MERIT BADGE SERIES

DIGITAL TECHNOLOGY

BOY SCOUTS OF AMERICA

How to Use This Pamphlet

The secret to successfully earning a merit badge is for you to use both the pamphlet and the suggestions of your counselor.

Your counselor can be as important to you as a coach is to an athlete. Use all of the resources your counselor can make available to you. This may be the best chance you will have to learn about this particular subject. Make it count.

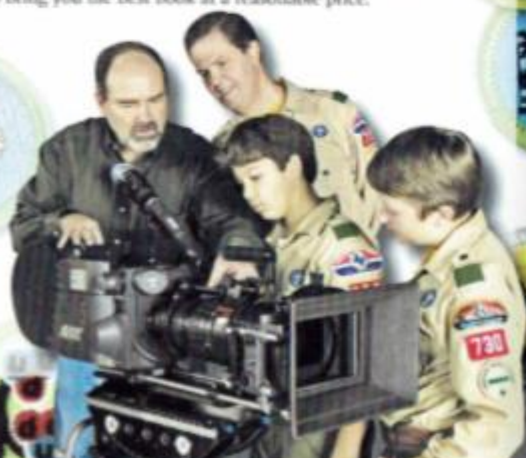
If you or your counselor feels that any information in this pamphlet is incorrect, please let us know. Please state your source of information.

Merit badge pamphlets are reprinted annually and requirements updated regularly. Your suggestions for improvement are welcome.

Send comments along with a brief statement about yourself to National Advancement Committee, S209 • Boy Scouts of America • 1325 West Walnut Hill Lane • P.O. Box 152079 • Irving, TX 75015-2079 • merit.badge@Scouting.org.

Who Pays for This Pamphlet?

This merit badge pamphlet is one in a series of more than 100 covering all kinds of hobby and career subjects. It is made available for you to buy as a service of the national and local councils, Boy Scouts of America. The costs of the development, writing, and editing of the merit badge pamphlets are paid for by the Boy Scouts of America in order to bring you the best book at a reasonable price.



BOY SCOUTS OF AMERICA
MERIT BADGE SERIES

DIGITAL TECHNOLOGY

"Enhancing our youths' competitive edge through merit badges"

BOY SCOUTS OF AMERICA

Note to the Counselor

The new Digital Technology merit badge was designed to show the close relationship between humans and the technical world surrounding us. The fleur-de-lis in the center represents the Scout who, acting as the "brain" of a typical computing device, interfaces with the digital technology world through the means that those electronic devices can "understand"—electrons, bits of data, and specialized pathways for information. As we increasingly use digital technology in our everyday world, this relationship extends from the Scout to the digital devices.

Eventually, the machine becomes an extension of the Scout's will, carrying out what the Scout directs it to do. The challenge for the Scout and for every user of digital technology is to understand this boundary and relationship, to not lose one's own identity in the machine. We humans must remember that machines are simply an extension of—not a replacement for—the human mind.

The American Standard Code for Information Interchange, or ASCII, is used to transmit information between computers. To manage the alphabet, this binary system uses numbers 0 to 9 and special characters for 256 possible combinations with an eight-digit binary number. Those numbers would be 00000000, 00000001, 00000010, 00000011, 00000100, up to 11111111. In decimal it would be 0, 1, 2, 3, 4, and so on, up to 255. That's 256 combinations, including zero.

Where does that number come from? Computers at the most fundamental level handle circuits that are like "on" and "off" switches. In the decimal system, we typically use 10 symbols—numerals 0 to 9—and every digit uses a factor of 10. The binary system uses only two symbols—0 and 1—and a factor of 2. In the digital technology industry, these conditions are typically referred to as a binary number system with 1 for "on" and 0 for "off." In decimal, the number 12 would be written as $12 = (1 \times 10) + (2 \times 1)$. In binary, it would be written as $1100 = (1 \times 8) + (1 \times 4) + (1 \times 0)$.

35733
ISBN 978-0-8395-0000-0

2014 Printing

This chart includes a "translation" of zero through 9, the entire alphabet (capital and lowercase letters), and a few other characters. See "Understanding Data and Files" for more information on ASCII translation.

The original design for the Digital Technology merit badge contained a special ASCII encoding for "BSA." However, due to constraints in the badge making process, this idea was abandoned. As a fun aside for Scouts, see if they can figure out the message. For the letters "B," "S," "A" in ASCII, here is the standard assignment:

B = 01000010 S = 01010011 A = 01000001

Starting from the tab in the top row to the far left, notice a trace that stops at a circle, which represents a zero. Going clockwise, the next trace twists and radiates outward. The next two end at circles. Then going down the right side of the yellow tabs, combinations of 1s and 0s are found. Eventually, if you go around the entire badge, you get the 1s and 0s to spell out "BSA" in ASCII format.

Requirements

1. Show your counselor your current, up-to-date Cyber Chip.
2. Do the following:
   a. Give a brief history of the changes in digital technology over time. Discuss with your counselor how digital technology in your lifetime compares with that of your parent's, grandparent's, or other adult's lifetime.
   b. Describe the kinds of computers or devices you imagine might be available when you are an adult.
3. Do the following:
   a. Explain to your counselor how text, sound, pictures, and videos are digitized for storage.
   b. Describe the difference between lossy and lossless data compression, and give an example where each might be used.
   c. Describe two digital devices and how they are made more useful by their programming.
   d. Discuss the similarities and differences between computers, mobile devices, and gaming consoles.
   e. Explain what a computer network is and describe the network's purpose.
4. Do the following:
   a. Explain what a program or software application or "app" is and how it is created.
   b. Name four software programs or mobile apps you or your family use, and explain how each one helps you.
   c. Describe what malware is, and explain how to protect your digital devices and the information stored on them.

