1st Class

Computers & Networks Organization

تركيب الحاسبات والشبكات

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Lecure1:

Introduction

Computer: electronic device that accepts input, stores large quantities of data, execute complex instructions which direct it to perform mathematical and logical operations and outputs the answers in a human readable form. (See fig. 1)

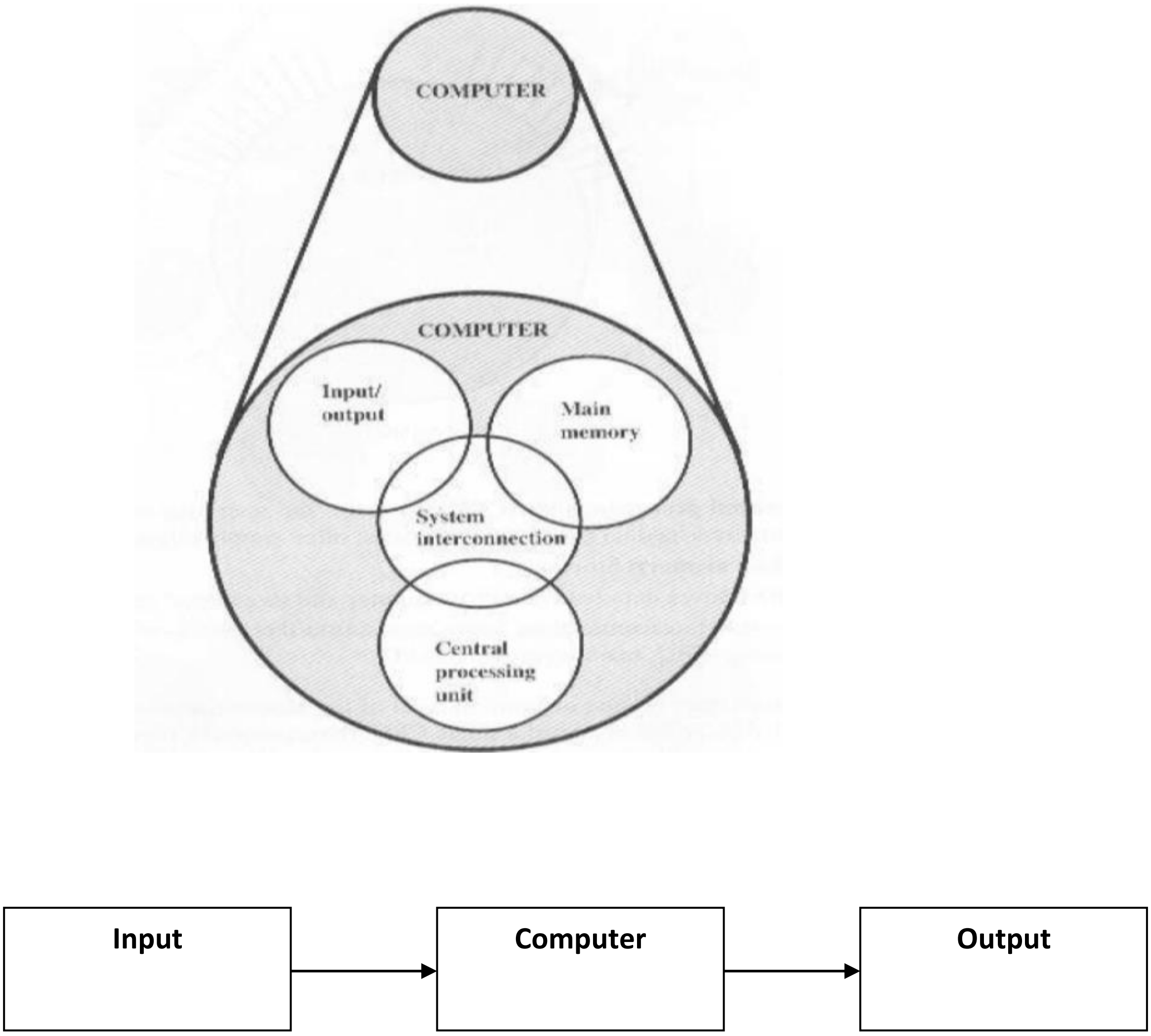


Figure (1) Simple computer Model

Another definition: computer is a complex system; computer contains millions of elementary electronic components.

Advantages of computer system: -

1- Store and retrieve large quantities of data.

2-The speed is faster than in any other form of data processing.

3-A single computer can perform a wide variety of activities as directed by a set of instructions (program).

4-Once data and instructions are fed into the computer, processing is continuous with a minimum of human intervention.

5-Data and programs may be stored inside the computer indefinite and be retrieved quickly.

6- Accuracy is greater than any other system.

Computer generation:

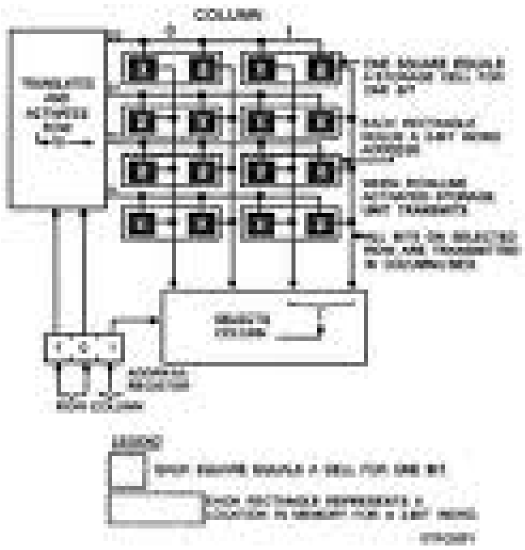
1- The first generation from 1946 to 1958 used electronic valves and frequent breakdowns and a rise in temperature due to the large size and weight. Use complex programming language.

2-The second generation from 1958 to 1964 used transistors instead valves, small size, low cost, and high speed. Use high programming language.

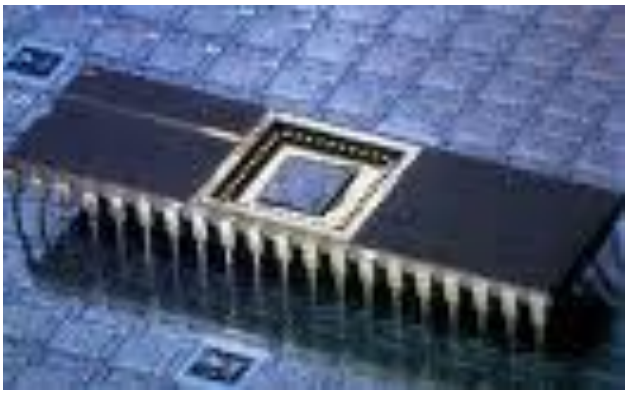
3- The third generation from 1965 to 1970 used complete circuit electronic, high speed, accuracy operations, and uses more users. Use high programming language.

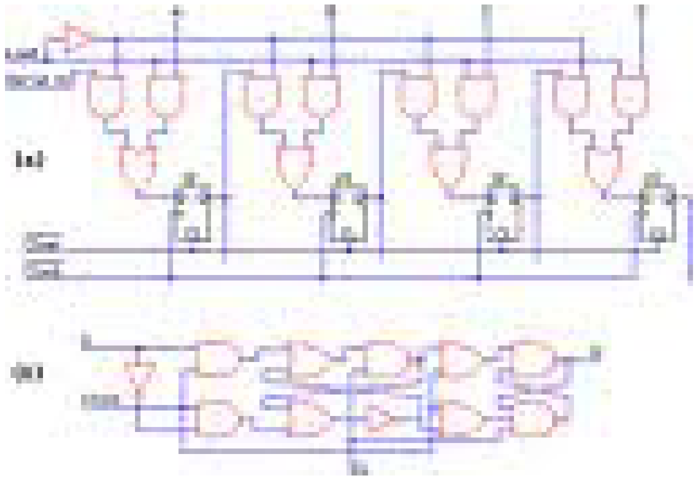
4- The fourth generation from 1971 to 1980 used complete circuit electronic involves large number of transistors, small size, high speed in save data and information.

5- The fifth generation from 1980 to 1997 uses complete circuit electronic very large and very high speed. As personal computer (PC), supper computer, and use artificial intelligent**.**



Circuit VLSI





Circuit MSI

Computer structure: -

Computer system is made of two main parts: -

1-Hardware: refers to the physical components of the computer such as: - Keyboard, memory, printer…

2-Software: refers to programs, languages, procedures and instructions that make the hardware work for us.

Main components of hardware:

The basic components of a computer system are: (see fig. 2)

1-Input unit

2-Central processing unit: -which consists 1- control unit.

2- Arithmetic and logic unit.

3- Register.

3- Output unit.

4- Memory unit (internal memory).

5- External storage.

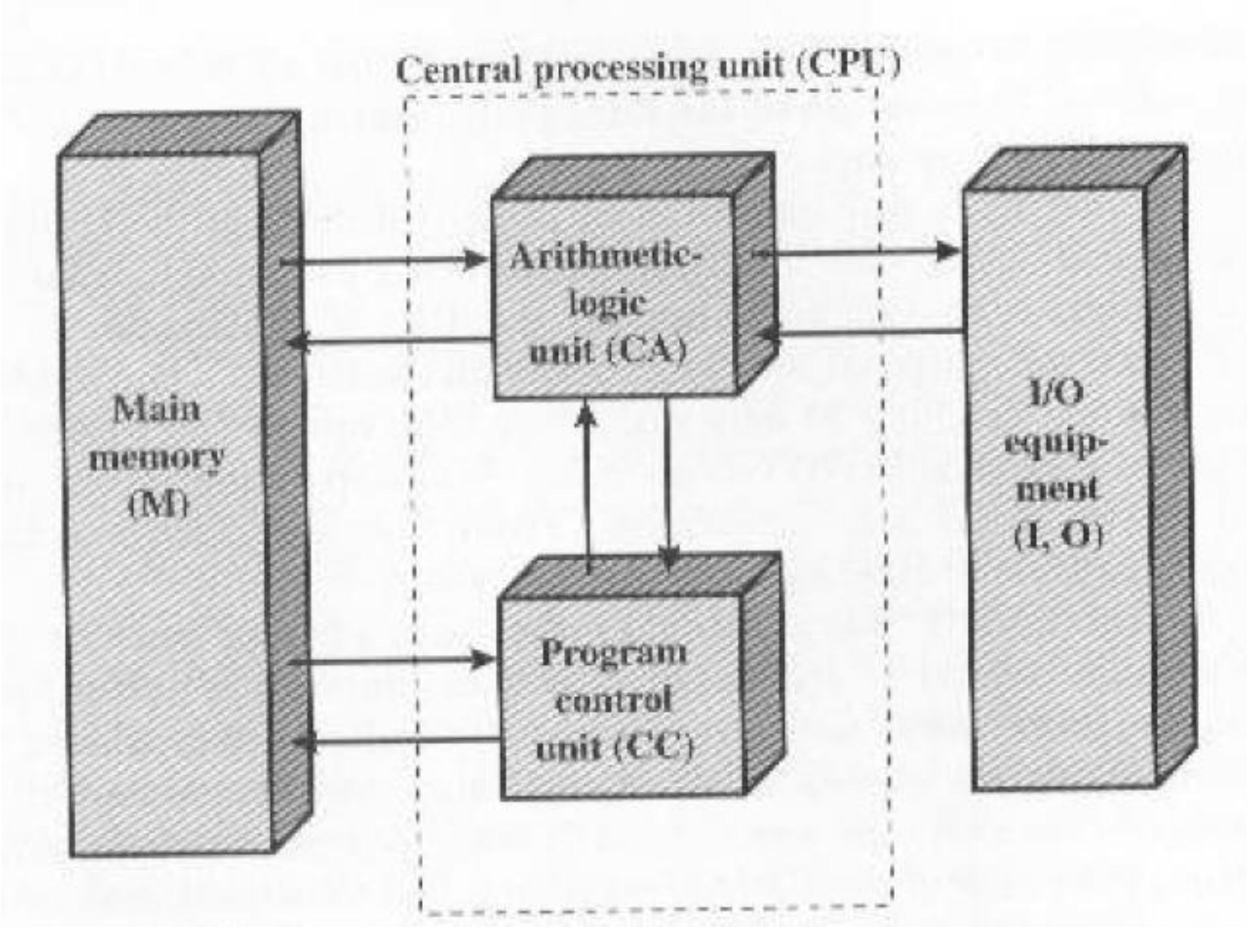


Fig (2) the Logical Structure of Computer

Lecture2:

