Module 3

Introduction

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Hardware refers to the tangible parts of a computer or digital device and typically includes support for processing, storage, input, and output.

From huge servers that support the needs of thousands of users, to slim laptops, to tiny smartwatches, computing devices share certain characteristics. They all manipulate digital data and share the same fundamental processes. By learning about these underlying processes and their components, you can develop a better understanding of what computing devices are capable of and how you can benefit from those capabilities. You can become empowered to competently use digital devices whether they are old or the latest rage. Understanding hardware will also allow you to be a wise consumer, purchasing computers and digital devices that best suit your needs.

Consider all of the computer hardware brands in existence today. Which would you say has had the biggest impact on the market in recent years? If you said Apple, you are on the mark. Apple has grown from the underdog computing platform to one of the largest PC, smartphone, and wearable manufacturers in the world. In fact, Apple has held the title of being the largest company in the world by market value since 2015! Once considered a brand appropriate only for some households, Apple is now a major force in digital technology at home, at school, and in business. Macs, iPhones, and iPads are seeing rapidly increasing adoption among enterprise users. Nearly all Fortune 500 companies approve and support iPhones and iPads on their networks.

In many cases, the move to Apple isn't the idea of corporations but originates with the employees. In a trend called BYOD (for "bring your own device"), workers who have fallen in love with their iPhones, iPads, and MacBooks at home are bringing them to work and pressuring employers to support Apple products at work. Similarly, companies have to deal with employees bringing Android phones and tablets to work.

Many people have multiple digital devices to serve different needs: desktop and laptop PCs, tablets, smartphones, and now wearables. For individuals, deciding on the best hardware requires a careful analysis of their computing and communication needs as well as of the environments in which they live and work. Special consideration must be given to processing power, storage capacity, and input and output requirements for each device. As you read this unit, consider the ideal combination of devices that will serve your needs as a professional. Also consider the computing needs of your personal and home life. Which tech company's ecosystem best serves your unique hardware needs?

Hardware is the foundation on which digital technologies and services are built. The hardware we use directly impacts our computing experiences. Hardware manufacturers like HP, Dell, Apple, Microsoft, Google, LG, Samsung, Motorola, and thousands of others compete to provide their customers with the best user experience. Whether it's a desktop computer, a mobile computer, a smartphone, or a smartwatch, if your hardware is outdated or not well suited for your activities, your experience is likely to be frustrating. Matching hardware to specific needs is an important skill for getting the most out of digital technologies.

This section explores the intricacies of hardware devices, which can be organized into three categories: processing hardware, storage hardware, and input/output (I/O) hardware. Here you will learn how microprocessors work to power computers, mobile phones, digital cameras, and a host of other digital electronic devices. You will gain insight into how to choose the best computer for your needs. You will learn about different types of storage options that provide convenient access to information and services wherever they are needed. You will also learn about new ways to interact with computers through innovative I/O devices.

In this unit you will once again face the fact that computers are becoming increasingly intelligent and that humans are becoming increasingly dependent on them for fundamental and essential tasks. While continually increasing processing speeds mean new opportunities for humanity, they also imply a tilt in the balance between responsibilities given to human intelligence and those delegated to computer intelligence.

The growing reliance on mobile computing and cloud computing supports an environment where work and communication can take place wherever and whenever possible. While some find this liberating, others feel that they can never escape the pressures of work. Streamlined interfaces like Apple's Siri, Google Now, Amazon's Alexa, and Microsoft's Cortana have provided the first step toward reliable digital assistants that are able to provide information as soon as it is needed and with very little effort. The current pace of development of hardware (and software) technologies has humanity on the brink of colossal changes in the way we live and work. As you read this unit, consider how new developments in hardware technologies impact the way you live and work.

Lesson 3.1: The Development of Computers

Lesson 3.1 Introduction

Computers were, prior to the invention of electricity, and its subsequent application to programmed mathematical and logical calculations, any mechanical device or person that performed these same calculations.

Mathematics and formal logic are disciplines that have been studied and practiced by humans throughout recorded history. Unlike more subjective disciplines, such as art, music, and literature, math and logic follow strict, unambiguous rules that solve specific problems with regular, reproducible procedures, a fact that did not escape the notice of mechanical engineers and inventors.

Ada Lovelace in 1852. Authored by: Henry Phillips, License: CC0 1.0 Universal (CC0 1.0)

Before the development of electronic computers, numerous mechanical devices were designed and built to perform many of the same tasks now handled by digital devices. In some way, mechanical clocks can be considered special-purpose mechanical computers, and the Antikythera mechanism, found in a shipwreck off the coast of the Greek island of the same name, maybe have been an early, but surprisingly sophisticated, navigational computer.

In many ways, all modern computers are successors to Charles Babbage's Analytical Engine, and all programmers are heirs to the pioneering code written for it by Ada Lovelace.

Reading: Computing History

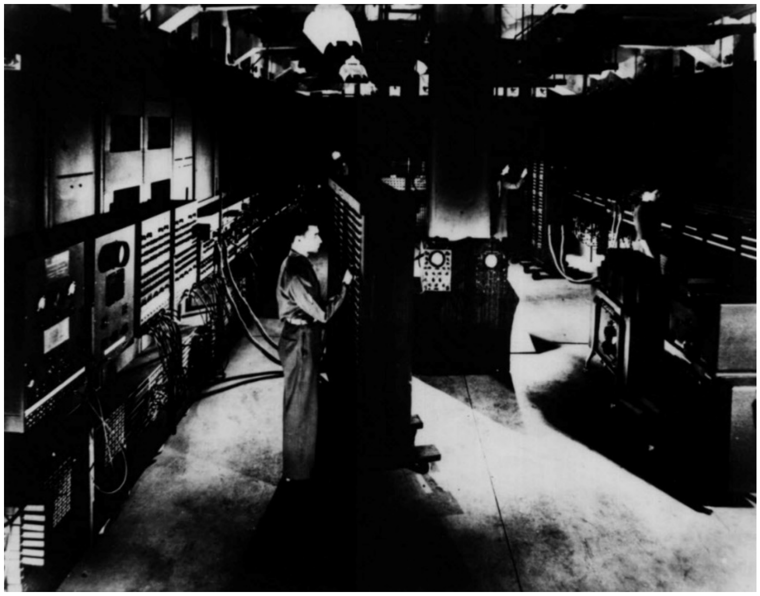
Computing History

The history of the electronic computer dates from around 1940 where it played a significant role in World War II, initially using electric relays for processing, progressing to vacuum tubes, then to diodes and transistors, and finally to the integrated circuits used today.

Why This Matters

Humankind has progressed through a series of technological revolutions, each of which has propelled us to a higher level of existence. The agricultural revolution brought a dependable source of food production; the scientific revolution brought higher-level thinking and understanding through mathematics, physics, astronomy, biology, and chemistry; the industrial revolution brought more productive manufacturing processes; and the digital revolution provided us with higher order computational capabilities, advanced communications, and powerful information processing. The computer is responsible for ushering us into the digital age. Understanding its evolution assists us in understanding its impact on humanity.

Early computers such as ENIAC filled large rooms with cabinets full of vacuum tubes, diodes, relays, resistors, capacitors, and wiring.



U.S. Army. Authored by: Collections of the University of Pennsylvania Archives, License: Public Domain

Essential Information

During the late 1930s, a German engineer by the name of Konrad Zuse, began working on a machine that could carry out Boolean operations (those that govern processing with 1s and 0s) using electrical relays like those used in telephones. Zuse's third generation of that machine, named the Z3, was completed in 1941 and is considered by most to be the first working programmable, fully automatic, digital computer. The Z3 was used to perform statistical analyses of wing flutter.

Zuse's work was cut short by World War II because computer research was not considered "war-important." Ironically, at the same time that Zuse lost his funding, enemies of Germany were busy building computers to use against Germany.

Several generations of early computers were funded by the war effort. An electro-mechanical machine called Enigma, invented by the German engineer Arthur Scherbius at the end of World War I (1918), was used for enciphering and deciphering secret messages. In 1939, at the start of World War II, England created a more sophisticated device called the Bombe to help decipher German Enigma-machine-encrypted secret messages. The battle of ciphers and code breaking became increasingly complex between Germany and its enemies. In 1943, Colossus—the first programmable electronic digital computer—was developed by British codebreakers. Colossus used 1,500 vacuum tubes and rolls of punched paper tape to test code solutions, reducing the time required to crack a code from weeks to hours.