5. Do the following:
   a. Describe how digital devices are connected to the Internet.
   b. Using an Internet search engine (with your parent's permission), find ideas about how to conduct a troop court of honor or campfire program. Print out a copy of the ideas from at least three different websites. Share what you found with your counselor, and explain how you used the search engine to find this information.
   c. Use a Web browser to connect to an HTTPS (secure) website (with your parent's permission). Explain to your counselor how to tell whether the site's security certificate can be trusted, and what it means to use this kind of connection.
6. Do THREE of the following. For each project you complete, copy the files to a backup device and share the finished projects with your counselor.
   a. Using a spreadsheet or database program, develop a food budget for a patrol weekend campout OR create a troop roster that includes the name, rank, patrol, and telephone number of each Scout. Show your counselor that you can sort the roster by each of the following categories: rank, patrol, and alphabetically by name.
   b. Using a word processor, write a draft letter to the parents of your troop's Scouts, inviting them to a troop event.
   c. Using a graphics program, design and draw a campsite plan for your troop OR create a flier for an upcoming troop event, incorporating text and some type of visual such as a photograph or an illustration.
   d. Using a presentation software program, develop a report about a topic approved by your counselor. For your presentation, create at least five slides, with each one incorporating text and some type of visual such as a photograph or an illustration.
   e. Using a digital device, take a picture of a troop activity. Send or transfer this image to a device where the picture can be shared with your counselor.

f. Make a digital recording of your voice, transfer the file to a different device, and have your counselor play back the recording.

g. Create a blog and use it as an online journal of your Scouting activities, including group discussions and meetings, campouts, and other events. Include at least five entries and two photographs or illustrations. Share your blog with your counselor. You need not post the blog to the Internet; however, if you choose to go live with your blog, you must first share it with your parents AND counselor AND get their approval.

h. Create a Web page for your troop, patrol, school, or place of worship. Include at least three articles and two photographs or illustrations. Include at least one link to a website of interest to your audience. You need not post the page to the Internet; however, if you decide to do so, you must first share the Web page with your parents AND counselor AND get their approval.

7. Do the following:

   a. Explain to your counselor each of these protections and why they exist: copyright, patents, trademarks, trade secrets.

   b. Explain when it is permissible to accept a free copy of a program from a friend.

   c. Discuss with your counselor an article or a news report about a recent legal case involving an intellectual property dispute.

8. Do TWO of the following:

   a. Describe why it is important to properly dispose of digital technology. List at least three dangerous chemicals that could be used to create digital devices or used inside a digital device.

   b. Explain to your counselor what is required to become a certified recycler of digital technology hardware or devices.

   c. Do an Internet search for an organization that collects discarded digital technology hardware or devices for repurposing or recycling. Find out what happens to that waste. Share with your counselor what you found.

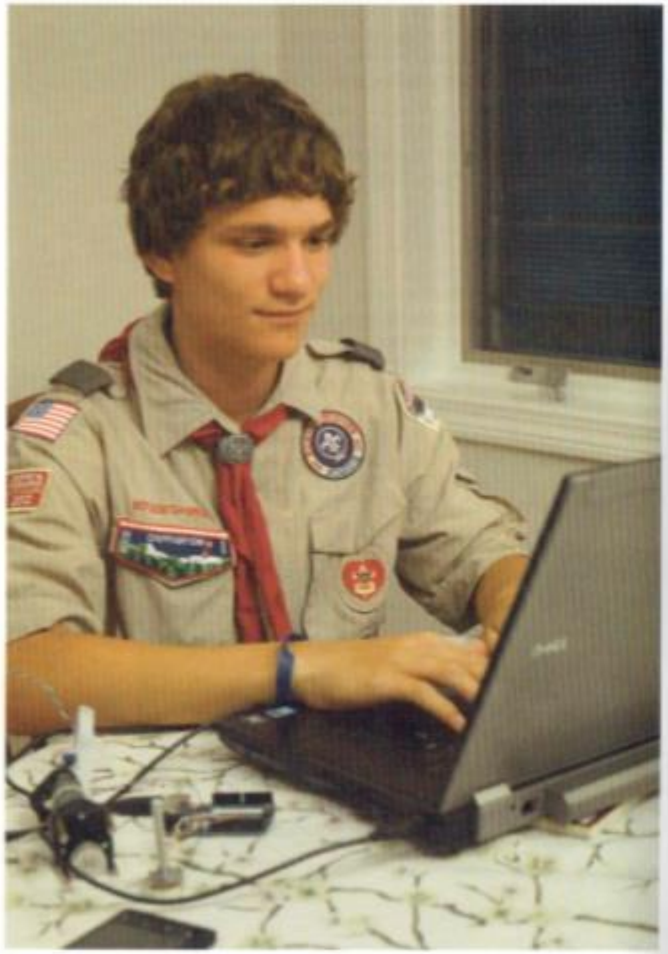
   d. Visit a recycling center that disposes of digital technology hardware or devices. Find out what happens to that waste. Share what you learned with your counselor.

   e. Find a battery recycling center near you and find out what it does to recycle batteries. Share what you have learned with your counselor about the proper methods for recycling batteries.

9. Do ONE of the following:

   a. Investigate three career opportunities that involve digital technology. Pick one and find out the education, training, and experience required for this profession. Discuss this with your counselor, and explain why this profession might interest you.

   b. Visit a business or an industrial facility that uses digital technology. Describe four ways digital technology is being used there. Share what you learned with your counselor.



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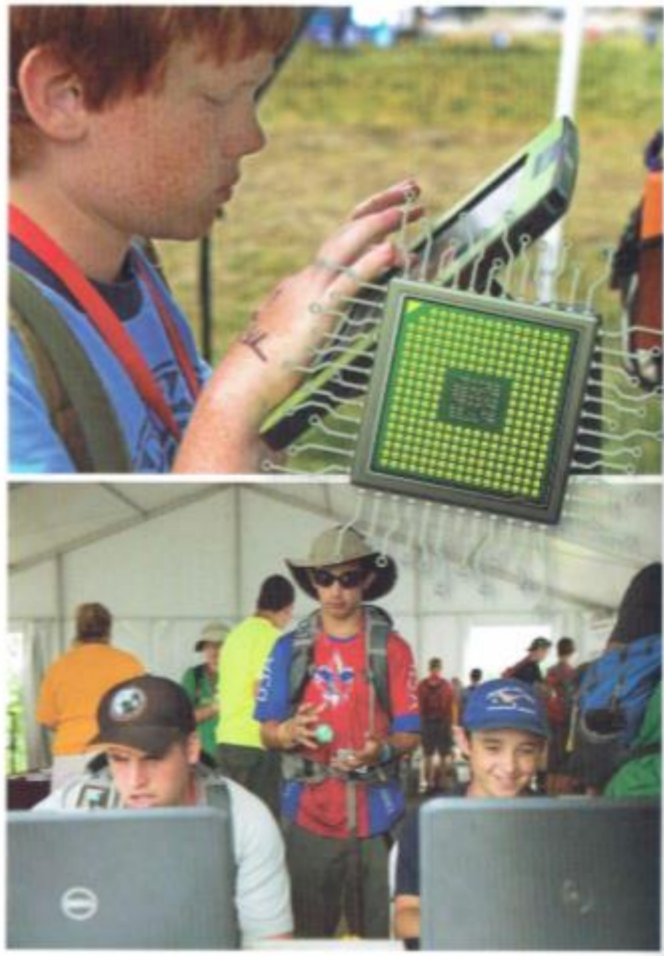


Digital Technology All Around Us

Simply put, a computer chip is a machine that can perform simple commands: adding numbers, comparing values, moving data from one place to another, all at remarkable speeds. By performing many simple calculations exceedingly fast, computers can operate robots that build cars, send pictures and words to a video monitor or printer, run fast-paced video games, and send email messages around the world.