1- Input unit

The input unit of a computer system accepts data, convert it into electrical impulses that are sent in to internal memory or to the central processing unit (CPU) where can be processed. Such as Punched cards (old system), Magnetic tape, Floppy disk, keyboard, mouse.

2-Central processing unit (CPU)

The brain of any computer system is the CPU, which is sometime called “Processor” or “Microprocessor” in personal computer. The CPU supervises and controls all of the peripheral equipment; perform arithmetic and makes logical decisions. The CPU is responsible for includes the data movement computations and logical operation necessary to convert data into meaningful information. It is divided into three sections: -

-Arithmetic and Logic unit (ALU).

- Control unit.

- Register.

2.1 Arithmetic and Logic unit (ALU)

Perform the processing of data including arithmetic operations such as addition, subtraction, multiplication, division and logic operations including comparison (ex. A<B) and sorting.

2.2 Control unit

- Direct and coordinates all units of the computer to execute program steps.
- Direct and coordinates all operations of the computer systems.

These operations include: -

1- Control to the input and output devices.

2- Entry and retrieval of information from memory.

3- Routing of information between the memory and the arithmetic and logic unit.

Control unit automatically coordinates the operation of the entire computer system, although the control unit does not performed any actual processing on the data, It acts as a central nervous system uses to sent control signal to other units.

2.3 Register

Register are devices capable of sorting information, receiving data from other areas within the computer and transferring information as directed by the control unit, it is used for temporary storage of data or instruction and the most important register are: -

1- Program counter (PC): It contains the address of the next instruction to be executed.

2- Instruction Register (IR): It contains the instruction being executed.

3- Address Register (AR): holds the address of memory location.

3- Output unit

Output units are instruments of interpretation and communication between human and computer, that let you see (or here) the result of the commands you enter, the most common output device are a display screen (monitor), printer or other device that let you see what he computer has accomplished.

The CPU executes each Instruction in a series of steps: -

1- Fetch the next instruction from memory to IR.

2- Changes the program counter to point to the following instruction.

3- Determine the type of the instruction to be fetched.

4- IF the instruction uses data in memory determines where they are.

5- Fetch the data into the internal CPU register.

6- Execute the instruction.

7- Store the result in the proper place.

8- Go to step 1 to being executing the following instruction.

4- Main Memory units

The memory is the part of the computer that holds information (data and Instruction) for processing, main memory also known as primary or internal memory or primary storage, there are two types of main memory are ROM (Read Only Memory) and RAM (Random Access Memory).

The specific function of main memory is to hold (store):

1- All data to be processed.

2- Intermediate result of processing.

3- Final result of processing.

A computer system generally includes two types of storage:

1- Primary storage

2- Secondary storage

1- Primary storage

There are two Primary storage Media

1.1 Magnetic core storage

The second and third generation computers contained primary storage units composed of magnetic cores each core could store one bit when electricity flowed through the wire making up the cores a magnetic field was created the direction of the magnetic field was created the direction of the magnetic field determined which binary state s core represent a magnetic field in one direction indicate an one "1" condition a magnetic field in the other direction indicate an off "0" condition, So the core Memory stores data magnetically unlike semiconductor memory and operates at lower speed.

1.2 Semiconductors memory

It is a set of electronic circuits that put on the silicon chip. This circuit is often called "gates' because they represent a (1) when current is permitted to flow and a (0) when it is not.

The type of main memory contains a large number of semiconductor storage cells, each capable of storing one bit of information a bit which is a short of binary digit which either 1 or 0 (full or empty).

4.1 Type of main memory

There is basically two type of memory

4.1.1 Random access memory (RAM):

And also called read/write memory, it is used for storing data and instruction, in this type the stored information will be lost when computers power is turned off so that it is called the volatile memory, it's used only for temporary storage and the ram can be either dynamic or static.

a- Static RAM: it is a semiconductor memory device in which the stored data will remain permanent stored as long as power is supplied without the need for periodically rewriting the data in to memory.

b- Dynamic RAM: it is a semiconductor memory device in which the stored data will not remain permanent stored even with power is applied unless the data are periodically rewritten in to memory; the later operation is called a refresh operation

4.1.2 Read only memory (ROM)

Is read only memory which can be read from but not written on so that it is called a non-volatile memory, when the user turn the computer off the content of ROM are not changed, the type of ROM is:

1- Programmable Read Only Memory (PROM):

It is prepared by the maker and can be electrical programmed by the user, it can not be erased and programmed a gain this means its content can never be changed.

2- Erasable Programmable Read Only Memory (EPROM):

The maker prepares it and can be electrical programmed by the user, it can be erase (deleted) by exposure to ultraviolet light and programmed many times.

3-Electrically alterable Programmable Read Only Memory (EAPROM): read only memory that is electrically reprogrammable.

** The Difference between RAM and ROM: -

RAM	ROM
• Stand for Random- Access Memory	Stand for Read Only Memory
• Read /Write memory	Read Only memory
• Sending data (writing) to RAM Memory address is called destructive Write because the new data erases Whatever was there before.	Sending data to ROM memory address is in effective because the contents of ROM can not be Changed (write not allowed) because this memory for read only.
• Form of primary storage for holding temporary data and instruction.	Form of primary storage for Holding permanent data and instruction.

RAM	ROM
• Volatile: program and data are Erased when the power is off	Permanent: program and data remain intact even power is off.
• Type of RAM is - Static RAM - Dynamic RAM	Type of ROM is - PROM - EPROM - EAPROM

5-Secondary storage (External storage)

It can be classified into two types:

1- Mechanical storage devices: - is punched paper card and punched paper tape, both of this type is less popular now than the past.

2- Magnetic storage devices: - In personal computer system , external storage store information as magnetic spots on oxidizer surfaces because the magnetic spots do not need constant supply of power to refresh themselves, since 1 bit represented by magnetized spot and 0 is represented by the absence of magnetized spot.

A magnetic devises can be classified into:

1 -sequential storage media.

2-directs storage media.

3- Sequential storage media as the magnetic tap in old computer system.

4- Directs storage media as the magnetic hard disk, magnetic floppy disk, and flash memories.

1- Magnetic Hard Disk: A magnetic hard disk is a circular plate constructed of metal or plastic coated with magnetic material. Often both sides of the disk are used and several disks may be stacked on one spindle with read\write heads available on each surface. All disks rotate to together at high speed and are not stopped or started for access purpose. Bits are stored in the magnetized in sports along concentric circles called tracks. The minimum quantity of information which can be transferred is a sector. A magnetic hard disk is organized or formatting into tracks and sectors. Each track is divided into a number of sectors, and each track and sector has physical address that is used by the operating system to locate particular data record. Hard disks typically have from a few hundred to thousands of tracks. There are a constant number of tracks/sectors, with outer sectors using more surface area than the inner sectors. The arrangement of tracks and sectors on a disk is known as the format, shown in down hard disk scheme.

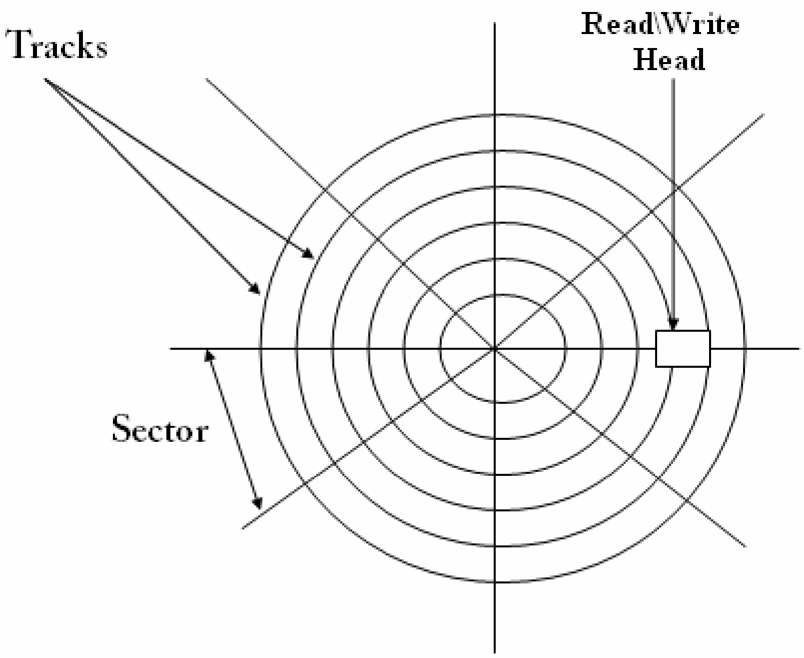


Figure (3) Hard Disk

Hard Disk Performance:

Several basic parameters determine the performance of a given hard disk drive. A seek operation is the movement of the read/write head to the desired track.

1- Seek Time: A seeks time is the movement of the read\write head to the desired track. The seek time is the average time for this operation to be performed. Typically, hard disk drives have an average seek time of several milliseconds, depending on the particular drive.

2- Latency Time: The latency period is the time takes for the desired sector to spin under the head once the head is positioned over the desired track. Latency time depend on the constant rotational speed of the disk.

• The sums of average seek time and the average latency time is the access time for the disk drive.

2- Magnetic Floppy disk: The floppy disk is an older technology and derives its name because it is made of a flexible polyester material with a magnetic coating on both sides. The early floppy disks were 5.25 inch in diameter and were packaged in semi flexible jacket. Current floppy disks or diskettes are 3.5 inches in diameter and are encased in a rigid plastic jacket. A magnetic floppy disks transport consists of the electrical, mechanical, and electric components to provide the parts and control mechanism for a magnetic floppy disks unit.

