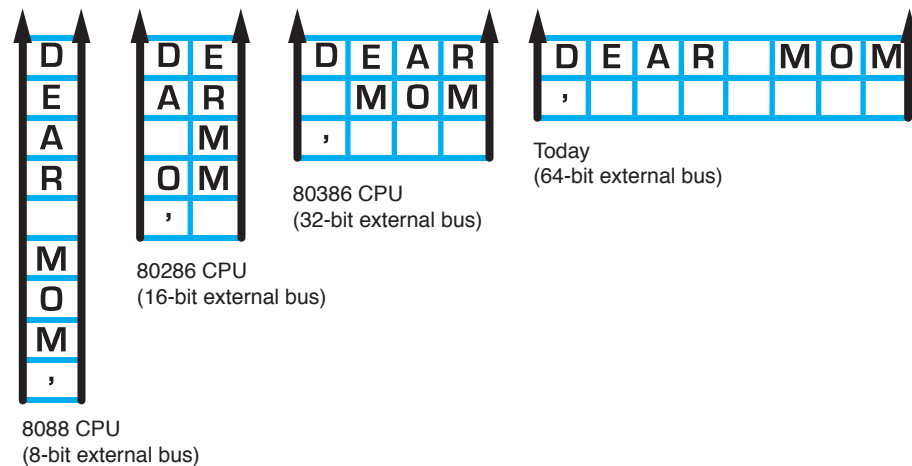
A processor has a special component called the arithmetic logic unit (ALU), which does all the calculations and comparison logic that the computer needs. Figure 3.3 shows the basic idea of how the ALU connects to the registers, control unit, and internal bus. The control unit coordinates activities inside the processor. The I/O unit manages data entering and leaving the processor. The registers in the CPU make up a high-speed storage area for 1s and 0s before the bits are processed.

## Processing Data

To understand how a computer processes data, consider a letter typed on a computer that starts out *DEAR MOM*. To the computer, each letter of the alphabet is a different combination of eight 1s and 0s. For example, the letter *D* is 01000100, and the letter *E* is 01000101. Figure 3.4 demonstrates that the size of the bus greatly increases performance on a computer much the way increasing the number of lanes of a highway decreases congestion.

### DEAR MOM,

The larger the bus (more lanes), the better the performance.



**FIGURE 3.4** Bus performance

## Pipelines

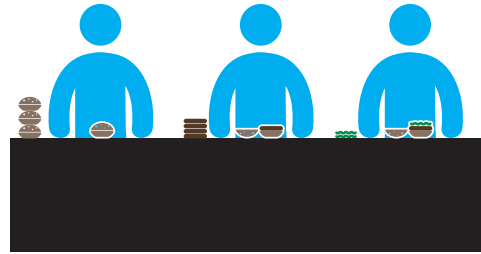
Processors have multiple pipelines (separate internal buses) that operate simultaneously. To understand pipelining, take the example of a fast-food restaurant. In the restaurant, assume that there are five steps involved in making a burger and giving it to the customer. To make this burger process go faster, you could (maybe) do one of the things shown in Figure 3.5.

To relate this to processors, you could increase the CPU clock speed, you could change the structure of the CPU pipeline in terms of how many steps are in each pipeline, and/or the CPU could have multiple pipelines. For example, if a processor has two pipelines, the Dear Mom letter can be in one pipeline, while a photo upload using a different application can be in the other pipeline.

1. Make your employees work faster



2. Break the tasks into smaller tasks



3. Have more lines of people doing exactly the same process tasks

**FIGURE 3.5** Ways to get faster processes

## Speeding Up Processor Operations Overview

You can determine the speed of a processor by looking at the model number on the chip, but processors frequently have devices attached to them for cooling, which makes it difficult to see the writing on the chip. A processor commonly does not use its maximum speed all the time in order to save power or stay cool. Also, a processor is not always functioning at its maximum potential for a lot of reasons, including coding used within an application, the user switching from application to application, inadequate bus width, or the amount of RAM installed. A processor can also operate beyond its rated specifications to handle periods of increased workload.

### TECH TIP

#### Locating processor speed

An easy way to tell processor speed with Windows is to go to File Explorer and right-click *This PC* and select *Properties*.

We have already taken a look at how increasing the CPU pipeline can, to some extent, improve processor operations, but other technologies also exist. We start by defining some of the terms that relate to this area and associating those terms with concepts and the various technologies used. Table 3.1 list some terms related to speed.

TABLE 3.1 Motherboard speed terms

Term	Explanation
<b>Clock or clock speed</b>	The speed of the processor’s internal clock, measured in gigahertz.
Front side bus (FSB)	The speed (commonly called motherboard speed) between the CPU and some of the motherboard components. Sometimes listed in megatransfers per second, or MT/s. With MT/s, not only is the speed of the FSB considered, but also how many processor transfers occur each clock cycle. A 266 MHz FSB that can do four transfers per second could be listed as 1064 MT/s.
Back side bus	The speed between the CPU and the L2 cache located outside the main CPU but on the same chip.
PCI bus speed	The speed used to deliver data on the PCI bus. Common speeds for the PCI bus are 33 and 66 MHz, allowing bandwidths up to 533 MB/s.
PCIe bus speed	The speed used to deliver data on the PCIe bus (the main bus used on the motherboard). Common data transfer rates follow. Note that to find the total throughput, multiply the transfer rate by the number of lanes. For example, with PCIe 4.x transfer rate of 16.0 GT/s (gigatransfers per second), the throughput on a 1x card is 1.6 GB/s and on a 16x card is 128 GB/s: > PCIe 1.1: 2.5 GT/s > PCIe 2.x: 5 GT/s > PCIe 3.x: 8 GT/s > PCIe 4.x: 16 GT/s > PCIe 5.x: 32 GT/s > PCIe 6.x: 64 GT/s
AGP bus speed	The speed used to deliver data on the AGP bus, an older standard used for video cards.
<b>CPU speed</b>	The speed at which the CPU operates; it can be changed on some motherboards.
<b>CPU throttling</b>	Reducing the clock frequency to slow the CPU in order to reduce power consumption and heat. This is especially useful in mobile devices.

Clocking

A motherboard generates a clock signal that is used to control the transfer of 1s and 0s to and from the processor. One clock cycle is from one point on the sine wave to the next point that is located on the same point on the sine wave later in time. In older computers, data was sent to the CPU only once during a clock cycle. Today, data is sent four times during a single clock cycle, as shown in Figure 3.6.