Shortly after the war, in 1946, a computer named ENIAC was designed by John Mauchly and J. Presper Eckert to calculate artillery firing tables for the United States Army's Ballistic Research Laboratory. ENIAC is considered the first fully electronic general-purpose computer. One of ENIAC's first jobs was to study the feasibility of the hydrogen bomb. ENIAC contained 17,468 vacuum tubes, 7,200 crystal diodes, 1,500 relays, 70,000 resistors, 10,000 capacitors, and around 5 million hand-soldered joints. People joked that whenever ENIAC was switched on, lights in Philadelphia dimmed. ENIAC's input and output utilized punched cards. ENIAC inspired a whole generation of computers that used vacuum tubes to store and route bits of data.

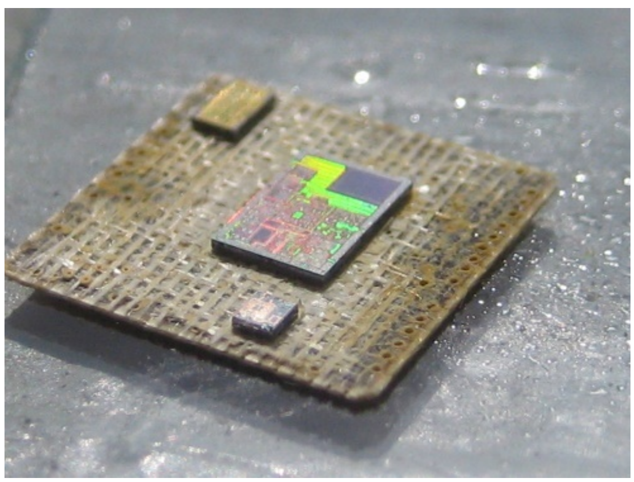
In 1947, the transistor was unveiled by Bell Labs. Transistors were able to function like vacuum tubes but were much smaller and more reliable. Computer engineers gradually moved from vacuum tubes to transistors for processing. In the late 1950s, Jack Kilby of Texas Instruments and Robert Noyce of

Fairchild Semiconductor developed a method to integrate multiple transistors into a single module called an integrated circuit. The invention of the integrated circuit (also called microchips or simply chips) allowed electrical engineers to create more complicated electrical circuits in a much smaller package.

Today, chips utilize silicon-based transistors with two types of silicon, called n-type silicon and p-type silicon for the negative and positive aspects of their electrons (shown as n and p in the figure). By applying and removing voltage to the gate and drain of the transistor, electrons are allowed to flow through the transistor or are stopped. When electricity is flowing through a transistor, it represents a 1; when it is not flowing, it represents a 0. By combining transistors and using the output from one or more transistors as the input to others, computers control the flow of electricity in a manner that represents mathematical and logical operations.

The trend in digital technologies has always been toward smaller, more powerful, and faster devices. Chip manufacturers strive to reduce the size of transistors and the connections between them so that electrons flow more quickly through the circuits. A circuit is created by combining transistors, and sometimes other components, in a manner that accomplishes a specific task. Intel was able to create a circuit for storing data in flash memory that is only 25 nanometers in size. It would take about 4,000 of these microscopic circuits to span the width of a human hair. The transistors in today's processors are so small that over two billion can be stored on a surface the size of your thumbnail.

Reading: Moore's Law



MC13224. Authored by Travis Goodspeed, License: CC BY 2.0

Moore's Law states that the number of transistors on a chip will double about every two years.

Moore's Law provides an understanding of the exponential rate of advancement in processor technologies. A processor that has double the amount of transistors is twice as fast and powerful. Using Moore's Law, we can gauge how fast processors might be in coming years.

Why This Matters

Moore's Law states that the number of transistors on a chip will double about every two years. This is illustrated by the fact that in 2006, there were 1 billion transistors on Intel's most powerful chip; and in 2008, Intel announced a chip with 2 billion transistors. Similarly, in 2008, CPUs were engineered using 45 nm technology; in 2009, it shrunk to 32 nm; in 2012, 22 nm; and now we're at 14 nm processors built into 3D processing cubes for even faster processing. Utilizing Moore's Law, one could guess at processor size and speeds over the next decade.

Essential Information

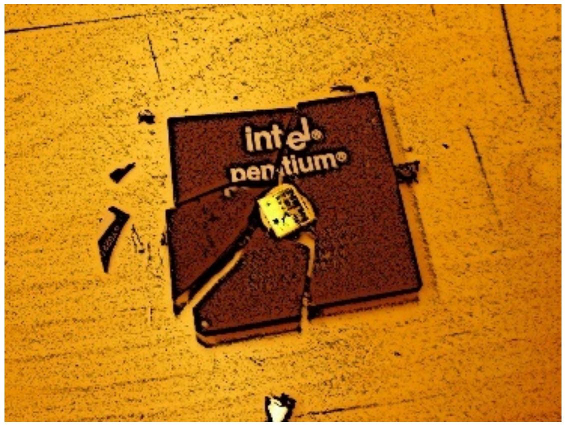
It is also important to note that most experts, including Moore himself, believe that Moore's Law will eventually exhaust itself as transistors become too small to be created out of silicon. Intel started using hafnium in place of silicon to create transistor gates and reduce the scale of transistors from 75 nm to 32 nm. Such a reduction would have been impossible using silicon gates due to the physical properties of silicon. Many other materials and processing technologies are being studied in order to continue, if not speed up, the progress of technological innovation. For example, IBM was able to store one bit of data using only 12 iron atoms, using an unconventional form of magnetism. Japanese scientists built a processor from a single layer of molecules that calculates in parallel like the human brain. Google's D-Wave quantum computer is able to process and run certain operations 100 million times faster than a traditional silicon processor. The table below lists some of the most promising new processing technologies.

New Processing Technologies

Technology	Description
High-k materials	The use of materials with a high dielectric constant (k), such as hafnium and zirconium, creates smaller transistors than silicon can support.
Optical computing	Some companies are experimenting with chips called optical processors that use light waves instead of electrical current. The primary advantage of optical processors is their speed. It has been estimated that optical processors have the potential to be 500 times faster than traditional electronic circuits.
Three-dimensional processing	Recently, Intel has made the transition from two dimensions on a thin wafer to three dimensions on a cube. Stacking wafers into 3D arrays speeds processing by allowing it to occur horizontally and vertically simultaneously.
Quantum computing	Quantum computing proposes the manipulation of quantum states to perform computations far faster than is possible on any conventional computer. A quantum computer doesn't use bits, but rather a fundamental unit of information called a quantum bit or qubit. The qubit displays properties in adherence to the laws of quantum mechanics, which differ radically from the laws of classical physics.
DNA computing	DNA computing, or molecular computing, is a very promising new technology emerging from nanotechnology and based on DNA. Israeli scientists built the first "programmable molecular computing machine," composed of enzymes and DNA molecules, that can perform 330 trillion operations per second—more than 100,000 times the speed of the fastest PC.

Lesson 3.2: Processors

Lesson 3.2 Introduction



smashed cpu. Authored by: fab:ian, License: CC BY 2.0

Processing carries out the instructions provided by software, using specially designed circuitry and a well-defined routine to transform data into useful outputs.

Processing is at the core of computing. Understanding how processors function can help users appreciate the abilities and limitations of computers and can be of great value when shopping for computers.

Digital devices process bits of data into useful information and services. The output from processing can include life-changing information like the genetic code for human DNA, or it could be poll results for a presidential election, an entire 3D animated motion picture, a cell phone conversation, or the music you listen to on your way to class. Any type of output from a digital device is the result of processing.

New types of processors are released every year, each one more powerful than its predecessor. Processors are designed to excel in a particular type of activity. There are processors designed for computer graphics, for general-purpose personal computing, for artificial intelligence, for industrial use in mainframe computers, and for use in special-purpose computers like ebook readers, digital cameras, and medical equipment.

This section takes you on a tour of processors: how they work, what different types are available, and how they interact with other components in a computer to process data into information.

Reading: Central Processing Unit

Central Processing Unit

The **central processing unit** (CPU) is a group of circuits that perform the processing in a computer, typically in one integrated circuit called a microprocessor.

Why This Matters

The development of the CPU enabled computer engineers to further consolidate transistors from several chips and circuit boards to a single chip called a microprocessor. The CPU is a microprocessor that governs all actions that a computer of any type carries out.

Essential Information

Over time, the number of transistors on a chip increased as technology enabled them to be produced on increasingly smaller scales. Processing became faster because electrons had shorter distances to travel. In the early 1970s, it became possible to fit all the circuitry needed for a computer on one chip. The CPU, or microprocessor, was born.

The CPU is made up of many components. The quality of its components establishes the quality of the CPU. The following table lists the main components of a CPU along with their functions.