The floppy disks itself is a strip of plastic coated with a magnetic recording medium. Bits are recorded as magnetic spots on the floppy disk along several tracks. Read\write heads are mounted one in each track so that data can be recorded and read as a sequence of characters. Magnetic floppy disks units can be stopped, started to move forward or in reverse, or can be rewound. 3- Flash Memories: Flash memories are high-density read\write memories (high-density translates into large bit storage capacity) that are nonvolatile, which means that data can be stored indefinitely without power they are sometimes used in place of floppy or small. Capacity hard disk drives in portable computers. High-density means that along number of cells can be packed into a given surface area on a chip, the higher density, the more bits that can be stored on a given size chip. This high density is achieved in flash memories with a storage cell that consists of single floating. A data bit is stored as charge or the absence of charge on the floating gate depending if a 0 or a 1 is stored.

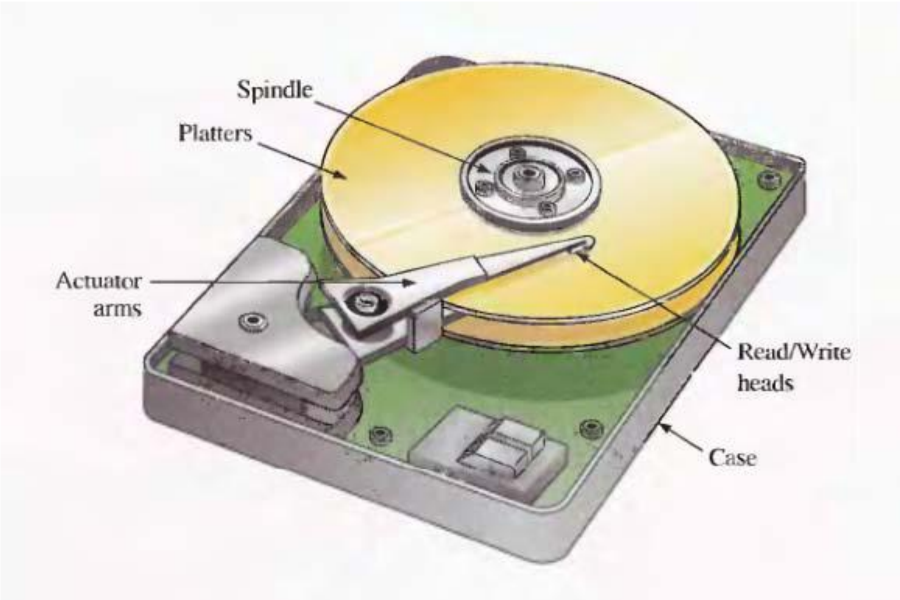


Figure (4) Portions of Hard Disk Drives

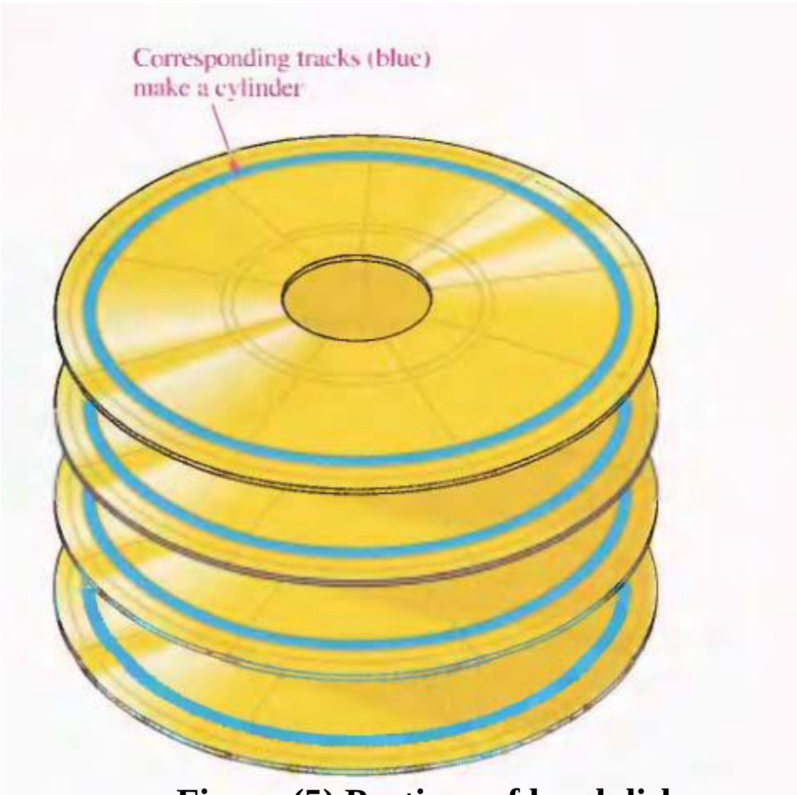


Figure (5) Portions of hard disk

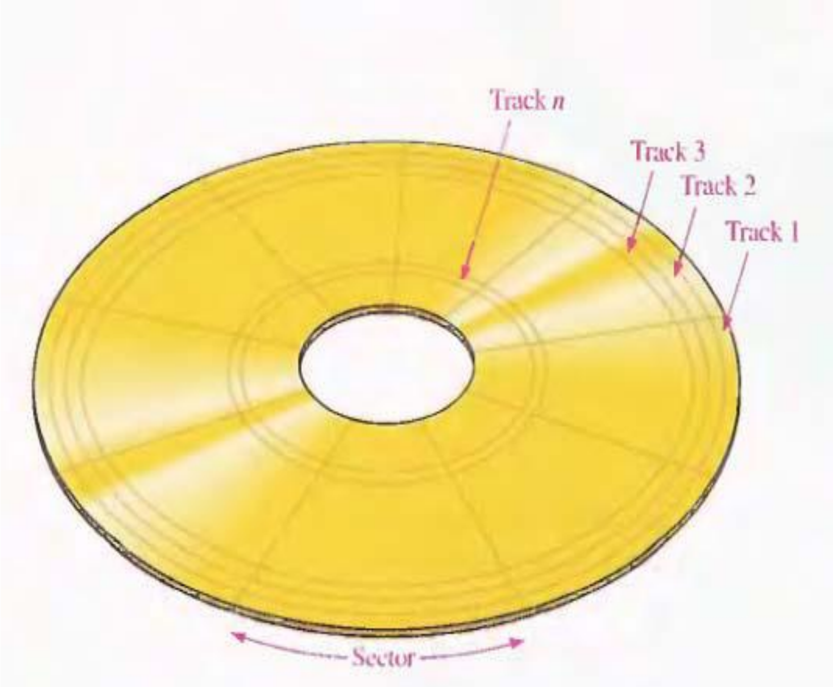


Figure (6) Hard disk

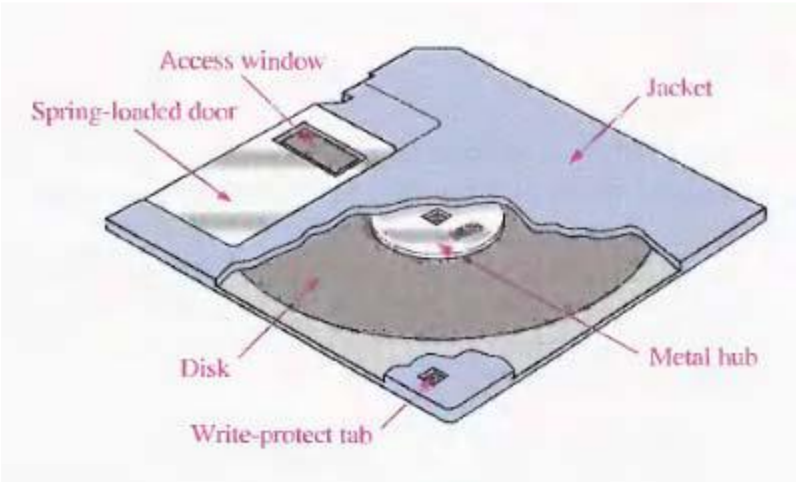


Figure (7) Floppy Disk

6- Operating System:

An operating system is a program that acts as an intermediary between a user of a computer and the computer hardware. The purpose of an operating system is to provide an environment in which a user can execute programs. The primary goal of an operating system is thus to make the computer system convenient to use. A secondary goal is to use the computer hardware in an efficient manner.
An operating system is an important part of almost every computer system. A computer system can be divided roughly into four components: the hardware, the operating system, the applications programs, and the users.

7-Computer Classification:

1-Analog Computers

Analog Computer is a computing device that works on continuous range of values. The results given by the analog computers will only be approximate since they deal with quantities that vary continuously. It generally deals with physical variables such as voltage, pressure, temperature, speed, etc.

2-Digital Computers

On the other hand a digital computer operates on digital data such as numbers. It uses binary number system in which there are only two digits 0 and 1. Each one is called a bit. The digital computer is designed using digital circuits in which there are two levels for an input or output signal. These two levels are known as logic 0 and logic 1. Digital Computers can give more accurate and faster results. Digital computer is well suited for solving complex problems in engineering and technology. Hence digital computers have an increasing use in the field of design, research and data processing.

There are many computers which are different from each other in various aspects. Classification of computers is given below. Classes by size:

(1) Micro computers: These computers use a microprocessor chip and this chip is used instead of CPU means that this microprocessor chip works as a CPU.
These computers are also called personal computers. Two major types of these computers are laptop or Desktop computers. Only one user uses these computers at time that's why they are also known as personal computers.

(2) Mini Computers: These are powerful computer. These computers come into existence in 1960s at that time mainframe computer was very costly. Mini computers were available in cheap prices, so users start using it.

(3) Mainframe Computer: It as a very powerful and large computer. You can get idea of its power as it can handle processing of many users at a time.
Terminals are used to connect a user to this computer and users submit their task through mainframe. Terminal is a device which has keyboard and a screen. By using terminal users put inputs into the computer and get the output through screen.

(4) Super Computers: As the name "super computer" specifies that these are most powerful computers even than mainframe. Actually, when we optimize a mainframe computer then we get super computer.

(5) Microprocessor: You will find these computers everywhere. Microprocessor chips are used many devices as I-pod, DVD, headphone etc.

Classes by function:

1-Servers

Server usually refers to a computer that is dedicated to provide a service. For example, a computer dedicated to a database may be called a "database server". "File servers" manage a large collection of computer files. "Web servers" process web pages and web applications. Many smaller servers are actually personal computers that have been dedicated to provide services for other computers.

2-Workstations

Workstations are computers that are intended to serve one user and may contain special hardware enhancements not found on a personal computer.

3-Information appliances

Information appliances are computers specially designed to perform a specific user-friendly function —such as playing music, photography, or editing text. The term is most commonly applied to mobile devices, though there are also portable and desktop devices of this class.