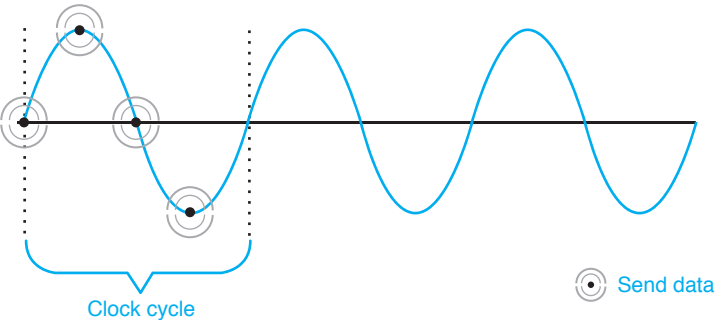


FIGURE 3.6 Clock cycle that clocks data four times per cycle

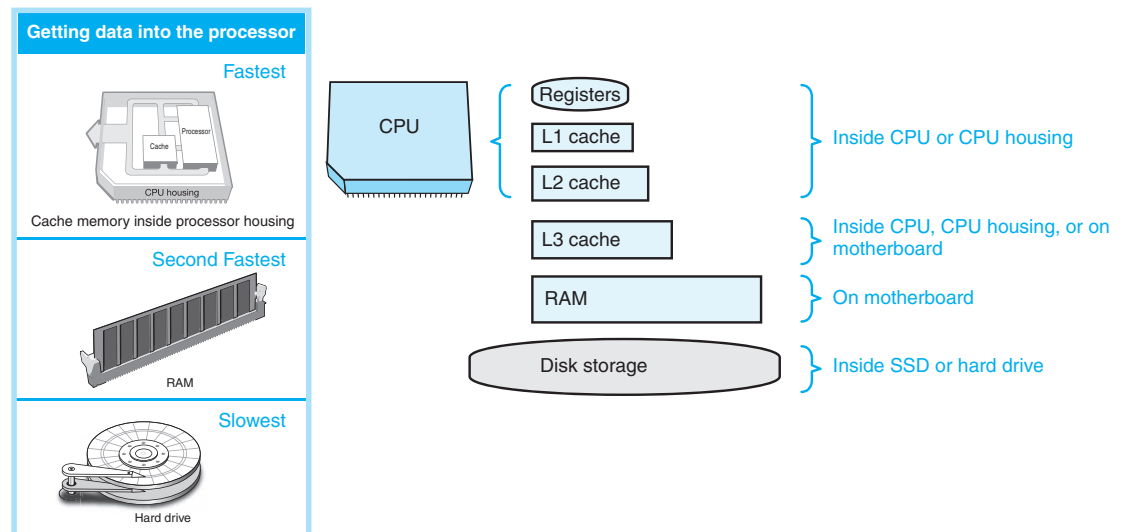
## Cache

An important concept related to processor speed is keeping data flowing into the processor. The data or instruction the CPU needs to process is usually found in one of four places: cache memory, motherboard memory (main memory), a solid-state drive (SSD, which is also memory), or the hard drive.

**Cache memory** is a very fast type of memory designed to increase the speed and efficiency of processor operations. Cache provides the fastest access. If the information is not in cache memory, the processor looks for the data in motherboard RAM. If the information is not there, it is retrieved from the hard drive and placed into the motherboard memory or the cache. Hard drive access is the slowest of the three. Table 3.2 lists the types of cache. Figure 3.7 shows the hierarchy of where the CPU looks for data.

**TABLE 3.2** Types of cache

Type	Explanation
<b>L1 cache</b>	Cache memory integrated into the processor and the fastest type
<b>L2 cache</b>	Cache in the processor packaging but not part of the CPU; also called on-die cache
<b>L3 cache</b>	Usually found in more powerful processors and can be located in the CPU housing (on-die) or on the motherboard

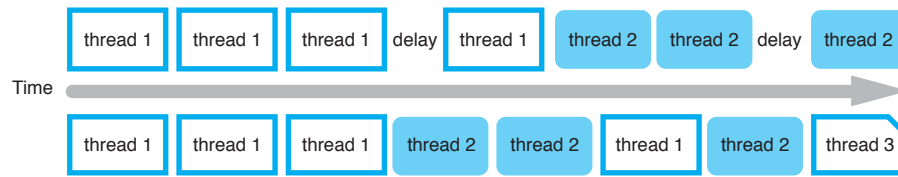


**FIGURE 3.7** CPU data sources and data access hierarchy

## Threading Technology

Two common threading techniques are used to speed up processor efficiency: multithreading and HT (Hyperthreading Technology). A **thread** is a small piece of an application process. An operating system such as Windows schedules and assigns resources to a thread. Each thread can share resources (such as the processor or cache memory) with other threads. A thread in the pipeline might have a delay due to waiting on data to be retrieved or awaiting access to a port or another hardware component. **Multithreading** keeps the line moving by letting another thread execute some code. This is like a grocery cashier taking another customer while someone goes for a forgotten loaf of bread. Figure 3.8 shows this concept.



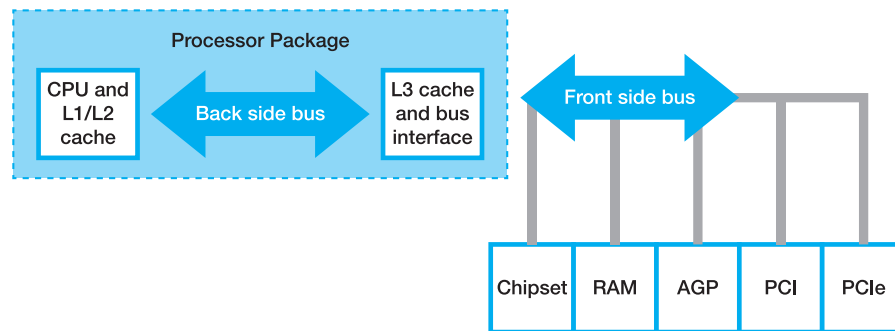


**FIGURE 3.8** Multithreading

Intel's HT (**Hyperthreading**, Hyper-Threading, or HT Technology) allows a single processor to handle two separate sets of instructions simultaneously. To the operating system, HT makes the system appear as if it has multiple processors. Intel claims that the system can have up to a 30% increase in performance, but studies have shown that the increase is application dependent.

## Connecting to the Processor

Accessing L2 cache and motherboard components was a bottleneck in older systems. The solution to this problem is to use two buses: a back side bus and a front side bus. The back side bus connects the CPU to the L2 cache. The front side bus (see Figure 3.9) connects the CPU to the motherboard components. The front side bus is considered the speed of the motherboard.