Digital technology devices use computer chips to perform specific functions. The range of devices that use computer chips is ever-growing. The remote control for your TV, the TV itself, mobile phones, game machines, tablet computers, digital cameras, and industrial robots all depend on digital signals from computer chips.

These devices do not think on their own. Software engineers write instructions for computers called *programs*. Software programs accomplish complex tasks by performing the computer's simple yes-or-no logic more than a billion times per second. Even though some digital devices seem to have intelligence, they are actually following the exact instructions they were given, extremely quickly.

Just how quickly does a computer chip work? Using a watch or clock to time yourself, count (by ones) as fast as you can in 10 seconds. How high did you get? 50? 70? 100? An average computer chip can count (by ones) to over 20 billion (20,000,000,000) in this same time. It is this mind-boggling speed of computer chips that has been harnessed in digital devices to do the incredible things they do.

Besides counting, digital devices can process information—troop rosters, for example, or the amount of water your family used at home last month, or the measurement of a car's speed. Many digital devices can also store information to be retrieved later.

Digital Technology Is Everywhere

Computer chips are found in almost all modern machines and electronic gadgets. Often you can't see the tiny computer processors built into the device and powered by a sometimes equally small battery. But these processors make possible digital technology devices like garage door openers, DVD players, house thermostats, cameras, wristwatches, fuel-efficient vehicles, MP3 players, GPS units, and even recordable greeting cards.

Each global positioning system (GPS) satellite—an orbiting digital device in space—sends a constant stream of location data. This is interpreted by a handheld digital device (or smart phone) that converts the signals into an exact location on a map, which can tell hikers or drivers where they are.

Computers continue to be used in many more ways. A traveler's passport—the little booklet that identifies a person entering or leaving a country—now has an embedded computer chip. On the highway, a computerized tag attached to a car allows the driver to pay the toll while driving through a tollbooth without slowing down, and the car owner gets billed automatically.

Video games also use lots of computing power. These games once required a big desktop computer. But with the increased power and lower cost of computer chips, they now play with ever-better quality on ever-smaller portable devices.

Digital devices don't just make our lives easier, safer, and more comfortable. They have become essential to business, industry, science, medicine, and communication: practically every part of society. For instance, stores can track product inventories with barcode scanners and keep just the right amount of products on their shelves. When you buy a shirt at a store, the computer at the register subtracts one shirt from the inventory list so the manager knows exactly when it's time to order more shirts. This saves money because it helps the store keep the right quantity of products on hand.

The worldwide network of computers known as the Internet has revolutionized communication. Now, instead of waiting days or even weeks to receive a letter through the postal mail, people can use computers to send emails that zip around the world in seconds. Also, text messages and photos can be sent and received directly from a person's digital device. Vast databases of information are available through web browsers, mostly for free, allowing students and scientists to research from any location that has an Internet connection. People can shop online for vast arrays of items.

The team that developed this pamphlet used online meeting tools, enabling people from all over the country to collaborate on the project.

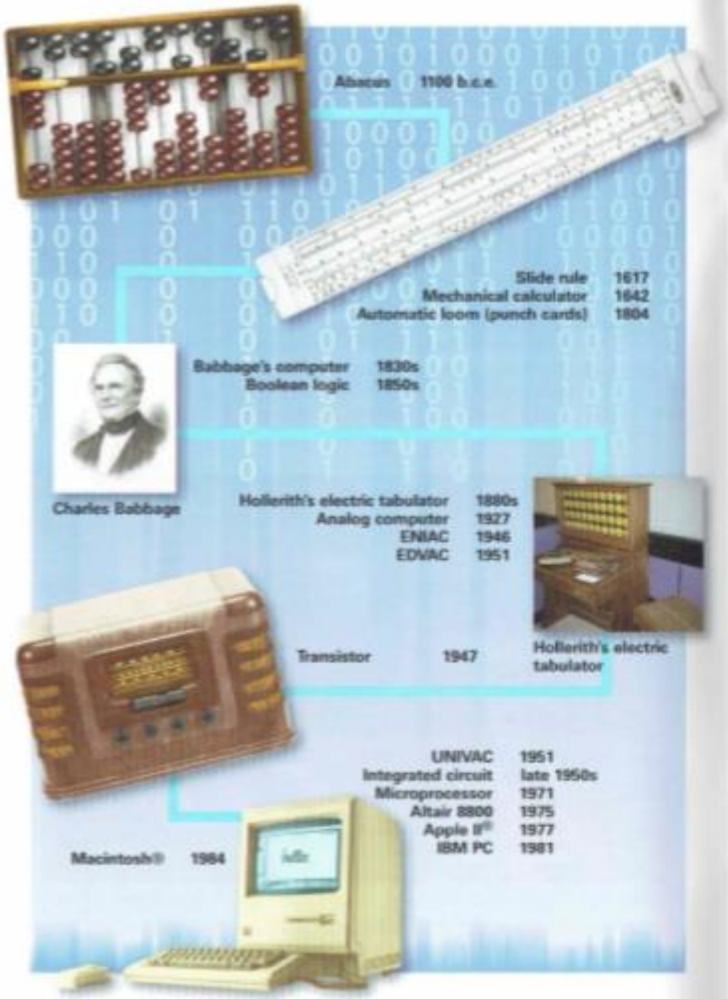
In industry, digital devices have streamlined every step of the production process through computer-aided drafting, design, engineering, and manufacturing. Advanced software programs allow products to be conceived, designed, and tested virtually—that is, before they have taken physical form. In this way, a car designer can make a three-dimensional model of the car parts, "fit" them together, and test how well they work, all without tightening one bolt. When it's time to manufacture the product, digital devices control the machines that fabricate and assemble the parts.