CPU Components

CPU Component	Function
Control unit	Sequentially accesses program instructions, decodes them, and coordinates the flow of data in and out of the ALU, the registers, RAM, and other system components, such as secondary storage, input devices, and output devices
Arithmetic/logic unit (ALU)	Contains the millions of circuits created to carry out instructions, such as mathematical and logical operations
Registers	Hold the bytes currently being processed
Cache	A temporary storage area for frequently accessed or recently accessed data; speeds up the operation of the computer; size measured in megabytes (MB)
Clock speed	Speed of the processor’s internal clock, which dictates how fast the processor can process data; usually measured in GHz (gigahertz, or billions of pulses per second)

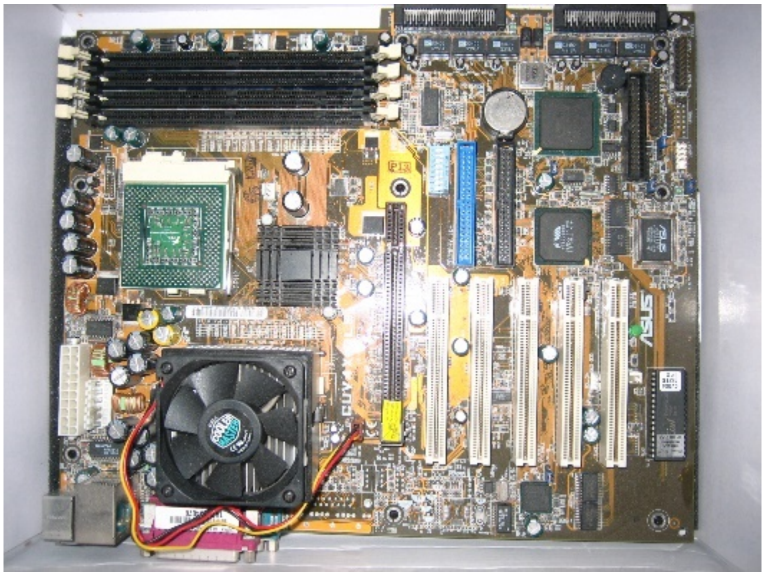
Most of today’s computers use microprocessors that contain multiple CPUs, or cores. Multicore processors, such as dual core (two processors) and quad core (four processors), use an architecture that allows the cores to work together for faster processing. Intel has recently developed 3D processing technologies that allow multiple surfaces of circuits to be joined together in 3D connections. Rather than a single plane of circuits, 3D processing utilizes processing cubes.

CPU performance influences the quality of the device that it powers. No one enjoys waiting for information to be delivered. A state-of-the-art CPU can deliver information and services nearly instantaneously. For this reason, devices using top-of-the-line CPUs are more expensive than others with less powerful CPUs. Other components can also affect device performance, including size and type of RAM, bus speed, size and type of graphics processor and memory, and network bandwidth. Of these components, the processor has the greatest impact on quality and price.

Multiprocessing, also called parallel processing, is processing that occurs using more than one processing unit to increase productivity and performance. The most powerful computers in all categories rely on multiple processors working together to solve problems. From the Mac Pro PC, which can be configured with two 6-core processors, to China’s TaihuLight supercomputer, which has 10.65 million processing cores, multiprocessing defines ultimate processing power.

Reading: Motherboard

Motherboard



Motherboard. Authored by: Iwan Gabovitch, License: CC BY 2.0

The **motherboard** is the primary circuit board of a computer to which all components are connected, including the CPU.

Why This Matters

The motherboard connects all of a computer's components and enables them to communicate. Both general-purpose and special-purpose computers utilize motherboards.

Essential Information

Desktop PCs, laptop PCs, tablets, smartphones, smartwatches, servers, supercomputers, and almost all digital electronic devices have a motherboard that holds system components and allows outside devices to be connected to the system components.

A typical personal computer motherboard includes a socket for the microprocessor, RAM, ROM, expansion slots, and many other components, along with electrical pathways called buses that connect the components.

There are different types of buses that connect different system components. The most important bus on a PC motherboard is the front front-side bus, or FSB. On Intel processors, the FSB connects the CPU to the northbridge, a memory controller hub that controls access to RAM and graphics systems. The FSB feeds data and instructions to the CPU at least as quickly as the CPU can process those instructions. For that reason, FSB speed is important and is typically listed with the specifications of a computer.

The motherboard dictates the form factor of the system components. It may be small and tightly packed with components for tablets or smartphones. Or, it can be large and spacious with powerful components and advanced cooling systems.

Small, inexpensive motherboards containing entire computer systems and costing less than $40, have inspired a generation of makers and hackers. Amateurs and professionals alike are using circuit boards from Arduino and Raspberry Pi to build all kinds of electronic gadgets from robots, to objects on the Internet of Things, to fully functional computers. They are also used as standard computers in poorer regions of the world where standard computers are too expensive to afford—just hook up a keyboard, mouse, and display and you're ready to go!

Lesson 3.3: Storage Devices

Lesson 3.3 Introduction

Storage. Authored by Marcin Wichary, License: CC BY 2.0

In computing and digital technologies, **storage** refers to the ability to maintain data within the system temporarily or permanently.

Breakthroughs in storage technologies have empowered individuals to access information anywhere and anytime, easily share information with others, and maintain huge libraries of documents, music, photographs, movies, and other digital information—sometimes in a device no larger than a fingernail.

Storage technologies allow us to carry billions of bytes of data in our pockets to access anywhere, anytime.

Many different types of storage are available to support a wide variety of computing needs. From fast access RAM that supports today's fastest processors to robotic-delivered magnetic tape cartridges storing petabytes in storage silos, storage is accessed at varying speeds. From ultra-portable micro SD cards and USB flash drives to optical CDs, DVDs, and Blu-ray discs, to huge terabyte hard drives accessed directly on a device or wirelessly in the cloud, storage has many forms and various capacities.

Storage devices and technologies vary in terms of access speed, capacity, portability, and price. Storage media that provide faster access speeds are generally more expensive than media that provide slower access.

The term storage device is used for the hardware that stores and retrieves data. The term storage media is used for the material on which the data is stored. A DVD drive is the storage device, and the DVD is the media where data is stored. In some cases, the device and media are considered one and the same, such as with USB drives and hard drives.

RAM, random access memory, is also called primary storage because it is the main store for data being processed. Secondary storage refers to permanent storage that holds data without the need for electricity. Other forms of storage include ROM (read read-only memory) and graphics memory.

Secondary storage can be classified as either sequential access, as in the case of tape, or direct access, as with disks. Methods of storage include magnetic storage, optical storage, and solid-state storage. A storage device may be located on the computer or device in use, in which case it is considered local storage; or it may be accessed over a network, in which case it is considered network storage. Data may also be stored on Internet servers, in which case it is called cloud storage. This section covers these technologies and shows the benefits and drawbacks of each.

Reading: System Storage

aluminum MacBook memory upgrade. Authored by: blakespot, License: CC BY 2.0

System Storage

System storage refers to storage used by a computer system in its normal operations, which includes RAM, ROM, and video memory.

Why This Matters

The processor works hand-in-hand with system memory, from the moment a computer is turned on to the time it is powered off. System memory provides the instructions required to start the computer. Instructions and information is shuffled in and out of system memory as the processor runs software. Without system memory, the processor would not function.

Essential Information

Read-only memory (ROM) provides permanent storage for data and instructions that do not change, such as firmware—programs and data from the computer manufacturer, including the boot process used to start the computer. ROM stores data, using circuits with states that are fixed. Therefore, the data represented by this combination is not lost if the power is removed. ROM stores a program called the BIOS (basic input/output system). The BIOS stores information about your hardware configuration along with the boot program. The boot program contains the instructions needed to start up the computer. After running some system diagnostics, the boot program loads part of the operating system into RAM and turns over control of the processor to the operating system.

Random access memory (RAM) is temporary, or volatile, memory that stores bytes of data and program instructions for the processor to access. RAM acts as the primary storage area in a computer for software and the data that it works with. RAM plays a crucial role in computer systems and can contribute to or detract from a computer's performance. Having too little RAM or using low-quality RAM that cannot deliver instructions quickly enough to the processor can cause a computer to drag. Typically, computer manufacturers install RAM in a computer to match the processor's abilities. Today's

PC operating systems and software require at least 1 GB of RAM for minimal performance quality. Even the most basic computers today come with at least 4 GB of RAM.

RAM exists as a set of chips grouped together on a circuit board called a single in-line memory module (SIMM) or a dual in-line memory module (DIMM). Most of today's PCs use DIMMs, which have a 64-bit data path—twice that of a SIMM. RAM DIMMs are inserted into slots in the motherboard near the processor. A new desktop computer typically comes with two or four RAM slots, half of which are occupied with DIMMs and half left available for future expansion. Laptop computers typically have two RAM slots. Tablet computers and smartphones have embedded RAM not designed for access by users.