**FIGURE 3.9** Front side bus and back side bus

Many people think that the higher the CPU speed, the faster the computer. This is seldom true. Several factors contribute to the speed of a computer. One factor is bus speed. Bus speed describes how fast the CPU can communicate with motherboard components, such as memory, the chipset, or the PCI/PCIe bus.

Intel and AMD have technologies to replace the front side bus in some parts. AMD's solution is Direct Connect. Direct Connect allows each of the processor cores to connect directly to memory, to the other motherboard components such as the expansion slots, and to other processor cores by using a high-speed bus called **HyperTransport** (see Figure 3.11, later in the chapter). AMD is upgrading HyperTransport to Infinity Fabric. Intel has Ultra Path Interconnect (UPI), Serial Peripheral Interface (SPI), and Direct Media Interface (DMI), which are point-to-point connections between the processor and one or more motherboard components.

## Multicore Processors

A **single-core processor** is just one processor. Both Intel and AMD provide **multicore** processors, which means more than one CPU in the same housing (see Figure 3.10). Each core can execute programs or threads. One Intel Core i9 CPU has 18 cores, and AMD's Ryzen Threadripper has 64 cores and 128 threads. Figure 3.10 shows how multiple Intel processors connect. Figure 3.11 shows how each AMD CPU accesses RAM and where the HyperTransport bus is used for connectivity.



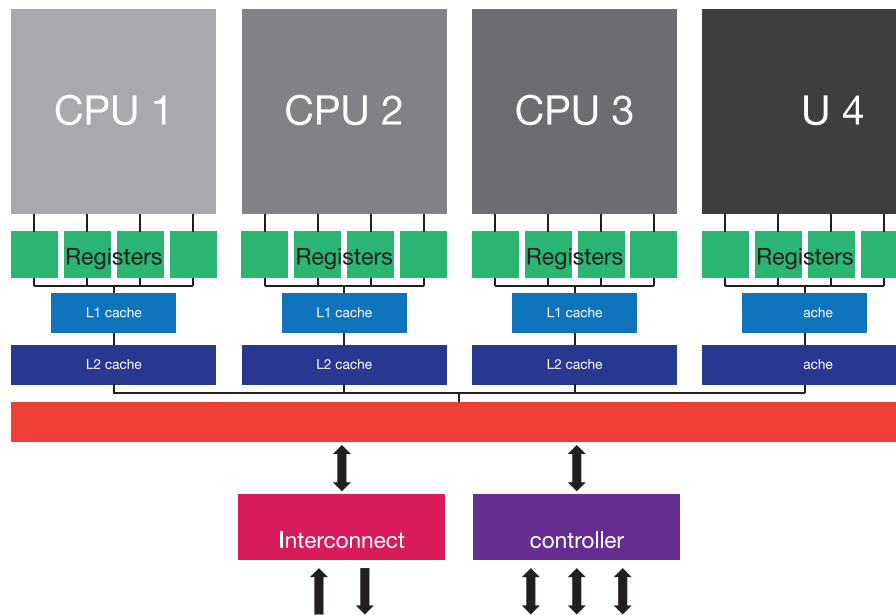


FIGURE 3.10 Intel multicore architecture

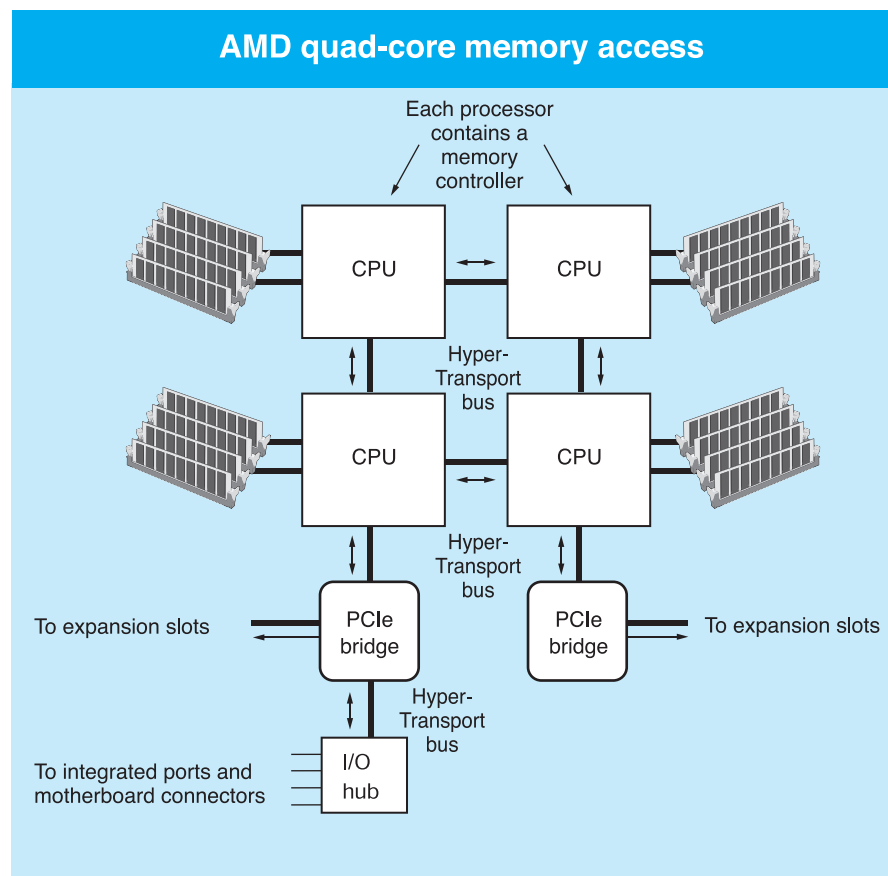


FIGURE 3.11 AMD quad-core memory access

**TECH TIP****How many cores and threads do you have?**

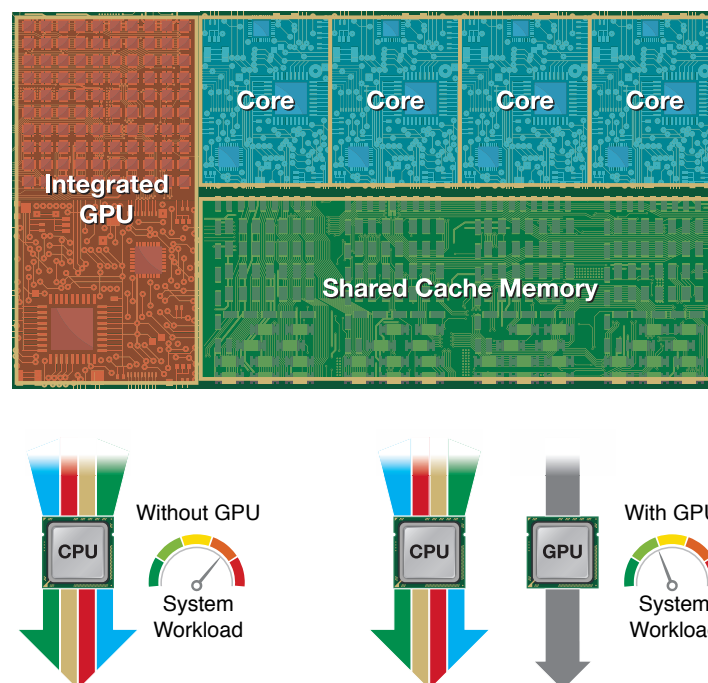
Right-click on Windows taskbar > *Task Manager* > *Performance* tab > *CPU* > look for *Cores*, *Logical processors*, and *Threads*.