Using digital technology, phone companies keep track of millions of customers. They send each a detailed bill every month showing precisely which phone numbers were called, how many minutes customers talked on the phone, how much texting they did, and how much each transaction cost.

Digital technology is also common in the entertainment industry. One person using a synthesizer can make music that sounds like a whole orchestra playing. Animation workstations help artists create special effects in movies, such as making superheroes appear to jump from building to building. The video game industry is almost as big as the movie industry and it uses digital technology to produce these same special effects.

Digital technology has changed photography. Not long ago, most cameras used rolls of light-sensitive film to capture pictures. If a picture was blurry or if someone blinked, you would not know until the photo was developed. Now with digital cameras, you can take lots of pictures, delete the ones you don't like, and print only the good ones. Digital technology also makes it possible to alter a digital photo and add special effects.

With digital technology being used all around us, it's good to be aware that anything you say and do could turn up in unexpected places—even posted online by complete strangers.



History of Digital Devices

The modern computer reflects the ingenuity of many inventors, mathematicians, and philosophers working over a period of centuries, often improving on the work of others who came before them.

Today, we use handheld electronic calculators at home, school, and work. But another calculating aid, the abacus, has been around since about 1100 B.C. and is still used in some parts of the world. An abacus consists of a wooden frame with beads that slide along rods. By assigning a value to the beads and sliding them up and down the rods, users can add, subtract, multiply, and divide.

Early Math Aids

In 1617, Scottish mathematician **John Napier** invented an aid to calculation—the concept of logarithms, which simplify the task of multiplying and dividing into a form of addition and subtraction. He inscribed his logarithms on a set of calculating rods he called "Napier's bones." Soon after, English clergyman **William Oughtred** invented a device based on Napier's logarithms: the slide rule. It remained in use for the next 350 years, until the electronic calculator was invented. Like the earlier inventions, however, the slide rule was only an aid to calculation, not a true calculator.

William Oughtred

First Calculator

Blaise Pascal

The first practical mechanical calculator was invented by a French mathematician. In 1642, while still a teenager, **Blaise Pascal** invented an adding machine called the Pascaline, which worked with wheels and gears. His father, a tax collector, used the Pascaline to add up how much money people owed the government—something modern computers still do today. In 1670, a German named **Gottfried von Leibniz** improved on Pascal's invention, developing a calculator that not only could add and subtract, but also could multiply and divide.

The First Computer

In 1804, a French weaver named **Joseph-Marie Jacquard** invented an automatic loom, or weaving machine, controlled by sets of instructions coded into punched cards. Different cards held instructions for different patterns to be woven into fabrics. The idea of using coded instructions readable by a machine became the basis of computer programs, years later.

In the 1830s, English mathematician **Charles Babbage** designed plans for the analytical engine. His machine, intended to automatically produce mathematical tables for navigation at sea, consisted of four main parts, all found on today's computers:

- An input device to read instructions from punched cards
- A memory to store the instructions and results
- A processor, which Babbage called a mill
- An output device to print the tables of numbers

Babbage's analytical engine could be programmed to perform different tasks. That feature also made it like a modern computer—although the analytical engine was completely mechanical and powered by steam, not electricity.

For more about computer programs, see the *Programming* merit badge pamphlet.

Augusta Ada King, who wrote a program for the analytical engine, is considered to be the world's first computer programmer. Unfortunately, Babbage was never able to complete the machine or test it. A model of his earlier design, the difference engine, was finally built at London's Science Museum for display in 1991. It had 4,000 parts and weighed three tons.

Augusta Ada King

Boolean Logic

In the 1840s and 1850s, English mathematician and philosopher **George Boole** developed a kind of logic that allows thoughts to be expressed in mathlike terms. The basic forms of Boolean logic (also called Boolean algebra) are the AND, OR, and NOT operations.

- An AND operation is one in which two or more conditions must be true to achieve a result. For example, before you can safely cross a street intersection, the walk sign must be lit AND cross traffic must be stopped.
- In an OR operation, the result will happen if either condition is met: If it is cold outside OR if it is raining, you will put on a jacket before leaving home.
- With a NOT operation, a result happens when a particular condition is not met: You will go to school today if today does NOT fall on the weekend.

Years after Boole died, computer designers arranged electric switches to perform these operations in what became known as logic circuits, allowing digital computers to mimic human thought processes. Later still, Boolean logic would be used in Internet search engines and in specialized computer languages used to manage data in databases.

George Boole

Edison's Vacuum Tube

In 1883, a few years after Thomas Edison invented the electric lightbulb, he noticed something peculiar about how electricity flowed inside it. To protect the brightly glowing filament, air had been removed from the bulb, creating a vacuum tube. Surprisingly, if he placed a metal plate inside the bulb, electricity would flow across the vacuum from the filament to the plate. Edison patented the discovery of how electrons flowed across a vacuum, now known as the Edison Effect, though he made little use of it.

Thomas Edison

In 1906, American inventor Lee de Forest discovered that placing three electrodes inside the bulb created an amplifier. Besides making radio and television possible, this vacuum tube could also serve as an extremely fast on-and-off switch. This discovery would prove crucial in the development of digital computers.

Special-Purpose Calculators

Every 10 years, the U.S. government conducts a census, or study, to collect information about everyone who lives in the country. By 1880, the population was so large—over 49 million—that the task took seven years to complete.

To speed things up for the 1890 census, the government turned to American inventor **Herman Hollerith.** His electric tabulating machine automatically recorded punched cards prepared for every individual. The cards held information that could be presented in different ways—for example, to find out how many married people lived in Tennessee, or how many owned farms smaller than 3 acres. This machine was the beginning of automated data processing.

Soon, other companies were formed to build special-purpose calculating machines to help businesses. Eventually, universities joined in, finding scientific and military uses for the technology. These machines were one of a kind, and each had its peculiarities.

Herman Hollerith, the father of automated data processing, formed a company that would later become the giant IBM corporation.

Hollerith punched card

Massachusetts Institute of Technology engineer Vannevar Bush invented the differential analyzer, an electromechanical analog computer, in 1927.

At Harvard University, professor **Howard Aiken** worked on the Mark I computer using electromagnetic relays as switches. At the University of Pennsylvania, **John William Mauchly** and **J. Presper Eckert Jr.** designed the EDVAC and the ENIAC, using vacuum tubes as switches, which worked a thousand times faster than the relays in the Mark I.