4-Embedded computers

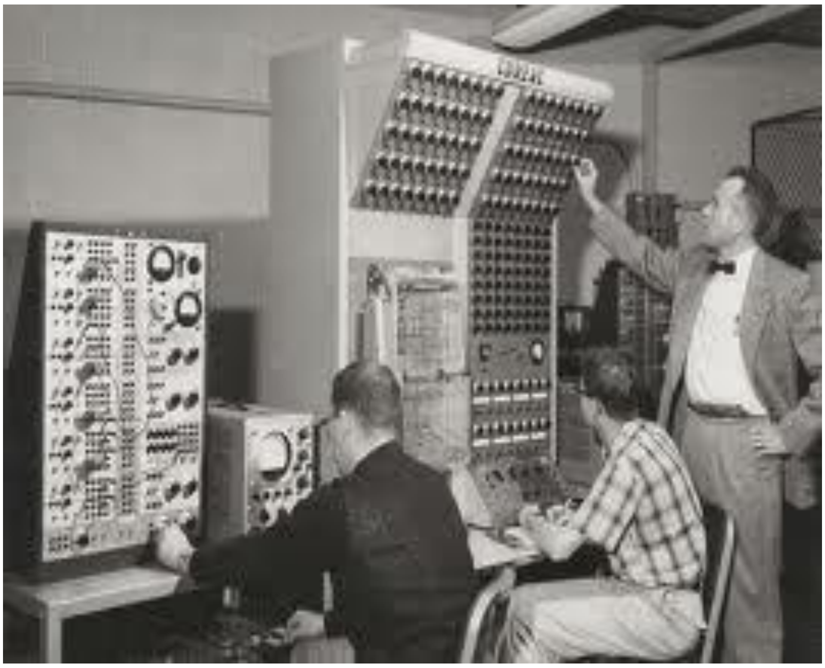
Embedded computers are computers that are a part of a machine or device. Embedded computers generally execute a program that is stored in non-volatile memory and is only intended to operate a specific machine or device. Embedded computers are very common. Embedded computers are typically required to operate continuously without being reset or rebooted, and once employed in their task the software usually cannot be modified. An automobile may contain a number of embedded computers; however, a washing machine and a DVD player would contain only one. The central processing units (CPUs) used in embedded computers are often sufficient only for the computational requirements of the specific application and may be slower and cheaper than CPUs found in a personal computer.

Computer

Analog digital hybrid

Digital Computer

Super Computers **Mainframe Computers** **Minicomputers** **Microcomputers**



Analog computer

High-level-Language (HLL)

High-Level-programming language is one of programming language available. The other type of programming language is known as Low-level-language or assembly language.

- High level-language is easier to learn and understood than the assembly language, because high level languages uses names and commands the resemble English, while the assembly language uses mnemonic codes.

- Some of the common high-level-languages are:

• Fortran (Formula Translation) for engineers.

• COBOL (Common Business Oriented Language) for business programmer's.

• Basic (Beginner's All-purpose symbolic Instruction Code) for engineers and scientists.

• Pascal.

Unlike assembly programs, high-level-languages programs may be used with different makes of computers, while the assembly languages are machine oriented.
Other advantages of high-level-languages are:

1) They are easier to learn than assembly languages.
2) They are easier to use for problem solving, than assembly.
3) They require less time to write, than assembly.
4) They provide better documentation.
5) They are easier to mention.

Compiler Translations

Naturally, a source program written in a high-level language, must also be translated into a machine usable code, that can be executed by the computer.
A translating program that can perform this operation is called" compiler".
The compiler: - converts the entire source high level languages program into a machine language object program, before the program is executed as in FORTRAN. Another type of translating program called "Interpreter" with the interpreter each statement line is translated and executed immediately (one statement at a time) as with Basic.

High-level language → **Compiler** → **Machine language (object program) binary**

Basic → **Interpreter** → **Machine Language program**

(Therefore the interpreter is slower than compiler)

Assembly language

Assembly language program using instruction abbreviation called mnemonics, such as LD(load), ST(store) and ADD(Add to Accumulator).
This is converted to machine language program with a translator called" assembler".
Assembler: - is a special program that enables assembly language program (called source program) into own machine language program (called an object code).
Note: - Compilers are similar to assemblers in the fact. That they take the source program and convert (translate) it in to an executable machine language program (object program).

Software

Type of software:-
Software can be divided into two main types:
1- System software.
In general includes all programs designed to help programmers or to control the computer system.
System software includes:

- Operating system (O.S).
- Programming languages (H.L.L&L.L.L).
- The language processor translator (interpreter, compiler and Assembler).

- Utility (Service) programs.

2- Application system (software)

This type of software's comprises programs written to perform specific tasks for the user, and can be divided as:-

_ Application systems:

These types of systems are written by a special software houses. E.g. bank systems, salary system, airlines system, information banks.

_ Application programs:

These programs direct the computer to accomplish specific activities and it in general small programs and called user programs. e.g. writing a letter using word processor aided design packages.

System software

System software has main objectives:-

_ Making it easier for the user to get a job into a computer.

_ Making it easier for the user to run the job and test it when it is in the computer.

1- Operating system (O.S):- is asset of inter-related by provided by a computer infact that control the basic operations of the computer (such as loading) and manage the execution of the programs. It also store and retrieves files on disk.

The main parts of an operating system are:

a. Supervisor (Kernel).

b. Input / output manager.

c. File manager.

d. Command processor.

A. Supervisor (kernel): this part is responsible of loading the application into memory, making sure they do not interfere with one another and allowing them to share use of CPU efficiently, the Kernel also handles file storage to and from secondary devices such as hard disk and optical drives.

The Kernel handles the following:

- Loading /unloading applications from memory.
- Scheduling tasks to run on the CPU.
- Memory management.
- File management.
- Data security.

B. Input/output manager: In general, all data transformed to and from peripheral devices are filtered through the I/O manager. It is insulates the rest of the programs in the computer from the special of the peripheral devices. For example the I/O manager might translate the keyboard character codes into the coding system used by the rest of the computer. With a good O.S, it is possible to add a hard disk or a faster printer to the computer system just by modifying the I/O manager without making any changes to other software). This is called device independence. An even stronger from of hardware independence, called machine independence (or software portability).
Allows application software to be moved from one type of computer system to another without programming changes.

C. File manager: Anything on disk is stored in file. Each file has its own name and stores one type of information, either program or data. A data file might be a digitized picture, while a program file might be a Basic program or word processor. Whatever the contents of a file the file manager takes care of saving, deleting, coping, loading. As we know data are stored on disks as individual bytes, grouped into sectors, with each sector forming part of a track people think of a data file in logical terms as a letter are stored physically on the disk in tracks and sectors. The file manager translates between the logical and the physical arrangement of data maintaining a file allocation table (FAT) for each disk.
The file allocation table (FAT) is an index telling where each file is stores.
Another function of the file manager is to format (also called initialize) disk. Formatting a disk involves erasing the disk and giving it an empty file allocation table. Disk comes from the manufacture in blank (or unformatted) condition; files cannot be stored on an unformatted disk. Disk cannot be used until it has been formatted, but formatting a disk by mistake erases its content completely. Therefore formatting should be approached with careful. e.g. 2.1 hard disk
360 KB 2.88 byte floppy disk
D.Command processor:-The command processor communicates between the user and the rest of the operating system. It accepts commands and the user makes sure they are valid, and then takes the appropriate action.
Ex: - If the ask to copy (file name) and call the new file, the command processor will translate the command and send request to the file manager. If the disk does not have enough room to store, then the file manager sends a error code massage,

which the command processor might translate to, Insufficient free spare on disk command aborted.

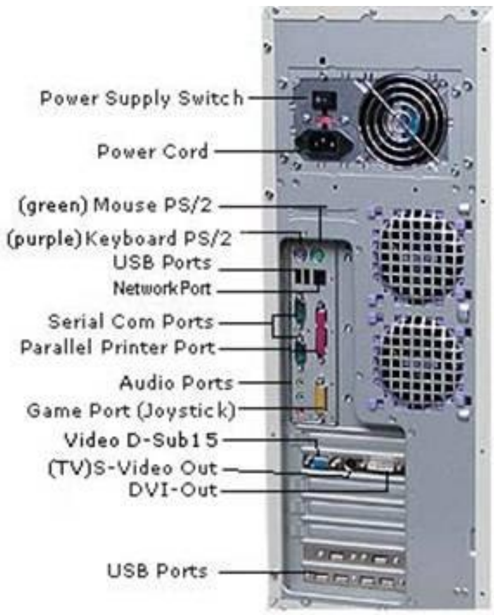
Computer Ports

Another important component of the computer system that is present outside the case is computer ports. Basically they are defined as the different types of slots located at the back side of the computer for making the connection with other devices are called as computer ports. There are different ports for different functions and devices. They generally play a role of socket in the computer system because it is very convenient for the users to attach the external devices with the help of these ports. They also provide the instructions from one the system to other system.

Types of Computer Ports

On the basis of the connection and function with the computer system computer ports are differentiated into different categories. There are different ports that are used in the computer system for the sake of the expenditure of the network and connect different additional devices to the computer. Some of the common computer ports are as follows

1. Serial ports.
2. Parallel ports.
3. SCSI ports.
4. MIDI ports.



Type of computer ports

1- Serial Ports

The first type of the port is the serial port. Generally in the family of the computers it is called as the male ports that handle all the major processes of the computational world. These types of ports consist of 9 to 24 pins in them and commonly used for the devices such as mouse, printer's etc. serial ports are able to sends the data in the range of more than 18 feet. Every device has its own separate serial port. Generally ports one of the computers is called as COM1 and other is COM 2. Serial ports have ability to do one and two way data transmission with complete responsibility.

2- Parallel Ports

Basically it is a female port in the family of computers. A parallel port generally consists of 25 holes or pins and commonly connected the devices related to the printers or scanner with the personal computer. The working performance of the parallel ports is faster as compared to the serial ports or other types of ports. They are built in the mother board and contain 25 wires from which 8 are involved in the data transmission and examining controls the whole circuit. Parallel ports have ability to sends 8 bits data per second and every port is labeled separately such as LPT 1 and LPT 2.

3-SCSI Ports

SCSI ports stands for the small computer interface system ports that are regularly in the system for the connection of the additional devices with the system such as scanners, USB and many other zip drives. They are able to connect more the 6 devices at a time but not more then 8.

4-MIDI Ports

These ports stand for the musical instrument data interface ports and are generally used for connecting the different types of musical devices with the computer system. Different types of music composer are used MIDI ports to connect their musical instruments with the system to enhance the working. The advantages of the MIDI ports are that musicians can easily record or edit the required music.

Universal Serial Bus

What is USB?

Anyone who has been around computers for more than two or three years knows the problem that the Universal Serial Bus is trying to solve in the past, connecting devices to computers has been a real headache!

- Printers connected to parallel printer ports, and most computers only came with one. Things like Zip drives, which need a high-speed connection into the computer, would use the parallel port as well, often with limited success and not much speed.
- Modems used the serial port, but so did some printers and a variety of odd things like Palm Pilots and digital cameras. Most computers have at most two serial ports, and they are very slow in most cases.
- Devices that needed faster connections came with their own cards, which had to fit in a card slot inside the computer's case. Unfortunately, the number of card slots is limited and you needed a Ph.D. to install the software for some of the cards. The goal of USB is to end all of these headaches. The Universal Serial Bus gives you a single, standardized, easy-to-use way to connect up to 127 devices to a computer.