A logical processor can execute its own set of instructions. All applications can take advantage of the multicore technology and the background processes that are associated with the operating system and applications. This improves operations when multitasking or when running powerful applications that require many instructions to be executed, such as drawing applications and games.

## Graphics Processing Unit (GPU)

Another bottleneck for computer performance is video. Computer users who want better video performance buy a separate video adapter that contains a GPU. Both Intel and AMD have a graphics processing unit (**GPU**) within the CPU on some of their processor models. With an **integrated GPU** (iGPU), sometimes called an integrated graphics processor (IGP), an external video card with a GPU is not required, and graphical data is processed quickly with reduced power consumption.

Today's CPUs contain multicore processors, and GPUs contain hundreds of smaller core processors. GPUs can also be used for other purposes that are not directly related to graphics but that increase system performance. These GPUs are sometimes referred to as general-purpose GPUs (GPGPUs). Figure 3.12 shows how an IGP is within the same housing as the CPU cores.

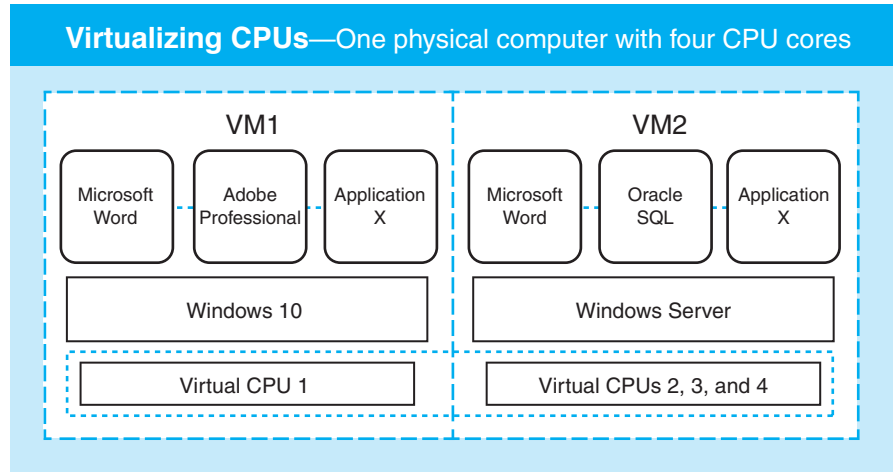


**FIGURE 3.12** CPU vs. GPU

AMD calls its processors that have a GPU integrated with the CPU accelerated processing units (**APUs**). Intel calls its integrated GPU Intel HD Graphics and Intel Iris Graphics.

## Introduction to Virtualization

One advantage of having multiple processor cores is that they allow both home and business computers to take advantage of virtual technology. **Virtualization** allows you to have one or more virtual machines (**VMs**) on the same computer. Virtualization software, such as VMware Workstation, Oracle VM VirtualBox, or Microsoft Hyper-V, enables one computer to act as if it were two or more computers. The computer can have two or more operating systems installed through the use of the virtualization software. Each operating system has no knowledge of the other operating system(s) on the computer (see Figure 3.13).



**FIGURE 3.13** The concept of virtualization

Windows 8, 10, and 11 have Hyper-V, which allows an application to run in a virtual environment as if an older operating system had been installed. Businesses often use virtualization so they can use legacy software on newer machines but keep it separate from the main operating system or another virtualized machine on the same computer. Reduced costs and physical space are benefits of virtualization. Home computer users can install multiple operating systems in separate VMs (virtual machines) within the same physical box, with each VM being seen as a separate computer. To better prepare yourself for the CompTIA A+ certification exams, you could install Windows 10 or 11 and Linux.

Selecting a motherboard and processor is important when in a virtual environment. Refer to the virtualization software documentation to determine whether the CPU used is supported. Be sure to enable **virtualization support** in the firmware (covered in Chapter 4, “Introduction to Configuration”). Another issue regarding processors and virtualization is licensing. For virtualization software that must be purchased (that is, is not freeware), the software manufacturer may charge on a per-processor or per-socket license basis or on a per-core basis.

## Intel Processors

Traditionally, Intel has rated its processors by GHz, and people have compared processors based on speed alone. Now, Intel arranges its products by family numbers. In a family of processors, you can compare attributes such as speed and the amount of cache memory and other technologies. Table 3.3 shows Intel’s processor families. Figure 3.14 shows a close-up of a processor installed into a motherboard. Figure 3.15 shows how to decipher Intel processor models.

**TABLE 3.3** Intel processor families

Processor family*	Comments
Xeon	CPU for server and professional PCs that need ECC memory, large amounts of memory, larger cache, more cores, and multiple sockets.
Core X	18-core processor (at press time) for high performance, extreme gaming, intensive content creation, and multitasking.
Core i9	Powerful multicore processor for gaming and intensive content creation as well as multitasking.
Core i7	Multicore with cache memory shared between cores and on-board memory controller. Good for virtualization, graphic/multimedia design and creation, and gaming.

Processor family*	Comments
Core i5	Midrange dual- and quad-core processor. Used for video, photos, email, and internet access.
Core i3	Low-end desktop and mobile processor used for common tasks such as word processing and internet access.

\*Intel is constantly upgrading processors. For more information, visit [www.intel.com](http://www.intel.com).