Video memory, sometimes called video RAM, VRAM, or graphics memory, is used to store image data for a computer display in order to speed the processing and display of video and graphics images. Video memory and graphics processing provide important capabilities for today's graphics-intensive computer systems. Microsoft Windows, Mac OS and today's demanding 3D computer games require high-capacity video memory and sophisticated graphics support to provide a rich and realistic graphics environment for work and play.

Reading: Magnetic Storage

Magnetic Storage

Magnetic storage is a storage technology that uses the magnetic properties of iron oxide particles rather than electrical charges to store bits and bytes more permanently than RAM.

Why This Matters

Data stored in a computer's RAM is temporary and only available while the computer is powered on. Magnetically stored data lasts years, even decades, before deteriorating. Magnetic storage, in the form of a hard disk drive (HDD), provides an inexpensive, high-capacity form of permanent storage that acts as the main storage medium in most low-end desktop and laptop computers.

Essential Information

In magnetic storage, a surface is coated with a layer of particles that are organized into addressable regions (formatted). In the process of reading and writing data, a read/write head passes over the particles to determine, or set, the magnetic state of a given region. Two types of media use magnetic storage: disks and tapes.

Magnetic disks are thin steel platters. When reading data from or writing data onto a disk, the computer can go directly to the desired piece of data by positioning the read/write head over the proper track of the revolving disk. Thus, the disk is called a direct access storage medium.

Magnetic disk storage varies widely in capacity and portability. Fixed hard disk (hard drive) storage has large storage capacity—storing terabytes of data on many new laptop and desktop PCs. For these reasons, personal computers rely on the hard drive as the main secondary- storage medium. External hard drives connect to a computer through its USB port and provide a convenient extension to storage or a backup medium to safeguard data. With the price of solid -state drives (SSDs) dropping, many computer manufacturers are moving to SSDs over HDDs since they are much faster than HDDs at delivering data. All Apple MacBooks use SSDs.

Magnetic tape is used by businesses and organizations that need to store and back up large quantities of data. Similar to the kind of tape found in the old audio or video cassettes, magnetic tape is Mylar film coated with iron oxide particles. Magnetic tape is an example of a sequential access storage medium because data is written and read in sequential order from the beginning of the tape to the end. Although access is slower, magnetic tape is usually less expensive than disk storage. For applications that require access to very large amounts of data in a set order, sequential access is ideal. For example, government agencies, such as the U.S. Census Bureau, and large insurance corporations store large quantities of data on tape.

Businesses and organizations often provide large quantities of storage to employees over a network. Server computers can provide a central store for important corporate data for employees to share. Arrays of disks can be formed and used in groups to handle terabytes of data. A technology called a storage area network, or SAN, links many storage devices over a network and treats them as one huge disk. Cloud storage utilizes magnetic disk drives connected to Internet servers to make them accessible anywhere, anytime.

Reading: Optical Storage

Optical Storage

Optical storage media, such as CDs, DVDs, and Blu-ray discs, store bits by using an optical laser to burn pits into the surface of a highly reflective disc.

Why This Matters

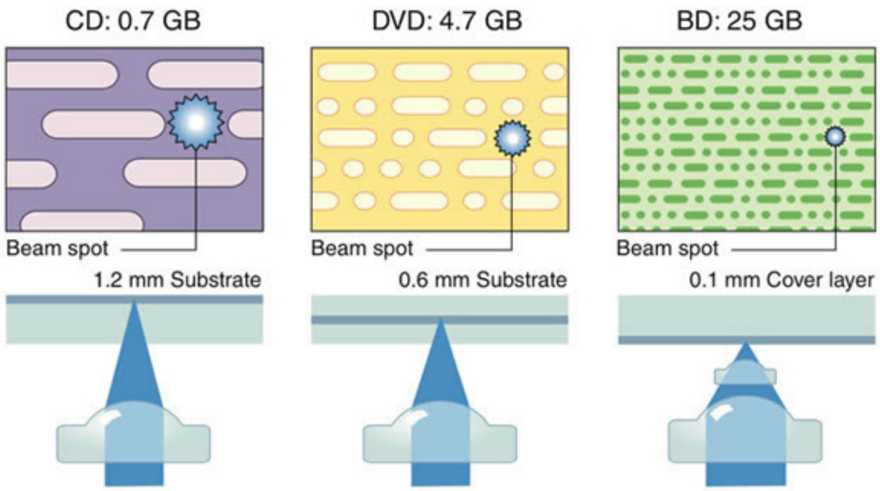
Optical storage provides an extremely portable storage medium for quantities of data up to several gigabytes. Although it does not match the high capacity and data access rates of magnetic and solid-state storage, it is ideal for storing music, movies, photos, software, and data for mobile access and sharing.

Essential Information

The 1s and 0s stored on optical discs are read from the disc surface by using a low-power laser that measures the difference in reflected light as it passes over pits burned into the disc surface. Audio CDs that store music, data CDs that store software and computer files, and DVDs and Blu-ray discs that typically store motion pictures and high-def movies all use the same fundamental technology. See the table at the bottom of this page for more details.

The popularity of the CD and DVD rose with the introduction of recordable optical discs. The process of writing to an optical disc is sometimes called burning. Manufacturers use R to indicate that a medium is recordable; that is, it can be written to only once. RW, for rewritable, is used to indicate that a disc can be rewritten numerous times just like a hard drive. Some new PCs come with a combination drive that functions as a CD and DVD burner. Some support Blu-ray as well. Most ultrabooks are so slim that there isn't room for an optical disk drive.

Since users are increasingly accessing software, music, and movies from the cloud rather than from DVDs, the need for optical disks is diminishing. MacBooks and other super thin laptops have sacrificed their optical drives for a thinner body. Users of these laptops that want to access optical disks must purchase an external device.



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Optical Media

Media	Description
CD	A compact disc read-only memory (CD-ROM), commonly referred to as a CD, is an optical medium that stores up to 700 MB of data. CDs are used for music distribution, software distribution, and various forms of data storage.
DVD	A digital video disc read-only memory (DVD-ROM) stores more than 4.7 GB of data in a fashion similar to CDs, except that DVDs can write and read much smaller pits on the disc surface and can sometimes write to and read from multiple disc layers. Unlike a CD, a DVD can store an entire digitized motion picture.
Blu-ray	Blu-ray discs (BDs) make use of the shorter wavelength of blue light to read and write even smaller pits on the optical disc surface for higher capacity. Just as the DVD was developed primarily for motion picture distribution, Blu-ray was developed for high-definition movie distribution. A single-layer disc (25 GB) can hold a 135-minute high-definition movie and still have room for two hours of bonus material in standard definition. Two-layer discs storing 50 GB are available, and there is talk of 100 and 200 GB versions coming soon.

Reading: Solid-State Storage

Solid State Drive. Authored by: ericnvntr, License: CC BY 2.0

Solid-State Storage

A **solid-state storage** device stores data using solid-state electronics such as transistors and, unlike magnetic and optical media, does not require any moving mechanical parts.

Why This Matters

Magnetic storage devices have high capacity and are convenient in terms of read and write ability, but they have slow data access rates due to the use of mechanical moving parts. Optical storage media is convenient in terms of mobility but has limited storage capacity and is slow to write to. Solid-state storage devices offer fast access times because they have no moving parts. They are also increasing in capacity, and dropping in price each year and can store nearly as much as hard drives. As the cost of solid-state storage continues to decrease, it will continue to replace uses of magnetic storage on many devices.

Essential Information

Solid-state storage devices store data permanently without any moving parts or the need for electricity. Flash memory is a form of solid-state storage that updates (flashes) the data it holds in large blocks. Unlike other secondary storage, such as magnetic disks and tapes and optical CDs and DVDs, flash memory requires no moving parts to read and write data. It is therefore much faster and much quieter, requires less power, and produces less heat. Because of these significant benefits, solid-state storage looks to be the wave of the future. The slightly higher price of the technology is the only thing holding it back from replacing other forms of secondary storage; however, prices are rapidly dropping. Solid-state storage devices include flash memory cards, USB flash drives, and solid-state drives.

A flash memory card is a small chip encased in a plastic housing that stores data permanently without the need for power. Flash chips are small and can be easily modified and reprogrammed, which makes them popular in computers, smartphones, digital cameras, and other products. When used in devices such as digital cameras, camcorders, and digital music players, flash memory cards are sometimes referred to as media cards. Secure Digital (SD) cards, mini SD cards, and micro SD cards are popular flash memory cards for mobile phones, digital cameras, and other devices that need to store a lot of data in a tiny package.