How USB Ports Work

Just about any computer that you buy today comes with one or more Universal Serial Bus connectors on the back. These USB connectors let you attach everything from mice to printers to your computer quickly and easily. The operating system supports USB as well, so the installation of the device drivers is quick and easy, too compared to other ways of connecting devices to your computer (including parallel ports, serial ports and special cards that you install inside the computer's case), USB devices are incredibly simple!, we will look at USB ports from both a user and a technical standpoint. You will learn why the USB system is so flexible and how it is able to support so many devices so easily it's truly an amazing system.

Just about every peripheral made now comes in a USB version. A sample list of USB devices that you can buy today includes:

- Printers.
- Scanners.
- Mice.
- Joysticks.
- Digital cameras.
- Webcams.
- Scientific data acquisition devices.
- Modems.
- Speakers.
- Telephones.
- Video phones.
- Storage devices such as Zip drives.
- Network connections.

USB Connections

Connecting a USB device to a computer is simple you find the USB connector on the back of your machine and plug the USB connector into it.

If it is a new device, the operating system auto-detects it and asks for the driver disk. If the device has already been installed, the computer activates it and starts talking to it. USB devices can be connected and disconnected at any time.
Many USB devices come with their own built-in cable, and the cable has an "A" connection on it. If not, then the device has a socket on it that accepts a USB "B" connector. The USB standard uses "A" and "B" connectors to avoid confusion:

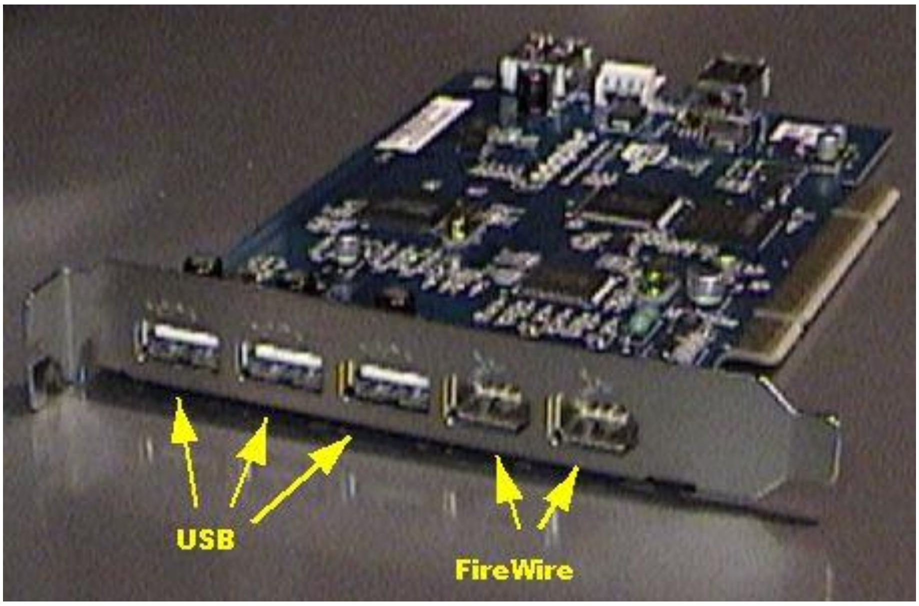
- "A" connectors head "upstream" toward the computer.
- "B" connectors head "downstream" and connect to individual devices.

By using different connectors on the upstream and downstream end, it is impossible to ever get confused if you connect any usb cables "B" connector into a device, you know that it will work similarly you can plug any "A" connector into any "A" socket and know that it will work.

FireWire ports

Are forms of a serial port that make use of FireWire technology to transfer data rapidly from one electronic device to another? The FireWire port has been in common use since 1995, when Apple, Inc. first began to include the port on a number of digital camcorders. Today, the FireWire port is used on a number of other devices. As a multi-platform serial bus, the FireWire port has the ability to interact with a number of different devices. For example, a FireWire® connection can provide an ideal way to connect a scanner to a computer system. Because the transfer rate of a FireWire port can reach up to 400 Mbps, the data transfer is relatively fast and also results in excellent quality.

A similar approach is taken when uploading captured images from a digital camera to a computer hard drive. Use of a FireWire® port can mean images that are free of an loss of quality, and are excellent candidates for print after the download is complete. Once the images are uploaded, the storage drive on the camera can be cleared, making the camera ready for more use.



Data and Signals

Introduction

One of the major functions of the physical layer is to move data in the form of lectromagnetic signals across a transmission medium. Whether you are collecting numerical statistics from another computer, sending animated pictures from a design workstation, or causing a bell to ring at a distant control center, you are working with the transmission of data across network connections. Generally, the data usable to a person or application are not in a form that can be transmitted over a network. For example, a photograph must first be changed to a form that transmission media can accept. Transmission media work by conducting energy along a physical path. To be transmitted, data must be transformed to electromagnetic signals.

ANALOG AND DIGITAL

Both data and the signals that represent them can be either analog or digital in form. Analog and Digital Data Data can be analog or digital. The term analog data refers to information that is continuous; digital data refers to information that has discrete states. For example, an analog clock that has hour, minute, and second hands gives information in a continuous form; the movements of the hands are continuous. On the other hand, a digital clock that reports the hours and the minutes will change suddenly from 8:05 to 8:06. Analog data, such as the sounds made by a human voice, take on continuous values. When someone speaks, an analog wave is created in the air. This can be captured by a microphone and converted to an analog signal or sampled and converted to a digital signal. Digital data take on discrete values. For example, data are stored in computer memory in the form of Os and 1s. They can be converted to a digital signal or modulated into an analog signal for transmission across a medium.

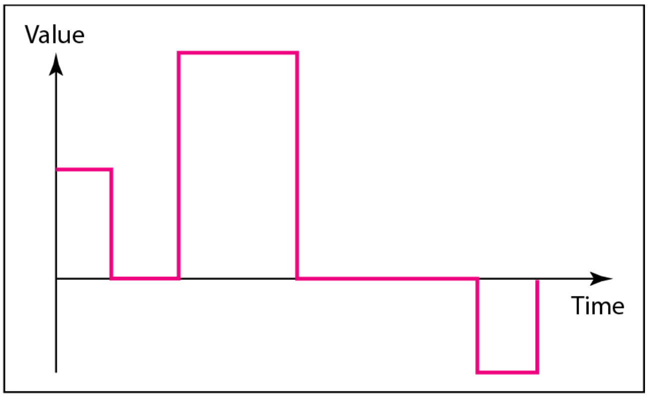
Like the data they represent, signals can be either analog or digital. An analog signal has infinitely many levels of intensity over a period of time. As the wave moves from value A to value B, it passes through and includes an infinite number of values along its path. A digital signal, on the other hand, can have only a limited number of defined values. Although each value can be any number, it is often as simple as 1 and O. The simplest way to show signals is by plotting them on a pair of perpendicular axes. The vertical axis represents the value or strength of a signal. The horizontal axis represents time. Figure 3.1 illustrates an analog signal and a digital signal. The curve representing the analog signal passes through an infinite number of points. The vertical lines of the digital signal, however, demonstrate the sudden jump that the signal makes from value to value. **Signals can be analog or digital. Analog signals can have an infinite number of values in a range; digital signals can have only a limited number of values**.

To be transmitted, data must be transformed to electromagnetic signals.

Data can be analog or digital. The term analog data refers to information that is continuous; digital data refers to information that has discrete states. Analog data take on continuous values. Digital data take on discrete values.

Data can be analog or digital. Analog data are continuous and take continuous values. Digital data have discrete states and take discrete values.

a. Analog signal



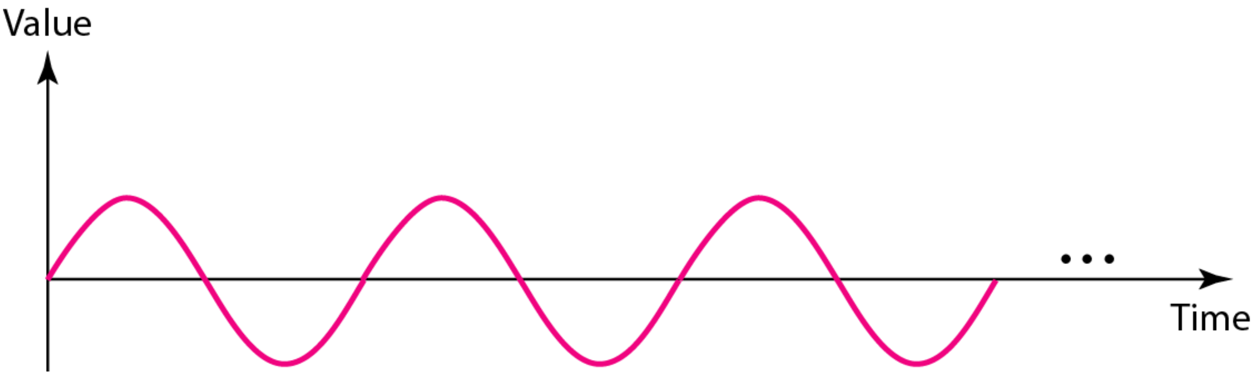
b. Digital signal

In data communications, we commonly use periodic analog signals and nonperiodic digital signals.

PERIODIC ANALOG SIGNALS

Periodic analog signals can be classified as simple or composite. A simple periodic analog signal, a sine wave, cannot be decomposed into simpler signals. A composite

periodic analog signal is composed of multiple sine waves.

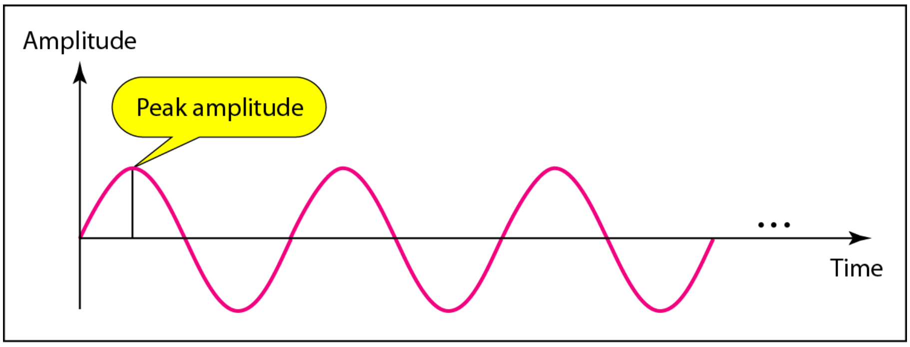


Sine wave

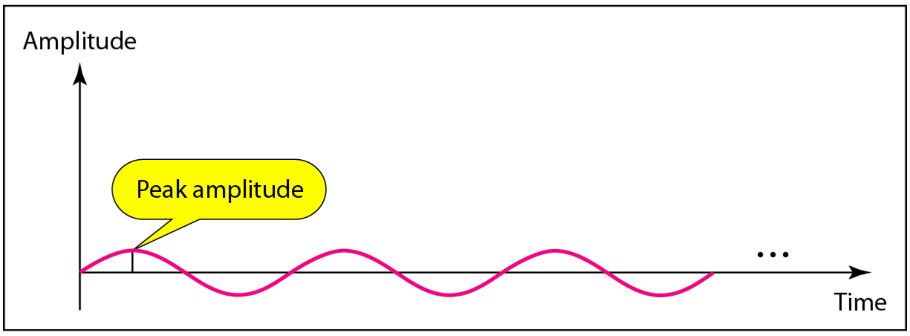
Example: 1

The power in your house can be represented by a sine wave with a peak amplitude of 155 to 170 V. However, it is common knowledge that the voltage of the power in U.S. homes is 110 to 120 V. This discrepancy is due to the fact that these are root mean square (rms) values. The signal is squared and then the average amplitude is calculated. The peak value is equal to $2^{½}$ × rms value.