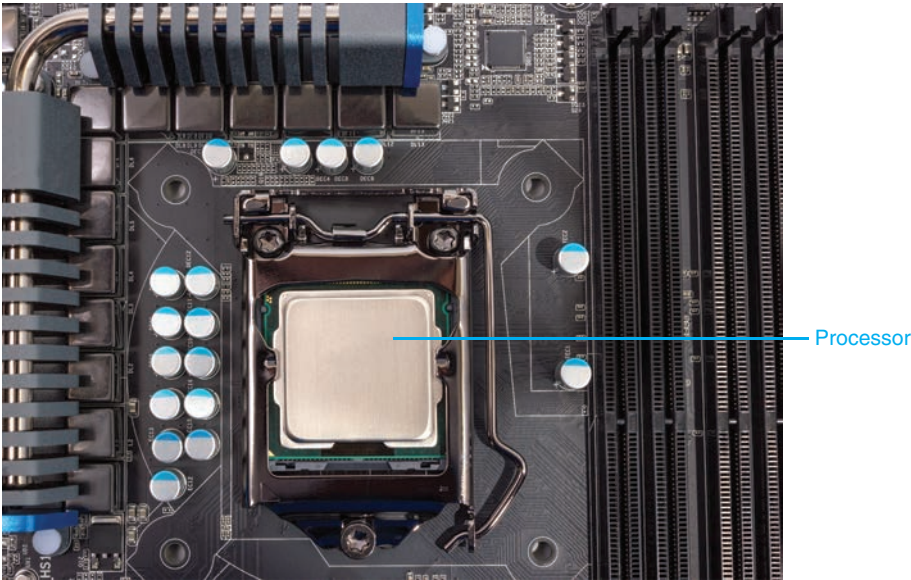


FIGURE 3.14 Installed processor

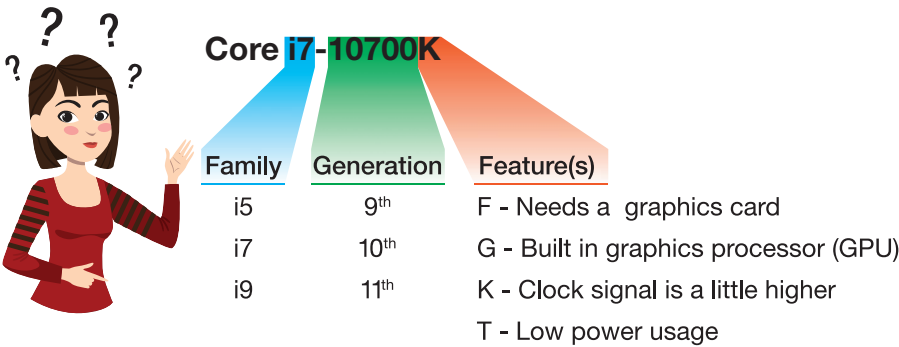


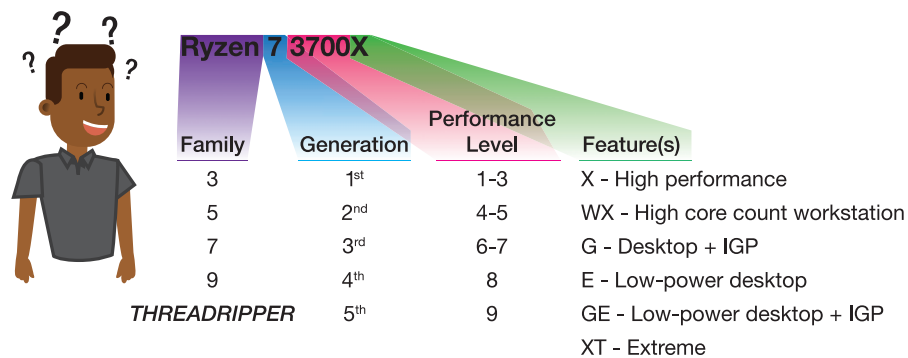
FIGURE 3.15 Deciphering Intel processor model numbers

### AMD Processors

AMD is Intel’s largest rival in computer processors. Anyone buying a processor should research all models and vendors. Table 3.4 lists the AMD processor families, and Figure 3.16 shows how to make sense of the AMD CPU model numbers.

**TABLE 3.4** AMD processor families

Processor family	Comments
Ryzen Threadripper	8 to 64 cores, 128 processing threads, and 20 to 292 MB cache for extremely high-end desktop processor
Ryzen 9	8 to 16 cores, 32 processing threads, and up to 72 MB cache for gaming or creating multimedia
Ryzen 7	8 cores, 16 processing threads, 20 MB cache for gaming, high-end content creation, and multitasking
Ryzen 5	4 to 6 cores, up to 12 processing threads, and up to 20 MB cache for workplace or home computing use
Ryzen 3	4 cores and up to 18 MB cache for standard computing use

**FIGURE 3.16** Deciphering AMD processor model numbers

## CPU Sockets

A processor inserts into a **CPU socket**. There are different types of sockets, but each socket has a specific number of pins and only accepts specific CPUs. A motherboard that can take more than one CPU will show in the documentation/specifications as a **multisocket** motherboard. Typically, it is motherboards on a server, a more powerful computer used in networks, that has a multisocket motherboard. Figure 3.17 shows a desktop motherboard CPU socket.

**FIGURE 3.17** CPU socket

Processor sockets are also called zero insertion force sockets, or **ZIF sockets**, and they come in different sizes. A ZIF socket has a small lever to the side that, when lifted, brings the processor slightly up and out of the socket holes. When installing a processor, you align the CPU over the socket and press the lever down to bring the processor into the socket with equal force. In Figure 3.17, notice the lever beside the socket that is used to lift the metal cover.

TECH TIP

Buying the right CPU

If you buy a motherboard and processor separately, it is important to ensure that the motherboard CPU socket is the correct type for the processor.

Intel sockets: LGA 1151, 1155, 1156, 1200, 2066, 3647

AMD sockets: AM5, AM4, TR4, TRX4

Processor Cooling

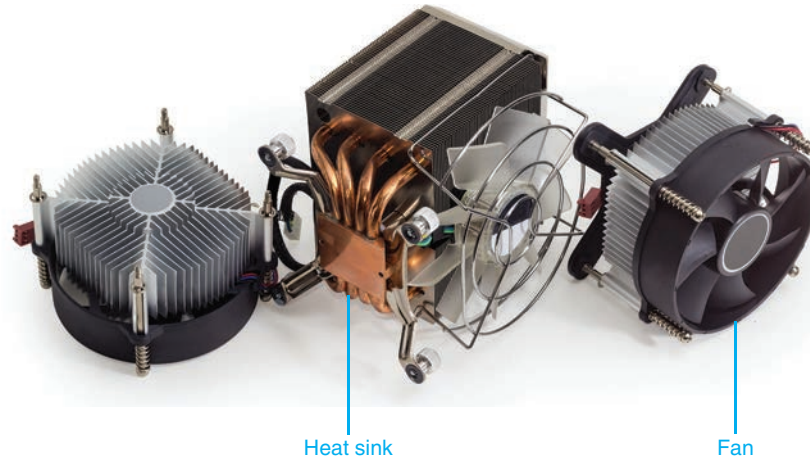
Keeping a CPU cool is critical. Both Intel and AMD have technologies that reduce processor energy consumption (and heat) by turning off unused parts of the processor or slowing down the processor when it starts to overheat. But these measures alone are not enough. Today’s systems use one or more of the methods listed in Table 3.5. Figure 3.18 shows a heat sink and a fan.