A flash drive—also called a USB drive or thumb drive—is a small flash memory module about the size of your thumb or smaller that conveniently plugs into the USB port of a PC or other digital electronics device to provide convenient, portable, high-capacity storage. Although they are called drives, they contain no moving parts. A 64 GB flash drive can be purchased for around $15.

As flash drives grow in capacity and capability, they are threatening the future of magnetic hard drives as the first choice for secondary storage in PCs. Samsung produced the first solid-state disks (SSDs) using flash technology to replace the traditional magnetic hard drive in PCs. An SSD reads data 300 percent faster and writes data 150 percent faster than a traditional hard drive. It boots up a computer much faster, is lighter and more durable, uses less power, and runs cooler and quieter than a hard drive (in fact, it is silent). SSDs are being used in MacBooks, ultrabooks, and small, light sub-notebooks and are making their way into the mainstream market. SSDs are also used as the storage media for tablets, smartphones, and digital media players.

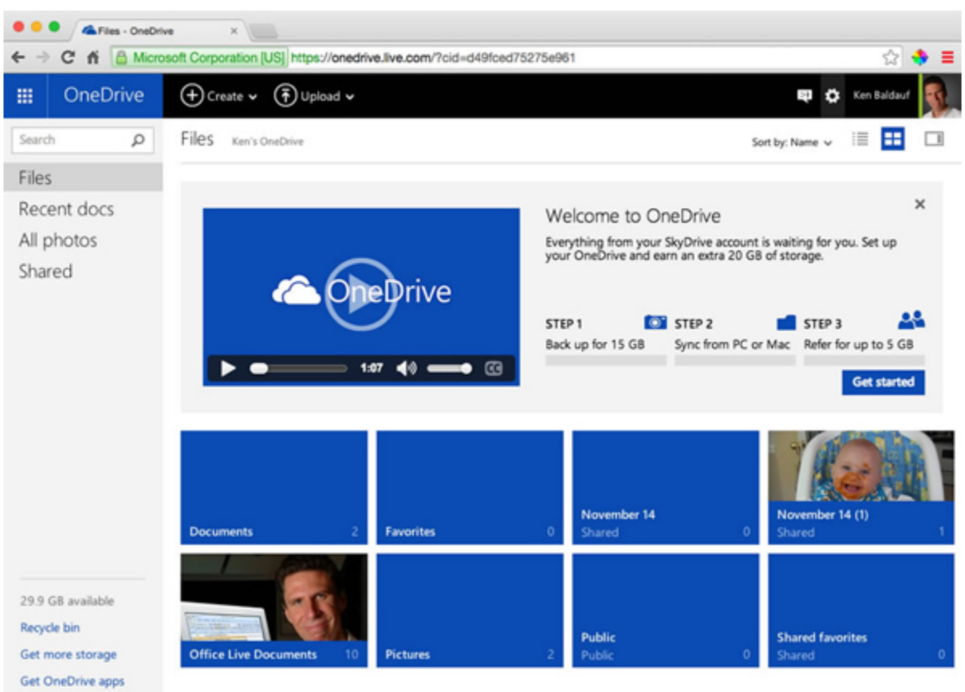
Reading: Cloud Storage

Cloud Storage

Cloud storage stores data on Internet servers for access from any Internet-connected device.

Why This Matters

Cloud storage is fundamentally changing the way people use digital technologies. It offers important benefits, including the ability to store files and media in a single location for access from any location or device. Also, it makes it easy to share and collaborate on files. The drawback is that if you lose Internet connectivity, you may no longer have access to your files.



Authored: Courtesy of Microsoft Corporation, License: Fair Use

Essential Information

People are storing increasing amounts of data and information online. Photos are uploaded to Facebook, iCloud, or some other online service; movies and music are streamed from Netflix, iTunes, Amazon, or Google; email, calendar, and contacts are stored online; and more and more files are being stored on Microsoft OneDrive, iCloud, Google Drive, Dropbox, and other services.

A few years ago, the Internet was given a new catchy name: the cloud. The name comes from the use of a cloud image to represent the Internet on network diagrams. Many functions and services that used to be managed by local computers, are now being managed by Internet servers in “the cloud.” Storage is among the most useful of those services.

The ability to store and access files and media from the cloud across all of your devices has eliminated the need to manually “sync” files between devices. It has also made sharing documents with others much easier. Several group members can edit a single document. Each person’s edits are marked for easy reference. Versioning features allow old versions of a document to be accessed.

Microsoft, Google, and Apple allow members generous amounts of storage space for documents. Cloud storage is an important consideration when choosing a technology ecosystem. The more files that are stored in the cloud, the more difficult it becomes to move them to a new cloud storage provider. This is especially true for media such as movies, music, and books.

The down side of cloud storage is that, usually, documents and media are not available unless you have access to the Internet. This can become a significant problem in underserved areas. The most popular cloud storage services now have tools that allow users to store copies of documents on their devices for access while offline. It is easy to imagine a time in the not-too-distant future when the idea of storing files on a device will be an unusual concept. Someday you will be telling your grandchildren about the old days, before the cloud, when files were stored on drives.

Lesson 3.4: I/O Devices

Lesson 3.4 Introduction

Non-shiny new X220 keyboard. Authored by: Kai Hendry, License: CC BY 2.0

I/O refers to **input and output** —the manner in which data is received into a computer system, and the manner in which information and the results of processing are provided to the user.

Users interact with computers through input and output (I/O) devices. Of all the computer hardware components, I/O devices have the most direct impact on a user’s computing experience. To accommodate a wide variety of data and the many environments in which data is processed, there are literally hundreds of different input devices on the market. By learning about input devices, you also learn what computers are capable of. Output devices connect directly with our senses. Although most output from a computer is visual, much is auditory, and some more exotic devices even affect our other senses.

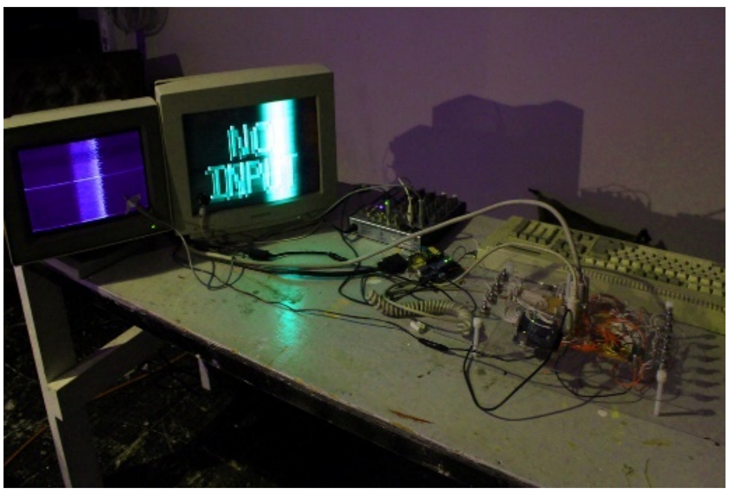
Personal computers typically use only a handful of I/O devices. Nearly everyone is familiar with the keyboard, mouse, display, and printer. More recent product designs present new methods of input. Touch pads and multitouch displays make it simple to navigate the interfaces of mobile devices. Speech recognition systems like Siri, with audible responses, make it possible to interact with devices without touching a thing or looking at a display.

Professional environments sometimes require specially designed input devices in order to capture data more directly. From drawing tablets used by graphic artists, to magnetic ink character readers used by banks, to bar code readers used at the supermarket, a variety of input devices have been designed to accommodate the unique needs of professionals.

In addition to input and output devices, many computers accommodate other types of devices, such as wireless adapters and external storage. Many different types of devices can be connected to computers and mobile devices to expand their capabilities. One example is a sensor that can be connected to an iPhone to test food for allergens. The ability to increase the capabilities of a computer system by connecting external devices, referred to as peripherals, is called expansion.

Reading: Input Device

Input Device



No input - Arcanebolt. Authored by Rosa Menkman, License :CC BY 2.0

An **input device** assists in capturing and entering data into a computer system.

Why This Matters

Getting data into a computer system rapidly and accurately is the purpose of input devices. Some activities have very specific needs for input, requiring devices that perform specific functions. For example, many reporters use digital recorders to record and transcribe human speech to ease the stress of typing late-breaking stories. The more specialized the application, the more specialized the associated I/O device. Self-checkout systems include many input devices such as touch screens, keypads, bar code scanners, sensors, and scales.