Grace Hopper coined the term "bug" for a computer fault. The original bug was a moth that created a hardware problem in the Mark I. Hopper was the first person to "debug" a computer.

The U.S. military used first-generation digital computers like this ENIAC to calculate trajectories of artillery shells and to help build weapons.

The military used these first-generation digital computers to calculate weapon trajectories and help build atomic bombs. Each of these computers weighed tons, filled an entire room, and consumed enough electricity to light up a small town. They also required thousands of vacuum tubes, which tended to overheat and burn out, needing to be replaced often.

The "Universal" Computer

The first commercially built computer was Mauchly's and Eckert's UNIVAC. It was designed to be a general-purpose, or "universal," computer that would serve scientists, business people, and engineers alike.

The UNIVAC was a stored-program computer, meaning the program didn't have to be fed into the computer as it was running. Another innovation in the UNIVAC was its ability to take input from data on magnetic tape, rather than from punched cards. This ability made it faster and easier to operate.

Customers for the new computer—which cost about $1 million in the early 1950s—included the U.S. Census Bureau, the Air Force, and insurance companies.

The Transistor—A Major Breakthrough

In 1947, engineers **John Bardeen, Walter Brattain,** and **William Shockley** at Bell Laboratories ushered in the second generation of computers by inventing the transistor. Like a vacuum tube, the transistor had three terminals. It could function as an amplifier and a switch, but it was much smaller, used far less power, and performed thousands of times faster. Early transistors were also used in consumer products, most notably the portable transistor radio.

Silicon, the most widely used semiconductor material, is used to make silicon chips.

The Integrated Circuit—An Even Bigger Breakthrough

A major limitation of transistors was that they had to be connected to other electronic components (resistors, capacitors, and diodes) to form circuits. An early computer could have tens of thousands of transistors and other components that required tens of thousands of hand-soldered connections.

This problem was solved in the late 1950s when **Jack Kilby** of Texas Instruments, and a few months later, **Robert Noyce** of Fairchild Semiconductor, thought of the integrated circuit. The concept was simple: Instead of connecting components after they were made, manufacture them all on the same chip of silicon, with built-in connections. The integrated circuit, also called the microchip, revolutionized computing. It also made possible such products as the handheld calculator and the digital wristwatch.

The Apollo space program of the 1960s, with a mission to put an American on the moon by the end of the decade, was an early user of integrated circuits.

Integrated circuits were also used in so-called minicomputers, which, though smaller than the big mainframes of the day, still cost tens of thousands of dollars each.

The Microprocessor

In 1971, engineers at Intel Corporation, founded by Noyce, advanced the integrated circuit to a new level: They designed the first microprocessor, putting all the circuits needed for a computer's central processing unit (its "brain," which could run coded instructions) onto a single chip. This invention made the personal computer possible.

Altair 8800

Personal Computers

The Altair 8800 was an early model personal computer sold in 1975 as a mail-order kit for hobbyists to build themselves. That year, boyhood chums **Bill Gates** and **Paul Allen,** along with **Monte Davidoff,** wrote a programming language called BASIC that would run on the Altair. For a fee, they licensed the program to the computer maker and formed their own company, Microsoft®. Meanwhile, two other young friends, **Steve Wozniak** and **Steve Jobs,** were busy working on the Apple II, a personal computer released in 1977 by their new company, Apple®. Unlike most early computers, the Apple II® had color graphics. This asset made it good for games, and it became extremely popular with home users.

The year before the release of their Apple II® computer, Wozniak and Jobs had worked together making a video game for Atari, a company founded by Nolan Bushnell. Atari had already become successful by selling a console that played one video game—called "Pong"—in arcade and home versions. Pong was the beginning of the multibillion-dollar video game industry.

In 1979, **Daniel Bricklin** and **Robert Frankston** created a software program for the Apple II called VisiCalc, short for "visible calculator." The program automatically calculated rows and columns of numbers arranged in a form known as a spreadsheet. This program, which was not available for mainframe computers, helped start a trend of companies installing personal computers in the workplace.

Two years later, IBM introduced its PC (or personal computer) based on the Intel 8088 microprocessor. The PC ran its own version of VisiCalc as well as other software programs, including a word processor. IBM contracted with Microsoft to supply a form of BASIC for the new computer, as well as an operating system, the program that gets the computer up and running, and then interacts with application programs.

The original IBM PC cost $3,000 when it debuted in 1981—around $7,500 in 2012, adjusted for inflation. Today's desktop computers, thousands of times more powerful, can be purchased for only a few hundred dollars.

Microsoft later created a similar operating system, MS-DOS, for use on computers made by many different companies. The IBM PC and other computers using the MS-DOS platform dominated the business and home computer markets, helping make Microsoft one of the world's largest corporations.

Apple's Macintosh® computer also had great influence on the industry. Introduced in 1984, the Mac's operating system featured several innovations that made computers easier to use, many of which had been developed years earlier by researchers working for Xerox. These innovations included a handheld pointing device, or mouse; the use of little pictures called icons to represent programs and files on the computer screen; and a system of pull-down menus and movable screen displays called windows.

Apple II®

Despite the Macintosh innovations, the PC grew ever more popular, in part because IBM allowed other companies to sell less expensive "clones" of its PC design, while Apple did not. By 1990, Microsoft managed to incorporate many user-friendly advantages of the Macintosh into the latest version of its operating system, called Windows®.

Computers continue to drop in price and grow in power, much as they have throughout their history. In 1971, a microprocessor held 2,250 transistors; by 1993, it was 3.1 million. In early 2008, Intel® announced the creation of the first microprocessor to hold two billion transistors. Experts say this exponential growth in computing power cannot continue indefinitely.

Computers in Your Hand

Rapid increases in computing power have allowed computers to get ever smaller and faster. The early years of the 21st century saw an explosion in handheld computing devices—not only calculators, but also GPS units, which people now commonly use to find their way while driving; and personal digital assistants (PDAs), small computers that could fit in a pocket and be used as portable media players, electronic address books, mobile phones, and web browsers.

Likewise, enhanced cell phones, called "smartphones," do many tasks beyond making phone calls. This includes taking pictures, doing calculations, browsing the Internet, texting, using apps, playing games, utilizing social media, and storing information.

New software programs are continually introduced to take advantage of the increased power and to expand the ways in which we use computers.

Another category of handheld computer is the personal translator. These small, inexpensive devices act like a "speaking dictionary," so you can hear how to pronounce words and phrases in various languages and see how they are spelled on a display screen.