TABLE 3.5 Processor cooling methods

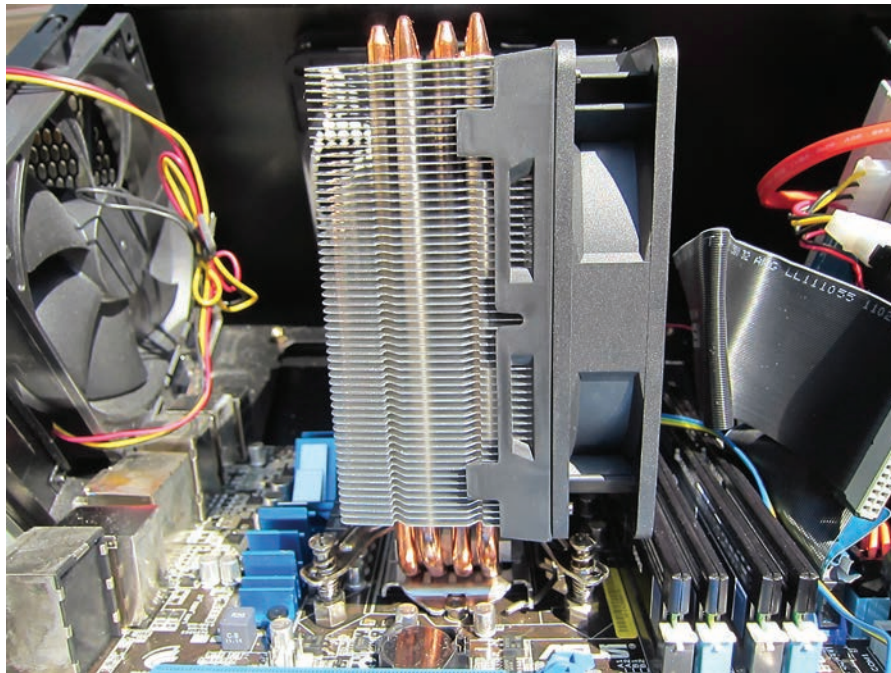
Method	Description
Heat sink	A heat sink is a block of metal (usually aluminum or copper), metal bars, or metal fins that attach to the top of the processor or other motherboard components. Heat from the processor is transferred to the heat sink and then blown away by the air flow throughout the computer case.
Fan	Fans can be attached to the processor, beside the processor, and in the case.
Thermal paste or thermal pad	Thermal paste, compound, or grease can be applied to the top of a processor before a heat sink is attached. Some heat sinks and fans have thermal paste pre-applied. A thermal pad provides uniform heat dispersion and lies between the processor and the heat sink.
Liquid cooling	Liquid is circulated through the system, including through a heat sink that is mounted on the CPU. Heat from the processor is transferred to the cooler liquid. The now-hot liquid is transported to the back of the system, converted to heat, and released outside the case. CPU temperature remains constant, no matter the usage. Some systems require the liquid to be periodically refilled.
Phase-change cooling (vapor cooling)	This expensive option uses a technique similar to a refrigerator: A gas is converted to a liquid that is converted back to gas.

The largest chip on the motherboard with a fan or a heat sink attached is easily recognized as the processor. Figure 3.19 shows an Intel Core i7 that has a fan and a heat sink installed. Notice the heat pipes that are used as part of the heat sink.





**FIGURE 3.18** Heat sink and fan



**FIGURE 3.19** CPU with heat sink and fan attached

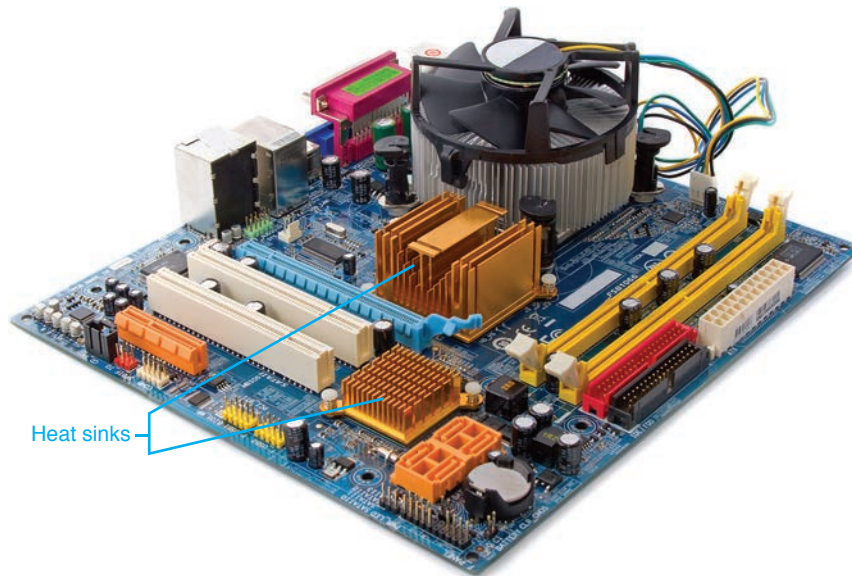
### TECH TIP

#### Cooling the CPU

Do not apply power to a computer until the CPU and the heat sink, fan, and/or cooling unit are installed. Running the CPU without installing appropriate cooling mechanisms will overheat the CPU and destroy or weaken it.



Additional motherboard components can also have heat sinks attached. They are normally the chipset and/or the I/O (input/output) controller chips. Figure 3.20 shows a motherboard with these cooling elements.



**FIGURE 3.20** Motherboard heat sinks

### TECH TIP

#### When thermal paste acts like glue

Over time, thermal paste can act like glue, making a processor hard to separate from a heat sink. You can use a thermal paste cleaner, acetone, or denatured alcohol to separate the two parts. Do not pry them apart!