Essential Information

Different types of input devices are designed to accept different types of data. Human-readable data can be directly read and understood by humans. A sheet of paper containing lists of customers is an example of human-readable data. In contrast, machine-readable data is read by computer devices. Customer data that is stored on a disk is an example of machine-readable data. It is possible for data to be both human-readable and machine-readable. For example, people and computer systems can both read the scantron sheets used for some multiple-choice exams.

Regardless of how data gets into the computer, it is important that it be captured near its source to avoid data entry errors. Source data automation involves automating data entry where the data is created, thus ensuring accuracy and timeliness. Source data automation is used by librarians who use scanners to check out and check in library materials. Rental-car companies use automated scanners that scan vehicles as they exit and enter the rental lot. The scanner collects data on the vehicle, including gas gauge data, mileage, date, and time, and prepares a customer invoice before the customer returns to the counter.

Input devices can be classified as either general-purpose or special-purpose. A general-purpose input device is designed to be used for a wide variety of computing activities. This category of I/O devices includes keyboards and mice. A special-purpose input device is designed for one unique purpose. An example of a special-purpose input device is the pill-sized camera from Given Imaging, called the PillCam, which, when swallowed, records images of the stomach and the small intestine as it passes through the digestive system.

Reading: General-Purpose Input Device

General-Purpose Input Device

A **general-purpose input device** is an input device that is designed to be used for a wide variety of computing activities.

Why This Matters

Many computing activities across platforms have common input needs. For example, many computer devices require a way in which to input characters and to select items on the display. For these purposes, a keyboard and pointing device are ideal. There are many different variations of these two common general-purpose input devices. On mobile devices, input is typically accepted through touch screen and voice commands.

Essential Information

QWERTY keyboards, named after the first five characters used in the keyboard's design, are alphanumeric data entry devices used on all types of personal computers as well as mobile devices. They provide fast, one-character-at-a-time input for users with keyboarding skills. Some variations on the traditional QWERTY keyboard are available, including Microsoft's ergonomic keyboard, which that was designed to reduce the risk of carpal tunnel syndrome (CTS). Soft keyboards (or software keyboards) provide a picture of a keyboard for typing on touch-sensitive displays. They are used primarily on tablet computers and smartphones. Some people have difficulty typing on soft keyboards due to the lack of tactile feedback. Soft keyboards also take up valuable screen real estate. External keyboards can be connected to tablets to make typing easier and to reclaim screen space.

Several types of pointing devices are used to select objects on a display. A mouse is used on desktop and laptop PCs to move the mouse pointer on the display. On laptop PCs, a touch pad can be used in place of a mouse. On devices with touch screens, a pointing device isn't necessary since the user simply touches the display to select items.

Touch screens used on some smartphones, tablets, and kiosks, allow the user to select items on the screen by touching them directly with a finger or stylus—a pen-like device. Some touch screens support handwriting recognition, enabling the user to write letters or words on the display with a stylus and automatically translating them into ASCII characters through the use of artificial intelligence. Multitouch displays allow the user to use two, three, or up to all 10 fingers on a touch display to manipulate objects on the display. For example, two fingers moving apart on the screen causes an object to zoom in, the opposite motion zooms out, and a twisting motion rotates an object.

Microphones serve as yet another general-purpose input device. Microphones can take human speech as input, digitize the sound waves, and use natural language processing to translate the input into dictated text that appears on the screen or into commands. Apple’s Siri, Google Now, and Microsoft Cortana, and Amazon Alexa, serve as AI-driven personal assistants to send messages, request information, schedule meetings, place phone calls, and complete other tasks.

Speech recognition software can also be used to take dictation, translating spoken words into text. Voice recognition, a similar technology, can be used by security systems to allow only authorized personnel into restricted areas.

Reading: Special-Purpose Input Device

Special-Purpose Input Device

Input devices. Authored by Marcin Wichary, License: CC BY 2.0

A **special-purpose input device** is designed to provide input for one specific type of activity.

Why This Matters

Many software applications require unique input devices to input specialized types of data in a convenient and reliable manner. The medical profession utilizes hundreds of such devices to collect biological information. Businesses use varying types of scanners to automate the collection of standardized information. Special-purpose input devices are available for nearly every industry and for many personal applications.

Essential Information

Video game enthusiasts enjoy specialized input devices that let them quickly react to game action. Most gamers prefer to use a game controller device to control game characters and objects; some games, such as flight simulators, are easier to navigate using a joystick, a device resembling a stick shift. The Nintendo Wii brought entirely new forms of input to gaming, utilizing motion sensors in handheld controllers to control gaming action, and with Wii U, a tablet controller with a second display. Microsoft developed Kinect, a motion motion-detecting controller for the Xbox that allows gamers to control game characters just by moving their body. The Kinect can also be used to control television programming with hand gestures and voice. Leap Motion designed a gesture control input device that can be attached to a laptop computer. Games designed for smartphones make use of the built-in accelerometer, which allows for controlling game-play by holding the device at different angles. Guitar Hero and Rock Band video games make use of toy instruments that act as input devices to play virtual instruments in the game.

A digital camera can be connected to a PC or embedded in a laptop computer to provide photo and video input to the computer. A webcam is an inexpensive video camera that has become popular for video chat over the Internet.

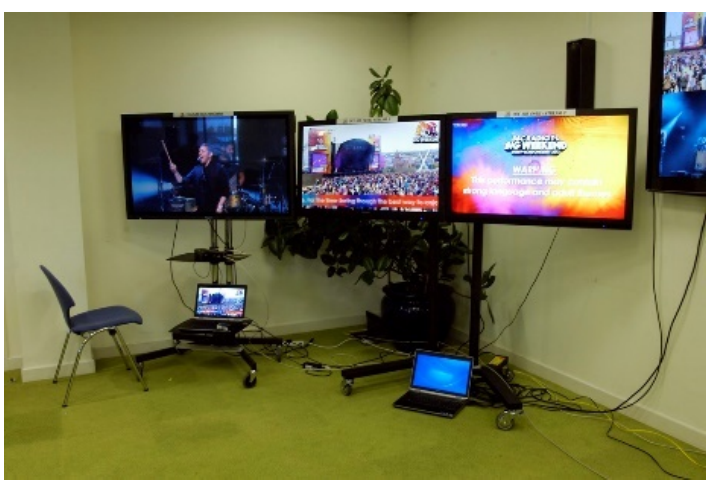
You can input both image and character data using a scanning device. Both page scanners and handheld scanners can convert monochrome or color pictures, forms, text, and other images into digital images. Biometric scanners and software can verify an individual's identity by examining biological traits such as retinal or iris patterns, fingerprints, or facial features.

Businesses and organizations use a number of special-purpose scanners and optical readers to collect data. A magnetic ink character recognition (MICR) device reads special magnetic-ink characters such as those written on the bottom of checks. Optical mark recognition (OMR) readers read "bubbled-in" forms commonly used in examinations and polling. Optical character recognition (OCR) readers read hand-printed characters. Point-of-sale (POS) devices are terminals or I/O devices connected to larger systems, with scanners that read codes on retail items and enter the item number into a computer system.

Card swipers are yet another way to collect data into a computer. Card swipers are used to verify the identity of individuals wishing to access secure locations. Card swipers are also used to facilitate credit card transactions. Devices from Square and PayPal allow smartphone users to use their phones as card swipers to conduct credit card transactions over the Internet. Wireless technologies such as near field communication (NFC) are beginning to replace card swipes. Using Google Wallet or Apple Pay, customers can swipe their smartphones across a receiver pad at checkout to pay for their purchases. This is an example of how output from one device can serve as input to another.

Reading: Output Device

Output Device



Output. Authored by Steve Bowbrick, License: CC BY 2.0

An **output device** allows a user to observe the results of computer processing with one or more senses.

Why This Matters

Output devices communicate the results of processing to the computer user. Output devices are evaluated by the efficiency and effectiveness with which they communicate different types of information in different types of environments. A good output device delivers information—visual, audio, or other—in a manner that allows the information to be interpreted easily and, in some situations, enjoyably.

Essential Information

Computer output consists of the results of processing produced in a manner that is observable by human senses or that can be used as input into another system. Output can be visual (on a display or printed page) or audio (through speakers or headphones). In the case of virtual reality systems, output can even be tactile and olfactory to recreate realistic environments. High-quality output can provide realistic impressions. Telepresence uses large high-def displays and surround sound to allow individuals to meet around a virtual conference table and hold meaningful remote discussions without the need for travel.

Output from one system can be provided to another system as input. For example, a smartphone can be used as a remote control for a television, and a GPS navigation system can be used to control an auto-pilot system on an unmanned aerial vehicle (UAV).