In recent years, tablet computers have become popular handheld devices. Tablets are generally larger than a smartphone. A tablet's touchscreen allows the user to operate the device with finger or stylus gestures. Some models have detachable physical keyboards, but a tablet computer is generally self-contained like a smart phone, with an on-screen "virtual" keyboard for typing and on-screen icons for accessing the many software applications that run on these versatile devices.

A Quick Response (QR) code is a two-dimensional bar code that is widely used to cause a Web page to download to the user's smartphone when scanned with a mobile tagging application (app).

The Web Is Born

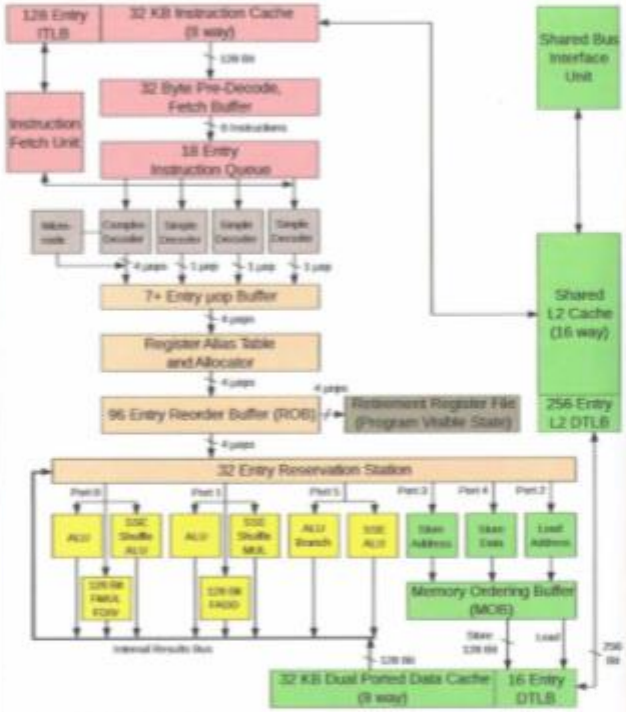
The 1990s brought another significant revolution: the rapid expansion of the Internet and the World Wide Web, linking computers around the globe and changing the way people communicate and do business. Today, many activities we used to do in person can be done by connecting our digital devices to distant computers called *servers* or via *Wi-Fi* (a wireless network access point). By connecting to a server at a bank, for example, we can transfer money from one account to another or pay bills; by connecting to the server at a library, we can renew a book we checked out; by connecting to a server at an online store, we can order all manner of products and even rent movies. Students now check assignments due and turn in homework online through a website kept by their schools or teachers. There are online colleges that grant degrees for work done through the Internet.

See "The Internet and the World Wide Web" later in this pamphlet for more about online communications.

Cloud Computing

What do you get when you combine advances in software with advances in Internet connectivity? One result is cloud computing. The term refers to the "cloud" of powerful computers (servers) scattered throughout the Internet. Increasingly, these servers provide "temporary" software that exists on a distant "cloud" and is loaded into a computer's Web browser only temporarily, while being used.

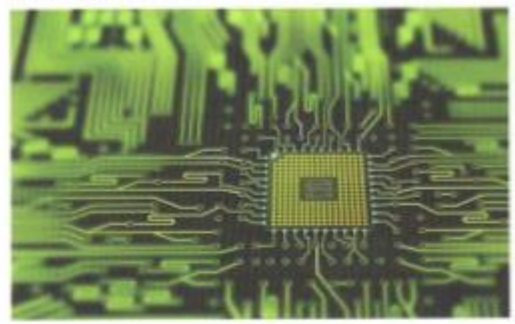
You can visit a site, upload photographs, and edit them (say, making them sharper or more colorful) without actually downloading any software. An auxiliary program that temporarily loads into the Web browser makes this possible.



Intel Core 2 Architecture

Performance of Digital Devices

Every digital device—from large multiuser computing systems to a handheld mobile device—has a central processor and memory. These fundamental building blocks determine the system performance and ultimately what kind of experience awaits the device's user.



Central Processor

The "brain" of a digital device is the central processing unit (CPU). This part has four main functions: It fetches instructions from memory, decodes those instructions, executes the instructions, and places the result back in memory. All of these functions are typically contained in a single chip mounted on a circuit board. The CPU has many different circuits all working together to process and move the data around.

Some CPUs contain multiples of these processors in a single part. A "quad-core" CPU has four CPUs on a single device. If a program is written to take advantage of the four processors, they can share the workload and complete tasks sooner.

In 1971, Intel's first processor had 2,300 transistors in it. Today's processors have more than 1 billion (that's 1,000,000,000!). The transistor has gotten ever smaller over the years, and processors are doing more in less space, allowing huge computing power to be put into small devices like smartphones and tablets.

The speed of early processors was measured in kilohertz (kHz): 1,000 cycles per second. Today's processors are measured in gigahertz (GHz) in billions of cycles per second. To get an idea of how much faster today's processors are, think of sprinting coast-to-coast across America in no more time than it would take you to walk across your bedroom.

Between 1993 and 1999, processor speeds increased tenfold. Since then, processor speeds have not even doubled. The reason for the declining rate of increase lies in the physical limitation of the silicon being used to make semiconductors.

Most digital devices have coprocessors to help the CPU with specialized functions such as graphics and sound capabilities. This further improves the system performance. Collectively, the various components that perform critical functions are known as the chipset.

Memory

The CPU and memory work closely together. Everything the CPU does comes from memory and ends up in memory. The two main types of memory are ROM (read-only memory) and RAM (random-access memory). ROM is permanent memory that remains in place even when the device is turned off. Information stored in ROM is "maintained" in BIOS (Basic Input–Output System), a small program that starts—or boots—the digital device, checks its components, and launches the operating system.

RAM is temporary memory. When you launch an application program, it is loaded into RAM. Information that you put into the device during a particular work session is stored in RAM. RAM remembers this information only while the computer is turned on. If you turn off the computer, everything in RAM is lost.

Flash card

Flash memory is a type of memory that retains data after the device is turned off but can be used like RAM. Flash memory chips are found in digital cameras, handheld computers, cell phones, USB drives, and other devices.