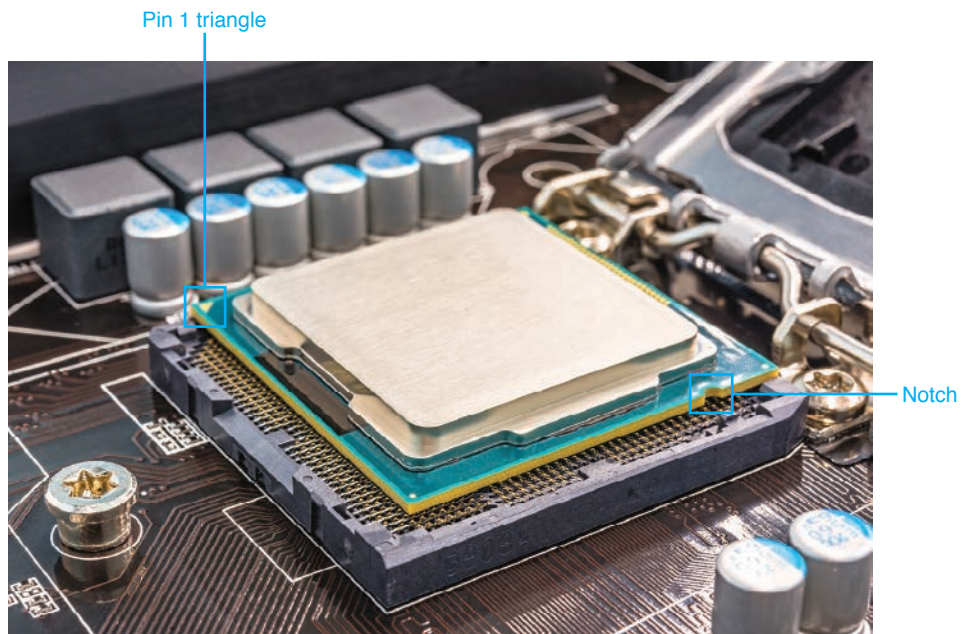
## Installing a Processor

Processors are sold with installation instructions. In addition, motherboard manuals (or other documentation) include the steps to upgrade or install the CPU. The following are the parts and the general steps for installing a processor:

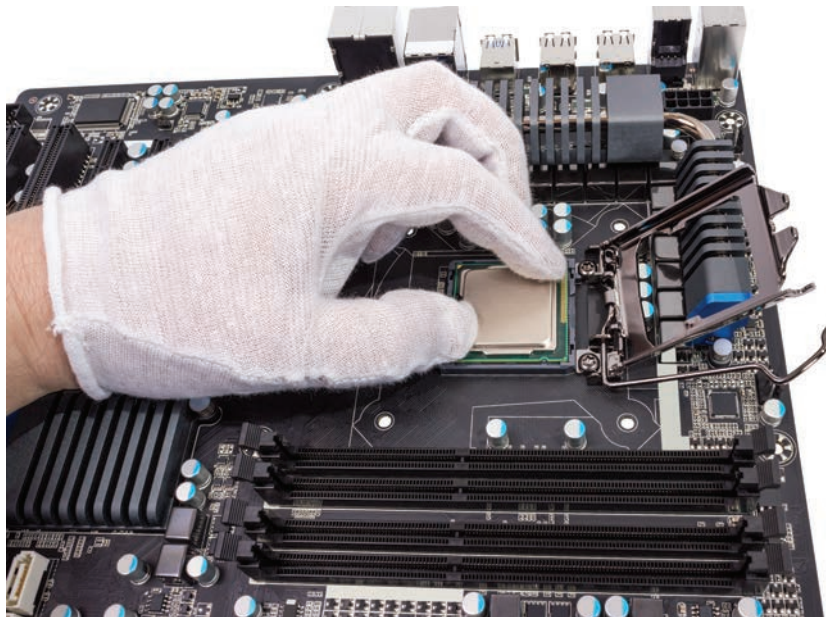
**Parts:** Proper processor for the motherboard (refer to motherboard documentation)  
Antistatic materials

- Step 1.** Ensure that power to the computer is off and the computer is unplugged.
- Step 2.** Place an antistatic wrist strap around your wrist and attach the other end to a ground or an unpainted metal part of the computer. Alternatively, use an antistatic glove.
- Step 3.** Push the retention lever down and outward to release the CPU retention plate. Move the handle backward until the retention plate is fully open. Do not touch the CPU socket. If a plastic cover is installed in the CPU socket, remove it.
- Step 4.** Remove the processor from packaging, taking care to hold it by the edges and never touch the bottom metal portion of the processor. Remember that a CPU fits only one way into the socket. Look at the processor and the socket before inserting the chip to ensure proper alignment. A socket and CPU normally have a triangle marking or dot to indicate pin 1, as shown in Figure 3.21. The processor also has notches on each

side that align with the socket. Insert the CPU into the socket by aligning it with the socket and lowering it until it is flush with the socket, as shown in Figure 3.22. (Do not force it!)



**FIGURE 3.21** Pin 1 and notch on a processor



**FIGURE 3.22** Installing a CPU

## TECH TIP

### Handling the CPU

Always hold a CPU by the edges to avoid bending or touching the pins underneath. Do not touch a CPU until you are ready to install it in the socket.

## Upgrading Processors

Two common questions asked of technicians are “Can a computer be upgraded to a higher or faster processor?” and “Should a computer be upgraded to a higher or faster processor?” Whether or not a computer can be upgraded to a higher or faster processor depends on the capability of the motherboard. When a customer asks if a processor should be upgraded, the technician should ask, “What operating system and applications are you using?” The newer the operating system, the more advanced the processor should be. Some games and applications that must perform calculations, as well as graphic-oriented applications, require a faster, more advanced processor. The motherboard’s documentation is very important when considering a CPU upgrade. Read this documentation to determine whether the motherboard can accept a faster processor.

### TECH TIP

#### Upgrading a CPU

Do not upgrade a processor unless the documentation or manufacturer states that the motherboard supports a newer or faster processor.

**Throttle management** is the process of controlling the speed of a CPU by slowing it down when it is not being used heavily or when it is hot. Usually this feature is controlled by a system BIOS/UEFI setting and the Windows *Power Options* Control Panel. Some users may want performance to be at a maximum and so may not use CPU throttling. Laptop users, on the other hand, may want to conserve power whenever possible to extend the time the computer can be used on battery power. Use the *Battery* Windows Settings link to control how apps affect battery performance.

Upgrading components other than the processor can also increase speed in a computer. Installing more memory and/or higher capacity and faster storage commonly improve a computer’s performance more than installing a new processor. All devices and electronic components must work together to transfer the 1s and 0s efficiently.