Reading: Display

Display

A **display** provides visual computer output for observation on a monitor or screen.

Why This Matters

The most common form of computer output is visual on a display. There is a wide assortment of displays and display technologies, each designed to provide an appropriate quality image for specific environments and applications. From checkout counter displays to hi-def television displays, from small smartphone displays to jumbo LCD displays at stadiums, displays are an ever-increasing part of our daily lives.

Essential Information

Remarkable progress has been made with display screens (sometimes called monitors), including those used with personal computers. With today's wide selection of monitors and displays, price and overall quality can vary tremendously. The table below lists the primary types of display technologies used today.

The first consideration when selecting a display is typically size, measured diagonally, from corner to opposite corner, across the screen. Many sizes are available to meet every computing and media need. Smartphone displays range roughly from 3 to 5 inches; tablets and ebook readers from 5 to 10 inches; 11 to 17 inches for laptop computers; and 17 to 27 or more inches for desktop displays.

There are several types of display technologies in use today (listed in the table at the bottom of this page). Most computers use LCD (liquid crystal display) technology, although LED (light-emitting diode) and OLED (organic LED) are becoming more common on high-end laptop PCs. The trend has been toward technologies that provide clearer, crisper images that require less power. Perhaps the only exceptions to this trend are ebooks. The original ebook reader, the Kindle, sacrificed image quality for lower power consumption. The e-ink displays used in the early ebook readers do not use a backlight, are easy to read in outdoor light, and provide a monochrome image that is ideal for displaying the pages of a book.

Traditional computer displays use a 4:3 format: four units wide and three units tall. More recently, a widescreen format has become popular that uses either a 16:9 or 16:10 ratio. Widescreen formats are used by motion pictures and are also handy for viewing documents side-by-side on the display.

The quality of a display image is often measured in pixels—picture elements, that combine to form an image on a display. Display resolution is a measure, in width by height, of the number of pixels on the screen. Display resolutions range from 1334-by-750 for an iPhone 7, to 2880-by-1800 for a 15″ laptop display, to 3840 × 2160 resolution for a top-of-the-line 78″ 4K Ultra HD Smart TV, to 5120- by- 2880 for a top-of-the-line 27″ desktop computer display. Note that the 27″ desktop display actually has a higher resolution than the 78″ HD TV, which works well because the audience is sitting much further back from the TV than the computer user is sitting from the display.

A video card (graphics card) controls the video output for computers. These circuit boards combine video processing and storage onto an expansion card or integrate them onto the motherboard to manage video images for display. Today's high-end graphics cards include a graphics processing unit (GPU) to process the graphics and take the load off the CPU. They also include video memory, video BIOS, and a RAM digital-to-analog converter or RAMDAC. Support for special 3D processing in high resolution and highly detailed colors and shading may also be included. The quality of the graphics card has a big impact on the virtual environments of computer games.

Today's display technologies offer many options for televisions as well as computers. High definition TV (HDTV) delivers a resolution of 1920×1080p, called 1080p, that is more than twice that of traditional television displays for sharper, crisper images. HDTV uses a widescreen format, which means it uses the same height and width ratio used in movie theaters. HDTVs have begun using OLED technology to produce even sharper images with deeper blacks on large displays that consume less power than plasma or LCD TVs. The latest TV display technology is called Ultra HDTV (UHDTV) or 4K for short since it delivers roughly 4,000 horizontal pixels (3840 x 2160 to be precise), that's twice as many pixels delivered by 1080p hi-def.

3D displays use polarization technologies that generally require the viewer to wear special glasses to experience the 3D effect. These displays add depth and realism to sports, movies, and computer games. Content providers are working hard to create content that takes advantage of 3D displays. Manufacturers are working to refine 3D technologies so that viewers need not wear special glasses. 3D displays have also been used for handheld games, smartphones, and computer displays.

While 3D televisions aren't selling as manufacturers had hoped, virtual reality (VR) systems sales are increasing significantly. VR systems use headset displays that place the wearer right in the middle of the action. Augmented reality uses glasses that allow the wearer to see the real world with computer-generated objects overlaid across the scene.

Display Technologies

Technology	Description
Liquid crystal display (LCD)	A thin, flat display that uses liquid crystal—an organic, oil-like material—placed between two pieces of glass to form characters and graphics images on a backlit screen. LCDs are popular for all types of personal computers and televisions.
Plasma display	A thin, flat display that uses plasma gas between two flat panels to excite phosphors and create light. Plasma displays are used primarily for televisions and compete head-to-head with LCD in that market.

Technology	Description
Light emitting diode (LED) display	A thin, flat display that utilizes LEDs to provide the backlight for the display rather than the fluorescent light used in traditional LCDs. LED is gaining in popularity as a green technology that uses less energy, does not require the use of mercury in its production, and presents a bright, brilliant image.
OLED (organic light-emitting diode)	Similar to LED, with the ability to create the best picture quality of any technology with deep blacks and brilliant colors on a super-thin display.
Electronic paper (e-paper)	A technology that does not use backlighting like other display technologies but instead uses pixels made of particles or oils that reflect light to more closely resemble the pages of a book. E-paper requires less energy and is easier to see in outdoor lighting but is impossible to read in the dark. E-paper is used for ebook readers like the Kindle, although some more recent ebook readers use color LED displays.
Flexible display	Samsung and others are working on delivering flexible displays that provide color images on a flexible film of plastic. The new technology not only provides some interesting new display applications but also provides us with displays that won't shatter if you drop them.
Cathode ray tube (CRT) display	Deep, relatively bulky display that uses a large vacuum tube in which an electron gun shoots an electron beam rapidly across a fluorescent screen to create moving images. CRT displays have effectively been replaced by thin display technologies.
Head-up display (HUD)	A transparent display that presents data as a layer on top of a normal field of view. Used by fighter pilots, and more recently by the general population with the release of Google Glass, a glasses-mounted display, and Microsoft Hololense.
Virtual reality (VR) headset	A headset strapped over the head covering the eyes with a box containing two displays (one for each eye) that provide a 3D view of a virtual world that can be navigated with hand controls and viewed by rotating the head.
LCD projector	LCD projectors are designed to project presentations from your computer onto a larger screen. Typically costing thousands of dollars, these portable devices are a must-have item for businesspeople who make presentations to large audiences.

Reading: Printer

Printer

Printer. Authored by: projectidea, License: CC BY 2.0

A **printer** is an output device dedicated to providing computer output printed on paper.

Why This Matters

Computer users often wish to create printed copies of the work they've created. It may be output that is as simple as a grocery list, or it may be something as serious as a work of art ready for framing. There are many types of printers that provide varying quality of paper-based output, as well as specialized printers that produce three-dimensional output.

Essential Information

A useful and popular form of output is called hard copy, which is paper output from a printer. A variety of printers with different speeds, features, and capabilities are available.

The speed of a printer is typically measured by the number of pages printed per minute (ppm). The quality of resolution of printers is similar to the resolution of displays. A printer's output resolution depends on the number of dots printed per inch. A printer with a 600 dots-per-inch (dpi) resolution prints more clearly than one with a 300-dpi resolution. When shopping for a printer, consider the quality of the output (judged by resolution specs and personal evaluation of the printed copy), the speed of the printer (pages per minute or ppm), the price of the printer, and how quickly the printer consumes toner or ink along with the price of toner refills. Also consider which printers work with your computer platform. Not all printers work with Mac computers, for example. The initial investment in a printer typically pales in comparison to the price of toner or ink cartridge refills over time.

Some printers combine printing capabilities with other useful functions. All-in-one, or multifunction, printers combine printing, copying, and faxing functions. Wi-Fi printers connect to your home or work Wi-Fi network so that they are accessible to any device on the network. More recent innovations, such as Google's Cloud Print, allow printers to connect to the Internet so they can be accessed from any computer with an Internet connection.