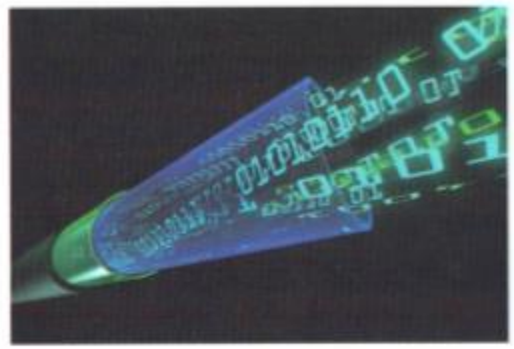
The speed of a digital device depends largely on how fast the CPU can store information into memory and retrieve information from it. In the 1960s, memory could be accessed only once every 10,000 nanoseconds (that's every 0.00001 seconds). Today, memory can be accessed every 60 nanoseconds (or once every 0.00000006 seconds), which means memory speed has improved more than 10,000 percent.

Storing Files in a Flash

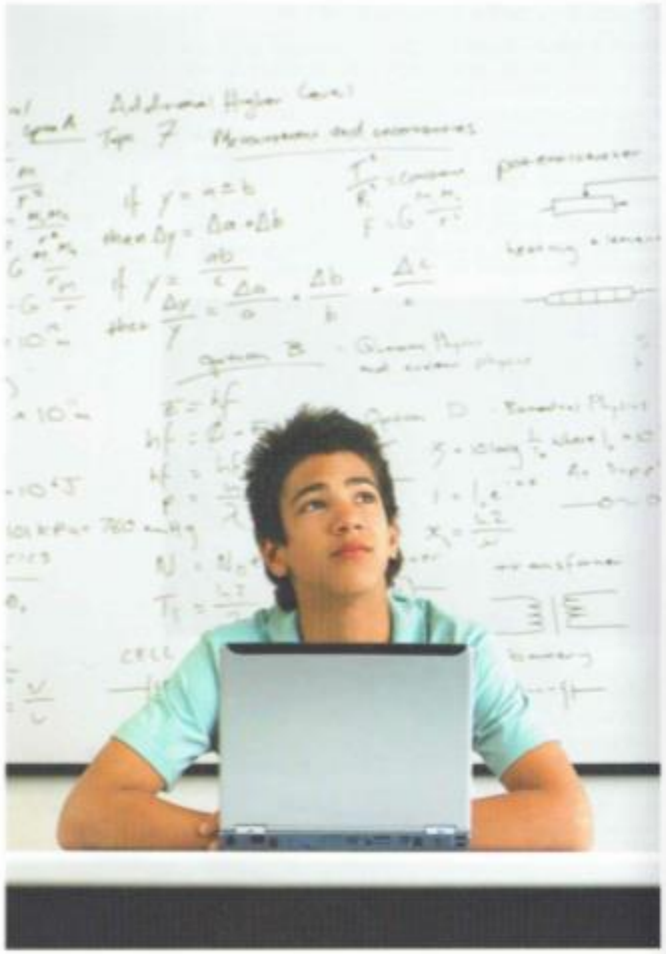
The portable USB flash drive (or thumb drive) is a handy little pocket device that allows you to easily transport files and take files anywhere you go. Just plug it into your computer's USB port and it will pop up on the screen as a portable or removable device.

Digital Device Performance

Simply having a fast processor does not guarantee a fast device. The memory needs to be fast enough to keep up with the processor, and they must be connected to each other in a way that ensures data flows freely between them. Think of driving a high-performance racing car through a crowded city. That super-fast car is slowed by stoplights, pedestrians, and other traffic. Similarly with processors and memory, if the processor can't access the memory because other devices like graphics cards also try to use the same "highway" called the data *bus*, then having a fast processor is of little advantage. Devices can be rated by the speed of this highway.



Some devices use multiple buses to improve the flow of data between the processor and memory to improve system performance.



Understanding Data and Files

Data and *information* are two terms commonly used to mean the same thing. However, each term has its own definition. "Data" refers to symbols—letters, numbers, and other characters—that may or may not have meaning. "Information" is data placed into a context that gives them meaning. For instance, a data set may include 89, 93, 85, 90, and 96. Alone, these numbers are data with little meaning. But if it is revealed that these numbers were the high temperatures of three consecutive days or a student's test scores in a course, then the data become information. Digital devices store data and can help organize data into context to make usable information.

Almost all data is stored in the form of *files*. The many different types of files include number, text, picture, sound, and video files. The type, or format, of the file is identified by the suffix, or extension—usually several letters long—that follows a dot after the file name. For example, in the file name *badger patrol.txt*, the ".txt" indicates a text file.

Software programs are set up to properly interpret specific types of files. Most programs can use multiple file formats. However, the types of files a program can interpret are typically limited to the program's function; for instance, audio players can process only sound files and not spreadsheet files.

What Extension, Please?

When creating a file name, using the correct extension is important, particularly if the file will be emailed to another computer or viewed on a Web page. If the servers that display Web pages or help send email can't read those extensions, they can't tell the receiving device what sort of file it is receiving, and the recipient won't be able to process the file.

There are thousands of different types of files and file extensions. Some can be read only by a specific brand of device or software program. However, many popular file formats can now be read on any operating system as long as the digital device is running the required software.

On many devices and in operating systems, these extensions are not displayed as commonly as they once were. In many cases, file types are distinguishable by the different icons.

Extension	File Type
Text files	
.txt	ASCII text
.doc	Microsoft Word® (word processing)
Document Files	
.pdf	Portable document format for files compatible with the Adobe Acrobat® Reader; can include text and images
Image files	
.jpg	Popular for saving photographs; adjustable compression ratio to achieve exact desired file size
.gif	Nonphotographic images such as icons, buttons, drawings, and figures
.png	Image format with better color reproduction than .gif
.bmp	Short for bitmap, a standard Windows® graphics format
.tif	Offers a lossless way to compress graphics; produces much larger file than .jpg
Presentation files	
.ppt	Microsoft PowerPoint®, a slide-based presentation program
Spreadsheet files	
.xls	Microsoft Excel®, a spreadsheet program
Sound files	
.mp3	High compression of sound data with only a slight loss in quality
.aiff, .au	Macintosh®-platform sound file
.wav	Windows®-platform sound file
.aac, .wma	High compression; even better quality than .mp3 file
Video files	
.avi	Windows® video file
.mov, .mpg, .mpeg	Movie file in Mac® or Windows® platform
Web files	
.htm, .html	Hypertext markup language
.asp, .aspx	Active server page (.aspx is used for dynamic pages)
.php	Dynamic Web pages
.css	Cascading style sheet

Storing Data

Let's look at some main types of data and how they are stored on digital devices.