## Overclocking Processors

**Overclocking** involves changing the front side bus speed and/or multiplier to boost CPU and system speed. Overclocking has some issues:

- > The processor, motherboard, memory, and other components can be damaged by overclocking.
- > Applications may crash, the operating system may not boot, and/or the system may hang (lock up) when overclocking.
- > You may void the warranty on some CPUs if you overclock.
- > When you increase the speed of the CPU, the processor’s heat increases. Extra cooling, using fans and larger heat sinks, is essential.
- > Input/output devices may not react well to overclocking.
- > The memory chips may need to be upgraded to be able to keep up with the faster processing.
- > You need to know how to reset the system BIOS/UEFI in case the computer will not boot properly after you make changes. This process is covered in Chapter 4.



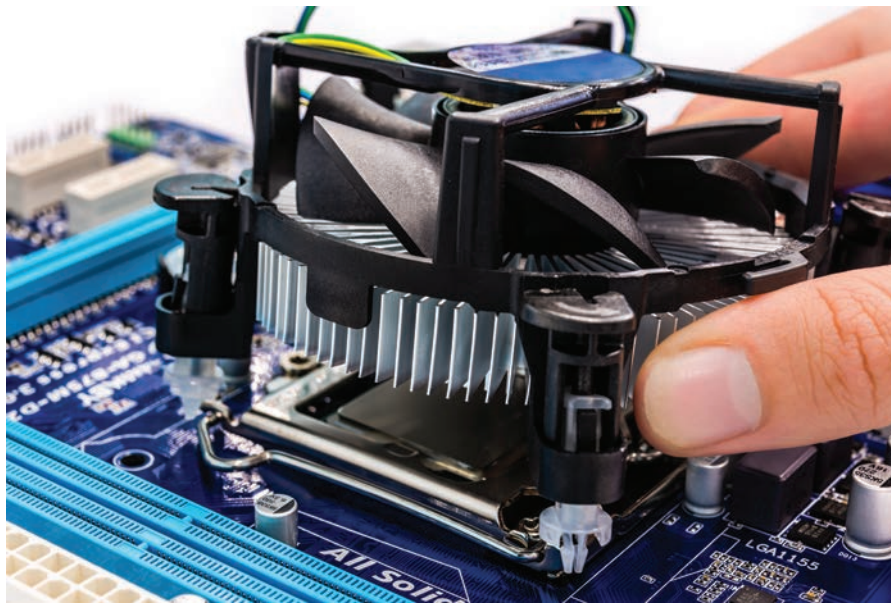
**TECH TIP****Being ready to cool**

The primary problem with overclocking is insufficient cooling. Make sure you purchase a larger heat sink and/or extra fans before starting the overclocking process.

Many motherboard manufacturers do not allow changes to the CPU, multiplier, and clock settings. The changes to the motherboard are most often made through BIOS/UEFI Setup. However, CPU manufacturers may provide tuning tools in the form of applications installed on the computer for overclocking configuration. Keep in mind that overclocking is a trial-and-error situation. There are websites geared toward documenting specific motherboards and overclocked CPUs.

## Installing CPU Thermal Solutions

A CPU may come with a thermal solution such as a heat sink and/or fan. The thermal solution commonly comes with a pre-applied thermal paste or an attached thermal pad. Heat sinks and fans attach to the processor using different methods, such as screws, thermal compound, and clips. Clips can involve retaining screws, pressure release, or a retaining slot. The type of heat sink and/or fan installed must fit the processor and case. Additional hardware may have to be installed on the motherboard to be able to attach a CPU thermal solution. Figure 3.23 shows a CPU cooler being installed.



**FIGURE 3.23** CPU heat sink/fan installation

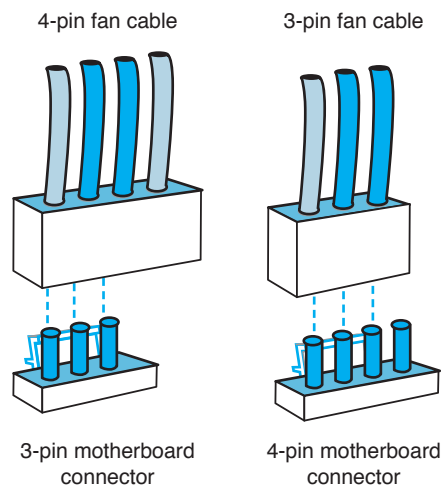
**TECH TIP****Take a photo of the CPU**

Before attaching a heat sink and/or fan to a CPU, take a picture of the markings on top. You might need to use these markings if you ever need technical support and need the exact specifications. Techs often take pictures to document motherboard replacements and wiring.

If a thermal solution is being installed, then the thermal pad or old thermal paste should be removed and new thermal paste applied. Do not scratch the surface of a heat sink. Use a plastic scribe or tool to remove a thermal pad or old paste. A thermal paste cleaner, acetone, or denatured alcohol with a lint-free cloth can be used to remove residual paste.

When installing thermal paste, apply the prescribed amount in the center of the processor. Spread the compound evenly in a fine layer over the center portion of the CPU that comes in contact with the heat sink. When the heat sink is attached to the processor, the thermal compound will spread (hopefully not over the edges). Always follow the heat sink installation directions.

A CPU fan is likely to have a 3- or 4-pin cable that attaches to the motherboard. The motherboard might have a 3- or 4-pin connector. A 3-pin fan can be attached to a 4-pin motherboard connector, and a 4-pin fan cable can be connected to a 3-pin motherboard connector, as shown in Figure 3.24. Note that when a 3-pin cable attaches to 4-pin connector, the fan is always on and cannot be controlled, as a 4-pin cable to a 4-pin connector can.



**FIGURE 3.24** CPU fan connectivity

## Troubleshooting Processor Issues

Processor issues can appear in different ways, as illustrated in Figure 3.25.

The following tips can help you solve CPU issues:

- > The number-one issue related to processor problems is heat. Ensure that all fans work. Listen for a **grinding noise** indicating that something is caught in the fan, lack of oil, or a failing fan. Adding fans costs very little compared to replacing a processor and/or a motherboard. Ensure that the computer has adequate circulation/cooling. Vacuum dust from the motherboard/CPU. Cool the room more.
- > Many BIOS/UEFI screens show the CPU temperature. (This is covered in more detail in Chapter 4.)
- > Research any visual codes shown on the motherboard LEDs or listen for audio beeps as the computer boots. Refer to the computer or motherboard manufacturer's website.

Processor issues are difficult to troubleshoot, and it is often very challenging to determine whether a problem is a CPU or motherboard issue. If you have power to the system (that is, the power supply has power coming out of it), the hard drive works (try it in a different computer), and the monitor works (try it on a different computer), then the motherboard and/or CPU are prime suspects.