Two signals with the same phase and frequency, but different amplitudes



a. A signal with high peak amplitude



b. A signal with low peak amplitude

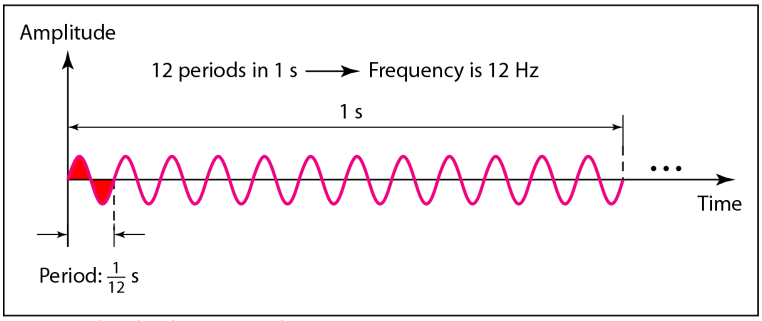
Two signals with the same phase and frequency, but different amplitudes

The voltage of a battery is a constant; this constant value can be considered a sine wave, as we will see later. For example, the peak value of an AA battery is normally
1.5 V.

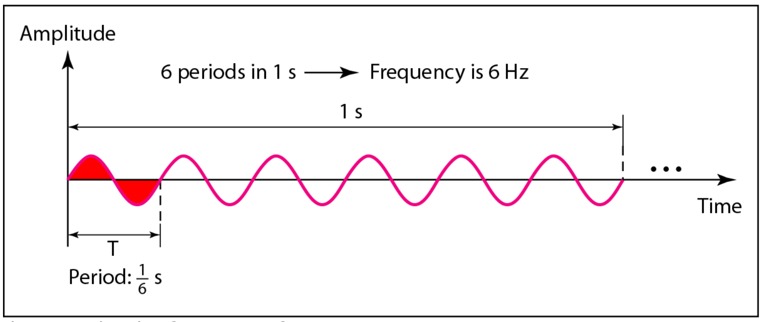
Frequency and period are the inverse of each other.

$$f = \frac{1}{T} \quad \text{and} \quad T = \frac{1}{f}$$

Figure 3.4 Two signals with the same amplitude and phase, but different frequencies



a. A signal with a frequency of 12 Hz



b. A signal with a frequency of 6 Hz

Table 1 Units of period and frequency

Unit	*Equivalent*	*Unit*	*Equivalent*
Seconds (s)	1 s	Hertz (Hz)	1 Hz
Milliseconds (ms)	10^{-3} s	Kilohertz (kHz)	10^3 Hz
Microseconds (μs)	10^{-6} s	Megahertz (MHz)	10^6 Hz
Nanoseconds (ns)	10^{-9} s	Gigahertz (GHz)	10^9 Hz
Picoseconds (ps)	10^{-12} s	Terahertz (THz)	10^{12} Hz

Example 2

The power we use at home has a frequency of 60 Hz. The period of this sine wave can be determined as follows:

$$T = \frac{1}{f} = \frac{1}{60} = 0.0166 \text{ s} = 0.0166 \times 10^3 \text{ ms} = 16.6 \text{ ms}$$

Example 3

Express a period of 100 ms in microseconds.

Solution

From Table 3.1 we find the equivalents of 1 ms (1 ms is 10^{-3} s) and 1 s (1 s is 10^{6} μs). We make the following substitutions:.

$$100 \text{ ms} = 100 \times 10^{-3} \text{ s} = 100 \times 10^{-3} \times 10^{6} \text{ μs} = 10^{2} \times 10^{-3} \times 10^{6} \text{ μs} = 10^{5} \text{ μs}$$

Example 4

The period of a signal is 100 ms. what is its frequency in kilohertz?

Solution: First we change 100 ms to seconds, and then we calculate the frequency from the period (1 Hz = 10^{-3} kHz).

$$100 \text{ ms} = 100 \times 10^{-3} \text{ s} = 10^{-1} \text{ s}$$

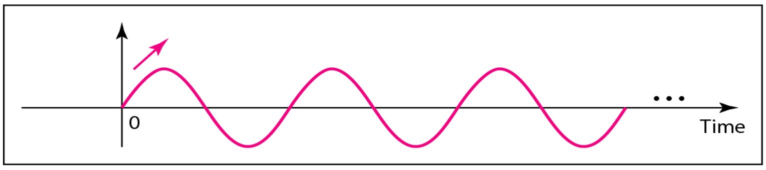
$$f = \frac{1}{T} = \frac{1}{10^{-1}} \text{ Hz} = 10 \text{ Hz} = 10 \times 10^{-3} \text{ kHz} = 10^{-2} \text{ kHz}$$

Frequency is the rate of change with respect to time. Change in a short span of time means high frequency. Change over a long span of time means low frequency.

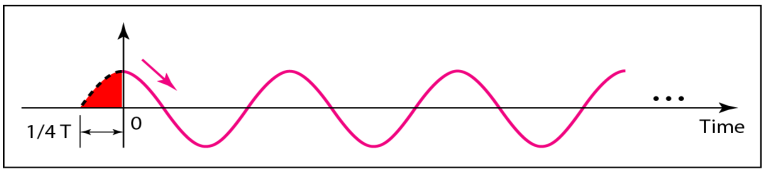
If a signal does not change at all, its frequency is zero.If a signal changes instantaneously, its frequency is infinite.

Phase describes the position of the waveform relative to time 0.

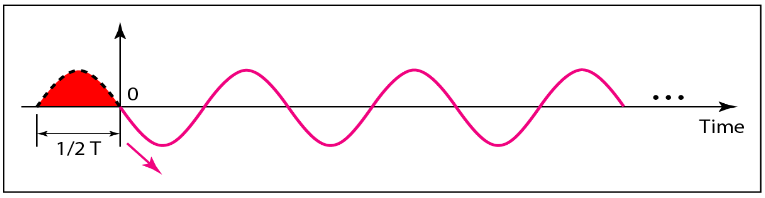
Figure 3.5 Three sine waves with the same amplitude and frequency, but different phases



a. 0 degrees



b. 90 degrees



c. 180 degrees

Example 5

A sine wave is offset 1/6 cycle with respect to time 0. What is its phase in degrees and radians?

Solution : We know that 1 complete cycle is 360°. Therefore, 1/6 cycle is

$$\boxed{\frac{1}{6} \times 360 = 60^\circ = 60 \times \frac{2\pi}{360} \text{ rad} = \frac{\pi}{3} \text{ rad} = 1.046 \text{ rad}}$$

Figure 3.6 Wavelength and period

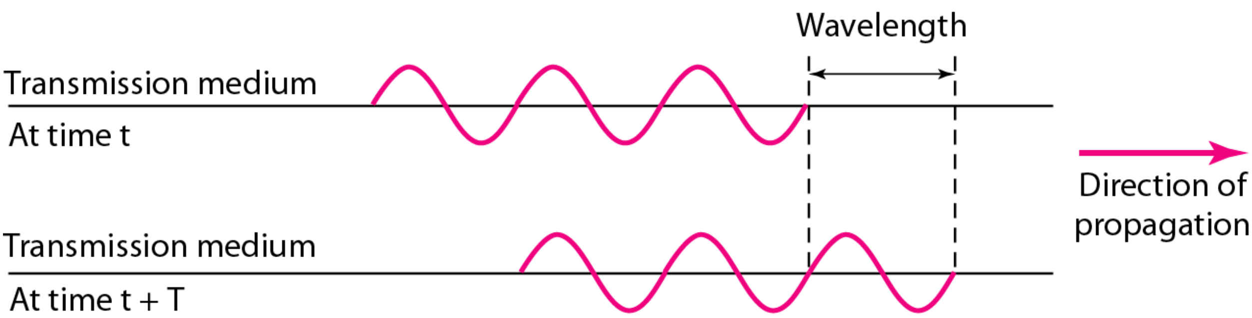
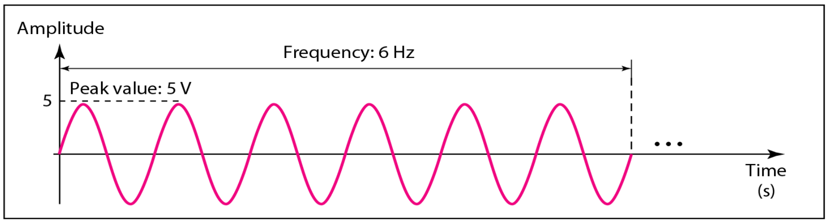
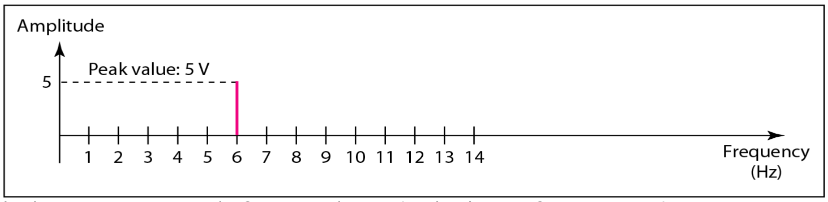


Figure 3.7 The time-domain and frequency-domain plots of a sine wave



a. A sine wave in the time domain (peak value: 5 V, frequency: 6 Hz)



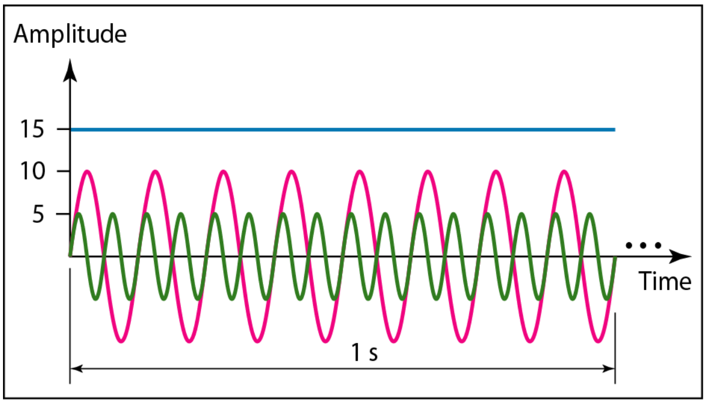
b. The same sine wave in the frequency domain (peak value: 5 V, frequency: 6 Hz)

A complete sine wave in the time domain can be represented by one single spike in the frequency domain.