For more about machine languages, see the *Programming* merit badge pamphlet.

Numbers

Think of a digital device as a collection of billions of circuits, each with just two positions, off and on. These two positions are represented by the numerals 0 and 1, which make up the binary number system. All data is stored on a digital device as groups of 0s and 1s. Each individual numeral is called a *bit*, short for binary digit. Bits are arranged in sets of eight bits, which is called a *byte*. The byte is a fundamental unit of data storage.

01000010 01101111 01111001 00100000 01010011 01100011
01101111 01110101 01110100 01110011 00100000 01101111
01100110 00100000 01000001 01101101 01100101 01110010
01101001 01100011 01100001

This binary code translates to "Boy Scouts of America."

Binary numbers do not look much like the decimal numbers we are used to seeing. For example, written as a binary number, the decimal numeral 101 is 01100101. Binary numbers make up machine code, the low-level language that digital devices translate all data into before performing operations on it.

Text

Text is stored using a special code corresponding to the numbers between 0 and 255. The code is called ASCII (American Standard Code for Information Interchange). Similar to the way it stores decimal numbers, the device represents each text character as a single byte of information. For example, the letter A is assigned the number 65 in ASCII code, which is 01000001 in binary form. ASCII text is stored without any formatting, such as indentations or boldface.

An ASCII text file is often referred to as a plain text file and can be read by almost any word-processing program. Depending on the program, you can add formatting and save the text in another format.

Pictures

Pictures are stored as a series of small dots called *pixels*. A monitor might display, for example, 1,024 x 768 pixels; each horizontal row contains 1,024 pixels, and there are 768 rows stacked vertically. In a black-and-white monitor, each pixel requires only one bit of information, telling it to display either 1 (black) or 0 (white). A grayscale monitor designates up to 256 different shades of gray between black and white for each pixel.

A device screen that is in color displays pixels with three color components—red, green, and blue. Different colors, displayed in various shades and strengths, produce the desired final color. Eight bits of information per pixel will produce 256 different colors on the screen; 16 bits will produce 32,767 colors; and 24 bits will produce 16.7 million colors—the maximum number the human eye can see, sometimes called true color.

When digital cameras take pictures, the resolution, or number of pixels, are important for the quality of the picture. Each pixel is a dot that has information of the picture in that location.

A television (old analog or today's digital) also has pixels. For example, a high definition television labeled 1080i indicates that the picture is 1920 pixels wide by 1080 pixels tall. That means each picture has about 2.1 million pixels. This is also known as 2.1 mega-pixels.

Figure 1 is a "high" resolution picture of 1.4 mega-pixels. Figure 2 is a "low" resolution picture of only 30 thousand pixels, or 30 kilo-pixels, 0.3 mega-pixels. Figure 2 has much less information on the image. It might not seem that way, but let's magnify part of the pictures, shown by the red boxes.

Figure 3 is the detail from Figure 1. Some detail is still there, but individual pixels are starting to be noticed. This is sometimes called pixelation. Figure 4 is the detail from Figure 2. The individual pixels are clearly seen. Depending on the photographer, a high or low resolution picture would be important.

Figure 1, pixels, hi-res

Figure 2, pixels, lo-res

Figure 3, pixels, med-res

Figure 4, pixels, detail from Figure 2

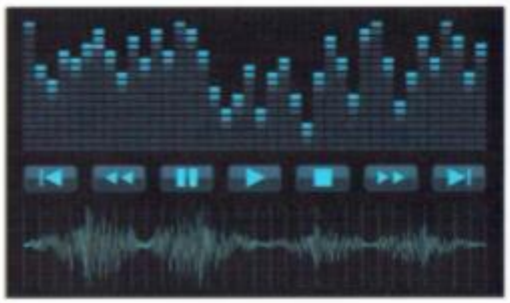
Compression

Picture and image files are stored in many different formats. Some formats use specialized mathematical formulas to compress the picture. The file takes up less disk space and is easier to email or display on the Web, but some of the original data is sacrificed. This is called *lossy* compression. Another type of compression, called *lossless*, can temporarily shrink a file by removing parts that are repeated and then, later, restore the file to its full size. Lossless compression is often used with text files and database files. Lossless compression is also used when you want to retain the original picture size.

Sound

Sound is made up of vibrations that travel through the air by passing from one molecule to the next. These vibrations are called *waves*. If you could see them, they would look like the waves at the beach. The height, or *amplitude*, of the wave determines the volume or loudness. How close together the waves are determines the *frequency*, or pitch—whether it's a bird's whistle or a boom of a bass drum and how that sounds to your ear.

A digital device "hears" through a microphone or media player, via an *analog* signal consisting of these sound waves.



The device's audio circuitry feeds this signal through an analog-to-digital converter chip that converts the signal into bits that the computer can read and save as a digital file: basically a long list of 1's and 0's. When you replay the file, the data is sent back through a digital-to-analog chip, which rebuilds the shape of the wave and sends that information to the speakers, which vibrate the air, re-creating the original sound wave that you can hear.

Video

Faster microprocessors have made it possible for devices to display moving pictures. Today's digital devices can record and store entire movies. Digital video, even when compressed, uses up enormous amounts of storage space. As storage capacity increases, ever more people will use digital devices to store and edit their video collections.

Java is one of the most popular programming languages in the world because it is free and runs on many different platforms, a quality referred to as "Write Once, Run Anywhere." Java is easy to learn if you are already familiar with another text-based language.

Computer Software

Software, a set of instructions organized into a program, is what makes hardware work. The central processing unit (CPU) uses this list of instructions to move and manipulate data in the digital device.

The three main categories of programs are operating systems, application programs, and programming languages. Operating systems control the basic operations of the computer and set up the environment for the applications to run. Application programs allow users to do specific tasks with their digital devices, such as write letters or touch up photographs. Programming languages are used to write other programs; for example, application programs.

Operating Systems

Operating system (OS) software is the foundation software on which all other programs run. This set of programs controls all of the digital device's basic operations. This includes accepting input, displaying output on the monitor or graphic display, keeping track of files and directories on the hard drive or other internal storage, and controlling peripheral devices such as disk burners, printers, scanners, speakers, and the mouse.

Because of the work done by the OS, programmers who create application software do not have to write code (instructions) into their applications to control these basic functions.

Hardware is the physical, electronic, and electrical devices that make up a computing device, such as the CPU, disk drive, keyboard, and monitor.