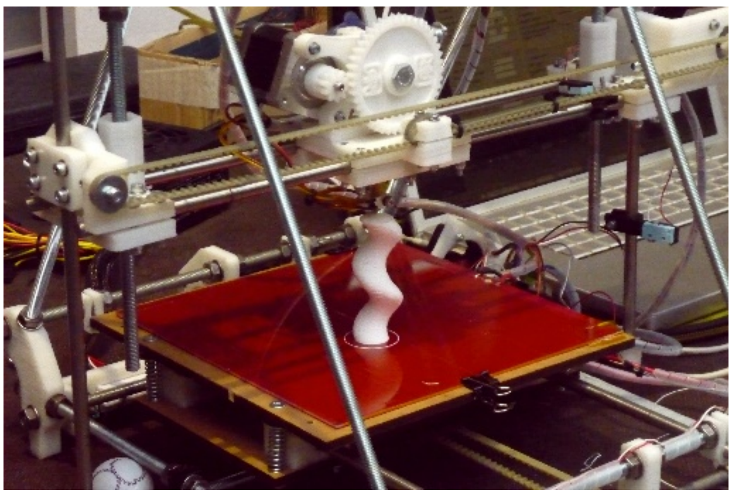
Types of Printers

Printer Type	Description
Laser printer	A laser printer uses techniques similar to those of photocopiers to provide the highest-quality printed output. Color laser printers can be rather expensive, so many home users settle for either

Printer Type	Description
	a less expensive black and white laser or a color ink-jet printer.
Ink- jet printer	An ink-jet printer sprays droplets from ink cartridges onto paper to create pixels. Although ink-jet printers create good-looking hard copy, it is not quite as polished as what laser printers provide. Also, ink may run if it gets wet, so use care when printing addresses onto envelopes and hope they aren't delivered on a rainy

Reading: 3D Printer

3D Printer



3D printer. Authored by Mirko Tobias Schäfer, License: CC BY 2.0

A **3D printer** builds 3D objects by adding one layer of material at a time from the bottom up until the object is completed.

Why This Matters

Just as digitization changed the world by allowing us to represent real-world objects digitally, 3D printing is changing the world by allowing us to turn bits into tangible objects. 3D printing is empowering individuals to transform ideas into usable objects, powering the "maker" revolution. In addition to inspiring hobbyists, 3D printing is transforming every industry from healthcare to food and fashion, to engineering and manufacturing by allowing professionals to test ideas, and easily manufacture custom products.

Essential Information

Many people have seen or heard about simple 3D printers that print small plastic objects. These printers are available at Walmart, Home Depot, and other retail stores for around $1,000. Using these consumer-grade printers and raw material called filament, individuals can print out small toys and novelty items as well as useful utensils for the home.

What many people don't realize is that these small consumer 3D printers make up only a small portion of the 3D printing movement. Today, people are printing in just about every available material, including plastic, nylon, wood, clay, concrete, and metals, and even glass and carbon fiber using printers ranging in cost from $500 to $500,000.

A more sophisticated and accurate name for 3D printing is additive manufacturing. There are four techniques for additive manufacturing, shown in the table below:

3D Printing (Additive Manufacturing) Techniques

Technique	Description
Fused deposition modeling (FDM)	A model is produced by extruding small beads of material, which harden quickly to form layers.
Granular materials binding	A model is produced by laying out one layer of powder at a time and applying heat or liquid to selective areas of each layer to bind the powder into a solid.
Lamination	A model is produced by bonding layers of a material—typically sheets of paper—and cutting each layer at specific points.
Stereolithography	Produces a solid part from a liquid polymer one layer at a time, solidifying the polymer with UV light.

3D printers print objects from an STL (stereolithography) file (STL stands for stereolithography). There are several ways to acquire STL files. Many printers come with a catalogue of files to print. They are also freely available at thingiverse.com. Another way to acquire STL files is to scan physical items with a 3D scanner. A final way to produce an STL file is to create it from scratch using CAD or 3D design software such as AutoCAD, Maya, Rhino, Blender, or Tinkercad.

3D printing is most useful for rapid prototyping and customization. Rapid prototyping allows engineers and designers to experiment with designs for parts and products quickly and easily. Prior to 3D printing, it was costly and time consuming to have models created from designs. 3D printing is especially useful for creating one-of-a-kind products, something costly and time consuming for traditional mass production systems.

The following table shows how 3D printing is impacting many professions and industries.

3D Printing Professional Uses

Profession	Possible uses
Engineer, architect, interior design	3D printing allows these professionals to test their designs and view them in three dimensions rather than on the computer screen.
Sculptors, potters, and artists	3D printing is being used to create sculpture and ceramics. Artists can create works of art with clay or other materials and then further craft the objects with their hands.
Construction	Using massive 3D printers, buildings and building parts can be constructed in any shape and design that can be imagined.
Physicians	Bio printing is a form of 3D printing that builds organs from stem cells.
Chefs and nutritionists	3D printing makes it possible to create food items from specific ingredients in a variety of shapes to meet an individual’s nutritional needs and tastes. Meat and leather are being printed from cow cells. Chefs are creating candy confections from chocolate and sugar.

Profession	Possible uses
Fashion	Designers are printing shoes, headwear, jewelry, and even clothing from a variety of materials in unique shapes and forms.
Education	Classroom lab objects and manipulatives can be printed for a fraction of the cost that schools typically pay. Museums are also making their collections available to download and print.

Reading: Audio and Special Media Output

Audio and Special Media Output

Speakers. Authored by futureshape, License: CC BY 2.0

There are a number of **audio and special media output** devices designed to provide output to all of the senses.

Why This Matters

Since the early days of the PC, speakers have been used to provide audio output to users. With the development of mobile digital media devices and their rapid adoption by the public, headphones have become popular for enjoying audio output. As computer scientists work to create more realistic virtual environments, output devices have been designed to provide information to all of the senses.

Essential Information

Most of today's personal computers include at least low-quality speakers to output sound. Sound is used by the computer's operating system and other software to cue the user to certain events—for example, the flourish of music that plays when Microsoft Windows starts up and shuts down. Other event-driven sounds draw the user's attention to important information, such as a beep when something goes wrong or a ding when a new text message arrives.

Sound systems also support entertainment applications. Headphones are used for portable digital music players and mobile phones or in situations where the user wishes to listen to media without disturbing others.

Multimedia and video gaming enthusiasts often purchase more expensive sound systems for their computers. For example, a surround sound system with a subwoofer can provide additional realism to games in a virtual reality simulation or to a hi-def movie.

A computer's ability to output sound is particularly important to make computing more accessible to individuals with limited vision. Screen-reader programs, such as JAWS by the Freedom Scientific Corporation, read aloud the text displayed on the screen.

Output devices have been designed for every human sense. When you silence your mobile phone, you may set it to vibrate to alert you to arriving calls. Output that you can feel is referred to as haptic output. Digital scent technology includes a USB device that can deliver thousands of fragrances as commanded by the computer. One company even produced an experimental printer that printed flavored pieces of paper for tasting samples sent over the Internet.

The area of virtual reality has produced a number of unique and interesting I/O devices as well. For example, the virtual reality headset—a type of head-mounted display—can project output in the form of three-dimensional color images. Spatial sensors in the headset act as input devices, and when you move your head, images and sounds in your headset change. Virtual reality devices allow architects to design and "walk through" buildings before they begin construction. They allow physicians to practice surgery though virtual operations and pilots to simulate flights without ever leaving the ground. Head-mounted displays have entered the consumer market in the form of opaque spectacles that allow the user to view video from a media player or computer.

Reading: Expansion

Expansion

Expansion refers to a computer's capacity to interface with a variety of external devices, such as I/O devices, network devices, and storage devices, by connecting through ports, slots, and wireless technologies.

Why This Matters

Many computer systems accommodate different types of I/O devices as well as network connections and external storage. The ability to increase the capabilities of a computer system by connecting external devices, referred to as peripherals, is called expansion. Expansion allows computer users to enjoy computing benefits above and beyond those provided by the computer alone.

Essential Information

Most computers provide users with the means to add devices and expand their computer's functionality. A desktop computer user might wish to add a video card for high-quality gaming; a laptop user might want to add a cellular connect card to gain access to the Internet; and a tablet user might want to add a Bluetooth keyboard for more convenient typing.

The universal serial bus, commonly referred to as USB, was invented to standardize computer interfaces around one type of connection. Today's computers come with a number of USB ports that all kinds of devices can use. It is not unusual to find six or more USB ports on a new computer, into which you can plug the keyboard, mouse, and additional devices of your choice, such as mobile phones, digital cameras, network devices, musical instruments, joysticks, memory modules, and other devices, all using a common connector design. USB provides not only a connection to the computer for data transfer but also a power line that can be used to power a number of useful and entertaining gadgets, such as keyboard lights, fans, hard drives, and even miniature Christmas trees. There are three versions of USB, each faster than the previous. The fastest, USB 3.0, is used on many of today's new PCs.

More specialized peripheral devices may come with their own circuit board, called an expansion board or expansion card, to be installed in a desktop computer. Installation of these devices is not as convenient as simply plugging in a USB connector, but typically it is straightforward. The method of installing expansion cards varies from machine to machine, so users should consult their owner's manual for specific instructions.

Wireless technologies can also be used to expand the capabilities of a computer. For example, a cell phone can be connected to a headset over a Bluetooth wireless connection to provide hands-free operation.