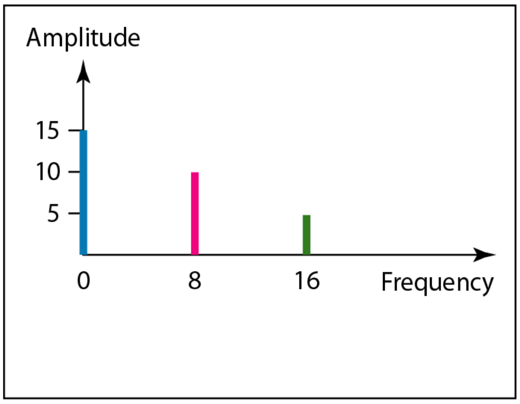
Example 6

The frequency domain is more compact and useful when we are dealing with more than one sine wave. For example, Figure 3.8 shows three sine waves, each with different amplitude and frequency. All can be represented by three spikes in the frequency domain.

Figure 3.8 The time domain and frequency domain of three sine waves



a. Time-domain representation of three sine waves with frequencies 0, 8, and 16



b. Frequency-domain representation of the same three signals

A single-frequency sine wave is not useful in data communications; we need to send a composite signal, a signal made of many simple sine waves.

According to Fourier analysis, any composite signal is a combination of simple sine waves with different frequencies, amplitudes, and phases.

If the composite signal is periodic, the decomposition gives a series of signals with discrete frequencies; if the composite signal is nonperiodic, the decomposition gives a combination of sine waves with continuous frequencies.

Example 7

Figure 3.9 shows a periodic composite signal with frequency f. This type of signal is not typical of those found in data communications. We can consider it to be three alarm systems, each with a different frequency. The analysis of this signal can give us a good understanding of how to decompose signals.

Figure 3.9 A composite periodic signal

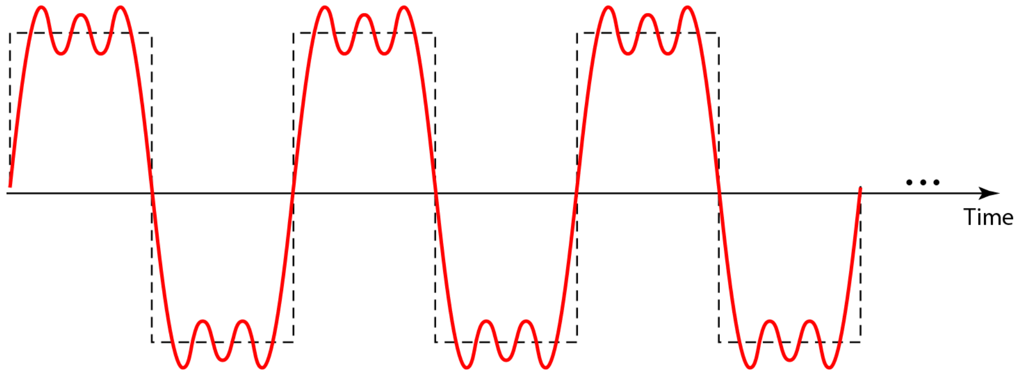
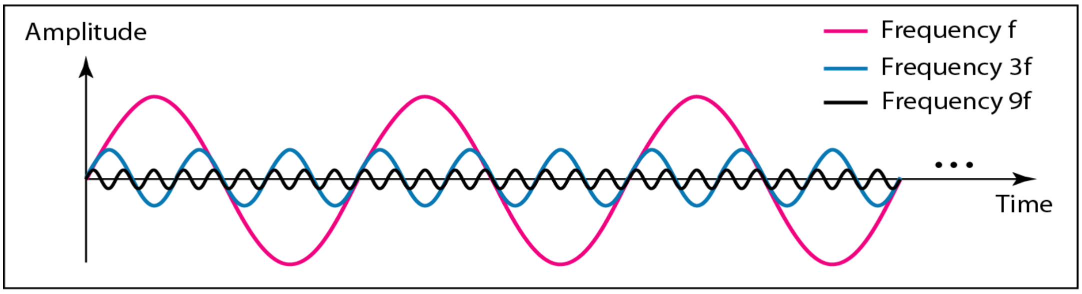
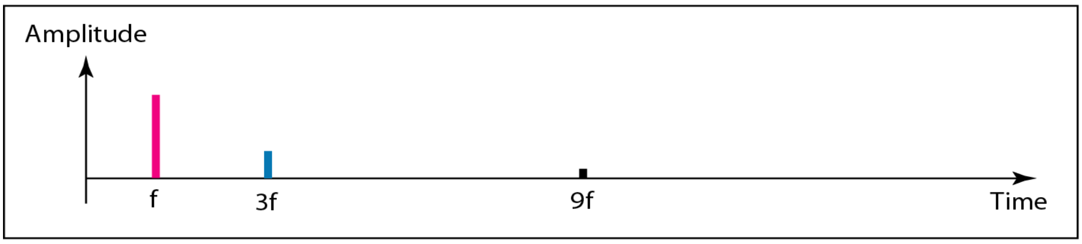


Figure 3.10 Decomposition of a composite periodic signal in the time and frequency domains



a. Time-domain decomposition of a composite signal

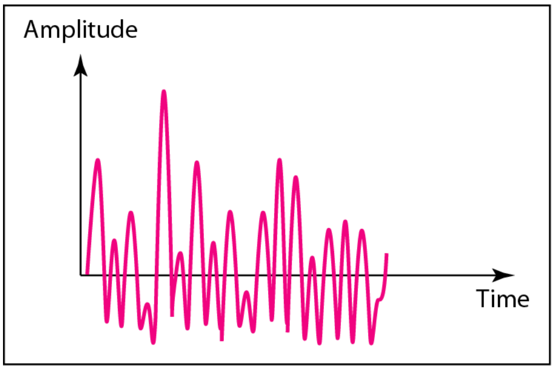


b. Frequency-domain decomposition of the composite signal

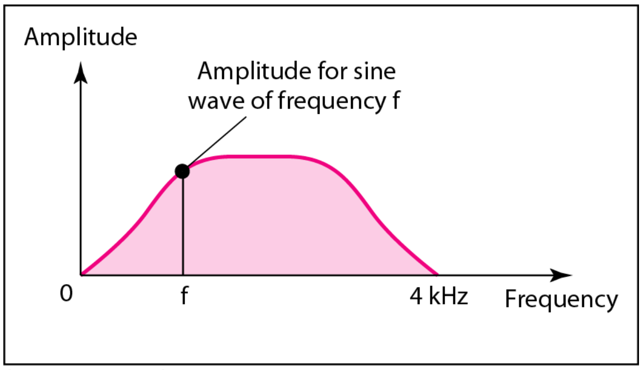
Example 8

Figure 3.11 shows a nonperiodic composite signal. It can be the signal created by a microphone or a telephone set when a word or two is pronounced. In this case, the composite signal cannot be periodic, because that implies that we are repeating the same word or words with exactly the same tone.

Figure 3.11 The time and frequency domains of a nonperiodic signal



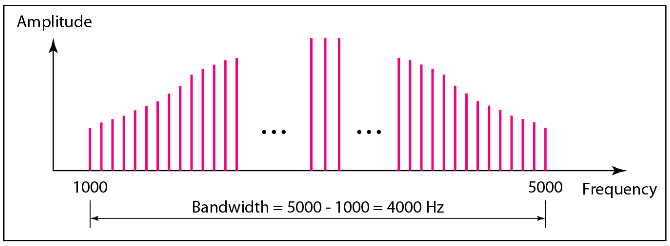
a. Time domain



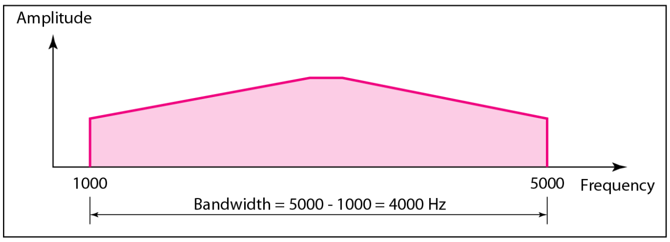
b. Frequency domain

The bandwidth of a composite signal is the difference between the highest and the lowest frequencies contained in that signal.

Figure 3.12 The bandwidth of periodic and nonperiodic composite signals



a. Bandwidth of a periodic signal



b. Bandwidth of a nonperiodic signal

Example 9

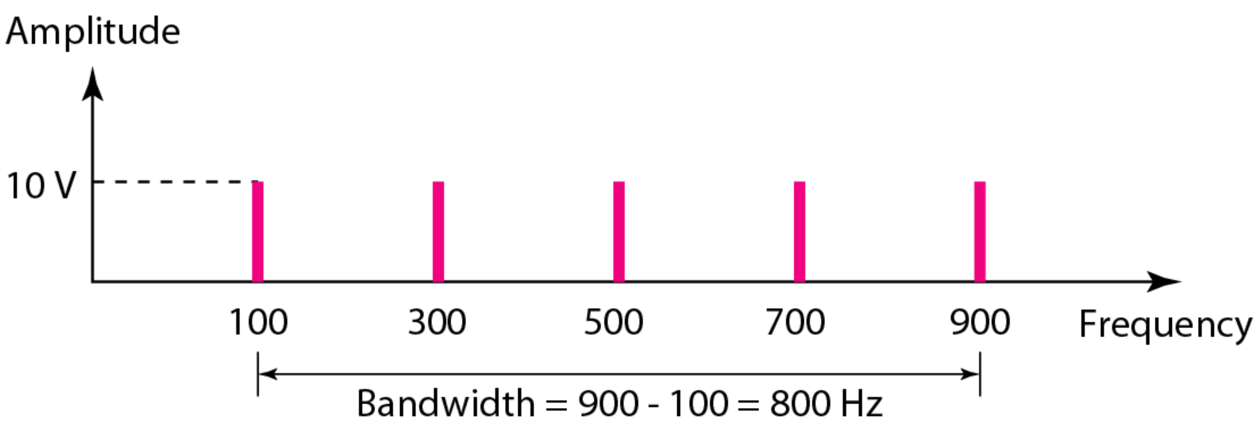
If a periodic signal is decomposed into five sine waves with frequencies of 100, 300, 500, 700, and 900 Hz, what is its bandwidth? Draw the spectrum, assuming all components have a maximum amplitude of 10 V.

Solution : Let f_h be the highest frequency, f_l the lowest frequency, and B the bandwidth. Then

$$\boxed{B = f_h - f_l = 900 - 100 = 800 \text{ Hz}}$$

The spectrum has only five spikes, at 100, 300, 500, 700, and 900 Hz (see Figure 3.13).

Figure 3.13 The bandwidth for Example 3.10



Example 10

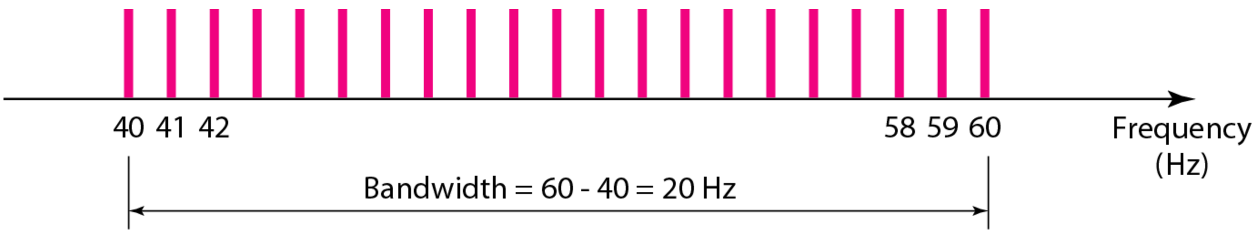
A periodic signal has a bandwidth of 20 Hz. The highest frequency is 60 Hz. What is the lowest frequency? Draw the spectrum if the signal contains all frequencies of the same amplitude.

Solution Let f_h be the highest frequency, f_l the lowest frequency, and B the bandwidth. Then

$$B = f_h - f_l \quad \Rightarrow \quad 20 = 60 - f_l \quad \Rightarrow \quad f_l = 60 - 20 = 40 \text{ Hz}$$

The spectrum contains all integer frequencies. We show this by a series of spikes (see Figure 3.14).

Figure 3.14 The bandwidth for Example 3.11

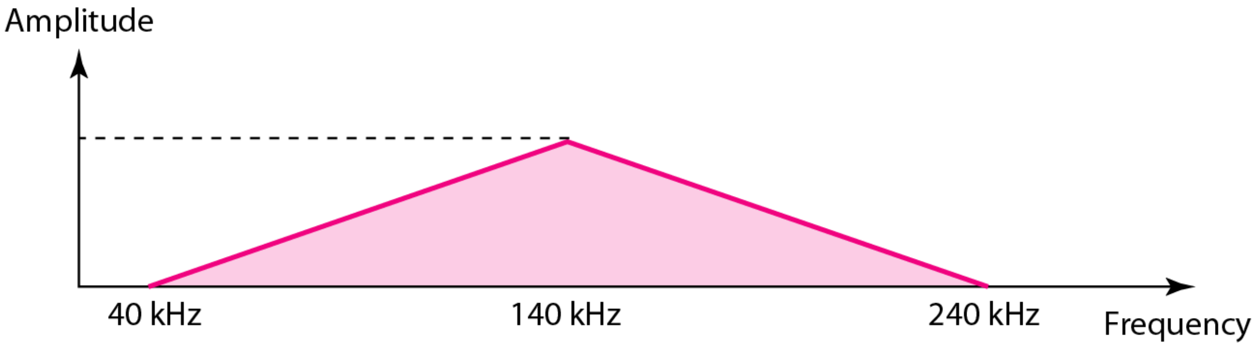


Example 11

A nonperiodic composite signal has a bandwidth of 200 kHz, with a middle frequency of 140 kHz and peak amplitude of 20 V. The two extreme frequencies have an amplitude of 0. Draw the frequency domain of the signal.

Solution : The lowest frequency must be at 40 kHz and the highest at 240 kHz. Figure 3.15 shows the frequency domain and the bandwidth.

Figure 3.15 the bandwidth for Example 3.12



Example 12

An example of a nonperiodic composite signal is the signal propagated by an AM radio station. In the United States, each AM radio station is assigned a 10-kHz bandwidth. The total bandwidth dedicated to AM radio ranges from 530 to 1700 kHz. We will show the rationale behind this 10-kHz bandwidth.

Example 13

Another example of a nonperiodic composite signal is the signal propagated by an FM radio station. In the United States, each FM radio station is assigned a 200-kHz bandwidth. The total bandwidth dedicated to FM radio ranges from 88 to 108 MHz. We will show the rationale behind this 200-kHz bandwidth.

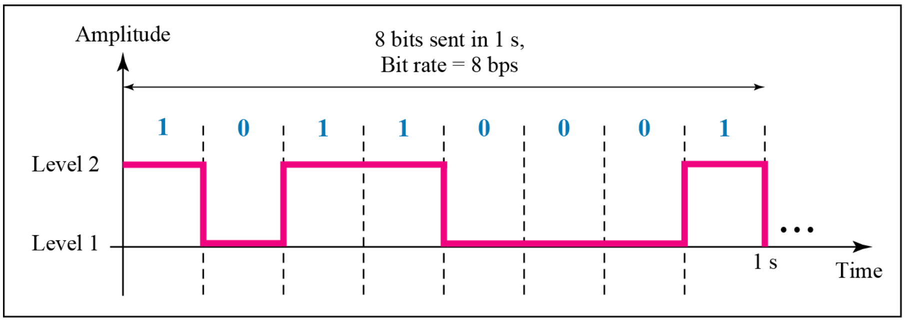
Example 14

Another example of a nonperiodic composite signal is the signal received by an old-fashioned analog black-and-white TV. A TV screen is made up of pixels. If we assume a resolution of 525 × 700, we have 367,500 pixels per screen. If we scan the screen 30 times per second, this is 367,500 × 30 = 11,025,000 pixels per second. The worst-case scenario is alternating black and white pixels. We can send 2 pixels per cycle. Therefore, we need 11,025,000 / 2 = 5,512,500 cycles per second, or Hz. The bandwidth needed is 5.5125 MHz.

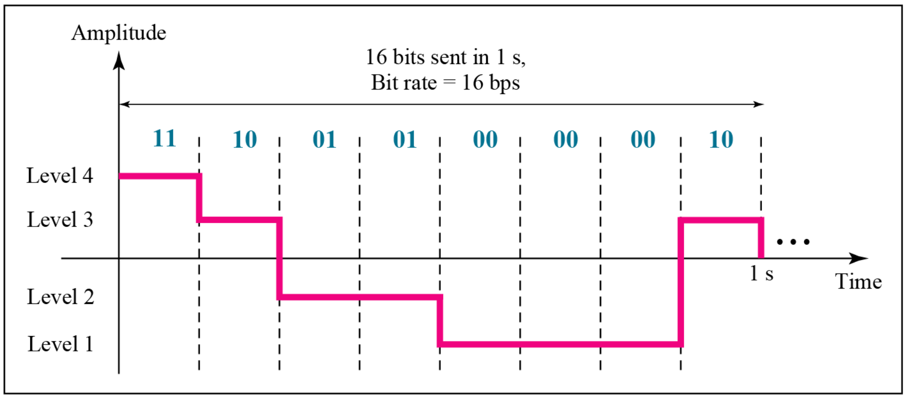
DIGITAL SIGNALS

In addition to being represented by an analog signal, information can also be represented by a digital signal. For example, a 1 can be encoded as a positive voltage and a 0 as zero voltage. A digital signal can have more than two levels. In this case, we can send more than 1 bit for each level.

Figure 3.16 Two digital signals: one with two signal levels and the other with four signal levels



a. A digital signal with two levels



b. A digital signal with four levels

Example 15

A digital signal has eight levels. How many bits are needed per level? We calculate the number of bits from the formula

$$\boxed{\text{Number of bits per level} = \log_2 8 = 3}$$

Each signal level is represented by 3 bits.

Example 16

A digital signal has nine levels. How many bits are needed per level? We calculate the number of bits by using the formula. Each signal level is represented by 3.17

bits. However, this answer is not realistic. The number of bits sent per level needs to be an integer as well as a power of 2. For this example, 4 bits can represent one level.

Example 17

Assume we need to download text documents at the rate of 100 pages per minute. What is the required bit rate of the channel?

Solution

A page is an average of 24 lines with 80 characters in each line. If we assume that one character requires 8 bits, the bit rate is

$$\boxed{100 \times 24 \times 80 \times 8 = 1{,}636{,}000 \text{ bps} = 1.636 \text{ Mbps}}$$

Example 18

A digitized voice channel, as we will see in Chapter 4, is made by digitizing a 4-kHz bandwidth analog voice signal. We need to sample the signal at twice the highest frequency (two samples per hertz). We assume that each sample requires 8 bits. What is the required bit rate?

Solution: The bit rate can be calculated as

$$\boxed{2 \times 4000 \times 8 = 64{,}000 \text{ bps} = 64 \text{ kbps}}$$

Example 19

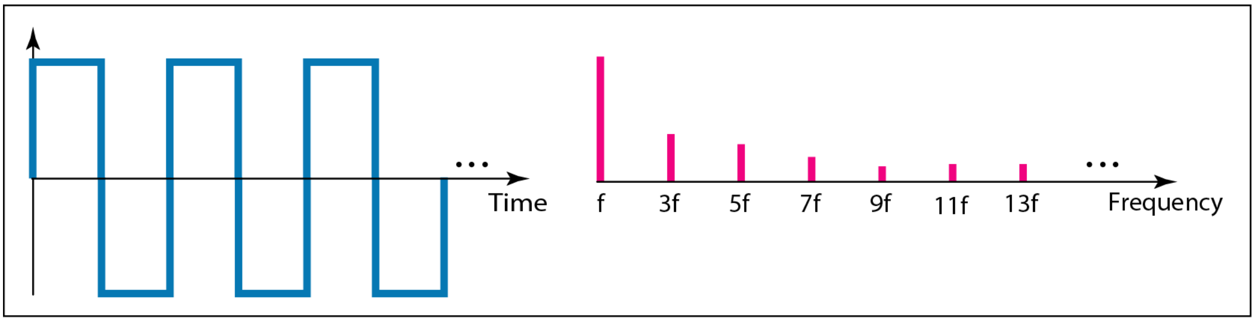
What is the bit rate for high-definition TV (HDTV)?

Solution :HDTV uses digital signals to broadcast high quality video signals. The HDTV screen is normally a ratio of 16 : 9. There are 1920 by 1080 pixels per screen, and the screen is renewed 30 times per second. Twenty-four bits represents one color pixel.

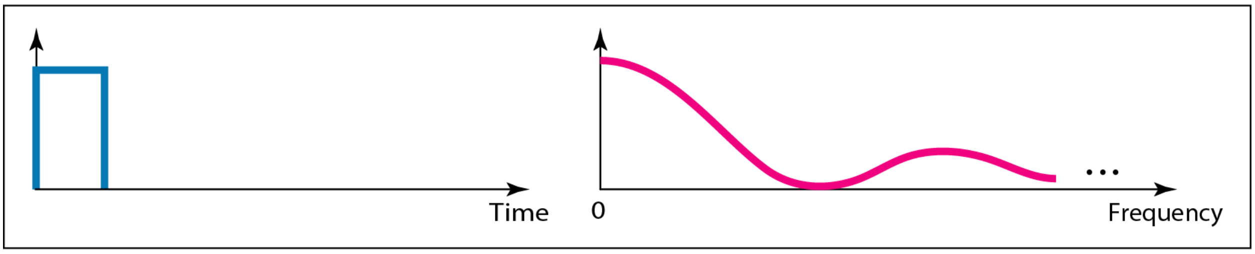
$$1920 \times 1080 \times 30 \times 24 = 1{,}492{,}992{,}000 \text{ or } 1.5 \text{ Gbps}$$

The TV stations reduce this rate to 20 to 40 Mbps through compression.

Figure 3.17 the time and frequency domains of periodic and nonperiodic digital signals



a. Time and frequency domains of periodic digital signal



b. Time and frequency domains of nonperiodic digital signal